

## WATER BUDGET FOR WIND AND JEWEL CAVES

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### Objectives

The objectives and scope of this research topic were defined as: 1) Establishment of a sampling network for measuring; a) precipitation and evaporation, b) monitoring stream flow across park boundaries, c) spring discharges, and d) infiltration rates in the caves. 2) Assessment of transpiration rates in the parks. 3) Development of new options in managing water resources in cooperation with other federal and state agencies administrating lands adjacent to Wind and Jewel Caves.

### Methods

The objectives of the research are being accomplished in an effort that: builds on and extends our 3-year hydrologic study of the caves, makes use of the often ongoing projects of other workers in the area, and builds on and uses the excellent cooperative relationships that have been established with the Park personnel and managers. We are assuming that the sampling network to be established under objective 1 above should be designed to be operated on a long term basis by Park personnel and/or subsequent workers.

Objective 1.a: The precipitation and evaporation network already exists. Both Wind and Jewel Caves maintain weather stations that monitor precipitation, temperature, etc. In addition, Wind Cave has a network of rain gauges that monitor variations in precipitation across the Park for at least part of each year. We are upgrading these networks and interpreting the data in terms of the areas' water budgets.

Objective 1.b: The stream flow monitoring pertains mainly to Wind Cave National Park. Jewel Cave National Monument has no perennial surface stream flow. Three perennial streams flow onto Wind Cave National Park and then sink underground on Park property -- Highland Creek, Beaver Creek, and Cold Spring Creek. Rahn and Gries (1973) have published two measurements of the flow of Highland Creek from 1968 and 1969 and monthly flow data from Beaver Creek from July 1967 through May 1970. These data provide an invaluable time perspective. We are establishing permanent stream gauging stations on all three streams at points after they flow onto Park property and before they sink. The grant does not provide enough resources for the construction and instrumentation of

1, much less 3, permanent gauging stations. We therefore are working with the Park maintenance staff to construct the stilling wells and control structures and are borrowing the needed instrumentation. We are establishing the stations and beginning to accumulate flow data with borrowed instrumentation in the hope that the Park will be able to purchase permanent instrumentation as funds become available.

Stream flow data are critical to our water budget study of Wind Cave National Park. Such data are also critical for management questions of water supply for the Park and will provide the information necessary to establish the Park's "water rights" to the streams' flow. A dye trace from the sink of Beaver Creek to the Wind Cave water supply well (Alexander and others, 1989) highlights the importance of the sinking streams to the Park's underground waters.

Objective 1.c: Measurement of spring discharges pertains to both Wind and Jewel Caves (and to the major resurgent springs at Buffalo Gap, Hot Springs, and Cascade Springs). Rahn and Gries (1973) initiated flow measurements of the major resurgent springs and that work has been continued by them and by U.S.G.S. personnel. We assume that this important and fundamental work will continue.

There are only two small springs, Prairie Dog Spring and Choke Cherry Spring, on the property of Jewel Cave National Monument but both represent important water sources for wild life. Choke Cherry Spring is piped into a water tank whose overflow quickly sinks underground. It is easy to measure accurately the flow out the end of the pipe with a container of known volume and a stop watch. We periodically measured the flow of Choke Cherry Spring. Typical flow values are about  $Q = 20$  ml/s or 0.3 gal/min. Prairie Dog Spring was at one time also piped into a tank but the structure was not maintained and is no longer operational. It would be a fairly simple task for the Jewel Cave maintenance staff to repair the structure which would then allow simple flow measurements and provide water for wild life in the western part of the Monument. We will continue periodic measurements of these springs to look for seasonal variations in the flow.

There are four small additional springs on Forest Service land immediately east and south of the Monument borders, Lithograph, Stockade #1, Stockade #2, and Log Trough Springs. All four have been piped to water tanks and represent important water supplies for wild life and cattle on Forest Service land. We continue to periodically measure the water quality and flow in these four springs.

Wayne Schroeder (1987) initiated a careful, detailed survey of the flow in springs and other water sources in Wind Cave National Park. He has identified over 12 springs. The springs are all small but are the only available water source for the wild life in much of the Park. Given all of the field work that Wayne accomplished, we plan periodically to measure the flow and water quality in about 6 representative of Wind Cave Springs.

Objective 1.d: Infiltration rates are traditionally one of the most difficult parts of a water budget to determine. In porous media situations, infiltration rates are normally determined either by difference or by looking at the response of the water table to precipitation events. In karst environments, one potentially has direct access to some portion of the infiltrating water in the cave drips. The situation is not simple, however. Smart and Freiderich (1986), for example, in an elegant study of cave drips in the Mendip Hills of England have documented the very complex reaction of the vadose zone to precipitation events. Nevertheless, study of the rate and fluctuation of cave drips in response to surface precipitation provides one of the few direct ways to study infiltration phenomena.

Mike Wiles (oral communication, 1987) has initiated a study of the drip rates in Jewel Cave. We plan to continue Mike's work and measuring the drip rates at several of the wet areas in Wind and Jewel Caves. We are determining the flow rates with a fine enough time resolution to allow direct correlations with the surface precipitation data generated as part of Objective 1.a).

Monitoring the water levels in the lakes in Wind Cave is an important part of the infiltration study. We installed staff gauges in Calcite and Windy City Lakes in 1985. A continuous record of the water level in the Lakes will allow correlation with individual precipitation events. USGS and NPS personnel have installed a continuous water level and temperature recorder at the lakes (Greene, 1988).

Finally, under Objective 1, we are determining the chemistry of selected water samples collected from the caves, springs and wells. When ever feasible, we are sampling points from which we have generated chemical data in our recently completed Hydrologic Study (Alexander and others, 1989). This will establish a 5-year time series to investigate temporal changes in water quality. In addition, with the quantitative water volume data to be generated by the water budget, we can begin to do mass balance calculations of the rates at which chemical species move through the hydrologic system. We plan one additional set of isotopic measurements -- of the water from a new water supply well that has been drilled at Jewel Cave National Monument but which has not yet been sampled due to pump failures. Additional isotopic measurements on the areas' waters are being funded through other sources.

Objective 2: The transpiration rates of the vegetation in the Parks are being assessed using existing inventories of surface vegetation along with literature values for the transpiration rates of the relevant species, and the climate data generated under Objective 1.a.

Objective 3: The development of new interagency water resource management options is the most subtle, challenging, but in many ways the most exciting objective of this project. As research hydrogeologists it is not our job to tell NPS, USFS, State, or local officials and/or local

residents how to manage their respective water resources. Our job is rather to generate the information necessary to convince all of the various water managers and users that it is useful and mutually advantageous to work together. Then our job is to provide the scientific data, models, and understanding which will allow the various parties to make informed, workable management decisions.

The first part of our job consists in part of demonstrating that the hydrology of the entire area is interrelated. Dye tracing provide a particularly graphic demonstration of the interrelation of water from two different points. We are continuing, as part of this Water Budget Study, dye trace studies. It is evident that many parts of the Wind and Jewel Cave hydrologic systems have time constants measured in months to years. The major dye traces under way at the two Caves will continue through 1989 and perhaps beyond. These experiments are irreversibly underway. We only need to continue to collect and analyze the samples. The Beaver Creek trace directly ties all human activities that affect water quality in the Beaver Creek drainage to the water quality in the Wind Cave water supply well.

We are continuing selected flow and chemical measurements at sites off the National Park and National Monument property. The four Forest Service springs immediately southeast of Jewel Cave National Monument illustrate the type of data we are gathering. These springs are important because exploration has extended the known cave beyond the surface boundaries of the Monument in southeastern and southwestern directions. At some point in the future, the Monument will need to be extended in those directions to assure the continued protection of the cave. In any proposed extension, the question of the water rights to these four springs may become an important and accurate information on the quantity and quality of water involved will be necessary.

The goal of all of the activities under Objective 3 is to study and document the interrelationships of the Park and Monument with the surrounding areas and to generate the information needed for management decisions.

### Results

Most of the first field season was consumed finding the good sites for the stream gauges in Wind Cave National Park. We are minimizing any construction or other alteration of the Park's natural areas. We have located existing structures on Cold Brook and Highland Creek which will serve as control structures for the gauges and have installed a stream gauge on Highland Creek which is measuring flows using an analog recorder. We located an appropriate natural control site on Beaver Creek. We have borrowed a Campbell Data Logger and are acquiring the necessary pressure transducer and control cables.

About 6 water samples were collected from remote areas of Jewel Cave and

subjected to chemical analyses. The results of these analyses are reported in Alexander and others (1989). Three samples from Cascade Springs and a sample from the Lakes in Wind Cave have been collected and submitted for tritium analyses.

Mike Wiles has made available to us a significant body of data he has obtained on the drip rates in Jewel Cave. That data is being evaluated and our next field season's efforts will build on Mike's data.

In cooperation with Park personnel we have continued to gather samples following the dye traces started during our previous Hydrologic Study of Jewel Cave/Wind Cave. Dye continues to be detectable in Jewel Cave drips from the 1986 fluorescein and 1987 Rhodamine WT parking lot traces. Dye continues to be detectable in the Wind Cave trace supply well from the 1987 Beaver Creek trace. Dye trace data through January 1989 is tabulated in Alexander and others (1989).

#### Literature Cited

- Alexander, E. C., Jr., M. A. Davis and S. C. Alexander. 1989. Final report, Hydrogeologic Study of Jewel Cave/Wind Cave. March, 1989, 196 pp. + figures and appendices.
- Greene, E. 1988. Continuous monitoring of water level and temperature at Wind Cave's Lakes. Paper presented at the 1988 Hot Springs NSS Convention, June 30, 1988.
- Rahn, P. H. and J. P. Gries. 1973. Large springs in the Black Hills, South Dakota and Wyoming. South Dakota Geol. Surv. Report of Investigations No. 107, 46 pp.
- Schroeder, W. 1987. Report on the study of the surface water distribution within Wind Cave National Park during the summer of 1987. (unpublished report) Sept. 25, 1987. 42 pp.
- Smart, P. L. and H. Friederich. 1986. Water movement and storage in the unsaturated zone of a maturely karstified carbonate aquifer, Mendip Hills, England. In: Proceeding of the Environmental Problems in Karst Terranes and Their solutions Conference, October 28-30, 1986. Bowling Green, Kentucky. Nat'l Water Well Assoc., Dublin, Ohio. pp. 59-87.