National Cave Management Symposium - XI

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PROCEEDINGS OF THE

1993 NATIONAL CAVE MANAGEMENT SYMPOSIUM

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The 1993 National Cave Management Symposium Proceedings are respectfully dedicated to:

RUSSELL GURNEE

Explorer, Administrator, Speleologist, Engineer, Author, and Specialist in Cave Management

Russ passed away on February 21, 1995; and this issue of proceedings reminds us of the many facets of his life and of his deep interest in maintaining the quality of the cave environment-whether it be through ownership, custodianship, development, or other means.

He spent more than 35 years exploring, studying, and documenting the world underground; and his interest in caves open to the public developed at the same time as the exploration of wild caves. He realized early that it was not enough to enjoy exploration only - and that inevitably study, documentation, recommendation, adn preservation must follow. He began this process in the 1950's and it continued until his death.

Russell Gurnee was a president of the National Speleological Society, president of the first International Congress of Speleology to be held in the Western Hemisphere, president of The Explorer's Club (an organization of world-class explorers and scientists), president of the National Speleological Foundation, and member of the governing bureau of the International Speleological Union, Italy.

He co-authored a number of books, particularly *Cave Life* with Charles E. Mohr; *Discovery at the Rio Camuy* (English and Spanish editions) with Jeanne Gurnee; *Discovery of Luray Caverns, Virginia*; and *Gurnee Guide to American Caves* with Jeanne Gurnee.

He led cave studies and expeditions at Harrison's Cave, Barbados; Ensneno Cave in Puerto Rico; Rio Camuy Cave, Puerto Rico; Fountain Cavern, Anguilla, British West Indies; and other caves worldwide. The corporation shared with Jeanne, Cave Management Associates, Inc., developed Rio Camuy Cave, Puerto Rico for visitors, and this has recently become a National Park. The Gurnees also redeveloped Harrison's Cave for the government of Barbados.

While Russ began his serious interest in caves in the 1950's, after 1977 he and Jeanne devoted full time to speleology. This work continued to the time of his death, when they, with a team of specialists, were working on an air, water, and pollution study for the government of Barbados.

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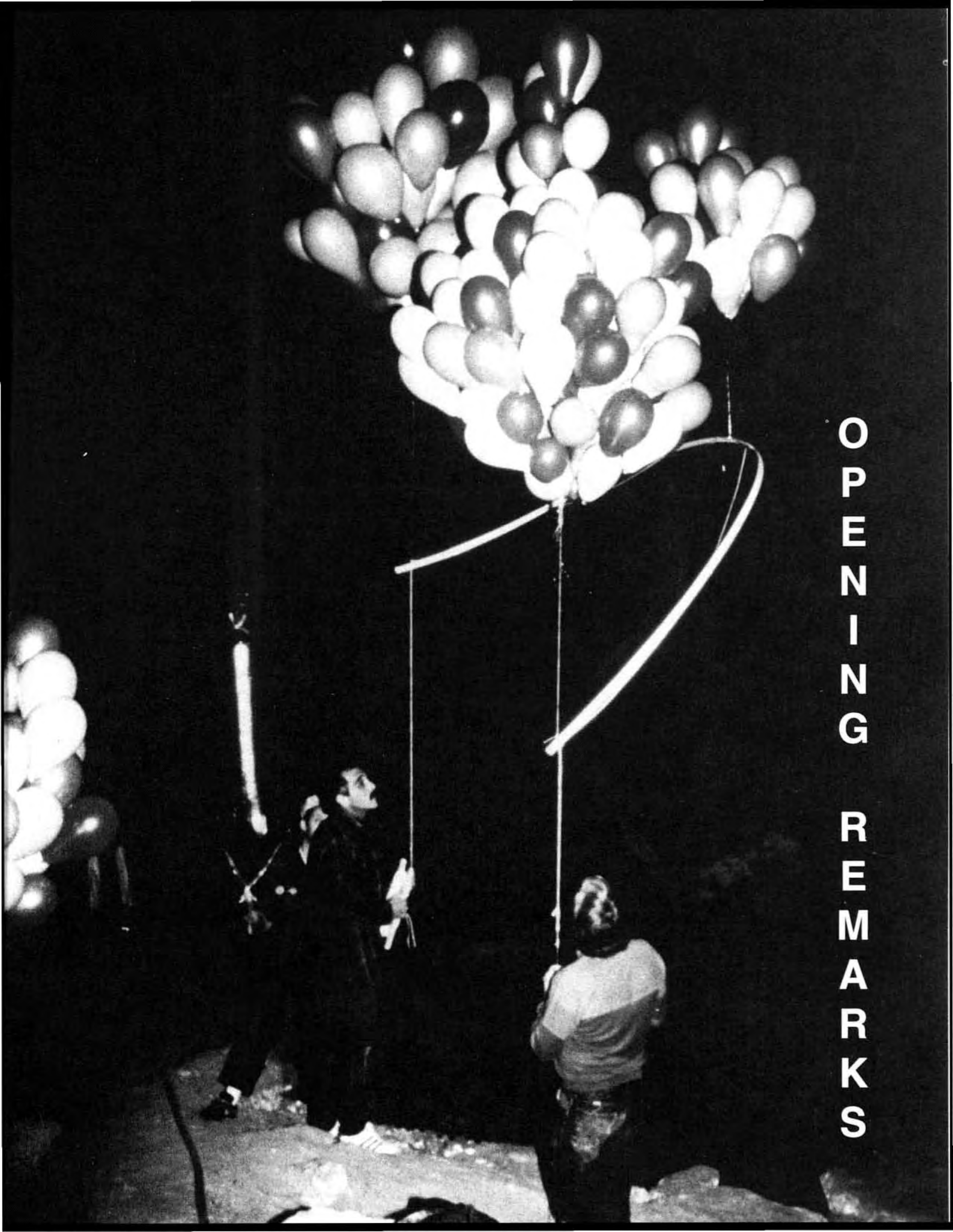

OPENING REMARKS

Photo Caption -- Party in the Big Room? Actually, Ronal Kerbo and Michael Queen using balloons filled with helium in an attempt to place a cord around a large stalagmite visible from the trail at the Top of the Cross in the Big Room of Carlsbad Cavern, Eddy County, New Mexico. The attempt was ultimately successful and a new area, which was named Spirit World, was explored and surveyed.

National Park Service Photo

BUREAU OF LAND MANAGEMENT

Bill Calkins

On behalf of the Bureau of Land Management, Welcome! It's great to see you. For those of you who are not from New Mexico, welcome to New Mexico and Carlsbad. We're really looking forward to hosting this symposium and showcase our karst resources in the state and particularly in our Roswell District. I think the timing of this session is particularly good because of the several opportunities lined up for us. First, for me personally, it's an opportunity to become more familiar with the Roswell District's Cave Program with the BLM which is known throughout the BLM as the Country's biggest and most progressive cave program that we have and how this interrelates with the national field program and interests. Second, is the coming together of all of us. Some of the most knowledgeable cavers in the world as well as some of the best cave managers are here today.

At a time when Federal agencies are just beginning to implement the regulations of the Federal Cave Resources Protection Act, it is also a tremendous opportunity to insure long-term cooperation and coordination of this effort. This is also an opportunity for me, the BLM's representative, to express my thanks to the caving community for their long-term support of our cave management program of New Mexico. This, of course, has allowed us to reach the state we're at today and finally its an opportunity for all of us to continue the dialogue that we've started through informal and formal discussions.

I'd like to mention something about the Dark Canyon Environmental Impact Statement (DCEIS) and what led up to that. As you know, the DCEIS has become a national issue. It was one of the first briefings that I received when I arrived in New Mexico as the Acting State Director and I also know that it was one of the first Congressional briefings that I've been involved with in Washington. This level of national attention obviously reflects the significance of what was proposed and what we have to go through. To my knowledge, this is the first time a federal agency has prepared an environmental impact statement specifically for the protection of cave resources. Later in this session, Joe Incardine, will present to you a paper on the process of the DCEIS. For those of you who are not familiar with the EIS, Larry Woodard, former State Director of the BLM, decided to prepare an EIS primarily because of a gas well which was proposed to be drilled in the Dark Canyon Special Management Area. Located north of Carlsbad Caverns National Park, it was within one and one-half miles of the known extent of Lechuguilla Cave. The EIS process is not complete but there are several things to mention in terms of positive success already. First of all the BLM and the NPS have cooperated in every sense of the word in the development of the EIS. This includes not only the analysis of the impact, but includes describing the environment and identifying the mitigating measures and probably more important describing the alternatives. This has been truly a collaborative effort and we appreciate the NPS for this role. Also, it is my intent that the decision that will come as the result of this process will ultimately be the result of that partnership and collaboration. The BLM received over 500 comments on the EIS. This public involvement process has proven to be extremely helpful. As a result, there were significant modifications to the final, including two viable alternatives. Most of these comments came from the caving community, so those of you who provided those comments, thank you! You've been very helpful. And finally, the DCEIS reflects multiple use and management at work.

Our Federal Land Policy and Management Act of 1976, BLM's land management act, charged us to try and strike a balance of public uses for over 270 million acres of land under our administrative jurisdiction. As many of you can imagine, that's not an easy task. For example, many people in this room place a high value on public land, cave and karst resources, but the nation, for example, places a high value on oil and gas reserves. So a balance must be struck. I believe that finalization of the cave regulations, the final DCEIS and the BLM's increasing emphasis on managing entire ecosystems which is a new focus for us, is improving our ability to strike a balanced use of resources. Many of you in this room helped us to get where we are today. I encourage your continued involvement and cooperation in the process. Public involvement is a vital element to successful land management where a balanced use is required.

Again, I would like to welcome you to Carlsbad and to this symposium and to the diverse cave systems that exist on public land here. Again, welcome and thank you.

NATIONAL PARK SERVICE

John Cook

I hope you will bear with me a moment and let me share a story with you, a story my grandfather told me over 50 years ago.

He said "Grandson, in the beginning all life was created as a flowing spirit stream. All things have life and those things come from that ever-flowing stream into a container of one type or another. It may be a butterfly, a hummingbird, an eagle, a rose, a wolf, a man, a woman, maybe even the mountains."

I said," Grandfather, how can mountains have life? I understand all the rest."

He said," Son, remember the mountains come from Mother Earth, they rise, and they wear down, returning to the spirit stream. All life begins in that spirit stream. Emerging pure, gaining impurities along the way, but always returning to the spirit stream of life to continue on and emerge again as new life."

I didn't really understand my Grandfather very well when he was talking to me, remember it was over 50 years ago. It gives you the idea that I was very, very young. But I thought about those things over the years and I remember, when I was in Alaska, the fight the little white tundra flower has to emerge, to live, to die, and emerge again. I remembered my Grandfather's story of the spirit stream of life. All life comes from that stream and continues and returns to it. When I read Larry Lopez's quote about rocks having rights, how did he find the ability to talk to my grandfather? He has been dead since 1950. Because my Grandfather would have said, rocks have rights. All things have rights. Where in the world could this be coming from in this room today. Well, those of you who have been in Lechuguilla Cave or deep in any cave of Mother Earth, those rocks are alive. They grow, they create, they continue, they come from that stream of life and they ultimately return to that stream of life. We together my friends are truly protectors of the planet. As you discuss management issues of caves, public or private, remember you are discussing living things. You, we, us, the decisions we make with regard to Mother Earth are in fact life and death living decisions. I will leave you with a welcome from the National Park Service and a quote from my Grandfather which in English translates as "Walk as one". When you leave here I hope you will join hands to protect the resources of this planet, this Earth and walk as one.

UNITED STATES FOREST SERVICE

Roger Deaver

I don't think I'm going to be surprised as to what goes on in the great state of New Mexico. For those of you who are staying in the south side of the motel unit, you probably noticed those trucks parked out there overnight. But did you notice those labels on them? They say "Payment Dressing Conditioner". I didn't know whether those trucks contained salad oil or shampoo. That's the petroleum industry for you in the state of New Mexico.

I am pleased to represent the Southwest Regional Forester of the US Forest Service, Larry Henson, in welcoming you to this symposium. Quite frankly, he would have loved to have done this himself. He has a personal identity with caves. He had quite a lot to do with the development of the caves in Arkansas, the Blanchard Caves. He spent a lot of time and a lot of Forest Service money in developing those resources. He frightened a lot of people, but he's quite proud of it really. I personally have an identity with caves. I began my caving career as a very young spelunker in high school. Not knowing a thing about it, I checked one book out of the library and thought I knew everything. So I started my wild caving experience in the Mount St. Helen's area, exploring the caves and lava tubes in that part of the country, and I've enjoyed it ever since. If I can talk Ransom Turner into it, I'll be having another wild caving experience later this winter in the Guadalupes.

The Forest Service, along with our partners, the Bureau of Land Management (BLM) and the National Park Service (NPS) are very deeply committed to the cave resources and how important they are. To that end, we share a management responsibility with a Memorandum of Understanding so that we can manage these caves in cooperation. As you know, caves do not follow geographic boundaries or agency boundaries that were drawn on maps. It's important that the cooperation continue.

The Forest Service is also blessed with a unique and abundant cave resource particularly in this part of the country. In the Guadalupe Escarpment alone, the Guadalupe Ranger District has identified over 120 significant caves. This is a very important resource. Our focus in this part of the country has been on wild caving. How that may change in the future, we don't know. We are in the process of looking at cave management and how we are going to approach it. We do know that you, as an important audience in the caving community are very concerned about the speed with which we work towards getting the regulations in place and the policies in place in the agencies to manage and to protect these valuable cave resources. We've heard you, we've stepped up our efforts to get these approved. You will learn more about that, but actions have been taken this very last week which I think will move us significantly forward. That will be talked about in a later session so I won't dwell on it here.

There are two key points that I want you to hear me on, that I want you to take back with you. The first is, and Bill spoke to that, both the USFS and the BLM are taking a different approach to managing these resources. You know that the Forest Service has the Multiple Use Act and under that act we are to manage a multitude of resources in perpetuity. But our approach to managing those have been a single management approach. As John Cook eloquently described to you, these resources are everflowing and everchanging. They depend upon each other in an ecological environment as much as we are approaching our management of resources on an ecosystem basis. Taking whole ecosystems and managing as opposed to single resources. This is going to have a lot to do with managing, protecting these valuable cave resources because we will not be single-use focused and have some of the extracting commodities competing with the amenities aspects of our management. And I'm going to talk just a bit more about that. But I want you to keep that in mind, our ecosystem management is probably going to be a very valuable tool. As testimony to our commitment to that, this will be one of our first attempts ever to manage caves under an ecosystem management effort. This is done by the Lincoln National Forest, it is in draft. This is an ecosystem management plan for the caves in the Guadalupe area. Each cave is in and of itself a very unique resource and as such it has to be managed on a sustaining basis to protect that resource. This particular draft plan will be available for you to look at. In fact, there will be a sign up sheet that will allow you to be able to get a copy of this when it is final. What this does is to ensure that these caves will be managed and protected under the ecosystem management direction.

As you know, we had to ensure that surface activities such as mining, mineral exploration, development of facilities on the surface, even wildfire management needs do not cause damage to the valuable biota and speleothems that we find in the caves. This plan will ensure that all is considered.

The second point that I want to leave with you is a new challenge, and there couldn't be a better community of people and experts to deal with this new challenge than the audience in this room. I believe that we are facing a new challenge as it relates to the use of caves. I think right now we've seen a dimension of use that reflects a lot of care about caves. I think people that enter caves now are technically competent, they have a lot of experience and they have a passion for caring about the cave resources. Now we may be entering a new dimension and I think you've all experienced this in some way. When I was in college you probably wouldn't get a date with a young woman if you talked about your rock climbing experience. It was just not something that was done, or that you were a kayaker or that you cross-country skied. Admittedly that's a long time ago folks, but today I think the young man on campus that is looking for a date better be physically equipped to get into the backcountry and to do some bivouacking if they're going to catch up with those young women. The women are out there doing things that they had not done before. I believe that there is a new dimension coming as far as cave users. I think we're going to see that adventuresome, young American population looking for wild cave experience in numbers that we've never believed possible before. We had better be prepared for that and the answer is not to be simply "the caves are closed." That is not going to work. Particularly when there are other solutions that we can find. Perhaps we're going to develop a whole new industry of outfitter guides that have the competency and the knowledge and experience to take people into caves without damaging those resources. Now that may be upsetting to some of you, but I think it's a reality that we must face. We have to protect those cave resources, but we cannot deny the public that may want to enter them.

So with those two thoughts in mind, go through the week and hopefully some additional experiences and additional experiences and some conclusions for us. Thank you very much.

NATIONAL SPELEOLOGICAL SOCIETY
NATIONAL CAVE MANAGEMENT SYMPOSIUM STEERING COMMITTEE

Janet Thorne

Good morning and thank you, Jim.

I hope all of you are looking forward to this Symposium as much as I am! The National Cave Management Symposia have been held approximately every other year since 1975, and they always have been useful and important, but this year, and right now, is a particularly significant milestone in the progress of cave management. Most of you know that on October 1st, the Department of the Interior published its regulations required under the Federal Cave Resources Protection Act of 1988, and Agriculture's regulations are expected to be out shortly. These regulations focus the attention of Federal agency land managers on the current state of management of the cave resources under their jurisdictions.

We can understand why some land managers may be horrified by the idea that they now have to worry about caves! I hope, over the course of this Symposium, that idea will become a little less threatening and a little more ... manageable!

Those of you who have been to a Symposium before know that there are several goals we hope to achieve during the few days we have together. One, of course, is to increase everyone's awareness of the types of resources which are found in caves, their sensitivity to outside influences, and the important niche they occupy in our environment.

Second, we want to help each other solve cave management problems by presenting examples of how similar problems have been solved by other managers in other areas.

Third, and perhaps most important, we want to create an atmosphere in which you will talk with each other! I hope all of you will make a special effort over the next few days to introduce yourselves to people you don't know and to talk about your own cave management concerns. Many of the people attending this Symposium have been involved with cave management on one level or another for years, and I'm sure that everyone here is quite willing to share their experiences.

I don't want to take much more time from the important sessions which have been scheduled for this conference, but before I close I do want to be sure you know that overall coordination for these Symposia is provided by a Steering Committee. That Committee is composed of representatives of a number of Federal government agencies and private interest groups which are involved on a national level with cave management. I want each of those representatives to stand so you will know who they are, and if you have any questions about the Symposia or ideas for improvements, please talk to one of us.

The Federal agencies on the Steering Committee are the Bureau of Land Management, represented by Delmar Price; the Fish and Wildlife Service, Bob Adamcik; the Forest Service, Brent Botts; and the National Park Service, Ron Kerbo. From the private sector are the American Cave Conservation Association, Dave Foster; Cave Research Foundation, Mel Park; National Caves Association, Gordon Smith; and The Nature Conservancy, Geoff Roach. Of course the National Speleological Society, which I represent, also is part of the Steering Committee, and the NSS representative serves as Coordinator of the group.

So again, I urge you to talk with the Steering Committee members and talk with each other. I hope you have a very enjoyable and rewarding time over the next few days.

Thanks for coming.

CAVE RESEARCH FOUNDATION

Pat Helton

On behalf of the Cave Research Foundation (CRF) let me welcome you to warm and sunny southeastern New Mexico. I can say that because I'm not from New Mexico I'm from the state east of here, Texas, which is host to the 1994 NSS convention. And, in true Texas fashion we feel like it's going to be the biggest and best convention ever. Also in true Texas fashion let me just say, "Ya'all Come!".

The CRF is a national organization active in the Guadalupe area. In addition, we are active in Mammoth Cave, Kentucky; in Missouri, California, and an ongoing project in Arkansas. In the Guadalupe area, the CRF regularly works with Carlsbad Cavern National Park, Guadalupe Mountains National Park, Bureau of Land Management, Carlsbad and Roswell Districts, and the National Forest Service. Carlsbad Cavern is the main focus of the CRF volunteers in this area. We hold six major expeditions in the park per year with 25 to 30 people attending. Our work in those expeditions concentrates on exploration, survey, and mapping. We also have off-expedition trips usually averaging twice a month. These are smaller groups, usually more informal with two teams of four people. Again, we work on exploration, survey, and mapping.

Once a year we hold a one week Field Restoration Camp. This is an amazing group of people. On the last session in June, we had 27 people who contributed 1200 in-cave hours. They moved 30 tons, or 60,000 pounds of rock, debris, and trash. If you go into the Cavern this week, take a look at the old lunchroom area and see the work that they have done. They've taken a really kind of unsightly area and uncovered rimstones, flowstone, and other formations that have been buried for 50 years. It's really amazing the work they have done. Along with the Field Restoration Camp, there is a Lint Restoration Camp. Pat Jablonsky will be telling you more about that, but they meet for one week every year.

CRF is now involved in upgrading our survey skills and doing a more comprehensive mapping program. We are bringing in more detail to our maps to aid geologists, researchers, and other people needing the use of cave maps. This is a fairly new attempt for us, but it's already proved to be valuable. The information that is coming out of the cave is much better than in years past. Along with this, we are also doing biological and geological inventories with one person going with the survey team to make notes on the rocks, formations, minerals, and biological species found. This is proving valuable in establishing a GIS database in caves that we work in. We are excited by the results that we are seeing to date.

We are involved in producing 3-D computer generated maps of the Cavern. You will get a chance to see these this week. We will have a video running out in the display area where you will see 3-D maps of Carlsbad Cavern that will come up in plan view, rotate a full 360 degrees, then pull up in profile and rotate 360 degrees. They are very interesting and fun to watch, but we are finding them valuable. We had a preview of a rough cut shown to some of the interpretation rangers a few weeks ago. Their comments were that it really helped them to see how the Cavern was put together. It was the first time they could see how all of the pieces of the Cavern fit together. Since then, it has helped them to explain to the general public how the Cavern was formed, how the Scenic Rooms fit with the Big Room and how the Lefthand Tunnel comes in. In exploration, these 3D maps are showing us the major joint tendencies and areas that should produce more cave. The copies you'll be seeing later are the rough cuts. They are not finished products for television production, but they will give you an idea of some of the things CRF is involved with in our new mapping efforts.

In Carlsbad Cavern, our total contribution to the National Park over the last five years has totaled approximately 31,600 hours in-cave. This doesn't include driving hours, map work, only in-cave hours over the last five years. A couple of years ago, the Department of the Interior used a standard of fifteen dollars per volunteer-hour which would put the value of these hours at 474,000 dollars over the last five years. That's an amazing amount of dollar valued contribution by CRF volunteers.

CRF is busy in the backcountry areas of Carlsbad Caverns National Park. Our activities include ridgewalking, exploration, survey, and inventory. During our Labor Day expedition, we located two new caves and surveyed them bringing the official total to 81 known caves in the Park. In addition to these activities, Diana Northup's biological inventories are producing information we have never dreamed of getting before. This is a long term project that Diana will be telling you about later in the symposium.

Outside the National Park, in the Carlsbad BLM District, we have been active for many years. Currently, CRF is involved with BLM in ridegewalking the gypsum karst areas, surveying, and assisting in gathering hydrology information. We have recently reopened the Dry Cave survey which was closed for many years. This is very exciting for us. They left this survey years ago at 25,000 feet. We will more than double that in the next few years. There is so much unsurveyed passage in this cave. On our first trip in Dry, one team of four people surveyed over 600 feet of virgin survey near the entrance. Dry Cave is going to be a big one. It's also going to be a long term project. So, if you are going to be in this area and know how to survey, we are looking for help.

In the BLM Roswell District, CRF, under the direction of John Corcoran, has undertaken a precision survey in Fort Stanton Cave. This is a very precise, long term project which produces very outstanding results. Along with the survey, they are doing restoration work in the cave.

In the Lincoln National Forest, CRF is conducting the Capitan Mountains Project. We hold a week long trip out there doing ridgewalking, cave exploration, survey, and inventory. The last camp was completed last week. I talked to project manager Dick Venters who reported that they had located seven new sink holes and three new caves with one blowing tremendous amounts of very cold air. They are excited out in the Capitan Mountains area. This is a new, virgin caving area. Little work has been done over the years. Much remains.

In the Guadalupe Mountains National Park, CRF is involved in ridgewalking, cave location, and cave relocation. For one reason or another, caves have been located over the years and then lost. So, we're busy trying to relocate those caves in this Park.

As a brief history, the Cave Research Foundation - Guadalupe Escarpment Area is successor to the old Guadalupe Cave Survey. It is now entering its fifth decade of service to Carlsbad Cavern National Park. Its hard to realize that work that is being done today is going to be used by people in the year 2050. We regularly use forty to fifty year old surveys. It is exciting, but it also places a great responsibility on CRF and what we do. The rate of new discovery in Carlsbad Cavern is increasing rapidly. I remember on Labor Day 1991, just two years ago, the Cavern survey was at 19.6 miles in length. Today, the cave is at 28.77. So we're busy working trying to do the right thing. We need your input, your help, and we invite your comments.

On a personal note, I am enjoying this meeting. I'm getting to meet people and friends I haven't seen in years. I'm also getting to meet people I've only heard of over the years. Let me say I've enjoyed reading your books. I've been educated by reading your papers and encouraged by hearing your success stories over the years. Thank you.

SOUTHWEST REGION - NATIONAL SPELEOLOGICAL SOCIETY

Jeff Lory

I would also like to welcome everybody to New Mexico. Sorry about the rain! Basically, what we're here to talk about is cave management into the 21st century. What I'd like to talk about this morning is getting to know your resource area and how you go about doing this. Obviously, you have your staff but it also takes a lot of work on the part of volunteers such as what you heard from Pat Helton earlier. CRF and NSS. I'd like to give you an example. Recently the Black Range District of the Gila National Forest asked our local grotto in Las Cruces and the Lucia Valley Grotto to assist in a project in the old ghost town of Hermosa. We were told about a cave there, we didn't know anything about it. Yet here in this ghost town was a cave that had been known about for 100 years and we were just now finding out about it as cavers. We were excited so we went up there and the Forest Service showed us the resource. We said, "Well, we've got a pretty busy schedule but we'll come back and start mapping it." Here about a month ago we finished mapping the cave and we found about 4000 feet. Last spring the southwest area had a regional meeting in this cave resource area in Hermosa and I just got word that a whole new species of spider had been found in this cave.

The other thing I'd like to note in this challenge is to work with your volunteers. Recently we took a young gentleman from Great Britain up into the southern area of the Black Range to show him some of the caves there. A Pastor from the town of Peterson had seen their cave file in the Forest Service office and wanted to get some more information about some of the other caves there. But the Forest Service hardly knew anything about it. It appears now, that the cavers in Las Cruces know more about the cave resources in the area than the Forest Service. So my challenge to you is, all across the country, get out there and try to get to know the cavers, try to get some arrangement to start being shown all of the different resources in the area. I know that the cavers in the Southwest Region are very eager to work with the different government agencies. We want you to know about the resources, we have the Federal Cave Resources Protection Act and in order to implement that act you have to know about your resources.

And that gets me off in to another aspect that people aren't considering. Over five years ago we started a digging project over in Big Manhole cave. This was brought about by the discovery of Lechuguilla Cave. Lechuguilla, before digging was a cave of only a couple hundred feet. What's it stand at now, about 65 miles? They found basically 66 miles of cave by digging. They now have a humongous area of land that they're trying to do gas well drilling in that may effect Lechuguilla. What about the other cave resources in the area? A lot of the natural entrances have been found but what about the zero entrance cave? You've got to find it by digging out there. And you've got to be able to work with the cavers. A lot of us are really enthusiastic about it. That's why in Big Manhole Cave we realized the significance of what we were working with. It has the same potential that Lechuguilla has. We know that cavers across the country are digging. Are you aware that digging is going on in your area? I think it's important that we work together. There may be a lot of scientific information being lost, inadvertently. The cavers for the most part do not want to destroy scientific evidence. But you've got to work with cavers and the cavers have to work with you. So what we're going to talk about this week is some aspects of this. Let's start getting together. Let's start talking to each other. The important thing that I'd like to stress is that when someone is applying for a permit, let's not put it on a back burner for a year, two years, three years. That seems to have happened to some of my projects. It gets kind of disturbing. Also, I think some of the government agencies have to have a willingness to know about the cave resources in their area. Not knowing what's underground is not proper management in my mind set. And I put that challenge to you. That if cavers are willing to go out there and volunteer their time and effort to walk the hills and find the blowing hole and to come back to report to you and to get together. I know that a couple of years ago at the NSS convention we put together an average dig proposal. Steve Kiran and myself got together and came up with a blue print plan of how to mange a cave dig. How to manage your bones that you may find. How to mange the biology that you may encounter and so on and so forth. It's not a complete plan. It probably needs a lot of refinement but above all I think you should tolerate this, because it helps you to get to know your resources.

Recently we came across some information down in the City of El Paso. There were some city workers , they were putting in a city manhole right up next to the Franklin Mountains. They were using a jackhammer. They were using this to dig the hole to put in this manhole for a sanitary sewer so that the line was at the proper elevation so that water would flow downhill. What'd they do? They punched right into the top of a cave. The foreman looked into the hole and couldn't believe what he saw. So they got a small person, rigged up a cable and spotlight, and lowered this guy down into the hole. He shined his spotlight in two directions. Turns out, one of the major arterial streets in El Paso runs up against the mountains. The cave was thirty-five feet deep with seventeen feet from floor to ceiling and only about ten feet of rock holding that street up. What'd they do? Got a piece of plywood, poured some concrete to fill up the hole put in a manhole, buried it and forgot about it. We caught wind of it here about four to eight months ago. I was in the Navy when this happened in the seventies. I didn't think anything of it when I got out, I was on reserve duty down in El Paso and I was talking to these reservists about this cave that had been discovered about two years ago. And I thought to myself, well most of the caves that you find in that part of New Mexico and west Texas are just joint caves and didn't think much of it. Well, we had a new member from back in the New York City area who moved to El Paso recently. And she had been told about this by some friends. So she started doing some digging. Found the story and found the person who wrote the story. She did some more digging to find out that the story was true. The city of El Paso was ignoring a potential hazard right under one of their main city streets. And now, we're trying to get them to open up this resource to make sure that this street does not collapse. Everybody knows about collapsing sink holes. They don't want to know much about this resource and I think that's a tragedy. It could be a hazard to the general population using that street. There may be hazards all across this country. Get to know your resource. That's my challenge to you. To make a long story short, the City of El Paso said, "We want you to come up with $60,000". Then they brought it down to $5,000. Then a private company came in and said they'd drill a test hole for us to lower a camera for $1,000, next to this manhole. So we can lower a TV camera down there and prove to the City of El Paso that there's a big cave down there. We're hoping to make our way in, sometime in the near future.

In closing, all I have to say is try to make some arrangements with all the volunteer cavers. There's a lot of cavers out there that are willing to work with you, the managers. An I know that I'm one person willing to work with you all and my wish for now is that you all enjoy the upcoming sessions. Thank you.

TOOLING UP FOR THE TWENTY-FIRST CENTURY

Jeanne Gurnee

As I look at the abstracts of the papers that will be presented in the next two days, I see an almost ardent dedication by many of the presenters for all caves--from those caves that have been developed for visitors to those that still remain wilderness.

There is an urgency now, brought on by the implementation provisions of the Federal Cave Resources Protection Act which will go into effect on November first. Some who are here today have worked hard to bring this act into being, and now all of us together must strive to define and manage public caves, knowing that their numbers are finite on this continent.

The urgency has many causes, one being that 70 years ago Carlsbad Caverns and other caves in parks were just beginning to be set apart as public lands. Back then the population in the US was near 100 million. Today's population is over 250 million, and the new pressures on our natural resources are well known to us. What was a satisfactory way of doing things in the 1920s, 30s, and subsequent decades will not fulfill the needs and pressures of today. The forethought and purpose of federal agencies to define and protect the cave resource is one of the most important steps in the custodianship of natural lands today.

There are great numbers of people who work full time to save rain forests, wetlands, redwoods, mammals, and every kind of life; but caves--perhaps because they are hidden under the earth where not many of us can see them--have had few champions. Most people have not seen the waterfalls, canyons, crystalline draperies of stone, and pristine rivers under the earth, nor the creatures that adapt to this laboratory-like environment.

The speakers in the next two days will present the techniques for delineating and tending this unique environment. Each of us, according to our own background, education, and experience is offering personal expertise to compile the master database of significant caves. All of us have the opportunity to contribute to this goal so that together we can examine our personal and organizational resources and tool up for the Twenty-first Century. Listed here are some of these resources:

(In the presentation, the following material was accompanied by 35mm slides.)

Fortunately, we do not really have to pioneer a process, because teams of us have been delineating and managing caves for over fifty years; and the National Speleological Society as early as 1953 had performed a two-year study of conservation and management legislation of all the states of the Union. The methods developed those many years ago and followed since contain the three words in our mission: We are dedicated to the exploration, study, and conservation of caves.

If these three process were followed for every cave for which a person or group accepts a responsibility, there would be no need for a law. But in today's world mutual understanding is important to gaining the finished result; and the law is one way of accomplishing that result.

For us, the first word in the mission statement is exploration; and everything stems from this. The Society and its members as well as many here today have been carrying out exploration assignments in many federal, state, and private caves. The method for working with public land administrators is known to many of us who have cooperated in such projects. An example are the caves of the Guadalupe Ridge which, to no one's surprise, does not only contain Carlsbad Caverns, but a group of caves of exceptional interest. A complete issue of the NSS 1979 *NSS BULLETIN* (our scientific publication) was dedicated to a definitive study of Ogle Cave, including maps and studies of the biology, mineralogy and geology of the cave. From such studies, management judgements can be made.

A similar study occurred in Russell Cave National Monument in Alabama. Aside from its archaeological interest, the cave itself is much more extensive than exploration teams had first thought. The map connects it to a second cave, Montague Cave, and because of the presence of water and other indicators, biologists, hydrologists, and other specialists have made studies in preparation for management decisions. The map that our cartographers have prepared of Russell Cave have made it possible for park visitors to see the extent of this cave system.

Each of the NSS Cave Preserves throughout the US has a complete management plan. Over a period of time biologists have made a detailed study of, as an example, Shelta Cave, Alabama; and any planning for interpretive or other use is dependent on the management plan. More land above this cave has just been purchased to further protect the underground environment.

There are many methods for locating a cave entrance; and at Onondaga Cave State Park in Missouri, non-invasive means are used to look at a cave, as a camera is lowered down a hole to photo a room that has never been entered. Some investigators use the Global Positioning System for locations of entrances and prominent karst features.

Once inside cave wilderness, no one understands more profoundly than the first explorers of Lechuguilla Cave the need for caving, as we say, "softly," or as I remember it as one of the first explorers in Sonora Caverns, Texas.

Exploration expertise often involves the climbing methods used and taught by our Vertical Section, a group of over 200 specialists in these techniques using as a text reference the book, *ON ROPE*, written and published by the NSS.

The key to the work accomplished is constant documentation of findings and often the use of monitoring devices. Without this constant record of activity, there is no exploration or accomplishment except in the minds of the explorers who had the original experience.

Mapping is an important element in the next word of the mission statement, *study*. Computers in the field and laptops on the surface fulfill today's needs for immediate reporting and for accuracy. As I write this, I think of the technology of the future and how primitive the design and capabilities of the equipment of today will be to the next generation. Tying in surface features with the underground is vital to give the complete picture.

Project caving of all kinds has been carried out by members for over fifty years so that caves can be delineated and studied not only as a record for the explorer and scientist, but also for those who use the published material as reference, as well as teaching and management tools.

Commonly, the NSS has published studies of individual caves and cave systems authored by those both inside and outside the Society, so that we may serve our common educational goals.

Through our 200 Chapters, Conservancies, Conservation Task Forces, and Sections in the sciences and cave management, we can align ourselves to perform the chore that is ahead. Chairmen of these internal organizations have pledged their help, which in many cases is an extension of the work they are already doing. Among the almost 200 members of the Indiana Karst Conservancy alone, many projects are currently in work including prioritized cave acquisition programs, gating, conservation and restoration projects, installation of new temperature recording devices, taking part in studying the effects of major highway construction across a major karst area affecting cave biota, and a sixteen-month study of Amblyopsis spelaea. It is this group that will co-host the 1995 National Cave Management Symposium with the Hoosier National Forest.

By uniting all of us in a common purpose, this country's speleologists will be able to present a unified source for those seeking information about speleology and the exploration of caves in the US.

All means are used to record findings in a cave--sometimes through art or photography. In one monograph, a pen and ink detail depicted a stalagmite carved the bye Arawak over 1,000 years ago. The study and art representations of the cave's petroglyphs were a strong factor in the decision of a government to make the site a national park.

Water often leads both the explorer and scientist on, including several hundred members that form the NSS Cave Diving Section. We have just added a Florida spring to our land trust program and the water-filled cave provides an exceptional site for study and exploration. Members of both the Cave Diving Section and the US Deep Caving Team are at the cutting edge of technology and are providing their expertise in various federal and state cave systems including those in Florida and Indiana.

And the last word in our mission statement is: *Conservation*. It is a word that all of us understand. Now we must work to make the conservation of caves understandable to all Americans. We experience the rare moments of communion with the wonders underground, and we dedicate ourselves to protecting them--not as a museum does behind glass, but as nature has instructed us: to see, explore, and respect.

That is the ideal, but the reality is sometimes years of neglect and lack of human understanding of the underground. It was not unusual years ago when developing a cave to place spoil from trail building in some corner of a cave that no one would see. Today, our members are clearing this away and in one of the conservation issues of the monthly *NSS NEWS*, photographs show the "before" condition where dirt fill was dumped into a cave crevice. After removal of the soil, a canyon passage was restored.

Restoration of caves, both public and private, has been a dedication of many of our 11,000 members, and Pat Jablonsky will be showing the unusual findings of the teams who have carried out restoration work here at Carlsbad and elsewhere. The techniques are refined and not invasive; and the general public is now treated to a cave that looks closer to its natural state. Even vandalized formations can sometimes be restored; and I remember many years ago our team made what was probably the first formation transplant. Those early transplants are now covered with growing and crystalline calcite, and guides describe the area as one of the most beautiful natural parts of the cave. How to do this and many other techniques to preserve and restore caves are covered in our publications.

As a last resort, sometimes gates are employed; and our Caving Information Series addresses this subject as well as many other specific cave topics.

But perhaps above all, one of the most effective conservation tools is photography, as our Photo Salon members bring what is best about the underground environment to everyone both caver and layman alike. Photographs are a symbol of where the National Speleological Society and all of us stand in offering a human resource of specialists whose prime dedication is to caves.

The slides shown with the above presentation must be seen with the talk to be appreciated; because had it not been for the photographs of Lechuguilla Cave that were given to subcommittee members in Washington, lawmakers would not have been able to understand the treasure that lies beneath us here at Carlsbad Caverns National Park.

It is photos like those and the dedication of many that have brought us to this moment; and we offer you as specialists on federal lands our human and technical speleological resources so that together we can define and preserve our country's underground wilderness.

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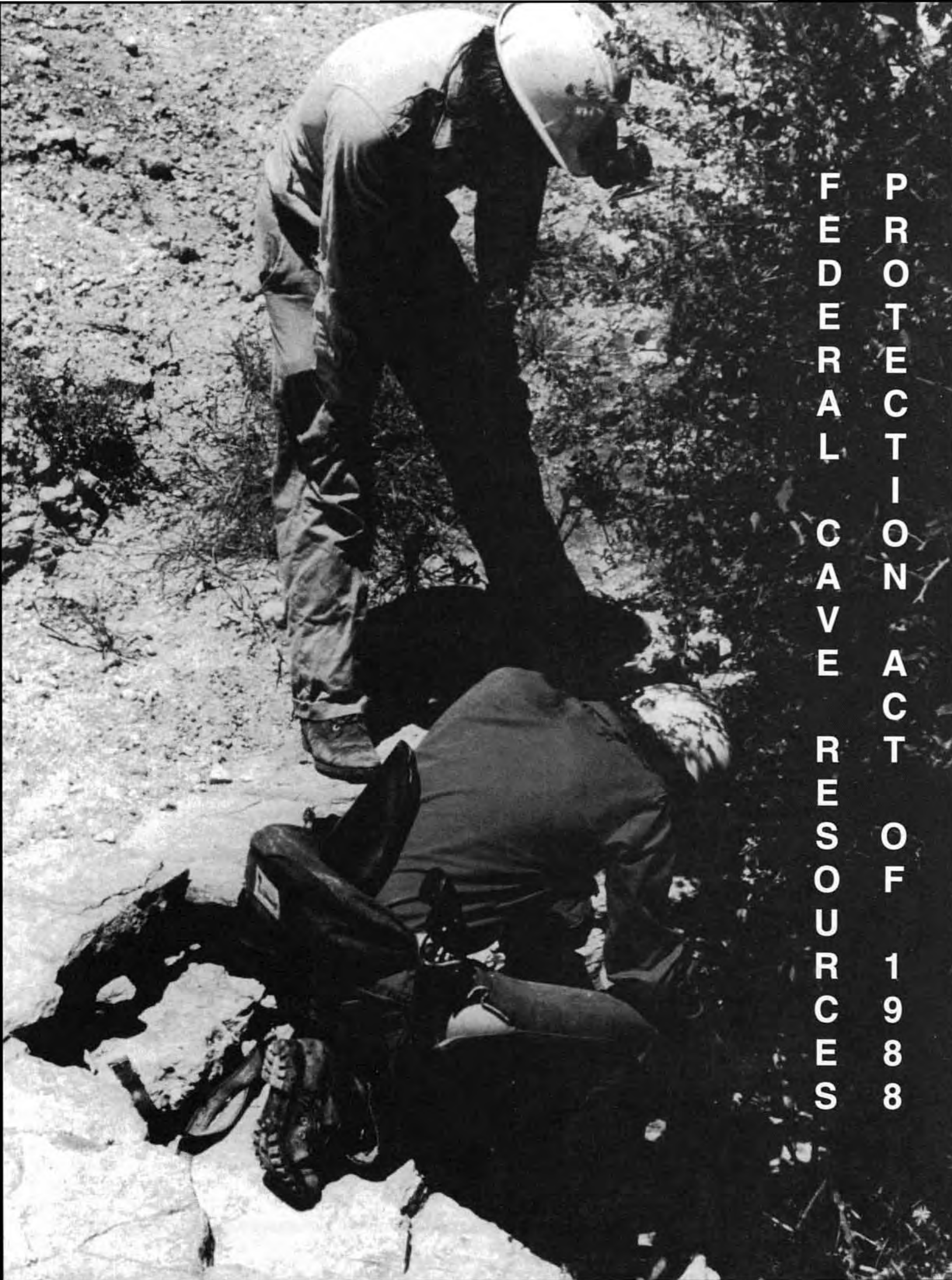
FEDERAL CAVE RESOURCES
PROTECTION ACT OF 1988

Photo Caption -- Ron Fieseler and James Reddell prepare to enter Rambie's Cave, Uvalde County, Texas.

Photo by Dale Pate

CAVE REGULATIONS IMPLEMENTING THE FEDERAL CAVE RESOURCE PROTECTION ACT OF 1988

Del Price
Cave Program Leader, U.S. Bureau of Land Management

I appreciate the opportunity to address you on the Cave Regulations. They have been a long time in coming and we still have a ways to go since the companion Forest Service regulations have not yet been published.

It might be helpful if I gave you a little personal history. I have been the BLM program leader for caves since the mid 1980s. I had the opportunity to review several early drafts of the cave legislation before it was introduced in the House or Senate. I participated in the House and Senate hearings. I can't say that I had a lot of impact on the final product but never-the-less it was interesting to monitor the process.

I was temporarily pulled off the cave program during the initial development of the regulations and didn't reenter the effort until after the first draft had been completed and sent forward to the Secretaries Office for approval. The Secretaries Office returned the draft requesting major changes. By the time I got involved in the development process the basic structure had been set.

Since that time, I have been involved in the long and often frustrating process of developing the proposed regulations which were published in January 1992 and the final Interior regulations which were published on October 1, 1993.

The requirement for developing a regulation was set forth in the Act. It required the Secretaries of Interior and Agriculture to "...issue such regulations as he deems necessary to achieve the purposes of this Act. Regulations shall include, but not be limited to, criteria for the identification of significant caves."

The significant cave provisions apply only to lands under the jurisdiction of the Secretaries of Interior and Agriculture. This includes the Bureau of Land Management, National Park Service, Fish and Wildlife Service, and Bureau of Reclamation in Interior and the Forest Service in Agriculture. The wording in the Act precluded the Bureau of Indian Affairs. Other federal lands such as Defense lands were not included in the Act. Consequently, the regulations apply only to the 5 agencies.

The process for developing regulations requires that a proposed regulation be published in the Federal Register for public review and comment. As mentioned previously, the proposed cave regulations were published in 1992. We received 45 public comments and the Forest Service about 60.

After a careful review of these comments ....

I have no intention of boring you with a line by line discussion of the provisions in the final regulations. You can get most of the information you need by reading them. Rather, I would like to focus on 2 or 3 of the major issues that were raised in the comments on the proposed regulation and discuss how they were treated in the final regulations.

The first issue I will characterize as the "best of the best" issue. The proposed regulations included the following statement:

> "A significant cave....shall possess one or more of the following features, characteristics or values which are deemed by the authorized officer to be unusual, significant, or otherwise meriting special management."

There were also several modifiers in the criteria such as "outstanding", "unique", etc. which left the impression that a cave would have to be special to be listed as a significant cave.

The cavers read these statements and felt that they had been betrayed --- their comments reflected this feeling. They pointed out that it was the federal agencies who had recommended the inclusion of the "significant caves" provisions and their reasons for doing so was to protect them from having to manage "every little hole in the ground". They felt that the proposed regulations were promoting a "best of the best" policy and they pointed out that this was not the intent of the Act.

It may be helpful at this point to review the events that led up to the inclusion of the significant cave provisions in the Act.

The significant caves provisions were added late in the legislative process during the conference between the House and Senate version. The federal agencies were concerned that the cave definition in the Act was so general that practically any hold in the ground, alcove, or overhang would meet the definition of a cave. They proposed a screening process be included in the Act to screen out features which should not be interpreted as caves.

Hence, was born the concept of listing of significant caves. May people, including myself, regret the selection of the term significant because it implies something special when in fact the intent was to develop an "inventory" of caves exclusive of holes in ground, overhangs, alcoves, etc.

Needless to say, the team putting together the final regulation that there were statements in the proposed regulations that at least inferred that a significant cave was something special and these statements were removed. In the preamble to the Interior Regulations we also added a paragraph to clarify this issue.

> "It is clearly the intent of the Act that significant caves include all caves that have value for scientific, educational, and recreational purposes. There is nothing in the Act or the Legislative history that indicates that a cave would have to have 'special value' to warrant designation. Although the work 'inventory' is not used in the Act, it is clear that the significant cave designation process is an inventory process for identifying caves that will require some form of management. the designation of a cave as significant does not require protection of the cave resources, according to Section 2(c) of the Act, which requires that "...federal lands be managed in a manner which protects and maintains, to the extent practical, significant caves." Thus, the effect of the rule would not be analogous to the Endangered Species Act, and the presence of a significant cave would not automatically halt all other activities on the public lands involved. It is clear that Congress intended that the " extent practical" and the type and degree of protection be determined through the agency resource management planning processes (see Section 4(c)(1) of the Act), and not through the significant cave designation process..."

Let me summarize the points covered in this statement:

1. The listing of a significant cave is an inventory process....
2. Significant cave listing does not give a cave special protection status....
3. Agencies must determine the type and degree of protection offered a cave through their resource management planning process with full public participation.

The second major issue raised by the respondents to the proposed regulations concerned the confidentiality provisions. The respondents felt that the confidentiality provisions were applied too broadly. The proposed regulation stated that 'cave location information' would not be subject to provisions of the Freedom of Information Act, but it also inferred, at least in the minds of the reviewers, that other information would be held as confidential.

Once again, the cavers felt they had be betrayed. The way the proposed regulation was written, it appeared that only agencies and educational and research institutions would have access to confidential information --- these were the entities listed under the 'exceptions' provision (see Section 37.12(b)). This would be a real kick in the seat of the pants since in many cases it would be the cavers who would provide the agencies with the cave information through the nomination process and then it appeared they would not have access to it. We made a concerted effort to deal with these concerns in the final regulation.

We changed the confidentiality provision to apply only to cave location information but we interpreted location broadly. For example, the name of a cave frequently is location oriented (i.e., Johns Canyon Cave). In this case, the name would be considered confidential since it would reveal the general location of the cave.

The concern that cavers will not have access to confidential information is a little confusing and complicated but is not true.

The law says that information concerning the specific location of any significant cave may not be made available to the public under the Freedom of Information Act, unless the Secretary (Authorized Officer) determines that disclosure of such information would further the purposes of this Act and would not create a substantial risk of harm, theft, or destruction of such cave.

Conversely, it is clear that the authorized officer may make confidential information available to the public providing it would "...further the purposes of the Act...and not increase risk to cave resources....". For example, if a person walks into an NPS visitor center and asks for the location of the Carlsbad Cavern, the receptionist will likely give them detailed information on the cave location.

The bottom line is that the Authorized Officer has authority to release of confidential information to cavers --- it will depend on the situation.

IMPLEMENTATION OF THE FEDERAL CAVE RESOURCES PROTECTION ACT

Brent Botts
Caves Program Manager, USDA Forest Service
Washington, D.C.

ABSTRACT

The passage by Congress of the Federal Cave Resources Protection Act (FCRPA) in 1988 mandated the Departments of Agriculture and Interior work cooperatively to identify and list significant caves. The proposed rule for establishing criteria to be considered in identification of significant caves appeared in the Federal Register / Vol. 56, No. 246 / Monday, December 23, 1991. The final rule is currently being reviewed.

Proposed procedures to nominate, evaluate, and determine significant caves for listing was made available at the time the proposed rule was published. Draft procedures for implementation of the (FCRPA) have now been established following consultation with the Secretary of the Interior and analysis of comments received from reviewers. Finalization of these precedures will be effective upon publication of the final rule implementing (FCRPA).

Once the final regulations are promulgated, the Act provides that agency land managers will have one year in which to develop an initial list of significant caves under their jurisdictions.

The listing of significant caves invloves two separate processes. The initial listing process of known caves and subsequent listings of newly discovered caves, caves that were not submitted previously, or caves that have had additional evaluation of criteria that might indicate significance. The subsequent listing will continue indefinitely. Both processes involve three general steps: (1) nomination, (2) evaluation, and (3) determination. An outline of the process explains how each step will be accomplished.

Implementation of the cave regulations is an interagency effort. There are five Federal agencies and two Departments involved in the implementation procedures, the Bureau of Land Management, Bureau of Reclamation, Fish and Wildlife Service, National Park Service of the Department of Interior and the Forest Service of the Department of Agriculture. It is anticipated that thousands of caves will be nominated for consideration in the initial listing.

In order to coordinate a national process for nominating, evaluating and determining cave significance that was constant from one agency to another, an interagency meeting was held in Denver October 5 through October 8, 1992. Attending the meeting were cave management specialists from the five agencies and the National Speleological Society.

The discussions centered on the process for the initial listing of significant caves. The discussions were broken into five areas:
The discussions were broken into five areas:

Interagency Review Teams
Nomination Process
Evaluation/Decision Process
Designation/Documentation/Dissemination Process
Handling of Confidential Information

From discussions on the above topics, the group recommended the following actions for implementation of the cave regulations:

1. **Establish Interagency Review Teams to provide technical review of the cave nominations and National Oversight Teams to facilitate work and insure consistency.**

   Both Regional Interagency and National Oversight Teams were recommended. The role of the Interagency Review Team is to:

   1) Review nominations and make recommendations to the authorized officer.
   2) Establish a collection point for nominations.
   3) Insure that nominations comply with regulation criterion and determination of completeness of the applications.
   4) Acknowledge receipt of application to applicant and notification to applicants if application is incomplete.
   5) Track all applications and forwarding of information to agency representative on national oversight team.

The need to continue the Regional Teams will be evaluated annually by the National Oversight Team. The decision to continue the teams will depend mostly on the number of subsequent nominations after the initial listing period. The Regional team shall be an interagency team of individuals knowledgeable about caves. Agencies shall be represented as appropriate, no more than two representatives from any one agency, with a maximum of five members on a team including the team leader. The team may utilize experts outside the government if needed. The members shall be appointed by the agency heads. Each agency will set criteria for selection stressing knowledge of cave resources. The regional team will transmit findings to the authorized officer. It was recommended that the signing authority for final significance determination be designated to the lowest line officer level possible for each agency.

The role of the National Oversite Team is to:

1) Facilitate work of the regional review teams.
2) Provide training for regional teams or leaders to standardize processes, responsibilities.
3) Provide written guidance to the authorized officers.
4) Insure agency compliance with regulations and implementation procedures.
5) Disseminate information to the teams and agency.
6) Establish quality assurance for the listing process.
7) Develop an interagency agreement, one assuring interagency coordination and cooperation.
8) Review annually the need to continue the Regional Interagency Teams.

The National Oversite Team is intended to be an ongoing Interdiciplinary Team consisting of one national program manager from each agency. These individuals should be knowledgeable about caves.

2. **Establish six geographical regions with an interagency review team for each region.**

   * Northwest Region---WA, ID, OR, AK
   * Central West Region---MT, WY, SD, ND
   * Western Region---CA, NV, HI
   * Southwest Region---CO, UT, AZ, NM, Western TX
   * Northeast Region---New England, PA, MI, WI, WV, MD, IL, IN, MO, IA, ME, DE, RI,
   * Southeast Region---Eastern TX, OK, LA, AL, AR, KY, TN, VA, NC, SC, FL, GA

3. Funding for these teams will be borne by each participating agency with the lead agency providing administrative support.

For each regional area the agency with the most potential cave nominations will become the lead agency. Regional leadership responsibilities are shown below:

* Northwest Region---USFS
* Central West Region---NPS
* Western Region---BLM
* Southwest Region---BLM
* Northeast Region---USFS
* Southeast Region---FWL

4. Discussed and developed nomination procedures and tracking processes to insure that applications are not lost and/or not acted upon.

During the initial listing period, nominations shall be collected at local offices and channeled to the regional review teams. Non-profit organizations such as the NSS may collect nominations and forward. The regional review teams will acknowledge receipt of the nominations and log them in to track evaluation process.

Discussed how we will get the information out to the public for action. Discussed the creation of a Significant Cave Worksheet to help in nomination process and tracking. We discussed the times allowed for the initial listing period and what information should be in the nomination and on the worksheet.

From the approval of the regulations we have allowed for:

One month for notification of publics.
Five months for nomination process.
Three months for Regional Team review and recommendation
Three months for authorized officer decision

Subsequent nominations will be an ongoing process; the regional team will meet as needed or at least annually. When it is determined that the regional team is no longer needed, the authorized officer will receive the nominations and make decisions within 6 months of submission.

Duplicate nominations will be logged in individually and grouped together.

Incomplete nominations will be returned for additional information.

The regional team leader will receive and log in each nomination by cave name, date application was received, name of person making the nomination, agency location where cave is situated, and tracking path. The team leader will also review the nominations for completeness, returning them for more information if needed.

For nominations with adequate information, the team will evaluate the nomination against criteria in the implementation regulations. If the cave meets the criteria, the application will be forwarded to the appropriate authorized officer for a determination of significance. A copy of the log will be forwarded to the appropriate National Oversite Team representative.

Team decisions will be made through consensus.

Regional team leaders will have the following roles and responsibilities:

* Assure that the review only addresses the criteria and that it doesn't become a "ranking" exercise.
* Handle and sort all applications and provide logistics for all meetings.
* Responsible for making sure process is completed.
* Track applications (logs).
* Chair all meetings.

Authorized officers will have the following roles and responsibilities:

* Receive recommendations from regional review teams.
* Verify questionable data relevant to the evaluation process and consult with nominator, internal staff, interagency staff and/or consultants.
* Make final determinations.
* Notify national oversite team representative through appropriate channels of determinations concerning individual caves.
* Notify nominator of findings.
* Assure that information retained is maintained in a confidential manner.
* Insure interim protection of caves pending determination.
* Insure determinations are reflected in agency planning process.

The authorized officer will process applications in the following manner:

1. If the finding (determination) is YES, the application will be retained. Notify National Oversite Team of decision.

2. If the finding (determination) is NO, the application is returned to the applicant. Notify National Oversite team of decision.

3. If data/application needs to be verified, pending final determination, files will be retained until that time. Status will be reported to the applicant and the National Oversite Team.

4. If no response is received from a nominator within three (3) months of a request for additional information, the application will be considered inactive. This status will be reported to the applicant and the National Oversite Team. (The applicant may re-nominate the cave at any time additional information is available.)

Who will be the authorized officer?

The team recommends that the lowest line officer in each agency be appointed.

5. Designation/Documentation/Dissemination Process

How will designation be documented?

A permanent file will be retained for each cave by the authorized officer and/or appropriate field unit. The following information, at a minimum, will be maintained:

1. Record of Decision.
   . Name of cave
   . Decision (yes or no)
   . Rationale (use check list of criteria and narrative if "no".
2. Signature/Date
3. Memo/transmittal letter with decision record to nominator and agency reps.

Where will the listing of significant caves be kept?

1. The individual administrative unit will keep cave files and maintain a listing of significant caves in their administrative area.

2. The National Oversite Team will have copies of logs.

How will a call for nominations be announced?

* A press release prepared by each agency will be distributed to:

  1. Special interest groups (NSS, CRF, ACCA, IKC, BCI, NCA, etc.) for publication through their newsletters.

  2. Environmental groups (NPCA, Sierra Club, Audobon, etc.)

  3. Other media is discretionary.

Subsequent nominations after initial (one-year) nomination period.

Nominations will be made directly to local administrative offices where the authorized officer will establish a log of all nominations and their dispensation. Copies of the logs will be sent (at least) annually to the National Oversite Team. Acknowledgement of receipt of a nomination will be sent to the nominator generally within one week. Nominations will be reviewed and processed and a determination made. Following the determination, the nominator will be notified of the finding. For any cave not listed, the nomination will be returned to the nominator.

Special interest groups, or anyone, wanting to nominate a cave may do so at any time through the appropriate local administrative office.

Security Actions

To maintain security of information concerning significant caves, or caves in the nomination process, the following actions are recommended:

1. Assure all information is kept under lock and key with access by authorized personnel only.

2. Appoint an individual as keeper of the information and all requests be channeled through that individual. An alternate person may also be authorized.

3. Assure that public contact persons are carefully instructed and trained in confidentiality requirements and that information concerning significant caves is not accidentally given out.

6. The team wished to make clear that the information contained in the nomination remain confidential as specified in section 5 of the Federal Cave Resources Protection Act.

The following guidelines will be followed to assure confidentiality of information contained in nominations:

* Information will be kept confidential throughout the process. Even if a cave is not designated, it will remain confidential and theinformation will be returned to the applicant.

* All offices are instructed to maintain confidentiality through the entire process.

* On all applications and work sheets "CONFIDENTIAL" is to be prominently printed or stamped.

* The need for confidentiality will be stressed in all training sessions.

7. To facilitate cooperation between the involved Departments of Interior and Agriculture agencies, the team recommended that an interagency agreement be developed.

An interagency agreement will be drafted to coordinate implementation of the act and to facilitate cooperation between departments. Drafting the agreement will be the responsibility of the National Oversite Team and will include details describing how the agencies will work together and standardized procedures which will be followed.

8. The team wanted to emphasize that determination of significance is an inventory process and does not constitute a land-use allocation decision.

The Federal Cave Resources Protection Act requires that a determination of significance be made before the authorities provided by the act can be applied. In designating a cave "significant," no land-use allocation is made. All land-use decisions will continue to be made through the land-use planning process. Listing of caves is viewed as beneficial to resource management and is strongly encouraged.

Both listed and non-listed caves will be managed through forest plan standards and guidelines, and FSM 2356. Listed caves will have the benefit of additional management authorities provided by the act.

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CAVE RESTORATION & MONITORING

Photo Caption -- Volunteers mend a large, broken stalagmite in Endless Cave, Eddy County, New Mexico.

Photo by Val Hildreath

SETTING UP A LONG-TERM MONITORING SYSTEM AT TIMPANOGOS CAVE NATIONAL MONUMENT

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&
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ABSTRACT

In order to develop a long-term cave monitoring system at Timpanogos Cave National Monument, preliminary data had to be gathered. Initially; survey, inventory, GIS, geology, hydrology, and photomonitoring projects were completed. From this data, major sections of the cave were identified. Next, we determined what types of resource management questions we had and what type of data would answer those questions, specifically looking at the hydrological and environmental systems. Once those steps were completed, the resource management staff developed a long-term monitoring system. The cave monitoring system was designed to obtain the goals of the resource management office, which included: documentation, restoration, mitigation, research, and preservation of the delicate cave systems. The automated system involves a series of dataloggers, probes, drucks, and rain buckets, along with a line monitor, storage module, and keyboard. The manual system involves collecting additional drip rates, recording selected lake levels, and hydrochemical sampling. Temperature, humidity, lake levels, drip rates, and light-switching information is downloaded periodically and entered into a spreadsheet program and then dumped into a graphing program for analysis. The final step was to develop an ongoing data-analysis program. Once the data is graphed, it becomes a valuable tool for current and future cave management.

INTRODUCTION

The Timpanogos Cave System is located on the south side of the steep-walled American Fork Canyon, Utah County, Utah. Timpanogos Cave National Monument was created by Warren G. Harding in 1922 to protect the "unusual scientific interest and importance" of these caves. The caves are accessed by a 1 1/2 mile long trail that gains 1,065 vertical feet. The cave system consists of three main caves, Hansen, Middle, and Timpanogos Cave, each with a natural entrance (Figure 1). There is a total of 5,500 feet of passage, with a vertical relief of 185 feet. The caves are located an average of 150-400 feet below the surface and range in temperature between 43-49 degrees F. The caves have formed along three minor faults and the bedding planes in the Tetro and Uncle Joe members of the Deseret Formation. They are highly decorated and are most known for their profusion of delicate helictites and anthodites. They are also known for their unique origin and a rich cultural history dating back to 1887. The caves are located at an elevation of 6,700 feet. Due to severe winters, the caves are only open to the public six months of the year. The caves have been connected by two man-made tunnels, creating a one way tour roughly 1,800 feet long. Between 60,000-80,000 visitors tour the caves each season. This article documents a four-year (1990-1993) project to develop an automated, long-term cave monitoring system within the Timpanogos Cave System. This system was set up to provide scientific documentation for current and future cave management decisions at the Monument. This system will help achieve a number of goals that the Monument has, including:

- Document changes in the environmental or hydrological systems
- Restore the cave to its natural state
- Mitigate effects of commercialization
- Determine effects of unnatural pressures put on the cave
- Preserve delicate environmental and biological systems
- Fulfill the purpose and mission of the National Park Service

Although the project officially started in 1990 (Tranel, 1991), some of the data used was collected as early as 1986. The installation of this monitoring system fills the requirements outlined in the current cave management plan, part of the Monument's general resource management plan (Horrocks, 1992).

To set up an automated monitoring system in the caves, several preliminary steps were necessary. First, some preliminary data needed to be gathered so that major sections of the cave could be identified. With the cave system divided into major sections, it was necessary to determine what types of resource management questions we had and what type of data would answer those questions. Next, a monitoring system was set up to study and document the hydrologic and environmental systems found within the caves. The final step involved developing an ongoing analysis program.

IDENTIFYING MAJOR SECTIONS

In order to set up a long term cave monitoring system at Timpanogos Cave National Monument, it was first necessary to divide the cave into major natural sections. Several types of detailed preliminary data were needed to divide the cave system into sections, including: survey, inventory, GIS, geology, hydrology, and photomonitoring. With the completion of these preliminary projects, the cave was divided into natural sections. This division was necessary because this cave system, like most, can be divided into a series of unique areas or sections. The differences between sections can be obvious, like passage morphology, or very subtle, only identifiable by using delicate sensors. The geological structure often contributes to the creation of these separate hydrological and environmental systems. These natural sections were identified by a combination of features and conditions present that make them unique. When the cave was commercialized, we further divide the caves into sections, areas that have tours and areas that don't. By allowing tours in the cave, we alter environmental conditions, creating microsystems. Only detailed studies and looking at a combination of factors allowed us to completely differentiate between these sections.

PRELIMINARY DATA GATHERING

Detailed survey, inventory, GIS, geology, hydrology, and photomonitoring projects provided the necessary preliminary information on the geologic, hydrologic, and environmental systems present in the caves. Ultimately, this combined information helped us identify major sections in the caves.

A surveyed baseline, created using foresights and backsights and recoverable points, was established for each major passage in the caves and surface traverses between entrances. Plans, profiles, and cross sections were sketched at a scale of 4 meters to the inch for all survey lines. Accuracy was assured through numerous loop closures with errors kept, for the most part, under 1% (Electrical wiring and pipes caused errors up to 1 1/2% in some areas). The survey data was then processed on a Macintosh cave survey processing application called CavePlot.

Features in the caves were inventoried as the survey progressed. All inventory data was tied to the nearest survey station. Inventoried information included: speleological, geological, hydrological, historical, and biological features along with hazards and vandalism. This information was noted on an established inventory form (TICA-21), which was photocopied on Rite In The Rain paper and included in the survey books.

The survey and inventory data was then entered into a Geographic Information System

(GIS) designed for cave data. Eventually, many different data layers will be created relating to the cave, including: surface contours, surface geology, electrical systems, trails, and monitoring system information. Coupled with the long-term monitoring system, this information will be an invaluable resource management tool.

To study the entire geologic system, both the surface geology and the cave geology were mapped. This involved making a geologic map of the Monument and a detailed stratigraphic section of the rocks exposed inside the Monument. Likewise, the underground geology was mapped. Five types of geologic features were mapped on a plan map of the cave system, including faults, joints, domes, bedding planes, and natural fill. In addition, detailed geologic cross-sections were completed at strategic locations throughout the caves. This combined information proved valuable in deciphering the hydrologic system and identifying major sections.

To better understand the hydrologic regimes, several aspects of the groundwater system were studied, including the nature of the flow paths, water chemistry, relative flow-through times, flow routes, and the extent of the cave watershed.

The major hydrologic regimes in the cave system were further defined by looking at the hydrogeology, specifically the nature of the flow paths. Several geologic observations were factored in, including the strike and dip of faults, joints, and bedding planes and the distance passages are located below the surface.

To better understand the nature of flow paths from the cave watershed to the cave, the hydrochemistry of snow from the watershed and drip water from the cave and its lakes were looked at. Both solute and isotopic chemistry were analyzed from four lakes and three drip rate points in the cave system. Samples were collected monthly the first two years and quarterly the third year. Ph and temperature of these samples were determined in the field, and samples were collected and taken back to the laboratory for analysis. The solute chemistry involved determining saturation indices for calcite, aragonite, dolomite, and magnesite. The isotopic work involved analyzing tritium, CO13, Determinate O, and Sulfur 34.

Flow-through times were determined by selecting fourteen drip rate points and five lakes, several from each of the major cave sections. Using graduated cylinders, drip rates were manually measured weekly for a three-minute interval. Where the drip was too slow for hand collection (<.01 ml/3 min.), a pyrex flask was left for a week. An average volume/minute measurement was then calculated from the weekly total. This information was recorded on an established Drip Rate Form (TICA-23). Lake levels were observed from graduated stage meters. All of this data was then typed into a spreadsheet program (QuatroPro) and transferred into a graphing program (Sigma Plot), where it could be graphed and more easily analyzed.

Flow paths were further documented with a dye tracing project. Rhodamine dye was used in an unsuccessful attempt to trace the stream at the bottom of Soda Pop Pit. Optical brighteners and fluorescein will be used to trace water from the cave watershed into the cave itself.

The boundaries of the cave watershed were also mapped and a weather station was installed at the top of the watershed (Figure 2). Precipitation, temperature, and relative humidity are gathered from this remote station. This station is automated by a CR10 datalogger and powered by a solar panel. Data is periodically downloaded using a storage module.

Photomonitoring points were established along the paved trail in each of the caves. Each individual station was etched into the cement trail. A series of overlapping photos were then taken up one wall, across the ceiling, and then down the opposite wall. Each photomonitoring trip was documented on an established Photomonitoring Sheet (TICA-20). Such information as roll number, station, frame, camera height, bearing, lens angle, f/stop, and distance from subject among other things was recorded.

MAJOR SECTIONS

Once the survey, inventory, GIS, geology hydrology, and photomonitoring projects were completed, major sections were identified. Major sections were based upon general characteristics of the hydrologic, geologic, and environmental systems. Since the general geologic structure of any given section of the cave also affects the hydrologic and environmental systems, this criteria was heavily weighted when delineating major sections of the caves. The inventory was specifically used to look at secondary speleothem types and concentrations, also a good indication of separate hydrological sections.

Five major sections were identified in the Timpanogos Cave System based upon geologic structure, passage morphology, entrance location, speleothem inventories, air temperature, and winds. It was found that each of these sections has unique characteristics. Sections identified were: Hansen Cave, Middle Cave, Heart of Timpanogos, Timpanogos Fault, and Soda Pop Pit.

Table 1. Major sections of the Timpanogos Cave System and their characteristics.

Section	Characteristics
Hansen Cave	Oblique Strike-Dip Passages, 200 Feet Below Surface, Hansen Fault, Conduit Flow, 45 Degree Temperature, Massive Secondary Speleothems, and Sandstone Unit
Middle Cave	Middle Cave Fault, Fissure Passages, 150 Feet Below Surface, 46 Degree Temperature, and Strike Passages
Heart of Timpanogos	Dip Passages, 48 Degree Temperature, Diffuse Flow, and Speleothem Types
Timpanogos Fault	Fault, Diffuse/Conduit Flow, Fissure Passages, and Massive Secondary Speleothems
Soda Pop Pit	Vertical Nature, 43 Degree Temperature, Wind, Boneyard, Stream Slots, Stream

MONITORING SYSTEM

The monitoring equipment is capable of monitoring the hydrologic and environmental systems found within the caves. With the major sections identified, we needed to determine what types of resource management questions we had and what type of data would answer those questions. We needed to design a system that would monitor hydrologic and environmental systems in all major sections of the caves and help us obtain our goals in resource management. We then had to determine which sites we wanted to monitor and what type of information we wished to document from each site. Finally, we needed to set up an on-going data analysis program.

WHAT NEEDS TO BE MONITORED

A combination of automated and manual data collections are used to collect hydrological and environmental data. The data collected had to satisfy the goals of the resource management plan. These goals involved: documentation, restoration, mitigation, research, and preservation.

The hydrologic systems needed to be monitored to help us understand the nature of the flow paths, water chemistry, relative flow-through times, flow routes, and the extent of the cave watershed.

The environmental systems needed to be monitored to determine the range of temperatures, the percentage of relative humidity, and the effects of chimney-effect winds.

This monitoring system would be used to document any subtle changes in the environmental or hydrological systems, changes that would likely be missed by observation alone. Due to the capability of combining different types of data into graphs, previously unrecognized patterns could also be found.

Returning the cave to its natural state would concentrate on impacts from previous mining activities in the cave. Literally hundreds of tons of tunnel blasting and mining debris have been dumped in the cave system. Not only have natural hydrological drains and lakes been filled in, but growing formations were buried.

Mitigating the effects of commercialization would concentrate on dust, lint, algae, and cement introduced to the caves. It would also look at alteration of environmental conditions in the caves.

Determining the effects of unnatural pressures put on the cave would concentrate on what effect pumping the lakes in the cave has on the delicate cave systems. Later, increased CO2 levels, due to nearly 80,000 visitors a year, may be looked at.

Preserving the delicate environmental systems would concentrate on the altered air flow patterns created when the caves were connected by tunnels. Specifically, chimney-effect winds would be looked at.

Fulfilling the purpose and mission of the National Park Service would involve preserving the natural and cultural resources found in the cave system for the enjoyment, education, and inspiration of this and future generations.

EQUIPMENT

Most of the automated equipment used in this particular monitoring system is Campbell Scientific equipment. The monitoring system consists of dataloggers, a keyboard display, temperature/relative humidity probes, drucks, tipping buckets, line monitors, and a storage module. Other necessary items include a PC and software.

The dataloggers, or microloggers, are model CR10. This piece of equipment is a computer that allows the entry of programs which retrieve, process, and store data in final memory storage. The CR10 allows manual input from a keypad or automatic downloading from a PC via a storage module. There are 64K of available memory storage. The CR10 allows six or a maximum of twelve input channels from sensors. It can be powered by a stand-alone 12 volt battery, a 12 volt battery and an AC charger, or by solar panels.

The keyboard display is a CR10KD. This unit allows manual input of programs and display of programs and data. Although, programs can be written with this device, composing them with PC208 software on a PC is easier. However, being able to make minor changes with the keyboard is useful.

The temperature/relative humidity probe is a model HMP35C. This small sensor can be mounted inside a protective lantern housing and attached to a pole.

The druck is a model PDCR 950. This pressure transducer is used to measure lake or stream levels. This piece of equipment is sensitive to electrical charge, and shouldn't be used if any electrical wiring from lighting systems discharges into the water.

The tipping bucket used is a model TE525. This tipping bucket measures precipitation or drip rates. Because the amounts are figured in inches or cm/per given time period, this information had to be converted to volume measurements to be compared to the manual drip rate points.

The line monitor used is a model ACL1. This detector senses when lights or pumps are turned on or off.

The storage module used is a model SM192. This device is used to download data from the CR10 to a PC. The datalogger automatically downloads its final memory storage to the storage module when it senses the storage module has been connected to it. This device can also be used to upload programs to the CR10.

An IBM compatible computer is used for all aspects of data analysis and storage. A computer with four meg of RAM, a math coprocessor, and a 80386 CPU is recommended.

Software packages required to run the system and analyze the data are PC208 (datalogger database), QuatroPro (a spreadsheet), and SigmaPlot (a graphing program). These applications work best with DOS 5.0 or higher.

MONITORING

The cave monitoring system automatically monitors several types of data, including: temperature, relative humidity, lake levels, drip rates, precipitation, light and pump switching, and battery voltage. However, some manual data collection is still performed, including additional drip rates, easily accessed stage readings, and hydrochemical sampling.

Air temperature is taken every 30 seconds and then averaged every two hours. A high and low for each 24 hour time period is also recorded.

The relative humidity is taken every 30 seconds and then averaged every two hours. Since the relative humidity probes aren't designed for use in constant 100% humidity environments, they require extra maintenance.

The lake levels are taken once every 24 hours at the remotely located sites. Due to the cost of these probes and the simplicity of manually reading a stage meter, the lakes adjacent to the trail are all read manually. Experience has shown us that the lakes don't oscillate like drip rates do, but they experience a gradual curve (Figure 3). Based on this observation, using expensive drucks to monitor easily accessed lakes at Timpanogos Cave was deemed unnecessary.

Drip rates are collected in a rain bucket and are accumulative each hour as well as daily. The type of drip rate data obtained is reflective of the collecting method used. Tipping buckets are the most desirable, since they provide continuous measurements. However, since they measure in a linear measurement, inches per unit of time, they must be converted into a volume measurement, ml per unit of time. Manual measuring using a graduated cylinder measures a specific point-in-time measurement. This method misses many precipitation events that occur between measurements. Since this method also misses the oscillate nature of drip water, the graphs tend to be smoothed out (Figure 4). Collecting drip rate water in a flask averages the entire collecting period out, creating a spiky graph.

Precipitation is recorded every five minutes if an event has occurred. The 24 hour total is also recorded. The accumulative precipitation is also recorded. Like the drip rates, this information is collected in inches per hour and is difficult to compare with ml/min.

The line monitor records when lights or pumps are turned on or off. This device was used to determine if the lighting affected temperature.

Battery voltage checks are drawn to monitor for power failures. When the voltage drops below 10 volts, the datalogger can be programmed to automatically shut down, in order to preserve data.

Solute chemistry sampling was conducted monthly and isotopic sampling was done quarterly. Temperature and pH were measured in the field at the time of sampling.

MONITORING SITES

After looking at the preliminary data gathered during the four-year project, the major sections, and resource management goals, we were able to determine which sites we wanted to monitor for the long term and what type of information we wanted to monitor.

Temperature and relative humidity are recorded at all monitoring sites. Lake levels are only recorded at the remote sites, Hansen Lake and Soda Pop Pit. Drip rates are continuously recorded at three spots with a tipping bucket, one in each of the three caves. Four other drip rates are recorded manually to insure that some data is collected from each of the major sections of the cave. Lake level readings are manually recorded for two lakes located near the visitors trail. Hydrochemistry is sampled for seven sites in the caves and in the cave watershed.

Table 2. Monitoring Sites and what's monitored at each.

Site	Drip Rate	Temp.	RH	Lake Level	Hydrochemistry
Hansen Lake*				X	X
Hansen Lake Single*	X				X
Hansen Entrance Room*		X	X		
Middle Cave Lake+				X	X
Middle Cave Double+	X				X
Middle Cave Column+	X				
Big Room Fill+	X	X	X		
Hidden Lake=				X	X
Chimes Chamber Drip=	X				X
Lower Passage**		X	X		
Upper Passage**		X	X		
Saint Bernard Drip**	X				
Soda Pop Pit++	X	X	X	X	X
Cave Watershed	Precipitation	X	X		X

Sections

* Hansen Cave
+ Middle Cave
= Heart of Timpanogos
** Timpanogos Fault
++ Soda Pop Pit

DATA ANALYSIS

The most crucial part of the entire system is an ongoing data analysis program. Without this program voluminous amounts of data would be stockpiled, become overwhelming, and eventually lose value. At Timpanogos Cave, a Physical Science Technician is responsible for weekly downloading the CR10's and collecting manual drip rates and lake stage readings. The technician then downloads or manually enters both types of data into a spreadsheet. This data is then transferred to SigmaPlot where it is graphed. Graphs are then analyzed for any situation the Resource Management Specialist should be made aware of, including malfunctioning equipment. Sometimes various combinations of files are requested to answer a particular resource management concern.

Many different resource management concerns can be addressed regarding the temperature and relative humidity, lake levels, and finally drip rates. When looking at temperature and relative humidity, concerns such as visitor effects, opening and closing of doors, and the lighting systems can be analyzed. When looking at drip rates and lake levels, the effects of flow paths, flow-through times, the cave watershed, pollution, and the dissolution or precipitation of speleothems can all be analyzed.

During the course of the project, many important observations were noticed relating to hydrologic flow regimes, hydrochemistry, temperature, and relative humidity. It became obvious that the cave could be divided into natural hydrogeologic sections. Ultimately, the caves were divided into five distinct sections.

The hydrochemistry of the drip water and lakes were analyzed. The temperature and pH were determined in the field, while the solute and isotopic chemistry was contracted out. This analysis confirmed that evaporation plays a significant role in saturation of the air and precipitation of secondary minerals in the caves. The greatest effect from evaporation was seen in the shallow lakes, Cavern of Sleep and Hidden Lakes, while the deeper Hansen Lake showed a limited effect. Although no effect from acid precipitation has been found, a baseline has been created that can be referenced in the future (Tranel, 1991).

The temperature in the caves remains relatively constant until a couple of weeks before the season starts, at which time it starts to fluctuate a little (Figure 5). This corresponds with the time that maintenance crew begins getting the cave ready for tours. When the first tours start, the temperature raises 1/2 degree every time a tour passes the sensors (Figure 6). The temperature finally flatlines the day the season is over, when human activity in the caves stops.

Although relative humidity is a constant 100%, except near entrances, evaporation proved to be an important component of calcite deposition. This suggests that the balance between temperature, relative humidity, calcite saturation levels, and recharge rates must be a delicate one (Tranel, 1991). Due to this fact, monitoring the temperature increase when a tour comes through becomes important.

SUMMARY

Before a long-term cave monitoring system could be set up, preliminary data collection, study, and analysis were required. This was followed by an identification process whereby major sections of the cave system were outlined. Based upon this information, a monitoring system was designed. Once the long-range cave monitoring system was in place, the collection of drip rate information and the downloading of data loggers was a routine job that could be carried out by a Physical Science Technician. This technician is now in charge of imputing the data into the computer, data management, and preparing it for analysis by a Resource Management Specialist (Figure 7). This Resource Management Specialist is also in charge of programming and maintaining the monitoring system. This process is an on-going process that allows the manager to periodically create new graphs, using various data combinations. It also prevents the accumulation of more data than can be handled. These graphs then become a valuable aid in making resource management decisions.

ACKNOWLEDGEMENTS

The vision and much of the backbone for starting this project can be attributed to Michael J. Tranel, the former Chief of Interpretation and Resource Management at Timpanogos Cave National Monument. A significant amount of work was also performed by Patrick Smith and Becki J. Cluff, Physical Science Technicians at Timpanogos Cave National Monument. Volunteer, Larry Martin provided invaluable technical advice and labor towards the completion of several of the preliminary projects. Literally hundreds of volunteers from the National Speleological Society, Boy Scouts of America, local Junior and Senior High Schools, and students from Brigham Young University helped on various resource management projects. During the four-year project, nearly 8,000 hours of volunteer help was donated. A project of this magnitude could never have been completed without their combined help.

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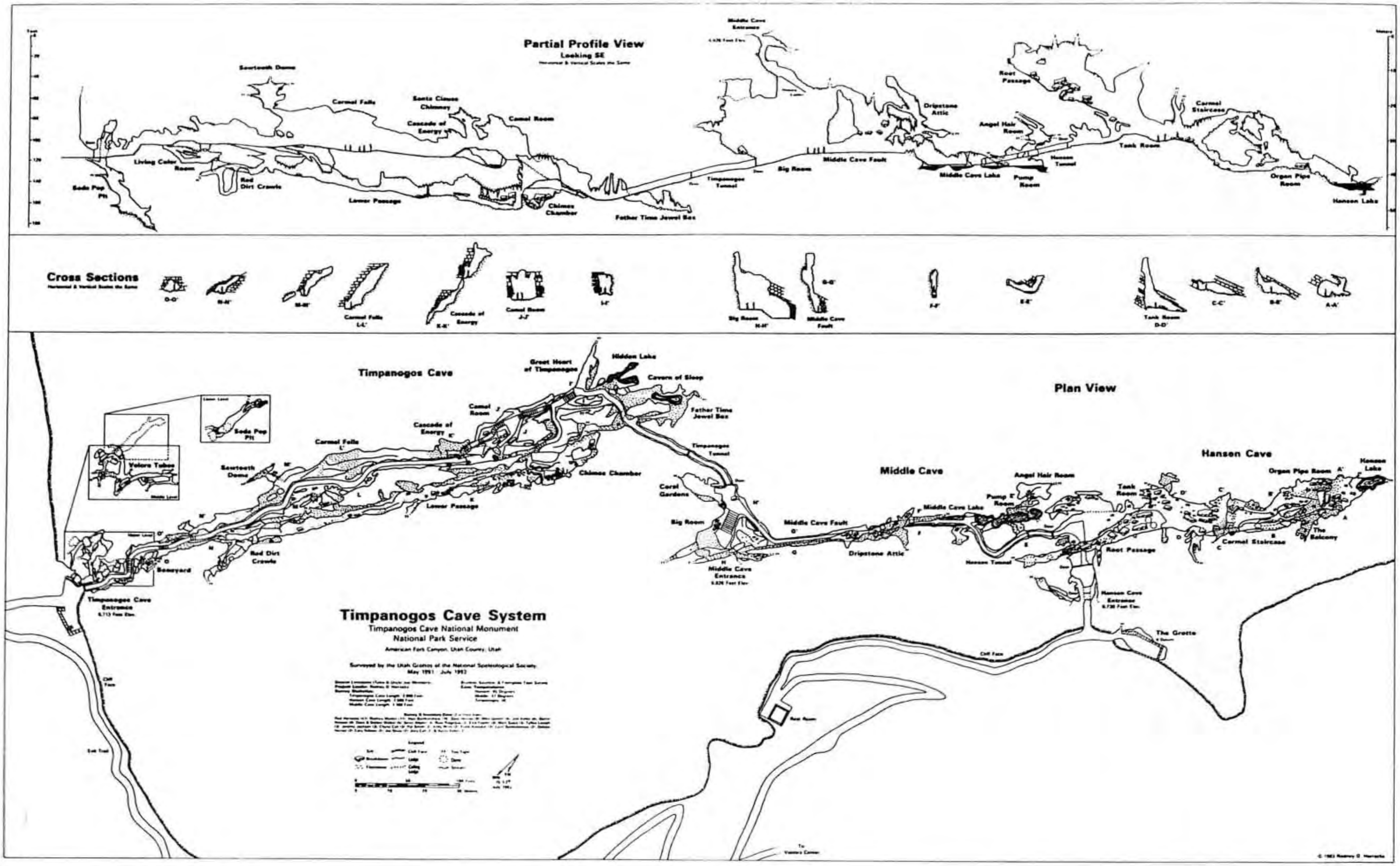
Figure 1. Map of the Timpanogos Cave System, which includes Hansen, Middle, and Timpanogos Caves.



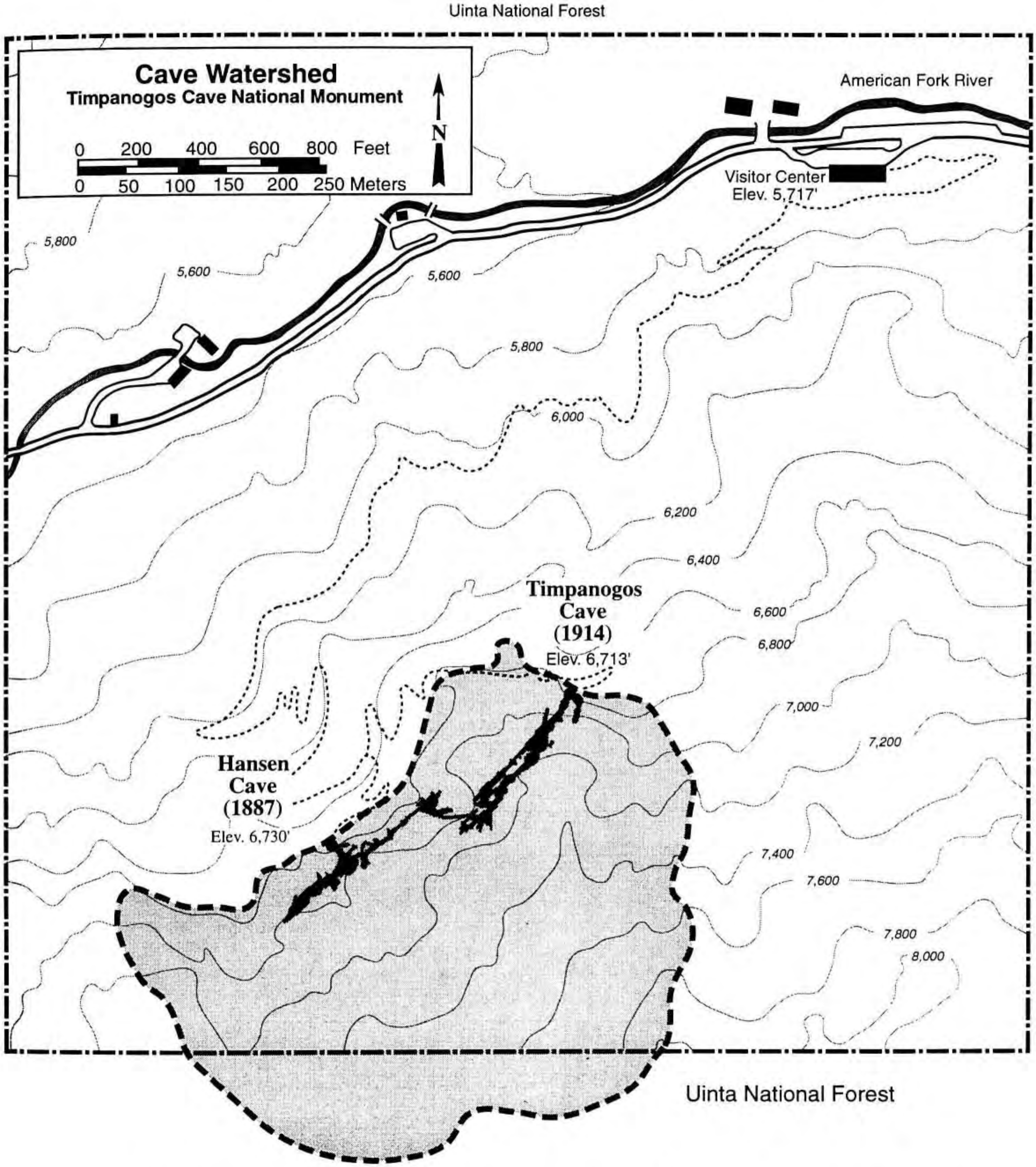
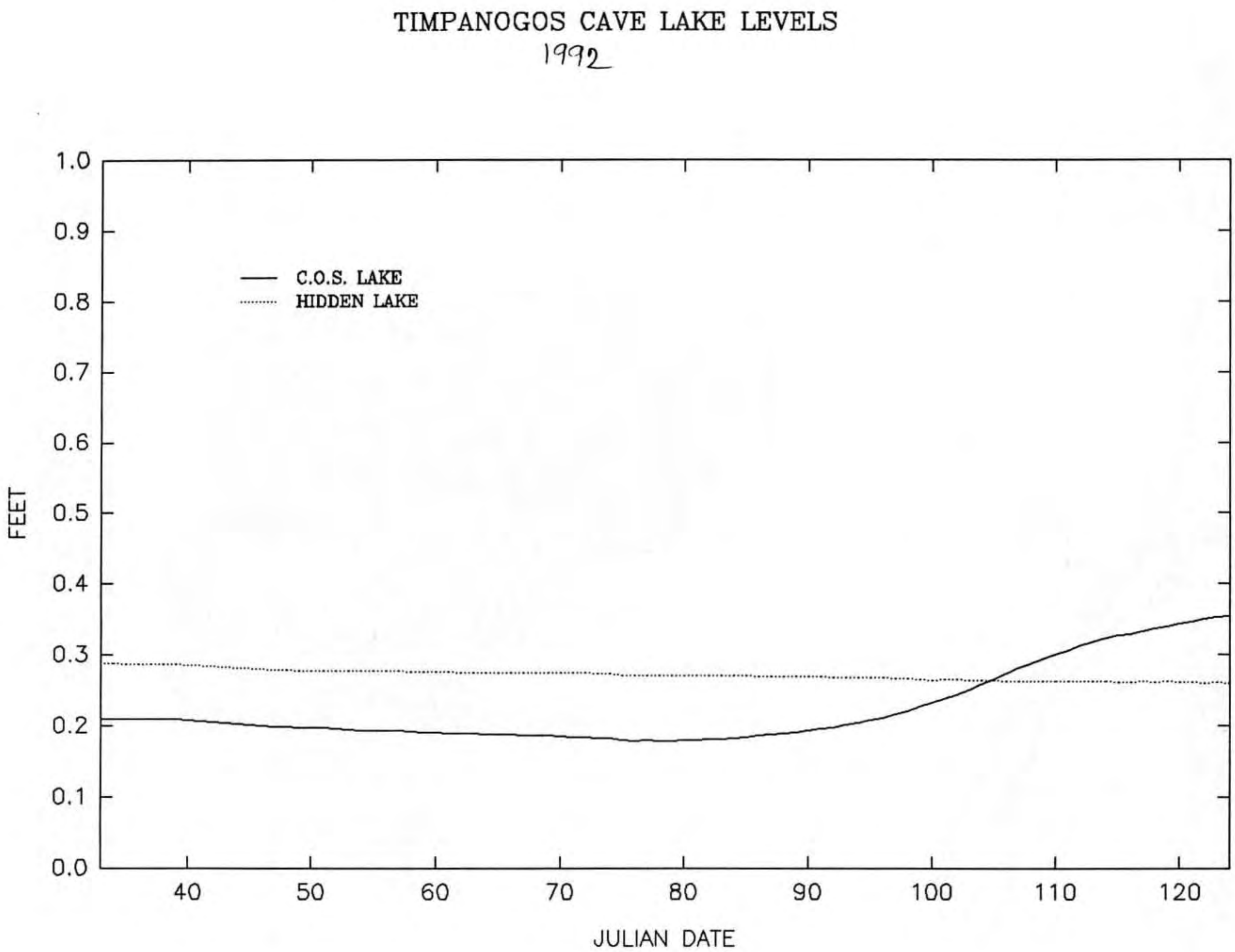


Figure 2. The extent of the cave watershed was determined by mapping the surface geology, measuring a detailed stratigraphic column, creating a detailed topographic map of the surface, and dye tracing water to the caves. Notice that a significant portion of the cave watershed lies outside the boundaries of Timpanogos Cave National Monument. This land is managed by the Uinta National Forest.

Figure 3. Using a pressure transducer, it was determined that the lakes in the Timpanogos Cave System do not oscillate. Based on this observation, drucks are only used at remote lake sites, while staff meters are manually read at all easily accessible sites.



MIDDLE CAVE DOUBLE DRIP RATE
1993

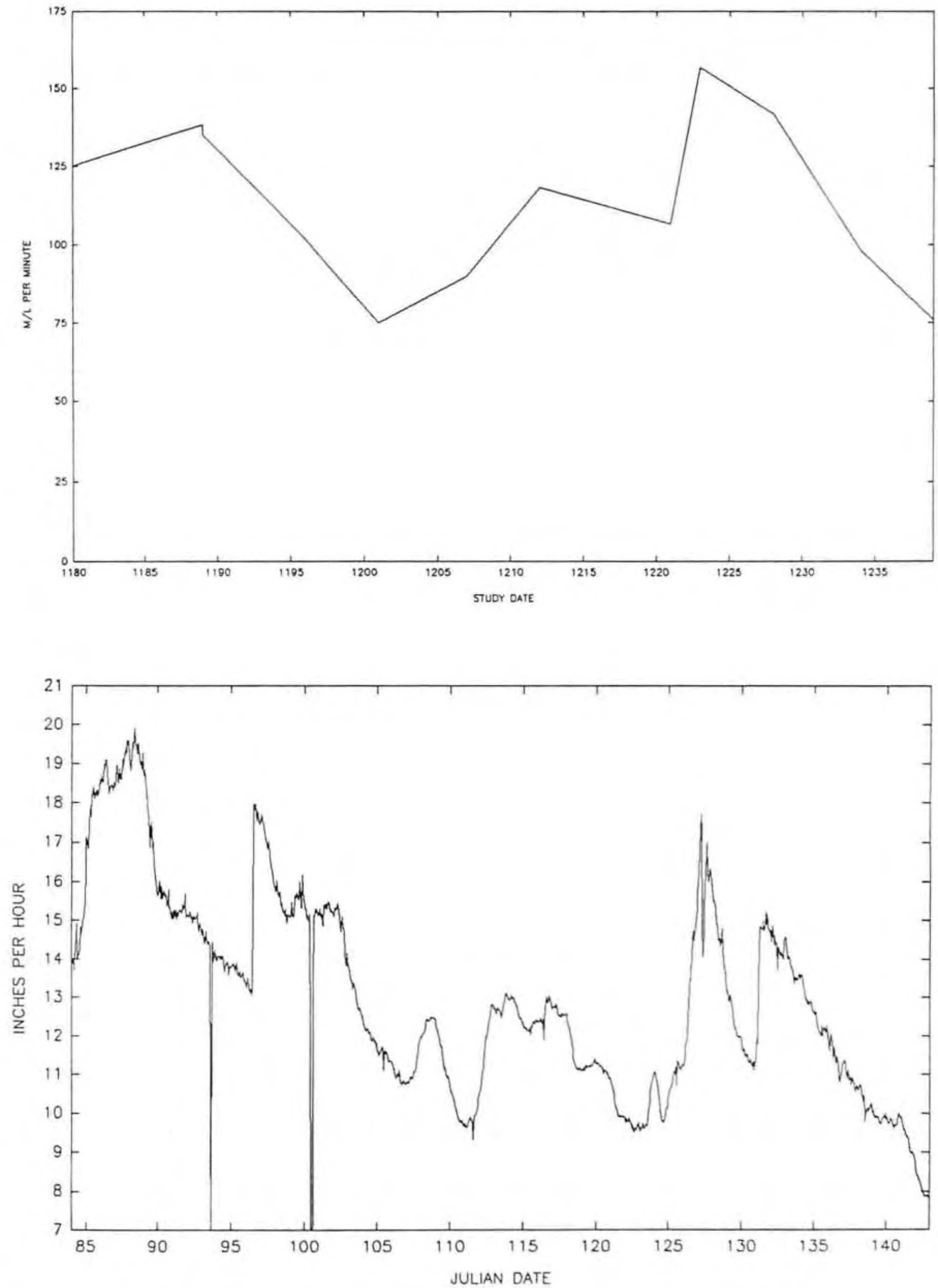
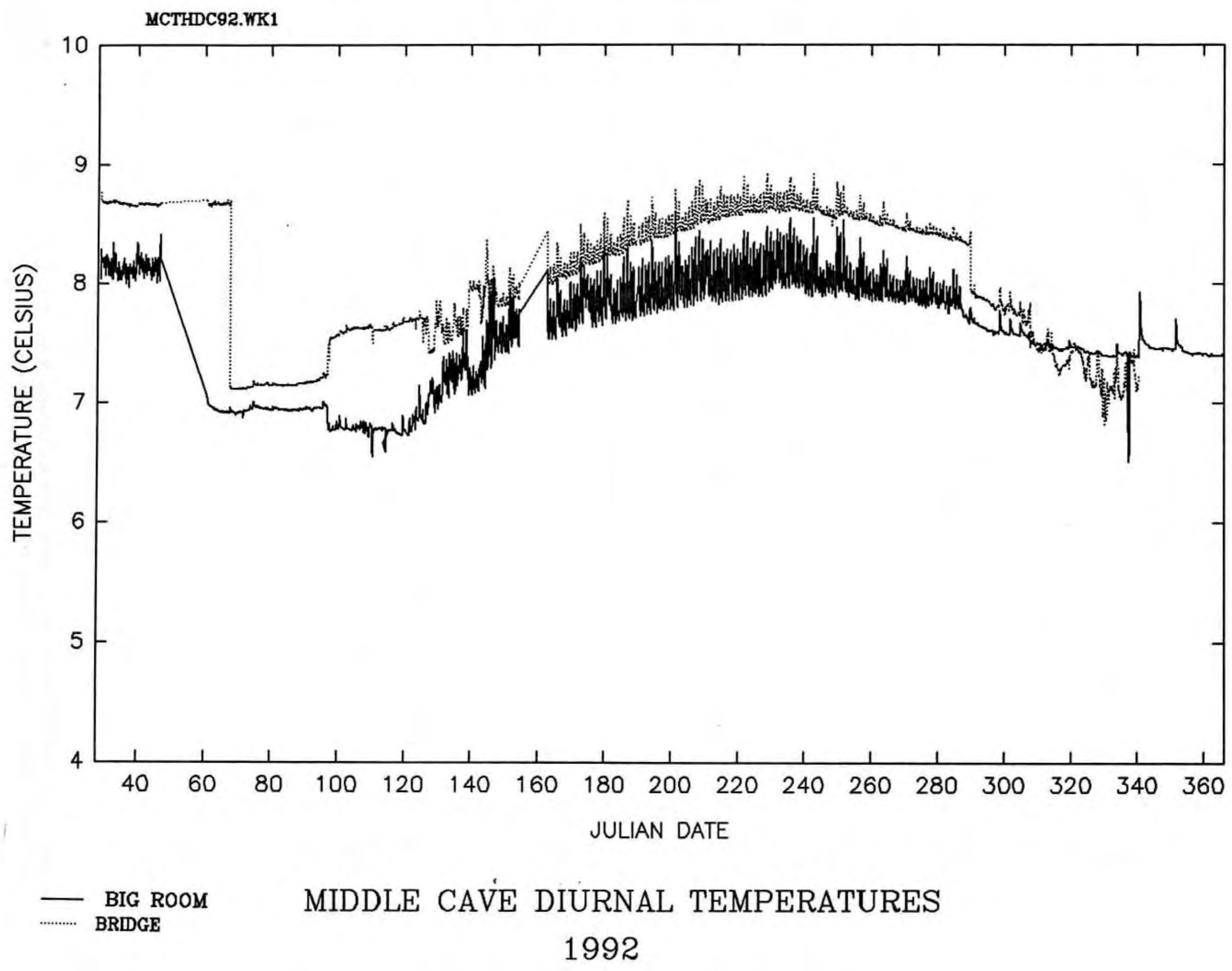


Figure 4. A graph created by manual data collection is compared to a graph created using an automated tipping bucket. Notice that entire surge events in the cave are missed by manually collecting drip rates.

Figure 5. Temperature probes placed in Middle Cave record the day that maintenance began preparing the cave for the season, the day that tours started, the day that tours stopped, and the activities of resource management staff working in the cave after the season was over.



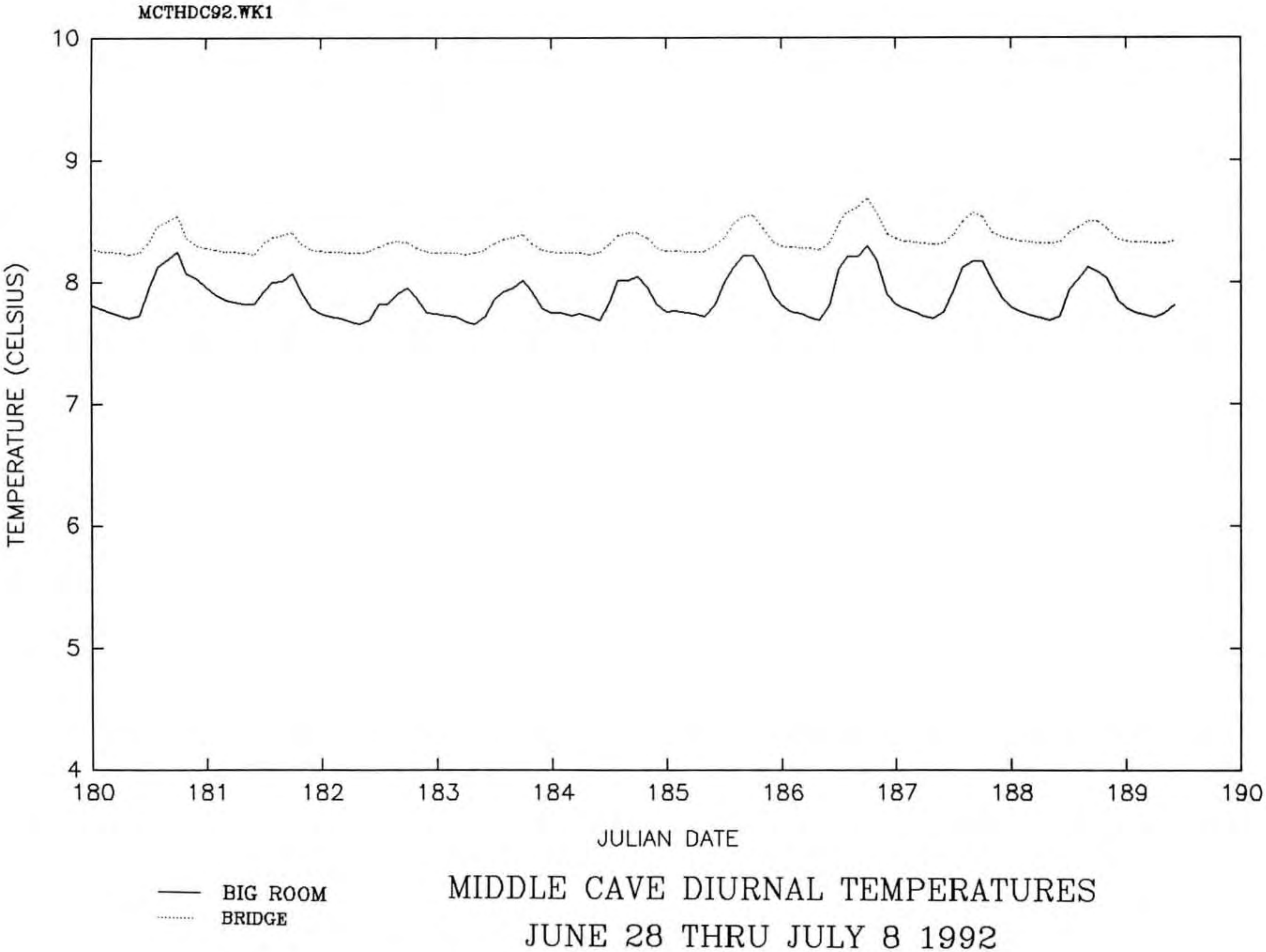
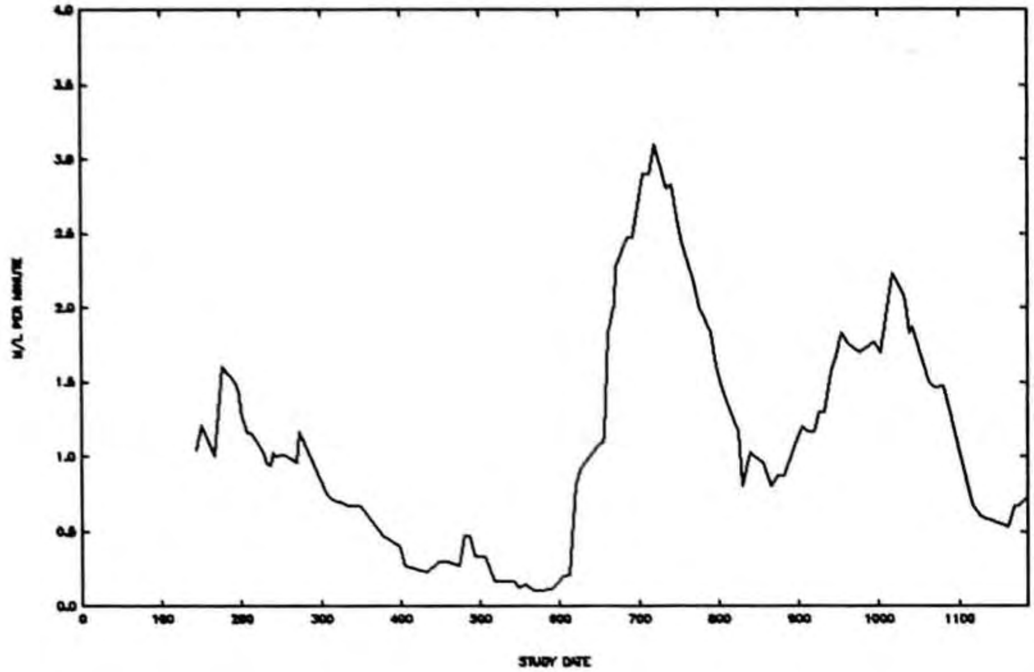


Figure 6. One half degree temperature oscillations are recorded by a temperature probe each time a tour of 20 visitors pass.

CHIMES CHAMBER DRIP RATE
1990–1993



VISITOR CENTER DAILY PRECIPITATION
1990–1993

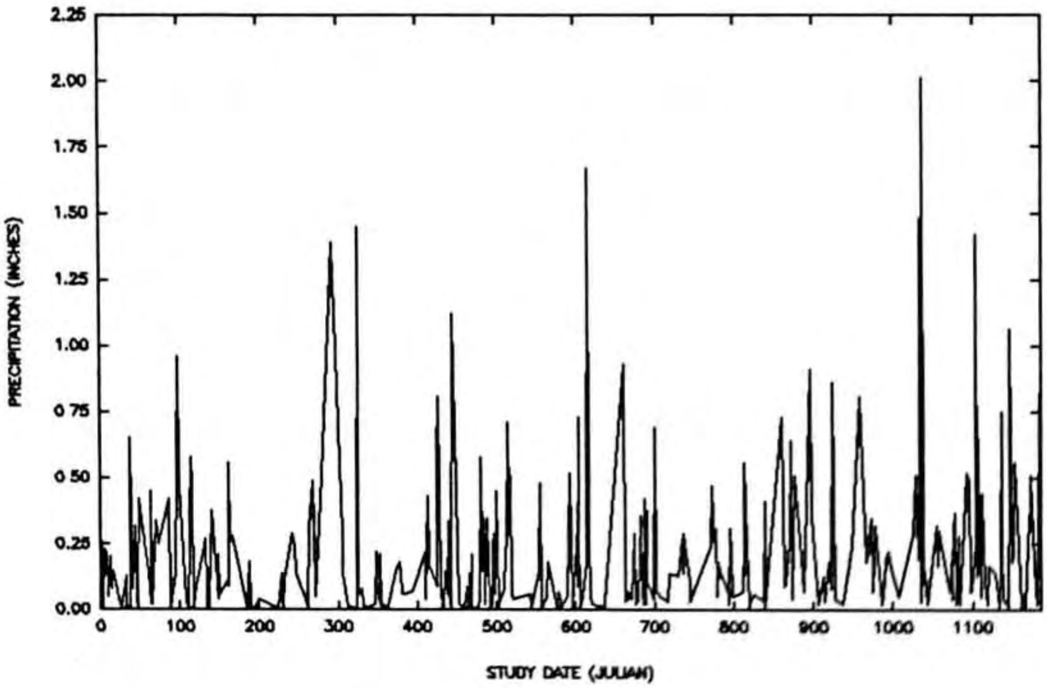


Figure 7. The Physical Science Technician prepares graphs to be analyzed by the Cave Management Specialist. This on-going process prevents voluminous amounts of data from stockpiling and keeps the manager aware of any changes in conditions within the cave.

AIR MONITORING DURING CONSTRUCTION OF A CAVE GATE

William R. Elliott, Ph.D.

ABSTRACT

In February, 1992, the writer performed industrial hygiene studies during the construction of an iron gate in Gorman Cave, Colorado Bend State Park, San Saba County, Texas. The gate was built to limit human access to the rear of the cave while allowing bats to fly through the gate. During the work I measured carbon dioxide, oxygen, air contaminants, temperatures, and air flow rates and patterns. I also installed a temporary exhaust ventilation system over the work area and made other observations. Results are provided along with conclusions and recommendations to avoid airborne hazards to humans and fauna in caves.

INTRODUCTION

From February 12 to 18, 1992, I was under contract to the Halliburton Company, Energy Services Group, on behalf of the Texas Parks & Wildlife Department (TPWD), to provide industrial hygiene and biospeleological services during the construction of an iron gate in Gorman Cave, Colorado Bend State Park, San Saba County, Texas. The purpose of the gate was to limit human access to the rear of the cave where bats tend to roost and where there are well-known hazards, such as "bad air" and difficult crawlways. The gate, which covered 15-16 m^2 of passage area, weighed about 1,000 kg and was designed to allow bats to fly between the bars, which were 14 cm (5.5 in) apart. During the work I measured carbon dioxide (CO_2); oxygen (O_2); several air contaminants that are generated by arc welding; and air flow rates and patterns. I also installed a temporary mechanical exhaust ventilation system over the work area.

Gorman Cave (fig. 1) is an intermittent-resurgence cave which empties directly into the Colorado River upstream from Lake Buchanan in central Texas. The cave is in the Gorman Formation, Ellenburger Group, an Ordovician limestone (Smith, 1973). The cave has been popular with cavers and the general public for many years and provides an easy caving experience as far as the Big Room, about one-third of the distance into the cave. The cave is about 1 km (3000 ft) long and ascends slightly from the downstream entrance toward the back. A lower level stream passage is only about 3 m below the entrance level. The first third of the cave is up to 5 m high and 5 to 10 m wide, but there are several low areas that constrict airflow. Ceilings reach up to 10 m in the Big Room. Beyond the Squeeze, about halfway through the cave, the passage becomes a muddy crawlway with slippery slopes and climbs. Air quality noticeably declines farther from the Entrance, as indicated by the name "CO_2 Alley" for the final section leading to a sump (Reddell, 1973).

Elliott (1986) conducted a baseline study of air quality in Gorman Cave and Gorman Falls Cave (Bad Air Hole) on September 14, 1985; March 1, 1986; and October 11, 1986. Seven sampling locations were used in Gorman Cave, although flooding prevented access to the last three stations on the last visit. Fig. 2 illustrates the changes in CO_2 and O_2 with distance from the entrance and with time. O_2 decreases and CO_2 increases in a linear relationship with distance from the entrance. Low areas, such as GS3 at the lower stream level, have slightly higher CO_2 and slightly lower O_2 levels than the adjacent main passage (GS4) because of the poor air circulation in the cave and the tendency for CO_2 to settle in low areas because of its greater density. Air quality improves during the winter, possibly the result of cold fronts which gradually flush the cave with fresh air. During the summer and fall, visits to the end of the cave are physiologically stressful, resulting in rapid panting, dizziness, and headaches. During the winter and spring such visits are less stressful. This seasonal pattern has been reported by cavers for many years and also has been observed at Bad Air Hole by the writer. The same pattern has been documented in other caves in the park since 1986 (Keith Heuss, pers. comm.).

Many caves in the Ellenburger Group and the Austin Chalk are known to have bad air, whereas caves in the Edwards Limestone and Lower Glen Rose Limestone tend to have better air quality (my unpublished data). The exact source of the high CO_2 and its concomitant O_2 depletion in Ellenburger caves is unknown. I do not think it can be adequately explained by washed-in organic matter or soil microbial activity, which probably differ little among these karst areas. It is my hypothesis that CO_2 in caves of the Ellenburger Group may originate from deep geochemical or hydrological sources, and that temporal and spatial distributions of the gas are modulated by barometric and temperature changes, wind, size of entrance, depth and length of a cave, and the air exchange patterns of a cave. In the Ellenburger, short or shallow caves do not exhibit the bad air phenomenon as much as vertical pits or long caves. During a recent drought, however, air quality has been better in some caves in the area, indicating that water seeping into the caves off-gasses most of the carbon dioxide (Rober Burnett, pers. comm.).

MATERIALS AND METHODS

In preparation for this study there was extensive discussion among the writer, TPWD, and the gate contractor about limiting air contamination during the welding. The planning was out of concern for humans, the cave environment, and the bats in the cave, which include large colonies of *Myotis velifer* and occasional individuals of *Pipistrellus subflavus* and *Lasiurus borealis*. It was decided to do the work in the winter when air quality was better and when bat activity was low, and to avoid using a welding machine in the cave, which would produce carbon monoxide, nitrogen dioxide, ozone, and hydrocarbon vapors. A 14 cm-diameter (5.5 in.) borehole was drilled into the ceiling of the cave above the work area to provide access for electrical cables, communications, and to hoist tools and materials. The borehole was 27.9 m (91.5 ft.) deep, and the ceiling was 6.0 m (19.6 ft.) above the floor, for a total depth of 33.9 m (111.1 ft.). I had planned to monitor the work with instruments and then set up a box fan to blow contaminants away from the work area, if necessary.

It soon became apparent that welding fumes would accumulate too rapidly at the work area without mechanical ventilation. I borrowed a Homelite gasoline-powered exhaust blower from Brownwood State Park and we built a plenum box from scrap lumber. The plenum box was temporarily sealed to the ground with mud around the borehole and had an airtight, plywood lid that could be removed to allow materials to be hoisted. The exhaust unit was connected by a 3-m (10-ft.) long, 20-cm (8-in.) diameter hose to a short duct in the side of the plenum box. Personnel on the surface tended the equipment. Communications were by FM radios, which usually propagated a good signal along the electrical cables in the borehole. The exhaust unit was rated at 1,244 ft^3/min, or $ft.^3$/min (35 m^3/min, or m3/min) in free air, and at 1,011 $ft.^3$/min with one 90° bend in the hose.

Air-flow rates were measured at orifices with an Alnor Jr. velometer, which had a minimum measureable value of 50 linear ft./min (15 m/min). In the cave, where air velocity was extremely low, air flow patterns were checked with an MSA Ventilation Smoke Tube Kit, which employs a rubber squeeze-bulb to blow puffs of fuming sulfuric acid from a glass ampoule. Such puffs of smoke were sufficiently thick and coherent to be followed for up to half a minute before dissipating by reacting with the moisture in the air (the smoke was not particulate matter). Extensive notes were taken and puffs were followed for paced distances and timed with a stopwatch.

A battery-operated Edmont Oxygen Analyzer was used to measure O_2 levels in the cave. The instrument had a new sensor tip and electrolyte gel. The Analyzer was calibrated by turning it on, checking the battery level, adjusting the meter to 20.9% in fresh air, then readjusting the meter every few minutes until the reading stabilized. Typically the meter would drift a few tenths of a percent over several hours during actual use, but the meter could be readjusted after taking a CO_2 reading, since the elevated level of CO_2 had been found to be exactly complimentary to the decrement in O_2 in this cave (Elliott, 1986).

A Drager Multi-gas Detector with a 100-cc hand pump was used to measure CO_2 (0.5-10%)and the likely air contaminants of welding: carbon monoxide (CO, 2-60 ppm), ozone (O_3, 0.05-1.4 ppm), and nitrogen dioxide (NO_2, 0.5-10 ppm). All detector tubes were purchased fresh in

January 1992 and had expiry dates between November 1993 and January 1994. The pump was tested for leaks by compressing the pump and placing an unopened detector tube in the inlet orifice for ten minutes. Particulate and hydrocarbon sampling were not done owing to a lack of equipment.

RESULTS

Results are detailed day-by-day below. Instrument calibrations were done on the evening of February 12, 1992, before starting work the next day.

February 13— I arrived at the borehole at 10:25 am and found that air was flowing naturally out at about 50 linear ft./min, or 8 ft^3/min (0.23 m^3/ min). The air was at 17° C (63° F), weather cloudy. Inside the entrance at 11:19 a smoke tube indicated very slight air movement, mostly local eddies with air rising to the ceiling and slight flow from the main entrance and out the second, Skylight entrance, which had been dug open recently. The stream was flowing out very well, was clear and 19° C (66° F). The cave had backflooded about a week before. I saw one pipistrelle bat on the ceiling near the Skylight. Beyond the Skylight air movement was slight with local eddies until reaching the Big Room. Here the O_2 was 20.5% and air rose slowly. I waded through water up to 80 cm deep just before the borehole. At 12:00 pm under the borehole the smoke tube showed air rising slowly. Air was 20°C (68°F). At 12:45 pm at the sump just past the bat gate: CO_2 = 0.9%, O_2 = 20.0%. Under borehole at 1:00 pm: CO_2 = 0.9%, O_2 = 20.0% (corrected). At 1:45 pm at GS1 in the Big Room near the downstream constriction: CO_2 = 0.7%, O_2 = 20.2% (corrected), smoke tube showed air rising slightly but no direction. At 2:00 the gate construction crew arrived. At 2:10 at the Detour area: CO_2 = 0.4%, O_2 = 20.5% (corrected), 19°C (66°F); at 1.2 m above floor, smoke rises slowly. At 2:23 pm outside, readjusted O_2 meter from 21.2 to 20.9%. Readjusted again at 2:45. 19°C (66°F), cloudy. At 2:51 at GS1, O_2 = 20.3%. Smelled cigarette smoke here from workers at the borehole. At 3:00 at the borehole, three men were smoking. At 3:14 the smoke tube showed rising air but little direction near the borehole. On the upstream side the air may have moved upstream near the ceiling, but on the downstream side it moved downstream slightly near the ceiling, so air must have been sinking down the borehole. Cigarette smoke obscured the entire area and Big Room and was not clearing out. At 3:57 the workers started drilling holes in the walls for reinforcing bars. At 4:45 we finished and left. At 5:15 outside, the borehole was sucking air according to the smoke tube, but the velometer reading was too low to read accurately (< 50 linear ft. per min.) It was obvious from observations on cigarette smoke and with the smoke tube that the cave would not have sufficient natural ventilation to ensure a healthy work environment once welding started.

February 14— The construction team was delayed by a lack of proper-sized cables. I obtained a Homelite gasoline-powered ventilation unit from Brownwood State Park. Keith Heuss and I fabricated a plenum box from scrap lumber.

February 15— At 10:00 am at the borehole, 16°C (60°F), clear day, air rising from borehole at about 10.1 ft^3 ft^3/min (0.29 m^3/min). We set up the plenum box and sealed it to the ground. With the plywood lid on and the power unit set slightly downhill, the hose straight and set on suction , the exhaust side of the blower produced over 2,500 ft./min, more than the velometer could register. This was at least 873 m^3/mi (24.7 m^3/min). At 12:30 pm I arrived at the work area in the cave. A smoke tube indicated fair air movement from chest height to the borehole— about 30 sec. to ascend. However, there was poor air flow upstream from the gate and better downstream. The air was stagnant at the sump. We sent for an electric box fan. CO_2 = 0.7%, 19.5°C (67°F). At 1:30 I rigged a box fan behind (upstream from) the gate area, but it blew air up the Mouse Hole. I repositioned the fan on the north side behind the gate and angled it upwards. Smoke then moved toward the gate along the stream surface from downstream and upwards to the borehole. At 1:45 welding of re-bar began at 150 A. At 1:54 the welder was set to 175 A. I took photographs. At 2:15 there was a smoky smell downstream after 15 min. of heavy welding, but the smell cleared a few seconds after pausing the work. At 2:19 the plenum lid was off while steel was lowered and the welding continued. At 2:21 the plenum lid was back on. At 2:30 O_3 was "none detected " (ND) at 10 strokes of the Drager pump and 3 m downflow from the welding. This was checked again at 1.5 m from the welding, but ND again. At 2:40 the uprights were tacked up. At 3:15 the smoke tube indicated air traveled slowly in the Big Room but faster past the ceiling drop 15 m from the gate. At 3:25 NO_2 was ND at 1.5 m from the welding. At 3:40 CO was a trace (about 1 ppm) at 10 strokes but welding had stopped on stroke 4. At 4:04 CO was ND 1.5 m from the welding. I tried to clock the travel of a smoke puff in the constricted tunnel downstream from the Big Room, but it was too slow and dissipated. At 60 m from the Skylight the air was slowly moving out of the cave, not toward the borehole, even though the exhaust was still on and work continued. I exited at 4:42, wrote notes, and gave instruments and instructions to Ed Young to continue sampling while I was gone for two days. I returned home.

February 16 (from Ed Young's notes)— Entered cave at 11:00 am. The construction crew had arrived at 10:30 and were smoking, but not welding yet. At constriction before Big Room air was clear and moving slightly toward Big Room. Big Room was full of cigarette smoke but was clear from floor up to 1.5 m. Smoke tube showed slight air flow along floor toward construction area. Above 1.5 m the air drifted very slowly toward the ceiling. The upper passage over the restriction to the Big Room showed very slight flow toward entrance. No air flow beyond the gate and smoke from water to ceiling with slight rise to ceiling. Once welding started it was surprising that the air was not much worse than the cigarette smoke alone. No stream flow. At 3:30 pm the welding intensified. Between gate and borehole NO_2 = ND (5 strokes), O_3 = ND (10 strokes), CO = 2 ppm , CO_2 = 0.5%. At 4:30 it was 20°C (68°F). At 5:00 there was more smoke in gate area. The engine on the ventilator had slowed down due to a vibrating throttle. After full throttle again, the smoke cleared near the gate in 10 to 15 min.

February 17 (from Ed Young's notes)— The bat gate is 95% complete. Ed helped weld on the gate. At 6:45 pm readings were taken between the gate and the borehole: CO_2 = ND, CO = 2 ppm, O_3 = ND, NO_2 = ND, 20°C (68°F). The lake near the bat gate dropped 60 cm (2 ft.) since February 16. Smoke tube showed dead air beyond the gate with slight movement toward ceiling. The air was thoroughly mixed by the box fan downstream from the gate. At 10 to 12 m downstream from the gate there was a draft along the floor about 1 to 1.5 m high, moving approximately 30 cm/sec (1 ft./sec) toward the gate. At 15 m from the gate to the restriction at the entrance to the Big Room, the air was moving about 9 cm/sec. (0.3 ft./sec.) toward the gate. The smoke accumulated about 1.2 to 1.5 m above the floor after only a few cigarettes were smoked and before welding. At the end of the day the smoke stratified along the ceiling in a layer 60-120 cm thick from the Big Room to within 60 m of the Skylight, where the air became clear.

February 18— The writer returned to the cave and obtained notes and a briefing from Ed Young. At 2:30 pm it was clear and 18 C (64 F) with almost no breeze. Air was rising from the Skylight moderately fast, as shown by a smoke tube. At 2:40 at the main entrance, air was oscillating and out every 30 sec. A smoke puff traveled 13 ft. (paced) in 28 sec. in a section about 3 m (10 ft.) in diameter, giving a local flow rate of 62 m^3/min (2,187 $ft.^3$/min). The stream was not running. At 2:49 the air was flowing slowly in at the Skylight. There were many cave cricket nymphs in ceiling domes. The pipistrelle observed on February 13 left on February 14 and had not returned. The stream was a trickle. Past the Skylight air was moving in slowly along the floor and out along the ceiling. At 2:55 bad smoke layer in upper half of passage halfway to Big Room. At 2:58 in the duckunder leading to the Big Room a smoke puff traveled 3.3 m in 15 sec. in a 1.5-2.1 m diameter section, giving a local flow rate of about 35.3 m^3/min (1,244 $ft.^3$/min). At 3:08 I took vapor readings in the smoky layer 30 m from the gate: NO_2 = ND, CO = trace (< 1ppm), and CO_2 = 0.1%. I asked the workers not to smoke anymore because it was polluting most of the cave and the exhaust could not remove it all. I asked for the ventilator to be configured as a blower for about 15 min. This began to push air toward the Big Room, but the smoke rose into the ceiling and could not escape because of the low ceiling at the downstream end of the room. At 3:30 I had the ventilator put back on exhaust. At 4:20 at one-third of the way from the Big Room to the entrance it was 19.5°C (67° F) at the floor and 20°C (68°F) 3 m up. At 4:40 the gate welding was finished and I took photographs. They planned to wipe down the gate with methanol, then spray it with up to 6 20-oz. cans of "Rubberized Undercoating". I asked them to keep the exhaust on and I left at 5:05. At the Skylight at 5:15 the air moved out along the ceiling and in along the floor. At the borehole outside I could smell in the exhaust air the undercoating being applied to the gate.

CONCLUSIONS

Conclusions about the cave and the gate construction project are as follows:

1. Gorman Cave has very poor natural ventilation according to gas measurements and air flow patterns, the latter evidenced by smoke tubes, welding fumes, and cigarette smoke.

2. A moderate amount of air was exchanged between the two entrances, but little natural circulation goes beyond the second entrance (Skylight). With mechanical exhaust, a flow path occurred along the floor of the cave, which tended to create vertical cells in some areas. Warm air, which tended to flow along the ceiling toward the entrance, was dammed up by low areas in the passage. After three days of mechanical ventilation the CO_2 at the work site dropped from 0.7% to about 0.1% (the normal atmospheric concentration is 0.035%) but smoke accumulated due to stratification of warm air above about 1.5 m.

3. Avoiding the use of a welding machine in the cave was useful because it could have created hazardous levels of combustion vapors in the cave as well as an electrical safety hazard due to the water at the work site.

4. The borehole was extremely useful to the project, allowing efficient transfer of materials and communications, and providing a ready-made duct for an exhaust system.

5. Smoke accumulated in the Big Room and main passage at least as much from cigarette smoking as from welding activities. The smoke probably was a cloud formed by water condensing on particulates suspended in the atmosphere. No dangerous levels of CO, O_3, or NO_2 were found in the cave, probably a result of the mechanical exhaust employed. However, since cigarette smoke contains many harmful substances, such as acrolein, formaldehyde, benzo()pyrene, nicotine, and other chemicals, which could not be measured with the instruments available, it cannot be concluded that the smoke in the cave was harmless. This is because each compound, some of which is attached to cigarette smoke particulates, would initially be at a different concentration, and the reaction chemistry of each in the humid cave atmosphere would be difficult to predict. I should emphasize that air pollutants in the cave may acutely affect cave-dwelling creatures, such as bats and invertebrates, more severely than humans.

6. The mechanical exhaust system provided via the borehole was moderately effective at ridding the work area of the most dangerous pollutants. This was shown by the low levels of contaminants that were detected near the welding. The box fan helped to loft welding fumes towards the ceiling, where they could be taken out through the hole. However, the fan also caused some pollutants to escape and pollute the rest of the cave.

7. A more effective exhaust system would have involved fabricating a temporary duct from the hole in the ceiling to near the floor, with a flexible hose and scavenging hood taking off near the bottom end. This hood could have been placed at the work to scavenge nearly all welding fumes and paint vapors. The duct could have been made from PVC and could either be jammed into the hole and removed when necessary, or fitted with a door on the bottom to allow hoisting of materials.

8. There was no prior discussion, policy, or contract requirements provided by the hiring agency regarding smoking in the cave. Even a good mechanical exhaust system cannot overcome the output of several smokers.

RECOMMENDATIONS

1. A cave's meteorology shoud be studied before welding at the entrance or inside. Welding in a cave can create the same hazards as welding in any confined space and could lead to health and safety problems, which could be in violation of state and federal occupational health laws. Mechanical ventilation is not usually needed for gates built at cave entrances if the usual ventilation pattern will continually sweep contaminants out of the cave. If the gate is to be constructed inside the cave, or the natural ventilation is poor or sometimes flows into the cave, then welding should be preceded by provision of mechanical exhaust ventilation sufficient to protect workers and the cave environment.

2. Whenever possible, the exhaust should be localized so as to scavenge pollutants efficiently, and conveyed directly to the outside through a duct system, not dumped to the cave air. This can be accomplished either with a borehole through the ceiling, or by fabricating a temporary ductwork system, such as reinforced hose. The materials in the hose must be able to withstand the flow rates required. The more efficient the capture of pollutants, the less necessary it becomes to maintain high flow rates. Note that charcoal or HEPA filters will not capture some contaminants, such as nitrogen oxides and CO, nor will they maintain oxygen levels.

3. Welding in a cave or cave entrance should be monitored with industrial hygiene instruments to ensure that pollutants do not exceed the Threshold Limit Values (TLVs) of the American Conference of Industrial Hygienists, or the Permissible Exposure Limits (PELs) of the U.S. Occupational Safety & Health Administration, whichever is more stringent. If feasible, pollutant levels should never exceed a small fraction of the appropriate TLV or PEL. TLVs and PELs are designed to prevent injury to the average worker, but should not be considered "safe levels", especially for the delicate cave environment and its inhabitants.

4. Smoking should not be allowed at any time in a cave if one is interested in protecting the cave environment and visitors.

ACKNOWLEDGEMENTS

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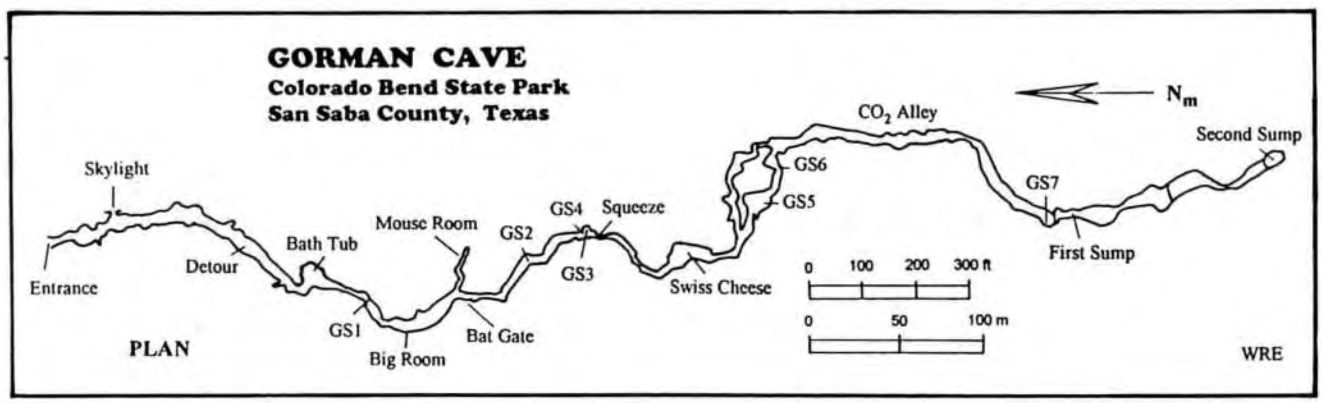

Figure 1. Air monitoring locations in Gorman Cave.

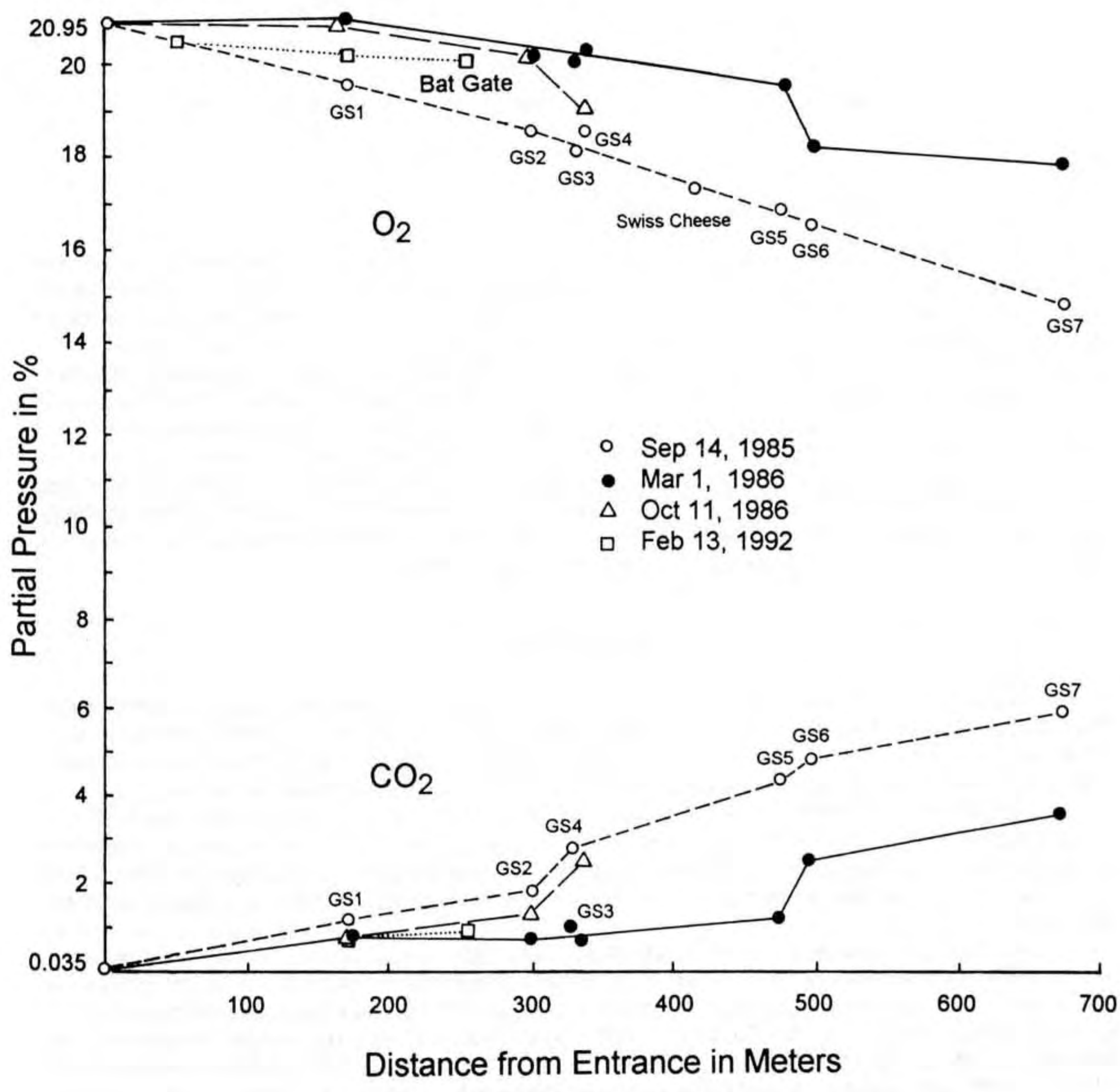

Figure 2. Oxygen and carbon dioxide in Gorman Cave.

THE AMERICAN CAVE AND KARST CENTER
A Bridge Between the Scientific Community and the Public

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ABSTRACT

The American Cave Conservation Association moved its national headquarters to the town of Horse Cave, Kentucky in 1987 with the goal of establishing a national educational and research center for cave and karst resources. Since that time, the Association has raised more than a million dollars from public and private sources towards the creation of the American Cave and Karst Center.

The Center's museum of caves opened in May of this past year. At the same time, efforts to restore Hidden River Cave, located adjacent to the Center, have been successful. The once heavily polluted cave is now being visited for the first time in 50 years. Efforts are still underway to complete additional exhibits, expand tours, construct a library, and develop educational outreach programs.

The American Cave and Karst Center will provide a long-term source of funding and technical assistance to both public and privately managed caves. This paper will summarize the effort to develp the Center and describe its goals and objectives, future plans, and the benefits that the Center will provide to caves and cave managers throughout the United States.

BACKGROUND

The American Cave Conservation Association, (ACCA), is a national non-profit conservation and educational organization which was incorporated in Richmond, Virginia in 1983. In 1987, the American Cave Conservation Association moved its national headquarters to Horse Cave, Kentucky with the goal of establishing a national educational center for caves and karst resources.

In addition to initiating the effort to establish a national cave and karst center, the ACCA has conducted a variety of conservation and educational programs over the past decade. Foremost is the National Cave Management Seminar program. These professional workshops have been held in 12 states and have helped train more than 500 federal land managers in the techniques of cave management.

ACCA helped pioneer modern "bat friendly" cave gate construction, and ACCA volunteers and staff have installed more than 50 bat gates at cave preserves throughout the United States. ACCA staff have provided educational programs to schools throughout Kentucky, and are now providing interpretive tours and educational programs at Hidden River Cave and the American Cave Museum (a part of the American Cave and Karst Center). Recently, ACCA has begun development of a cave and karst curriculum guide and has developed a school newsletter which is distributed to approximately 100,000 school children per semester.

The idea for the American Cave and Karst Center began in the early 1980's when the ACCA was still located in Richmond, Virginia. ACCA was looking for a new location for its headquarters. One idea that was suggested was for ACCA to purchase a commercial cave and operate it as an educational facility. The ACCA staffed researched this idea and found that most financially secure commercial caves were not available at a price that was affordable. However, ACCA received an invitation from Bill and Judy Austin of Horse Cave, Kentucky to take a look at Hidden River Cave, a former commercial cave which had been closed for decades due to sewage pollution.

ACCA staff members, Jer Thornton and Dave Foster, visited the Austins and became enthused by the possibility of restoring Hidden River Cave and building an educational center at the site. The Austins had been pursuing this idea for a number of years, but had been unable to find a sponsor to initiate the effort. ACCA's Board of Director's held a meeting in Horse Cave in 1986 and voted to move the entire organization to Kentucky and undertake the effort to build the American Cave and Karst Center.

Prior to developing the American Cave and Karst Center, the ACCA realized that it needed to conduct a feasibility study to identify goals and objectives, determine the need for such a facility, and determine whether the Center should be located in Horse Cave or if a better site existed. A feasibility study, summarized in part by this paper, was conducted in 1987 by the Ozark Underground Lab with funding from the U.S. Economic Development Administration and the ACCA.

With the completion of the feasibility study, ACCA began moving forward with efforts to acquire funding for the American Cave and Karst Center. The first break came in November 1987 with the approval of a $250,000 community development block grant for the project. In order to acquire these funds the City of Horse Cave agreed to borrow approximately $226,000 as a match for federal support. The building which would eventually house the Center's museum was purchased and renovated with this funding.

By 1991, donations from private foundations enabled the ACCA to begin constructing exhibits in the American Cave and Karst Center's museum. A Grand Opening was held for the museum in July 1993 following the completion of the museum's first floor exhibits and several temporary exhibit areas. Currently efforts are underway to establish additional exhibits, restore the historic tourist trail in Hidden River Cave, and expand the staffing and educational programs of the Center.

NEED FOR THE AMERICAN CAVE AND KARST CENTER

About 20% of the United States is underlain by the "cave rocks" of limestone, dolomite, marble and gypsum. These regions, called karst areas, are typified by an assemblage of environmental problems which include land collapse, groundwater pollution, inadequate water supplies, and damage to cave resources.

The major American karst areas extend from the Ozarks across Kentucky and Tennessee to northern Alabama, then northward through the Appalachians. America's rural karstlands are commonly areas of economic poverty, a poverty rooted in natural resource conditions and our poor adaptations to these conditions.

Few residents of karst lands have an adequate or accurate understanding of how the land "works". Many of the natural resources are "out of sight" and, as an unfortunate result, the resources are damaged because they are also "out of mind". The people of America's karstlands urgently need a deeper look at, and a deeper understanding of, the lands upon which they live. Such an awareness will benefit both the people of the karst lands and the natural resources of these areas.

The economic and environmental costs of America's inadequate and inaccurate understanding of how karstlands function are staggering. Multi-million dollar cleanup costs are routinely incurred when wastes are allowed to enter karst groundwater systems. Green Forest, Arkansas, illustrates the nature and magnitude of one type of problem which can occur.

Green Forest is a small town in the limestone karst of northern Arkansas. The town is the location of a large chicken processing plant. Poorly treated wastes from the town and the processing plant entered the regional groundwater system through a losing stream and a sinkhole. Wells and springs in a 50 square mile area were affected by the discharges of sewage. The direct economic losses, including the cost of constructing rural water lines to serve the affected area, are about 10 million dollars. This value does not include any monetary estimate of the associated health costs even though the affected groundwaters are contaminated with bacteria, viruses, and parasites.

The American Cave Conservation Association (ACCA) concluded that major educational efforts were needed if cave and karst resources were to be protected and wisely used. Out of this need grew the idea of an American Cave and Karst Center; a Center with three interlocking programs: a national scale museum and library; educational programs; and direct help programs.

DESCRIPTION OF PROGRAMS

The Center, as envisioned, will have three basic interlocking programs which are designed to attain five primary objectives. The three programs are:

1. A national scale interactive museum devoted to caves, karst, groundwater, and man's interactions with, and dependence upon, these resources. There is no museum in the United States which deals extensively with caves, karst, or groundwater; this is a major gap. The museum will be far more than a repository for natural and cultural artifacts. It will be a modern, interactive, exciting facility that creates public understanding of today's environmental problems and ways to prevent and solve them.

2. Educational programs to increase understanding of natural resources in karstlands. These programs will be focused primarily on school children. We will never adequately prevent natural resource damage and environmental problems in karst areas until we have broad public understanding of how man's actions can affect natural resources. Understanding should begin with children; the most critical concepts are basically simple. Children are fascinated by caves; caves can be a vehicle to help demystify science.

3. Networking and referral services to help industry and other entities understand and reduce karst-related problems. The objective is to develop a functional karst awareness among those who need our services. There is a growing public perception that karst and groundwater resources are doomed to destruction. That perception is wrong and has damaging consequences. What we need are bridges between what is known by scientists and professional resource managers and what is perceived by the public, government, and industry. The services we envisage will build these bridges, protect resources, and prevent costly mistakes.

The American Cave Museum

The museum is a crucial facet of the American Cave and Karst Center. The museum must be a significant facility in order to provide a national level of visibility for the programs of the Center. The Center cannot be simply a local or regional museum of interest mainly to people in a particular area. It is crucial and essential that the Center be a national facility in both perception and reality.

Educational Programs

Educational programs for the American Cave and Karst Center will focus primarily on children from kindergarten through grade 12 and on the general public. These segments of society currently are not receiving adequate education about caves, karst and groundwater.

A number of colleges and universities have courses which deal with some facets of caves and karst, and with groundwater and water resources. While the American Cave and Karst Center will undoubtedly benefit programs of higher education, the focus of the Center will be on groups which are currently not receiving appreciable attention from existing educational programs.

Dramatic improvements in the protection and prudent use of natural resources in cave and karst areas will not occur until the public has a much improved understanding of the nature and value of these resources. Additionally, the public must understand that, while these resources can be used, abuse of the resources has dire environmental, social, and economic consequences. The same applies to groundwater resources, whether in karst areas or elsewhere.

The educational programs will primarily enhance existing programs within the school systems rather than add distinctly different curriculum units. As an illustration, an existing curriculum unit on local wildlife should, in a cave area, focus some attention on bats that use caves and the importance of these animals.

High school courses in earth science typically ignore karst landforms, even in areas where such features are common. Providing information focused on cave and karst features will help students in karst areas find ties between what they learn in school and what they see near home. Many earth science teachers in high school lack adequate information on caves, karst, and groundwater; one can help the students by helping the teachers. Teachers can be helped through field trips, seminars, and materials which are usable in the classroom. These things will be provided and produced through the American Cave and Karst Center.

Direct Help Programs

Direct help programs will assist business, industry, agriculture, communities, and government in appreciating and wisely using the natural resources of cave and karst areas. The programs will be primarily focused on networking and referral services rather than on problem solving work. There are consulting engineers, hydrologists, geologists, and others who are routinely involved in problem solving work and it would be inappropriate for the Center to compete with these firms and individuals. However, the direct help programs we envision are outside the typical domain of consulting firms.

Examples of the type of direct help programs which the American Cave and Karst Center will offer are: seminars, workshops, literature, networking, and library research. Our goal is not to do the job of consulting firms. Our direct help programs will make general information about karst more available to the public to enable people to make better decisions about land uses in karst regions.

As an illustration, most people unfamiliar with karstlands do not recognize sinkholes and do not realize that they can flood. The flooding can result either from the direct runoff of waters into sinkholes, or by waters backed up into the sinkhole from underlying cave passages which have flooded. Flooding problems may be greatly increased by local land use changes or by sediment deposition which partially fills some of the passages which transport the groundwater. Sediment deposition is often the direct result of inadequate erosion control during construction. There are many examples of land developments that have been attracted to karst areas and seriously damaged by sinkhole flooding that was readily predictable.

The American Cave and Karst Center direct help programs will work because they will focus on preventing the direct causes of environmental problems. To help eliminate the kind of sinkhole damage described in the previous paragraph, for instance, the Center will encourage the delineation of areas likely to be affected by sinkhole flooding if lands are developed. Such mapping has now been done around Springfield, Missouri; the data have benefitted business, industry, and government. The Center will also develop and distribute educational materials to help people understand how natural features like sinkholes "work" and how to predict and prevent environmental problems associated with them.

OBJECTIVES OF THE AMERICAN CAVE AND KARST CENTER

Five primary objectives were identified for the American Cave and Karst Center. Each objective is identified and briefly discussed.

Objective #1. Encourage and assist in the development of school curriculums that deal with caves, karst lands, and the natural, social and economic resources of cave and karst regions of the United States.

The natural, social, and economic resources of cave and karst regions of the United States are poorly understood by the public. Development of an adequate public understanding must begin with students from kindergarten through the 12th grade. We seek to develop generations of citizens who are better prepared to deal with the opportunities and problems typical of karst areas.

Objective #2. Develop programs to enhance public appreciation of caves, karst areas, and the people who live and work in such areas.

While we should focus educational programs on students living in cave and karst areas, we must not ignore other segments of the general public. The American Cave and Karst Center must have programs which enhance public appreciation of how living in cave and karst country affects people.

Objective #3. Prevent natural resource damage in cave and karst areas through increased understanding and awareness of mans' impacts on the resource base. This will be accomplished by direct help to business, industry, agriculture, communities, and government; information and awareness are the key ingredients.

Most damage to natural resources in cave and karst areas occurs as a direct and predictable result of a lack of on-site understanding and awareness of natural processes operating in these regions. There is a great chasm between what is known by the expert and scientific community and what is assumed by many of the people who make plans and decisions in cave and karst regions. One important reason for this information gap is that natural conditions in cave and karst areas are dramatically different from conditions in other landscapes.

There are many examples of activities which may be very appropriate in some landscapes, but which have highly undesirable consequences in cave and karst areas. The typical professional has been trained in understanding the general case; his comprehension of the unique conditions prevalent in karst areas is typically weak to almost nonexistent. This applies even to most professionals who have attended schools located in states with significant karst areas.

Every region of the United States has experienced at least some disastrous natural resource losses from businesses and industries which were inappropriately located, poorly planned and designed, or poorly operated. These problems have been particularly common and severe in cave and karst areas. There are segments of the American business community that have learned just enough about conditions in karst areas to conclude that they never again want to use a site in such an area. That is generally not the kind of strategy that is needed; such a strategy is harmful to the economic well-being of karst areas and to the businesses themselves. The challenge lies in applying knowledge and understanding of he natural systems and processes of cave and karst areas with sufficient accuracy and skill that natural resources are protected. It will be a big task, but it can be done. In reality, it must be done to protect natural resources and maintain or establish economic vitality in cave and karst areas.

Objective #4. Enhance the quality of life of people who live and work in cave and karst areas.

The federal government periodically publishes maps depicting areas where mean annual family income is deemed representative of poverty. A disproportionately large part of America's karstlands persistently appear on the poverty area maps. The explanation for the correlation between karst areas and areas of rural poverty lies in the fact that karst areas are typified by a collection of natural resource conditions which can have adverse economic consequences. The natural resource conditions, of themselves, are not the cause of the rural poverty. Instead, the root of the problem is the way in which people interact with the natural conditions. Much of this interaction is based upon incorrect presumptions of the natural conditions in karst areas. Correction of the presumptions is a key to preventing and minimizing problems, which will in turn enhance the quality of life of people living in karst areas.

Objective #5. Enhance public understanding and awareness of the nature and enormous value of all groundwater resources in the United States, not just the groundwater resources found in cave and karst areas.

It is important in these objectives to also consider groundwater conditions both inside and outside of the cave and karst areas. There are several reasons for this. First, groundwater is important both in karst and in non-karst areas. Second, groundwater conditions in karst areas are dramatically different from conditions in other types of landscapes. If attention is focused only on karst groundwater it would almost certainly create (at least in some visitors) the incorrect perception that all groundwater systems are similar to those found in karst areas. The Center has an inherent obligation to dispel incorrect perceptions about groundwater.

By explaining all groundwater systems, visitors to the Center will be able to better understand karst areas and their unique conditions. There is probably no better way to introduce the public to groundwater than through a facility such as the American Cave and Karst Center.

LOCATION OF THE AMERICAN CAVE AND KARST CENTER

Regional Site Considerations

In order to determine the most appropriate location for a national cave and karst center, the feasibility study first identified the major national cave areas and evaluated them according to six regional site considerations. The areas evaluated were Virginia & West Virginia; Florida; Kentucky,Tennessee & Missouri; Texas; South Dakota; and New Mexico. Below were the regional site considerations.

1. The Center must be located in a cave and karst region. There are two important reasons for this. First, such a location will enhance the relevance of the Center and of the Center's program. Secondly, the Center seeks to benefit the region in which it is located through various programs of the Center. Such benefits must accrue to cave and karst regions and regions where groundwater resources are important.

2. The regional location of the site must contribute to the facility being a truly national scale facility. The Center must be located in an area with significant karst features. Such features must be significant both in public perception and in reality.

3. The Center must be located in an area where there are significant environmental and economic problems and opportunities associated with groundwater and with cave and karst features and conditions. This requirement is essential for insuring that the Center produces a wide range of benefits to the area in which it is located. The Center must be a needed and valuable asset to the local community.

4. Many of the environmental and economic problems and opportunities associated with karst areas are related to industrial development, urbanization, and agriculture. All of these activities should be common in the region in which the Center is ultimately located. A region experiencing substantial industrial growth would be more desirable than a region with a static or decaying industrial base unless construction of the Center could reverse these latter conditions. A region with diversified agriculture would be more desirable than a region where agriculture was confined to grazing or pasture land.

5. The American Cave and Karst Center must be located in an area with a well developed national travel pattern. This will insure that the Center has national exposure and national impacts. If the Center is to function as planned, it must be nationally "visible". Additionally, a well developed national travel pattern will help insure extensive visitation of the Center.

6. The American Cave and Karst Center must be located in an area where it will be capable of

200,000 visitors per year or more. An annual visitation of 200,000 is necessary to insure that the Center has major regional and national impacts in education and problem prevention. Furthermore, desirable annual visitation should exceed 200,000 per year. An annual visitation of 500,000 is possible with an ideal site and this attendance is selected as the target visitation level.

Based on these 6 regional site considerations the major cave regions were ranked in the following order:

1. Kentucky/Tennessee/Indiana
2. Missouri/Arkansas
3. Virginia/West Virginia
4. Texas
5. Florida
6. New Mexico
7. South Dakota

Only the first four sites met or exceeded all of the important regional site considerations. Eight potential sites were then selected from these four areas. The eight potential sites were as follows:

Horse Cave, Kentucky
Bowling Green, Kentucky
Springfield, Missouri
Perryville, Missouri
Branson, Missouri
Lewisburg, West Virginia
Abingdon, Virginia
Austin, Texas

The eight potential sites were then ranked based on the following site-specific considerations:

1. The site should include significant and readily visible karst features. As illustrations, the site should be within view of a karst window, or a spectacular cave entrance, or a sinkhole plain, or a large spring which obviously discharges from a cave system.

2. The site should, to the greatest extent possible, physically and visually tie together caves, surface karst features, groundwater, and people. Establishing such ties is a crucial objective of the Center; the selected site should assist in this effort. A site which physically assists in this effort will be of great value to the Center.

3. The site must be readily accessible to substantial numbers of school groups. Schools within one hour travel time of the Center will be viewed as being located within a highly accessible zone. Schools within two hours travel time of the Center will be viewed as being located in a readily accessible zone. Schools within five hours travel time of the Center will be viewed as being located within a zone which is readily accessible for two-day field trips.

4. The site must be readily accessible to large numbers of tourists. The impacts of the Center and its various programs will increase as visitation of the Center increases. In general, the greater the number of potential visitors, the better the site.

5. The site must be highly visible to maximize its impacts. If the Center is located in a community, the Center should be highly visible within that community.

6. The Center must be compatible with the immediate area or else it must be capable of adequately modifying the image of the area so as to be compatible. The Center will be designed and operated in such a manner as to provide a high quality experience.

7. The selected site must be suitable for year-round operations. A national level facility should not

be a seasonal operation.

8. Sites with significant opportunities for outdoor exhibits are particularly desirable. Outdoor interpretation requires relevant natural features and other outdoor conditions appropriate for outdoor exhibits. Outdoor displays will decrease the amount of building space needed by the Center. Additionally, where favorable conditions exist, outdoor exhibits can enhance the relevance of the displays.

9. The Center must be able to readily establish and develop strong local and regional support. Support is essential; mere local and regional tolerance of the Center and its objectives are inadequate. To be effective, the Center must be viewed by the community in which it is located as a major asset.

10. The selected site should be located in an area where potential visitation and associated staffing needs are as well distributed through the year as possible. The Center will require a regular permanent staff to insure a high quality professional operation. Visitation to the Center may acceptably involve seasonally different clientele.

11. The site and surrounding lands should be of adequate size to accommodate substantial future expansion.

12. The site should have other appropriate site attributes. These include proper zoning, adequate parking, adequate utilities, and adequate fire and police protection.

13. The site must be available under acceptable terms and arrangements. The purpose of this consideration was to recognize any appreciable site attribute not assessed in any of the previous considerations. For instance, the site at Horse Cave contained some old buildings which were offered for museum use. Funding to renovate one of these buildings was also available through local government funding sources.

Site Location Conclusions

Based upon a consideration of all 13 rated factors, the three best potential sites for the Center were, in descending order, Horse Cave, Kentucky; Lewisburg, West Virginia; and Springfield, Missouri. Based simply on the potential for visitation, the three best sites were, in descending order, Horse Cave, Kentucky; Austin, Texas; and Lewisburg, West Virginia. A more in depth comparison of the Horse Cave, Kentucky and Lewisburg, West Virginia sites concluded that the Horse Cave site was the best location for an American Cave and Karst Center, and that the site would be adequate to meet the minimum scale visitation figures of 200,000 annually. The study further concluded that a facility at Horse Cave could ultimately (through expansion of all facilities) reach target scale visitation of 500,000 per year.

FINANCING THE AMERICAN CAVE AND KARST CENTER

A major consideration in the creation of the American Cave and Karst Center was a financing mechanism. The effort to establish the American Cave and Karst Center has been successful largely because we have developed diverse funding sources and have been consistent over a long period of time in our efforts to obtain funding. In other words, ours is a "keep at it, and don't put your eggs in one basket" approach. The Horse Cave, Kentucky site received considerable up front support from both federal and private funding sources.

Funding for the construction of the American Cave and Karst Center's museum and initial exhibits has come from four primary areas; federal government, state government, local government, and private support. Without any one of these sources, the project would not have opened this year. Grassroots level funding, such as fundraising projects, membership dues, direct mail fundraising, etc. has also been important, particularly in providing support for the development effort to raise large grants.

The capital costs of constructing the American Cave and Karst Center do not begin to show the true cost of such a facility. In order for it to be successful, there must be a way to provide long term and stable financing for administration and program services, as well as for maintenance and improvement of facilities.

Reliance on grants is not acceptable from a long term perspective. Most donors don't want to support projects forever. Reliance on government sources for operating needs is also problematic. During periods of public budget woes, programs that are not perceived as mainstream programs are likely candidates for loss of funding. Cave and karst programs, important as they are, are not perceived positively enough by the general public to count on long term funding from government sources. Furthermore, a privately operated Center would have much more program flexibility than a publicly operated Center.

For these reasons, the American Cave Conservation Association decided that the American Cave and Karst Center needed to be set up as a non-profit 501(c)(3) organization to enable the facility to be structured in a way that would allow it to accomplish its mission.

The best solution for providing long term financing for the Center was to locate it at a site where an interpretive cave tour could be provided. Cave tours are inherently interesting to tourists. Cave tours which emphasize an educational and conservation message also help fulfill the mission of the Center. Thus the Horse Cave, Kentucky site provided the opportunity to establish the Center at a cave site which maximized the potential educational message and the potential program related income. As visitation of the site approaches the target goals, the income produced from cave visitation may be used to develop educational outreach programs and, perhaps, a conservation grants program on a national scale.

CONCLUSION

Cave and karst resources are among the most widespread but poorly understood natural resources in America. The feasibility study conducted by the American Cave Conservation Association in 1987 determined that there is a tremendous need for public education programs which could help prevent karst related ecological and economic damage.

The study also determined that an American Cave and Karst Center was possible, and that there was a need for a facility to bridge the gap between scientists, cave managers, and other cave resource experts and the general public.

In response to this need, the American Cave Conservation Association undertook the effort to establish and develop funding for a national cave and karst center. To date, the ACCA has raised over $1,000,000 to construct the Center's museum at a site in Horse Cave, Kentucky. A variety of educational and interpretive programs are already being operated at the site.

The American Cave and Karst Center is now in the first phase of a long term effort to create a truly comprehensive and national-scale educational facility. It is our hope that the completed Center will be able to provide program assistance, technical help and financial support for the conservation of caves throughout the United States. Ultimately, a successful American Cave and Karst Center will reap tremendous rewards for caves and for the people who live in cave areas.

FORMATION REPAIR

Jim C. Werker

Increased human impact on caves is resulting in the need for more frequent repair of formations. This paper suggests ways to repair formations and the materials and equipment needed to facilitate repairs.

As with any project of this kind, it is necessary to consider the environmental impact of the materials being used and the safety of the people doing the work. Before using epoxies, hardeners, cyanoacrylates, solvents, or metal fixtures, it is important to obtain data sheets from the manufacturer detailing the chemical properties of the materials. Material Safety Data Sheets are often available that discuss any hazards connected with the materials. It is also advisable to consult with a biologist or geologist to ascertain the effect of the material on the cave environment. Failure to do so could result in considerable damage or introduction of toxins to the cave environment.

The following materials have been most effective for repairing cave formations:

Epon Resin 828 combined with V-40 curing agent works in dry environments; when combined with V-25 curing agent, Epon Resin 828 can also be used for wet applications. These adhesives develop a strong bond with a shear strength of up to 6,000 psi. Shrinkage is minimal, and the bond is resistant to a broad range of chemicals. Epon 828 with V-25 curing agent can be used to bond formations under water.

Fast-drying cyanoacrylate adhesives such as Special "T" that have a drying time of 50-60 seconds can be accelerated with Kick-It. These adhesives are useful for repairing small formations such as soda straws, helictites, and thin draperies. They can also be used for repairing stalactites up to 2 inches in diameter by applying a small amount of the instant adhesive in the center and a ring of Epon epoxy around the outer edge.

Metals that have worked best in the cave environment are stainless steels, particularly types 304 and 316, which are both highly resistant to corrosion. These may be purchased in round stock and cut to the length of pin required.

STALACTITE REPAIR

First, install the pin in the upper section by drilling a hole the same size as the pin and epoxying the pin in place. Then drill a slightly oversized hole in the lower section to allow for alignment of the formation and the pin. Fill the hole with epoxy and join the lower section to the upper section, using wire as shown inserted through the horizontal holes to hold the formation in place while the adhesive dries.

Allow the epoxy to set for at least 24-hours, then remove the wire and fill the small holes with epoxy and ground-up material of the same type and color as the speleothem being repaired. The best source of ground-up material is the powder that results from drilling the hole for the stainless steel pin; the dust can be retained in a plastic bag and applied after the epoxy dries. The same mixture can be used to fill any voids in the fracture area.

Hold the formation in place with wire until the epoxy has set. Afterward, remove the wire and fill the holes with more epoxy.

In the event that the section is too thich to drill holes for wires, drill holes for pins as shown in Figure 2 and wire them together on the outside to hold the formation in place.

STALAGMITE REPAIR

Drill a larger hole in the lower section to allow for misalignment. Epoxy the pin into the upper section first. Then fill the hole in the lower section with epoxy and attach the upper section to the lower section. Be sure to check the alignment prior to filling the large hole with epoxy.

DRAPERY REPAIR

Draperies can be repaired by applying instant adhesive to thin sections or applying pins and epoxy much the same as for stalactites.

For drilling holes, a small, battery-powered drill and metal drill bits are sufficient for small formations up to 4 inches in diameter. For larger formations, a Hilti, battery-driven hammer drill in capable of drilling much larger holes to greater depth. Caution is essential, as it is very easy to shatter the formation.

After the hole is drilled, canned air with a nozzle is useful for blowing dust out of the hole.

If repairs are done ina part of the cave that is still active, it is not necessary to fill small voids or fractures with epoxy, as nature will most likely take its course and cover them with new calcite deposits.

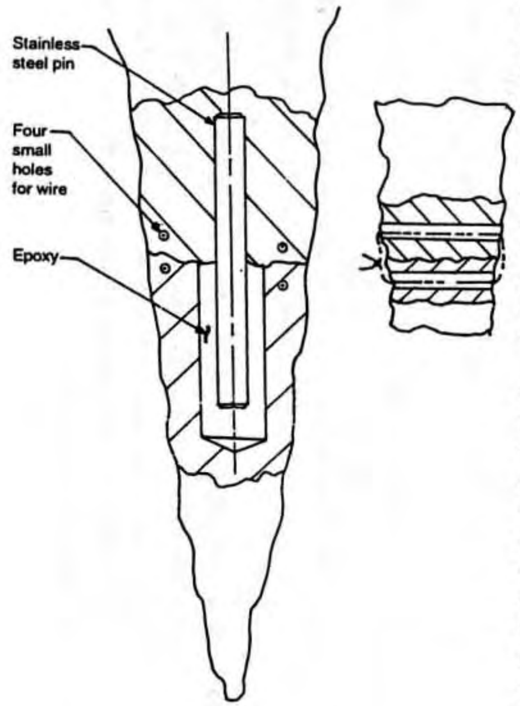
To obtain the approximate location of the hole on both the upper and lower portions of a formation, drill a hole in the center of one section. Next, take a piece of clear plastic wrap and place it over the end. Trace a line around the edge of the formation cross section and mark the center of the hole. Now, transfer the plastic to the opposite portion, line up the formation with the traced pattern, and drill a hole at the center mark.

RIMSTONE DAMS (Method Developed by Jerry Trout)

Repair to rim dams may be accomplished by using Portland cement mixed to a stiff consistency. Using hands and a brush, shape the cement as required to fill in for missing pieces. To speed up the curing process, add lime. If coloring is added, it is best to test this outside in daylight as it is very difficult to match in artificial light. Be sure to wear rubber gloves when working with cement. Also, be sure that the coloring agent has no toxic chemicals.

AUTHOR'S NOTE: If I can be of any further assistance, or if anyone has any new methods, materials, or techniques that aren't discussed here, please contact me. *I would like to thank Jerry Trout for information on repairing rim dams and Linda Doran for help in preparing this paper.* *My address and phone number are as follows: Jim Werker, 111 Hwy. 222, Tijeras, New Mexico 87059, Phone 505/281-9132.*

Stalactite Repair



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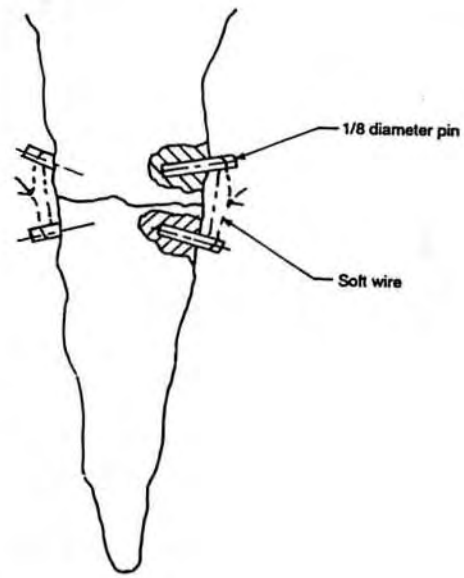
Allow the epoxy to set for at least 24 hours, then remove the wire and fill the small holes with epoxy and ground-up material of the same type and color as the speleothem being repaired. The best source of ground-up material is the powder that results from drilling the hole for the stainless steel pin; the dust can be retained in a plastic bag and applied after the epoxy dries. The same mixture can be used to fill any voids in the fracture area.

Hold the formation in place with wire until the epoxy has set. Afterward, remove the wire and fill the holes.

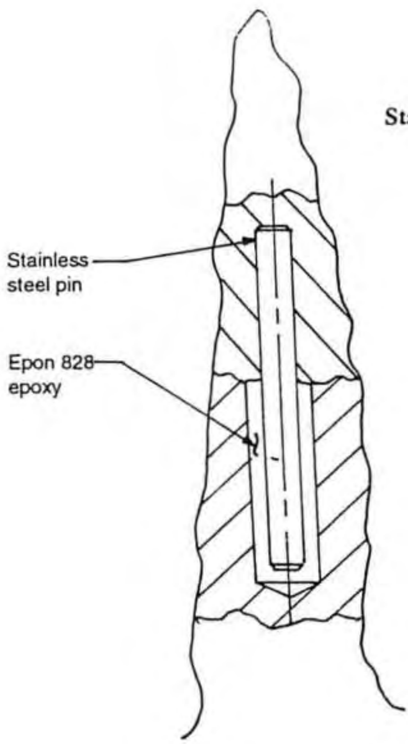
Stalactite Repair
(Alternate Method)



In the event that the section is too thick to drill holes for wires, drill holes for pins as shown and wire them together on the outside to hold the formation in place.

Figure 1. Stalactite Repair

Figure 2. Stalagmite Repair



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THE RESTORATION OF A VANDALIZED SHOW CAVE: CAVE WITHOUT A NAME, TEXAS

George Veni
George Veni & Associates

INTRODUCTION

This report is a case study of the successful restoration of a vandalized show cave. The achievement of this project stems from detailed research, excellent advice from experts in speleothem repair, the experience, insight, and care of the restoration crew, and the support of the cave owners and the local community. As in most situations, luck also played an important role. But since good luck cannot always be relied upon, this paper is presented as an example of a successful methodology which may be a useful model for restoration work in other caves.

One of the loveliest caves in Texas, Cave Without A Name has operated as a show cave since 1939. It is located about 50 km north of San Antonio, near the town of Boerne. A staircase spirals down along its entrance pit to a depth of 24 m, and opens into a well-decorated passage measuring 7 m high by 12 m wide by 186 m long. Large columns, stalactites, stalagmites, and draperies divide the passage into four distinct sections. The commercial trail ends where the southern end of passage intersects an underground stream that makes up most of the cave's 4.3 km surveyed length. Cave Without A Name is currently the 7th longest cave in Texas (Elliott, 1991).

Joleen and Eugene Ebell are the cave's owners and sole operators. Cave Without A Name receives relatively little traffic due to the Ebells' limited financial resources and advanced age, which restrict their ability to publicize this small but outstanding cavern. Security for the cave is minimal, consisting only of a gate at the entrance. There is no other barrier to restrict access to the entrance, and cars are often parked within 2 m of the gate. Prior to 1987, activity at the entrance could be effectively monitored by the owners since they lived in a wing of the gift shop located next to the cave entrance. Currently they live in a mobile home about 300 m from the cave. Prior to 1993 there had been no significant vandalism of the cave.

THE VANDALISM

At about 2 a.m. during the nights of 30 January to 3 February 1993, vandals entered Cave Without A Name by prying up a corner of the roof of the entrance building and climbing down a ladder to the trail. They used the tour lights to travel through the cave, where they kicked over stalagmites, used one as a club to smash other speleothems, lights and light shields. They also shattered a beer bottle, threw mud, rocks or broken speleothems to damage speleothems that were out of reach, and scratched a name in the wall. Several speleothems were removed from the cave.

Due to the low tourist traffic at the cave, the vandalism was not discovered by the owners until the cave had been entered at least twice. The local sheriff was called on 1 February 1993, but the vandals re-entered the cave for a final time that night. The vandals' total damage included 7 broken lights, 8 damaged light shields, one stolen road-sign advertising the cave, trash left in the cave, one name scratched on a wall, 47 broken or damaged speleothems, and 30 missing speleothems. The broken or missing speleothems ranged in size from 3 cm up to nearly 2 m in length.

RESTORATION

During the evening of 5 February 1993, I received a call from Eugene Ebell. The tone in his voice indicated a great loss or trauma. "They busted it all up," he told me in a shakily, and asked if

I could help him the next day. The following morning we surveyed the damage. It was bad, but could have been much worse. The cave is so well decorated that while 77 broken speleothems are inexcusable, they would not be noticed by the average visitor.

Cleaning and repairing the damage would have been difficult for the Ebells, so I took the work upon myself and my first priority was to get the cave ready for business. I spent the day replacing broken lights, picking up broken glass, removing broken speleothems from the trail so no one would step on them, sweeping the trail clean of mud, rock and gravel, and securing the roof to prevent further access from that route. The second priority was to inventory the damage for restoration work on the following weekend.

The next day I began to search the literature for information on speleothem restoration. Several reports have been written on the subject (anonymous, 1965; Day, 1975; Rhoades, 1976; Rohde and Kerbo, 1977; Tinsley, 1979; Wiggins, 1979; Dentella, 1981; Rohde, 1982; Bonwick and Ellis, 1985; Crisman, 1985; Rose, 1985; Hill and Forti, 1986) but little specific information exists on speleothem repairs. Clearly most repairs are conducted in isolation and without benefit from the experience of other restoration efforts. Not wanting to reinvent the wheel or exacerbate the damage in the cave, I called around for ideas and advice. My phone search led me to Jim Werker.

Jim came highly recommended as the careful and thorough person who for several years has conducted the speleothem repairs in Carlsbad Caverns and the surrounding area. Prior to using any glues or other repair materials, Jim sends the stuff to a chemist to rule out adverse impacts on the speleothems, the cave waters, or cave life, either in the application or by the long-term presence of the material in the cave. When I called, he expressed interest in my problem and was extremely helpful. Unless otherwise specified, the repair techniques described in this paper were suggested by Jim.

On the weekend of 13-14 February 1993, a total of 12 cavers from the Bexar Grotto in San Antonio and 3 cavers/staff from Caverns of Sonora began the restoration work at Cave Without A Name. Additional volunteers abounded, including other cavers, groups of explorer scouts, and even cave tourists, but I felt it best to keep the group to a small team. Few cavers in Texas have done this sort of work before, so while most of my group was inexperienced, I wanted to be certain they were conscientious. The small group size also made for better instruction, discussion, and quality control of the restoration work. The speleothem repair was conducted in 5 stages.

STAGE 1: MATCHING THE BROKEN PIECES

The first stage was to match the broken pieces to their original locations. This proved more difficult than it might sound since many of the broken pieces were carried throughout the cave and dropped far from their sources. Thirteen stalactites and two stalagmites still await repair as soon as we discover where they belong. The matching of pieces was also crucial to effective reconstruction of single speleothems broken into several sections; often the pieces would fit together only when assembled in a certain order.

STAGE 2: SPELEOTHEMS NEEDING SUPPORT RODS

Some speleothems required an internal support rod to regain their strength and stability. This process required two days, and since the restoration effort was scheduled for only two days phase 1 of that work had to be completed on the first day so phase 2 could be completed on the second day. Phase 1 consisted of first identifying the speleothems needing a support rod. These were generally at least 8-10 cm in diameter and no less than a meter long. Exceptions included top-heavy stalagmites, and speleothems in high-traffic areas where they are more likely to be bumped by tourists.

The next step in Phase 1 was to mark the drill holes. This could sometimes be accomplished by targeting the center of the speleothems' concentric growth rings, but off-centered growth or recrystalization of some speleothems sometimes prevented the use of this technique. In its place the team used a variety of methods such as careful measurement, or placing a dot of mud on one broken end and pressing it against its matching piece to mark the spot. The upper piece was then drilled to the diameter of the stainless steel support rod, either 6.4 mm (1/4") or 4.8 mm (3/16"), and the rod was epoxied into place. I had read and heard that iron rebar, aluminum, and brazing rods had been used in other repairs for support, but Jim Werker strongly advised against them. Only stainless steel maintains its strength and does not significantly degrade with time. The holes drilled into the speleothems were no more than 10 cm deep. Deeper holes do not provide appreciably greater strength and in fact may weaken or result in greater harm to the speleothem. Regardless of the size of the support rod, the lower hole was drilled to a larger diameter of 12.7 mm (1/2") to allow for an easier fit of the rod when the top and bottom pieces were joined. All drilling was conducted with carbide-tipped bits to minimize rattling and possible shattering of the speleothems.

Phase 1 was completed when the supporting rod was epoxied into the upper drill hole. For best results and greater stability, the epoxy was allowed to dry overnight before proceeding with Phase 2, which involved gluing together the matching ends of the speleothems. Before epoxy was applied, the broken ends were put together to be certain the lower hole would well accommodate the support rod and did not prevent a snug fit. With one speleothem the lower hole had to be enlarged and with another the rod was slightly bent to gain a tight seam. Poor fits sometimes resulted from drilling powder being pressed into the broken ends of the speleothems, and was easily remedied by scraping it out with a stiff-bristle brush. When the broken ends were found to fit well together, the lower hole was half-filled with epoxy, a thin film of epoxy was applied to one of the broken ends, and the broken ends were pressed together. The weight of stalagmites' pieces were generally adequate to hold them together while the epoxy dried. Details on the epoxy and on securing stalactites are presented in the next section.

STAGE 3: SPELEOTHEMS NOT NEEDING SUPPORT RODS

Small broken speleothems that did not require support rods were reassembled with a slow-drying epoxy used in the plastics industry. Called Shell-Epon 828, the epoxy was mixed in a 60:40 ratio with V-40 hardener. The usual 50:50 mix is also adequate, but Werker found that the 60:40 mixture produces a stronger bond. The mixture is creamy-white when wet and colorless when dry. Small amounts were mixed and its slow drying time was helpful as the epoxy was judiciously applied and passed from one repair job to another. The epoxy mixture remained soft and useable for more than an hour after mixing. The drying time for maximum strength of its bond was about 24 hours.

The only problem I had with the epoxy was that it was not available in San Antonio. Werker mentioned that Cadillac and Regal Plastics companies carry the materials, but I learned that the branches of these nation-wide stores obtain their supplies from different distributors, and no one in San Antonio had ever heard of the names I used. I suspect that chemically identical epoxies and hardeners exist under different brand names, but since I wasn't sure of this and didn't know what other names to ask for, I ordered the materials from Albuquerque where Werker had found them. The epoxy and hardener are only sold in 1-gallon units at about $35 per gallon. For the Cave Without A Name repairs I didn't need that much epoxy; fortunately the folks at Caverns of Sonora offered to buy the remainder for some minor repair work.

To apply the epoxy we used small disposable items like nails, popsicle sticks, or scrap pieces of stainless steel rod. The application was identical for stalactites and stalagmites, painting a thin film of epoxy mixture on one of the broken ends. The mixture covered the broken face to within 5-10 mm of the outer edge of the speleothem to prevent leakage (see Stage 4 for clean-up of leaked epoxy). As described in the previous section, the pieces were reassembled prior to gluing to assure proper fit and to determine if reconstruction required a particular order.

Stalagmites were generally the simplest speleothems to repair. Once the epoxy was applied, the broken end was set on the lower intact stump and its weight held them together until the epoxy dried. Stalactites were difficult to repair because of the need to create a steady, secure, vertical upward force to hold them in place. Equipment was brought in to build scaffoldings, wrap the stalactites in slings, and even to drill small holes above a break to cinch the broken end into place with wire or cord. All these techniques had been used in other restorations with varying degrees of success.

The Cave Without A Name restoration team was lucky enough to include an engineer. I was puzzling over the best way to secure a heavy stalactite when I noticed Dan Hogenauer had just finished working on a stalagmite. I reminded myself that I was supposed to be coordinating the restoration and shouldn't get bogged down on one speleothem, so I volunteered Dan with the off-the-cuff comment "You figure this out." He had it set up in about 2 minutes.

The solution was elegant and effective. Dan created a lever. A board was set under the stalactite and a rock was placed on its opposite end to hold the speleothem in place. Figure 1 illustrates the technique. Key concepts are that fulcrum be at about the same elevation as the lower tip of the stalactite when set in place, and that the weight at the opposite end of the board can be set far from the fulcrum when more pressure is needed, or closer to the fulcrum when pressure needs to be reduced. For repairs close to the floor a fulcrum can be made by stacking rocks or other available materials (gravel, buckets, boxes, etc.). For repairs more than 1 meter above the floor, a scaffolding can be built to support a fulcrum at higher elevations.

While this leverage method is quick, easy, and effective to apply, it has certain limitations. First, the tip of the stalactite must not be fragile. Second, the technique is easier to apply if the tip of the stalactite is rounded or flat. Third, if the break is angled from horizontal, the stalactite may need to be supported along its side to prevent it slipping out of place when upward pressure is applied. One method we used to keep the speleothem in place was to lash a small board to the broken piece, which jammed between it and the wall or neighboring stalactites.

The most lengthy repair operation was the restoration of speleothems broken into several pieces. With stalagmites, especially those that were top-heavy, several days were required to reassemble them. Following the restoration weekend, I made three additional trips to Cave Without A Name just to glue on another piece to stalagmites broken into 3-5 sections. We attempted to simultaneously join more than 2 pieces together before the epoxy was dry, but found this was not effective for most heavy or weight-bearing pieces.

While stalagmites were rebuilt by adding to the stump until the speleothem was whole, stalactites were more easily restored by reassembling the broken pieces into one unit and then attaching that to the stump. The stalactites were repaired by turning the top-most piece upside down, planting it firmly into the dirt/mud floor, then adding its lower pieces as if reassembling a stalagmite. The weight of each piece held the unit intact until the epoxy was dry enough to either add an additional piece, or to turn the rebuilt unit right-side up and attach it to the stump. Before epoxy was applied, dirt and mud were cleaned off the stalactite end that was in the ground.

At the time of this writing (April 1993), repairs on several speleothems have not been completed because they are actively dripping water. The epoxy is able to dry despite the water, but in stalactites where the water originates inside the speleothem enough hydrostatic pressure develops to prevent a good bond between the broken pieces. Since the cave becomes less active in the summer and fall, repair of these speleothems has been delayed until those favorable conditions develop.

The most difficult speleothems to repair were the draperies. At first I was concerned that their thin edges would not provide a significant surface for the epoxy to stick to, but this was not a problem due to the epoxy's high adhesive strength. The problems turned out to be in reassembly and holding the pieces in place for the epoxy to dry. The fragile nature of the draperies resulted in their breaking into dozens of pieces which were very difficult to put together. Additionally, their fragility creates the need to find the delicate balance between maintaining enough pressure to hold the pieces together, while knowing that slightly more pressure could add to the existing damage. Thus far repairs have only been attempted at one drapery and with mixed results. Touch-up work may be attempted later this year when the cave becomes drier (see discussion of Stage 5). Based on those results additional attempts at drapery repair will be assessed.

STAGE 4: CLEAN-UP OF REPAIR WORK

Ideally, once speleothem pieces are joined together the repair is complete. In reality, epoxy sometimes leaks from the seams and runs down the speleothem. Once a speleothem is epoxied together the bond is permanent, so there was a tendency among restoration personal to be sure enough epoxy was applied. Consequently some repairs had too much epoxy and leaked.

The best clean-up method was to catch the leakage at the seam. Wiping with a rag was effective but sometimes smeared the epoxy into tiny pits giving the wiped area a wet appearance when the epoxy dried. The most effective technique was to swab the leakage along the seam with a cloth rag draped over the flat head of a screwdriver or nail.

Occasionally epoxy forced its way out of the seam after the restoration team left the cave for the day. The impact of the drippage varied according to the surface of the speleothem. With most speleothems the dried epoxy could be easily peeled off leaving no trace of its presence. These low impact speleothems usually had a thin silt film on their surface which prevented adhesion to the calcite, or had a finely pitted surface which also prevented adhesion (unless the epoxy was forced into the pits by swabbing). The moderate impact speleothem surface was of clean, smooth calcite. The epoxy had greater adhesion to this surface and sometimes had to be pried off with a knife blade or a flat-head screwdriver. Minor scratches sometimes resulted. The speleothem surfaces most prone to damage from leaked epoxy are those which are case hardened and inactive. Case hardening is the development of a hard thin outer layer, usually a medium to dark brown color, underlain by softer material, usually a white or cream color. Leaked epoxy adheres to the outer layer, which readily peels away from the inner layer when the epoxy is removed and creates stripes of white inner material surrounded by brown outer material.

STAGE 5: TOUCH-UP WORK

As indicated above, additional restoration work will resume when Cave Without A Name is drier. Some people will try to match more broken pieces to their sources but the main effort will be to touch-up the existing repairs. While some seams are nearly invisible, others are quite evident. We will use cement dyed to match the color of the speleothems to fill in seams and reconstruct small missing pieces. This technique has been successfully used by Dentella (1981) and will be supervised by personnel from Caverns of Sonora who have experience in color matching cement in some of their trail construction. Cement will only be used to repair opaque speleothems. Werker suggested that a mixture of epoxy and pulverized rock or speleothem fragments be used for translucent speleothems. In either case, the technique will first be applied to small repairs in areas not easily seen from the tourist trail. Larger touch-ups in more visible areas may follow depending on the results of the first attempts.

MISCELLANEOUS REPAIRS

While the focus of the restoration work was to repair the broken speleothems, other assistance was also provided to the cave owners. During the project weekend the gate to the cave was reinforced, all of the light shields were repaired (most had simply been molded out of cave clay), and two troublesome light switches were fixed. Miscellaneous speleothem restoration work included washing off some soiled speleothems, fishing out broken pieces tossed in the stream, and picking up the "Cedar Post," a 1.9 m high stalagmite that was pushed over and fortunately not broken. By using a dripping sodastraw stalactite as the target, the Cedar Post was reset to within 7 mm of its original position.

PUBLICITY, COMMUNITY SUPPORT, AND PROSECUTION OF THE VANDALS

The restoration of a vandalized cave goes beyond the physical repairs of the speleothems. It includes the capture and prosecution of the vandals, and the education of the community that cave vandalism is a reprehensible act which harms everyone. To meet these goals I targeted three groups, my purpose being to:

- -- publicize the vandalism;
- -- advertise the $250-$1000 reward offered by the National Speleological Society for cave vandalism;
- -- develop sympathy for the cave and cave owners; and
- -- develop leads that may identify and contribute to the prosecution of the vandals.

The first group I contacted was the Kendall County Sheriff's Department and met the deputy in charge of the investigation. It was important he know how many people were outraged by the vandalism, that cave vandalism is specifically listed as a Class A misdemeanor in Texas, that there is a reward offered for the cave vandalism, and that he was welcome to call me anytime (which he did) when he needed help or had questions about the cave or about the vandalism.

The second group I called was the local weekly newspaper, The Boerne Star. I discovered that its editors are big fans of Cave Without A Name and reporter Charles Wood has long wanted to become a caver. For three weeks the vandalism was a front-page story, detailing the damage but emphasizing that it was still a beautiful cave and worth visiting -- especially after the restoration when almost none of the damage would be noticeable (anonymous, 1993a). I invited Wood to the restoration project and he produced a very positive article about the cave (Wood, 1993). For two weeks publisher David Tuma made Cave Without A Name the focus of his editorial page column (Tuma, 1993a and 1993b). The story was picked up by the San Antonio newspaper (Winingham, 1993), and was the subject of a San Antonio television news broadcast (Lovell, 1993). One columnist for a regional newspaper wrote a sentimental piece on his visit to the cave (Pape, 1993).

In talking with my wife Karen about the vandalism, I speculated that the vandals were probably high school kids looking for cheap thrills. She gave me the best advise possible when she suggested I call the third information group, embodied by the Boerne High School principal. Mr. Champion turned out to be yet another person who was enchanted by Cave Without A Name. Appalled to hear about the damage, he was more than happy to announce the NSS reward to the students over the school public address system. The next day he called to say a student had come forward with information on who the vandals were and that they had speleothem pieces at home. I advised him to relay the information to the Sheriff.

Over the next two weeks as the Sheriff investigated the allegations, one youth confessed and apologized for his part in the vandalism (anonymous, 1993b). This confession prompted numerous confessions and identified a total of 18 participants in the vandalism. They had gone out to the cave for 3-5 nights in groups as large as 8 persons. Five were 18 years old or older; the rest were legally minors. Beginning on 26 February 1993 they were charged in front of the Kendall County magistrate.

The Sheriff and I set the cost of damages at $35,439.86 from the actual costs of repair materials and the market value hourly wage of the restoration workers (assuming they had to be paid for their voluntary contribution). This figure includes costs of missing of irreparable speleothems, determined by totaling the cost of actual repairs, dividing by the number of repaired speleothems for an average price of $460.26/speleothem, and multiplying that value by the total number of damaged and missing speleothems.

At the time of this writing the alleged vandals have not yet been tried in court. My discussions with law enforcement officials suggest that they will not be severely punished since this is a first offense for all of them, yet the public's disgust with the matter will not allow them off unscathed. In any case, it is clear that the people of Boerne realize that cave vandalism is not only a legal offense but is morally offensive. Without their support the vandals may not have been brought to justice.

SUMMARY

The vandalization of caves is a sad event, yet their restoration can be used as an opportunity to promote positive public support for cave conservation. The general public becomes impressed when they see how volunteers organize to help victimized cave owners. This image also shows the public the fragile beauty of the underground world, and gains their pro-active support in apprehending the people responsible for its desecration.

To the best of my knowledge, this report is the most in depth and detailed discussion of speleothem repair procedures to date. Most of the repair work only requires care, patience, and common sense, yet some tasks certainly benefit from the voice of experience. Jim Werker should be encouraged to write a truly comprehensive book on speleothem repair.

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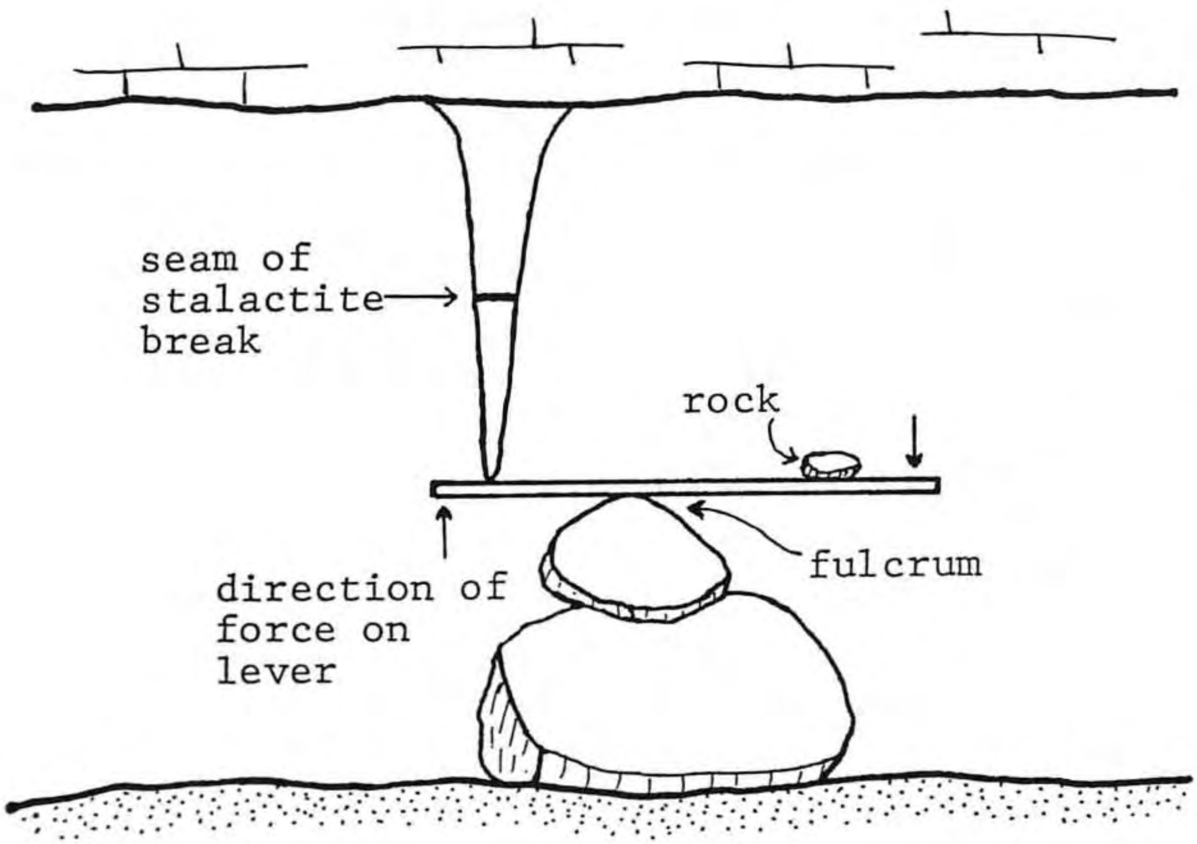
Figure 1. Diagram of lever method to stabilize broken stalactite pieces while the epoxy dries along the seam.



LINT IN CAVES

by Pat Jablonsky, Sandy Kraemer, and Bill Yett

ABSTRACT

Implications and control of lint deposits in show caves has received scant systematic study. The potentially detrimental effects of uncontrolled lint accumulations in caves includes degradation of the appearance of the cave, provision of a food source for opportunistic organisms, and even a medium for dissolving cave surfaces. A number of show caves regularly clean tour trails and cave surfaces with water and a few, use some other methods of cleaning for the abatement of lint. Plausible and useful techniques to control lint are being examined by the authors who are also studying the composition of lint by laboratory methods and the dynamics of lint movement in caves. Preliminary conclusions indicate that the most promising strategies to control lint deposits in caves involve careful attention to trail design, custodial and maintenance procedures. The application of some "clean room" technology may also be useful.

BACKGROUND

Much of the information contained in this article was accumulated for a Rocky Mountain Region National Park Service funded research project for Wind Cave National Park (Project Number COLR-R92-0199). This investigation is in progress and will be completed May, 1994. Observations and conclusions should be regarded as tentative. Comments and criticisms are encouraged.

A few show caves have instituted maintenance procedures to remove lint and other debris from their caves. For example, Caverns of Sonora in Texas, Cave of the Winds in Colorado, Carlsbad Cavern in New Mexico and Timpanogos Cave in Utah. However, the earliest systematic and continuing cleaning effort the authors are aware of are the Jenolan Caves, New South Wales, Australia. Published reference to cave cleaning efforts there were from the early 1960's. The motivation for these efforts was an awareness that the caves had lost some aesthetic value and could, in fact, be described as dusty and dirty. The goal was to restore the cave tour route to an acceptable level of pristine original beauty. Our research is similarly oriented. In the process of the practical aspects of how to most effectively reduce and remove visitor introduced lint and dirt, interesting tangential information has emerged.

THE MANAGEMENT PROBLEM

Every cave visitor unintentionally leaves something behind when they visit a cave. While the residue left by each individual may be only a few tens of particles, the accumulation in a heavily visited show cave is significant. Popular, privately-owned show caves have visitations of a quarter to a half million per year. Two National Park Service caves, Carlsbad and Mammoth, have annual rates of three quarter of a million and two and a half million annual visitors, respectively. Thus the few tens of particles contributed by each visitor becomes a significant accumulation. The accumulated particles visitors and staff unknowingly leave behind are mainly made up of garment fibers, soil particles, epidermal material, hair and other matter. The term lint suggests garment fibers. However, for the purpose of our research, lint includes the broader range of what falls off visitors as they move through a cave tour route. We are not addressing what can best be described as litter (seed shells, coins, tissues, gum wrappers, smokeless tobacco residue, etc).

In 1988, a very labor intensive volunteer lint removal effort began at Carlsbad Cavern. The endeavor required four years and 2,500 volunteer hours to clean the full 3.72 mile length of the cave trail. This was done with hand tools such as brushes, tweezers, and a sort of synthetic "feather duster". In some delicate popcorn areas progress was no more than a few square feet per hour. During the continuing project the collected material was sorted and weighed. 75 pounds of lint was collected from cave surface areas within three feet of the trail. In addition, 200 pounds of visitor associated litter was also collected. It should be noted that this is a minor part of what visitors actually leave behind. It does not include what falls on the actual trail itself and is collected by the Park's cave trail crew. The trail design and cleaning procedures at Carlsbad Cavern are considered by the authors to be above average for facilitating trail maintenance. While the collecting techniques used at Carlsbad Cavern may not be a generally feasible model for other show caves, the collected materials do quantify the magnitude of the problem.

During the 1991 lint camp at Carlsbad Cavern, an observation was made that was quite startling and seemingly elevated lint from a benign aesthetic nuisance to a medium that facilitates the dissolution of calcite minerals. A particularly thick and moist mat of lint was observed and it was noted that there was an obvious erosion and pitting of the area beneath the lint mat. While the corrosive mechanism is not yet understood, it is probable that the lint provided an environment conducive to a dense microbial colony and the metabolic process within the mat was reacting with the cave surface. The management response, of course, should be to prevent the accumulation of lint to such an extent.

As part of the Wind Cave lint study, an effort is under way to precisely measure lint deposition rates. The technique adopted is the use of metal collection pans with raised sides which are painted flat black and set out near the visitor trail system (within 1 meter of the trail). On a regular basis, these pans are examined under ultraviolet (UV) light. The UV light provokes a visible light response from fibers treated with optical brighteners which are added during the manufacturing or washing/rinsing process. The color is an intense blue white which contrasts well with the black background. A photograph of a representative twenty-five square centimeter area is taken and later projected for a count of the particles. The collection pan is carefully cleaned of all UV responsive lint and replaced for the next check. Successive monthly monitoring began in early June and at the time of this paper's due date, no significant generalizations could be made. However, one collector in the first monitoring period (June 13-July 10, 1993) showed a density of 5 particles per square centimeter with 3,500 visitors passing the collector during that period. It should be noted that only UV responsive lint was counted which is probably half or less of the total lint deposited. The collector was approximately one meter from the center of the visitor trail.

In 1992, a questionnaire asking for statistical data, cleaning techniques and if they (managers) were aware of lint deposits, was sent to 113 show caves in the U.S., Australia, New Zealand and Europe. Management responses were received from 73 caves. A majority of responses indicated they took no lint abatement measures. While a number of those who responded recognized a lint problem, many did not. An examination of individual responses, however, gave a different view. The caves with little or no noted lint had low annual visitation rates (under 50,000). Caves with higher rates (200,000 or more) generally appeared to be aware of lint problems and some were pursuing some form of lint control program, most by a quarterly to annual wash down of the cave. A few were vacuuming or using "feather dusting" techniques. Jewel Cave National Monument, because of its unique open grill walkway and stair design, has installed collection tarps under its trail. This is a recent installation and is presently in an experimental stage of development.

BIOLOGICAL STUDIES OF CAVES RELEVANT TO LINT STUDIES

Caves are generally described by biologists as low energy environments, unless they are heavily impacted by introduced organic material from surface sources. These sources may come from flooding, or wind or animals such as bats, pack rats or people. Any significant amount of regular cave visitation will probably elevate an impacted area of the cave to a higher energy environment. There are organisms that have adapted to the normal low energy environment of caves. It is likely that the new higher energy environment of a tour route will be exploited by opportunistic surface origin organisms better adapted to high energy environments. While there is no strong evidence of cave tour routes being heavily infected with detrimental molds and bacteria, insects or other organisms, prudent management would suggest that this concern be kept in mind.

NON-CAVE LINT CONTROL STRATEGIES

Airborne particles are a serious workplace health hazard in industrial facilities such as cotton, lumber and moulding mills. Particle control techniques in such industries were reviewed to determine if they were applicable to show caves. The systems used in such industries are essentially the same. Particles are collected at the source by air suction and moved through ducts to an area where they are allowed to settle out by gravity or trapped in filters. There might be additional filtration of the general work place air as well. These techniques do not seem to have any likely application to show caves, if for no other reason than they require complete control of the environmental air flow.

In a further search for the most advanced technology, Johnson Space Center, NASA, was contacted to determine how airborne material is controlled in the Space Shuttle Crew Compartment. It was learned that in early Orbiter missions, debris in the compartment was so extensive that there were concerns about crew health, physiological discomfort, and equipment malfunction. Corrective measure began with collection and analysis to determine the source of the debris. Ground support equipment and some Orbiter equipment was redesigned to lessen particles being generated and deposited in the Orbiter. Rigorous cleaning and housekeeping was required in orbit and during ground mission preparation. Crew uniforms were "delinted" by placing them in a household type cloths dryer on "air only" for a period of time immediately before flight. The only equipment specifically designed and tested for general lint reduction by NASA is called an "Orbiter cabin air cleaner" and is essentially the same as a home room air filter or a ductless range hood. Air is pulled in by a fan through a filter and returned to general circulation. The Orbiter cabin air cleaner was found to have made a significant contribution to controlling debris and was recommended for regular use.

Inquiries were made to museum conservators, who also have to deal with lint contamination from visitors. Museum exhibits have traditionally been isolated from the public by glass because of detrimental effects of visitors. Museums are now creating exhibits that are open to the public to allow closer involvement and access. It is possible to protect these exhibits from air borne debris in much the same way that clean rooms are kept clean (the area is kept under a constant positive pressure "wash" of highly filtered air). As with industrial mills, complete control of air movement is necessary for this approach to be successful.

The Denver Museum of Natural History is presently completing an open exhibit on ancient life forms, called "The Prehistoric Journey". The clean room approach was considered for keeping the exhibit areas free of lint but was rejected as too costly for the benefits. It was felt that rigorous custodial and maintenance procedures would be adequate. There seems to be a consensus among museum conservators that technological "fixes" generally have not replaced rigorous custodial techniques.

One suggested technique that has not yet been examined to any significant extent is that the electric charge of particles can be used or manipulated in desirable ways. For example, it might be possible to attract lint to collection containers or establish barriers at trail edges to repel particles and contain them to the more easily cleaned paved area.

RESEARCH AT WIND CAVE NATIONAL PARK

Laboratory analysis of lint from Wind and other caves has been a continuing part of our research. Identification and testing of fiber material types was made to determine the ratio between natural and synthetic fibers. Through laboratory analysis we have established a ratio of natural to synthetic garment fibers to be about 50/50 plus or minus 10% Next, samples of loose materials were removed and collected by vacuuming from visitors before entering and after exiting the cave to determine if it would be effective to use "air shower" compartments. The principal of an "air shower" is to blow loose particulate matter off visitors before they enter a cleanroom-type environment. The air shower produces a gust of air from above which is combined with a strong vacuum from below to collect loose material off of visitors. Observations seem to indicate that this technique might significantly reduce the initial depositional rate commonly found on any cave tour. Other observations based on laboratory analysis are that human hair, pet hair, epidermal tissue, dirt particles, insects, and insect fragments do make up a significant component of what we call lint.

Very useful insights on the dynamics of lint movement in the cave came from a test "seeding" of introduced lint. The seeded lint responded to UV light in a sharp orange color and was quite distinct from the blue-white of the indigenous lint. The material was plucked rather than abraded from the fabric. This resulted in mainly long-bunched fibers which were allowed to fall to the trail surface. Several hours and 75 visitors later, the seeded lint was observed to have migrated up to 300 feet down the trail and much of it had moved to the edge or off the trail. Over subsequent months, small particles of the seeded lint were observed moving higher up the walls and ultimately on to low ceiling areas. The original goal of the seeded lint test was to check the utility of curbs for the containment of lint to the paved trail areas. It appears that this is a useful design improvement, but only if there is frequent and appropriate trail cleaning. A well-designed trail curbing system can contain, trap, and snag lint as natural and visitor caused air currents move the lint along and across the trail. However, it is important that lint be removed before the grinding action of visitors shoes reduces the lint particles to a size that allow sufficient "hang time" which permits the lint to escape over the curbs. An additional advantage of curbed trails is that they can be used to channel and hold run-off waste water during trail and cave wall washings. They can also reduce the visitors' natural inclination for leaving the trail.

LABORATORY ANALYSIS

INTRODUCTION

Laboratory analysis of lint fibers has been an ongoing endeavor since the lint project began. Thanks to the generosity of Doug Kendall, Peggy Forney, and Marcela Siao of the EPA Labs at the Denver Federal Center, conducting the analyses was easy and convenient. The instrument used was a Leitz Wetzlar polarizing microscope; magnification ranged from 100X to 250X.

Lint from six cave systems, involving a total of 74 microscopic slides with 301 records (areas scrutinized on the slides) was examined. These examinations were for the sole purpose of determining synthetic vs. natural fiber content of the lint.

Under the microscope it was very obvious that lint was more than just fabric fibers. The slides also revealed dirt, wood, insect parts, human hair, animal fur, fungus, processed tobacco, paper, and a number of other things. For the purposes of this study, fiber identification included fabric fibers, human hair, and animal fur. When lint was weighed, all materials were included.

CAVE SYSTEMS

Carlsbad Cavern

Carlsbad Cavern is located in southern New Mexico. Lint samples were examined from two general areas of the cave--the Queen's Chamber and the entrance corridor to the men's rest room just off the lunchroom. All the samples are considered to be both new + old lint since neither area had been previously cleaned. The lint at the men's room was relatively dry, whereas the Queen's lint was damp. The samples from the men's room corridor should be an illustration of men's clothing, while the samples in the Queen's Chamber are those of the general public. It is interesting to note that there is little difference in fiber content at the two locations. Table 1 tabulates the fiber analysis of all the caves looked at.

Cave of the Winds

Cave of the Winds is located in Manitou Springs, Colorado. Lint samples were taken from three areas of the cave: 1) along the regular visitor trails, 2) at the transition point between the regular visitor trail and a no-longer-used trail, and 3) at a point on the no-longer-used trail quite a distance from the visitor trail. These three areas should give satisfactory samples of new (1 year-old), new + old, and old (4-5 year-old) lint, respectively.

From the data it can be seen that there has been a definite change in fiber content over the last five years. Within the last year the fiber content of new lint was 36% synthetic. The new + old fibers also gave a low synthetic content of 31%; whereas, the old fibers showed 72% synthetic.

Dunmore Cave

Dunmore Cave is just south of the city of Kilkenny, Ireland. Three lint samples were collected by pulling the muddy, wet fibers off the lights and off the rocks near the lights. Dunmore is definitely high in synthetics at 75%. (Author's note: from personal observation Ireland is a land of "wool and blue jeans". The high amount of synthetics appears to be anomalous with the appearance of the general public.)

Jewell Cave

Jewell Cave is located near Custer, South Dakota. Lint was taken at eight different places along the visitor trail. The samples were collected by conventional methods - tweezers, paint brushes, and black lights. All the samples had high synthetic content.

Mammoth Cave

Mammoth Cave is located northeast of Bowling Green, Kentucky. Two different areas of the cave were sampled for lint. The first area was the Giants Coffin and the second was the Drapery Room, both along the visitor trail. As can be seen from the table, the synthetic content of the Giants Coffin area is 45%, while that of the Drapery Room is 76%.

Wind Cave

Wind Cave is located just north of Hot Springs, South Dakota. Lint samples were taken by three methods in the cave: 1) lint traps were set out along the visitor trails to catch clean new lint; 2) three areas were vacuumed along the visitor trail to collect new + old lint; 3) old lint was collected by conventional methods in a now little-used area off the visitor trail. The lint traps consisted of low-sided cardboard boxes lined with either butcher paper or roofing felt. The samples consist of strictly air-borne particles that settle onto the cave surfaces. The samples are very clean. The vacuuming gave two types of samples--those from the vacuum canister and those collected on a fine filter. There was no noticeable difference in the two types of samples--fiber content, fiber size, and dirt on the fiber were all about the same on each set of samples. Conventional methods of lint collection included black lights, paint brushes, and tweezers.

Table 1. - Lint Samples

Sample Location	New/old Fiber	Average % Fibers Synthetic	Average % Fibers Natural
Carlsbad Cavern			
Men's Room Corridor	New + Old	**67**	**33**
Queen's Chamber	New + Old	**72**	**28**
Cave of the Winds			
Old Trail	Old	**72**	**28**
Transition Point	New + Old	**31**	**69**
Regular Visitor Trail	New	**36**	**64**
Dunmore Cave			
Visitor Trail	New + Old	**75**	**25**
Jewell Cave			
Regular Visitor Trail	New + Old	**69**	**31**
Mammoth Cave			
Giants Coffin	New + Old	**45**	**55**
Drapery Room	New + Old	**76**	**24**
Wind Cave			
Lint Traps	Old	**78**	**22**
Trail Vacuuming	New + Old	**38**	**62**
Conventional Methods	New	**42**	**58**

Cave Systems Summary

Tables 2 and 3 highlight the information in the previous discussion. The information is presented in two ways--with respect to cave systems and with respect to new/old fiber types.

Table 2. - Summary of all Lint Samples with respect to Cave System

Sample Origin	Cave Temp.	New/old Fiber	% Fibers Synthetic	% Fibers Natural
Carlsbad Cavern, New Mexico	60°F	New + old	70	30
Cave of the Winds, Colorado	56°F	Old	72	28
		New + old	31	69
		New	36	64
Dunmore Cave, Ireland	50°F	New + old	75	25
Jewell Cave, South Dakota	47°F	New + old	69	31
Mammoth Cave, Kentucky	55°F	New + old	45	55
		New + old	76	24
Wind Cave, South Dakota	54°F	Old	78	22
		New + old	38	62
		New	43	57

The old lint samples illustrate that the fibers which were picked up were mostly synthetic. This could be due to several factors. Two possible reasons for this are 1) more synthetics were worn when the fibers were deposited and 2) the natural fibers which were deposited have decomposed or were consumed.

It is interesting to note that there is no set pattern for amounts of synthetic fibers when looking at the new + old deposition. Synthetic fiber content ranged from 31% to 75%. Again there could be many reasons for this variation. It is possible that temperature plays a role in the breakdown of fibers, but it was not evident from the data.

Table 3. - Summary of all Lint Samples with respect to New/old Fibers

New/old Fiber	Sample Origin	Cave Temp.	% Fibers Synthetic	% Fibers Natural
Old	Cave of the Winds, Colorado	56°F	72	28
	Wind Cave, South Dakota	54°F	78	22
	Average % Fibers		**75**	**25**
New + old	Carlsbad Cavern, New Mexico	60°F	68	32
	Dunmore Cave, Ireland	50°F	75	25
	Jewell Cave, South Dakota	47°F	69	31
	Mammoth Cave, Kentucky	55°F	76	24
	Average % Fibers		**72**	**28**
	Cave of the Winds, Colorado	56°F	31	69
	Mammoth Cave, Kentucky	55°F	45	55
	Wind Cave, South Dakota	54°F	38	62
	Average % Fibers		**38**	**62**
New	Cave of the Winds, Colorado	56°F	36	64
	Wind Cave, South Dakota	54°F	43	57
	Average % Fibers		**40**	**60**

The new lint samples from Cave of the Winds and Wind Cave indicate that lint which is now entering those caves consists primarily of natural fibers. This does not correlate with the American Fiber Manufactures Association report which states that the fiber content of all materials made is 60% synthetic and 40% natural. It also does not equate with lint vacuumed directly off visitors before they entered or after they left the cave.

VISITOR VACUUMING

A total of forty-eight visitors volunteered to be vacuumed as they entered and again as they left Wind Cave. Three sets of shoulders and five sets of shoulder and legs were vacuumed and samples of the materials were taken. The results of the entrance and exit fiber content were consistent--15% synthetic on entering and 16% synthetic on exiting. It is quite evident that natural fibers are by far the primary fiber being carried into the cave.

Vacuuming of visitors was also used as a basis to determine the change in the amount of lint generated. Even after being vacuumed when entering the cave, enough lint is generated in one hour (the length of the tour) to be collected when exiting the cave. The weight of lint from each visitor was determined and the percent change was calculated. The amount of lint from the entrance vacuuming was greater than the exit vacuuming in all but one case. This indicates, for the most part, that vacuuming will significantly decrease the amount of lint entering the cave.

CONCLUSIONS FOR LAB ANALYSIS

It is apparent from the fiber analysis that no rule of thumb can be generated from the data collected. Each cave system is unique unto itself and at this point in time each will have to be evaluated individually. The data does support the idea that once a cave system is adequately appraised the analysis will be constant for each type of fiber (old, new + old, new) in that cave or cave area.

It is also evident that, under perfect conditions, if visitors are cleaned before they enter a cave, potential lint deposition will be less near the entrance and will increase as they walk through the cave.

PROBABLE CONCLUSIONS OF RESEARCH

The bottom line instruction in the Wind Cave lint study was: "Given the composition and characteristics of the lint, propose and test several methods for preventing, or at least slowing the accumulation of lint in Wind Cave." Tentative recommendations under consideration now are:

1. Consider the feasibility of acquiring one or more air showers for voluntary use by visitors and required use by employees.
2. Alter the current trail to incorporate raised curbs and widening the trail in lint drop zones and other areas where applicable.
3. Install periodic foot cleaning features in the trail such as open grills with collection chambers below and removable in-door/out-door carpet (no fabric or shedding rugs though).
4. Review custodial techniques and frequency of trail cleaning.
5. Develop baseline lint deposition rate measurements.
6. Monitor deposition rates as abatement measures are put in place and periodically measure thereafter.

A STRATEGY FOR LEADERSHIP IN CAVE CONSERVATION

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National Speleological Society
Administrative Vice-President

ABSTRACT

The successful harnessing of volunteer resources represents perhaps the single most productive return on an investment of time and resources for the cave manager in today's perspectives. This presentation will provide a detailed plan for the condeptual design, development, and implementation of a long-term volunteer resource development program. Effective mobilization of volunteers for short-term projects will also be discussed.

VOLUNTEERS

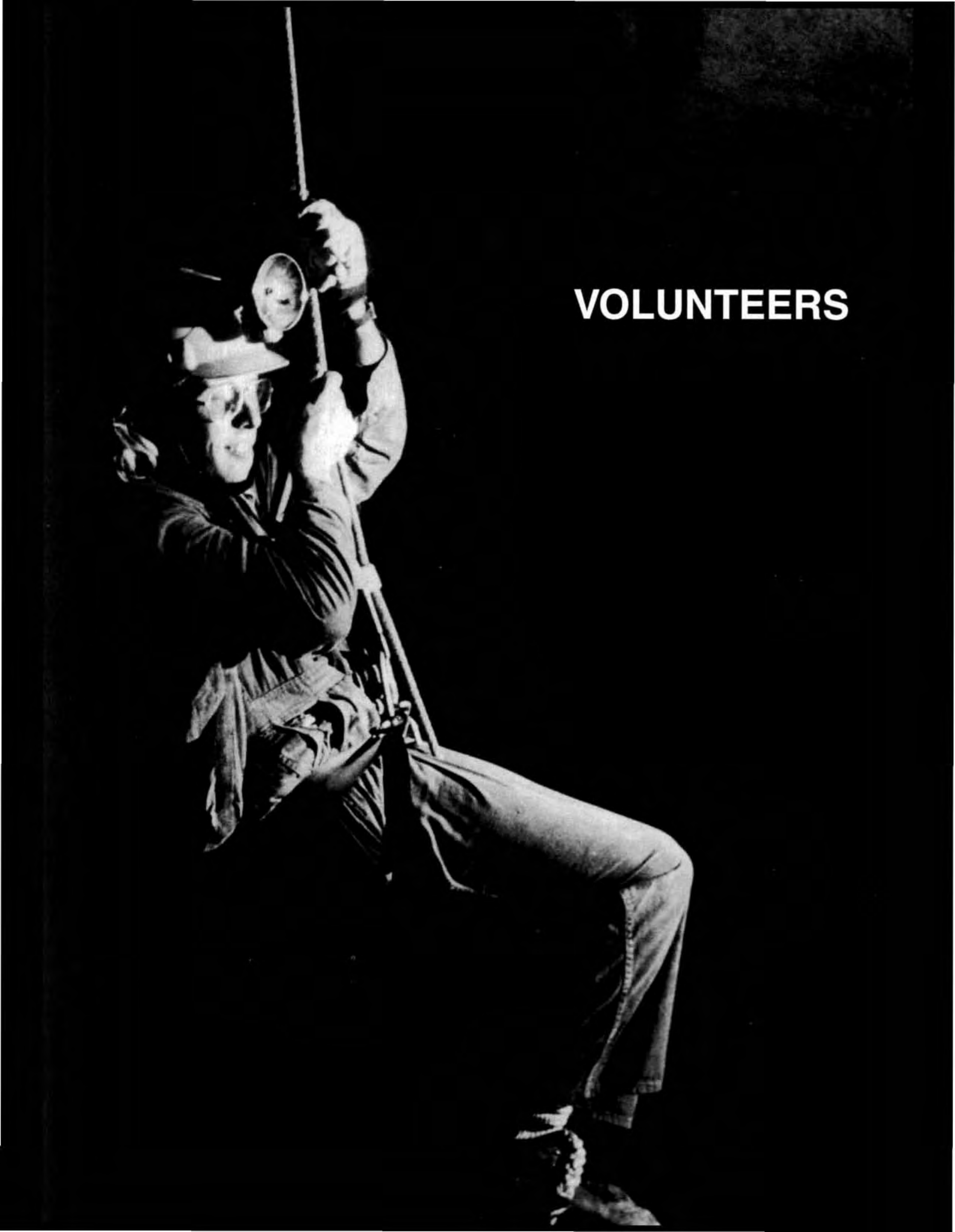

Photo Caption -- Mike Hill ascends the 90-foot upper entrance to Midnight Cave, Edwards County, Texas.

Photo by Dale Pate

USE OF VOLUNTEERS

Harry Burgess

With today's developing cave management concerns (increased visitation, environmental assessments, restoration technizues, and the Federal Cave Resources Protection Act), land managers can find themselves confronted with many necessary tasks. In order to complete these tasks, volunteer labor can be an important aid. At the same time, however, stricter guidelines for the use of volunteers are being implemented, with specific regard to worker compensation and environmental assessments for proposed volunteer projects. The question is how to overcome these obstacles and make the best use of volunteers.

Cave managers are a step ahead in obtaining volunteers in that most already have some communication with the resource users through the permitting process. Additionally, cavers are often willing to volunteer their own time on projects due to their interest in the resource. What is necessary is more structure with regard to how these volunteer's efforts are implemented. Below are some suggestions for organizing volunteer projects and some examples of successful ones.

SUGGESTIONS

1. Increase inter-action between cave managers and volunteers.

With an increased reliance on volunteers, it would be beneficial to both cave manager and user to increase their communication. A "pick-up trash" project does not require much supervision on the manager's part, yet the manager's presence, even if brief, will make the volunteers feel more necessary, and could provide opportunities for education on both the manager and the caver.

2. Plan ahead.

Have several possible projects outlined, just in case. Often, volunteer support is offered and managers can be caught unprepared. With increasing planning restrictions, this pre-planning is necessary to get approval for a project. Otherwise, by the time a proposal goes through the proper channels, the volunteers can be several states away.

3. Structure.

Volunteers naturally have varying degrees of experience with any given task. Therefore, it is necessary to reduce confusion/errant results by providing the volunteers with a straight forward procedure/explanatin of tasks which is "foolproof". If possible, this should be a hard copy that can go with volunteers into the cave.

4. Focus.

Since the develpment of a plan for managing volunteers involves a certain expenditure of time, such a plan should be productive in its implementation. What we are talking about here are projects which can make a difference, those which can aid in the management of the cave. The shift that is necessary is from one-day clean-up trips to ongoing data-gathering, results-producing projects.

EXAMPLES

Restoration, trail marking, and clean-up trips are still very valid uses of volunteers. The question is can there be other uses of volunteer labor in more involved projects. Survey and mapping, inventory, and photo-monitoring projects are all areas where volunteer labor can be very useful, if not necessary, especially in larger cave systems. One example of a project which meets all the aforementioned priorities would be the photo-monitoring project developed by Terry Peters for Bighorn Caverns. For this project Terry has develped a three-ringed notebook which includes all the necessary information. For each photo-monitoring site, there is a corresponding page in the notebook which describes the distance from the subject, aperture, flash settings, and even a sample picture of the site. All the gear is provided by the National Park Service, and even a first-time participant of this project finds it relatively simple to produce useful results. Obviously, it took Terry some time to develp this notebook, yet his efforts, combined with that of the volunteers, will be providing the managers of Bighorn Caverns with information for years to come. (An example of a page out of this notebook is provided at the end of this article).

CONCLUSION

In conclusion, the way in which volunteers are incorportated into the cave management scheme is changing. As we move towards the 21st century, the trends towards more people wanting to use the resource, and thus more need for documenting/managing the resource should only continue. Therefore, the use of volunteers in facilitating cave management is becoming increasingly important. The expenditure of time is necesssary in developing projects which can be performed by the average resource user, and which can provide a high-rate of return in the information each project provides for the cave manager.

A CASE STUDY OF RELATIONS BETWEEN THE NATIONAL PARK SERVICE AND ORGANIZED EXPLORATION CAVERS

Jim Nepsted
Cave Specialist
Wind Cave National Park

Bill Yett
Colorado Wind Cave Coordinator

ABSTRACT

The structural and organizational relations between park units containing significant caves and organized cave groups associated with exploration differs from park to park. These relations also differ significantly within any given park over time. This presentation will provide insights from the perspective of Wind Cave National Park and the Colorado Grotto on the History and development of the current exploration work in Wind Cave.

ASSISTANCE AGREEMENTS: A PARTNERSHIP

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ABSTRACT

Assistance agreements form a partnership between an agency and an interest group for at benefit of the resources involved. They may involve the exchange of monies or provide for the mutual acceptance of services without the exchange of money. Weather or not money is exchanged, the successful resource manager needs to know what type of agreements are available, and how and when to use them. This paper discusses the situations in which various types of assistance agreements are used and the authorities to authorize them.

INTRODUCTION

Assistance agreements can be one of the most efficient tools available to any manager. They are essentially sophisticated volunteer agreements which set up an affiliation between an agency and a special interest group for the benefit of public resources. Assistance agreements are specific instruments to solve specific problems and can be successfully used by the creative manager.

No matter what kind of assistance agreement is used, the best way to get what you want as a resource manager is to make sure you have <u>clearly stated objectives</u>. Two types of agreements will be discussed in this paper. The first type is one in which money is exchanged. The second involves no money exchange.

There are two basic kinds of assistance agreements in which there is a transfer of money, property, or anything of value. They are the cost sharing agreement and the cooperative agreement. Cost sharing agreements are legal instruments used to reflect a relationship between the federal government and a state or local government or other recipient whenever the principal purpose of the agreement is the transfer of money or other valuables to the recipient in order to accomplish a public purpose authorized by federal statute. Of the cost sharing agreements, there is the challenge grant and the challenge agreement. The difference between the challenge grant and challenge agreement is the grant is used in cases where the federal government will <u>not</u> be substantially involved, and the agreement is used where substantial involvement <u>is</u> anticipated between the federal government and the recipient during performance of the contemplated activity.

Substantial involvement occurs in situations where the terms of the agreement indicate that the recipient, during performance of the contemplated activity, can expect federal agency collaboration or participation in the management of the project. BLM manual 1511 (Assistance Agreements) gives examples of what the BLM considers to be substantial and non-substantial involvement (Attachment 1).

These two types of agreements are used to promote cost sharing by requiring the recipient to obtain or provide additional funding from non-federal sources at a mutually agreed upon sharing ratio. The authority by which federal agencies can enter into these types of agreements is the Federal Grant and Cooperative Agreement Act of 1977 (PL 95-224), as amended by PL 97-258 (31 USC Chapter 63, 6301-6308). More detailed procedures for processing these agreements can be found in the Office of Management and Budget Circular A-110.

Cost sharing agreements do not require competitive procedures in order to award them. However, these agreements are not contracts and should not be viewed as a sole source contract as a way to circumvent the procurement process. If a more binding commitment is needed to ensure completion of the project and to establish more stringent remedies if an action is not performed, USE A CONTRACT. An example of cost sharing would be if a university pays the salary of one of their research professors to conduct biological studies in a specified area and manner and the agency would provide the necessary room, board, transportation, or other appropriate funding. The amount of agency involvement would determine if the agreement was a challenge grant or a challenge agreement.

A cooperative agreement is similar to a challenge agreement although it does not require the recipient to obtain additional funding from a non-federal source. An example of this would be an agreement in which you wanted to provide funds to a caving organization for assistance they provide in inventorying and mapping caves of a specified area and preparing files for each.

Generally, money is appropriated by Congress each fiscal year for use in cost sharing agreements. Prior to entering into a cost sharing agreement monies must be made available to the agencies for this propose. The development of an assistance agreement is quite simple. There are only three parts. 1) propose, 2) authority, and 3) duties and responsibilities.

The purpose section should briefly describe the objectives of the agreement including any special emphasis that will be focused on. If necessary, a list of objectives can be developed to more clearly outline the purpose.

The authority section should cite the legislative authority to enter into the agreement. There are several different authorities which authorize the use of assistance agreements. These authorities can be in the form of laws or executive orders and may vary depending upon the type of project entered into. Other sections may be added as each contracting officer deems necessary.

Probably the single most important enabling legislation which allows the use of assistance agreements is the Federal Grant and Cooperative Agreement Act. This authorizes you to enter into any of three types of instruments: contracts, cooperative agreements, and grants. Other authorities which may be appropriate are:

* Fish and Wildlife Conservation and Water Resources Development Coordination Act, as amended under PL 85-624, 16 USC 661.

* Federal Water Project Recreation Act, as amended under PL 89-72.

* Wild and Scenic Rivers Act, as amended under PL 90-542, 16 US 1282.

* National Trails System Act, as amended under PL 90-543, 16 USC 1246(h).

* Endangered Species Act of 1973, as amended under 16 USC 1531.

The enabling legislation for each federal agency probably authorizes the agency to enter into assistance agreements. That should be checked on the make sure.

The duties and responsibilities section should clearly state the activities and products required of the cooperators and the agency. An example of this can be seen in the attached cooperative agreement (Attachment 2).

A useful assistance agreement in which no funds are exchanged is the Cooperative Management Agreement (CMA). In most cases this type of agreement is tiered off of a broader Memorandum of Understanding (MOU). The terms of the CMA should be written out in sufficient detail for all parties to clearly understand what is expected. They should outline the mutually agreed upon plan of action between the agency and the cooperators and identify the responsibilities and performance standards that apply to each of the participants.

The first cooperative cave management agreement entered into by the BLM was for Lost Cave in Carlsbad, New Mexico. This agreement was first signed in 1983 on a one year trial basis (Attachment 3). The cooperators were the BLM and the Pecos Valley Grotto. The agreement outlined the BLM's responsibility as issuing permits, contacting the Grotto for trip leaders, and review and approve of the leader list submitted by the Grotto chairman.

The responsibilities of the Grotto are to clean up and maintain the cave, and lead permitted trips for the BLM. All recreational, educational and scientific trips shall require permits. However, work trips require no permits, only a list of participants. Additionally, a semi-annual report of activities at the cave is submitted to the BLM on March 15 and September 15. The report is to include a list of the trips led during each period, the work accomplished, and any materials donated or used.

This CMA is a very simple one but it is also very specific. It spells out the responsibilities of each party, what should be in the required reports, and when these reports are due. To date, we have had very good cooperation with this agreement with many successful clean up trips and permitted trips conducted.

SUMMARY

In summary, if you want to provide monetary assistance use either a cost sharing agreement or a cooperative agreement. If the cooperator plans on obtaining additional funds provided by a non-federal agency, it will be a cost sharing agreement. If the cost sharing agreement is one in which the agency will not be substantially involved the agreement should be a challenge grant. If the agency will have a substantial involvement in the project the agreement should be a challenge agreement. If money is exchanged but no additional non-federal funds are obtained, a cooperative agreement is used. When no money or anything of value is to be exchanged, use a Cooperative Management Agreement.

Most importantly, be specific in your written agreements as to the responsibilities of each party and what is expected of the cooperator. In times of tight budgets and minimal personnel, partnerships with various user groups can make a critical difference in accomplishing resource management goals.

ATTACHMENT 1

ASSISTANCE AGREEMENTS

substantial involvement: substantial involvement is used as the criteria for distinguishing between use of grant or cooperative agreement. Substantial involvement occurs when the terms of the instrument indicate that the recipient can expect Federal agency collaboration or participation in the management of the project, i.e., when:

1. Federal and recipient's officials work closely together, and;

2. Federal officials need to closely oversee a recipient's activities to ensure that the program or project objectives are achieved. Since the term is a relative rather than an absolute concept, the following guidelines are to assist in selecting the proper assistance instrument. Substantial involvement may be construed to include one or more of the following situations:

a. When the agreement indicates that the recipient can expect Bureau collaboration or participation in the management of the project.

b. When the Bureau has the power to immediately halt an activity if project specifications are not met.

c. When the Bureau must review and approve one stage of the work before work on a subsequent stage can begin.

d. When the Bureau has review and approval authority of substantive provisions in the selection or award of subagreements, grants, or contracts awarded under the assistance agreement.

e. When the Bureau has an active involvement in the selection of key recipient and subrecipient personnel.

f. When the Bureau is required to monitor the activity of the recipient to permit specified kinds of direction or redirection of the work to ensure desired interrelationships with other Federal projects.

g. When substantial, direct Bureau operational involvement or participation during the activity is anticipated to ensure compliance with appropriate statutory requirements.

h. When highly prescriptive Bureau requirements, prior to award, limit recipient discretion with respect to scope of services offered, organizational structure, staffing, mode of operation, and other management processes, coupled with close monitoring of operational involvement during performance over and above the normal exercise of Federal stewardship responsibilities.

i. When Bureau involvement and assistance is necessary, due to complexity or novelty of the project.

j. When the capacity of the recipient to implement without Bureau direction is in doubt.

Attachment 1 (Continued)

Conversely, substantial involvement during performance would NOT include the following which can normally be expected during the term of an agreement:

1. Bureau approval of a recipient's plans PRIOR to award (as opposed to during the award).

2. Normal exercise of Federal responsibilities during the project such as site visits, performance reporting, financial reporting, and audit to ensure that the objectives, terms, and conditions of the award are accomplished.

3. Unanticipated Bureau involvement to correct deficiencies in project of financial management of an assisted project.

4. Enforcement of appropriate statutory requirements understood in advance of the award.

5. Bureau review of recipient's performance AFTER project completion.

6. Enforcement of recipient's compliance with general administrative requirements, such as those set forth in OMB Circular A-21, A-87, A-102, and A-110.

7. The normal practice of providing technical assistance, advice, or guidance to recipients, if:
   A. It is provided at the request of the recipient;
   B. The recipient is not required to follow it; or
   C. The recipient is required to follow it, but it is provided prior to the start of the assisted activity and the recipient understood this requirement prior to receipt of the financial assistance award.

The Bureau will normally limit Federal involvement in assisted activities to a minimum level that is consistent with program requirements. In some instances, it may become necessary to convert a grant to a cooperative agreement or vice versa if programming considerations dictate more or less involvement during the period covered by the agreement or grant. See 505 DM for further guidance.

ATTACHMENT 2

COOPERATIVE AGREEMENT BETWEEN
CAVE RESEARCH FOUNDATION AND
THE ROSWELL DISTRICT, BUREAU OF LAND MANAGEMENT

I. PURPOSE

To gather baseline speleological data on cave and karst resources on public lands managed by the Roswell District, Bureau of Land Management (BLM) in Chosa Draw Area of Critical Environmental Concern. Resource data gained from this project will also be used for cave significance determination as will be required by the pending Department of the Interior regulations implementing the Federal Cave Resources Protection Act (FCRPA) of 1988. However, this project does not depend on issuance of the regulations.

II. AUTHORITY

Federal Land Policy Management Act of October 21, 1976 (90 Statute 1743, 43 U.S.C. 1702, Sec. 307(b).

III. DUTIES AND RESPONSIBILITIES

The **Cave Research Foundation**, hereinafter referred to as CRF, **will provide the following:**

1. Prepare a list of features for each cave currently on file using the draft criteria. Information may be obtained from existing files.

2. Gather data necessary to complete existing cave files in accordance with: Roswell District Cave Resources Management Plan (3.6.1); the basic elements of the Cave Inventory & Classification System (Part I, Hazards & Contents Class; Part II, Biotic Community Profile); Part III, Cave Mineralogic & Geologic Features Profile); provide photographs of each cave entrance and any notable features in the cave where photos do not already exist in BLM files. The original slide or negative of each photo will be retained by CRF with duplicate negatives or slides provided to BLM.

3. Develop new cave files as per #2 for known caves which are not currently in BLM files. A block of numbers will be issued to identify each newly inventoried cave.

4. Set a permanent entrance marker of a size and type specified by BLM at each cave not so marked.

5. Provide a draft report to the Roswell District BLM office by March 15, 1991, to outline progress on the above items with copies sent to the Carlsbad Resource Area BLM office.

6. Provide a final report to the Roswell District BLM office, with copies sent to the Carlsbad Resource Area BLM office by September 15, 1991.

7. Provide all necessary materials and supplies necessary to complete the project except for the items listed in Duties and Responsibilities, Roswell District, Bureau of Land Management. This includes, but is not limited to, cameras and film, survey equipment, drafting supplies and caving equipment.

8. Nominate suitable caves for the Significant Cave List based on inventory data and using criteria listed in the regulations when they are issued.

ATTACHMENT 2 (Continued)

The Roswell District, BLM will:

1. BLM agrees to make payment of $1,000 to CRF for a project worth $12,000. The remaining amount will be matched by services rendered by CRF.

2. Provide CRF access to all applicable cave files and aerial photos for use in this project.

3. Provide CRF with 1:100,000 scale land status maps.

4. Provide CRF access to a BLM photocopier and paper and necessary supplies to create new files, including folders, tabs, and dividers.

5. Provide work space for CRF members working on the project in the Carlsbad Resource Area office.

6. Provide forms and instructions (i.e., manuals, District Cave Resources Management Plan) for conducting cave resource inventories.

IV. OTHER PROVISIONS

1. Nothing in this agreement shall be construed as obligating either party hereto in the expenditure of funds or for the future payment of money in excess of appropriations authorized by law.

2. Individuals coordinating the project will be: Jim Goodbar, Outdoor Recreation Planner for the Carlsbad Resource Area BLM office, and David Dell, Guadalupe Escarpment Regional Coordinator for the CRF.

3. Billings will be done by CRF in the form of an invoice, citing services performed, total cost not to exceed $1,000. Invoice to be mailed to the Bureau of Land Management at P.O. Box 1397, Roswell, New Mexico 88202-1397.

4. Partial payments will be made in two (2) equal installments to CRF. The first will be due after completion of a draft report by March 15, 1991. The final payment will be due on receipt of the final report.

5. This contract shall become effective when signed by the designated representatives of parties hereto and shall remain in force until terminated by mutual agreement or by either party upon thirty (30) days notice in writing to the other of its intention to terminate upon a date indicated. Amendments to this agreement may be proposed by either party and shall become effective upon approval of both parties.

6. Both parties agree to the stated objective and provisions by signing this agreement.

V. SIGNATURES

ATTACHMENT 3

COOPERATIVE MANAGEMENT AGREEMENT
between
Bureau of Land Management, Roswell District, Carlsbad Resource Area
and the
Pecos Valley Grotto of the National Speleological Society

I. PURPOSE

This agreement will provide for a more direct and effective means of managing LOST CAVE on public lands in the Carlsbad Resource Area, BLM, by allowing the primary local user group (Pecos Valley Grotto members) to play a greater role in cave management. This will allow for more direct management activities than the BLM is currently capable of, and initiate long-term cooperative cave management through the recognition of interested volunteer groups who have contributed, and will contribute, to the protection of LOST CAVE as well as to the recreational and educational use of the cave.

II. AUTHORITY

This agreement is made under the authority of the Federal Land Policy and Management Act, PL 94-579, October 12, 1976, and a memorandum of Understanding between the Bureau of Land Management, the National Speleological Society, and the Cave Research Foundation, signed on July 11, 1985.

III. TERMS OF AGREEMENT

The Roswell District of the Bureau of Land Management and the Pecos Valley Grotto, National Speleological Society, jointly agree to the following management plan for LOST CAVE, located in T22S, R26E, Sec. 22, NW/4NE/4NW/4, Eddy County, New Mexico. This agreement can be canceled or amended by either party at any time by written notification.

IV. AREAS OF RESPONSIBILITY

The BLM shall be responsible for issuance of recreational, educational, and scientific permits for cave visitation to LOST CAVE and will contact the designated Grotto representative(s) for leaders for trips. Additionally, the BLM shall review and approve the leader list submitted by the Grotto Chairman and include the approved leaders in the BLM Volunteer Program.

The Grotto shall clean up and maintain the cave, the cave gate, access within the cave, and lead permitted trips for the BLM. All recreational, educational, and scientific trips shall have a valid BLM cave permit. However, work trips shall not require permits, but a record of the work effort and participants shall be maintained. A BLM-approved trip leader shall accompany all trips, work or otherwise, to the cave.

A semi-annual report of activities at the cave shall be given to the BLM on March 15 (for October to March) and September 15 (for April to September). This report shall list the trips led during the period, the level of work effort during the period, and the materials donated or consumed.

The Grotto Chairman, or his/her designate, shall be responsible for adherence to this agreement and shall obtain consultation and concurrence from the BLM prior to any modifications to the cave.

RESOURCE-RESPONSIBLE PROFESSIONAL CAVER EDUCATION PROGRAMS ON PUBLIC LANDS

Douglas C. Pflugh
National Outdoor Leadership School

ABSTRACT

A professional caver education program can be considered to be resource responsible if it minimizes both short and long term impacts to the resource. Such a program will be guided by twin principles: its operations must be conscious of and responsible to the resource and its students must receive a resource education rather than just skills training. These will be accomplished by thoughtfully recruiting students, selecting appropriate operating areas, providing a high level of supervision and feedback, following a curriculum that emphasizes safety and conservation, maintaining a quality staff, and developing an ethic of resource-responsibility in its students. The benefits to a land manager and the resource of the operation of such a program are described as: user education, project assistance, and heightened volunteer service. The help of such programs is seen as especially important as the requirements of cave management increase.

INTRODUCTION

Over the last few years, the American caving community has focused much attention on the negatives associated with "cave-for-pay" operations. Cavers, in general, have reacted negatively to any professional operation, lumping all commercial outfitter, natural history association, and caver education programs into one mass of "those who exploit the resource for profit." Fears center around increased traffic through the caves, the potential for incidents harmful to the users and the resource, and long term resource degradation. Of particular concern is a "ripple effect" leading to a drastic increase in the caving population as the clients and graduates of these programs share their new-found avocation. Land managers exposed to these fears might shy away from permitting any professional operation out of legitimate concern for the resource. Especially against the backdrop of the Federal Cave Resources Protection Act (FCRPA), a superficial examination of the situation might suggest that a land manager's mission would be best served by restricting any use.

Four years ago, as a caver and recent graduate from an academic program in resource management, I held a similar view. Caving was starting to emerge from the shadows; articles were on the covers of popular magazines and gear was being sold through the REI catalog. Growth had been evident in the time I had been caving and I saw the impacts increase as more people visited "my" caves. I felt that the less others knew about caving the better.

This preconception was challenged when I found myself a student in an outdoor education program that offered caving as part of its curriculum. My experience there told me that it was possible for a carefully-run *professional caver education program* to minimize both short and long term impacts on the resource. Such a program can be referred to as *resource-responsible.*

This initial impression has been refined by three years of work as a professional educator of cavers. It is my belief and experience that not only can professional caver education programs be conducted with limited impacts on the caves but that they also can benefit the land manager in carrying out her mission. As the value of formal training becomes increasingly recognized in the American caving community, the land manager is likely to face more requests for access to her caves. This paper, in taking a deeper look at the issue of these programs operating on public lands, will address two topics: (1) The key elements of resource-responsible caver education programs and (2) The benefits to the land manager and resource that can result from these operations.

ELEMENTS OF RESOURCE-RESPONSIBLE CAVER EDUCATION

Just as some public lands are managed well and some poorly, a variety of quality will be encountered in professional education programs. How then, can a resource-responsible program be distinguished? Such a program will be guided by twin principles: its operations will be conscious of and responsible to the resource and its students will receive a *resource education* rather than only skills training. An *educated* graduate will be able to apply her knowledge to new situations through an ethic of resource-responsibility rather than merely mimicking what she did on her program. Safety will be emphasized both for the sake of the students but also the resource; rescues are hard on the cave. Key elements in meeting these principles are presented below to give the land manager a basis for evaluating programs.

STUDENT RECRUITMENT

An important component of student recruitment is the program concept that is being sold. Pre-program information sets expectations of the nature of a program and these expectations influence the students actions during the program. A program that attracts students interested in learning about safe and enjoyable underground travel and the natural systems of caves can be expected to maintain higher standards of impact minimization that a program promoted as an adrenaline-rich adventure. Students committed in advance to a resource-responsible approach may also be more likely to retain the program standards in the future, becoming a positive force in their local community. By examining a program's advertising, catalog, and other student based information, a land manager can learn much about what students will be expecting and demanding. A resource-responsible program will leave no doubts; conservation and safety will be prominently featured in the literature.

OPERATING LOCATIONS

For entry-level programs, and absolute necessity is a cave or portion of a cave in which the first few trips with neophytes can be conducted. This should be a heavily used, relatively durable location with limited objective hazards. New cavers require several trips underground to become aware of the extent of their body and the techniques for careful movement; the cave should be able to absorb the "dinks" and "bumps" that are certain to result. Caves that have been easily accessible for a long time and subjected to "mining" or "partying" are often good choices for first timers (and are likely to be in low demand from the local caving community). Neophytes also require time to learn about the hazards found underground; a low risk environment will allow for more personal discovery. Higher level students can enter areas that offer appropriate challenges of judgment and ability as well as the aesthetic rewards of caving. The opportunity for "discovery" keeps their interest alive and allows the educational process to proceed. Use of dates and caves that are in low demand by the local caving community will help to minimize user conflict, another important element of impact.

SUPERVISION AND FEEDBACK

Students will gain the most when they are allowed to learn through direct experience with an instructor "safety net" to protect them and the cave rather than being guided through each experience. The maximum desirable student to instructor ratio is 5:1 for a maximum party size of six on a "normal" educational trip. Beyond that size, it is extremely difficult to monitor a group's activities effectively. This ratio may need to be lowered due to the level of challenge and sensitivity of the cave and the student population (e.g. vertical work, fragile areas, or young students might require smaller groups or more supervision).

An educational program will be distinguished from a guiding service by providing the students an opportunity to learn from their experiences through feedback. Students need input on their progress and suggestions for improvement to facilitate their growth as cavers. Formal evaluations can be helpful but timely, ongoing feedback is more effective. An awareness of their own abilities will allow them to make responsible decisions with lower levels of supervision. It is important for students to hear the "why's" and not just the "what's" so that they can apply what is learned beyond the program; students should leave with judgement sufficient to decide if a cave or passage is appropriate to their safety and conservation abilities.

CURRICULUM

A caver education program's curriculum can be divided into two components: caving techniques and supporting academics. The depth of curriculum covered will depend on the focus of the program and backgrounds of the students. The basic structure presented here represents a minimum student experience for developing neophytes into well-skilled, resource-responsible cavers through an educational program.

The key for teaching caving techniques is to keep the students' abilities and awareness a step ahead of their potential to do damage to themselves or the cave. An aboveground introduction to their equipment and basic safety procedures (e.g. Hefty Bag shelters) allows the students to get comfortable with these with minimal distractions. This leaves fewer unknowns for their first underground excursion, making it easier for the students to focus on the environment. A basic movement class utilizing an aboveground obstacle course (furniture, vehicles, garbage cans, and logs are among possible items) begins the process of body awareness in a resource-safe environment. Guidelines for evaluating passages for safety and conservation concerns should be presented; these can be modified as students develop experience and judgement.

The first underground trip should be a short excursion (two to three hours) to apply what was learned above ground. Careful feedback and discussion on this experience will set expectations for resource-responsibility that will carry throughout the program. Two or three short trips (three to four hours) into the durable cave area should follow with an emphasis on refining and reinforcing the basics. By the end of these trips the students should be able to conduct themselves responsibly in these impact resistant areas. Four or five longer trips (up to six hours or more) should follow and combine increasing difficulty, sensitivity, and student leadership. Vertical work, surveying, photography, and other special topics can be introduced during these trips (after students are comfortable with the basics of each above ground). Focus throughout the underground time should be on route finding, hazard evaluation and minimization, conservation techniques, emergency procedures, and environmental awareness. A mock search and rescue can be a powerful final exercise, reinforcing the skills that the students have learned and leaving them with a poignant reminder about safety. At the conclusion of this progression (thirty to fifty hours underground), students should have not only the techniques, but also the experience to responsibly cave on their own.

Simultaneously, the academic component should be taught. Formal classes or "field trips" can present speleogenesis, speleothems, and speleobiology when the students have gained sufficient underground experience to place the concepts in a familiar context. Further time underground will allow them to question instructors and discuss among themselves, bringing the "academic" into the "real." An effective emphasis is on relating the topics to the caving experience and understanding conservation as more then, "don't touch that!" Students should also be exposed to land management topics, preferably through agency speakers, to facilitate their development as informed users.

Programs providing specific training for already experienced cavers will obviously be structured differently. Some time should be spent at the onset of the program assessing the students abilities and attitudes so that the curriculum can be geared to their (and the resource's) needs. It is important to remember that experienced cavers are not necessarily conservation or safety conscious and that these "training" programs can be an excellent way to reach them with some of the basics covered above.

PROGRAM STAFF

Caver education program staff are first and foremost caving group leaders. The ability to take a group underground for a safe (both for the student and the cave) and enjoyable experience should be a basic standard. This requires a competence and comfort in the underground environment sufficient to allow the instructor to focus on the student's needs rather then her own. Specific requirements are hard to define; at the least, staff on program trips should be caving well below the limit of their abilities and have significant experience leading others in similar settings. Familiarity with the particular cave may be helpful, but is not essential. Instructors should be able to deal with likely underground emergencies and perform limited self-rescue.

Role modeling is a powerful tool in education. Students are more likely to truly learn what they experience that what they hear. Therefore, the "who" of the instructors is as important as (if not more important than) the "what" of the instruction. For a resource-responsible program it is essential to have not only qualified cavers, but those who are *committed* to the values of cave conservation. Exemplifying the concepts presented will go much further than the most eloquent speech. Excellent cavers do not always make excellent educators though; The ability to teach is certainly also important. A talented educator can not only turn a potentially dangerous situation around, but also help the students understand how to avoid such situations in the future.

PROGRAM LENGTH

The curriculum presented above can be covered either in an intensive two week program or more traditional quarter or semester structure. The seven to nine trip, thirty to fifty hour curriculum is considered a minimum for developing resource-responsible cavers capable of being the most experienced member of a party in relatively challenging conditions. Programs requiring a shorter time may still be resource-responsible. The key for shorter programs is generating in the students a thorough understanding of their level of competence, so they do not jeopardize their safety or that of a cave on future caving excursions. For example, a weekend program might be sufficient for neophytes who will only visit short lava tubes or experienced cavers who are learning the basics of cave photography.

DEVELOPING AN ETHIC

To be resource-responsible in the long term sense, a program must not only teach techniques but must also impart an ethic of "resource-responsible caving." Students should leave the program not only knowing how to act correctly, but wanting to do so. This is developed through feedback, curriculum, role modeling, and active discussion. If the program, as a whole, demonstrates the ethic (through staff and operations), it will come easier to the students.

From a human-time perspective, caves are a basically static resource and cannot absorb use like a whitewater river or a forested mountain. The question is, how can a land manager ensure that a professional caver education program does not have a **significant** impact on the resource? The level of acceptable change will be set by the land manager and she will ultimately retain the responsibility to maintain impact a non-significant levels. The high level of monitoring (through the permitting process) to which these programs are subject will assist the manager in this task. It is also critical that the land manager be familiar not only with the program's concepts, but its day-to-day operations. Frank discussions with staff (preferably those who will lead the trips) about impact standards particular to a given area and off-limit regions can greatly increase mutual understanding. Resource-responsible programs will most likely welcome the opportunity for interaction with the managing agency as this contact can benefit both students and staff. Presenting land management discussions, sitting in on classes, or joining trips (especially service oriented trips) are all effective means of checking in with the operation.

BENEFITS TO THE LAND MANAGER AND RESOURCE

With an understanding that it is possible to operate professional caver education programs in a resource-responsible manner we can go on to look at the benefits to the land manager and resource that can result from such operations. A program might be expected to produce tangible results in any of the three areas outlined below.

USER EDUCATION

"We have long recognized education as the best strategy for reversing the trend of damage to wilderness and undeveloped areas caused by recreation visitor... " - Dale Robertson, Chief of the USDA Forest Service, April 1992.

"Education...is a preemptive strike...to teach the American people how to enjoy the wilderness without destroying it. All other methods merely try to repair the damage after it is done. Stronger wilderness education programs would dramatically decrease the need for law enforcement and cleanup." - Jim Bradley, staff member, Subcommittee on National Parks and Public Lands, U.S. House of Representatives, *Journal of Forestry*, February 1993.

As demonstrated above, education is well accepted as a powerful tool for effective management. A USDA Forest Service publication, *Wilderness Visitor Education: Information About Alternative Techniques* (Douchette and Cole, 1993), cites visitor education as the most appropriate approach for managing recreation in wilderness areas. It is further stated that wilderness problems are primarily a result of inappropriate behavior and that this behavior can be changed through education. It can be easily argued that wild caves are one of the premiere examples of wilderness. And happily, with a private caver education program, the burden of expense for visitor education lies outside the managing agency.

Estimates on growth in the caving population are staggering. The National Speleological Society estimates a membership of 20,000 by the year 2002 (doubling today's figure), and perhaps 60,000 by the year 2041. This growth will represent a drastically increased stress on the cave resources. But, as NSS President Jeanne Gurnee has pointed out, it is not just the amount of caving that is the danger, but rather the style of that caving. One hundred careful cavers will certainly leave a mark, but the same mark can be just as easily left by one uninformed and careless caver. As the caver population increases, which it doubtlessly will, the need for care on the part of each caver will increase. Either caver education can increase or regulation and restoration needs will increase.

As caving grows, it can be expected that its notoriety will also. More public exposure of caving will lead to more non-cavers interested in "taking a look." Therefore, it is important to reach not only "caver" with safety and conservation messages; those who may casually interact with the resource should also be influenced. It has been shown by John Ganter that a mass media approach to this problem could be less that productive, as the result may primarily be greater exposure of the activity to the general public. More effective would be a targeted approach reaching those who are likely to be exposed to either the desire or opportunity for a "caving experience." The message reaches those intended with less chance of a negative "ripple effect."

Private caver education programs can address both of these needs. Their very mission is education of cavers. If they are resource-responsible that education will be at the cutting edge of safety and conservation standards. Acting as seeds for growth, graduates return home, becoming active in programs where, by role modeling or actively educating, they can increase the level of resource-responsibility. Even graduates who do not launch extensive caving careers are able to relate the ideas of cave conservation to friends, family, and others involved in outdoor recreation. They can do much to combat the myths of mass media's view of the caver (the glory of standing in the Chandelier Ballroom versus the reality of a grueling ten-hour mock search and rescue operation). Exposure to the challenges of cave management during the program make for more sympathetic, politically participatory, and enlightened users.

PROJECT ASSISTANCE

Professional caver education programs can assist managers with projects through both manpower and expertise. A variety of one-time and on-going service projects can be undertaken based on the availability of time and complexity of task. Caver education programs can provide both relatively large numbers of trained and enthusiastic cavers and reliable schedules, facilitating project planning. Program students generally find these tasks very rewarding and leave with a greater appreciation of the realities of resource management.

Past service projects that have been conducted include:

- -blast rubble removal and concrete portaging for the Wind Cave tour loop
- -a bat inventory at Horsethief Cave
- -trail maintenance at Jewel Cave
- -routine replacement of locks and registers on McKittrick Hill

-assisting with the installation of a gate at Coyote Cave (WCNP)
-photo-monitoring in Bighorn Caverns
-observations for a temperature and relative humidity study at Jewel Cave

A particular project for which private caver education program assistance may be especially useful is inventory work. The lack of information concerning a resource has been identified as a principal constraint to responsible management; the regulations promulgating FCPRA have made that information a necessity. Without a clear picture of the geology, hydrology, biology, archeology, or even the location of a cave, it is difficult to plan for its wise use and preservation. A caver education program could be expected to use the same area for a number of trips. The result is a staff that is familiar with the terrain and any human-caused or natural changes. Staff can direct trips to areas in need of observation and use the activity to further their own curriculum; inventory work allows staff to have students focus on their surroundings and identify what they are seeing. It is essential for there to be clear communication and timely feedback between the manager and program about the subject and needed quality of the inventory to avoid frustration on both sides. With advance work on the part of the manager and educational program, the result can be a large body of information at minimal cost.

Regardless of the enabling paperwork of the program (special use permit, commercial use license, or memorandum of understanding), the manager should be able to set up mutually agreeable projects. The key will lie in striking a balance between the manager's needs and the program's curriculum.

VOLUNTEER SERVICE

A side benefit to the manager can be the return of a caver education program's students and staff to the site in a volunteer capacity. The manager is handed assistance in the form of a trained caver familiar with her resource, excited about the opportunity to return. Placement of the volunteer will of course vary, depending on academic background, caving ability, and commitment, but both interpretation and resource management are strong choices. Especially with staff, this arrangement has proven very beneficial as employees of both the agency and program have gained a greater understanding and appreciation of each other.

CONCLUSIONS

It has been shown that it is possible for professional caver education programs to operate on public lands in a resource-responsible manner. Such a program will have twin objectives: its operations must be conscious of and responsible to the resource and its students must receive a **resource education** rather than just skills training. This ensures that in addition to the program itself not having significant impact, its graduates will maintain the same standards on future trips of their own. Concerns over a "ripple effect" leading to drastic numbers of new cavers are mitigated by the relatively few cavers these programs produce. Programs developing resource-responsible cavers actually strengthen the overall caving community by improving standards; the caver-to-be is given a solid underground education rather that the piecemeal, opportunistic training most cavers experience.

Land managers face the dual challenges of the increasing requirements of cave management and slow, if any, growth of budget. As the manager struggles to meet the pressures at today's use levels, she faces the prospect of drastic increases in demand in the near future. Professional caver education programs offer one method of meeting these challenges. Just as managers have realized the benefits of volunteer assistance, they can appreciate the mutual gain from professional programs that are compatible with their missions.

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PROJECT CAVING ON PUBLIC LANDS

Mel Park
Cave Research Foundation
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ABSTRACT

The Cave Research Foundation (CRF) has been conducting scientific and exploratory cave projects for over 35 years, first at Mammoth Cave National Park and, later, at other sites on federal or state managed land. At most of these locations, CRF acts as an independent organization performing scientific and cartographic work. Almost from the start, the Foundation has adopted a formal managerial approach that has proved itself important, in guaranteeing successful long-term, productive work. At the national level, we operate under Memoranda of Understanding with the National Park Service and United States Forest Service. In each of our operating areas, such as Carlsbad Caverns National Park, we have local operating agreements. These agreements legitimize our standing as an independent organization with our own financial resources, planning process, and lines of accountability. The heart of our methods lies at camp level, where our approach differs from that which most informally-organized cavers would take. There is a hierarchical leadership structure, considerable preplanning, and set practices that provide an efficient and familiar framework. The result is that, during an expedition, all energies can be devoted to the projects at hand. Details differ slightly among our project areas, but the procedures used at Mammoth Cave can serve as a model.

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HYDROLOGY

Photo Caption -- Water passage in Border Cave, Culberson County, Texas.

Photo by Dale Pate

FLOODING OF SINKING CREEK, GARRETTS SPRING KARST DRAINAGE BASIN JESSAMINE AND WOODFORD COUNTIES, KENTUCKY

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Kentucky Geological Survey
University of Kentucky

ABSTRACT

Tashamingo Subdivision in Sinking Creek Karst Valley, a tributary of the Garretts Spring Drainage Basin in Jessamine and Woodford Counties, Kentucky, was flooded in February 1989. To determine the cause of flooding, the ground-water basin boundary was mapped, discharge data were measured to determine intake capacity of swallets, and hydrologic modeling of the basin was conducted. Swallet capacity was determined to be limited by the hydraulic parameters of the conduit, rather than by obstruction by trash. Flooding from a precipitation event is more likely, and will be higher, when antecedent soil moisture conditions in the watershed are near saturation. Hydrologic modeling shows that suburban development of twenty percent of the southeast basin will cause a small increase in flood stage at Tashamingo Subdivision.

INTRODUCTION

From mid-February to early March of 1989 the Tashamingo Subdivision and the Delaneys Ferry Road area of Jessamine County flooded when the Sinking Creek Karst Valley was unable to accommodate prolonged and intense storm runoff (21 cm.; 8.4 in. from February 13-16). Several homes were isolated by blocked roads, and two homes were flooded; one was damaged extensively.

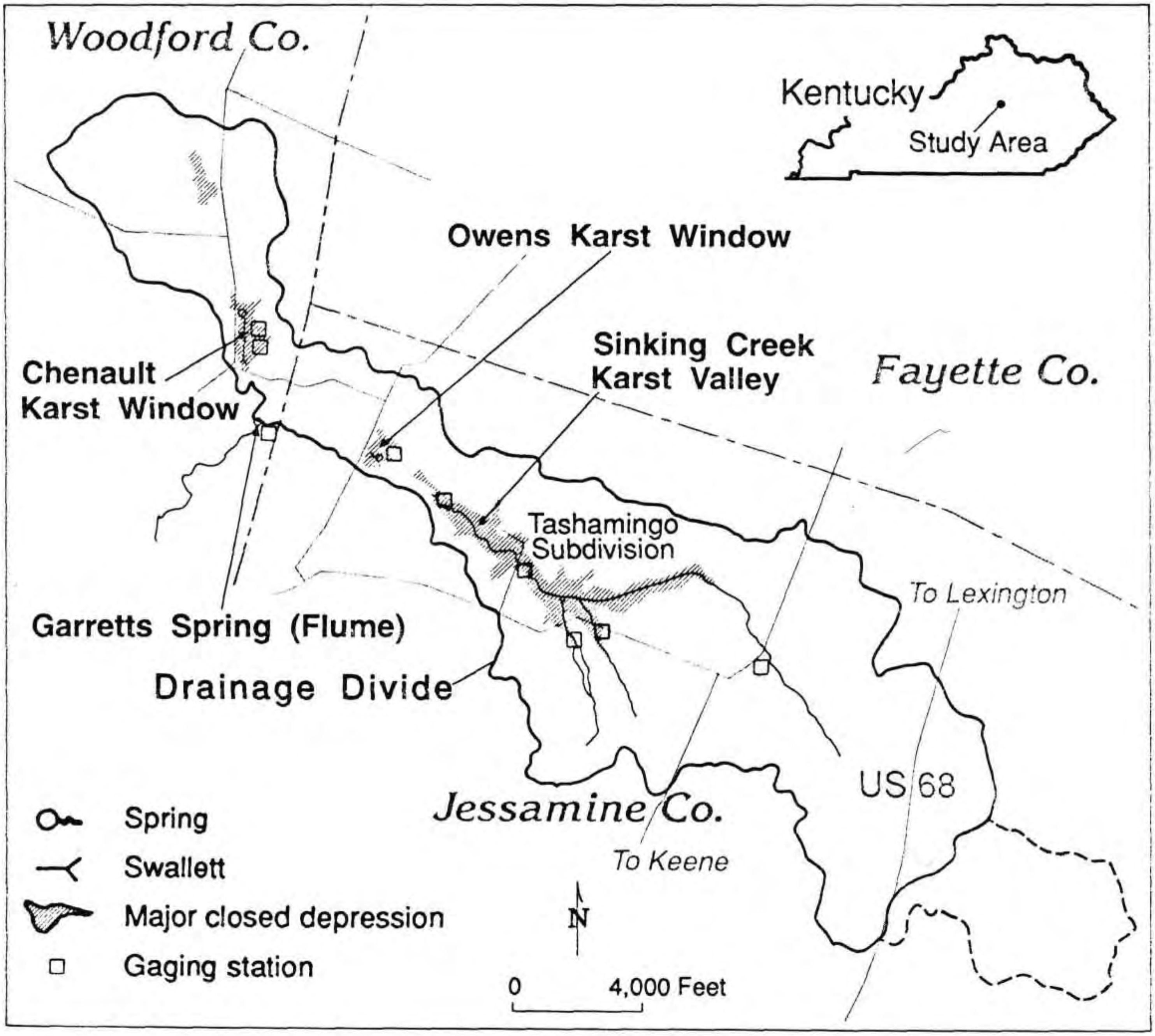
The first goal of the study is to predict what type of storm will cause flooding that threatens property, given the current degree of residential development. The second goal is to determine, for any given storm, what the effect of continued development in the basin will be. In addition, significant hydrologic data will be collected for an Inner Bluegrass karst drainage basin.

The Garretts Spring Karst Drainage Basin lies in Jessamine and Woodford Counties in the Inner Bluegrass Region of central Kentucky (Fig. 1). The Inner Bluegrass is a gently rolling upland with a subdued karst topography formed on Ordovician limestones. The drainage basin covers approximately 1,929 hectares (4,766 ac.). Garretts Spring is naturally impounded, but has been further dammed for an irrigation supply. The spring is the headwaters of the northern branch of Clear Creek, which flows approximately 22.5 kilometers (14 miles) to the Kentucky River. The basin is composed of two branches, the confluence of which is underground near the resurgence at Garretts Spring.

There are three major karst features within the drainage basin and hundreds of smaller ones. Chenault Karst Window lies in the northwestern sub-basin. Water emerges from a spring at the north end of the karst window, and sinks at the south end. The water then flows 580 meters (1,900 ft.) to Garretts Spring. Owens Karst Window lies in the southeastern branch between Sinking Creek and Garretts Spring. Flow from Sinking Creek rises in Owens Karst Window at several springs along the eastern, upstream wall, and sinks in a series of swallets on the western wall to flow to Garretts Spring, 1,158 meters (3,800 ft.) to the west.

Sinking Creek Karst Valley forms the headwaters of the southeastern branch. The topographically closed portion of the basin covers 78 hectares (197 ac.). Sinking Creek originates as small springs and surface runnels. The stream follows a smooth gradient to the karst valley, without apparent flow loss, until it approaches the footwall area.

Figure 1. Map of the Garretts Spring drainage basin. The area with the dashed outline at the east is included in the basin on topographic maps, but ground-water tracing shows flow is pirated to the south.



The Garretts Spring Basin is underlain by the Lexington Limestone, which consists of thinly interbedded carbonates, argillaceous carbonates, and shales of Middle Ordovician age (Cressman, 1965). Members of the Lexington Limestone exposed within the drainage basin of Garretts Spring are, from bottom to top, the Grier Limestone Member, the Tanglewood Limestone Member, the Brannon Member, and the Devils Hollow Member. The Grier is irregularly thin bedded, with occasional shale or silt interbeds. The Macedonia Bed, a mappable argillaceous unit a maximum of 2.7 meters (9 ft.) thick, occurs within the Grier, 15 meters (50 ft.) below the top of the Grier. Overlying the Grier is the Tanglewood Limestone, a thinly crossbedded, but relatively pure carbonate. The Tanglewood intertongues with several other lithologies within the Inner Bluegrass. The Brannon Member, a thin-bedded argillaceous carbonate, is from 2.4 to 9.1 meters (8 to 30 ft.) thick and intertongues with the Tanglewood, only 3 to 7.6 meters (10 to 25 ft.) above the top of the Grier. The Devils Hollow Member is a pure, highly fossiliferous limestone, 3 to 4.6 meters (10 to 15 ft.) thick, which also intertongues with the Tanglewood approximately 9 meters (30 ft.) above the Brannon.

The study area is near the crest of the Cincinnati Arch, and although the strata are relatively flat lying, they dip gently to the northwest at 2.8 meters per kilometer (15 ft. per mile). No faulting is mapped within the drainage basin, although prominent joints have been observed in the field.

The general hydrogeology of the Inner Bluegrass has been described by numerous authors (Hamilton, 1950; Palmquist and Hall, 1961). Thrailkill and his graduate students have conducted more detailed studies in recent years (Thrailkill and others, 1982). Thrailkill has defined two principal types of karst aquifers in the region, interbasins and ground-water basins. Interbasins occur around the margin of the ground-water basin where shallow flow is perched on argillaceous units. This flow quickly returns to the surface, but commonly sinks again toward the interior of the basin. The interior of the basin is the ground-water basin where aquitards are breached. This deep flow occurs in well-developed caves or conduits to resurge at a major spring near local base level. Both interbasin watershed boundaries and basin boundaries are known to cross surface watershed boundaries, although most commonly the interbasin boundary roughly coincides with the surface watershed.

METHODOLOGY

Three separate tasks were recognized as essential for understanding flooding in the basin: first, mapping the watershed boundary; second, measuring the intake capacity of the Sinking Creek swallets under various stages of flooding; and third, collecting hydrologic data, which are input into a digital hydrologic model to estimate the basin response caused by various storm events and changes in land use.

The drainage basin boundary for the Garretts Spring basin could not be unambiguously drawn because of the karst topography. Sixteen ground-water dye traces were conducted to determine where the divide lay. Data for 11 other traces performed by Larry Spangler (personal communication, 1989) were also obtained. Traces conducted by the authors utilized four fluorescent dyes; Fluorescein (C.I. Acid Yellow 73), Rhodamine WT (Acid Red 388), Diphenyl Brilliant Flavine (C.I. Direct Yellow 96), and Tinopal CBS-X (optical brightening agent 351) (Smart, 1984). Straight-line distances traced ranged from 580 meters (1,900 ft.) to 1,920 meters (6,300 ft.).

Dye detectors were mounted on concrete anchors ("gumdrops" of Quinlan, 1987) and consisted of activated carbon charcoal in fiberglass screen-wire packets and bleached cotton broadcloth (Testfabrics, cat. no. 419) or surgical cotton. Surgical cotton was occasionally lost because of mechanical erosion and attack by aquatic animals (crayfish). Wire frames supporting a cotton-fabric swatch were tried (Thrailkill and others, 1983); however, manufacturing the "bugs" was time-consuming. Experimental traces were run using fabric both on a frame and as a ribbon, 3 cm x 50 cm (1 1/2 x 18 in.), tied into a "bow tie." Visual inspection of the positive fabric bugs suggests equally good dye adsorption for both methods, but the bow ties proved much more durable than surgical cotton.

Samples for quantitative traces were collected with ISCO model 2900 programmable automatic samplers. Intake lines were purged before each sample and emptied after sampling to minimize mixing with residue from earlier samples. The ISCO model 2900 is only available with polyethelyne bottles, which adsorb Rhodamine readily. Therefore, glass culture tubes were used that closely fit inside the mouth of the plastic ISCO bottles and were of correct length to allow the sampler distributor to clear the mouth of each tube. Dye concentrations were determined on a Turner Designs model 10 flurometer. Discharge measurements were made with Price meters during the traces.

Seven gaging stations, involving 10 channel cross sections, were established for monitoring stream and spring flow. Three sites were instrumented with continuous stage recorders: Chenault Karst Window (CHEN recorder), Owens Karst Window (OWEN recorder), and Sinking Creek at Cherrywood Lane in the Tashamingo Subdivision (TASH recorder). Telog Instruments WLS-2109 single-channel digital recorders were coupled with Druck PDCR 830 pressure transducers. Observations of the water depth, calibrated in feet, were made every second, and the mean was recorded every 15 minutes. Two of the Druck transducers have a 0 to 10 psi range (7.04 m; 23.11 ft. of water), and the third has a range of 0 to 20 psi (14.08 m; 46.22 ft. of water) with an accuracy of +0.3 percent. The pressure transducers were mounted in stilling wells constructed of PVC, which were imbedded in the stream bank. Elevations were leveled to a datum scribed on each stilling well to obtain elevation head.

Discharges were measured using the partial sections method (Buchanan and Somers, 1976) and Price flow meters (Teledyne-Gurley models 622 and 625). Because the water-level recorders were installed in karst valleys and windows, ponding influenced the hydrograph during high flow. Determination of the inception of ponding was based on topography and the elevation of the stage recorder relative to the sinking point of the stream, changes in the hydrograph curve, and other on-site observations. The ponding at the swallets had two effects on discharge measurement. First, even at those sites where flow was still confined to a distinct channel, measurements were logistically more difficult because of deep water (2 to 5 meters; 6 to 15 ft.). Second, the precision of Price flow meters was reduced because of the sluggish velocities of the ponded flow.

Perhaps the most important water-level recorder was the installation in Tashamingo Subdivision at Cherrywood Lane because it provided the only continuous record of runoff from the headwaters of the southeastern branch of the basin. Sinking Creek flows under Cherrywood Lane through three corrugated steel culverts penetrating an earth-fill causeway. The causeway creates an effective dam, and virtually all flow upstream of Cherrywood Lane is forced through the culverts until the roadway is overtopped at a stage of 3.4 meters (11.2 ft.). The station misses minor discharge from small springs and overland flow between the recorder and the swallets.

Discharge data at Garretts Spring were obtained from a flume installed by Dr. Gary Felton of the University of Kentucky Department of Agricultural Engineering. Conditions at the site imposed limits on the dimensions of the flume, which has a maximum capacity of 0.85 cubic meter per second (cms) (30 cubic feet per second, cfs). Unfortunately, the maximum discharge at Garretts Spring is known to exceed 1.7 cms (60 cfs). Further, the dam supporting the flume has leaked at various times since its installation. Also, a secondary spring downstream is known to receive a small but unknown percentage of flow from the basin. When possible, discharges from Garretts Spring were also measured with flow meters.

The principal control on the flooding of Sinking Creek Karst Valley is the intake capacity of the swallet zone at the western end of the valley. Access to the footwall area of Sinking Creek Karst Valley wad denied during the first year of the project, which precluded direct observation of both stage and inflow at the swallets. Measurement of the intake capacity by indirect methods was tried until access was obtained in January 1991. The methods used to measure intake included determining head loss coupled with estimated hydraulic characteristics of the conduits, budgeting measured outflows at Garretts Spring and Chenault Karst Window, budgeting estimated storage and inflow, measuring inflow at critical points in the stage hydrograph, and directly observing inflow at the swallets and outflow at Owens Karst Window. The two budgeting techniques proved too imprecise to develop a rating curve, although the values set limits on realistic swallet inflows. The most useful data were eventually obtained by observing discharge at critical stages and directly measuring inflow.

Rating curves were constructed using techniques developed by the U.S. Geological Survey (Kennedy, 1984). A gage-zero flow for each station was selected by choosing the offset resulting in the largest Pearson correlation coefficient for the regression of the discharge on the stage. Data were insufficient to define hysteresis from overbank storage.

The stage-discharge relationships for all three stage-recorder sites and the Sinking Creek swallets are complex. The rating curve for the Sinking Creek and Chenault swallets consists of free-fall and confined-flow limbs. The rating curve for Tashamingo is in two parts, free-fall and ponded. The rating curve for Owens Karst Window is even more problematic in that the flow data suggest a multiple-step curve, but data are insufficient to clearly define the curve. A single, straight line was regressed to the available Owens data. Discharge data for the free-fall segment of the curve for Sinking Creek swallets were measured at a cross section upstream from the divergence of the first distributary. Discharge data for the pressure-flow segment are derived from discharges measured at Owens Karst Window and were coupled with stage observations at either the swallets or Tashamingo. Also, only 85 percent of the flow through Owens is accounted for at the three discharge measuring stations during moderate to high flow. The Owens data were adjusted for the unaccounted-for flow because the swallet rating curve was to be used with the HEC-1 model.

Precipitation data were obtained from the NOAA weather station at nearby Bluegrass Field, 7.3 kilometers (4.6 mi.) northwest of Garretts Spring, and a volunteer NOAA station at Keene, 6.1 kilometers (3.8 mi.) southeast of the spring.

After the basin boundary was mapped, land use was determined by Felton (personal communication, 1992). These data were compiled into Soil Conservation Service (SCS) cover type and hydrologic condition categories based on the percentage of each hydrologic soil group in each sub-basin (McDonald and others, 1983). A weighted-average runoff curve number was then determined for each sub-basin as defined by the U.S. Army Corps of Engineers (SCS, 1986). These values were used in modeling runoff in the basin.

The Louisville office of the U.S. Army Corps of Engineers was contracted by the Federal Emergency Management Agency to determine the 100-year flood plain for the Sinking Creek Basin (U.S. Army Corps of Engineers, 1990). Their study was completed with the use of the HEC-1 Flood Hydrograph Package (Computer Program 723-X6-L2010) developed by the Corps to predict the impact of storm runoff. The Corps made the program and data files available to KGS. The Corps data were coupled with the land-use and swallet capacity data gathered by this research to compute the model flood hydrographs for Sinking Creek.

RESULTS

The most common cause of sinkhole flooding is the obstruction of an outlet by natural or manmade debris. However, only occasional small pieces of trash and limited quantities of natural debris have been seen in swallets in the Garretts Spring basin. Natural debris consists of wood and leaves that either float during a flood or rot, break up, and are carried through the conduit. Because the swallets are generally clear of debris, the flooding is unlikely to be related to limited swallet capacity.

The qualitative ground-water traces resulted in several significant findings. The Nicholasville 7 1/2 minute topographic quadrangle map indicates that the headwaters of the basin extends several hundred meters east of U.S. Highway 68 (dashed area on Figure 1). Tracing indicated that this area had been pirated to the south. All traces conducted in this area were made during low flow, and whether high-flow diversion into Sinking Creek occurs is unknown. Also, the headwaters of the northwestern branch were delineated, and two sub-basins were discovered. The three main swallets of Sinking Creek were independently traced to Owens Karst Window; all three principal springs at Owens were found to receive dye from each of the three swallets. Finally, since it was thought possible that the flow from Chenault and Owens did not join underground and that the Garretts Spring rise pool is a double resurgence, dye detectors were placed in the obvious boils in the rise pool and traces were run from both Chenault and Owens Karst Windows. All detectors were positive for both traces. However, Garretts Spring does appear to be a distributary resurgence, because positive traces to Garretts have also been detected at Hoffmans Spring, the nearest downstream spring.

The quantitative dye traces were used to measure mean flow velocity and determine effective conduit cross-sectional area (Table 1). Two traces were conducted from Sinking Creek to Owens Karst Window. The centroid of the dye plume and dye recovery (85.1 percent) were calculated for the first trace. Only velocity was calculated for the second trace to Owens. Because of a higher than expected velocity, the leading edge of the dye breakthrough curve was missed for a trace from Owens to Garretts Spring. Its centroid was estimated.

The straight-line distance traces traveled was measured from topographic maps. Previous researchers have used a meander distance to straight-line distance ratio of 1.5:1 (Mull and others, 1988; Thrailkill and others, 1990) for studies in Kentucky. For this study the meander ratio was determined by measuring the meander and straight-line distances of passages with flowing streams from maps of five Inner Bluegrass caves (O'Dell and O'Dell, 1992), including one cave within the basin, and averaging the ratio. The ratio is 1.11:1, and is reasonable in light of the linear nature of many cave passages in the Inner Bluegrass.

TABLE 1: RESULTS OF QUANTITATIVE DYE TRACES.

Sinking Creek to Owens Karst Window (640 m X 1.11 = 710 m)

Date	Elapsed Time Seconds	Velocity m/sec	Discharge cms	Cross Section m2
2-11-91	5,460	0.13	0.32	2.5
1-07-92	3,540	0.20	0.71	3.5

Owens K. W. to Garretts Spring (1,158 m X 1.11 = 1,286 m)

Date	Elapsed Time Seconds	Velocity m/sec	Discharge cms	Cross Section m2
3-19-92	9,120 est.	0.14	1.40	9.98
3-19-92	9,120 est.	0.14	0.91*	6.49

*Discharge at Garretts less inflow into Chenault Karst Window.

Data from the March 19 trace suggest that the Owens to Garretts conduit is twice the cross-sectional area of the Chenault to Garretts conduit. Both tributaries were likely to have been under pressure flow during the trace.

Calculations of the maximum discharge for the February 1989 flood were made because it provided the highest stage recorded to date for Sinking Creek Karst Valley (Table 2). The cross-sectional area of the January 7, 1992, trace was used to represent the Sinking Creek-Owens Karst Window conduit under pressure flow conditions. Data from the March 19, 1992, trace were used for the Owens-Garretts Spring conduit area. The Darcy-Weisbach equation was chosen to approximate the flow regime because it represents energy loss from turbulent flow in pipes. The Darcy-Weisbach friction factor was calculated for the conduits between Sinking Creek and Owens Karst Window and from Owens Karst Window to Garretts Spring using velocity and discharge data from the quantitative dye traces. The value used in these calculations is the apparent friction factor, and represents total head loss in these conduits. The values calculated fall well within ranges reported by other researchers for karst conduits (Ford and Williams, 1989). The elevations of flotsam marks in Sinking Creek, Owens Karst Window, and Garretts Spring were recorded soon after the 1989 flood.

TABLE 2: CALCULATION OF MAXIMUM DISCHARGE FROM SINKING CREEK AND OWENS KARST WINDOW DURING FEBRUARY 1989 FLOOD.

Darcy-Weisbach equation: $Q^2 = 2dga^2/f \times dh/dl$
d = conduit diameter
g = acceleration of gravity
a = conduit cross-sectional area
f = Darcy-Weisbach friction factor
dh/dl = conduit gradient or slope
Q = discharge

Sinking Creek to Owens Karst Window
g = 9.8 m/sec^2
dh/dl = 0.009 (2-89 flood)
f = 2.6 (2-11-91 data) (apparent friction factor)
a = 3.52 m^2 (1-7-92 data)
d = 2.12 m (1-7-92 data)

$Discharge^2 = (2 \times 2.12 \times 9.8 \times (3.52)^2/2.6) \times 0.009$
Discharge = 1.3 m^3/sec = 47.3 $ft.^3/sec$

Owens Karst Window to Garretts Spring
g = 9.8 m/sec^2 (gravity constant)
dh/dl = 0.014 (2-89 flood)
f = 8.5 (3-19-92 data) (apparent friction factor)
a = 6.49 m^2 (3-19-92 data)
d = 2.88 m (3-19-92 data)

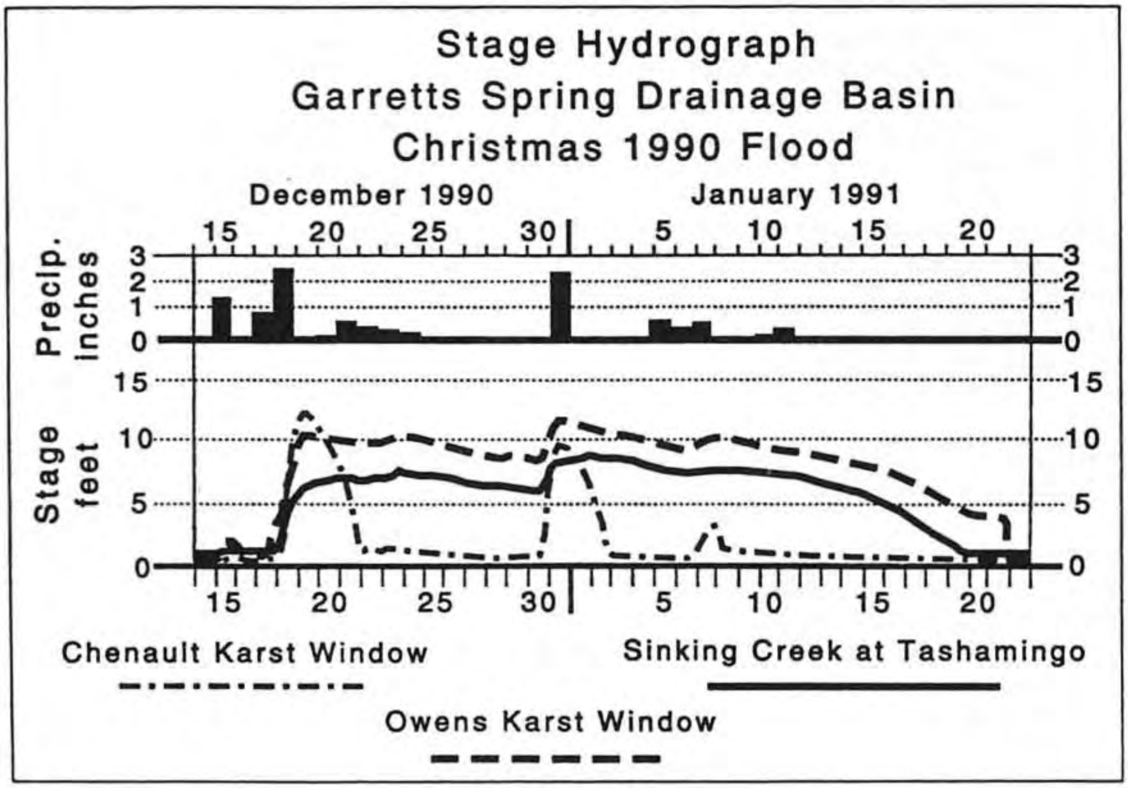
$Discharge^2 = (2 \times 2.88 \times 9.8 \times (6.49)^2/8.5) \times 0.014$
Discharge = 2.0 m^3/sec = 70.6 $ft.^3/sec$

These calculated discharges compare favorably to discharges projected from lesser events. The flow from Owens Karst Window to Garretts Spring includes an unknown contribution from several additional inputs downstream of the window. Inspection of flow budget data from three flood events suggests 25 percent of the flow from the southeastern branch may be contributed by this unaccounted-for area. Flow from conduits inaccessible during high flow is known to occur in Owens Karst Window, based on direct observations during low and moderate flows. Also, the quantitative dye trace data suggest only 85 percent of the flow is accounted for during high flow. Seventy-five percent of 2 m^3/sec is 1.5 m^3/sec (53 $ft.^3/sec$), which compares favorably with the calculated flow into Owens Karst Window from Sinking Creek of 1.3 m^3/sec (47.3 $ft.^3/sec$), and if the unaccounted-for flow into Owens is considered, the comparison is even better.

Stage data have contributed directly to understanding the hydrology of the basin. A hydrograph for the Chenault, Tashamingo, and Owens recorders for the largest flood since the project began is presented in Figure 2. An important consideration in interpreting the stage data is the position of the recorders relative to the swallets. Both the Tashamingo and Chenault Karst Window recorders are many meters upstream of the swallet, where ponding is minimized. Under ideal circumstances two recorders should be used, one upstream to record inflow and one at the swallets to record head. However, only staff gages were installed at the swalletts, and the data obtained from them was unevenly distributed through time.

The hydrograph at the Tashamingo recorder displayed curves typical of unconfined flow until ponding of the swallets rose to its intake. After ponding reached the recorder, the hydrograph flattened out, and slowly dropped as storage was removed from the karst valley. The hydrograph very closely paralleled stage data for Owens Karst Window when both features were flooded (Fig. 2).

Figure 2. Stage hydrograph for the Tashamingo, Owens Karst Window, and Chenault Karst Window water-level recorders, December 1990 event.



The recorder at Owens Karst Window was closer to the swallets than the other two recorders and was influenced by ponding earlier in a flood event. The stage recordings at Owens showed a consistent, very steep rise and fall in stage from 0.6 to 1.2 meters (2 to 4 ft.). Discharge data have been very difficult to obtain for this limb of the hydrograph because of its short duration. During a series of observations on March 18, 1992, to record this change, discharge increased from 0.16 cms (5.7 cfs) to 0.29 cms (10.2 cfs), while stage rose 0.43 meters (1.4 ft.) in 2 hours, 15 minutes. The rapid increase in stage and discharge at Owens Karst Window is caused by the onset of flow from its north spring. The north spring at Owens Karst Window begins flowing at stage 0.49 meter (1.6 ft.) at the Sinking Creek swallets and discharges vigorously when the swallets are completely inundated. The north spring is the outlet of a higher conduit now acting as an overflow route.

The parallel between the Tashamingo and Owens hydrographs reveals the close match of outflow from Sinking Creek and outflow from Owens Karst Window. Soon after the Tashamingo hydrograph begins to rise, flooding at the swallets reaches sufficient depth to activate the north spring in Owens. Its discharge, coupled with overland and quick-return ground-water flow in the Owens catchment, rapidly floods Owens Karst Window. Once flooded, the outflow from Owens Karst Window no longer increases rapidly with stage because inflow into its swallets is controlled by the pressure limb of the hydrograph. Inflow from Sinking Creek is then slowed by the hydrostatic pressure in flooded Owens Karst Window. The hydrographs remain parallel, with inflow into Owens nearly matching outflow, until Sinking Creek Karst Valley empties. The sudden stoppage of flow from the north spring then allows Owens Karst Window to empty rapidly.

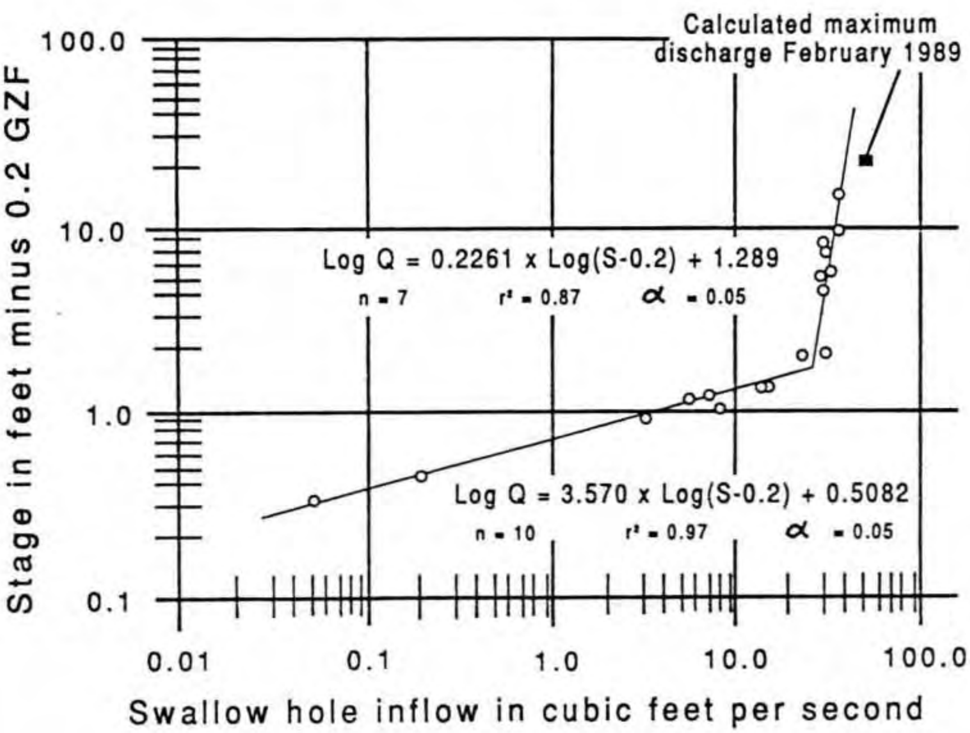
The hydrograph for Chenault Karst Window is distinctly different from Owens or Tashamingo, showing both a rapid rise and fall in stage (Fig 2.). While the recorder is nearly 300 meters (900 ft.) upstream of the swallets, the available staff gage readings at the swallets suggest the fall in stage continues until free fall-flow is restored.

No relationship has been observed between stage at Chenault Karst Window and stage at Owens Karst Window. The swallets at Chenault are roughly 3 meters (10 ft.) lower in elevation than the swallets at Owens. The rapid drop in stage at Chenault Karst Window implies that it has a more efficient flow route to Garretts Spring. The conduit from Chenault to Garretts Spring is substantially shorter, and the gradient from the Chenault swallets is slightly steeper, 0.007 versus 0.006 for the Owens swallets.

Stage data for Garretts Spring are converted directly to discharge by software in the monitoring equipment and the stage data are not retained. In general terms, the stage hydrograph at Garretts Spring shows sudden drops when Chenault Karst Window and Owens Karst Window empty.

The stage-discharge relationship for the Sinking Creek swallets is complex (Fig. 3), and overall is typical for a ponor (Bonacci, 1987). However, the pressure flow segment is not quite vertical, probably because a component of the discharge continues as unconfined flow through normally abandoned conduits, joints, and bedding planes during high-flow events. The estimated discharge from Sinking Creek for the February 1989 event has also been plotted on Figure 3. Inflow into high-stage swallets at Sinking Creek and multiple high-stage springs at Owens has been observed during floods. The regression lines for the free-fall and pressure-flow segments converge at a stage of 0.58 meter (1.9 ft.) and a discharge of 0.72 cms (25.5 cfs). Field observations indicate that all major swallet openings are completely inundated at this stage.

Figure 3. Rating curve for the Sinking Creek Karst Valley swallets. The estimated maximum discharge through the swallets for the February 1989 event is plotted with a solid square.



Computer software, the HEC-1 Flood Hydrograph Package (Computer Program 723-X6-L2010) developed by the U.S. Army Corps of Engineers, was used to model the effects of changing land use and moisture conditions in the southeastern branch of the drainage basin. The data file was originally set up by the Corps using their survey data for channel gradient, channel width, bridges, and culverts. The data file was modified for this study by applying the rating curve for the Sinking Creek swallet inflow capacity and by making new estimates of the SCS curve number from soil survey maps and land-use data gathered for this study. Each time the model was run, hydrographs were calculated for the 1989 storm and 12 hour design storms of 10-, 50-, 100-, and 500-year frequencies.

Although suburban development is accelerating in the basin, agricultural land use still predominates. Approximately 79.5 percent of the Garretts Spring Basin is in pasture or row crop. Land use in the southeastern branch, up drainage of the Sinking Creek swallets, is distributed as follows: 76 percent agriculture (pasture 63 percent, row crops 13 percent), 8.5 percent golf course, 8 percent residential (farmsteads, individual lots, subdivisions), 6 percent woodland, 1 percent lakes, ponds, etc., and 0.5 percent roads and highways. For this study, future suburban development was defined as 0.4 hectare (1 ac.) lots, and all development was assumed to occur in former pasture. Further, the increased impervious area created by access roads for the additional development was not considered. The increase in development was also assumed to be evenly distributed between each hydrologic soil type. However, most development will probably be on group B soils, since they are the most common in the basin, and type C and D soils primarily occur in poorly drained areas. The relative increase in SCS curve numbers for suburban development on type B soil is twice that of the same development on type D soil, and would increase surface runoff.

The percentage of each soil in the basin was determined from soil survey maps (McDonald and others, 1983) and classified into hydrologic soil groups. The hydrologic groups were found to be distributed at follows: 69 percent type B, 23 percent type C, and 8 percent type D. No type A occurs in the basin, and type D occurs predominantly along the course of Sinking Creek. Curve numbers for each land-use category were individually calculated according to soil-type occurrence.

Field experience gained during the course of the study indicated that vegetative cover and antecedent soil moisture content are critical to both volume and rapidity of runoff in the Garretts Spring basin. Antecedent moisture condition II represents "average moisture content," and antecedent moisture condition III represents nearly saturated soil. Condition III is frequently obtained during the winter months when there is little evaporation or plant uptake. The SCS runoff curve numbers were calculated for both soil moisture conditions. The weighted mean for the southeastern branch for condition II is 70 and for condition III is 85, under current land use. Frozen ground will produce even higher curve numbers and greater runoff.

The HEC-1 computer model was first run with basin areas, and SCS curve numbers determined by the Corps, and the initial estimate of swallet capacity. The second run was with the new swallet rating curve, new runoff curve numbers (moisture condition II), and the reduced basin area to reflect ground-water tracing results. The third, and all subsequent runs, were run with the new data and moisture condition III. For the fourth run the land-use data were modified to reflect future suburban development of 20 percent of the southeastern branch. Current suburban development is 2.3 percent. Residential development of other size lots was not considered. The fifth model run was for a totally forested watershed.

The results for the current land-use model revealed the importance of antecedent soil moisture. A 12 hour/100 year frequency storm 13.5 cm (5.3 inches) will produce a stage elevation at Tashamingo of 280.57 meters (920.5 ft.) under antecedent soil moisture condition II, while the same storm will result in a stage elevation of 281.33 meters (923.0 ft.) under antecedent soil moisture condition III. The total accumulated precipitation for the 1989 storm from February 13 through 16 was 21.3 cm (8.4 inches) at Keene, and 18.0 cm (7.1 inches) at Bluegrass Field. The rain on February 13, 1.6 cm (0.64 inches), was sufficient to saturate the soil in the prevailing conditions of near-freezing temperatures and absence of transpiration. For the 1989 storm, using the Keene total, the model calculated a stage at Tashamingo of 281.67 meters (924.1 ft.) for condition II and 282.18 meters (927.2 ft.) for condition III. Increasing development in the basin to

20 percent with 0.4 hectare (1 ac.) lots resulted in an increase in stage to 282.67 meters (927.4 ft.), 0.06 meter (0.2 ft.) higher than with current land use. Treating the basin as virgin forest resulted in a stage of 282.18 meters (925.8 ft.) at Tashamingo, 1.4 feet lower than current land use. For comparison, the estimated maximum stage actually reached at Tashamingo in 1989 was 282.95 meters (928.3 ft.); the elevation of Cherrywood Lane is 281.94 meters (925 ft.).

HYDROGEOLOGY AND PALEOHYDROGEOLOGY

The shales and siltstones interbedded with the thin-bedded limestones in the Garretts Spring Basin are major inhibitors of ground-water movement (Thrailkill and others, 1982). Numerous springs can be observed at contacts with argillaceous units of mappable thickness. Two units, the Brannon Member and the Macedonia Bed, are important aquitards. Jointing and unmapped faulting may play a major role in conduit location and orientation because of the inhibiting influence of the argillaceous units (Thrailkill and others, 1983). The projected outcrop of the Macedonia Bed at Garretts Spring is just above the elevation of the spring.

Garretts Spring has an annual median discharge of 0.18 cms (6.5 cfs) (Felton, personal communication, 1992). The maximum discharge measured to date is 1.66 cms (58.6 cfs), although discharges exceeding this amount are known to have occurred. The flow from Owens and Chenault Karst Windows joins underground within 457 meters (1,500 ft.) of the resurgence at the spring. The recession limb of discharge hydrographs for Garretts shows a stepped recession (Felton, personal communication, 1992).

Floods in Chenault Karst Window recede more quickly than in Owens Karst Window or Sinking Creek because of the smaller size of the northwestern branch of the basin, and the relatively more efficient flow from Chenault to Garretts. No relationship has been observed between stage in Chenault and the rate of discharge from Owens Karst Window.

Nominally, three springs are active in Owens Karst Window. Water tracing shows that flows from the three principal swallets in Sinking Creek are tributaries to a single conduit, which branches into a distributary system as it approaches Owens. During low flow only the middle and south springs are active, and during extreme low flow all are dry. Several additional openings, from 0.3 to 3 meters (1 to 10 ft.) above the three main springs, discharge during high flow. One of these, the upper north spring, has a significant impact on stage changes in Owens Karst Window. The north spring only flows when swallet capacity has been reached at Sinking Creek. When flow begins or ends at the north spring, stage changes rapidly in Owens Karst Window. During extreme high flow, hundreds of small openings discharge into Owens Karst Window.

Sinking Creek Karst Valley differs in geomorphology and hydrology from an open-upstream polje only in size (White, 1988). Downstream reaches of the valley are characterized by steep, cliff-forming valley walls with local reliefs of 15 meters (50 ft.). Flooding of the valley occurs frequently in winter and early spring, and persists for days, sometimes weeks. Springs, perched on the Brannon Member, rim the valley just above the grade of Sinking Creek where the Brannon crops out. Although an outcrop of the Macedonia Bed is not visible, the location of several lower elevation springs and a minor "nick point" in the gradient of Sinking Creek just upstream of the swallets suggest that a perching horizon is present at the projected elevation of the Macedonia Bed. The swallet zone at the headwall of Sinking Creek Karst Valley receives flow via a distributary system that has three branches. Throughout the footwall area are hundreds of openings, varying in size from 2.5 cm (1 in.) to 40 cm (16 in.) in diameter. Each branch feeds a cluster of macro-swallet openings, many of which only accept flow during high stage.

A potentially important factor in flooding at Tashamingo is the contribution of flow from the pirated extreme tip of the southeastern sub-basin. During extreme events it is possible that flow is diverted below ground, and potentially on the surface, to the west. Unfortunately, an opportunity to trace or even observe the area during a major flood has not occurred since its potential significance was recognized.

Spangler (personal communication, 1989) thinks that a wide and long dry valley, extending from the vicinity of Tashamingo Subdivision northward to Shannon Run (a tributary of South

Elkhorn Creek), may be an abandoned channel of a surface-flowing Sinking Creek. The piracy of Sinking Creek, if it occurred, would have happened after the initial development of the swallets at the footwall of present-day Sinking Creek Karst Valley. It is possible that the conduits from the swallets to Garretts Spring may have had insufficient geologic time to adjust to the higher inflows from the geologically sudden increase in catchment area.

CONCLUSIONS

Flow from Sinking Creek is controlled by the stage in Owens Karst Window. The discharge from Owens Karst Window is controlled by the hydraulic parameters of the conduit system to Garretts Spring. The conduit is not blocked by any manmade debris, but discharge is limited by the conduit diameter, gradient, length, and roughness. This is supported by the absence of trash, the large measured discharges, and flow velocities and cross-sectional areas of the conduits as determined by ground-water dye traces. The intake capacity for the Sinking Creek swallets at the moment flooding begins is 0.72 cms (25.4 cfs). The maximum capacity is approximately 1.34 cms (47.3 cfs), while inflows into Sinking Creek Karst Valley can exceed tens of cubic meters per second (hundreds of cubic feet per second). Hydrologic modeling of the basin suggests that antecedent moisture conditions are critical to the potential flooding from a given storm. It also suggests that the February 1989 storm would have flooded the valley to the elevation of Cherrywood Lane even if there was no development in the basin, but also that further development will cause a limited increase in depth of flooding.

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DEVIL'S ICEBOX WATER QUALITY STUDY
June 1982 to July 1984

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ABSTRACT

For many years, there has been a concern that Devil's Icebox Cave has had a water quality problem from possible contamination by domestic sewage, livestock sewage, toxins from sinkhole dumps, chemically treated agricultural land and bats. In 1981, a population of amphipods, *Gammarus pseudolimnaeus*, suffered a massive die off. It was feared they were completely lost to the cave stream system. The cause of the death of the amphipods was undetermined, but the incident did illustrate the vulnerability of the Devil's Icebox Cave system to outside contamination. Of particular interest to the Missouri Department of Natural Resources' Division of State Parks (DSP) is the preservation of habitat for two rare and endangered species. It is the policy of DSP to take whatever reasonable steps are available to protect the Devil's Icebox Cave from any kind of environmental degradation. Therefore, a two-year monitoring program was designed to determine water quality in the Devil's Icebox cave system. The study looked for existing problems and developed baseline water quality information.

Four stream sites were chosen for monitoring. The entrance is the discharge point for the entire cave system and was chosen to represent the overall water quality for the cave. At 1810 meters upstream from the entrance, a major tributary joins the main stream from the southwest. At 2200 meters another major tributary comes in from the east. Sampling points were located in each of these side streams with the fourth sampling point being just upstream of the confluence of the stream at 2200 meters. This allowed us to measure different water sources. The entrance site was monitored weekly. The recharge area for the cave includes the Pierpont Karst (1200 acres) and the headwaters of a losing stream, Bonne Femme Creek (7,000 acres). Approximately 500 acres of the Pierpont Karst are protected within the boundaries of the state park. Total park acreage is 2238. The remaining Pierpont karst area is predominately in private ownership - best characterized as low density residential and agricultural.

While sampling showed measurable chemical and biological contamination, the level of contamination is not generally a threat to aquatic organisms within the cave. It was interesting to learn that certain easily measured water quality parameters seem to provide predictive information regarding characteristics of the recharge method and area. In retrospect, we can easily see these relationships. Yet, they were neither known nor appreciated prior to the study. For instance, during the study we learned that a surface stream was a major recharge source for the cave's main stream. Comparative water temperature measurements alone could have predicted this! This and other observation gave new insights to the physical characteristics of the Devil's Icebox cave system. This type of study could have value in understanding other cave systems.

Devil's Icebox cave, one of the longest caves in Missouri, is owned and operated by the Division of State Parks in Rock Bridge Memorial State Park. The Division of State Parks is a division of the Missouri Department of Natural Resources. From June 1982 through July 1984 an extensive water quality study was conducted in the cave. The primary objective of the study was to establish baseline water quality information, which could provide a frame of reference by which to evaluate future water quality conditions.

This paper explains how the water study was conducted, the results, and an interpretation of the data.

BACKGROUND

The water quality of the Devil's Icebox stream (Rock Bridge Creek) has been a concern for many years. The water was used by early inhabitants as a water source and later as the water in whiskey distilled at the site. Environmental and scientific concerns for the quality of the water and the integrity of the stream ecosystem began to surface in the 1950's when cavers began to explore the Devil's Icebox in earnest.

Massive amphipod kill, shows need for water quality study.

On July 9, 1981, it was reported that there had been a die off of amphipods in the stream just below the Conner's cave discharge. The USFWS National Fisheries Research Laboratory and the US EPA had been collecting amphipods from this area for the previous 15 years. The amphipod, *Gammarus pseudolimnaeus*, from this stream had become the standard amphipod used for toxicological studies at the National Fisheries Research Laboratory. Within days we made a trip into the cave to check the status of amphipods in the cave streams. During that trip we noticed many dead bats. Several dead bats were collected and analyzed. We found high concentrations of dieldrin in the brains of the bats. Although we also found dieldrin to be unusually high in the amphipods we do not believe that dieldrin was the cause of amphipods kill-off.

Purpose of Study

The sudden and complete loss of what had been for at least 15 years a stable population of amphipods was alarming. Not only were we unable to determine the cause, but we lacked good data with which to compare current water quality. This was a major shortcoming. If we had good data for the background water quality for the cave stream system we might be able to measure changes in the future to assist us in identifying problems when they occurred. Good data and the ability to track changes in water quality could also give us an opportunity to prevent problems.

Our objectives were.

1. To determine the quality of water in the Devil's Icebox Cave system.
2. To establish baseline data for future reference.
3. To establish differences in feeder streams within the cave, focusing on relationships between water quality, volume, drainage areas and surface contamination.

Sampling Procedures

The sampling period was from July 1982 through June 1984. During that period we sampled every week at the entrance of the Devil's Icebox. On the third Wednesday of each month we sampled the entrance site and three others inside the cave. If we were unable to enter the cave on the third Wednesday we attempted to conduct the sampling on the following Wednesday.

Four sample sites were selected. Although we would have liked to develop a more complete profile of the cave's stream system we settled on four sites as the minimum number that would give us some differences in the types of streams sampled. With the four sites selected, we were able to reach and sample all four sites, exit the cave and deliver the samples to four different labs within five to seven hours.

<u>SITE</u>	<u>DESCRIPTION OF SITE</u>
0001	The only entrance to the cave and the discharge of the stream system. Drains the entire watershed of the Devil's Icebox cave system. This site reflects overall water quality of everything accumulated in the cave stream system.
1810R	Sample site is five meters upstream in the side passage tributary located 1810 meters from the entrance. This tributary lies under the Grassland Restoration area of the park and it is assumed to drain sinkholes in that area and to the south of the park across Highway N.
2200	Located 2200 meters from the entrance on the main passage collector stream. Sampling was just upstream from the junction of the stream coming in from the "left fork" of the cave. Site 2200, also a main trunk station, receives flow from the upper reaches of the cave system, and data from here shows collective water quality of that portion of the system. Note: During the period of this study it was determined that a significant portion of the cave stream comes from Bonne Femme Creek (a losing stream). Bonne Femme Creek's water enters the system upstream from this collection point.
2200L	This site sampled the water in the tributary of the "Left Fork." The Left Fork is the largest side passage in the Devil's Icebox. The drainage lies to the east of Pierpont and is probably recharged from the row of houses along Highway 163 east of Pierpont as well as a portion of the park that lies north of Highway 163. Although the Left Fork is the largest side passage the stream flow is not as large as the two side passages on the opposite side of the cave. The sample site "2200L" is approximately 30 meters upstream from the confluence with the main passage collector stream.

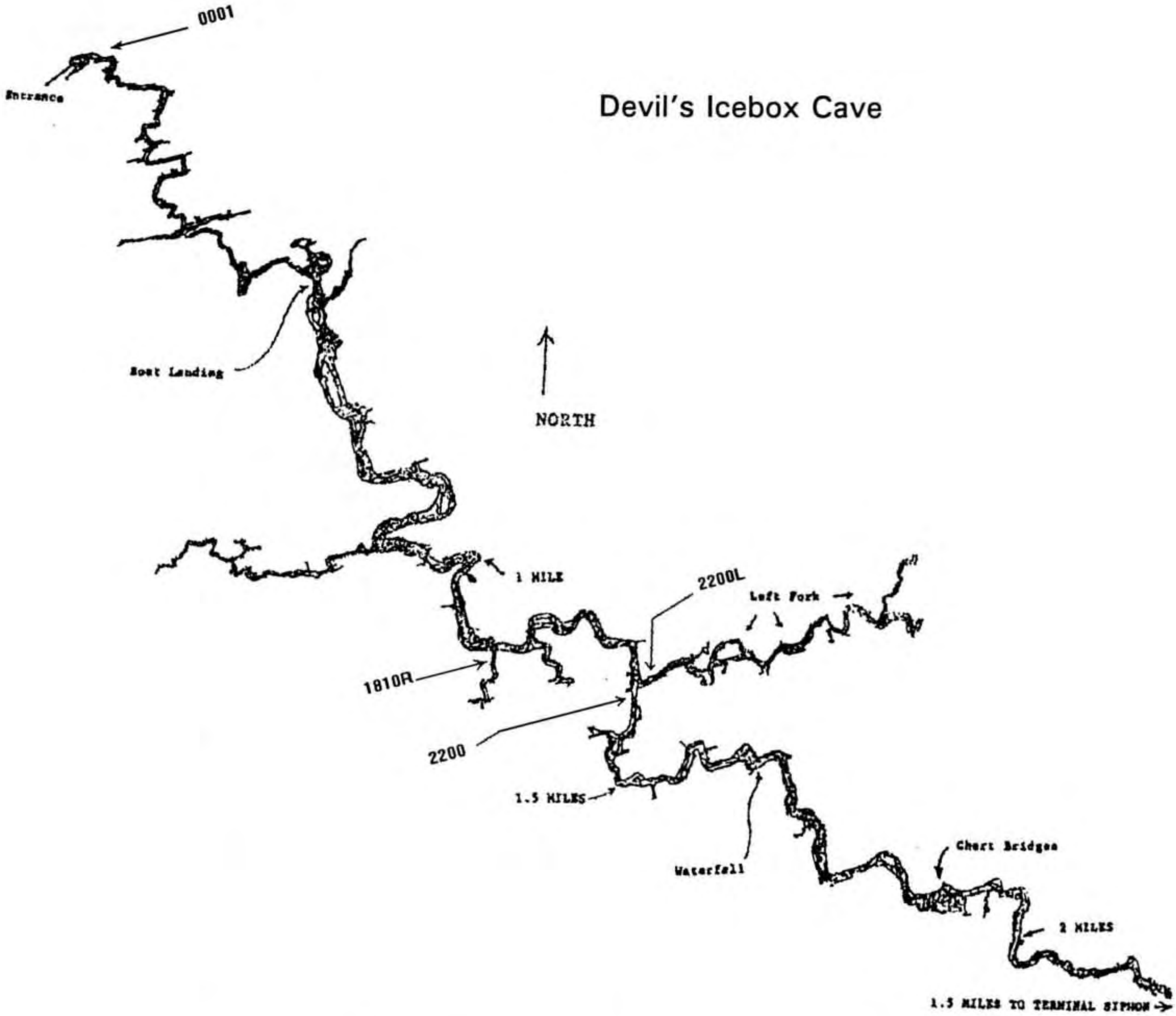
Details on sampling and analysis procedures are shown in appendix A.

<u>Findings by parameter</u>

A print out of raw data collected from the monthly sampling trips is shown in appendix B. While additional weekly monitoring at the entrance was conducted, only those measurements from the hydrolab probe were obtained. Generally these weekly measurements fell within the range of observations shown by the monthly (complete) sampling. The notable exceptions were temperature and stream flow.

Interpretation of Data

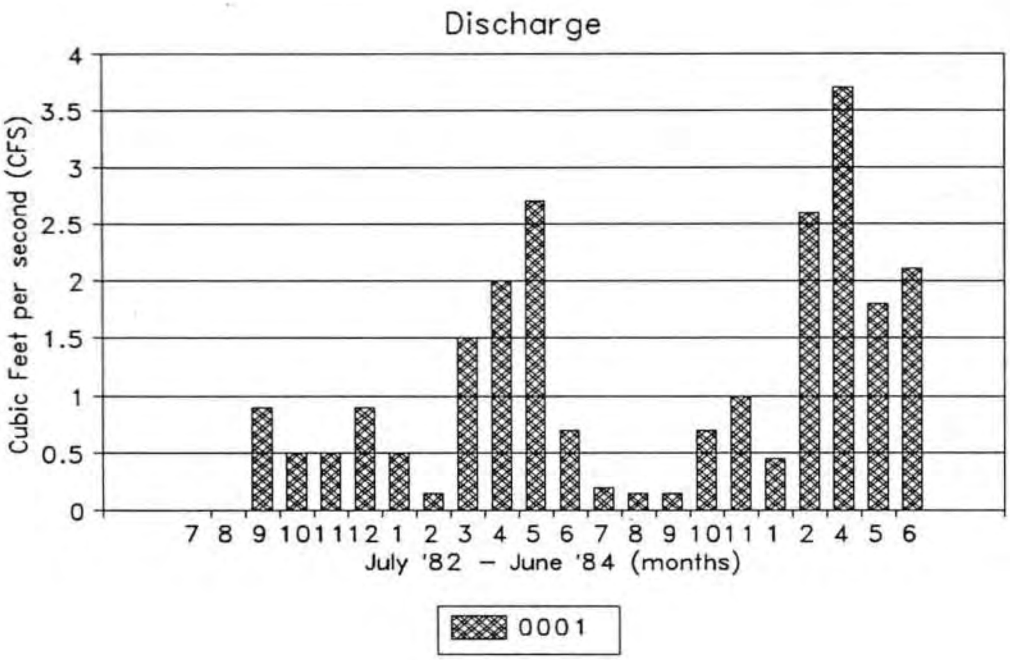
The following section discusses the values measured and an interpretation of the findings. Graphs are provided to assist in depicting the relationship between the sites and over time. Some parameters display obvious patterns, while others are less apparent in showing a relationship to time or location.



Sample Locations

Discharge

The volume of water exiting the cave was measured in various ways during the duration of this study. Initially we recorded the water level at the entrance as either: very low, low, moderate, high, or very high. From March 23, 1983 to February 8, 1984 we measured the height of the water by using a yard stick at a specific location between Conner's Cave and the Rock Bridge. Beginning on February 8, 1989 the stream measurements were made with a recording stream gauge. The stream gauge is located where we took the yardstick measurements.



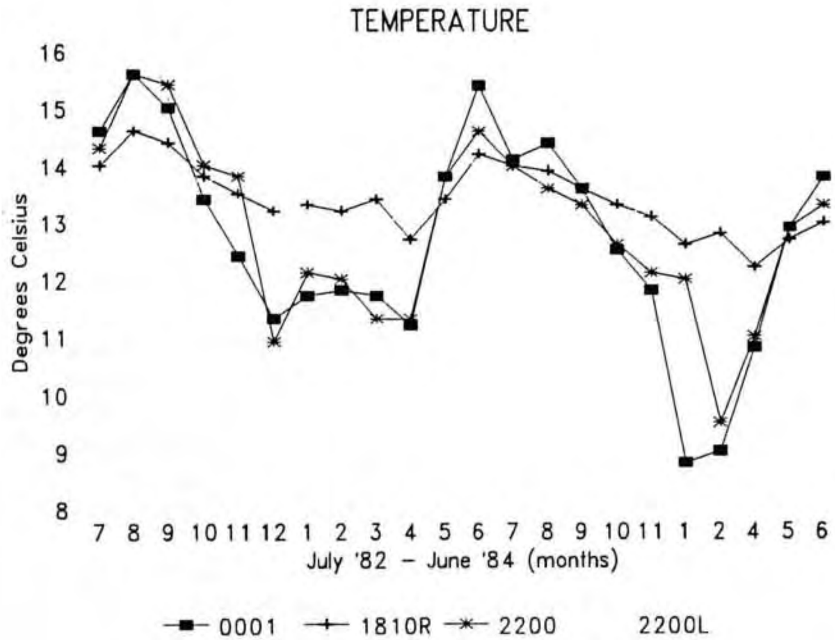
We measured discharge at several stream levels and established a discharge rating curve. The discharge volume from March 23, 1983 is based on the rating curve at measured stream level. The values prior to that date are estimates based on the observations recorded as very low to very high.

Since we were unable to enter the cave during the high water periods - the discharge measured during sample taking dates always indicated low to moderate stream flow. Higher flows close the cave. We have measured discharge from the cave as high as 14 cfs. Therefore, no data is represented in this study for high situations. We did not measure stream flow at individual sample sites.

<u>Temperature</u>

Temperature and flow rate can be used to estimate size of recharge area and recharge efficiency. Large fluctuations in flow indicate an open system, one that is recharged rapidly after precipitation events by means of discrete openings such as sinkholes and losing streams. Steady flows indicate a less open system where recharge is released more slowly, such as infiltration through soil material and smaller openings in rock. Volume of flow reflects recharge area size.

The greater variation in temperature shown by both main stream sites, 0001 and 2200, indicate the direct influence by surface conditions. This information alone would point strongly to a loosing stream or some other direct conduit to a surface water source. The temperatures of the water at 1810R and 2200L are relatively stable and probably more closely represent Mean Annual Surface Temperature (MAST).



The average temperatures of the side passage streams were the same, 13.4°C. The entrance site, 0001 had the coolest average of 12.7°C and 2200 had an average temperature of 12.9°C. All temperature measurements are in degrees Celsius.

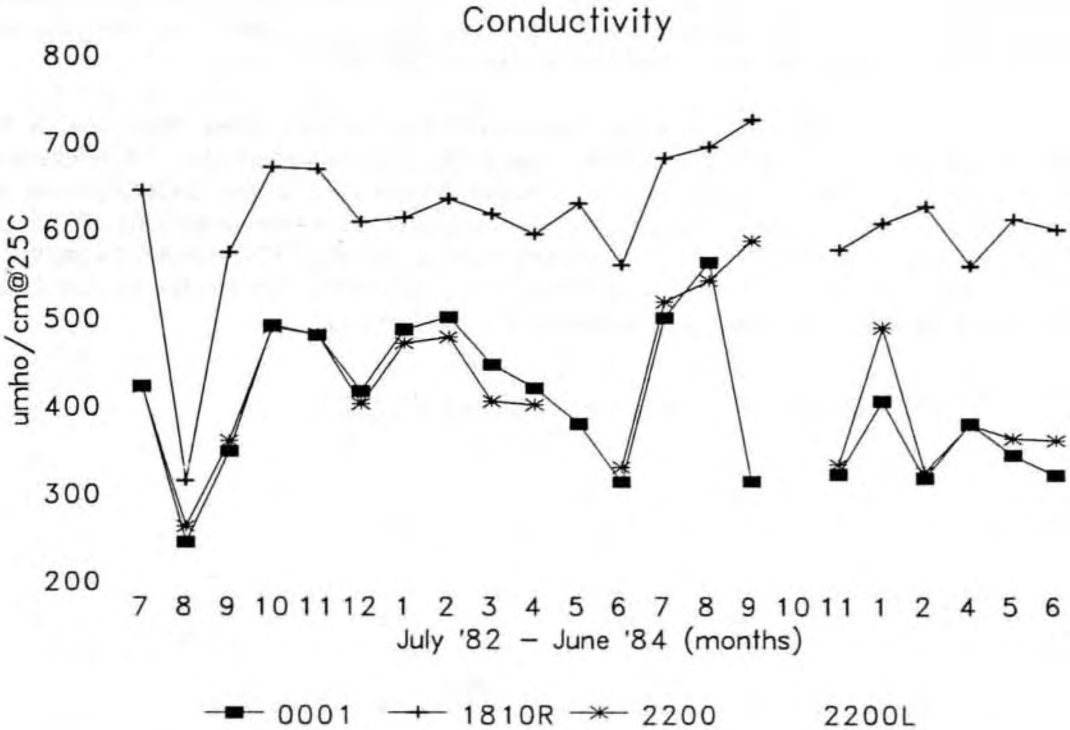
Changes in water temperature reflect the length of time water has been in contact with subterranean materials. Wide variations in temperature from mean annual surface temperature show the water either moves rapidly through the system, or indicates the recharge area is quite close to the point of measurement. Generally, a station with flow that is low but uniform, with a fairly uniform temperature, is receiving diffuse recharge from a relatively small area. Conversely, a station where flow and water temperature vary greatly is receiving recharge through an open system where colder or warmer recharge water has insufficient time to reach equilibrium with the system.

SITE	Temperature in degrees celsius			
	Average	Minimum	Maximum	Range
0001	12.7	8.8	15.6	6.8
1810R	13.4	12.2	14.6	2.4
2200L	13.4	12.6	14.1	1.5
2200	12.9	9.5	15.6	6.1

Water temperature at site 0001 ranged from 8.8°C to 15.6°C, a variation of 6.8°C. This is an average for the entire cave system. Temperatures at site 1810R had a narrower range, from 12.2°C to 14.6°C, a variation of only 2.4°C which indicates either longer travel time, less volume of recharge, or a slower recharge mode. Site 2200L also had a fairly narrow range of temperatures, from 12.6°C to 14.1°C, a variation of 1.5°C. Once again, it may show more distant travel, less recharge volume, or slower recharge mode. The water temperature at site 2200 ranged from 9.5°C to 15.6°C, a variation of 6.1°C. Such variation is probably due to short travel time and rapid recharge with direct surface connection.

During the coldest times, cold air being drawn into the cave would freeze the surface water in the entrance. When the cave stream was frozen we decided not to access the cave for safety reasons. This resulted in a loss of consideration of extreme cold conditions. In other trips we have entered the cave over ice and feel that the effect of extreme cold air at the entrance does not influence stream temperatures inside the cave as significantly as snow melt. Snow melt results in the lowest extremes of stream temperature in the main passage stream. This is especially true upstream of 2200 meters. Between 2200 meters and 1300 meters there are several contributing side streams whose waters are less influenced by surface conditions and therefore serve to moderate the overall water temperature somewhat. Since we did not monitor water temperatures between the entrance and 2200 meters we are not certain of the effect. Measurements at the entrance may represent more the influence of air circulating in contact with the water, than the overall effect of the recharge components of the cave stream.

Conductivity

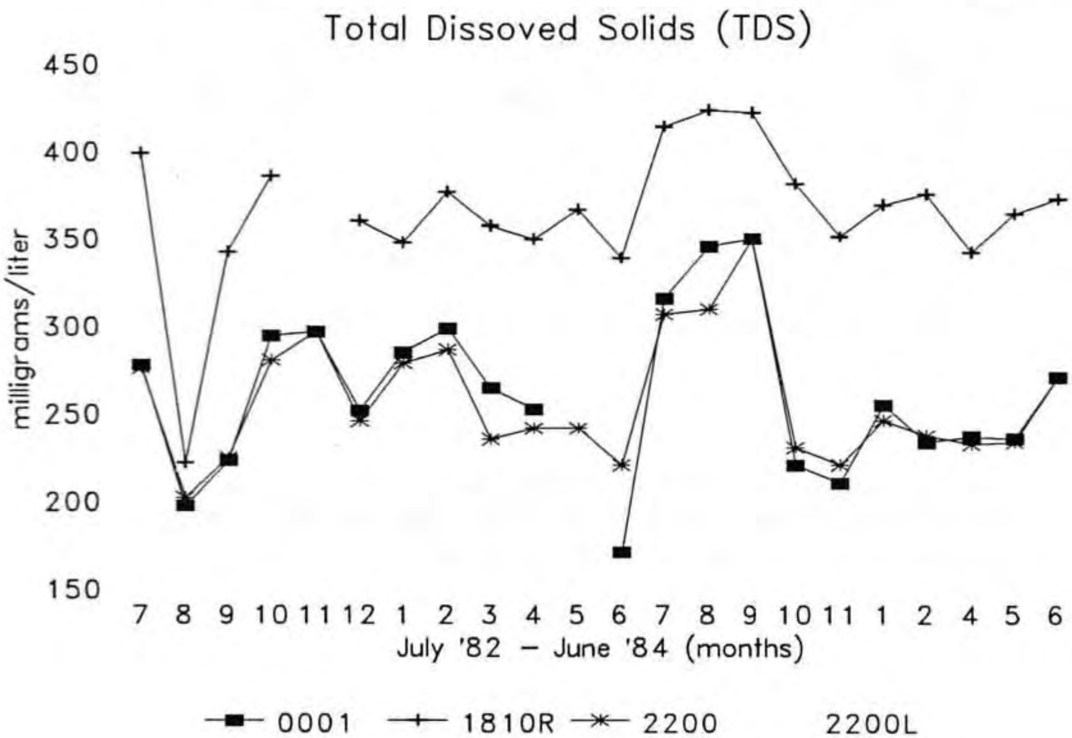


Each of the side passage streams had consistently higher conductivity values than the main stem. 1810R had the highest readings with 2200L being the next highest. Sites 0001 and 2200 were found to have similar conductivity values.

Total Dissolved Solids

Since conductivity of water is directly related to amounts of dissolved solids, total dissolved solids (TDS) mirror those of conductivity. There is a very close similarity (graphically) of the trends exhibited and the same differences by site are shown.

Total dissolved solids averages of three stations are quite similar. Sites 0001, 2200L and 2200 TDS averages are 261 mg/l, 298 mg/l, and 257 mg/l, respectively. Total dissolved solids at site 1810R average abut 100 mg/l higher, 364 mg/l. Hardness ($CaCO_3$) was also analyzed for about 1/2 of the study period. The average values for sites 0001, 2200, and 2200L were between 183-197 mg/l, while the average for site 1810R was 244 mg/l. The higher hardness at site 1810R indicates much of the difference may be due to dissolved calcium and bicarbonate; these constituents were not analyzed.

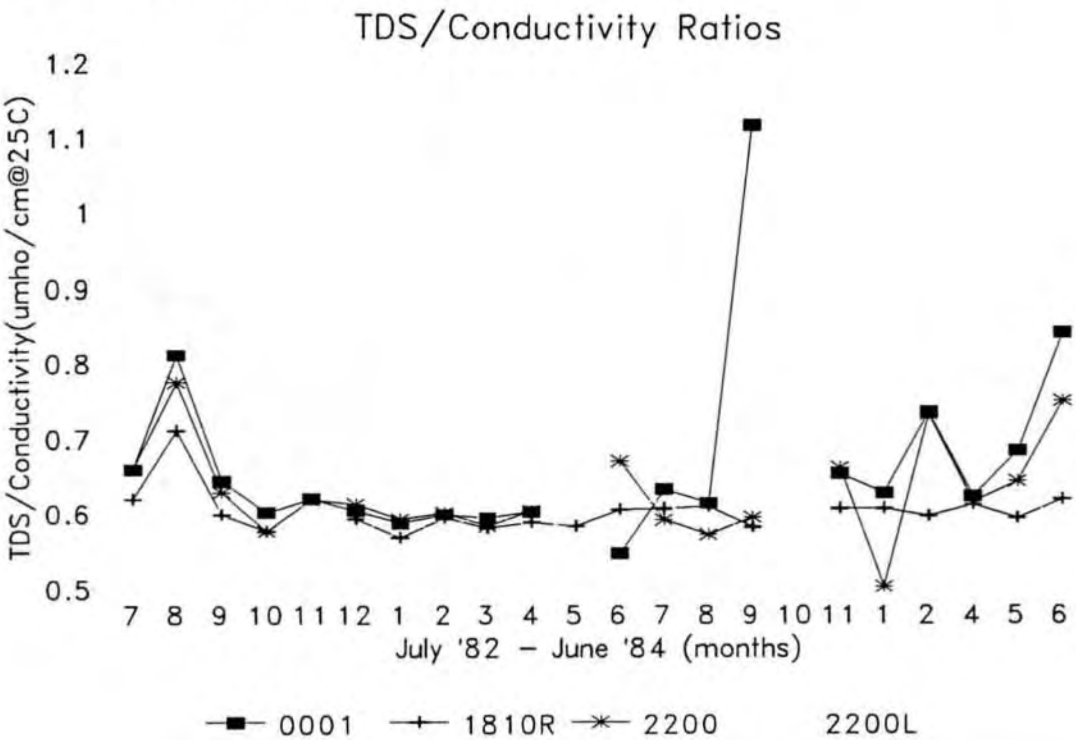


The strong correlation between conductance and total dissolved solids will prove useful in further studies. Overall water quality can be monitored at the entrance easily by routinely measuring specific conductance. Water inflow points in the cave other than those sampled here can be measured for conductivity, and the gross water quality for these sites determined.

TDS/Conductivity Ratios

Total dissolved solids to specific conductance ratios can be used to establish a mathematical relationship, allowing easy estimation of dissolved solids by simply measuring specific conductance. There is excellent correlation between the two parameters at all of the sites. Ratios differ significantly only when turbidity is high, generally above 10.

At sight 0001, TDS conductivity ratios vary from 0.54 to 1.11, and average 0.67. If data are eliminated where turbidity is above 10 (a total of five data points), ratios vary from 0.54 to 0.68, and average 0.62. Thus, for this site, total dissolved solids can be estimated by multiplying specific conductance by 0.62.



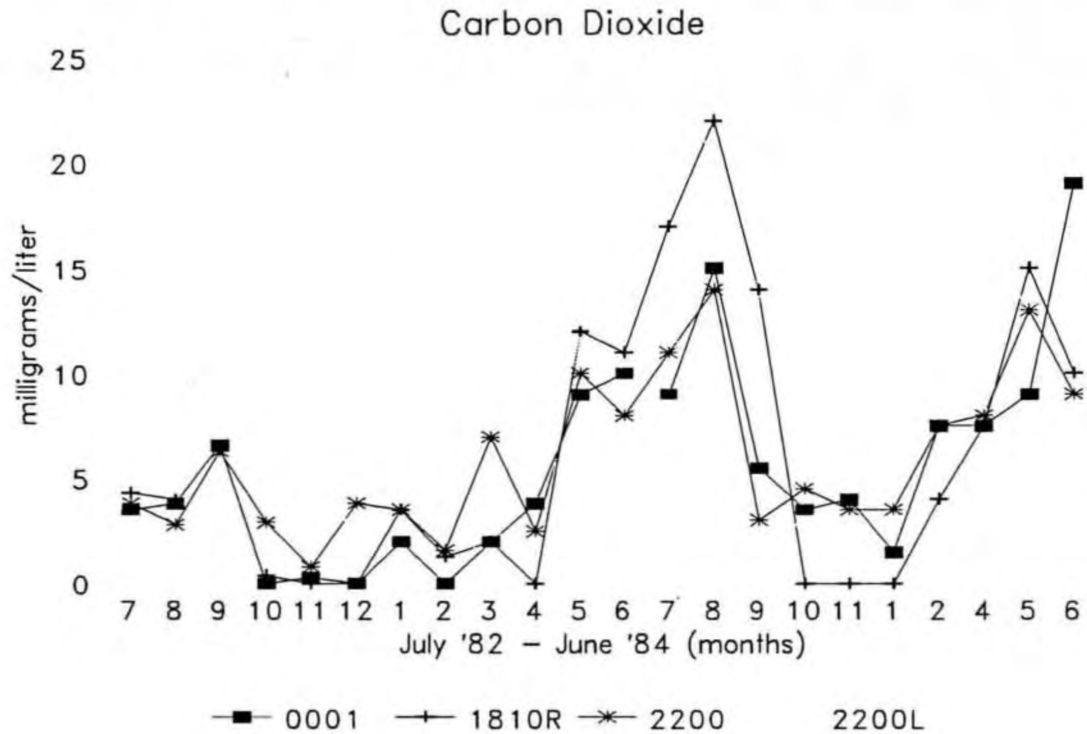
Total dissolved solids-conductivity ratios at site 1810R are even more constant; turbidity is less at this sight, one value being above 10. Here the ratios vary from 0.57 to 0.71, averaging 0.60. Eliminating the data where turbidity exceeds 10 (one value, 0.71) ratios vary from 0.57 to 0.62, again averaging 0.60.

For site 2200L, ratios vary from 0.57 to 0.68, and average 0.60 (high turbidity on 2 values). Low turbidity ratios vary from 0.57 to 0.65, averaging 0.59.

Site 2200 ratios vary from 0.57 to 0.77, averaging 0.63 (including ratios with turbidity exceeded 10). Low turbidity ratios vary from 0.57 to 0.67 an average of 0.61.

Carbon Dioxide CO_2

Seems to show a general trend for higher values in summer. The averages for side passages were higher than main stem readings. 2200L had the highest average level.

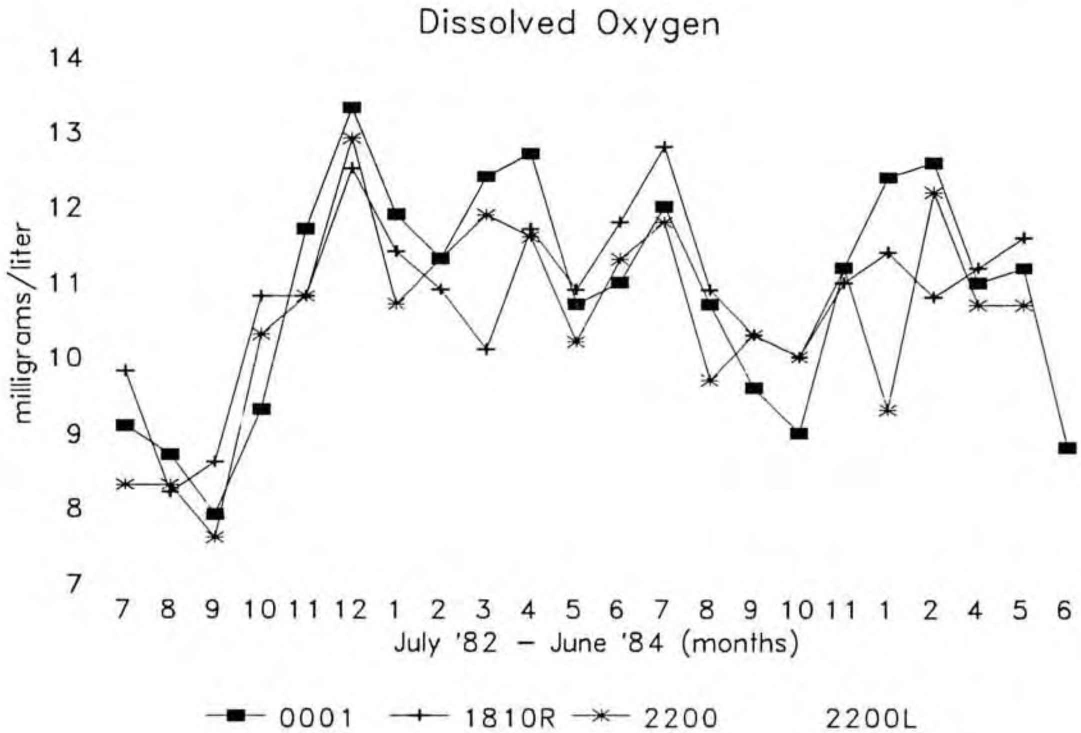


Dissolved carbon dioxide levels at the stations vary, but are generally highest in the summer and lowest in the winter. Dissolved carbon dioxide can be present from several sources. Atmospheric CO_2 is always present, but at fairly low concentrations. Carbon dioxide is generated in soil due to biologic activity. Seasonal variations in CO_2 are probably due to higher levels of CO_2 generated during warmer seasons, with lesser amounts present in soil when biologic activity is low.

<u>DO Dissolved Oxygen</u>

Varied considerably and none of the sites seemed to stand out as having differing characteristics from the other.

Dissolved oxygen is an excellent indicator of chemical and biological contamination. Water moving along a rocky stream bed under turbulent flow conditions should be well aerated, and at or above oxygen saturation. Thus, cave water significantly below oxygen saturation may well be contaminated.

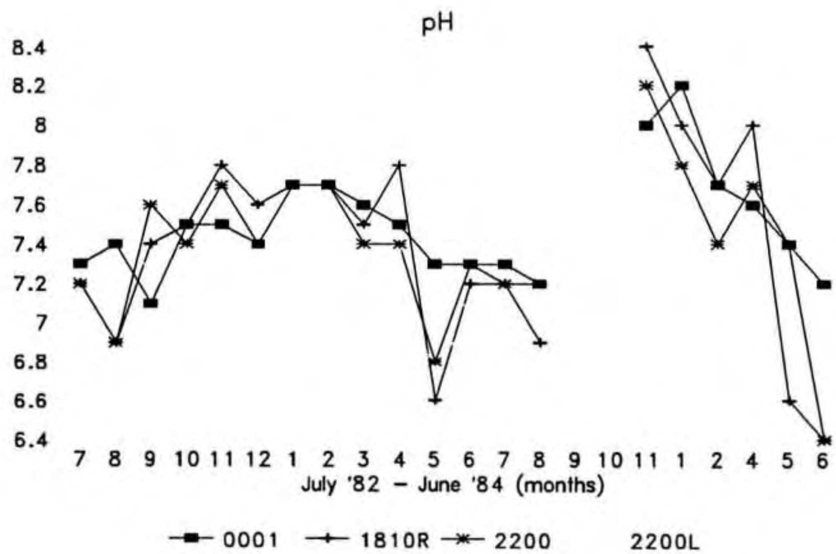


Dissolved oxygen content of water in a stream (surface or subsurface) in contact with air containing a normal level of oxygen is dependent on atmospheric pressure and temperature. For practical purposes, air pressure in a cave can be considered to be 1 atmosphere, thus water temperature is the most important factor in oxygen solubility. For the temperature ranges measured at the four sampling sites, solubility of oxygen in the cave stream varies from about 10 mg/l at 16°C to 11.6 mg/l at 9°C. Certain inorganic chemicals, organic substances, and living organisms require oxygen for chemical reactions and metabolism, and can remove oxygen from water. If these substances are introduced into groundwater, dissolved oxygen will decrease. Fortunately, turbulent flow in a cave stream allows oxygen depleted by biologic and chemical reactions to be replenished by aeration. If water is grossly contaminated, though, dissolved oxygen can still remain low.

Dissolved oxygen at the four stations varies considerably. Dissolved oxygen at site 0001 varies from 7.9 mg/l to 12.7 mg/l (78% to 115% saturation). Seven of 22 samples are undersaturated; 15 are saturated or oversaturated. Oxygen is much the same at site 1810R, varying from 8.2 mg/l to 12.8 mg/l (80% to 125% saturation). Here, five samples are undersaturated and 16 are saturated or oversaturated. At the other two sites, dissolved oxygen is lower. Dissolved oxygen at site 2200L varies from 8.0 mg/l to 11.7 mg/l (77% to 113% saturation). Eleven samples are undersaturated and 10 are at or above 100% saturation. Dissolved oxygen at site 2200 varies from 7.6 mg/l to 12.9 mg/l (55% to 116% saturation). Nine samples are undersaturated and 12 are at or above 100% saturation.

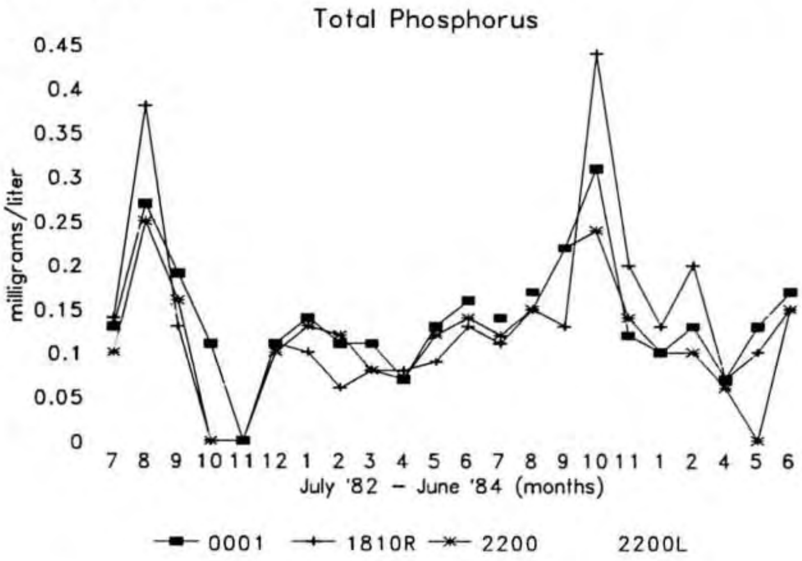
Based on dissolved oxygen data, contamination is greatest in the areas recharging the streams at sites 2200 and 2200L. Other factors must be considered, however, such as flow conditions (steady, smooth flow versus highly turbulent flow), flow rate, and length of stream traveled.

None of the values were low enough to be considered critical to reproduction and well-being of most aquatic organisms.



pH

These values remained within limits generally acceptable for most aquatic organisms. Average values between stations were nearly identical.



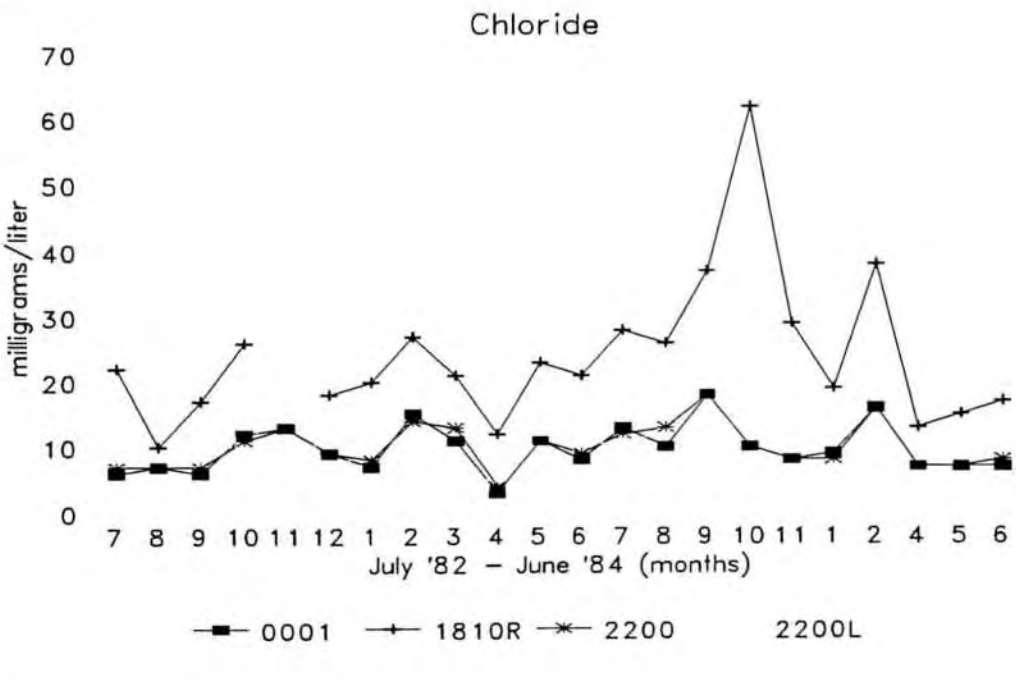
Total Phosphorus (TP)

These values were not high enough to indicate any serious problems. These values would be considerably higher if the cave system were receiving significant amounts of decomposable organic wastes. It is doubtful that statistical tests would show a significant difference.

Turbidity

The main stream exhibited considerable range in turbidity. The side passages showed relatively little variation. These two side passages generally appear clearer than the main stream.

Chloride



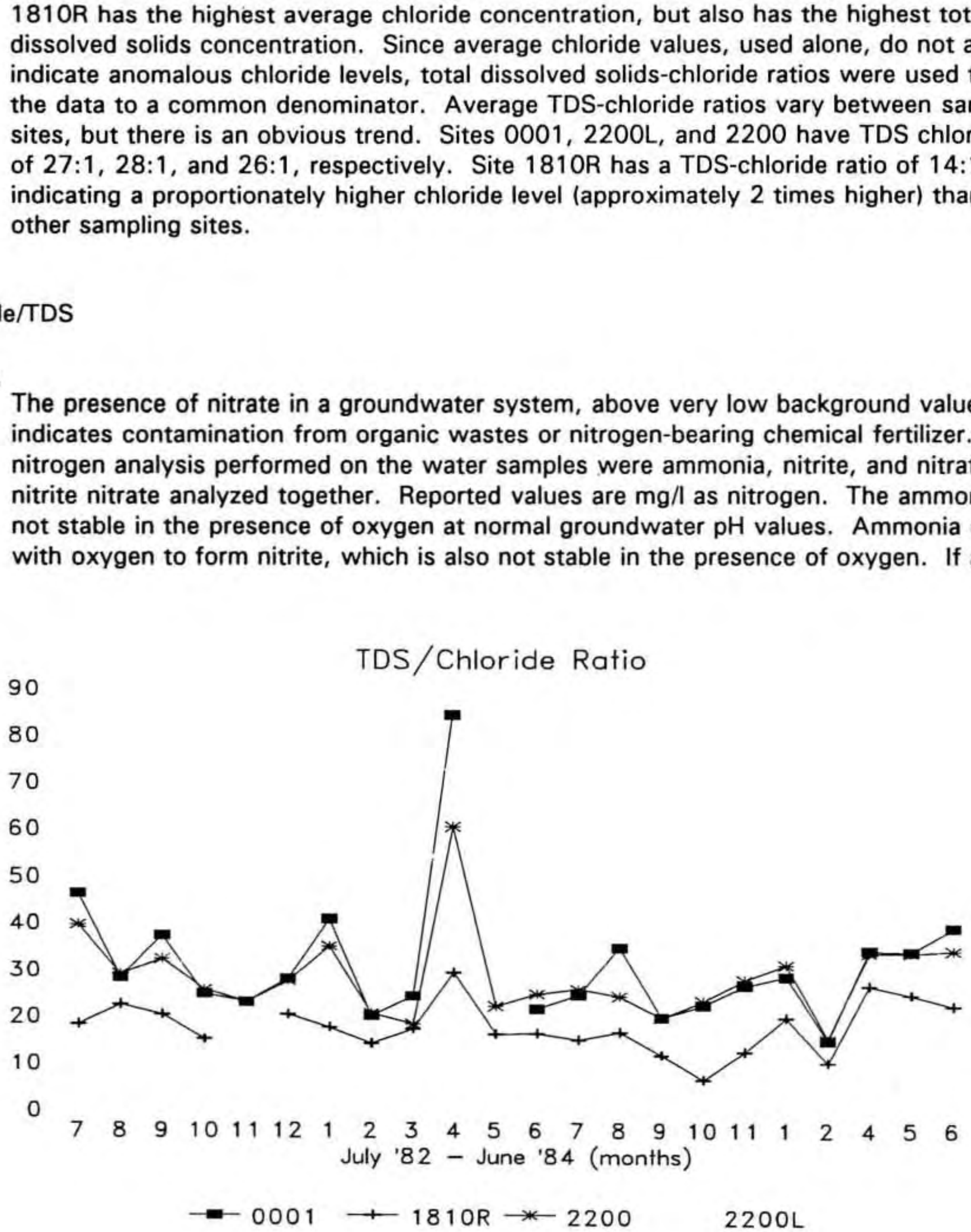
Results of the chloride analysis are also quite interesting. Chloride is present in low concentrations in most Missouri groundwater as a result of dissolution of small amounts of chloride bearing minerals in rock. It can also be a good indicator of contamination. Chloride is a common constituent in septic tank lagoon effluent. Elevated chloride and nitrate concentrations are both useful indicators of contamination from organic wastes. Other sources of chloride contamination are salts (calcium and sodium chloride) applied to highways to improve winter driving conditions, and high-chloride water from back-washing of home water-softener units.

Chloride values vary between stations, and also vary between sampling periods. Site 1810R has the highest average chloride concentration, but also has the highest total dissolved solids concentration. Since average chloride values, used alone, do not always indicate anomalous chloride levels, total dissolved solids-chloride ratios were used to reduce the data to a common denominator. Average TDS-chloride ratios vary between sampling sites, but there is an obvious trend. Sites 0001, 2200L, and 2200 have TDS chloride ratios of 27:1, 28:1, and 26:1, respectively. Site 1810R has a TDS-chloride ratio of 14:1, indicating a proportionately higher chloride level (approximately 2 times higher) than the other sampling sites.

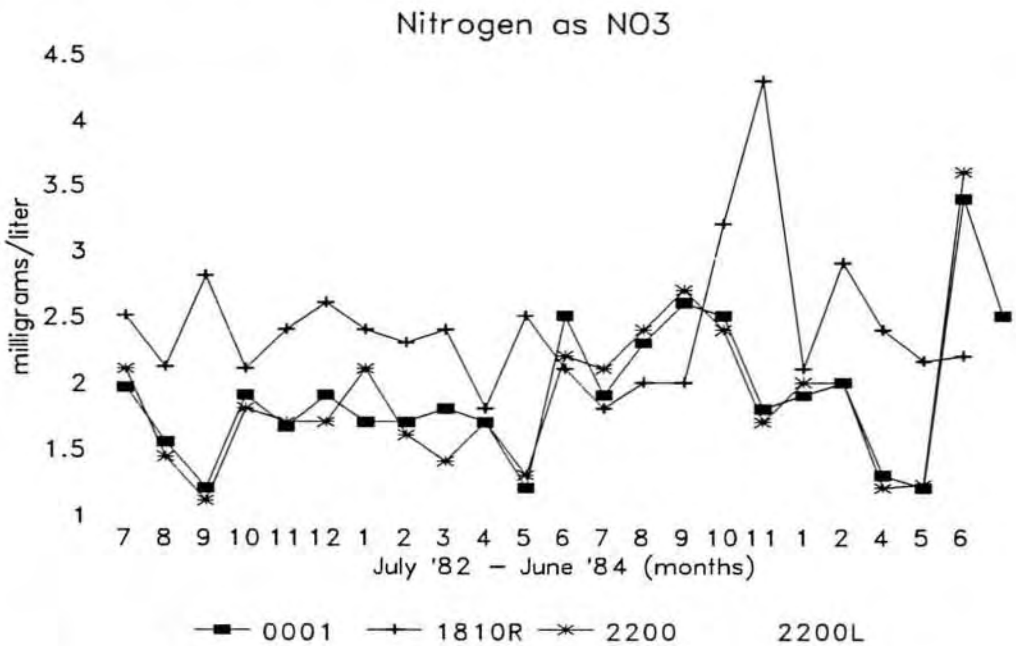
Chloride/TDS

Nitrate

The presence of nitrate in a groundwater system, above very low background values, indicates contamination from organic wastes or nitrogen-bearing chemical fertilizer. The nitrogen analysis performed on the water samples were ammonia, nitrite, and nitrate, with nitrite nitrate analyzed together. Reported values are mg/l as nitrogen. The ammonia ion is not stable in the presence of oxygen at normal groundwater pH values. Ammonia combines with oxygen to form nitrite, which is also not stable in the presence of oxygen. If ample



oxygen is present, nitrite will convert to nitrate. The NH_3--NO_2--NO_3 reaction consumes oxygen dissolved in the water. If enough ammonia or nitrite is introduced into a groundwater system, oxygen can be depleted, and aquatic fauna die from lack of oxygen. In a cave stream environment, this seldom happens unless large quantities of ammonia or nitrite are introduced into the system. Turbulent stream water in contact with a normal atmosphere will, in time, replenish dissolved oxygen lost in the ammonia --> nitrite --> nitrate conversion.



Ammonia

Ammonia concentrations from all sampling sites are low, often less than 0.01 mg/l: the apparent detection limit for the method used for analysis. Nitrite and nitrate were analyzed combined. It is likely that nitrite, like ammonia, is very low, and nearly all of the nitrogen measured is in the form of nitrate. Nitrate is commonly present in springs and cave streams. Unlike most other constituents measured, nitrate is almost entirely due to man's activities in the recharge where chemical fertilizer or organic wastes are introduced into the ground system..Samples at Devil's Icebox indicate that though contaminants are present, gross contamination is not occurring. Nitrite + nitrate (as nitrogen) varies form 1.1 mg/l to 4.3 mg/l, and averaged 2.1 mg/l. Missouri Public Drinking Water Standards recommend nitrate less than 10 mg/l as nitrogen. Nitrate concentrations at the four sampling sites indicate some contaminants are entering the system. However, the site highest in nitrate is not necessarily the most contaminated. Dilution plays an important role. Two stations receiving the same amount of contaminants will have varying nitrate concentrations, depending on flow rates at the sites. Site 1810R has the highest average level of nitrate, but may or may not be receiving the greatest amount of contaminants. Knowing relative flow rates of the stations is necessary to determine contamination amounts and patterns.

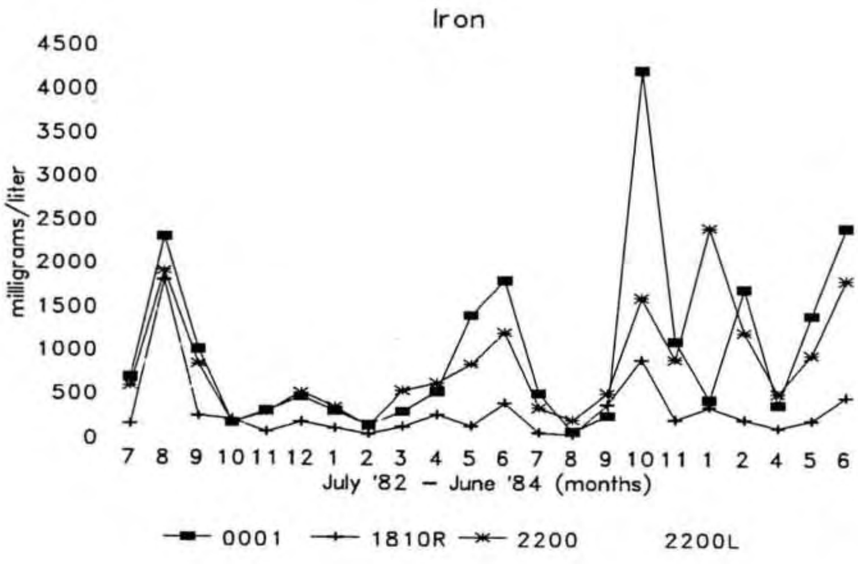
Ammonia levels were generally below detectable levels. The highest reading was .17 mg/l. This information became useful for determining background levels. In the pipeline spill that occurred in fall of 1985 this information was useful in evaluating the effects of the spill on the cave system.

<u>Dissolved metals</u>

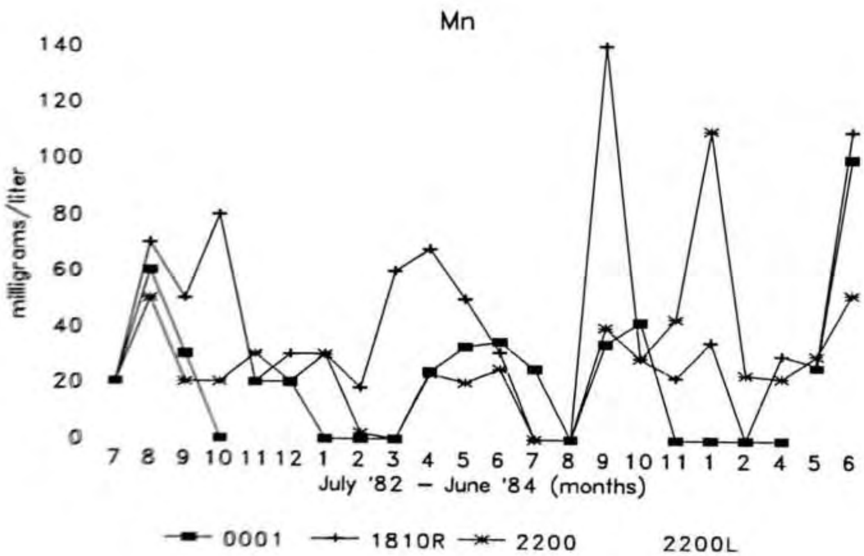
Dissolved metals at all of the sites are typically low. Iron and manganese are highest, but not high enough to indicate significant contamination. Dissolved iron and manganese in streams where pH is between 6.5 and 8.5 should be only a few micrograms per liter. The higher levels reported here may be due to sampling technique (samples may not have been filtered through a 0.45 um filter). Copper and mercury are relatively low. Zinc is somewhat higher, but zinc is somewhat more soluble and more mobile in oxidizing conditions.

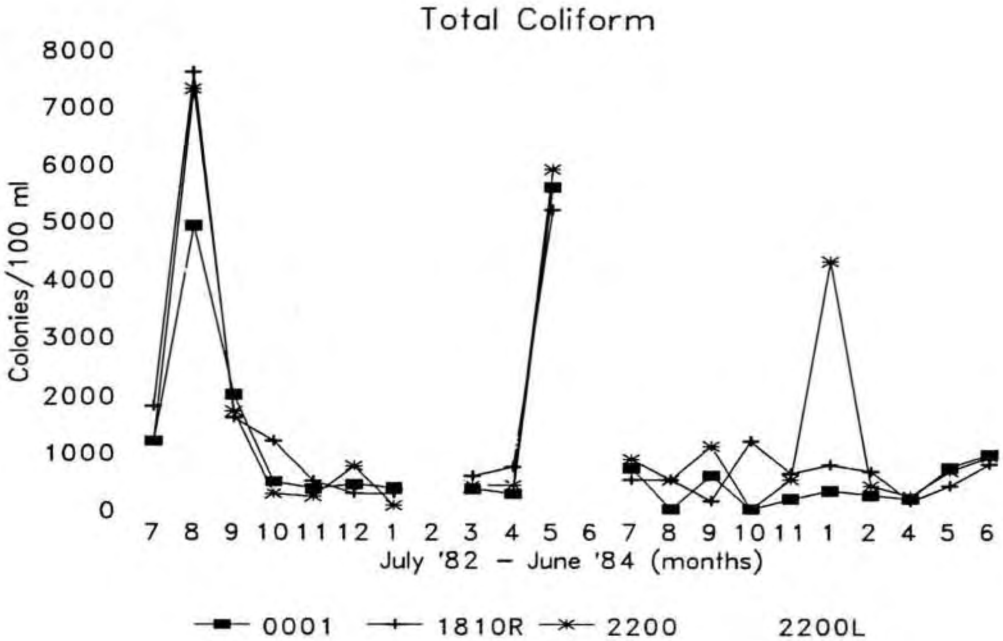
Copper was generally below detectable levels. 2200L had the highest average.

Iron



Mn





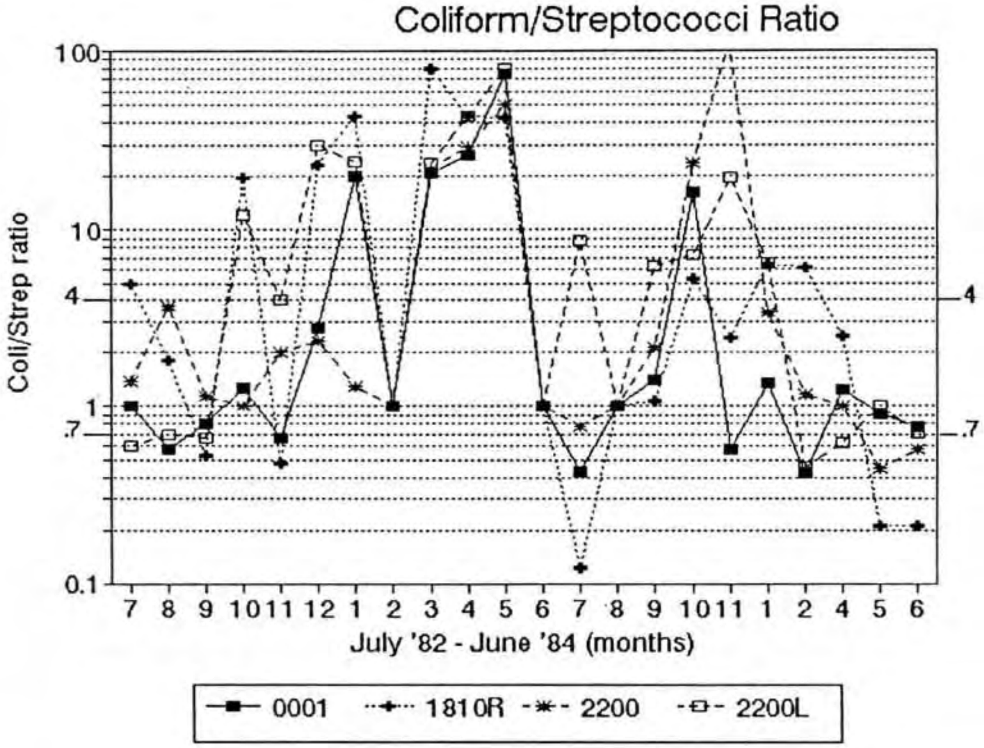
Bacteria are present at all sites, demonstrating 1) rapid infiltration of water into the cave system, 2) short travel times, and 3) relatively large amounts of bacteria introduced into the cave system, presumably from septic tanks and/or lagoons. However, the average bacteria numbers are not as high as would be expected if the stream was heavily contaminated by sewage. The bat population in the cave may be introducing some, or even much, of the bacteria. With additional studies it may be possible to determine how much contamination is due to the bats and how much is due to external contamination sources.

The total coliform, fecal coliform, fecal streptococci, analysis provide some insight concerning the amount of bacteriological contamination and even the type of contamination source.

The coliform group includes all of the aerobic and facultative anaerobic, gram-negative, non-spore-forming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. This group includes numerous bacterial species sharing a few broad characteristics. They include both fecal and non-fecal species. Fecal coliform bacteria produce gas from lactose broth at a higher temperature than other coliform organisms, 44.5°C. While coliform-bacteria are present throughout most of the environment, fecal coliform bacteria are associated almost exclusively with waste products of warm-blooded animals.

Fecal streptococci counts, used with fecal coliform counts, can help delineate between human and animal waste products. Fecal coliform densities in humans exceed fecal streptococci densities by a factor of about 4 to 1. Thus, fecal coliform/fecal streptococci ratios above 4 indicate human waste products. The reverse is found in animal wastes. Fecal coliform/fecal streptococci ratios are generally less than 0.7.

Most of the previous research done concerning fecal coliform/fecal streptococci ratios used surface water samples. Bacteria ratios and numbers can change with time. Depending on conditions, bacterial densities can increase or decrease substantially after waste products are introduced into water. Groundwater conditions undoubtedly introduce factors different than those of surface water conditions.



The bacterial data collected in Devil's Icebox indicate the cave is receiving both human and animal waste products. At the three in-cave sites (1810R, 2200,1100L) fecal coliform/fecal streptococci ratios vary greatly, from much less than 0.7 to much greater than 4. Also, many values are between 0.7 and 4.

Of 20 bacterial samples collected at site 1810R, five values are below 0.7, nine values exceed 4, and six values are between 0.7 and 4, perhaps indicating both human and animal contaminant sources. For site 2200L, four values are less than 0.7, 12 values are above 4, and three values are between 0.7 and 4. At this site, contamination from human waste products appears to be predominant. At site 2200, two values are below 0.7, five values are above 4.0, and 13 values are between 0.7 and 4, indicating both animal and human waste products are entering the cave system upstream from the sampling point.

Plots of fecal coliform/fecal streptococci ratios plotted against time do not show a conclusive relationship with season or area rainfall. Linear regression analysis of data plots against other sites in the cave also show poor correlation, with correlation coefficients less than 0.75 on all variations (1810R vs 2200, 1810R vs 2200L, 2200 vs 2200L).

In summary, the data indicates both human and animal waste products are entering the cave system. It is possible that human waste products enter more continuously due to a relative constant flow of water through septic systems, with animal wastes entering after rainfall as fecal material in the soil is flushed into the cave system through discrete bedrock openings.

SUMMARY AND CONCLUSIONS

Objective One — To determine the quality of water in the Devil's Icebox Cave system.

Although we monitored periodic high levels of bacteria, the stream did not appear to be suffering from conspicuous levels of chemical pollution.

Objective Two — To establish baseline data for future reference.

The data we collected in this study will definitely be helpful in the future. We were able to establish good information on a variety of components of the overall water quality within the cave stream system. Future events and studies will have this information for comparison purposes. The data has already been used. When a accidental release of ammonia nitrate was put into Gans Creek we were able to refer to our data and monitor the cave to determine if any of the ammonia nitrate entered the cave system. (a small but inconclusive amount was detected in the cave stream.)

Objective Three — To establish differences in feeder streams within the cave, focusing on relationships between water quality, volume, drainage areas and surface contamination.

The data shows some definite differences between the sample sites in some of the parameters measured. Seasonal variations and variations caused by water level were also experienced. Each site varied in how it was affected by seasons and water level.

Site 0001, where water quality is essentially an average of the quality of all inflow into the cave, shows evidence of measurable chemical and biological contamination.

Site 1810R shows the highest level of contamination. Chloride and nitrate averages are greatest for this site. Fecal coliform and fecal streptococci averages are also high at this site. However, low average turbidity, higher dissolved solids, and relatively constant water temperature indicate, less direct recharge than the other sites. Slower recharge allows more material to be dissolved, and slower velocities of groundwater decrease turbidity. Knowing relative flow rates at the sites is necessary to establish levels of contamination. Flow at site 1810R is thought to originate as recharge in a grassland restoration area within the park and sinkholes south of the park across highway "N". The contaminants may be from septic effluent and livestock waste in the southern part of the recharge area. Another theory is that since this area drains what was once an intensive hog farm operation that the contaminants measured are due to residue still on and in the ground.

Site 2200L has the highest bacterial contamination; the recharge area of this side passage at that site is presumed to include septic effluent from a row of homes east of Pierpont. The nitrate concentrations also appear to substantiate this.

Nitrate and chloride concentrations are fairly low at site 2200. Bacteria levels, however, are fairly high. No doubt, flow passing this station originates either as recharge from an area contributing low-quality water into the cave system, or bats roosting upstream from the station are introducing the bacteria. However, most bat observations are down stream from this site.

With regard to background levels of these contaminants, I believe we should comment only with some well qualified reservations. Obviously the nitrate and bacteriological data is well above background for uncontaminated ground waters; what is less clear is whether these values are also high for water in a cave system with substantial hydrologic connections to the surface.

Temp, Cond., Turbidity, TDS all show that the main branch of the cave system has closer connections to the surface. What is not possible to determine is the amount of contaminants brought into the cave system by each of the 3 main branches. The left and right branches have higher concentrations of nitrate and chloride but there is no flow data from which to calculate #/day loading. (The main branch may carry the most water and may therefore carry the greatest amounts of contaminants into the cave.)

Suggestions for further studies

The data generated in this study will provide a base line for future studies. A logical extension of the water quality study is a dye tracing study to positively establish the recharge area of the cave stream. Ideally, dye collection packets should be placed at water sampling stations used in the water quality study. The packets could be left in place for several weeks after dye is injected, and retrieved only when dye has traversed the system. Dye collection packets at the entrance would monitor the passing of the dye. Dye collection packets at the other stations would better define the actual flow path of the recharge.

Equipment to measure flow of the cave stream is still in place. Better knowledge of the recharge area, and precipitation data from a recording rain gauge in the recharge area would be useful for determining recharge rates and efficiency.

Water Levels: Statistical tests should be made to correlate water level with each of the parameters. This might aid in interpreting the results, particularly the NFR, TDS, and turbidity results.

.**

In your letter, you requested information regarding credits. I think it would be appropriate to indicate Department of Natural Resources, Division of Environmental Quality, Laboratory Services Program. The Water Pollution Control Program should also be listed (DNR, DEQ).

Douglas N. Edwards, Supervisor
Water Quality Monitoring Unit
Field Services Section

CREDITS

In the final version of this report credit will be given to all those that contributed to this study. To insure that credit is given properly, please include in your response a list of individuals from your organization that participated in the study, the correct name of the department or organization to be recognized and what was done.

Appendix A

Monitoring Parameters and Frequency of Collection

Site 0001 was sampled every Wednesday during the two year study period. One Wednesday per month a trip would be made into the cave to sample the entrance and other sites.

Water Volume	Continuous below Conner's Cave
Temperature	Weekly at Station #0001, & monthly @ all sites
pH	Weekly at Station #0001, & monthly @ all sites
Conductivity	Weekly at Station #0001, & monthly @ all sites
Dissolved Oxygen	Weekly at Station #0001, & monthly @ all sites
Turbidity	Weekly at Station #0001, & monthly @ all sites
Carbon Dioxide	Weekly at Station #0001, & monthly @ all sites
Hardness ($CaCO_3$)	Weekly at Station #0001, & monthly @ all sites
F. Coliform	Monthly @ #0001, 1810R, 2200, 2200L
F. Streptococcus	Monthly @ #0001, 1810R, 2200, 2200L
Total Coliform	Monthly @ #0001, 1810R, 2200, 2200L
NH_3 - N	Monthly @ #0001, 1810R, 2200, 2200L
NO_2 + NO_3 - N	Monthly @ #0001, 1810R, 2200, 2200L
T - P	Monthly @ #0001, 1810R, 2200, 2200L
Chloride	Monthly @ #0001, 1810R, 2200, 2200L
Filterable residue	Monthly @ #0001, 1810R, 2200, 2200L
NFR	Monthly @ #0001, 1810R, 2200, 2200L
Cd	Monthly @ #0001, 1810R, 2200, 2200L
Cu	Monthly @ #0001, 1810R, 2200, 2200L
Fe	Monthly @ #0001, 1810R, 2200, 2200L
Pb	Monthly @ #0001, 1810R, 2200, 2200L
Mn	Monthly @ #0001, 1810R, 2200, 2200L
Zn	Monthly @ #0001, 1810R, 2200, 2200L
Hg	Monthly @ #0001, 1810R, 2200, 2200L

Collecting Methods

pH, Temperature, Conductivity and Dissolved Oxygen were measured at the site using a portable multi-probe Hydrolab, which was provided by the Missouri Department of Conservation.

Collapsible 1 liter plastic bottles were used for collecting water samples at each of the sites. Three liters were collected at each site for chemical analysis. One liter went to the Vet Diagnostic lab, another to Ron Crunkleton at Department of Conservation and the third to Division of Environmental Quality lab at Jefferson City. Bacteriological samples were also taken at each site in bottles that were provided by the Division of Health for that purpose.

Samples collected for the Division of Environmental Quality and Division of Health laboratories were recorded on the forms provided by the respective agencies and chain of custody procedures followed in delivering the samples to those two laboratories in Jefferson City.

All sample containers were prelabeled prior to entering the cave, to prevent any mistaken identity of samples and to expedite the collection process.

Samples were collected on the way into the cave with the furthest sample site being the last one collected. The actual collection of the sample was done with care taken to collect water while facing upstream so that water collected was not contaminated with stirred up sediment from the collectors. Collection trips averaged about 3 hours with the longest being 4 hours. Immediately upon exiting the cave the samples were divided. The samples for the Vet Diagnostic Lab and Department of Conservation were placed in the refrigerator. These were later picked up by a representative from the Vet Diagnostic Lab. The samples for Jefferson City were immediately cleaned in cool water and then placed in an insulated cooler for transportation to Jefferson City. Scott Schulte or Paul Anders then took the samples to Jefferson City to Division of Health and Division of Environmental Quality. Elapsed time from collection to delivery at the Jefferson City labs was always within six hours.

Preservation and Analysis Methods

Parameter	Sample Preservation	Hold Time	Analytical Method Reference
Water Volume			Recording stream gauge*
Temperature			4041 Hydrolab probe
pH			4041 Hydrolab probe
Conductivity			4041 Hydrolab probe
Dissolved Oxygen			4041 Hydrolab probe
Turbidity			Hach 2100 Turbidometer**
Hardness ($CaCO_3$)			APHA standard methods
F. Coliform			Membrane filter ***
F. Streptococcus			Membrane filter ***
Total Coliform			Membrane filter ***
NH_3 - N	H_2SO_4	28 days	EPA 350.1
NO_2 + NO_3 - N	H_2SO_4	28 days	EPA 353.2
T - P	H_2SO_4	28 days	EPA 365.4
Chloride	none	28 days	EPA 325.2
Filterable residue	4°C	7 days	EPA 160.1
NFR	4°C	7 days	EPA 160.2
Cd	HNO_3	6 months	EPA 213
Cu	HNO_3	6 months	EPA 220
Fe	HNO_3	6 months	EPA 236
Pb	HNO_3	6 months	EPA 239
Mn	HNO_3	6 months	EPA 243
Zn	HNO_3	6 months	EPA 289
Hg	HNO_3	28 days	EPA 245

* Calibrated to flow rating curve established by Jim Vandike of Mo. DGLS

** Calibrated with 10 JTU standard

*** Technique in accordance with current (as of 1981) edition of Standard Methods for the Examination of Water and Waste Water

DEVIL'S ICEBOX WATER QUALITY STUDY June 2, 1982 to June 30, 1984 MONTHLY MONITORING (does not include weekly monitoring at entrance)

DATE MM DD YY	SITE	W.L. cfs	TEMP oC	pH units	DO mg/l	COND umho/cm	TURB JCU	CO2 mg/l	HARD mg/l	TDS mg/l	NFR mg/l	NH3 mg/l	NO3 mg/l	CL mg/l	Cu ug/l	Fe ug/l	Mn ug/l	Hg ug/l	Zn ug/l	TP mg/l	F COLI colonies/100 ml	F STREP colonies/100 ml	T COL colonies/100 ml
7 21 82	0001		14.6	7.3	9.1	421	1.0	3.5	192	277	3	<.01	1.96	6	<5	680	20	<.5	260	0.13	<160	<160	1200
8 18 82	0001		15.6	7.4	8.7	243	35.0	3.8	118	197	20	<.01	1.55	7	6	2300	60	<.5	20	0.27	360	620	4900
9 22 82	0001	0.90	15.0	7.1	7.9	347	8.0	6.6	162	223	5	<.01	1.20	6	<5	1000	30	<.5	<10	0.19	460	570	2000
10 20 82	0001	0.50	13.4	7.5	9.3	490		0.0	250	294	<1	<.01	1.90	12	<5	170	<20	<.5	<10	0.11	380	300	470
11 24 82	0001	0.50	12.4	7.5	11.7	479	0.7	0.3	226	296	4	<.01	1.66	13	6	300	20	<.5	10	<.05	60	90	340
12 22 82	0001	0.90	11.3	7.4	13.3	416	1.4	0.0	195	251	4	<.01	1.90	9	<5	460	20	<.5	10	0.11	83	30	430
1 26 83	0001	0.50	11.7	7.7	11.9	485	1.5	2.0	224	284	9	<.01	1.70	7	<5	300	<20	<.5	10	0.14	340	17	360
2 16 83	0001	0.15	11.8	7.7	11.3	499	0.3	0.0		298	<1	<.01	1.70	15	<5	140	<2	<1	<10	0.11			
3 16 83	0001	1.50	11.7	7.6	12.4	445		2.0		264	8	<.01	1.80	11	<5	290	<20	<.5	<10	0.11	83	<5	340
4 20 83	0001		11.2	7.5	12.7	419	5.6	3.8		252	4	0.03	1.70	3	9.3	520	24	<.5	27	0.07	53	<5	270
5 25 83	0001	2.70	13.8	7.3	10.7	378	3.0	9.0			8	0.03	1.20	11	9.1	1400	33	<.5	20	0.13	150	<3	5600
6 22 83	0001	0.70	15.4	7.3	11.0	312	22.0	10.0		170	19	<.01	2.50	8	<5	1800	35	1	12	0.16			
7 20 83	0001		14.1	7.3	12.0	499	5.0	9.0		315	7	<.01	1.90	13	<5	500	25	<.5	<10	0.14	43	100	720
8 24 83	0001	0.15	14.4	7.2	10.7	563	2.0	15.0		345	3	0.01	2.30	10	<5	70	<20	<.5	16	0.17	<100	300	<100
9 28 83	0001	0.15	13.6		9.6	313	1.0	5.5		349	1	<.01	2.60	18	<5	250	34	0.3	<10	0.22	270	190	580
10 26 83	0001	0.70			9.0		20.0	3.5		220	18	0.07	2.50	10	<5	4200	42	0.2	18	0.31	>2000	128	>3000
11 16 83	0001	1.00	11.8	8.0	11.2	322	4.0	4.0		210	4	0.01	1.80	8	<5	1100	<20	0.2	<10	0.12	160	280	170
1 18 84	0001	0.45	8.8	8.2	12.4	405	4.0	1.5		254	<1	0.03	1.90	9	<5	430	<20	<.2	<10	0.10	54	40	320
2 15 84	0001	2.60	9.0	7.7	12.6	317	20.0	7.5		233	14	0.06	2.00	16	<5	1700	<20	<.2	72	0.13	77	184	235
4 18 84	0001	3.70	10.8	7.6	11.0	379	5.0	7.5		236	4	0.01	1.30	7	<5	370	<20	<.2	<10	0.07	10	8	170
5 16 84	0001	1.80	12.9	7.4	11.2	344	4.0	9.0		235	23	0.05	1.20	7	<5	1400	26	<.2		0.13	310	340	710
6 13 84	0001	2.10	13.8	7.2	8.8	321	22.0	19.0		270	23	0.05	3.40	7	<5	2400	100	<.2	17	0.17	260	340	950
7 21 82	1810R		14.0	7.2	9.8	643	0.3	4.3	300	398	2	<.01	2.50	22	<5	150	20	0.7	30	0.14	500	<160	1800
8 18 82	1810R		14.6	6.9	8.2	313	22.0	4.0	138	222	26	<.01	2.12	10	13	1800	70	<.5	50	0.38	3300	1800	7600
9 22 82	1810R	0.90	14.4	7.4	8.6	573	1.3		240	342	1	<.01	2.80	17	<5	240	50	<.5	<10	0.13	200	380	1600
10 20 82	1810R	0.50	13.8	7.5	10.8	670		0.4	336	385	<1	0.01	2.10	26	<5	200	80	<.5	<10	<.05	590	30	1200
11 24 82	1810R	0.50	13.5	7.8	10.8	667	0.3	0.0	240			<.01	2.40		<5	70	20	<.5	10	<.05	110	230	490
12 22 82	1810R	0.90	13.2	7.6	12.5	603	0.8	0.0	210	360	4	<.01	2.60	18	<5	180	30	0.9	<10	0.11	93	4	260
1 26 83	1810R	0.50	13.3	7.7	11.4	612	0.4	3.5	242	347	1	<.01	2.40	20	<5	100	30	<.5	<10	0.10	87	<3	270
2 16 83	1810R	0.15	13.2	7.7	10.9	634	0.5	1.3		376	<1	<.01	2.30	27	<5	40	18	<1	<10	0.06			
3 16 83	1810R	1.50	13.4	7.5	10.1	617		2.0		357	4	<.01	2.40	21	<5	120	60	<.5	<10	0.08	160	<5	570
4 20 83	1810R		12.7	7.8	11.7	594	1.1	0.0		349	1	0.03	1.80	12	<5	260	68	<.5	<10	0.08	130	<5	730
5 25 83	1810R	2.70	13.4	6.6	10.9	629	3.0	12.0		366	12	0.03	2.50	23	<5	130	50	<.5	10	0.09	85	<3	5200
6 22 83	1810R	0.70	14.2	7.2	11.8	559	3.0	11.0		338	4	<.01	2.10	21	<5	390	31	2	<10	0.13			
7 20 83	1810R		14.0	7.2	12.8	682	2.0	17.0		413	<1	0.01	1.80	28	<5	60	<20	<.5	<10	0.11	37	300	510
8 24 83	1810R	0.15	13.9	6.9	10.9	695	2.0	22.0		423	<1	<.01	2.00	26	<5	33	<20	<.5	<10	0.15	<100	100	500
9 28 83	1810R	0.15	13.6		10.3	726	1.0	14.0		421	<1	<.01	2.00	37	<5	370	140	0.4	<10	0.13	25	23	130
10 26 83	1810R	0.70			10.0		6.0	0.0		380	5	0.03	3.20	62	<5	890	29	0.4	<10	0.44	740	140	1200
11 16 83	1810R	1.00	13.1	8.4	11.0	578		0.0		350	1	0.01	4.30	29	13	200	22	0.3	48	0.20	88	36	610
1 18 84	1810R	0.45	12.6	8.0	11.4	608	<1	0.0		368	<1	0.02	2.10	19	23	350	35	<.2	<10	0.13	240	38	760
2 15 84	1810R	2.60	12.8	7.7	10.8	627	1.0	4.0		374	<1	0.03	2.90	38	<5	200	<20	<.2	<10	0.20	280	46	650
4 18 84	1810R	3.70	12.2	8.0	11.2	558	1.0	7.5		341	2	<.01	2.40	13	<5	110	30	<.2	19	0.07	40	16	120
5 16 84	1810R	1.80	12.7	6.6	11.6	612	1.0	15.0		363	4	0.01	2.16	15	<5	190	27	<.2		0.10	46	220	400
6 13 84	1810R	2.10	13.0	6.4		600	1.0	10.0		371	13	0.13	2.20	17	<5	460	110	<.2	12	0.15	160	750	770
7 21 82	2200		14.3	7.2	8.3	420	1.2	3.8	184	276	4	<.01	2.10	7	<5	580	20	<.5	20	0.10	830	600	1200
8 18 82	2200		15.6	6.9	8.3	261	32.0	2.8	118	202	15	<.01	1.44	7	<5	1900	50	<.5	20	0.25	1900	520	7300
9 22 82	2200	0.90	15.4	7.6	7.6	359	7.0	6.3	170	225	4	0.01	1.10	7	<5	830	20	<.5	<10	0.16	380	330	1700
10 20 82	2200	0.50	14.0	7.4	10.3	487		2.9	236	280	24	0.01	1.80	11	5	170	20	0.8	10	<.05	<6	<6	260
11 24 82	2200	0.50	13.8	7.7	10.8	480	0.4	0.8	190	296	6	<.01	1.70	13	<5	280	30	<.5	10	<.05	200	100	210
12 22 82	2200	0.90	10.9	7.4	12.9	401	1.9	3.8	180	245	4	<.01	1.70	9	<5	510	20	<.5	<10	0.10	190	82	750
1 26 83	2200	0.50	12.1	7.7	10.7	470	2.2	3.5	205	278	46	<.01	2.10	8	<5	350	30	<.5	<10	0.13	13	10	50
2 16 83	2200	0.15	12.0	7.7	11.3	477		1.6		286	<1	<.01	1.60	14	<5	120	2	<1	<10	0.12			
3 16 83	2200	1.50	11.3	7.4	11.9	404		7.0		235	9	<.01	1.40	13	<5	530	<20	<.5	<10	0.08	67	<5	410
4 20 83	2200		11.3	7.4	11.6	400	7.0	2.5		241	10	0.03	1.70	4	6	620	23	<.5	34	0.07	87	<5	410
5 25 83	2200	2.70	13.8	6.8	10.2		3.0	10.0		241	13	0.03	1.30	11	<5	830	20	<.5	<10	0.12	100	<3	5900
6 22 83	2200	0.70	14.6	7.3	11.3	329	20.0	8.0		220	28	<.01	2.20	9	<5	1200	25	3.4	<10	0.14			
7 20 83	2200		14.0	7.2	11.8	518	2.0	11.0		306	5	<.01	2.10	12	<5	340	<20	<.5	10	0.12	70	90	870
8 24 83	2200	0.15	13.6	7.2	9.7	541	2.0	14.0		309	3	0.01	2.40	13	<5	190	<20	<.5	11	0.15	<100	<100	500
9 28 83	2200	0.15	13.3		10.3	587	3.0	3.0		349	10	<.01	2.70	18	<5	500	40	6.6	16	0.22	30	14	1100
10 26 83	2200	0.70			10.0		15.0	4.5		230	14	0.14	2.40	10	<5	1600	29	0.2	<10	0.24	>2000	89	>4000
11 16 83	2200	1.00	12.1	8.2	11.2	333	1.0	3.5		220	17	0.03	1.70	8	<5	890	43	0.2	<10	0.14	220	<1	500
1 18 84	2200	0.45	12.0	7.8	9.3	489	<1	3.5		245	4	0.05	2.00	8	60	2400	110	<.2	10	0.10	27	8	4300
2 15 84	2200	2.60	9.5	7.4	12.2	324	8.0	7.5		237	17	0.05	2.00	16	<5	1200	23	<.2	10	0.10	210	182	400
4 18 84	2200	3.70	11.0	7.7	10.7	378	5.0	8.0		232	9	0.01	1.20	7	<5	500	22	<.2	27	0.06	10	10	220
5 16 84	2200	1.80	12.9	7.4	10.7	363	5.0	13.0		233	4	0.03	1.23	7	<5	940	30	<.2	<10	<.05	270	>400	650
6 13 84	2200	2.10	13.3	6.4		360	15.0	9.0		270	22	0.06	3.60	8	<5	1800	52	<.2	10	0.15	320	560	910
7 21 82	2200L		13.7	7.1	8.7	475	2.0	3.8	218	298	8	<.01	2.10	8	<5	360	20	<.5	<10	0.10	<160	200	1000

8 18 82	2200L		14.1	6.8	8.2	322	23.0	4.0	154	220	13	<.01	1.25	8	8	1500	30	<.5	10	0.24	670	970	4100
9 22 82	2200L	0.90	14.0	7.3	8.0	448	3.1	3.1	176	268	1	0.01	1.60	8	<5	550	<20	<.5	<10	0.14	330	500	1000
10 20 82	2200L	0.50	13.7	7.3	10.0	565		5.0	280	316	<1	<.01	2.90	11	<5	120	<20	<.5	<10	<.05	240	20	430
11 24 82	2200L	0.50	13.8	7.6	9.8	528	0.2	1.7	187	321	1	<.01	2.80	15	<5	190	20	<.5	<10	0.15	190	47	310
12 22 82	2200L	0.90	13.2	7.4	11.6	470	0.6	3.5	166	274	6	<.01	1.80	8	<5	460	60	<.5	<10	0.12	240	8	1100
1 26 83	2200L	0.50	13.3	7.6	10.6	533	1.5	2.5	200	309	33	<.01	2.50	8	<5	750	60	<1	<10	0.18	240	10	450
2 16 83	2200L	0.15	13.3	7.6	10.8	554	0.2	0.1		322	3	<.01	2.70	9	<5	120	10	<1	<10	0.18			
3 16 83	2200L	1.50	13.2	7.2	11.1	485		2.8		290	6	<.01	2.00	8	<5	320	20	<.5	<10	0.11	70	<5	400
4 20 83	2200L		12.9	7.4	11.1	491	2.6	1.0		286	10	0.02	2.00	4	<5	240	20	<.5	20	0.09	130	<5	440
5 25 83	2200L	2.70	13.3	6.7	10.6	509	3.0	12.0		298	3	0.02	1.70	11	<5	270	27	<.5	<10	0.09	160	<3	8000
6 22 83	2200L	0.70	14.0	7.1	11.5	430	11.0	10.0		271	18	<.01	1.80	10	<5	1100	<20	1.1	21	0.16			
7 20 83	2200L		13.7	7.1	11.7	569	3.0	9.0		346	33	0.01	2.20	11	<5	1600	110	<.5	20	0.14	870	100	2100
8 24 83	2200L	0.15	13.7	7.0	9.5	610		24.0		366	33	0.01	3.20	12	<5	320	<20	<.5	<10	0.17	<100	<100	2000
9 28 83	2200L	0.15	13.5		9.8	617	1.0	14.0		352	2	<.01	3.00	18	<5	110	<20	<.2	<10	0.22	270	44	910
10 26 83	2200L	0.70			10.0		3.0	3.0		300	2	0.04	2.90	22	<5	420	22	<.2	<10	0.18	450	62	2600
11 16 83	2200L	1.00	13.2	8.1	10.1	437	3.0	1.5		240	14	0.02	2.40	14	<5	620	25	0.2	<10	0.13	1100	56	1800
1 18 84	2200L	0.45	12.8	7.8	9.4	503	<1	22.5		304	248	0.02	1.90	11	99	1300	74	<.2	<10	0.14	26	4	980
2 15 84	2200L	2.60	12.9	7.3	10.6	426	3.0	6.0		278	8	0.01	2.20	13	<5	900	20	1.2	<10	0.13	30	66	400
4 18 84	2200L	3.70	12.6	7.7	10.1	472	1.0	8.0		285	5	<.01	1.80	7	<5	150	<20	<.2	<10	0.08	5	8	320
5 16 84	2200L	1.80	12.9	7.5	11.2	534	1.0	13.5		310	5	0.17	2.14	8	<5	310	26	<.2		0.10			
6 13 84	2200L	2.10	13.1	6.7		488	3.0	13.0		307	10	<.01		10	<5	520	50	<.2	<10	0.23	540	760	2500
			TEMP	pH	DO	COND	TURB	CO2	HARD	TDS	NFR	NH3	NO3	CL	Cu	Fe	Mn	Hg	Zn	TP	F COLI	F STREP	T COL
COUNT OF ITEMS		74	84	80	85	83	77	87	28	86	87	88	87	87	88	88	88	88	85	88	79	79	79
AVERAGE VALUE		1.1	13.1	7.4	10.6	482.5	5.3	6.3	204.9	295	11.4	.0	2.1	13.4	2.9	668.6	29.5	0.2	10.9	0.1	260.1	165.8	1311.6
MINIMUM VALUE		0	8.8	6.4	7.6	243	0	0	118	170	0	0	1.1	3	0	33	0	0	0	0	0	0	0
MAXIMUM VALUE		3.7	15.6	8.4	13.3	726	35	24	336	423	248	0.17	4.3	62	99	4200	140	6.6	260	0.44	3300	1800	8000
STANDARD DEV.		0.9978	1.3063	0.395	1.2694	113.23	7.5949	5.563	49.70	57.5	27.14	0.029	0.576	8.63	12.5	698.36	28.6	0.831	30.07	0.074	450.96	281.54	1789.6
VARIANCE		0.9957	1.7064	0.156	1.6116	12822.	57.683	30.95	2470.	3315	736.7	0.000	0.332	74.6	157.	487710	818.	0.691	904.2	0.005	203370	79267.	3E+06
0001 AVERAGE			12.7	7.5	10.8	399.9	8.3	5.6	195.3	261	8.2	.0	1.9	9.7	1.4	990.0	21.3	0.1	23.4	0.1	157.7	176.9	988.3
1810R AVERAGE			13.4	7.4	10.8	609.8	2.5	6.1	243.7	364	3.8	.0	2.4	23.9	2.2	297.4	41.8	0.2	8.5	0.1	345.6	205.7	1268.5
2200 AVERAGE			12.9	7.4	10.5	419.1	6.9	5.9	183.3	257	12.2	.0	1.9	10.0	3.2	830.9	27.7	0.5	8.5	0.1	246.2	129.8	1382.0
2200L AVERAGE			13.4	7.3	10.2	498.4	3.4	7.5	197.3	298	21.0	.0	2.2	10.6	4.9	555.9	27.0	0.1	3.4	0.1	292.7	150.3	1623.2

1) NO DATA FOR LAST TWO WEEKS OF 83 DUE TO EXTREME COLD
2) TESTS FOR CADMIUM WERE ALL BELOW DETECTABLE RANGE
3) TESTS FOR TOTAL NITROGEN WERE DROPPED AFTER 3 MONTHS AND ARE NOT SHOWN
4) WATER LEVELS PRIOR TO 3-23-83 WERE BASED ON ROUGH ESTIMATIONS OF RELATIVE LEVEL
5) WATER LEVELS FROM 3-23-83 TO 2-8-84 ARE BASED ON MEASURED STREAM LEVEL
6) WATER LEVELS FROM 2-8-84 TO 6-27-84 ARE FROM RECORDING STREAM GUAGE
7) TESTS FOR LEAD WERE ALL BELOW DETECTABLE RANGE
8) FROM 10-19-83 TO 11-9-83 FIELD DISSOLVED OXYGEN MEASUREMENTS WERE TAKEN WITH HACH KIT
9) FROM 10-19-83 TO 11-9-83 THE HYDROLAB WAS NOT USED WHILE BEING REPAIRED

BEST MANAGEMENT PRACTICES COMBINING CAVE PROTECTION AND AQUIFER RECHARGE ENHANCEMENT

Ronald G. Fieseler
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Barton Springs/Edwards Aquifer Conservation District

The Barton Springs/Edwards Aquifer Conservation District (District) is a political subdivision of the State of Texas. As the local groundwater district, it is charged by the State Legislature and the residents of the District with the conservation, protection, preservation, and enhancement of the Barton Springs segment of the Edwards aquifer. This segment of the Edwards Aquifer is located in Central Texas in portions of Hays and Travis counties south of Austin, the state capitol. Barton Springs is the fourth largest spring in Texas, and provides a portion of Austin's drinking water, base flow for the Colorado River, and extensive recreational uses.

The Edwards aquifer is a major limestone karst aquifer and is utilized for municipal, public water supply, rural domestic, commercial, and irrigation purposes. As the only source of drinking water for tens of thousands of local residents, a large portion of the Edwards aquifer has been recognized by the U.S. Environmental Protection Agency (EPA) as a Sole Source Aquifer. The Edwards aquifer is extremely dynamic and prolific. Due to a thin soil cover, well developed karst features, high transmissivity, large springs, and extensive water well use, it exhibits rapid depletion and recharge. This, combined with extensive growth and development taking place over and adjacent to the aquifer, has resulted in the Edwards aquifer being designated by the Texas Water Commission as the aquifer in Texas most subject to potential pollution from non-point sources.

The District has recently completed an engineering and environmental assessment, funded in part by matching grant funds from the Texas Water Development Board, of potential recharge enhancement opportunities along a 9.6 mile reach of the Onion Creek watershed overlying the recharge zone of the Barton Springs segment. Onion Creek, in northern Hays County, provides approximately 34% of the total recharge to this segment of the aquifer. Water recharging via Onion Creek will flow through nearly all of this segment of the Edwards aquifer before it discharges at Barton Springs. During its journey, it will provide hundreds of well owners and thousands of aquifer users with the opportunity to benefit from the District's recharge enhancement project.

Where it crosses the recharge zone of the Edwards aquifer, Onion Creek is typically dry with no base flow except during significant rainfall events. Obviously, recharge could be enhanced by three methods: (1) slow down the floodwater and allow more time for recharge; (2) provide easier paths for water to enter the aquifer; and (3) improve the quality of the water.

Four sites, utilizing one or more of these concepts, were identified for possible implementation as separate recharge enhancement projects. Two of the sites propose the construction of small recharge dams to temporarily impound and slow floodwater to allow recharge over a greater time period. Each of these two sites contains a cave entrance in the creek bed which will be utilized as a primary recharge point. One cave, Antioch Cave, has been known to a few long-time local residents. The other cave, Crippled Crawfish Cave, was located when a District field crew noticed remnants of old barbed wire sticking out of the almost plugged entrance. Someone apparently placed the wire in and around the entrance many years earlier in an attempt to protect livestock.

Historically, both caves have undergone extended periods of debris plugging with a subsequent reduction in their ability to accept recharge water. The two cave sites provide an opportunity to dramatically increase recharge quantity with relatively little cost or environmental impact. In order to increase the recharge capability of the two cave, the entrances must be kept open and available for recharge at all times. This would be a relatively simple management task involving regular debris removal. However, the District has identified other concerns which require additional planning and management considerations.

Following heavy rains on the Onion Creek watershed during early 1991, the entrance to Antioch Cave was reopened by violent floodwaters. It had been covered by debris and sediment for an estimated 15-20 years. A whirlpool formed over the entrance, the noise of which attracted two men walking along a nearby road. One of them waded into the water to investigate and was swept into the cave and drowned. Not surprisely, this resulted in the owners of Antioch Cave and Crippled Crawfish Cave having serious concerns about their potential liability should the maintaining of open cave entrances lead to future incidents.

The Onion Creek watershed is generally rangeland with some small acreage developments. The non-point source pollutant loadings carried by Onion Creek floodwaters are typical of such land uses and include sediment loadings, organic and man-made debris, and high total coliform bacteria counts. The cave entrances, although barely large enough to allow human access, are relatively large compared to solutionally enlarged fractures, joints, or other recharge features. The cave entrances provide essentially no filtration of pollutants. Should the District maintain the cave entrances in a continually open state, this could allow recharging floodwaters to carry additional quantities of pollutants and/or large debris into these direct conduits to the aquifer.

Another concern of the District was the potential for the caves to be habitat for rare or endangered species. The Central Texas area is well known for a wide variety of endangered species, many of which are cave adapted species known to inhabit caves formed in the Edwards limestone. Onion Creek is located between San Marcos Springs and Barton Springs. Both are inhabited by cave adapted salamanders and other aquatic fauna, many of which are listed as endangered species. Aware that other cave related aquifer recharge projects have caused extensive and perhaps permanent negative impacts on resident cave fauna, the District was concerned that increasing the quantity and frequency of recharge through the caves might harm resident species in the caves or affect overall aquifer habitat.

The District will utilize several Best Management Practices (BMP's) to address these projects and concerns. These BMP's will be based on the recently completed study and will incorporate ongoing efforts with local, state, and federal agencies, the landowners, engineers, scientists, speleologists, and District staff. The EPA has recently indicated its approval of a $271,550 matching funds grant application submitted by the District for design and implementation of BMP's to protect the two caves and mitigate non-point source pollution impacts upon them. The BMP's developed under this grant will include both proven and innovative structural and non-structural controls. Water-quantity and quality will be monitored with automatic samplers and flow meters to determine the effectiveness of the BMP's. Management policies and maintenance techniques will be assessed as part of the project.

While awaiting the EPA grant funds and in anticipation of the implementation of the BMP's, some additional activities were undertaken by the District during and subsequent to the previously mentioned engineering and environmental assessment. These include a limited amount of field work and the organizing of meetings, briefings, and project site tours for landowners, elected officials, and staff members of local and state agencies.

The highest priority was the exploration, mapping, and biological assessment of the caves. The District utilized the author and other experienced speleologists toward this end. Crippled Crawfish Cave was entered twice and completely explored, photographed, and mapped. The cave was almost devoid of life and no significant species were found. Antioch Cave has proven more difficult. The first exploration was limited by a lack of time and the extensive rainfall and flooding of the creek and cave which began the next day. The second effort was delayed for over a year due to streamflow entering the cave. When the speleologists finally entered the cave for the second time, they were halted by concentrations of carbon dioxide as high as 4%. However, the entrance area and a short portion of the main passage of Antioch Cave were explored, photographed, and mapped. Like Crippled Crawfish Cave, Antioch Cave was observed to have very little fauna, none of which was significant. Little more can be done until the air quality improves in the cave. Based on the fauna observed and the fact that both caves undergo regular inundation, it appears that no significant negative impacts will occur to the cave habitat should the District pursue recharge efforts involving these two caves.

The District negotiated with the cave owners for temporary and occasional access to the caves. This working relationship has continued throughout the previous studies and continues to this day. The District and the owners have begun investigating various options for ownership, access, management, and operations of the sites should the projects continue. Both cave owners are interested in reducing or eliminating their liability. The transfer of ownership of the caves and a small parcel of surrounding land to the District is the most obvious choice, but other options such as conservation easements are also under consideration.

The BMP's under consideration include structural controls, such as weirs and gabions, which will provide a significant increase in recharge water quantity and quality by: (1) filtering floodwater to reduce sediment and pollutant loading, (2) diverting flood debris around the caves to avoid closing of the entrances, (3) restricting human access and debris entry by means of design and installation of cave gates, and (4) preventing the "first flush" of floodwaters (which contain the highest concentrations of pollutants) from entering the caves. Nonstructural controls will include long-term management plans and a maintenance program for the structural facilities and the cave entrances. A monitoring program will be conducted on the water quantity and quality to analyze the effectiveness of the BMP's and to determine if further BMP enhancement or design modification is warranted.

Future efforts at these sites would focus primarily on two options. It has been noted that recharge could be increased by modifying the cave entrances. This would involve removal of alluvium and loose or deteriorated rock around the entrances, and perhaps even some of the actual bedrock, to increase the entrance surface area available to recharge flow. Preliminary calculations indicate that such modifications could conceivably result in an additional recharge volume equal to all currently un-allocated water rights. As mentioned previously, the construction of small recharge dams to slow floodwaters and allow time for additional recharge to take place is another option that will be examined closely. It is, however, an option involving considerable expense, time, and an extensive permitting process. The implementation of this option is likely to be several years in the future, if ever.

It is anticipated that the District's Onion Creek Recharge Project will provide not only increases in recharge quantity and quality, but will serve as a model for the integrated management, protection, and utilization of caves in recharge enhancement projects. The experience and data derived from this effort will be invaluable to those considering similar projects in other cave areas and karst aquifers. The increased quantity and quality of water recharged to the Edwards aquifer will benefit thousands of residents who rely on this aquifer as their sole source of drinking water.

GROUND-WATER DYE-TRACE DATA BASE FOR KENTUCKY

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ABSTRACT

A data base of ground-water dye traces in Kentucky is being constructed by the Kentucky Geological Survey. The data base containes nearly 300 dye trace records contributed by KGS and many other karst researchers. Data contained in the data base are available for use by karst researchers, and others, and can greatly facilitate karst basin investigations. The data base is still growing and KGS continues to seek additional contributions.

INTRODUCTION

In 1986 work was begun at the Kentucky Geological Survey (KGS) on creating a ground-water data base for Kentucky. By 1990 programming was completed for the first generation of the data base and data entry began. The data base includes data on springs and dye injection points such as swallow holes and karst windows. Entry of dye-trace data begain in late 1990 on an as-time-permits basis. In the summer of 1992 a student worker was hired to canvasss karst researchers, government agencies, and consulting companies for ground-water dye-trace data they would be willing to release. The results were gratifying; several well-known researchers released maps and records for over 100 traces. In addition, published reports, thesis', and dissertations were reviewed for dye-trace data. Although work is in progress to convert the original Digital Equipment Corporation (DEC) Datatrieve program to DEC's RDB software, the data base remains in service.

RESULTS

Although the ground-water dye-trace data base is far from complete, substantial data are now available for use by researchers. Nearly 300 dye injection points are entered, and hundreds of locations of springs. The ground-water dye-trace data on the system as of July 1, 1993, are being compiled into a publication that will list the location of the final resurgence of the trace, the location of the input, the dat of input and recovery, and other relevant data (Table 1). This publication is only a summary of the information available, and some traces have additional extensive commentary and other supporting information. An index map of the traced basins will be included in the report.

KGS continues to seek contributions to the ground-water dye-trace data base. Data in written form with coordinate locations provided are preferred, rather than only posting on maps. However, maps by themselves are accepted. Even though some researchers consider it desirable to rerun all traces for new investigations, the information available in the data base greatly shortens the amount of reconnaissance conducted while mapping a karst basin. Further, the compilation of these data into a single archive makes regional maps of karst ground-water basins possible.

MANAGEMENT OF CAVE & KARST AREAS

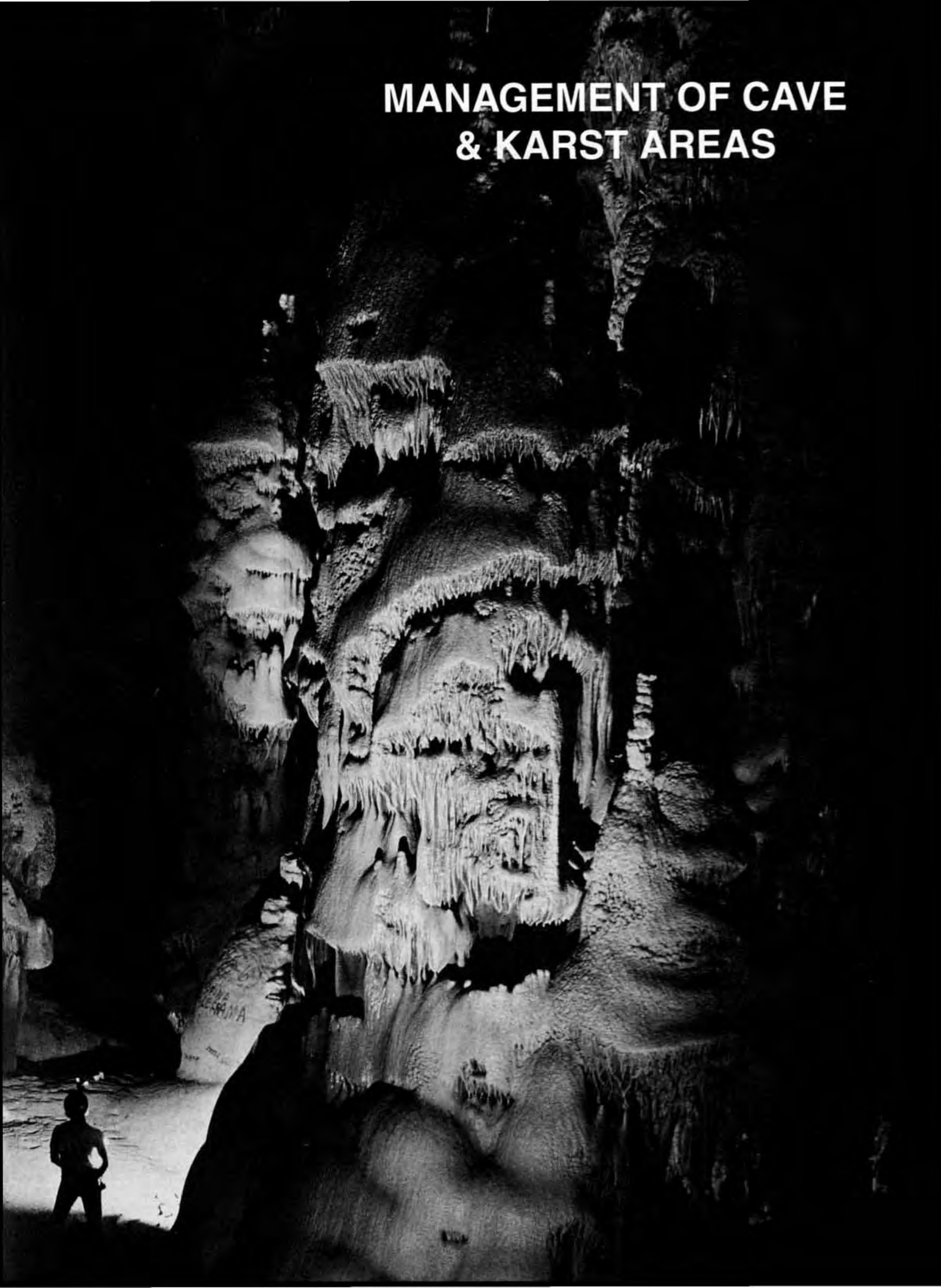

Photo Caption -- Lynn Thompson lights up massive formations in the Hall of the Giants, La Gruta del Palmito, Nuevo Leon, Mexico.

Photo by Dale Pate

MANAGEMENT OF CAVES AT MOUNT ST. HELENS NATIONAL VOLCANIC MONUMENT

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Mount St. Helens National Volcanic Monument
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In the late 1800's Ole Peterson led the first tourists on visits to Ole's Cave, a mile long lava tube south of Mount St. Helens. Since that time an additional 50 caves have been discovered and the caves area has become part of Mount St. Helens National Volcanic Monument. Visitation has grown from Ole's few guests to an annual visitation at Ape Cave of 130,000 people. Monument visitors now have the opportunity to learn about lava tubes and the unusual animals that inhabit them. Interpretive naturalists lead cave tours during the summer months.

Visitor impacts to undeveloped caves have created a need for special management. Measures are being taken to protect sensitive cave resources while allowing compatible recreational use. Caves are ranked and classified depending upon resource sensitivity and importance, then placed into one of three classifications: sensitive, undeveloped, or directed access.

In this paper the reader will learn the natural history of Mount St. Helens caves, and management measures developed for their protection.

LOCATION AND SETTING

The caves considered by this plan are found in association with the Mount St. Helens Cave Basalt Flow (1,950 years old) located on the southern slope of Mount St. Helens. The Cave Basalt Flow extends from near the summit of Mount St. Helens, eight miles to the south, to the Lewis River near Swift Dam. A western arm of the flow reaches as far as Kalama Falls along the Kalama River. This flow arm is largely covered by recent pyroclastic flow deposits and mudflow debris. These materials have covered, filled, or obscured any caves which may have existed. No known caves are located in this western flow unit and as a result the area is not further considered by this plan.

RESOURCE DESCRIPTIONS

TREE AND LOG MOLDS

Although tree and log molds are not normally considered caves, molds in the Cave Basalt Flow are highly developed and found extensively in the area and by the technical classification of being both underground and frequently possessing total darkness, rank as caves. The microclimates, invertebrate components, mammal use, and delicate geologic features of the tree molds are as sensitive to disturbance as lava tubes. The molds found in the Cave Basalt Flow are considered to be unequaled on the North American Continent by the USGS (pers. commun.) and a resource unique in its quality and extent.

Near the margins of the flow are found excellent examples of tree molds (casts) formed when the fluid basaltic lava invaded a forest of Douglas fir, western hemlock, Pacific silver fir, western redcedar, and western hemlock. When lava surrounded trees, it chilled sufficiently to solidify and preserve the shape of the trees. Eventually, the trees burned off, where surrounded by the lava, and fell to the surface of the lava flow. In some cases, small subsequent lava flows spread across the surface covering the felled timber, creating horizontal log molds. These are well exhibited along the Trail of Two Forests interpretive trail. A vertical tree mold here is fitted with a metal access ladder allowing visitors to descend six feet, then crawl through two interconnected log molds and leave by a second entrance.

In the walls of the molds are frequently found imprints of charcoal (often mis-identified as bark imprints) resulting from the combustion of tree trunks. Charcoal masses in horizontal log molds sometimes were infiltrated by low viscosity basalt leaving a honeycombed mass of lava preserving both charcoal patterns and an imprint of wood grain. These features are seldom found outside the Mount S. Helens area and are considered rare.

LAVA TUBES

The lava tubes of the Cave Basalt Flow are numerous, extensive, and well preserved. The caves tend to contain less breakdown than other caves in the region, a fact that can at least partly be attributed to their young age. At 1,950 years, they are the youngest lava tubes in the contemporaneous United States. The lava tubes of the Cave Basalt Flow are one of the National Volcanic Monument's most sensitive and unusual resources.

FORMATION OF LAVA TUBES - From observations of active lava flows in Hawaii, much has been learned about lava tube formation. The first requirement is pahoehoe basalt, a fluid lava which moves rapidly down slope. Other more viscous forms of lava do not form lava tubes.

Lava tubes form most commonly in the main channels of an advancing lava flow. As lava spreads from the eruptive vent, it tends to become channelized much like a river between levees. The lava on either side of the active channel stagnates, cools, and solidifies, leaving active flow concentrated within the channel. The advance of the flow depends upon a continued supply of fresh lava fed through these channels.

As an eruption continues, lava begins to solidify along the sides of the lava channel, gradually forming a ledge over the flowing lava. As the ledges growing from opposite sides of the channel meet, a roof is formed across the lava stream. This process normally starts near the vent and works its way down slope.

Other processes affect the initial tube roof, speeding its formation. Plates of lava frequently break loose and raft along on the surface of the lava stream. These often jamb up, like an ice floe, against bridged portions of the lava stream and accumulate in a floating mass. In this way, a tube roof can be extended upstream from an obstruction.

Anchored to the downstream side of an obstruction, or an already formed segment of tube roof, a thin, floating crust often forms. As this crust becomes thicker and more solidified, it is able to both support and extend itself rapidly downstream. Once started, this process advances rapidly and is the principal factor responsible for tube roof formation.

SURFACE TUBES - Surface tubes are generally small secondary caves that form in low volume tongues of lava near the advancing edge of the flow or at points where lava spills from a cave or channel. They are easy to identify by their shape and monolithic structure. Most typically, they have a crescent shaped cross section with a horizontal floor. Walls, ceiling, and floor are a single homogeneous flow unit. Dimensions are usually a few feet high and up to ten feet wide.

Surface tubes form when a small tongue of lava advances, the top and bottom solidity, and the molten interior drains out. Surface tubes ten feet or greater in width are rare since their roofs are seldom thick or strong enough to be self supporting once the buoyant support of the lava is withdrawn. Roofs of these wider tubes are often found deflated (looking like a fallen souffle) and lining a linear depression.

MODIFICATIONS OF LAVA TUBES - Lava tubes once formed, are continually modified. Eruptive duration, lava temperature, flow volume, and lava viscosity are factors which interact to modify tubes.

Flow duration affects the length and complexity of tubes. Downward erosion of tube floors by flowing lava may create stacked or multi-level tubes. Ape Cave, Lake Cave, and Little Red River Cave exhibit this development as well as lateral erosion beneath a hillside (Greely and Hyde, 1973). Passages with high, narrow cross-sections are frequently found in areas of lava erosion.

Downward erosion in Hawaiian lava tubes has been monitored through skylights (unroofed tube segments) of active lava tubes. The lava stream surface in some of these tubes has been observed to drop more than ten meters with no reduction in flow volume at the vent. This has been interpreted as downward erosion through melting and mechanical plucking by the moving lava.

Changes in lava volume can create a number of structural variations in cave linings and surface features. Blockage of a tube or surges in eruptive volume can coal tube walls with lava linings. Linings are found several inches to several feet in thickness, coating the upper walls and ceiling. Combined with long duration flows and downward erosion, linings can grow toward each other from opposing walls, converge and create a horizontal lining pattern across the passage. This process accounts for most multi-level stacked tubes.

If lava volume exceeds the capacity of the tube, it is common for lava to rise and flow onto the surface through unroofed skylights (residual entrances, Larson, 1989). If openings are not present to relieve lava pressure, the tube roof may be deformed by hydrostatic pressure or ruptured allowing lava to escape. The entrances of Beaver Cave, Little Red River Cave, the upper and skylight entrances of Ole's Cave and all the Ape Cave entrances are the result of this process.

The spilling of lava to the surface, and its flow over the top of active tubes can be a significant factor in the thickening of tube roofs. Caves have been found on the Gifford Pinchot National Forest with roof thicknesses of 165 feet. Roof thicknesses of 10 to 30 feet are most common.

Cave entrances are of two general types. Residual entrances where no roof formed or a weak roof segment was lifted off by the pressure of upwelling lava. Collapse entrances formed where the ceiling is too weak to support itself and collapses into the tube. Most researchers agree that collapse is closely related to cooling and contraction cracking of the lava. This leaves wall and ceiling sections unsupported and free to fall. Most breakdown occurs as the tube begins to cool. After initial collapse, the continued collapse proceeds at a very slow rate.

Following an eruption, residual lava drains from the tube. This leaves behind small lateral accumulations of lava on the tube walls called flow marks or flow ridges. These mark temporary levels of lava in the tube and are sometimes compared to bathtub rings. Flow marks can also form at other times in the active life of the tube, but are most common as lava volumes diminish.

Another modification related to draining of lava from a tube is plastic deformation and collapse of wall linings. It is common for tubes with thin roofs to deform under the force of gravity when the buoyant support of lava is removed. It is common to find the ceilings of small, immature tubes deformed by sagging along their central axis.

When lava drains from a tube, it is common for linings of poorly solidified, partly molten lava to collapse inward. This results in both accumulations of breakdown on the floor and also exposure of baked soil where downward erosion has taken place. This is common in Little Red River Cave, Ape Cave, and Lake Cave.

As the lava drains from the tube, it is common for a tube-in-tube to form. These are miniature lava tubes which form in the tube floor as the last molten lava leaves the tube. Many are too small to enter, but some are large enough to crawl through such as those found in Ape Cave, Ole's Cave, and Flow Cave.

SPELEOTHEMS - Lava stalactites, stalagmites, runners, blisters, lava roses, and slumped glaze are common to the Mount St. Helens caves. The first of these formations are related to the extrusion of lava from the walls, ceiling, and floor of a tube. Although the extrusion process is imperfectly understood, most researchers agree it is related to degassing of the tube walls which carries along with it a small molten fraction of lava. As this lava emerges, it creates lava stalactites where it can drop free from the walls or ceiling; runners where it runs down inclined surfaces; and lava roses or blisters where it bubbles up from the floor. Lava stalagmites form beneath lava stalactites where piles of lava droplets accumulate. Lava stalactites and stalagmites are the most fragile and easily broken of the speleothems.

Above the level of flowing lava, it is common for the tube walls to soften and melt often producing a black shiny glaze. On inclined surfaces the glaze often slumps producing a pleated pattern which is quite distinctive.

EROSIONAL CAVES

The most unusual caves found in association with the Cave Basalt Flow are formed by erosion of paleo soil beneath the basalt flow. All caves of this type have been found to occupy a 24-30 inch thick layer of buried soil that has been eroded by water percolating through the lava and following the lava-soil contact. Water following this contact easily erodes the soil layer, but is stopped by a cobble rick lahar deposit below the soil. Cobbles from the lahar deposit are found armoring the cave floors preventing additional downward erosion. This results in caves having ceiling heights seldom more than two to three feet high.

Five major caves of this type have been identified of which Warm Spring Cave is the largest. With a perennial stream and 600 feet of surveyed passage, this cave is the most interesting found to date. Warm Spring Cave, along with several others, are located at or near the flow margin where water from the surrounding terrain finds its way beneath the lava flow.

Wall lining collapse in Ape Cave, Little Red River Cave, and Lake Cave have allowed erosional caves to become connected to lava tubes. Lake Cave has a forked passage of this type approximately 300 feet in extent. During periods of heavy precipitation and/or runoff, water flows from this passage and cascades six feet to the cave floor. Sand from erosion of the passage blankets the floor to the end of the cave and the stream which flows from the passage supplies water to the intermittent lake at the end of the cave.

Tree and log molds are frequently found exposed in the ceiling or erosional caves and in some cases have helped control cave development. Erosion of the paleo-soil during the formation of these caves has exposed carbonized roots. Carbon from these roots collected in Lake Cave were used to determine the area of the flow through Carbon 14 dating in the early 1960's.

Large flooded passages of this type may be part of a complex underground network that drains the Cave Basalt Flow watershed.

HYDROLOGY

At the southern end of the Cave Basalt Flow are two large springs where water rises from beneath the lava. Cougar Spring is the largest (120 cfs+) and is the source of Cougar Creek. Cougar Creek provides important spawning habitat for the cokonee of Yale Reservoir, a type of land-locked salmon. Dry Creek Spring is a second resurgence and the head of Dry Creek. Several other small or seasonal springs are located along the southern flow edge, but are not considered significant to the large scale hydrology of the area.

Surface water drainage on the Cave Basalt Flow is limited to a single losing, seasonal stream found in the upper flow area which disappears completely two miles above the large springs. The watershed covers approximately 15 square miles in which all water is eventually transmitted underground to the two principal springs.

Upper Cougar Creek ends at Grass Lake along the western side of the flow about three miles above Cougar Spring. Intermediate between Upper Cougar Creek and Cougar Spring is Lost Creek which also looses its flow beneath the lava.

Fluorocene dye placed in Cougar Creek in July, 1988 reappeared at Cougar Spring within seven days. This established the connection and evidence of rapid water movement beneath the lava flow. The flow rates determined by the dye tracing are consistent with those found in limestone karst terrains (Aley, Ozark Underground Laboratory, 1988).

According to Tom Aley (Karst Hydrologist, Ozark Underground Laboratory), the dye trace performed beneath the Cave Basalt Flow is the first ever attempted in igneous rocks of this type. The success of the trace and the rapid water movements show that there is little or no filtration of water taking place. Pollutants spilled on the Cave Basalt Flow or into upper Cougar or Lost Creeks would be rapidly transmitted to the springs.

A more detailed dye tracing project needs to be undertaken to identify discrete recharge areas for the Cave Basalt Flow. Without this data, the sensitivity of the watershed to pollution remains largely unknown.

CAVE BIOTA

The caves of the Mount St. Helens Cave Basalt Flow were inventoried under Forest Service Contract by Dr. Clyde M. Senger and Rodney L. Crawford and their findings issued in the 526 page report titled "BIOLOGICAL INVENTORY, Mount St. Helens Cave Basalt Flow Area." Recommendations from the report have been incorporated into management of the caves area.

The study developed an inventory of the biota, habitats, present and potential impacts on caves in the Cave Basalt lava flow. A survey of flora and fauna was conducted in 23 caves from March 18 to August 7, and again from October 5 through December 9, 1983. Surface geology and vegetation were recorded within 200 feet of each cave entrance, and twilight zone vegetation (mostly mosses and liverworts) was sampled at intervals from the entrances to furthest penetration. Vertebrates were recorded by direct observation, distinctive signs, and live trapping of deer mice. Invertebrates were recorded by direct observation, hand collection, cheese baited pitfall traps, drift netting in cave streams and lakes, Berlese funnel extraction from organic litter and woodrat nests, and a few from collected moss samples.

The study disclosed a number of species which require special consideration in cave management, and makes a number of specific recommendations. The report notes the following:

VERTEBRATES - Townsend's big-eared bat is the vertebrate of most concern as a potentially endangered species in the Cave Basalt area. Fortunately, it is also one for which both the cause of the problem and the management approach apparently are straightforward. Disturbance of the bats in hibernation and maternity colonies is the problem and a reduction or elimination of that disturbance is an appropriate management goal.

"We feel there is enough data at present to indicate that *Plecotus townsendii* is unusually sensitive to disturbance in both hibernation and nursery colonies. They do not readily move to new sites outside their "home range", and thus are unlikely to recolonize a suitable area once a local population is destroyed." Protecting nursery colonies "without disturbing the bats in any way would be an appropriate management goal. They seem to require caves with rather specific conditions for hibernation, and such sites are few in Washington."

"Populations of the Townsend's big-eared bat, *Plecotus townsendii*, are declining throughout its range and declined dramatically in the Cave Basalt area between 1964 and 1970. they have recovered somewhat since then, but only to 20-30% of 1964 numbers; we feel the species may be in danger of extinction in this area. Preventive measures recommended include closing the chief hibernating areas to visitor use November 1 - April 1, and locating and protecting nursery colonies."

"The only other possibly rare and vulnerable vertebrate species found is the Larch Mountain salamander; its population in Ole's Cave (at the third entrance) should be protected." *Plethodon larselli* is now a candidate for the Federal threatened and endangered species list, and a State listed sensitive species. *P. vandykei* is also found at this location and since the time of the report has been proposed as a State sensitive species.

INVERTEBRATES - "We classify 7 invertebrate species found in the area as rare and vulnerable; the four stygobiont species found in Little Red River Cave, the troglobitic mite *Elliotta sp.*, and *Grylloblatta chirugica*. The habitats of these species should be protected, as should those of a number of other species which may be rare but are inadequately known. Some habitats are vulnerable in themselves, including groundwater, slime, rough floors, roots, small passages, and twilight flora."

FLOOD IMPACTS - "Protection from flood impacts is recommended for Gremlin, Spider, and Little Red River Caves, and others if necessary. Most caves studied contain vulnerable habitats and species and are not suited for directed recreational use, as increased visitor traffic would impact them adversely. They should be protected by minimizing publicity and road and trail access; we do not recommend gating caves except as a last resort, because of often observed environmental effects from cave gates and their susceptibility to vandalism. Public education in cave conservation and safety at Ape Cave, and perhaps by posting tactfully worded signs inside the entrances to some wild caves, is recommended."

GROUNDWATER - "Subsurface habitats such as caves and groundwater are affected by management of the overlying surface, and could be adversely impacted by inappropriate surface activities such as manipulation of vegetation, use or storage of toxic chemicals, dumping, use of septic tanks, construction of permanent work or residence facilities, introduction of non-native species, stream diversion, or excessive pumping from wells, and these should be avoided on the Cave Basalt or in its hydrologic setting."

CAVE NAME	BIOLOG-ICAL	HYDROL-OGIC	HISTORIC	RECREAT-IONAL	GEOLOGICAL, PALENTOLOG-ICAL, ETC.	EDUCAT-IONAL, SCIENTIFIC	CAVE CLASSIFICATION
Trenchside Cave		2	0	1	1	2	3
Two Column Cave		3	0	1	2	2	3
Utterstroms Cave	4	0	1	2	4	3	1
West Cave	1	0	1	1	1	1	3
Wram Spring Cave	4	4	1	3	4	5	1

CAVE NUMBERS

Cave numbers have been assigned to each cave entrance. Some caves with multiple entrances carry the same number at each entrance followed by alpha characters (A,B,C, etc.) to differentiate between individual entrances. Cave numbers are assigned by Region, Forest, and Unit, followed by consecutive numbers for each cave on the unit. For example Ape Cave in No. 631-1A.

6 = Region 6,
3 = Gifford Pinchot National Forest (Forest 3),
1 = Mount St. Helens NVM (Unit 1)
-1 = Cave No. 1 on the Unit
A = First Entrance of Ape Cave

Brass cave inventory caps, stamped with the cave number, are grouted into a drill hole at each entrance. The caps are placed in an obvious, easily found location. Care has been taken to place the markers in locations which will not visually impact the aesthetics of the caves. After one or two seasons of weathering, the markers acquire a dark patina which blends well with the rock color.

The brass caps are used to provide a permanent identification marker at each cave entrance. Due to the large number of caves found at Mount St. Helens, markers at each entrance are used to identify caves that are inventoried. Each season new caves are reported by interested cavers. Many times the same cave is reported more than once leading to confusion. Inventory markers leave no doubt as to a cave's identity.

COMPLIANCE WITH THE FEDERAL CAVE RESOURCES PROTECTION ACT

The Federal Cave Resources Protection Act of 1988 (FCRPA) makes it "the policy of the United States that Federal lands be managed in a manner which protects and maintains, to the extent practical, significant caves."

No attempt is made here to replicate all the requirements of the FCRPA, or the implementation regulations which describe application of the act. Both the Act and the regulations are included as appendices to this document.

CONFIDENTIALITY

The act discusses the handling of confidential information concerning the nature and location of significant caves. In general, information concerning the specific location of any significant cave may not be made available to the public under section 552 of title 5, United States Code (Freedom of Information Act), unless the Secretary (of Agriculture) determines that disclosure of such information would further the purposes of the Act and would not create a substantial risk of harm, theft, or destruction of a significant cave.

Specific information concerning significant caves at Mount St. Helens will not be made available to the public. This information will be treated as confidential and maintained in such a manner as to prevent access by non-authorized individuals. The cave coordinator will maintain the cave files and assure that access is provided on a need-to-know basis only.

DETERMINATION OF SIGNIFICANCE

The implementation regulations establish guidelines for determination of cave significance. All caves found within specially designated areas of Mount St. Helens National Volcanic Monument, where the area was designated in whole or part due to cave resources, are automatically qualify as significant and fall under requirements of the Act. Even though all caves within the Monument meet the criteria, their names and supporting documentation must be submitted for official recognition. The computer data base, into which all cave data has been entered, will be used to generate the appropriate nomination information.

Caves found outside the boundary of the legislated Monument require separate consideration and evaluation to determine significance. The regulations describe specific resource values that need to be considered when an evaluation is made. It is expected that any cave containing resources specified by the regulations will be determined to be significant.

Caves that are determined to be significant fall under the full protection of the FCRPA. Any cave not found to be significant will still be managed under the standards and guidelines of the Gifford Pinchot National Forest Land and Resource Management Plan, and FSM 2356.

PURPOSES OF THE FCRPA

The FCRPA has two purposes. The first is "to secure, protect, and preserve significant caves on Federal lands for the perpetual use, enjoyment and benefit of all people". This first purpose is met through the analysis and implementation of this management plan. Caves with special resource values will be protected, while those which are capable of withstanding recreational use will be either developed for directed access (Ape Cave), or will remain open for "wild caving" for those persons who know the cave's locations.

The second purpose of the Act is "to foster increased cooperation and exchange of information between governmental authorities and those who utilize caves located on Federal lands for scientific, educational, or recreational purposes". The Monument will invite the "caving community" to participate in various aspects of cave management. The Forest Service currently has a national Memorandum of Understanding (MOU) with the National Speleological Society (NSS) for cooperation in matters relating to caves. The Monument has a more specific MOU with the Oregon Grotto, a local chapter of the NSS, for local cave management projects (see appendix).

This MOU, and yearly volunteer agreements, will be continued. The Oregon Grotto MOU allows other chapters of the NSS to join them on projects, under their auspices.

Every effort will be made to involve caving organizations, educational institutions, and other interested governmental authorities in management of caves at the Monument. This will be accomplished through MOU's, volunteer, challenge cost share, interagency, and participating agreements, or other actions consistent with the FCRPA, FSM 2356, and the standards and guidelines from the Gifford Pinchot National Forest Land and Resource Management Plan.

COLLECTION OR REMOVAL OF CAVE RESOURCES

The Act authorizes the Secretary of Agriculture to issue permits for the collection and removal of cave resources under such terms and conditions as the Secretary may impose, including the posting of bonds to insure compliance with the provisions of any permit. Specific guidelines are found for the issuance of such permits in the Act.

The Act further states "any person who, without prior authorization from the Secretary knowingly destroys, disturbs, defaces, mars, alters, removes, or harms any significant cave or alters the free movement of any animal or plant life into or out of any significant cave located on Federal Lands, or enters any significant cave located on Federal lands with the intention of committing any act described in this paragraph shall be punished...". The Act goes on to describe specific punishment, and sets civil penalties.

The Monument will comply with the Act by requiring permits for any collection of cave resources, or when studies are proposed that could adversely impact cave resources. (See definition of Cave Resources in the FCRPA, in appendix)

Permits will be issued only when it has been determined that collections or studies will not create long term impacts to cave resources. All permits will contain a provision requiring, and will be issued only under the condition, that a copy of study results will be provided to the Forest Service. All permits shall require assurance from the permittee that the locations of significant caves will remain confidential. Permits will only be issued when it has been determined that the proposed activities are consistent with the FCRPA, FSM direction, and are within Forest Plan Standards and Guidelines.

Collection permits will be issued for scientific research purposes only. No permits will be issued for removal of cave resources intended for personal collections, or for purposes unlikely to general new contributions of scientific knowledge or understanding of Monument caves.

PROHIBITED ACTS

The following acts will be prohibited in the Mount St. Helens National Monument through issuance of appropriate Code of Federal Regulations orders:

> *36 CFR 216.58(s) Possessing a cat or dog within any cave within the Mount St. Helens National Volcanic Monument.*
>
> *36 CFR 261.52(a) Building, maintaining, attending, or using a fire, campfire, or stove fire within any cave.*
>
> *36 CFR 261.52(c) Smoking within any cave.*
>
> *36 CFR 261.52(f) Possessing, discharging, or using any kind of fireworks, or other pyrotechnic device within a cave.*
>
> *36 CFR 261.58(m) Discharging a firearm, air rifle, or gas gun within any cave.*
>
> *36 CFR 261.58(e) Camping within the Ape Cave Geologic Site.*

36 CFR 261.58(bb) Possessing a beverage which is defined as an alcoholic beverage by state law within any cave.

36 CFR 261.53 It is prohibited to go into or be upon any area which is closed for the protection of: (a) Threatened, endangered, rare, unique, or vanishing species or plants, animals, birds, or fish. (Bat, Ole's, Beaver, Spider, Flow, and Blue Ribbon Caves will be closed to entry between November 1 and April 1.) (Little Red River Cave will be closed. Visitation will be allowed by permit only.)

CAVE MANAGEMENT ACTIONS

RECORDS

A file of pertinent data will be maintained for each cave. This file will remain locked with access provided on a need-to-know basis only. A separate computer data base will be maintained with important statistics on each cave. At a minimum, the following information will be collected and maintained for each cave: Cave Name, Cave Number (entrance number), Date Marker Cap Set, Cave Length, Latitude, Longitude, Elevation, Township, Range, Section, Quadrant, Cave Classification, Special Management Concerns, Alternate Cave Names, Descriptive Notes, Cave Map

In addition to the above information, photographs, scientific reports, copies of newspaper clippings, or other printed materials relating to a specific cave should be included in the file.

INVENTORIES

The best cave inventory data currently available is used for the development of this plan. However, due to the complexity of cave resources found in the Monument, and large number of caves, this data is considered preliminary. New caves are being found yearly, and must be added to the inventory. Cave mapping is incomplete, and in some cases of poor quality. As time allows, unsurveyed caves are being mapped, and in other cases, inadequately mapped caves are being resurveyed. The process of placing brass caps at cave entrances, and collecting precise entrance locations using GPS receivers, is on-going.

The Monument will continue to aggressively pursue collection of inventory data. This will be accomplished mostly through partnerships with caving organizations. Collection of this information will be coordinated by the cave management specialist.

CAVE LOCATIONS

Information concerning the location of caves will be kept confidential in accordance with provisions of the FCRPA. Only the location of Ape Cave will be made available to the public.

Cave locations recorded in GIS will be placed on a separate, secure, layer, and all inventory records will be maintained in a locked file. Access to these records will be permitted on a need-to-know basis only. Generalized information which does not lead to the disclosure of cave locations may be made available, if it is determined that such disclosure is consistent with the purposes of the FCRPA, the implementation regulations, Forest Plan Standards and Guidelines, and FSM 2356.

PARTNERSHIPS

The Forest Service will use partnership agreements or volunteers to assist with cave management. Agreements have been used and will continue to be used in such areas as cave inventory, cave surveying, exploration, monitoring or use, restoration and cleanup, conservation projects, research, cave evaluations, planning, groundwater tracing, and interpretation.

The Forest Service will actively seek and participate in interagency agreements and partnerships with both Federal, State, and private partners, to meet the goals of this management plan. Opportunities for co-operative bat management will be emphasized.

In many cases partners have provided information to the Forest Service concerning the location of caves. This information will be safeguarded under the confidentiality provisions of the Federal Cave Resources Protection Act of 1988. Partners may be given access to certain cave location information during the collection of additional field data, or during cave management projects. This information will be made available only when assurances have been provided that such information will be maintained in a confidential manner.

MANAGEMENT OF SPECIFIC CAVES

BAT, OLE'S, BEAVER, SPIDER, FLOW, AND BLUE RIBBON CAVES (Class 1, Sensitive)

These caves provide important hibernation habitat for Townsend's Big-eared bats. Due to the bat's sensitivity, and potential mortality caused by disturbance, these caves will be closed to visitor use between November 1 and April 1 each year. Roads, such as the 8300-030, which provide access to the southern part of the Cave Basalt Flow will remain locked year-round to reduce visitor use.

Signs describing the nature of the closure and its need will be placed at the entrance of the closed caves. Notice of the closures, and a request to impose a self-moratorium on use will be distributed to cave user groups.

LITTLE RED RIVER CAVE (Class 1, Sensitive)

Little Red River Cave contains the only perennial stream of any Mount St. Helens lava tube. Several rare and vulnerable invertebrates are found here which can be adversely impacted by uncontrolled recreational use (See discussion of Invertebrates). The cave also contains a series of steep lava falls or vertical drops, which are unsafe for unprepared visitors. One of these has a conifer pole used as a makeshift ladder. The cave was gated in the early 1960's, but the gate was poorly designed. The bar spacing frustrates bat usage, while the door can be easily bypassed by lifting it off the hinges. The result has been uncontrolled visitation.

This cave is the third most heavily visited cave after Ape and Lake Caves. Estimated visitation is 2,500 people per year, and increasing. Littering, writing names on the cave walls, carbide dumps in the cave stream, and trampling of cave biota is taking place.

Actions will include removal and replacement of the existing gate with a state-of-the-art air-flow bat gate. Human transported organic material and "improvements" such as the pole ladder will be removed from the cave. The goal is to return the cave to a natural condition, without human modifications.

A CFR order will be issued closing the cave to anyone without a permit. Visitation will be limited to 12 people per week, one party per day. A brochure will be developed describing the permit system, the sensitivity of the cave, resource protection requirements, and equipment needed for safe exploration. A photo monitoring program will be initiated. A partner will be sought to help monitor biological recovery. If bats return to and begin to use the cave, seasonal recreational limitations may be imposed.

PILLARS OF HERCULES CAVE (Class 1, Sensitive)

This recently discovered cave contains the largest and best developed lava stalagmites of any cave in Washington, and one of the best displays in the Northwest. The formations are fragile, vulnerable, and could be easily broken and destroyed by uninformed or inexperienced visitors. Elsewhere in the cave are found tree roots and clay floors that support a potentially important cave biota. Biologists have not yet studied the cave. Caving organizations have known of the cave since 1988, but visitation has been limited through self-moratorium. The general public is unaware of the cave's existence.

Areas of fragile features, because they are often hard to see, have been marked with surveyors plastic flagging to prevent trampling. Photo-monitoring and placement of cave registers will be undertaken. If it is determined that degradation of cave resources is taking place, the cave will be gated and access controlled by permit.

WRAM SPRING, UTTERSTROM'S, AND PRINCE ALBERT CAVES (Class 1, Sensitive)

These caves contain cave resources which are unique or sensitive to human disturbance. Use levels are so low, however, that no particular threat to the resources presently exists. Cave registers will be placed at each cave to determine the level of use, and photo-monitoring used to determine visitor impact. If adverse impact is identified, management action will be taken.

APE CAVE (Class 2, Directed Access)

This is the only directed access cave in the Monument. Management will be consistent with that described for class 3 caves. The cave will be maintained to provide a recreation and educational opportunity for visitor. Interpretative tours will be provided in cooperation with the Northwest Interpretive Association, and to the extent time and funding is available.

Lanterns, interpretive materials, and tours will be provided during summer months only. The cave will be open for self-exploration year-round. Visitors may accompany a guided tour or explore the cave on their own.

Law enforcement emphasis will be placed on discouraging parties at the cave, or other acts described under prohibited acts. During periods of low visitation, particularly during the winter, the gate to the parking lot will be locked. A second gate, just west of the Trail-of-two-Forests, will be locked when snow is present. The intent is to provide a non-motorized winter recreation opportunity while at the same time reducing the possibility of vandalism to facilities at Ape Cave. Visitors will be allowed to ski or walk over the snow to visit the cave. Snow will be plowed only as far as the gate at Trail-of-two-Forests, but not beyond.

RECREATIONAL USE MONITORING/MANAGEMENT (Class 3, Undeveloped Caves)

The following actions pertain mostly to undeveloped caves, but may also be applied to sensitive or directed access caves.

Recreational use of nearly all caves in the Monument is taking place. This is recognized as an appropriate activity providing there are no irreversible impacts to cave resources. Cave registers will be placed in all larger undeveloped caves receiving recreational use. This will be accomplished with the assistance of the National Speleological Society. Register forms will be placed in a sealed PVC pipe tube with a removable cap at one end. The tubes will be attached to the wall near cave entrances.

A brochure will be developed describing the sensitivity of cave resources to disturbance, and precautions explorers should follow to prevent damage to caves. Caving safety and equipment will also be described. This brochure will be developed in partnership with the Oregon Grotto.

Cave entry permits will be issued for Little Red River Cave after replacement of the existing gate. Other caves may be added to the permit system if monitoring indicates a need to reduce use levels for resource protection.

Litter and names marked on cave walls will be removed from caves when found. This will be accomplished through the use of volunteer groups or with Forest Service employees.

CAVE EVALUATION

All Monument caves have been evaluated using the following rating system. The system allows values to be assigned to various cave resources. The assigned values have been used to determine cave classification and will be used in determining cave significance under the implimentation regulations of the Federal Cave Resources Protection Act of 1988.

BIOLOGICAL RESOURCES

VALUE	EXPLANATION OF VALUE
0	Biological components lacking.
1	Biological components exist but of low apparent significance.
2	Biological components present and numerous, sensitivity low.
3	Biological components present, numerous and of moderate sensitivity.
4	Biological components numerous and sensitive to disturbance.
5	Biological components very numerous and highly sensitive to disturbance. Habitat is critical to species survival. The cave contains unique species, or ones found on State or Federal sensitive, threatened, or endangered species lists.

HYDROLOGY

VALUE	EXPLANATION OF VALUE
0	Hydrologic components lacking.
1	Hydrologic components present but of low importance.
2	Hydrologic components present but of low sensitivity.
3	Hydrologic components present and of moderate sensitivity.
4	Hydrologic components important and very sensitive.
5	Hydrologic components complex and highly sensitive.

CULTURAL / HISTORIC RESOURCES

VALUE	EXPLANATION OF VALUE
0	Cultural resources lacking.
1	Potential for cultural resources low.
2	Potential for cultural resources moderate.

VALUE	EXPLANATION OF VALUE
3	Cultural resources present or implicated by historic records. Site may be eligible for the National Register of Historic Places.
4	Cultural resources present and sensitive to disturbance. Site eligible for the National Register of Historic Places.
5	Cultural resources present and highly sensitive to disturbance. Site eligible for the National Register of Historic Places.

RECREATIONAL VALUE

VALUE	EXPLANATION OF VALUE
0	Cave lacks recreational value.
1	Recreational value low. Little or no scenic appeal.
2	Recreational value low but receiving some use. Scenic values low.
3	Recreational values, scenic values and use moderate.
4	Recreational values, scenic values and use high.
5	Recreational values, scenic values and use very high. A major cave of regional or National significance.

GEOLOGICAL / MINEROLOGIC / PALENTOLOCICAL VALUE

VALUE	EXPLANATION OF VALUE
0	Features of significance lacking.
1	Some interesting features present.
2	Features present and resistant to disturbance.
3	Feature present and of moderate sensitivity to disturbance.
4	Features numerous and of high value. Features sensitive to disturbance.
5	Features rare, valuable, numerous and/or of great sensitivity to disturbance.

EDUCATIONAL OR SCIENTIFIC VALUE

VALUE	EXPLANATION OF VALUE
0	Caves lacking educational or scientific value.
1	Caves with low educational or scientific value.

VALUE	EXPLANATION OF VALUE
2	Caves with features which can be used for educational or scientific study but are otherwise considered common to the area.
3	Caves which provide opportunity for educational or scientific study.
4	Caves providing *unusual* opportunity for educational or scientific use.
5	Caves with *unique* opportunity for interpretation and public education or scientific study.

CAVE CLASSIFICATION

Caves have be placed into one of the following classes based on management objectives consistent with identified cave resource values.

As new caves are discovered they will be temporarily managed as Class 1 until an analysis of resource values is completed.

CLASS	EXPLANATION OF CLASSIFICATION
CLASS 1	**SENSITIVE CAVES.** Caves considered unsuitable for exploration by the general public either because of their pristine condition, unique resources or extreme safety hazards. They may contain resources that would be impacted by low levels of visitation. These caves are not shown on maps or discussed in publications intended for general public use such as guides, brochures or magazines. Specific management guidelines will be developed for each sensitive cave for the purpose of protecting and maintaining their resources.
CLASS 2	**DIRECTED ACCESS CAVES.** Caves with directed public access and developed for public use. These caves are shown on maps or have signs directing visitor access; frequently have guided tours and artificial lighting. Regardless of the level of development, public visitation is encouraged. The caves may have sensitive resources that are protected.
CLASS 3	**UNDEVELOPED CAVES** Caves that are undeveloped but are suitable for exploration by persons who are properly prepared. In general, these caves contain resources that resist degradation by moderate levels of recreational use. Public attention will not be directed toward these caves. They will not appear on maps, or in brochures or publications intended for general public distribution.

CAVE EVALUATION AND CLASSIFICATION

CAVE NAME	BIOLOG-ICAL	HYDROL-OGIC	HISTORIC	RECREAT-IONAL	GEOLOGICAL, PALENTOLOG-ICAL, ETC.	EDUCAT-IONAL, SCIENTIFIC	CAVE CLASSIFICATION
Ape Cave	2	1	3	3	3	4	2
Barney's Cave	2	0	1	2	2	2	3
Beaver Cave	4	0	1	3	3	3	1
Beaver Bay Cave	3	0	1	2	2	3	3
Bat Cave	5	0	1	3	4	5	1

CAVE NAME	BIOLOG-ICAL	HYDROL-OGIC	HISTORIC	RECREAT-IONAL	GEOLOGICAL, PALENTOLOG-ICAL, ETC.	EDUCAT-IONAL, SCIENTIFIC	CAVE CLASSIFICATION
Breakdown Cave	2	0	1	1	1	1	3
Blue Ribbon Cave	2	0	1	3	4	3	1
Christmas Canyon Cave	2	0	1	2	4	4	3
Column Cave	3	0	1	1	3	1	3
Dollar-And-A-Dime Cave	3	0	1	4	3	4	3
Dogwood Cave	1	0	1	2	2	1	3
Duckwalk Cave	2	0	1	1	1	1	3
Flow Cave	3	0	1	3	3	3	3
Gremlin Cave	2	2	1	3	4	4	3
Helium Cave	2	1	0	2	1	1	3
Hunter's Cave (Three-Corner)	2	0	1	2	1	1	3
Lake Cave	2	3	1	4	2	3	3
Little Peoples Cave	3	1	1	3	2	3	3
Little Red River Cave	3	4	1	4	4	4	3
Low Cave	2	0	1	1	3	1	3
Manhole Cave	2	0	1	2	1	1	3
Mosquito Caves	1	0	1	1	3	1	3
Ole's Cave	4	0	3	3	3	5	1
Pillars of Hercules Cave	2	0	1	4	5	5	1
Prince Albert Cave	3	0	1	4	5	4	1
Rockpile Cave	2	0	1	2	2	1	3
Sand Cave	1	1	1	1	1	2	3
Shortstop Cave	1	0	1	1	1	1	3
Snow Pit	1	0	1	1	1	1	3
Spider Cave	5	0	1	1	4	5	1
Stan's Cave	1	2	1	1	1	3	3
Thermal Cave	3	0	1	3	2	1	3
Trenchend Cave	2	0	1	1	2	1	3

ACTIVITIES OF THE TEXAS CAVE MANAGEMENT ASSOCIATION

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ABSTRACT

Five years ago, environmental regulations for karstlands did not exist within the State of Texas. Today, it is a "legally" pursued process of investigations and report filings required by City, State, and Federal entities precluding land planning, engineering, commercial and residential development within the "CRISIS" zoned areas of Austin in Travis and Williamson Counties, Texas.

Range and distribution of species study projects for the invertebrate biology of karstlands continues to be performed to serve as guideline criteria for a federal plan that is designed in scope for addressing up to forty-one Texas counties. The progression of biological and environmental karst runs barely ahead of an the expanding giant, the "Legal Processing Machine". This compares to the environmentalist that runs just ahead of the "bulldozer".

Observing the planning attempts for large scale preserve lands protecting endangered birds and karst invertebrates has been like watching a political "rugby game" with the ball as the issue. Regardless of who wins the game, cave and karstlands management lies at the end of the road. Hidden in the weavings, and quite detached from the "big" political arena, the TEXAS CAVE MANAGEMENT ASSOCIATION (TCMA) eases ahead with the very first "active" management contract for three cave sites that contain endangered cave invertebrate species.

IN THE FACE OF CHANGE......A TIDE OF PRESERVATION

The decade of the 1980's has marked the beginning of distinct and meaningful changes of environmental views and concerns from Texas caves and karstland areas. The prime areas in which most significant changes have occurred are described as the "CRISIS" areas, or areas subject to rapid oncoming construction and development. Prior to 1986, environmental concerns for the protection and preservation of numerous karstland features in these areas were shared on an active basis primarily by cavers, a small handful of biologists, and environmentalists who recognized early on that many sensitive sites would become lost and/or destroyed in the rapid growth process. A massive wave of growth and development in the Austin and San Antonio areas from 1981 to 1985 heightened environmental awareness and concern as numerous caves and sinkholes were being either filled or destroyed in the path of new land developments. Local groups of cave explorers and field related individuals began efforts to inform various public officials of the devastation, but soon became overwhelmed by the frustrations and slow reacting responses containing little or no cure. Initial responses to the problems were weak and indirect without any specific environmental regulation in effect. Most were simple "unaware" of the presence of karstland features, aside from any real comprehensions of what lay beneath the surface of the ground. This was the "climate of the times" in which the TEXAS CAVE MANAGEMENT ASSOCIATION was born in early 1986. This year was particularly ear-marked by an upswing of environmental consciousness across the country for both air and water-quality controls. At about that time, as continues to the present day, "Environmental Karst" has been described by many newspapers and magazines as "a science coming of age" in this country.

Among the first of the agencies to express environmental concerns was the EDWARDS UNDERGROUND AQUIFER RESEARCH CENTER in San Marcos, Texas. The time had come in which the scientific recognitions of the role of caves and sinkholes as insurgent recharge paths into the aquifer needed to be launched forth into some form of public education effort. The subject matter had risen to a level of both controversy and concern in the Austin area. Finally, public officials began their attempts of constructing regulation and ordinance proceedings. That same year, TCMA members served in an advisory capacity to the City of Austin's formation committee to address the importance of karst terrain features. The product of that committee's efforts became known as the "Comprehensive Watershed Ordinance of 1986". This ordinance was the first in the area with provision for the protection/preservation of karst features being defined as "recharge features". It was also one of the first "silent" victories for the TCMA. A short time later, an Austin and San Antonio led effort by TCMA members and concerned cavers attempted to introduce new state cave legislation at the State Capitol. The first attempts were not successful, but not a dead issue either. At a later date, the efforts resulted in legislative law that provides a greater degree of liability relief to private land/cave owners in Texas. This provision was included within the "Texas Sportsman's Law", while the main body of what was the "Texas Caverns Protection Act", lies buried within the headings of "septic and sewage treatment".

At about the same time and unbeknownst to many, noted speleobiologists were making a submission of rare and unique karst invertebrates for potential listings for the Federal Register of Endangered Species (Endangered Species Act of 1973). This effort was led by James Reddell and William Elliott, and much to their surprise, five invertebrates were included in the register in September of 1988 (U.S. Fish & Wildlife Service). At the same time, no one would have imagined the degree of change to our lives this and other environmental regulations would effect.

In about November of 1988, the Texas Water Commission made it's opening move with regulations on karst features, with provision for protection of all karst features studied and evaluated as "point recharge" features. This provision became incorporated into the reporting process of all "water pollution abatement" plans for new developments in the Austin area jurisdiction. At this point, the environmental "gaps" were now filled. Regulation, by virtue of activity, was restricted to the Austin metropolitan area and has only recently begun to expand outwards of this region.

The federally endangered species program, as applied to Texas karst, was initially designed in scope, to eventually address potential issues in a total of forty-one Texas counties. In some of the less well received areas, hard-nosed political factions will have to bend far enough to incorporate "environmental stabilities" where needed. By the time that these battles are resolved, it may indeed be too late for effectiveness in some prime areas of the State...but at least the "train is coming!" Water quality control programs are also being designed to eventually address the true "wholeness" of the Edwards Aquifer, which is one-quarter the size of the state and further more, the single largest expanse of karst aquifer in the country. Within these areas, each city's growth situation is more likely than not to develop it's own watershed ordinances, or adopt another city's for karst hat has been proven to work.

In the state capitol area, the first official study site processed for environmental evaluation under the regulation for "Endangered Invertebrate Species Habitat" was the old "Kretschmarr Ranch" of which had become partially encroached upon by commercial and residential developments in 1987-88. The site included the now infamous "Tooth Cave" from which the original invertebrates were found and studied since the early 1960's. This site study project became contracted to George Veni & Associates. Together, George and I wrote our evaluations and interpretations of the site. The first biologically designed cave gates were designed, built, and installed under this regulatory process.

Looking back after five years, I can still vividly recall our first meetings in the field with U.S. Fish & Wildlife personnel. It was early on a foggy morning atop the "Jollyville Plateau" karst. Somehow we expected, or at least anticipated, that these representatives would be able to tell us exactly what and how to do things under this study process. Some "magically" produced set of guidelines would surely follow, and we would now become as students under a federally guided process. Well..."this didn't happen!" Instead, we were to become servant to filling the "teacher" role positions of the karst study processes, the finders and evaluators of invertebrate habitats, the databank gatherers of scientific facts, and ...true diligent students of delineated karstlands. Some of us would go on to lead the way and refine many site study processes. A tremendous load of data has been generated since then. The values of this data under a process of federal review has been the difference between usable and non-usable land areas for development. Non-usable areas have been designated as protected preserve lands and sites.

The study of karst is not an exact science. Still in an infancy of study, each question that becomes answered typically generates more questions. It is..."the nature of the creature." During a span of 33 years of active caving, many times have I heard a colleague say the following. "Some day, some how, I will find a way to make a living from karst." Call it good karma or whatever you will, unexpectedly, I had found that I was in the right place at the right time and I had been thrown a "ball" of opportunity. I had said my farewells to petroleum geology, and to soils mechanics, and ran with this "ball" all the way to the karstlands goal post. I became an environmental contractor for these processes in 1989, have since formed a company which has pioneered a "fine-tuned" methodology for evaluating and documenting karst terrain features. Thus-far, it has been a highly successful venture due to a critically "strong" conviction to do things the right way, because in this business there can be no short-changing of quality for quantity. We are proud of and enjoy and excellent reputation for our work performance, and "yes" we have been trying to set an example for the methods in which legal karst work of this nature is done. We are currently working on and developing a forthcoming publication with intent of attempting a "standardization" for the methodology in which this work process is performed. We've been told many times locally, that we are making other environmental companies look bad. Well...we feel that things happen mostly for a reason. I will stick to what I have stated from the very beginning...I don't worry about the competition!" In fact, I really don't care about how many people do karst work, as long as they are doing it right! What else can I say? We love karst, and the jobs that this activity has afforded us, but the red tape and paperwork is truly tough. Some of the feedback from local caving communities has been interesting, as there seems to have been a popular misconception that our jobs and what we do is all fun and games. However, this thinking is usually returned to stark reality and diffused when we extend an open invitation to join us for a local sinkhole excavation in the August heat. And so it goes. Some of the most difficult and labor intensive occupational work that we have ever experienced has been a component in karst study projects. Often, there are hard tasks performed out of a labor of love as much as any other aspect.

Since 1989, my company's records have indicated the following data of new caves produced: Travis County, 67 new caves; Burnet County, 19; Hays County, 3; Williamson County, 143; Bexar County, 4; and Coryell County, 14. Most (95%) of these new caves carries an official "protected assignment classification status. In Williamson County, the numbers of new caves found as a result of the activity is soon expected to exceed the number of previously known caves filed with the Texas Speleological Survey (TSS). A total of 45 caves have been gated in Travis, Williamson, Bexar, San Saba, Crockett, Pecos, and Medina Counties. The largest Texas bat cave gate, of which lies 800 feet inside and 110 feet underground was built at Gorman Cave (San Saba County) in 1992 by our firm, with assistance from the Texas Parks & Wildlife Commission, Texas Cave Management Association, and the Texas Speleological Association volunteers. This successful, record setting feat produced a "wall" gate measuring 15 feet wide by 15 feet high. Observations from a year later in the cave have indicated that a greater percentage of the bat population now roosts beyond the gate then ahead, between the gate and the cave entrance.

Many of these environmentally sensitive cave and karstland sites are ripe for cave management and stewardship programs. Because environmental regulation exists now, where it was absent in the past, it has been possible for the Texas Cave Management Association to accomplish many good things. As we in Texas stand back and look at this organizations "position in the universe", we know that no successful organization is built and survives without commitments, and the pains of growth and personal sacrifice.

In Texas, this organization presently owns two cave preserves, and manages five additional sites. The organization is the first to initiate by contract and actively manage an "Endangered Invertebrate Species Habitat" and major "Point Recharge" preserve site. This site is known as the Marigold Cave Preserve and consists of three caves; Marigold Cave, Pebblebrook cave and Forest Trail Cave and is part of a greater structural and "living" cave system in a defined area in Williamson County known as the Buttercup Creek Karst. Marigold Cave is presently the largest with 430 feet of mapped passages. An additional recent discovery during an excavation and gating project led explorers to the first known perennial cave stream of the Northern Edwards Plateau. This stream passage has been explored in excess of 1,000 feet and continues in both upstream and downstream directions.

The Marigold Preserve caves contain an endangered troglobitic invertebrate cave beetle species known as *Rhadine persephone*. The scientific documentation of these caves and relation to the larger structural system is still very young at this site. A great wealth of knowledge is anticipated from this cave system in the years to come.

The TCMA has recently extended site management positions to it's members in West Texas with the Permian Basin Speleological Society for the continued management of O-9 Well in Crockett County and Amazing Maze Cave in Pecos County. These members are doing a fine job!

The City of Austin finally recognized through a cave management contract that it needs the TCMA's assistance to help identify and inventory the karstlands and caves that it owns. TCMA member William Russell is actively leading that effort and much progress is being made. It has since further provided the city's park and recreation department with valuable data from which they have developed policy planning towards the usage extents of their caves.

The city of San Antonio is another "crisis" area of environmental concerns. This city desperately needs to develop an environmental ordinance to provide protection for the remaining karst features it has left! State and federal regulations need to expand into this area as well. Massive karst education programs need to be implemented there for the general public, and for many public officials. Political factions there must bend to provide environmental protection of karst if that city is to continue to survive solely off of the Edwards Aquifer for its water needs. The TCMA stands ready to do everything that it can to assist in these processes, and support the efforts of the many fine and concerned citizens who live there. It appears that the protective process there will come slowly at best, cavers and friends of karst will surely have to weather a lengthy storm of uncertainty on their road to progress.

Several "range and distribution" study projects for karst invertebrates have been funded and undertaken to gather additional scientific data. These studies are being performed for many reasons. Among them is the potential for the expanded protection of species. Such a study was recently performed in Bexar County (San Antonio). We remain hopeful that environmental regulation will migrate to Bexar County on the state and federal levels in the near future. In the face of change and struggle of troubled areas, the future outlook for the TCMA to do what it was designed to do has never been brighter. Communications and education are the mastering tools in which it's members can make the difference that will be ultimately reflected in the caves that we know and love, and our share for preservation in the world's environment in which we must live, and hopefully survive!

CAVE MANAGEMENT ISSUES IN A NORTHERN FLORIDA STATE PARK

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INTRODUCTION

Florida Caverns State Park is a 1,279 acre area located in northwestern Florida in Jackson County, approximately two miles north of the city of Marianna (Figure 1). It is one of Florida's most unique public parks, and the only state park featuring cave tours.

Florida Cavern, the cave from which the park derives its name, was originally developed as a tour cave by the Civilian Conservation Corps. An average of 65,298 visitors a year toured Florida Cavern during the five year period of 1987 through 1991. Approximately twenty-five limestone caves have been reported to exist in the park. However, a complete survey of caves in the park is lacking.

The Florida Department of Environmental Protection, Division of Recreation and Parks, hereafter referred to as the Florida Park Service (FPS), assumed management of the park in 1935. The FPS is responsible for the management of all of the park's resources, with the exception of the 9-hole golf course which is leased to a private organization (the Marianna Golf Association Inc.). The FPS strives to manage the park in accordance with the Division's mission, which is stated as follows: "To provide resource based recreation while preserving, interpreting and restoring natural and cultural resources."

Prior to 1991, cave management at Florida Caverns State Park consisted primarily of biannual applications of bleach to control algae in Florida Cavern and the construction of gates across selected cave entrances to exclude unauthorized entry. In 1991, the FPS initiated a cave management project for the park. This paper discusses the history of the project, some of the surprising discoveries made during the project, and the results and consequences of the project to date.

PROJECT INTIATION

In early 1991, I had the opportunity to attend and evaluate a "spelunking tour" at Florida Caverns State Park which is located approximately sixty miles west of the FPS District Two office in Tallahassee where I worked as a biologist. I had never considered entering a wild cave, but nevertheless I was enthusiastic and interested.

I arrived at the park early one Saturday morning thinking that I was "ready" to attend the tour. I was equipped only with one FPS issued maglight.

The group I was with visited three "wild caves." The third cave we visited, known as Miller's Cave, was perhaps the most enlightening. Our tour guide informed us that 90% of the speleothems which had once existed in Miller's Cave had been destroyed by vandals. Signs of the vandals, such as spray painted graffiti, broken speleothems, and trash were visible throughout the cave.

As our group of twelve crawled on our stomachs through a rather tight passage in the cave, another group of twelve passed us going in the opposite direction. The leader of the second group informed our tour guide that there was yet another group, presumably the same size as ours, following closely behind his. As I crawled along hoping that we would not bump into the third group in the tight passageway, I overheard the leader of the second group casually ask our tour guide how to get out of the cave. Needless to say, my evaluation of the event was not positive.

Following the submittal of my evaluation of the tour, I was requested to develop a management plan for the caves of Florida Caverns State Park. Knowing practically nothing about caves and absolutely nothing about cave management, I decided that my first action should be to read the management plan for the park, which touches briefly on cave management. I was shocked to see that our own plan called for restricted entry to Miller's Cave because it had been used as a transient cave for federally endangered gray bats (Myotis grisescens). As I reflected on my visit to Miller's Cave during the recent spelunking tour and realized that I had been in the cave with some thirty-three other people, I became quite concerned. In my new role as District Cave Biologist, I immediately called for the discontinuation of the spelunking tours. I began researching caves and cave management. In addition, the assistance of an National Speleological Society (NSS) member was enlisted. He generously volunteered to conduct a basic evaluation of the park's caves over a one year period. Unfortunately, an inordinately large amount of rain fell during that year and, due to cave flooding, the evaluation project had to be extended another six months.

I began visiting the accessible caves with the NSS volunteer and with some of the park rangers. In one beautiful cave we visited, park rangers described how they forced their way into a room in the cave which is considered by some people to be the prettiest room in the park. The rangers had enlarged the passageway into the room, which is known as the Dragon's Belly Room, just five years prior to my visit. Although the cave had been gated, fairly uncontrolled access to the gate key had taken its toll on the cave and especially the Dragon's Belly Room. Broken speleothems littered the cave floor and muddy footprints stained once beautiful white flowstone. The NSS volunteer project leader could not find a single area in the large, decorated room where he could take a photograph without showing some type of damage from careless, uncontrolled visitors.

CAVE MANAGEMENT ISSUES ENCOUNTERED

My proposal to close the wild caves, coupled with the FPS decision to grant exclusive entry rights to the NSS volunteer, led me to my first major discovery in cave management -the politics of caving. I quickly learned that there were three caving organizations in Florida and that all three of them had knowledgeable, willing and able members who would have loved to have been involved in the assessment of the cave resources of Florida Caverns.

Rumors about my intentions spread throughout the caving community and I was soon receiving letters and phone calls questioning my motives. Fortunately, I was invited to attend a statewide gathering of cavers where I was able to dispel almost all of the rumors by explaining that my decisions had been based on ignorance of cave management and an honest attempt to initiate a responsible cave management project which would protect the remaining cave resources.

The positive response to my painfully honest presentation was encouraging. I began to receive supportive letters and phone calls from concerned cavers throughout the state. Cavers sent important historical information about the caves in the park and one caver even wrote a draft cave management plan for the park which included much useful, helpful information. The support from the caving community was genuine and abundant.

Numerous cavers from around the state participated in the volunteer evaluation project. Their participation was vital and appreciated. After the seasonal rains stopped, previously flooded cave passageways became accessible and the volunteers picked up the pace on the assessment project. This led to another important discovery. In December of 1991 the volunteer project leader noticed dark stains on the ceiling and floor in a room of Boyer's Discovery Cave.
The volunteer believed that the stains might have been caused by leaking sewage.

The Director of the FPS quickly closed the restrooms above the cave, which happened to be at the visitors center, and had porta-potties installed. A simple test for sewage leaks was devised by the FPS. On 29 January 1992, approximately 2 quarts of Rhodamine dye were poured into one sink and one toilet of the men's restroom at the visitors center. At the same time, six empty buckets were deployed in the cave under some of the dark stains to catch any liquid drippings. On 31 January 1992, the buckets were recovered. Of the six buckets, four were full of Rhodamine stained solution, one had fallen over, and one was full of clear liquid. This was the evidence we needed, and in February, the septic tank was drained and several holes in the tank and pipe leading to the tank were repaired and sealed. The restrooms were immediately reopened.

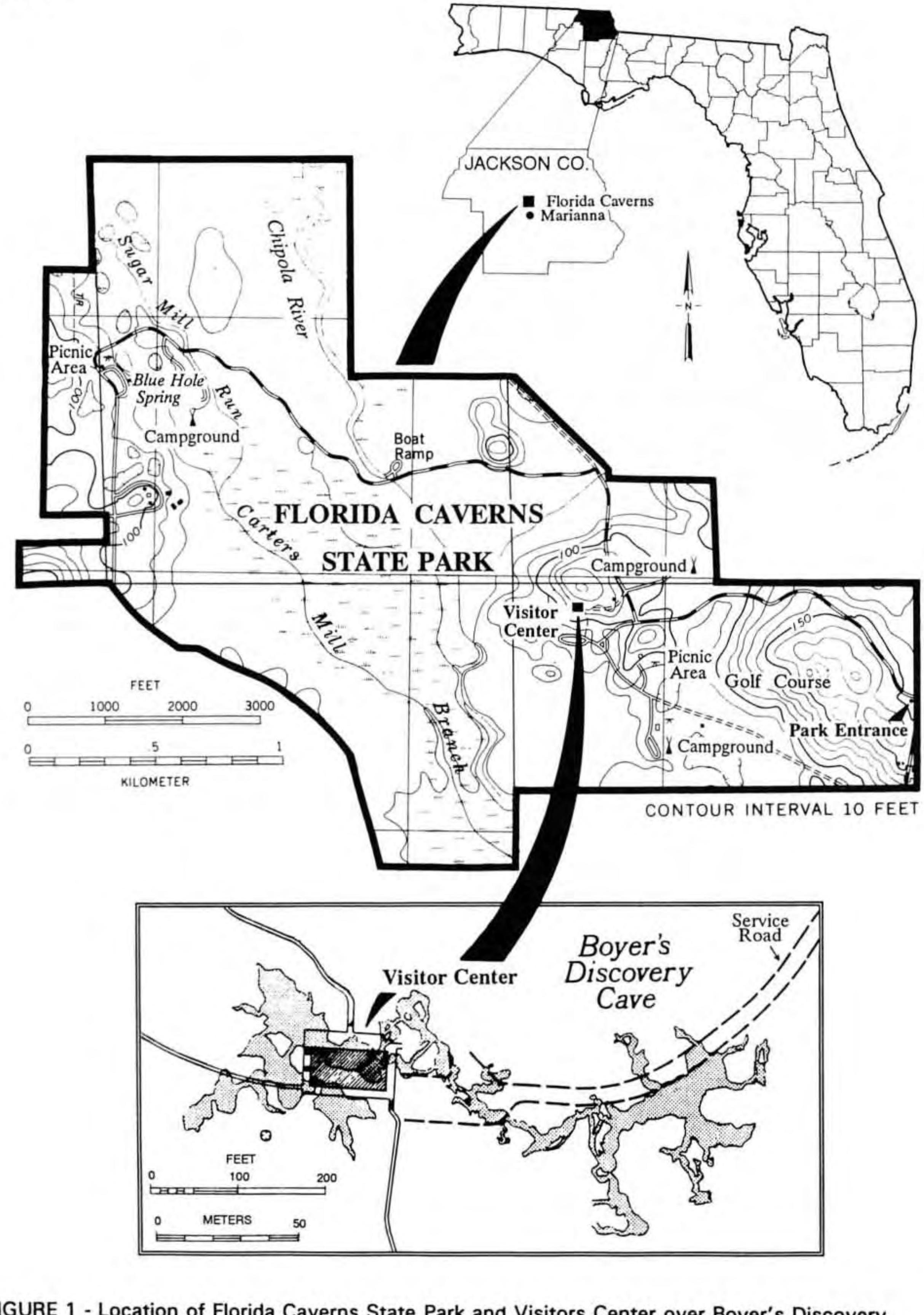

FIGURE 1 - Location of Florida Caverns State Park and Visitors Center over Boyer's Discovery Cave. (Florida Caverns inset map modified from U.S.G.S. 7.5' Marianna quadrangle map; Boyer's Discovery inset map after Maddox, 1987.)

A subsequent inspection of the 15 other septic tanks on the park revealed that two of the tanks had two small holes each, the floor of one of the tanks had several soft spots, the sides of one tank were cracked and probably leaking, and three septic tanks had dirt floors (Norris, 1992). Although these problems were significant, no action was taken because of budgetary restraints. The district manager hoped to address the problems in the future.

My research led me to another potentially significant discovery. Through conversations with various cave management specialists, I learned that unnatural algae and moss growth in Florida Cavern is not only aesthetically unpleasant, thereby diminishing the quality of a visitor's experience in the cave, but is also potentially damaging both biologically and geologically (Dr. Tom Aley, personal communication, February, 1992). Although the park staff had occasionally sprayed the plants with pure bleach, no control or eradication plan was in place. Rangers spoke about lingering bleach odor and of opening all three doors to the cave to get rid of the smell. Unaware of the negative impacts of these plants, management allowed one patch of plants to grow so that visitors could see plants growing in the cave.

Continued research into cave management led me to realize that the small northern Florida park had many more problems than I had imagined. The problems seemed endless. Once I discovered that the management issues were bigger than I could possibly handle, I called National Park Service (NPS) Cave Management Specialist, Ronal Kerbo, who graciously offered to visit the park. The NPS agreed to Ron's visit and we were fortunate to work with him for one week in March 1992.

During his visit, Ron brought another major issue to our attention. A paved road in the park passes directly over China Cave. Ron observed that the limestone appeared to be quite thin between the pavement and the cave ceiling. Meanwhile, we received information from an NSS member that an informal map of the cave had been made in 1973 and the map revealed that the distance between the pavement and the cave void was just seven feet.

MANAGEMENT ACTIONS TAKEN

The evaluation of the cave resources at Florida Caverns revealed more problems than we had anticipated. However, with the assistance of volunteers throughout the state, Ron Kerbo and a multitude of cave managers and biologists who provided suggestions over the phone and through the mail, a twenty-four section management plan for the caves was developed which addressed all of the observed problems. With Ron's permission, much of the information in the plan was taken directly from various successful NPS cave management plans. A draft of the plan was distributed for public review in July of 1992.

Response to the plan was positive. A six hour meeting was held with representatives of the three existing caving organizations in the state, two newly formed caving organizations, the park manager, one park ranger, and other FPS staff. The concern for the park's resources was displayed by the volunteer's willingness to come from all over the state and spend six hours on a Saturday to assist the FPS with the plan. All of the suggestions made during the meeting were taken into consideration and incorporated into a final draft of the plan which was produced in January 1993.

During the meeting in July, it was decided that some type of action should be taken at the park to get the cave management plan implemented. Since none of the wild caves could be open to recreational activities until a biological assessment was complete, a complete biological assessment was given the highest priority. By the late fall, we had selected two cave biota specialists to conduct the biological assessments.

Like many other state government agencies, the FPS was in terrible financial condition in 1992. Thirty FPS employees were laid off during the summer and we no sooner had selected the biologists to conduct the biological assessment of the caves when our budget was cut. The biological assessment was not considered a necessity by the FPS and consequently funding for the project was withdrawn. In fact, the need for a district office was questioned. By the time I notified the biologists that we could not afford the assessment, I was told that the entire district office would be closed.

Luckily, I was offered a job with the Florida Geological Survey and was given time to finish the final draft of the cave management plan for the FPS. However, with the loss of my position and two other biologists in the district, no action has been taken to implement the plan.

The Florida Speleological Society (FSS) volunteered to assess the road situation at China Cave. Volunteers from the FSS remapped the cave and confirmed the depth of substrate between the road and the cave void. The FSS evaluation of the cave was completed and submitted to the FPS in January 1993. The FPS sent a thank you letter to the FSS and no further action was taken. Although the FPS acknowledges the situation, staff and budget constraints have precluded further action.

The condition of the septic tanks was given priority and the FPS has continued to look into the problem. At the time of this writing the FPS intends to repair all of the leaking tanks and, when funding is available, remove the tanks and connect to the city sewer system.

RESULTS AND DISCUSSIONS

To observers outside of government or cave management, the history of Florida Caverns State Park may seem pathetic and unbelievable. However, managers of public caves throughout the nation may read this report and feel as though they might have written it themselves.

At one time, the FPS managed Florida Caverns State Park almost as if it was purchased by the state as a money making venture. In fact, the total income graph still hangs in a prominent position on the wall in the park office. Recent revelations in the fields of speleology and cave management have shown, however, that focusing on profit alone may result in permanent destruction of fragile, nonrenewable cave resources.

The Florida Caverns project reveals that progress in public cave management comes from open, honest communication with the caving community and the land management staff. Public employees charged with the responsibility of managing publicly-owned caves must be willing to learn, to change management strategies in response to advances in research and technology, and to acknowledge mistakes when they occur.

The director of the FPS has followed this philosophy and as a result the visitor's center septic tank was repaired, the FPS is working with city officials to connect the park to the city's sewer system, and a park biologist was hired in June 1993. Despite budget and bureaucratic constraints, progress occurs, albeit slowly.

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THE CREATION AND IMPLEMENTATION OF RESTRICTIVE CAVE MANAGEMENT POLICIES

THREE EXAMPLES FROM SEQUOIA AND KINGS CANYON NATIONAL PARKS

Joel Despain

The implementation of a cave management program in Sequoia and Kings Canyon National Parks, which includes the creation of a cave specialist position and a cave management plan, has caused many changes in the management of most Park caves. The management policies and practices for three Park caves, commercialized Crystal Sequoia Cave, Lost Soldier's Cave, and Hurricane Crawl Cave have been particularly challenging to create, implement, and enforce. The results of these efforts have been better protected caves and cave restoration work, but the costs include the creation of rigid rules and procedures, complex in-cave infrastructure, a dramatically increased work-load for the park management staff, and inconvenience for a wide range of park users including casual visitors, cavers and cave-researchers. Future efforts involving the management of park cave resources will be influenced by the benefits and short-comings of these management programs.

GEOLOGIC, GEOGRAPHIC, AND HISTORIC INTRODUCTION:

Sequoia and Kings Canyon National Parks cover an area of 863,680 acres in the southern Sierra Nevada of California. Park elevations range from 1370 feet along the Kaweah River near park headquarters to 14,495 feet atop Mount Whitney, the tallest peak in the contiguous 48 states. Geologically, the Parks are a segment of the Sierra Nevada Batholith composed chiefly of granitic plutons of Jurassic and Cretaceous age. Metamorphic roof pendants, of marine origin and believed to be of Triassic and Jurassic age, cover approximately 20% of the Parks' surface. Dominant types of metamorphic rocks include meta-volcanics, schist, quartzite and marble. Marble exists as narrow bands along the Parks' lower-elevation, western-edge, near the crest of the Great Western Divide in the Mineral King area and along the main crest of the range in central Kings Canyon near Mt. Pinchot.

Most Park marble is cave-bearing and to date 178 caves have been discovered. Cave temperatures vary from near freezing to over 60 degrees. They range in length from a few meters to more than 20 kilometers and can be found at elevations from under 1,500 feet to more than 11,000. One park cave is commercialized.

The first formal accounting of Park caves is from a 1918 Superintendent's report which lists and describes five caves. A 1980 report by the Cave Research Foundation lists 80 caves. Cave management efforts in the Parks began in the early 1980s and included brief drafts of cave management plans and the assignment of cave management as a collateral duty to a permanent member of the park staff. A formal cave management program began in 1990 with the creation of a seasonal Cave Specialist position, and a Cave Management Plan for the Parks was completed in the fall of 1992.

Not surprisingly, the activities of the new cave management program, including the implementation of the management plan, and the condition and status of certain Park caves have led to the creation and implementation of specific restrictive management policies and plans. In the case of three park caves these plans have been challenging to create and implement and remain controversial. Crystal Sequoia, the Parks' commercialized cave is being managed with newly implemented tour size limits, severely restricting access to the cave. Lost Soldier's, a popular vertical, wild cave is undergoing a mandated restoration before new requirements for trip leaders and new limits for trip sizes are fully imposed. Hurricane Crawl, a well-decorated, newly-discovered cave will be managed under a complicated structure of access and activity restrictions. The creation and implementation of the restrictions and requirements in these caves and the shortcomings and problems with these management practices are the subject of this paper.

CRYSTAL CAVE

Crystal Cave has formed at an elevation of 4,600 feet where the oak woodlands, chapparal and grasslands of the Sierran foothills begin to give way to mixed conifer forests of the mountain's higher elevations. The cave is reached via a six-mile-long dead-end road and a half-mile-long steep trail. The trail descends into a canyon formed by Cascade Creek to the cave's main entrance, which lies along this perennial stream.

Crystal has formed as a complex maze whose dominant trend is perpendicular to the narrow steep ridge in which the cave lies. The ridge is defined by Cascade Creek to the south and Yucca Creek to the north and has formed immediately above the confluence of these streams. The piracy of water from Yucca Creek to Cascade Creek has been the dominant hydrologic force in the development of the cave. Currently Crystal is known to have four entrances and 12,800 feet of passage. Most of the cave consists of phreatically -formed, anastomostic mazes, but areas of vadose overprints and breakdown mazes are also common. Many sections of the cave contain rich speleothem development, including large areas of flowstone and rimstone, thousands of soda straws, stalactites and curtains, and more than 50 shields.

Crystal was first noticed by Europeans in 1918 when two park employees stumbled upon it while fishing. The Park Superintendent, Walter Fry oversaw exploration of some of the cave and was impressed with its features. The cave entrance was boarded-up for twenty years and only occasional groups of tourists and rangers visited Crystal. In 1938 funding from the Works Progress Administration was obtained to develop the cave. The Civilian Conservation Corps began a two year project to install a half-mile-long, packed-dirt, loop trail and more than 100 incandescent lights. As is typical, commercialization of the cave was very destructive. Hundreds of formations were broken and hundreds of tons of rubble from blasting tunnels and enlarging passages were left in the cave, filling and damaging many passages.

The loop trail has allowed two tours to move through Crystal simultaneously, and generally eleven 50-minute tours per day enter the cave. Tours begin at half-hour intervals and occur during the summer months of May through September. For most of the years the cave has been open, tours ran from Thursday through Monday. Many passages along the tour route are narrow and confined and the trail is often in close proximity to cave formations. No protective walls or railings between the trail and delicate areas were built during the commercialization of the cave.

Tours began in 1941, and the cave was immediately popular. Except for a brief hiatus during World War II, visitation grew steadily during the Forties, Fifties, and Sixties. The heaviest daily visitation recorded at the cave was during Labor Day weekend of 1969 when 2,100 people saw the cave on 12 (one extra to accommodate the crowd) tours, for an average of 175 people per trip. Similar heavy visitation was common on August and holiday weekends during the Seventies and Eighties. During this time it was also fairly common for individual tours to contain more than 200 people. Rarely was there more than one guide on a tour.

In 1981, saddled by budget cuts, the Park Service relinquished control of the Crystal Cave operation to the Sequoia Natural History Association (SNHA), a non-profit corporation which has been operating in the Parks since 1940. The SNHA's greater flexibility in scheduling and financing allowed for efforts to reduce the size of tours at Crystal. In 1985, the staff was enlarged to allow the cave to be open seven days per week, adding 22 tours. In 1986, an informal limit of 180 people per tour was created, and a limit of 140 was imposed in 1988.

Though, the SNHA Management Staff had made serious efforts to reduce the number of individuals on trips through the cave, tours remained too large, and in 1991 disaster struck. Approximately three-square feet of curtain-type formation was broken from the bottom of "The Pipe-Organ" in the Organ Room, during Labor Day Weekend. This formation had already been seriously damaged in the late 1950s during a two-year period when tourists were allowed into the cave without guides. The subsequent serious damage in 1991 has permanently altered the appearance, shape, and micro-hydrology of the formation.

Due to the overwhelming size of tours (140 people each) three tours walked past the site of the damage before employees had an opportunity to examine the broken formation and collect pieces not pilfered as souvenirs. The culprits were not caught but other tourists on the tour reported that the individuals were trying to take a photo when the damage occurred.

REMEDYING THE SITUATION AT CRYSTAL CAVE

While it is impossible to know if the damage done to the Organ formation would have occurred had tours been a more reasonable size, this incident made it clear to Park staff that the large tours at the cave were a serious problem. Public reaction was also negative and the Park and SNHA were sternly criticized for the incident in an editorial by the *Visalia Times Delta* Newspaper. Through discussions with other park service units where commercial caves operate, it was, also, painfully clear that Crystal Cave was dramatically out of step in its ratio of tourists to guides. (See Table 1)

A memorandum to the Park Superintendent in September of 1991 summarized the problems created at Crystal Cave by the large tours.

1. Interpretation: Groups with more than 90 people can make only one interpretive stop during the course of the 50-minute-long tour. The explanation and interpretation of Crystal Cave's geology and biology is difficult in a single stop, using the features of only one room as examples for visitors. Large tours often contain multiple crying babies or upset children, and hecklers or generally disruptive persons who may make effective interpretation impossible. Groups of this size also limit access to the tour leaders, thus a smaller percentage of people in the group have the opportunity to ask questions or to engage the guide in informal conversation.

2. Safety: As the only representative of the Park on tours, the guides employed by the Natural History Association are responsible for safety on these excursions into Crystal Cave. With large tours this task is simply impossible. Reports of injuries are often slow to reach the tour leader (they may move through a crowd of over 100 people strung out over 1,000 feet of cave passage) and are often inaccurate. When these reports do reach the guide it is often difficult to reach the person in distress due to the clog of people filling the cave's rooms and passages. With a single guide on a tour, communicating with other employees at the cave entrance about problems in the cave and caring for an injured or sick person, simultaneously, is not possible.

3. Resource Protection: Thousands of people pass within a few feet of delicate cave formations, and large tours preclude careful supervision of these park visitors. This has resulted in the damage to the "Organ", the incessant touching of many formations, permanently altering their growth and coloration, coins in the cave's stream and rimstone pools, other broken formations in the Dome and Junction Rooms, visitors stepping on formations near the trail, and small formations or broken pieces of formations being stolen from the cave.

4. Other problems: Due to California's cultural diversity, and the popularity of California with foreign tourists, many visitors to the cave do not speak English or do so poorly as a second language. Communicating rules and recommendations to these visitors is difficult. With large groups there are often people speaking seven or more different languages on a single tour.

Table 1: tour sizes at selected Park Service commercial caves.

Park Service Cave	Maximum tour size	Number when a second guide is added	Number when a third guide is added
Crystal Cave before 1992	140	-	-
Crystal Cave in 1992	70	Most weekend tours have two guides	
Oregon Caves	18 adults or 24 children	-	-
Mammoth Cave	20 to 60	27	50
Jewel Cave	40	50% of all tours have two guides	
Wind Cave	40	-	-

All data from personal communications with respective Park staff, September 1991.

In the Fall of 1991 and Spring of 1992 an informal committee composed of the Executive Director of the SNHA, the District Ranger for the section of the Park which contains Crystal Cave, the Park Management Assistant, and the Cave Specialist met to create a plan for the future management of Crystal. It was agreed that the maximum tour size was to be reduced by 50% to 70 people and that the SNHA would hire an additional naturalist to allow many weekend tours to have two guides. With 70 people tours make three interpretive stops, and visitor supervision is greatly increased.

The challenge to the implementation of this plan involves the infrastructure of the Crystal Cave operation. It was expected that up to 40% of the people who came to the cave expecting to see it on any one given day, would be turned away due to the new restrictions. In addition, the road to the cave is narrow, steep, very windy, and often very congested (sections of it were built in the late 1880s) and during busy weekends it has been a source of problems for park rangers. To avoid having large numbers of disgruntled tourists in the cave parking lot and to create less congestion on the road the committee agreed to sell tickets in advance at the Lodgepole Visitors Center approximately 1 hour from the cave. Park maintenance altered a small room in the Visitors Center and additional staff was hired to work in this space. SNHA employees sell tickets up to three days in advance, keep a running count of tickets sales for each tour, and mark each ticket with the proper day and time.

To advertise the alteration in Crystal Cave management, two signs were posted along the cave road informing visitors of the change, the bi-weekly park newspaper, *The Bark,* did a feature story and several large follow-up stories about where to buy tickets and the reason for the change, and rangers featured discussions of the new ticket policy at campfire programs and on interpretive walks.

SHORTCOMINGS OF THE NEW SYSTEM

Many problems with the new system appeared quickly. Even with the effort to inform visitors, hundreds of people arrived at the cave parking lot without tickets and had to return to Lodgepole to purchase them or simply missed seeing the cave. Some people lacking a knowledge of Park geography assumed that Lodgepole was down the same road as the cave, while others assumed that they could see the cave without a tour and thus did not need to purchase a ticket. However, the majority of those confused about the system were recent immigrants or foreign visitors whose lack of English made reading the road sings or *The Bark* difficult. Visitors who entered the Park at the south entrance were required to drive approximately 20 minutes past the beginning of the cave road to purchase tickets. This extra time and effort irritated many local visitors who were familiar with and expected to encounter the old system of ticket sales. For many Park visitors and the SNHA staff members it was a particularly frustrating summer with many negative interactions. An overall reduction of 9879 visitors (from 67,280 in 1991 to 57,401 in 1992) during the 1992 season led to a drop in SNHA revenues of $26,282.

However, 1992 was an outstanding year for visitor safety and resource protection for Crystal Cave and the cave naturalists believed that the interpretation and visitor experience at Crystal had improved. The cave employees also strongly supported the changes at the cave, even with the increase in negative interactions with Park visitors, because of the added protection the new program has provided for the cave.

Crystal Cave has been closed for 1993 to allow construction of a new bridge where the cave road crosses the Marble Fork of the Kaweah River. This has provided a year for further analysis of the management situation at Crystal Cave. Informal discussion among Park staff members has resulted in proposed changes which include: 1) selling tickets at Park headquarters near the south entrance and at Lodgepole. Ticket sales would be coordinated by a computer system connected by modem at the two sites. The cost and availability of the hardware and software for this setup remains to be researched. 2) Attempt to communicate more effectively with foreign-language speaking Park visitors. This may include additional signs, notices in the *Bark* in several of the most commonly spoken languages, and or handouts at the Park entrances in the appropriate language. 3) A fee increase to offset the cost of additional staff and reduced revenues for the cave operation. Currently ticket prices are $3.00 for adults and teenagers and $1.50 for children and senior citizens. Costs will likely be raised to $4.00 for adults and teenagers and $2.00 for children and seniors. These prices appear to be reasonable compared to the cost of visiting other caves in the Western United states. See table two.

While challenges to the successful management of Crystal Cave remain, progress in protecting the cave seems assured. The changes in management of the cave's commercial tour system listed above probably represent but the first of generations of alterations and adjustments required to make the cave operation run successfully and with maximum visitor satisfaction.

Table 2: Tour prices for selected Park-Service-operated commercial caves in the Western United States and privately-operated commercial caves in California.

Commercial Cave	Price Per Adult	Price Per Child
Crystal Cave before 1993	$3.00	$1.50
Crystal Cave after 1993	$4.00	$2.00
Carlsbad Caverns N. P.	$5.00	$3.00
Oregon Caves N. M.	$6.75	$3.75
Timpanogos Cave N. M.	$5.00	$4.00
Lehman Cave (Great Basin N. P.)	$4.00	$3.00
California Caverns	$6.25	$3.00
Moaning Cave	$6.25	$3.00
Boyden Caverns	$5.50	$2.75
Lake Shasta Caverns*	$12.00	$6.00

*Cave tour includes a boat trip and a short bus ride

All data from personal communication with cave employees, July 1993

LOST SOLDIER'S CAVE

The entrances to Lost Soldier's Cave lie in the wall of a small canyon at an elevation of 4,000 feet in the southern part of Sequoia National Park. This area is dominated by mixed-oak woodland and dense growths of shrubs, vines, and herbaceous plants. The three entrances lie within thirty feet of each other and two of them join immediately while the third ties into the cave two hundred feet from the surface.

Lost Soldier's is a complicated, anastomotic maze, created by the actions of a sinking stream. The generally dry cave has formed on several levels and most passages denote fossil hydrology patterns. Access to the lowest and largest level of the cave requires the negotiation of three rope-drops with respective lengths of 40, 60 and 30 feet. The explored and mapped length of the cave is just under 1 mile. Many areas of Lost Soldier's are well-decorated with mostly inactive speleothems including outstanding helectites, a few gypsum and melanterite flowers, dog-tooth spar crystals, and many small white curtains, stalagmites, stalactites and soda straws.

The original discovery date of the cave is unknown, however the name refers to a Park legend involving an army soldier who was lost and trapped in the cave in the early 1900s. Serious exploration of the cave began in 1949 and most areas of Lost Soldier's had been seen by people by 1950. Degradation of the cave's fine features began immediately. Inadvertently, through the years of visitation by cavers from across California, many formations, including a five-foot-tall broomstick stalagmite, several multiple-foot-long soda straws and many smaller speleothems, were broken. In addition many square feet of flowstone, and calcite crusts and blisters were coated with mud and dirt from the boots, gloves and clothes of cavers. Carbide dumps were found throughout the cave and trash was common in several areas.

CHANGES AT LOST SOLDIER'S CAVE

The cave's remaining fine features and the serious degradation which had taken place over previous decades, led the Park Service to place special emphasis on new management policies for the cave in initial drafts of the Cave Management Plan. The focus of this was the creation of "Trustees" (a term first used by San Francisco Bay Chapter caver, Mike Harrell). Trustees have been envisioned by the Park as active trip leaders who are fully involved in the conservation efforts in the cave and in the selection of participants for entrance to the cave. Trustees are limited in number, (the maximum number of Trustees for Lost Soldier's Cave is 16 and for the "wild" sections of Crystal Cave is 10) and are expected to participate in annual weekend-long training sessions and meetings on the management of the cave. Individuals interested in Trusteeship must apply to the Park in a letter format by describing their caving experience and their dedication to cave conservation. Other restrictions from the new management plan include a reduction in the number of people on trips from 8 to 6, and a requirement that trips be spaced at least two weeks apart.

In 1991 members of the Southern California Grotto began a clean-up and restoration project in the cave. Several problems with cleaning the cave became evident: 1) the volume of work was far larger and more time consuming than expected; 2) The cave lacks a natural water source for cleaning and the transportation of water into the cave was difficult and time consuming; 3) non-clean-up trips entering the cave at this time often re-dirtied cleaned areas, which frustrated the restorers and slowed progress.

Late in 1991 a significant white curtain was broken in the Helectite Room of the cave by an unknown group of cavers. Discussion among Park staff led to the conclusion that the cave should be closed until the new restrictions in the Management Plan could be put in place. Park staff also realized that the eventual reopening of the cave provided an opportunity to support and properly structure clean-up efforts within the cave. Thus, the Superintendents closure order included a stipulation that the newly selected Trustees coordinate the cave's restoration and that no "tourist" trips enter the cave until all clean-up work was completed to Park satisfaction. This insured an adequate supply of labor for the project and water transportation, and helped solve the problem of "tourist" cavers re-dirtying cleaned areas.

The Park Cave Management Plan was adopted in September of 1992 and the cave was reopened in the spring of 1993 with the first weekend Trustee training in April. At that time the cave was divided into specific sections adopted by individual Trustees or groups of Trustees from the same grotto. The techniques and equipment required for cleaning specific areas of the cave were discussed, and Trustees drew upon past cave restoration experiences when making decisions on the structure of the project and equipment choices. Two trips entered the cave to examine the specific areas to be cleaned.

CHALLENGES TO THE NEW SYSTEM AT LOST SOLDIER'S CAVE

The creation of Trustees is a by-product of an understaffed and under-funded cave Management Program and National Park. By granting volunteers certain responsibilities involving the management of the cave and the coordination of its cleanup, the Park has created a body within the caving community upon which it is dependent for resource protection, visitor management, and information about the cave, its contents and status. Cavers as a whole and in particular some of the individuals who have volunteered their services as Trustees, have made tremendous contributions to the caves and cave management of the these Parks. However, that does not remove the obvious danger of a caver with a personnel agenda or ambitions creating problems for the program, the Park or even within the cave. Predicting and reacting to such a situation will be difficult.

The restoration work holds dangers of its own. Common restoration concerns involving the use of acid on formations to remove calcified-in sediments and the determination of which areas are naturally soiled versus damaged by human activity abound in Lost Soldier's. In addition, keeping restored areas restored will be an ongoing challenge for Park Management and the Trustees. In several locations in the cave formations have provided obvious handholds and footholds for traversing down steep walls or around pits. Correcting this problem will require the placement of permanent or semi-permanent equipment for bypassing the formations. Rigid ladders, constructed so they may be dismantled for moving into the cave, are a likely solution.

Cavers who have been visiting the cave for years will be subject to new sets of restrictions, including boots- and gloves-off areas, closed passages and rooms, delineated trails, and group-size limits in certain delicate areas. Compliance with these changes will be a test of the Trustee program and will determine the long-term health of the cave and the overall human impact on this resource.

HURRICANE CRAWL CAVE

Both entrances to Hurricane Crawl Cave lie within lower elevation riparian zones at elevations of 4,300 and 4,500 feet. The entrances are small and are obscured by the dense growth of maples, alders, oaks, dogwoods and many shrubs and herbaceous plants.

The cave is composed of mostly simple, linear, vadose canyons. However areas of phreatic development, which have created large rooms and passages, can be found in the central sections of the cave. Also a branchwork maze exists at the downstream end of the cave and a well developed anastomotic maze has formed at the rear of the explored sections of the system.

Prior to 1988 Hurricane Crawl was a 30 foot-long cave which ended in a breakdown choke from which strong airflow emanated. In July of that year cavers from the San Francisco Bay Chapter and Park employees who were National Speleological Society (NSS) members breached the collapse. Today 8,500 feet of passage has been explored and surveyed. The cave has two entrances, three streams and contains a plethora of speleothems. Secondary formations of note include selenite needles and angel hair, three varieties of helectites, many shields, large numbers of long soda straws, broomstick stalagmites, large curtains, and a variety of formation colors including yellow, orange, red, black, gray and white.

Early explorers realized the significance of the cave's discovery. Specific routes were delineated and many delicate areas have never been entered. While it would not be appropriate to refer to Hurricane as pristine due to the presence of flagging, signs, trails, and a few broken formations, the cave is excellent condition and presents a rare opportunity in this National Park to preserve and study a cave in a natural, nearly undisturbed state.

MANAGING HURRICANE CRAWL

In August 1989, cavers involved with Hurricane Crawl created the Yucca Creek Conservation Task Force of the NSS to function as an integrated organization to survey the cave and to support its conservation. The Park administrative staff was briefed on the status of the cave in December 1989. This body decided to seek the specific recommendations of involved cavers and to hold a "scoping session" on the cave with participation from these cavers and Ron Kerbo of Carlsbad Caverns National Park. In addition the cave was closed by the Superintendent, pending decisions on its future.

Three letters addressing the nature and recommended management of the cave were received by the Park from October 1989 to February 1990. They were authored by John Tinsley, the California Operations Manager for the Cave Research Foundation, Steve and Barbara Maseo Ruble, the coordinators of the Yucca Creek Karst Conservation Task Force and Joel Despain, an NSS member employed by the Sequoia Natural History Association involved with the cave's exploration. The letters encouraged the conservation of the cave and its features and also consistently expressed a belief that the cave constitutes a unique Park resource.

The scoping session was held on May 12 of 1990. The specific features of the cave, the administrative requirements for the management of the cave, future use of the cave, and the specifics of the cave's protection were discussed.

In the following three years, two exceptions to the Superintendent's closure order were allowed. The first was to allow an initial biological survey of the cave. This work was encouraged and supported by Tinsley and was conducted by W. Calvin Welbourne of Ohio State University and Darryl Ubick and Tom Briggs of the California Academy of Sciences in July of 1991. Results indicate that the cave has several unique species of invertebrates and shares several unusual species with nearby caves. The Rubles and the Yucca Creek Karst conservation Task Force requested permission to continue their survey work in August 1990 and were given permission to do so in December of that year pending completion of the biological survey of the cave.

Thus the Park's current body of knowledge of Hurricane Crawl includes a survey and completed map and a basic biological inventory. In addition a large body of ideas and recommendations on conserving the cave and its features have been penned by cavers interested in Hurricane.

With the 1992 completion of the Park Cave Management Plan directing the overall nature of cave management in the Parks, it is now an appropriate time to formalize a long term comprehensive plan for Hurricane Crawl. The consensus through the years of discussion on this question has been that some areas of the cave will be closed and that the number of trips allowed into the cave will be small. But a wide variety of opinions have existed on which areas should be closed, how thoroughly the areas should be closed and how many trips is a small number. Some have argued for complete closure or a single trip per year while other have suggested no more than 20. In addition the park staff believes that to properly manage the cave it must be sufficiently understood. Because of the cave's strong airflow and complex hydrology, surface activities could easily disturb the cave. It is thus important that restrictions designed to protect the cave, do not inhibit or prohibit further appropriate scientific research in Hurricane.

The specifics of the currently drafted management plan (which has not been signed by the Park Superintendent) allows four trips into the cave per year and closes 17 areas including a section in the middle of the cave, essentially dividing Hurricane into two parts accessible from two different entrances. Closed areas include short, heavily decorated passages with bypasses, the floors of large rooms excluding specific trails, and several sections of the cave which are impossible to traverse without causing speleothem damage. Four easily damaged, nearly pristine areas are limited to one trip per year to maintain their character. An additional four areas with flowstone and formations along major routes through the cave, require boots and gloves off. Twelve locations near sensitive cave features have specific routes delineated through them. Squirt bottles and small brushes will be cached in eight areas in the cave to allow for the immediate cleaning of soiled formations. By cleaning formations immediately the slow, almost unnoticeable build-up of dirt that often occurs in decorated cave passages regularly visited by cavers will not occur. Also sediments which are removed quickly will not become calcified-in and the cavers responsible for damaging an area will be the individuals who also clean it. Broken brushes or bottles will be removed by the cavers who notice the problem and will be replaced on the next trip.

All trips into Hurricane Crawl must be research oriented; light-soled boots are required in the cave; outer clothing layers are limited to PVC or nylon coveralls, which transport less dirt and sediment, and a specific number of trips will be reserved for photo-monitoring and the maintenance of cave equipment such as clean-up gear, flagging and signs.

The Park also plans to create a Hurricane Crawl Research Plan to carefully define the information to be gathered in the cave in support of the cave's management. Specific projects to be included will be a photo-documentation of the cave and the creation of a photo-points for photo-monitoring, research into hydrology and air flow, and further biological work. The overall Management Plan for the cave and the Research Plan will be reviewed after four years for changes and possible tightening of the restriction on the cave.

CHALLENGES TO THE MANAGEMENT OF HURRICANE CRAWL

The presence of a wide variety of closed areas, areas with limited access, boots-off areas, areas with specific foot- and hand-holds, specific trails, and areas with delicate floors, and other aspects of the cave and management plan mean that the Plan's implementation and enforcement will be complicated, and difficult to enforce, understand or even remember.

Signing the 17 closed areas will require the presence of 20 signs in the cave. The other restrictions and aspects of the Management Plan could entail many more additional signs and a great deal of flagging. If part of the effort to protect the cave includes a concern for Hurricane's aesthetics, then there is a point where the infrastructure designed to protect the cave begins to harms it and the also reduces the experience of seeing and visiting the cave. Determining where this point lies in the cave as a whole and in specific areas will be difficult and can be no more than an arbitrary, opinion-based decision.

CONCLUSION

While the creation of a Cave Management Plan, a Cave Specialist Position, and subsequent additional management plans for specific caves has undoubtedly advanced the protection and knowledge of caves in Sequoia and Kings Canyon National Parks, significant challenges to the implementation and creation of these programs remain. The job of managing caves is complicated, fraught with compromises and creates a self-perpetuating situation requiring the need of increasing management involvement to manage more complicated situations and increasing or destructive visitor use. The needs and dangers of specific user-groups in specific caves, the limitations of the park staff and budget, and the examples and lessons learned from the management challenges described in this paper will act as important factors in shaping the future of cave management in Sequoia and Kings Canyon National Parks.

CAVE MANAGEMENT IN RESIDENTIAL SUBDIVISIONS IN HAWAII

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ABSTRACT

About 40 years ago, numerous large subdivisions were laid out in cavernous sections of Hawaii County, Hawaii without regard for cave resources or values. Only recently, however, has a major population influx begun to impact the caves heavily. The overall problem is reviewed, with an example of a management plan proposed for a subdivision cave with major resources and values currently at risk.

INTRODUCTION

The pahoehoe lava flows of Kilauea volcano's Ailaau Shield comprise one of the world's most important areas for vulcanospeleological study. Further, it is also of special importance for other volcanological study. Most of the area is in Puna District, Hawaii County, Hawaii. These flows extend some 25 miles from the rim of Kilauea Crater to the sea south of Hilo. On them are numerous residential subdivisions now patchily, but increasingly built-up. Numerous other speleoliferous subdivisions exist throughout much of Hawaii, but probably nowhere are the stakes as high and the issues as clear as within the Ailaau Shield flows.

Some of the world-class caves here are:

Kazumura Cave, one of the world's four longest and most voluminous lava tube caves.

John Martin Cave System, subparallel to part of Kazumura Cave and especially notable for unusual lava forms and sequences.

Keala Cave, subparallel to part of Kazumura Cave and the John Martin Cave System, about 5 miles long and with exceptional features of thermal erosion by downcutting of subterranean lava streams.

Olaa Cave, with lavafalls up to 30 feet high, an underground hornito, and at least two lesser subparallel cave systems.

Kurtistown Civil Defense Cave, a short and very sensitive cave with remarkable recessed shelves and a very unusual feathery-appearing lava tongue.

Paradise Park Cave System, which may or may not be a detached continuation of the Kazumura Cave lava tube.

Uilani Caves, the lower of which is perhaps the world's most notable lava distributory complex with almost two miles of braided and distributory passages mapped.

Maps and/or information on numerous other lava tube caves of these flows (such as Thurston Lava Tube) also are on file, and many reported entrances have not yet been investigated. Unquestionably, much more remains to be learned about the lava tubes of this area.

At the present time, it is not clear whether the Pahoa Cave System is part of this study area or in another flow sequence immediately adjoining it. The flows in which it is located may have arisen from a vent on the East Rift Zone of Kilauea Volcano rather than from the Ailaau Shield vent. Although part of it is in a geothermal development zone (McEldowney and Stone, 1991), very little of this system underlies residential subdivisions and thus its management is not part of this topic in any event.

Currently the Ailaau Shield flows are of particular interest to staff members of the U.S. Geological Survey's Hawaiian Volcano Observatory. Field studies by this institution currently are reevaluating the age of these flows, previously believed to be 300 to 800 years B.P.(before present). Lacking staff speleologists, its scientist-in-charge has asked the Hawaii Speleological Survey and hawaii Grotto of the National Speleological Society to obtain complementary subterranean field data for these studies. The Survey and the Grotto have given a high priority to this request. During the resulting studies we are constantly confronted with self-imposed questions about the preservation and management of this remarkable resource.

HUMAN IMPACT

Residential use of this area is a few to several hundred years old. Physical evidence is unequivocal that resource utilization and management have varied markedly during that time. Principal uses by pre-Contact and early post-Contact Hawaiians clearly were as cave shelters in wartime and /or meteorological emergencies, and as mortuaries. Interments are known in about 18% of Puna District caves in Hawaii Speleological Survey records. They vary from single pole burials to mass sites of disposal of victims of war or epidemic. Emergency shelter use was so important that on a current topographic map, the boundary line of an ahupuaa (traditional extended family land divisions) is seen to have an uncharacteristic elbow to include a deep, overhanging pit which was used for such a shelter.

Formal, modern-style residential subdivisions began 40 or 50 years ago in this area. No one considered the caves resources and values as we now define them. Lot sizes varied from perhaps 10,000 feet to three acres or more. Many of the roads required by law were mere bulldozed tracks; others were paved with less-than-permanent surfacing. Thought to be on basically worthless land, many were sold very cheaply, mostly to mainlanders enticed by impressive advertisements that had little to do with the actual nature or appearance of the lots. Unsurprisingly, for a long time, actual settlement was sparse and scattered. Depending somewhat on population density, the caves remained largely unknown, unentered, and largely unthreatened unless they were in someone's backyard.

Ultimately, the more desirable subdivisions began to fill. Just as described by Veni (1986) in the case of caves in San Antonio and Austin, more and more people began to encounter caves. A curious dichotomy resulted. In part, caves in developing areas were considered nuisances. It appears that especially in Hawaiian Beaches Estates Subdivision, caves were considered nuisances and filled when encountered in road or building construction. In Ainaloa subdivision, the entrance of Pukalani Cave was filled and a road built over it. The main entrance of Lower Uilani Cave was almost completely filled also, and other examples are known in other subdivisions.

The other view of these caves was that they were potential sites for cesspools and convenient garbage receptacles. We have not yet encountered any examples as horrible as the Garbage Entrance of Kaumana Cave in South Hilo District, nor Trash Cave near the former site of Kalapana, but the Ailaau Shield caves have not been spared. Worse, it is locally said that even in this decade, piping a home's raw sewage into caves has been approved by building inspectors. Entry into Eddie Dawson Cave will be by sawing off the lid of such a cesspool, but our teams have lacked enthusiasm for that project.

As pointed out by Veni (1986), it was inevitable that many caves were discovered and explored by local noncavers. As for organized speleology, however, the area was largely out of sight and out of mind.

EARLY CONSERVATION AND MANAGEMENT

Biospeleologists were the first to become aware of and concerned for these and other Hawaiian cave areas. In 1982, Howarth and Stone persuaded the National Speleological Society's Board of Governors to pass a strong resolution and formed a N.S.S. Conservation Task Force. In order to control entrances, I also proposed a Hawaii Cave Conservancy some 20 years ago, but the effort floundered. Fortunately, some individual landowners were aware of cave resources and values, and at least three important cave entrances were purchased by individuals to protect the caves. The upper entrance of Upper Paradise Park Cave was acquired by the state of Hawaii and gated to protect cultural values. The Conservation Task Force worked behind the scenes with state and federal agencies, but obviously this had limited relevance to these residential subdivisions.

NATIVE HAWAIIAN ISSUES

A further complicating factor in planning cave management in this area is divergent attitudes of Native Hawaiians. These range from friendliness through apathy to assertive and even aggressive behavior. In some ways, they parallel Native American issues.

Until recently, Native Hawaiians were concerned only with cave burials of their own family and family friends. Often they raided others' interments for various cultural purposes (Scully and halliday, 1991). Some consider all Kilauea caves sacred to the goddess Pele; this faction is divided on whether all entry into all Kilauea caves should be prohibited. Another faction urges that all burial caves be bulldozed (as some burial caves have a dozen or more entrances, this is a bit problematical). Some caves have been declared KAPU - sacred and forbidden - by the landowner or by someone else, with or without the concurrence of the landowner. We respect Kapu declarations and consider such caves to be closed. But the traditional marking or KAPU areas with ti leaves is neither permanent nor widely understood, and it is far from clear who has the spiritual authority to declare KAPUs legitimately.

LAWS

State law requires that all cave burials be reported to the State Office of Historic Preservation, and that no burial be disturbed. The Hawaii Speleological Survey and the Hawaii Grotto comply fully with these laws. Some Native Hawaiians feel that staring at interments or photographing them are forms of desecration, decreasing their mana (spiritual energy). The Survey and the Grotto avoid staring at interments when we encounter them, and avoid photography beyond minimal documentation.

One interpretation of a state law insists that title to all caves in Hawaii has been preempted by the state. We are unaware of any state agency with cave management plans based on this interpretation. Hawaii Volcanoes National Park has a cave management plan based on the belief that caves in the Park are not state property, so we are proceeding on the common law principle that with specific exceptions like mineral rights, property owners also own caves beneath their property.

Environmental protection laws may apply to residential subdivisions. These are widely ignored in Hawaii, by government and others alike. We have not yet even considered their relevance in cave management in residential subdivisions.

MOBILIZATION OF COMMUNITY SUPPORT

Under these circumstances, approaches that elicit broad community support must be chosen carefully. In general, our approach is to alert other conservation-oriented organizations to cave conservation and management problems, to orient cave owners to the value of caves in general and their cave in particular, to coopt and orient unaffiliated local cavers, to make common cause with Native Hawaiians and their organizations whenever possible, and to educate governmental agencies on the value of caves and the assistance we can provide them -- at no expense. The Survey and Grotto are public service organizations and make no charge for any service other than excessive xeroxing.

MANAGEMENT PLANS

The complexities of management plans in this area are well exemplified by Lower Uilani Cave in Ainaloa Subdivision. For this cave we prepared a comprehensive proposal distributed to those with a need to know: the County of Hawaii Planning Department, Ainaloa Community Association, Ainaloa Development Corporation, the Waikahekahe Nui Ahupuaa Ohana (council), the state's Historic Preservation Division, Nature Conservancy of Hawaii, Greenpeace Hawaii, the local Sierra Club chapter, the Bishop and Lyman Museums, the U.S. Geological Survey, the N.S.S., and the owners of the present entrance and a skylight which formerly was the cave's main entrance (Halliday, 1993). The impetus for the proposal wa expectation that Ainaloa Development Corporation would soon use Ainaloa Boulevard for heavier construction equipment than the thin, fractured roof of the cave would withstand and attention inevitably would be directed to the cave. In the field work we included officers of Greenpeace Hawaii and the Waikahekahe Nui Ahupuaa Ohana, and kept them aware of the planning process. Some of them subsequently have joined us in other field work and have become important assets to Hawaii speleology. In addition to the written proposal we prepared a large scale map which was given to the two most affected landowner, the Planning Department, the Community Association and the Development Corporation. To avoid potential problems if the map fell into other's hands, the exact location of Ainaloa Boulevard was omitted but could easily be deduced from the text of the proposal. Information in the proposal included the significance of the cave, its basic geology and geomorphology with a smaller explanatory map, biological values, potential commercial value (as a show cave) of a section near Ainaloa Boulevard, wilderness,recreational, and scenic values, cave hazards and the need for hazard mitigation, cultural values (minimal), and past damage to the cave (incomplete fill during original construction of Ainaloa Boulevard. Its single interment was mentioned but its location was reported only to the State Historic Preservation Office, as required by law.

Recommendations included engineering studies of the dangerous ceiling section (to be made by enlarging the adjacent skylight), protection of specified geologic features with strict access control to protect these and biological values, several alternative approaches for further scientific study, compliance with wishes of property owners, and consideration of development of a small show cave. The possibility of a N.S.S. conservation grant was mentioned.

RESULTS

It would have been foolish to expect this single proposal to halt all the threats to caves of the Ailaau Shield flows, or even this single cave. It is too soon to evaluate its effectiveness. The owner of the entrance wrote that he had closed it to entry; we have not had time to discuss selective entry with him. The U.S. Geological Survey Hawaiian Volcano Observatory expressed appreciation for the information. The Planning Department seems to have considered it a hot potato. We received a courteous acknowledgement together with the information that they had forwarded their copy to the Development Corporation. But it is clear that its preparation and dissemination educated important groups and agencies and key individuals to some of the resources and values of Hawaiian caves. We perceive this as a good beginning. And we significantly expanded our network of concerned individuals and organizations.

While some of its details are specific to the needs of Hawaiian caves, we feel that this approach is applicable in other urbanized areas of the United States. Perhaps more relevant, we are aware that others are ahead of us in cave management in urbanized areas, and we would like to learn from them. Little has been published on this subject, and so much is at risk that we urge that much more attention be focused on it.

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MANAGEMENT OF CHINESE CAVES

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ABSTRACT

Cave management in China has a history of at least 1300 years, yet in the most populous country on earth, many caves suffer from overuse and unenlightened management practices. China has a wide variety of caves, ranging from great limestone caves to lava tubes, gypsum caves and sea caves. Many of the caves are developed for the tourist industry and there are still vast areas of China where the speleological resources are still being explored. At the present time an expedition to China can cost a group as much as $50.00 to as little as $35.00 per day. There is a great interest in China in assistance in development strategies for commercial caves to methods to encourage eco-tourism.

EVOLUTION OF KARST MANAGEMENT ON THE KETCHIKAN AREA OF THE TONGASS NATIONAL FOREST:
Development of an Ecologically Sound Approach

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Abstract

At about the time of the passing of the Federal Cave Resources Protection Act, the Ketchikan Area of the Tongass National Forest began to recognize the presence of the significant cave resources within it's boundaries. In the five years following the recognition of the cave resources, the Area has been involved in an active program of cooperative inventory, exploration, mapping, and evaluation of the caves and their associated resource values. Preliminary Standards and Guidelines were developed to insure protection of these unique and fragile resources, mitigating the impacts of timber harvest on the associated karst. Some applied mitigation provided adequate protection, but mitigation was often insufficient resulting in degradation of the cave resources.

With the Area's ever-growing recognition of the significance of the karst and cave resources came an awareness of resource vulnerability. It became apparent that an understanding of the functions of karst systems and the characteristics of the local karst landscape was needed . It was recognized that caves and associated features and resources are an integral part of the karst landscape and that karst must be managed as an ecological unit to ensure protection of the cave resources. In February, 1993 the Ketchikan Area sponsored a Karst Management Seminar with the help of the American Cave Conservation Association. The focus of this seminar was on the characteristics and functions of the karst landscape. From this seminar, an idea arose to contract with a team of specialists to: (1) assess the significance of the karst in an international and national context, (2) determine the effectiveness of present strategies for protecting karst resources and recommend appropriate changes, and (3) recommend focused resource evaluation goals and research for karst areas. Based on the findings of the team, the Ketchikan Area is rapidly moving toward a karst management strategy based on system recognition and protection instead of feature preservation.

Introduction

The karst and cave resources on the Ketchikan Area of the Tongass National Forest are a newly discovered and recognized portion of the lands within southern-most southeastern Alaska. Until the first caves were mapped in 1987, only a few local residents knew of the caves and karst features hidden within the thick vegetation of the temperate rain forest. It is now known that over 700 square miles of karst exists on the Ketchikan Area, about 11 percent of the lands administered by the Area (Baichtal, 1993a). In 1988 the Thorne Bay Ranger District of the Ketchikan Area began cooperative work with the local caving organization to begin mapping and identifying caves threatened by proposed timber harvest. In 1990, the Ketchikan Area became aware of the extent of karst development. In the spring of 1991 the inventory process was greatly expanded, locating nearly 100 new caves and significant karst features within or adjacent to proposed timber harvest units. Inventory efforts were focused on the northern end of Prince of Wales Island where the majority of timber harvest was proposed. Mitigation strategies were developed with the intent of protecting the caves from the effects of timber harvest. This mitigation was based on field observations from within previously harvested karst areas, and was focused on karst feature preservation. Cave resource mapping and

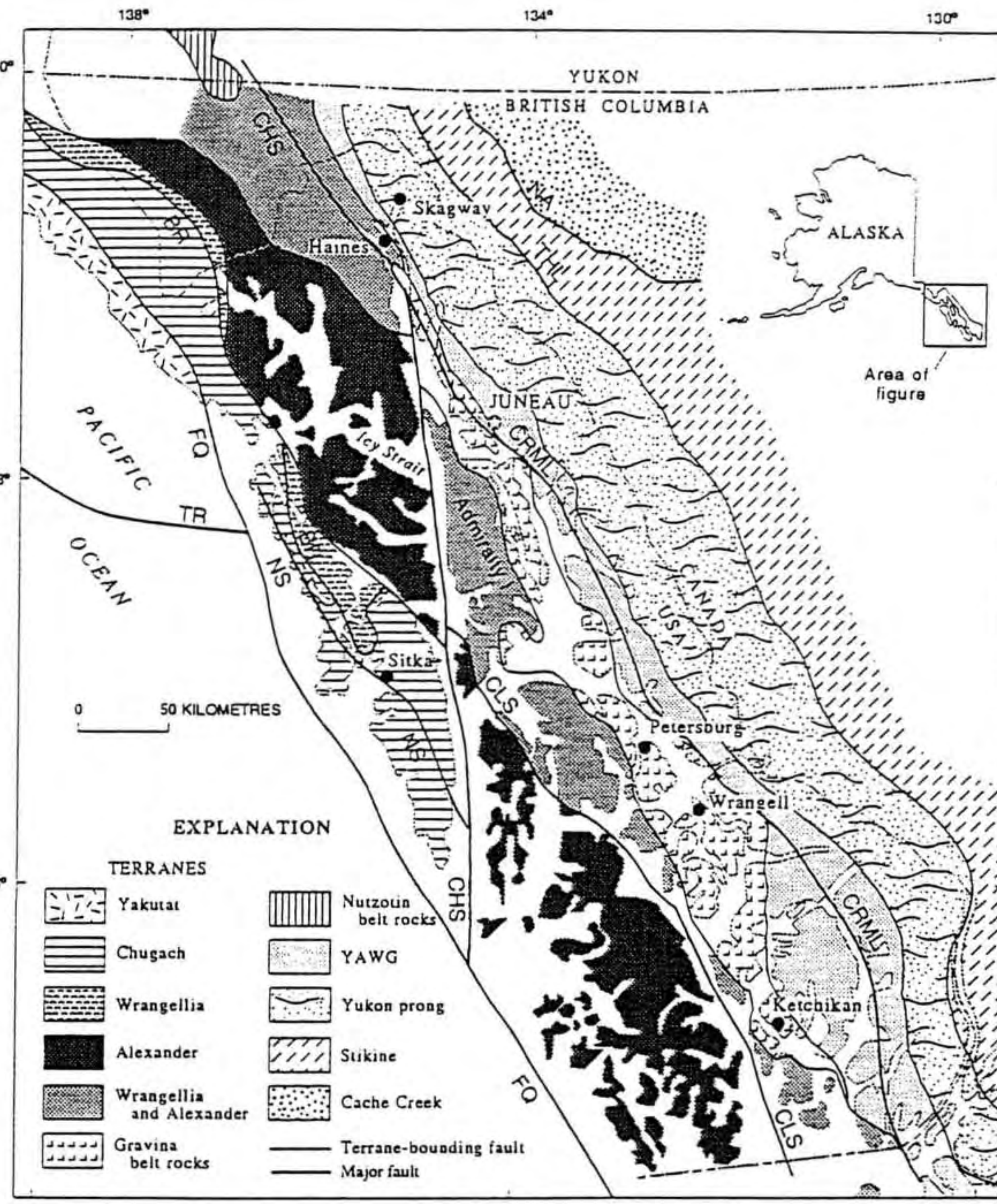

Figure 1. Lithotectonic terrane and major fault map of southeastern Alaska. From Brew et. al., 1992a and Brew et al. , 1992b. Major faults, indicated by heavy lines, are labeled as follows: BR, Border Ranges; CHS, Chatham Strait; CLS, Clarence Strait; CRML, Coast Range megalineament; FQ, Fairweather-Queen Charlotte Islands, NA, Nahlin; NS, Neva Strait; THL, Tally Ho-Llewellyn, and TR, Transitional. The majority of the karst landscape is found within the Alexander Terrane. Note how the Chatham Strait Fault offsets the Alexander Terrane approximately 100 miles.

inventory efforts during 1991-1992 resulted in cursory descriptions of over 100 caves and greater than 33,000 feet of passage. In 1992 the Tongass Cave Project, as the cooperative inventory had become known, became a sanctioned project with the National Speleological Society and the U.S. Forest Service. This inventory effort began to yield important paleontological and archaeo^_logical finds and the first look at a wide variety of other resource values. Exploration yielded the longest cave in Alaska, El Capitan Cave at over 11,000 feet of passage, and the deepest vertical shaft in the United States, El Capitan Pit with an initial drop of 598.3 feet and a total depth of 624 feet. To date nearly 300 caves have been inventoried, with approximately 50 caves being discovered annually.

The first mitigation attempts fell short of being effective. As timber harvest continued on northern Prince of Wales Island, it became apparent that buffers intended to protect the resources only resulted in their degradation when they failed. Not all mitigation attempts failed. Mitigation was effective when timber harvest unit or buffer design was such that it protected a block of forest large enough to surround the karst feature insulating it from the effects of windthrow, roading, and micro-climatic change. Mitigation was especially effective if the forest block surrounding the cave remained intact and the recharge area for the system was not affected by timber harvest or road building. It became apparent that caves and their associated resources were an integral part of the karst landscape and that wise management of the cave resources meant that an understanding of how karst systems function was required. It became further apparent that karst must be managed as an ecological unit to ensure protection of the cave resources.

Recognizing the need for training in the characteristics of karst development and systems, the Ketchikan Area and the American Cave Conservation Association sponsored a "Karst Management Seminar" in Ketchikan, Alaska during February of 1993. This was the first seminar of its kind. Similar seminars had been sponsored by other Federal agencies in the past, but had focused on cave resource management and not karst management. This seminar focused on the function and characteristics of the karst landscape. It was well attended by Forest employees, other federal and state agencies, conservation groups, and industry. In his opening remarks, the Forest Supervisor challenged the attendees to propose several priority actions on which Area management could focus to better understand the karst and cave resource issues. From this seminar, an idea arose to contract with a team of specialists to: (1) assess the significance of the karst in an international and national context, (2) determine the effectiveness of present strategies for protecting karst resources and recommend appropriate changes, and (3) recommend focused resource evaluation goals and research for karst areas. Such a contract was let and the field work by the contractors completed during July and August of 1993. The Ozark Underground Laboratory from Protem, Missouri was awarded the contract. Tom Aley, director of the Laboratory was team leader. The team consisted of Tom and Cathy Aley, Dr. William Elliott, and Dr. Peter Huntoon. Based on the findings of the team (hereafter referred to as the Karst Panel or Panel), the Ketchikan Area is rapidly moving toward a karst management strategy based on system recognition and protection instead of feature preservation.

Concurrently with the Ketchikan Area's coming to grasp with the karst resource issue, conservation groups were also working to better understand the function and extent of the resource. As a result of continued emphasis on timber harvest in karst areas throughout southeast Alaska, the Southeast Alaska Conservation Council (SEACC) contracted with Icy Strait Environmental Services to prepare a report on the status of karst and cave resources in land management strategies on the Tongass National Forest. The report entitled "Cave Lands of Southeast Alaska, an Imperiled Resource" was completed in February 1993. This report focused on the known extent and possible extent of the karst and cave resources on the Tongass National Forest and outlined current management strategies on the three Areas (Streveler and Brakel, 1993).

The intent of this paper is to describe the karst management strategy proposed by the Panel and currently being adopted by the Ketchikan Area. Before a discussion of the proposed karst management strategy, a description of the components of the karst landscape is necessary.

The Karst Landscape

In southern southeast Alaska the karst landscape can be characterized as an ecological unit found atop carbonate bedrock on which karst has developed and the recharge areas on adjacent non-carbonate substrate. A few of the characteristics of this ecological unit include: older, well-developed spruce and hemlock forests, increased productivity for plant and animal communities, extremely productive aquatic communities, well-developed subsurface drainage, and the underlying unique cave resources. The interactions of the variables controlling the karst landscape are not fully understood at the present time. Extensive research is needed to fully understand and describe the characteristics of this ecosystem. The following description of the karst landscape discusses its geologic and hydrologic characteristics, biologic characteristics, and natural history.

Geologic and Hydrogeologic Characteristics

Karst development in southeastern Alaska is controlled by the purity of the carbonate bedrock, the structural component of the bedrock (i.e., the faulting, fractures, bedding, etc.), occurrence of intrusions, proximity of the carbonates to peatlands, the development of the epikarst, the glacial history, precipitation, and temperature. Karst existed on Prince of Wales Island long before the latest glacial advance. Passages in two caves have dissolved through Tertiary (?) paleokarst breccias (Aley et al., 1993). One small cave has yielded a marmot tooth which has been dated to greater than 30,000 years. Most caves predate the most recent glaciation based upon the presence of glacial clays, glacial sediments, wood, Pleistocene vertebrate remains, and possibly even ancient ice. The current karst formation model holds that glaciation modified a pre-existing karst landscape, collapsing some passages and systems, gouging into others, and filling some with sediments. The epikarst, which is exceptionally well developed in higher elevations, seems to have been destroyed at lower elevations by the most recent glaciation. With deglaciation, a terrain similar to those found in some of the alpine karst areas would have remained. As vegetation re-established itself on the deglaciated land, in effect a forested alpine karst developed. Peatlands developed on compacted glacial sediments and glacial silts on the karst and on the poorly drained lithologies adjacent to the karst. Many of the glacial deposits on the karst may have been left atop collapsed karst features. With the development of the peatlands and the associated acidic waters, a system of vadose caves and vertical shafts developed, combining with the pre-existing cave systems.

The best karst rocks are >70 percent calcium carbonate ($CaCO_3$). Full karst and cave development requires that the bedrock be 90 percent calcium carbonate or better. Chemical analysis of 67 limestone and marble samples collected from the northern half of Prince of Wales and surrounding islands showed the range of calcium carbonate varied from 91.47-99.46 percent. The samples averaged 97.65 percent $CaCO_3$ (Maas et. al, 1992).

These very pure carbonate rocks have had a long tortured history. The carbonates on which the karst has developed originated as marine reef and lagoonal deposits near the equator during Silurian time, some 438 to 408 million years ago. These deposits were rafted atop spreading oceanic plates until they docked on the ancient shores of southeast Alaska. These rocks are part of what is now recognized as the Alexander Terrane, one of five sub-continental blocks of rock which have combined to form the Ketchikan Area. The oblique collision of the Alexander Terrane with North America resulted in the rocks being compressed from east to west and smeared northward along the coast. The Alexander Terrane was spectacularly fractured and then fragmented at all scales as it was rifted apart and smeared northward along the Alaskan coast. This smearing occurred along large, northwest-southeast trending, strike-slip faults. Second order, intersecting, north trending strike slip faults allowed the terranes to break into huge blocks. Figure 1 shows the terrane map of southeastern Alaska (Brew et. al, 1992a and b). What makes the picture more interesting is that the grand blocks bounded by the large faults are themselves broken into smaller blocks by smaller faults which mimic their large counterparts. This same fault pattern can be seen from terrane boundaries to the outcrop and hand specimen scale. The fractures serve two very important functions in the karsts associated with the Alexander Terrane. First, the intra-island and mountain-block scale faults commonly define karst system boundaries. Secondly, cave passages, chains of sinkholes, and many of the other karst features are localized along sets of small to intermediate scale faults. Epikarst development is largely a function of these fractures and faults (Aley et al., 1993; Coney et. al, 1980; Brown and Yorath, 1989; Brew et al., 1992a and b; Gehrels and Berg, 1992).

Epikarst is exceptionally well developed throughout the karst areas. The alpine epikarst is characterized by deep shafts, crevasse-like dissolved fissures, eroded dissolution rills of all sizes, and spires and spikes of limestone. In the sub-alpine, the epikarst has virtually the same characteristics found in the bare alpine settings except it is vegetated. Typical thicknesses of the epikarst zone range from more than 100 feet in the alpine areas to less than 5 feet along the coast and lower elevations. The epikarst thickness appears to be more a function of glacial history than altitude. The epikarst is extremely important in moving water, nutrients, organic matter, and soil from the land surface and from the rooting zone into the subsurface where these materials can move laterally to seeps and springs or to vertical collector structures which channel them downward into cave networks (Aley et al., 1993).

Peatlands form atop poorly drained non-carbonate rocks and glacial hardpans that lie atop carbonates. Surface waters originating from these poorly drained areas seldom flow more than a few yards onto carbonate substrate before diving below the ground, down vertical shafts or into cave entrances. The highly acidic waters from the peatlands accelerate cave and karst development. It has been found that pH levels within these Sphagnum-dominated wetlands can be as low as 2.4 (Aley et al., 1993). Waters flowing from these wetlands have been measured to have a pH range of 2.4-5.8. Waters flowing from the cave systems have shown pH in a range from 7.5-9.0. The buffering capabilities of the pure carbonates is evident.

Most of the study caves are hydrologically active. Those that carry streams are subject to extreme variations in flows. Rainfall in the area varies greatly ranging from annual average precipitation of 60 to >250 inches per year. The largest floods occur when heavy rains fall on wet snow packs. These systems can best be described as very dynamic. Limited dye tracing work to date demonstrates that karst groundwater systems in the study area routinely transport water for several thousands of feet to receiving caves, springs, and surface streams (Aley et al., 1993). The limited specific conductance information gathered to date suggests that values from karst systems here are about half the mean values typically encountered in most American karst areas. However, karst areas in southeastern Alaska yield annual runoff which is typically on the order of 8 to16 times greater than that found in other American karsts. The net effect is that solution of soluble bedrock occurs on the order of at least 4 to 8 times faster in southeastern Alaska (Aley et al., 1993).

Hydrologic models currently used for estimating the cumulative effects of proposed surface management activities are not designed to model the effects of timber harvest on the karst landscapes. Evidence suggests that timber harvest increases runoff, thereby increasing sediment and debris transport capabilities and flooding passages which have not flooded for centuries. Observations in some caves suggest that passages which now flood result in fragile ceiling formations becoming tannin stained and showing signs of dissolution. Many cave entrances are infilled and/or blocked by logging slash, sediment, and debris. Additional runoff generated from road surfaces commonly are diverted into karst features. It is not known what cumulative effects past timber harvest has had on the karst landscape (Baichtal, 1993c).

Biologic Characteristics

Only limited information is available on the importance of the karst landscape to the plant and animal life. The following characterizes what is known about the vegetation/forest, wildlife, and fisheries components of the karst landscape:

Vegetation/Forest. There is a definite tie between the karst and the productivity of the spruce and hemlock forests found there. The major contributors are believed to be the nutrient rich soils, well developed subsurface drainage, and dissected bedrock surface which allows the tree roots to hold fast and become somewhat more windfirm. The old growth on the karst provides a well structured, multi-layered canopy resulting in important winter habitat. The structure of the forest provides many forbs and shrubs for wildlife. It is possible that the available forage contains, at a minimum, higher calcium levels allowing for better bone, muscle, and antler development. The combination of quality forest structure and abundant nutritional browse could make the karst landscape exceedingly crucial habitat (Gustafson, 1993).

One way of demonstrating the productivity of the karst area is to compare timber volume differences of the karst to non-karst areas. Exceptionally dense stands of very large diameter spruce and hemlock are characteristic of the karst. Past timber harvest on the karst landscape has been disproportionately high most likely due to the high percentage of very large, dense forest stands. For instance, in the Central Prince of Wales FEIS analysis, 66 percent of the commercial forest land on known karst has been harvested while only 33 percent of non-karst areas have been cut (Baichtal, 1993c). It has been estimated that in some areas 70 to 80 percent of the commercial forest land on known karst areas on the Ketchikan Area have been harvested (Streveler and Brakel, 1993; Baichtal, 1993d).

On karst landscapes worldwide, timber harvest has led to serious, often long-term declines in soil depth and fertility, in some cases culminating in permanent deforestation. Trees growing on karst generally have roots extending down into the dissolved cracks in the bedrock. These roots act to pump water and nutrients back up into the forest canopy. Much of the site productivity is tied up in this nutrient cycle and in the forest canopy. When trees are harvested this nutrient cycle is broken. Soils tend to be thin residual soils on these karst areas. The greater the development of the epikarst, the greater the surface/sub-surface connection. The greater the epikarst development, the easier nutrients and soil can be transported vertically beyond the rooting depth of vegetation and into the conduit systems of the karst drainage. Vertical migration of nutrients and soil becomes possible in areas of heavy rainfall and well developed sub-surface drainage once the forest canopy is removed (Harding and Ford, 1993; Gams, 1993). Karst systems are productive but fragile (Huntoon, 1992 a and b; Streveler and Brakel, 1993).

Field observations and aerial photo interpretations show strong evidence of greatly increased surface runoff on karst areas after harvest, which increases sediment, nutrient, and debris transport capability of these systems. Transport capability increases both vertically and laterally. Current harvesting techniques leaves the slash within the unit, which helps to protect the shallow fragile soils from erosion and drying. The Ketchikan Area's timber regeneration information is from low elevation, flat topography, karst areas, where there seems to be few regeneration problems. Most easily accessible low-level karst areas within the Area have been harvested. Timber harvest is now moving onto steeper, higher elevation karst areas which are characterized by shallower, better drained soils. Observations suggest that with harvest atop these soils, much of the soil may be removed if adequate log suspension is not achieved. Often, only a thin organic mat covers the karst. The exceedingly shallow soils become excessively dry once the protective forest canopy is removed. The high rainfall of the Area can rapidly move these fragile soils into the well developed epikarst. Observations suggest that these steeper, higher elevation karst areas show less than desirable regeneration or remain as bare rock slopes within harvested units.

Wildlife. Many wildlife species find the surface karst features and the stable environment and shelter provided within the caves to be valuable habitat. Caves have been used as natal den sites for otters, and as resting and denning sites for deer, bear, wolves, and small furbearers. Deer are known to rest around cave entrances both in summer, when the air coming from the caves is cooler, and in winter, when the cave entrance environment is warmer than elsewhere.

Cave systems provide critical roosting and hibernating habitat for bats. The stable environment within the caves provides roosting habitat both in summer and winter. Bats select cave sites because they fulfill very specific requirements involving cave structure, air circulation patterns, temperature profiles, humidity, and location relative to feeding sites (Hill and Smith, 1992). Preliminary surveys show some bat usage of most of the caves inventoried. Bats have been found within a few caves once temperatures drop below freezing. Roost sites are beyond where freezing air temperatures penetrate from the cave entrance. Three species of bats have been reported from caves in the

Ketchikan Area: Myotis lucifugus, M. californicus, and a possible Lasionycteris noctivagans. During the summer of 1993 the first ever specimen of Myotis volans has been collected from Prince of Wales Island (D. Baichtal, 1993). In December 1991, the first ever recorded hibernating bat in Alaska was described and photographed from within El Capitan Cave. The Myotis californicus collected in El Capitan cave in February of 1992 was the first live record of that species in Alaska (D. Baichtal and Cook, 1993).

Cave systems provide habitat for many invertebrate organisms. Preliminary studies conducted during July 1992 identified 77 species from collections made within several caves. Taxonomic identification of these species must be done before further biological correlation's or associations can be made. One amphipod has been identified as Crangonyx obliquus-richmondensis, the first ever record of this amphipod's occurrence in a cave in all of northwestern North America (Carlson, 1993a). Field work continued during the 1993 field season, with collections made from a number of caves. A troglobitic Stygobromus amphipod was collected by Dr. William Elliott, a member of the Karst Panel, on Heceta Island to the west of Prince of Wales Island. This species is morphologically identical with Stygobromus quatsinensis from two caves on Vancouver Island, British Columbia, Canada (Holsinger, 1987, 1993). This discovery is possibly a high-latitude world-record for a cave adapted species (Aley et al., 1993). Similar Stygobromus species were discovered in caves and karst springs on the western shore of Dall Island during the summer of 1993 (Carlson, 1993b).

Some bird species ^^ including dippers, thrushes, and swallows ^^ have been known to use cave entrances for nesting and feeding. Rookeries for seabirds including cormorants and pigeon guillemots have been found in some littoral caves.

Fisheries. The karst landscape influences productivity of its aquatic habitats in several aspects. The geochemistry associated with karst development contributes to productivity in aquatic environments through its carbonate buffering capacity and carbon input dissolved from the limestone bedrock. This will have significant downstream effects on the aquatic food chain and biotic community. Preliminary studies suggest that the aquatic habitats associated with the karst landscape may be eight to ten times more productive than adjacent non-karst dominated aquatic habitats. The karst dominated aquatic habitats support a higher biodiversity than the non-carbonate based systems, have higher growth rates for smolts and resident fish, reflect less variable water temperatures and flow regimes, and contain unique habitat affecting species distribution, abundance, and adaptations (Swanson, 1993). It is believed the karst waters have the following connection to fisheries:

1. The carbonates have important buffering effects. Very acidic waters flow from the peatlands (pH 2.4 to 5.8) into karst systems, emerging at a less acidic pH of 7.5 to 9.
2. Resident time for groundwater in the karst systems results in cool, even temperature water. Flow rates through caves are somewhat consistent. The storage capability of the karst systems results in lower peak flow events and higher low flow periods. This helps to moderate the effects of storm events on resurgence streams. The systems do remain flashy though.
3. The cave systems filter out some debris and sediments, although they do not filter out chemical impurities or microorganisms.
4. Smolts and resident trout use the cave systems for protection from predation, for shade, and for a feeding area since many insects utilize the photic zone of the cave system for breeding and shelter. Adult salmon have been seen spawning through some cave systems, and evidence of salmon spawning in the caves has been found. Salmon are reported to spawn within one river cave system on Chichagof Island.
5. Karst streams have a much greater and more diverse aquatic insect population, both within the caves and in the streams. There also seems to be greater moss and algae growth within the carbonate dominated systems, most likely reflective of nutrient availability (Swanson, 1993).

Natural History, the Paleontological and Cultural Resources

The potential cultural and paleontological significance of the caves and karst landscape is high.

The Pleistocene paleontology of the area is primarily known from cave and rock shelter deposits, which are often intimately related to archaeological sites. The cool, stable, basic environments in the caves result in exceptionally good preservation of bone and organic materials (Aley et al., 1993). Recent work on Prince of Wales and surrounding islands on the extensive karst resources, combined with botanical surveys of alpine areas and genetic studies on chum salmon populations, strengthen the argument for a well developed coastal refugium along the western coast of southern southeast Alaska. The evidence sheds new light on problems of glacial chronology, climatic change, biogeography, and archaeology along the western margin of North America (Autrey and Baichtal, 1992; Heaton and Grady, 1992; Dixon et al., 1992). To date, significant archaeological and paleontological materials have been discovered in at least thirty caves and rock shelters on the Ketchikan Area (R. Carlson, 1993). During the summer of 1993, at least three new bone deposits were located during inventory of the cave resources.

Recently, four black bears, one of which dates to approximately 11,565 years before present (B.P.) and five grizzly, now extinct on Prince of Wales Island, one dating to approximately 12,295 years B.P., have been discovered. Natal otter dens dating to 8,535 B.P. have been described (Baichtal, 1993b). Early humans were exploring caves some 3,300 years ago. The remains of both red fox and marmot, now extinct on the islands, have been recovered. The marmot was dated to over 30,000 years B.P. From botanical studies on Dall and Prince of Wales islands, plant populations have been described which suggest ancestry from local remnant populations that escaped glaciation (Hulten, 1968; Muller, 1991). Recent research concerned with chum salmon populations from the Queen Charlotte Islands and southeastern Alaska has shown that the greatest genetic variation exists in the fish along the western coastlines of Queen Charlotte and Prince of Wales Islands (Kondzella, 1993). These significant genetic variations suggest longer habitation of streams in these areas, therefore the possibility of coastal refugia. The occurrence of the Stygobromus species on Heceta and Dall Islands also supports the refugia theory. The apparent lack of troglobites on Prince of Wales Island appears to be correlated with the glacial history of the region (Aley et al., 1993). This new information, combined with limited data on raised marine beaches in the area, strengthens the argument for a coastal refugium, in which Pleistocene mammals and humans may have migrated south.

Karst Management

As a practical matter, all lands in the Ketchikan Area which are underlain by carbonate rocks should be considered a karst environment. This approach is appropriate because climatic circumstances are particularly favorable for the development of dissolution permeability in all the carbonate rocks present. No carbonate blocks within the region have been identified that do not contain karst features of one extent or another (Aley et al., 1993).

Current land management strategies consider only the dimensions of width and breadth. Karst lands add a third dimension to land use planning, a vertical dimension. The Karst Panel's second charge was to determine the effectiveness of present strategies for protecting karst resources and recommend appropriate changes. The Panel recommended a separate management track for karst lands, recognizing that not all ecosystems in the forest function the in same way. The following rationale was given as to why karst areas must be treated with special management approaches and careful planning:

"Karst systems impose major land management liabilities not encountered in non-karst areas. The subsurface karst drainage networks generally operate independently of, and with more complexity than, the surface drainage systems above them. Three important considerations apply. First, the size and shape of the karst systems often have little or no relationship to the overlying surface drainage systems. Second, the direction of flow through the karst systems often cannot be predicted from surface topography or geologic mapping. Third, the discharge from a karstic groundwater system is not always localized at one spot as occurs in a surface drainage basin. Water entering one sinkhole in a basin may discharge from several springs at diverse compass bearings from the input sinkhole. Flow velocities in the groundwater system often equal or approach surface stream velocities. Pollutants such as diesel fuels or fine sediments from roads or other disturbed lands can arrive unexpectedly at one or more distant springs within hours to a few days. Human water supplies and fisheries are routinely, and severely, impacted by such events in karst areas.

In non-karst portions of the study area sediment must move laterally to a stream, and then flow down the stream. Management efforts are made to protect riparian corridors from logging and its impacts. The large amounts of slash and cull materials remaining on the ground after logging, plus the heavy moss
growths on the ground prior to logging, help trap and retain substantial amounts of the sediment. Vegetation can rapidly become established on trapped sediments.

Karst areas transport sediment differently from non-karst areas. In karst, much of the sediment must move laterally for only a few feet before it is directly transported downward into conduit portions of the karst groundwater system. Once sediment is in the conduits there are no effective natural processes for trapping and retaining it within the system; as a result, it is delivered to a receiving spring or stream. As demonstrated by the dye tracing work conducted by the Panel, the receiving spring or stream may be several thousand feet away from the point of sediment introduction.

Areas with deep and well developed epikarst have more closely spaced near-surface openings into which sediments can be flushed than is the case in areas with only shallow epikarst. As a result, sediment transport potential is typically much greater in areas underlain by deep and well developed epikarst.

Observations by this Panel indicate that most of the thin epikarst occurs in areas at relatively low elevations on the inner islands. These are also areas with typically less rugged relief. Much of the remaining virgin forest on karst is underlain by deep and well developed epikarst and is characterized by steeper slopes; sediment transport and erosion problems will be substantially greater on such lands than on the thin epikarst and lower relief lands" (Aley et al., 1993).

The Panel is not suggesting that the karst landscape is any more or less important that other ecosystems in southeast Alaska. The important point here is to understand that karst systems function differently than other systems. The challenge is to integrate management of the karst landscape into existing land management practices.

Recommended Karst Landscape Management

The Karst Panel reviewed the current standards and guidelines under which the Ketchikan Area manages its karst and cave resources. The Panel noted that these guidelines contained commendable features and in some cases provide adequate protection for cave features (Aley et al., 1993). These guidelines attempted to recognize the importance of karst systems in placing protection around all significant karst features with atmospheric and/or hydrologic surface connection. Though well intended, much of this mitigation fell short of intended resource protection. Mitigation was successful if entire harvest units were deleted or if the block of forest in which the karst feature was located was large enough to buffer against the effects of adjacent harvest, road construction, and windthrow. As harvest continued on the karst, from spring of 1991 until the summer of 1993, it became apparent the current mitigation had less than desirable results. The Area moved from mitigating the effects of harvest adjacent to karst features towards avoidance. Some of the shortcomings of the mitigation was not in design but in communication between resource specialists and road design engineers, timber harvest layout crews, and timber sale administrators. Often the inventory showed that a significant karst feature was adjacent to planned activity but never received the intended protection.

The panel spent long hours evaluating the effectiveness of these guidelines by looking at applied mitigation in previously harvested units. From this assessment the Panel identified six short comings of present resource protection actions. They are as follows:

1. The level of effort expended in reconnaissance work to locate and assess caves has been inadequate. This is to be expected in a fairly new program. Adequate reconnaissance, especially in the densely forested and rugged topography of the study area, requires detailed field examination.

2. There has been insufficient time between reconnaissance work to locate and assess caves and the start of road construction or timber harvest activities. This results in last minute surprises and

band-aid mitigation efforts instead of sound resource management.

3. There has been a lack of adequate recognition of the adverse impacts of roads on cave resources.

4. There has been a lack of adequate recognition of the adverse impacts of quarries on cave resources.

5. Typical cave resource protection in the study area has focused almost exclusively on those caves reached through humanly accessible cave entrances. There are karst portions of the study area where surface features clearly demonstrate that caves, and probably very sizable caves, underlie the area. Such caves are not receiving resource management attention equal to that provided for caves with open entrances. This is not a desirable resource management situation.

6. Typical cave resource protection actions have focused upon cave features (and particularly cave entrances) rather than upon cave systems. Cave resource protection must shift its focus from feature protection to system protection strategies (Aley et al., 1993).

Recharge Area Delineation and Vulnerability Mapping

After review of the current management strategies being applied on the karst ecosystem, the Karst Panel recommended a management strategy which focused on recharge area delineation and vulnerability mapping. The panel characterized the two components of the strategy as such:

"A recharge area for a cave or spring is the area which contributes water to the cave or spring. In some cases the recharge area is little more than the land which overlies the cave. However, in many cases (and especially when the cave contains streams or lakes) the recharge area may be very large. Groundwater tracing is a fundamental tool for recharge area delineation. The general approach is to introduce fluorescent tracer dyes at points where surface waters sink into the groundwater system and then sample for these dyes at springs, caves, and other relevant points.

An approach called "vulnerability mapping" (sometimes called "hazard area mapping") is a land management tool which has been used effectively in a number of karst areas (Aley and Aley, 1993). Vulnerability mapping utilizes the fact that some lands in a karst area create appreciably greater groundwater contamination risks than other lands. As an illustration, lands in close proximity to a sinkhole or other direct and open connection with the karst groundwater system represent greater contamination risks than similar lands further from such features. We believe that recharge area delineation, in land use and land management actions in karst portions of the study area is appropriately tailored to site conditions" (Aley et al., 1993).

Vulnerability Mapping Steps

The Karst Panel has outlined the steps required for vulnerability mapping and recharge delineation. Such delineation and mapping will help insure that land use and land management actions on the karst landscape will be specifically tailored. This method of land classification focuses on the fact that not all karst areas require the same management strategies. This land classification method takes into account the many resource values found within the karst landscape, those which contribute to karst development, those on and within the unique karst areas, and those which benefit from the processes within the karst (Aley et al., 1993). The following are the steps outlined by the Panel to facilitate vulnerability mapping:

The first step is to separate lands underlain by carbonate rocks from those underlain by non-carbonates. The carbonates clearly require a higher environmental vulnerability rating for management purposes. The recommended vulnerability mapping would apply only to carbonate rock areas or areas which contribute waters to such areas.

The second step is to identify important features through inventory methods. These features would include, but not necessarily be limited to, the following:

A) The presence and locations of caves which contain, or may contain, features of significance. This type of inventory work is already being done on the study area; it should be continued and expanded.

B) The presence and locations of springs, gaining surface stream segments, active swallow holes in streams, and apparent losing stream segments (surface stream segments which appear to lose appreciable water into the groundwater system).

C) The location of sinkholes or, where sinkholes are particularly abundant, the boundaries of areas with intensive sinkhole development. Some of the karst areas we visited contain linear karst valleys; such valleys should be viewed as sinkholes even though they may not be totally encircled with closed topographic contour lines.

The location of sinkholes, sinkhole areas, and linear karst valleys is of particular importance because of the hydrologic functioning of such features. Sinkholes are visible in forested areas because they function as transport features for water, sediment, and organic material. Sinkholes which were incapable of transporting sediment and suspended organic material would soon plug with these materials and either fill with water or else lose their surface expression because of infilling. The existence of a sinkhole is an ipso facto demonstration of the sinkhole's ability to transport sediment and suspended organic material into the karst groundwater system. Furthermore, if the karst groundwater system could not also transport the introduced sediment and suspended organic material then the sinkholes would plug with introduced materials and either create small ponds or else ultimately lose their surface expression.

D) Identification of sensitive habitats and features which might be adversely affected by land use changes in the area being investigated. These habitats and features must specifically include, among other things, streams important to fisheries and streams or springs used as domestic water supplies. The inventory work must recognize that many sensitive habitats and features are likely to be located appreciable distances away from points where waters enter the karst groundwater system.

The third step is to conduct groundwater tracing to determine the point(s) to which a particular karst area drains. Such tracing work will also provide useful insight into the responsiveness of the karst systems within the area under investigation. The tracing work is a crucial component of vulnerability mapping; you must know where the water goes if you are to credibly assess and characterize impacts. Furthermore, the tracing work must place particular emphasis on features identified in step 2.

The forth step is to delineate the land under investigation into various vulnerability categories. In general four categories can be established for most karst areas; low, moderate, high, and extremely high vulnerability to resource degradation (Aley et al., 1993).

Conclusions

The karst and cave resources found within the Ketchikan Area of the Tongass National Forest have been found to be of international and national significance for a wide variety of reasons (Aley et al., 1993). These are newly discovered and recognized resources. The Area needs to move rapidly to insure wise management of the karst landscape, given the focus of proposed timber harvest on these lands and the cumulative effects of past harvest. The challenge is integrate management of the karst landscape into current land management strategies. The Area needs to recognize that the karst landscape cannot be managed the same as other, non-karst lands. The Federal Cave Resources Protection Act requires protection of caves on Federal lands. The intent of this act is to protect cave resources not karst resources. However, it is important to recognize that caves and associated features and resources are an integral part of the karst landscape. Karst must be managed as an ecological unit to ensure protection of the cave resources. Sound karst management means recognition of all the resource values of the karst including timber and recreation values. The Karst Panel has proposed a method by which karst lands can be managed by continued inventory, recharge delineation, and vulnerability mapping. This management strategy weights the various resource values and functions of the karst landscape outlining the level of management appropriate for each vulnerability class. The Panel further points out that land management and land use decisions must recognize the archipelago setting and be island specific. The highly fractured blocks of carbonate biologically become islands within islands. In the Panel's final conclusions the members point out that

"The Area's goal must be ecologically sound and scientifically credible resource management of the karst lands of the study area." The Ketchikan Area is rapidly moving to apply these management strategies to the karst landscapes of southeast Alaska.

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MANAGING THE BUSIEST CAVE IN WASHINGTON

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Ape Cave has attracted the attention of North Westerners from the time of its discovery by a local logger just after World War II. Following a long series of political and natural events the cave is now a major attraction within Mount St. Helens National Volcanic Monument. In the 1993 season 130,000 people visited the cave.

DISCOVERY AND EARLY EXPLORATION

Ape Cave is widely known as the longest intact lava tube in the continental United States with a length of 12,810 feet. The cave was discovered in 1946 by Lawrence Johnson of Amboy. Lawrence was logging at the time and might have driven his bulldozer into the entrance if his attention hadn't been attracted by something unusual. What he saw was a log with roots attached, projecting into the air. Later told speleologists: "I have worked in the woods all my life, and I knew trees don't grow upside down". He climbed down from the dozer, parted the huckleberry brush, and discovered the pit-like entrance of Ape Cave. The tree had fallen into the overhanging entrance then inverted itself, leaving its roots in the air.

Following its discovery, the cave remained unexplored until 1951 Harry Reese, leader of the local Speelyai Boy Scout Troop, learned of the cave and decided it would make an interesting outing. The Scouts had already explored nearby Ole's Cave, and were eager for another adventure. To enter the cave the scouts had to crawl down the inclined trunk of the tree first seen by Johnson. Once at the sinkhole bottom, a large black opening beckoned the group down slope. The adventure this day was short lived, however. About 100 feet inside, the floor dropped away into a dark pit. They could see the bottom 18 feet below but there was no way to climb down. The next weekend they returned with a rope, tied a loop around the chest of a willing volunteer, and with everyone else holding the rope, lowered him into the darkness. Using a Coleman Lantern, the lone explorer walked down slope and was gone for so long the others were becoming worried. A rescue was about to commence when light from the lone scout's lantern started to cast long dancing shadows across the cave walls, signaling his return.

As soon as he was pulled from the pit, he began to tell stories about the long seemingly endless passage, and weird sand formations along the floor. The following weekend they came equipped to build ladders and open the cave for everyone to explore. Long poles were cut and rungs nailed between them to form ladders. As the weeks passed, the scouts explored the furthest reaches of the cave. They found large rooms, sand castles, a skylight opening to the surface, a lavafall. and a second entrance at the far up-slope end of the cave. The scouts, who liked to call themselves the Mount St. Helens Apes after the legendary Sasquatch, began to take newcomers to the cave. The cave became known as the Ape's Cave; eventually the name was shortened to Ape Cave.

From the beginning the "Apes" were staunch conservationists. When they took newcomers to the cave, Harry Reese and the scouts would conduct a solemn ceremony which climaxed the tour. With all lights turned off, everyone was invited to repeat an oath to protect and preserve the cave and all its features. With everyone's eyes widely adapted to the darkness, Harry would strike a single match causing the cave to come alive with light--an impressive symbolic demonstration of the effect of one light in the darkness. Reese would then welcome them into the order of Mount St. Helens Apes; a special brotherhood sworn to live their lives as true conservationists.

A select group of naturalists have been authorized by the original Mount St. Helens Apes to continue the initiation rights. Today a select few visitors that are offered the opportunity to take the oath, become "Apes", and swear their allegiance to conserving caves. In this way the tradition started so long ago continues to live with a new generation.

The cave first came to the attention of speleology in the late autumn of 1958 when a Seattle-based Western Speleological Survey team headed for nearby Ole's Cave. The team returned to Seattle dead-tired but literally bubbling about a lava tube "nearly three miles long". Dr William R. Halliday, the survey director, knowing how easy it is for even the most experienced speleologist to overestimate, skeptically volunteered to eat every inch of the new cave over two miles. For a long time Northwest cavers goaded him with fanciful recipes for fried, baked, or boiled 1,000 foot lengths of lava tube pasta. When the main parts of the cave were hastily mapped a few days later on Christmas day, the total came to 11,215 feet: 2 1/8 miles.

Finally in March 1978, the Cascade Grotto of the National Speleological Society re-mapped the cave in detail, finding the total slope length of its passages is about 12,810 feet. Almost 90 degrees of this length (11,334 feet) is along the main corridor from the lava seal at the upper end of the cave to the sand fill at the lower end of the terminal crawlway. The rest is about equally divided between short upper levels (such as that at the main entrance) and short side passages.

EARLY MANAGEMENT

As early as 1961 there was a move afoot to see Ape Cave and the surrounding Mount St. Helens area established as a national monument. In October of 1961 Congresswoman Julia Butler Hansen was invited to the cave--in the rain--with a large contingent of government officials and representatives of local chambers of commerce. All entrance was then by way of Reese's slippery pole ladders, which were not designed with congresswoman's skirts in mind! She demurred. A National Park Service feasibility study was commissioned which described the political and natural attributes of the area. The forest service also started to take notice of the cave, which at the time was owned by the State of Washington, as an inholding within the Gifford Pinchot National Forest.

The Forest Service developed a management plan for the Mount St. Helens Lava Cave Recreation Area which emphasized development for recreational use. Lands were identified for acquisition and after exchange of 13,500 acres with the State of Washington, the Forest Service had acquired title to 80% of the area. In the early 1960's the State of Washington Department of Natural Resources, logged the area surrounding the cave entrance, an impact which only today, (thirty years later) is beginning to look natural again. The remainder of the wasn't acquired until early spring, 1983.

By summer of 1967 the Forest Service had developed a parking lot near the entrance, and built a stone and metal stairway into the cave. A site sign was installed and the cave was open for self-exploration. A rustic split rail fence surrounded the entrance. Starting in 1974 the Oregon Grotto of the National Speleological Society approached the Forest Service about becoming volunteer hosts at the cave. Members spent the next six summers hosting the cave on weekends between 10:00 A.M. and 4:00 P.M., answering questions and handing out litter bags and informational leaflets. Some came equipped to demonstrate proper caving equipment and proper techniques. Members would take a weekend each spring to thoroughly clean litter and spray painted names from the cave. The experiment proved a resounding success, and by 1976 they counted 016,500 visitors.

MOUNT ST. HELENS ERUPTS!

By the time Mount St. Helen's erupted in 1980, signaling a two year closure of the area to all recreation, the grotto was counting up to 26,000 visitors each summer. A significant increase in use and impact to the cave. The cave was again opened in 1983, in a flood of public interest surrounding Mount St. Helens. Interest in Ape Cave immediately increased, and within two seasons it became one of the two most popular places to visit. The Oregon Grotto was again at hand to assist with interpretation and management. The need for season long attendance was obvious, and was accomplished at first with volunteer interpreters, and later supplemented by paid naturalists.

During the spring and summer of 1983, following land exchange for acquisition of the upper entrance, the Oregon Grotto took on one of its most aggressive projects. For years people visiting the cave would exit by the upper entrance and try to find their way back to the main, lower entrance, through the woods. This resulted in frequent lost person reports, and a number of rescues. Following Forest Service plans, the grotto constructed a 1 1/4 mile long trail between the two entrances. On some days as many as 24 volunteers would be working at one time on the construction. In one day alone over 1,000 feet of high standard train was completed.

By August the trail was complete, but that was not the end of their involvement. They have since assumed permanent adoption of trail and cave maintenance. Their hard work contributed toward the designation of Ape Cave as the first underground National Recreation Trail in 1979.

Following the 1980 eruption, the area surrounding Mount St. Helens, including the cave area, was declared a Geologic Area by the chief of the Forest Service. By 1982, this earlier designation was replaced when President Carter signed into law legislation creating the Mount St. Helens National Volcanic Monument. When Mount St. Helens was designated, the law required the forest Service to develop a management plan within a year. Through this planning process, the Ape Cave area was identified for a face-lift. By 1988, construction was completed. Road 8303 had been moved away from the cave, the old road bed rehabilitated, a new parking lot constructed, the "Apes Headquarters" (a lantern rental-interpretive center) constructed, new rest rooms, a barrier free trail to the cave entrance, and interpretive kiosk built.

In 1983, the first edition of Ape Cave and the Mount St. Helens Apes was written by William R. Halliday and Charles V. Larson. Published by ABC Printing & Publishing, this is an authoritative, illustrated guide to Ape Cave. Sold for $1.95, this has become very popular and sells hundreds of copies each season. Charles Larson's excellent photographs grace the book and are used for wall murals in the Apes' Headquarters.

The Northwest Interpretive Association, a non-profit organization, now rents lanterns and sells interpretive materials at the cave. Proceeds from the sales pay the wages of employees at the site, and allow the Forest Service to provide free interpretive tours of the cave. During 1993, total visitation to the cave exceeded 130,000 people, making it one of the most heavily visited caves in the country, and the envy of many commercial cave owners.

Working with the Northwest Interpretive Association, the Oregon Grotto has revised and updated the popular Ape Cave brochure, and prints copies for free distribution at the cave and other interpretive centers. With the Association buying the paper, the Grotto prints the brochure on their offset printing press, providing a valuable service to visitors. The brochure discusses the history, geology, and formation of the cave. The brochure also provides a simple guide of the cave and gives guidelines for safe caving.

SUMMARY

From the time of its discovery, Ape Cave attracted the attention of speleologists, recreationists, and government agencies. It was early recognized for its potential as part of a national monument, but its designation had to wait for the attention drawn by the 1980 eruption of Mount St. Helens. The cave is now one of the most visited sites in the Monument, with a yearly attendance envied by commercial cave operators across the country. Making this cave accessible, providing maintenance and interpretive programs, has been possible through the generosity of the Oregon Grotto of the National Speleological Society and the Northwest Interpretive Association. The dedication of these partners is critical to the yearly operation of the site and serves as a growing example of public-private cooperation.

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The author gratefully acknowledges permission granted by ABC Printing and Publishing for use of historical excerpts from the book "Ape Cave and the Mount St. Helens Apes".

THE DARK CANYON ENVIRONMENTAL IMPACT STATEMENT: THE PROCESS AND THE PRODUCT

Joe Incardine
Bureau of Land Management

ABSTRACT

The Bureau of Land Management (BLM) is preparing an Environmental Impact Statement (EIS) on Yates Energy Corporations's Application for Permit to Drill (APD) the Diamondback Federal No. 1 well, located in BLM's Dark Canyon Special Management Area, north of Carlsbad Caverns National Park and with 1 1/2 miles of the known extent of Lechuguilla Cave. Since approval of an APD is a federal action, BLM has the responsibility and authority for the following: ensuring appropriate resource protection; assessing the cumulative impacts of the proposed action and reasonable foreseeable development scenarios in this sensitive cave area; developing mitigative measures; and considering reasonable alternatives. Three public meetings/hearings have been held over the past two years to present information and receive comments. BLM is working closely with the National Park Service to respond to the substantive public comments received on the Draft EIS (August 1992). Based upon comments received, analyses of new information, as well as subsequent consultation with NPS, EPA, and the caving community, the Final EIS is changing dramatically. The final EIS will be incorporating new geologic information which was presented by a science panel to the NPS, establishing a "Cave Protection Zone" north of Carlsbad Caverns National Park on BLM public lands.

THE IMPORTANCE OF KEEPING RECORDS

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Cave Specialist
Coronado National Forest
Sierra Vista Ranger District

ABSTRACT

As more and more individuals and/or groups become involved in cave management as employees, volunteers, researchers, etc., it will become increasingly important to maintain an accurate accounting of information accumulated in cave files. It is well known that often the greatest impacts to cave resources are activities such as surveying, photography, and various types of research. Meticulous record keeping and a system that safeguards information must be established in order to minimize duplication of efforts and properly manage documents.

CAVE SURVEY STANDARDS FOR CARLSBAD CAVERNS NATIONAL PARK

Dale L. Pate
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Carlsbad Caverns National Park

INTRODUCTION

"Modern day" cave exploration and surveying began in Carlsbad Caverns National Park (CCNP) in the 1960's with the advent of the Guadalupe Cave Survey. Carlsbad Cavern, many back-country caves, and more recently, Lechuguilla Cave have seen large numbers of teams surveying and resurveying many miles of cave passages and rooms. Though all surveyors have had good intentions, there have been extreme variations in the quality and accuracy of field notes and survey methodologies. Recent management of the caves of CCNP have increasingly relied on more accurate and complete survey and inventory notes.

In order to impact the caves as little as possible while gathering a maximum of information from each survey trip, we have developed a set of survey standards that must be adhered to by all parties interested in surveying in the caves of CCNP. The Cave Resources Office will work with each group to help bring everyone up to these standards. The main objective of surveying teams should be the gathering of quality data.

A survey team may not have more that 4 individuals per team. Teams may be given permission to have more than 4 individuals if they can show a specific need. In addition, no one may enter unexplored or unsurveyed passages without surveying as they go.

There are many passages in Lechuguilla Cave and Carlsbad Cavern that have been "scooped", but not surveyed. In order to avoid further abuse by relatively few individuals, everyone must adhere to this policy.

All original notes will be kept in the park unless a written formal agreement, such as a Memorandum Of Understanding, specifically states that original notes will be kept by the originating party. The notes should be turned into the Cave Resources Office before leaving the park. Copies of notes will be provided to those doing the work upon request.

THE SKETCHER

The sketcher is the most important person on the survey team and has the most responsiblities regarding the survey trip. He or she is responsible for the team. The sketcher must ensure that any unsurveyed passage seen by any member of the team is surveyed on that trip. He or she must also ensure that backsights are read and recorded.

Once the team begins to survey, the sketcher is the leader of the team and controls the speed and ultimate direction the team takes. All other team positions should work with the sketcher to help accurately survey the cave passage.

Park provided cover sheets and data sheets should be used unless specifically stated in a written formal agreement that the originating party can use their own sheets. This is to help bring consistency to the various surveys being performed in the park. All surveys should have a cover sheet and should be filled out completely. When filling out the cover sheet, be sure to record the name of the cave, the general area of the cave, and the more specific area if possible. Also record the full name of those individuals participating in the survey.

Data sheets are straight forward and should make note-taking easier. Enter one station per box with the distance, azimuth, vertical angle, and passage dimensions in the corresponding boxes. DO NOT write two station numbers per box. This is confusing when it comes to data entry. Also, record all numbers using decimal points, not fractions. This makes it much easier for data entry.

Sketchers should have designated letters to use for new stations before entering the cave.

These will be provided by the expedition cartographer or the Cave Resources Office.

The sketchers goal is to produce a quality sketch that accurately depicts the passage that has been surveyed and to record all necessary notes, numbers, etc. that accompany the sketch. The sketcher is responsible for making sure that all needed items are done correctly. <u>There are three types of drawings that must be produced for all surveys.</u> These are the plan, profile, and cross-sectional views. All drawings must be drawn to scale, on graph paper, and should have a north arrow and a distance scale on <u>each page.</u> The sketcher should use an appropriate scale for the passage being sketched. The sketch should not be so small that it is impossible to show any detail, but it should also not be so large as to not fit well on the page. If the passage is small to medium in size, then 20 or 30 feet to the inch would work well. If the passage is large to extremely large, then 50 feet to the inch is appropriate.

Heavy dots or small triangles can be used to denote survey stations. Make sure the stations are marked accurately and labeled clearly on the sketch. If during the course of the survey, you change scales on your notes, be sure to clearly indicate that a scale change has taken place.

The sketcher should also strive to take legible notes that are clean and neat.

<u>PLAN VIEW</u> - This drawing should be done with a protractor and ruler, to scale on graph paper. The plan view should concentrate mostly on floor detail. Cave walls, boulders, columns, flowstone, drops in the passage, etc. should be drawn in their proper positions and orientations. Smaller features should be added with general symbols such as gravels, sand, mud, dirt, etc. The use of floor-sloping symbols are OK and necessary in places, but the composition of the floor should also be apparent from your sketches. Writing a general statement such as "All floor detail is gypsum" is not an acceptable practice for most situations. Sketchers should take the time to fill all floor detail in on the plan view with the proper symbols.

If you have plotted stations accurately, any major survey errors should show up in your sketch.

<u>PROFILE VIEW</u> - A running profile, taken from survey point to survey point, should accurately depict ceiling height changes, floor changes, height of station above the floor, formations such as stalagmites, stalactites, soda straw areas, rocks, boulders, bedrock, and other important features that help relay more information about that particular passage. Be sure to include ceiling leads on the profile as well. The profile should also be plotted accurately. It can be located next to the plan sketch or done on a separate sheet of graph paper. Label the survey points with heavy dots or small triangles and the station name.

<u>CROSS-SECTIONS</u> - Cross-sections are an important part of the sketch and should be done whenever there is a significant change in the character of the passage or every 100 feet or so. You can never have too many cross-sections. Make sure the cross-section and the view direction is clearly marked on your sketches. Like the profile view, they should depict all important features that are found when looking in cross-section at that particular point in the passage. Obviously, this should include the general shape of the passage. When surveying a large room, cross-sections as well as a running-profile down the middle of the room are very helpful.

PASSAGE DIMENSIONS

Passage dimensions are most accurately being recorded on the plan, profile, and cross-sectional sketches. However, it is very time consuming for someone to go back over all sketches to retrieve needed data. It is much easier to record passage dimensions as the stations are being established. The goal is to record numbers for left-wall, right-wall, ceiling, and floor that best represent the actual passage dimensions at that point. Sometimes a station will be located in a position that is not indicative of the passage itself and it will be necessary to assume that the station is in the middle of the passage. In most cases, the distance from the floor and ceiling as well as left and right wall will be an estimate. For left and right wall try to estimate the distance across the passage from the station. Measure across if this is feasible and more helpful. If the ceiling height is very high, try to triangulate to a point on the ceiling and a point of the floor. Fig.1 shows a graphical way for determining ceiling heights.

Figure 1. GRAPHICAL SOLUTION FOR DETERMINING CEILING HEIGHTS

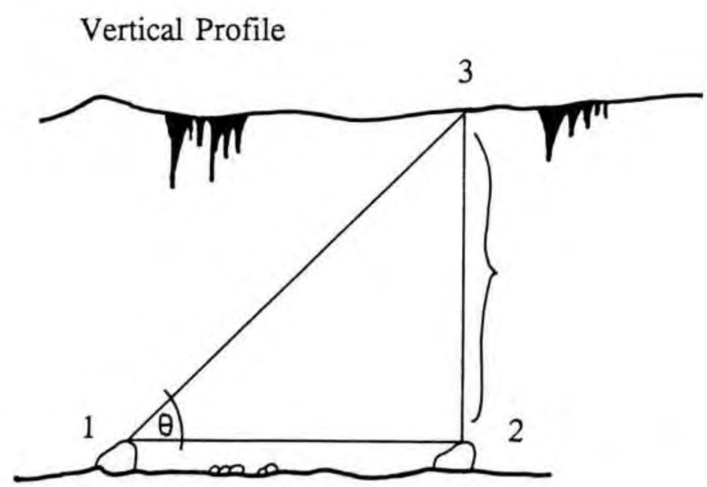
Using graph paper,pick a point on the ceiling to be measured. Establish station 2 directly under this point.

Measure the distance between station 1 and station 2 (Vertical angle MUST be 0).

Take the inclination between station 1 and the point on the ceiling directly above station 2 (3 on the illustration).

Plot this data in the survey book. Drop a perpendicular line from the point on the ceiling to station 2. This is the ceiling height which can be measured directly from the graph paper.

Vertical angle = θ



MAPPING ROOMS AND LARGE PASSAGES

When mapping a large room, you can either pick a spot in the middle of the room and do a series of spray shots to determine wall locations or do a perimeter survey around the room. Figs. 2 and 3 are graphical representations of these two methods of surveying large rooms. Spray shots or perimeter surveys do not contribute to the caves total length. These extra survey shots are used to firmly establish shapes and sizes of the larger rooms and passages.

Just remember, the goal of each survey is to produce a quality set of notes with minimal impact on the cave features.

Figure 2. SPRAY SHOTS

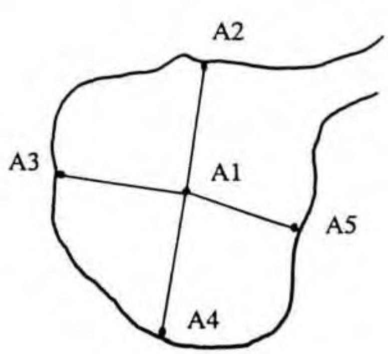
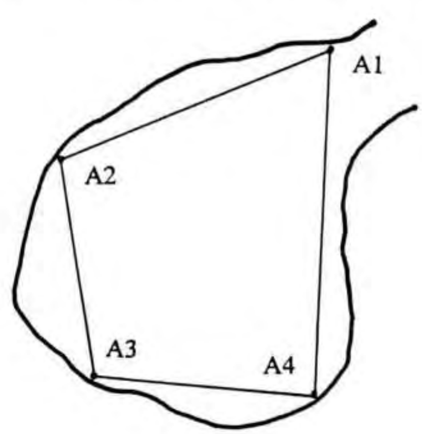


Figure 3. PERIMETER SURVEY



INSTRUMENT PERSON

The instrument person is a very important position and requires diligence and care. This person is responsible for making sure the instruments are in good working order and have been run through the test course near the CRF huts before using.

Several different types of instruments may be used; however, they must all be in degrees and must be oriented to magnetic north. Instruments utilizing quadrants or degrees and minutes may not be used. Readings should be to at least .5 degrees, i.e. 105.5 degrees. If the instrument reader can comfortably read to the nearest .25 degrees, then that is acceptable also.

In order to prevent resurveys because of loop closure errors, <u>BACKSIGHTS as well as FORESIGHTS</u> must be read whenever possible. When compared, the resultant readings should be no more than 2 degrees different. If a discrepancy of larger than 2 degrees occurs, then the readings should be redone. REMEMBER, the goal is to produce a QUALITY SURVEY. This is not a race. Sometimes, because of the difficulty of reading instruments between two particular stations, no amount of rechecking will provide agreement between the foresight and backsight. Usually, the instrument reader will have more confidence in either the foresight or backsight. He or she should communicate to the notekeeper which one is thought to be more accurate. The notekeeper will then circle the better reading. Certainly, this will not be the case at all stations, but should help when looking at loop closure errors. Loop closure errors of greater that 2% are considered unacceptable and may show the need for resurveying a portion of that loop. In order to avoid resurvey, it is very important that the instrument person be experienced and careful.

Every effort to read backsights should be made; however, sometimes this is impossible. Tight crawlways and other hard-to-get-to positions are examples of impossible conditions. This does not relieve the team of the responsibility to get backsight readings whenever possible. Once again, the real push is to produce a quality survey and as such it takes time.

For those using a Suuntos compass and inclinometer, be sure to use just ONE eye and move the instrument back and forth or move your eye up and down to accurately line up the station point and the line in the instrument. Using the two-eyed method often introduces errors in your readings because the eye looking through the instrument and the eye looking at the station point are in two different locations.

LEAD TAPE POSITION

This position on the survey team is as important as the sketch and the instrument reader. The lead tape determines the route to take unless the sketcher overrides his decision. (Remember the sketcher controls the survey team at all times.) It is the responsibility of the lead tape to locate survey stations an optimum distance from the previous station while planning ahead to the next station. A station should also be set at any leads that will be surveyed at a later date. While setting stations, the lead tape must set them with the idea that the instrument person has to be able to read the instruments from that point.

SURVEY MARKERS - At this time, we have not established any one method for marking stations. Presently in use are hard plastic pieces with the station number written on them in permanent ink or blue flagging tape that have the station numbers written on them. Neither are ideal for every site, but work adequately. Station sites must be recoverable and well-marked. In addition, stations should not be located on extremely fragile formations.
The tape to be used should be in feet and tenths/hundredths of feet or meters and tenths/hundredths of meters. **Tapes in feet and inches are not acceptable.**

The lead tape position is also responsible for flagging the trail as it is being surveyed so as to minimize the impact of future visitors to these areas. Other members of the team should help in this endeavor also.

INVENTORY POSITION

The fourth person on a team inventories the features found near every station. If there are less than 4 people on the survey team, then one of the others can produce the general inventory of the areas being mapped. Recognizing cave features are essential for whoever does the inventory process. Novices should not be doing the inventory.

The mineral inventory process being accomplished in Lechuguilla Cave is a more complex inventory that requires specialized training. The contract leader for the mineral survey has the final say over who may participate in that inventory.

DESIGNATED SURVEYORS

In order to ensure that quality information is gathered on surveying trips, only approved sketchers will be allowed to sketch in the caves of CCNP.

SKETCHERS

The Cave Specialist or the Assistant Cave Specialist will work with each group to help bring and keep sketchers up to approved standards, but will have the final say on each individual. Any group or expedition to survey in caves of the park should submit names of individuals that they would like to be sketchers to the Cave Resources Office. This should be done well before any expedition begins. Copies of notes taken on other cave trips by individuals unknown to our Cave Resources personnel should be included if they wish to be sketchers. Our cave specialists will then work with the Chief Cartographer or Expedition Leader of each group to establish the designated sketchers for that expedition. Constructive critizsm will be provided to each sketcher after each expedition.

For those who have not sketched in caves of the park, to become a designated sketcher you must submit copies of sketches you have produced on trips outside the park.

SPECIAL NOTE: SURVEY TEAMS NOT HAVING A DESIGNATED SKETCHER MAY NOT ENTER ANY CAVE IN THE PARK

INSTRUMENTS READERS who consistently show unacceptable loop closure errors will not be allowed to read instruments in the caves of CCNP.

EXPLORATION

Please remember that caves in CCNP are contained within a National Park and, as such, there are strong conservation mandates that relate to the caves. It is essential that everyone do whatever possible to minimize their impacts to the caves of CCNP.

NO ONE HAS PERMISSION to explore virgin or unsurveyed passages in any of the caves of CCNP. Survey is a required activity that must be done in conjunction with exploration. Looking at (SCOOPING) passages without surveying them is totally unacceptable and will not be tolerated.

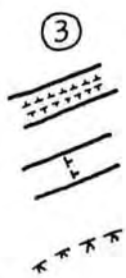
The caves of CCNP contain very fragile, very sensitive areas. Digging, breaking or altering formations, or enlarging any passages requires permission from the Superintendent or his designated representative. Breaking a trail through ultra-sensitive areas, such as aragonite bushes is strictly prohibited. You are required to notify the Cave Resources Office so that the NPS can be involved in making a decision of such magnitude. This also includes wading in, swimming through, or disturbing any newly found pools. FAILURE TO COMPLY WITH THESE CONDITIONS MAY THREATEN YOUR FUTURE ACCESS TO THE CAVES OF CCNP.

CAVE MAP SYMBOLS FOR CARLSBAD CAVERNS NATIONAL PARK

PASSAGE SYMBOLS

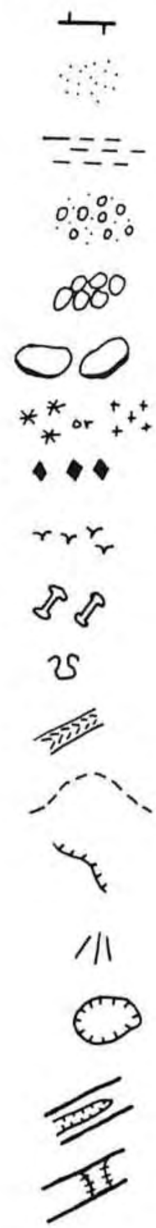
- Passage walls
- Lower level passage
- Unsurveyed or indefinite walls
- Breakdown walls
- Passage too low
- Flowstone choke
- Breakdown choke
- Breakdown walls
- Flowstone walls
- Bedrock pillar
- Unexplored lead (Describe on lead list)
- Survey station

CEILING AND WALL FEATURES



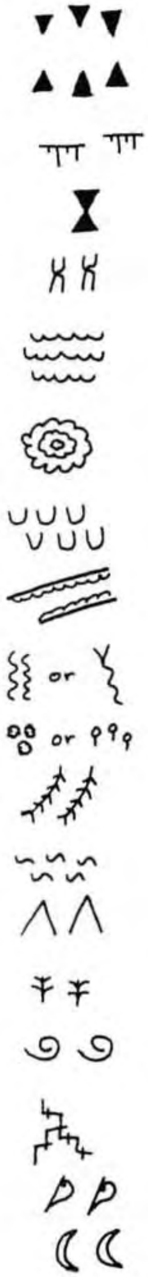
- Ceiling height
- Ceiling channel
- Ceiling lowers (hatch points to low side)
- Dripline

FLOOR SYMBOLS



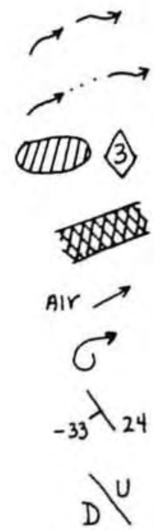
- Bedrock
- Sand or silt
- Mud or clay
- Gravel or cobbles
- Small breakdown or talus
- Large breakdown drawn to scale
- Gypsum
- Spar
- Guano
- Paleontological material
- Archeological material
- Paved trail
- Trail
- Sharp drop in floor, down in hatchured direction
- Slope
- Pit; entrance pit if so indicated
- Ledge or drop in passage Canyon in floor
- Natural bridge

SPELEOTHEMS



- Stalactites
- Stalagmites
- Soda straws
- Columns
- Helictites
- Flowstone on floor (bulged side downslope)
- Flowstone mound or large stalagmite
- Rimstone dams (drawn to shape and scale when possible)
- Flowstone on walls
- Drapery, bacon
- Popcorn
- Chandeliers
- Rafts
- Raft cones (hoodoos)
- Aragonite
- Gypsum flowers
- Boxwork
- Shields
- Moonmilk

WATER SYMBOLS, ETC.



- Stream
- Intermittent stream
- Lake or pool with depth
- Sumped passage
- Air direction
- Scallop direction
- Strike and dip
- Fault, D side moved down relative to U side

CARLSBAD CAVERNS NATIONAL PARK
SKETCHER EVALUATION SHEET

SKETCHER:			
DATE:			
SURVEY:			
COVER SHEETS & DATA PAGES	**YES**	**PARTIAL**	**NO**
Is there a cover sheet and is it completely filled out?			
Is the data legible?			
Have the passage dimensions been recorded?			
SKETCH	**YES**	**PARTIAL**	**NO**
Is there a North arrow and scale on every sketch page?			
Is the passage drawn to scale and plotted at the measured orientation (plan & profile)			
Is the sketch drawn at a scale that shows adequate passage detail?			
Is the sketch legible?			
Is there adequate floor detail?			
Does the sketch contain cross sections?			
Is there a running vertical profile?			
Are the stations clearly labelled on the plan and profile?			
OTHER	**YES**	**PARTIAL**	**NO**
Have all the pages been numbered and labelled with the sketches name & date?			
Is there a lead list?			

COMMENTS:

THE CURRENT STATE OF COMPUTER APPLICATIONS FOR CAVE SURVEY AND INVENTORY

Mel Park
Cave Research Foundation
and the University of Tennessee

ABSTRACT

Computer programs in caving have traditionally been written by amateur cavers and designed for one purpose, the generation of Cartesian coordinates from cave survey data. Some useful programs of high quality have resulted because the authors have, nonetheless, been skilled computer science professionals. The mathematics involved is trivial so that the caver/programmers engaged in this labor of love have become interested in other aspects of the problem, such as graphics, user interface, loop closures, and data archiving. Cave managers have other needs and could not be expected to find these traditional cave survey programs useful for their purposes. Managers need to know not only where the cave is, but what is found there, a requirement that has led to the Geographical Information System (GIS) model for cave software. The lead GIS caving program is SMAPS/GIS. Cave Map Language (CML) is also being used to process the large Mammoth Cave data set. The state of the art is rapidly advancing. There is an active Internet forum, having international participation, that will continue to be important in the shaping of cave software. Current trends are the implementation of more rigorous loop closure methods, implementation on workstation class machines, improved graphics, a consensus on what constitutes an universal exchange format, and important user-interface standards.

CAVE MANAGEMENT IS CONTROL OF ACCESS

Russell Gurnee

Man is basically a territorial animal and civilization has not tempered this instinct; nor culture softened the universal urge to protect self and family. A view of the television evening news shows examples of violence and aggression by individuals, as well as nations, on a scale never imagined by our "primitive and savage" ancestors. Several millions of years of evolution have sharpened our ability to influence our environment, but have done little to assure our survival when naked and alone in a hostile wilderness.

SHELTER

One of the earliest shelters used by man was the entrance of natural caves. Rock shelters afforded protection from the elements, predators, and a defensive position against enemies. Limestone cave entrances also provided drinking water and adequate space and year-round occupancy for large families. Excavation of *Cueva de Santaminia* in Spain reveals the cave was continuously occupied for more than 25,000 years; Meadowncroft Rockshelter in Pennsylvania, US shows bones of kills made by hunters 17,000 years ago.

Shelter caves also served locally as sanctuaries, fortresses, storage sites, and often as catacombs or disposal pits. Wherever caves exist throughout the world, people include them in their legends, myths, histories, and customs.

The caves became part of the economic value of a community, and possession of a cave entrance established a power base for class domination. A certain favored few people controlled the food storage, religious activity, and burial sites within the cave. This was the beginning of a system that would mature into cultures ruled by family, feudal, and fraternal power.

Oral history and apprenticeship helped man to learn from his parents, improve his lot, and lift himself out of cave shelters into more suitable structures. Written history permitted man to retain and build on the knowledge of his ancestors and change from a nomadic life to an agricultural one. Exploration of natural resources began in earnest, and "slash and burn techniques" denuded forests and fields. Areas with little rainfall, marginal land for agriculture, turned into desert. The great limestone (karst) areas of the world without surface streams became huge areas of pitted pavement unable to retain topsoil and support agriculture.

Caves retained their importance in the community however as historical and religious sites. They also had an economic value in creating local industries. Caves in Sarawak, Indonesia, and Thailand, provided hunters with bird nests highly prized as a food; saltpeter earth from caves round-the-world gave soldiers a major ingredient for black gunpowder; bat guano and bird droppings supplied farmers with valuable fertilizers before the use of manufactured chemical additives.

OWNERSHIP OF LAND

Ownership, to primitive man, meant taking for himself everything within his ability to take and keeping all he was capable of defending. It was possible for an individual to protect the entrance of a cave, but not the hunting grounds, or fields. He was forced to share with his family and fellow hunters a communal and cooperative agreement that led to leadership, organization, and government. Land that an individual could not defend became common property controlled by laws passed by the group. Since the essence of possession is the power to exclude others, the most powerful took over the land by force, and in Europe and Asia a feudal system of agriculture evolved where the surfs worked the land, but could never become landowners.

The landlords did exploit some economic value from the caves. For example: Storage for wine, cheese, vegetables, and growing of mushrooms became a major industry in western Europe.

The Church became a major landholder and used many caves as sanctuaries and catacombs; cave springs became a point-of-destination for pilgrims to "take the waters" in hopes of a cure, or simply to feel better.

In recent years, transportation, communication, and technology, have combined to make the economic use of caves unprofitable and one-by-one the interest in caves has waned. Mechanical refrigeration has made the storage of foodstuffs possible in any season. Air conditioning has made meeting rooms comfortable; and laboratories and operating rooms are humidity controlled, filtered and uniform in temperature. Public awareness and interest in caves have diminished as farmers move off the marginal agricultural karst. Cave spring water is locally useful, but with the exception of show caves (open to the public) there is little promotion or information about the value of caves that reaches the public.

SHOW CAVES

In the United States there are approximately 200 caves open to the public as tourist attractions. Modified to permit easy access and artificially lighted to display the rooms, the caves usually have a knowledgeable guide to direct the visitor. Most of the show caves are privately owned, but the major world-class caves are now under state ownership.

In many of the states west of the Mississippi River most of the land is owned or controlled by the Federal Government and the caves that exist on Department of the Interior land are subject to the recent Federal Cave Resources Protection Act (FCRPA). Development of a show cave on these lands would require compliance with this law and exhibition of the cave would have to conform to the "ownership" requirements as described in that directive. It is not known at this time how many caves are on Federal lands, but it is speculated that 4,500 caves are directly subject to this recent law.

PRIVATE CAVES

Most of the cave of the rest of the country, approximately 45,000, are on private or individual state land and are not subject to these regulations.

Ownership of land means responsibility of liability as well as control of access. Public liability of vacant land is not a great risk to the owner unless modifications have been made to create a hazard or trap for visitors, invitees, or trespassers. There are a finite number of caves that are accessible or suitable for the entry of man. These caves contain aesthetic, historical, and cultural evidences of our heritage. They also provide a habitat for specialized creatures who can not survive anywhere but in caves. These animals live on the edge of extinction, subject to the climate, environment and evolution of the surface area. We are at a crossroads in speleology with world moving toward private ownership and the "control of access" being determined by economic pressures on the surface. Approximately one third of the world's caves were owned by the Communist nations in Europe and Asia. The breakup of the Soviet Union into independent states and the introduction of local control leaves the fate of thousands of caves in doubt. During the last few years of the Soviet leadership, many local administrators attempted to stimulate the economy of individual regions by exploiting the caves. Mining of cave onyx to make trinkets as a part of local cottage industries was one example but it only achieved the destruction of many fine cave formations.

Except for show caves and other limited exceptions, natural caves are of little intrinsic value and are not considered an important asset in the appraisal of vacant land. Why should we then be concerned about ownership of these holes in the ground--of seemingly little value?

There is a long history of concern by the federal and state governments regarding forests and public lands of the United States. The Bureau of Land Management was established in 1812 to survey the public lands of the US for disposal and administrative purposes. In 1891, the United States Forest Service was created and later charged with the management of the national forest system for "its most productive use for the permanent good of the whole people." The United

States National Park Service (a bureau of the Department of the Interior), in 1916, was authorized to "promote and regulate the use of federal areas known as national parks...to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

It is obvious that the above organizations have evolved over the years and now play a different role then their original sponsors intended. There is a dichotomy in the National Park charge to "conserve...unimpaired for the enjoyment of future generations", and the provision of the Forest Service to provide "its most productive use for the permanent good of the whole people." The present Federal Cave Resources Protection Act of 1988 adds a further dimension for the various departments to add to their inventories and responsibilities regarding natural caves that exist on land managed by the US Government.

Most of the caves in the United States however, are not federally, or even state owned. Few caves are gated, many land owners do not even know that there is a cave on their property. Control of access is non-existent in most cases and unfortunately few visitors ever request permission to enter. The "wild" or natural caves are not systematically recorded or inventoried and there is so little statistical information of the history of risk or liability that the Insurance Service Office (a not-for-profit underwriting organization for the Insurance industry) does not have a rating for the liability involved in entering caves. Only in the past 50 years has the term, *management*, been applied to the "use" of these caves and without an economic base of measurement such as an exhibition cave or a water supply there seems to be little to "manage".

Ownership also implies responsibility and the natural environment is just as demanding of "defending" as our most valuable possessions. We may not be able to control or influence the weather, the sea, or the rainfall, but we can learn to live with the extremes of these forces and benefit from their bounty. It is our responsibility to be prudent and judicious in the use of these resources and pass on a healthy environment to our children. To do this we must begin now, and fortunately the government has the resources and experience to administrate this program to attain a goal consistent with prudent responsibility, for those caves in their care.

MANAGEMENT

Management is one third of a triumvirate designed to carry out a specific policy or reach a specific goal. The other two functions are Organization and Administration.

The Organization is the keystone of the structure and it provides the framework to carry out the project. The Administration sets the policy and the Management coordinates the elements through the use of men, materials, and machinery. Administration and Management are not the same although they are often confused and policy decisions are often made by management personnel. This is a mistake as the policy should be the function of Administration; the carrying out of these policies to achieve the aim of the enterprise is management. Management, because it deals with cooperation of individual employees, is considered an art rather than a science. Scientific management has achieved methods of measuring of performance, but the important ingredient is the coordination of the human element in reaching goals. Caves are ill-suited for the occupancy of man and with the exception of show caves have little to do with traditional personnel management. The term *Cave Management* presupposes that the administration has a policy or goal in mind for the use of the interior of the cave. Regardless of what that use proves to be, the management team must control access to the cave. No action is not a viable option--it makes *Cave Management* superfluous.

SUMMARY

Ownership of caves has been driven by economics through out history. Exclude show caves, and there is little intrinsic value to most caves of private or public lands. This limited monetary interest has served two diametrically opposed purposes in recent years.

PROTECTION	DESTRUCTION
Little visitation	Waste disposal
No infrastructure	Storm drain
Difficult access	Sealing entrance
Confidentiality	Water pollution
Responsible cavers	Vandalism

Awareness of the "value" of caves has been stimulated by the Federal Cave Resources Protection Act and unwittingly the Act provides a source of economic return to several diverse groups.

1. Scientists and researchers now have an opportunity of employment to prepare studies and receive grants to produce "white papers" on caves to conform with the law.

2. Outdoor outfitters who provide "Caving for Pay", soft-adventure tours are taking one-time visitors into caves that maybe ill-suited for public traffic.

3. Insurance brokers (with no history of the risks involved) are increasing premiums or refusing liability insurance policies for land owners who have caves on their property.

SOLUTIONS

The Department of the Interior implementation of the Federal Cave Resources Protection Act of 1988 provides an opportunity to define and inventory the natural caves under their care. The success of their efforts will depend upon the cooperation of the various field offices and personnel and the acceptance of the public in recognizing the need to preserve and protect this resource. The present act includes "confidentiality" as one means of protection and access. This must be supplemented by an informative program that provides awareness of the reasons for limiting access.

It is important that close cooperation and coordination is maintained between the public, the caving community, and the interagency of the government to achieve a successful management plan. Public or private, the control of access to the caves is the beginning and end of cave management.

CONSERVATION CONSIDERATIONS IN CAVE RESCUE: A CASE STUDY

Jay Jorden

ABSTRACT

Rescues in caves can have adverse consequences for speleothems,biota and other features of the underground environment if reasonable steps are not taken to minimize damage. An example, Airman's Cave in Travis County, Texas, is described. Emphasis on conservation and saving the environment vary among various cave rescue courses and instruction. Greater sensitivity for cave conservation is needed by cave rescue groups.

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A 1993 rescue in an Austin, Texas cave has emphasized the need for greater sensitivity of conservation considerations in such efforts. As the events in Airman's Cave unfolded, it became apparent that the cave -- at least for a time -- was in danger of being damaged because of what rescuers call a "seek-and-find" for a non-caver who had no serious injuries.

The cave, with more than two miles of mapped passage that has kept it on the top 10 longest list for years (Pate, 1990 et seq.), has been threatened for some time by urban development.

Airman's is located in a limestone cliff face along the banks of Barton Creek in south Austin. A very accessible cave, it was described to the author when he joined the University of Texas Grotto of the National Speleological Society in 1971, and later became the object of many visits. Above Airman's are located numerous houses and highways, including MoPac Boulevard, and the cave is well-known to nearby residents. Access to the cave is by trails which pass between and behind some of the residences.

The cave is currently open to anyone who wants to enter it. But for some years, a chain had been installed across the tight squeeze that forms the entrance, preventing all but a small child from entering.

"After many repairs and improvements, the gate was a success, but about this time the city of Austin began negotiations to buy theland as part of the Barton Creek Greenbelt, and the owners gave up worrying about who was on their land. It was then decided that it was less trouble to remove the trash, names and string than maintain the gate, so the cave has been open to all.

This policy of open access will doubtless eventually result in the need for a cave 'rescue' in Airman's Cave. Many groups of cavers encountered in the cave have only one flashlight, and were this light to fail, they would be trapped." (Russell, 1975).

This statement proved to be prophetic. On the evening of Feb. 23, 1993, a 21-year-old woman wedged herself briefly in a constriction known as the "One-Legged Man" crawl, not far inside the cave's entrance, while exploring with a friend. That prompted a rescue call-out to local law enforcement agencies and fire departments, including those of Austin and the suburb of Oak Hill. At least some of the Oak Hill firefighters have been active participants in week-long cave rescue coursework.

The woman, who was described as overweight, effected a self-rescue from the cave -- known for its series of long, low passageways -- after discovering that she could not go through the tight crawl. But arriving firefighters, rather than evaluating the situation to discover the low-grade nature of the emergency, began preparations to modify the cave entrance.

"To free the woman, workers were using an air hammer late Monday to enlarge a passageway leading to the spot where she was trapped... ." (Burgess, 1993).

One Austin caver, Mark Minton, said he talked with Bill Russell, another cave explorer in the city, about the "incredible overreaction to the woman stuck in Airman's Cave" and was disturbed by what he heard. (Minton, 1993).

"He was called to the scene, as he has been for many years," Minton wrote. "The difference is that now, in addition to a few cavers who know the cave and its pitfalls, there were also loads of rescue and media types. They had, among other things, a jack hammer which they proposed to use to enlarge a tight squeeze just inside the entrance. Bill said it was totally inadequate for the job (which did not need doing) but they decided to use it anyway, perhaps just because they had it, and they did not have anythingelse to do."

Minton pointed out that, in the event the rescuers had really needed to widen the cave opening for a stretcher, Russell said the work would have taken days.

"The squeeze is a fun obstacle that also serves as a very effective natural gate," wrote Minton (1993). "To remove it would only open up the cave to even more traffic."

Traditional instruction in cave search and rescue (SAR) has taken environmental concerns into account. But the emphasis in some cases has been the challenge of removing the patient from the cave presented by its dark and rocky environment, as opposed to any conservation ethic.

"It is important that potential cave rescuers have an understanding of the cave environment and the special adaptations and techniques that are required to effect a rescue under these conditions. This understanding will guide rescuers in the selection and dispatch of personnel, and in the choice of search routes, evacuation plans and equipment." (Hudson, 1988).

But another assessment would include the environment in such an evaluation. "Become aware of the need and importance of conservation and safety," an outline on the cave environment states. "... Conservation considerations during rescue: A. Caves are a non-renewable resource; B. Value of a human life; C. Future use of the cave." (West Virginia Speleological Survey, 1993).

The rescue of Emily Davis Mobley from Lechuguilla Cave, the United States' deepest, in New Mexico was cited in one study guide. "The rescue took four days and involved over 100 people. But the cave was not significantly damaged in the effort. The Lechuguilla cave rescue was an example of how the patient and the rescuers worked together to protect the cave. The patient requested that the route be prepared and rigged to prevent damage to the cave. Her medical condition permitted this consideration and the cave was spared significant damage." (West Virginia Speleological Survey, 1993).

But it was pointed out that caves have been heavily damaged by negligence in ineffective rescues, and that how a patient is packaged and extricated can have an impact on the cave environment for years to come.

Proper training in cave rescue is a subject of much debate. The National Cave Rescue Commission of the National Speleological Society is the pre-eminent training and resource organization. But other, sometimes competing organizations teach specialized cave SAR techniques. One such course, entitled "Rigging for Rescue," is operated out of Invermere, British Columbia, Canada. And additional groups, including the Center for Emergency Medicine of Western Pennsylvania in Pittsburgh, Pa., and the Appalachian Search and Rescue Council, provide wilderness SAR courses.

The politics of cave rescue have created different philosophies about who -- and how many -- should be trained in equipment and techniques. There is some sentiment that only cave explorers can appreciate the need for conservation.

"... Damage caused by caving and rescue activities will remain visible for many decades. The NSS motto: 'Take nothing but pictures, leave nothing but footprints, kill nothing but time' is a guide to cave by. It may, however, get compromised during a rescue. During rescues, we must try to preserve the natural splendor of the cave while saving a life." (West Virginia Speleological Survey, 1993).

Therefore, the importance of saving a patient's life can necessitate use and possible alteration of the cave environment during a rescue. However, rescuers must keep willful or accidental damage to a minimum in those cases.

But another observation, in an announcement for a basic cave rescue course in the NCRC's Eastern Region, is that instruction should be broadened beyond the caving community.

"Several recent NCRC courses have been canceled for lack of advance interest. It may be time to send in a second echelon of students not exposed to this important program and to recruit new interest in the non-caving rescue community. The caves are still there and cave-related accidents are still occurring. As one student said recently after completing the course, 'Those people really know their stuff. And I also learned how to avoid becoming a victim."' (Bradshaw, 1993).

Gating, which has been used as a cave management solution in many caves, would not have been effective in the Airman's example. "(It is on public land within the city, and could probably not be effectively gated for long,)" wrote Minton (1993).

But there is hope for other alternatives. And better response plans can evolve from evaluations of problem searches and rescues.

"On the positive side, as a result of the buffoonery, expense and publicity associated with this debacle," wrote Minton (1993), "Bill (Russell) has arranged to meet the appropriate authorities and arrange for there to be an initial call to experienced cavers to make a quick recon trip to assess the situation and determine what sort of further response is needed, if any. Meanwhile, the rescue types would be put on alert, but not actually dispatched. That way, if they were actually needed, they would know exactly what the situation was and what sort of equipment and personnel were required. Hopefully, that will go a long way toward avoiding such a scene in the future, especially in a case like this where there was a firsthand report of the situation, and it was clearly not life threatening."

EPILOG

As an epilogue, some city officials and residents who were horrified by the massive rescue operation they watched on television in February 1993 began discussing alternatives. One apparent outgrowth of the discussions has been that experienced cavers in the Austin area, instead of firefighters and others all too eager to justify purchases of expensive equipment by using it at the slightest opportunity, should be called first when a rescue is eminent.

But resource managers, explorers and other friends of caves elsewhere would be well advised to re-evaluate SAR plans to take environmental and conservation concerns into account.

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WHAT PRICE RESEARCH?

Joel M. Sneed
Co-director, Kingston Saltpeter Cave Study Project

Not long ago a federal agency prosecuted several individuals for opening up a burial cave and desecrating the graves of a dozen Indians interred therein, in their search for burial goods. But it wasn't enough for the agency involved to make an evaluation of the damage that had been done and re-seal the cave. Rather, they chose to further desecrate the burial site by continuing the work of the vandals, in the name of science, unearthing over a hundred more caves in the cave.

In another cave a few hundred miles away, a college professor, using student labor, has excavated the floor of nearly the entire cave, totally altering its appearance, in his quest for paleontological specimens. This was accomplished with no regard for the archeological resources encountered; the historical value for which the cave was noted; or for the cave itself. The damage complete, all specimens recovered have now been removed to a distant state.

Is this sort of activity really necessary? What is being accomplished? Is the value of the information gained worth the destruction wrought in retrieving it? Could satisfactory results be obtained with less destruction?

Perhaps this topic has been addressed before, but it is one with which anyone involved with caves should be concerned. As new caves are discovered, or when archeological or paleontological remains are discovered in any caves, careful consideration should be given at the outset as to how to proceed with the study. The scope of the project should be clear, ensuring that any excavation done will not negatively impact upon the cave. The entire cave and its resources, both non-living and living, must be considered. Will the activity disturb any cave life? Alter water flow? Consideration should be given to placement of excavated material and to restoration of the site afterwards. Will screening be done in the cave, and if so, what will be the impact on the cave from either wet or dry screening? If matrix is removed from the cave, what impact will that have? What will be the limits of the excavation, and what will the controlling factors be?

At Kingston Saltpeter Cave, we decided from the outset that our excavation would be limited to one small, obscure area that is not encountered by most visitors to the cave. We have determined that much more paleontological material exists in various areas of the cave, but have chosen to forego any large-scale removal of earth from other areas until the study of the initial site is complete and we can determine if a need exists. The matrix was removed from the cave for wet screening at a distance location, and the excavated area restored to a near-natural appearance. We have to date identified over 150 Pleistocene vertebrates from this small sample of matrix. We are, of course, very curious about what other remains might lie beneath the floor of the cave in other areas, but in the interest of preservation of the resources for future scientists with perhaps better methods, we have put any further excavations on hold. Are we limiting the significance of the project by doing this? Or does it really matter? Would the possibility of discovery of another species or two at this site be worth the negative impact on the cave at this time? We think not.

In addition to looking at what an excavation will do to the cave itself, consideration must be given to the impact upon other studies there. I have had several "discussions" with a paleontologist who feels that his recovery of specimens from a cave outweighs the value of the archeological resources lying above, in which he has no interest. This individual has been alerted to paleontological remains by pot hunters who, he feels are doing a service and not doing anything wrong because (1) they need the money to be made from the sale of the archeological materials and (2) they are bringing the paleontological materials to light! This is perhaps an extreme example, and hopefully his reasoning is not too commonplace, but it illustrates the fact that cooperation is needed to properly assess the value of our resources, and all aspects of the cave and its resources must be considered.

Caves provide a laboratory for many different types of studies, and management plans for the cave must be written to include methods to deal with the potential conflicts or problems that might arise. The questions and problems that have been raised herein are but a few of the many to which considerations must be given. If done properly, we will realize the optimum value from our caves and preserve them for future generations.

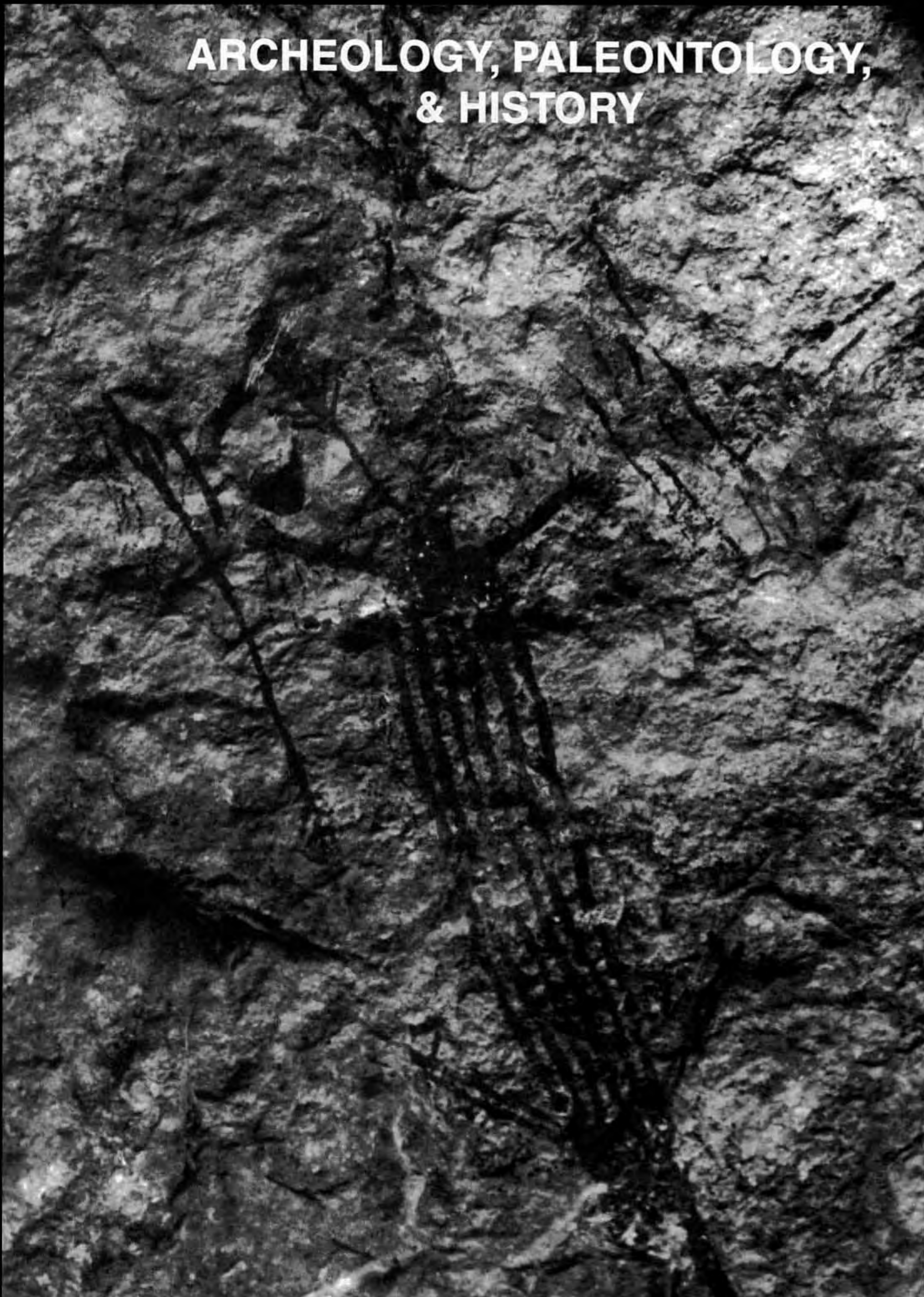
ARCHEOLOGY, PALEONTOLOGY,
& HISTORY

Photo Caption -- Pictographs from Panther Cave, Val Verde County, Texas.

Photo by Dale Pate

IT'S NOT ALL FUN OR OTHER VALUES TO CONSIDER DURING CAVE MANAGEMENT AND USE

James E. Chase, Ph.d.

ABSTRACT

The opinions expressed in this paper are solely the authors and do not necessarily represent the opinion of the any Federal Land Management agency.

While caves, rock shelters and karsts may posses geologic attributes which people may find enjoyable they are also most often locations of other important attributes (resources) that require consideration during decision making and that will influence, if not determine, their management and use. We do not consider caves, rock shelters, and karsts important because they exist; in reality they are nothing more than a hole in the ground. We consider them important because they are the locations of other resources; archeology, paleontology, Native American, recreation, environmental, and so on.

Many caves contain resource values of greater concern and importance than the recreational aspects. It is these other values that must be given consideration during deliberations concerning use. The value of these other resources must be weighed against the recreational use and primacy should be given to protecting those values which are important. In most cases accommodating recreation while protecting other values is achievable. However, in some cases this is not achievable and the cave must be closed to all uses which may affect the primary resource value(s) of the cave; be it archeology, paleontology, Native American, or other values. We have a responsibility under law and regulation to consider and protect archeological, paleontological, and Native American resources. We have no such mandate to guarantee recreational use of caves.

INTRODUCTION

Caves, rock shelters and karsts are features of the landscape formed over long periods of time under specific environmental conditions. While they may posses fascinating geologic attributes, which many people may find enjoyable, they are also most often locations of other important attributes (resources in management terms) that require consideration during decision making and that will influence, if not determine, their management and use. We do not consider caves, rock shelters, and karsts important because they exist; in reality they are nothing more than a hole in the ground. We consider them important because they are the locations of other resources; archeology, paleontology, Native American, recreation, environmental, and so on.

There are many definitions of these features, most developed by specific scientific disciplines for their own purposes. However, for our purpose the distinction between cave and karst is moot. The distinction between cave and rock shelter is relevant. For ease of definition a cave is deeper than it is wide and a rock shelter is wider than it is deep. However, a shelter may have an opening to a cave somewhere within it's confines. For simplicity sake we will call all of these features caves except where specific purposes are intended.

CAVE MANAGEMENT CONSIDERATIONS

Caves are often the location of archeological, paleontological, Native American rock art, and other scientific material and deposits. They also are often places of cultural and religious importance to Native Americans. Unfortunately caves are also often locations of vandalism. The latter may often be caused by the very people who are present for some sort of a recreational experience.

Long before the days of wood, concrete, and steel construction people used caves as places to live, die, and for religious and other cultural purposes. Other animals also use these places for shelter and as places to live, breed, and die. People and other animals while using these features brought things, including themselves, inside the feature that existed in the outside world. The animals and people have left a record of the environment, and themselves, we can obtain from nowhere else. These features sometimes act as traps for material and animals, including humans, originating outside the cave. Material trapped may be carried in by animals, people, water, wind, may simply fall in, and a host of other agents. This material may have been deposited over hundreds, thousands, or millions of years. All of these aspects create, over time, irreplaceable information vitally important for making sense out of our own lives and the planet we live on.

A great many caves contain deposits constituting a record of the environment, animal biology, and evolution covering perhaps millions of years. These deposits usually consist of floor material, wall material, bat leavings, and the nests of the simple cave rat. These deposits contain material and deposits that can not be replaced or may be the only occurrence of it's kind. In each cave a unique set of circumstances occurred, and continues to occur, to produce the deposits and record. Some caves represent unique assemblages, e.g., Natural Trap in northern Wyoming.

People using caves dig up, disturb, and contaminate the environmental, and other, record by simply walking and moving deposits during crawling and excavation. Cave rat nests are often burned or otherwise destroyed to gain access to other parts of the cave or merely as "fun". These rats are collectors. They collect material within their exploitation area and deposit it in their nests. This material often consists of material from outside the cave and represents the environment surrounding, and in, the cave. These animals collect representative samples of everything.

Over time these rat nests become time capsules with representations and representatives from the area over which the rat roamed. These nests often include material from human occupation and use of the cave. Some of these rat nests have served thousands of generations of occupants and may have been used continuously over thousands of years. There are nests that exceed 15,000 years in age. These nests represent valuable information sources for archeologists, paleontologists, and others who study the environment and many other aspects of the past.

In unoccupied caves, deposits may represent millions of years of information formed by the slow accumulation of material being deposited by various forms of animal and other natural processes. These are often destroyed by people, introducing disturbance or other environmental attributes, during other uses of the cave.

Cave deposits and material may also result from human cave inhabitants. Humans living and using caves produce deposits that, because of human behavior, become discrete or continuous records of these occupations. Often human use and occupation of caves is not obvious, thus protecting the deposits from vandals and unknowing recreationists. If humans do not actually occupy a cave they will often live outside, or nearby, and use a cave for religious or other cultural concerns such as burials, storage, or ceremonies. Humans and caves seem to go together. Recreationists, cavers, and vandals all destroy parts of the archeological record by disturbing cultural deposits in caves. Some disturbances are unknowing, some uncaring, and some intentional.

Past people often associated caves with various religious activities. A cave may have been the entrance to the underworld; e.g., to Mother Earth, or represent other important religious aspects, e.g. a spirit cave or a place for religious rites and burial. Often you will find rock art inside, adjacent to, or nearby caves. Sometime we may find sculpture, artifacts, human remains, and other human produced material inside caves. The maker, and people in general, by leaving these markers, have identified the place as important for any number of cultural or religious reasons, many of which we may never know.

When these are looked at we most often see art or things, we rarely see religion or culture. This is our bias. Try to visualize the rock art as you would many examples of paintings, or other fine art, in your own church. Try to visualize other material as a cemetery, as offerings to a deity, just as we have in our own society. It may carry the same meaning so respect it as you would like your's to be respected.

The use of caves continues today. It is this use that brings the resource protection aspects into conflict with the present day users. Much of the current emphasis is on recreational, or other, use and not resource protection. For example, livestock love caves and shelters and do their best to destroy the contents and information in their effort to find shelter. Spelunkers and other cave users, park outside, build fires, camp, dig in, pick up, and crawl through caves with seemingly little thought to what they may be destroying. Secondary impacts to the resource are often not considered either by the users or the Federal agency charged with management responsibilities.

Priorities have been reversed. In general, the resource base suffers and the other, perhaps more important, attributes of these features are relegated to a secondary, or even tertiary position. Permits may be issued with little thought for other resource concerns. In some cases the resources associated with these features cannot be protected because of prior existing law and regulation. A good example of this is mining. Some caves are the location of significant mineral deposits, such as uranium, which can be claimed and mined with little consideration or protection for other resources or values associated with caves.

Rarely are Native Americans asked for their input to developing management plans for these features. However, the law and regulation requires their input. Some, or many, caves may represent what can perhaps be best termed Native American churches or shrines. We should ask Native Americans for their opinion concerning the religious and cultural aspects of any cave we manage and particularly those for which we issue permits for recreational or other uses. As a result of not being asked or because the cave was of extreme importance I have seen Native American's seal cave entrances or portions of caves to preclude access for any use. If we do not voluntarily include Native Americans I can foresee the day when we will be required, under less than amiable conditions, to include them in our deliberations concerning cave management. We may, in fact, lose some caves for other uses.

Caves, karsts, and shelters and the information they contain are fragile and irreplaceable. The simple act of breathing can destroy some aspects of the cave resources that may have existed for thousands, or more, years in a stable condition. The caves of Europe which contain wonderful examples of Pleistocene cave art have now mostly been closed to the public simply because the public's breathing has caused significant deterioration of the murals and other archeological material inside the cave. The same thing occurs in the New World.

In many caves, rock shelters, and karsts, exist the remains of past human and animal activity. People permitted, and not permitted, to enter caves sometimes carry out bones, deface rock art, and vandalize archeological sites co-located with the cave. Conversely these same people carry in contaminates, such as microbes, that work to destroy fragile cave resources, not the least of which is the paleontological and cultural material associated with the cave. Many materials and animal remains can remain in caves, rock shelters, and karsts for a very long time and appear as if they are yesterdays leavings. These can be destroyed in a very short time. I have watched a National Register Eligible archeological site slowly disappear over a period of four years. From this same site, paleontological material has been taken from deep within the cave. All of this represents material for which we have no explanation of it's affinity or how it came to be a seven hour crawl inside the cave. I have seen cave deposits destroyed by over zealous explorers in their attempts to gain entrance to deeper portions of the cave.

SUMMARY AND CONCLUSIONS

Some of these features and the information they contain are so important that they should be closed to all but scientific, religious or other endeavors. When developing plans or permitting uses of caves all resource values should be considered and not just the recreational or any other single use. In the absence of information, acquire the information before permitting activities that may produce adverse impacts to cave resources. Evaluate all sources and types of information present and then make an informed decision concerning whether to permit use of the cave under specified conditions or whether to preclude all use except for a specific circumstance; e.g., science or Native American Religious practices.

Many caves contain resource values of greater concern and importance than the recreational aspects. It is these other values that must be given equal consideration during deliberations concerning use. The value of these other resources must be weighed against the recreational use and primacy should be given to protecting those values which are important. In most cases accommodating recreation while protecting other values is achievable. However, in some cases this is not achievable and the cave must be closed to all uses which may affect the primary resource value(s) of the cave; be it archeology, paleontology, Native American, or other values. We have a responsibility under law and regulation to consider and protect archeological, paleontological, and Native American resources. We have no such mandate to guarantee recreational use of caves.

AUTHOR'S BIOGRAPHICAL SKETCH

Dr. Chase is currently a Bureau of Land Management Archaeologist in Cody, Wyoming. Dr. Chase has over 30 years of Archaeological experience and over 20 years of Federal Cultural Resource Management experience. He has worked for five Federal Agencies, major universities, and private consulting firms with varying degrees of geographical and development responsibility from the small areas associated with the BLM Resource Area to large areas encompassing all states west of the Mississippi River. Dr. Chase's archaeological experience is world wide and encompasses all geographic areas of the United States. Dr. Chase has published hundreds of professional articles and monographs on a variety of subjects and presented a great many papers at professional meetings. Dr. Chase assists in the management of hundreds of caves, rock shelters, and karsts of varying degrees of importance. Some are world class resources such as Natural Trap and Horsethief Caves. Both of these caves are noted for archeological, paleontological, and Native American values. Other caves for which Dr. Chase has some responsibility include those of local and regional importance for a variety of values.

MANAGEMENT IMPLICATIONS OF HISTORIC WRITINGS AND ROCK ART IN CAVES

Barbara and Mike Bilbo

ABSTRACT

Over the years many restoration projects have been undertaken to remove graffiti from cave walls or rock shelter surfaces. While this work has been carried out with the best of intentions, in a number of cases where historical writings or prehistoric or historic Indian rock art were present the measures used to remove graffiti also removed the writing and/or art as well.

This paper cautions cave managers and conservation-oriented groups to study a vandalized site for the presence of historic writings and rock art and to consult with historians and rock art specialists as part of the planning process prior to initiating restoration projects. This is especially critical when considering a cave for significance inventory and nomination. A graffitied, vandalized cave may be significant.

INTRODUCTION

At Hueco Tanks State Historical Park, Texas; rock faces near Abo, New Mexico; in Fort Stanton Cave, New Mexico; and at El Morro National Monument, New Mexico all contain historic writing and/or prehistoric or historic Indian rock art. These sites are mentioned here as they have something in common with each other: **graffiti** has been executed at all of them (**Figure 1**). There are many such sites in Texas and New Mexico and more nationally and internationally. We will limit the examples to Southwestern United States and refer to several elsewhere in the U.S. and in Europe.

This paper was prompted when we became aware that historic names in Fort Stanton Cave may have been inadvertently mistaken as graffiti and subsequently removed during restoration work. We also became concerned by several articles, one on restoration, published in 1993 that appear to disparage Indian rock art and equate it with graffiti. With cave significance criteria and procedures before us, it is critical that we <u>completely</u> identify and inventory for the presence or absence of cave resources. Historic writings and rock art can be very subtle cultural resources.

The entrance to Crystal Crawl in Fort Stanton Cave was once covered by modern paint graffiti. Through the efforts of cave restoration volunteers on several occasions, the graffiti was successfully removed. Recently faint remnants of an unreadable name, and date from 1862, were noted at this location. 1862 is particularly important in relation to the nearby Fort Stanton because that is when the fort was reoccupied by the five companies of the 1st New Mexico Volunteers under Col. Kit Carson.

The study in America of history through historical writings and prehistoric or historic rock art on cave or shelter walls is still a young endeavor. Formal study of rock art roughly coincides with the establishment of the American Rock Art Research Association (ARARA) in 1974. Since then, however, natural and cultural site scholars, researchers and managers have become more aware of the need to assess all aspects of a site's character.

An overall goal of cave management has been to restore caves to as natural a condition as situations warrant. Historic remnants fit into this goal and the possible existence of both historic writing and rock art at a graffitied location must be considered. Hopefully such materials would be identified and recorded prior to restoration. During restoration, workers must be vigilant in case something shows up.

The increasing cave graffiti restoration projects may have led to the removal of more historic writings and rock art than realized. Fifteen years ago rock art researcher James G. Bain (1978:97) pointed out that rock art in interior cavern settings in the United States might be rare but believed that more sites existed. He asked cavers to become acquainted with rock art and watch for it as they explored and surveyed caves. It is important to note that in the caving community historic writings and rock art are now being more frequently recognized in caves and for their significance. Herein lies the main problem facing managers and restoration workers: the abilities to identify what is historic writing and to "see" historic or prehistoric art.

RECOGNIZING HISTORIC WRITING AND HISTORIC/PREHISTORIC ROCK ART

Pictographs are rock paintings, while **petroglyphs** are rock engravings made by pounding or incising. Incised petroglyphs are known as filiforms. Historic writings can fall under both categories, although they tend to be predominantly pictographic.

In the effort to remove graffiti from cave walls and other surfaces in natural settings, historic art and writings have been overlooked because they could not be "seen." The way in which we recognize rock art and writings depends on the depth of the petroglyph, color of the pictograph, time of day, weather condition, light source, glare, mineral occlusion, technique of drawing and other factors. To observe for **pictographs and historic writing**, we scan a likely location for a few minutes, allowing the eyes to become adjusted to shadows, textures, glare, forms and lines different from the overall natural pattern. Colors tend to be **flat, earth-tone pastels of red, white, charcoal or grey, yellow and brown**. Historic writing is usually flat **carbon black**. The edges of pictographs and letters help differentiate them from natural rock fractures, lines and texture.

Recognition of most petroglyphs depends on the patina through which designs are pounded, leaving the lighter rock interior exposed in a negative-like pattern. When the patinated surfaces do not exist at a suspect location, the textural differences of petroglyphs can sometimes be felt by touch. Sidelighting in a cave situation or at night in an open-air site is the solution to such identification.

Rock surfaces along with rock art and historic writing in caves and elsewhere are gradually being destroyed by natural causes over time. However, historic writings and rock art may be thinly coated with a mineral layers deposited by water or moisture seeping down the rock surfaces in some sites, occluding the motifs and words (Ralph and Sutherland 1979:276), resulting in variations of visibility under different lighting devices and angles of incidence. The rate of occluding varies widely from site to site. In caves, coatings may develop more rapidly that at surface sites.

At Slaughter canyon Cave in Carlsbad Caverns National Park, modern D-cell batteries, discarded perhaps ten or twenty years ago by some thoughtless visitor or tour participant, were observed by Bilbo and Bilbo (1993:61) to be still visible but encased by developing flowstone. Few, if any, studies on the rate of occlusion on rock art or historic writings have been done. The coatings may protect rock art or writings from removal during spray paint removal using certain cleaning techniques (ARARA, 1977; Bilbo and Ralph, 1984; Ralph and Sutherland, 1979).

Sometimes it takes a rock art specialist, either avocational or professional, to recognize art existence at various localities. From experience of pattern recognition, rock art specialists can usually identify rock art quickly. However, it has been our experience to refrain from stating "nothing is on this wall," for we have gone back at a different time or with different lighting, and observed rock art motifs.

Weaver (1993:3) discussed and defined some terms related to rock art in caves and also biological marks such as bear claws, and footprints of humans and other animals. He includes graffiti in his discussion and states that the writing of names and other words in caves has become unacceptable and unethical behavior for cavers, with the development and growth of the National Speleological Society in the late 1950's.

HISTORIC WRITINGS

Historic writing on natural rock surfaces is considered that which is 50 years old or more. In the U.S. such writing was historically executed by explorers, soldiers, and settlers: Spanish and Euro-American, after the time of the Spanish Entrada in Southwestern North America in the early 1500's, and Euro-American settlement along the Eastern coast of North America in the early 1600's. Writings were done in charcoal, carbon paint (lamp black), or by carving or incising. Writings can consist of one or more of the following: a name or names, writer(s) place of origin, dates, military affiliations, or other information.

Letter styles are [1] Roman Cursive, [2] Modern Roman , [3] Roundhand Script and [4] Monumental or Block. Roman Cursive is the manuscript printing characteristic of Spaniards and other early Europeans and dates from 1500 to 1800 A.D. It is identified by long, curved appendages and slight hooks or loops on the ends of the appendages (**Figure 2a**). Three cursive substyles that may be seen in Spaniard's inscriptions are: Humanistic Cursive, Black Letter Cursive and Black Letter Gothic (**Figure 2b**). Humanistic Cursive, dating from 1450-1600, consists of sloping and well-rounded letters, with distinctive terminal blots, hooks or small loops at the ends of ascending letters. Black Letter Cursive and Gothic refer to a "dense textural pattern of compressed, angular manuscript letters" which predominated from the Medieval to early Renaissance period. Individual writers sometimes mixed elements of the parent and three substyles.

Modern Roman dates from 1600 to 1900 A.D. It is a printed style usually identified by serifs. Serifs are characterized as any short lines stemming from and at an angle to the upper and lower end strokes of a letter (**Figure 3a**). Roundhand Script is an italic style characterized by strongly slanted thick and thin strokes. Capital letters are composed of distinctive sweeping flourishes. This style is the longhand contemporaneous with Modern Roman printed (**Figure 3b**). Roundhand is also known by the term "Copperplate," although this actually refers, primarily, to typesetting.

Most often seen after 1900 is Block or Monumental style. This style of lettering tends to be heavy in line weight and with no serifs. During exploration of caves in the early 20th Century signatures seem to be more often inscribed or drawn in block letters, but may also include the Roman and Roundhand styles. Jim White and other explorers of Carlsbad Caverns and nearby caves such as Ogle, left their names on cave walls in these styles (**Figure 4**).

Historic writings may often be situated in locations similar to rock art (described below). Names, dates, or other information (or portions of them) in these styles may be adjacent to or sticking out of the edge of graffiti overpainting and/or incising. Many Americans would not be familiar with writings or art of an earlier time period; slogans and such may have absolutely no meaning to our modern culture.

For instance, can you confidently explain the ramifications of "slavocrat" and how it was used? (derogatory term used by Unionists toward States Rightists just before the Civil War). Or, "O'Reiley stole a blanket and shoved it up, I hear. He shoved it for a dollar and invested that in beer." (He pawned the blanket off). A clue that one is looking at historical writing is when the meaning of a message (slogan or name) being communicated is not clear.

Some names recorded on rock walls are known in history, such as an early Spanish colonizer, Don Juan de Onate, who inscribed his name and the date (1605) on the rock face now included at El Morro National Monument. Other Spanish colonizers left their names there as well, including several Euro-Americans of the 19th Century (**Figure 2**). At most sites, however, are the names of common every-day people who indicated their passing. While their writing on rocks may seem insignificant, the opposite is often true - research resulting from the seed of an inscription has revealed unique and important histories. Examples in this region include names and dates left by stagecoach travelers and 49'ers in the mid-nineteenth century during stops at what is now Hueco

Tanks State Historical Park east of El Paso, Texas (**Figure 5**).

For instance, who was Santiago Cooper, 1878? He wrote his name in a shelter near a stagecoach stop east of El Paso, Texas. The date and lamp black paint type suggested a check with a local historical society. From their files we found he was associated with stagecoach driving but no specification was given as to pre- or post-Civil War times. Later, reference was found in Gillett (1976) that Cooper had been stationed in El Paso with Company C of the Texas Rangers in 1877. Why, of all the Texas Rangers - who often stopped at Hueco Tanks for water, did Cooper alone write his name? The location of the name may also suggest the actual location of the original stage stop, which probably has not been correctly identified. Many more questions and associated research are suggested by one name. All over America, in shelters and caves, are names and dates like this.

An inscription in Matthews Cave, Alabama, was found by members of the Huntsville Grotto during a clean-up project (Varnedoe and Lundquist, 1993, p. 251-152). Varnedoe noticed "J C'A'T Co A 6th RGT NY 1898" along with recent spray paint by soldiers from the nearby Redstone Arsenal. Having knowledge of area history, the authors knew that Redstone was not established until World War II. Research revealed that U.S. Army troops had been sent to the area in 1898 to secure crops, probably in relation to the Spanish-American War.

Bilbo (1982) recorded names and dates left from 1855 in Fort Stanton Cave, one mile east of old Fort Stanton, by the U.S. Army 1st Dragoons (now the 1st Cavalry). The names and dates had been incised on flowstone in Roundhand Script letters (**Figure 5**). Research revealed that the names were those of men in the regiment that built Fort Stanton in 1855 and were probably inscribed within three months of arriving at the fort site. The names included Pvt. Emil Fritz, a German immigrant-soldier, who later played a principal role in the Lincoln County Wars (the most notable associated person being Billy the Kid).

We now know that Fort Stanton Cave has at least six interior areas in the cave with historic writing, dating from 1855 to 1943. Names from the 1877 mapping of the cave by the Wheeler Expedition, and 1891 Great Divide expedition, correspond directly to period articles and reports. The Wheeler Expedition was one of four great surveys of the West which resulted in the formation of the U.S. Geological Survey.

INDIAN ROCK ART

In the Southwest many persons are aware of Native American petroglyphs and pictographs. Numerous sites exist where this cultural feature has been preserved, emphasized and interpreted. However, the number of sites that are known but undocumented or unprotected are at least five times more numerous. The primary cultural time periods in the Southwest are: Paleoindian (ca. 12,000-8,000± B.C.), Archaic (±8,000-300 A.D.), Pueblo (±300-1450 A.D.), Historic (1520 A.D.+)

Indian Rock art consists of pictographs (painted) and petroglyphs (pecked, carved, or incised). Three thousand or more years of early Native American visual ideas may be seen painted or incised on boulders, rock faces, walls of shelters, around the entrances to caves and in caves. Recently, a dark-zone pictograph site was documented in Slaughter Canyon Cave (Bilbo and Bilbo, 1993). At the time of the initial study in 1991 we were able to identify only three other dark zone rock art sites in the United states. In the early stages of the study, we had a notice included in the July, 1991, NSS News, asking cavers who knew of cave rock art sites in the United States to respond with information.

Responses brought to twelve the number of U.S. deep cave rock art sites known at the time (Faulkner, 1979, 1984, 1986, 1992, 1993; Gurnee and Gurnee, 1985; Greer, 1992; Veni, 1993). In other parts of the continent and the world, motifs dating several thousand years have been found in caves, the most famous of which are depictions of Pleistocene fauna in caves such as Lascaux in France, or Altimira in Spain.

STYLES

There are two basic rock art styles: Representational and Abstract. Both styles are subdivided into regional and local styles where distinct stylistic differences are noted. The Representational Style is found in most time periods (Paleoindian motif examples are unknown) and consists of motifs usually recognizable as human, animal, or plant forms, or geometric designs similar to those on pottery. Motifs include such forms as masks, humans, animals (bear, mountain lions, birds, sheep), human hands (**Figures 6a and b**). Abstract motifs, which are probably carry-overs from earlier times, form a lesser part of representational art. In the Southwest, the style continued to be used less frequently into historic times (19th Century) by recent hunter-gatherers, such as the Apache, Comanche and other nomadic groups. These Plains Indians, however, seemed to have preferred subjects that are more recognizable to us.

The Abstract Style (**Figure 7**) is primarily characteristic of the Archaic and was practiced by hunting and gathering societies in North America beginning at least 6,000 years ago and probably dates into Paleoindian times. Spirals, wavy lines, hourglass shaped forms, rows of lines or dots, circles, crosses, stylized animal or human forms, and other geometrical shapes are depicted in the abstract style art and represent an array of mostly unknown ideas which may include representations of the supernatural, of cosmology and other forces (Schaafsma, 1992: 3-4).

While some motifs in the style seem recognizable, the ideas behind abstract forms are not known. Abstract motifs are stylized and represented something known only to the people executing the motifs. Some abstract motifs in North America are recognized by older members of some Native American tribes, although the exact meanings are not known or revealed. Modern cultures such as the Australian Aborigine and African Bushmen still create both representational and abstract style rock art. Comparative studies of these cultures and their art has revealed some insight into the unknown motifs of early American cultures.

Abstract art is actually the most common style that Americans come into contact with. The basic style is fairly uniform as to motif types and size (larger than fist-sized). However, some anthropologists do not recognize or acknowledge abstract motifs as rock art. Unless a rock art site containing abstract motifs is of the density and coloration of Painted Grotto in Carlsbad Caverns National Park, New Mexico (**Figure 8**), it can be overlooked.

SLAUGHTER CANYON CAVE

This is especially true when the motifs are few on a site, faded, or worn away by time and the elements. Such a site is in Slaughter Canyon Cave (formerly New Cave), also in Carlsbad Caverns National Park. Over forty abstract motifs were recorded in 1990-1991 by Bilbo and others (Bilbo and Bilbo, 1993). We found the motifs in Slaughter Canyon cave to be essentially like those seen at many other sites in the Southwest. Dimmed by time, occluded by thin mineral coatings, the motifs faded to near invisibility in the yellow light of carbide lamps, flashlights and Coleman lanterns.

Ron Kerbo, Cave Specialist at Carlsbad Caverns National Park at the time, had suspected something different when he asked us to go to the cave and study the site. Several black motifs, easily seen, had long been believed by the park interpretive staff to be the work of guano miners or, possibly, Indians. An interpretation passed on to visitors stated that the motifs were Cherokee and represented a map and canyon.

When we looked at the site we easily identified the black motifs, and superimposed by them, other, faded, black motifs. And in either direction up and down the wall were more faded yellow and red motifs, dimly visible in the yellow light of the lanterns (**Figure 9**). Careful examination under the "whiter" light of our halogen bulbs revealed the art to be the familiar abstract motifs common throughout the Guadalupes.

Yet when a National Park Service staff archeologist from Denver viewed the sight as a part of a resource management planning process, presence of any motifs other than the black ones were essentially discounted. Even though an archeologist, she was not a rock art specialist. Her experience with rock art apparently had been the most known kind of rock art, that of Anasazi, Pueblo and other representational styles.

Even representational motifs have been overlooked, however, as in the case of a well-intentioned but not well planned cave clean-up effort in Cave du Mayriers, in Southwestern France early in 1993 (Art News, 1993:50; Weaver, 1993:2-3). Brushing away graffiti, a group of young people brushed away significant portions of 15,000-year-old paintings of bison. French officials were indignant. The group's leaders responded by stating that the cave had not been designated as a historical site and therefore it was not known to be protected.

CONTEMPORARY ROCK ART

Contemporary Native Americans have continued the tradition of rock art at some Southwestern sites. Zuni create both pictographs and petroglyphs on sandstone rock faces within their reservation. While some sites are considered ritual, a number sites have been done for artistic pleasure. A very artistic petroglyph of a Plains Indian Dancer seen at the Gallup Indian Ceremonial Dances in the 1980's was incised by a Zuni because of the influence it had on him (Young, 1990).

Younger Zuni create motifs depicting various contemporary subjects, including cars, women, and "George loves Bettina". Techniques used are the traditional incising and painting, but the paint often comes from aerosol cans and has occasionally been superimposed over traditional motifs. Some younger Zuni who have lost contact with tribal identity have defaced older traditional sites (Young, 1990).

Other Native Americans also create contemporary rock art. The Hopi draw traditional rock art in the Chaco Canyon area, east of their Reservation, and at other locations, such as Mesa Verde National Park. These ritual sites have been used traditionally for centuries and their locations are usually away from areas frequented by visitors. The Ojibwa draw motifs and inscribe their names at traditional sites to insure good health. Other tribes also draw rock art, creating both traditional and contemporary motifs. It is conceivable that caves may be the site of some of these activities. Because a traditional motif created by a Native American for ritual or religious purposes has been executed in the 1990's, is it to be considered graffiti?

GRAFFITI AND VANDALISM

Is graffiti vandalism? Vandalism is the purposeless destruction of cultural or natural objects. There are two forms of vandalism, <u>unintentional</u> and <u>intentional</u>. Unintentional vandalism is caused by ignorance of visitors as to what constitute resources protected by law, or by their own definition of vandalism. A visitor, having not "seen" rock art motifs, or educated through interpretive means, may build a fire in a shelter under the motifs - either causing obliteration by soot, or rock spalling due to heat expansion.

Intentional vandalism, which includes graffiti, is created as a reaction against authority or the 'establishment', for group or individual recognition, as a vindictive act or simply because there nothing better to do (Bilbo, 1987: 9). Graffiti, an Italian word for scribblings, has been applied by archaeologists to early Roman words and phrases scratched or chalked on walls of buildings. The statements included political and social statements, hate and love messages, obscenities, and sexual propositions and observations. There are numerous sites in the West where cowboys and others in the late 19th Century and into the 20th Century incised cattle brands, railroad trains, names and dates, and other items into rock faces.

Currently the term is applied to the same ideas but it now also includes drawings of cars, sexual organs, phrases such as "K loves M", "John 1989", racial hate statements, and illegible gang identifiers and messages. Graffiti is a graphic expression of vandalism using paint or other media, or by incising the graphic expression on natural or cultural surfaces, such as rock faces or building walls with no regard for other resources, which will be impacted. In what appears to be a macho trend, late 20th Century writers (vandals) tend to superimpose their names over earlier historic names.

SO, DO WE REMOVE IT, OR WHAT?

Mid- and late-20th Century graffiti, much of it consisting of roadside name painting or urban secretive or illegible personal identifiers and gang territorial messages will persist considerably into the future. The question arises then that graffiti done in 1993 will be considered historic after the year 2043 according to the provisions of the Antiquities Act of 1906. But does modern graffiti need to be preserved? Does the Antiquities Act need to amended to provide for exclusions of gang as well as roadside graffiti and contemporary rock art done by Native Americans?

Some graffiti is very artistic. A recent bold geometric mural-like design in south El Paso is indecipherable gang graffiti, but very artistically executed. Colorful pictorial murals are seen covering entire walls of buildings in Artesia, New Mexico, El Paso, Texas, Los Angeles, California, and elsewhere. Paintings of religious subjects adorn one or several walls of homes in North Central New Mexico. To some observers, these artistic endeavors are not graffiti.

The gang message in geometric design, however, has been photographed and included in the graffiti files of the El Paso Police Department, and the design will probably be obliterated by rival gang "X-outs" and over-painting. Restoration projects will be initiated in time to remove both. According to Steve Bayes, Roswell, New Mexico, Police Department, some sites subject to graffiti, if restored several or more times will ceased to be used.

According to police officers dealing with gangs, graffiti of the gangs in nearly all areas of the country is being studied now by police task forces, psychologists, sociologists, educators, civic and federal officials and others. Steven Bilbo, a detective with the El Paso, Texas, Police Department, states that police departments have special units which interpret graffiti and have learned which gangs execute what style and color of graffiti in their areas. Graffiti is executed to define gang territories, hierarchy, gang and personal identifiers (street names), advertisements for drugs (sell or buy), statements toward the next victim, and other messages (**Figure 10**). The graffiti is photographed and time, location and meanings noted.

The answer is, <u>Yes</u>, remove it. Both Bayes and Bilbo state that gang graffiti should not be preserved, now or 50 years from now. Because of all the study of graffiti, these records will be available 50 years from now. Research indicates that leaving graffiti in place tends to breed more graffiti (ARARA, 1977:85; White, 1992). Therefore, the present-day activity of graffiti removal and site restoration projects being carried out by agencies and volunteer organizations in cities, along highways, in parks and natural area, at rock art sites and in caves, is more appropriate than most people realize.

IS ROCK ART GRAFFITI?

Far more is known and documented about gang members as individuals and as a culture, and their graffiti, than will ever be known about the creators of prehistoric/historic rock art or historic writings. Usually the best that we can describe about rock art is that a culture in a stated time frame defined by archeological evidence may be the creators of a given rock art site or style. In some instances, historic rock art can be assigned to a known group. Creators of most rock art are essentially unknown and the time period problematic, although that done by contemporary Native Americans can be comprehensively studied because the authors are still present. Much of the modern Native American art is not being recorded at present, however.

Folklorist Roger L. Welsch (1993:32) states, rather flippantly, that "petroglyph is a fancy word for graffiti". He goes on to say that "some were probably the product of too much time and leftover paint", showing lack of knowledge in the subject of rock art. He confuses petroglyphs with painting. Petroglyphs are rock art motifs created by carving or pecking into a rock surface, not by painting, although there are indications that some petroglyphs were painted.

Army Corps of Engineers outdoor recreation planner Christopher White (1993:1) has recently written that "...rock art is interesting and sometimes historically important" but then goes on to use the term 'rock art' for modern graffiti. White observes that "human beings have been obsessed with marking our passage in time and space..." and states that early cultures in North

America created rock art as "...perhaps an early illiterate signature."

Prehistoric Native American cultures, while lacking a written language according to the standards of modern cultures, were certainly not illiterate for their time. Their "written" communication consisted of visual statements similar to the picture writings of the Maya and the Egyptians. While the hieroglyphics of those cultures have been "translated" into modern meanings, the fact that most Indian rock art motifs have uncertain or unknown meaning does not make them illiterate marks. White's remarks could be taken seriously, but they are probably the result of considerable frustration in having to deal with constant and increasing vandalism at sites under his jurisdiction. The answer is, No, rock art is not graffiti! And **NO**, historical writing is not graffiti.

SIGNIFICANCE OF CULTURAL RESOURCES

The significance of rock art and historic writings as cultural resources must be identified, inventoried and preserved under the various laws currently in place, such as the Archaeological Resources Protection Act of 1979, and the Federal Cave Resources Protection Act of 1988. The Federal Antiquities Act of 1906 defined protected cultural artifacts as those which are 50 or more years old and includes rock art and historic writings.

It is up to those responsible for vandalized sites to make the decision as to whether or not graffiti is to be removed. After a restoration plan is written, or verbalized, a decision can be made not to restore a vandalized site if all other conditions are such that removing the graffiti may cause excessive impact on the site. This alternative in a plan is part of current practice in land management and will remain so in the future as well.

Not all cave or natural area restoration or clean-up projects, however, are carefully thought out in relation to cultural resources and most do not involve consultation with agency archaeologists or local or state historic preservation officials. Sometimes, the self-interest of a specific group dictates actions which do not consider any effects on the original nature of a site.

In several New Mexico locations prehistoric Pueblo Indian rock art motifs were scraped away or had crosses incised over the sites, or both during the 1700's. Franciscan priests exorcised what they believed to be pagan sites by these methods (Carrillo, 1989). To the Indians this was sacrilegious vandalism. This action is not currently considered vandalism or graffiti, but evidence of a significant historic event.

For similar reasons in the 1980's, however, a fundamentalist Christian sect used white spray paint to spell out their religious opinions over panels of pueblo art near Mountainaire, New Mexico (**Figure 11**). Such spray painting, seen widely in the U.S. in similar relationships, is considered graffiti by most definitions and insulting to present-day Native American people. But there are people who consider such work to be legitimate and proper, especially when religious in nature.

Where can the line be drawn between graffiti and religious statements applied to a rock surface? In the United States, the First Amendment and the American Indian Freedom Act protect one's right to practice religion. A few other nations have similar laws. Ojibwa Indians (Canada) have developed traditions in which a person goes to certain rock art sites to paint or carve their name on the rock surface, adjacent to the original art or even across one or more motifs, to enhance their spiritual nature (ARARA, 1977: 85). A discussion on the difficulty in addressing this aspect of graffiti is presented in the ARARA conference proceedings of the Symposium on Rock Art Conservation and Protection (ARARA, 1977, p. 84-86).

Despite public education to the contrary, some subcultural elements in America still see spray paint graffiti in their neighborhoods, and, consequently, in regional natural settings, including caves, as power or "turf" messages and as personal identifiers.

In a small shelter in Carlsbad Caverns National Park the words "ALIEN WILL" have been scratched across a panel containing five red motifs, not damaging any of them however. After consulting a forensic psychologist, (a person who works with the social and legal aspects of criminals, gangs and other fringe groups) the words are believed to be to work of some followers of the "New Age" beliefs regarding aliens, crystal power and so forth. Possibly the same line of thought went into the incising of flying saucers on the extensive rock art panels at Comanche Gap, near Santa Fe, New Mexico (**Figure 12**). Yes, this is intentional graffiti.

Different groups of people have different attitudes toward preservation of cultural and natural landscapes. Those who value the cultural artifacts of the past need to communicate reasons for their approach and actively support conservation of sites in all situations, support and participate in the management and protection of sites, and participate in educational activities about the significance and value of preserving cultural history (ARARA, 1977: 17). There are those who do not seem to value rock art and historic writings as part of cultural history.

Welsch (1993) and White (1993) both appear to disparage rock art. Welsch (1993:32) considers some that rock art may be "symbolic, mystic or artistic" but may be more likely to be power statements or personal identifiers. Perhaps, but for prehistoric cultures, for which there is no written history, the visual statements, along with other artifacts (potsherds, lithics, middens, tipi rings, pueblos, etc.) help us know something about the early cultures. Historic writings and historic period rock art are interesting and valuable additions to written history as they may document a name or culture in time, and perhaps a purpose of someone, at a particular place.

RESTORATION PROJECTS - SOME GOOD, SOME NOT SO GOOD

Restoration projects intended to remove modern graffiti have had varying results. Few have included looking for and recording historic or prehistoric writings or art before graffiti cleaning began. Some have included recognition of the historic aspects of the site such as that described at Matthews Cave by Varnedoe and Lundquist (1993), who also removed quantities of military debris, including a barrel of diesel fuel, a 90 mm shell and other "junk". More often the results are less acceptable, such as the efforts at Cave du Mayrieres, Crystal Crawl in Fort Stanton Cave, or Hueco Tanks State Historical Park, which became a state historical park under Texas Parks and Wildlife Department in 1969.

That year, under orders from state park headquarters in Austin, the Hueco Tanks park staff started sandblasting "graffiti" from cave shelter walls in Rock Art Site 1. Mike Bilbo and fellow rock art researcher Kay Sutherland happened upon the activity and asked what was being sandblasting. "Graffiti!" Bilbo and Sutherland, familiar with most of the 5000 motifs in the various shelters at Hueco Tanks, went to the superintendent and asked that the work be stopped. They were referred to Texas Parks and Wildlife headquarters in Austin. With the exception of TPWD archaeologist Ron Ralph, Headquarters personnel were only vaguely cognizant on the differentiation between rock art and modern graffiti. The sandblasting was stopped and several baseline studies of rock art and historic writing begun (**Figure 13**).

In 1984, Boy Scouts from El Paso wanted to be part of the graffiti clean up efforts at the park. With no understanding of what they should look for and no clear directions or direct supervision from park staff, the scouts scrubbed off a number of historic Plains Indian motifs from Site 13, also known as Comanche Cave. Bilbo happened to talk to them as they left the park and then went to look at the site. He found that six or seven motifs had been removed.

Fortunately, hundreds of rock art sites across Texas, including those at Hueco Tanks, had been carefully recorded by Kirkland and Newcomb (1967) in the 1930's. Because of their work, what had been lost at Hueco Tanks was at least known although not restorable. The primary problem in the loss of art at Hueco Tanks, and of writings at Fort Stanton, was lack of coordination and planning with those persons knowledgeable of historic writings and rock art.

In Cave Mountain Cave, West Virginia, a graffiti clean-up project removed all "graffiti" not dated before 1900 (NSS News 1993:114). Not included in the news note, however, was how the decision to use 1900 as a cut-off date was determined. Writings up to and including 1943 should have been recorded or preserved at that cave.

RESTORATION

The agency or land owner must determine whether or not graffiti is to be removed. Policies, which include the basis for such decisions, need to be in writing and even be part of a management plan, for the decision to be credible and legal.

Management plans cause agencies, organizations, and owners of land which include caves whether operated as commercial caves or not, and individuals, to pay attention to all resources and create an awareness of aspects not included in regulations and laws.

Restoring caves to as natural a condition as possible has been the overall goal in cave restoration projects. The possible existence of historic writings and rock art at a graffitied site must be considered. The restoration plans must involve tieing the site into the cave survey and photographing and recording all writings and rock art before the graffiti is removed. Standardized recording methods and forms are available from local archeological societies and state historic preservation offices. It is also desirable to send copies of completed forms, including drawings of the writings and/or rock art, to the SHPO and the societies as well.

The important first step in a restoration project is to photograph and record all writings or rock art present. The photographs will document the graffiti and its relationship to the art or writings impacted and allow study of the site before beginning graffiti removal. It will also document the writings or rock art in case it is removed during restoration. At the same time the site must by surveyed in to the cave survey. If there is no cave survey then it must be done and the site tied into the survey to pinpoint its exact location.

CAVE SURVEY

An accurate survey of a cave must be completed in order for a resource inventory to be effective, otherwise there would be no way to identify where a historic site or any other attribute is located. This would include tying into the survey all cultural resource sites as well as biological and natural resources attributes, such as bat nursery locations or the locations of springs or hazards. Having an inventory and survey describing and locating each attribute is essential in planning for restoration projects, removal of hazardous materials, or even cave rescue efforts.

RESOURCE INVENTORY

Graffiti removal and site restoration projects, whether carried out by agencies or by volunteer groups need to be part of a planned approach. Agencies and land owners managing caves should have already completed a resource inventory of not just surface attributes but of any caves and their resources - physical, biological and cultural. Specialists need to be involved in each of the resources inventoried so that there is a knowledge, for example, of the endangered species in a cave, as well as cultural resources. It is common in cave survey activities to inventory biological and physical attributes, as it is the natural environment of the cave that is uppermost in thought. In addition, historic writings and rock art are seemingly overlooked, perhaps even ignored at times.

When historic writings or rock art are found, research by a specialist will need to be done to determine the history involved. Not always does a caver or agency manager recognize the historical significance of cultural artifacts, which would include knowledge of names in local history, rock art motifs of the Archaic cultures (abstract motif style), or the recognition of a bundle of reeds as a prehistoric torch.

ENVIRONMENTAL ANALYSIS

Restoration plans must consider the impacts or effects of methods on the site, not only on biological or hydrological conditions but on the appearance of the rock surface after restoration. Environmental analyses (EA's) done prior to restoration projects consider impacts of project methods and recommend preservation, mitigation or restoration actions. An EA can recommend that not every speck of paint be removed from every pore of rock so that a more natural rather than totally scrubbed surface results. The decision can be made to disguise any paint remnants using in-situ mud or left as is.

Bilbo experimented with several different mixtures of gypsum in a test to make a naturally appearing cover for modern incised lines at an historic writings site in Fort Stanton Cave. Such testing can become part of an EA for a specific site designated for restoration. Tests on non-decorated surfaces as to the effects of surface wetting, drying and integrity should also be considered.

A number of restoration projects mentioned the untested use of substances such as Easy-Off Oven Cleaner. While the use of oven cleaner is an inexpensive way to remove spray paint it also leaves lighter rock surface areas exposed, calling attention to the site of the removed graffiti. It also has to be washed off, leaving questionable chemical residues along the path of water runoff. Thus, if a graffiti removal project is planned, the effects of any chemicals or other methods used must be evaluated as to their effects on the physical attributes of the cave as well as cave species and habitat.

Discussions of the effects of various restoration methods are included in ARARA (1977), Bilbo (1987; 1983), Bilbo and Ralph (1984), Morton (1989), Rhodes (1976), Ralph and Sutherland (1979), and White (1993). In addition, the annual restoration issues of the NSS News should be consulted for the latest techniques and cautions. Many chemical techniques may adversely affect cave ecology, as well as the appearance and integrity of rock surfaces. Distilled water and careful handwork may be the best choice.

OTHER CONSIDERATIONS

Other cultural artifacts which may be found in caves need to be included in the resource inventory. For example, in Carlsbad Cavern and in Ogle Cave, New Mexico, relics of the guano mining activity of the 1930's and 1940's are still "in situ" (in place), uninventoried and forgotten. Debris or "junk" removal as part of a cave clean-up project needs to be taken into account as some of it may be historic. Even moonshine equipment in a cave reflects a cultural attribute of a curious period in American history. Perhaps it should be removed, but first a historian from a state historic preservation office, a federal agency, a university, or other agency should be involved.

Identification of debris is important, as in the case of the clean-up of Matthews Cave, Alabama (Varnedoe and Lundquist 1993:251), both in terms of history and hazardous materials: a barrel of diesel fuel is pretty serious from the toxicity point of view. On the other hand, 90-mm shell casings can be dated, as well as give an indication of the military activity in absence of other historical indicators (anti-aircraft service practice, circa World War II, leading to other research questions).

In sinkhole entrances to caves in the west, certain persons regularly dispose of refuse, including car bodies, paint, lead-acid batteries, electrical wire and so forth. Cleaning up such sites involves hazardous material (haz-mat) specialists. If the cave inventory involves specialists, whether from the owner/agency or those consulted from a local society, a state historic preservation or environment office, or other organizations, then knowledge of these conditions will be quickly found out and taken into consideration in cave exploration, survey and inventory.

PUBLIC EDUCATION

Public education is initiated to help people understand the advantages of preserving cultural artifacts. Efforts include signs and interpretation (Bilbo and Ralph, 1984). The effectiveness of this approach depends on the presence of physical barriers, and the consistent availability of interpretive staff or volunteers to monitor sites as well as given on-site interpretation.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

This paper cautions cave managers and conservation groups to study vandalized sites for the presence of historic writings and rock art. Historic writings and rock art are non-renewable cultural resources. While there may be verbal discussion between cave managers and volunteers or others involved with cave clean-up projects, the preparation of written resource management documents and policies, enforcement of regulations, and conducting public education (Anderson, 1977: 58) are among the most effective ways to ensure that a graffiti restoration project is designed to meet the best end result in a given situation.

Cave significance criteria and procedures are now applied to federal caves. Therefore, it is important that complete resource inventories be done according to standard methods. Cave Significance Nomination Work Sheets, which will offer a standardized format, will be issued in the near future.

Often a site must be judged separately from others on the basis of what is in the best interest for that site. Rock art researchers throughout the U.S. and the World continue to conduct various rock art surveys and inventories of both historic and prehistoric sites.

CONSULTATION

Involving subject specialists in the inventory as well as the planning process is necessary to treat all resources equally and to prevent the possible loss of any resources. Some important consultants in history and in rock art research are listed in the appendix.

In addition, each state has a State Historic Preservation Office (SHPO) in association with a state agency responsible for archeology and historic sites. These are usually located in state capitol complexes. Federal and state agencies have archaeologists and historians who are responsible for sites on lands under their jurisdiction.

Cave managers and restoration project leaders should be aware that just because a vandalized cave site is trashed out and painted doesn't necessarily reduce its significance. Many restoration projects have been undertaken to remove all graffiti from cave walls or rock shelter surfaces. An understanding of what constitutes graffiti, as opposed to what is historically and culturally significant, is a critical part of both inventory and restoration planning processes.

Let us not lose any more historical writings, or historical or prehistorical art. This paper specifically cautions cave managers and conservation-oriented groups to study a vandalized site for the presence of historic writings and rock art and to consult with historians and rock art specialists as part of the planning process prior to initiating restoration projects. Again, a vandalized cave may contain surprising values, providing that it is thoroughly evaluated before restoration.

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APPENDIX - HISTORIC WRITING AND ROCK ART CONSULTANTS

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American Rock Art Research Association
P.O. Box 65
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J.J. Brody
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University of New Mexico
Albuquerque, NM 87103

Dr. Charles H. Faulkner
Department of Anthropology
252 South Stadium Hall
University of Tennessee
Knoxville, Tennessee 37996-0720

Getty Conservation Institute, Getty Trust
401 Wilshire Blvd., Suite 1000
Santa Monica, California 90401-1455

John and Mavis Greer
Archeological Consultants
4803 West East Ridge Road
Columbia, Missouri 65202

Ken Hedges, Curator
San Diego Museum of Man
1350 El Prado
San Diego, CA 92101

Paul and Suzanna Katz
Archeological Consultants
C/O Carson County Square House Museum
Box 276
Panhandle, Texas 79068

Ron Ralph, Archaeologist
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78712

Polly Schaafsma
P.O. Box 2087
Santa Fe, New Mexico 87504-2087

Dr. Solveig Turpin, Archaeologist
Texas Archeological Research Laboratory
University of Texas
Austin, TX 78712

U.S. Army Military History Institute
Chief of Military History
Carlisle Barracks, Pennsylvania 17013

(Also: U. S. Army, Navy, etc. museums at military installations for historical information concerning activities at each installation)

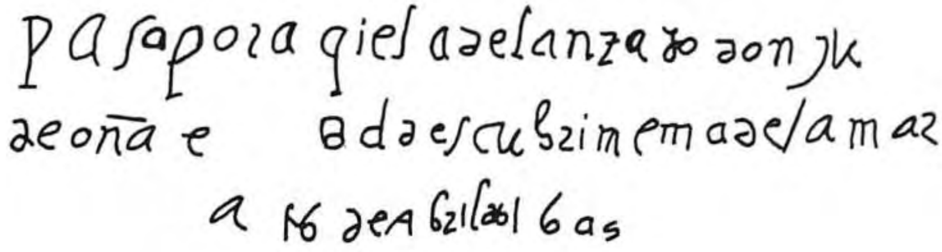
Utah Rock Art Research Association
East 200 South
Salt Lake City, UT 84111

H. Dwight Weaver
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, Missouri 65102-0176

In addition, there are local, regional and state historical and archeological societies nationwide from which information can be obtained. To identify them, consult local libraries and museums. There are also historic preservation offices in every state. Libraries, archeological consultants, and university or college history or anthropology departments will have sources which identify the addresses for them. Federal agencies can also be contacted for information.

FIGURE 1. Previous impact to a backcountry cave, Southeastern New Mexico. Several layers of spray paint graffiti cover historic 19th Century inscriptions (drawn from a photograph by Michael Bilbo).

FIGURE 2a. Historic Period Cursive Script of Spanish Explorers, 1605-1709, El Morro National Monument, New Mexico. 1. Inscription of Juan de Onate, 1605.
2. Inscription of Eulate, 1620 (the area of intersecting lines is that of an erased word). 3. Inscription of Ramon Garcia Jurado, 1709 (drawn from photographs in Southwest Parks and Monuments Association, 1989).



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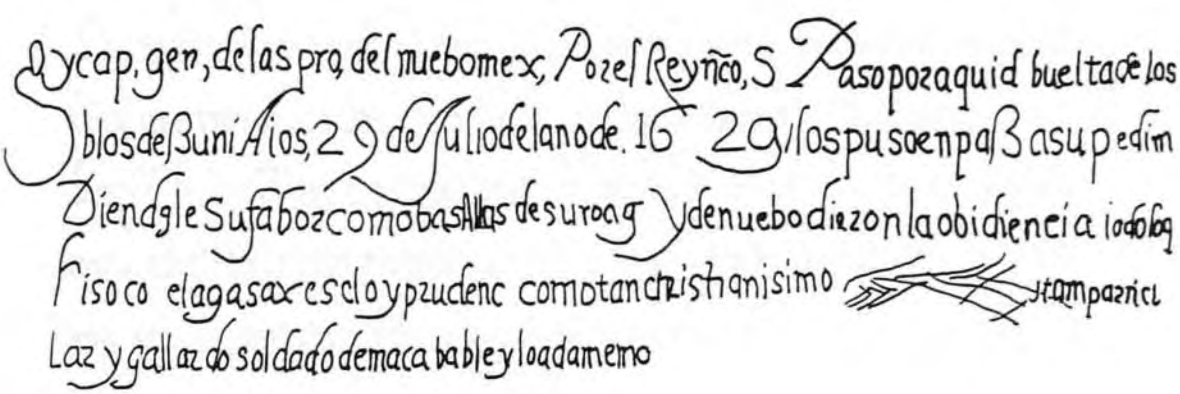


2.

3.

FIGURE 2b. Cursive Script of 1400 to 1800 A.D. **1**. Late Roman Cursive Script. **2**. Black Letter Cursive Script. **3**. Black Letter Gothic.

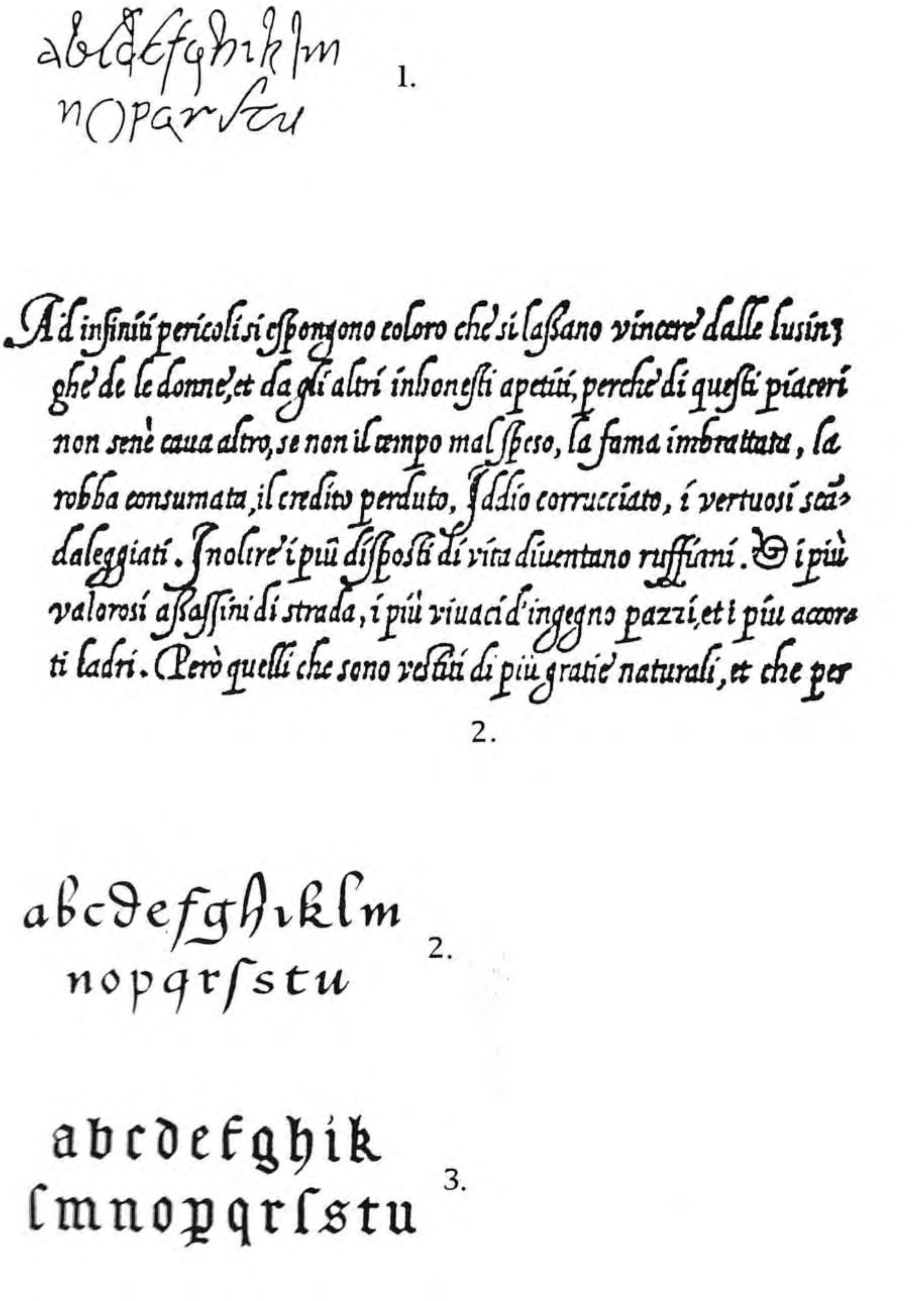


FIGURE 3. 19th and 20th Century Roundhand Script and Roman Letters. **a**. Carved inscriptions of the mid-19th Century Roman letter style, El Morro National Monument, New Mexico. Simpson left the "r" out of 'inscriptions' and later added it (redrawn from Southwest Parks and Monuments Association, 1989). **b**. Inscribed and carbon black writings, Fort Stanton Cave, New Mexico. Illustrating the value of historic research, Baker, H Troop 8 Cavy (cavalry), is significant in that the 8th Cavalry was only stationed in New Mexico in 1872, at F. Bayard, 236 miles from Ft. Stanton (drawn from a photograph by Buzz Hummel. **c**. Inscription in roundhand script at El Morro National Monument, New Mexico, possibly done between 1850 and 1862 (redrawn from Southwest Parks and Monuments Association, 1989).

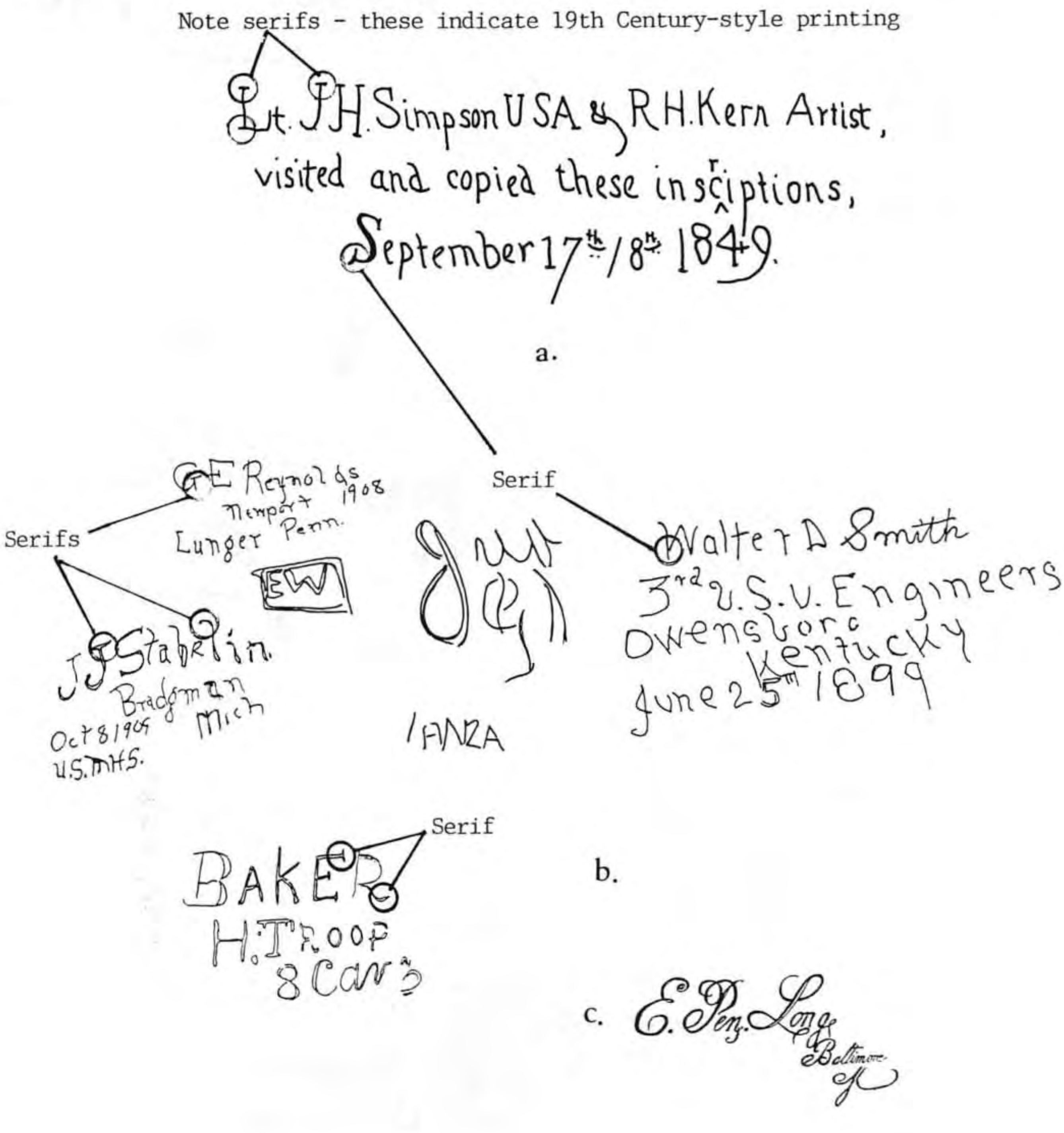
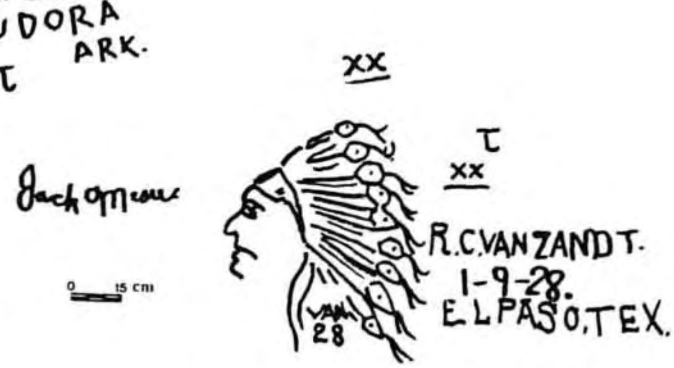


FIGURE 4. Block or Monumental Style Letters of the late 19th and early 20th centuries. Note combination of letter styles in place name 'El Paso' in **d**. All these writings were done in Ogle Cave, New Mexico using carbon black (drawn from a photograph by Michael Bilbo).

a.

b.

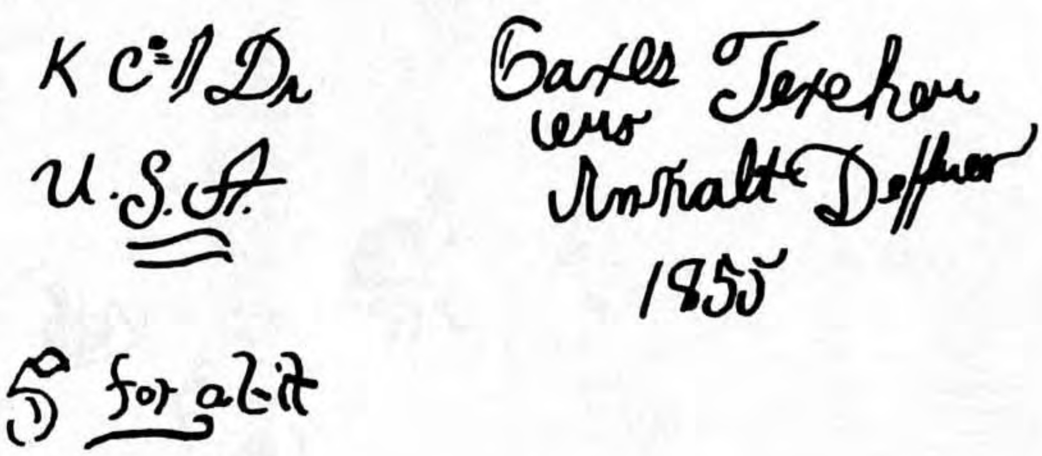
c. Detail of **b**.
Large block letters are portions of 'Clements'.



d.

FIGURE 5. Historic Signatures. **a.** Carbon black signatures illustrating 19th Century Roman style letters, Hueco Tanks State Historical Park, Texas, Site 34 (drawn from a photograph by Michael Bilbo). **b.** Historic roundhand inscriptions incised on flowstone in Decoration Passage, Fort Stanton Cave, New Mexico, (From Bilbo, 1982).

a.



b.

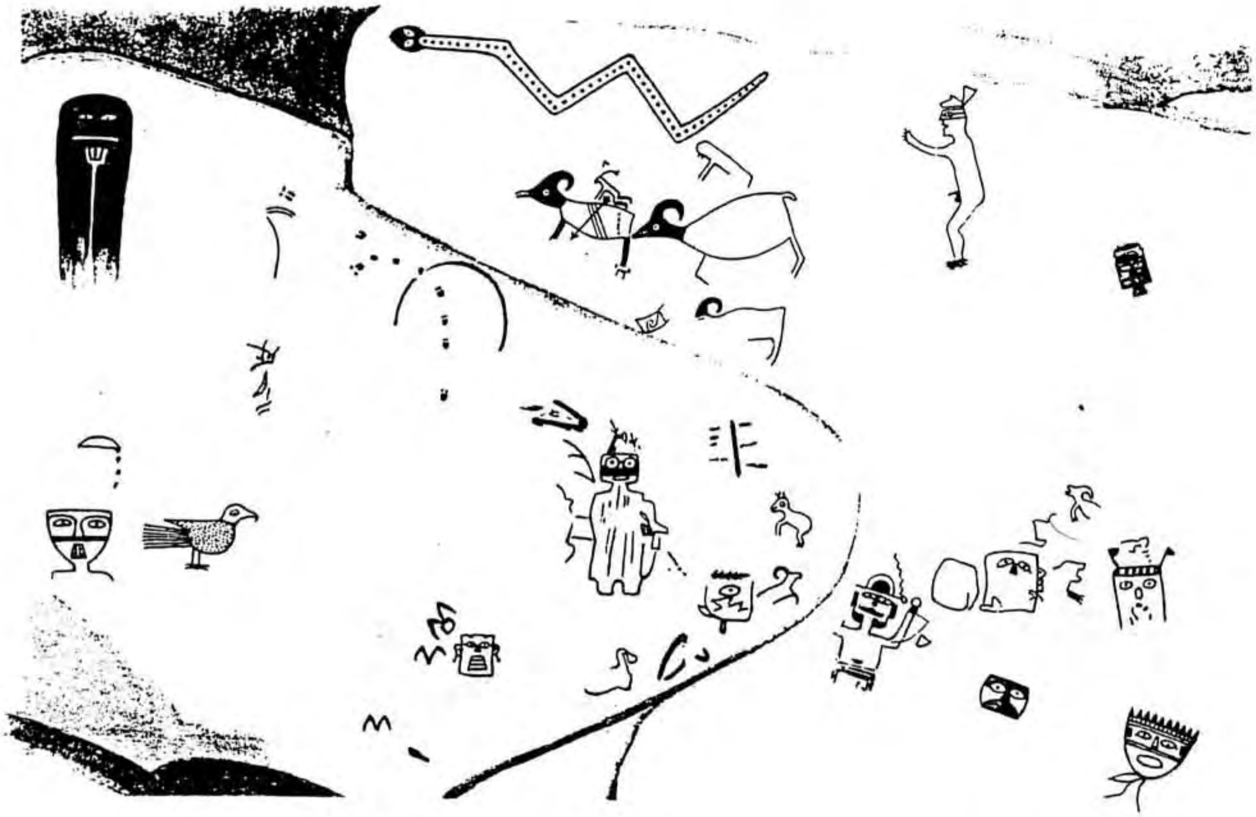
FIGURE 6a. Archaic Pictographs. 1. Lower Pecos Style representational pictographs in red, ocher, and black. Panther Cave, Seminole Canyon State Park, Texas (from Kirkland and Newcomb, 1967, Plate 24). 2. Archaic representational and abstract pictographs in red, black, ocher, and white. Hueco Tanks State Historical Park, Texas, Site 26 (from Kirkland and Newcomb, 1967, Plate 147).

1.

2.

FIGURE 6b. Historic Period Pictographs, illustrating European and Spanish influence.
1. Historic and Pueblo pictographs in white, red, ocher, and black, Hueco Tanks State Historical Park, Texas, Site 17 (from Kirkland and Newcomb, 1967, Plate 137). **2.** Black pictograph, Lower Rio Grande/Pecos River area, Texas (from Bilbo and Sutherland, 1986). **3.** Black pictograph, Hueco Tanks State Historical Park, Texas, Site 2 (from Bilbo and Sutherland, 1986). **4.** Black pictograph, Hueco Tanks State Historical Park, Texas, Site 1a (from Bilbo and Sutherland, 1986). **5.** Petroglyphs showing the influence of Spanish entrada on Plains Indian rock art, Alamo Mountain, New Mexico (from Bilbo and Sutherland, 1986).

FIGURE 6c. Prehistoric Pueblo Period Representational Rock Art. **1** Pictographs in red, and black, Hueco Tanks State Historical Park, Texas, Site 23 (from Kirkland and Newcomb, 1967, Plate 144). **2.** Petroglyphs, Monte Carlo Gap, New Mexico, Site 2 (from Bilbo and Sutherland, 1986).



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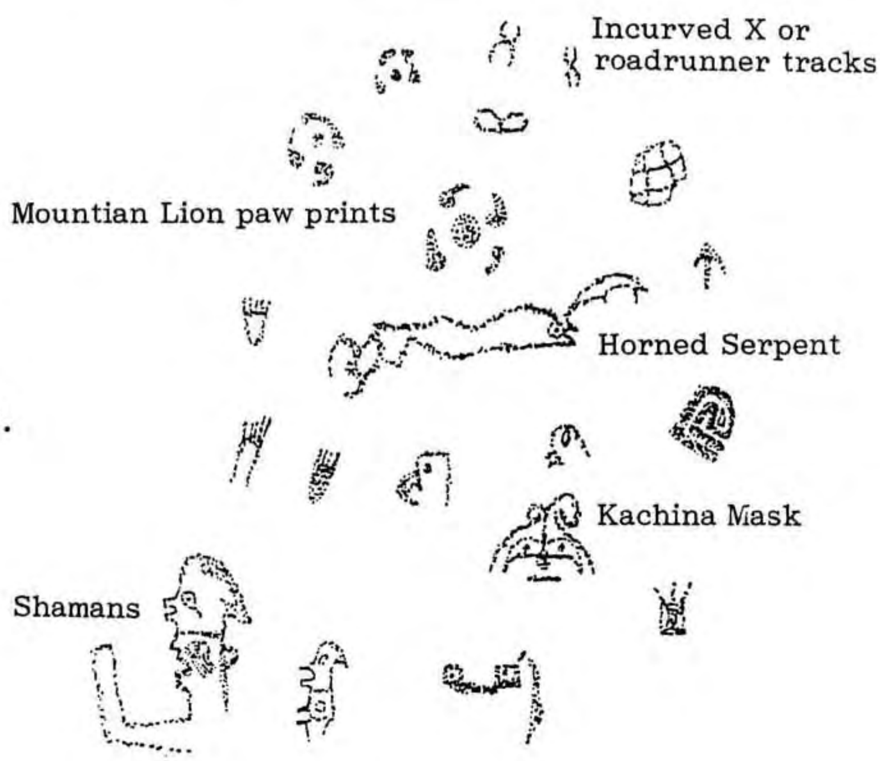

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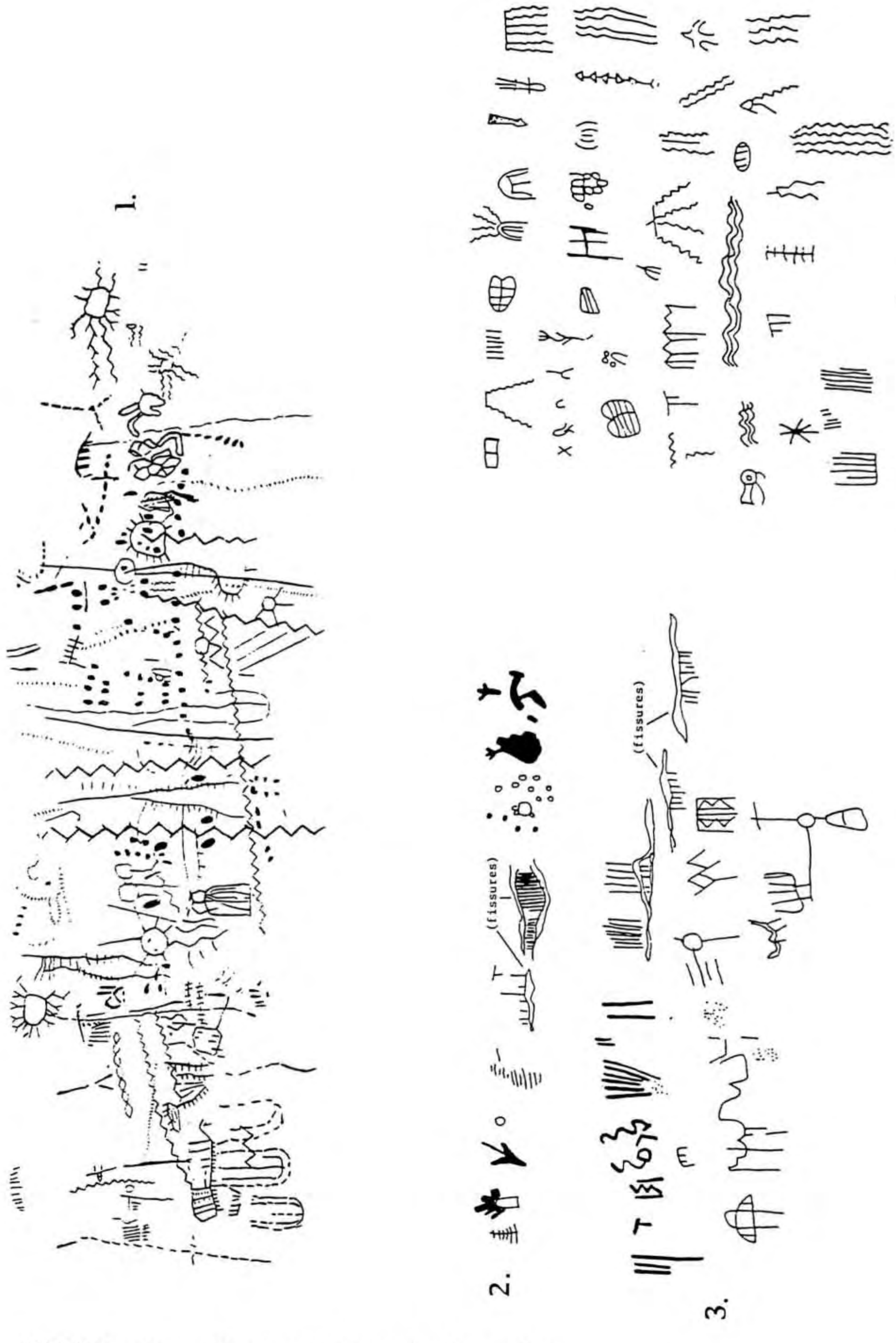


FIGURE 7a. Archaic Abstract Rock Art. 1. Black pictographs, Bee Cave, Texas (from Kirkland and Newcomb, 1967, Plate 55). 2. Red pictographs, vicinity of White Rock Shelter, Texas. 3. Red pictographs, Soledad Canyon, New Mexico. 4. Petroglyphs, Whispering Springs, Texas (2-4 from Bilbo and Sutherland, 1986).

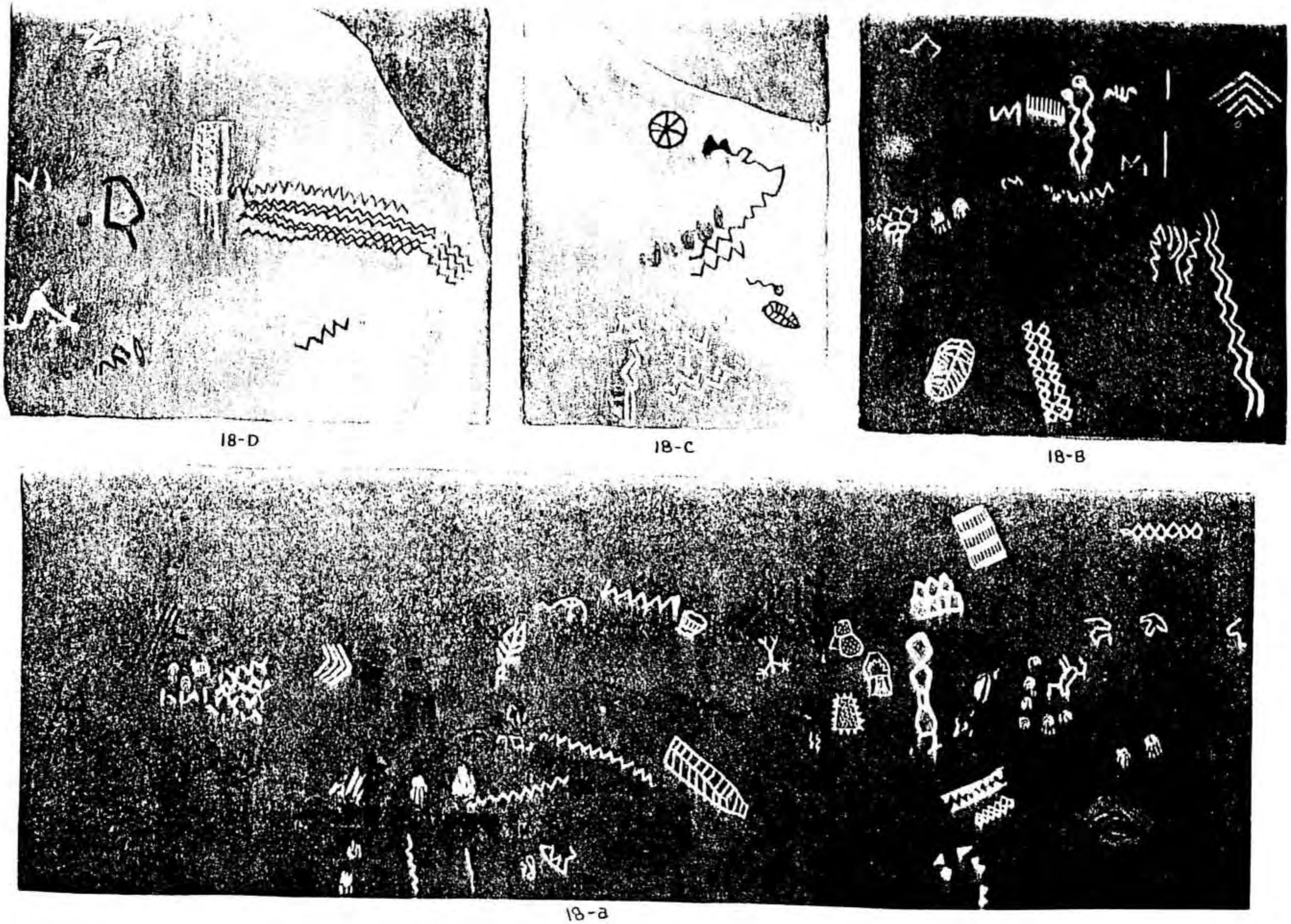


FIGURE 7b. Plains Indian Prehistoric Abstract Pictographs, Hueco Tanks State Historical Park, Texas, Site 18. Pictographs in white, red, ocher, and black. Panels include several small Pueblo Period masks (from Kirkland and Newcomb, 1967, Plate 139).

FIGURE 8. Painted Grotto, New Mexico. Lower: detail of Archaic and Apache abstract pictograph panel in Painted Grotto. Horizontal lines represent ocher, diagonal lines represent red, black represents dark red, and outlined figures are in white.

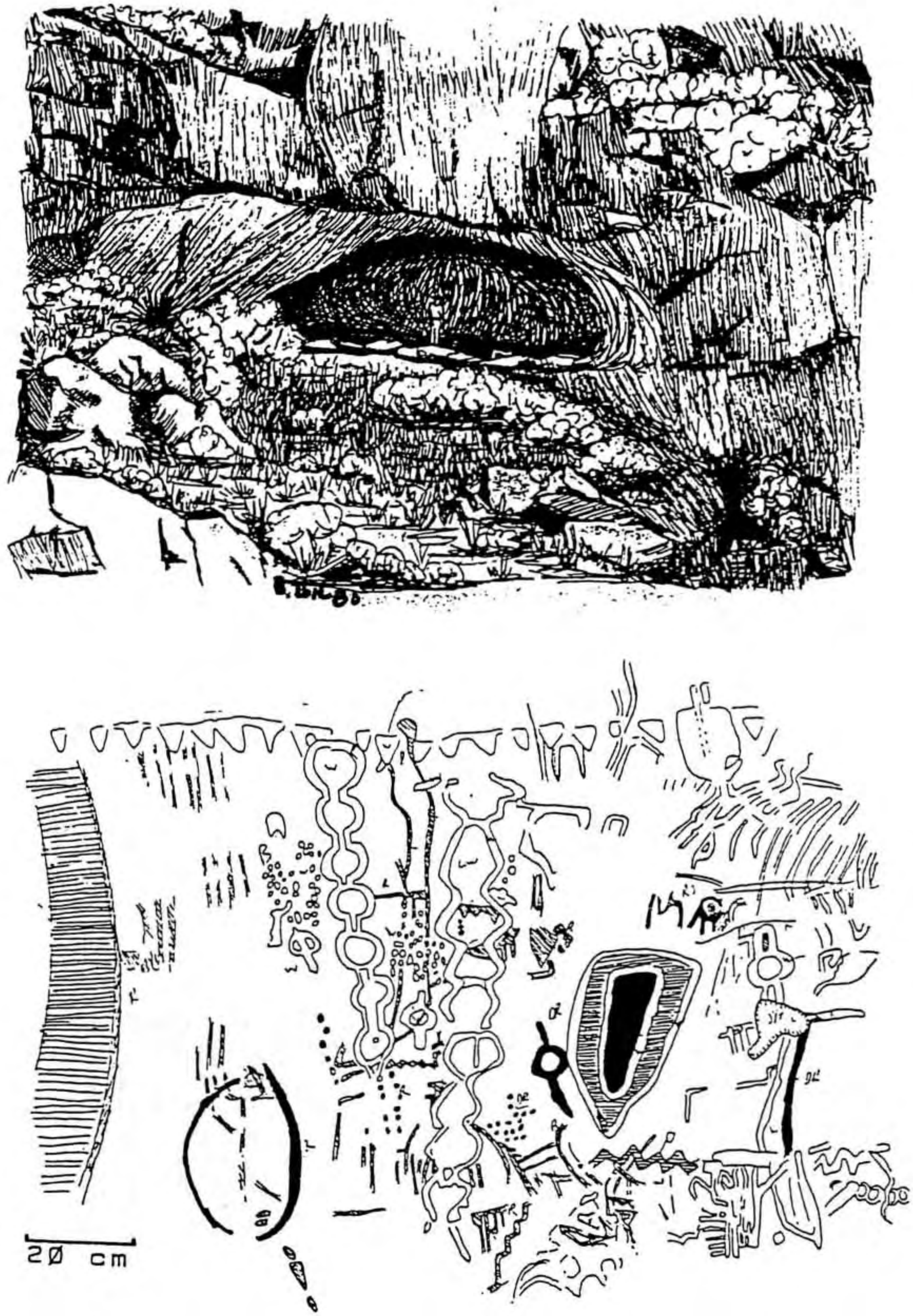
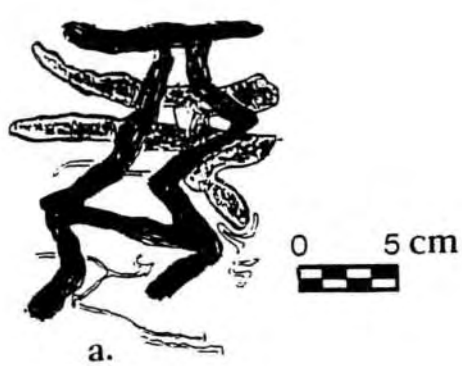
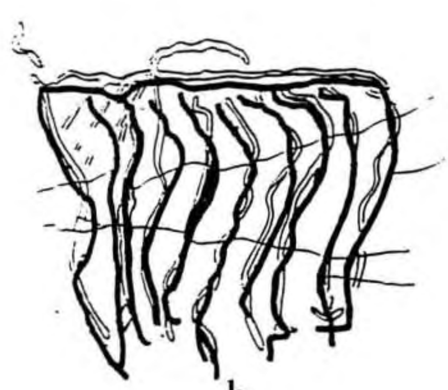


FIGURE 9. Slaughter Canyon Cave Pictograph Site, New Mexico. Late Archaic abstract pictographs in red, ocher, and black (from Bilbo and Bilbo, 1993). a. Black figure superimposed over another black figure. Both are superimposed over another faint yellow design. b. yellow figure outlined by charcoal. c. Selected pictographs (not to scale).

c. Selected pictographs in Slaughter Canyon Cave (not to scale).



a.



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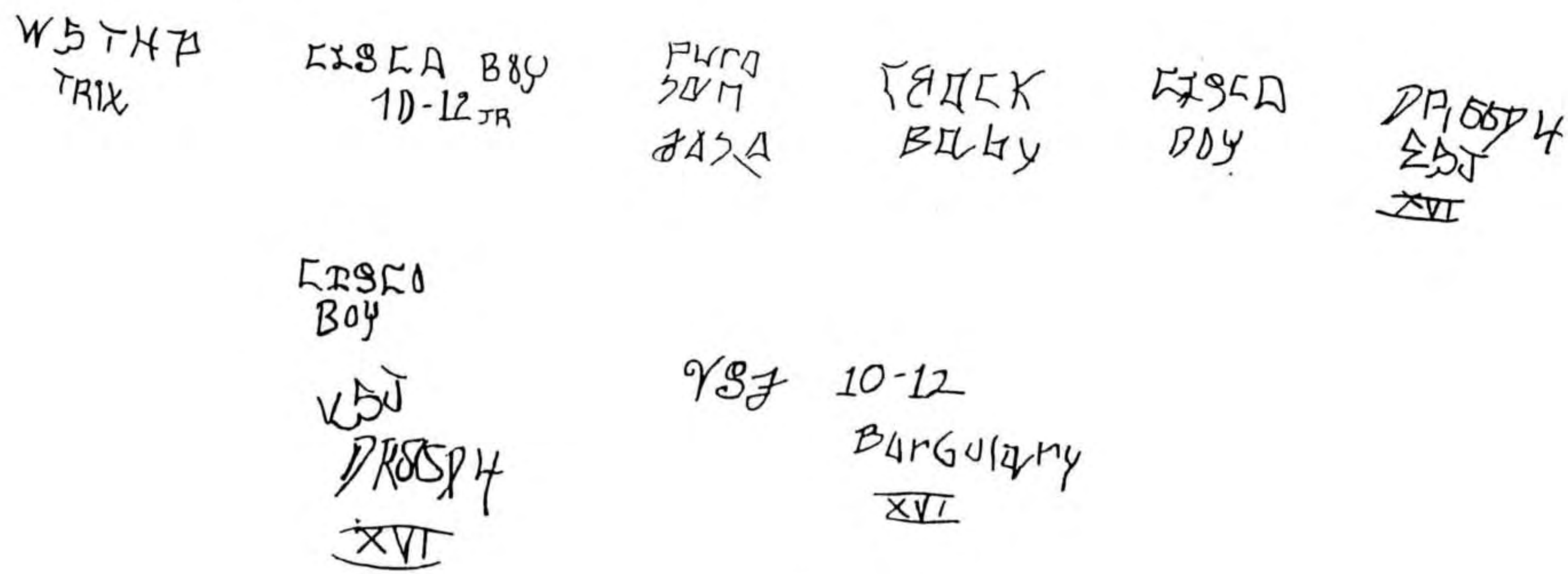


a.

b.

FIGURE 10. Gang graffiti of October, 1993, Roswell, New Mexico. a. Upper messages done by an east city gang in a west city gang territory. b. A gang identifier on a cinder block wall.

FIGURE 11. Rio Grande Style Tompiro-Abo masks and a possible fighting scene between a Native American and Spaniard, possibly 16th Century. The masks are crossed out with heavy white enamel paint using a paint brush. The work 'Jesus' is written over the fighting scene. Under the 'U' is an adarga, a Spanish shield of Moorish origin made of bullhide, verified by research of Spanish military equipment (drawn from a photograph by Michael Bilbo).

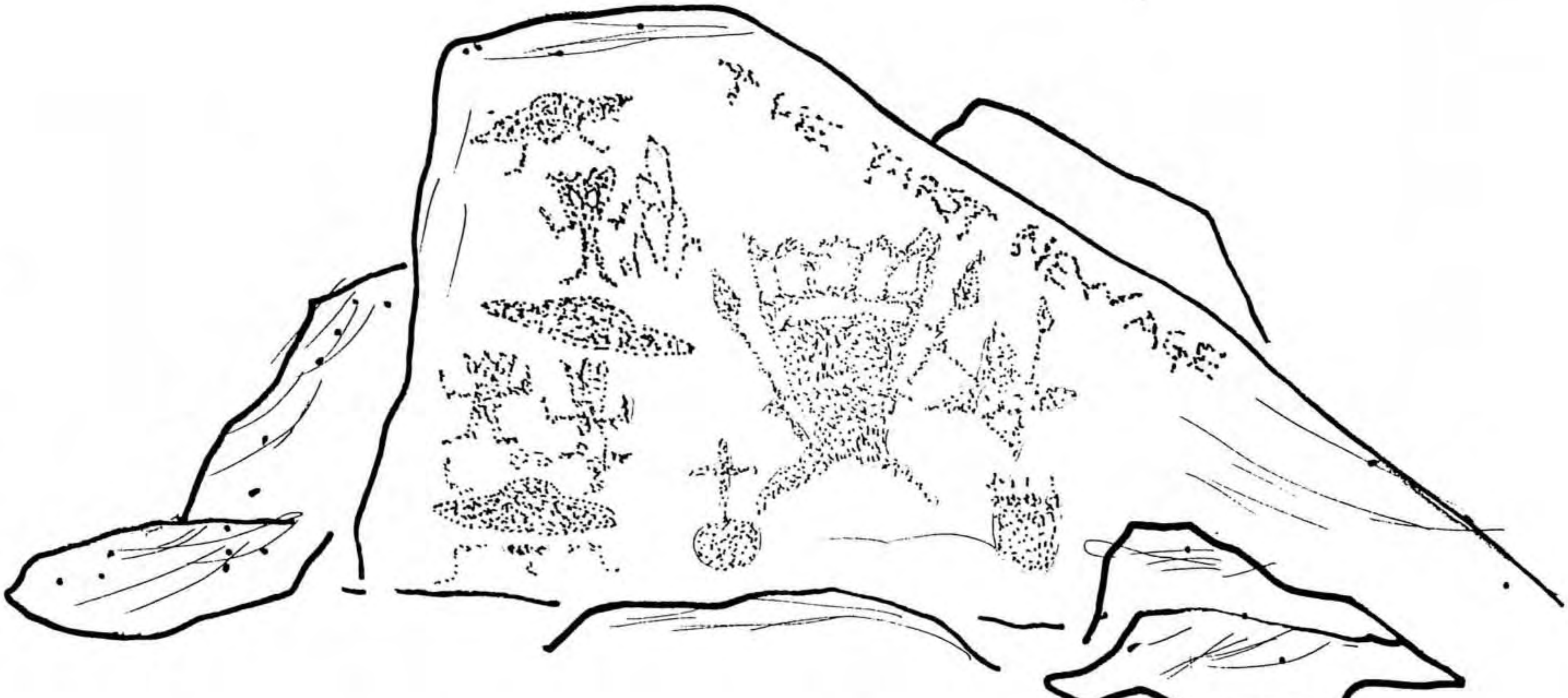
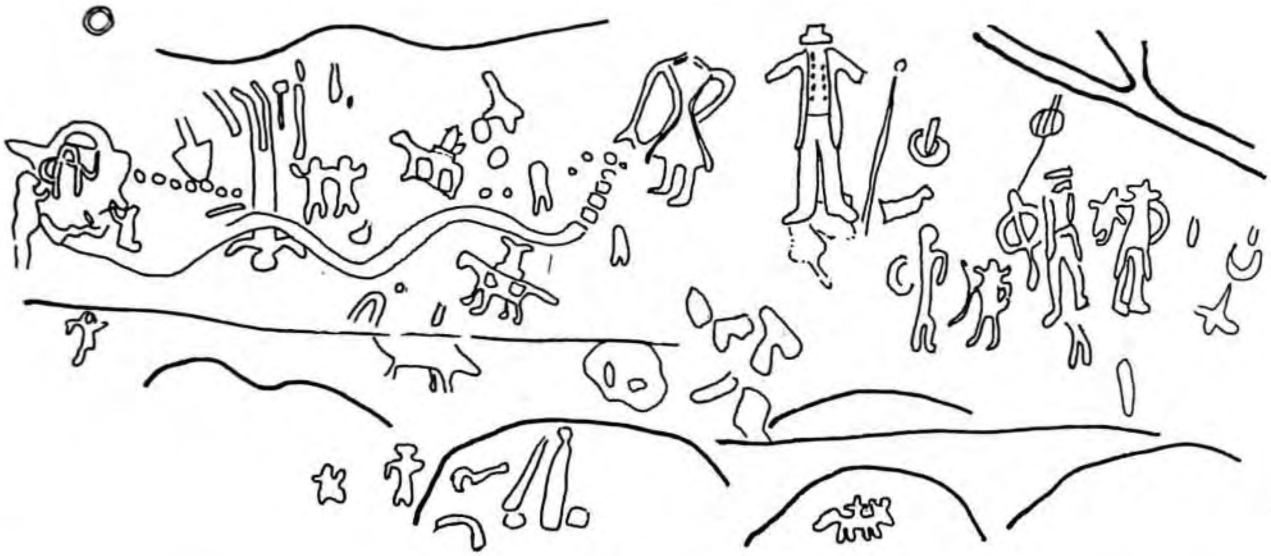
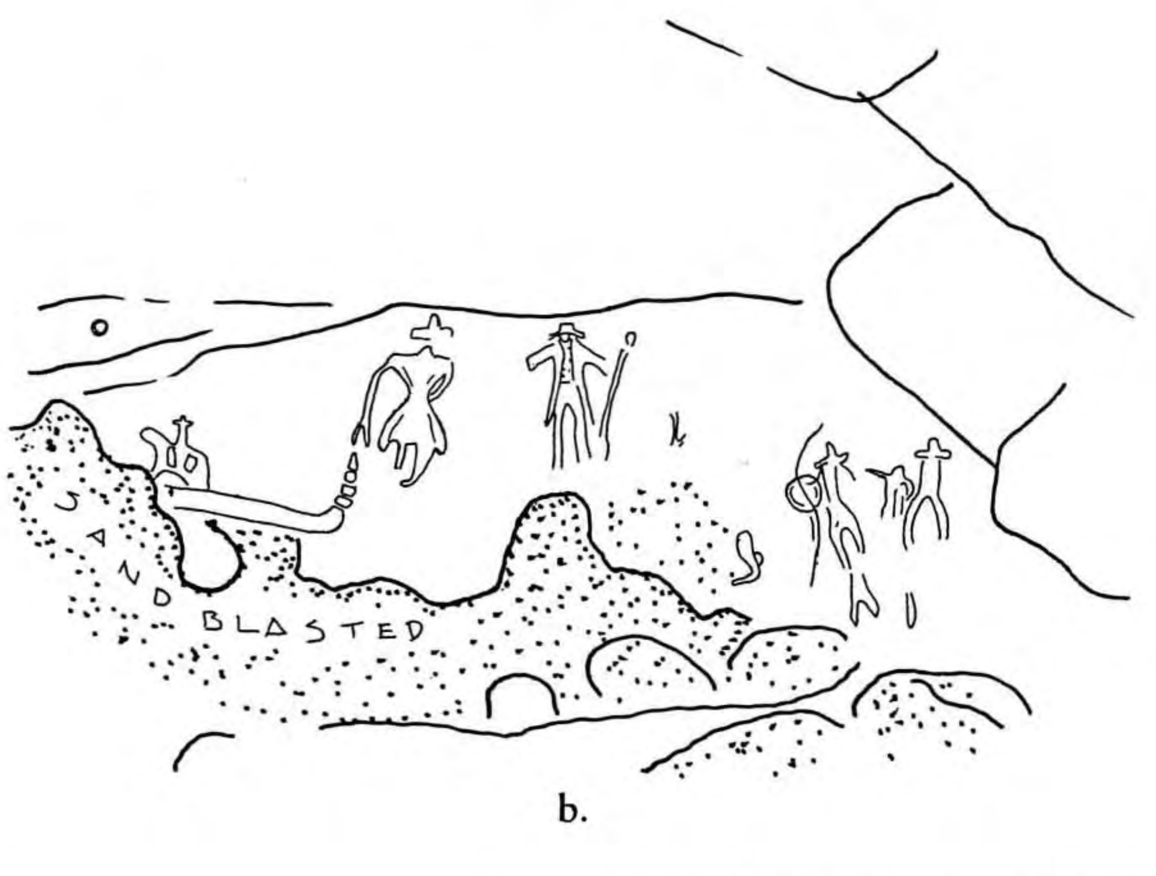


FIGURE 12. Gallisteo Basin, New Mexico. "New Age" petroglyphic graffiti on 16th Century Rio Grande Style Pueblo petroglyphs. Peckings of words and flying saucers done at some point during the last twenty years to the left of the Tompiro Mask. The words are faint but the 3 flying saucers, a cluster of possible crystals, and 3 figures mimicking the mask, are more obvious. The makers of the recent peckings have attempted to show that the projectile points of the Tompiro figure are crystal points. Where the Tompiro figure has a feather headdress as verified from ethnohistoric research, the recent peckings have tried to show a helmet of crystals. The lower pairs of mimic figures and the flying saucer below them was pecked over an existing 16th Century figure, destroying most of it (drawn from a photograph by Michael Bilbo).

FIGURE 13. Hueco Tanks State Historical Park, Texas. a. Site 1-A in 1939 (redrawn from Kirkland and Newcomb, 1967, Plate 124). b. Drawing from a photograph of Site 1-A taken in 1983. Dotted pattern indicates areas removed by sandblasting during graffiti removal project by Texas Parks and Wildlife Department in 1969. Note absence of other figures as well, due to 20th Century vandalism. Hat on human figure in an 18th Century coat (top, center) was not recorded by Kirkland, perhaps due to lighting conditions during the time of day he was at the site.



a.



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CAVER SAFETY

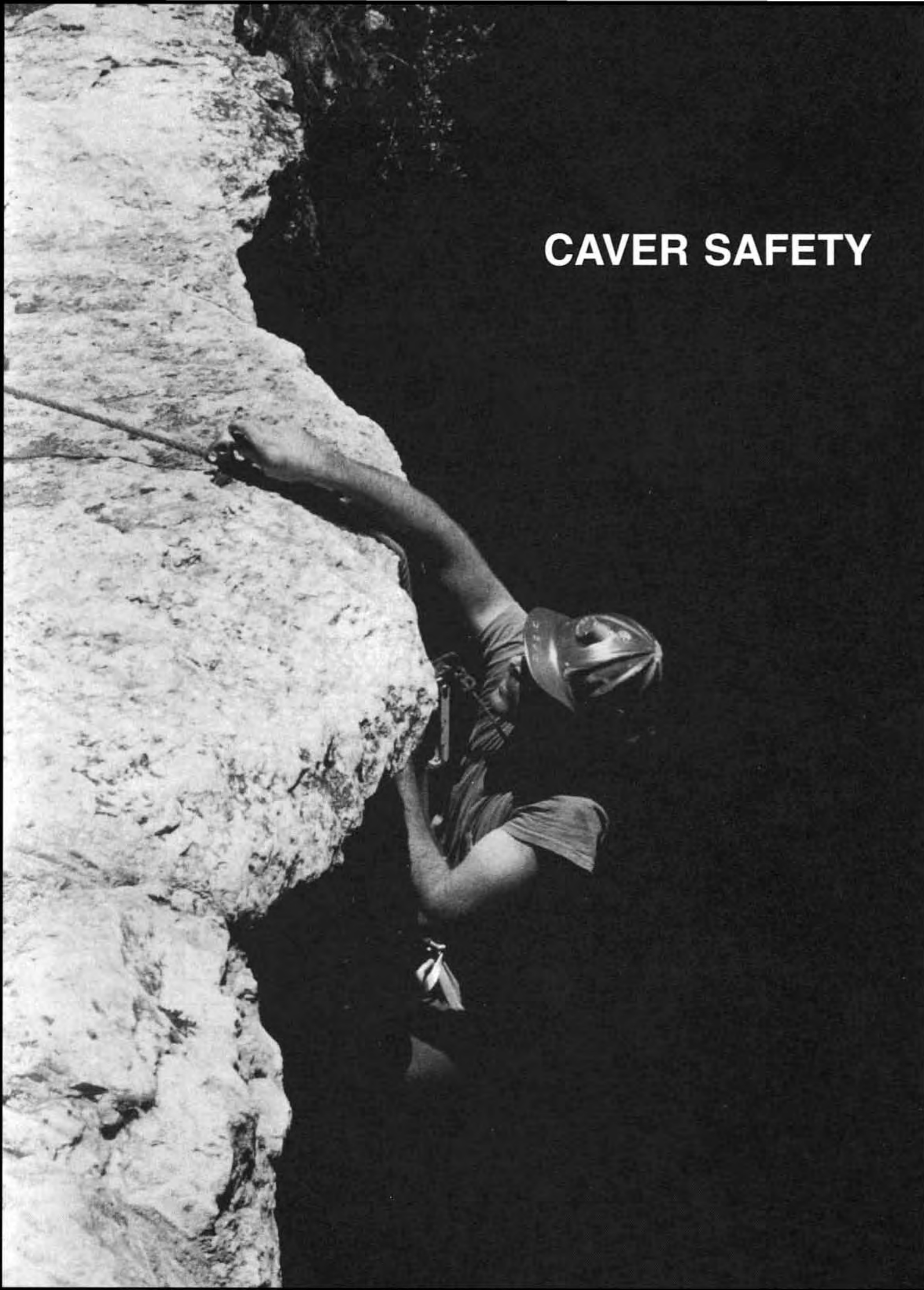

Photo Caption -- Steve Fleming negotiates the lip of the Devil's Sinkhole, Edwards County, Texas.

Photo by Dale Pate

SEARCH & RESCUE PREPLANS FOR CAVES

John Gookin

Preplans are documents that organize personnel and equipment for urgent incidents. They provide guidance through the initial response and they usually terminate at the end of the first shift of personnel responding to the incident. They are replaced by a plan drawn up during the first shift. Search and rescues are different types of urgent events. Both are emergencies since human life is at risk. The preplan is not supposed to provide step by step instructions for all personnel. The preplan is a document from the park superintendent to his/her staff that uses the incident command system[1] (ICS) to provide clear leadership and organizational guidelines in urgent situations. Your document should not restate what ICS is, or even what is in your Park or Regional Rescue Preplan; it is a simple document that helps organize cave rescues. Fremont County, Wyoming uses a one page plan with four pages of appendices. The Worland, Wyoming Bureau of Land Management (BLM) District[2] uses a 20 page plan that lists all local resources, item by item, and provides much more specific guidance. You should develop a plan that will help you move fluidly in a time of urgency.

CONTENTS OF A CAVE PREPLAN

1. AUTHORITY: list pertinent regulations that delegate rescue authority. List any regulations that allow you to access regional or national resources. Be sure to give a lay person's explanation.

2. CAVE DESCRIPTION: describe the cave, including temperature, humidity, flood potential.

3. ACCESS: describes how to get to the cave in simple terms so a deputy or ranger can go there to see if anyone's there.

4. CAVER PARKING AREA: this is a description of how to get to the most likely spot to find an overdue caver's vehicle. It also helps rescuers find the cave.

5: DISPATCHERS CAVE SEARCH AND RESCUE (SAR) CHEAT SHEET: this tells the dispatcher what to ask the reporting party.

6. SEARCH INITIAL RESPONSE PLAN: this tells the Ranger who initially takes charge (Incident Commander)[3] how to respond and who to initially involve.

7. RESCUE INITIAL RESPONSE PLAN: this is like the above, but specific to rescues.

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[1] The Incident Command System is a simple team organization structure, popularized by forest fire fighters, now widely adopted by emergency management teams across the United States.

[2] Source: Dave Baker, Worland District BLM Office, P.O. 119, Worland, Wyoming 82401 (307) 347-9871.

[3] The person put in charge of directly managing the incident is the "Incident Commander". They report to the "responsible agency", but need full authority to manage the incident.

8. CAVE RESCUE PERSONNEL LISTS (with home phone numbers):
   Internal
   Local
   State and Regional (have a copy of the National Speleological Society (NSS) Members Manual available)

9. CAVE RESCUE LOGISTIC:
   Internal
   Local
   Regional (find your Regional Cave Rescue Coordinator by calling the NSS[4])

10. MEDICAL PREPLAN:
   List of local medics who have trained in caves.
   Copy of Manual of U.S. Cave Rescue Techniques[5] so a medical coordinator can read up on the medical aspects of cave rescue.

11. FORMS: (keep master copies of cave specific forms, just like in your ICS plans book)
   A. Search team debriefing sheet (Maze caves need this more than others).
   B. Lost caver questionnaire
   C. Overdue caver questionnaire
   D. Injured caver questionnaire

12. REFERENCES: (these should be kept in your Emergency Operations Center)
   A. Manual of U.S. Cave Rescue Techniques by Steve Hudson
   B. Latest copy of the NSS Member's Manual
   C. Next or last year's copy of the NSS Member's Manual (format alternates annually)
   D. Any search text (e.q.-NASAR Field Commander's Notebook for SAR)[6]
   E. ICS Plans Book (this has master forms needed for photocopying)
   F. Appropriate phone books for locales and agencies.

13. DISTRIBUTION OF THE WRITTEN PREPLAN: This plan should be kept in your dispatcher's notebook. It should also be posted on the wall in your Emergency Operations Center (EOC): the EOC is often either a room in the Sheriff's Office with a phone and a radio, or else your Chief Ranger's Office.

TRAINING AS PART OF YOUR PRE-PLAN

Internal training begins with familiarization with the written preplan by dispatchers and rangers. A next step is having your rangers read Manual of U.S. Cave Rescue Techniques. They don't need to memorize the book, but they need to be comfortable with first 4 chapters and they need to be aware of the rest of the book as reference material. Finally, a simple mock rescue that your rangers participate in will be the most valuable preparation you can ever do.

External training can be done at your site or at national seminars. National Cave Rescue Commission (NCRC) runs annual week-long cave rescue seminars and currently offers four levels of training (four weeks total). NCRC also runs many weekend workshops. The best use of your

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[4] Source: The NSS, Cave Avenue, Huntsville, Alabama 35810-4431 (205) 842-1300

[5] Steve Hudson, Ed., Manual of U.S. Cave Rescue Techniques, National Speleological Society, 260 p.

[6] Source: The National Association for Search & Rescue (NASAR) PO 3709, Fairfax, Virginia 22038 (703) 352-1349.

staff's time would be to have an NCRC instructor offer a short workshop on your site; inviting other local agencies to participate will help organizations coordinate and it will provide personnel numbers large enough to better simulate a typical cave rescue event. Other external training includes ICS training and especially MSF (Managing the Search Function: a 40-hr NASAR course).

AUTHOR'S BACKGROUND

John Gookin is the Curriculum Manager at the National Outdoor Leadership School (NOLS). He is an instructor for the National Cave Rescue Commission (NCRC) and the National Association for Search and Rescue (NASAR).

THE FOLLOWING IS THE CAVE RESCUE PREPLAN USED FOR FREMONT COUNTY, WYOMING. IT IS PRESENTED HERE AS AN EXAMPLE:

CAVE RESCUE PREPLAN

Fremont County, Wyoming

AUTHORITY: this pre-plan is a document generated by the cavers of Fremont County and the National Cave Rescue Commission. It is intended to help speed up rescue efforts only and has no legal authority whatsoever.

PERSONNEL

Call the following people to actually perform underground rescues. Most people on these lists have the numbers of the others and usually know whether they are in town or not. Most cave rescues demand very specialized skills and you need to let the cavers determine who would be best for which jobs.

INITIAL RESPONSE TEAM (for an explanation, see Appendix 4: Initial Response Teams)

John Gookin (phone 332-7716): Instructor for the National Cave Rescue Commission and NASAR and member of Fremont Co. SAR. See also appendix 1: NOLS cavers

Blaine Davis (phone 332-9213): President of the Wind River Grotto of the National Speleological Society. See also Appendix 2: Wind River Grotto and Appendix 3: Wyoming NSS cavers.

PLANNING FOR THE SECOND SHIFT

Rick Rigg (phone 208-524-5688 hm/208-533-7816 wk/208-533-7735 fax): NW Regional Coordinator for the National Cave Rescue Commission. Rick knows many of the 5,000 cavers in the Northwest Region and has a well rehearsed call-out plan. Rick doesn't come to the rescues; he coordinates the cavers in the area from Seattle to Omaha. Rick can basically mobilize the operations section for the second and third shifts. He'll need to know the location of the nearest commercial airstrips and he'll expect locals to provide ground transportation that can haul personnel and trailers from the airstrip. NCRC Cave Rescue Personnel typically arrive with their own caving, camping, and rescue gear.

EQUIPMENT

FCSO has ropes and wetsuits in the SAR garage. NOLS-Lander has one of the largest cave rescue caches in the United States. Each of the four caches spends 3 months of the year at a remote location. Contact the NOLS Evac Coordinator at 332-4784 to gain access. Rick Rigg can also locate caches. The second closest cave rescue cache is with the BLM's Worland District

Office (347-9871). The third is with North Bighorn Search & Rescue (548-6372) in Lovell.

STRATEGY

OVERDUE PARTIES: Have a deputy confirm that the caver's vehicle is actually at the cave entrance and not at Pizza Hut. Consider immediately warning an Initial Response Team (IRT) leader to develop a plan if there's a probable incident.

KNOWN ACCIDENTS: even a broken leg is a life-threatening injury due to the cold temperatures of Fremont County's caves. Mobilize as quickly as possible. Especially, get an IRT to the site ASAP. This team needs cavers who know first aid. Don't expect a non-caver EMT to be able to function in a part of the cave that is so difficult that an experienced caver had an accident there.

LOST PERSONS: if one caver disappears and his partners can't find him, small cavers will be needed for searching.

CAVE DIVING ACCIDENTS: Most cave diving accidents are fatalities, hence not emergencies. There are cave divers in Casper and Denver who can perform recoveries.

INITIAL RESPONSE TEAM

USE: The Initial Response Team (IRT) responds to a known accident as quickly as possible. Their goals are to (1) stabilize the patient, (2) assess the situation, (3) mark the route to the cave entrance and to the accident site for other rescuers, (4) bring the patient out if possible, (5) keep the command informed.

WHO?: The hasty team has 2-6 cavers in it. Numbers depend on the nature of the cave, the accident scenario and who's available. At least one needs medical expertise. The IRT leader is the Incident Commander until a surface team is on site. (The deputy in charge at the SO is the Commander of the Fremont Co. Emergency Operations Center.) If a deputy is at the surface, they are the IC and the senior person underground is called the "Underground Coordinator." Do not expect non-cavers to be able to function on an IRT if they are going to a part of a cave that is so rough that an experienced caver already had an accident there.

EQUIPMENT: Each caver needs their own three sources of light and enough food, water, and gear for a 12-24 hour cave trip. They should expect to operate in pairs and may even cave alone when functioning as a runner to the surface. They will be moving very quickly for a while, then sitting at the accident site for hours. They will need appropriate clothing. They may also need the following equipment in certain situations:

- rope and ascending rigs
- wetsuits with gloves and booties
- "packaging" to keep the patient warm
- pre-heated IV solutions for on-site hypothermia treatment
- dustmasks, 2 each

DISPATCHER'S SHEET FOR CAVE SEARCH & RESCUE

OVERDUE PARTIES: (cavers haven't returned home as expected)

Date:___________________ Time of call:_________________

(1) Who is calling?___________________ Their phone #_______________

(2) Are they the contact person that the cavers were supposed to notify when they were out of the cave? ___________________________

(3) What time was the group supposed to return? _________________________

(4) Where, other than the cave, could the group be?

(5) Has this happened before? _________________________

(6) Please describe the vehicle they are in: ________________________________

(7) What cave were they going to? ___________________________

(8) What type of equipment did they take besides lights and helmets? (ropes, wet suits, scuba gear?) _______________________________

(9) Have you contacted anyone else to go see if their car is still at the cave?

(10) Does anyone in the group have any known medical concerns?

LOST CAVER: (one or more cavers are missing inside a cave)

Time of call:_________Reporting party:______________ Phone # __________

(1) Who's missing?

Name:______________________

Age:______________________

Address:____

Physical condition:_________________________________

Medical concerns? (Asthma, Diabetic, Allergies, etc.) ______________

Experienced in caving?____

Been in this cave before?____

(2) Point Last Seen (PLS)

Where was the point last seen?_________________________________

What time were they last seen?_________________________________

What time did they enter the cave?_____________________________

Time due out of the cave?_____________________________________

(3) Do you have any guesses where they are or what happened to them?

What equipment were they carrying?

How long do you think their lights will last?

(4) Where are the other group members now?_________________________

Can they do a hasty search of the most probable areas?____________

Do any of them know basic first aid?_____________________________

Is someone watching the cave entrance to see if they come out?_____

Have you contacted anyone else to help with the search?____________

DISPATCHER'S SHEET: CAVE SEARCH AND RESCUE

INJURED CAVER: (a caver reports that one of their partners is injured and still in a cave)

Date:________________ Time of call:____________________
Reporting party:___________________ Phone #_____________________

(1) Who is injured?
Name:_______________Age:______Ht:______Wt:______Sex:________
Home address:____
Physical condition:____
Medical concerns: (Asthma, diabetes, allergies, medications?)

(2) What's wrong?
What's wrong with the patient?____
How did the accident happen?____
What time did it happen?____
Did anyone do anything to keep them warm? What?______________________
Who is with them?____
Will they be able to help drag themselves out?___________________________
Can other members of your party help? How many?______________________
We especially need a guide to take our Initial Response Team into the site. Who should do that? ____
Can you call some other cavers to come help?___________________________
Please call back to let us know who's coming to help.____________________

(3) Where are they?
Cave name:____
Where are they inside the cave?_______________________________________
How hard is it to get to that part of the cave?___________________________
Are they in a safe spot?____

CAVE SEARCH TEAM DEBRIEFING REPORT

(To be filled out by Search Team Leader and turned into the Operations Director)

Team Leader:________________________ ________________________

Team Members:________________________ ________________________

________________________ ________________________

Headed into cave: date/time________________________Returned:______________

Area of search assigned by Operations Director (general description):

Type of search: ____Hasty ____Detailed ____POD[1]

Area actually searched (detailed description, please put a map on the back):

Have all passages in this area been thoroughly checked?__________________

Is additional searching required for this area?________________________

Describe what you recommend we do next?________________________

Any comments, hunches, or opinions?

TIPS FOR SEARCHERS:

1. Look for clues more than the person.
2. Stop and listen for banging rocks once in a while. Banging rocks against the cave floor travels much farther than other cave noises. Call out the person's name and listen carefully for a response.
3. Tape off searched areas with labeled flagging (e.g.Team B,95% 7/28/93 10pm).
4. Work in pairs, but keep the team together.
5. Be sure to return to the surface with enough time and energy to brief the next shift of searchers. You will then be expected to get some rest before relieving that shift.

[1] The Probability of Detection: If the person was actually in the part of the cave that you searched, what is the chance you would have found them using your search techniques? 100% means that here's no way they could possibly be in there. 5% means you could search that area forever and not be sure they're not there.

HELPING CAVE MANAGERS EVALUATE CAVING SKILLS AND CAVE HAZARDS

David McClurg
NSS Vertical Section Board Member
Coordinator, Vertical Techniques Workshop

ABSTRACT

This paper provides both background information and guidelines to help cave managers:

* Judge the caving skills and experience of potential cave visitors.
* Evaluate the hazards in their caves, including vertical and water hazards.
* Learn about the equipment used by safe and responsible cavers to overcome these hazards.

The paper concludes with a summary of vertical equipment and the pros and cons of the three most popular ascending systems.

EVALUATING CAVING SKILLS

Sizing up potential visitors to your caves isn't terribly difficult--if you've done your homework. First, you have to know what hazards your caves have.

Second, you have to know what equipment and techniques experienced cavers use to overcome those hazards.

QUESTIONS FOR PERMIT APPLICANTS. For example, suppose one of your caves has a slippery but otherwise climbable 20 foot slope. It isn't steep enough to require vertical gear, but it's a lot more comfortable with a handline.

So when you have your little chat with the prospective cave visitor, you describe this slope and its characteristics. Then you innocently ask: "What kind of handline do cavers in your part of the country usually use?"

If the answer comes back: "Beats me. What's a handline?" This should let you know they aren't very experienced cavers. Any properly equipped cave group should be carrying at least one handline -- even in an essentially horizontal cave.

Or if the answer is something like this: "We like to use a length of one-inch manila. It's real easy to hold on to. We got it from a junior-high school that was throwing it out when they refurbished their 15 year-old obstacle course." This second response says these visitors aren't part of mainstream caving. They may know a handline is sometimes needed. But they aren't familiar with what experienced cavers really use. (What they really use most often is about 50 feet of 8 or 9 mm - 5/16 or 3/8 in Perlon.)

If you get either of these responses, you may elect to steer them to a horizontal cave with less vertical extent.

FIFTY-FIVE FOOT PIT. Or suppose you have a pit that needs to be dropped - say a 55-foot pit some distance into the cave that leads down to a lower level.

You can ask what type of vertical system their group prefers, Gibbs ropewalker, Mitchell, or Frog. And which one they plan to use for your pit.

Again, experienced vertical cavers will be happy to describe their vertical systems and how they use them. Some may even launch into a lengthy discussion about all the special bells and whistles they've included. You may hear more than you wanted about floating double bungies and cows tails for passing rebelays.

But at least you'll have found out that they've had some experience. Other questions can be about the type of pits they've done. Their depth, free of against the wall, easy on and off the rope, tough lips, that kind of pit talk.

You can also ask how do they plan to rig the pit. Perhaps you've installed your own bomb proof bolts. Or maybe you prefer to have them use natural anchors. This would be the time to discuss these details. Experienced cavers should be able to understand your requirements and describe which main anchor and which backup anchors they'll be using. Every rigging should have a back up. Some need more than one.

WATER HAZARDS. If your cave has streams and lakes, you should be asking what kind of protective clothing the group plans to wear. This could range from woolen socks to a full wetsuit, as we discuss below. So find out exactly how they're prepared to meet the challenge of hypothermia - the killer of the unprepared.

Do you have steep sinkhole entrances or base level passages subject to flooding in severe storms? Are there safe areas and caches of food and supplies? If you're blessed with these kinds of hazards, they need to be discussed beforehand along with the clothing and gear needed to protect against them.

PRE-TRIP GEAR INSPECTION. Inspecting the actual equipment that's going to be used for vertical or water hazards is so basic as to be almost mandatory. But be sure to let permit seekers know ahead of time in your information packet or permit application that gear will be inspected.

Include everything in your inspection - basic caving gear, vertical gear, exposure suits, and wet suits. We know that carrying out a gear inspection can cause scheduling problems depending on your staffing level and location of your office relative to the caves. Such problems not withstanding, checking out equipment is fundamental to managing your resource to prevent accidents.

Rule number one is:

* All cavers must have their own gear - gear that fits them and they're experienced with. No gear, no go. Ferrying a set of vertical gear up and down the drop for the next person is unsafe. It also slows down the trip creating delays and bottlenecks. And if the cave is cold, wet, and breezy (as many are), this can give a headstart to hypothermia by chilling those waiting in the queue.

Rule number two is:

* Equipment should not be brand new. If it's still in the shrink wrap, the chances are these folks don't know how to use it. At the top of the first drop is not the place to be cutting slings to length and trying to figure out which leg goes into which hole in the seat harness. Above-ground practice climbs should be the setting for lashing up new equipment.

Nor should equipment be so worn that slings are heavily abraded or the teeth on ascenders are worn way down. Deep grooves in the rack's brake bars or the Figure 8 may be macho, but are potentially unsafe. So are muddy ascenders and slings.

These rules also apply to exposure suits and wet suits. They should fit and be in good condition - clean with no rips or tears. Wet suits are easy to repair. Cavers who repair their wetsuits - and other cave gear - are probable safety conscious in other matters too.

Rule number three is:

* Ropes and hardware must be clean. Take a look at their rope. If it's dirty, they're probably no careful cavers. It's not a sure sign, but it's a pretty good indicator of careless caving. Cleanliness is next to godliness when caving ropes are concerned. Dirt and grit cuts into rope fibers. Muddy ropes clog up ascenders and make prusiking difficult. Dirty slings and climbing hardware are equally unacceptable.

If you've warned them ahead of time, you are justified in asking them to come back later with clean gear and ropes. And dry ropes too, not just dunked in a nearby stream and still wet. (Wet nylon ropes may lose up to 10 to 15% of their dry strength, which they will regain when dry).

MAKE A LIST. Are your caves cold or do they have vertical or water hazards? you should seriously consider making up a list of the specific equipment required for these conditions. Equipment beyond the hard hat, cap-mounted lamp, two other sources of light, and stout boots.

Send the list in answer to inquiries or with the permit as a prelude to your pre-trip gear inspection. This way you've alerted them that you expect all members of the group to be properly dressed and equipped for the trip - and you expect clean ropes and slings too.

EVALUATING CAVE HAZARDS

The best way to understand the hazards in your caves is to experience them first hand. If you haven't already done so, take a trip into each cave with some experienced cavers, either from your own staff or from a local caving club. Explain why you're looking over the cave. Seasoned cavers can help you judge hazards and suggest solutions.

To help you to understand and evaluate your hazards, we've defined three classes of caves - beginner, intermediate, and advanced. Each has specific characteristics and levels of danger. Our categories are based on these dangers and the techniques and equipment needed to explore them. They're very generic and somewhat oversimplified so as to be as accessible.

Several government agencies also have classification systems, some of which may seem to parallel ours. Our desire is not to add to the confusion with another complicated categorization. Our analysis is quite straightforward and concentrates on the dangers in caves and the proper equipment to handle them.

* Beginner caves are basically horizontal.
* Intermediate caves are also basically horizontal but often have several levels connected by pits and fissures.
* Advanced caves are multilevel or multimile.
* Intermediate and advanced caves may or may not have unclimbable vertical pits or water hazards as well.

Thus, we prefer to consider these vertical and water hazards separately and superimpose them over the basic classes.

VERTICAL HAZARDS. Vertical hazards mean unclimbable pits which require ladder climbing or vertical rope work - rappelling and prusiking. Thus we have Intermediate Vertical Caves with one or two short vertical pits. Similarly, we have Advanced Vertical with several pits of deep pits.

WATER HAZARDS. Water hazards means streams, lakes, and flooding which require woolen clothing at one end of the spectrum and wet suits at the other end.

CONCLUSION

Note that we set up these criteria on difficulty, not on beauty or natural values. Even so, we must never forget that any visit to a cave can cause damage. So the environmental impact and the possible need for carrying capacities or seasonal closures must always be considered.

Our goal with this classification scheme is to give some general guidelines that will tell you what to expect and what experienced cavers use in the way of equipment for each class of cave.

Each class of cave, vertical hazards, water hazards, and types of vertical pits are described with accompanying illustrations. Finally, we briefly discuss vertical equipment and the pros and cons of the three main ascending systems: Gibbs Ropewalker, Mitchell System, and European Frog System.

Beginner Caves
Figure 1

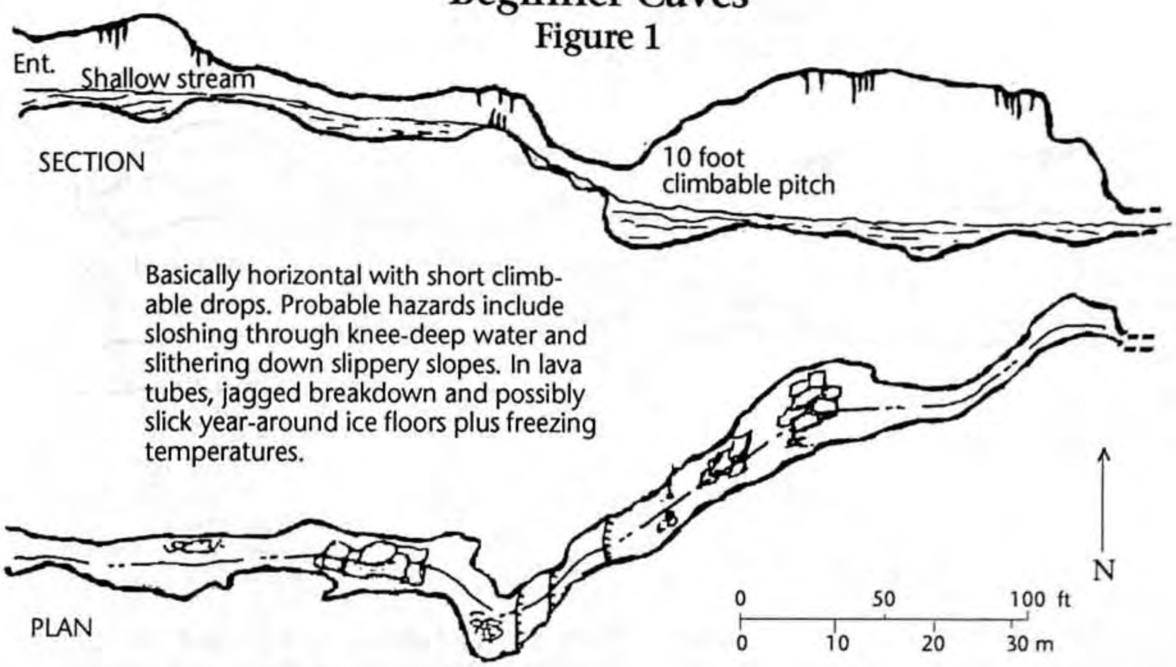


Figure 1. Beginner Caves. These caves have essentially flat or sloped passages with no unclimbable slopes, fissures, or pits. Require walking on rough terrain, some crawling, scrambling, chimneying, or climbing down short (ten to 25 foot) pitches or breakdown blocks. Length is a few hundred to a few thousand feet. Trips last two to three hours, five to six hours maximum.

Equipment:
- Helmet with light and two other light sources each.
- Lug-soled (non-marking) boots.
- If cold (below 50° F), coveralls over two insulating layers (wool or polypro).
- If wet, woolen or polypro bottom layer and woolen socks or wet suit booties.
- If several crawls, knee pads.

Pack with:
- Lamp spares.
- High energy snack foods.
- Caver's sling with locking carabiner and safety loop (see below).
- Garbage bag (emergency poncho and shelter).
- One quart of drinking water.

Group Equipment
- Minimum first aid kit and space blanket.
- An extra warm sweater or jacket
- 50 foot hand line (8 or 9mm)
- Watch to keep track of time.

Caver Sling Uses
- Made from ten-feet of one-inch sling plus locking carabiner
- Rigging runner— conserve rope or position main rope better.
- Emergency diaper seat sling (back up with safety loop.)
- Haul line—for more length, tie several together with water knot.
- Hand line—use several for more length.
- Emergency chest sling for ascender or carabiner.
- Tail or grab line with figure-eight loops—hang below lip at top of drop.

Safety Loop Uses
- Made from five-feet of seven-mm Perlon tied into a loop with Grapevine knot.
- Prusik loop for ascending or tie-in to standing line.
- Leverage loop to release carabiner on Spelean Shunt.
- Backup for diaper sling.
- Tie-in when you're belaying (**always** tie in).Use single or two loop version.
- Two loop version with small loop in each end to tie into an anchor.

Intermediate Caves
Figure 2

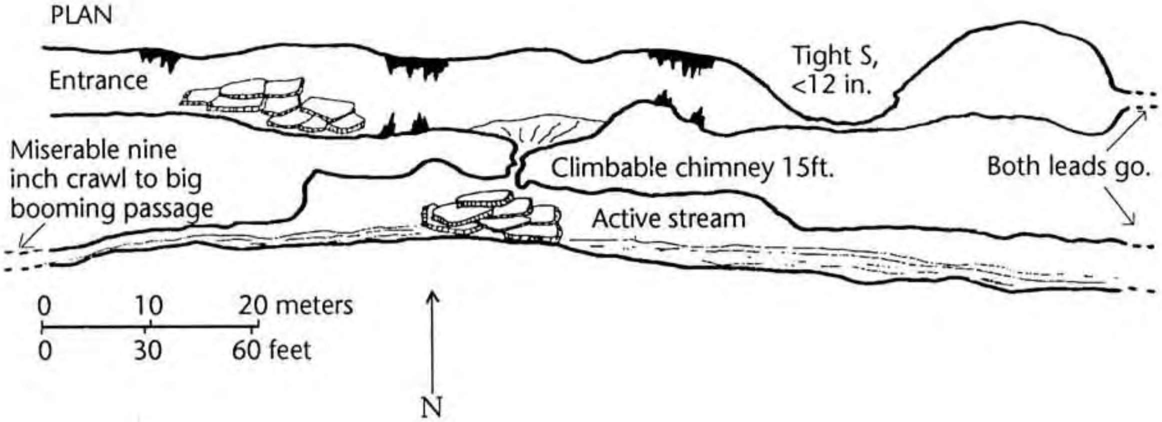


Figure 2. This category of cave is still loosely called horizontal, but now the levels are connected by several steep slopes, climb downs, pits or giant breakdown blocks. The drawing shows a typical section of an intermediate cave not requiring vertical rope work. Other areas and other intermediate caves may have unclimbable or unavoidable pits neding rope work.

Total cave length is from a half-mile to several miles with a mixture of walking, stooping, crawling, scrambling, chimneying, traversing, and climbing (sounds great, doesn't it). Skills required for the climbable pitches may extend from beginner almost to advanced. But the number of them is still small enough to call the cave intermediate. Handlines and belays are often needed. Unclimbable pits call for vertical gear, the exact type depending on the depth and other factors.

Trips average six to eight hours, but frequently stretch to ten to 12 hours. Hazards include active streams and lakes, steep slopes, traverses along narrow ledges, breakdown blocks, pits, and snug crawls 12 inch and under—the shoulder-in-front-and have-to-turn-over-in-the-middle kind).

Equipment
- Full caving gear as listed under Beginner Caves.
- Proper layered clothing or wet suit if really sloppy.
- Seat harness for belayed climbs or traverses.
- Full vertical gear for unclimbable pits that can't be bypassed or the group prefers to drop.

Pack with:
- Spares and back up light sources.
- Food for snacks and one to two heated meals.
- Garbage bag for emergency shelter.
- Cavers sling and locking carabiner plus safety loop (see Beginner Caves for details)
- Drinking water—one to one-and-a-half quarts.

Group Equipment
- First aid kit with two space blankets.
- Extra warm sweater or jacket.
- 50 foot hand line (8 or 9mm).
- Jumar with etrier.
- Map of cave.
- Watch to keep time.
- Heat tab, sterno, or other solid fuel stove.

Advanced Caves
Complex Multilevel or Multimile Caves
Figure 3

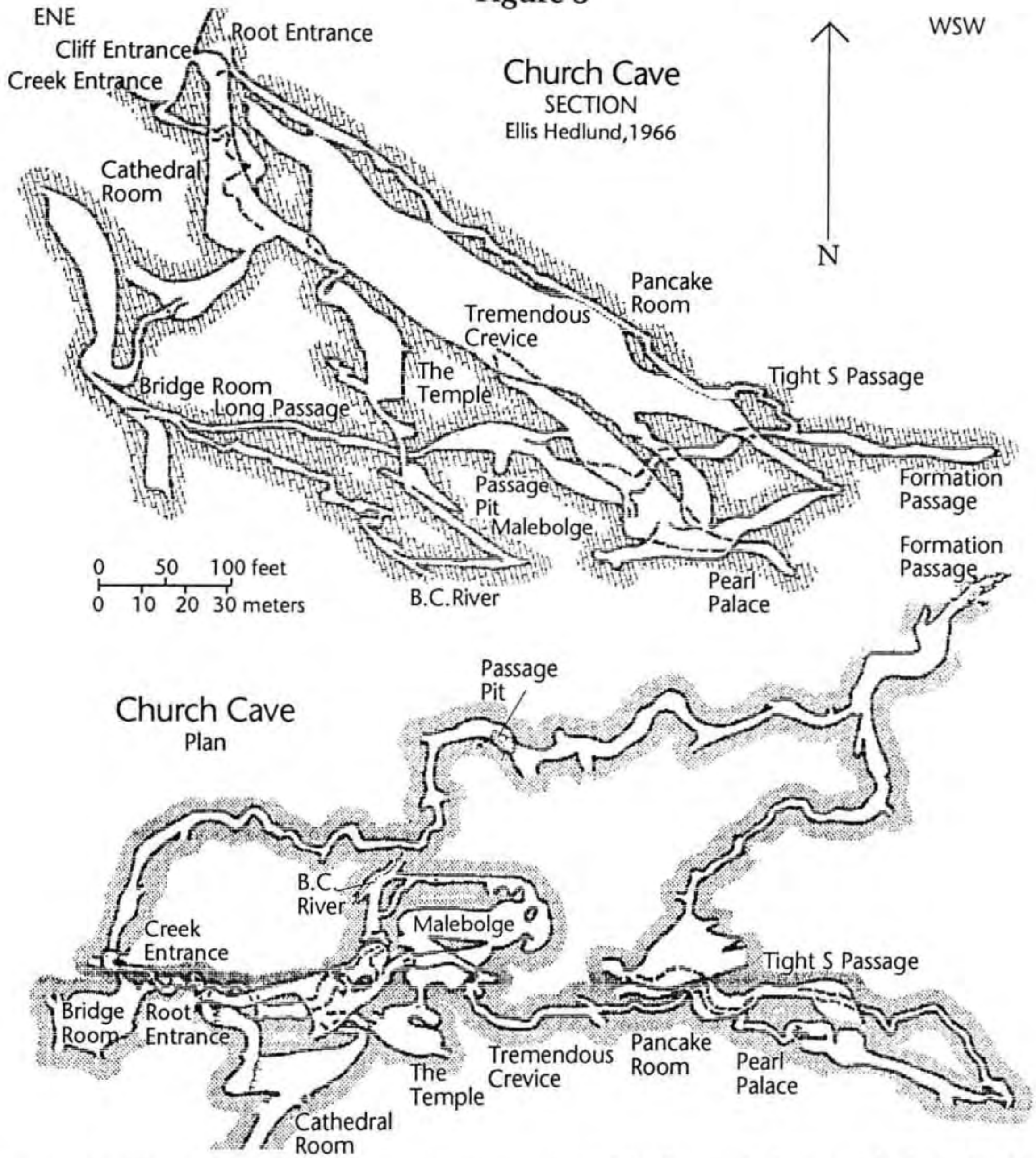
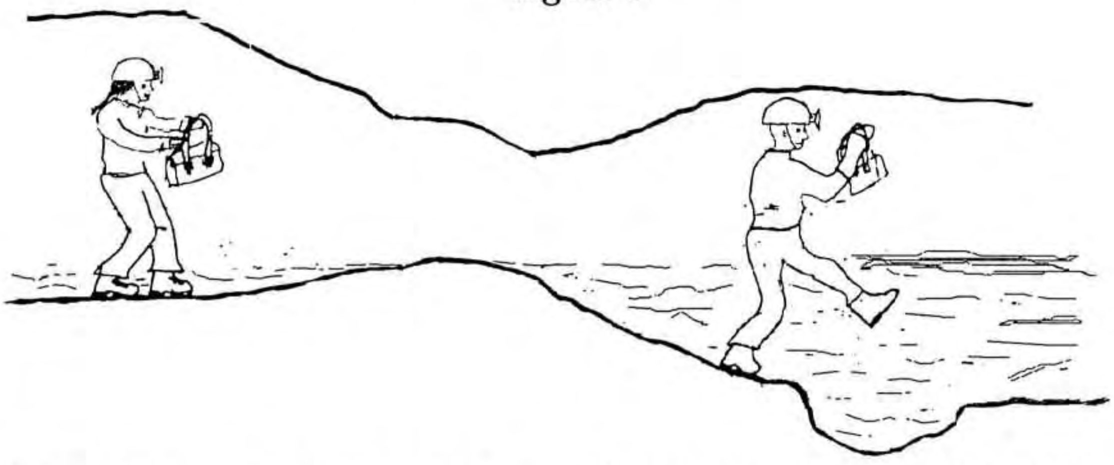


Figure 3. Advanced Caves. These caves have several miles of passage and require 10 to 16 hours to tour all levels—16 to 20 hours is not unusual. They often have considerable vertical extent, but not always. For example, Church Cave shown here, is a real caver's cave. It requires the full panoply of caving skills—free climbing fissures and walls, scrambling down slippery chutes, chimneying in bell-bottom fissures, squeezing through tight tubes, crawling on rough floors—to traverse its rugged terrain, everything but vertical rope work. Typical trip is 12 to 16 hours. A seat harness is often worn throughout.This and many other advanced caves are actually more difficult than the average 185 foot pit-bopping open air pit. Gear for advanced caves:

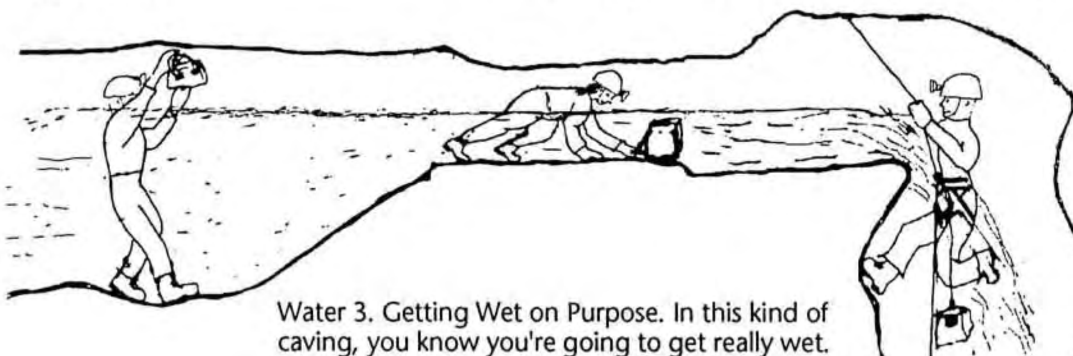
- All personal and group gear needed for intermediate caves, plus additional food for several snacks and two or more meals.
- If vertical—complete vertical pack with rappel and prusik gear and ropes.

Water Hazards
Figure 4



Water 1. Shallow streams. These caves have ankle-to-knee deep streams and small lakes. Getting wet can often be avoided by hopping between banks and rocks. For protection, wear woolen socks or wet suit booties, and woolen underclothes. Carry a plastic garbage bag. For a long or slow trip (photos, survey), bring a small ensolite pad to sit on and possibly carry a change of clothes.

Water 2. Accidentally Getting Soaked. Streams with deep pools and lakes that you could fall into and get really soaked can cause hypothermic chilling. If this happens, you are in real danger without protective clothing. Wear several layers including woolen or polypro underclothes covered by PVC coveralls. Bring a change of clothes. Wear a wetsuit if really bad. Be prepared.
Hypothermia is the killer of the unprepared.

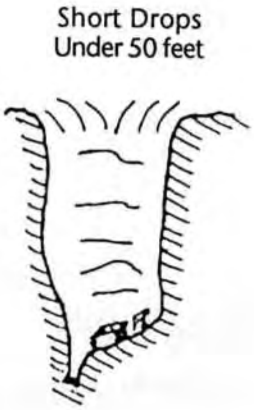


Water 3. Getting Wet on Purpose. In this kind of caving, you know you're going to get really wet. You have to swim in deep water, crawl in low water filled passages, and negotiate water fall pitches. In other words, to explore the cave you have to get wet. To do it safely, you need a wet suit or you're in danger.

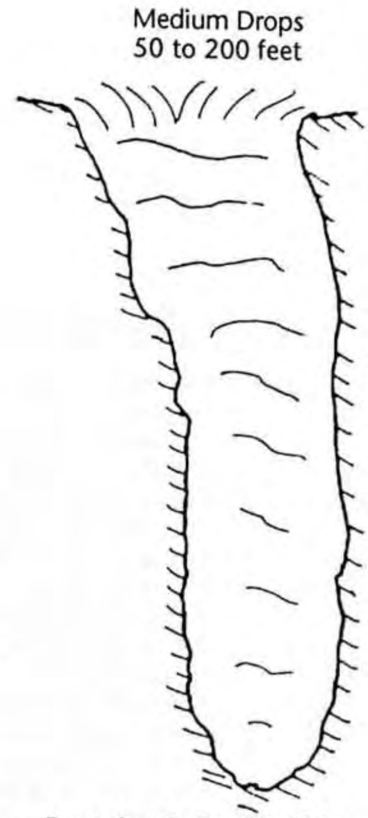
Figure 4. Many caves have water hazards, in addition to their other challenges. More subtle than vertical hazards, water hazards are no less dangerous. Many northern and high elevation caves with their cold, wet conditions present an almost perfect environment for hypothermia, the killer of the unprepared. Proper clothing and food, plus a positive mental attitude, are the first lines of defense.

Flooding is also a danger particularly in caves of the South and Midwest with steep sinkhole entrances, or base level entrances and passages containing active streams. In threatening weather, it's best to stay out of such caves.

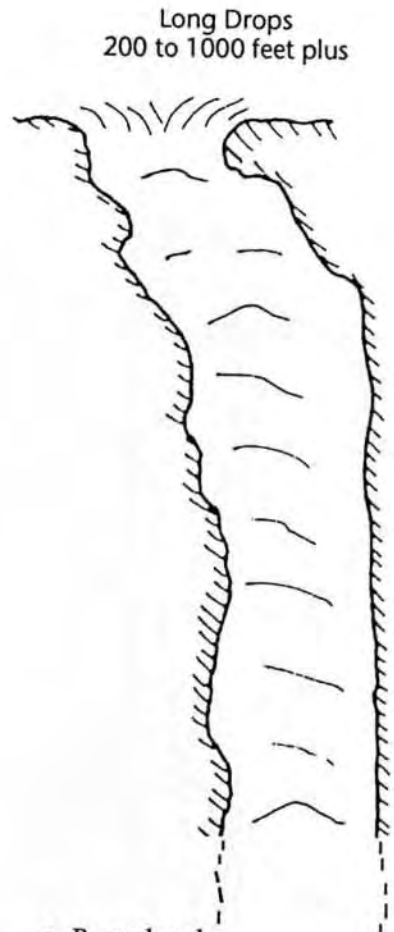
Vertical Categories
Figure 5



- Figure 8, Petzl bobbin, or mini-rack.
- Sewn seat harness, swami seat, backed-up diaper sling.
- Locking carabiner or delta screw link.
- To ascend—knots, Frog, Texas, or Mitchell.
- For the Mitchell, a simple chest harness and carabiner, or a chest box (Gossett or double Simmons).
- If this is the only pit, and a seat harness isn't needed later for traverses or hand-line pitches, a minimum system with a backed-up diaper and Prusik knots will work.
- If only pit is 30 feet or less, could be better to rig a ladder, rappel down belay line, climb out on ladder.
- Or if only one pit, and seat harness isn't needed later for traverses or hand-line pitches, a minimum system with a backed-up diaper and Prusik knots will work.



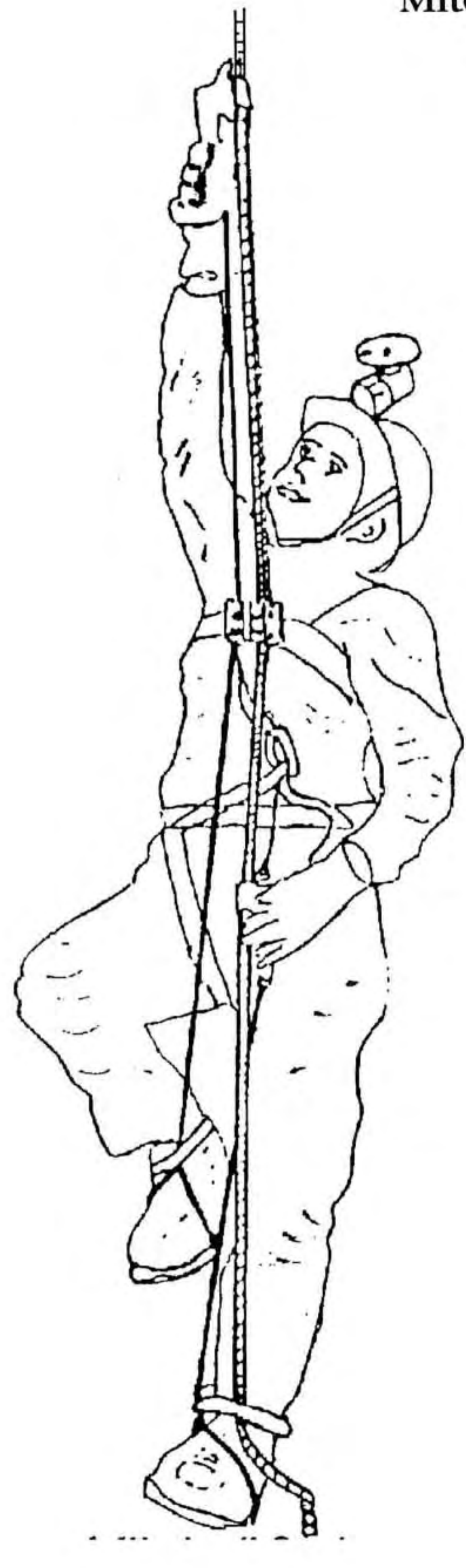
- Rappel rack, Petzl bobbin, Figure 8, or mini-rack.
- Sewn seat harness or two-inch swami seat.
- Locking carabiner or delta screw link.
- Spelean shunt.
- Mitchell, Texas, Frog, Gibbs.
- For the Mitchell a chest box (Gossett or double Simmons).
- For Gibbs, Simmons or Gossett.
- One-inch four-step etrier with Jumar.
- Safety loop (5 feet of 7mm Perlon. See Beginner Cave for details).
- If near the 200 foot range, rappel rack and Mitchell or Gibbs system preferred.
- This level is more of a step up than many cavers realize so careful training above ground is recommended.



- Rappel rack.
- Sewn seat harness or two-inch swami seat.
- Locking carabiner or delta screw link.
- Spelean shunt.
- Gibbs or Mitchell system with floating ascenders and chest box.
- One-inch four step etrier with Jumar.
- Two safety loops. (5 feet of 7mm Perlon. See Beginner Cave for details).
- Special problem is rope weight reaching 50+ lbs at top of range. Practice with weighted rope(e.g. spare tire on end) before trying 500 foot plus drops.

General Notes:
- For a cave with several pits separated by climbs or water pitches, an easy-on-off system like the Frog, Mitchell, or Texas is preferred.
- Safety Jumar and etrier are useful for crossing undercut lips and as a handline safety.
- Safety loop (5 ft. 7mm Perlon) for: Diaper back-up, rigging runner, prusik sling, anchor tie in.
- Seat harness is often worn throughout caves with climbs and traverses, even single pit caves.

Mitchell System
Figure 6

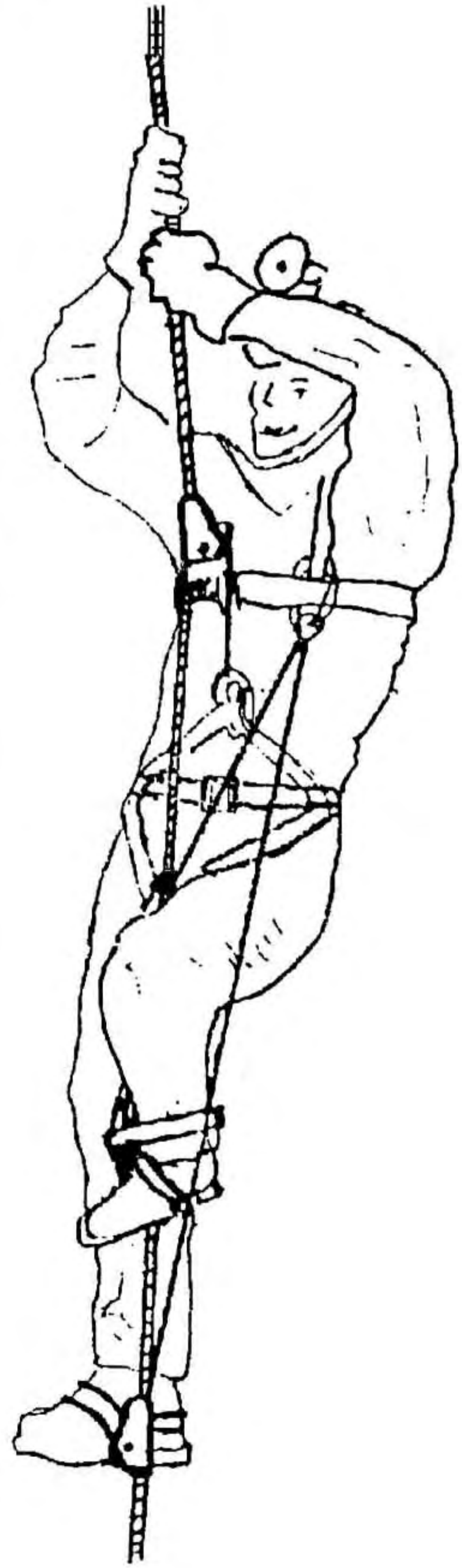


Summary of Main Points

- Mitchell System is a ropewalker like Gibbs System, except:
  - Hands must raise ascenders making it more tiring for some.
- Uses two Jumar type ascenders and a two channel chest box.
- Easier to put on than Gibbs—can be done with one hand.
- Better for technical pitches (e.g. need to climb or traverse while on rope) and for rebelay rigging.
- Converts to Texas system when ascent is better away from rope.
- Needs sling between seat and chest harness in case of ascender or sling failure.
- Chicken loops vital to keeps slings on feet.

Gibbs System

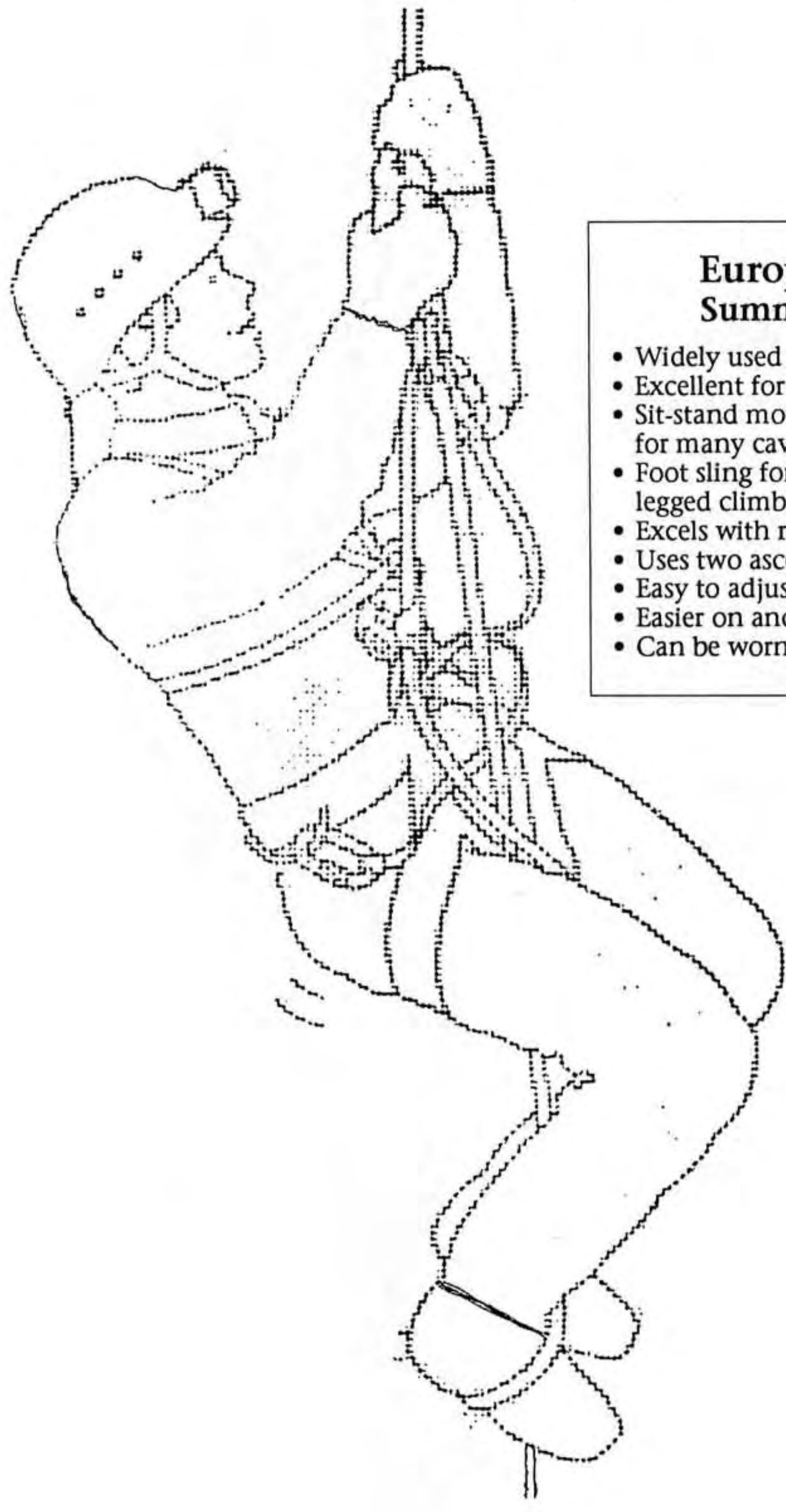
Figure 7



Summary of Main Points

- Very efficient, thus best for long free drops.
- Less tiring for most cavers.
- Most efficient version floats both lower ascenders.
- Better against walls, both hands are free.
- Uses two or three ascenders and a single channel chest box.
- Newer systems replace one or more Gibbs with Petzl jammers for quicker on off rope.
- Chicken loops vital to keeps slings on feet.
- Needs sling between seat and chest harness in case of ascender or sling failure.
- Slower to put on rope.
- Doesn't work well with rebelay rigging.

European Frog System
Figure 8



European Frog System
Summary of Main Points

- Widely used in Europe and rest of world.
- Excellent for multiple-drop caves.
- Sit-stand motion easy to learn, but more tiring for many cavers.
- Foot sling for both feet allows powerful two-legged climbing.
- Excels with rebelay (multiple point) rigging,
- Uses two ascenders, seat and chest harnesses.
- Easy to adjust, not so critical on size.
- Easier on and off rope than American systems.
- Can be worn while caving between drops.

THE PREVALENCE AND SIGNIFICANCE OF DEHYDRATION IN SPORT CAVERS

Lyle R. Moss

ABSTRACT

A study of dehydration was conducted in five sport cavers during a five day exploration trip in Lechuguilla Cave, the objectives were to document presence of dehydration and, if present, to correlate with caver performance. The design of the study was to measure urine output as an overall indicator of dehydration, along with testing of each urine sample for ketones, protein, and specific gravity, factors in the urine which help confirm a dehydrated state. Caver performance was only subjectively evaluated due to the nature of the trip and small sample size. No intervention including encouraging fluid intake was done. The conclusions reveal significant dehydration was present in the majority of the participants for long periods of time during the strenuous exploration which involved negotiation of over 2000 feet of rope, technical rock climbs, and exploration of difficult virgin passage. The medical literature documents impaired athletic performance with dehydration, of which sport caving is reasonably comparable. Suggestions for management of urine waste is presented.

INTRODUCTION

Due to the long and deep nature of Lechuguilla Cave in Carlsbad Caverns National Park, human impact on the cave is of great concern to those involved in cave management policy decisions. This study of dehydration was conducted to help identify any problems and to aid in rational policy decisions regarding disposal of urine waste within the cave. Traditionally over the three years of exploration of this pristine cave, urination has been allowed due to lack of enforced guidelines and traditional exploration practices. Concern over the "stink factor" and unknown effects of urine solutes on the cave environment (such as alterations of speleothem crystal structures) would rationally lead to a policy of carrying out all urine. Little thought has been given to damage to the cave due to bulky, heavy urine laden packs, or to adverse health effects on the explorers with this policy.

METHODS

Urine volumes were measured by graduated liter clear plastic bottles. The piss bottle would have been previously poured out (in the cave, away from high traffic routes as per tradition) and the caver would urinate into the bottle, the volume read to an accuracy of 25 mls, and the fresh urine poured over a hand-held urine test strip (Ames Multistix 8-SG 2304, measuring glucose, ketones, specific gravity, blood, pH, Protein, Nitrite, and Leukocytes). The bottle was new, and the cap was always replaced to protect the desiccant in the 100% humidity of the cave environment. No interference in the normal pattern of sport caving was done, specifically; alterations in normal voiding patterns, encouraging fluid intake, or discussing in-cave urine results (my own data was known to myself as a participant and recorder of the data). Evaluation of BUN, creatinine, electrolytes, and venous pH were considered invasive and impractical. A few urine samples were lost due to leaky bottles and lack of piss bottles at time of voiding, and the calculations factor out the missing data.

RESULTS

The average urine output, probably most reflective of overall hydration status next to changes in body weight (1), ranged from 90ml/hr (D.J.) down to 35ml/hr (G.G.). Over specific time intervals in all study participants, the urine production was often 10 to 20 ml/hr. For healthy kidneys, urine output should be 30 ml/hr and at a bare minimum needs to be 20 ml/hr (as a guide for intravenous fluid administration, urine flow should be 30 ml/hr at a minimum). The urine specific gravity commonly showed maximally concentrated urine with good correlation to production of ketones and spilling of protein. Six of seven urine samples in (S.G.) were maximally concentrated. No samples showed any leukocytes, glucose, nitrite, blood, or wide variations in pH as was expected.

DISCUSSION/CONCLUSIONS

Significant dehydration was present in the majority of the participants, in some for long periods of time. The medical literature studies athletes in strenuous competition and well documents impaired performance (1,2,3,4). Most Lechuguilla cavers adopt a one-step-at-a-time, slow-and-steady, pace-yourself level of moderate energy expenditure with periods of strenuous activity. The athletic performance literature is comparable due to the periods of high caloric demands, the continuous pace lasting commonly more than 20 hours at a time before significant rest periods, exploration lasting upwards of five days per trip, and periods of limited water availability. Impaired performance in the five participants subjectively correlated to their periods of lack of adequate hydration.

Cavers need to be aware of the hazards of dehydration. Dark yellow low-volume urine should be watched for. Prevention is preferable to trying to play catch-up (2). Adequate fluid containers should be carried, suitable for the regions to be visited. The solute load in dilute vs. concentrated urine output per caver is equivalent, so if urine is allowed to be left in the cave, urine volume is no concern from an environmental standpoint (little is definitely known at this time about the effects of urine solutes on the cave environment; they most likely degrade, aerosolize into volatile gases, and eventually exit the cave under high equilibrium pressures). There is a natural tendency to restrict fluid intake if large volumes of urine are to be carried out great distances. The removal of "processed drinking water" obtained from within the cave should be considered in the homeostatic water balance within the cave. In light of these considerations, a reasonable cave management regulation or guideline in a cave of this size would be to allow urine to be left in the far reaches of the cave, away from concentrated speleothem areas, and away from trade-routes. The prevention of even minor injuries by maintaining good levels of hydration should be encouraged.

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BIOLOGY

Photo Caption -- Accumulation of bat bones and skulls, Carlsbad Cavern, Eddy County, New Mexico.

National Park Service Photo

ENDANGERED SPECIES, GROUNDWATER PROTECTION, AND THE ROLE OF INVENTORIES IN ASSESSING REGIONAL SIGNIFICANCE

Andy Grubbs

The Endangered Species Act (EAS) was passed in 1973 to better safeguard the nations valuable heritage in fish wildlife and plants. Congress found, as a consequence of development untempered with adequate concern for conservation that some species had been so depleted that they were in danger of extinction. The ESA was one of the first laws to protect habitat as the way to preserve populations. A list of protected species was established. Several types of species were placed on the list. This included species that were once widespread, but had suffered large declines in population size. Species that have habitats threatened by large scale changes, and rare species known from only small specific places were also listed. Because cave animals are often known from a small number of specific places, and karst habitats are easily affected by surface land use, some cave animals have been placed on the list. In Texas a total of 8 cave species have been listed.

One policy of the ESA was to mandate that Federal agencies cooperate with State and local agencies to resolve water resource issues in concert with the conservation of endangered species. A number of species that rely on groundwater supplies to provide their critical habitat were listed. Among them several cave animals. At the present time nine such cavernicoles are on the list. Two fish, a salamander, 3 shrimp, a crayfish, an amphiopod and an isopod. More cave animals are protected by various state wildlife and cave protection laws.

One early case where groundwater use was regulated to protect habitat happened in Nevada in the 1960's. The amount pumped out was limited to keep the water level in the Devil's Hole up high enough for the endemic pupfish to survive. This was protecting an aquifer from depletion. In Arkansas in the late 80's opponents of a proposed landfill in a karst area used the local listed specie, the Ozark Cavefish, in their case against permitting the site. This was a case of protecting the aquifer source from pollution.

In Texas the ESA has been used to protect aquifer supplies from depletion. The Edwards aquifer is the sole source of drinking water for more than 1.5 million people. Regulating use of the aquifer is one of the most contentious political issues in the state. Three groups of users have never been able to agree and the local groundwater conservation district has no real powers to enforce. Four endangered species rely on the outflow of the springs for their critical habitat. In a recent Federal court case the Sierra club sued the United States Fish & Wildlife Service (USFWS) to enforce the ESA and declare overpumping of the aquifer as a taking of habitat. The Federal judge found that overpumping does threaten the species. He ordered the State to formulate a management plan or face a court imposed one. Finally serious negotiations between the three groups began. The state is steering up a new underground water district that is tied up in a suit over appointed versus elected board members. Meanwhile the State Attorney General has declared that the aquifer is a underground river and therefore belongs to the state. This is karst management on a regional scale.

Other protected cave species in Texas strongly influence site development in expanding urban areas. Central Texas has several cities where expansion is causing urbanization of karst. It has been known since the mid-60's that the area northwest of Austin had a number of small caves very rich in cave adapted species. Many of the species are not known from other nearby karst areas. As Austin continued to expand, development reached the area and began to threaten some of the caves. In 1985 the City's Comprehensive Watershed Ordinance (CWO) began to protect caves and sinkholes. They were designated as Critical Environmental Features (CEF) because of their connection to the local aquifer. The CWO required setbacks of 150 feet and 300 feet and prohibited developers from including CEF's within lots. More development oriented city councils eased restrictions through the late-80's. A citizens movement dedicated to preserving water quality of the local springs mounted a campaign. Through a petition drive and a city wide vote, they forced a recalcitrant city council to readopt the original standards. In 1988 five invertebrate species from the caves northwest of Austin were placed on the protected list. Several of the species were known from only one or two caves, and these were threatened by development. While the owner threatened to fill the caves with concrete local members of Earth First occupied the cave and drew media attention to the cave. The Travis County Audubon Society petitioned the USFWS for emergency listing of five of the cave species. The Service found that the species were indeed in danger from development and placed them on the list.

Sometimes when a species is listed, or considered for listing the service commissions a status report. The report determines what state the populations are in and identifies any threats to them. Often status reports are funded by Section 6 grants from the USFWS to state agencies that oversee the actual field studies. After a species is listed, a habitat recovery plan is developed. Critical habitats, specific areas within the range of the species, that are essential to its conservation and may need special management considerations are identified.

The ESA was amended in 1982 when Section 10 was added. It provides a way to balance economic and environmental needs. It permits development to proceed in protected areas if a Habitat Conservation Plan (HCP) has been developed or if a suitable habitat preserve is established to offset the damage from the taking of other habitat. A HCP allows development in some areas as a trade off in return for protecting other areas as nature preserves. A HCP seeks to protect large enough areas of critical habitat to preserve the species while allowing development in less important areas. To do this a system of nature preserves is set up. Land acquisition in the preserve areas is paid for by mitigation fees on development and by land trades. The HCP in Texas is called the Balcones Canyonlands Conservation Plan (BCCP). BCCP will protect most of the known endangered species caves. BCCP will preserve about 5 acres for every one released for development.

One Section 10a permit for incidental take has been issued to construct a 78-acre shopping mall that impacts several known endangered species caves. To qualify for the permit, a 232 acre karst preserve was bought. A 5 and 10-year monitoring study of the impacted caves and the preserve caves will be undertaken. Forty thousand dollars will be given for use on the BCCP and a fire ant control program for the 30-year duration of the permit.

As the number of known locations has increased, the taxonomy of the cave species has been changed slightly. The Bee Creek Cave Harvestman was originally known from three locations. Now it is known from more than fifty locations. Some of the populations have been described as a new species. Under the Sec1533(e) Similarity of Appearance Regulation, the new species was also placed on the Endangered Species list. The same for *Batrisodes texanus* which was split out of *Texamaurops reddelli*.

As the inventory of caves in the area becomes larger the picture of regional significance becomes more complete. Mapping of caves on a regional scale is collected into a survey. In many states the local speleological survey has National Speleological Society affiliations. The Texas Speleological Survey began in 1961. Cave surveys are only as good as the information that local cave explorers put in. In some areas there are very good biological records and in some areas there are not any biological records at all. Texas is one of the areas where cave biology has proceeded right along with the survey from the start. Listing of the species has resulted in a very intensive survey of the cave areas being impacted around Austin. As other areas in the adjacent region are investigated, very exact mapping of the ranges of the various species can be done.

In areas where permits are needed for biological collecting or for cave access, the permitting agency can require survey results to be filed at the location of their choice.

To assess the biological resources of a cave, an organized system of field collectors and laboratory taxonomists is needed to collect and then identify the animals. Cave collections must be done by trained personnel to be valid. It takes at least four to six months of constant training to learn how to adequately survey for cave fauna. Cave animals are not evenly distributed through the caves, and a number of visits are needed to find out what species occur in a given cave. There are many examples of cave species that are common on one trip and totally absent on other visits. It is also important to survey as large a number of caves as possible so that as many different habitats can be seen. Some caves are very rich in fauna, but most caves are average or have poor fauna. While finding nothing may indicate a lack of cave fauna, it can also mean that a return trip during a wetter part of the year may be needed.

The study of the distribution of cave animals is intertwined with the study of the geology of the caves. How cave systems have formed, where they have integrated into larger systems, and where they have been chopped up into smaller remnants are important to understand.

In Central Texas the intense survey of the last several years has resulted in numerous new sites where the endangered species are known from. The areas studied are expanding especially to the north and west. New species are being found, and the exact ranges of other species are becoming clear. Some are quite restricted and some have much larger ranges than previously thought. Some exceptional caves are also showing up that are very rich with lots of unique species. Even with the very intense level of study this area has had, new species continue to be discovered there. Continued searching will probably uncover more.

Studies to see how different types of development affect the cave fauna populations are needed. Studies on the life cycles, habitat requirements, and sensitivity to impact from surface influences are next. There is a need for a system so that files are all kept together. This is needed to prevent the later loss of some of the data, or duplication of efforts. When ESA listed species are involved the USFWS can require this as part of the permit process. In Texas all collections must be sent to the Texas Memorial Museum after they are identified. As more cave fauna surveys are done a caver\scientist\agency system should be organized.

The controversy over endangered species and the listing of cave fauna in Texas has not been good for landowner access to caves in some areas. Biologists working on the status of animals proposed for listing in Bexar County are having a very difficult time obtaining the necessary permission to work in the caves.

The endangered karst fauna in Texas is important for protecting the groundwater sources. The choice is to pay now to protect the karst or pay a lot more later when the groundwater goes bad. Development in the Texas Hill country would not be possible without the local aquifer. Endangered species listing is so far the strongest way to protect the karst. Learning how to mitigate the impact of developments, and what is a reasonable level of development that also protects karst resources are the next step.

Cave biology must rely on field collections of specimens because trained personnel using laboratory equipment are needed to determine the species. As more State and Federal permits are needed to work on cave animals, fewer field workers will be able to collect cave fauna. More emphasis will be given to non-taking studies which are more easily permitted or do not require permits. As the importance of cave faunas becomes more widely appreciated interest in the fauna in the general caving public will increase and better regional data bases will develop.

CONSERVATION OF INVERTEBRATES AND MICROORGANISMS IN THE CAVE ENVIRONMENT

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ABSTRACT

Few studies in the literature have discussed the conservation of cave invertebrates and microorganisms. As a backdrop to conservation/management recommendations, the authors provide a brief overview of major groups ofinvertebrates found in caves, and habitats and food sources for these invertebrates and microorganisms. Threats to cave biota include pollution from agricultural sources, dumping of garbage in sinks, the disposal ofindustrial wastes in caves, quarrying and drilling, physical trampling by visitors, some restoration techniques used by cavers, heavy visitation, and the enrichment of the cave environment with extra organic matter. An important management tool to study cave biota and the effects of these threats is the inventory, which includes the seasonal investigation of species composition and abundance, and the measurement of abiotic factors. A variety of inventory techniques are detailed. The desired outcomes of the inventory process include a list of biota found, an abiotic profile, a reference collection of invertebrates species (which may be deposited in a reputable museum), photo-documentation, and recommendations for managing the biota. Conservation strategies involve minimizing the introduction of extra organic matter and pollutants resulting from human activities, giving the cave and biota time to rest, preventing the destruction of habitats, using low impact restoration techniques, and continual monitoring to detect problems at the beginning stages.

INTRODUCTION

A recent search of the literature in five major databases containingbiological information (Biosis,Zoological Record, Life Sciences Collection, Scisearch, and Pascal) forcave invertebrate conservation revealed few articles, demonstratingthat little attention has been paid to this important area of cavemanagement in the mainstream biological literature. The speleologicalliterature which is less well indexed contains a few management andconservation studies. Poulson (1976) provided an overview of threats to caveinvertebrates, discussed the importance of scientific research, and listedguidelines for reviewing research proposals for biological research incaves. Poulson and Kane (1977) stressed the importance of baseline data onthe cave system and its biota so managers can judge the effects ofdisturbances to the cave environment.Howarth (1983) stressed the importance of conducting ecologicalstudies to identify requirements of cave invertebrates as a first step intheir conservation and the need to protect habitats for long-termconservation. The conservation of cave microorganisms has received evenless study and discussion.

The goal of this paper is to provide information which willaid cave managers in studying, managing, and protecting their invertebrateand microbial populations. We provide a brief overview of major groupsof invertebrates found in caves, habitats and foods sources forinvertebrates and microorganisms within caves, and threats to theseorganisms. Following this, we present a more detailed discussion ofmanagement strategies such as the use of inventories, and specificconservation suggestions.

OVERVIEW OF INVERTEBRATES AND MICROORGANISMS FOUND

Major reviews of cave biota and their ecology include Barr (1967),Botosaneanu (1986),Chapman (1993), Culver (1982), Howarth (1983), Mohr and Poulson (1966), andVandel (1965).Some North American reviews include Barr and Reddell (1967); Christiansenand Culver (1987); Gardner(1986); Hobbs Jr. et al. (1977); Hoffmann et al.(1986); Holsinger (1976); Holsinger and Culver (1988);Holsinger and Peck (1971); McEachern and Grady (1978); Mitchell and Reddell(1971); Peck (1988 and 1990); Peck and Christiansen (1990); Peck and Lewis(1978); Reddell (1981); and Welbourn (1978). In addition, the Studies onthe Cave and Endogean Fauna of North America, edited by Reddell (1986,1992) provide a number of detailed studies on specific North Americaninvertebrate groups. We present a brief overview here.

Microorganisms were first reported from caves in the late nineteenthcentury (Caumartin 1963). Since that time, several studies, primarily from European researchers, have reported on the presence of different algae, bacteria, and fungi in caves. One of the more common groups of bacteria that can be visually observed in caves is the actinomycetes which occur in entrances and lend the musty odor to cave entrances (Vandel 1965). Within the deep cave area both heterotrophic (bacteria that use preformed organic carbon) and chemolithotrophic (bacteria that derive energy from the metabolism of inorganic compounds containing iron, sulfur, nitrogen, etc.) bacteria may be found. A comprehensive list of bacteria present in caves does not yet exist.

Even less is known about fungi occurring in caves, but Rutherford (in press) has recently conducted a literature review and Vandel (1965) provided a listing of studies on fungi. Vandel notes that "No fungi are exclusively cavernicolous, with the exception of certain insect parasites...." A recent study in Lechuguilla Cave by Northup et al. (1992) found that Aspergillus and Penicillium were the genera most often found.

Within the cave environment, the greatest species diversity occurs among the invertebrates, especially the arthropods. Our review of the invertebrate taxa showed that most of the arachnid orders have cave associated organisms while less than half of the insect orders have cave associated species. Major taxonomic groups found in caves, excluding marine cave fauna, are listed in Tables 1(general taxon groups), 2(Chelicerata and Crustacea), and 3(Uniramia). These tables generally follow classification of Brusca and Brusca (1990). Groups within phyla are listed alphabetically.

HABITATS FOR BIOTA IN CAVES

Food resources in the cave environment are patchy. The key factors for both invertebrates and microorganisms are moisture and organic (or for a few bacteria, inorganic) material. Organic matter may take the form of detritus from the surface (twigs, leaves, etc.), fecal material (bat, bird, and cricket guano, scat of larger mammals, rodent droppings), or, in some cases material brought in inadvertently by humans (skin, hair, pieces of clothing, urine, feces, food, or building materials). Key areas in which microorganisms are found include pools, soils, corrosion residues, aquifers, guano, and organic matter. Bacteria are most often found at interfaces such as that between a pool surface and the air or the bottom of the water column and the sediments. Invertebrates are found where moisture is available, in cracks and crevices, under rocks, on, or in guano or other organic matter (including lint), and on surfaces of pools. A greater number of species and individuals are often found near the entrance of caves due to the sheltered and more equable environment compared to the surface (Jefferson 1983) in addition to the accumulation of organic matter there.

THREATS TO THE BIOTA

There are many threats to cave biota. Stitt (1977) and Poulson and Kane (1977) list some of these threats. Perhaps the most publicized threat to cave organisms in recent years has been pollution. Surface runoff of pesticides, nitrates, and herbicides from agricultural land and petrochemicals from roads, pose major problems for karst waters and cave biota. Contamination of cave waters by gasoline and septic leakage can kill aquatic species. Surface modification, such as the construction of parking lots and campgrounds, causes alteration in the input of organic matter and water from the surface and may even introduce further pollutants.

Dumping of garbage in sinkholes leads to the entry of harmful substances into the cave environment. Chapman (1993) discusses the problem of dumping of animal carcasses and wastes. Industrial wastes have been disposed of in caves resulting in groundwater pollution. Details of several instances of industrial and agricultural pollution are described by Chapman (1993). One of the more bizarre episodes he recounts is the extermination of an entire cave fauna by the introduction of fermenting molasses from an overlying field. Most recently, the proposed drilling near Lechuguilla Cave has raised the possibility of the release of explosive gases into the cave. Hagan and Sutton (1991) note that restoration activities, designed to remove physical damage to the caves by humans, may cause harm to cave biota. The dumping of carbide (Lavoie 1980, Peck 1969) which is toxic to invertebrates and cigarette smoking (nicotine is an insecticide) in the cave could be harmful to organisms (Howarth 1982).

Physical actions of humans in caves may be detrimental to cave biota. Physical trampling by cave explorers can kill invertebrates which are either not noticed or are hiding under the rocks on which the cavers walk. Due to their greater species diversity and the amount of activity that often occurs, entrances may be especially vulnerable to physical disturbance by humans visiting the cave. Physical trampling causes compaction of soil and can affect nutrient availability for microorganisms (Feldhake 1986). Blasting open of cave passages and/or digging open of entrances can affect organisms either by altering air currents (Tuttle and Stevenson 1978) and moisture, or by releasing toxic fumes.

Just the act of visiting caves may affect biota. The impact of visitation on bats is well known (Mohr 1976, Chapman 1993), but the impact on invertebrates has received little or no attention. Northup, et al. (1992) found evidence that large exploration expeditions in Lechuguilla Cave, reduce numbers of invertebrates caught in pitfall traps during an expedition. Over-collecting by biologists can affect cave populations.

Introduction of organic matter into the cave ecosystem affects both invertebrates and microorganisms. Early studies in Lechuguilla Cave by Northup, et al. (1992) showed mainly fungal spores present, but little in the way of fungal growth. Over time, in areas of heavy use (i.e. main trails and camping sites), fungal mycelia began appearing, both on the soil, food particles, and human hair. This may seem of little consequence, but the problem lies in the build up of organic matter and the eventual impact on native species. It's important to preserve native microorganisms which may be important to the cave ecosystem and which may produce as yet undiscovered compounds important to human welfare.

A significant case study of contamination is the discussion of the "Maladie Verte" of Lascaux (Lefevre and Laporte 1969). The algae covering the famous paintings was the result of the buildup of organic matter from visitors and the workers who prepared the cave for visitation. This buildup changed the conditions and allowed the algae which had been introduced by visitors and workers to grow heterotrophically and more rapidly. Similar organisms may have been introduced by the original painters, but in the absence of further introduction of organic matter during the 20,000 years the cave remained abandoned, the algae died out. Chapman (1993) also notes that the composition of cave fauna changed in an area containing food trash from cavers.

A continuing debate in biospeleology has been whether to remove wood that has been colonized by biota in the cave. It is our feeling that "historic" wood which has developed an ecosystem should be left in place. Over time it will decompose allowing the community of organisms time to adjust to changing levels of resources. However, in the interest of preserving the current ecosystem, new organic matter should not be introduced into the cave.

MANAGEMENT OF INVERTEBRATE AND MICROBIAL RESOURCES

INVENTORIES

In order to properly manage and conserve cave biotic resources, a thoroughinventory of the biota present is required. Inventories can identify threatened or endangered species that need special protection measures; they allow the identification of key habitats for cave restricted species; and they identify critical times of the year when traffic should be limited. It is veryimportant that newly discovered caves be studied soon after their discovery before the cave community is modified by human impact. Baseline data on species composition allows managers to monitor the health of the ecosystem by identifying indicator or keystone species whose status can be monitored. With sufficient data, managers will be able to predict the kinds of events that would disrupt a cave community or at least identify which disturbances caused a particular change in the cave community (Poulson and Kane 1977).

A variety of inventory techniques and components have been reported in the literature (Gardner 1986, Hess 1976, Poulson and Kane 1977, and Trout 1977). A good inventory includes the identification of species present, habitats in which biota are found, the measurement of abiotic factors, and the identification of seasonal trends in biotic populations. If endangered or threatened species are present, managers can steer visitors away from these areas. Cavers and other visitors may be willing to avoid certain areas if they understand their impact on endangered or threatened species. Researchers may also find the undesirable presence of something like Histoplasma capsulatum (the fungus which causes histoplasmosis) and managers may wish to caution visitors to avoid areas where it occurs. Identification of key habitats may also lead to the establishment of trails through these area to minimize impact on the biota. Educating cavers and the general public about where invertebrates live within the cave may help encourage their careful behavior when in these areas.

Abiotic factors to be measured include air and substrate temperature, pH ofpools, relative humidity, water and air flow, light intensity, vertical heterogeneity, and mineralogy. Such data can be used to correlate what particular species occur in particular microclimate regimes. They may also be useful in future ecological studies.

Collecting and inventorying should be done during all four surface seasons.Conditions in caves are not as static as once thought, especially near the entrance (Cropley 1965 and Jefferson 1983). Heavy precipitations, times of higher human traffic, and different surface temperature regimes, may affect species composition in the cave. These changes will be primarily among the species that use caves for part, but not all of their life cycles. Abiotic factors should be monitored during all seasons to provide data that can be correlated with species composition and relative abundance.

HABITATS TO BE SAMPLED

Cooper and Poulson (1968) provided a general guide for biological collecting in caves. Knowing where to look for biota takes practice, but certain areas offer more productive study. The different zones of the cave, Entrance, Twilight, and Dark, should be inventoried. The Entrance and Twilight Zones are dynamic and critical habitats containing the greatest diversity (Jefferson 1983). These zones may receive the greatest input of surface organic matter. Scat from various mammals or guano from birds roosting in the entrance are often found in these areas. Carcasses of animals, leaf litter, and twigs may be found in this area and are rich habitats for biota. The under sides of rocks and crevices, and alcoves provide good habitat for biota. Troglobites, trogloxenes, troglophiles, and accidentals are all found in these zones.

In the Dark Zone of the cave, study should concentrate on areas with organic matter and moisture. Bat roosts can be especially high in species richness (Poulson 1972, and Welbourn and Northup, unpublished data). If the cave floods, there may be organic matter in crevices in the walls and ceiling. In commercial caves lint, inadvertently left by visitors, represents a habitat that is notfrequently sampled. Caves with high visitation, such as Carlsbad Cavern, have extensive amounts of lint which have been found to contain a community of invertebrates (Welbourn, unpublished data).

Microorganisms also occur anywhere organic matter is available including the organic matter that is invisible to the human eye. If one is attempting to sample for possible indigenous fungi, one should sample areas that have just been discovered and have not been heavily impacted by humans. In general cave soil is an excellent substrate to sample for fungi. Aquatic zones, such as an artesian well associated with the Edwards Aquifer, have also been shown tocontain fungal spores (Kuehn and Koehn 1988). Sampling for chemoheterotrophic bacteria should be done in a variety of habitats including pools, soils, flowstone, and speleothems. Sampling for chemolithotrophic bacteria should concentrate on deposits of sulfur, manganese, iron, or other unusual deposits.

INVENTORY TECHNIQUES

Inventories can vary considerably in their completeness. Poulson and Kane (1977) suggested a three level evaluation of a cave and its resources. The first two levels are specific for the particular resource (i.e. biological, geological, etc.) and the third was an integration of the first two and management recommendations.

For each species, only a few individuals need to be collected for proper identification by taxonomists. This allows for variation in morphology, the inadvertent collection of non-adults, and for the collection of both sexes. Some species can only be identified from one sex or with a particular instar. If the species has not been previously described a series of instars may be needed. Poulson and Kane (1977) suggest only a single specimen of each species be collected during the first phase of an inventory. The number of taxonomists and in particular those who specialize in cave organisms, has declined dramatically in the last few decades. Because there are many fewer individuals to do the work, identifications may take awhile.

When to do a biological inventory? The timing of an inventory depends primarily on timing of rainfall and organic input. Poulson and Kane (1977) suggested it is best to census in the early fall. Actually, a cave should be inventoried at different times of the year. Work with the invertebrates of bat and swallow guano in Carlsbad Caverns, New Mexico suggests there are different taxa present at different times of the year depending on the bat or swallow guano input (Welbourn and Northup unpublished data). A one visit inventory could result in an incomplete analysis. In addition, information from inventories at different seasons would provide data that could be used in management decisions.

Inventory of terrestrial invertebrates requires several methods to ensure adequate sampling for all species. One of the primary techniques to observe and sample the invertebrate fauna is visual inspection of habitats. These habitats include organic material (leaf litter, wood, guano, feces, carcasses, roots, etc.) as well as different substrates (soil, under rocks, cracks, crevices, flowstone, and in the dryer caves of the southwestern US, drip areas). When doing a visual inspection a good rule of thumb is to think small as most invertebrates are less than 10 mm long. A great aid in visual searches is a magnifier such as the OptiVisor or some other device that allows you to see the small invertebrates that would otherwise be overlooked. One way to enhance the chance of finding some invertebrates would be to set bait (i.e. rolled oats, limberger cheese, feces, etc.) to attract invertebrates. Bait generally attracts non-troglobitic invertebrates.

Another technique for sampling the invertebrate fauna is pitfall trapping, which uses small plastic cups (16 oz. or smaller) with funnel shaped inserts. These are buried in the substrate up to the rim and can be baited or unbaited. Pitfall traps should not be left in a cave for long periods as they will continue to catch animals as long as they are in place. Some researchers use ethylene glycol or other chemicals to kill and preserve captured animals; this is not recommended as it does not allow the release of unneeded specimens. We recommend leaving pitfall traps for no more than 24 hours at a time.

The most efficient technique to sample invertebrates, especially the very small taxa (>5 mm) is to extract them from the organic matter and soil in which they live. There are two methods of extracting invertebrates from these habitats: one is Berlese (Murphy 1962) and the other is flotation (Hart and Fain 1987, Kethley 1991, and Walter et al. 1987). If at all possible, organic material removed for invertebrate extraction should be returned to the site of collection after extraction. The advantage of flotation over Berlese is you do not need a large sample and it is much more efficient than Berlese. Flotation will not work for the guano of insectivorous vertebrates. Care should be taken not to overcollect organic material from the cave.

Sampling for fungi requires aseptic technique to insure that what is cultured actually came from the cave. Most fungi exist in deep cave zones only in spore form, but occasionally actively growing fungi are encountered. The authors used sterile rayon tipped swabs with a Stewart transport media culture tube for sampling in caves. These swabs can be inserted into soil or rubbed gently across other surfaces to sample fungal spores. Another technique is to aseptically expose petri dishes filled with potato dextrose agar to culture airborne fungal spores. Care must be taken not to contaminate the media with spores brought in by the samplers.

Sampling for bacteria in caves, and indeed in other natural environments, is an area currently undergoing active research and only a brief overview will be provided here. The debate centers around a recent finding that environmental sampling results in only a minority of what actually occurs in the environment being cultured (Ward, et al. 1992). Mallory (personal communication) suggests incubation for at least 48 hours in the cave may enhance the number of species that will grow on a given enrichment. A good knowledge of the chemistry of each habitat sampled will allow the researcher to use special enrichments to target the organisms likely to occur in a particular habitat. Other researchers have experimented with artificial substrates which bacteria colonize (Thompson and Olson, 1988). Pace (in press) and Ward (1992) recommend molecular phylogenetic techniques as a mechanism to identify bacteria in nature. Inventorying bacterial populations is a complex and expensive process requiring aseptic techniques and substantial expertise.

INVENTORY OUTCOMES

Beginning the inventory process is relatively easy, but the production of useful results requires a great deal of diligence. The following is a list of what we consider to be essential outcomes:

LIST OF BIOTA: The absolute bare minimum end product should be a taxonomic list of organisms found in the cave or caves. Relative abundance data (including seasonal changes), a trophic level list, and maps of locations of biota are useful. If time and money were available, data on ecological and community relationships will be quite useful for managers.

ABIOTIC PROFILE: A spatial and temporal profile of abiotic conditions throughout the cave is useful. Such data can be used in future monitoring studies and in ecological correlations.

REFERENCE COLLECTION/DEPOSITION IN MUSEUMS: Whether a reference collection of invertebrate species is assembled will depend on local requirements and legislation; the availability of a curator, space, and supplies to maintain the collection; and a need for such a collection. Simply having a reference collection with no commitment to longterm maintenance is not recommended. A viable alternative is the provision of a photo collection showing at least the most common and important species.

Collected specimens should be deposited in a reputable museum or university collection with a longterm commitment to curation. This allows the collection to be available for future study and reference. The manager may designate a museum or collection where specimens should be deposited.

PHOTODOCUMENTATION: Slides for exhibit production or educational lectures, photographic prints of invertebrates, with identifications listed, for future field monitoring, and photographs of habitats for use in monitoring change are useful for cave managers.

RECOMMENDATIONS: Researchers doing the inventorying should prepare a list of recommendations for managing the invertebrate and microbial populations to help guide the cave managers.

MANAGEMENT RECOMMENDATIONS

General insect conservation strategies stress the need to prevent habitat destruction. Samways (1992) notes that most insect extinctions are due to loss of habitat and that "At least 80 of all vertebrates have been discovered, but probably less than 3 of insects have been given scientific names." Drewett (1988) emphasizes that ..."tiny 'microhabitats' are often more important to an insect. Without a precise understanding of the requirements of individual species, there is always the risk that management might wipe out the insect rather than protect it." Both points, the need for habitat protection and study to understand the needs of all the species are important for cave invertebrate and microorganism protection and conservation.

Eliminating, or at the very least, minimizing the introduction of organic matter and pollutants originating from human activities (i.e. human wastes, wooden staircases, pollution, food, etc.) is a critical step in conserving existing invertebrate and microbial populations. Several guidelines can be followed to limit organic matter input. Encourage cavers to have clean clothes, boots, and hair to minimize the introduction of exotic microorganisms. Prevent the construction of housing and paved roads and parking lots over caves. Educate land owners about the impact of dumping garbage and other noxious substances down sinkholes. If wood from the building of staircases and other human activities has been in place long enough to have a community of invertebrates, leave it in place and allow for its decay. This gives time for the community's gradual adjustment to the decrease in resources.

Restoration activities need to be carefully planned and executed to minimize impact on invertebrates (Plantz 1978 and Rhode and Kerbo 1978). Curl (personal communication, Cavers Forum) recommends against using muriatic acid which upon contact with limestone forms calcium chloride, which due to its high degree of solubility forms strong ionic solutions. Invertebrates immersed in this solution will die. Curl recommends a dilute solution of sulfuric acid. High pressure jets of water used to clean walls and formations could injure or kill invertebrates. Many small invertebrates are so small that they may not be seen by people working to restore the cave. Fungal growth should be controlled with a weak Clorox solution (Lavoie, personal communication), and more importantly, sources of organic matter for the fungi should be eliminated.

Further recommendations to insure protection of invertebrates include giving the cave and the invertebrates time to rest between major influxes of humans, allowing invertebrates to live undisturbed; flagging trails to minimize trampling, especially in entrance areas and regions that receive high traffic; and limiting collection to what's essential for scientific study. Inventories of caves that have never been studied and immediate study of newly discovered caves are critical research activities. Continual monitoring allows managers to know the health of the communities dwelling in their caves. When a community is in trouble there are several indications: 1) bats leave the site. 2) the ratio of predator to prey species drops, with a dying community having few prey species and many predators. 3) numbers of keystone species will drop. To identify which changes actually signal trouble, managers must know the normal cycle for a community.

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THE EFFECTS OF URINE DEPOSITION ON MICROBES IN CAVE SOILS, OR: TO PEE OR NOT TO PEE

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ABSTRACT

Concerns about human impact on cave environments is particularly problematic in new caves, like Lechuguilla Cave, and in areas far from entrances and tourist areas, as in Mammoth Cave. Carlsbad Caverns national Park has a policy for expeditions into Lechuguilla that requires individuals to pack out fecal waste but allows them to urinate in the cave. This research project examines the impact of human urine on cave soil, particularly the microbiota, and by extrapolation, possible impacts on higher trophic levels of cave organisms.

In preliminary experiments with a sandy soil and a muddy soil from Mammoth Cave and from Lechuguilla Cave, urine was applied (amended) to each soil at the beginning of the experiment. A second application of urine or water was made towards the end of the experiment. A control adding water alone was done for each soil type. Changes in total heterotrophic bacteria and fungi (those able to use organic matter for energy) were monitored using plate counts. Total urea was assayed from the amended soils as a way of determining rate of disappearance of urine.

Starting populations of bacteria from Mammoth were comparable with other studies of cave soils, approximately 10^6 CFU/g (Lavoie and Crossnoe, 1983). Bacterial numbers in the Mammoth soils decreased after about two weeks as fungal populations increased from low values of 10^4 CFU/g soil to 10^6-10^7 CFU/g. Counts from the muddy soil were typically higher than from the sandy soil. By about 40 days, nearly all urea was gone from the single urine amendment soils while adding urine again caused elevated levels of urea. Both treatments showed continued high populations of bacteria and especially fungi compared to water controls.

Populations of bacteria and fungi were initially very low in soils from Lechuguilla ($<10^4$ CFU/g). Urine amendment resulted in populations increasing 100-1000 times to 10^6-10^7 CFU"/g compared to water controls, which remained below the detection level of 10^4 CFU/g soil. Responses to re-amendment with urine followed a pattern similar to that observed with the Mammoth Cave soils. Subjective observations of changes in gross texture of the soils to become increasingly slimy were noted. Preliminary visual examination using Scanning Electron Microscopy showed a build-up of an organic residue on urine amended soils compared to water amended controls.

Further experiments with a wider range of soils from Lechuguilla are in progress, but based on these preliminary experiments, urine depositions in caves can have drastic changes on population levels of microbes in the soils. These changes persist after urine has been removed by biological action.

Urination in pristine deep caves and into or near standing pools, will have negative consequences including growth of fungi and opportunistic bacteria, changes in populations of indigenous microbes, reduction in troglobitic organisms and their distribution, interference with foraging by cavernicoles, and negative aesthetics including offensive odors and changes in substrate texture and appearance. The effects appear to be additive, and responses of the microbial community to repeated applications is increasingly rapid. I strongly recommend that the best action to take is packing urine out.

INTRODUCTION

Urine (Guyton, 1981) is a dilute waste product made up mostly of water with a specific gravity in adults of 1.001 - 1.030 (pure water is 1.000). Specific gravity increases with increasing concentrations of dissolved materials. Adults typically void between 600 - 1600 ml of urine in a 24 hour period. Volume decreases with excessive exercise and sweating while the concentration of solutes increases. Daily output averages 1100 ml and each urination event is 250 ml or more.

Urine contains a wide range of organic and inorganic components (Table 1). In particular, the major organic component is urea. Urea is present in amounts ranging from 20 to 25 g per 24 hours and accounts for about 84% of the total nitrogen present in urine, the remainder mostly coming from amino acids, ammonia, creatinine, and uric acid. Glucose is not found in urine from normal individuals. Urine is regarded as a good growth medium for bacteria, which often causes problems in the clinical analysis of urine. To demonstrate the ability of urine to support microbial growth, the concentrations of urine components is compared in Table 1 to the composition of urea broth (Difco Manual, 1991), a medium used to determine the ability of microbes to hydrolyze urea.

Urea is a commonly used commercial fertilizer (Diem, 1962) due to the ready availability of nitrogen as ammonia upon breakdown in soil by microbial action. Ammonia is a form of nitrogen readily utilizable by planes and by microbes. Carbon dioxide is also produced.

This study was done to quantify the effects of urine deposition on cave soil microbes, and by extrapolation, possible impacts on higher organisms. Recommendations for urine management can also be made.

MATERIALS AND METHODS

Three experiments are reported on in this preliminary study.

1. A *pilot study* was done using BACCO potting soil. This study allowed methods to be developed and evaluated.
2. *Mammoth Cave.* Soil from both a sandy and a muddy area from River Hall in Mammoth Cave were collected by Lavoie.
3. *Lechuguilla Cave.* Soil from appropriate locations in Lechuguilla were collected by Diana Northup and shipped by next day service to the lab in Michigan. Soils were light colored (1L) and dark colored (1D) (further classification pending).

Soil columns were set-up for all three experiments using a 6-inch piece of PVC tubing (ID 7.5 cm) with a support base of hardware cloth held in place by duct tape. Later studies switched to plastic flower pots with trays. All columns were incubated in the dark at 15°C and 100% R.H. for the duration of the study to simulate abiotic conditions found in Mammoth Cave. Later studies of soils from Lechuguilla Cave were incubated at 19-20°C to simulate conditions there. Since most individuals exploring caves are male, the study used freshly-voided urine from a healthy male volunteer (30's) for the duration of the study. Initially, 250 ml of urine was used at each treatment, but that amount was later reduced to 100 ml to reduce drainage and collection of excess urine in the incubator. Control columns received identical doses using distilled water.

Samples (1 g) were removed aseptically at appropriate intervals from the top 0.2-0.5 cm of soil, weighed, and used to make a dilution series. Dilutions were plated on Plate Count Agar (Difco Manual, 10th Edition) to assay for total heterotrophic bacteria. Preliminary experiments to quantify changes in the number of urea-utilizing bacteria using urea agar and soil dilutions for the pilot study and on Mammoth Cave soils proved unreliable and were not continued. Results from the Mammoth Cave soils indicated an increase in the number of fungi during the experiments, so dilutions were plated on Sabouroud's Dextrose Agar (Difco Manual, 10th Edition), a semi-selective medium to quantify the number of fungal spores and hyphae in the soil samples. Fungal data collection began on Day 5 of the Mammoth Cave soils experiment and were done throughout the Lechuguilla soil study. Plates were incubated at room temperature for 5-7 days prior to counting.

We successfully developed an assay for the quantification of urea from soil. This procedure is very useful as it directly measures changes in the amount of urea and provides information of the time required to recycle urine by indigenous soil microbes and reflects changes in that population. The assay is a slight modification of the Urea Nitrogen Test from Sigma Diagnostics using an initial 1:2 or 1:10 dilution of soil in water.

Microscopic examination of the soils was begun with air-dried specimens using an AMRAY 1810 Scanning Electron microscope. We are continuing to examine several of the soils and pieces of calcite to detect damage to the calcite and gypsum from contact with urine and from ammonia vapors. These observations may have implications specifically for management of formation areas.

RESULTS

Results are presented in this paper for the preliminary experiments using the two soils from Mammoth Cave (Fig. 1 & 2) and from Lechuguilla Cave (Fig. 3). Additional studies on a range of soils from Lechuguilla Cave in progress may be presented at the Symposium.

MAMMOTH CAVE

Initial populations of bacteria from Mammoth were comparable with other studies of Mammoth Cave soils at approximately 10^6 CFU per gram of soil, with higher numbers from the muddy soil than the sandy soil (Lavoie and Crossnoe, 1983). Bacterial counts were generally 10-100 times greater in urine amended *vs.* water amended soils. The soils gradually dried out over the course of 35 days, with a decline in bacterial populations in all Mammoth Cave soils. Urine (Pee 1) or water (Pee 2 and Water 1 & 2) was reapplied on day 36 to the indicated soils. Bacteria responded very quickly compared to starting values in the urine amendment and increased to pre-drying values. Re-adding water had no discernible effect on bacterial populations in the water controls, which remained low, but did cause an increase in the soil previously amended with urine. This increase probably represents the growth of bacteria on residual organics.

Fungal counts were begun on the Mammoth Cave soils on Day 5 of the experiment. Urine amended soils showed an increase in the number of fungal propagules compared to the water-amended soils. The effect of drying was less pronounced on the fungi than on the bacteria. The second urine amendment on Day 36 resulted in a large increase in fungi after only five days in the Pee 1 soils. Water amendment had less of an affect in the Pee 2 soils, suggesting that many of the fungal growth nutrients had already been removed, or were monopolized by bacteria. Adding water to the water controls on Day 36 had no effect on fungal populations, which remained very low.

Urea concentrations showed an initial increase after urine amendment, with a steady decline to undetectable levels over the next 36 days. Adding urine again to Pee 1 caused a large increase in urea, as expected. Water controls never showed any significant levels of urea.

LECHUGUILLA CAVE

The preliminary experiment using soils from Lechuguilla (Fig. 3) was done over only 16 days to establish baseline populations counts, and to establish consistency of responses to the results from the Mammoth Cave soils. Population counts for both soils were very low with bacterial and fungal counts less than 10^4 CFU/g soil. These low values may partly be an artifact of the shipping and handling of the soils. Populations were slightly higher and responded to urine amendment better in the Light soil (1L) compared to the Dark soil (1D). A second urine amendment was done to the "High 1L" and "High 1D" soils on Day 13, while the "Low 1L" and "Low 1D" soils received only the single urine amendment on Day 0 followed by water amendment on Day 13. Water amended controls showed populations of both bacteria and fungi to be less than 10^4 per gram of soil throughout the experiment. The pattern of response was generally similar to that observed with the Mammoth Cave soils. The great increase in bacteria in the Low 1L soil is inconsistent, and not explainable at this time.

Urea concentration declined somewhat more slowly in the Lechuguilla soils than in the Mammoth Cave soil. Re-amendment with urine caused a similar large increase in the urea concentration. More work needs to be done on the Lechuguilla soils. Studies are in progress and may be presented at the Symposium.

SEM

Only one soil examination was done comparing the appearance of sandy soils from Lechuguilla in urine-amended *vs.* water-amended controls using a Scanning Electron Microscope. The preliminary, and not the best quality, micrographs are shown in Figure 4. The accumulation of a mat of material is clearly seen on the sand granules in the urine-amended soil. Photo A. shows the distinct individual sand grains in the water-amended control. Photo B. is a view from the top showing an edge of the urine-amended soil. Note the loss of resolution of individual sand grains under the organic mat. Photo C. is a side view of the edge shown in Photo B. The edge, seen diagonally on the right, shows the discrete organic mat on the surface. (The loss of detail on the left side of the micrograph in Photo C. is due to a processing error.) Further studies in progress may be presented at the Symposium.

DISCUSSION

The quicker the return of the soil populations to normal conditions, the less impact urine deposition has on the cave microbes and higher organisms. If the recovery time is less than the time between expeditions, then there is little need for concern about human impact due to urination the cave. These preliminary studies indicate that comparisons of low *vs.* high impact treatments will provide the most useful data, and result in the best recommendations. From the preliminary studies of soils from Mammoth Cave and Lechuguilla, urine amendment results in increases in the numbers of bacteria, and particularly the numbers of fungi. Fungi accumulate in the soil as spores and hyphae where they quickly respond to re-amendment of urine. This build-up of a dormant population explains the observation that a second deposition of urine in an area very quickly results in foul odors.

I know urine deposition can be great; I have heard tales of dumping a 5-gallon bucket in one location (D. Northup, personal communication). The amount of ammonia produced from that single deposit is staggering: each molecule of urea is degraded into one molecule of carbon dioxide and two molecules of ammonia.

HYPOTHETICAL CALCULATIONS

Urea has a molecular weight of 60.06 while ammonia has a molecular weight of 17.03. If urine has a 18.2 grams per liter (normal) to 91 grams of urea per liter (estimated with exercise), with 3.8 liters per gallon, then the infamous "5-gallon bucket" of urine which was dumped in Lechuguilla contained 345.8 - 1729 grams of urea. If all the urea is converted to ammonia, then we had 260.35 - 1301.76 grams of ammonia produced. Ammonia is detectable by human noses at a concentration of 0.04 g/m (3), so 6507.75 m(3) of cave air could be impacted.

What that impact would be is debatable; surely aesthetic from the perspective of unpleasant odors. Many cave organisms find food by scent, so there might be interference with foraging, although there are no known troglobites deep in Lechuguilla, the same cannot be said for most other caves, and certainly cannot be assumed for any newly discovered caves. The effects on populations of indigenous microbes also cannot be evaluated at this time. Effects on formations cannot be evaluated at this time either.

I have not found any other studies on the effects of urine amendment on the growth of microorganisms, although adding carbon and nitrogen is known to greatly increase the growth of opportunistic microbes in any ecosystem. Several studies of the response of higher organisms to urine amendment have been done, especially the effects of grazing herbivores on pasture-land. In general, there is an increase in plant biomass as well as an increase in the average nitrogen content of the plants. These plant responses often result in preferential grazing of urine patches by domestic herbivores. Excess levels of urine deposition can result in plant death, referred to as urine scorch.

A study of the effects of urine deposition on grassland patches on open range and responses of bison grazing was reported in 1990 by Day and Detling. Their study supported earlier work done with domestic herbivores and pasture-land ecosystems. Day and Detling (1990) suggested that the improved forage nitrogen quality and extra growth could be especially important earlier and later in the growing season.

It has been well-established that populations of fungi in caves are highest in areas with high organics (Dickson and Kirk, 1976). Northup *et al.*, (1992) has done the most intensive study of microbes in caves, based on work done in Lechuguilla and reported on in the Lechuguilla Cave Biological Inventory. She found a low incidence of fungi overall, with an average of 60% (range 48.4 - 69.4%) of swabbed surface samples producing no fungal growth. Comparisons of areas with low human impact with high impact areas (trade routes) showed no statistically significant differences in the frequency of fungi, although very low sample size makes comparisons difficult. Anecdotal evidence of macroscopic fungal colonies up to 8 inches in diameter around camps is of interest. Samples from urine sites were not high compared to camp sites, which may be explained by an effect of scorching, where ammonia levels eventually get high enough to kill off any fungi. Much more work needs to be done.

The conclusions of the Lechuguilla Cave Biology Inventory (Northup, *et al.*, 1992) regarding bacteria are more tenuous. Quantitative studies of bacterial populations were not done. A moderate community of heterotrophic oligotrophs in pools in Lechuguilla were regarded as being indigenous to the cave. It is well established that high organic inputs have detrimental effects on oligotrophic communities, resulting in changes in populations and community structure. Chemolithotrophs, such as those reported in corrosion residues and sulfur deposits, are also negatively impacted by organics. Urine deposition may seriously impact indigenous populations of microbes. Northup's suggestion for establishing "microbial cave preserves" would allow for study of the indigenous populations without human impacts.

The implications of urine deposition for cave organisms are clear. Amendment of pristine deep-cave soils with urine increases the growth of opportunistic bacteria and especially of fungi. Extensive work done be Poulson and colleagues have shown that true troglobitic cavernicoles avoid areas of high organic input, while opportunistic troglophiles respond positively to increased food availability. High organics can cause extirpation of troglobites in some areas.

Urination in areas of the cave where the soil is rich in nitrates or animal wastes (ie. bat roosts) is of no consequence (supported by urine-amendment studies of bat guano done by Barb Martin, personal communication). Limited urination into flowing water is probably of little consequence as the organics and nitrogen would be rapidly diluted. Urination in pristine deep cave and into or near standing pools will have negative consequences including growth of opportunistic bacteria and fungi, reduction in troglobitic organisms, interference with foraging by cavernicloes, possible changes in distribution of cavernicloes, and negative aesthetics including offensive odors and changes in substrate texture and appearance with possible damage to formations. I strongly recommend that the best action to take is packing urine out of Lechuguilla and out of most caves. Alternatively, cave managers must establish latrines in "sacrificial" areas with no hydrologic outflow and accept the negatives.

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Table 1. Component and concentrations in human urine and urea broth.

Human Urine		Urea Broth
Electrolytes Sodium (128 mEq/l); Potassium (60 mEq/l); Calcium (4.8 mEq/l); Magnesium (15 mEq/l); Chlorine (134 mEq/l); Bicarbonate (14 mEq/l): Sulfates (33 mEq/l); and		10 mg / 100 ml as yeast extract
Phosphates	50 mEq/l	1860 mg/100 ml
Urea	**1820 mg/100 ml**	**2000 mg/ 100 ml**
Uric Acid	42 mg/100 ml	---
Creatinine	196 mg/100 ml	---
Glucose	0 mg/100 ml	---

Figure 1. Mammoth Cave, Sandy Soil. Changes with time in the counts of viable bacteria and fungi, and urea concentration in a sandy soil from River Hall, Mammoth Cave National Park. Urine was added to the Pee 1 and 2 soils after population counts were done on Day zero, and again to the Pee 1 soil on Day 36 (arrow). Water was added to the Water 1 and 2 soils on Day 0 and Day 36, and to the Pee 2 soil on Day 36.

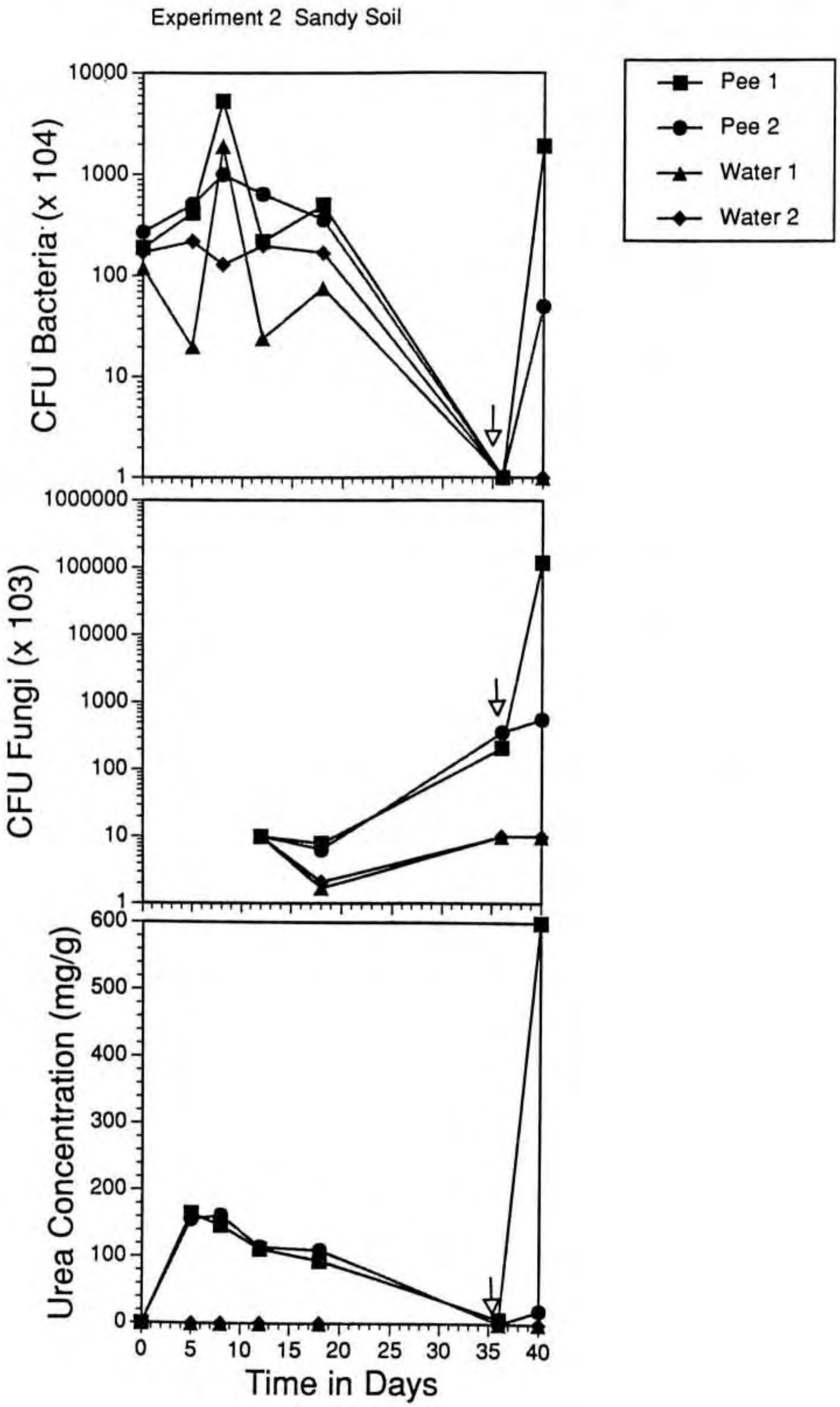


Figure 2. Mammoth Cave, Muddy Soil. Changes with time in the counts of viable bacteria and fungi, and urea concentration in a muddy soil from River Hall, Mammoth Cave National Park. Urine was added to the Pee 1 and 2 soils after population counts were done on Day zero, and again to the Pee 1 soil on Day 36 (arrow). Water was added to the Water 1 and 2 soils on Day 0 and Day 36, and to the Pee 2 soil on Day 36.

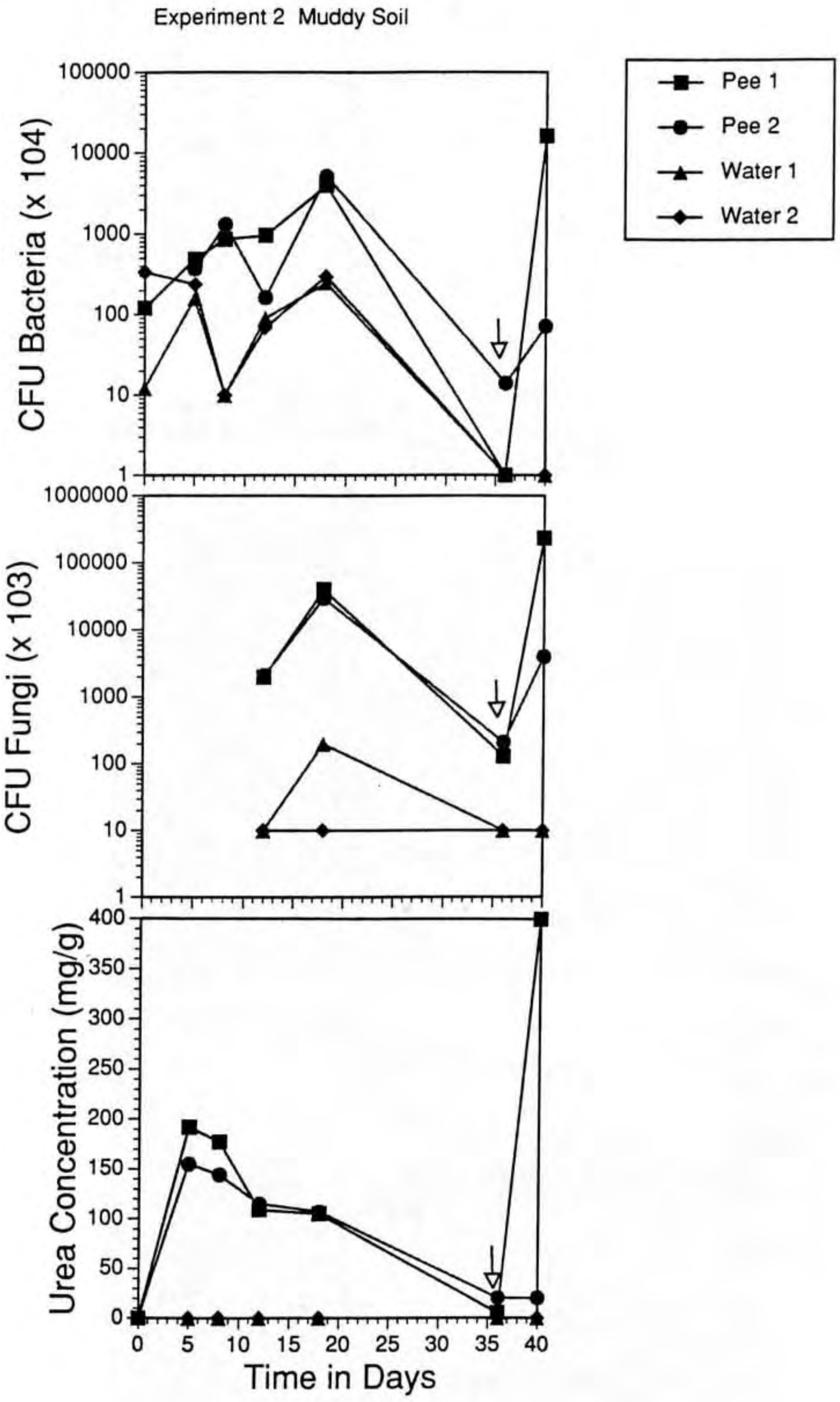


Figure 3. Lechuguilla Cave, Light Soil (1L) vs. Dark Soil (1D). Changes with time in the counts of viable bacteria and fungi, and urea concentrations in a Light Soil and a Dark Soil from Lechuguilla Cave in Carlsbad Caverns National Park. Urine was added to the Low and High 1L and 1D soils after population counts were done on Day zero, and again to the High 1L and 1D soils on Day 13. Water was added to the Water controls on Day 0 and Day 13, and to the Low 1L and 1D soils on Day 13.

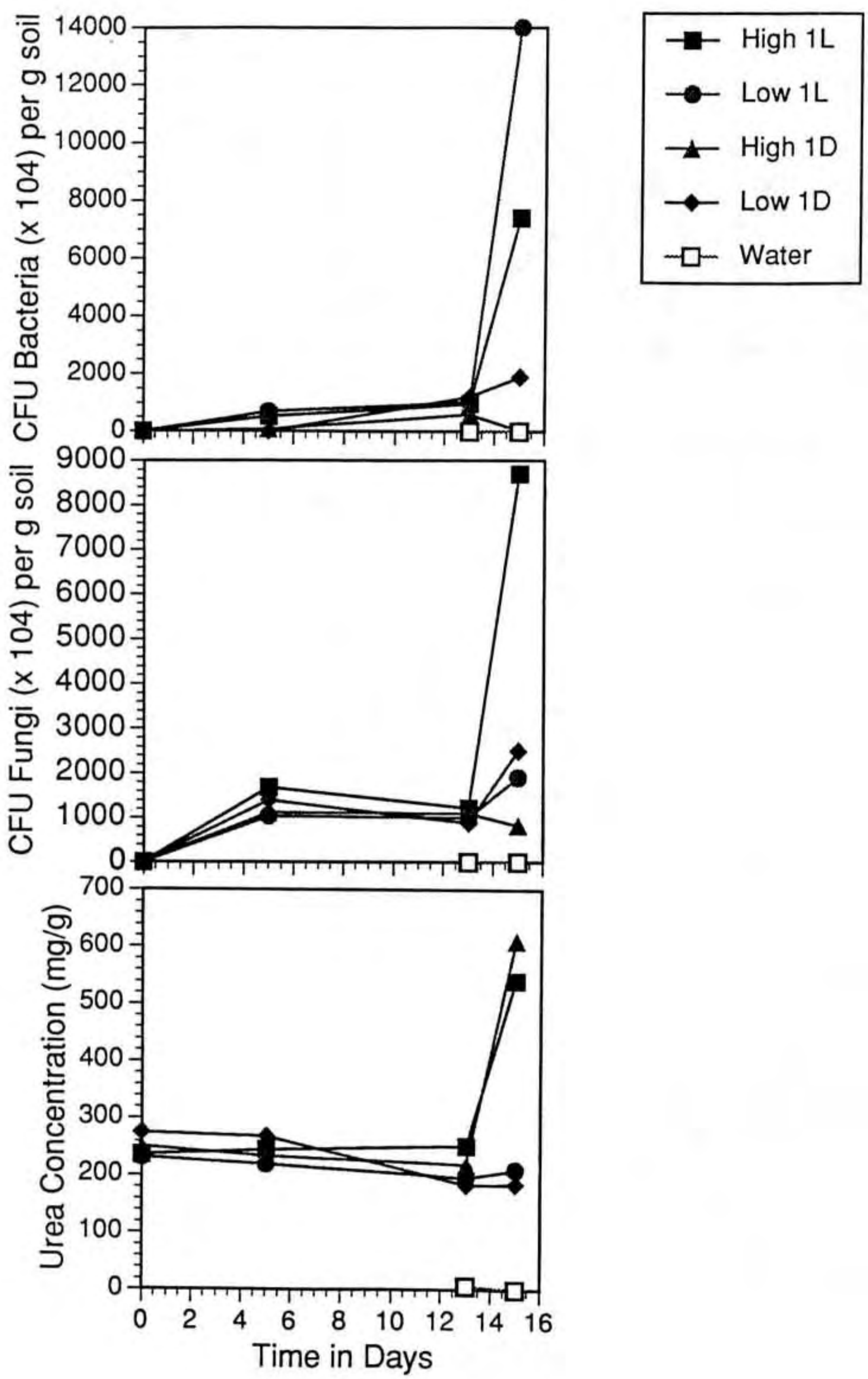
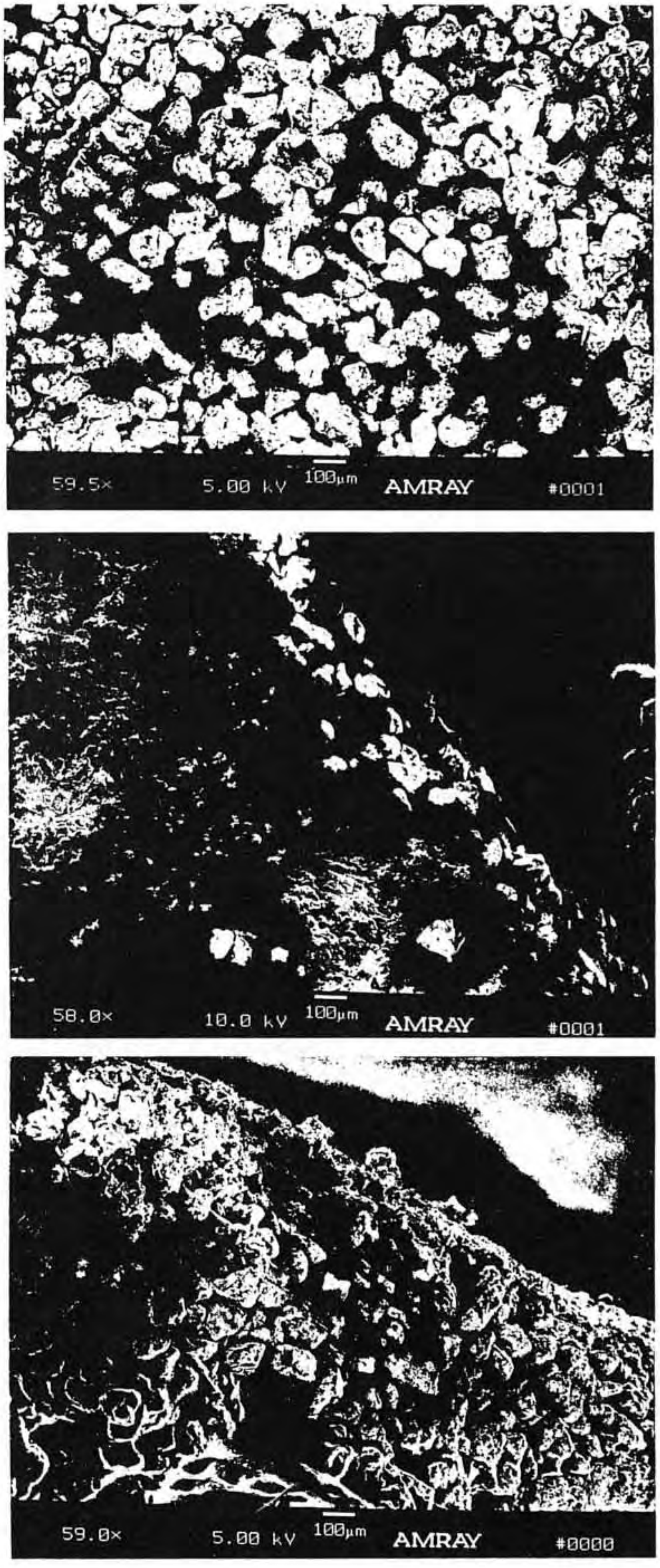


Figure 4. Scanning Electron Micrographs of a sandy soil from Lechuguilla that had been treated with water (Photo A) top view, or urine (Photo B) top/edge and (Photo C) side view.

A.

B.

C.



LOW DISTURBANCE TECHNIQUES FOR MONITORING BATS

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ABSTRACT

Human disturbance through recreational caving and research has been a factor in the decline in bat populations in the United States. In recent years there has been an increased effort on the part of land management agencies to preserve the unique features and biologic contents of caves. This process has been accelerated with the passage of the Federal Cave Resources Protection Act. The federal agencies have frequently depended upon volunteers to perform many of the cave monitoring tasks needed to make sound management decisions. Unfortunately, this monitoring may lead to additional disturbance of bat roosts. It is imperative that the cave monitoring process not contribute to the decline of bats.

The low disturbance techniques used at Kartchner Caverns State Park in Arizona were developed to monitor a maternity colony of Cave Bats (Myotis velifer). These techniques are particularly suited for use by volunteers. Because bats may abandon a roost if disturbed, as much information as possible should be collected when the bats are not occupying the cave. With proper scheduling of cave visits before the bats seasonally return to the roost, information such as species identification, and favored roost locations can frequently be determined. Once the bats are using the cave, the size of the colony can be monitored by counting bats at the entrance when they exit in the evening. Agencies managing caves should develop monitoring programs that will provide management information while protecting bat roosts and educating volunteers in low disturbance techniques.

INTRODUCTION

Since 1990, when the Federal Cave Resources Protection Act was enacted, federal agencies have been mandated to address the management of their caves and karst resources. In order to do this, the cave managers have suddenly needed to know what caves they have on their lands. Many times the agencies have turned to cavers and speleologists to help them locate and inventory the caves. It appears to be a reasonable partnership with the overall goal of all parties to protect the cave resources. Unfortunately this inventory process, with added visitation, has increased the impact to many caves and the cave inhabitants. The information needed by the cave managers is important to future management plans but there are a number of methods that can be used, particularly in caves used by bats, that minimize this impact. It would be counterproductive to adversely disturb the bats that you plan to protect.

In Arizona a non-profit organization performed a thorough baseline study of Kartchner Caverns, a well decorated cave, for Arizona State Parks prior to its planned development as a show cave. The cave houses a maternity colony of the Cave Bat (Myotis velifer) and a number of inventory techniques were utilized that minimized the disturbance to the bats in the roost while still getting data. These techniques minimized but did not eliminate disturbance to the bats. Bats are aware of human visitation in their roosts. Although we greatly reduced our presence by these procedures, we could not totally eliminate the disturbance. It may take a bit longer to acquire some of the data using "low disturbance" techniques, but the intolerance of many bats to human intrusion in their roosts (Smidley, 1991; Fenton, 1992) makes it worth the extra time. In many cases the inventory process is not on a tight schedule anyway, so timing is not the critical element.

This paper will only address those bats that utilize caves and mines. It has been suggested that bats' ancestors began to use caves to avoid predation, conserve moisture and provide a stable temperature (Kunz, 1982). Such roosts provide protection from many predators, particularly since bats can hang from the ceiling above danger on the floor. Unfortunately, this in not sufficient to protect bats from human intrusion into their roosts. As early as 1953, Charles Mohr, biologist and caver, was warning that man was playing a major role in the bats' decline. In 1972, at a symposium on cave bats held at the American Association for the Advancement of Science, scientists and cavers reported rapid declines in bat populations and confirmed that man contributed to the mortality of bats (Mohr, 1972). Even well-meaning humans performing cave inventories will cause disturbance. Therefore, it is imperative that this process of inventorying and monitoring bat roosts proceed with caution.

Some of the specific questions to be addressed regarding a bat roost include: a) what time of year do the bats live in the cave, b) what areas of the cave do the bats use, c) how many bats are in the roost, d) what species of bat uses the cave? At Kartchner Caverns State Park in southern Arizona, a number of low disturbance techniques were applied to answer these questions.

One of the first tasks of an inventory is to assess if and when bats are using the cave. There are a few caves that are used by bats year-round but many caves have conditions that are only favorable to the bats during a particular season (Kunz, 1982). A search through historical records and cavers' reports are the first place to look for any references to bats and their seasonal use of a particular cave. Bat excrement (guano) on the floor and formations will indicate that bats have roosted in the cave. The guano will also indicate which rooms in the cave are favored by the bats.
If a cave receives a lot of human traffic the guano may have become so compact that it is hard to identify. In addition to guano on the floor, staining on the ceiling can also be a good indication of bat use. The white or brown stains from urine and the body oils of bats may leave evidence of a bat roost on the walls and ceiling. Bat skeletons will also be evidence that bats have used the cave in the past. The temperature of the cave may indicate whether the site would be preferred by bats in the summer or the winter, since the temperature requirements of bats during these two seasons are so different (Kunz, 1982; Hill and Smith, 1984). If it is concluded that bats still use the cave, a low disturbance monitoring program can be established to answer the many questions about bat use of the site.

A number of inventory tasks can be performed during the season that the bats are not using the cave. The existing guano piles can be inventoried and photographed as baseline data. A complete photomonitoring of the roost when the bats are gone is an excellent basis for monitoring the site over time. Sometimes there are a number of guano piles throughout a bat cave in varying degrees of decay. Some piles will look like a dark soil, some will have complete pellets, and others will fall somewhere in-between. Noting the condition and location of the guano piles during the initial inventory will help later when assessing changes. Notes about mold and its condition on the guano should be recorded as mold is usually an indication of more recent deposition. Another such indication of recent deposition is any evidence of invertebrates living in the guano. Without at least a seasonal boost to their food supply, the numbers of invertebrates will diminish (Welbourn, 1992).

Another task that can be done during the time the bats are not in residence is an inventory of the bone material in the roost. A trained mammalogist will be able to tell what species of bat is using the cave from the bone material and may be able to determine whether it is a maternity colony if juvenile bone material is present (Anthony, 1988). Macro photographs, with a ruler for scale, will aid in identification of the species. Careful measurements with a sketch will also help, but care must be taken as bat bones are *extremely* fragile and may break apart if touched. If specimens will be removed from the site, the biologist who will do the identification should be contacted before material is removed as they may have the necessary permits and possible recommendations on the collecting procedure. Care must be taken to precisely record what bone material is taken and from what location. A plastic sign and inventory number can be left in place to facilitate the return of the bones after identification. Not *every* bone should be removed from the cave during this process. Indiscriminate collecting should be discouraged because once material has been removed, important information could be lost. Any bone material that is left in place should be clearly flagged to prevent damage from foot traffic.

Just before the bats are expected to return to the roost, guano sheets can be placed over existing guano piles and below ceiling stains. The first year or two, until it is determined where the bats prefer to roost , most areas indicating past use by the bats should be covered by a guano sheet. Care must be taken, however, that guano sheets be a material that does not suffocate living mold and invertebrates, impair the natural decay of the guano, nor introduce into the food chain new food by its own decay. A synthetic (non-cotton) netting like bridal veiling has been found to work quite well. To minimize disturbance in the roost, any trip into the cave to check the guano sheets should occur after the evening bat flight. This inventory may show what areas are currently being used by the bats. But these use areas may change during the season as the temperature and humidity requirements of the bats change. The guano sheets should be cleaned off each time before a deposit forms which "cements" the sheet to the guano pile. The invertebrates live on the top 1"-2" of the guano, and if the guano sheet becomes part of the pile, more damage will be done to the inhabitants when the cloth is removed (Welbourn, pers. comm).

Once the bats have returned to the site in spring, the task of figuring out how many bats use the roost may begin. In the past, researchers have entered the cave and used a white light to estimate how many bats were clustered on the ceiling. With this disturbance, bats would begin to drop off the ceiling into flight and soon if would be impossible to count the bats. To be sure all the bats were counted, a cave trip would have to include all the passages - which for some caves could be quite extensive. In addition to the confusion that flying bats would contribute, the researchers' estimates might vary greatly between individuals. This method of counting bats is particularly detrimental when using volunteer help because their lack of experience or knowledge will cause them to disturb the bats without getting much accurate data (Thomas and LaVal, 1988). Perhaps worse, it suggests to volunteers that it is acceptable to enter bat roosts and the practice of disturbance is applied to other sites.

At Kartchner Caverns, techniques suggested in *Ecological and Behavioral Methods for the Study of Bats* (Kunz, 1988) for observing and counting bats while minimizing disturbance to the bats were very successfully used. Volunteers would sit quietly outside the entrance with the sky backlighting the exiting bats (Thomas and LaVal, 1988). The conditions at Kartchner Caverns were ideal for this process because small constricting passages near the entrance caused the bats to leave in small groups. Although the entrance area at Kartchner lent itself to this technique, the same procedure has been successfully used at other caves with larger entrances and more bats. For this method to work with little or no disturbance, the volunteers must arrive with enough time so that they are seated before the first bat begins light testing. It is important that observers find a comfortable position to sit quietly for a long time because the flight can last an hour (or hours) depending on the number of bats in the roost. Only a small group (1-3 people) should sit near the entrance because the bats are aware of human presence and this can affect the exit pattern. The volunteer(s) should sit out of the flight path of the bats, preferably with the evening sky backlighting the bat flight. Sometimes, due to the orientation of the entrance, backlighting is not possible and it is then preferable to sit to one side of the entrance and allow the bats to exit in front of the viewer. A light should not be used unless absolutely necessary, but if used, a red filter should cover the headlamp (Thomas and LaVal, 1988). Many bats see red light but experience has shown us that they panic less, as determined by alterations to their flight behavior, with filtered light. It is also better to use an electric light with a rheostat so that a very dim light can be produced. Observers should not whisper to each other because whispering is very noisy in the ultrasonic range and certain sounds (like 's', 'p' and 't') are very audible to the bats. Thus, while talking is not recommended, if it is necessary, it should only be spoken in low tones. The volunteers should sit quietly until the flight is over. The number of bats leaving may fluctuate during the flight and care should be taken to allow enough time after the last bat to be assured that it isn't merely a lull in the flight.

Different equipment can be used to count the exiting bats. The most inexpensive is an inventory counter, which records one event (individual) each time a button is pressed. The disadvantage of this method is that when bats are milling about in the entrance early in the flight, the volunteer must keep track of returning bats and not add another count when this bat exits a second time (Thomas and LaVal, 1988). This can be very confusing, especially in inclement weather when the bats fly repeatedly in and out of the cave. This method produces a total number of bats exiting the site but tells nothing about the dynamics of the exit flight itself.

A more informative count can be made with a handheld calculator or lap top computer that is programmable and has an internal clock. Once the keys have been programmed, a particular key adds an additional count and records the time of that count and another key can be used to subtract a bat. Keys can be programmed to increase the count by 10 and/or 100 depending on the size of the colony. This technique may not work at large roosts (i.e. Carlsbad Caverns, New Mexico with 3/4 million bats or Bracken Cave, Texas with 20 million bats); however, many bat caves on federal lands have so few bats that they are easy to count, particularly with practice. It is recommended that the same volunteer(s) count at a particular cave as precision improves with practice. Constantly changing observers will introduce additional error into the results.

A piece of equipment that helps the accuracy of the count is a bat detector (Thomas and LaVal, 1988). As available light dims during the latter part of the exit flight, it becomes more and more difficult to see individual bats leave. A bat detector alerts the observer that a bat is exiting. In addition, if a site has more than one species of bat roosting in it, a bat detector might help the volunteers distinguish between the species if the bats echolocate on different frequencies. Some species of bat leave to forage later in the evening than other species. If the bat species being monitored leaves well after dark it may be necessary to use a night vision scope or infrared goggles (Barclay, 1988) with an infrared filter over an electric light. In the past such equipment has been very expensive but recently a number of models have become available at a more reasonable price.

Species identification of bats is not always correct when made by untrained observers. For this reason an experienced bat biologist may be necessary when the inventory requires species identification. At Kartchner Caverns the project mammalogist, a trained bat biologist, not only provided correct identification of bats, but was also instrumental in performing the technical work that required the necessary permits to net and handle wild bats in the field. Certain species of bats may be identified from a distance in the site. This is best accomplished by a bat biologist so that additional trips are not required to confirm the observations made by non-biologists. Identification should be accomplished using the low disturbance light techniques already discussed. However, some species of bats, for example, the bats of the genus Myotis, must be examined in the hand for correct identification.

One method to confirm the species of bat(s) using the cave is by netting them in the site. This can be very disturbing to the bats and may cause the animals to abandon the site (Kunz and Kurta, 1988). Because of this risk, at Kartchner Caverns we decided to net first at a water tank close to the cave. While bats netted there were disturbed, they would not necessarily associate the experience with the cave roost.

Over two summers, the dates of critical reproductive events for the (Myotis velifer) that used the cave were learned by netting at the water tank (Kunz and Kurta, 1988). Netting for at least a two year period allowed for annual variation in the dates of these events. By netting away from the cave, the bat biologist was able to decipher the period of pregnancy, parturition, lactation, and fledging of juveniles (Racey, 1988) without disturbing the bats in the roost and potentially driving then away. Confirmation of species identification in the roost itself was made in several ways. The bones and carcasses of bats found in the active roost area after bats had departed were all those of Myotis velifer. Two isolated individual bats were plucked off the wall away from the roost and identified. During the maternity season, fourteen bats netted at the water tank were banded with reflective tape on their bands (Barclay, 1988). A few nights later, a light was shone across the cave entrance and 5 reflective bands were seen on exiting bats. This confirmed that the (Myotis velifer) that had been banded at the water tank, where reproductive information was learned, were indeed the bats using the cave. Finally, late in the season, just before the bats left naturally for hibernation, exiting bats were netted outside the entrance and identified by species.

To confirm the presence of non-volant juvenile bats in the cave, a bat biologist made a trip into the roost ***after the evening bat flight*** to take a quick photograph of the juvenile bats on the ceiling. By using a telephoto lens the resulting photograph can be projected on a wall and the number of young and their different stages of development can be ascertained with less disturbance to the bats than observing them at length in the roost. On one such trip, the photo showed an adult female in the cluster of juveniles and this female was wearing a reflective bat band on her wing - again confirming the identity of these bats as those netted and studied away from the cave. It should be noted however, that even though the trip was made by a small party familiar with the cave and using red filtered light, the one or two adult females left in the roost were disturbed and attempted to move their young. After counting bats at the entrance of Kartchner Caverns for six years some very interesting patterns begin to emerge. By not using a white light to estimate the surface area of the cave ceiling covered by bats to calculate their numbers in the roost, the disturbance in the site was minimal. Also, since the bats were counted as they exited, some interesting fluctuations in the out-flight can be observed which may be worth additional study. If volunteers had entered the roost on a weekly basis (instead of making weekly counts at the entrance), it is possible that the female bats would have abandoned the site for a safer roost. They may have had to choose less favorable conditions in which to raise their young. This in turn would reduce the chances for survival of the young. It has been shown that maternity roost selection is one of the most important determinants in the survival of the juvenile bats (Tuttle and Stevenson, 1982). It is therefore imperative that any bat roost suspected to be a maternity colony be aggressively protected from human disturbance (Kunz, 1982; Fenton, 1992) whether it is by sport cavers or volunteers performing cave inventories.

A different type of roost is the cave or mine where bats hibernate. This type of roost is more difficult to monitor because the bats don't leave every evening and allow time to enter the roost to find out what part of the cave is being used. Guano sheets have limited value because when bats are in hibernation they are not defecating. However, they are still extremely critical sites to protect. As with maternity sites that have the best environmental conditions to assure the survival of the young, a hibernaculum also provides a particularly stable temperature and humidity for the species of bat that uses it (Hill and Smith, 1984; Smidley, 1991). Suitable hibernacula are in limited supply and once the bats have settled in for the winter - the site should be closed to sport caving.

A bat accumulates fat in the late summer for metabolic use during hibernation (McNab, 1982). It has been calculated that if disturbed, whether by cavers or monitoring personnel, a bat that awakens will burn the equivalent of 17 days of uninterrupted sleep (Harvey, 1992). If disturbed a number of times during the winter, a bat could literally starve to death before spring when it could again forage for food (Smidley, 1991). This is especially critical for juvenile bats because they potentially stored less fat by fall than the adults (McNab, 1982). It is therefore important for a hibernaculum to have a different monitoring program than a summer roost. The U.S. Fish and Wildlife Service census schedule is once every two years for endangered species and any researcher wishing to disturb a roost more often than once a winter should be required to submit a detailed proposal outlining the need for such a study before it is approved by the controlling agency.

After six years of monitoring the bat colony at Kartchner Caverns, an incredible amount of data have been collected that are still being analyzed. Because the low impact techniques have worked so successfully at this and other sites in Arizona, we recommend their use for any caves on federal land that will no doubt become part of the inventory process of the Federal Cave Resources Protection Act. Many notable researchers have stated that the decline in the numbers of bats is primarily due to human disturbance. If cave locations will be tabulated by the federal agencies, as required by the Federal Cave Resources Protection Act, then an aggressive management plan will need to be initiated to protect bat roosts from additional traffic.

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AUTOMATED MONITORING OF BAT ACTIVITY

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ABSTRACT

An inexpensive infrared interrupting beam counting system can be used to monitor the activity of bats leaving and returning to a roost and can be constructed from readily available parts. It offers the advantages of collecting data over many nights with no human presence which may disturb patterns of activity. It also provides a simple method of determining long term trends in bat populations and usage that is independent of observer biases. Such a system can be used to make reliable estimates of the number of bats in many instances.

INTRODUCTION

Knowledge of the types and numbers of bats utilizing a roost is an important parameter on which most bat management is based. Traditionally the size of the population and species identification was performed by entering the cave, capturing bats for identification and estimating the total population based on either a manual count or estimating the area covered by bats. These methods are time consuming and require a person skilled in identifying bats and making reliable population estimates. Such methods have also led to major disturbance of roosts and should be used infrequently. In recent years workers have used sophisticated night vision equipment, infrared or star-light scopes to observe and count the numbers of bats exiting a cave. Such methods can provide reliable estimates of the population size, activity and in some instances species identification with reduced disturbance. These methods have the drawback of being expensive both in terms of specialized equipment and trained personnel. It is also questionable whether occasional observations provide a true indication of bat populations or roost utilization. A particular site may be important to bats only during migration or as a night roost. The size of bat populations and activity may also fluctuate due to weather, moonlight, prey abundance and presence of observers.

An inexpensive solution to these problems has been used as part of the ongoing study of bats at Kartchner Caverns State Park in Arizona. Here an infrared beam of light is projected across a small passageway used by the bats. As bats break the beam the interruption is recorded on a small computer (Figure 1). Kartchner Caverns is home to a maternity colony of several hundred myotis velifer bats during the summer. Studies of the bats which inhabit Kartchner Caverns have been conducted since 1988. In order to provide a more complete record of bat utilization an infrared beam counter was installed at the cave in 1992. The bats must traverse a series of small constrictions as they enter or leave the cave. This makes it possible to install an infrared beam across one of the smaller passages and automatically count bats as they leave and return to the cave. The beam counter was installed in the "Blockade Room" approximately 50 feet from the entrance. The passage at this location is approximately 18 inches high and 12 inches wide at the widest. The infrared beam is oriented vertically along the center of the passage. In this location it appears reasonable to assume that any bat leaving or entering the cave would break the beam.

The original counter is a modified infrared beam burglar alarm detector designed for battery operation. It is readily available from Radio Shack electronic stores for less than $40. This unit produces a modulated infrared beam which is highly immune to interference from other light sources. One drawback to the detector is that the relay is closed for several seconds when the beam is broken. This limits the maximum counting speed to 5 or 6 bats per minute. Fortunately the long delay on the relay can be bypassed by tapping into the signal off the indicator LED. I used an optocoupler which allows the detector to be connected to the RS-232 port of a computer. The computer, a Radio Shack Model 100 is ideal for use this purpose because of its low power requirements and rugged design. A simple BASIC program logs the total number of counts which occur each minute to a file for later analysis. Data is recorded only during the night time hours to conserve memory. The computer has sufficient internal memory to save about two weeks of counts. The detector and computer draw a total of 100 milliamps at 12 volts. A deep cycle car battery provides sufficient power for approximately three weeks of unattended operation.

The detector and computer was tested by counting beam interruptions caused by blades from a rotating fan. This showed that the set-up was capable of counting 1200 interruptions per minute with an accuracy of 1 or 2 counts. In the original detector the infrared beam is reflected back to the detector by a plastic reflector. However at Kartchner the reflector is less than two feet from the detector and visual observations indicated that many bats were not being counted. This was found to be caused by bats flying close to the emitter in the small passage. While the beam was still being interrupted the intensity of the I.R. reflected off of the bat prevented the detector from registering the break. To overcome this problem the infrared emitter was detached from the detector and placed on the opposite side of the passage. This arrangement eliminates errors due to reflected I.R. and has proven to quite reliable.

During the summer of 1992 the infrared beam counter was in place from April 21 to October 21. During this time the counter was in operation for 148 of the 184 days (80% of the time.) The most common problem was not being able to schedule trips for battery replacement before it had totally run down. Results for a single night are shown in Figure 2. Here the number of counts during each minute is plotted for the entire night. The exit flight shows up as a sharp peak at 19:00, activity remains low until 4:00 in the morning when there is a broad peak of activity as bats return. The counter allows us to collect considerably more data than can be done with manual methods. The automated system makes counts each day independent of the weather or other variables. The data on time of emergence shows a much more definite pattern over the course of the summer, Figure 3. This plot shows that the time of emergence varies from slightly before sunset early and late in the year to much later than sunset during the middle of the summer.

In order to determine if the I.R. counter could be used to make reliable estimates of the bat population manual counts of the bat exit flight were made on 33 dates from May 10 to October 4 . The entrance sinkhole of Kartchner Caverns is ideally situated to allow accurate counts of the exit flight to be made as bats leaving the cave are silhouetted against the sky. Visual counts were tallied on a laptop computer which recorded the exit time of each bat to the nearest second. On nine occasions there were two independent observers counting the exit flight. The average discrepancy between the two visual counts was 3% with a maximum discrepancy of 8.5%.

A comparison of the counts recorded by the I.R. counter and the visual counts (Figure 4) shows that they have the same overall shape and that the I.R. counter records approximately 4 to 5 counts per night for each bat which was seen to exit the cave. This appears reasonable if we assume that each bat makes two trips out of the cave per night, crossing the beam a total of four times. Visual counts were then used to develop a correlation between the values recorded with the infrared beam counter and the number of bats observed.

Visual to I.R. Exit Count

Visual = 0.735 X I.R. Exit + 23
Corr = 0.89   n=23
F=71.46   P=0.0000

Visual to I.R. Return Count

Visual = 0.948 X I.R. return + 104
Corr = 0.93   n=21
F=115.39   P=0.0000

Visual to Total Night I.R. Count

Visual = 0.244 X I.R. total -14
Corr = 0.96   n=24
F=210.9   P=0.0000

Visual to Preceding Morning's I.R. Return Count

Visual = 0.870 X I.R. Preceding Morning -113

Corr = 0.911 n=18

F=78.26 P=0.0000

The best correlation is between the exit visual count and the total nightly I.R. count. The exit and return correlations show that the I.R. counter records more counts than the observed number of bats in each case. In the evening exit flight the I.R. detector counts about 36% more counts than bats. This is not unexpected as the bats frequently make several test flights before deciding that it is safe and dark enough to leave the cave. The counts recorded for the morning return flight correspond much more closely to the observed number of bats leaving the cave the previous evening. The I.R. detector records about 5% more counts than bats. This is apparently due to less in and out activity by the returning bats. These correlations are useable only for the set-up used at Kartchner Caverns, a separate calibration would be necessary for each location.

The concept of using an interruptable beam to monitor the activity of bats is not new, it has been used by a number of European researchers in the last 30 years. While the concept appears to be quite simple some researchers have raised questions about the method. The counter use at Kartchner Caverns counts only each break of the beam and does not indicate whether a bat is leaving or entering the cave. For this reason the counts may seem to be only roughly correlated to the true number of bats. There are many other sources of errors. A bats may make several passes through the beam before deciding to leave the cave. Several bats may cross the beam at the same instant and produce a single count. The beam may also be broken several times by the tip of a beating wing, producing multiple counts from the same bat. Despite all of these possible sources of false counts the results do show an excellent correlation to the number of bats counted visually.

A second problem encountered with single beam counters is the inability to resolve multiple bats which exit at the same time. Two or more bats may break the beam simultaneously and produce a single count. This error increases for higher numbers of bats. It is possible to statistically correct the count for this type of error. If bats are assumed to leave at random intervals (over a short time period) and the average time the beam is blocked by a single bat is known, then a statistical correction factor can be calculated. As can be seen in Figure 5 the correction is quite small for rates of less than several hundred bats per minute.

Even without calibrating the I.R. counter with a visual count a reasonable approximation of the true number of bats can be made based on the geometry of the opening. For large numbers of bats the counter can be considered as "sampling" a section of the opening. The area being sampled is the distance between the emitter and detector times the average wingspan of the bats. The true number of bats is then the ratio of the sample area to the passage cross sectional area times the infrared count. This method can be further refined by estimating the area of the passage which is actually used by the bats. Bats typically will avoid flying close to the walls and floor. The usable area of the passage can be estimated by subtracting out these avoidance areas (Figure 6). It is also better to orientate the beam in a vertical direction rather than horizontally across the opening as many bat flights are vertically stratified. While it may appear that many assumptions need to be made these are compensated for by the fact that this is usually only necessary for large roosts.

Here the large number of bats exiting produces a more statistically uniform flight which is more in line with the assumptions.

Overall the beam counter system installed at Kartchner Caverns has shown that valuable data can be collected from a simple low cost system. The system has the following advantages:

* The system is reasonably low cost, a digital readout system could be assembled for approximately $100. A system utilizing a small computer could be assembled for approximately $500.

* By utilizing the exact same beam location useful long-term population trends can be followed. The method is reproducible and counts are independent of observer bias.

* Correlation's with visual counts allows the counter to be used to estimate the population size. Where visual counts are not available the population size can be reasonably estimated from the number of counts and passage geometry.

* Multiple days of data allow the effect of human disturbance and natural fluctuations in population size to be differentiated.

* The counters are inexpensive enough to allow several sites to be monitored simultaneously with multiple counters. This allows small bat populations to be economically monitored.

* The equipment is simple, readily available and quite reliable.

It should also be remembered that a beam counter has the following disadvantages:

* A beam counter cannot distinguish between different species of bats.

* Changes in the number of counts can be caused by changes in the number of bats or by changes in activity patterns. The system records beam interruptions not individual bats.

* The current system does not indicate the direction of travel of the bat.

* The beam may be broken by other animals using the cave. When mounted vertically the beam could be broken by an animal as small as a cave cricket.

* Two or more bats which overlap will produce a single count. At higher flight densities the likelihood of overlapping bats increases but can be statistically corrected.

OTHER POSSIBILITIES:

The beam counter used at Kartchner Caverns used a computer to record counts at one minute intervals. The computer can be replaced by a simple electronic counter which will keep a running total. While this provides less information about the time distribution of bat activity it is considerably less expensive and still provides qualitative information about the number of bats. Additionally the computer uses a large proportion of the battery power. A simple beam counter and electronic counting module can be made which will run for several days off a 9 volt battery.

For use in other locations a set of I.R. emitter and detector were constructed from commonly available electronic components. These have the advantage of being smaller and are capable of operating off of a 9 volt battery for several days. The emitter and detector can be separated by as much as 70 feet. By adding a simple 2" lens to the detector the range can be further increase to several hundred feet.

Directional counting. By adding a few simple circuits the direction of travel, out of or into the cave can be determined. This may allow for a more accurate determination of the number of bats. It will also double the amount of data that must be collected. Such a system may not be as accurate as a single beam arrangement.

The use of an infrared beam counter is not limited to use at a cave. An infrared beam can be projected several hundred feet. This would enable us to monitor the activity of bats in other habitats. A beam counter could be installed across a pond where bats come to drink or between the walls of a canyon. In either case such a counter would provide information on the use of a specific area by all bats not just those who roost together in a large colony. Multiple beam counters at different elevations would provide information about the spatial distribution of bats. Long term monitoring from fixed locations could provide evidence for general population trends over several years.

Figure 1 - Initial I.R. Beam Counter Set-up

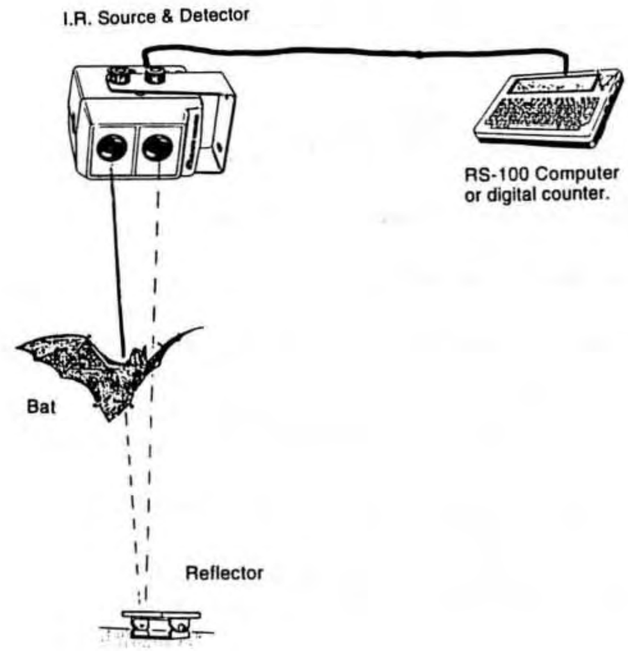


Figure 2 - Typical All Night Plot Of Bat Activity

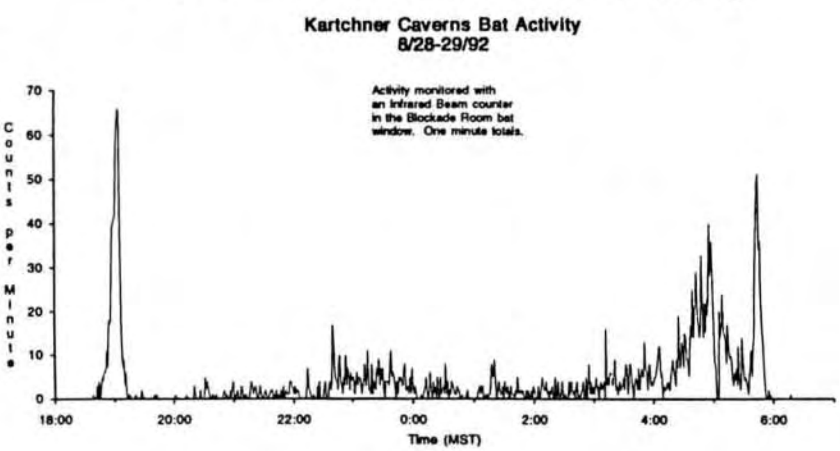
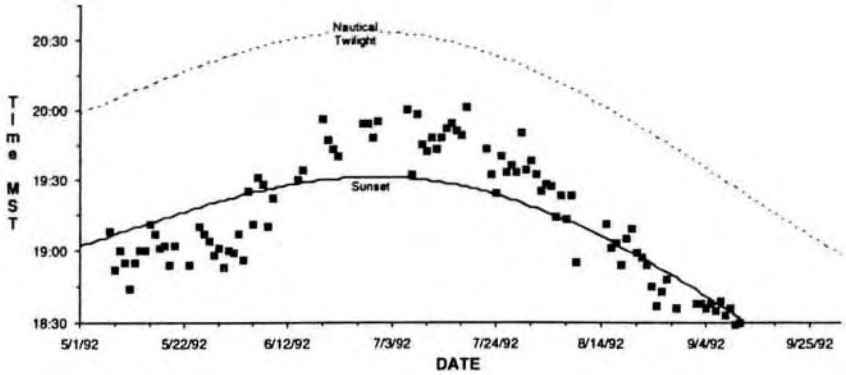


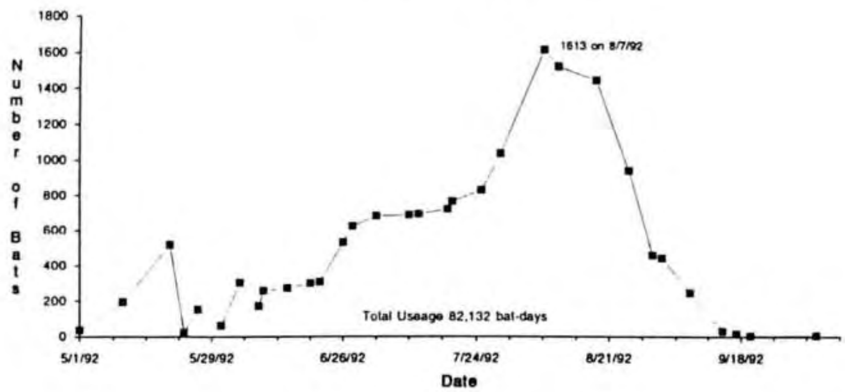
Figure 3

Kartchner Caverns - I.R. Counter
Bat Exit Times in Blockade Room



Visual Counts

Kartchner Caverns Bat Exit Counts 1992



I.R. Beam Counter

Kartchner Caverns Bat Activity
Infrared Beam Counter at Blockade Room
Total Nightly Activity

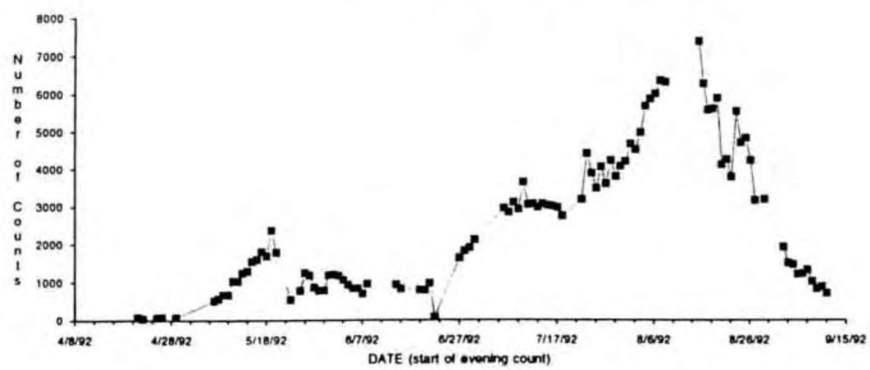


Figure 4 - Comparison of Visual Counts To I.R. Counter

Figure 5
Correction for Simultaneous Counts

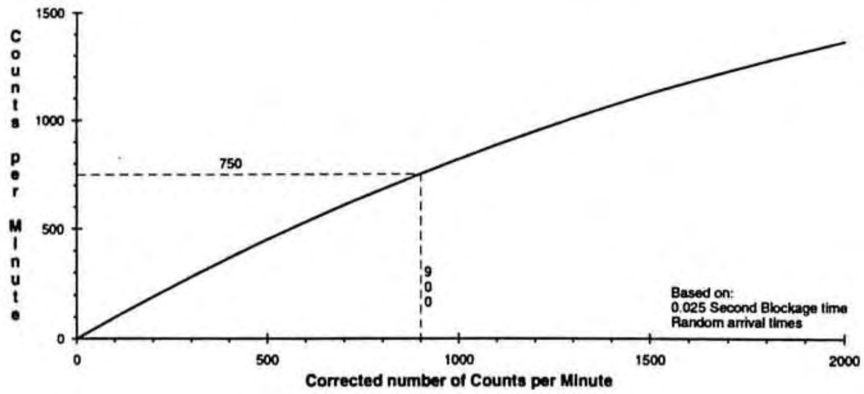
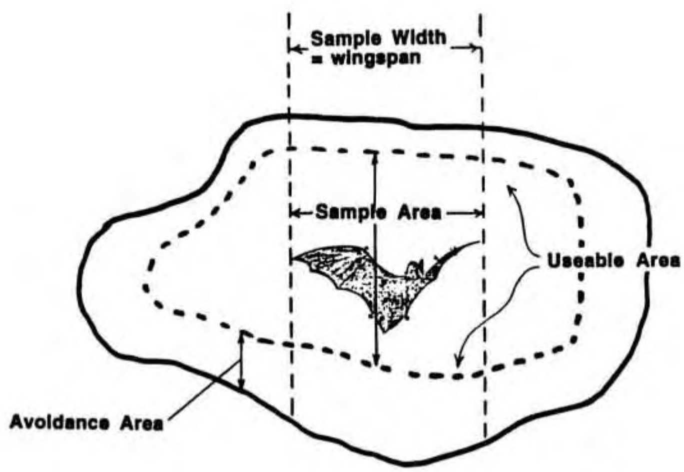


Figure 6 - Area of Passageway Utilized by Bats



Total Number = Corrected Count X Factor $\left(\frac{\text{useable area}}{\text{sample area}}\right)$

BAT MANAGEMENT: A MEMORANDUM OF UNDERSTANDING BETWEEN BAT CONSERVATION INTERNATIONAL AND THE BUREAU OF LAND MANAGEMENT

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ABSTRACT

On March 20, 1993, a Memorandum of Understanding was signed in Washington, D.C. between Bat Conservation International (BCI) and the Bureau of Land Management (BLM). Its purpose is "to provide a framework for cooperative activities necessary to maintain and enhance the productivity of bats and their habitats on public lands administered by the BLM..." . This presentation recounts how the MOU came about; what has happened between BCI and the BLM since the signing of the MOU; and describes training courses, training videos, watchable wildlife projects and other cooperative activities being undertaken by the BLM and BCI pursuant to this MOU.

EVALUATION AND MANAGEMENT OF BATS IN ABANDONED MINES IN THE SOUTHWEST

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The need to secure abandoned mines for human safety seems in conflict with the fact that 64 percent of the bat species of the continental United States are known to roost in mines (Pierson et. al. 1991). In addition, populations of many species have experienced serious population declines in recent years (Graham 1966, Mohr 1972, Tuttle 1979, Perkins 1985, Clawson 1987, McCracken 1988, Pierson 1988). It is clear that relatively little is known about much of the very basic requirements of many species of bats and that closure of mine roosts could have serious, negative consequences to the species which use them. There is evidence that recreational activities and destruction of habitat have played a major role in this decline (Tuttle 1979, McCracken 1988) and that examples of human-caused mortality at traditional roosts are common (Mohr 1972, Tuttle 1979, Altenbach, unpubl. obs.) It is reasonable to assume that abandoned mines may have provided a refugium. In 1990 a cooperative agreement between the New Mexico Abandoned Minelands Bureau (hereafter AML) and the University of New Mexico established a program to evaluate bat use in all abandoned mines scheduled for closure. Since it is clear that roost requirements differ widely during different times of the year, the timing of surveys is critical and will be discussed in the context of different types of mine survey protocols. We describe herein the procedures we have used in the evaluation of abandoned mines for bat use and occupancy.

MINE INVENTORY AND SURVEY PROTOCOL

Inventory and Initial Survey: The initial survey of a project involves location and description of **ALL** mine openings (features) including: dimensions, elevation relative to other openings, airflow direction and airflow temperature, obstacles in opening (rocks, vegetation, limbs, trash, portal or headframe timbers, potential hazards, depth of the mine feature (vertical or horizontal) as can be observed from outside, presence of drifts as can be observed from outside, observations of any wildlife or wildlife sign (eg. excrement, carcasses, etc.), collection, if possible, of potential bat guano from immediately inside opening if safe to do so.

Internal Survey: If additional survey is warranted, an internal survey, conducted by an **experienced** bat biologist on a contract basis, has proved to be the quickest and least labor/time intensive of the survey options. The leader of any internal survey needs experience with identification of bats and general bat biology as well as with mines and mine safety. This person must make a decision that an internal survey is possible within the limits of safety and must decide whether an external survey is the only option.

When it is determined that an internal survey is possible the following approach is one that has been used in the cooperative program between the New Mexico Abandoned Mine Lands Bureau and the University of New Mexico. Aspects of this protocol are discussed in greater detail in the following section.

A	**Complete Internal Evaluation Possible**	**B**
A'	**Complete Internal Evaluation Not Possible**	**G**
B	**Cold Season Check**	
	No Guano, Sign or Residents	**F**
	Guano or Other Sign	**C**
	Residents	**C, E**
C	**Warm Season Check**	
	No Residents - Night Roost, Migratory Use	**D**
	Residents	**E**
D	**Fall or Spring Check, Dropping Boards**	
	No Residents, No Sign	**F**
	Residents, Additional Sign	**E**
E	**Decision to Bat Gate Involving Following Questions**	
	Is a Threatened or Endangered Species Involved?	
	Is Use Significant?	
	Are Alternative Features, Used In The Same Way, Nearby?	
	How Feasible is Bat-compatible Gating?	
F	**Closure By Any Means (If possible after a final inspection, mist netting and tarping or smoke bombing before closure)**	
G	**External Survey**	

Discussion of Internal Evaluation Protocol

Cold Season Check: During the initial cold season check note is made of the layout of the mine and the possibility that parts of the mine cannot be explored. If it is determined that parts of a mine cannot be explored, external evaluation of the mine is required. Careful checking of even tiny cracks or holes in the back is necessary since several species of bats hibernate in such openings. Measurements of temperature, relative humidity and airflow in different parts of the mine are made at this time and add to our understanding of the roost requirements for bats and our understanding of how internal mine environment correlates with external temperatures and conditions.

If bats are encountered in a cold season survey, they are identified by inspection under red light. Mine lamp beams are not put directly on hibernating bats for any length of time and any attempt at identification is limited to the minimum time possible. Getting exact counts of clustered or scattered bats does not warrant the disturbance involved. A quick estimate of numbers or of the size of a cluster is adequate and disturbance is kept at a minimum.

Warm Season Check: Internal surveys during warm season are conducted with extreme care. Many species of bats are intolerant of disturbance at a roost site, especially during the time they are having and caring for pups. Disturbance can easily cause relocation of a colony and worse, mortality of pups (Mohr 1972, Humphrey and Kunz 1976). A mine is approached, entered and explored quietly during a warm season check. Serious disturbance of alert bats in order to make an identification is not warranted. An experienced bat biologist can often make an identification of some species with only a quick glance. If bats cannot be identified without disturbing them, external evaluation involving netting, trapping or bat detectors is in order.

If no bats are found in residence, the bat sign (typically guano pile or scattered guano) can be carefully searched for the discarded invertebrate appendages and wings that indicate night roosting. If night roosting is suspected, the mine is again entered at night to observe the species and numbers involved or is mist netted at night. Bats are not often encountered in mines used as migratory stopover roosts and identification of the species typically involves a careful search for carcasses which can then be identified.

Decision to Bat Gate: If a threatened or endangered species is using a mine the decision to use some type of bat compatible closure is clear but must involve consultation with appropriate state and or federal authorities. To date only one threatened species (Myotis velifer brevis) has been found using mines in New Mexico.

The question of significant use is difficult. A single, hibernating Plecotus townsendii is probably not sufficient cause to close a mine with bat-compatible closure at great expense. Ten hibernating Plecotus probably is but must be weighed against the complexity, feasibility, cost and reliability of such a closure. It must also be weighted by the presence or absence of a comparable mine feature, used in the same way, being nearby. An example is a mine in Grant Co., NM which was used a hibernaculum by over 25 Plecotus towensendii. The mine was an open stope that averaged about 20 feet in width, was over 100 yards long and was over 100 ft deep in places. The cost of a bat-compatible closure was astronomical but within a quarter mile was another mine, used by this species as both a hibernaculum and maternity roost, that was much more suitable for a bat-compatible closure. The first feature was blasted shut during the interval between maternity and hibernation time (after clearing with smoke bombs the night before blasting) and the second was fitted with bat-compatible gating on three of its entrances and cable netting to maintain airflow on the others.

A maternity colony of any species is significant and is cause for installation of bat-compatible closure but must be weighed with costs, feasibility and availability of comparable, more easily gated features nearby. The use of a mine as a migratory stopover by Myotis yumanensis, a species about which nothing was known of non-warm-season occurrence in New Mexico, was considered significant and the mine secured accordingly.

External Survey: If a mine or mine complex is deemed possible bat habitat and cannot be entered because of hazardous conditions or because trained and experienced persons are not available for an internal survey, a series of three external surveys is in order.

A Spring survey (April through early June) and a Fall survey (late August through mid-October) might encounter migrating species and ones flocking in preparation for hibernation. A survey conducted from mid-June through early August should encounter maternity roosts and bachelor colonies.

These surveys are conducted on nights without rain or strong wind by observers stationed off to the sides of the mine portal. Setup is kept quiet and is complete at least 30 minutes before sunset. Observers are stationed at least 15 ft from the sides of a portal, not directly in front of it. After it is too dark to see bats silhouetted against an evening sky, red lights are shined across the portal, not into it. Observations are kept up at least 2 hours after sunset and as much information as possible about numbers counted going in or out of the mine are recorded.

All entrances in a particular area are checked, as many as possible on the same night. Bats often use only one entrance of a mine that may have several. Any disturbance at one entrance may cause bats to use an alternate. An external survey will certainly detect bats that are using a mine the night the survey is done. It must be kept in mind that it cannot detect bats that just left or that don't go out that night.

External Capture Survey: If unidentified bats are encountered in an internal survey during warm season, if a warm season external evaluation encounters bats or if a night roost is discovered, capture of some individuals for positive identification is warranted. Persons conducting capture surveys are thoroughly capable of field identification, rabies immunized and have necessary state and/or federal collecting permits. Setup of mist nets is completed at least 30 minutes before sunset and is done as quietly as possible. Nets (with someone in attendance at all times) are left up at least two hours after sunset or later if there is a possibility that the mine is used as a night roost. After enough bats have been caught for identification and released, the nets are taken down to minimize disturbance. Data on species, sex, and reproductive status is recorded.

Bat Compatible Closure and Followup: If the use is significant or if alternative, comparable sites do not exist nearby and closure is feasible, the mine feature is closed with bat-compatible gating. The bat-compatible closures are designed for each mine feature by AML engineers and include heavy, angle iron grates with horizontal, 6-inch openings similar to those described by Tuttle (1977) and White and Seginak (1987). Secondary openings not used by bats are cable netted to maintain airflow. If bat use is likely through a secondary opening which is closed by cable netting, angle iron-reinforced, 6 inch by 18 inch openings are provided in the net. After closing in this manner, the feature is checked periodically to assess subsequent use. At the present time, we are beginning the use of remote monitoring and data storage systems to collect data on all aspects of the use of mines we have closed with bat-compatible closures.

RESULTS

To date 42 percent of over 200 mine features evaluated have been found to have some form of bat use. The most common use is as cold-season hibernacula and the most common resident is Plecotus townsendii. Ninety five percent of the mines with bat activity are used as hibernacula by one or more individuals of P. townsendii and they have been observed in deep torpor in mines that varied from 3 to 11 degrees C. Other species hibernating in mines are Myotis ciliolabrum (22 individuals in 12 mines), Myotis californicus (3 individuals in 2 mines), Myotis auriculus (1 individual in 1 mine), Idionycteris phyllotis (1 individual in 1 mine) and Eptesicus fuscus (3 individuals in 3 mines).

Nursery colonies of Plecotus townsendii (one colony of about 1000, another of a few hundred and one of about 25 in 3 mines), Myotis thysanodes (1 colony of 25 in one mine) and Myotis velifer (1 colony of over 1000 and another colony of under 100 in 2 mines). Night roosts of Antrozous pallidus 14 night roosting groups in 14 mines), Myotis velifer (2 night roosting groups in 2 mines) and Myotis ciliolabrum (2 individuals in 2 mines).

A migratory stopover roost of Myotis yumanensis that is used by an undetermined number of individuals during April and October has been found nearly 100 miles from the known warm-season range of this species (Findley et. al. 1975). Until this discovery, nothing of the cold season habitat of this species in New Mexico was known. The mine used by M. yumanensis is also used in June by about 25 gravid Myotis thysanodes with well-developed fetuses. This is of interest since the bats were in shallow torpor during the day at a temperature of 14 degrees C. We speculate that the temperature selected by these bats may drive embryonic diapause. To date, 16 bat-compatible gates and 3 cable net closures have been installed on 8 mines (some with multiple openings). There are presently 42 bat-compatible gates and 5 net closures scheduled for 22 additional mines (some with multiple openings).

It was hoped when we began this evaluation of abandoned mine features that a pattern of use could be observed to allow some predictability based upon the initial external evaluation. It appears that in a mine of any size, there is little to indicate if bats might use it. Significant numbers of bats have been found in deep, single-opening shafts, on the rib of bald shafts and deep in horizontal features which show absolutely no evidence of bat use in their shallow passages. Another aspect of the unpredictability involves the near impossibility of determining the internal complexity, the number of interconnected openings and the internal volume of a large mine or mine complex based upon an internal evaluation. This unpredictability has been complicated by the observation that many mines which appear to have no warm or cold-season use, function as short-duration pre or post hibernation intermediate roosts. Mines which are not used for hibernation and have no sign of warm-season use have been occupied by Plecotus townsendii, Myotis velifer and Myotis auriculus when checked in mid March and September.

CONCLUSIONS

Mines can be used by different species of bats with widely differing requirements for temperature, relative humidity and air flow. The use can be for hibernation, intermediate roosting between warm and cold season, migratory stopover, warm season maternity roosting, bachelor colonies, night roosts and possibly for developmental diapause during warm season. Mines may provide last-resort habitat for bats displaced from traditional roosts used for any or all of the above by destruction or disturbance.

Bat biologists have much to learn about roost preference criteria but temperature appears likely as an important factor (Tuttle and Stevenson 1978). The simplicity of a mine may provide seasonal temperature fluctuation just as complexity may provide extreme regional temperature variation. Until comprehensive research provides a measure of predictability, we believe the systematic internal evaluation (if possible) of all mine features scheduled for closure by the New Mexico AML provides the best possibility for combination of the goals of securing abandoned mines for human safety and protecting bats that may rely on them. It is important to consider that nearly any mine can be habitat for bats at different times of the year, and until you look, you don't know if the mine is used by bats.

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INFORMED DECISIONMAKING FOR BAT-GATING ABANDONED MINES

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In July 1993, the National Park Service installed bat-gates, utilizing a state-of-the-art design, at the entrances to three abandoned mine openings in Buffalo National River's Rush Historic District, located in Marion County, Arkansas. The bat-gates will serve the primary purpose of reducing health and safety hazards to the park visitor, while also protecting bat habitat and the historic visual scene.

The National Environmental Policy Act of 1969 (NEPA), as amended, provided the approach to the planning and decisionmaking process that helped to make more informed decisions regarding technical, economic and environmental factors and a successful meeting of project objectives. This was accomplished through the preparation of an environmental assessment. An early identification of issues helped determine the makeup of the interdisciplinary team, other environmental laws that should be integrated into the planning process, and the appropriate public involvement strategy. As a result of using the NEPA process, informed decisions were made on gate design, construction season, and priorities.

When applying the NEPA process to abandoned mined lands (AMLs), two important considerations are biological and engineering surveys of the mines. Without sufficient data on the existing resources and conditions, planning for closure of mine openings or other decisions is arbitrary and haphazard. This can result in disastrous environmental consequences and does not meet the needs of the agency. As a result, increased costs are incurred by prolonging and redirecting the planning process, delaying receipt of other-agency approvals or permits, and correcting the deficiencies of comprehensive designs. All of these can contribute to jeopardizing the agency's credibility for resources stewardship and environmental leadership.

APPLICABILITY TO CAVES

There is a strong association between closure of abandoned mine openings and caves: The abandoned mine openings at Rush, like caves, have existing and potential habitat for threatened and endangered plants and wildlife. In this case, bat habitat for three endangered bat species will be protected by bat-gates.

The mine openings have historic significance. However, unlike caves, where a long period of time for cave development may have offered prehistoric man shelter, the abandoned mine openings are historically significant for their place in mining history.

Caves are also a source of recreation; therefore, like the abandoned mine openings at Rush that are receiving unauthorized recreational use, a liability issue associated with health and safety hazards and access are important objectives in closure.

While the Rush mine openings were experiencing loss of historic fabric from rock collectors, caves have the potential for loss of their natural geologic features.

BACKGROUND

Inventory of Abandoned Mined Lands

From 1984 through 1989, the National Park Service undertook an intensive inventory of abandoned mined lands within the 367 units of the System. As a result, 2,124 mine sites comprising 10,655 mine openings located within 127 units of the System were identified. These range from large mining complexes to small gravel pits less than an acre in size.

In the Southwest Region, 14 of 41 parks have abandoned mined lands within their boundaries. After the inventory, AMLs were prioritized by the health and safety hazards they present. The Rush Mining District at Buffalo National River, with 67 abandoned shafts and adits, became the Southwest Region's top priority for action. The June 1993 Environmental Assessment "Closure of Abandoned Mine Openings in the Rush Historic District" represents the first environmental assessment prepared by the Southwest Region, and the National Park Service, to address closure of hard-rock AMLs.

Buffalo National River

Buffalo National River was authorized by Congress in 1972 through enactment of Public Law 92-237 to conserve and interpret an area that contains unique scenic and scientific features and to preserve as a free-flowing stream an important segment of Buffalo River in Arkansas for the benefit and enjoyment of present and future generations. The park provides hiking, horseback riding, picnicking, camping, swimming, boating, fishing, hunting, caving, and other outdoor recreational experiences for an estimated one million visitors each year.

Rush Historic District

All 67 abandoned mine sites are located in the Rush Historic District of Buffalo National River. The Rush Historic District produced zinc from the early 1880's to the late 1950's. It is a geographically small area located between Rush and Clabber Creeks, and extending one-half mile upstream and downstream along the Buffalo River. At the peak of the mining boom, from 1915 to 1919, Rush was a good-sized town with 10 mining companies and 13 mine sites concentrated in its narrow confines. On February 27, 1987, 1300 acres of greater Rush was listed on the National Register as a Historic District, and represents a unique example of zinc mining in the early 1900's and the associated community life. The remains of seven mills, 36 other structures, numerous roadbeds and retaining walls exist within the district. Each of the 67 mine openings and the extensive underground workings are individual components that contributed to the district's listing on the National Register of Historic Places.

An estimated 30,000 people visit the Rush area every year. Access is possible by road or by boat. River use is the primary recreational activity at Buffalo National River, and Rush Landing is one of the most heavily used canoe put-in and take-out points. A developed trail provides direct access to many of the mine openings.

The terrain is steep with limited flat areas adjoining the creeks and the river. The mines are located in the Everton formation (consisting of compact blue-gray limestone, dolomite, and sandstone), where zinc-rich solutions replaced the limestone with sphalerite (zinc sulfide). In many places, this sphalerite has reacted with the limestone host rock, altering to smithsonite (zinc carbonate).

Health and Safety Hazards

Abandoned mine openings present many hazards to visitors and park staff. Hazards include falling into shafts (vertical openings to the surface), getting lost in adits (horizontal mine openings), being exposed to bad air, or being injured from falling rock or roof collapse.

People often make the mistake of equating an abandoned mine to a natural cave. Caves are naturally formed features and are generally associated with long-term stability. Mines, on the other hand, are manmade and designed to last only long enough to extract the ore, at which time they are abandoned. Timbers and rock bolts supporting dangerously unstable areas are left to rot and decay. Rock falls, by far, account for most accidents in active mining operations, and rock stability decreases after abandonment. The long-term action of air and groundwater on the rock causes it to become unstable. Vertical openings may be covered by rotten timber barely capable of supporting its own weight. Collars (the ground surrounding vertical openings) are often composed of loose rock sloping into the opening, making it easy to slip and fall in. Vertical openings may also be flooded, presenting a potential for drowning.

Past Actions

Realizing the dangers that mines present, the park initiated a fencing and signing project in 1985 throughout the Rush District to prevent accidental entry into mine openings and injury from rock fall or other hazards. Fencing was constructed to block visitor-made access trails leading to 8 mine areas to prevent accidental entry, and consisted of 6-foot high chainlink fences liberally posted with black-on-yellow signs reading "DANGER KEEP OUT, Unsafe Mine, UNSTABLE ROCK". As a designated trail system was in close proximity to many of these mines, it was hoped that fencing and signage would provide not only a warning but a deterrent.

However, determined visitors continue to circumvent the fences. Additionally, the chainlink fencing and bright yellow signs are visually intrusive on the historic scene and are visible from a considerable distance when the leaves are off the trees, acting as more of an attractant to these hazardous sites.

Almost every mine opening shows some sign of visitor entry. Some sites show evidence of significant visitation with fire rings inside openings and accumulated trash. Rock collecting is also evident.

USING THE NATIONAL ENVIRONMENTAL POLICY ACT PROCESS

The National Environmental Policy Act (NEPA) provides a procedural process for preparing an environmental assessment. The major headings of an environmental assessment may appear to suggest a linear and sequential process. However, as issues and environmental impacts are identified, for example, a remodeling of the proposal and objectives becomes evident; and so forth. Therefore, a circular approach is graphically more reflective of the process.

For example, a standard cable net closure may prevent access to an adit by the visitor, but environmental consequences to bats that use the mine opening would occur. When such impacts are identified, the proposal is modified to minimize impacts and bats are included as an objective.

Define the Purpose of and Need for the Proposed Action

The initial proposal was to eliminate access to abandoned mine openings, using various closure methods, in order to reduce health and safety hazards to visitors and park staff. Following the identification of issues (resources that might be affected) and development of the proposed action, the proposal became more defined: to reduce health and safety hazards to visitors associated with abandoned mine openings, using a variety of closure methods, while protecting bat habitat and the historic visual scene.

Define the Scope

The proposal and objective recognize that health and safety hazards associated with all abandoned mine openings in Buffalo National River should be corrected; therefore, closed by some method to restrict access into them. Due to budget constraints, sites were prioritized for closure based on availability of funding. Priority was determined on accessibility of a mine opening to visitors, level of hazard, and important resource issues affected.

Based on important resource issues, consultation with the Surface Mining and Reclamation Division, the State Historic Preservation Office, pursuant to Section 106 of the National Historic Preservation Act, and with the U.S. Fish and Wildlife Service, pursuant to Section 7 of the Endangered Species Act, was determined, and early involvement in the planning process was programmed.

Important resource issues also serve the purpose of determining the individuals who will participate on the interdisciplinary team preparing the environmental assessment. Because of the issues identified for this project, the team included park and Regional Office historians, the Regional Office Archeologist, park and Regional Office biologists, the Servicewide Cave Specialist, the park facility manager, a mine engineer from the National Park Service's Mining and Minerals Branch, and myself, as team leader. Roy Powers, engineer, was contracted to design bat-gates specific to meet the agency's objectives in reducing health and safety hazards while protecting bat habitat and the historic visual scene.

Determine Important Resource Issues

Resource issues considered but determined to not be relevant in closure design included air and water quality and were not used further in evaluating closure recommendations. Air quality in the mine openings is remarkably good. A 1989 monitoring survey found oxygen, carbon monoxide, and radon daughter levels varied insignificantly from the clean air outside.

Buffalo River, noted for its pristine water, is monitored regularly. Resource impacts from the abandoned mines at Rush are minimal. Two mine openings, both proposed for gating, have standing water; however, proposed closures would have no affect on water quality, drainage, or flows.

Wildlife, specifically protection of bat habitat, and protection of historic integrity were determined to be important resource issues that were evaluated along with visitor use and health and safety concerns in developing closure recommendations and design.

Early informal consultation with the U.S. Fish and Wildlife Service and the State Natural Heritage Program yielded updated listings of threatened and endangered, and category plant and wildlife species that may occur in the area. Four federally-listed endangered species on the updated list obtained from the U.S. Fish and Wildlife Service are known to occur within the park. These include three bat species: Myotis grisenscens, the Gray bat, Myotis sodalis, the Indiana bat, and the Ozark big-eared bat, Plecotus townsendii engens. The bald eagle, Haliaeetus leucocephalus, is known to overwinter in the park in the riparian corridors.

Protecting the historic integrity of each mine opening was an issue to keep in mind when developing closure recommendations because of Rush's listing as a historic district on the National Register of Historic Places. If it had not been listed, the State Historic Preservation Office would have been consulted with to determine significance of the resource and eligibility.

Develop Alternatives that Meet the Objectives

In April 1993, the National Park Service contracted with Roy Powers, an engineer who is nationally recognized for having extensive mine closure experience, particularly in the design and installation of bat-gates, to evaluate 50 mine openings and to provide recommendations for their closure. These 50 mine openings are associated with five mine complexes that are the more readily accessible of the total 67 mine openings. Site investigations were conducted with mine reclamation specialists from the Arkansas Department of Pollution Control and Ecology's Division of Surface Mining and Reclamation. Also accompanying Roy Powers were two park biologists and the park historian who surveyed the mine openings for existing or potential bat habitat and identified specific cultural resource concerns.

The resultant survey reports and recommendations formed the basis for the National Park Service's Proposed Action for the Environmental Assessment. A No-Action Alternative was developed and evaluated in addition to the Proposed Action. No other action alternatives were identified. The proposed action includes installing bat-gates on 30 adits, backfilling 6 adits and 1 shaft permanently closed, fencing to restrict access to 2 adits, grating over 3 shafts and 2 joints, and leaving 4 adits and 2 shafts alone. At 8 of the mine openings, signed chainlink fences would be removed; thereby, enhancing the cultural landscape of the historic mining district.

Various closure methods have been devised to keep people out of abandoned mines. The particular closure method used in a given situation depends upon a variety of considerations such as public safety, management objectives, rock conditions, resource degradation, historic significance, and habitat for endangered wildlife species, particularly bats.

Closure methods include installing gates; installing bat-gates to mine openings that have existing or potentially suitable bat habitat; permanent closures of the more hazardous openings by back-filling or blasting; and construction of masonry or concrete walls. Fencing could also be used to prevent access; however, location and choice of materials would be important considerations so that the historic scene would be protected.

After predicting the environmental impacts of the Proposed Action in the Environmental Consequences section of the environmental assessment, mitigation measures were included in the Proposed Action.

- Because the mine openings are part of a historic district, for the 7 mine openings proposed to be permanently closed by backfilling, Level III Historic American Engineering Record documentation would be completed prior to closure.
- Where fencing and signs would be used, the location and types of materials used would be sensitive to the backcountry environment and carefully sited. Therefore, black on yellow signs were changed to white on brown, and fencing would be constructed of a non-reflective material.
- An archeologist will monitor the backfilling of the 7 mine openings. If archeological resources are uncovered during backfilling, or if cultural resources appear threatened, damage would be avoided by project redesign, or if this is not possible, adverse recovery effects would be mitigated through an archeological data program per Section 106 of the National Historic Preservation Act, as amended.
- In order to not adversely affect bat species, installation is scheduled only during periods when bats are not using the mine openings.
- Bat-gates will be designed and fabricated of non-reflective angle iron to conform to the existing configuration of each mine opening to preserve the existing configuration of the mine opening and the historic integrity of the mine sites.

A major consideration in the design of gates was compatibility with existing and potential bat use of the mine openings. There is a close association between bats and abandoned mines. Bats use abandoned mine openings for hibernation, maternity roosts, and day and night roosts. The National Park Service is committed to protect abandoned mines important to bat populations and to design appropriate bat-gates.

Consideration for the placement and design of bat-gates were incorporated where such gates were proposed to prevent disrupting air flow and temperature within the mine opening. Placement of bat-gates inside the entrance of the adit as much as permissible permitted the closure to also be sensitive to the historic scene. A recessed placement allows the bat-gate to fall in the shadow of the portal, reducing the visibility of the bat-gate. Additionally, use of non-glare steel lessened visual impact on the historic scene.

All bat-gates were designed to include a lockable door to allow park and other qualified specialists access to conduct bat monitoring and survey functions. Lockable doors also permit mine historians access to conduct historical research. In one case, a lockable door was installed to permit access for future interpretive programs. Where safe access can be gained to a mine opening through another lockable door, such doors were reduced to the smallest number possible.

While some visitors will be disappointed by the restriction of access into abandoned mine openings and the loss of an unauthorized recreational experience, the majority of visitors will appreciate the protective measures. Strategic placement of interpretive signs at a select few bat-gates near the trail will explain the history and use of the site and explain the rationale for taking these steps to provide for public safety and to protect bat habitat from human intrusion. These signs might also be helpful in minimizing vandalism of the bat-gates, and, therefore, prevent future deterioration of mine sites.

Regular monitoring of the mine openings and inspection of the closures would continue.

<u>Cost to Implement</u>

An initial allocation of $17,000 was available to complete the first 3 bat-gates in July 1993:

- to purchase the steel for 3 bat-gates measuring 15'x20', 8'x7', 30'x8' and an expanded metal closure over an ore cart shaft measuring 5'x5'x5'
- contract a welder and 2 cutters who brought arc welders and portable generators and all other equipment and supplies to fabricate the gates onsite
- contract Roy Powers to supervise onsite fabrication and installation.

In subsequent closure work, welders and cutters will be hired as park staff rather than contracted, and supervision of the fabrication and installation will be provided by park maintenance staff who participated and gained training during the July 1993 closure work, resulting in overall project savings.

EXTREME LOW FREQUENCY RADIO EMISSIONS OF BATS IN LAIR CAVE

Walton C. Koemel

ABSTRACT

Flying bats randomly produce extreme low frequency (ELF) radio pulses that range from 2,000 to 3,500 cycles per second (Hz). These pulses have a duration of 3 milliseconds. The observed ELF radio emissions coming from the ceiling of the cave and those coming from the floor of the cave are diverse. Mosquito wings produce continuous 300 to 400 Hz ELF radio emissions when they fly in the Carlsbad, New Mexico area.

Dick Auld said bats might use radio emissions of some kind for aviation guidance because they would give a faster response than sound. On July 15, 1993, I observed very weak, ELF radio pulses produced by bats as they flew out from Carlsbad Caverns. The presence of 60 Hz A.C. power lines adversely affected my observations. I chose to visit Lair Cave because it had no power lines in it. The nearest power line was more than a mile away. On July 31, 1993, I visited Lair Cave. My equipment included a cassette tape recorder, a condenser electric microphone amplifier, and a radio receiver that detects the electric component of ELF electromagnetic fields and static discharges. I used an electronic noise detector of my own design (TRF radio receiver) to detect ELF electromagnetic (radio) emissions produced by flying bats. This instrument has been proven to not detect compressional waves (sound) of any kind. It uses an electric field antenna to detect the electric component of electromagnetic waves and electric fields. I used a cassette tape recorder with a shielded patch cord connected from the TRF radio receiver output to the microphone input jack of the cassette tape recorder to record the observed radio emissions. After the recordings were made, a frequency analysis was made by playing the recording into a Tandy TRS-80 computer with an Audio Spectrum Analyzer (Cat.No. 26-3156) (Tandy Corp., Fort Worth, Tex. 76102). W.R. McIntosh suggested the use of this computer in 1983 for the analysis of ELF radio frequencies (personal communication). It will analyze frequencies from 30 Hz. to 12,500 Hz. A TRS-80 computer analysis of the audio and ELF radio frequencies found in the cave entrance was made. The ELF radio emissions of flying bats are not obvious in this analysis.

My efforts to observe the very weak ELF radio emissions produced by flying bats were very adversely affected by the presence of underground 60 Hz A.C. power cables. These power cables act as waveguides for the ELF radio waves that travel along power lines. If more research is to be done on this subject, it should be done at least 100 feet away from any 60 Hz A.C. power cables or lines.

The cassette tape recordings were also analyzed by playing the recording into the shielded probe of a Heath-Zenith digital computer oscilloscope (model 4802, Heath C., Bent Harbor, Michigan). My digital computer oscilloscope is driven by a Tandy 1000Hx computer with a JP 250 printer. The oscilloscope print shows the oscilloscope parameters on the right side of the print. Under the display, C1 shows the location of cursor 1 on the waveform. C2 shows the frequency in cycles per second (Hz) of the waveform between the two cursors.

Fig. 1 shows representative ELF radio waves present outside the cave entrance. I observed the usual atmospheric static discharges and ELF radio frequencies, including a very weak 120 Hz electromagnetic field that associates itself with 60 Hz A.C. power lines. This is normal, even when power lines are 1/4 mile away. It might be of interest to note that the sun, moon, clear night time sky, thunder storms, sand storms, fog, and even cold fronts all have their own distinct ELF radio emissions. These ELF radio emissions are also detectable inside the cave.

After I entered the cave, I observed ELF radio emissions inside the cave. Fig. 2 shows the very strong 120 Hz electric field found near the ceiling of the cave. It also shows 160 Hz and 400-500 Hz of lesser strength. This condition could be the result of 60 Hz A.C. power ground return current. Fig. 3 shows the ELF radio frequencies observed near the cave floor. The 120 Hz electromagnetic field is not discernable in the TRF radio receiver earphone when the TRF radio receiver antenna is near the cave floor.

Fig. 4 shows the 120 Hz electromagnetic field with a 3,333 Hz radio pulse at the top of the second peak. The top of the pulse is 1.02V. The voltages indicated on the oscilloscope prints are not the actual voltages produced by the source. The presence of the strong 120 Hz electromagnetic field prevented clear observations of these random pulses produced by the bats. Peaks 4,5,and 6 have single peaked voltage spikes produced by atmospheric static discharges. The static spikes have a 'crack' sound in the earphone of the TRF radio receiver, while the ELF radio emissions produced by flying bats have a 'pop' sound in the earphone. The static spikes are single peaked. The radio emissions produced by flying bats have a 'pop' sound in the earphone. The static spikes are single peaked. The radio emissions produced by flying bats are multi-peaked with frequencies that range from 2,000 Hz to 3,500 Hz. The bats do not produce a steady flow of radio emissions. They produce random pulses that last about 3 milliseconds (ms).

Fig. 5 shows sonic frequencies produced by bats inside the cave. Some of the bats were flying bats were flying while some were perched on the cave walls and others were hanging from the ceiling. During my observations, the flying bats repeatedly impacted the electric field antenna. It seemed as though the bats were unable to detect the presence of the motionless antenna standing in a vertical position above my head. The metal telescoping antenna was 24 inches long and 1/4 to 1/8 of an inch in diameter.

It might be of interest to note that mosquitoes produce continuous ELF radio emissions when they fly. Their wings have a piezoelectric quality that causes the ELF radio emissions. Fig. 7 shows the ELF radio emissions produced while the mosquito is flying several inches away from the TRF radio receiver antenna. Mosquito ELF radio emissions can vary from 150 Hz to 500 Hz. I began observing these radio emissions in 1988. Philip S. Callahan (1966) postulated these emissions to exist. The bats need only to 'home in' on these emissions during predation. The ELF radio pulses produced by flying bats might be used as an electronic stun gun to paralyze insects during predation.

There are several possible uses for these ELF radio pulses. One use involves their use as a perturbing radio frequency in a magnetic resonance imaging system that uses the earth's magnetic field as the H-field. The Larmor frequencies (natural resonant frequency) of molecules in the earth's magnetic field are in the ELF region of the electromagnetic spectrum (Gadian, 1982). In this environment, it would be very easy for bats and insects to achieve resonance.

Another possible use for these ELF radio pulses is in a far-infrared imaging system. ELF radio and audio frequencies cause molecules to emit their far-infrared molecular spectrum (Callahan, 1989). I think this is the probable use of the ELF radio pulses produced by the bats. The configurations on the bat's nostrils make perfect waveguides for microwave and far-infrared receptors in the bats (Callahan, 1975).

Dale Pate called my attention to the counter-clockwise rotational flight pattern of the bats as they exited the cave. I think this flight pattern helps the bats orient themselves to the magnetic fields at the cave entrance (Buchler and Wasilewski, 1985). They could be using these magnetic fields as references for their return flight to the cave. This phenomenon can be observed in honey bees when the bee hive is moved 10 feet away from its original location during the daytime after worker bees leave the hive to forage. The honey bees are obviously using an invisible unscented reference to return to the hive's original location (Gould et al, 1978). They find the hive's new location by flying in a gradually expanding circular pattern, usually in a counter-clockwise direction.

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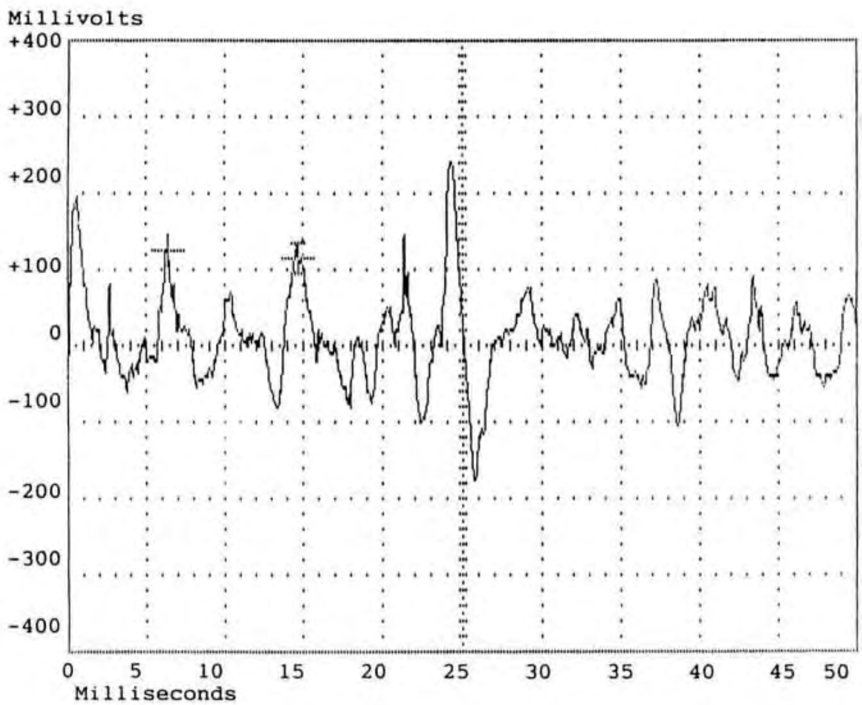

Fig. 1. Oscilloscope recording of ELF radio frequencies outside cave entrance. (50 ms sweep).

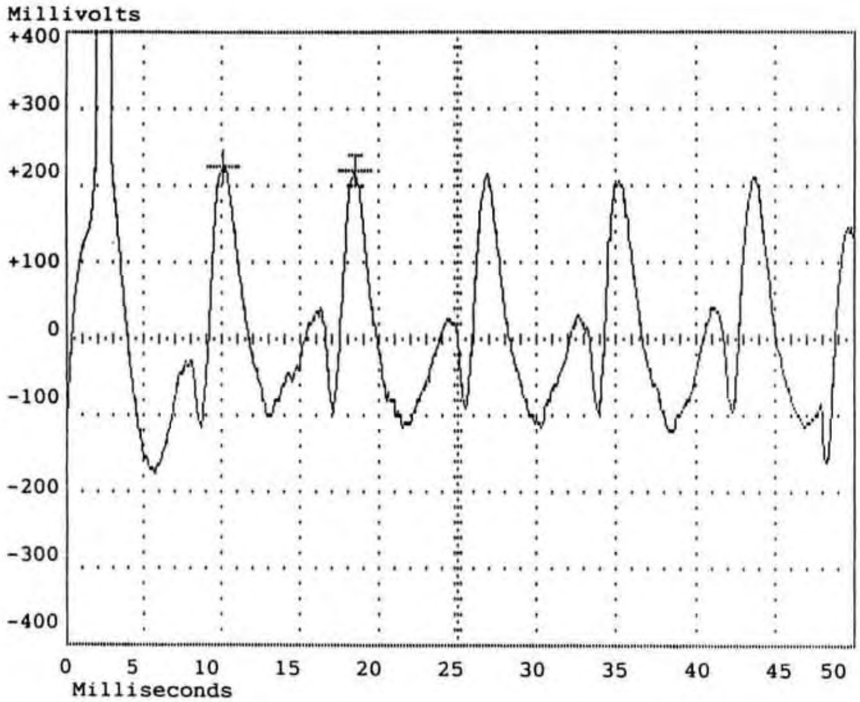

Fig. 2. Oscilloscope recording of ELF radio frequencies near cave ceiling. (50 ms sweep).

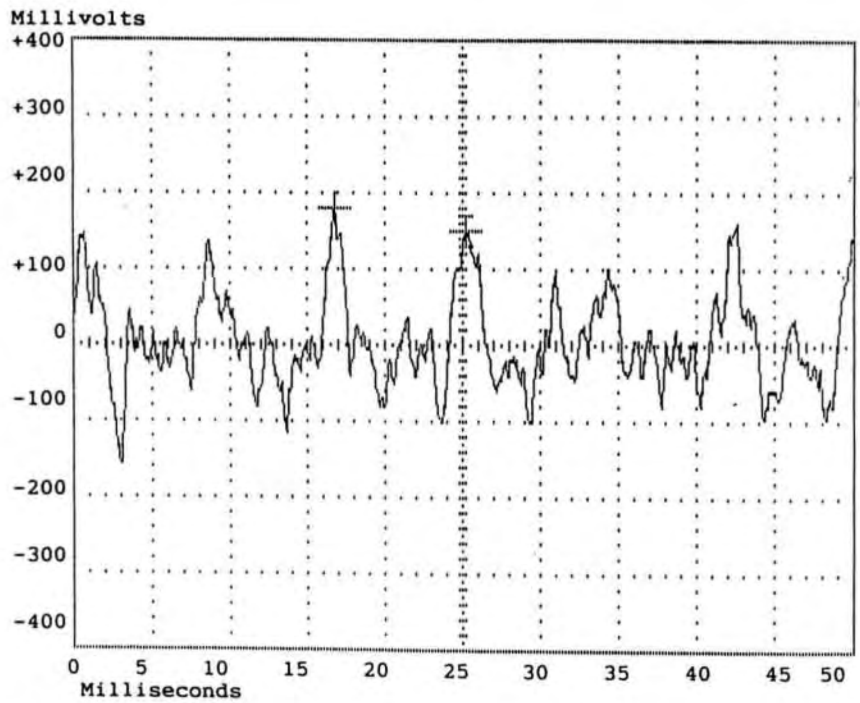

Fig. 3. Oscilloscope recording of ELF radio frequencies near cave floor. (50 ms sweep).

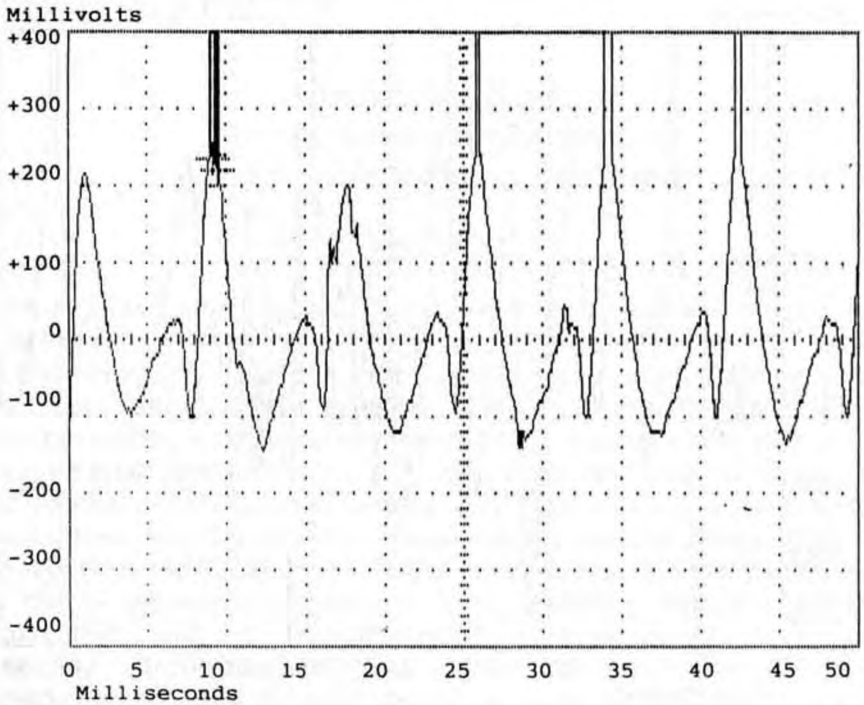

Fig. 4. Oscilloscope recording of ELF radio frequencies with a 3,333 Hz radio pulse produced by a flying bat at the top of the second peak. (50 ms sweep).

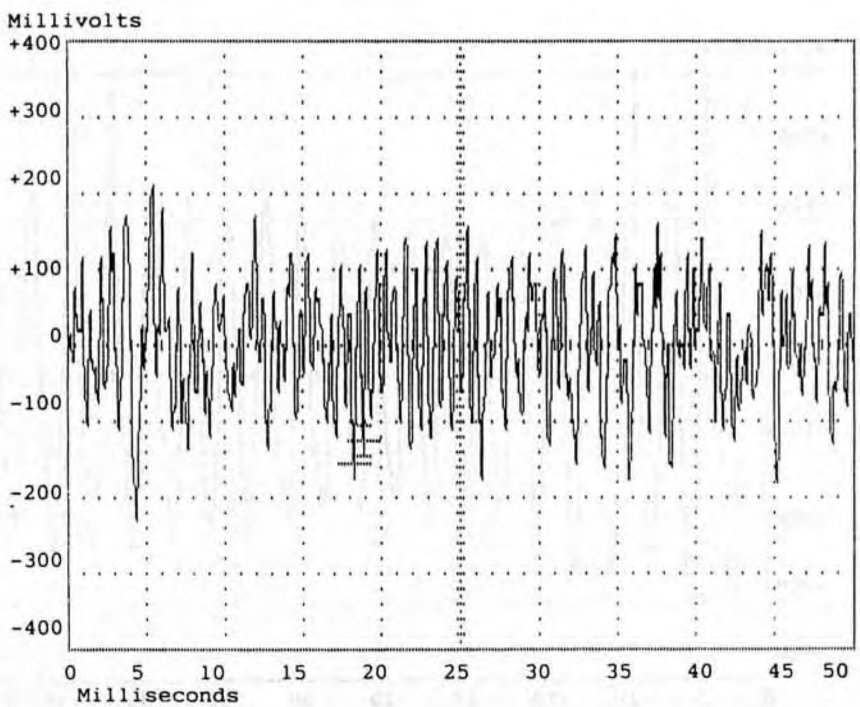

Fig. 5. Oscilloscope recording of sonic frequencies produced by flying bats inside cave. (50 ms sweep).

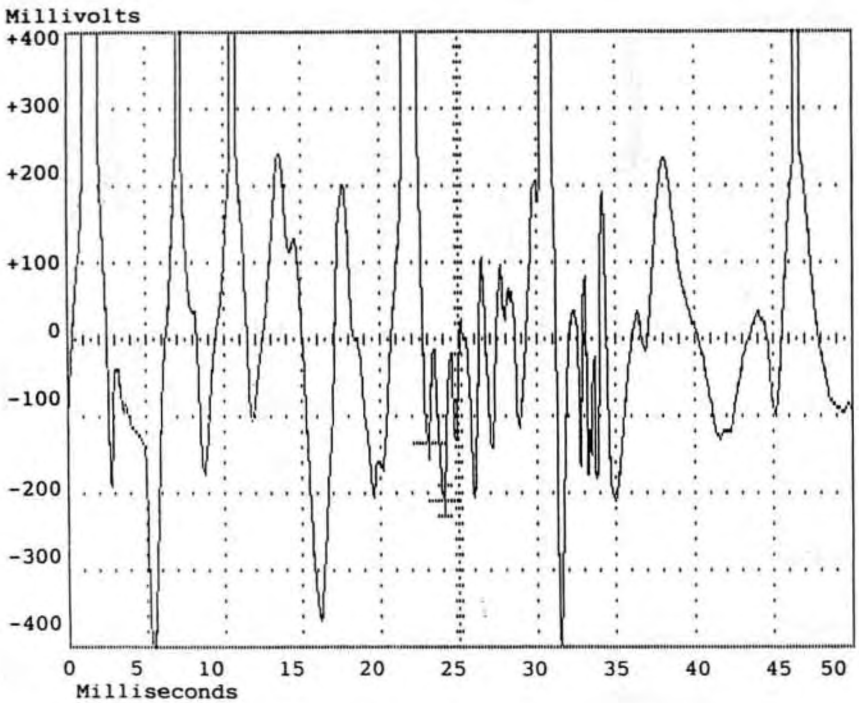

Fig. 6. Oscilloscope recording of ELF static discharges produced by flying bat impacting TRF radio antenna inside cave. (50 ms sweep).

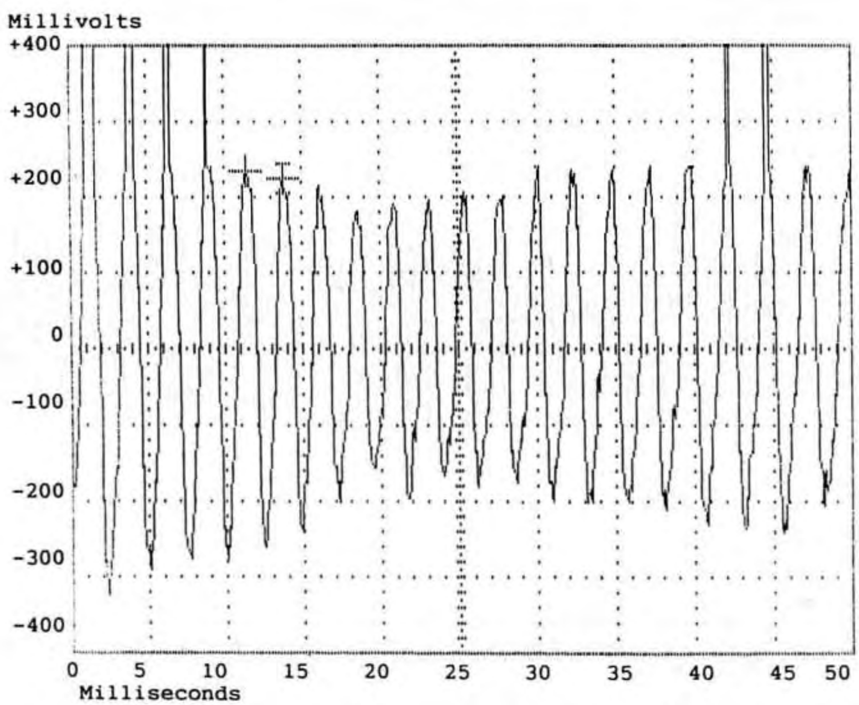

Fig. 7. Oscilloscope recording of ELF radio frequencies produced by flying mosquito. (50 ms sweep).

RECENT ACCOMPLISHMENTS IN BAT MANAGEMENT AND CONSERVATION IN ARIZONA

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ABSTRACT

Prior to 1990, the Arizona Game and Fish Department's Bat Management program was funded by Nongame Wildlife Checkoff, Pittman-Robertson Act, ESA Section 6, and various cost share agreements. In November 1990, Arizona voters passed the Heritage Initiative which allocated $10 million dollars from the Lottery to the Department. With this, a full-fledged Bat Management Program was born. During the winter, spring, and summer of 1992, the three biologists in the program mist-netted and surveyed caves, abandoned mines, bridges, dams, and buildings for bat roosts. Over 500 net hours were expended mist netting and surveys were conducted on approximately 1,000 caves or mines, 30 bridges or dams, and 10 buildings. These surveys resulted in many significant discoveries. As new data is discovered, the Department will begin to piece together many unsolved mysteries such as specific life history information, timing of roost utilization, natural population fluctuations, microhabitat requirements, and disturbance limitations. Applying this knowledge and experience will help conserve existing bat colonies in Arizona and possibly enhance others. Currently, intense conservation measures are being directed toward at least 15 colonies. This includes gating, monitoring, scientific analysis, environmental assessment, mitigation, and public education. These conservation efforts will increase in quantity and success as data and experience increase.

BAT CONSERVATION INTERNATIONAL SPECIAL GUEST SPEAKER

Merlin Tuttle

Thank you. It is really a thrill to get back together with you. Those of you who are old enough will remember in the early days of the National Cave Management Symposium I was an almost religious participant. Unfortunately over time, I've been stressed and strained in other directions and I'm sorry that even today I've had to fly in quickly and will fly out quickly after my talk, but it really is neat to be here and see so many special friends of mine and of bats. Many of you have done wonderful things for bats in your own right and probably as a group, there is none other in America that has the power to make a bigger difference for the future of bats than you here today.

Also I'm delighted to know that there are many of you here today who are looking forward to being introduced to bats. And so the first part of my talk will be directed toward those of you who have yet to become acquainted with American bats; with their diversity, with their fascinations, their importance, and their needs. The last part of my talk will deal with detailed management and conservation situations.

America's bats come in just about the most amazing diversity that you can imagine. They are spectacular animals, probably some of the most fascinating, colorful animals, with all kinds of diverse personalities and looks. The Hoary Bat, Leib's Bat, California Long Nosed Bat, Hog Nosed Bat, Ghost-faced Bat and a Mastiff. Now if that isn't a bit of diversity, I don't know what is. And if you could just see the amazing diversity of behavior that goes along with this you'd know exactly what I'm talking about.

Unfortunately however, the average person thinks only of bats as scary creatures to be avoided at all possible costs. And as a matter of fact, bats have been so fiercely misunderstood by the public for so long and neglected by scientists and conservationists that even here in America bats are only about one fifteenth as well studied as other mammals and more than half of our North American bats are either federally listed as endangered or listed as a category II species for that consideration. Even worse, many of the bats that aren't listed or in that category may be as endangered or more endangered than those already listed.

Most people are terrified of even a Little Brown Bat suddenly appearing in their home. Sure, bats can transmit rabies to people. But put in perspective, the danger from bats is just minuscule, if we just remember that any bat that can be caught and handled is probably sick. Leave it alone and don't try to pick it up , leave it where it is. Do you know what the biggest killer in terms of wildlife is? Bambi. Actually, car accidents involving deer. And yet no one thinks we ought to reduce deer populations so that automobiles won't run into them. Honeybees have killed more people in a year than bats have killed in all recorded history. Mans' best friend the dog, accounts for more people dead in out-and-out attacks annually than all people dead from bats in all history. And yet we don't go after dogs and honeybees and those other animals as somehow a threat to us. We understand that they have a value; honeybees make honey, dogs are good friends. Actually, it would be rather hypocritical for us to want to get dogs in our neighborhoods for killing maybe 20 people a year when in-fact 10,000 of us die at the hands of our own spouses. Seriously, one of the most dangerous things you can do is to get married!

One small bat alone can catch up to 600 mosquito sized insects in an hour and has tremendous impact ecologically. A recent report from Oregon tells of an organic farmer who had attracted 2000 bats by building bat houses on his organic farm. His corn-ear worm problems dropped from 3-4 corn-ear worms per ear of corn to nearly zero and the fact that this might happen is well supported by scientific literature. A study done in Canada suggests that if you just played fake bat calls over a field of corn, you could reduce the damage done by corn-ear worms by 30% to 50%. That's without any real bats, just faking bat sounds! You can imagine what it might do to have the real thing around!

And then talking about friends of farmers, if you'd have heard John Whitaker from Indiana State University, you'd have heard how the Big Brown Bat is about the best friend a farmer can have. He reeled off a long list of crop pests that are eaten in large quantities by these bats. An example of one of these pests is the Cucumber Beetle. Just one colony of these Big Brown Bats of 150 individuals in one summer, he reported, can eat 38,000 Cucumber Beetles. Well, big deal, what does that mean? Well, because of the timing in the way they do it, this protects the farmers from over 18 million Root Worms, the larval stage of the Cucumber Beetle.

I have often said to forestry people, that if I were in their shoes trying to properly manage a healthy forest, it is important to not only save endangered species, but also important to keep other bat species abundant.

Bats live in a wide variety of places. We have some, like Red Bats, that live out in the tree tops where they're not so much impacted by what we do to the other types of roosts that bats traditionally use. A key we found in our research in old growth forests out west is ancient snags. When we radio tracked four species of little known bats, all four returned to ancient snags of ponderosa pine. The current practice of cutting down a big track forest and leaving just a few old snags isn't going to hack it. What's going to happen when those few old snags fall down and the rest of the forest is still young? We must have a succession of these old forests and we must somehow preserve these old snags. They are key resources to bats and probably one of the biggest things that early on in the development of the U.S. deprived bats of their habitat. By cutting down old growth forests we've chased them out of old tree hollows and burned out interiors where some probably lived year round, but now are much more dependent on buildings, mines, and caves.

As the woods are cut back, the bats move into our old wooden barns and covered bridges and things like that. As you can see wooden barns and bridges are becoming extinct. They're being replaced by metal structures that bats can't use and so gradually step by step bats are losing their habitat. And in addition to that, one of the points I want to make is that there is no single cause of bat decline. There are many causes. Initially we heard much about pesticides, pesticides are in many cases dwarfed by many other things such as loss of drinking water. Any desert bat researcher that has been to a remote water hole can vouch for the incredible numbers of bats trying to get in to drink at these sites. Unfortunately when we remove cattle off, we don't do anything to keep the water available. We thought we could just let nature take its course, and everything would right itself once we got cattle off the land. The reality is that cattle overgrazing drastically reduced ground cover. The plants that used to catch the water and act as a sponge helped to ensure that springs flowed. The springs dried up with overgrazing. We drilled down to bring the water up to artificial containers. But now the cattle have been run off. I know that in Congress now there have been many discussions over grazing rights.

I'm very concerned about how quickly we take the cattle off these grazing areas. Who is going to have the incentive to maintain open water sources. It is very important. Most other mammals and most birds can simply walk up to a tiny bit of water and take a drink, that's not true of bats. These few remote water holes are key resources for bats, many of whom require a fairly long flight zone to drink. The Big Eared Bat is the contradiction of that, it can practically drink on a dime. But there are many bats which cannot. For example, the Western Mastiff Bat. Now here's a bat who's not listed as endangered, but every time I see Teri Vaughn from out in the southwest, he tells me that one of his greatest joys as a young man was to hear the Mastiff Bats. He then tells me that in areas where he used to hear many, he hardly ever hears one anymore. I have never caught a Mastiff bat over a pond that did not provide at least 100' of clear flight zone over the water. It is absolutely remarkable how many of these places have now been eliminated through new water use practices. So bats face a very serious threat just in the availability of water.

Of course, many of our bats live in caves, and that's what interests us today, so we're going to stick with caves. I want to point out that even with a cave like Bracken Cave in Texas, there are many things that can go wrong. Before modern humans came and overgrazed this area, it is believed that Bracken Cave was in a major prairie area with few to no trees around. Today, if someone doesn't occasionally cut back the trees, especially the mesquite, that colony could eventually be lost. We are not in a time in human history where we can just let things go, take the cows off, and assume that everything will right itself. In many cases we have often changed the environment so much that we must continue to manage. If we did not routinely cut back the mesquite trees around Bracken Cave, we could lose the bat colony. This is a key resource. There were once many more key resource sites in America. A photo of the roost site in Bracken Cave should say just about everything that needs to be said in looking at the vast numbers of bats. Almost everything you see in the photo is a bat. Literally, there are 270 tons of bats, covering thousands of square feet, with adults packed in up to 200 per square foot, and young up to 500 per square foot. These bats have to be one of the most vulnerable animals on Earth.

Our Mexican free-tailed bats fly south to Mexico for the winter. In recent years we have documented that some people, worried about vampire bats, will haul spare tires into the caves, douse them with kerosene and set them on fire. I am sure I can kill every bat in Bracken Cave with such a technique and in fact, this has already occurred widely in Mexico. Perhaps millions of bats have been burned. We really need to pay attention internationally, if we are to save one of the most abundant denizens of the southwest.

These bats arrive at Bracken Cave in early spring. By June they are giving birth to their pups. They are about a third the size of their mother. That's the equivalent to a human mother giving birth to a forty-pound baby. The pups remain attached to the umbilical cord until mother and pups can get closely acquainted to each other's scent and voice. For many years, biologists thought that mothers would find it impossible to find their young in these mass creches of literally tons of babies, sometimes as dense as 500 per square foot. As a result of Gary McCracken's work we now know that mothers do recognize their own babies. They remember within a small area where they leave them, then locate them by sound and scent. In fact the mothers don't roost with their own young, they move away from them and come back periodically to nurse.

If finding the baby wasn't hard enough, then imagine trying to fly for the first time in a cave like Bracken, where these little bats are moving 10 to 30 feet per second the first time they drop off the ceiling. The floor is covered with voracious dermestid beetles which will eat them and turn them into skeletons if they fall on the floor. They are flying rapidly, coming into a collision course with a cave wall within seconds. Yet, their feet are out in back. To land, the bat has to turn a virtual somersault with millimeter precision and grab some rough place on the wall. Failure to do so bashes his head, and ends him up on the floor. The bat has to do this, not just the first time it flies, but also has to use its echolocation in a traffic jam where a young bat is avoiding at least 3-5 collisions a second. This is like being placed in an airplane as a young pilot learning to fly, having the windows painted black, being given an instruction manual and told to read this. This is how you fly and this is how you read an instrument panel. When you feel confident take off, but just remember there are many other beginners up there that you're going to have to avoid every second. Truly, it is a marvel of nature how these bats have survived for so long, yet these large colonies are threatened by the way modern humans are changing the world.

Nearing dusk, Mexico free-tailed bats emerge from the cave in one of the most spectacular exodus' of nature. Flights that begin some hours before sunset can be seen for miles. Why do they have to go out so far, so fast, so early? Because they're going to cover probably thousands of square miles around that cave to feed at night. Free-tailed bats from just three caves in the San Antonio region are probably eating a million pounds of insects per night. Just the bats from Bracken Cave consume up to 250 tons of insects in a single night. Stop to think about not just mosquitos but bigger insects like moths. How many does it take to make a pound? Or 1000 pounds? It's almost beyond comprehension. Imagine what it takes to make 100 tons or more. We're just beginning to scratch the surface when it comes to understanding the ecological and economical importance of such feeding.

John Whitaker challenged me on a comment I made several years ago, and I challenged him to collect hard data on bat importance. That's how we found out about corn rootworm which incidently causes the loss of about 1 billion dollars a year in crops. If we could just learn a little bit more about what these bats mean to the balance of nature, we would have everybody on the bandwagon to save them.

Now it's not just what they do outside at night, it's partly what they do inside during the day that makes them important. Most of us don't think about how much unique life lives in guano ecosystems. In a single study from Bracken Cave, a team from Auburn University discovered that the guano, not just from Bracken Cave but from other bat caves as well, is one of the richest life sources. The guano from Bracken Cave supports an estimated 1000 species and 200 genera of bacteria per tablespoon. In a tablespoon you can have that kind of diversity. They found that one group of these bacteria produces enzymes that break down ammonia. Anyone who has ever been in one of these caves can understand that there is an abundant supply of ammonia there! These bacteria are of major interest to Dow, to Kodak, and to other industrial giants who need to detoxify chemical byproducts. They found, as many of us know, that bat guano is heavily laden with the exoskeletons of insects which are made of chitin. They have already sold 4-5 different species of bacteria to a detergent manufacturer. They have also found that about 70% of the species of bacteria living in this guano are from the bacterial group from which antibiotics are produced, and they have already identified antibiotic potential in these bacteria. They also found that many of these bacteria are unique. Taxonomy for bacteria is not exactly tight, we're still arguing over bats, so you can imagine how loose it is for bacteria, but they believe that many of the bacteria from Bracken Cave are genetically different from other groups at the genus level and these have not been found elsewhere. So, there is an amazing biodiversified resource that we sometimes just completely overlook. Loss of a single bat colony can jeopardize a whole ecosystem of unique cave life. Just how long has that guano ecosystem been building? Regardless of a bat species' status, what about the unique cave ecosystem and what it might someday do for humans?

Every winter North American bats have to go into mines, caves or migrate south. There are a few exceptions I wish I had time to tell you about... oh, I can't resist. The Hoary Bat goes south to a certain extent, but different populations do very different things. Some carry on year round. Some migrate long distances. Some migrate short distances and if I'd brought the right slides, I'd show you how a Hoary Bat was found hibernating on the side of a pine tree perfectly camouflaged. It's one of the nicest examples of cryptic coloration you've ever seen. The bat was watched for a full month in this position surviving temperatures as low as 7°F, snow all around. Now we know that the Hoary Bat can lower it's body temperature to 23°F. Apparently it has a natural anti-freeze which prevents it from freezing to death. Most bats can't do that, so they have to seek shelter. There are bats such as the Big Brown Bat which can survive sub-freezing temperatures. Most literature says that they can't, but those that wrote about them did not observe them in Northern Wisconsin mines where temperatures regularly fall below freezing and the bats body temperatures are recorded as low as 27°F.

Farther into the cave, in fact in totally different kinds of caves, we find the Eastern Big Eared Bat. These amazing fellows break most of the rules for eastern North American bats. They roost sometimes year-round in shallow cliff shelters and do things most bats wouldn't do, such as going out and feeding on cold winter days. There are very few bats in eastern North America that do that. The sad thing about these bats is that they tend to roost in entrances. When you find them in caves they typically are near the entrance. The biggest colonies I know of now are in rock shelters, but when these areas are opened up for recreation, these make ideal camp sites. If I were out camping or backpacking on a rainy night, I would love to go build my campfire in a rock shelter and camp there. But these are very, very vulnerable bats because they like to roost in rock shelters and in the entrances of caves where they are the first to be disturbed and are the first to be noticed because their very long black ears draw attention.

Farther inside caves, we find the little Pippestrels. They are neat bats as well. They are much more labile in what they can do. If I were to ask you where this little bat was more likely to freeze to death, you would more than likely answer up in the northern limit of its range in Wisconsin. The reverse is true, however. It is more likely to freeze to death in its southern limits in Florida. In Florida, it is often unable to find cold enough caves to live in, so it roosts in the entrance to take advantage of the cold air there. But when a large front moves in, it is likely to be caught in the cold and freeze to death.

Some of our more specialized hibernators, such as the Gray Bat, form dense colonies. The biggest bat hibernating caves in America weren't discovered until the 1960's when cavers began to develop deep vertical techniques. The Gray Bat is one of these bats that hibernate in deep, vertical caves where they were ignored and survived until we learned how to get there.

The Indiana Bat roosts in extremely dense clusters, 300 per square foot and is extremely vulnerable in the winter time. As cavers began to enter technically off-limit areas, they began to disturb bats. In the early days people would argue that bat disturbance does little harm, but I would challenge anybody today to dispute the scientific facts. Human disturbance has taken a dramatic, drastic toll on hibernating bats.

Recent studies by Don Thomas out of Sherbrook University show that Little Brown Bats save up to four years worth of fat supply to enter hibernation. Actually in the northern U.S. and Canada, these little bats have to stay in hibernation for eight months out of the year, which is pretty remarkable in itself. They put on this huge amount of fat and burn some 80 percent of it during just twelve arousals during the winter. Don calculates that in just waking up, these bats burn 30 to 60 days worth of fat. Now it is known that hibernating bats wake up every so often anyway, but at a research conference in Gainesville, Florida recently, Don presented data showing that when a hibernating bat is forcibly aroused, the bat's next arousal occurs within about 5 days. Under normal conditions, the next arousal should not occur for 19 days. The double jeopardy on them is that you've already aroused them and then they have to arouse sooner the next time before settling down into a normal hibernating routine.

Because disturbance during hibernation is so serious, many bats have moved from caves into mines, the more dangerous the better from the bat point-of-view, in order to avoid human disturbances. The sad story of the day is that such dangerous mines are the first to get targeted for closure, and yet they're often of vital importance as refuges of last resort for bats.

In checking mines last winter, we found a graphic example of why bats need to move into dangerous and remote mine areas. People think that vandalism and disturbance are things that just occasionally occur. Not so! Once people find a new concentration of bats, most of those bats, in my experience, especially if it's a public find, are gone within two years. During a recent mine survey, we found these empty hair spray cans. Kids had made blow-torches by lighting the spray with matches. They then torched clusters of hibernating bats to watch them burn. The floor was literally covered with dead Big and Little Brown Bats. We found seventy-thousand bats still in the mine. A local caver estimated that there were one-quarter of a million bats there two years earlier before kids started burning them.

Nearby, in the town of Iron Mountain, a caver and a member of the NSS, Steve Smith along with some of his buddies last fall roped down into a 200-foot mine shaft just to have a final look-see before the city was going to close it up. The city had already hauled in huge loads of earth and dirt and had bulldozers ready to fill the shaft in. The cavers reported that a huge number of bats, estimated to be a million, were hibernating in the mine. This ranks it as the second largest known hibernation population in the world. It is my opinion that it is relatively small compared to some that have already been destroyed or have yet to be discovered.

When Steve first attempted to notify officials about the colony and the need to save this mine, the local attitude was "Let someone else deal with this", and "this is never going to sell in an economically depressed community where people traditionally did not like the bats that got into their attics in the summer." City fathers and mining company executives avoided returning even our phone calls. I offered to come up and help, but the local DNR biologist feared it wouldn't do any good. He said "They won't return my phone calls or meet with me".

I said, "Okay. How many elementary schools do you have in the area?"

He said, "Two".

I said, "Fine, book me into those two elementary schools. Tell them it's going to be a good show. I'll bring a Flying-Fox. Tell the media about it. You know the media loves anything the kids love and book me into the town library for the next night for a community lecture".

Well, he said,"OK", but he was still very, very doubtful that anyone was going to show up. We got to the schools and I had a Flying-Fox with me. The kids absolutely went bonkers over her and I showed them some neat things about bats. I told them how exciting many other bats were and that I'd tell them much more if they'd just get their parents down to the library the next night. The kids went home and told their parents. The next night, on a sub-zero degree night with snow, so many people came to the town library, including the news media, that we couldn't get them all in. They had set up fifty seats thinking that we wouldn't get twenty-five. Three hundred people showed up to learn about bats for an hour and a half. Town politicians always have their ear to the ground as to what's going on and when everyone was turning up for the show, they turned up, too. By the end of the lecture, the politicians were emphatic in their support and local citizens donated their labor. Local companies donated materials and a large cage was placed over the shaft. At a later news conference, the state DNR, who originally thought they'd never live this down if they got involved, ended up getting national publicity. They said they'd never gotten such good publicity in all the years on the job. I now can show you newspaper headlines where they're not just saying they're going to check the rest of the mines, they're emphasizing that they want to find and protect any remaining bats. At the news conference, the local mine inspector, who didn't even want to talk with us initially said, "Thank God you got up here when you did. We closed twelve mines earlier. When I was a kid they had a lot more bats in them than the one you just saved." The head PR person for the biggest mining company in the area came up and said, "Let us know how we can help you in doing some seminars or doing whatever it takes. We want to be involved in this".

So let it be known that there are no hopeless cases, there are just challenges as to how to get people to listen. When they do listen, the story for bats is so powerful, they can't resist.

Now back to the world of caves. Which caves are most important to be protected. The sad thing is that today many of America's most important bat caves have no bats in them. Many of the caves where bats today live provide only marginal bat roosts. An analogy would be similar to a family from the midwest being taken off their fertile farm and shipped to Siberia. Many bats are being driven into sub-optimal roost conditions and we think this is where we have to protect them, when in fact there may be a cave right next door that may be vastly superior for their use. Their original caves have had to be abandoned because of human persecution and disturbance.

There are several ways of identifying old bat caves. If it is not too old, it is possible to still find guano on the floor under the roost - pretty unmistakable evidence. Also, typically there is deep staining on the ceiling if bats have roosted in the same place for a long period of time. This is not a rule but it happens so frequently that it is a reliable indicator that bats were there in the past. It's absence doesn't necessarily mean that they weren't. Often, you can see where they were. Nursery colonies prefer domed places in the ceiling, because they can trap body heat there in the summertime. Many times, the guano that was once on the floor is completely gone now and the only evidence is the stain on the ceiling.

Measuring old stains is one way, not a perfect way, to estimate how many bats might have lived in a cave at one time. Even when you think you've counted the number of bats in a cave, you may net the entrance and find that there are four times as many bats as you thought there were. So there is no way to tell exactly how many bats are in a cave, but measuring old stains is a conservative way to estimate the maximum past population that lived in the cave. For most of our eastern bats and bats of the genus myotis, we know roughly that their summer roosting densities are at least between 175 and 225 bats per square foot. It doesn't really make a difference in your calculations whether you use 175 or 225 bats per square foot as long as you use that same figure from year to year. By comparing the area of surface staining to the amount of new guano left each season on the floor you can get a relative figure of whether the bats have declined, increased, or remained stable. This is often a very important tool in the assessment of bat caves.

Very often the best bat caves no longer have bats in them. Many of the biggest cave systems in Florida are located on high ridges. This makes them most attractive for commercialization and for cave exploration. Many have been lost because people like to build big homes on high hills and they don't like cavers running through their back yards, so they just bulldoze caves shut.

The bats used to have many safe havens, but over time, to escape disturbance, they have been driven into low, wet caves where they now roost low over the water. Cavers avoid these because they are relatively small and miserable to enter. The trouble is, when recent floods hit Florida, a very large proportion of endangered Gray Bats and candidate southeastern bats were drowned. There were thousands and thousands of them found dead because they had gradually been driven into these dangerous havens of last resort. Then the floods came and wiped them out.

Let's look at kinds of caves bats can occupy. What I'll say about caves also applies to mines in some parts of the country. In places like Wisconsin, Minnesota, Michigan, and a number of western states, geothermal heating, particularly in areas that have deep mines, can affect where bats roost. Fortunately, in most areas we don't have geothermal heating, and bat roosts in caves are found in predictable places.

These are models of caves I have visited. I'm sure that most of you are aware, that if caves do not have significant air circulation with the surface, the interiors approximate the mean annual surface temperature. You're probably also are aware that warm air is light and rises and that cold air is heavy and sinks. Depending on where caves are found, they may or may not be useful for bats. Most caves found far enough south and at a low enough elevation can be used by bat nursery colonies seeking warmth. When they are rearing young, only a few species of bats will tolerate temperatures as low as the upper 50°s. Gray Bats will tolerate those temperatures, but they'll choose a cave that's 80° anytime if its available over one that's in the 50°s. Growth rates of the young are significantly higher at higher temperatures, so bats like temperatures above 60°, usually the higher the better above 60° for rearing young. For hibernation most American bats prefer temperatures between 40° and 50°, some of them between 32° and 40°.

In the most southern areas, it may not make any difference what kind of air circulation a cave has, because the mean annual surface temperature ranges above 65°. Bats may be found in any number of places in such caves because of this warmth. You can find summer nursery colonies of bats in almost any cave as long as the cave is far enough south and at a low enough elevation to be warm enough to rear their young. Same thing is true about most caves in the north for hibernation. Once you get far enough north, mean annual temperatures drop so that on the northern edge of the United States, you've got temperatures between 44° and 50°. Bats can hibernate in them wonderfully, but cannot use them for rearing young.

Blowing Wind Cave in Northern Alabama, is one of the best bat caves in America. It has the largest maternity colony of Gray Bats, probably numbering at one time over 1/2 million. It also has the southernmost hibernating population of Indiana Bats and it also used to have the southeastern Big Eared Bat. This cave has passages up to sixty or seventy feet in diameter. When the temperature outside is the same as the mean annual surface temperature you get no noticeable circulation out of either entrance. However, the further the outside temperature deviates from the mean annual surface temperature the stronger the air flows through its entrances because of the chimney effect between the two entrances. If the air gets very cold, you get warm air rushing out of the upper entrance. And contrary to all normal expectations there is such a vacuum created by the warm air flowing out that cold air is pulled into the lower entrance so strongly that even with a mean annual surface temperature of 65°, this cold wind produces temperatures below freezing deep inside the cave. In the summer you get a huge draft of cold air exiting the lower entrance. People used to park house trailers out in front of it for the natural air conditioning of cold air during the summer. In summer, warm air is sucked into the upper entrance and the summer nursery colony of Gray Bats benefits from 80° roost temperatures. Several years ago I was in this cave with the Southeast Regional Director of the Fish and Wildlife Service trying to convince them to save and protect the site. I was using a digital readout thermometer to find this connection, it's not quite as easy as it looks on the map. We got to the point where the cold air comes up, and there's actually a little side passage that goes down into a room. I was standing there and I said to myself, "My God, for all the years I've been coming to this site studying the Gray Bat summer colony, it never dawned on me that this also could be a winter hibernating site." But given this cold air that's coming up from below here, there should be a cold air trap that might be ideal. I asked, "Do you mind waiting five minutes while I go check that?" He said, "OK". Five minutes later I was back reporting the southernmost hibernating population of Indiana bats. Its that predictable once you know how cave contours effect air flow and the temperature.

This slide illustrates the typical cold air trap cave that hibernating Gray Bats select in the south. The chimney effect and large volume allow cold air to be trapped and held. Gray Bats enter hibernation in September when the temperature outside is still eighty to ninety degrees.

Even at summer sites, things can be very predictable if you understand bat needs. Hambrick Cave, also in northern Alabama, houses a quarter of a million endangered Gray Bats.

There is water in the cave so evidence on the floor of the guano would be washed out right away. I banded and studied these bats for years, but after I left the area, the colony was lost within two years due to disturbance of people bringing their boats on up, going in, and even building fires.

I did not know that the colony had been lost. I discovered the problem because Gray Bats are extremely loyal to their hibernating sites. Once they go to a certain site, they rarely switch. When banded individuals failed to return to their hibernation site over a period of two years, I went to see what was going on and found no bats left at the summer cave. Had they merely relocated to another summer cave, they still would have returned to their hibernating site. The banding results document that the displaced summer colony died from the human disturbance and did not just go elsewhere.

The TVA built a fence around the front of the cave and within just 15 years, we've now reestablished a colony bigger than I was studying before the disturbance led to the bat's demise

There are many ways to protect caves now. We have to be careful about the kinds of devices we use in caves, but clearly if Hubbards Cave in Tennessee can be protected almost any cave can. The gate to this cave, I'm told, weighed something like one hundred tons. Quite a feat to protect this site.

Some cave and mine entrances aren't very large. At a small and unstable mine entrance owned by the Homestate Mining Company, a gate could not be built in the entrance. So they shoved large concrete blocks inside and put a gate between the blocks. One reason the bats have tolerated the gate so well is because the gate is back in a ways from the entrance. The closer the gate is to the entrance the worse it is for bats. With the gate at the entrance, screech owls and every kind of visually orienting predator can just sit there and catch bats as they slow down to enter. The further in you go, the more narrow a diameter the bats will tolerate because the predators are not such a threat. Typically, Gray Bats will not tolerate gates at nursery caves, but will at hibernation caves. However, there are known cases where gates at nursery sites have been tolerated if the gates were beyond the twilight zone where much of the predator problems were eliminated.

Big Eared Bats are quite tolerant of gates. They're very agile flyers and they typically live in rather small colonies. The bigger the colonies a species forms, the less likely it is to tolerate a gate in a nursery cave. Too many predators are attracted, and they build up night after night to take advantage of this consistent food source. At hibernating sites the bats arrive in the Fall and leave in the Spring, and the predators don't have a chance to build up.

Unfortunately, many U.S. bats don't tolerate gates or at least the case is still out on them. I think we're getting better and better with gates. I know Roy Powers has done a lot to improve designs and reduce costs. A bat, like the Mexican Free-tailed Bat, does not tolerate gates and probably never will, it's just simply not the kind of maneuverable bat that can negotiate through a gate. If the cave is big enough, sometimes we can build a half gate that people cannot climb over and leave the upper half of the gate for the bats to fly over. Alternatively, protection may have to be provided with a fence and signs. I would always emphasize friendly signs. A sign should first appeal to the reason of respectable humans, but include a warning that applies to the others.

Fortunately more and more people, especially those who explore caves are becoming more concerned about bats, so it's much easier to gain protection these days without conflict or vandalism.

In Austin, Texas we have a perfect example of people living in harmony with bats. When bats first moved into 3/4" wide by 16" deep crevices in the underside of the Congress Avenue bridge over Town Lake, people were just aghast. National news media said that hundreds of thousands of rabid bats were invading and attacking the citizens of Austin. Today, the people of Austin value those bats tremendously. They know that the bats eat about 14 tons of insects a night, and these bats have become one of the top tourist attractions of Austin. Thousands of people come from all over the U.S. and even foreign countries to enjoy bat watching and from my experiences, you cannot see a more spectacular wildlife event, not even at Bracken Cave. No photograph I've ever taken can do it justice. They're just phenomenal. You can see up to seven columns of bats coming out of the bridge on a good night. The people of Austin have learned to live with bats and so can the rest of the world.

We now are offering workshops. We'll be providing six this summer, three in the West and three in the East, where we train wildlife biologists as well as the private conservationists in how to conserve, manage, and study bats. This is really making a big difference, and I'm really excited about this new program.

Scott Altenbach, who is here in the audience, will be helping us with some of our workshops, and we'll be doing one with Mary Gilbert of the BLM. These workshops can make a difference with all kinds of subsequent, spin-off effects. For example, a Japanese math professor spent almost all of last summer helping the Coconino Forest find where their bats live. We had a cooperative project there last summer with Arizona Game and Fish, the Coconino Forest and Bat Conservation International. We had a whole team of trained volunteers. There wasn't a biologist or a state or federal person there who didn't say, "My God, these are the best volunteers we've ever seen". And that's what colleagues like Ted Fleming have had to say, too. These are wonderful people who are willing to come and donate weeks and months at a time to help. We really did make a difference documenting these bats' roosting needs for the first time. This is already making a big difference in helping forestry people plan management that includes bats for the first time. I suggested that we should give these people a day or two off occasionally, however, the state biologist called them up later and said, "Let these people have a day or two off occasionally? We can't get a moment or two to go home and see our families. They give us a hard time if we leave for an evening on a weekend."

Finally, I would be remiss if I didn't point out just how important cavers can be in conserving bats. In many cases and in many places I hear about the worst things that biologists have done to cavers and the worst that cavers have done to biologists, but unfortunately we far too seldom hear about the wonderful cooperation that is occurring between biologists, conservationists, and cavers. At Hubbard's Cave years ago, cavers drove in from five states, weekend after weekend, to design and build a huge gate to protect bats. Has it really made a difference? About twenty years ago Wayne Davis, co-author of Mammals of Kentucky, predicted that the Gray Bat would soon become extinct. Well, what's happened? Years later we have hundreds of thousands more Gray Bats than when he predicted that they would become extinct. Why? I know of absolutely no reason that can even remotely account for it other than protection efforts at key sites, combined with collaborative efforts where cavers and biologists have exchanged lists of bat caves. Cavers and biologists no longer can afford to hide knowledge from each other. Eventually we discover each others treasures and then we do nothing but fight and clash. We might as well just open up to the fact that we're all going to discover them eventually and it's going to work out a lot better if we share our information and work together. In my experience this has really worked over the last 15 years and there's no better evidence today than the hundreds of thousands of Gray Bats in the United States that have been restored in large part because of cooperation between caving groups, conservationists, and land managers. There is a tremendous amount that we can do to save our bats. I don't know any area where we can make a bigger difference, nor one where our help is more urgently needed, especially where mine closures are occurring. Without prompt action, one of our most abundant bats, the Little Brown Bat, may have to be declared endangered in just a few years because of careless mine closures alone, if bats are not protected. Literally millions are being buried without us even knowing that they exist. That's why I found it so timely to come here today. And so I hope that each one of you who hasn't already, will want to join us at Bat Conservation International in making every possible effort to ensure the future for these masters of the night sky. Thank you!

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