Memorandum

• State Parks •

Arizona State Parks

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To: Jean Emery
Chief of Resources Management

From: Rick Toomey
Cave Resources Manager
Kartchner Caverns State Park

Date: October 1, 2003

RE: Kartchner Caverns 2003 Environmental and Research Report

The past year has seen much continued activity in improving our understanding and environmental protection of Kartchner Caverns. I continue to be involved in a variety of activities related to improving the environmental protection of Kartchner Caverns. These activities relate to 1) continuing to assess the environmental state of the cave; 2) developing improved monitoring of the cave, cave resources, regional caves, and related surface environments; 3) analyzing threats to the cave environment and recommending mitigation or avoidance strategies; and 4) improving our interpretation of the cave. Attached is my report on these activities and observations entitled *Kartchner Caverns 2003 Environmental and Research Report*.

Although it is impossible to cover the full range of cave protection, operations, and research issues on which I have worked over the past year, in this report I highlight some of the most important and far-reaching ones. In particular, I have addressed aspects of cave environment and climate, scientific oversight and advising, bat usage of the cave and park, biology (including algae and bacteria), geological studies, surface land use issues, cave protection during tours, Big Room development and planning, and inter-agency outreach and cooperation. Although I have been in my position for two years, many of the report's conclusions remain preliminary and many of the projects to improve monitoring are still under development. However, I feel that it is important to provide you with even preliminary interpretations, in order to begin discussion of potentially important issues. Likewise, I am including descriptions of on-going projects so you can see the directions of my continuing efforts.

As you might anticipate, each of the major areas with which I will be dealing in this report is complex. The information provided in this report is a fairly simple and generalized treatment of each subject. Full treatment is beyond the scope of this report. I would be happy to prepare individual reports on these or additional issues, if the Board would like.

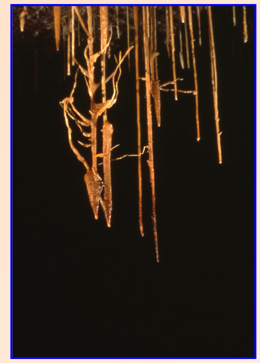
Overall, the environmental health of the cave is very good for a show cave. This is the best we can reasonably hope to achieve. Development and tourism almost always results in significant alteration of the cave environment. Kartchner Caverns is not an exception to this; although the degree of alteration is lower than is often seen. We must continue to work to guarantee the changes we have made minimally interfere with the natural functioning of the cave.

Although issues that raise concerns for the cave come up regularly, ASP staff (at KCSP, in the regional office, and in Phoenix) continually work to address them. I am pleased with the level of support that I have had in working to protect and conserve Kartchner Caverns. I believe that we will make progress on addressing existing areas of concern. I look forward to another successful year and hope to report next year that the cave remains in good environmental health.

Enc.

Kartchner Caverns State Park

2003 Environmental and Research Report



During the past year I have been involved in numerous activities devoted to the scientific study and monitoring of the environmental condition of Kartchner Caverns. Many of these are activities that have continued from the previous year (discussed in the 2001-2002 Report). In addition, we have undertaken some new initiatives as well. Overall, my work has consisted of analyzing data derived from cave monitoring, improving monitoring systems, providing expertise on issues related to the operation and continuing development of Kartchner Caverns as an Arizona State Park, and working with scientists from other agencies to promote further understanding of Kartchner Caverns, its processes and development.

My job as Cave Resources Manager involves working with numerous people from within State Parks and from outside agencies. I work in close cooperation with Dick Ferdon, Park Manager, Ginger Nolan, Head of the Cave Unit, Kelly Jackson, Head of the Discovery Center Unit, and the personnel of each of those units. It would not be possible for me to personally gather all of the data used in this report. In addition, I work with numerous scientists and resource managers from other agencies. So, although I am the author of this report, protecting, studying, and monitoring the cave must really be viewed as a team effort. This report is just one product of this effort. Another is the protection of the cave itself. And a third product is the scientific and management information and analysis that has been derived from work at Kartchner Caverns State Park.

This report summarizes activities that we have undertaken and the results of some of those activities under the following topics:

- Cave Environment and Climate – Data Collection and Analysis
- Biology Studies (Including Algae and Bacteria Control)
- Geological Studies of the Cave and Park
- Bats in the Cave and on the Park
- Establishment of a Scientific Oversight and Advisory Committee
- Protection of the Cave during Tours
- Big Room Issues and Activities
- Surface Land Issues Potentially Impacting Cave Resources
- Exploration of Interagency Outreach and Partnering Opportunities
- New Scientific Publications and Presentations on KCSP

Rickard S. Toomey, III, Ph.D.
Cave Resources Manager
Arizona State Parks

Although I have been on staff for more than two years, some of the efforts outlined below are still in their infancy. The reasons for this include that many of the projects take time to develop, that we continue to begin new projects, and results of work continue to drive us to ask new questions. Scientific conclusions based on the collected data are in many cases preliminary and are in some cases premature. Analysis continues as monitoring and management measures stabilize and take hold.

Cave Environment and Climate

Activities and Observations:

- **Continued to upgrade monitoring systems for cave climate.**
- **Identified sources of more sophisticated cave environmental monitoring equipment and continued study of advanced systems.**
- **Upgraded surface weather monitoring station at the Park.**
- **Re-establish two former deep cave Environmental Monitoring Stations using data loggers.**
- **Installed meters to quantify energy input into cave.**
- **Provided assistance in radon licensing process.**
- **Continued monitoring and assessment of cave carbon dioxide levels.**
- **Conducted daily, ongoing analysis of collected data.**
- **Initiated planning for a regional cave climate monitoring network.**

The first portion of this section contains a summary analysis of the data on cave climate and my observations about the significance of the data. More in-depth descriptions of the activities listed above follow that sub-section.

- **Continuing Analysis of Collected Data to Date**

An initial discussion of the changing cave climate of Kartchner Caverns was included as a supplement to the 2001-2002 Cave Resource Managers Report. This year's report continues the analysis of the changing climate based on both another year of data and on data from additional data sources. This supplemental data clarifies some of the interpretations in the 2001-2002 Report; however, it also complicates some of the interpretations.

As noted in the discussions of cave monitoring in both the 2001-2002 and this report, the monitoring system at Kartchner Caverns has been improved through the addition of data loggers such as HOBO temperature data loggers and of several new monitoring stations. However, this report relies heavily on the data that is measured weekly by the Cave Unit at Environmental Monitoring Stations throughout the cave. The reason is that it is the body of data that spans the entire period of record. That is, it is the only set where we can truly compare data from before, during, and after development without complications that arise from comparing different data collecting methods. These data are also all calibrated against a single thermometer, so they are easily compared. Although we are beginning to use the data from data loggers for specific questions, these data do not yet comprise a complete and solid dataset for the type of analysis that is appropriate in this report.

The data collected from the cave since 1988 indicate that changes in the cave microclimate have occurred and are continuing to occur. While some of these changes appear to be tied to the development of the cave, others appear to reflect regional warming and on-going drought conditions. The analysis of the additional year of data from Kartchner, as well as, additional data from other caves and from non-cave sources strongly supports this conclusion. Sorting out the various contributing causes to these changes remains elusive. Some of the factors are probably anthropogenic (human-caused); others are the result of natural processes. Still others may result from the interaction between development and natural changes. This report presents a summary of some of the data collected during the past year. It also contains some interpretation of that data and recommendations for further study.

In order to facilitate comparison with last year's report, I have maintained some of the conventions from that report. I will first present individual discussions of several areas of the cave, using the same areas used last year. Following the discussion of patterns in individual areas is a review of environmental changes seen in a few other caves in southeastern Arizona. I have also integrated local and regional data that help interpret the changes seen at Kartchner. These data provide a comparison by which to assess the possibility that some of the changes at Kartchner Caverns reflect regional changes.

The following pages provide information on the climate change exhibited by three different areas of the cave. **Figure 1** shows the current configuration of the basic Environmental Monitoring Station network being used in the cave. A network of stations is important because different areas of the cave show different patterns of cave climate change. The differences relate both to inherent differences in the areas and to their different histories of usage. The areas that will be discussed in detail in this report are Echo Passage, Cul De Sac (CDS), and Lower Throne (see **Figure 1**). These three areas were chosen to allow comparison of areas greatly affected by development with areas less affected. Echo Passage is an undeveloped area of the cave; Cul De Sac (CDS) is an area of the Big Room; and Lower Throne is in the portion of the cave that is currently open to public tours. Cave climate data has been collected at each of these stations from 1988 to the present.

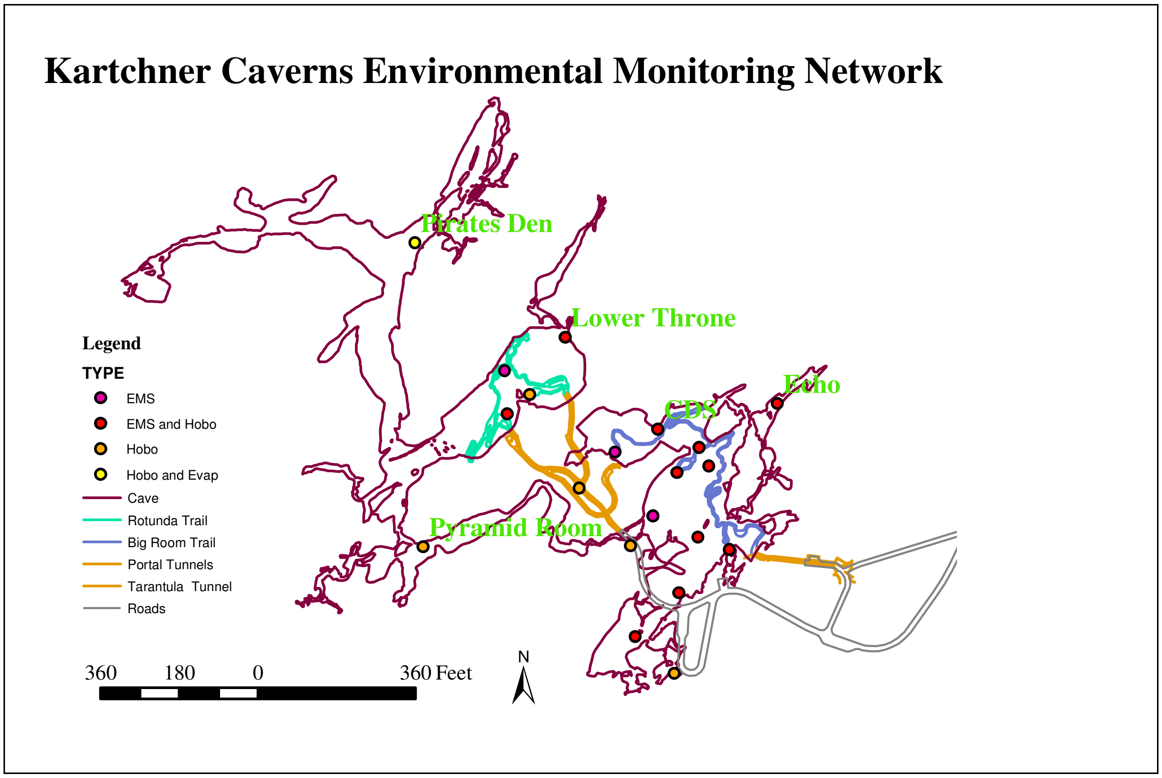


Figure 1 -- *Map of Kartchner Caverns showing locations of the currently active environmental monitoring stations. The stations mentioned by name in this report are labeled in green.*

Discussions of cave climate focus generally on measures of cave temperature and moisture. The temperature measure used here is air temperature, while the measure of moisture is relative humidity. **Figures 2, 3,** and **4** summarize the temperature and moisture histories at the three stations. Each graph shows the air temperature at an environmental station (small beige diamonds), a five-reading moving average of the air temperature (red line), the relative humidity at the station (small blue squares), and a five-reading moving average of the relative humidity (blue line). Because the individual data vary from reading to reading, the moving averages provide the most straightforward tracking of temperature and humidity.

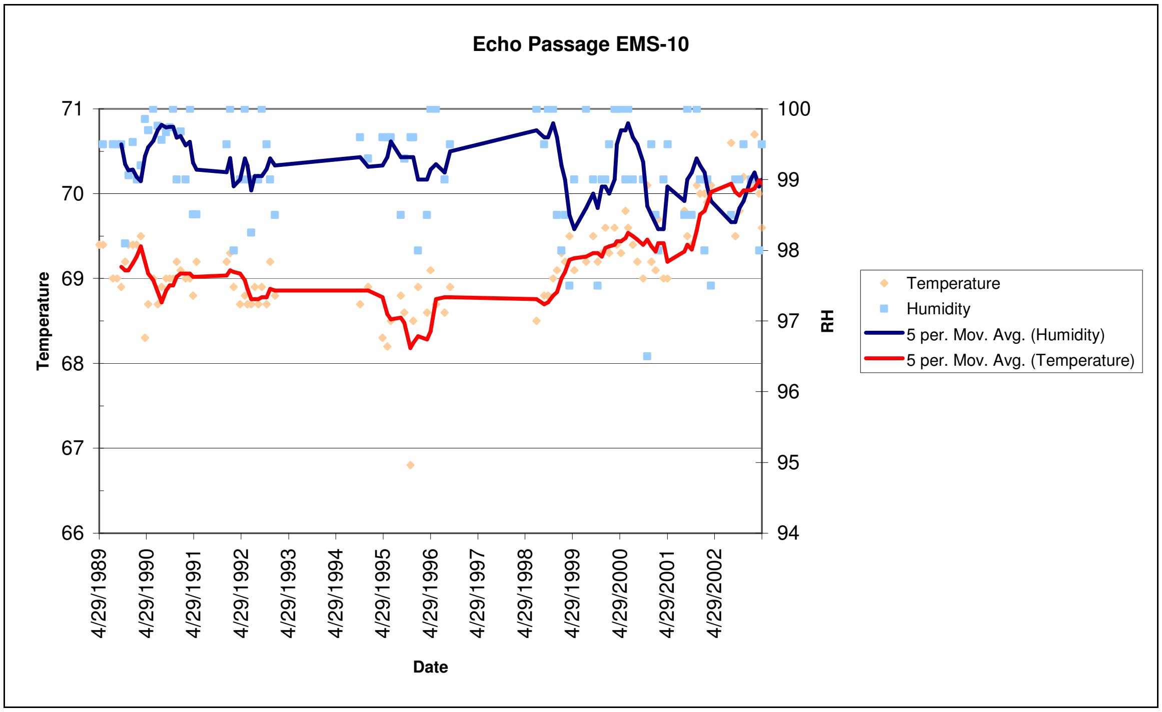


Figure 2 -- *Temperature and relative humidity data and trend at the Echo Passage environmental monitoring station (EMS-10).*

Echo Passage

Figure 2 shows the climate data from the environmental monitoring station in Echo Passage. This station is the existing deep-cave station that is farthest from current development impacts or visitor tours (**Figure 1**). The data suggest a small change in temperature or humidity has occurred in this area. The temperature during the development phase (October 1998 to present) shows a small increase (about 1ºF compared to pre-development temperatures). This value represents a continued increase from the temperature of this area in the 2001-2002 report. However, the rate of increase appears to have leveled and the amount of rise is only about 0.15º Fahrenheit. The humidity shows a small but statistically significant decrease during the period of development (from a mean relative humidity of 99.3% from 1989-1998 to a mean of 98.9% from 1999 to the present; unpaired, one-tailed, heteroscedastic, t-test probability p = 0.003), and it shows somewhat greater variability in humidity from reading to reading (1989-1998 standard deviation 0.57 to 1999-2003 standard deviation 0.83). The mean humidity has been reasonably stable between the 2001-2002 report and the current report as exhibited by the fact that the 1999-2002 mean and 1999-2003 mean are virtually identical. Overall, this station shows relatively little change in temperature and relative humidity from pre-development to the present.

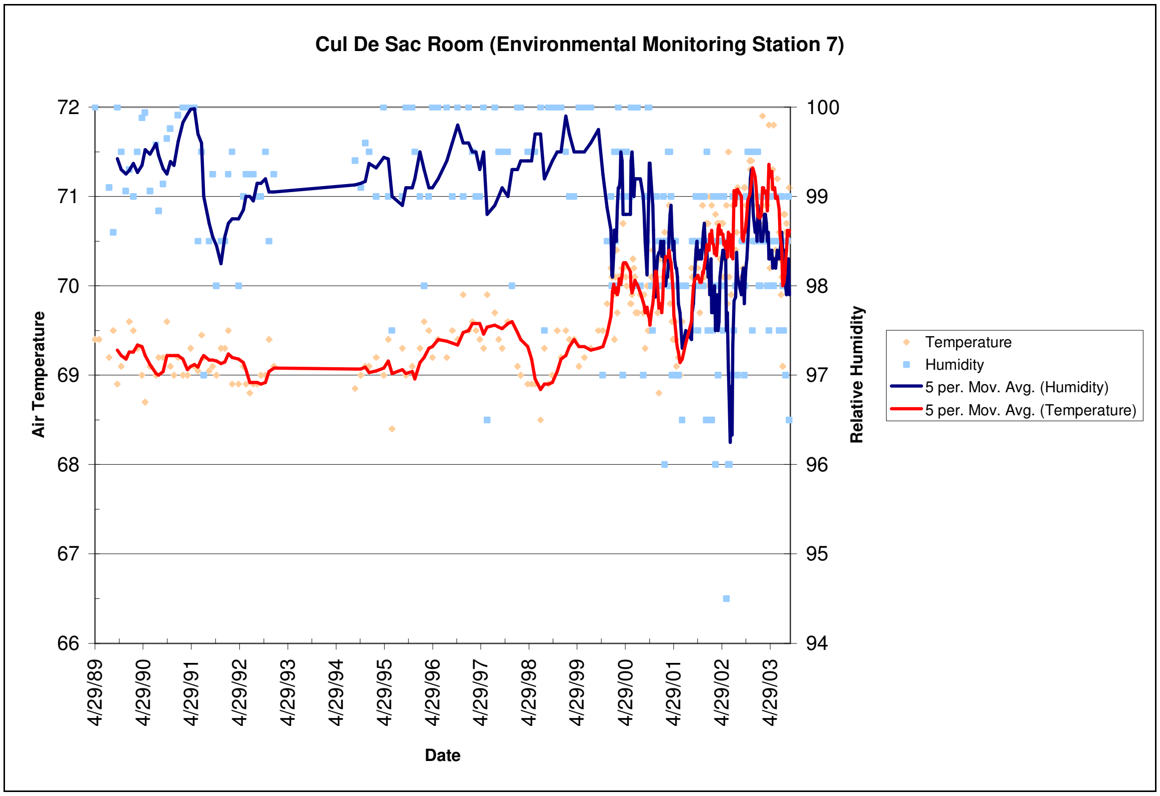


Figure 3 -- *Temperature and relative humidity data and trend at the Cul De Sac environmental monitoring station (EMS-7).*

Cul De Sac

The Cul De Sac environmental monitoring station shows a somewhat larger change in temperature and humidity (**Figure 3**) than seen at Echo Passage. This station is near the trail being developed in the Big Room complex, a portion of the cave that will soon be open to the public. This station is experiencing cave activities associated with development (development lighting and personnel levels, construction, concrete pours), but not with tours (tour style lighting and visitation levels). The data from Cul De Sac shows an approximate 1.5º Fahrenheit rise in temperature since the beginning of 1999; however, that trend showed some reversal this year. Between the 2001-2002 report and this report no significant rise was noted.

An important difference between the Cul De Sac and Echo Passage trends is that the temperature change in the Cul De Sac is accompanied by a larger change in humidity as well. Between 1989 and the end of 1998, the humidity at the station had a mean of 99.28% (standard deviation 0.73%). Since the beginning of 1999 the humidity at the station has been generally lower and more variable (mean 98.39%; standard deviation 0.96%). The decrease in relative humidity at this station between these periods is statistically significant (unpaired, one-tailed, heteroscedastic, t-test probability $p = 2.9\times10^{-13}$). As with Echo Passage, the humidity trend has been relatively stable since the 2001-2002 report; the mean and standard deviation of the humidity from 1999-2002 and 1999-2003 are the same. Other environmental monitoring stations with temperature and humidity trends similar to the Cul De Sac station are Kartchner Towers and Big Room

Overlook. The stations at Sharon's Saddle and Main Corridor exhibit trends between those of the Echo Passage and Cul De Sac stations.

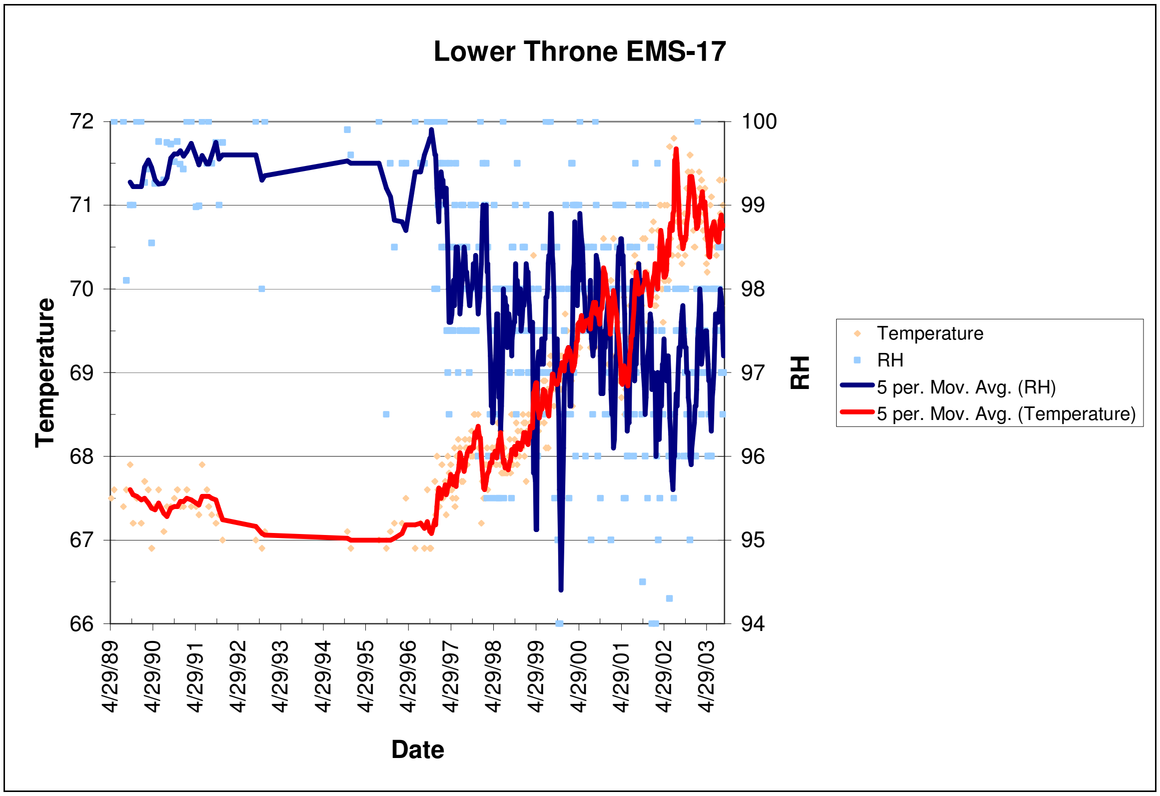


Figure 4 -- *Temperature and relative humidity data and trend at the Lower Throne environmental monitoring station (EMS-17).*

Lower Throne

The Lower Throne environmental monitoring station continues to show notably larger changes in temperature and humidity than are found at the stations discussed earlier (**Figure 4**). This station is in the Rotunda-Throne Room section of the cave. This station has been subject to changes associated with development (development lighting and personnel levels, construction, concrete pours) and those impacts associated with tours (lighting and visitation levels). The graph of the data from Lower Throne shows an approximately 3º Fahrenheit rise in temperature between the beginning of 1997 and the present. The temperature rise peaked with a running mean of approximately 71.6º Fahrenheit (approximately 4º Fahrenheit degrees warmer than the pre-development levels) early in the summer of 2002. However, the trend has reversed somewhat since that peak and the mean temperature at the station is now around 70.8º Fahrenheit. Accompanying the temperature increase at this station is a decrease in humidity. Between 1989 and the end of 1996 the humidity at the station had a mean of 99.43% (standard deviation 0.71%). Between the beginning of 1997 and the present, the humidity at the station was generally lower and more variable (mean 97.47%, standard deviation 1.34%). The drying trend has continued in the past year; the mean from 1999-

2003 fell slightly (approximately 0.1%) compared to that from 1999-2002. The difference in the humidity between two periods (1989-1998 and 1999-present) remains highly significant statistically (unpaired, one-tailed, heteroscedastic, t-test probability $p=3.9x10^{-17}$). The station in the Rotunda continues to show a similar record of environmental change to that shown for Lower Throne station. The temperature rise at the Rotunda station since the beginning of 1997 is approximately 4º Fahrenheit; this rise is slightly larger than that at the Lower Throne station. Like the Lower Throne, the temperature peaked in June 2002 (at approximately 5º Fahrenheit warmer than predevelopment levels) and has cooled about 0.5º Fahrenheit since that time. The humidity change is less pronounced in the Rotunda than in the Throne Room (1989-1996 humidity mean 99.26%, standard deviation 0.87, 1997-2003 humidity mean 98.44%, standard deviation 1.29). The humidity difference in the Rotunda between these two periods, although smaller, is still highly significant statistically (unpaired, one-tailed, heteroscedastic, t-test probability $p=1.4x10^{-10}$).

Analysis of factors contributing to temperature and humidity change

The data indicate recordable and statistically significant climate change in portions of the cave that are coincident with the beginning of development and the opening of the cave to tours. At this point, the change appears to be somewhat localized; that is, the areas with the most development and tour-related activity show relatively larger changes than in those areas more peripheral to these activities. However, at least some change is evident in all monitored areas of the cave. For the continuing management of the cave it is vital that we attempt to understand the source of the observed temperature and humidity changes.

Two basic classes of mechanisms (or a combination of them) may be responsible for the changes observed in the cave. The first class would be anthropogenic (human generated) causes related to the development of the cave. This class would include various factors that increase the amount of energy in the cave (and thus raise the temperature and increase evaporation of available water). Among these factors would be metabolic heat generated by humans while in the cave, heat from the lighting systems used in the cave, heat from the hydration of concrete. Anthropogenic causes could also include changes that affect the airflow in the cave to either increase temperature or allow the loss of moisture. This could include leaking of air through airlocks and tunnels. The second class of mechanisms would be local, regional or larger scale natural factors, changes, and trends that may be reflected in the microclimate of the cave. These factors, changes, and trends might include such things as regional warming and major droughts. Identifying the influence of each class of mechanisms at Kartchner is important for understanding the changes we see and to determine what our future course of action should be. Several approaches to data analysis can be combined to help determine whether regional climate change, anthropogenic changes related to development, or both are responsible for the change seen in the Kartchner data.

The first approach is to examine patterns within the Kartchner data to see if they are consistent with any one cause. Using this approach alone suggests that development is overwhelmingly the cause of the observed changes. The timing of the changes corresponds with the timeframe of development. That is, the changes seem to start at about the same time the tunnels (and subsequent development) were completed (**Figure 2,3,4**). In addition, the pattern of change (larger amounts of change in more developed areas) also supports the conclusion that the observed changes are related to development. This conclusion is basically the one that I came to in preparation of the 2001-2002 report.

However, if we also compare the data from Kartchner to a larger regional data set, the conclusion is a bit more complicated than presented in the 2001-2002 report. The regional data set includes limited data on the temperature (four caves) and humidity (two caves) of several caves in the area; water levels from four wells near Kartchner Caverns; and the temperature data from the KCSP weather data. These four data sets show that at least some of the climate change observed in the Kartchner Caverns record is probably related to regional (or larger) scale climate patterns.

Jerry Trout, USDA-Forest Service, provided limited temperature and humidity data on several caves in the Coronado National Forest in southeastern Arizona. The four caves are Whetstone Cake Cave #1, Whetstone Cake Cave #2, SP Cave, and Cave Mine Cave. They are all located in Cochise County relatively near Kartchner Caverns (Figure 5). Whetstone Cake Cave #1 and #2 are small caves (300-450 feet long) with relatively large entrances in the Whetstone Mountains above Kartchner Caverns State Park. They are not very good analogues to Kartchner Caverns, because their small size and large entrances result in large seasonal differences in temperature. However, they do provide data from non-park caves that are near the park. Cave Mine Cave and especially SP Cave are much better analogues for Kartchner Caverns. They are each relatively extensive caves with somewhat restricted entrances. They are each located in the Huachuca Mountains near Sierra Vista.

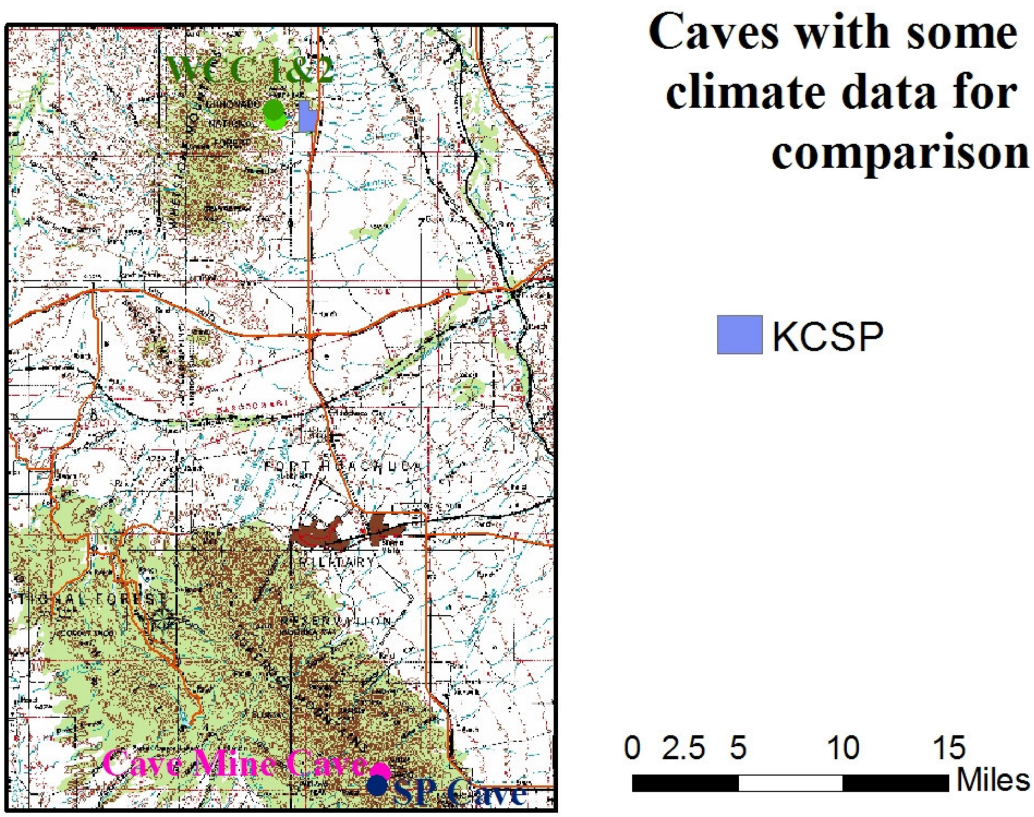


Figure 5 – *Location of Coronado National Forest Cave with climate data for comparison with Kartchner Caverns. The caves are Whetstone Cake Cave #1 and #2 (WCC 1&2), SP Cave, and Cave Mine Cave.*

The Forest Service has been collecting limited data on these four caves for approximately thirteen years. This data consists of quarterly to semiannual temperatures readings in each cave. In addition, quarterly to semiannual measurements of humidity were also made in both Cave Mine Cave and SP Cave. These data were not all taken by the same people or with the same instruments. However, the data comprise the only cave dataset that we currently have for comparison with the Kartchner Caverns data.

Figures 6 and **7** show graphs of the temperatures recorded in the four Coronado National Forest caves. In addition, the graphs show similar data from two areas of Kartchner Caverns (Echo Passage and Lower Throne). The two Kartchner datasets represent the range of climate change seen in Kartchner (as discussed above). For each of the datasets, a linear best-fit line has also been plotted. This provides an easy way to view the trend of the data. The graphs show that the cave temperatures show notable increases in each of the caves that have been studied. This is in spite of the fact that the other caves have not been developed in any way.

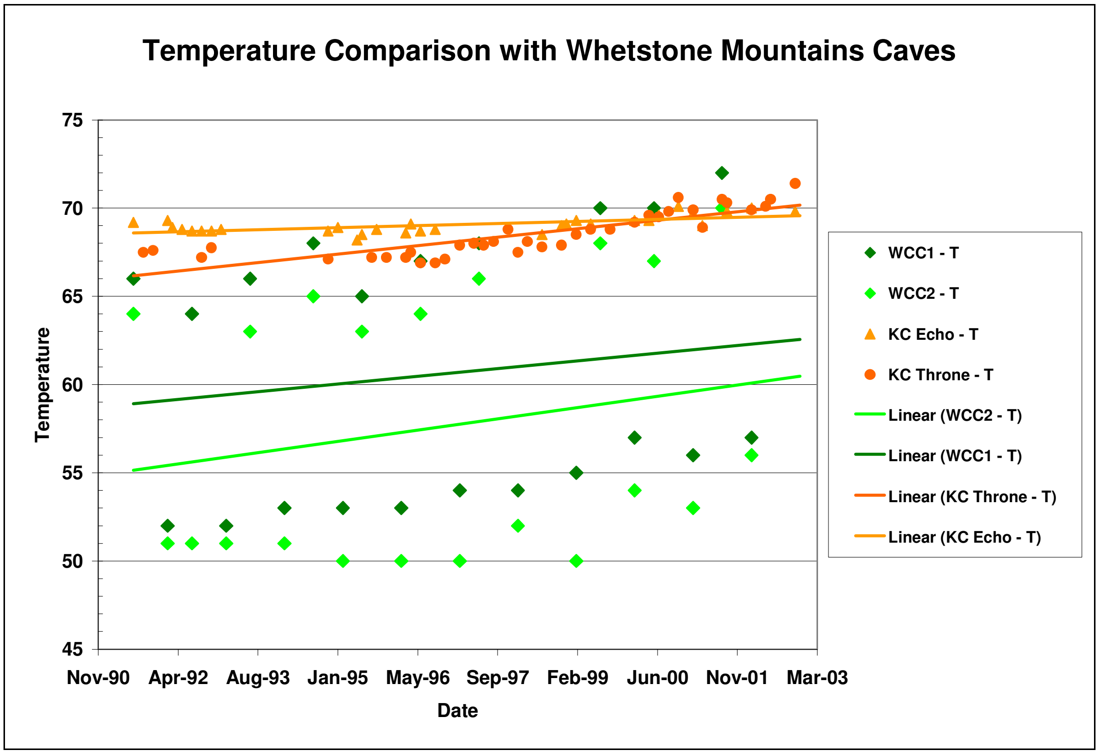


Figure 6 – *Temperature (and linear least squares best-fit lines for the temperature) of Whetstone Cake Cave #1 and #2 (WCC 1&2) and the Echo Passage EMS and Lower Throne EMS at Kartchner Caverns.*

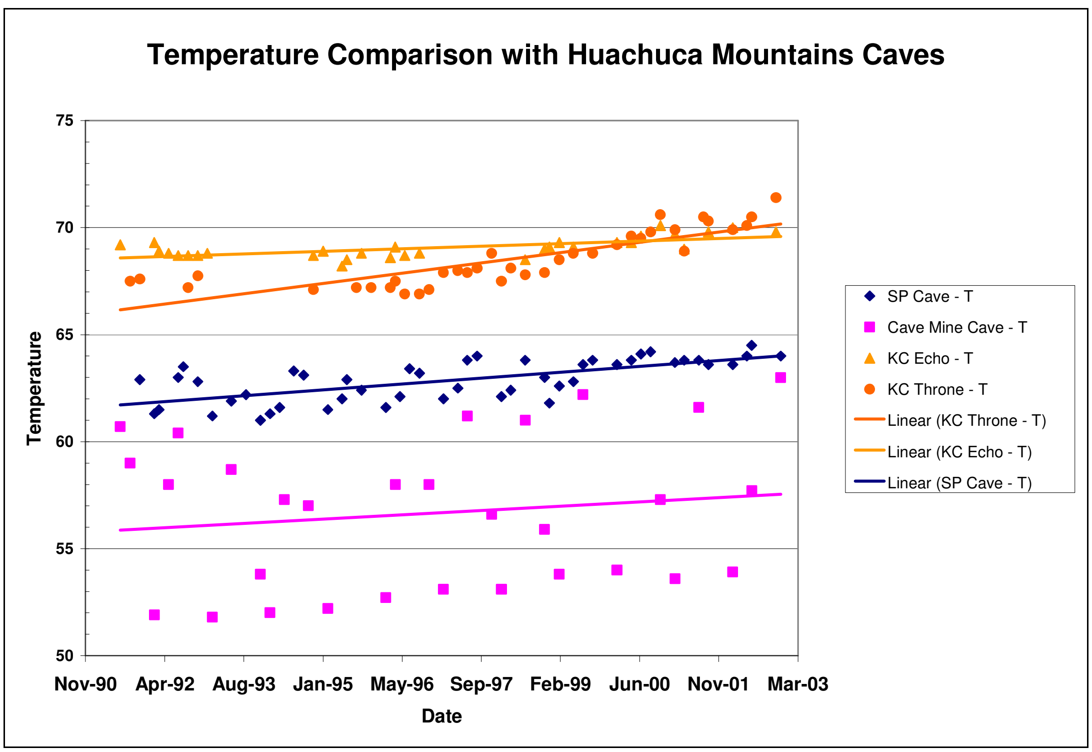


Figure 7 – *Temperature (and linear least squares best-fit lines for the temperature) of SP Cave, Cave Mine Cave and the Echo Passage EMS and Lower Throne EMS at Kartchner Caverns.*

Like the temperature record, the humidity records from SP Cave and Cave Mine Cave indicate that even non-developed caves in the region show climate change similar to that seen at Kartchner Caverns (**Figure 8**). Since 1990, the humidity measured in SP Cave has decreased to a similar degree as that measured in the Echo Passage. The humidity in Cave Mine Cave has decreased to even a greater degree than the humidity in the Lower Throne Room area of Kartchner Caverns.

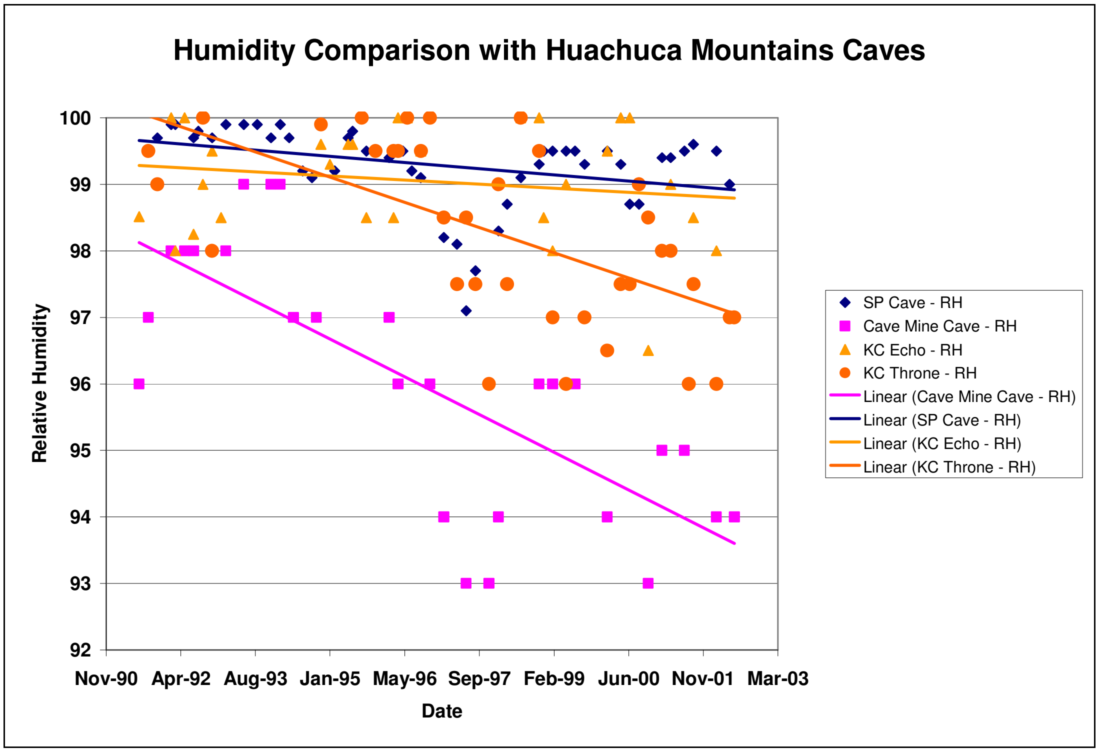


Figure 8 – *Humidity (and linear least squares best-fit lines for the humidity) of SP Cave, Cave Mine Cave and the Echo Passage EMS and Lower Throne EMS at Kartchner Caverns.*

Not only are the general trends of climate change in the non-developed caves similar to those seen in Kartchner, but also in some cases the details are similar as well. When the temperature and humidity records of SP Cave and Kartchner Caverns are viewed side by side (**Figure 9**), some striking similarities are evident. The timing of the warming trend is very similar in the two caves. In addition, details like the coincident drop in humidity in both caves in the 1996-1997 suggest that both caves are responding (at least in part) to regional climate changes.

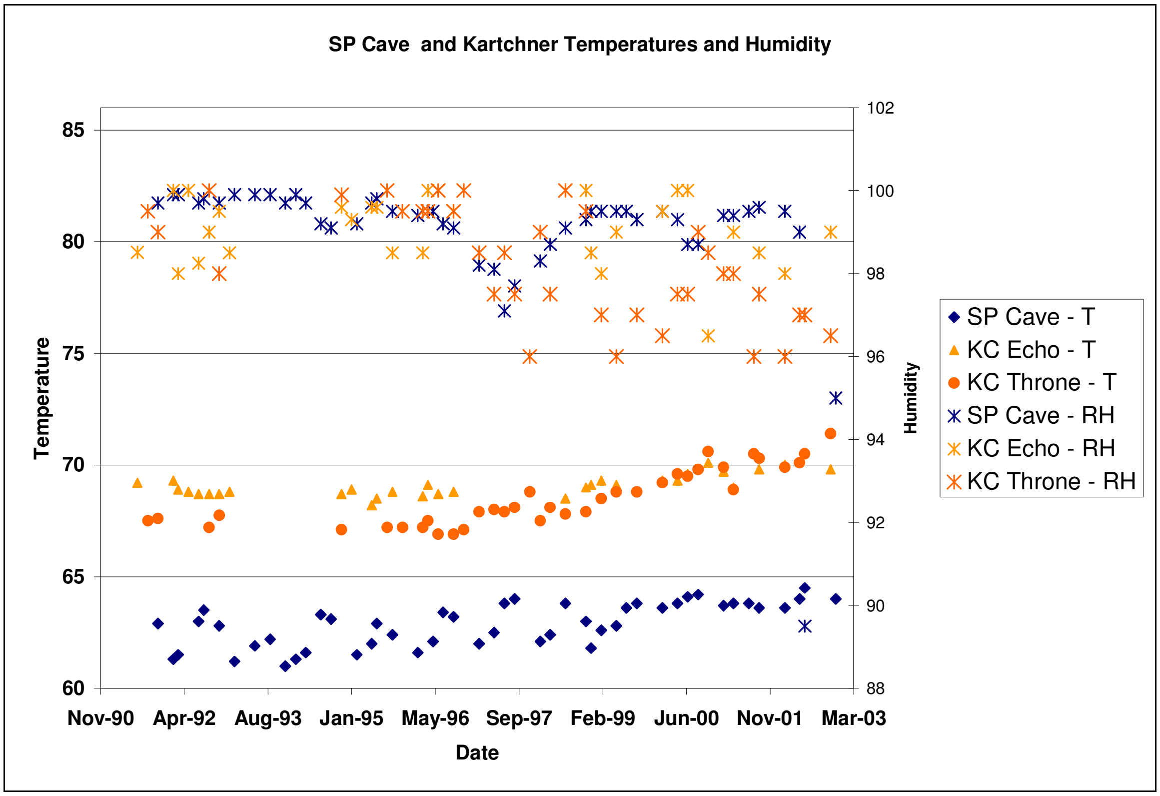


Figure 9 – *Temperature and humidity measurements from SP Cave and the Echo Passage EMS and Lower Throne EMS at Kartchner Caverns.*

An additional useful dataset for evaluating humidity change (and to a lesser extent temperature change) in Kartchner is water levels in wells on and near the park. The wells measure the level of the groundwater in the area surrounding the cave. The data that is most useful comes from wells such as the Kartchner, North, South and West Wells (as defined in the pre-development studies). These wells are shallow wells that sample water levels in the near-surface groundwater systems around the cave. In addition, they are not equipped with any kind of pumps, so they record natural changes in the water level that are driven by climate changes rather than changes in water use. None of the wells is in exactly the same perched aquifer as the cave (they are in surrounding alluvial aquifers); however, they still record the general area ground water responses to climate change. Since the cave water (humidity, mud, and pooled water) is also a portion of the local groundwater system, regionally controlled changes in it should be similar to those in the wells. That is, if the cave showed significant drying while the rest of the ground water system did not, it would be reasonable to attribute the drying to causes other than regional climate response. However, as **Figure 10** shows, this is not the case. The water level in all wells has been falling steadily since at least 1996. The water levels track the general drought conditions in the area fairly well as shown by the Palmer Drought Severity Index data in the graph. The fact that the wells track regional drought data is to be expected because the wells are from shallow aquifers with relatively small, local catchments. Like the changes at SP Cave and Cave Mine Cave this evidence suggests that the drying in the cave is, to at least some extent, the result of regional climate conditions.

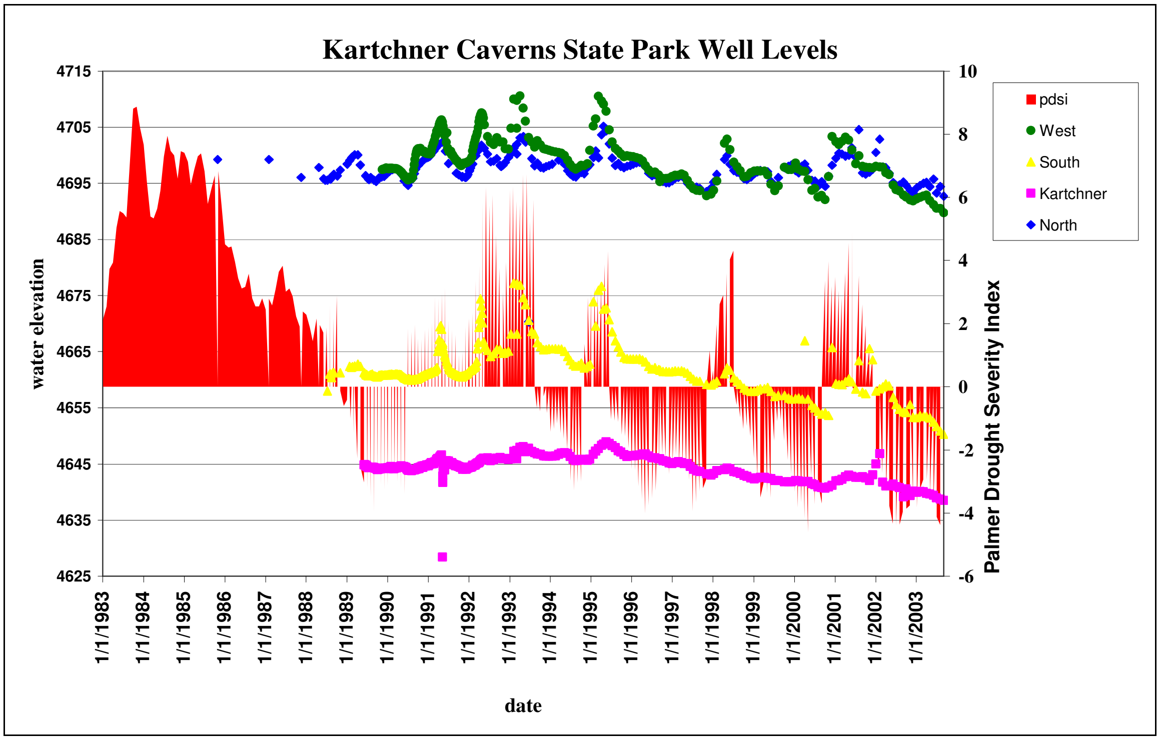


Figure 10 – *Water levels in unpumped wells around KCSP. These static levels represent the elevation of the water below ground. The higher the elevation the more water in the aquifer. As levels fall, this represents less water stored in the aquifer. In addition, the graph shows the monthly Palmer Drought Severity Index (PDSI) for the southeastern Arizona (NOAA-NSW AZ Region 7). The PDSI is an index of regional moisture conditions. Negative values indicate a moisture deficit, positive values indicate a surplus. Values below about -2 indicate significant drought conditions; values greater than about 3 indicate very moist conditions.*

An additional dataset that provides some information on possible regional ties to climate changes observed at Kartchner is the surface climate data for the park. The surface temperature of the area, as reflected by the mean daily temperatures recorded at the park's weather station between 1989 and 2003 has increased by about 3.5º Fahrenheit (**Figure 11**). The Kartchner site is not unique, National Weather Service data from Sierra Vista shows about 2º Fahrenheit warming and that from Tombstone exhibits about 1º Fahrenheit warming over the same period. The rise in the surface temperature in the area is potentially significant to understanding climate change in Kartchner Caverns. Although the temperature at Kartchner does not directly reflect the mean annual surface temperature (pre-development studies showed the cave temperatures to be a few degrees higher), it would be reasonable to expect that a rise in mean annual surface temperature to be reflected in a rise in the cave temperature.

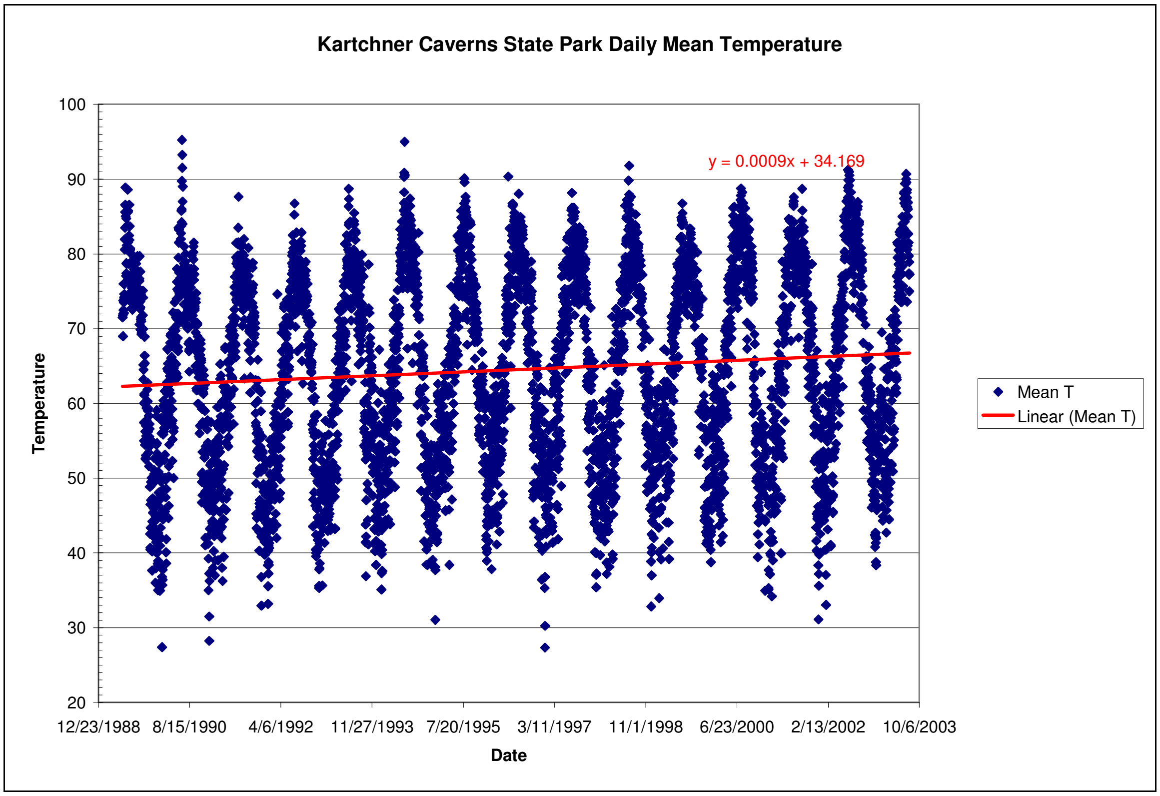


Figure 11 – *Mean daily temperatures (and linear least squares best-fit line) measured at Kartchner Caverns State Park weather station. The best-fit line demonstrates a trend toward rising surface temperatures at the park over the last 15 years.*

Together, the data on Kartchner Caverns' climate change from the cave itself and from other regional data sources indicates that the climate change seen at Kartchner is the result of both regional climate factors (probably both temperature change and drought) and development related activities. Although the regional datasets indicate a strong regional signal for the cave, the pattern of variation within the cave shows that a development signal is also present. The 2001-2002 Cave Resources Manager report discusses a number of possible ways that development may be influencing cave temperatures. It also discusses the ways that surface climate conditions (in particular drought) may affect cave temperature and humidity either directly or through interaction with development. The mechanisms discussed in that report continue to be likely mechanisms affecting the cave climate.

Significances of Cave Climate Change

Unfortunately, it is not possible at this time to determine what proportion of the temperature and humidity change seen in the cave is related to regional signal, what proportion is related to development, and what proportion is related to an interaction of these factors. If we were able to adequately separate these factors, we would be in a much better position to understand the observed climate change and to determine what actions ASP should take to deal with them. Unfortunately, development of the cave largely coincides with an apparent change in Arizona's climate to a drier mode. That has complicated the effort to separate the causes.

One approach to getting better data to separate regional responses of the cave from development issues is to develop a better set of data on the responses of other caves to the regional conditions. To do this we must work with other southeastern Arizona land management agencies (such as the Forest Service and Fort Huachuca) to develop a network of caves with microclimate data loggers to monitor changes in the region. We are currently working actively with these groups and with others in the area to develop such a network.

Ironically, recognizing that the change seen at Kartchner Caverns may be (at least partially if not largely) the result of regional climatic changes makes our job of conservation and protection much more difficult for several reasons. First, although it may be palatable to say that the changes we see are not our fault, this also means that we lack significant ways to reverse the changes. If we were able to identify the changes we see as caused by problems in development, we could try to take actions that would fix those development issues. We are not able to do the same with large-scale climatic patterns. Second, the regional changes could actually serve to mask changes that are caused by development. We cannot become complacent by saying that the changes are natural and beyond our control. To do so, we risk missing opportunities to fix problems that are the result of management actions. The mix of natural and development related changes also leaves us with an important dilemma from a conservation standpoint. How far do we go to mitigate changes that are a mix of regional and local developmental changes? Would it be both counter-productive and potentially damaging to the cave to mitigate natural changes artificially? Such a dilemma is not likely to be resolved soon, particularly since the on-going drought and warming are both conditions that may continue for an extended time.

The issues involving cave climate (and climate change) are complex, and it is difficult to address them fully in this type of report. Recordable changes have occurred in the cave microclimate since the beginning of development and the opening of the cave to the public. These changes appear to be related to regional climatic conditions, to development, and probably to an interaction of these factors. It remains unclear whether these changes have stabilized in the developed area or will continue to trend upward. Significant steps have been taken during the past year to improve our data collection and analysis processes so that sound science provides the basis for implementing effective mitigation measures, but we must continue to work towards a better understanding of the conditions at Kartchner and at other caves in the area.

- **Continued upgrading of data monitoring**

We have continued adding temperature and humidity data loggers to our Environmental Monitoring Stations (EMS). We also continue to use additional data loggers for supplemental monitoring (such as testing experimental modifications of areas and procedures, to look for air flow, and to test the effectiveness of modifications to the operations). We have added an additional Environmental Monitoring Station along the trail in the Big Room. It will provide additional data very close to the tour route. The current configuration of the backbone cave climate monitoring system is shown in **Figure 1**.

- **<u>Higher-precision monitoring system</u>**

Because of the great need for a more sophisticated, higher-precision monitoring system, I have continued investigating developing the specifications for such a high-precision, high-accuracy, data logging environmental system to track temperature, humidity, barometric pressure, and air movement in the cave. I have located several sources for systems that will monitor specific parameters of interest. We are working with HDS Systems of Tucson to develop a prototype for testing. In addition, we have identified other methods to measure some of these parameters, and we are continuing to investigate their feasibility.

The reasons that this effort has not proceeded further are numerous and relate to both cost and the many technical challenges involved with the effort. Developing a system that is capable of making the precision measurements needed in the cave environment (which is very unfriendly to electronics of all kinds) is difficult and expensive. Some of the potential off-the-shelf approaches are so inherently expensive that they are difficult to pursue. Alternatively, custom approaches require either large capital costs for development and testing, or they require protracted development schedules that trade time for cost.

- **<u>Surface Weather Stations</u>**

The surface climate in the area is important for examining several aspects of the cave environment. Surface climate is one of the important determining factors for the cave climate; in addition, it affects such parameters as radon and carbon dioxide concentrations in the cave. To improve our understanding of the surface climate, we have upgraded our weather monitoring activities at the park with the addition of a Davis Weather Station. We are also continuing to consult with University of Arizona and federal agency scientists to expand our coverage and to improve our capacities.

- **<u>Re-establishment of Remote Monitoring Stations</u>**

This past winter we re-established a temperature and evaporation monitoring station at Pirate's Passage and a temperature station at the Pyramid Room. These two stations are shown on the map in **Figure 1**. The temperature component of each of these stations is a HOBO temperature data logger. An evaporation pan provides the evaporation data at Pirates Passage. These two stations were among those removed after the pre-development studies, because of concerns that the monitoring of these stations required repeated staff travel through wet, muddy areas of the cave that would result in significant long-term impact. Because of the reduced in-person collection requirements of the data loggers, these re-established stations do not require frequent, damaging trips. Data from these stations will be useful in assessing whether climate changes in the cave extend to the more distant reaches of the cave.

- **<u>Installation of energy monitors</u>**

One of the most important artificial inputs of energy into the cave is the heat that comes from the electrical system (e.g. heat from lights, wire heating, and transformers).

Reducing excess energy input into the cave is one approach to minimizing the impacts of development and visitation. In order to do this, it is necessary to understand how much energy the electrical system is adding to the cave. To quantify the electrical usage in the cave, ASP has contracted to install electrical usage monitors on the circuits in the cave. The installation of these loggers is on-going. We are starting to get some preliminary data from these and we hope to begin analyzing the usage over the next year. These monitors will document energy inputs in certain areas, providing the basis for identifying areas where such energy inputs can be reduced. I am also working on modeling other factors that input energy into the cave and their contribution to the cave energy balance.

- **Radon licensing**

In 2002, the Arizona Radiation Regulatory Agency (ARRA) issued a radon license to ASP for development and operations. The University of Arizona Radiation Control Office has worked with ASP to develop a radon monitoring program and has agreed to oversee ASP's radon monitoring activities. Under the radon program, radon decay products are measured daily in several areas of the cave (both tour and development sections). This data is combined with amount the of time each employee or volunteer spends in the cave to quantify each person's radon exposure. That exposure is tracked by the Cave Unit, under the direction of Radon Safety Officer, Ginger Nolan, to ensure that no one exceeds recommended exposure levels.

The Occupational Safety and Health Administration Permissible Exposure Limit for radon is 4.0 working level months per year. Exposure is calculated using the average amount of radon decay products a person may be exposed to (such as the data shown in the graph above) along with the duration of the exposure to decay products. In 2002, the highest exposure level by a development worker at the cave was 2.071 working level months and the highest exposure level by an operations worker was 2.107 working level months.

Figure 12 shows the measured level radon decay products in the Imaginary Passage (on the current tour route) as an example. These levels are similar to those observed in pre-development studies.

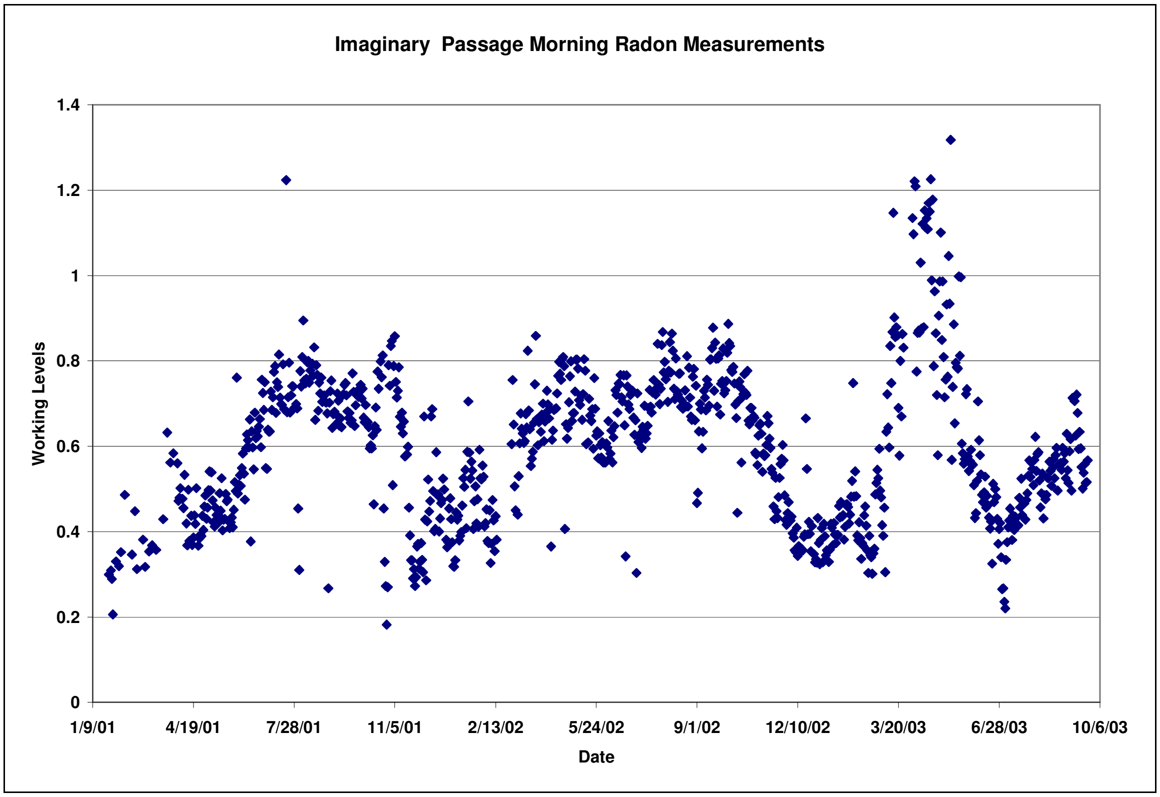


Figure 12 – *Morning radon decay products levels, expressed in working levels, in the Imaginary Passage, Kartchner Caverns.*

In January 2003, the ARRA inspected the Kartchner Caverns radon program and found it to be in compliance. ARRA advised us of means to ease program record keeping and Ginger Nolan and I are working with Computer Support to implement their suggestions. In consultation with The University of Arizona Radiation Control Office, is currently developing plans for continuing compliance monitoring of the Rotunda-Throne Room and for implementing radon monitoring of tour guides in the Big Room when it opens.

- **<u>Monitoring Carbon Dioxide Levels</u>**

Elevated carbon dioxide levels can affect the cave health by increasing dissolution of calcite, by slowing deposition of speleothems, and by encouraging growth of algae. Monitoring of carbon dioxide is accomplished by the cave unit using a Draeger pump system for spot measurements in developed and undeveloped areas. Current data indicates that carbon dioxide levels in Kartchner vary greatly in space and time and that they remain comparable to those obtained in the pre-development. Although we are examining the possibility of a more systematic and precise monitoring system for carbon dioxide, development of such a system remains a low priority, because we have no evidence that carbon dioxide levels pose a significant resources risk at Kartchner.

Using the Throne Room as an example, carbon dioxide levels, in general, are highest in the late summer and lowest in the winter and early spring (**Figure 13**). The reason for this is that the source of carbon dioxide in the cave is the soil overlying the cave. During the months that plant growth is limited (winter and early spring), less CO_2 occurs in the soil, and thus less CO_2 is transported into the cave. Conversely, when plants are more active (late summer and early fall) more CO_2 is in the soil and is transported into the cave.

Development and tourism in the cave may also cause a rise in the level of CO_2 in the cave, as a result of the exhalation of CO_2 from people working in or touring the cave. This exhaled CO_2 might theoretically cause an eventual long-term rise in CO_2 in the cave. However, data from predevelopment studies and present monitoring shows only a negligibly small increase in CO_2 levels in the Throne Room. Limited pre-development measurements showed the area to have a mean CO_2 level of 3125 parts per million (ppm) (range 1660-5400; standard deviation 1196 ppm); measurements during development and tours provide a mean of 3300 ppm (range 1000 – 6100 ppm; standard deviation 1595 ppm). The observed rise is not statistically significant (unpaired, one-tailed, heteroscedastic, t-test probability $p=0.69$) and is much smaller than the potential rise predicted in ACPI studies. If data from during development are ignored (comparing only pre-development with tours), the rise is slightly more pronounced (tour mean 3684 ppm; range 2000-6100 ppm; standard deviation 1461 ppm). However, this rise is also not statistically significant (unpaired, one-tailed, heteroscedastic, t-test probability $p=0.21$). Although the data from other areas of the cave are much sparser, they too suggest no demonstrable rise in the CO_2 levels due to development and tours. Even the highest levels of CO_2 found in the cave are not considered harmful for people, based on guidelines from the National Institute of Occupational Safety and Health (10,000 ppm for 8-hour exposure and 30,000 ppm for 15-minute exposure).

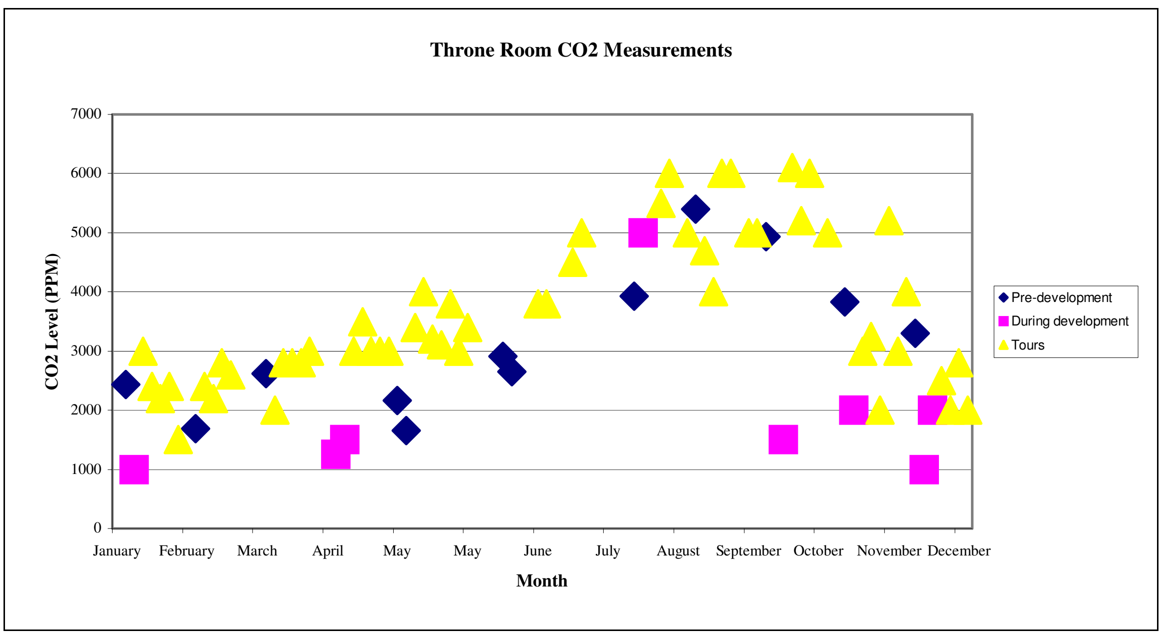


Figure 13 – *Measured carbon dioxide levels in the Throne Room by month.*

Biological Studies

Activities and Observations:

- **Continued monitoring of algae growth and treatment.**
- **Reduced potential for algae growth by minor modifications of lights and misters.**
- **Reduced potential for algae and bacteria growth in Big Room development.**
- **Continued bacteria studies by Dr. Raina Maier and Ms. Luisa Ikner.**
- **Sampled airborne bacteria and fungal levels in cave.**
- **Proposed Microbial Observatory at Kartchner Caverns.**
- **Discovered new beetle species discovered in Kartchner Caverns upper access tunnel.**

Algae growth is a widespread and serious problem among lighted show caves. Algae grow well in such warm, humid, high carbon dioxide places. Normally, in caves an essential element for algae growth is lacking--light. But when light is added to a cave to allow visitor tours, algae may "bloom" in an uncontrolled manner. This problem is so widely known that it has been given a name: lampenflora.

Precautions were taken during the development of Kartchner to minimize algae growth. The cave lighting design permits limited use of the lights for brief periods during each tour, inhibiting the type of growth that would occur if the lights were left on for hours. In spite of this, small amounts of algae growth have been found in the cave largely in the tunnels leading to the cave. The tunnels exhibit more algae growth because the lights in the tunnels remain on continuously during tour hours. The cave unit constantly monitors the cave for algae growth. When algae are observed, the affected area is immediately treated with a weak solution of bleach. The bleach is carefully used to reduce the potential impact on the cave. To reduce the potential for initial growth or re-growth, the staff has initiated a program to modify lights, misters, and camouflaging methods to eliminate situations conducive to algal growth. In addition, we have used what we have learned from the Rotunda-Throne Room operations to make decisions in the Big Room that will reduce the potential for algae growth.

Overall, we have not seen a very serious problem with algae growth in the cave. So far, limited treatments of affected areas with a weak bleach solution have controlled growth. We have studied using 13% hydrogen peroxide solution for control instead. This solution would potentially have less impact on the cave than does the bleach solution. Unfortunately, we find that the peroxide solution is not as effective overall. We continue to monitor algae growth in the cave and tunnels and to treat as needed. We will also continue to look for ways to reduce algae and the impact of controlling it.

As noted in my 2001-2002 report, we have identified a growth of slime-producing bacteria on some of the painted fiberglass surfaces in the Rotunda and Throne Room area. On-going work by Ms. Luisa Ikner under the direction of Dr. Raina Maier (University of Arizona, Department of Soil, Water and Environmental Sciences) has characterized the bacteria that produce the slime and other bacteria communities in the cave. Ms. Ikner has presented posters on this project at the last two American Society for Microbiology annual meetings (see publications listed below). Her study has provided important information about the microbiology of the cave and on how to reduce the possibility of getting similar slime in development of the Big Room. Using her work, we are beginning to examine the microbiology of the cave.

In addition, Dr. Maier and students from Dr. Ian Pepper's lab (University of Arizona, Department of Soil, Water and Environmental Sciences) sampled several areas of Kartchner Caverns for airborne bacteria and fungi. The results of that study indicated that the cave does not exhibit elevated levels of airborne bacteria or fungi. Indeed, the in-cave level was notably lower than that observed in many surface environments.

In the summer of 2002, Dr. Maier and I submitted a proposal to the National Science Foundation (NSF) to establish a Microbial Observatory at Kartchner Caverns. If funded, the proposal would have provided funds for a three-year, general study of the microbiology of the cave through the University of Arizona. Although that proposal was not funded, in July 2003 we submitted a new NSF proposal under the same program for a study this year that more directly focuses on the effects of cave development on the bacterial communities in the cave. We are awaiting the results of that proposal. We are developing a sampling protocol for the Big Room, so we can begin sampling before tours start in November.

In June 2001, Steve Willsey (Ranger II, KCSP Cave Unit) found some unusual insects while cleaning the light boxes in the tunnels. Mr. Willsey and I collected a small sample to identify the insects. Dr. Carl Olson (University of Arizona, Department of Entomology) tentatively identified the specimens as beetles of the family Staphylinidae. He indicated that he thought that they were potentially closest to the genus *Stamnoderus*. He sent a sub-sample of the beetles to Dr. Margaret Thayer of the Field Museum in Chicago, Illinois. A world expert on staphylinids, Dr. Thayer confirmed that the beetles were staphylinids and indicated that they are a new (undescribed) species in the genus *Stamnoderus*. The species does not necessarily seem to be cave-associated. They may have simply been using the moister tunnels due to the drought; however, we were fortunate to identify them. The new species will eventually be described but the time frame for this will almost certainly be several years.

Geological Studies of the Cave and Park

Activities and Observations:

- **Arizona Geological Survey mapping of McGrew Spring and Benson Quadrangle.**
- **University of Arizona geologist mapping of structural geology of Kartchner Block.**
- **Grant by Cooperative Extension to interpret hydrology of block and cave.**

Several important geological projects have taken place over the past year. The most important one from a cave protection standpoint is being undertaken by the Arizona Geological Survey (AGS). In response to a request from ASP, AGS geologists Charles Ferguson and Todd Shipmann have been mapping the McGrew Spring and Benson USGS 7.5-minute quadrangles. I have met with them and provided copies all of the geological studies that have been completed on the park as background for their project. In addition, Charles Ferguson has made several trips to the park for field work on the project. These trips included one trip to look at faulting in the tunnels and cave. When AGS completes the mapping of these quadrangles, the results will provide an important tool in better understanding the geology of the park and how it fits into a regional framework.

We have continued our close relationship with the UA Department of Geological and Mining Engineering. Dr. Bob Casavant has been advising several students from his department and from the Department of Geological Sciences as they have mapped the structural geology of the Kartchner Block. This work has resulted in several student posters that were presented at regional and national meetings. They are listed under publications below. In addition, Kartchner Caverns State Park served as a field site during the Department of Mining and Geological Engineering's summer field course. This year, students mapped rock strengths in the Cul De Sac tunnel and studied the engineering of the Tarantula Tunnel. This work was undertaken under the direction of Dan Sims, University of Arizona, and Ross Barkley, Call & Nicholas, Inc.

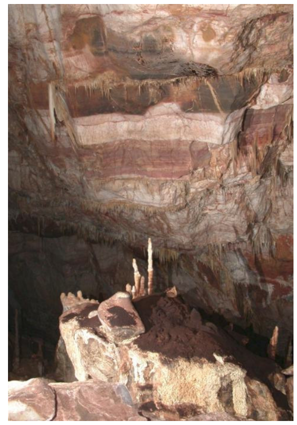
We are working with Susan Pater and Kim McReynolds of the Cochise County Cooperative Extension on a project to develop an interactive kiosk on the hydrology of the Whetstone Mountains and the cave. The project also involves the Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA) center of the University of Arizona, Department of Hydrology and Water Resources. The Cooperative Extension has received a grant for the development of the kiosk. We will be providing expertise and housing the kiosk.

We are also continuing to work with Dr. Julia Cole and several other researchers from the University of Arizona, Department of Geosciences, to use Kartchner Caverns to study regional climates of the past 100,000 years. This work could potentially allow us to better understand the long-term history of the cave environment.

Bats in the Cave and Park

Activities and Observations:

- **Bats continue to use cave despite on-going Big Room development.**
- **Adopted and implemented bat-based Big Room closure protocols to protect colony during last stages of development and during tours.**
- **Continued monitoring and archiving of bat sightings on Park.**
- **Worked with an Arizona Sonoran Desert Museum scientist to study lesser long-nosed bat use of agave on park.**



The bats at Kartchner Caverns are vital to the cave's continued environmental health because they provide the guano that is the basis for the cave's internal ecosystem. The cave serves as an important maternity roost for the southwestern cave *Myotis* (*Myotis velifer*). Our monitoring of the bat usage of the cave indicates that they continue to use the cave in numbers comparable to those seen prior to development.

Figure 14 shows the bat exit counts for each of the last 13 years. The past two years were good for bats at the park with a peak southwestern cave *Myotis* count of 1655 occurring on May 16, 2002, and later peaks of 1387 (August 15, 2002) and 1383 (August 20, 2002). The 2003 bat season has also begun well. Peak counts of 1345 bats on June 17, 2003, (early season) and 1795 in August 12, 2003, (late season) represent a healthy very population for the season. The graph shows the counts that were made of bats exiting the cave from about one-half hour before sunset until it becomes too dark to see bats leaving. Although every bat may not exit the cave during this time, the counts provide a good indication of the number of bats using the cave. The bat usage of the cave in both 2002 and 2003 is similar to previous years (pre-development and during development) in both numbers of bats and in patterns of usage. The unusual pattern seen for 2001 is attributed to the problems in getting useable counts during the very active monsoon season in 2001. The pattern does not seem to represent a change in bat usage.

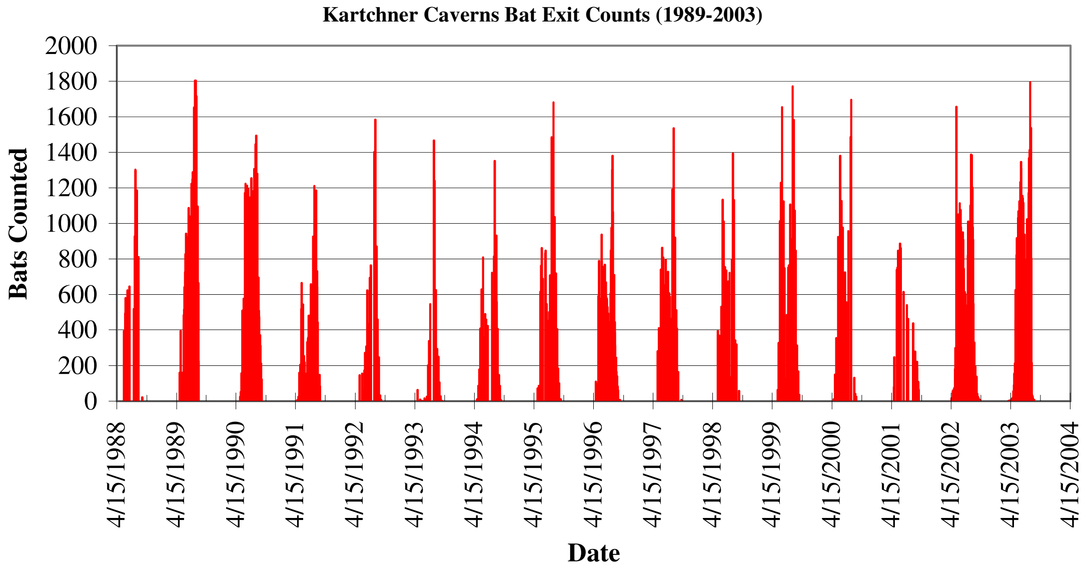


Figure 14 – *Kartchner Caverns bat counts from 1988 to the present.*

To continue to protect the bats when tours of the Big Room begin, we implemented protocols for determining when the Big Room will close and open each year. Adopted in May of 2002, the protocols are based on a combination of the date and the number of bats counted in exit counts. The draft protocols were reviewed by several local bat biologists, including Dr. Ronnie Sidner, Katy Hinman, Dr. Robert Steidl, Sherry Mann, and Debbie Beucher, and were modified based on the comments of these experts. In addition, the recently published development studies (see publication section below) informed the design of the protocols. Although a complete listing of the protocols is beyond the scope of this report, some of the many points are:

- Events in the Big Room (including tours) requiring advanced scheduling should not be scheduled between April 15 and October 15.
- The Big Room will close May 1 or when sufficient bats[1] arrive to trigger closure, whichever is earlier.
- The Big Room will open October 15 or when the bat population is small enough to trigger opening.
- The protocols will be continually monitored and revised as needed to protect the bat colony.

The implications of adopting these protocols are somewhat difficult to evaluate, particularly in predicting details of when the Big Room is likely to open and close. Two reasons contribute to the difficulty of predicting. First, in general, relatively few April and very early May counts have been performed. Second, the dates the bats come and go vary significantly from year to year due to differences in weather, insect availability, etc.

[1] The protocols spell out methods for counting bats and sets numbers that trigger closing and opening (including both immediate closure and closure in 7 days).

Data from 1988 through 2002 provide retrospective information on the dates of counts that would trigger closing and opening under the current protocols (see Table 1).

The spring data are sparse, but the bat arrival would have required a late April closure in least 1996 and probably also 2000. The latest closing to be expected based on reliable data would be the beginning of May. For this reason, May 1 was made the closing date even if numbers have not reached closing levels. The average re-opening date would be about September 15 for these years. The re-opening date in the fall is somewhat better constrained by data; however, it varies greatly from year to year. Opening, under the protocols, would have ranged from as early as September 5 (in 2000) to as late as October 5 (in 1997).

Year	Date of first count ≥ 50 * = first count of season	Count	Date of first count ≥ 125 * = first count of season	Count	Date of first count Fall ≤ 100 (or last count if none ≤ 100)	Count
1988	5/28/88*	328	5/28/88*	328	9/16/88	21
1989	5/5/89*	160	5/5/89*	160	8/29/89	225
1990	5/13/90	52	5/18/90	157	9/19/90	121
1991	5/8/91	160	5/8/91	160	9/10/91	81
1992	5/10/92*	145	5/10/92*	145	9/14/92	31
1993	5/2/93*	62	7/5/93*	201	9/20/93	27
1994	5/8/94	85	5/15/94	178	9/18/94	85
1995	5/8/95*	71	5/25/95	616	9/25/95	11
1996	4/28/96*	109	5/13/96	592	9/8/96	82
1997	5/11/97*	281	5/11/97*	281	10/5/97	6
1998	5/17/98*	395	5/17/98*	395	9/22/98	56
1999	5/17/99*	62	5/23/99	328	9/27/99	36
2000	5/4/00	149	5/4/00	149	9/5/00	40
2001	4/29/01*	79	5/2/01	246	9/27/01	69
2002	4/25/02	58	5/9/02	179	9/22/02	41

Table 1 – *Dates of Myotis velifer exit counts (and the counts on those dates) that would trigger events in the protocols in the years 1988-2002.*

In addition to the maternity colony of cave *Myotis*, several other bat species occupy the Park, including a small maternity colony of Mexican long-tongued bats, a moderate-sized colony of Mexican free-tailed bats, a small colony of pallid bats, and a few individual big brown bats. We have continued to monitor these bat roosts and to document new roosts or occurrences.

We are also assisting Karen Krebs, Arizona Sonoran Desert Museum in Tucson, in a study of lesser long-nosed bats (*Leptonycteris curasoae*) feeding behavior in southeastern Arizona. The park was chosen as one of the study areas for this study, sponsored by Luke Air Force Base, of the possible effects of night military operations on this endangered bat. The completed study will provide valuable information about one of the bats that uses the park.

Scientific Oversight and Advising

Key activities for year:

- **Interagency Service Agreement process stalled due to pressing budget concerns at both ASP and University.**
- **Continued successful individual partnerships with University, State and Federal Government, NGO, and independent scientists to address research needs and education/research opportunities.**

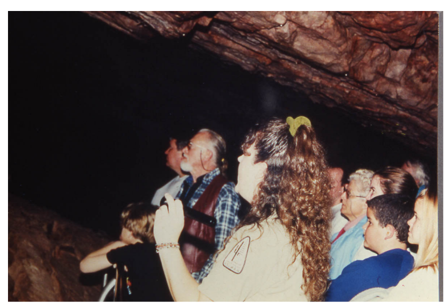
Although ASP remains committed to developing the Science, Education, and Research Advisory Committee ("SERAC") described in last year's report, we made little formal progress on this issue during the past year. An interagency service agreement has been drafted formalizing the relationship between ASP and the University, but it remains in review. Pressing budget issues for both the university and ASP displaced the SERAC ISA on the priority agenda.

However, the lack of a formal agreement between the University and ASP has not impeded our interactions with University and other researchers. We are in fact working with a larger array of researchers now than we were when the SERAC process started.

Cave Protection and Tours

Activities and Observations:

- **Most cave tours have both lead and trailing guides.**
- **Few visitors touch cave features, and an overwhelming majority of such touches occur to man-made features in the cave rather than natural cave features.**
- **Installed tunnel misting system to reduce lint.**
- **Installed portal air curtain to reduce lint and potentially improve protection of cave climate.**



Trailing Guides

Cave guides (both volunteer and ASP employees) are a vital element in our mission to protect and interpret the cave. While giving tours, we expect guides to educate and entertain our guests, to protect the cave from potential guest impacts, and to protect the guests from possible injury. One of the best means of accomplishing these tasks is to operate all tours with two guides, one leading the tour and the other trailing it. The second guide helps answer questions, interacts with guests, provides a set of eyes to watch for problems, and assists in case of an emergency.

Because the presence of a trailing guide is so important to the success of our mission, Kelly Jackson, head of the Discovery Center Unit, and I have been tabulating data related to this aspect of our operation (**Figure 15**). Shortages in staffing and budget constraints have led to our having a less than optimum number of tour guides. Over the past 20 months, over 22.5% of all tours have gone without a trailing guide. The percentage has varied seasonally from a low of 8% in January 2003 to a high of 39% in April 2002. Higher numbers of untrailed tours in the late spring and summer relate to seasonal fluctuations in the volunteer pool. Fortunately, in the past year we have improved volunteer recruiting and retention. For this reason, most months in 2003 have been better than the corresponding months in 2002.

Making sure that each tour is trailed by a guide will be more important in the Big Room tour because guests are so much closer to cave walls and formations and because the tour is more strenuous. A challenge for the coming year will be to keep staffing levels high enough to ensure that all Big Room tours will have trailing guides while not allowing a decrease in trailed tours on the Rotunda-Throne tours.

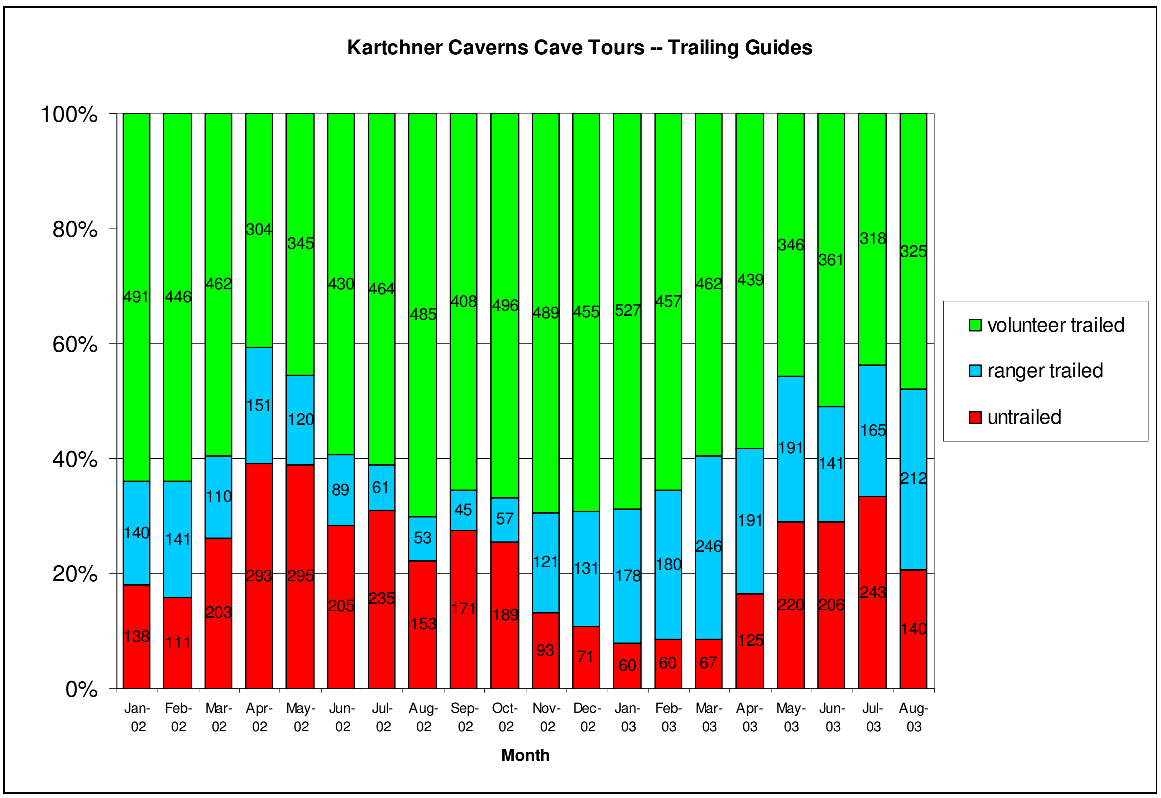


Figure 15 – *Percentage of Kartchner Caverns cave tours trailed by ASP employees, trailed by volunteers, and untrailed. Numbers within the bars indicate actual numbers of each type of trailer.*

Touching

One of the important roles the guides perform is to monitor the tours for prohibited activities that could adversely impact the cave. The most common prohibited activity is touching of trailside features by guests. Touching of cave features, such as formations, has several possible detrimental effects. It can leave oils that will (over time) discolor materials. In the case of formations, these oils could also interfere with growth. In addition, touching can leave behind bacteria, lint and other materials.

If a guide sees a guest touch a wall, the upper or outer portions of the curbing, a rock, or formation areas (which usually happens by accident), the lead or trailing guide will mark the spot with a piece of flagging. After the tour the guide will fill out a report that tells the Cave Unit what the flag represents. The guide reports such things as the location in the cave, the part of the cave that was touched (curb, wall, formations, etc.), whether the person who touched was an adult or child, which part of the body (or clothing) touched, etc. The Cave Unit is then able to take appropriate action to mitigate the touch. Under the direction of Kelly Jackson, Brian Stark (Ranger I, Discovery Section Unit) has compiled these "red flag" reports into a database. The data are being used to better understand how to protect the cave. The red flag reports provide several reassuring pieces of information (**Figure 16**). Overall, there are very few touching incidents. In spite of the fact that approximately 80,000 guests visited the caves during the six months represented on the chart, only 1142 red flag incidents were reported. Most of the red flag reports involve touching portions of the cave that are part of the infrastructure, such as the trail curbs or trail walls. Touches of the infrastructure, although potentially problematic if they occurred in large numbers, are of much less concern than would be touches of the natural cave features themselves. Only 15 reports in the six months shown represent touching of cave formations. This information is encouraging, but at the same time it reminds us that we need to remain vigilant to protect the cave during tours.

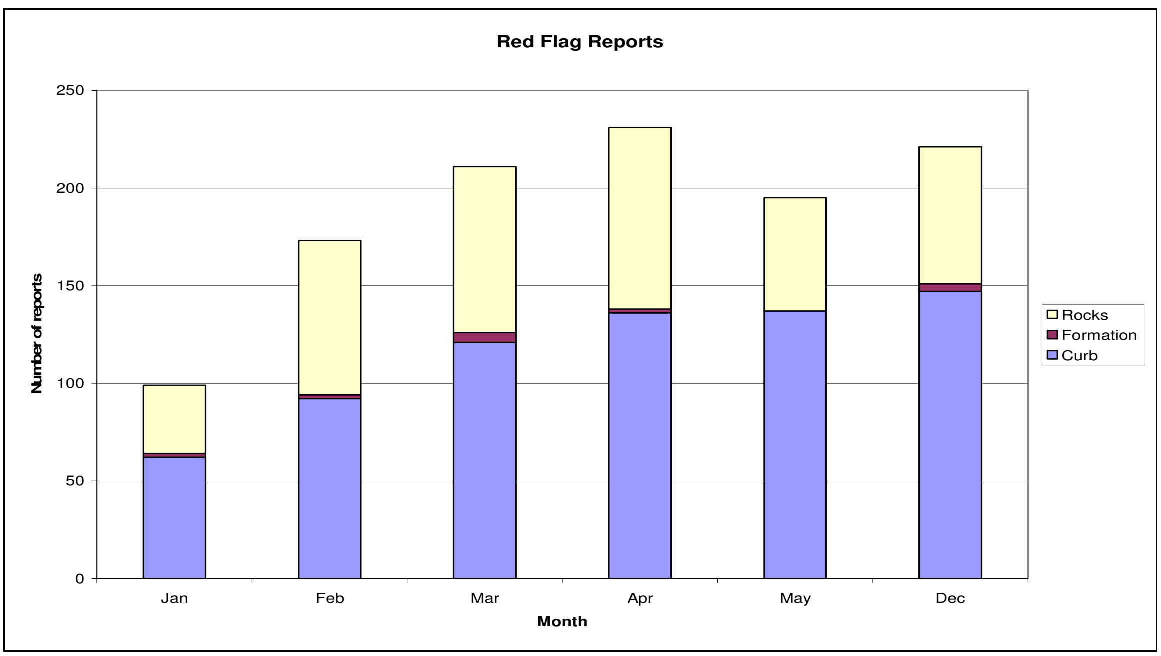


Figure 16 – *Number of touching incidents reported in "red flag reports" by cave guides divided up by month and portion of the cave or trail touched.*

Lint

One potential concern for the long-term protection of the Kartchner Caverns environment is the accumulation of lint derived from tourists, such clothing fibers, skin cells, hairs, and other particles that are shed by people as they walk through the cave. Over time lint can accumulate and damage the cave by dulling formations, contributing to their dissolution and serving as a nutrient source for algae and invasive insects. In many caves, years of lint build-up have resulted in either significant damage or extended remediation efforts. During development, ASP adopted several measures to reduce lint accumulation and impacts. These include curbs along the trails to confine to the trail the lint that falls. Another measure is washing down the trails several times a week to keep trail lint from accumulating and being dispersed. Two new features installed this year should reduce the potential for lint accumulation in the cave: tunnel misters and an air curtain.

We installed sets of misters in 20-foot-long sections of tunnel near the Rotunda entrance and Cul De Sac entrance. These misters serve to moisten the clothing of the visitors. The moisture should either cause the lint to remain on the visitors better or will make the lint somewhat heavier, so that it falls to the floor faster and stays within the trail boundaries. Secondarily, the misters serve to moisten the area of the tunnel near the doors to the cave.

As recommended by Dr. Arrigo Cigna, we have also added an air curtain at the entrance portal to the tunnels. The downward draft of air serves to remove some of the looser lint from the visitors before they enter the tunnel. The air curtain may also improve the separation of the outside air from the tunnel and cave air (like an additional door). There are several different ways in which an air curtain could be used. For example, it could be on all the time or it could be used only as people walk under it. We are currently studying how best to utilize the air curtain in protecting the cave.

As we prepare for opening the Big Room to tours, we are developing a lint monitoring project. We will be monitoring lint accumulation along transects from the trail to examine amounts and patterns of accumulation from the beginning of tour operations.

We do not have a significant lint problem at Kartchner at this time; however, it is important to make sure that we do not develop one.

Big Room Development and Planning

Key accomplishments for year:

- **Provided scientific assistance in development decisions relating to the opening of the Big Room.**

During the past year, I have continued to work on numerous projects regarding the development of the Big Room for public tours. This has included working with the development unit in construction and lighting decisions, and assisting the Big Room committee working to develop a tour schedule, appropriate tour size, necessary staffing, and accurate interpretation.

Surface Land-Use Issues

Key activities:

- **Addition of Whetstone Springs parcel to Park.**

This spring ASP acquired the 160-acre Whetstone Springs Parcel around McGrew Spring along the northern boundary of the park. ASP acquired this parcel through the eminent domain process to protect the cave from potential adverse impacts that might have occurred if the parcel were developed. Since the acquisition, I have been working with staff from Phoenix and at KCSP to integrate the new parcel into the park and to better understand the resources that it adds to the park.

Inter-Agency Outreach and Cooperation

Key activities for year:

- **Worked with numerous governmental and non-governmental groups to improve management and protection of Kartchner Caverns and its resources.**
- **Worked with numerous governmental and non-governmental groups to improve management and protection of other caves, cave resources, and bats.**

During the past year, I have initiated and encouraged cooperative and collaborative efforts with other governmental and non-governmental groups working on cave and bat issues. These include hosting field trips for cave management seminars and meetings, participating in professional conferences, and meeting with representatives of federal and state agencies on numerous cave protection issues.

The fruits of these collaborations should be evident from other sections of this report. Data sharing with the USDA-Forest Service, for instance, has provided useful comparative information on cave temperatures and humidities in other caves in southeastern Arizona. This data allows us to better understand changes that we see at Kartchner Caverns. I am continuing to work with scientists and resource managers from the Forest Service, Fort Huachuca, Arizona Game and Fish, and with private landowners and cavers to develop a better network for monitoring regional cave climates.

In April 2003, I participated in a National Park Service workshop on long-term ecological monitoring of caves. The aim of this workshop was to develop techniques, tools, and measures that can be used to track the environmental conditions and health of caves and cave resources. Participating in this workshop allowed Arizona State Parks both to share what we have learned in developing Kartchner and to gather new approaches from other caves to add to our monitoring.

New Scientific Publication and Presentations

Key accomplishments:

- **Publication of two peer-reviewed articles on studies at Kartchner Caverns.**
- **Five posters were presented at regional or national meetings on recent work at Kartchner.**

Articles

Cigna AA, 2002, Modern trend in cave monitoring. *Acta Carsologica* 31(1): 35-54.

Mann SL, Steidl RJ, and Dalton VM, 2002, Effects of cave tours on breeding *Myotis velifer*. *Journal of Wildlife Management*. **66(3)**: 618-624.

Posters

Casavant RR, Wagner S, Toomey RS III, and Nolan G, 2002, Preliminary kinematic study of the "Kartchner Block," southeastern Arizona. Poster presented at the 2002 AAPG-SEG Student Expo, October 20-21, 2002, Houston, TX.

Geauner S, Waldrip R, and Casavant RR, 2003, Eastern Whetstone Mountains fault model investigation. Poster presented at 31st Annual GeoDaze Geoscience Symposium, April 10-11, 2003, Tucson, AZ.

Ikner LA, Neilson JW, and Maier RM, 2002, Analysis of slime deposits on fiberglass surfaces in Kartchner Caverns. Poster presented at the 102nd General Meeting of the American Society for Microbiology. May 19-23, 2003, Salt Lake City, UT.

Ikner LA, Neilson JW, and Maier RM, 2003, Microbial diversity in Kartchner Caverns. Poster presented at the 103rd General Meeting of the American Society for Microbiology. May 18-22, 2002, Washington, DC.

Mann SL, Steidl RJ, and Dalton VM, 2002, Effects of cave tours on breeding *Myotis velifer*. *Journal of Wildlife Management*. **66(3)**: 618-624.

Wagner S, Casavant RR, Toomey RS III, and Nolan G, 2003, Preliminary kinematic study of the "Kartchner Block," southeastern Arizona. Poster presented at 31st Annual GeoDaze Geoscience Symposium, April 10-11, 2003, Tucson, AZ.

The Coming Year

Plans for 2003-2004 call for continued monitoring and analysis of data. As data from the additional data loggers accumulates, trends may be discerned and measures will be taken to address problems. The addition of new monitors to measure energy use correspondingly provide a new tool for protecting the cave. We also plan to have additional regional data with which to compare observations at Kartchner. The formation documents for SERAC will be finalized and ASP and the Committee will move forward to review and develop needed research projects. Observations of bat occurrences will continue and a protocol for operation and management of the Big Room relating to the cave's bat colony will be put in place. ASP will continue to seek scientific advice and consultation on issues relating to protection of the Kartchner Caverns resource.