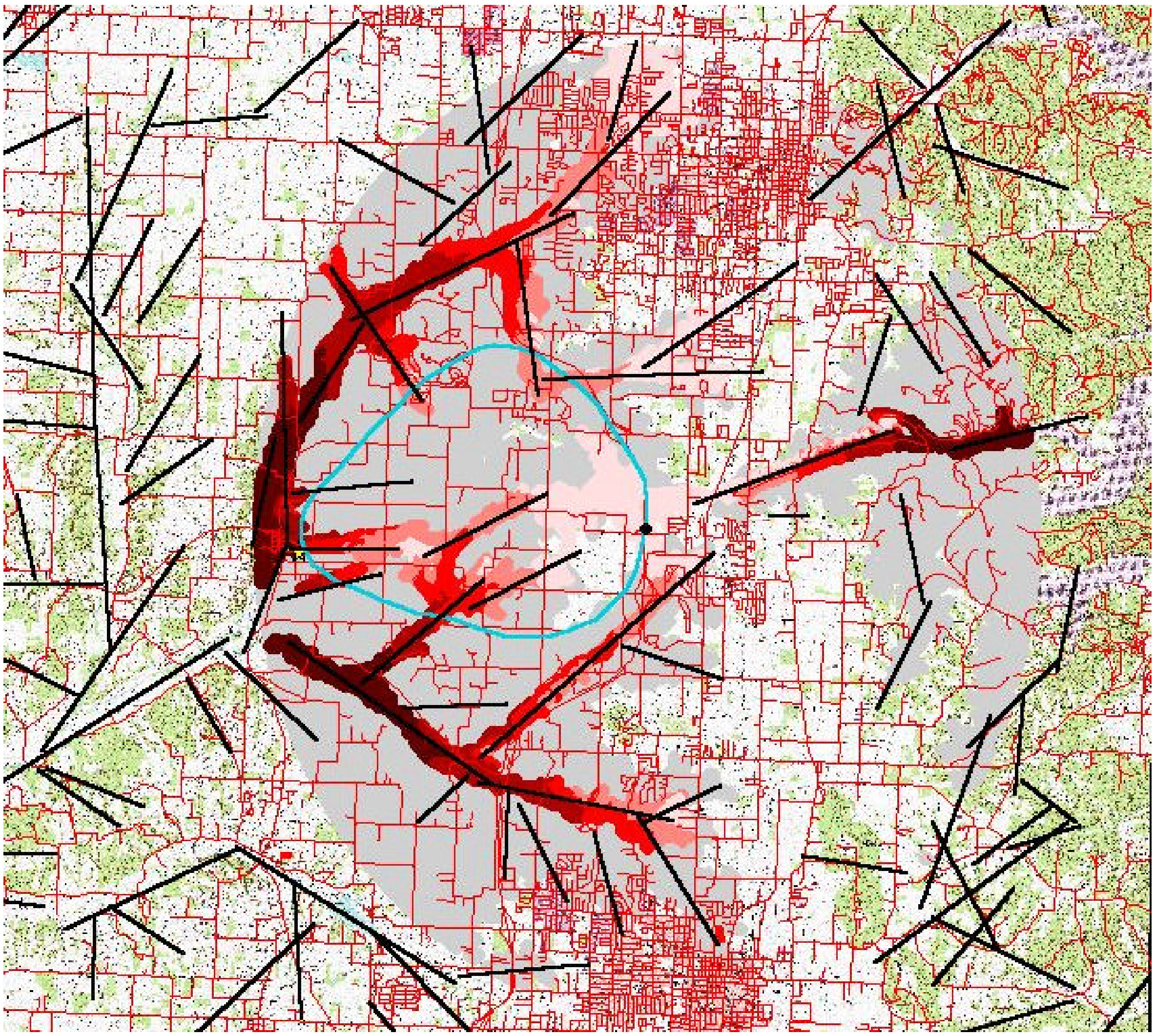
PROTECTION OF CAVE SPRINGS CAVE BIOTA AND GROUNDWATER BASIN



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Cover image by Terri Gorham.

EXECUTIVE SUMMARY

This is the fourth in a series of reports on the status of endangered biota and of environmental quality in Cave Springs Cave (CSC), Benton County, Arkansas (Brown *et al*., 1998; Graening and Brown, 1999, 2000), funded by the Arkansas Natural Heritage Commission (ANHC). As a result of these studies, Cave Springs Cave is now one of the most thoroughly studied cave ecosystems in Arkansas. This series of studies has spawned a renewed interest in cave ecosystems and their vulnerable condition. There are now many projects focusing upon the documentation of subterranean biodiversity and its protection. Partners include the Arkansas Game and Fish Commission, US National Park Service, US Forest Service, US Fish and Wildlife Service, Arkansas Department of Environmental Quality, *The Nature Conservancy*, and the Departments of Biological Sciences and Geosciences at the University of Arkansas. Two studies are particularly germane to this Natural Area: Graening *et al*. (2001) compared the fauna, water and sediment quality at CSC to 63 other caves in the State; and Graening and Brown (in progress) are comparing the ecosystem dynamics and pollution effects elucidated in these studies of CSC to three other priority caves in Benton County. Thus, ANHC's investment of resources in the study and protection of this Natural Area have been quite effective, and this investment is being leveraged to benefit other endangered species' habitats.

Very few long-term data sets exist for North American caves, and this seriously limits knowledgeable management of them. Cave Springs Cave should continue to be monitored to help fill this void and to enable successful management of its unusual biota and their habitat. But monitoring is only the first step - successful management sometimes requires taking bold actions to protect these natural resources. Our management recommendations at the end of this report outline the actions we feel need to be initiated now. Bacteria and some nutrient and metal concentrations chronically exceed Regulation 2 maximum contaminant levels and regional background levels. It is imperative to reduce the pollution input from septic leachates and land-applied manures in the CSC groundwater basin, especially if sensitive species, such as cave amphipods (*Stygobromus ozarkensis*, State Species of Concern) are to persist in this Natural Area. Despite the degraded water quality, the Ozark Cavefish population appears to be stable or increasing.

INTRODUCTION

Ozark Cavefish

Ozark cavefish, *Amblyopsis rosae*, are among the most rare and endangered animals in the world, and the majority of them live in Cave Springs Cave (CSC), Benton County, Arkansas. Surveys of this and other cavefish sites throughout the Springfield Plateau region of Arkansas, Missouri, and Oklahoma, show CSC to be their most important refuge (Brown and Willis, 1984; Willis and Brown, 1985; Brown and Todd, 1987; USFWS 1989). About 15-25 cavefish are usually found in a trip through Logan Cave, about 15 km west of this site (Brown and Willis, 1984; Brown, 1996), which is the second largest deme. In the remaining 15-20 caves where Ozark cavefish have been recently seen, no more than 5 fish may be seen during a visit and the norm is much less. Based on its rarity, special habitat requirements, limited reproductive potential, and declining numbers, it has been declared "threatened" by the US Congress (Federal Register November 1, 1984: 49 FR 43965). CSC is also an important refuge for endangered gray bats, *Myotis grisescens*, State-listed amphipods (*Stygobromus ozarkensis*) and isopods *(Caecidotea stiladactyla*), and other biota that deserve protection as components of an extremely diverse and vulnerable ecosystem of the Ozark karst ecoregion. We have been monitoring the environmental quality of the habitat and censusing the cavefish population for the ANHC under contracts since 1998 (Brown *et al*., 1998; Graening and Brown, 1999, 2000). The project for year 2000-2001 has been a continuation of these activities, and is a final chapter in this series of studies.

While the CSC cavefish population seems to be increasing since the cave and the species have been protected, the last four years of population censuses have varied considerably (102 to 166). The quality of the water in the cave appears to have significantly declined in recent years and this threatens the survival of the cavefish and other stygobites that share the environment. Thus, it is important that studies of the environmental quality and monitoring of the cavefish population continue as outlined in the recovery plan (USFWS, 1989). We have made considerable progress with analysis of Cave Spring Cave's recharge zone. The geographical information system (GIS) of the recharge zone will provide the ANHC and other agencies with a valuable management tool for determining the impact of different land uses at sites throughout this basin as rapid growth continues in this area of the state.

Retention Net

Cavefish and other stygobionts occasionally wash out of caves into surface streams. Graening has incidentally found three cavefish in the fish hatchery raceways downstream of Cave Springs Cave during the course of our studies there, although no planned effort to watch for them was involved. Although these three were transported back into the cave, it is likely that others were lost in this manner. It is quite certain that the white, blind cavefish would not survive for long in the clear, well-lit water with trout and other predatory fish present. Some losses from cavefish populations in this manner may be natural, but even so, some effort to preserve them from this fate seems appropriate. Besides, the resurgence for Cave Springs Cave, like many other cave springs, has been highly modified and this may have exacerbated the situation.

The small dam constructed outside the cave has created what may be a hazard for the cavefish. The impounded water at the mouth of the cave flows fairly slowly, but when the water enters the sluice leading to the water wheel its speed increases very abruptly (Fig. 3). Cavefish easily swim about in the resurgence pool, but it is doubtful that any cavefish would be able to swim against the currents in the water wheel sluice, even at the lowest flow rates we have observed there. When a cavefish swims past the opening to the sluice, they are very likely to be entrained by its fast current and swept out into the fish hatchery raceways where predators (fish, birds, crayfish) are abundant. At water stage levels above 10.96 ft., water begins to flow through a notch in the dam and forms a waterfall beside the sluice (Fig. 4). To alleviate this hazard, we decided to install a net across the mouth of the cave in an attempt to keep the cavefish from swimming out of the cave and near the entry to the sluice (Fig. 5).

GIS and Predicting Potential Pollution

A GIS-based advective transport model developed by Curtis (2000) was used to predict potential pollution routes as they flowed from a release point location near or in the CSC recharge area. The model was developed specifically for a mantled karst environment and, while simplistic in design, has produced results that compare favorably to traditional groundwater investigative methods such as dye tracing studies.

OBJECTIVES

1) Analyze an array of water quality parameters at base flow during fall and spring at the mouth of the cave and deep in the cave upstream of bat roosts, for a total of 4 sampling sets.
2) Sample four storm events with at least one in early fall and one in early spring, measuring the same parameters as above, with four samples per storm, for a total of 16 sampling sets. Use an automatic sampler to collect samples deep inside the cave during at least one of the storms for comparison with values at the mouth.
3) Analyze at least one sample of bat tissue for organo-chlorine pesticides and metals, if any bat tissue becomes available for analysis.
4) Count cavefish visible in the cave during fall and spring using the same methods used in all previous surveys.
5) Survey the cave for other aquatic and terrestrial biota.
6) Construct and maintain a retention net inside the mouth of the cave.
7) Complete stable isotope ratio analyses (SIA) of the Cave Springs Cave food web (bat tissue, if available).
8) Perform a SIA of the Logan Cave food web.
9) Continue to analyze the aquifer recharge zone to monitor potential problem areas using a geographical information system.
10) Monitor the air temperature outside the cave, and air and water temperatures inside the cave.
11) Perform a risk assessment of the Cave Springs Cave recharge area.

METHODS

Permits

This study was performed under the following permits: Federal Fish and Wildlife Service Permits No. PRT-834518, No. TE834518-2 and No. TE834518-1; ANHC Permit No. S-NHCC-99-005; and AGFC Educational Collecting Permits No.1082 and 1084. Impact was minimized by restricting visits into the cave to times when gray bats were not present and by avoiding wading in the cave stream whenever possible.

Environmental Quality Sampling

Meteorological data, including air temperature, barometric pressure, and rain accumulation, were taken from the Rogers Automatic Weather Observing / Reporting System (KROG), Rogers, Arkansas, and from Drake Field (KFYV), Fayetteville, Arkansas, at the following Internet URL's: http://tgsv7.nws.noaa.gov/weather/current/KROG.html and http://tgsv7.nws.noaa.gov/weather/current/KFYV.html. Stage (ft) was read on a USGS gauge *in situ* at the pool at the cave orifice, converted to meters (m), and discharge was computed from the relationship based upon USGS hydrological data (Brown *et al*., 1998): discharge (m^3/min) = 35.79 x (m) – 109.99. Stage and discharge measurements were measured every time water samples or other measurements were taken. Base flow samples were collected at the cave stream orifice in the sluice leading to the water wheel, and downstream of all bat roosts. Storm flow samples were collected at the same location during each different storm event before, during, and after the peak discharge.

Conductivity (µSiemens/cm), turbidity (nephlometric turbidity unit), pH, temperature (^oC), and dissolved oxygen (mg/l) were measured *in situ* at the cave orifice using a YSI model 85 ™ Dissolved Oxygen Meter, an Orbeco-Hellige Model 966 ™ portable turbidimeter, and a portable pH meter. Water samples were taken at the downstream and/or the upstream station, and all water samples were held on ice and processed within 48 hours. The samples were analyzed for some or all of the following: total coliform, *Escherichia coli*, and total viable cell densities, nitrate, nitrite, ortho-phosphate, total phosphate, total Kjeldahl nitrogen, total organic carbon, , sulfate, chloride, and dissolved metals. Analytical procedures followed approved USEPA methods, and appropriate quality assurance and quality control measures were taken. Depending upon the parameter, the water samples were analyzed by the authors at the Department of Biological Sciences, University of Arkansas at Fayetteville (UAF), at the Water Quality Laboratory (Arkansas Water Resources Center, UAF), Central Analytical Laboratory (Center for Excellence in Poultry Science, UAF) or at the Environmental Chemistry Laboratory (Arkansas Department of Environmental Quality, Little Rock, Arkansas). Dissolved organic carbon samples were prepared by filtering water samples through pre-combusted 0.45 µm Whatman ™ GF/C filters, and TOC samples were put into glass vials with Teflon ™ seals, then acidified (pH < 1) with HCl. TOC was measured at the Water Quality Lab using a Shimadzu TOC-500 Total Carbon Analyzer). For dissolved metals analyses, water samples were filtered through 0.45 µm Gelman Supor-450 ™ polycarbonate filters into glass vials with Teflon seals and acidified with nitric acid. For the metals analyses of cave sediments, the samples were collected in pre-washed glass containers, stored in ice and immediately transferred back to UAF where they were then dried in a drying oven at 60 ^0C, pulverized, and analyzed at Central Analytical Laboratory.

Temperature sensors (Optic Stow Away Temp by ONSET Computer Corporation) have been installed in Cave Springs Cave and programmed to record temperatures in the air and water each hour. After one year the temperature information recorded will be downloaded to a computer using a shuttle and base station interface system purchased from ONSET. The sensors will be left in place to continue recording until the batteries fail. They are equipped with a battery indicator light that should be checked every few months when the gray bats are not present. The sensors are hidden to prevent damage by vandals. Identical sensors were purchased by a separate grant and deployed in Logan Cave. Thus, data will be available for comparison with thermal conditions in Cave Springs Cave.

Ozark Cavefish Population Census

The visual survey was performed by the same method as previous surveys and included at least two of the people used in a previous survey (Willis and Brown, 1985; Brown and Todd, 1987). Using helmet lights as well as powerful diving lights underwater, three people moved slowly upstream and counted cavefish as they were sighted. During this study, length and location of cavefishes were also recorded. After sighting each cavefish, the fish length was visually estimated and put into one of three classes: 1) small – less than 2.5 cm; 2) medium – between 2.5 and 5 cm 3) large – greater than 5 cm. Michael Slay (UAF) and Brian Wagner (Arkansas Game and Fish Commission), assisted with the census.

Retention Net

On February 18th, 2001 we installed a net across the mouth of the cave far enough inside to avoid capturing debris (leaves, sticks, *etc.*) that falls into the resurgence from the surrounding forest (Fig. 5). The 2 m x 10 m net with 6 mm mesh was exactly the right size to span the opening to both the north and south cave channels. Holes were drilled in the rock face on each side of the opening and eye screws installed to secure the net. Rocks were placed along the lead line (bottom) the entire length of the seine net to help hold it in place. Some slack was left in the net vertically and the top eye screws were set above the base flow water level to allow the net to float up during storm flows. Flow rates were measured in the mouth of the cave where the net was placed, and in the water wheel sluice periodically during different flow conditions during the following months. Inspections of the net were performed daily for the first week, then weekly for a month, then at greater intervals.

Pollution Susceptibility Analyses

A geographic information system project was created using ArcView 3.2 and Spatial Analyst and Image Analysis Extensions (ESRI), by Terri Gorham, Owl Creek GeoConsulting. Aerial photographs of the recharge zone were furnished by Dr. John Harris of the Arkansas State Highway and Transportation Department. Aerial photographs were also purchased from the US Geological Survey (USGS) and from Harris Aerial Surveys, Inc., who shot new color aerial photographs in December of 1999. The recharge zone boundary, water table contours and photo-lineaments/fracture traces were redrawn from Williams (1991) onto the Bentonville South and Springdale quads and digitized. A Garman GPS III Plus global positioning system handheld unit (latitude/longitude, NAD 27 Continental US) was used to register specific locations (such as sinkholes or poultry houses) in the recharge zone during ground-truthing and was then reprojected to UTM/NAD27 in ArcView 3.2. See the Appendix for metadata documentation of files provided by GeoStor website (http://www.cast.uark.edu/cast/geostor) currently hosted by the Center for Advanced Spatial Technology (CAST), University of Arkansas, Fayetteville. Note that the "Datum" notation is for the data available from the website and is not the download datum chosen. Two coordinate systems and datums were used in this study: geographic (decimal degree)/Nad83, and UTM/NAD27. Any reprojections of shapefiles were accomplished using the ArcView 3.2 Projection Utility Wizard. The digital topographic maps (Bentonville South and Springdale 7.5-minute quadrangles) were obtained from the Spatial Analysis Laboratory (SAL), University of Arkansas, Monticello (http://sal.uamont.edu/sal/default.htm). The SAL website should be reviewed for metadata regarding this data layer.

The spill model of Curtis (2000) was applied using ArcView 3.2 GIS software and only required two datasets, a Digital Elevation Model (DEM) and digitized lineaments for the study area. The DEM utilized was the National Elevation Dataset (NED) for the study area. The NED is a new raster product from the United States Geological Survey (USGS) with a resolution of approximately 30 meters and based on the North American Datum of 1983 (NAD83). The NED is considered to be superior to the older DEMs because of processing steps that minimized artificial discontinuities and has no void areas. The lineaments for the study area were originally identified by Hanson (1973) and had already been digitized and georectified by Curtis (2000). A geographic (latitude/longitude) coordinate system was used based on NAD 83. A Digital Raster Graphic (DRG) of a USGS 7.5 minute topographic map downloaded from SAL-UAM and a road layer downloaded from GeoStor were also used to assist placement of the initial spill locations. The scope of the model is focused on advective transport only and does not consider any other data or mechanisms. Curtis (2000) states that the model is meant to be used only by persons knowledgeable in karst hydrogeology, and is meant to be used in conjunction with the discussion and instructions in his dissertation.

An initial spill location (point source) was chosen from which the model then predicted overland flow by identifying a path on the NED which had elevation values equal to or less than that of the initial spill location. Lineaments were then identified which were within 30 meters of the overland flow path. The lineaments were then used by the model as a spill point along the entire length of the lineament. Four different spill locations, all chosen along Highway 540, were modeled. Since the potentiometric head is an unknown value, the spill elevation is used so that a worst-case scenario for advective transport is modeled, and to eliminate the need for often-unavailable water table data. Placement of the initial spill location can greatly affect the obtained flow path. For example, one-cell differences in the placement of a spill point could result in placement within different basin boundaries, and thus, result in different predicted transport routes. Any interested user of this model must be familiar with the methodology of Curtis (2000).

RESULTS

Environmental Quality Assessment

Results of the water quality analyses are show in Tables 2 through 4. Table 3 shows a summary of 40 months of sampling by the authors in CSC. Although no bat tissue was available for pesticide screening, a base-flow grab sample of cave water was analyzed for a wide array of volatile and semi-volatile compounds (Table 4).

Retention Net

Although the seine net across the mouth of the cave should prevent cavefish from swimming out near the sluice, we have no way of knowing whether this happens. Flow rates ranging from 0.04 to 0.33 m/sec were recorded through the mouth of the cave where the net was placed (Table 1, Fig. 4). Flows from 0.62 to 2.55 m/sec were measured in the water sluice, and an almost instantaneous transition from the slow rate to the fast one occurs (Fig. 3). Crayfish (*Orconectes punctimanus*) were very abundant when the net was installed and seem to have increased on both sides of the net during the study.

Within a week after installing the net, one of the largest storm flows ever observed through the cave occurred. The net did not float up as high as planned and was covered by water up to 40-50 cm over the top at the peak discharge stage (Fig. 6, Table 1). During this stage, cavefish could have been swept over the net, if they were high enough in the water, so the net was at least partially ineffective at a critical time for it to perform its function. Observation of the net was ineffective during this period of deep, turbid water. No live or dead animals other than *O. punctimanus* were ever observed on the net. Ten or more of these crayfish were always clinging to the net on the upstream side, with a few on the outside, and many more were seen on the substrate on both sides of the net. After return of the gray bats (*Myotis grisescens*), some bat fecal pellets accumulated at the net. Two cavefish were observed swimming in the cave near the net when it was installed, but these were the only ones seen here during this study.

Table 1. Flow rates and other conditions at the resurgence of Cave Springs Cave, Arkansas, at different water levels (stages).

Parameters	Pre-Flood	Flood		Recession		Base flow
Stage (ft.)	10.8	12.24	11.84	11.66	11.07	10.34
Flow through mouth (m/s)	0.07	0.33	0.20	0.17	0.09	0.04
Flow through sluice (m/s)	0.39	2.55	2.26	2.13	0.75	0.62
Temperature (^{o}C)	14.0	13.5	15.0	14.5	15.0	15.0
Turbidity (NTU)	0.7	11.8	6.7	5.6	0.9	1.2

Table 2. Water quality at Cave Springs Cave during storm flows.

	Date	9/12/00	9/13/00	9/24/00	11/7/00
Physical					
Rain Accumulation	cm	1.5	---	0.5	0.5
Water Temperature	^{o} Celsius	15.0	15.0	15.5	---
Water Stage	m	3.13	3.13	3.15	---
Discharge	m^3/min	2	2	3	---
Dissolved Oxygen	mg/l	8.8	10.1	9.8	---
Specific Conductivity	μS/cm	354	356	330	---
pH		6.5	6.6	6.6	---
Turbidity	NTU	0.5	0.6	2.72	---
Nutrients					
TOC	mg/l	8.14	2.36	0.12	0.61
Nitrate-N	mg/l as N	5.216	5.415	6.691	5.718
Sulfate	mg/l	2.33	2.49	2.88	2.54
Ammonia	mg/l as N	0.01	0.01	0.07	---
Ortho-phosphate	mg/l as P	0.023	0.027	0.022	0.036
Dissolved Metals					
Aluminum	mg/l	n.d.	n.d.	n.d.	n.d.
Arsenic	mg/l	n.d.	n.d.	n.d.	n.d.
Barium	mg/l	0.07	0.04	0.13	0.06
Beryllium	mg/l	n.d.	n.d.	n.d.	n.d.
Boron	mg/l	n.d.	n.d.	n.d.	n.d.
Cadmium	mg/l	n.d.	n.d.	n.d.	n.d.
Calcium	mg/l	65.5	42.4	65	63.0
Chloride	mg/l	8.6	8.9	8.8	7.5
Chromium	mg/l	n.d.	n.d.	n.d.	n.d.
Cobalt	mg/l	n.d.	n.d.	0.001	n.d
Copper	mg/l	0.02	0.02	---	0.04
Fluoride	mg/l	0.03	0.04	0.07	0.03
Iron	mg/l	0.02	0.01	0.02	0.03
Lead	mg/l	n.d.	n.d.	n.d.	n.d.
Magnesium	mg/l	1.93	1.39	2.11	2.02
Manganese	mg/l	0.02	0.03	0.02	0.04
Nickel	mg/l	n.d.	n.d.	n.d.	n.d.
Selenium	mg/l	n.d.	0.01	0.01	0.02
Vanadium	mg/l	n.d.	n.d.	n.d.	n.d.
Zinc	mg/l	0.01	0.001	0.05	0.04
Microbial					
Escherichia coli	CFU/100ml	178	200	1110	7380
Total Coliforms	CFU/100ml	5310	7820	> 20050	>20050

Table 2, cont. Water quality at Cave Springs Cave during storm flows.

	Date	2/13/01	2/14/01	2/15/01	2/18/01	2/25/01	2/26/01
Physical							
Water Temperature	^{o} Celsius	15	15.5	13	14	13.5	---
Water Stage	m	3.10	---	---	3.32	3.73	---
Discharge	m^3/min	1	---	---	9	24	---
pH		6.5	6.9	6.9	6.1	6.5	---
Nutrients							
TOC	mg/l	1.1	0.4	1.3	1.3	2.7	1.9
Nitrate-N	mg/l as N	0	0	5.522	4.359	4.372	6.087
Sulfate	mg/l	3.47	3.42	5.33	4.26	4.45	4.32
Ammonia	mg/l as N	0.06	0.05	---	0.04	0.03	0.12
Ortho-phosphate	mg/l as P	0.024	0.022	0.029	0.023	0.065	0.068
Dissolved metals							
Aluminum	mg/l	n.d.	n.d.	0.03	0.01	0.18	0.11
Arsenic	mg/l	n.d.	0.01	0.01	0.01	0.02	0.01
Barium	mg/l	0.15	0.1	0.06	0.15	0.47	0.3
Beryllium	mg/l	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Boron	mg/l	0.03	n.d.	n.d.	0.15	0.08	0.04
Cadmium	mg/l	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Calcium	mg/l	61	60.2	51	49.3	35.8	39.4
Chloride	mg/l	9.9	9.6	5.4	8.7	7.3	6.9
Chromium	mg/l	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cobalt	mg/l	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Copper	mg/l	0.02	0.03	0.03	0.03	0.02	0.02
Fluoride	mg/l	70	60	30	30	100	30
Iron	mg/l	0.02	0.02	0.03	0.02	0.09	0.08
Lead	mg/l	0.03	0.03	n.d.	n.d.	n.d.	0.01
Magnesium	mg/l	2.03	2.06	2.29	2.38	2.4	2.48
Manganese	mg/l	0.01	0.01	0.01	0.01	0.02	0.02
Nickel	mg/l	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Selenium	mg/l	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Vanadium	mg/l	0.01	0.01	0.01	0.01	0.02	n.d.
Zinc	mg/l	0.06	0.04	0.02	0.17	0.25	0.13
Microbial							
Escherichia coli	CFU/100ml	10	100	530	1640	1920	2380
Total Coliforms	CFU/100ml	20	200	5040	5910	> 20050	16520

Table 3. Water quality at Cave Springs Cave during base flows.

	Date	9/7/00	10/5/00	4/7/01	40 month Summary		
Physical					Min.	Mean	Max.
Water Temperature	^{o} Celsius	14.9	---	15.5	13.4	14.5	15.5
Water Stage	m	3.12	---	3.20	3.10	3.74	10.5
Discharge	m^3/min	2	---	4	1	4	11
Spec. Conductivity	µS/cm	330	---	337	240	330	395
Turbidity	NTU	0.6	---	1	0.1	1	4
pH		7	---	6.1	6.1	6.9	7.5
Nutrients							
TOC	mg/l	3.4	0.59	1.8	< 0.2	1.7	5.0
Ammonia	mg/l as N	0.10	---	< 0.01	< 0.01	0.04	0.10
Nitrate-N	mg/l as N	5.41	5.34	7.06	4.28	5.62	7.45
Ortho-phosphate	mg/l as P	0.02	0.02	0.02	0.02	0.03	0.05
Sulfate	mg/l	2.48	2.35	2.46	2.35	3.54	7.13
Dissolved Metals							
Arsenic	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	0.003	0.005
Barium	mg/l	0.06	0.05	0.04	0.04	0.05	0.1
Beryllium	mg/l	< 0.1	< 0.1	< 0.1	< 0.1	---	1
Boron	mg/l	< 0.004	< 0.004	< 0.004	< 0.004	---	0.015
Cadmium	mg/l	< 0.1	< 0.1	< 0.1	< 0.1	---	1
Calcium	mg/l	64.7	61.5	53.8	53.8	59.7	64.7
Chloride	mg/l	---	8.7	8.1	6.1	7.9	9.5
Chromium	mg/l	< 0.4	< 0.4	< 0.4	< 0.4	---	4
Cobalt	mg/l	0.001	0.001	< 0.001	0.001	---	0.002
Copper	mg/l	0.03	0.01	< 0.01	0.01	0.02	0.05
Fluoride	mg/l	---	0.02	0.05	0.02	---	0.05
Iron	mg/l	0.01	0.01	< 0.01	0.005	0.04	0.22
Lead	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.04
Magnesium	mg/l	1.9	1.7	1.7	0.2	1.5	1.9
Manganese	mg/l	0.02	0.02	< 0.01	< 0.01	---	0.02
Nickel	mg/l	n.d.	n.d.	n.d.	---	n.d.	---
Selenium	mg/l	0.001	0.001	< 0.001	< 0.001	0.013	0.032
Vanadium	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	---	10
Zinc	mg/l	0.010	0.010	0.004	0.004	0.049	0.285
Microbial							
Escherichia coli	CFU/100ml	100	200	200	1	227	3240
Total Coliforms	CFU/100ml	4060	1500	2220	53	3008	10910

Table 4. Results of volatile and semi-volatile organics screening of a base-flow grab sample at Cave Springs Cave on 4/7/01.

Compound	ppm	Compound	ppm	Compound	ppm
1,1,1,2-Tetrachloroethane	< 2.5	3-Nitroaniline	< 0.2	Di-n-butyl-phthalate	< 2.5
1,1,1-Trichloroethane	< 2.5	4-6-Dinitro-2-methylphenol	< 0.2	Di-n-octyl-phthalate	< 2.5
1,1,2,2-Tetrachloroethane	< 2.5	4-Aminobiphenyl	< 0.2	Diphenylamine	< 2.5
1,1,2-Trichloroethane	< 2.5	4-Bromofluorobenzene	92	Ethyl Benzene	< 2.5
1,1-Dichloroethane	< 2.5	4-Bromophenyl-phenyl-ether	< 0.2	Fluoranthene	< 2.5
1,1-Dichloroethene	< 2.5	4-Chloro-3-methylphenol	< 0.2	Fluorene	< 2.5
1,1-Dichloropropene	< 2.5	4-Chloroaniline	< 0.2	Hexachlorobenzene	< 2.5
1,2,3-Trichlorobenzene	< 2.5	4-Chlorophenyl-phenyl-ether	< 0.2	Hexachlorobutadiene	< 2.5
1,2,3-Trichloropropane	< 2.5	4-Chlorotoluene	< 2.5	Hexachlorobutadiene	< 2.5
1,2,4-Trichlorobenzene	< 2.5	4-Methylphenol	< 0.2	Hexachlorocyclopentadiene	< 2.5
1,2,4-Trimethylbenzene	< 2.5	4-Nitroaniline	< 0.2	Hexachloroethane	< 2.5
1,2-Dibromo-3-Chloropropane	< 2.5	4-Nitrophenol	< 0.2	Indeno(1-2-3-cd)pyrene	< 2.5
1,2-Dibromoethane	< 2.5	Acenaphthene	< 0.2	Isophorone	< 2.5
1,2-Dichlorobenzene	< 2.5	Acenaphthylene	< 0.2	Isopropylbenzene	< 2.5
1,2-Dichloroethane	< 2.5	Acetone	< 15	Meta Xylene	< 2.5
1,2-Dichloroethane-D4	107.6	Acetophenone	< 0.2	Methyl Ethyl Ketone	< 2.5
1,2-Dichloropropane	< 2.5	Aniline	< 0.2	Methylene Chloride	< 2.5
1,3,5-Trimethylbenzene	< 2.5	Anthracene	< 0.2	Naphthalene	< 2.5
1,3-Dichlorobenzene	< 2.5	Benzene	< 2.5	Naphthalene	< 2.5
1,3-Dichloropropane	< 2.5	Benzo(a)anthracene	< 2.5	N-Butyl Benzene	< 2.5
1,4-Dichlorobenzene	< 2.5	Benzo(a)pyrene	< 2.5	Nitrobenzene	< 2.5
1-2-4-5-Tetrachlorobenzene	< 0.2	Benzo(b)fluoranthene	< 2.5	Nitrobenzene-d5(Surr.)	< 2.5
1-2-4-Trichlorobenzene	< 0.2	Benzo(g-h-i)perylene	< 2.5	N-Nitrosodibutylamine	< 2.5
1-2-Dichlorobenzene	< 0.2	Benzo(k)fluoranthene	< 2.5	N-Nitroso-di-n-propylamine	< 2.5
1-2-Diphenylhydrazine	< 0.2	Benzyl-alcohol	< 2.5	N-Nitrosopiperidine	< 2.5
1-3-Dichlorobenzene	< 0.2	Bis(2-chloroethoxy)methane	< 2.5	N-Propyl Benzene	< 2.5
1-4-Dichlorobenzene	< 0.2	Bis(2-chloroethyl)-ether	< 2.5	Ortho Xylene	< 2.5
1-Chloronaphthalene	< 0.2	Bis(2-ethylhexyl)phthalate	< 2.5	Para Xylene	< 2.5
1-Naphthylamine	< 0.3	Bromobenzene	< 2.5	Pentachlorobenzene	< 2.5
2,2-Dichloropropane	< 2.5	Bromochloromethane	< 2.5	Pentachloronitrobenzene	< 2.5
2-3-4-6-Tetrachlorophenol	< 0.2	Bromodichloromethane	< 2.5	Pentachlorophenol	< 2.5
2-4-5-Trichlorophenol	< 0.2	Bromoform	< 2.5	Phenacetin	< 2.5
2-4-6-Tribromophenol(Surr.)	59.9	Bromomethane	< 2.5	Phenanthrene	< 2.5
2-4-6-Trichlorophenol	< 0.2	Butyl-benzyl-phthalate	< 2.5	Phenol	< 2.5
2-4-Dichlorophenol	< 0.2	Carbon Tetrachloride	< 2.5	Phenol-d6(Surr.)	< 2.5
2-4-Dimethylphenol	< 0.2	Chlorobenzene	< 2.5	P-Isopropyl Toluene	< 2.5
2-4-Dinitrotoluene	< 0.2	Chloroethane	< 2.5	Pronamide	< 2.5
2-6-Dichlorophenol	< 0.2	Chloroform	< 2.5	Pyrene	< 2.5
2-6-Dinitrotoluene	< 0.2	Chloromethane	< 2.5	Sec-Butyl Benzene	< 2.5
2-Chloronaphthalene	< 0.3	Chrysene	< 2.5	Styrene	< 2.5
2-Chlorophenol	< 0.3	Cis-1,2-Dichloroethene	< 2.5	Terphenyl-d14(Surr.)	< 2.5
2-Chlorotoluene	< 2.5	Cis-1,3-Dichloropropene	< 2.5	Tert-Butyl benzene	< 2.5
2-Fluorobiphenyl(Surr.)	42.3	Dibenz(a-h)anthracene	< 2.5	Tetrachloroethene	< 2.5
2-Fluorophenol(Surr.)	68.8	Dibenzo(a-j)acridine	< 2.5	Toluene	< 2.5
2-Methylnaphthalene	< 0.2	Dibenzofuran	< 2.5	Toluene-D8	< 2.5
2-Methylphenol	< 0.3	Dibromochloromethane	< 2.5	Trans-1,2-Dichloroethene	< 2.5
2-Naphthylamine	< 0.3	Dibromofluoromethane	< 2.5	Trans-1,3-Dichloropropene	< 2.5
2-Nitroaniline	< 0.2	Dibromomethane	< 2.5	Trichloroethene	< 2.5
2-Nitrophenol	< 0.2	Diethyl-phthalate	< 2.5	Trichlorofluoromethane	< 2.5
2-Picoline	< 0.4	Dimethylaminoazobenzene	< 2.5	Vinyl Chloride	< 2.5
3-3'-Dichlorobenzidine	< 0.2	Dimethylbenzo(a)anthracene	< 2.5		
3-Methylcholanthrene	< 0.8	Dimethyl-phthalate	< 2.5		

Cavefish Population Monitoring

On November 11, 2000, a bioinventory of CSC was performed and 164 cavefish were counted. Approximate length of each individual and its position in the cave were also recorded (see Figure 1 below and the distribution map in the Appendix). The early return of the gray bats in spring forced the cancellation of a second census. The census will be performed in the fall after the departure of the maternity colony.

Previous studies reported a significant trend of increase ($n = 7$, $p = 0.004$, $r^2 = 0.95$) in the number of cavefish seen in Cave Springs Cave by Brown *et al*. (1998), and in 1999, the highest number ever reported was published (Graening and Brown, 1999). The low counts in 1998 and 2000 add variability to this trend that weakens the linear regression model, but does not invalidate it (Figure 2, $n = 11$, $p = 0.046$, $r^2 = 0.37$). Previously, Graening and Brown (1999) estimated a population doubling time of 23 years – with three more years of census data, the estimated doubling time is approximately 40 years.

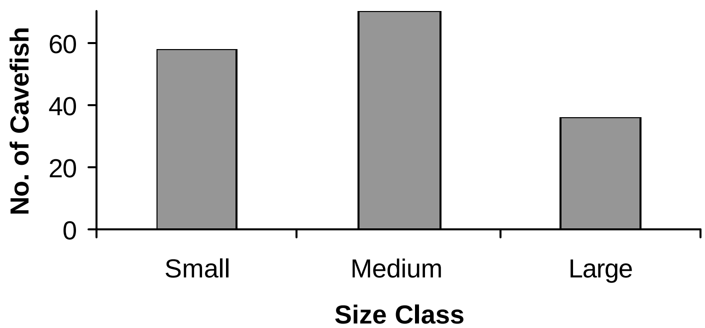


Figure 1. Population structure of the Ozark Cavefish population in Cave Springs Cave, Arkansas, based upon data from the November 2000 census. Sizes were defined as: small – less than 2.5 cm; medium – between 2.5 – 5.0 cm; large – greater than 5.0 cm.

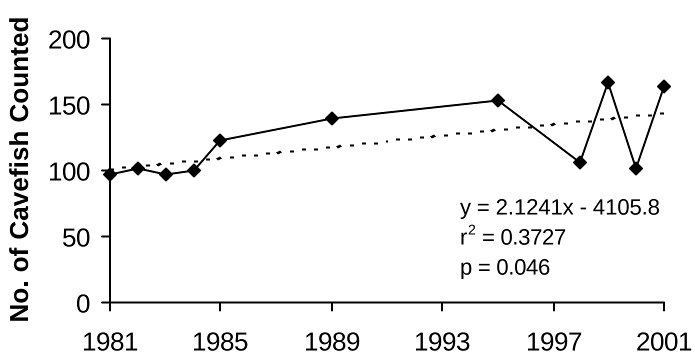


Figure 2. Summary of all visual surveys of the Ozark cavefish population in Cave Springs Cave, Arkansas, performed by the authors and colleagues (Brown and Willis, 1984; Brown *et al.*, 1998; Graening and Brown, 1999, 2000; this study).

Figure 3. Sluice leading to waterwheel at the mouth of Cave Springs Cave during base flow (stage < 10.98 ft.). Note that there is no waterfall to the left of the sluice.

Figure 4. Cave Springs Cave sluice during high flow (stage =12.24 ft.), with a waterfall formed from the overflow channel.

Figure 5. Retention net installed at the mouth of Cave Springs Cave on February 18th, 2001 with stage = 10.98 ft.

Figure 6. Retention net in Cave Springs Cave at high flow on February 25th, 2001 (stage = 12.24 ft.). The net was 25-30 cm below the surface of the water.

Stable Isotope Analyses

The results of the stable isotope analyses of Cave Springs Cave and Logan Cave are shown in Tables 5 and 6.

Table 5. Stable isotope analyses of components of the Cave Springs Cave ecosystem.

Sample Type	Date Sampled	d13C	d15N
Bat Guano	01/01/98	-24.1	11.3
	03/01/98	-24.6	13.3
	09/01/98	-25.0	9.7
	12/01/98	-24.3	13.9
	05/12/99	-24.1	14.2
Crayfish	01/01/98	-29.6	9.0
	03/12/98	-29.9	11.5
	08/01/98	-28.1	10.7
	12/01/98	-24.8	13.6
	04/01/99	-29.5	8.4
Cave Biofilm	06/20/98	-36.1	6.3
	07/01/98	-31.9	5.7
	12/01/98	-0.6	6.8
	04/01/99	2.9	9.2
Septic Waste	10/01/98	-21.9	4.0
	10/01/98	-21.2	4.0
	01/16/00	-23.6	4.9
Cave Sediment	10/01/98	-24.9	6.9
	11/01/98	-26.5	6.6
Cave Isopod	12/01/98	-21.8	11.6
	05/12/99	-22.1	14.3
Fescue	11/01/98	-28.8	6.3
Cavefish	03/01/99	-21.8	17.4
Cow Manure	12/01/98	-25.1	3.5
Chicken Litter	12/01/98	-15.2	7.9
Swine Effluent	12/01/98	-16.3	4.8
Sewage Sludge	04/01/99	-21.6	13.6
Limestone	04/01/99	2.9	
POM from	04/01/99	-25.1	8.5
cave water	04/01/99	-25.4	3.6
Leaf Litter	11/01/99	-29.3	0.1
Cave Salamander	02/16/00	-23.1	8.0
Soil	04/14/00	-27.7	-1.7
	04/14/00	-27.8	-0.2

Table 6. Stable isotope analyses of components of the Logan Cave ecosystem.

Sample Type	Date Sampled	d13C	d15N
O. neglectus	11/21/00	-25.7	9.6
O. punctimanus	11/21/00	-24.3	10.9
Sculpin	11/21/00	-28.0	11.3
Cave sediment	11/21/00	-25.7	6.1
Soil	11/21/00	-27.4	3.3
Isopods	1/5/01	-27.4	11.2
Grotto Salamander	12/1/99	-24.0	11.0
Bat Guano	12/1/99	-24.0	9.5
Bat Guano	11/21/00	-21.9	18.1

Pollution Susceptibility Analyses

Potential pollution point sources were identifed in this study and are shown in Figure 8 (tabular data in the Appendix). Potential pollution point sources identifed by Arkansas State and the US EPA are shown in Figure 7 (GeoStor website, http://www.cast.uark.edu/cast/geostor, Center for Advanced Spatial Technology, UAF). The major photo-lineaments and fracture traces of the Cave Springs Cave recharge zone identified by Williams (1991) and Hanson (1973) have been entered into the GIS, and are shown in Figures 9 through 12. Figures 9-12 also show four iterations of the toxic spill model of Curtis (2000), and identify areas most likely to be affected by a toxic spill at the given release point.

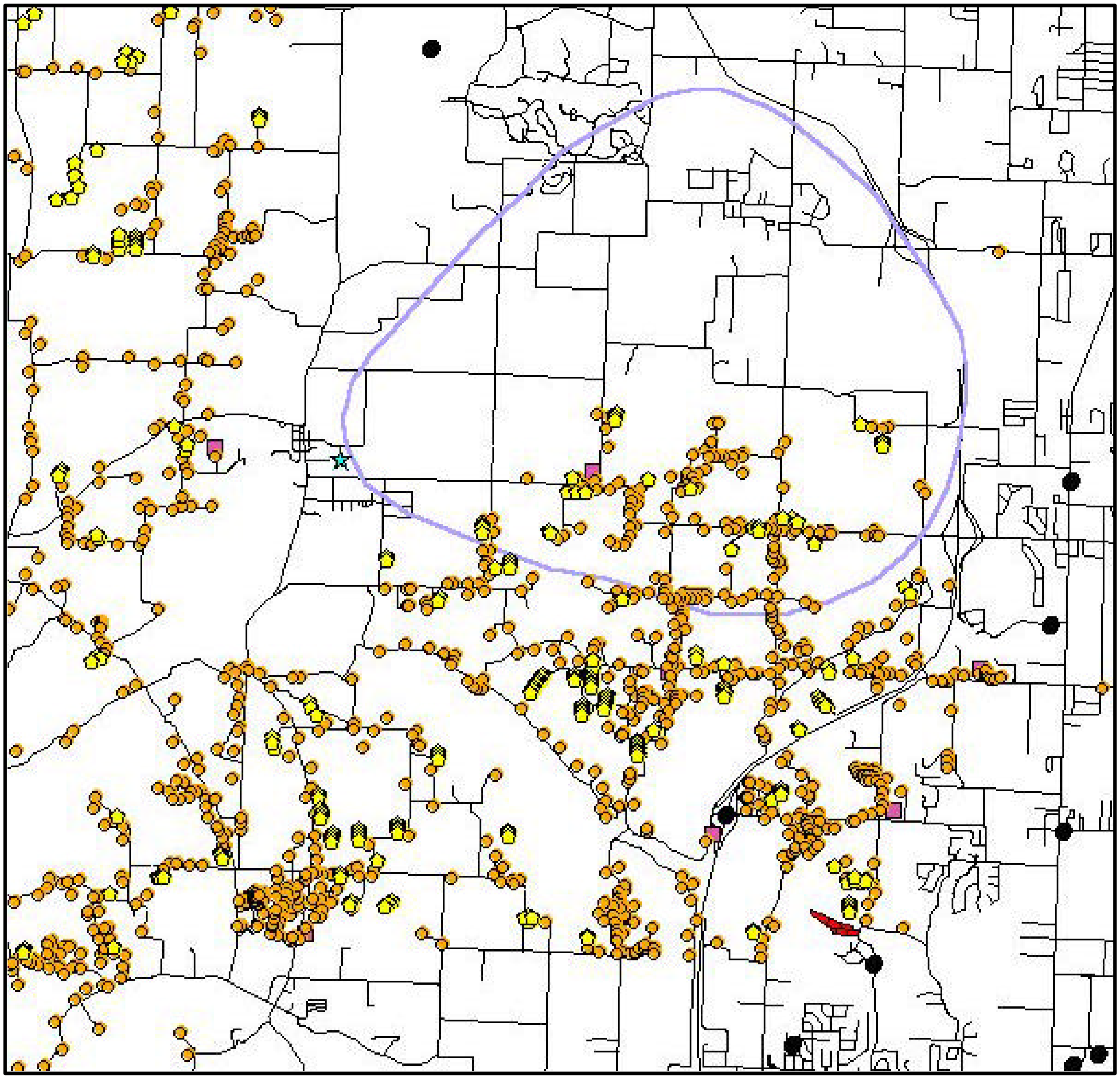
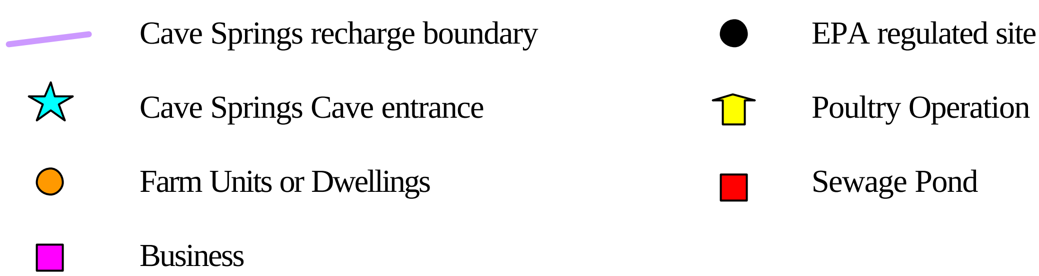


Figure 7. Potential pollution point sources GeoStor website, Center for Advanced Spatial Technology, UAF, http://www.cast.uark.edu/cast/geostor,).



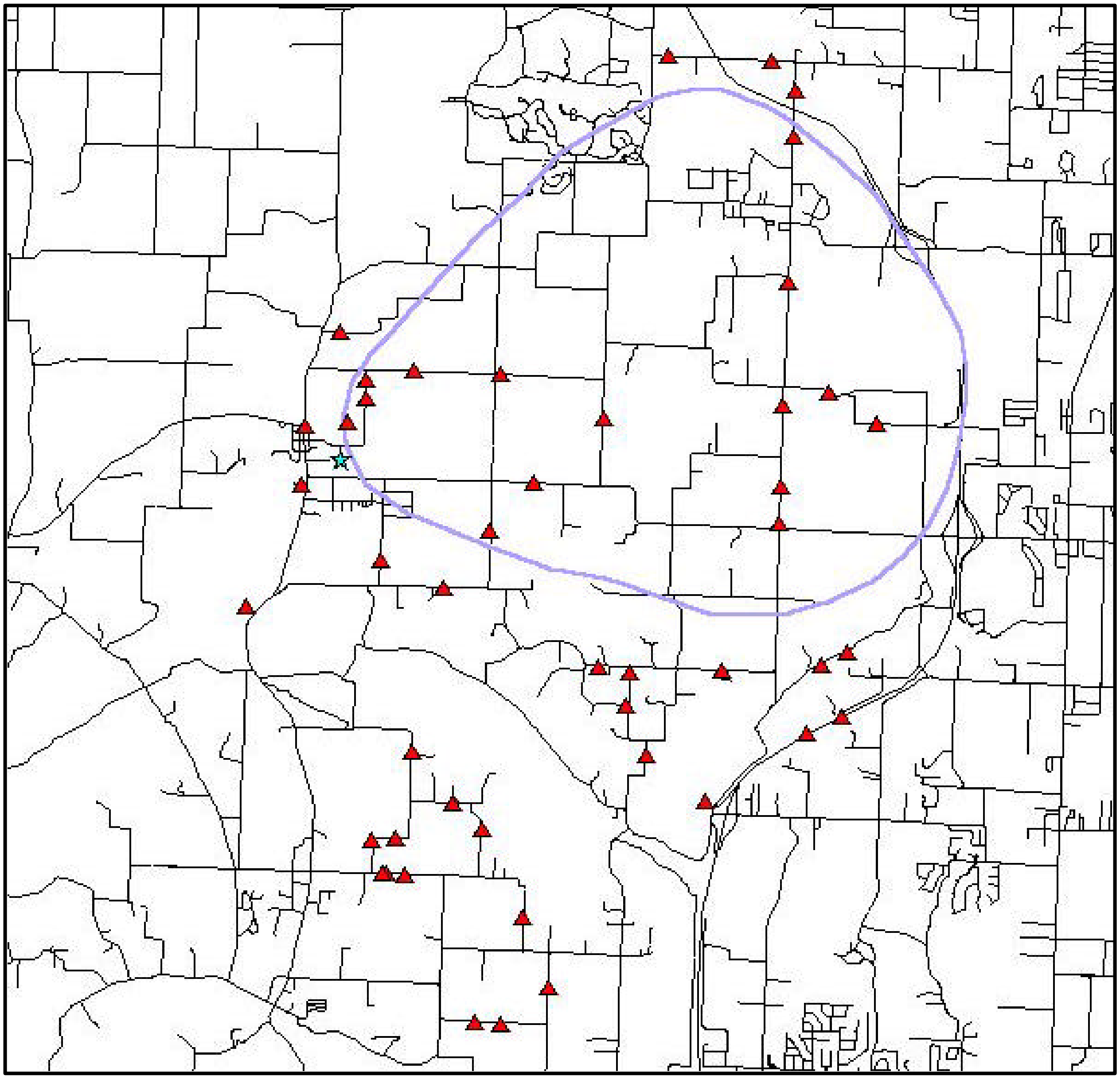


Figure 8. Potential point source pollution locations in and around the Cave Springs Cave recharge area identified in this study, including confined animal feeding operations, fuel tanks, and salvage yards.

Cave Springs recharge boundary

Cave Springs Cave entrance

Potential pollution source

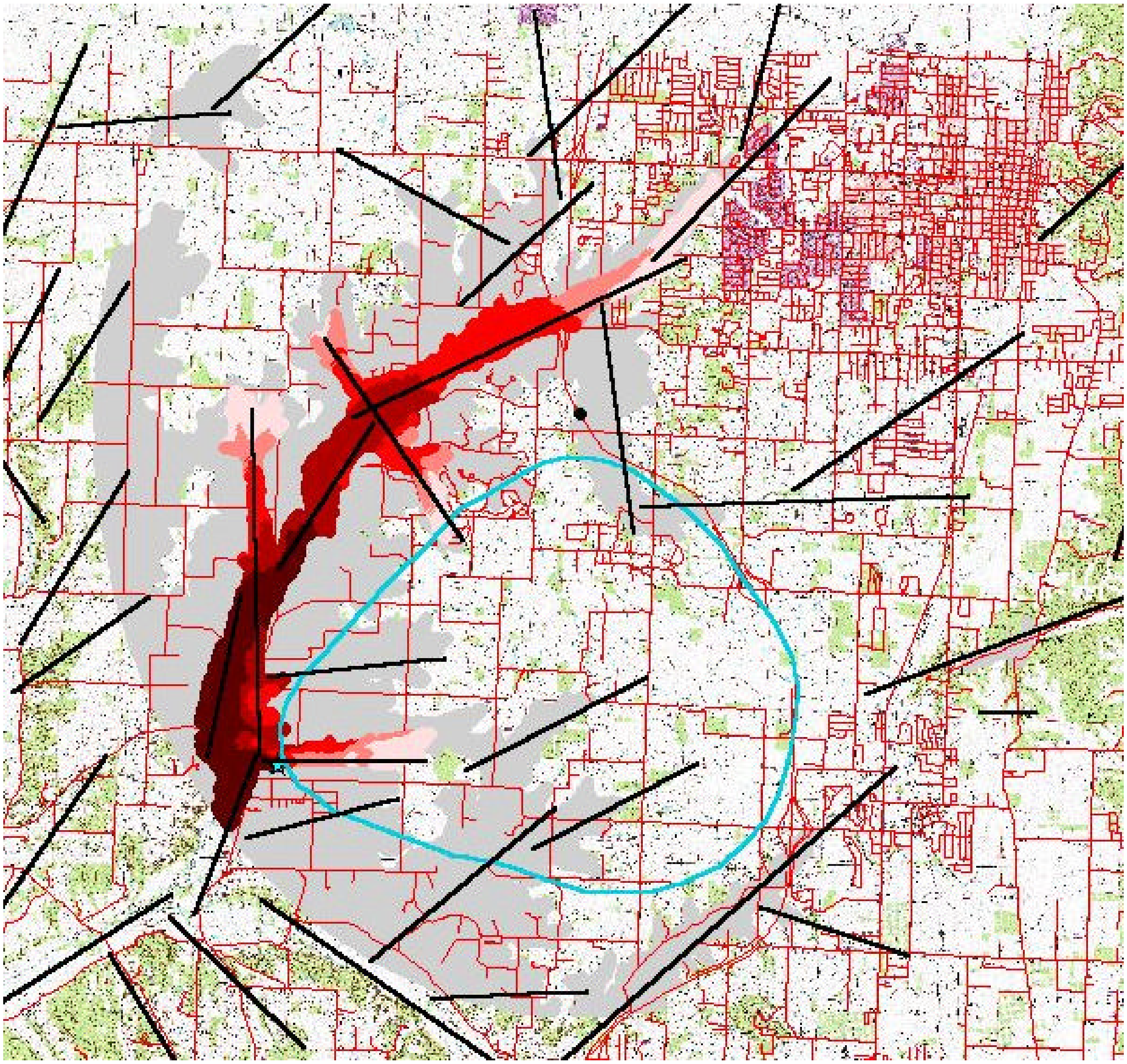


Figure 9. Spill Model 1.

Overland flow within a 5-mile radius of the spill location; elevations equal to or less than that of the spill point.

Graduated color range for elevations. Darker red areas indicate lower elevations and potentially greater discharge.

Photolineaments

Release Point

Cave Springs recharge boundary

Cave Springs Cave entrance

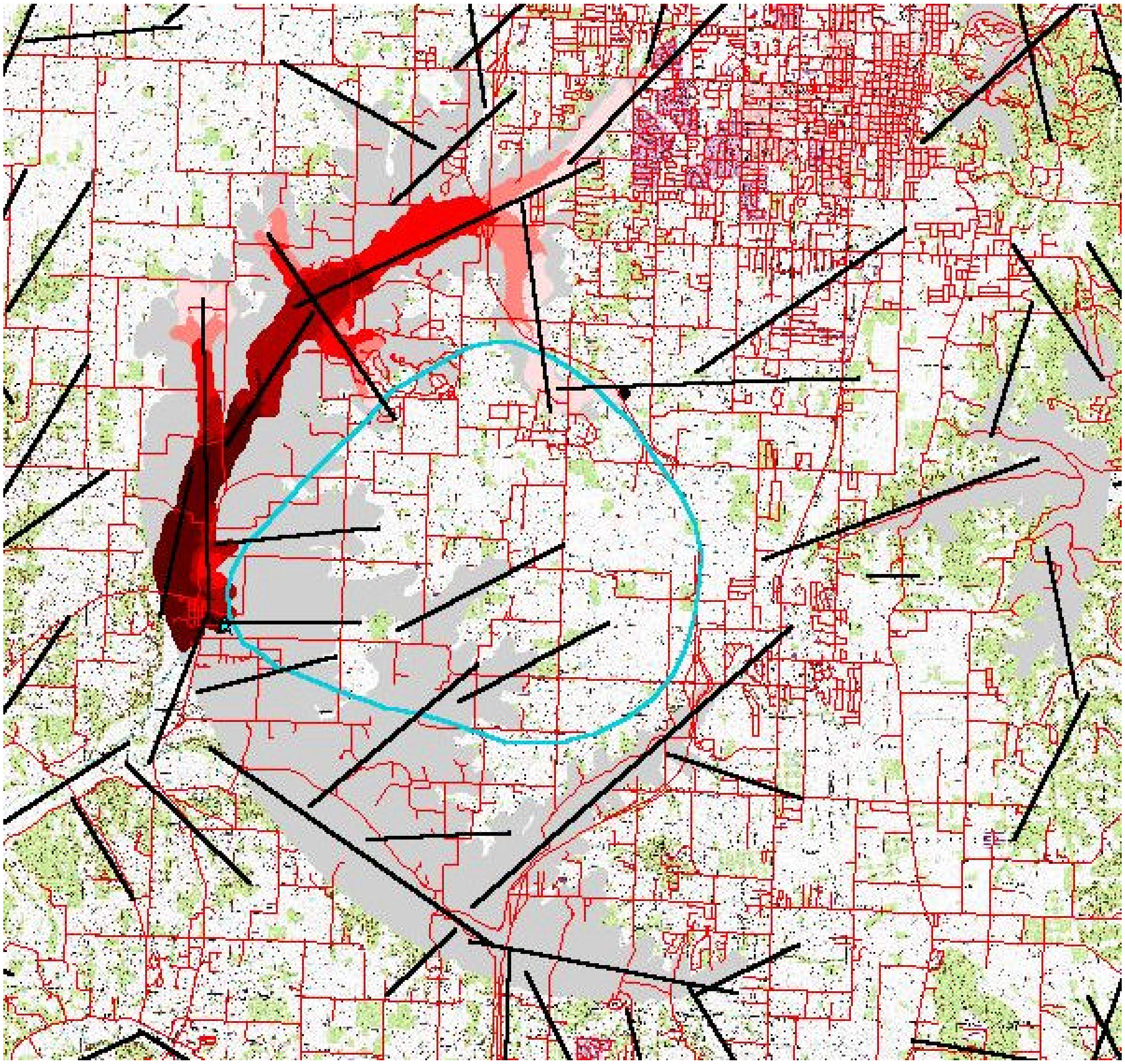


Figure 10. Spill Model 2

Overland flow within a 5.5-mile radius of the spill location; elevations equal to or less than that of the spill point.

Graduated color range for elevations. Darker red areas indicate lower elevations and potentially greater discharge.

Photolineaments

Release Point

Cave Springs recharge boundary

Cave Springs Cave entrance

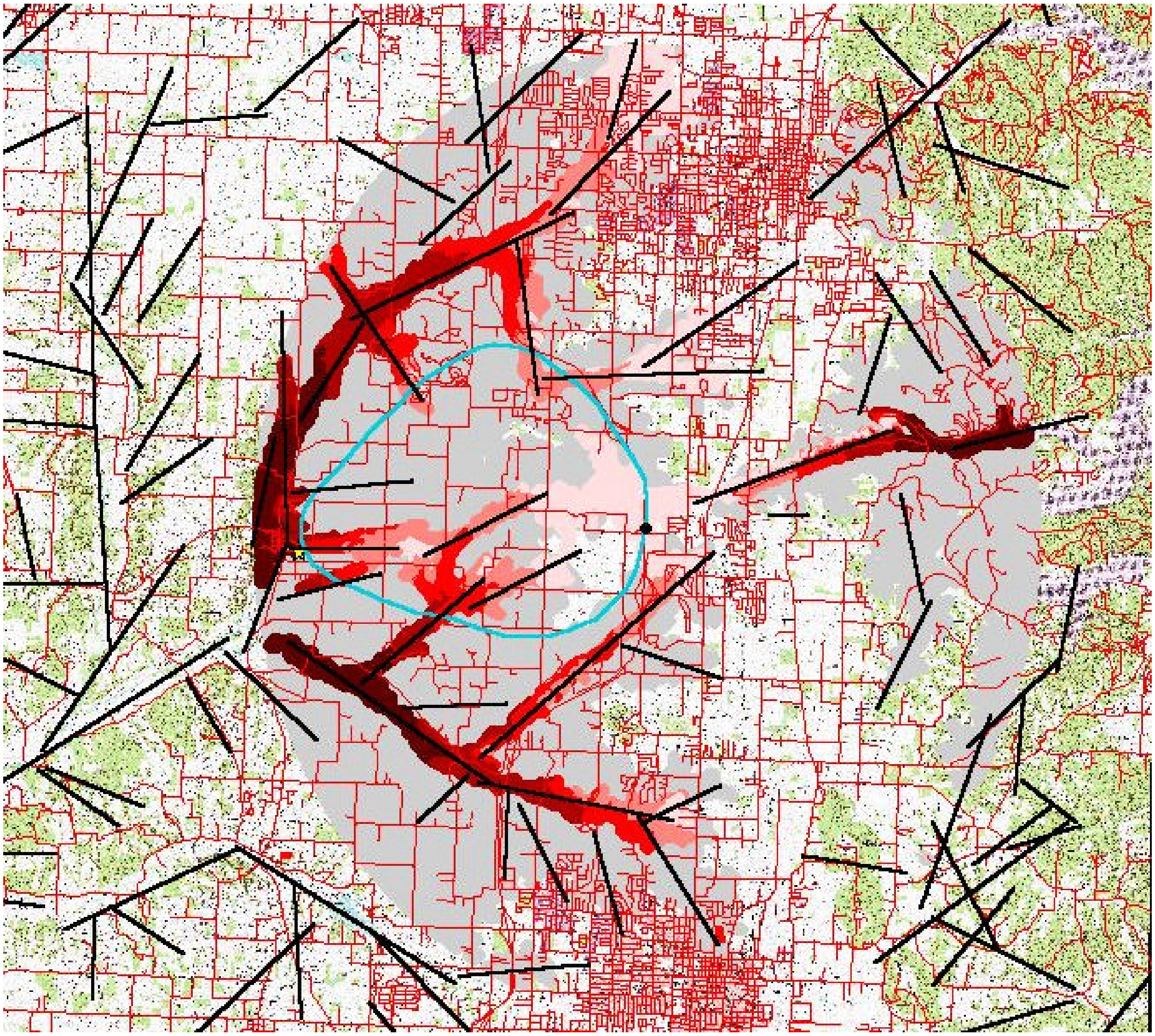


Figure 11. Spill Model 3

(grey box)	Overland flow within a 6-mile radius of the spill location; elevations equal to or less than that of the spill point.
(red color range)	Graduated color range for elevations. Darker red areas indicate lower elevations and potentially greater discharge.
(black line)	Photolineaments
●	Release Point
(cyan line)	Cave Springs recharge boundary
☆	Cave Springs Cave entrance

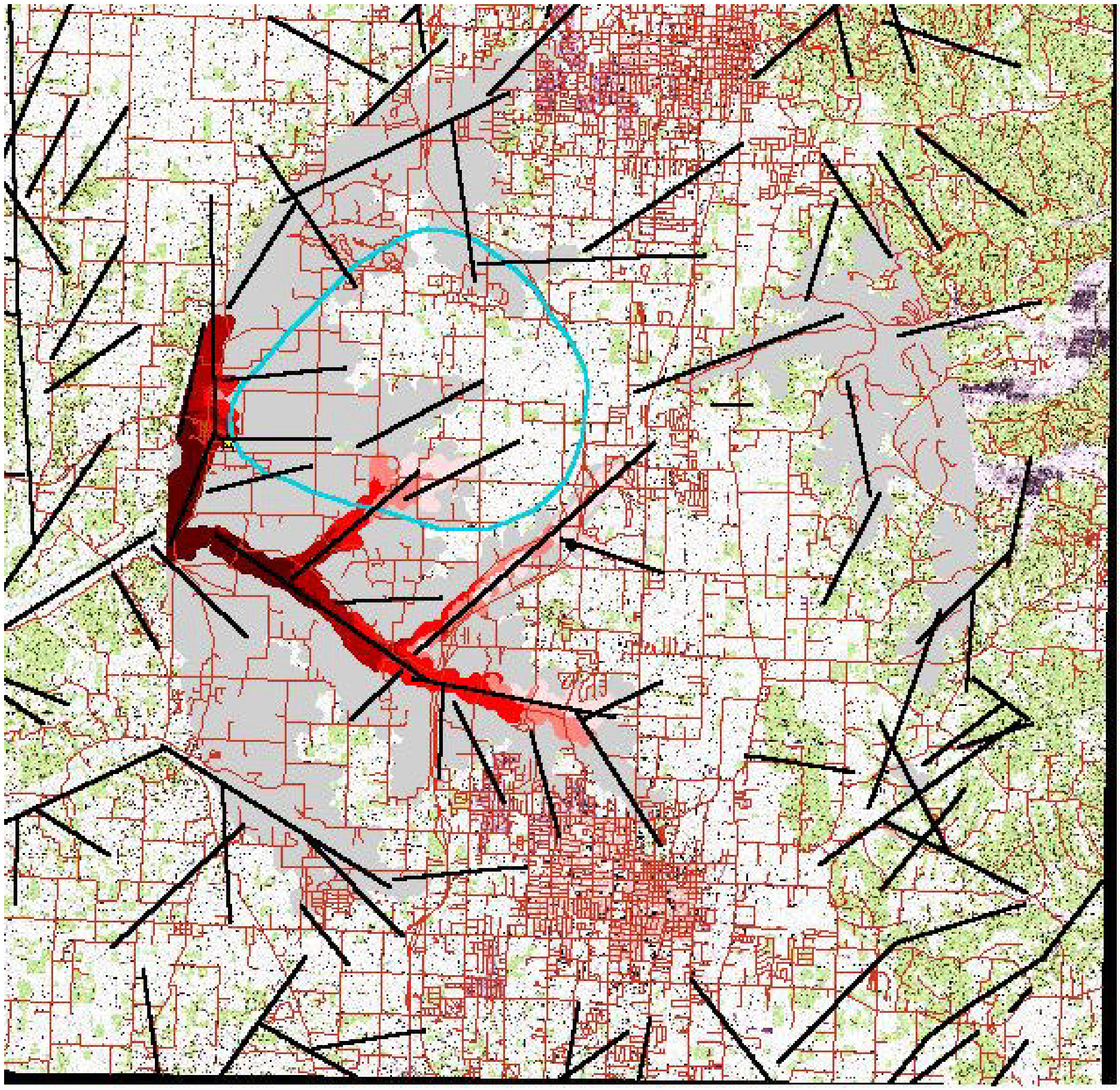


Figure 12. Spill Model 4

Overland flow within a 6-mile radius of the spill location; elevations equal to or less than that of the spill point.

Graduated color range for elevations. Darker red areas indicate lower elevations and potentially greater discharge.

Photolineaments

Release Point

Cave Springs recharge boundary

Cave Springs Cave entrance

DISCUSSION

Environmental Quality

Total coliform densities and some nutrient and heavy metal concentrations continue to exceed Arkansas State water quality standards (Regulation 2) maximum contaminant levels (Arkansas Pollution Control and Ecology Commission, 1998). Mean nutrient concentrations in CSC are higher than regional and national levels (Petersen *et al*., 1998; USGS 1999). The mean nitrate concentration in CSC is more than double the background level for the Ozarks (Petersen *et al*., 1998). Stable isotope analyses have indicated septic leachate and land-applied manures as probable sources (Graening and Brown, 2000).

Ozark Cavefish Population Dynamics

Cavefish counts in Cave Springs Cave increased steadily from 1981 through 1995, but have fluctuated greatly since then. We found only 106 fish in the cave in January 1998 using the same survey methods. Later, in December 1998 we returned to repeat the survey and found 166 fish. In February 2000 only 102 fish were seen. We are unable to fully explain the low counts, especially since high counts have followed each of them. The fish seen during a survey do not represent the entire population but some fraction of it. The cavefish can move in and out of the coarse rock substrate that forms the stream bottom in many areas. Similar surveys in Logan Cave indicate that about one third to one half of the fish in that population are seen during each census (Means, 1993; Means and Johnson, 1995; Brown, 1996). If something happened to the fish in the cave (chemical spill, illegal collection) just before our census in January 1998 this could explain the low counts. Subsequently fish could have moved into the cave from areas inaccessible to us to repopulate the cave before we did the next census in December 1998. The census in February 2000 was conducted during a period of very low water level. It is not known whether this could affect the number in the cave stream. The 2001 survey of cavefish was needed to help understand these population fluctuations, and it appears that the population is still increasing in numbers despite degraded water quality.

Retention Net

There seems to be no simple way to assess the effectiveness of the net across the cave mouth at keeping cavefish from being swept out through the sluice and waterfall. Apparently, larger floats are needed to keep the net near the surface during the high flow events, and these have been added recently. Suspending the seine net above the water might interfere with movements in and out of the cave by bats or other animals.

The highest flows occurred during an unusual storm event; one with an interval probably greater than 25 years. Weakly-swimming, larval fish can swim about 5-6 times their body length per second (10 mm length = 50-60 mm/sec; Armstrong and Brown, 1983; Brown and Armstrong, 1984). They could not escape impingement on the net at any but the slowest flows observed at the net. No data could be found for swimming abilities of cavefish, but it is presumed that they can swim faster than larval fish. When larvae, cavefish are supposedly retained in the buccal cavity (mouth) of their parent (Poulson, 1963). Still, there is some concern that cavefish may become trapped against the net during high flow conditions. Whether the potential for this fate is more hazardous than the potential for them being swept out of the cave to near certain death downstream is not known. The study does indicate the need for some non-lethal studies of cavefish swimming ability and associated behaviors, like avoidance of fast flows, and of crayfish predators. The presence of very large numbers of crayfish at the mouth of the cave may be cause for concern. Cavefish are probably easy prey of *O. punctimanus* and *O. neglectus* (Brown *et al.*, 1994). The seine net may provide the crayfish an easier way to capture them, especially during the highest flows.

We cannot be certain that cavefish, especially small ones, do not become impinged on the net by the force of the current by the fastest flow rates we measured in the vicinity of the net. Cavefish are not normally observed where water is flowing more than 5-10 cm/sec. If impingement occurs, the net would be a hazard to the cavefish during high flows, especially with the crayfish there. It is more certain that being swept out of the cave through the sluice or waterfall is hazardous to them.

Filling the pool at the mouth of the cave with large boulders, with ample interstitial spaces among them, would make the transition from slow to fast current speed more gradual and variable, providing the cavefish an opportunity to sense the increased current and avoid it. Whether they would do this or not is unknown. The boulders would probably provide the *O. punctimanus* an excellent habitat, especially for ambushing prey (like cavefish). So that situation would be unchanged. Eventually the spaces between the boulders would become filled with fine sediments. In that situation, with shallower water there, the crayfish would be more subject to predation by raccoons (*Procyon lotor*) and birds. This discussion ends without a management recommendation, but for now the net has been left in place.

Recharge Zone Susceptibility

Brahana (1995) identified the major factors that determine pollution susceptibility in the Boone-St. Joe aquifer:

> "*In general, the absence of the Chattanooga Shale, the more pure a carbonate unit, the presence of karst features at land surface, the thinner the cover overlying a pure carbonate, the shallower the depth to the St. Joe Member of the Boone Formation, the closer the distance to a major fault, joint, or lineament, the closer the distance to a major spring, the closer the distance to the Eureka Springs escarpment, the more environmentally sensitive the area of the Springfield Plateau.*" (Brahana, 1995)

Dye tracing confirmed that photolineaments are karst conduits and that natural adsorption is low in the Cave Springs area (Aley, 1978). Lineaments are defined according to Lattman (1958) as natural features (topographic, vegetative, or soil tonal alignments) identifiable on aerial photographs and at least one mile long (if less than one mile long, it is called a fracture trace). Straight cave passage orientation is correlated to photo-lineament orientation in Benton County and northwest Arkansas in general, which implies that straight cave passages form along fracture zones, which are expressed as photo-lineaments at the surface (Barlow and Ogden, 1979). Willis (1978) and Ogden (1979) found significant relationships between high nitrate, sulfate, and chloride concentrations and wells on photo-lineaments in Benton County, and implicated the poor filtration of surface pollutants in these fracture zones as the cause. Willis (1978) also found that the yield of wells near photo-lineaments was significantly higher than wells distant from photo-lineaments. Ogden (1979) determined the zone of influence of photo-lineaments (where surface pollutants were highly correlated to proximity to lineaments) to be up to 2000 feet for chloride and 250 feet for sulfate. Williams (1991) defined critical areas for pollution of Cave Springs Cave as those areas that lie along intermittent stream segments, especially those segments that coincide with fracture traces and photo-lineaments. All of the stream segments in William's (1991) study coincide with fracture traces and photo-lineaments. These studies suggest that these intermittent streams and other lineaments in the Cave Springs Cave recharge zone merit special protection. For this reason, it is suggested that areas within 100 m of photo – lineaments be identified as the highest pollution susceptibility zones in the CSC groundwater basin. It is also suggested that protection or enforcement measures be directed foremost in these buffer zones. It is also suggested that the Cave Springs Cave recharge zone be expanded to include those buffer zones that intersect the present recharge zone delineation because of the possible hydrologic connectivity with the surface near photo-lineaments.

Hazardous Material Spill Modeling and Response

The movement of water in the Boone-St. Joe aquifer occurs both as concentrated flow through conduits en route to resurgences and as diffuse flow through the aquifer under water table conditions (Ogden, 1979). The Chattanooga shale acts as a lower perching boundary (aquiclude) for the Boone-St. Joe aquifer (Ogden, 1979). Groundwater travel rates in the Cave Springs area range from 690 to 5640 ft/day (Aley, 1978). In the recharge zone of Cave Springs Cave, Aley (1978) estimated the mean travel rates of injected dye (based upon straight line distances) of 1,930 and 1,670 ft/day. This gives hazardous material response teams very little time to respond to a release of hazardous material. The spill model results demonstrate that the presence of lineaments has the potential to affect transport of pollutants to sensitive areas by possibly acting as conduits. Use of this model could alert landowners to possible contamination and potentially aid clean-up efforts.

MANAGEMENT RECOMMENDATIONS

1) Enforce the Arkansas Regulation 2 water quality standards for the streams in the recharge area (Cave Springs, Puppy Creek, Osage Creek, Cross Creek, and Spring Creek).

2) Formally designate the cave stream an "Ecologically Sensitive Water Body" because it has federal and state listed endangered species, or upgrade the water body status to "Extraordinary Resource Water Body."

3) Phase out the application of confined animal waste in the cave's recharge zone, especially in the sensitive areas indicated on the map on the accompanying compact disc.

4) Revoke any existing permits and deny future permit applications to apply biosolids from municipal sewage treatment plants onto the recharge area.

5) Apply the most stringent requirements for new septic systems in the recharge zone, and require the rehabilitation or upgrading of existing septic systems.

6) Afford the cave entrance more protection from unauthorized visitation. Specifically, refurbish the fence in front of the cave mouth and install electronic surveillance equipment.

7) Acquire cooperative agreements, titles, or conservation easements of lands in sensitive areas in the cave recharge zone.

8) Continue to monitor cavefish annually since the population may be experiencing large fluctuations.

9) Contact Hazardous Material Response Teams in the area to alert them to sensitive areas, and form an emergency response plan in the event of a large spill similar to that experienced in Meramec Cavern in 1981.

10) Continue to periodically monitor the chemical, bacterial, and physical water quality in the cave, including analysis of sediment or tissue metals (perhaps at 3 year intervals).

11) Continuously monitor temperature in the air and water of the cave by annually downloading and examining data from the loggers we installed, and replacing loggers as necessary.

12) Periodically remove as many surface crayfish as possible near the mouth of the cave. (perhaps annually).

13) Fill the cave resurgence with boulders to the level of the bottom of the water wheel sluice back to the bottom of the seine net.

14) Maintain the seine net in the mouth of the cave.

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APPENDIX

Metadata for GIS Datasets Obtained from GeoStor (http://www.cast.uark.edu/cast/geostor)

Title	**Business Establishments (Arkansas Highway and Transportation Department, 2000)**
Abstract	null
Purpose	null
Data Type	Point
Datum	NAD83
Scale	0.0
Resolution	null
Resolution Unit	null
West	0.0
East	0.0
North	0.0
South	0.0
Source Date	null
Beginning Date	null
End Date	null
Publication Date	null
Constraints	null
Graphic File	null
Graphic Format	null
Category	Socioeconomic
Theme Key	Buildings, Business
Place Key	United States, Arkansas
Project Name	SWAG
Data Format	null
File Size	0.0
Distribution	null
Distribution List	null
Content	null
Data Creator	Arkansas Highway and Transportation Department
Metadata File Name	null
Search Size	50.0
Statewide Flag	1
Cover Table Name	null

Title	**Chicken Houses (Arkansas Highway and Transportation Department, 2000)**
Abstract	null
Purpose	null
Data Type	Point
Datum	NAD83
Scale	0.0
Resolution	null
Resolution Unit	null
West	0.0
East	0.0
North	0.0
South	0.0
Source Date	null
Beginning Date	null
End Date	null
Publication Date	null
Constraints	null
Graphic File	null
Graphic Format	null
Category	Socioeconomic
Theme Key	Chicken Houses, Farming, Culture
Place Key	United States, Arkansas
Project Name	SWAG
Data Format	null
File Size	0.0
Distribution	null
Distribution List	null
Content	null
Data Creator	Arkansas Highway and Transportation Department
Metadata File Name	null
Search Size	150.0
Statewide Flag	1
Cover Table Name	null

Title	**EPA Regulated Facilities, 1997 (Environmental Protection Agency, 1997)**
Abstract	This data layer provides point locations of EPA-regulated facilities in the State of Arkansas. The point locations are derived from the following EPA program systems: Aerometric Information Retrieval System (AIRS), Permit Compliance System (PCS), Toxic Release Inventory System (TRIS), Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), Resource Conservation and Recovery Information System (RCRIS), National Compliance Database (NCDB), Federal Facility Information System (FFIS), PCB Handler Activity Data System (PADS), and Section Seven Tracking System (SSTS).
Purpose	This data layer is intended for use in state, regional, and local analyses.
Data Type	Point
Datum	NAD83
Scale	100000.0
Resolution	null
Res. Unit	null
West	-94.65
East	-89.6
North	36.5
South	33.0
Source Date	1998-11-30
Begin Date	null
End Date	null
Pub. Date	1998-11-30
Constraints	Acknowledgement of the US EPA would be appreciated.
Graphic File	null
Graph. Format	null
Category	Socioeconomic, Miscellaneous
Theme Key	Health, EPA, Environmental Protection Agency, Regulated Sites
Place Key	United States, Arkansas
Project Name	SWAG
Data Format	null
File Size	0.0
Distribution	null
Distrib. List	null
Content	United States Environmental Protection Agency 401 M Street SW Washington, D.C. 20460 nsdi@epamail.epa.gov
Data Creator	Environmental Protection Agency
Metadata File Name	null
Search Size	50.0
Statewide Flag	1
Cover Table Name	null

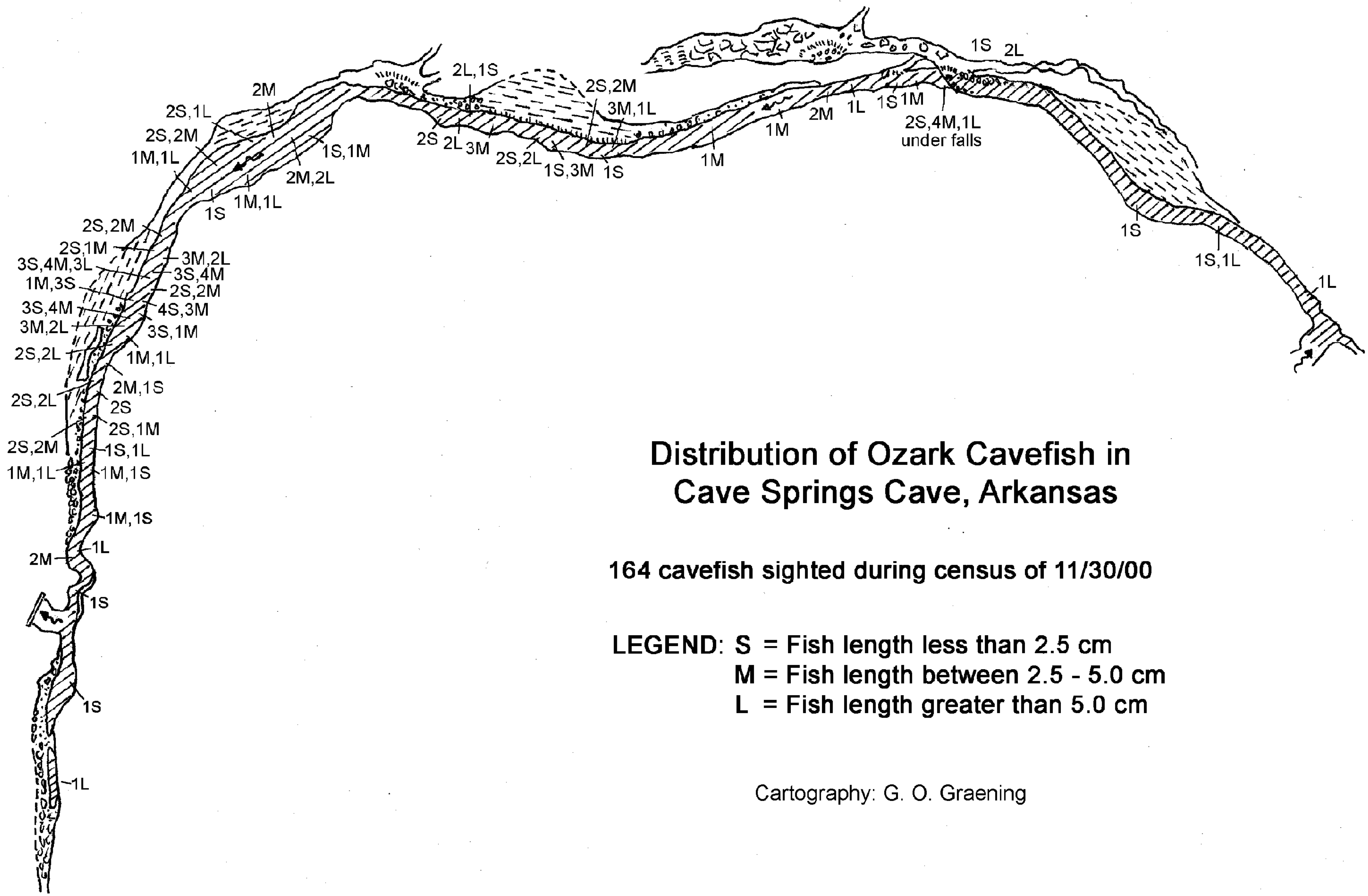
Title	**Farm Units or Dwellings (Arkansas Highway and Transportation Department, 2000)**
Abstract	null
Purpose	null
Data Type	Point
Datum	NAD83
Scale	0.0
Resolution	null
Resolution Unit	null
West	0.0
East	0.0
North	0.0
South	0.0
Source Date	null
Beginning Date	null
End Date	null
Publication Date	null
Constraints	null
Graphic File	null
Graphic Format	null
Category	Socioeconomic, Infrastructure
Theme Key	Buildings, Houses, Dwellings, Culture
Place Key	United States, Arkansas
Project Name	SWAG
Data Format	null
File Size	0.0
Distribution	null
Distribution List	null
Content	null
Data Creator	Arkansas Highway and Transportation Department
Metadata File Name	null
Search Size	15.0
Statewide Flag	1
Cover Table Name	null

Title	**Roads, All (Arkansas Highway and Transportation Department)**
Abstract	null
Purpose	null
Data Type	Line
Datum	NAD83
Scale	0.0
Resolution	null
Resolution Unit	null
West	0.0
East	0.0
North	0.0
South	0.0
Source Date	null
Beginning Date	null
End Date	null
Publication Date	null
Constraints	null
Graphic File	null
Graphic Format	null
Category	Infrastructure
Theme Key	Roads, Streets, Highways, Transportation
Place Key	United States, Arkansas
Project Name	SWAG
Data Format	null
File Size	0.0
Distribution	null
Distribution List	null
Content	null
Data Creator	Arkansas Highway and Transportation Department
Metadata File Name	null
Search Size	0.0
Statewide Flag	0
Cover Table Name	null

Title	**Sewage Disposal Ponds (USGS 100K DLG)**
Abstract	This file contains sewage disposal pond locations derived from 1:100,000-scale ("intermediate-scale") Digital Line Graph data created by the USGS. Coverage is of the entire State of Arkansas. Digital line graph (DLG) data are digital representations of cartographic information. DLG's of map features are converted to digital form from maps and related sources. Intermediate-scale DLG data are derived from USGS 1:100,000-scale 30- by 60-minute quadrangle maps. If these maps are not available, Bureau of Land Management planimetric maps at a scale of 1:100,000 are used. Data was imported into the ESRI software product ArcInfo 7.1.1 to create topology and then brought into ArcView 3.2 to assign attributes.
Purpose	DLG's depict information about geographic features on or near the surface of the Earth, terrain, and political and administrative units. These data were collected as part of the National Mapping Program. It is the intention of the Arkansas State Land Information Board to facilitate the dissemination of the 1:100,000-scale Digital Line Graphs.
Data Type	null
Datum	NAD83
Scale	100000.0
Resolution	null
Resolution Unit	null
West	0.0
East	0.0
North	0.0
South	0.0
Beginning Date	null
End Date	null
Constraints	None. Acknowledgement of the US Geological Survey and the Arkansas State Land Information Board would be appreciated in products derived from these data.
Graphic File	null
Graphic Format	Null
Category	Infrastructure
Theme Key	Sewage, Sewer, Utilities
Place Key	United States, Arkansas
Project Name	SWAG
Data Format	null
File Size	0.0
Distribution	null
Distrib. List	null
Content	Earth Science Information Center, USGS, 507 National Center Reston, VA USA 20192
Data Creator	United States Geological Survey or another mapping agency in cooperation with USGS.
Metadata File Name	null
Search Size	350.0
Statewide Flag	1

Table of potential pollution point sources in the Cave Springs Cave groundwater basin identified in this study.

Latitude	Longitude	Location Note
36.265120	-94.226320	4 poultry houses, not active, EPE = 24 ft; NAD27, Garmin III Plus GPS
36.267470	-94.224170	2 poultry houses, not active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.269330	-94.224050	3 poultry houses, active, EPE =18 ft; NAD27, Garmin III Plus GPS
36.270370	-94.218260	1 poultry house, not active, EPE =16 ft; NAD27, Garmin III Plus GPS
36.270020	-94.207470	3 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.265770	-94.194610	3 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.259260	-94.203190	3 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.254330	-94.208500	3 poultry houses, active, EPE = 13 ft; NAD27, Garmin III Plus GPS
36.248540	-94.214180	2 poultry houses, active, EPE = 17 ft; NAD27, Garmin III Plus GPS
36.251240	-94.222070	2 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.258680	-94.231910	Fuel tanks, gas station, EPE = 18 ft; NAD27, Garmin III Plus GPS
36.264690	-94.231610	Fuel tanks, gas station, EPE = 19 ft; NAD27, Garmin III Plus GPS
36.274160	-94.227460	3 poultry houses, active, EPE = 18 ft; NAD27, Garmin III Plus GPS
36.246400	-94.238750	Fuel tanks, Creeks Golf course, EPE = 18 ft; NAD27, Garmin III Plus GPS
36.227320	-94.181270	Quarry, McClinton Anchor, EPE = 18 ft; NAD27, Garmin III Plus GPS
36.231810	-94.188750	6 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.236800	-94.191280	10 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.240120	-94.190850	1 poultry house, active, EPE =15 ft; NAD27, Garmin III Plus GPS
36.240810	-94.194840	10 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.240480	-94.179560	4 poultry houses, active, EPE = 23 ft; NAD27, Garmin III Plus GPS
36.236040	-94.164380	4 poultry houses, active, EPE = 14 ft; NAD27, Garmin III Plus GPS
36.234310	-94.168720	2 poultry houses, active, EPE = 14 ft; NAD27, Garmin III Plus GPS
36.241250	-94.167100	2 poultry houses, active, EPE = 32 ft; NAD27, Garmin III Plus GPS
36.242470	-94.163890	2 poultry houses, active, EPE = 30 ft; NAD27, Garmin III Plus GPS
36.267300	-94.172340	3 poultry houses, active, EPE = 14 ft; NAD27, Garmin III Plus GPS
36.268680	-94.166500	4 poultry houses, active, EPE = 16 ft; NAD27, Garmin III Plus GPS
36.265480	-94.160480	3 poultry houses, active, EPE = 15 ft; NAD27, Garmin III Plus GPS
36.255360	-94.172510	2 poultry houses, not active, EPE = 21 ft; NAD27, Garmin III Plus GPS
36.259190	-94.172450	Fuel tank, farm, acitve, EPE = 23 ft; NAD27, Garmin III Plus GPS
36.279810	-94.171750	Performance Salvage, EPE = 23 ft; NAD27, Garmin III Plus GPS
36.294450	-94.171400	1 poultry house, not active, EPE = 20 ft; NAD27, Garmin III Plus GPS
36.299050	-94.171240	2 poultry houses, not active, EPE = 20 ft; NAD27, Garmin III Plus GPS
36.302010	-94.174160	2 poultry houses, not active, EPE = 21 ft; NAD27, Garmin III Plus GPS
36.302370	-94.186940	2 poultry houses, active, EPE = 19 ft; NAD27, Garmin III Plus GPS
36.231890	-94.217870	3 poultry houses, active, EPE = 22 ft; NAD27, Garmin III Plus GPS
36.226880	-94.212650	Fuel tank, farm, acitve, EPE = 23 ft; NAD27, Garmin III Plus GPS
36.224270	-94.209070	3 poultry houses, active, EPE = 24 ft; NAD27, Garmin III Plus GPS
36.215350	-94.203770	3 poultry houses, not active, EPE = 26 ft; NAD27, Garmin III Plus GPS
36.208300	-94.200460	2 poultry houses, active, EPE = 14 ft; NAD27, Garmin III Plus GPS
36.204670	-94.209500	Fuel tank, cattle operation, EPE = 20 ft; NAD27, Garmin III Plus GPS
36.204650	-94.206440	2 poultry houses, active, EPE = 14 ft; NAD27, Garmin III Plus GPS
36.219600	-94.218530	2 poultry houses, active, EPE = 13 ft; NAD27, Garmin III Plus GPS
36.219590	-94.220820	1 poultry house, not active, EPE = 14 ft; NAD27, Garmin III Plus GPS
36.219600	-94.221310	1 poultry house, active, EPE = 20 ft; NAD27, Garmin III Plus GPS
36.223000	-94.222720	8 poultry houses, active, EPE = 13 ft; NAD27, Garmin III Plus GPS
36.223180	-94.219640	4 poultry houses, active, EPE = 12 ft; NAD27, Garmin III Plus GPS



Distribution of Ozark Cavefish in Cave Springs Cave, Arkansas

164 cavefish sighted during census of 11/30/00

LEGEND: S = Fish length less than 2.5 cm
M = Fish length between 2.5 - 5.0 cm
L = Fish length greater than 5.0 cm

Cartography: G. O. Graening