INSIDE EARTH

A NEWSLETTER OF THE NATIONAL PARK SERVICE
CAVE & KARST PROGRAMS
Edited by Dale L. Pate

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SUMMARY OF NATIONAL CAVE ASSESSMENT PROGRAM FOR FY 1999

by Ronal Kerbo

The program for FY 1999 was focused on the following:

- service-wide small cave assessment projects
- technical assistance requests for cave resources management
- attendance at cave/karst professional meetings
- agency and federal wide meetings on cave/karst issues.
- Lectures/programs on Service-wide cave/karst issues
- National Cave and Karst Research Institute

A break down of the cave program's $30,000 was as follows: **<u>SERVICE-WIDE PROJECTS</u>: $20,260:** $7,160 to bat habitat protection and assessment in two parks and $13,100 to cave assessment projects in three parks; **<u>TECHNICAL ASSISTANCE</u>: $3,800:** was provided in cave /karst related issues at four parks. **<u>TRAVEL</u>: $5,940**: for presentations on cave/karst programs, professional meetings and training at four parks, the Oakland Museum of Natural History, The Winter Technical Meeting of the Southwest Region of the National Speleological Society, and the National Speleological Society Annual Convention.

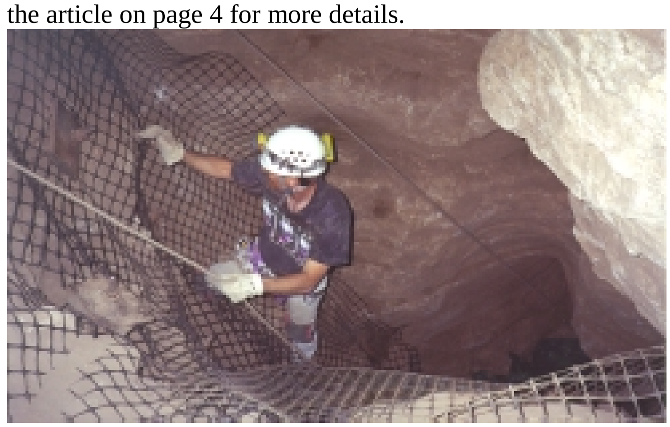
PARK UPDATES

Carlsbad Caverns National Park

by Dale Pate

Superintendent moves to Big Bend – Frank Deckert, Superintendent of Carlsbad Caverns since 1992, has recently accepted the position of superintendent at Big Bend National Park. While in his tenure, Frank was an advocate for the caves of the park and a major supporter for cave management issues. His willingness to confront tough issues, such as oil and gas drilling north of the park, will have a lasting effect on the long-term protection of ***Lechuguilla Cave*** and other caves of the park. More recently, he was the major decision-maker behind the push to protect ***Carlsbad Cavern*** by first studying infiltration routes and then developing a plan to remove or mitigate for the infrastructure built directly over the cave. Good luck to Frank in his new position.

Lechuguilla Cave Culvert Replacement Project – See the article on page 4 for more details.



Mark Bremer inspects the Tensar netting used to stabilize the slope where the old culvert in Lechuguilla cave used to be.
(NPS Photo by Dale Pate)

New Staff for Cave Resources Office – The park has recently received a $500,000 base increase for cave protection. This increase will provide funding for two permanent, full-time positions in the Cave Resources Office. Paul Burger was recently hired to fill the Karst

Hydrologist position while a Physical Science Cave Technician position is currently in the process of being hired. Additionally, a new Wildlife Biologist, a Law Enforcement Ranger, an Engineering Technician and a couple of Maintenance Technicians are also in the process of being hired. Part of this permanent funding will also be used to remedy infrastructure problems that have led to contamination of Carlsbad Cavern.

BLM Land Withdrawal – To protect cave resources north of Carlsbad Cavern National Park, the Bureau of Land Management (BLM) recently withdrew 8,470.59 acres of Federal surface and minerals and 480 acres of federal minerals underlying private surface property. A Finding of No Significant Impact (FONSI) was issued on January 7, 2000. This action withdraws this property from mining and mineral leasing, subject to valid existing rights. In addition, this withdrawal will apply to 8,198.72 acres of state lands and mineral estate if acquired by the BLM.

Lincoln National Forest Land Withdrawal - The U. S. Forest Service recently held a 2nd public meeting and has asked for written comments concerning their proposal to withdraw 27,299 acres from mining activities and oil and gas leasing. This proposed withdrawal is to protect cave resources found in the Guadalupe District of Lincoln National Forest.

National Geographic Magazine – In the January 2000 issue, **Diana Northup** and **Penny Boston** (two scientists that are studying microbes in caves of the park) are featured in an article by Joel Achenbach titled "Life Beyond Earth". The two are pictured in a full-page photo in ***Cueva de la Villa Luz*** in Tabasco, Mexico wearing respirators and tyvek suits.

In the April 2000 issue, our own **Stan Allison** and **Gosia Allsion-Kosior** are pictured in an article on the ***Chiquibul Cave System*** in Belize. Check them out on page 69.

Big Room Bat Guano – Preliminary findings for the age of the bat guano in the Big Room of ***Carlsbad Cavern*** indicate that the deposit is 44,680 years old (+/- 1200 years). Pat Jablonsky collected samples of the guano in 1999 and had it radiocarbon dated at a lab in Florida. Pat has been back this year to collect two more samples that will be used to verify this first finding.

Lower Cave Bat Skeleton – A bat skeleton from Lower Cave in ***Carlsbad Cavern*** was also collected this past year by Pat Jablonsky and dated at 2,060 years old (+/-40 years).

Craters of the Moon National Monument

by John Apel

This summer Craters of the Moon National Monument will continue the cave inventory begun last year. The NPS Geologic Resource Division has funded a Student Conservation Association position to assist with database development and inventory efforts. "Craters" has also received tentative approval of regional funding to conduct detailed biological inventories of the six most heavily visited caves within the monument in 2001.

Great Basin National Park

by Jon Jasper

The ***Lehman Caves*** Trail Rehab Project is close to completion. Replacement of the remaining four wooden stairs along the tour route with fiberglass stairs with stainless-steel handrails is completed. The project also has replaced 110 corroding electrical boxes with new non-corrodible PVC boxes. A total of 45 ft^3 of debris consisting of wood, asphalt, old wiring, concrete, and lint has been removed. As reported earlier, a non-slip surface was added on the cave's slopes, all of the handrails were replaced with stainless steel handrails, electrical problems were fixed, drains were added, a lint camp was held, the cave doors were repaired, and a cave GIS was created.

One of the recently constructed stairways. (NPS Photo by Jon Jasper)

The project plans to replace two old fiberglass stairs and remove two sets of off-trail, wooden stairs. The replacement of the main electrical feed from just outside the Visitors

Center to the cave's first breaker box is being planned. The project plans on tackling the cave's lighting problems such as dark spots, problems due to algae, and hard-to-reach lights.

Bat surveys are being conducted this year. Internal surveys of the caves and mines are being performed throughout the year. Dataloggers have been set up to record temperature readings every hour at seven locations in ***Lehman Caves***, ***Crevasse Cave***, and ***Ice Cave***. The park is getting ready to perform external surveys as part of the Inventory and Monitoring Initiative. These surveys will be completed through the use of mist netting and Anabat detectors. With this research, the park will be able establish baseline data for the Inventory and Monitoring Program and also will be able to provide information on how to make good management decisions to protect and restore bat populations.

The project of establishing the park's Cave Management Plan is starting again. The plan was near completion just before Cave Management Specialist, Rod Horrocks, accepted a position at Wind Cave. Since his departure the plan has been put on hold, until the position could be refilled. Seeing that the position would not be filled in a timely manner, the plan has been passed on to the Acting Cave Specialist, Jon Jasper, to be completed. The plan will define the park's sensitive cave and karst resources and establish protocols to properly manage these resources. To achieve this, intense surveying, inventory, monitoring, and research are planned for this summer. Show some interest in your park, volunteer and provide your input!

Oregon Caves National Monument

by John Roth

Infiltration studies in ***Oregon Caves*** should determine what effects prescribed burns have on the main cave. Dataloggers and tilt buckets are recording drip rates every ten minutes year round. Since chloride is not preferentially retained by soil biota, differences in chloride concentrations between rainwater and cave water should give a rough measure of evapotranspiration. The evapotranspiration rate should decrease after fire removes some of the surface vegetation.

More fossils continue to show up in sediments being screened by Dr. Mead of Northern Arizona University. These include the bones of mountain beaver, elk, woodrats, salamanders, snails, jaguars, bobcats, squirrels, rabbits, bears, moles, and voles.

A new species of snail was described that so far is only known from the Monument. It is found in and above the cave. Work is ongoing in describing cave millipedes, springtails, and beetles known only from Oregon Caves. A cave and aquatic interstitial species list for the US and Canada is now complete and will be put into a CDROM that will also contain glossaries, bibliographies, directories, subject matter summaries, and lesson, management and inventory plans. A bacteriological survey of ***Oregon Caves*** is slated to begin this summer. Bat populations near the bat gates continue to increase during the winter. This is more than likely the results of bats finding the gates and there being less disturbance due to the cessation of winter tours.

Another dye connection has been found between cave streams in the Monument and caves outside the Monument. This gives added weight to the boundary expansion legislation that is scheduled to be introduced in the fall. The bill would expand Monument boundaries to include all known connected karst areas presently outside of the Monument.

Wind Cave National Park

by Rod Horrocks

The Park's Cave Management Plan, last updated by Jim Nepstad in 1995, was recently updated and signed and is now in force. The major changes in this version are as follows: (1) reclassifying the types of off-trail trips, (2) standardizing terms, (3) rewriting the survey and inventory standards, (4) adding a glossary, and (5) updating facts.

We recently calculated a rough volume for the surveyed portions of ***Wind Cave***. Our volume estimate is 39,100,000 cubic feet, based on an average passage size for each of the nine sections (approx. 8'h x 10'w) and a length of 90 miles. In the 1960's Herb Conn conducted a barometric wind study and estimated that the total volume of the cave was around 2,000,000,000 cubic feet. Based on these two sets of numbers, the volume of the surveyed cave would represent only about 2% of the potential volume.

The new perched lake that sumped the route to the Lakes and the deep point in the cave in September, rose several inches in the 4 months after the initial sumping event and then dropped two inches during the last month. This is the first recorded drop in this new lake since its inception four years ago. This may be reflective of the very dry winter in the Black Hills. We will be closely monitoring this lake level in the future.

Dr. John Moore, from the University of Northern Colorado, has started three biological experiments in ***Wind Cave***. These experiments will look at sediment, colonization, and energy inputs.

The Park hosted a Sketchers Training workshop in February for participants in the monthly ***Wind Cave*** Weekend survey project. This included an in-class and an in-cave section. Over 20 cavers from Colorado and South Dakota attended the workshop.

Marc Ohms recently completed the monumental task of typing in the left, right, up, and down data for the first 40 miles of the ***Wind Cave*** survey. We're now concentrating on fixing loop closure problems (28% of our 1,020 loops are bad).

I'm currently working on a place name lexicon database for ***Wind Cave***. Data from over 1,100 names have been documented thus far. The data that is being collected includes; names, date of survey, surveyor's names, section of the cave, nearest station, and reason for the name.

The most recent Superintendent of the Park, Jimmy Taylor, retired in February after an eight-year term. He was very supportive of cave management projects in the Park and helped move the program forward. In recognition of his contributions, a room that was surveyed two days before his retirement, was named, "The Taylor Shop". This new room is located in the Historic Section near Upper Rome.

Recent survey and inventory work at ***Wind Cave*** has concentrated in the Historic, Club Room, Lakes, and Half Mile Hall sections of the cave. Since the last issue of Inside Earth, the surveyed length of ***Wind Cave*** has been increased by 3.08 miles, raising it to 89.6 miles and maintaining its status as the eighth longest cave in the world and the fifth longest in the U.S.

LECHUGUILLA CAVE CULVERT REPLACEMENT PROJECT

by Jason M. Richards

The Lechuguilla Cave Culvert Replacement Project (Carlsbad Caverns National Park) is progressing, not at an alarming rate, but coming along nicely. After the Environmental Assessment was approved and a Finding of No Significant Impact statement was released, work began on the removal of the old culvert. Beginning on January 22, 2000, volunteers from the Permian Basin Speleological Society (PBSS) from the Midland/Odessa, Texas area spend eight days removing lots of rubble and the old culvert. This material was moved to the upper

Thomas Fuller crawls through the old culvert one last time.
(NPS Photo by Miho Horokoshi)

area above the location of the old culvert. Since that time there have been 13 separate excavation days by 37 workers.

Upon the removal of the culvert, we were faced with a new problem, an unstable and slightly dangerous slope that still needed excavation before installation of the new stainless steel access culvert to the main portion of ***Lechuguilla*** could begin. To help with this problem we sought the expertise to solve this problem from the Waste Isolation Pilot Project (WIPP) staff. An initial reconnaissance to evaluate the unstable slope was made by Roy Burkham and Rick Supka. Rick, a senior geotechnical engineer, made some excellent suggestions and through WIPP, donated supplies that would stabilize the slope and make for safer working conditions. These supplies included three rolls of Tensar stabilization netting, 6-foot rock stabilization bolts that hold the netting in place, steel holding plates, plate pads, nuts and couplers.

Judy, Ruby & Jack, led by Jack Kincaid, move some of the heavy items to the cave entrance. (NPS Photo by Jason Richards)

Judy, Ruby and Jack transported these heavy, awkward supplies to the cave. These three sturdy individuals were able to get these supplies to the cave entrance in just two trips. I even threw in an oxygen bottle and acetylene bottle and they still didn't complain. However, a few dirty looks did come my way. I think if Judy, Ruby and Jack had not been mules I may have been in trouble, as it was they got even…..you ever walk behind a mule?

Mark Bremer and Jason Richards discuss stabilization efforts.
(NPS Photo by Dale Pate)

Currently, the completed excavation is near the bottom of the rubble pile with the slope being stabilized with Tensar netting. The rock bolts that are used to hold the netting in place are driven into the slope by a fence post driver and finished off with a sledgehammer. Many of the rock bolts have been driven into the slope to depths up to 12 feet and many more are driven in to 9 feet in depth. Pending the arrival of the stainless steel components for the culvert and airlock system, we are anticipating completion of the culvert project in August.

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Nutrient Loads Traced to Interbasin Groundwater Transport at Buffalo National River, Arkansas

by David N. Mott, Mark R. Hudson, Tom Aley

Everyone has probably looked at a spring and wondered where the water comes from. When water quality monitoring indicates that a spring is polluted, however, knowing the source of its water becomes more than a mere curiosity. Water quality studies at Buffalo National River have shown that springs, and streams influenced by springs, typically have the highest concentrations of nutrients and are significant contributors to the nutrient load of the National River during base-flow conditions.

Many units of the National Park Service are located in karst regions, or areas of soluble bedrock that are characterized by natural underground plumbing. Water resource assessments can be especially challenging in these terrains. Protection and management of karst watersheds is often made difficult because their limits are not known. Although obvious in many geologic settings - as one simply follows topographic divides - watershed boundaries of karst aquifers typically are not governed by surface terrain.

Buffalo National River is located in the Ozark Plateaus of northern Arkansas, one of the nation's largest karst regions. The term karst refers to a landscape modified by chemical and physical erosion of soluble strata, and is characterized by losing streams, sinkholes, caves, springs, and underground drainage. Two thirds of the Buffalo River's 857,607-acre watershed has soluble limestone and dolomite exposed at the surface (Scott and Hofer 1995). The study area (Figure 1) covers approximately 57,000 acres and contains numerous springs and caves including a commercially operated tour cave (***Mystic Caverns***) and the longest cave in Arkansas (***Fitton Cave***). The study area is characteristic of the National River's broader karst environment, and an understanding of ground water processes here can be applied to other karst basins, which contribute flow to the Buffalo River.

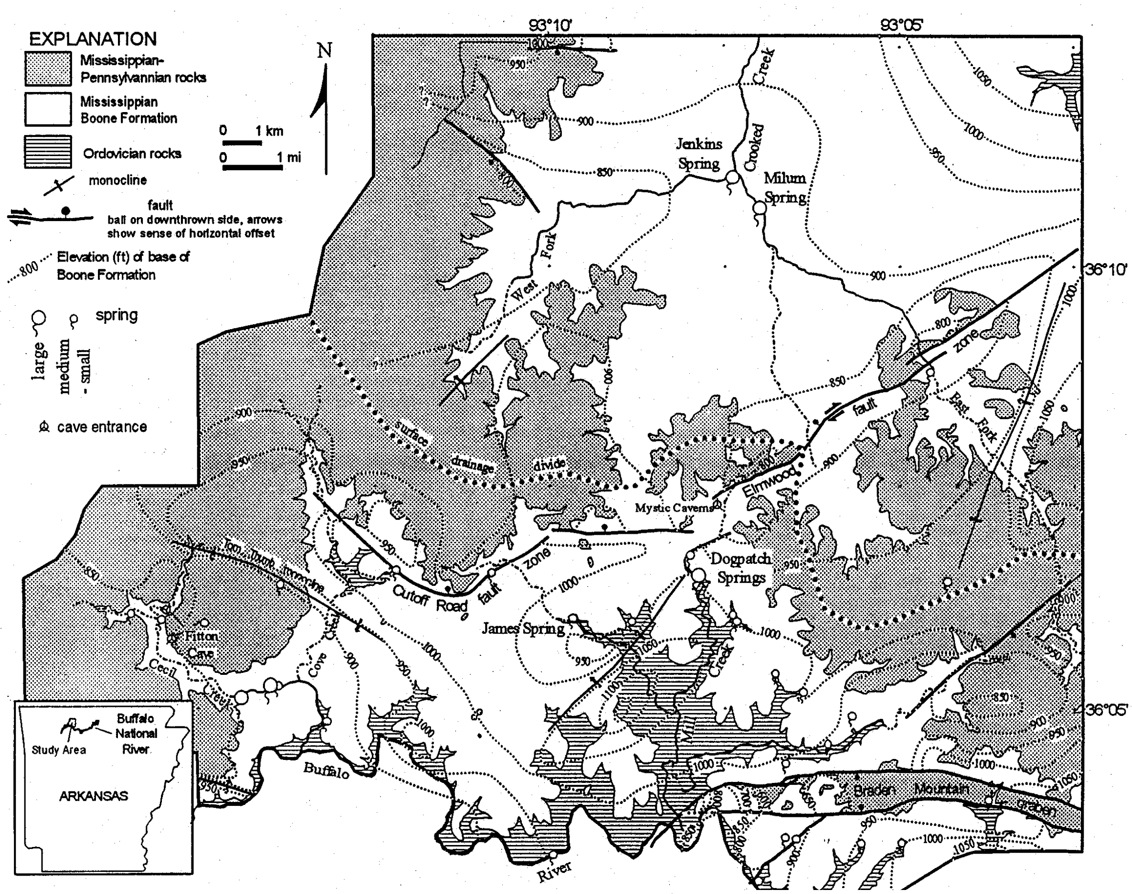

Figure 1. The study area and relative aspects of its hydrology and geology.

Of national significance, the Buffalo River is one of the country's few remaining undammed rivers over 150 miles in length. It is a clear water stream, it is biologically productive and diverse, and it is a scenic attraction drawing over one million visitors each year. Congress mandated the National Park Service to protect the "free-flowing" nature of this stream and its attendant water quality. This edict is extremely challenging given that the National Park Service owns only eleven percent of the River's watershed. With upstream land use and development dominated by agricultural and silvicultural activities, nonpoint source pollution is a major concern.

The State of Arkansas also recognizes the significance of this riverine resource and has designated it Extraordinary Resource Water, thereby mandating no reduction of water quality. To assess State and Congressional protection mandates, Buffalo National River launched a water quality-monitoring program in 1985 under the guidance of the National Park Service's Water Resource Division. The Arkansas Department of Environmental Quality (ADEQ) provides laboratory analysis as part of this program and assists with numerous water resource studies. As an unbiased earth science agency, the U.S. Geological Survey is providing geologic mapping and participates in developing a hydrogeologic framework of the area (Hudson, 1998).

Water quality monitoring determined that Mill Creek contributes as much as 96 percent of the nitrate load in the Buffalo River below their confluence (Maner and Mott 1991). This percent is highest during periods of low base flow (base flow in this paper refers to stream flow dominated by groundwater input as opposed to surface runoff), such as might be observed in late summer. Subsequent investigations showed that elevated nutrient (nitrate and phosphate) concentrations impact aquatic communities in both Mill Creek and the Buffalo River (Mathis 1991; Bryant 1997). A synoptic study over the length of Mill Creek showed that these nutrients originate from two springs (Upper and Lower Dogpatch) at the head of this tributary (Maner and Mott 1991).

Field observations suggested that the Dogpatch Springs discharged a relatively high volume of water considering their position near the head of the Mill Creek topographic basin. Discharge was measured once each season throughout a range of base flow conditions to estimate the yearly average where Crooked Creek and Mill Creek exit the study area. Average yearly base-flow for Mill Creek (23.6 cubic feet per second) was divided by its topographic watershed area (21.3 square miles; Sullivan 1974) to yield a discharge/area ratio of 1.1 cfs/mi^2 (Figure 2). Similar measurements for the adjoining Crooked Creek basin yielded a discharge/area ratio of 0.65 cfs/mi^2. The discrepancy between these ratios provided the first quantitative evidence that flow in Mill Creek is augmented by ground water transferred from the Crooked Creek basin via a subsurface drainage network.

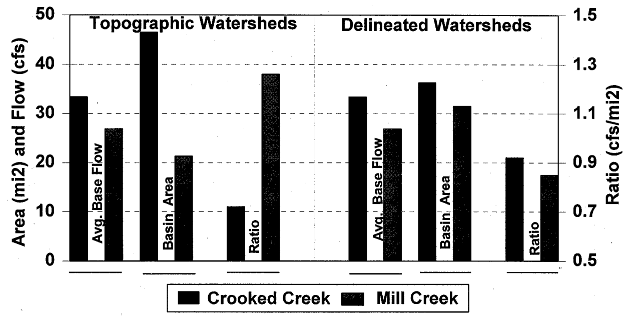

Figure 2. Average base flow and basin size comparisons for topographic and delineated basins with respective discharge/area ratios.

The overall goal of this study was to form a conceptual model of ground water flow and contaminant transport within the Buffalo River's karst aquifers. To achieve this goal the following studies were conducted: 1.) detailed geologic mapping; 2.) karst inventories; 3.) Groundwater basin delineations; and 4.) discharge and water quality measurements. The U.S. Geological Survey under a cooperative program with the National Park Service's Geologic Resources Division conducted geologic mapping. Karst inventories and basin delineations were conducted by the Ozark Underground Laboratory and funded by the National Park Service's Water Resources Division. Buffalo National River staff collected discharge and water quality measurements, with field and laboratory analyses completed by the park and the Arkansas Department of Environmental Quality.

Geologic controls on ground water are three-dimensional. The distribution of springs is strongly influenced by the study area's vertical succession of rock formations, or stratigraphy (Figure 3). Fifty three percent of the study area's thirty inventoried springs occurred within 40 feet of the unconformable contact between the Mississippian Boone Formation and the underlying Ordovician Everton Formation. The high frequency of springs near this contact is attributed to the less permeable nature of Everton Formation sandstones and dolomites, which variably underlie the 400-ft-thick more permeable (secondary porosity) limestone of the Boone Formation. Thirty six percent of the remaining springs lie near faults and monoclines (Figure 3, Hudson 1998). Three springs issuing from the middle of the Boone Formation are associated with a major chert horizon that is most prominent in the Crooked Creek portion of the study area.

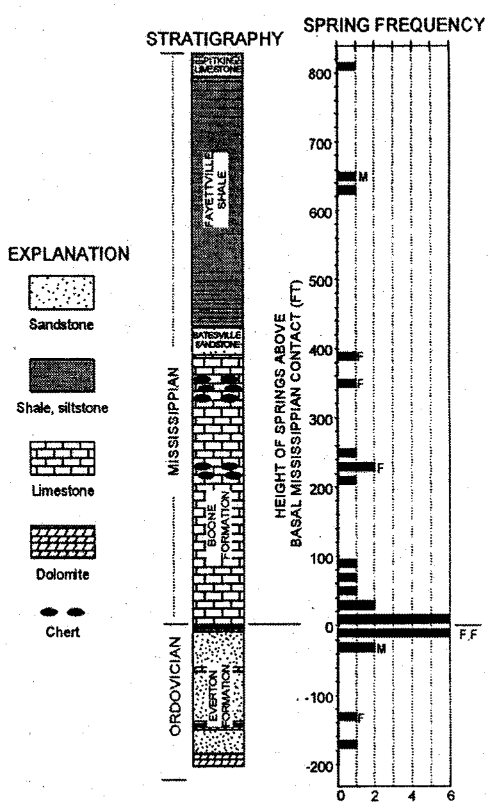

Figure 3. Relation of spring frequency to stratigraphy (F = fault, M = monocline).

Structure contours show the elevation of the base of the Boone Formation in map view (Figure 1). Large springs within the Buffalo River basin in the southern part of the study area are spatially associated with structural lows, suggesting that these lows may develop extensive karst networks and preferentially gather ground water from surrounding regions. In the southwest part of the study area for example, large springs along Cecil Creek, as well as ***Fitton Cave***, all lie within a broad structural trough bounded on the north by the Tom Thumb monocline. A second example is the location of Upper and Lower Dogpatch springs which emit near the base of the Boone Formation just south of a large low caused by downdrop of the intersecting Elmwood and Cutoff Road fault zones. Given the present topography, the Dogpatch springs occupy the lowest point where ground water could exit from the corner of this downdropped structural block, thus providing an element of structural control over the location of these large springs.

Trending toward the Dogpatch springs is the northeast-striking Elmwood fault zone, which contains an array of en echelon faults and associated fractures. This zone is the only major structure that traverses both the Crooked Creek and Mill Creek basins. A concentration of karst features, including ***Mystic Caverns*** that corresponds with the fault zone suggests that fractures associated with the zone have enhanced solutional processes. Based on these observations, this zone of solutionally enlarged fractures may preferentially drain ground water within the Crooked Creek watershed and allow it to flow southwest across the watershed boundary to discharge at the Dogpatch springs.

A total of 12 dye traces were conducted to delineate ground water recharge areas and test the interbasin flow hypothesis developed from the preliminary karst hydrologic inventories and geologic mapping. Paths of the various dye traces (Figure 4) along with intervening surface topography were used to delineate that 10.2 mi^2 of the Crooked Creek topographic basin supplies ground water to the Dogpatch Springs. The total area of the Dogpatch Springs' ground water basin is thus 13.8 mi^2, or almost four times larger than their topographic watershed (3.6 mi^2). Adding this additional area (10.2 mi^2) to the Mill Creek topographic basin, and subtracting this same area from the Crooked Creek topographic basin, resulted in discharge/area ratios for the delineated basins of 0.75 and 0.82 cfs/mi^2, respectively (Figure 2). These numbers are bracketed within accepted measurement errors, substantiating the accuracy of the karst aquifer delineations.

The shape of the topographic and delineated basins relative to the Elmwood fault zone provides an indication of its influence on surface runoff and ground water recharge. This fault zone appears to influence the shape of the surface basin probably as a result of decreased erosional resistance within this fractured lineament (Figure 4). However, the shape of the ground water basin appears to be independent of this structure as indicated by several dye introductions into this zone along its northeastward trend. The location and elevation of the delineated recharge divide, intermittent and perennial streams, and springs within the study area were used to simulate groundwater gradients within the Boone Formation. The southward gradient toward the Dogpatch springs (0.008) is about twice as steep as the northward gradient (0.004) toward Jenkins Spring, and is consistent with the regional potentiometric surface (Pugh 1998). These results indicate interbasin transfer is mostly independent of interbasin structures, and is principally a function of hydraulic gradient. However, the location of springs and the size of their recharge areas appear to be controlled by combined elements of groundwater gradient, stratigraphy, and structure.

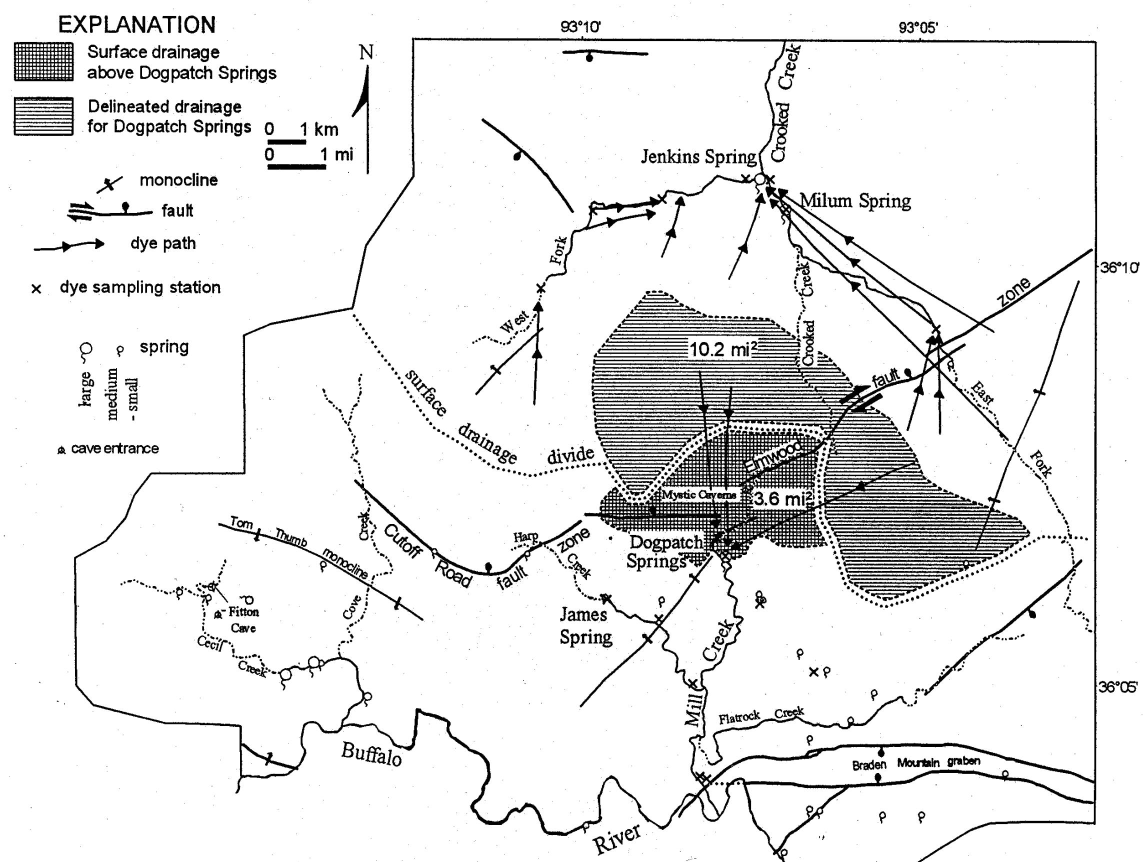

Figure 4. Dye Trace paths with surface and delineated watersheds

Land use in the Crooked Creek basin is dominated by agriculture, whereas the Mill Creek basin is dominantly forested. Agricultural land uses within the Crooked Creek basin include confined poultry operations, dairies, hay production, and beef cattle operations. Other ground water concerns arise from subdivisions served by on-site septic systems, service stations, illegal dumping in sinkholes and losing streams, and highways upon which hazardous materials are transported. The above concerns are heightened by the fact that karst ground water transport is rapid and provides little chance for attenuation of contaminants. As an example, dye introduced into a sinkhole filled with cattle carcasses moved over two miles from the Crooked Creek basin to the Dogpatch Springs at the head of Mill Creek in less than five days.

The sewage treatment plant associated with the defunct Dogpatch Amusement Park and Dogpatch apartments discharges below the Dogpatch Springs. Before this study started, however, raw sewage was observed spilling from a lift station into the ephemeral portion of Mill Creek just above the Dogpatch Springs. Contaminants from this sewage system could complicate interpretation of water quality comparisons between the Mill Creek and Crooked Creek delineated basins because of its proximity to the Dogpatch Springs. Recent permit enforcement and monitoring by ADEQ shows the

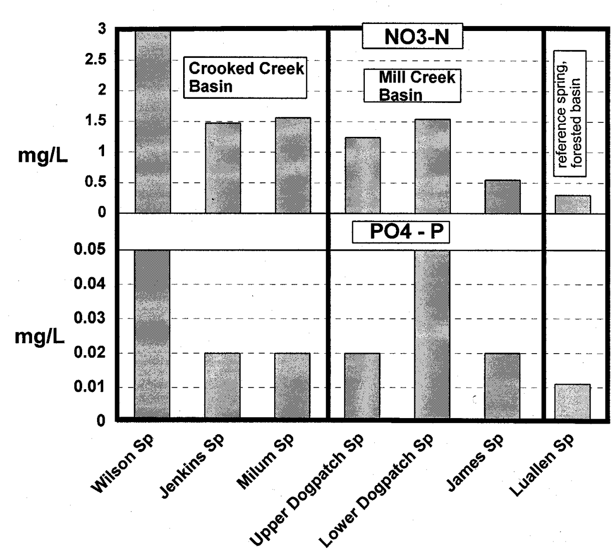

Figure 5. Average nitrate and soluble reactive phosphate values at major springs in the study area and at a reference spring.

sewage system is now compliant and that the problems, which caused the spills, have been alleviated. Chronic leakage from this aging system is also possible, but water quality results from this study did not implicate exfiltration.

Four base-flow water samples were collected and analyzed for a suite of water quality parameters during 1998 and 1999 at major springs within the Crooked Creek and Mill Creek basins, and at a reference spring (Luallen Spring) within a nearby forested basin (Figure 5). In comparing spring water quality it was noted that James Spring was not a recovery point for any of the dye traces from the Crooked Creek topographic basin, Upper Dogpatch Spring received dye from one trace, and Lower Dogpatch Spring received dye from two traces. The highest nutrient concentrations were recorded at springs within the Crooked Creek topographic basin, as would be expected given the more intensive agricultural land use there. Nutrient concentrations within the Crooked Creek springs, however, were closely mirrored by those Mill Creek springs which received dye from the Crooked Creek topographic basin (Upper and Lower Dogpatch). James Spring was significantly lower in nitrates than either the Crooked Creek or the Crooked Creek-influenced springs, and the reference spring was significantly lower than all sites for both nitrate and phosphate. Average fecal coliform bacteria concentrations showed similar relationships.

During summer, high water clarity, low discharge (and therefore low dilution), slow velocities, and warm temperatures make the Buffalo River susceptible to enhanced algal and cyanobacterial production caused by elevated nutrient levels. For perspective, the average nitrate concentration in the Buffalo River is 0.06 mg/L, whereas the average nitrate concentration at Lower Dogpatch Spring is 1.52 mg/L, twenty five times greater (Mott 1997). Dissolved reactive phosphorus averages were five times greater for this spring than for the river. Because nitrogen and phosphorus are limiting nutrients, raising their concentrations increases primary productivity. Increased aquatic plant production alters stream communities at various trophic levels, skewing them toward pollution-tolerant species or toward benefiting functional groups (filter feeders, scrapers or grazers, and herbivorous fish) (Mathis 1992; Bryant 1997; Petersen 1998). To park visitors, increased productivity means green water (phytoplankton), green slime (*Spyrogyra* and other filamentous green algae), and a general reduction in aesthetic appeal.

This study yielded the following conclusions: 1.) base flow discharge/area ratios can be used to screen areas for interbasin transfer; 2.) detailed geologic mapping and karst inventories, combined with dye tracing, can elucidate physical properties of aquifers which influence interbasin transfer and are therefore critical scientific, managerial, and interpretive tools in karst settings; 3.) areas of interbasin transfer can be significant both in their size and in their influence on water quality and aquatic communities, and must be accurately delineated for effective water resource management; and 4.) hazardous materials derived from spills, dumps, or leaks can be rapidly transported long distances via karst groundwater systems.

Based on these conclusions, the primary author recommends the following: 1.) the current moratorium on liquid waste management systems placed on the Buffalo River watershed should be expanded to include areas outside the topographic basin which yield water to springs within the Buffalo River basin; 2.) nonpoint source cost share programs should receive special emphasis in sensitive karst basins, especially where these basins harbor nationally significant water resources; 3.) a dye trace designed to detect exfiltration from the Dogpatch sewer system should be conducted to determine if leakage from this aging system is occurring; and 4.) spring inventories should be conducted to collect background water quality data, to screen for interbasin transfer, and to locate springs for immediate assessment and/or response in the event of a hazardous material release.

References

Bryant, Charles T. 1997. *An Assessment of the Macroinvertebrate Community of the Buffalo National River.* M.S. Thesis. Department of Biological Sciences. University of Central Arkansas. Conway, AR.

Hudson, Mark R. 1998. *Geologic Map of Parts of the Gaither, Hasty, Harrison, Jasper, and Ponca Quadrangles, Boone and Newton Counties, Northern Arkansas.* U.S. Geological Survey. Open-File Report 98-116. 1:24,000 scale.

Maner, Martin, and David N. Mott. 1991. *Mill Creek Survey.* Arkansas Department of Environmental Quality. Little Rock, AR.

Mathis, Mike L. 1991. *Macroinvertebrate Community Structure at Selected Sites on the Upper Buffalo River*. Department of Biological Sciences. University of Arkansas. Fayetteville, AR.

Mathis, Mike L. 1992. *A Survey of Trichoptera of the Upper Buffalo River and Its Tributaries, with Annotations on Their Distribution and Pollution Tolerances.* Department of Biological Sciences. University of Arkansas. Fayetteville, AR.

Mott, David N. 1997. *Ten Years of Water Quality Monitoring: Buffalo National River*. Resource Management Division. Buffalo National River. Harrison, AR: National Park Service.

Pugh, Aaron L. 1998. *Potentiometric Surface of the Ozark Aquifer in Northern Arkansas*: 1995. U.S. Geological Survey. Water Resources Investigations Report 98-4000. Little Rock. AR.

Petersen, James C., 1998, *Water-quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri and Oklahoma - Fish Communities in Streams and Their Relations to Selected EnvironmentalFactors*. U.S. Geological Survey. Water Resources Investigations Report 98-4155. Little Rock. AR.

Scott, Don H. and Kimberly R. Hofer. 1995. *Spatial and Temporal Analyses of the Morphologic and Land Use Characteristics of the Buffalo River Watershed*. Arkansas Water Resources Center. Publication number 170. University of Arkansas. Fayetteville, AR.

Sullivan, J. N. 1974. *Drainage Areas of Streams in Arkansas: White River Basin.* U. S. Geological Survey. Open-File Report. Little Rock, AR.