REPORT ON COLD WATER CAVE

A Summary of Research Results with Inclusion of Information Related to Potential Development of a New Recreational Facility by the State of Iowa

Submitted to

The Honorable Robert D. Ray
Governor
State of Iowa

by

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Iowa Geological Survey

for

Samuel J. Tuthill
Director, Iowa Geological Survey
and

Fred A. Priewert
Director, Iowa Conservation Commission

December 1974

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RECOMMENDATIONS OF THE IOWA GEOLOGICAL SURVEY

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The Iowa Geological Survey was charged with the responsibility of investigating Cold Water Cave and reporting to the Governor and the General Assembly the results of its investigations as they relate to the decision of how the State of Iowa should proceed in its relationship with those who now own the cave.

Implied in this charge, but undefined by either the Executive or the Legislative branch, are two sets of criteria; A. the scientific value of the cave and B. the aesthetic value of the cave. Furthermore, the Executive and the Legislative branch have the shared responsibility of determining the priorities for the expenditure of public monies. There are no scientific criteria applicable nor any charge upon the Survey for making recommendations in this sphere.

Therefore, the Iowa Geological Survey has defined the options it believes are available to the State of Iowa, and has briefly discussed the probable results of the occupancy of each.

OPTIONS

Option I

ACQUISITION OF COLD WATER CAVE IN ITS ENTIRETY AND THE DEVELOPMENT OF THE SITE AS A RECREATIONAL AND/OR COMBINED RECREATIONAL AND SCIENTIFIC RESEARCH FACILITY.

Probable Results:

1. Additional expense to the State of at least $1 million, plus the cost of acquiring the property.

2. The introduction of an unplanned for element in the Conservation Commission's long-range program.

3. The creation of a new type of recreational activity into the spectrum of facilities maintained by the State for the use of the public.

4. The most positive assurance that Cold Water Cave, as a natural phenomenon, will not be damaged under a system of use that includes entrance by the general public.

5. The most complete justification of the $75,000 of public funds that has already been expended by the State.

Option II

ACQUISITION OF COLD WATER CAVE AND THE RESERVATION OF DECISION AS TO FURTHER DEVELOPMENT AND/OR USE BY THE STATE.

Probable Results:

1. Cold Water Cave would be protected from possibly destructive private development.

2. The State would acquire control at the lowest present cost (i.e., the cost of land acquisition alone).

3. The State risks higher development costs by delaying a decision to develop. This assumes that inflation will continue. If this assumption is not valid the State stands to conserve public funds by delaying development. The choice between these two assumptions is not within the technical competence of the Iowa Geological Survey to judge.

4. The State maintains the maximum number of options at the lowest possible cost to the taxpayer. It offers small justification to the public on an individual basis because such a decision does not assure Iowans a chance to see the cave or work in it. It necessitates a decision on the part of the State to expend funds, but provides only the removal of control of the cave from the private sector as a justification for the expenditures.

Note: Cold Water Cave could be acquired as a scientific preserve under Chapter 111B of the Code of Iowa, if this option is to be considered.

Option III

ABANDONMENT OF ALL STATE INTEREST IN COLD WATER CAVE.

1. No additional expense would be incurred by the State.

2. Control of Cold Water Cave will remain in the private sector.

3. Because of the lease agreement with one land owner, access to Cold Water Cave now exists and will remain in his possession.

4. Neither the aesthetics of the cave nor its scientific potential can be assured if control of the cave remains in

the private sector. Thus the State would be taking the position that it had no commitment to the preservation of either the scientific value or the aesthetic value of the cave.

5. Cold Water Cave would not necessarily be available to the public. There is the possibility of private development for commercial access, but maximum protection of the cave environment might be jeopardized in the name of economy.

6. The State has expended nearly $75,000 in its investigation of Cold Water Cave. The rationale for such an expenditure might be questioned by the public that hoped to visit the cave.

An historical review of the State's activities in the Cold Water Cave project and a summary of the results of scientific investigations is presented in appendixes.

REPORT ON COLD WATER CAVE

INTRODUCTION

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Following a presentation on the discovery and exploration of Cold Water Cave (CWC) by Mssrs. David Jagnow and Steve Barnett, emergency funds in the amount of $13,000 were allocated for exploratory drilling to locate a site to construct a vertical shaft entry into the cave. In addition, operational and safety equipment were obtained from a portion of those funds. Subsequently, an additional $52,000 was allocated to the Conservation Commission to be used for shaft construction and procurement and installation of surface facilities. Research programs and operational costs were supported by appropriations to the Iowa Geological Survey (IGS) for the period 1 July 1973 - 30 June 1975.

An interim report on research progress was submitted to Governor Robert D. Ray on 13 February 1974. The present report is a final report on all construction work, the results of research programs that relate to the scientific value of the cave, and preliminary studies that relate to the potential for development of CWC as a recreational facility. Each topic is presented in appendixes of the report.

REPORT ON COLD WATER CAVE

APPENDIX I

LEASE AGREEMENT

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Governor Robert D. Ray charged the State Geologist, Dr. Samuel J. Tuthill, and the Director of the Conservation Commission, Mr. Fred A. Priewert, to represent the state in negotiations to explore and evaluate CWC as a possible recreation or preserve site for acquisition by the state. Because the natural entryway into the cave is through a series of water-filled chambers, it was necessary to locate a site for construction of an artificial entryway. A lease agreement was entered into on 4 June 1971 with Kenneth M. Flatland, Wanda K. Flatland, Henry A. Flatland, and Norma H. Flatland to permit the State of Iowa to proceed with exploration drilling on land in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 19, T. 100 N., R. 9 W., Burr Oak Township, Winneshiek County, Iowa. Authorization was provided to construct a vertical shaft for access to the cave to conduct formal research programs beneath the Flatland property. The lease agreement will expire on 17 January 1975.

Although this report is submitted prior to expiration of the lease agreement, all pertinent information is included. Under the conditions of the lease, the entrance shaft will be sealed, all surface structures will be removed, and the entrance site and accessways will be restored as nearly as possible to their former condition upon completion of investigations, unless the owners elect to use the entry shaft and appurtenances. The owners have elected to use the entry shaft and appurtenances upon expiration of the lease.

REPORT ON COLD WATER CAVE

APPENDIX II

EXPLORATION DRILLING

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Three exploration test holes were drilled to locate a site for construction of the vertical shaft entryway. A downhole television camera was used in hole number three to examine the structural stability of the ceiling at the site and to ensure that no large speleothems would be damaged by construction of a large diameter shaft. The rationale for the drilling program is described below:

Test No. 1

The location of this drill site was based upon a map of the cavern constructed by David Jagnow and Steven Barnett using the Brunton compass and pace method. An overlay of the map on aerial photographs indicated that the cavern passed beneath an upland drainageway on the Kenneth Flatland property.

Bedrock at 12', broken beds in top 4', relatively little weathering. No data was available on gradient of cavern floor or height of cavern ceiling at drill site. The void from 80'6" to 81'1" could have been part of an upper drainage system into the main cavern, so the hole was drilled to the upper part of the Decorah formation for stratigraphic control and to determine if the main cavern might be encounted at greater depth.

Test No. 2

Drill site located 20' south of Test No. 1, closer toward center of drainageway. Bedrock at 11'9"; broken, severely weathered, pockets of sandy, pebbley clay from 12'4" to 15'4", iron-stained to 37'. The relationship of the void from 77'6" - 82' to the main cavern was uncertain and the hole was drilled to 140'3" (1' above the base of the Galena limestone).

The bit was pulled after reaching the bottom of the void at 82'. Yellowish-brown silty clay adhered to the bit, probably a thin layer of residual clay in the bottom of the void. While drilling below the void the hole deviated about a half-hole diamter to the southwest, an indication that the floor of the void sloped in that direction. Therefore, Test No. 3 was drilled 18' southwest of Test No. 2.

Test No. 3

Bedrock at 11'10"; broken, severely weathered; very soft, granular zones; sandy, pebbley clay pocket 21'6" - 22'; crevice fill of clean gravel 26'6" - 26'10"; limestone iron-stained to 35'. Main cavern 77'11" - 93'10".

Logs of drill holes are shown in figure 1. Figure 2 is a composite interpretation of drill hole data.

Test No. 1

Date	Footage	Cumulative Footage	Remarks
1-17-72			Set up on drill site.
1-18-72	35'	35'	Very slow loss of fluid 18'-32'.
1-19-72	20'	55'	
1-20-72	26'3"	81'1"	Void 80'6" to 81'1"; lost circulation at 80'6".
1-21-72	2'	83'1"	Set 83' of 5 1/8" ID casing; about 6" of fluid in hole before setting casing.
1-22-72			Cement casing; allow to set up over weekend; (about 2' of fluid in hole before cementing).
1-25-72			Too cold to prime pump (-16°F).
1-26-72	2'5"	85'6"	Drilled out cement plug; lost circulation at 85'6" (cement seal broke around bottom of casing); bailer test showed 4' of fluid in hole.
1-27-72			Recement bottom of casing; allow to set up over weekend.
1-31-72	15'6"	101'	Cement job held; very minor fluid loss to 101'.
2- 1-72	36'1"	137'1"	No significant fluid loss.
2- 2-72	12'11"	150' TD	Top of Decorah formation at 141'.

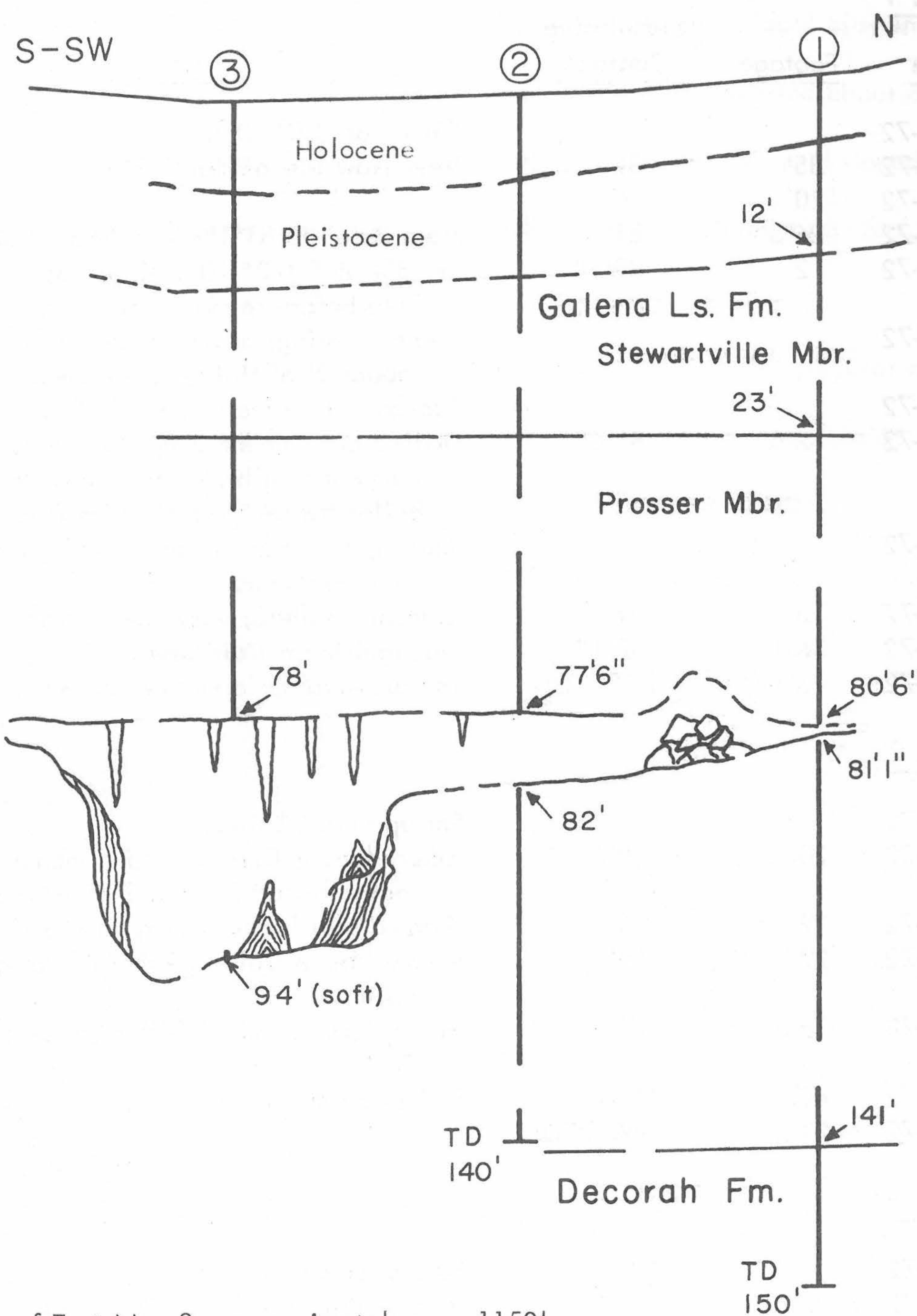
Test No. 2

Date	Footage	Cumulative Footage	Remarks
2-14-72			Set up on drill site.
2-15-72	20'6"	20'6"	Heavy loss of fluid at 11'9"; moderate loss 12-15'; heavy loss at 16'8", 18'6"-20'6", 27-31'.
2-16-72	9'6"	30'	Ground seal broke; heavy loss of fluid 27-30'.
2-17-72	29'	59'	Heavy loss of fluid 30-35'; set 36' of 5 1/8" ID casing.
2-18-72	16'6"	75'6"	Heavy loss of fluid 72-73'6"; lost circulation at 73'6".
2-19-72	40'6"	116'	Drilling with air; void from 77'6" to 82'.
2-20-72	24'3"	140'3"TD	

Test No. 3

Date	Footage	Cumulative Footage	Remarks
2-20-72			Set up on drill site.
2-21-72	34'6"	34'6"	Heavy fluid loss 11'-11'5", 11'10"-14', 26'-26'10"; lost circulation at 28'8"; set 28' of 5 1/8" ID casing (gravel and broken limestone falling into hole).
2-22-72	59'4"	93'10"	Drilling with air; void from 77'11" to 93'10".

Figure 1. Logs of drill holes.



Elevation of Test No. 3, approximately	1150'
Depth to cavern floor	94'
Elevation of cavern floor, approximately	1056'
Elevation of spring entrance, approx.	1020'
Distance from spring entrance to drill site along mapped course of cavern	2.4 miles
Gradient of cavern floor	15'/mile

Figure 2. Interpretation of drill hole data.

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APPENDIX III

FACILITIES AND SAFETY PROGRAM

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Facilities

A 30-inch diameter 94 foot, steel-cased shaft with ladder and electric winch was constructed by Nelson Brothers, Decorah, Iowa, between 8 July 1972 and 29 August 1972. A pole galvanized-steel building houses the access shaft.

A research office trailer and a crew quarters trailer were placed on the site and enclosed by a hurricane fence. Water, electricity, sewer and telephone services were installed.

Safety Program

All entrance into the cavern was conducted by IGS personnel under the control of Mr. Donald Koch, CWC Project Scientist. All entrance required the permission of the State Geologist. IGS acquired safety equipment and atmospheric testing equipment to ensure optimum safe operations. Much of the equipment listed below was recommended by the Metal and Nonmetal Mine Health and Safety Division, Bureau of Mines, United States Department of the Interior. Koch received mine rescue training and first-aid training from the Bureau of Mines.

SCUBA Equipment

- Air tanks
- Air tank paks
- Regulators
- Face masks
- Gauges
- Wet suits

Lighting Equipment

- Minespot cap lamps
- Single-unit chargers
- Hard-hats with lamp brackets
- Lantern

Atmospheric Testing Equipment	First-Aid Equipment
Oxygen indicator meter	Wool blankets
Methanometer	Wood splints
Universal gas tester	Air splints
a) carbon dioxide tubes b) hydrogen disulfide tubes	First-aid kits
Flame safety lamp	Wire basket stretchers
Sling psychrometer	Automatic resuscitator
Smoke tube kit	Oxygen administrator

No fewer than three people were permitted to work at any time while conducting research in the vicinity of the shaft entryway. At least four people were required for each work party while working more than about 500 feet upstream or downstream from the shaft. Prior arrangements were made for ambulance service from the Winneshiek County Memorial Hospital. Messages could be relayed directly from the county sheriff's radio to the hospital radio.

Minor cuts and scratches often were incurred while working in the cave. Infection was likely upon exposure to the mud and water. All cuts and scratches were thoroughly cleaned and disinfected. If infection developed and additional work remained, that person was not permitted to continue his or her work until the infection cleared.

Weather forecasts were monitored to insure that no personnel would be working far from the shaft if heavy rainfall was imminent. Water level of the stream rises rapidly when surface runoff discharges into sinkholes.

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APPENDIX IV

CAVERN ATMOSPHERE

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Atmosphere

During the initial safety inspection on 30 August 1972, it was discovered that atmospheric oxygen was low (O_2, 19%) and carbon dioxide was high (CO_2, 2%). National Mine Safety maximum for CO_2 is 0.75 percent and the minimum for O_2 is 20 percent for an eight-hour work day. The effect upon persons breathing high concentrations of CO_2 in the presence of adequate amounts of O_2 is to stimulate hyperventilation which, in turn, causes a physiological deficiency of CO_2. According to the American Conference of Industrial Hygienist Manual on Mine Atmospheres, various CO_2 concentrations have the following effects:

Subject at Rest -
- 0.5% - slight increase in breathing
- 2.0% - increase of breathing of about 50%
- 3.0% - increase of breathing of about 100%
- 5.0% - increase of breathing of about 300%
- 10.0% - survival is limited to no more than a few minutes

Work performed by a person breathing high concentrations of CO_2 increases the affects relative to the vigor of the work. There has been no apparent adverse affect on the health of personnel conducting research in CWC, even during the summer and early fall when CO_2 concentration is highest. However, no prolonged strenuous work was permitted that would result in fatigue. With few exceptions, work periods in the cave were restricted to four to six hours duration.

Measured periodic variations in CO_2 concentrations are listed in table 1 and are plotted graphically (fig. 3). Temperature and relative humidity data also are listed in table 1. The data on carbon dioxide show that the lowest concentrations occur during the winter months. Carbon dioxide increases during the spring

Table 1

CAVERN ATMOSPHERE AND TEMPERATURE DATA

Date	Percent Carbon dioxide (CO_2)	Percent Oxygen (O_2)	Temperature Air (°F)	Temperature Water (°F)	Percent Relative Humidity
8-30-72	1.9	19.09	48.0	47.5	>95
12-19-72	1.2	19.79	47.5	47.5	>95
1-22-73	0.7	20.29	47.5	43.0*	>95
1-30-73	0.6	20.39	47.5	47.0	>95
2-20-73	0.7	20.29	48.0	47.0	>95
3-13-73	0.7	20.29	47.5	46.5	95
4- 4-73	1.2	19.79	48.0	46.5	95
4-27-73	1.5	19.49	48.5	46.5	>95
5-22-73	1.5	19.49	48.5	46.0	95
5-30-73	1.5	19.49	49.0	46.0	93
7-12-73	1.6	19.39	48.0	47.0	95
8- 2-73	1.7	19.49	48.5	47.5	>95
9-26-73	2.1	18.89	49.0	48.0	>95
10- 8-73	1.9	19.09	48.5	47.5	>95
11-13-73	1.8	19.19	48.0	47.0	
11-24-73	1.7	19.49	48.0	47.0	>95
12-17-73	1.1	19.89	47.0	47.0	>95
1-18-74	0.8	29.19	47.0	47.0	>95
2-15-74	0.7	20.29	47.0	47.0	>95
3-12-74	1.2	19.79	47.0	46.5	>95
3-25-74	1.1	19.89	47.0	47.0	>95
5-21-74	1.3	19.69	49.0	48.0	>95
6- 4-74	1.3	19.69	48.0	48.0	95
6-18-74	1.3	19.69	48.0	47.5	95
6-24-74	1.3	19.69	48.0	47.5	95
7-11-74	1.3	19.69	48.0	47.0	95
7-24-74	1.4	19.59	48.0	47.0	94
8-14-74	1.6	19.39	48.5	47.5	95
8-27-74	1.6	19.39	48.5	47.5	95
10-15-74	1.5	19.49	48.0	47.0	>95
10-22-74	1.5	19.49	48.0	47.0	>95
12-10-74	0.7	20.29	47.5	47.0	>95

*Lowered temperature resulted from inflow of meltwater.

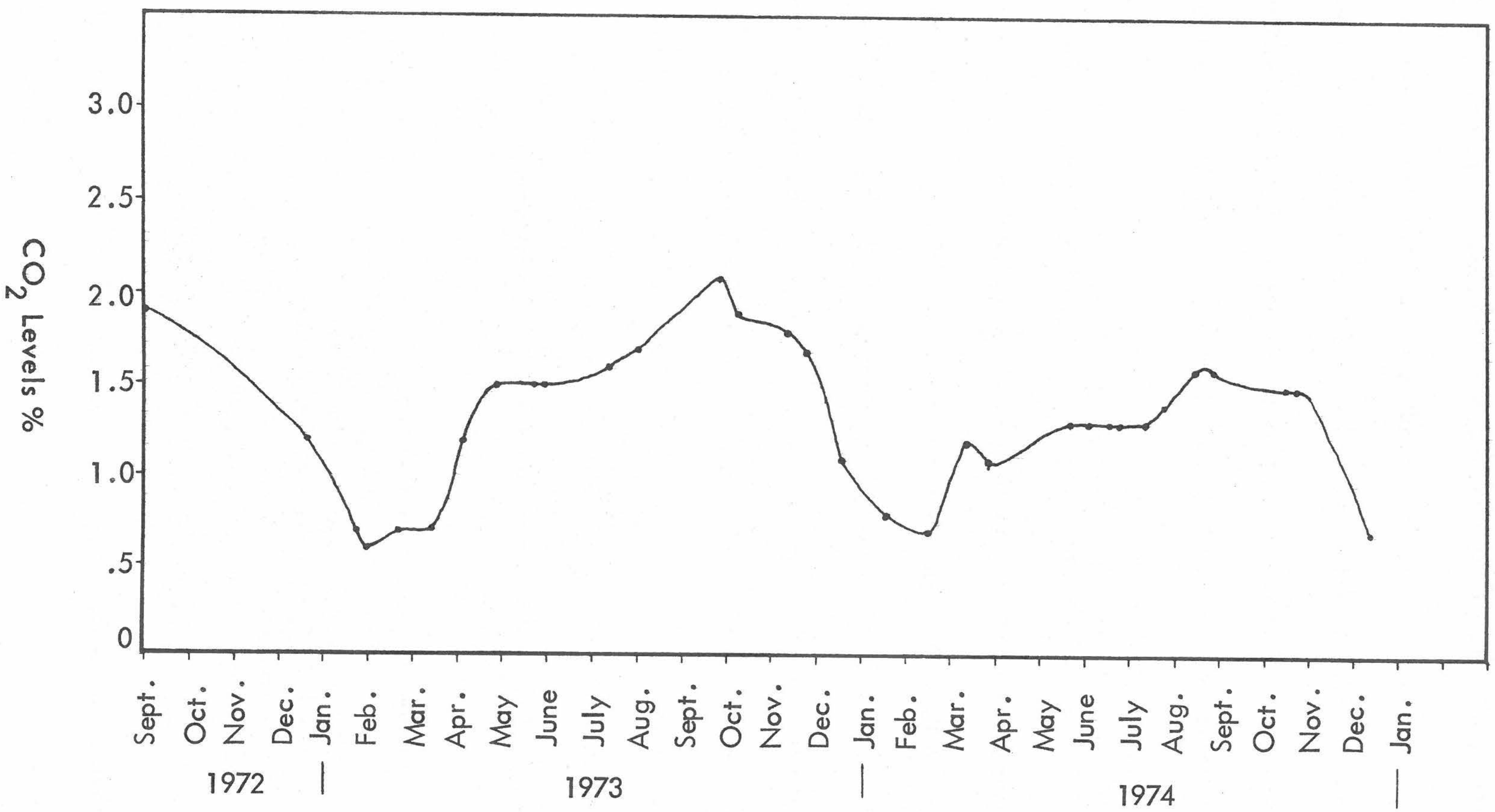


Figure 3. Cold Water Cave CO_2 Levels.

months, reaches a peak in the late summer or early fall, and decreases again to a winter low. The generally lower values during the spring, summer and fall of 1974 as compared with 1973 probably are the result of more frequent, heavy rainfalls in 1974, and the greater volumes of surface water discharge into the cavern system. Although CO_2 concentrations might be somewhat higher or lower under special circumstances, the measured concentrations probably are representative of long-term, seasonal variations.

The cave atmosphere is unlike the general atmosphere at the surface that experiences constant mixing by convection currents caused by solar heating and winds generated by slippage at the earth-air interface because of rotation of the earth. Although undoubtedly some amount of mixing of the cavern atmosphere with the surface atmosphere occurs in response to barometric changes, the volume is small compared to many other caves that have more direct connection with the surface atmosphere. Air in several commercial caverns was tested for CO_2, and the highest value measured was an order of magnitude less than the highest value for CWC. CO_2 values determined in other caves are:

Cave	Date	Percent CO_2
Wonder Cave; Decorah, Iowa	7-14-73	0.2
Enchanted Caverns; Eldon, Missouri	11- 5-74	<0.1
Bridal Cave; Camdenton, Missouri	11 -5-74	0.2
Blanchard Springs Caverns; Mountain View, Arkansas	11 -6-74	0.1
Onondaga Cave; Leasburg, Missouri	11 -8-74	0.2

Carbon dioxide is a heavy gas (1.53 times as heavy as air and 1.38 times as heavy as oxygen). Because pockets of higher concentrations of CO_2 might develop in low spots, the air was tested at different elevations below the ceiling and at different locations in the cave on the same day. No significant variation in CO_2 concentrations was observed. Usually, no variation was noted, and any apparent variation was no greater than 0.1 percent, either from the ceiling to the floor, or from the upper reaches to the downstream portion of the cave.

Air in CWC also was tested for the presence of hydrogen disulfide and methane. Although it is possible that small amounts of these gases might be generated from organic-rich material introduced into the cave through sinkholes during the spring and summer months, no trace of these gases was detected.

REPORT ON COLD WATER CAVE

APPENDIX V

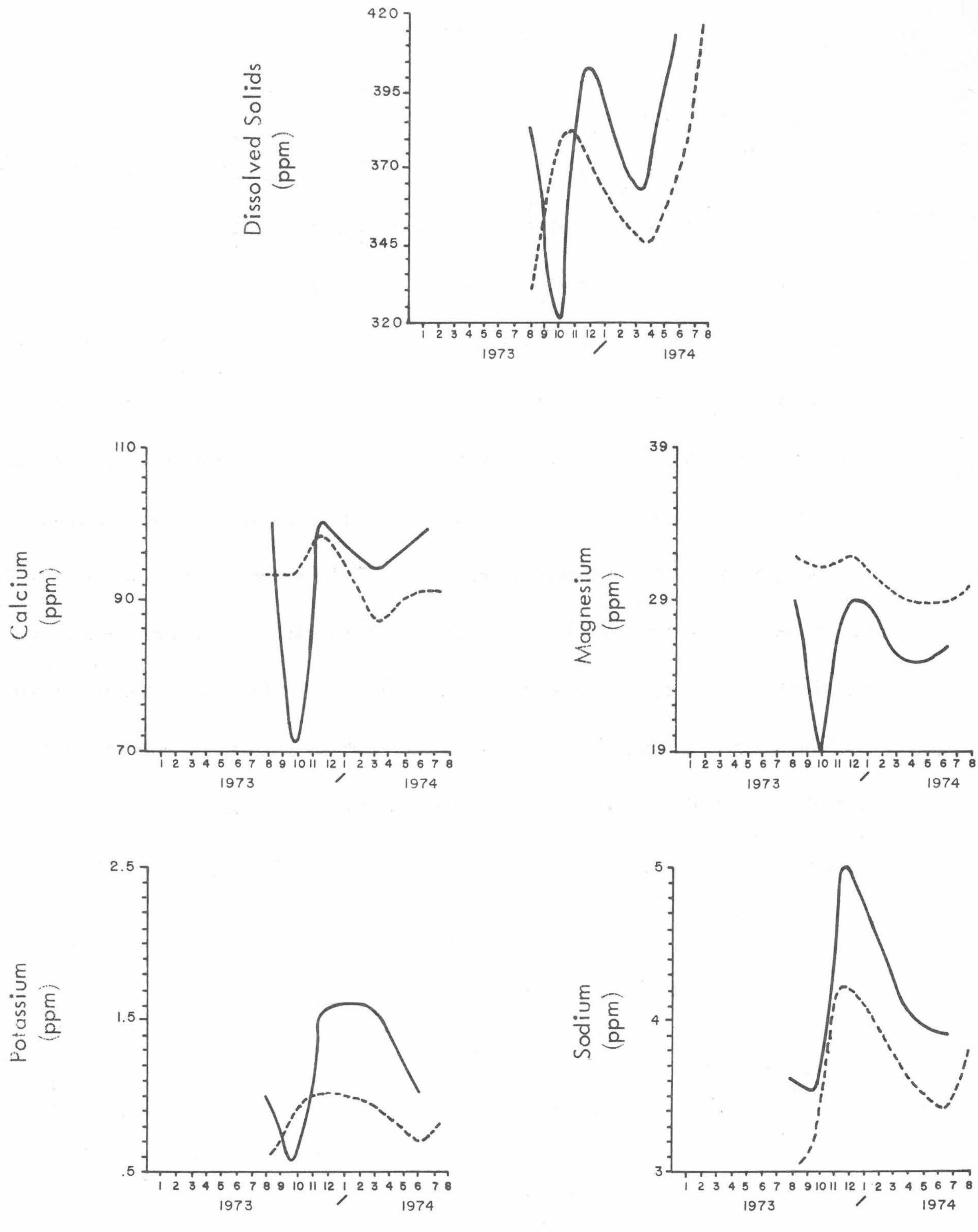
WATER ANALYSES: CHEMICAL ANALYSES

WATER QUALITY

WATER ANALYSES

Chemical Analyses

Water samples were collected periodically for analysis by the State Hygienic Laboratory to monitor changes in various ion concentrations. Seasonal changes occur in the chemistry of both dripwater and stream water. Total dissolved solids and the concentration of ions such as calcium, magnesium, potassium and sodium decrease to a low in late summer and early fall, and increase in late fall and early winter; a secondary low occurs in late spring (fig. 4). Dripwater follows a similar pattern, but although the period of change is nearly coincident with stream water the magnitude of change generally is less. The chemistry of both sources of water is affected by the amount and frequency of precipitation. Chemical analyses of water from one collection site are listed in table 2. Trace metals content (arsenic, barium, cadmium, chromium, copper, lead, zinc) was always less than 0.01 part per million with the exception of barium (less than 0.1 ppm).



stream water; -------dripwater

Figure 4. Variation in dissolved solids and selected ion concentrations; 600 feet upstream from shaft.

Table 2

TABULATION OF WATER ANALYSES
(Dissolved constituents in parts per million)

Collection Site	Date of Collection	°C	Diss. Solids	Mn	Ca	Mg	K	Na	CO_3	HCO_3	SO_4	Cl	F	NO_3	Hardness Cal as $CaCO_3$ tot.	carb.	non carb.	pH	Cond.
Dripwater; 600' upstream	8/ 2/73	8.3	329	.01	93	32	0.6	3.0	0	392	23	12	0.2	4	356	322	34	7.2	630
	9/26/73	8.3	377	.01	93	31	0.9	3.2	0	398	26	3	0.2	9	352	326	26	6.6	620
	11/15/73	8.3	377	.01	98	32	1.0	4.2	0	383	38	3	0.2	12	356	314	42	6.9	620
	3/12/74	8.3	345	.01	87	29	0.9	3.7	0	371	25	4	0.1	18	328	304	24	7.0	600
	6/14/74	8.3	379	.01	91	29	0.7	3.4	0	364	15	2	0.2	17	330	298	32	7.2	620
	7/12/74	8.3	417	.02	91	30	0.8	3.7	0	378	22	3	0.2	15	340	310	30	7.1	610
	8/ 2/74	8.3	378	.02	100	29	1.0	3.6	0	373	32	6	0.2	18	356	306	50	7.2	630
Stream water 600' upstream	9/26/73*	8.3	319	.51	71	19	5.5	3.5	0	268	26	8	0.1	17	252	220	32	6.8	510
	11/15/73*	8.3	402	.06	100	29	1.5	5.0	0	386	32	8	0.2	18	352	316	36	6.8	650
	3/12/74	8.3	362	.03	94	25	1.5	4.1	0	354	31	8	0.1	18	332	290	42	7.0	630
	6/14/74	8.3	390	.01	99	26	1.0	3.9	0	357	36	5	0.1	19	332	293	39	7.6	640

*Turbid water

Water Quality

Water samples tested for coliform bacteria showed levels unsafe for human consumption. Values for nitrate in stream water consistently were about 18 ppm. Nitrate concentrations in dripwater were approximately 17 ppm during the spring and summer, but diminish during the fall and winter.

Mr. Mike Osterholm, Luther College collected water samples on 2 August, 26 September, 8 October, and 14 November 1973. He analyzed the samples for total coliforms (TC), fecal coliforms (FC) and fecal streptococci (FS). The ratio FC/FS is used to indicate whether contamination is from human or nonhuman (e.g., cattle, hogs) feces. A ratio of four or greater indicates human contamination. Ratios developed for nearly all samples were less than one; a ratio of two was obtained for only one sample. The larger ratios were for samples collected after periods of precipitation. Thus the data indicates that groundwater contamination is the result of nonhuman wastes transported to the subterranean drainage system of CWC.

There is a direct relationship between surface runoff and water levels in the cave. Water levels rise rapidly when surface runoff discharges into sinkholes. Also, the stream water rapidly becomes turbid. The discharge rate of the stream during normal summer levels is about 5,800 gallons per minute near the shaft and about 8,700 gallons per minute at the spring entrance. Although no discharge rate was determined during flood stage, a rise of 2.9 feet above normal summer level was observed during a flood on 21 June 1974.

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APPENDIX VI

SURVEYING PROGRAM

SURVEYING PROGRAM

Introduction

The original explorers of CWC, Messrs, Steve Barnett and David Jagnow, mapped the cave using a Brunton compass and steel tape to delineate the course of the principal passageway and to record the location of side passages and other prominent features. Their map was reasonably accurate and was extremely useful during the early phases of this project. Ultimately, a more precise survey of at least the middle segment of the cave was necessary for the following reasons:

1. The position of the cave had to be defined precisely relative to surface property lines.

2. A more accurate map was needed in conjunction with preliminary design planning and analysis of construction costs for potential development of the cave as a recreational facility or preserve site.

Personnel

Assistants were needed for surveying on the land surface and in the cave. Precise surveying requires resistance to boredom, the maintenance of the highest degree of scientific integrity, and the possession of emotional maturity. Members of the Scouting organizations offered these qualities along with physical fitness and mental alertness. Nine positions were offered as Construction Aides for the surveying project. Three individuals were scheduled to work with IGS personnel for each of the months of June, July and August, 1974. The successful applicants were:

June Work Period

Richard A. Bishop, Eagle Scout
824 14th Avenue
Coralville, Iowa 52241

Mike Botts, Eagle Scout
1712 South 3rd Street
Marshalltown, Iowa 50158

James D. Skog, Eagle Scout
2662 Washington Street
Iowa City, Iowa 52240

July Work Period

Leanne J. Clark, Camp Fire Girl
616 C. Street
Fort Dodge, Iowa 50501

Ann Dolan, Girl Scout
1640 Morningside Drive
Iowa City, Iowa 52240

Kenneth W. Huck, Eagle Scout
906 2nd Avenue Place S.W.
Waverly, Iowa 50677

August Work Period

Mark S. Brown, Eagle Scout
1311 East 27th Court
Des Moines, Iowa 50317

Lori Ferguson, Girl Scout
802 12th Avenue
Coralville, Iowa 52241

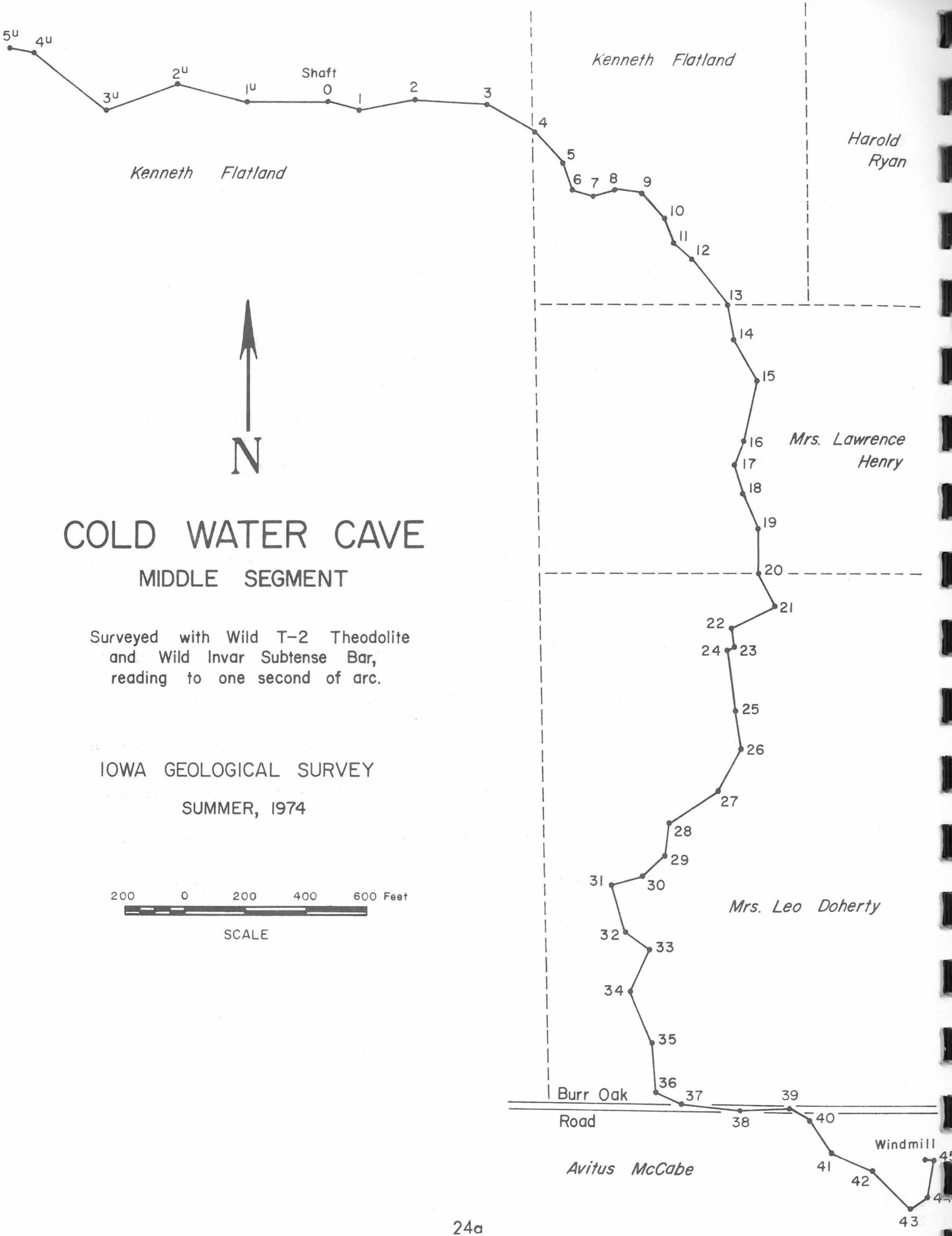
Kathy Thye, Camp Fire Girl
R.R. #1
Gowrie, Iowa 50543

Instrumentation and Procedure

A Wild T-2 Universal Theodolite and Subtense Bar were used to survey the middle segment of the cave and property lines over that portion of the cave. Distances can be determined accurately to one second of arc (0.057 inch in a distance of 1,000 feet) using this equipment.

Instrument stations in the cave were established by determining lines of sight between stations. Limiting factors that affected the selection of instrument stations included wall clearances for extension of the subtense bar, stability and thickness of sediments on the cave floor, and water depth. Forty-six instrument stations were established downstream from the access shaft and five stations were established upstream from the shaft.

A water well located about one mile southeast of the access shaft provided a reference point for closing the survey. The pump rod in this well extends through a side passage in the cave. The final map (following page) is an overlay of the shaft site, water well site and property boundaries upon the cave map. The linear error in closure between the shaft and well site on the surface, and the shaft and well site underground is 1.57 feet. A larger scale map that shows cross-sectional dimensions is available for engineering design and planning.


COLD WATER CAVE
MIDDLE SEGMENT
Surveyed with Wild T-2 Theodolite and Wild Invar Subtense Bar, reading to one second of arc.
IOWA GEOLOGICAL SURVEY
SUMMER, 1974
200 0 200 400 600 Feet
SCALE
N
Shaft
Kenneth Flatland
Kenneth Flatland
Harold Ryan
Mrs. Lawrence Henry
Mrs. Leo Doherty
Burr Oak
Road
Avitus McCabe
Windmill
5u 4u 3u 2u 1u 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 45

REPORT ON COLD WATER CAVE

APPENDIX VII

FAUNA AND FLORA

FAUNA AND FLORA

Introduction

The fauna and flora of Cold Water Cave were studied during three sampling periods from 20 December 1972 through 22 October 1974. Personnel who participated in this operation included staff members of the Iowa Geological Survey, Dr. George Cain and Victoria Smith of the University of Iowa, and Dr. K. Christiansen and Bruce Tucker of Grinnell College. Dr. Christiansen was the principal investigator.

Goal

This study was made to document the extant terrestrial and aquatic fauna and flora prior to excessive human entry into the cave. Because early entries into the cave were made after swimming through a series of water-filled passages, and because the biological survey was the first investigation scheduled after construction of the vertical entry shaft, the likelihood was small that organisms foreign to the cavern environment might have been introduced. The knowledge of prehuman entrance fauna in any cave is unique, and this information might prove very valuable to future research. The first collections were taken shortly after first entry, and since subsequent collections have provided no new material we feel confident that our survey represents an adequate sample of the fauna before human entry.

Procedure

During the first entry, baits (cheese) were placed at 18 stations and a thorough examination of the cave was made in an approximately one-half mile section of the cave upstream and downstream from the entrance shaft. These were visited on the next day and after rebaiting were examined again on 13 July 1973 and 22 October 1974. Soil samples were extracted with berlese funnels from 19 sites in December, 1972, and from four sites in July, 1973 and October, 1974. In December, 1972, Nematode samples were collected at 15 sites, and plates for fungi and bacteria were exposed at five sites. Plankton tows were taken at five sites in December, 1972 and November, 1974. Pitfall traps were attempted in January, 1973 with little success. The fauna and flora collected are shown in table 3.

Terrestrial Fauna of the Cave

The dominant faunal elements in the cave are listed below. Numbers in parentheses are total specimens collected during the study.

Annelida (worms)	-	abundant *Eisenella tetraedra* and *Allolobophora tuberculata*
Diplopoda (millipedes)	-	*Achemenides pectinatus* (25)
Collembola (wingless insects)	-	*Onychiurus* sp. (26) and *Folsomia candida* (120)

From the standpoint of numbers, the Collembola of the genus *Megalothorax* (21), staphylinids (beetles) (22), and mites (25) were about equal; however, all were much more localized and in the last case mites of several families were lumped together. Each genus was represented by 10 or fewer specimens. Minor elements in the terrestrial fauna include Nematodes (family Tylenchidae) (5) and family Dorylaimidae (5), spiders (2), Diptera (4), and Collembola of the genera *Tullbergia* (8) and *Arrhopalites* (3). Few earthworms were collected (8)

TABLE 3

FAUNA AND FLORA OF COLD WATER CAVE

Station Number	Location: (all right and left directions facing upstream); all distances estimated.	Number of specimens in parentheses (X = unexamined)		
		Specimens Collected Dec. 21-22, 1972	Specimens Collected July 13, 1973	Specimens Collected Oct. 21-22, 1974
1	Bank 20 feet above stream bed; clay covered with dark silt on top of bank; right bank of stream, 10 feet upstream of shaft.		Onychiurus (2) Folsomia (2) Earthworm (1)	Bait - X Soil-Berlese Megalothorax (18) Folsomia (10) Onychiurus (2)
	Earthworm castings 4 feet above previous station.	Unidentified nematode	X	X
	Same station at stream level.	Tylenchidae (1)	X	X
2	120 feet upstream from base of shaft; right bank of stream, 1 foot above base of wet silt.	Soil-Berlese Tullbergia (2) Parasitid (mite) (1)	Bait - 0 Berlese sample Folsomia (6) Spider (1) Tullbergia (1) Megalathorax (1)	Bait - 0 Berlese between stations 2 and 3 Staphylinids (8) Folsomia (15) Phoridae (1)
3	210 feet upstream from shaft. Left bank, 2 feet below ceiling.	Soil-Berlese Tullbergia (1)	Folsomia (3)	Onychiurus (6) Mites (7)
	Pool, 2 feet above stream bed.	Aquatic beetles (Dytiscidae) (6) Folsomia on surface (10)	Dytiscid beetles (4)	Dytiscid beetles (3)

Table 3 continued

Number of specimens in parentheses (X = unexamined)

Station Number	Location: (all right and left directions facing upstream); all distances estimated.	Specimens Collected Dec. 21-22, 1972	Specimens Collected July 13, 1973	Specimens Collected Oct. 21-22, 1974
4	On breakdown 300 feet upstream of shaft; 20 feet above stream bed, silty clay.		Onychiurus (2) Folsomia (1)	Millipede (1) Earthworm (1)
	Pile of earthworm castings near previous station in cavity of flowstone.	Soil-Berlese Megalothorax (2)	X	X
	30 feet upstream station 4 on base of rock fall	Onychiurus (1)	X	X
5	90 feet upstream from station 4, left bank, on clay.	Rhagiidae (mite)	Millipede (1)	0
	6 feet upstream from station 5, pool 3 feet above stream bed, on surface of pool.	Folsomia (7) Arrhopalites (1) Mites (1)	X	X
	45 feet upstream station 5, left bank--ceiling contact with clay.		X	X
6	60 feet upstream station 5, left bank; flowstone 5 feet above stream	Millipede (1)	Mites (2) Folsomia (2) Onychiurus (2) Millipede (1)	Onychiurus (1) Millipides (2)
	20 feet above station 6; earthworm castings and clay	Soil-Berlese Head capsules of beetle larvae.	X	Small pockets clay 10 feet above stream; Berlese-Diptera (2) Staphylinids (8) Onychiurus (1)

Table 3 continued

Station Number	Location: (all right and left directions facing upstream); all distances estimated.	Number of specimens in parentheses (X = unexamined) Specimens Collected Dec. 21-22, 1972	Specimens Collected July 13, 1973	Specimens Collected Oct. 21-22, 1974
6 cont'd	30 feet downstream station 6, 5 feet above stream; small pool.	Rhagiidae (1)	X	X
	Earthworm castings 20 feet upstream station 6	Dytiscidae (3)	X	X
7	75 feet upstream station 6; small clay pocket on left bank, 7 feet above stream bed.		Millipede	0
	20 feet upstream station 7, on small pool 3 feet above water.	Rhagiidae (1)	X	X
	15 feet upstream station 7; right bank 3 feet above stream bed--earthworm castings		X	X
	Pool 5 feet above stream bed, same site--on water surface.	Folsomia (1)	X	X
8	45 feet upstream station 7; earthworm castings on clay over flowstone	Oribatid (mite) (1) Dipteran larva (1) Dorylaimidae (5)	Folsomia (1) Millipedes (2)	Millipede (1) Earthworm (1)
	Clay 25 feet above stream bed, right bank, 15 feet upstream station 8; bat bones present.		Berlese Folsomia (1)	

Table 3 continued

Station Number	Location: (all right and left directions facing upstream); all distances estimated.	Specimens Collected Dec. 21-22, 1972	Specimens Collected July 13, 1973	Specimens Collected Oct. 21-22, 1974
		Number of specimens in parentheses (X = unexamined)		
8 cont'd	Pool, 1 foot above stream, same site	Dytiscidae (beetles)((3)	X	X
9	Entrance to side passage 180 feet upstream station 8, right bank; abundant earthworm castings and much debris in small side stream.	Soil- Folsomia (1) Tullbergia (1)	Onychiurus (7) Folsomia (3) Millipede (1) Annelids (Enchytraeids) (3)	Onychiurus (2) Mites (2) Berlese 7 feet above stream: Folsomia (50) Mites (6) Staphylinid (1)
	20 feet up side passage, right side	Earthworm	X	X
	Small stream in passage.		X	X
	18 feet upstream in side passage			
10	75 feet upstream station 9, 4 feet above stream; thin layer earthworm castings over flowstone and silt.	Soil sample Acarid (mite) (8) Tullbergia (1)	Onychiurus (2) Folsomia (7) Arrhopalites (2) Millipedes (4)	0
	Opposite station 10, muddy bottom, still water.		X	X
11	Silty clay 3 feet above stream bed; 105 feet upstream station 10, right bank.		0	Millipedes (5) Onychiurus (6)

Table 3 continued

Station Number	Location: (all right and left directions facing upstream); all distances estimated	Specimens Collected Dec. 21-22, 1972	Specimens Collected July 13, 1973	Specimens Collected Oct. 21-22, 1974
		Number of specimens in parentheses (X = unexamined)		
11 cont'd	Left bank, opposite station 11, earthworm castings, silt-roof contact.	Soil- Tullbergia (1)	X	X
	Mud-wall contact, right bank.		X	X
	Mud-stream edge, right bank.	Tylenchidae (4)	X	X
	15 feet upstream station 11, right bank, 6 feet above stream bed.	Millipede (1)	Berlese- Folsomia (3)	Millipedes (2)
	30 feet upstream station 11; second rock fall,on rock surface.	Staphylinidae Dytiscidae (2) Folsomia (1)	X	X
12	Rimstone pool 40 feet upstream from station 11, on pool surface.	Folsomia (1) Rhagiidae (1)	X	X
	Bait station, left bank, 7 feet above stream bed.		0	Millipedes (2) Folsomia (12) Onychiurus (2)
	20 feet upstream station 12; side pool		X	X
	30 feet upstream station 12, beneath rock fall; small eddy of stream--on surface	Folsomia (1)	X	Dead Carabid beetle
	Left bank, same spot, 5 inches above stream; small pool on bench.	Collembola ?	X	X

Table 3 continued

Station Number	Location: (all right and left directions facing upstream), all distances estimated	Specimens Collected Dec. 21-22, 1972	Specimens Collected July 13, 1973	Specimens Collected Oct. 21-22, 1974
		Number of specimens in parentheses (X = unexamined)		
	Stations downstream from shaft. (directions facing downstream)			
13	10 feet downstream, left bank, 5 feet above water.		Millipede (1)	Millipede (1)
14	30 feet downstream, right bank, 4 feet above water level.		X	X
15	150 feet downstream, $2\frac{1}{2}$ feet above water, left bank.	Dytiscidae (1) Folsomia (1) Mite (1)	X	X
	Rockpile 20 feet downstream station 15; rimstone pools.		X	X
16	55 feet downstream station 15.		X	X
	Same site	Folsomia (2) Rhagiidae (1)	X	X
17	100 feet downstream station 16, past gallery, left bank.	Soil - Unidentifiable fragments	X	X
	30 feet downstream station 17, 3 feet above water level, in pool.	Dytiscidae Staphylinidae (2)	X	X

Table 3 continued

Number of specimens in parentheses (X = unexamined)

Station Number	Location: (all right and left directions facing upstream); all distances estimated	Specimens Collected Dec. 21-22, 1972	Specimens Collected July 13, 1973	Specimens Collected Oct. 21-22, 1974
17 cont'd	Small pool 10 feet past previous collection		X	X
18	120 feet downstream station 17, left bank, 4 feet above water; clay on small rock bench.	Soil-Tullbergia (1)	X	X

during the study, but their abundance was indicated by the massive quantities of castings on sediment banks. Arrhopalites were greatly under represented in collections due to its neustonic habitat. Fragments of two bat skeletons were found but no living bats were observed.

Among the several species of invertebrates that occur commonly in caves, nematodes are perhaps the most incompletely studied, probably because of the widely held belief that there are no truly troglobytic species. To date, all nematodes reported from caves apparently are surface forms that have been carried into the cave with either surface water or soil. It should be noted, however, that the criteria usually applied to ascertain whether a given organism is troglobytic--e.g., lack of pigmentation, presence or absence of certain sensory structures--are not appropriate for nematodes because of their structural simplicity.

The density of nematodes in the samples collected was low. There was no discernable pattern as to the habitat specificity of the nematodes, with specimens recovered from pools, stream silt and cave silt alike. It is likely that the nematodes are surface forms that were transported into the cave. Because of their preadaptation to surface soil, they have been able to maintain a starvation level existence at the low trophic levels of the cave silt.

Flora and Aquatic Fauna

Bacteria recovered from exposed Petri plates were not identified but at least five species were collected. Fungi of the following genera were collected:

Penicillium (3), Rhizopus (1), Alternaria (1), Aspergillus (1), Cladosporium (1), Hormodendrum (1), Pullularia (1).

Organisms recovered from plankton tows include ostracods, copepods, cladocera and aquatic oligochaetes in very low densities. Several salamanders and a single crayfish of undoubted local surface origin have been observed upstream from the shaft. No fish have been observed in the upper reaches of the cave. One unidentified fish has been observed about one-half mile downstream from the shaft, and sculpins are common beyond a mile downstream from the shaft.

Seasonal and Spatial Distribution

Within the area sampled, organisms show no clear patterns of regional localization. Detailed studies would probably show localization to be associated with substrate nature and the availability of organic material. With the exception of the Staphylinid beetles, which were not found in the July collections, there is no clear evidence of seasonal variation in abundance.

Discussion

Cold Water Cave has a very depauperate fauna of troglophile and trogloxene elements. With the possible exception of the locally abundant dytiscid beetles, there are no surprises in the fauna present. Some elements commonly found in other caves of the region are absent. The supply of washed-in organic material is considerable and there often is a rather large supply of drowned earthworms. These factors make this cave a location to study the problems of introduced troglobitic aquatic forms. The fauna of the cave itself is of limited biological interest.

Conclusion

This cave holds some promise as a tool for future biological research. It has a very sparse fauna of both terrestrial and aquatic organisms. It is extensively in contact with surface organisms of the area and has an input of organic material. These factors, combined with the unique knowledge of the prehuman-contact fauna, support a possible role in the development of speleo-biological knowledge. Because the principal areas of biological interest are upstream from the shaft, the development of part of the cave downstream from the shaft as a recreational facility would in no way detract from scientific biological use of the cave.

Acknowledgments

Identification of the following groups were made by the people indicated.

Nematodes	-----	George Cain
Fungi	-----	M. Rosenski
Earthworms	-----	J.W. Reynolds
Millipedes	-----	W. Shear
Collembola	-----	K. Christiansen

REPORT ON COLD WATER CAVE

APPENDIX VIII

VERTEBRATE REMAINS

VERTEBRATE REMAINS

Vertebrate remains were collected periodically during the course of other research efforts and were submitted to Holmes A. Semken, Department of Geology, University of Iowa, for identification. The more nearly complete skeletons were partially exposed to view in the containing sediments. Fragmentary remains were recovered by screening silt deposits and sand-gravel deposits from the floor of the cave or from small potholes inches above normal stream level. In addition, eighty pounds of matrix, taken from four different locations, were collected from mud banks and were taken to the Iowa City laboratory, dried, and wet-screened on 1-32 screen wire. A concentrate containing Late Pleistocene vertebrates was recovered. No specifically diagnostic vertebrate remains were present, but a more intensive effort to isolate bone by this wet screening process might produce a diagnostic fauna. All specimens identified in table 4 were cataloged into the paleontological repository, University of Iowa (SUI) and bear catalog numbers of that institution.

Natrix was partially exposed in a silt bank about four inches above normal stream level in Snake Passage, the first sidepassage on the right, upstream from the entry shaft. Specimens of *Peromyscus* cf. *leucopus* were collected from the top surface of the highest mudbank deposits immediately upstream and downstream from the shaft. The four specimens were nearly articulated when collected and probably represent a different period of time than specimens collected from stream gravels. *Castor canadensis* was buried in a silt bank about 1,000 feet upstream

Table 4

VERTEBRATE REMAINS FROM COLD WATER CAVE

Taxon	Element	SUI	Name
Fish	pectoral spine	38675	------
Amphibia			
Bufo cf. *americanus*	R & L ilium	38676	American toad
Reptilia			
Natrix sp.	partial skull	37351	water snake
snake	vertebra & rib	38677	------
Aves			
Bubo virginianus	R femur	38678	great horned owl
Mammalia			
Scalopus aquaticus	L mandible	38679	eastern mole
bat (not identified)	skull	38680	------
Blarina b. brevicauda	3 L & 1 R mandibles	38681	shorttail shrew
Peromyscus cf. *leucopus*	4 partial skeletons	38682	white footed mouse
Peromyscus sp.	2 L & 1 R mandibles	38683	field mouse
Clethrionomys gapperi	R mandible	38684	redback vole
Pedomys ochrogaster	L mandible	38685	prairie vole
? *Pedomys*	2 R mandibles	38686	vole
Castor canadensis	skull, 2 L mandibles	38687	beaver
Mustela frenata	skull & mandibles	38688	longtail weasel
Mustela sp.	$C\underline{^1}$	38689	? mink
Odocoileus	molar fragment	37352	deer

Identification credits:

Amphibia, Reptilia; L. Carson Davis, Dept. of Geology, SUI
Aves; Paul W. Parmalee, Dept. of Anthropology, University of Tennessee
Fish, Mammalia; Holmes A. Semken, Dept. of Geology, SUI

from the shaft. All other specimens were recovered from channel sand and gravel deposits in potholes on the floor of the cave. Thus, there is no reason to assume that any specimen is contemporary with another.

Representatives of the fauna of Cold Water Cave, except *Clethrionomys gapperi*, the redback vole, presently reside in Winneshiek County. Therefore, a climate similar to that presently in the region is presumed for the Cold Water Cave fauna. Recent specimens of *C. gapperi* are known only from Pilot Knob State Park in Iowa. Fossils of this vole are known from Willard Cave in Delaware County, Rock Run Shelter in Cedar County, and from archaeological sites in Mills County, Iowa. All are radiogenetically dated as younger than 3,500 YBP (years before present) and suggest that *Clethrionomys* was widespread in Iowa within the last 3,500 years.

Sites regarded as Wisconsinan in age are known from Iowa County, Wisconsin, and from Johnson, Audubon, and Mills Counties, Iowa. These faunas have strong boreal components in their micromammal composition. No evidence of this Wisconsinan biota is present in the 24 individuals which comprise the Cold Water Cave vertebrate sample. Consequently, the recorded material best reflects post-glacial deposition of the stream and stream-bank sediments. The highest sediments on rock benches near the ceiling might be Wisconsinan in age.

REPORT ON COLD WATER CAVE

APPENDIX IX

SPELEOTHEMS: DESCRIPTION

RADIOMETRIC DATING

CLIMATIC HISTORY

GROWTH AND DISSOLUTION

SPELEOTHEMS: DESCRIPTION
RADIOMETRIC DATING
CLIMATIC HISTORY
GROWTH AND DISSOLUTION

Description

The "dripstone" formations observed in CWC are composed of calcium carbonate which accumulated slowly over a long period of time. The rate of precipitation of calcium carbonate probably is greatest during the summer and fall. The process is this--when calcium bicarbonate is taken into solution by groundwater, calcium carbonate is deposited and carbon dioxide is released from solution when some of the water that seeps through crevices and fractures is evaporated upon contact with the cave air. The resultant shapes and forms of dripstone are quite varied. "Speleothems" is the collective term for these deposits. The speleothems observed in CWC include:

1. Stalactites: inverted cones that hang from fractures in the ceiling.

2. Soda straws or straw stalactites: hollow tubes with water dripping through the central portion.

3. Stalagmites: upward projecting, broad-topped cones that form when water drips onto a surface above stream level.

4. Columns or stalacto-stalagmites: formed when a stalactite and stalagmite are joined.

5. Draperies or leaf stalactites: more massive speleothems that usually form where water seeps through the ceiling near the cavern wall; an undulating pattern of extended, coalescing stalactites.

6. Bacon rind: slightly wavy sheets of calcium carbonate with alternating light and dark color bands.

7. <u>Helictites</u>: small, twisted forms of calcium carbonate.

8. <u>Flowstone</u>: sheets of calcium carbonate that cover rock surfaces or encrust high mudbank deposits.

9. <u>Rimstone dams</u>: arcuate rims of calcium carbonate that form on flowstone or across the floor of a passage.

Cold Water Cave is well decorated with speleothems. Some areas show concentrations of soda straws and stalactites that hang in lines from criss-crossing fractures in the ceiling. Elsewhere, sheets of flowstone, with scattered stalagmites and an occasional column encrust partially hidden sediments on rock benches. White and brown banded ribbons of translucent bacon rind hang from inverted V-notches in the ceiling, or from sloping wall surfaces near the ceiling. Perhaps the most impressive display of speleothems is in the Gallery. Here, a series of varicolored, massive growths of flowstone extend twenty-two feet from the top of the wall to the cave floor.

Natural breakage of speleothems occurs for several reasons in all caves. Breakage can occur at some point in time because of the accumulated weight, especially if the speleothem is attached weakly to the ceiling or wall. Erosion of the supporting mud sediments will cause the collapse of flowstone crusts and their associated stalagmites. Large blocks of limestone can fall as a result of the additional weight of speleothems. Finally, floods can break off soda straws and stalactites if flood levels approach the ceiling. Although natural breakage is infrequent, a large amount of breakage can occur over a long period of time. Broken speleothems on the floor of the cave were observed at numerous places. In addition, several specimens were found while excavating sediments in the stream bed.

Radiometric Dating

Isotopes (atomic species) of uranium occur in nature and are present in all rocks. Trace amounts of uranium isotopes are removed from limestone and are transported by the dripwater that forms the speleothems. Thus, trace amounts of uranium isotopes are incorporated in the calcium carbonate of the speleothems. These isotopes can be used to date the growth layers in individual speleothems, that is, the time that has elapsed since a particular layer was formed. Stalagmites are particularly suitable for this dating technique because the growth layers can be sampled more readily and because they usually have less detrital material incorporated in them.

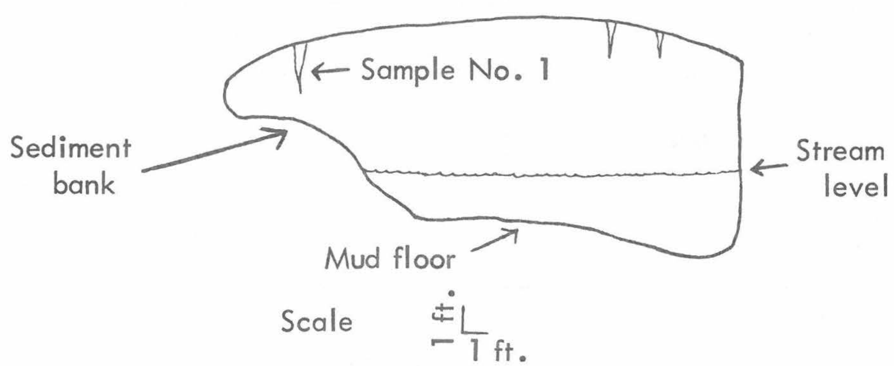
Professor Henry Schwarcz (McMaster University, Hamilton, Ontario) has established dates for speleothem growth in a number of caves, especially in West Virginia. He and a PhD candidate, Mr. Russell Harmon, expressed interest in working with speleothems from CWC. The information that follows is the result of their work.

Initially, two small columns were forwarded to their laboratory. A preliminary analysis of the core of the sample using the Thorium-230/Uranium-234 isotope ratio provided a date of 49,400 years ± 10,900 years B.P. (before present). The high ± value was the result of low Thorium-230 extraction, and could be improved upon by obtaining a larger number of Th^{230} counts. However, the single date obtained stimulated further interest in CWC speleothems. Subsequently six other samples were mailed to McMaster University. These were collected from various stratigraphic positions in the cave (figs. 5-10) that record a series of

Stalactite: length, 23 inches; maximum diameter, $4\frac{1}{2}$ inches; weight, approximately 8 pounds.

Location reference: 2,400 feet upstream from shaft, 6 feet downstream from dome pit on south wall.

Remarks: lower portion of stalactite probably under water during periods of recent flooding.



Cross-section of cave; view is looking upstream

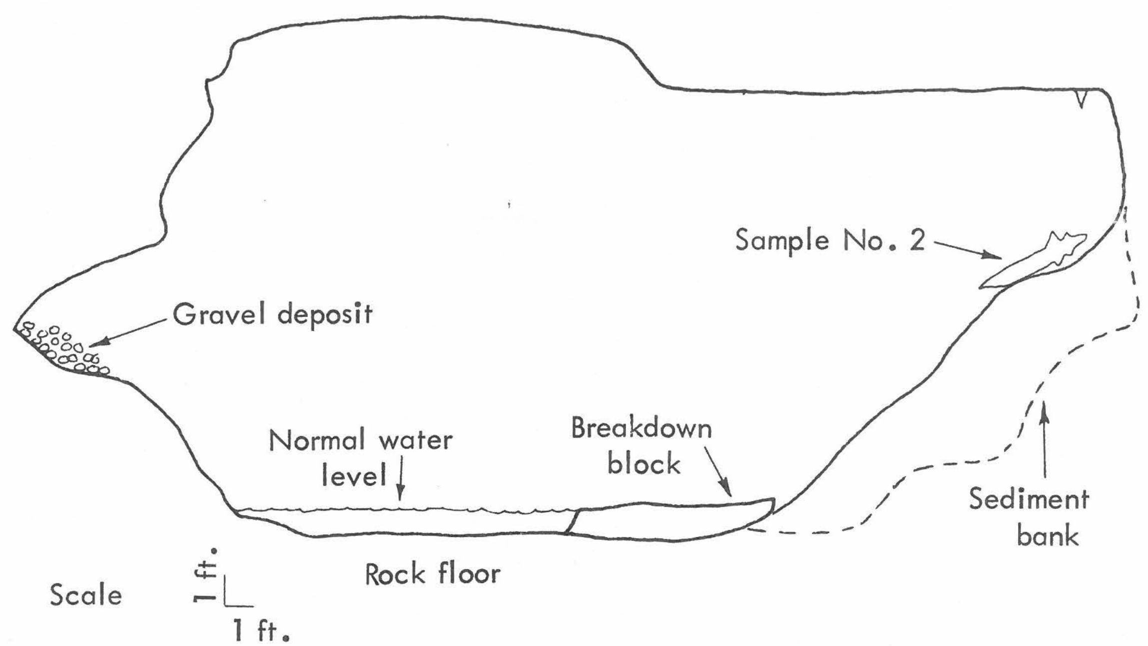
Figure 5. Speleothem Sample No. 1 (collected 8-26-74)

Stalagmite: height, 34 inches; maximum diameter above spreading base, $3\frac{1}{4}$ inches; weight, approximately 25 pounds.

Stratigraphic position: on sediment bank about 4 feet below ceiling; stalagmite had fallen as a result of sapping of sediment from base.

Location reference: 55 feet upstream from station 2 U (470 feet upstream from shaft).

Remarks: basal portion of stalagmite shows alternating laminae of mud sediment-carbonate deposition.



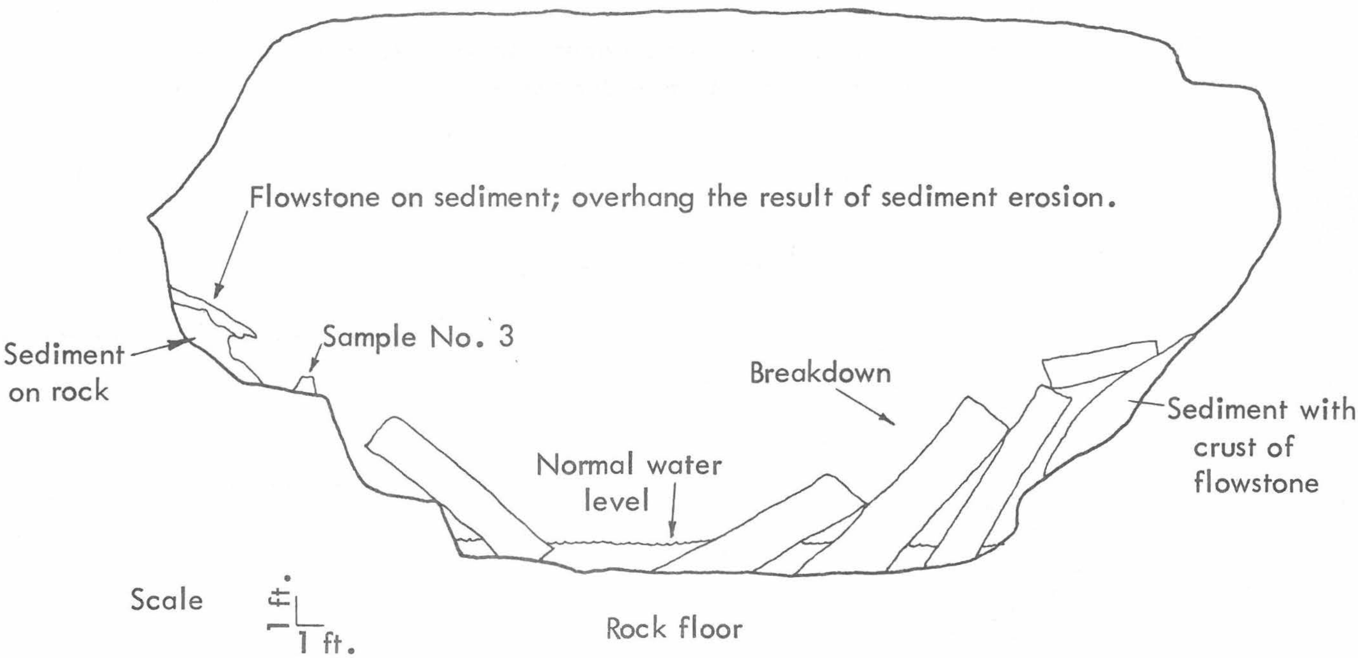
Cross-section of cave; view is looking upstream

Figure 6. Speleothem Sample No. 2 (collected 8-26-74)

Stalagmite: height, 6 inches; maximum width at base, 8 inches; weight, approximately 4 pounds.

Stratigraphic position: on limestone shelf above level of recent flooding.

Location reference: 310 feet upstream from shaft (76 feet upstream from station 1 U).



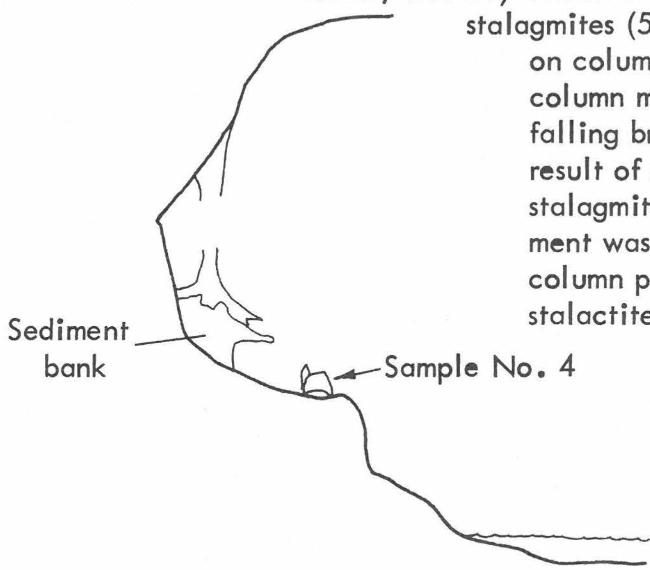
Cross-section of cave; view is looking upstream.

Figure 7. Speleothem Sample No. 3 (collected 8-26-74)

Central portion of column: length, 14 inches; diameter $4\frac{1}{2}$ inches; weight, approximately 25 pounds.

Stratigraphic position: on rock shelf 8 feet downstream from sample No. 3.

Remarks: oriented on rock shelf with long dimension parallel to stream; weakley cemented to rock by dripstone; two small stalagmites ($5\frac{1}{2}$ and $6\frac{1}{2}$ inches high) growing on column on side facing wall of cave; column might have been broken out by falling breakdown, but more likely the result of slumping of broad base of stalagmite when underlying mud sediment was eroded; concavity on side of column probably where adjacent stalactite formerly was in contact.



Cross-section of cave; view is looking upstream.

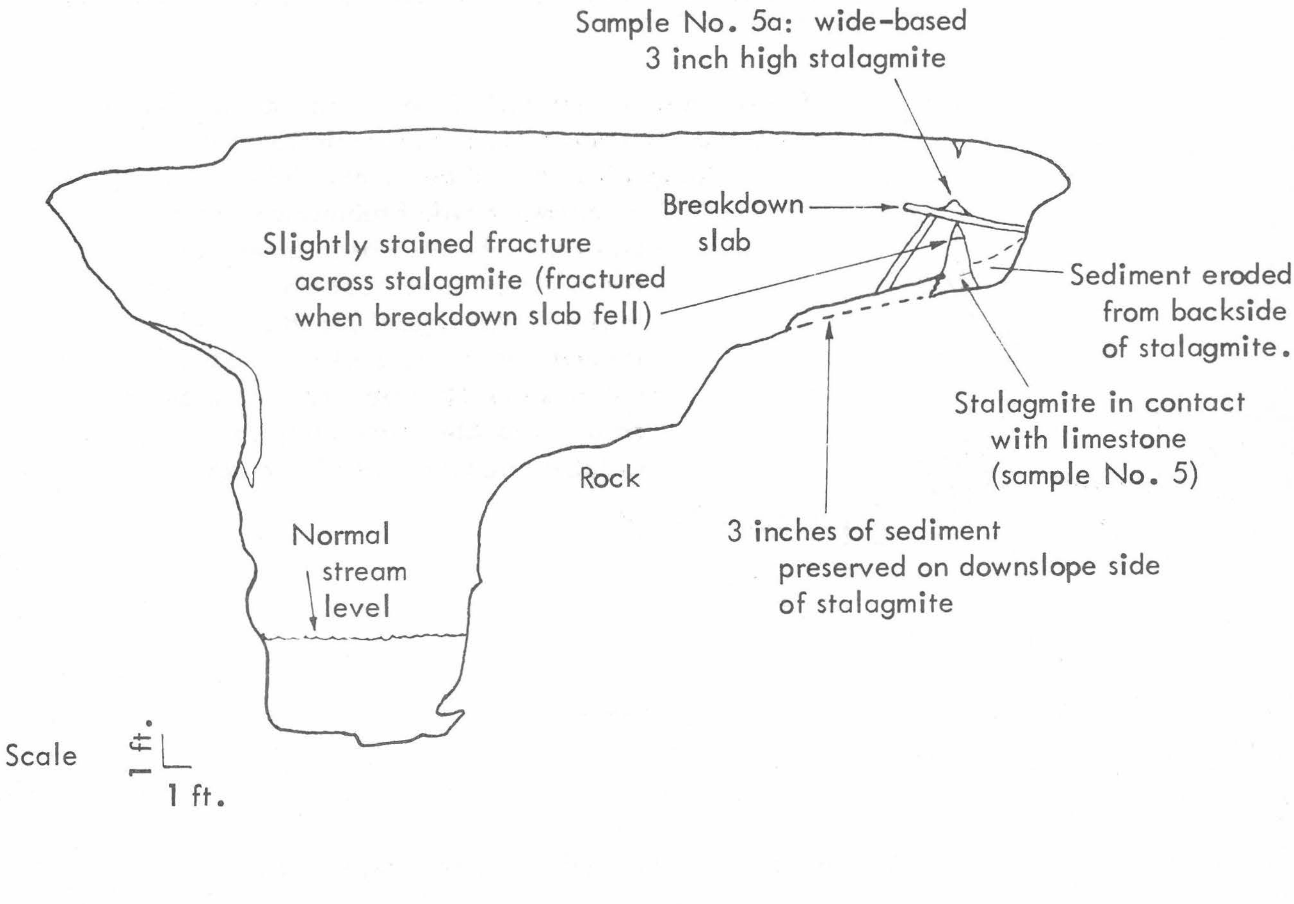
Figure 8. Speleothem Sample No. 4 (collected 8-26-74)

Stalagmite: length, 25 inches; basal diameter, about 9 inches; weight, approximately 75 pounds. (Smaller stalagmite = about 5 pounds).

Stratigraphic position: on high rock bench, about 15 feet above floor of stream.

Location reference: 150 feet downstream from shaft.

Remarks: good chronologic sequence of stalagmite growth, breakdown slab covering stalagmite, and new growth of stalagmite on breakdown slab (uppermost stalagmite apparently was still growing).



Cross-section of cave; view is looking downstream

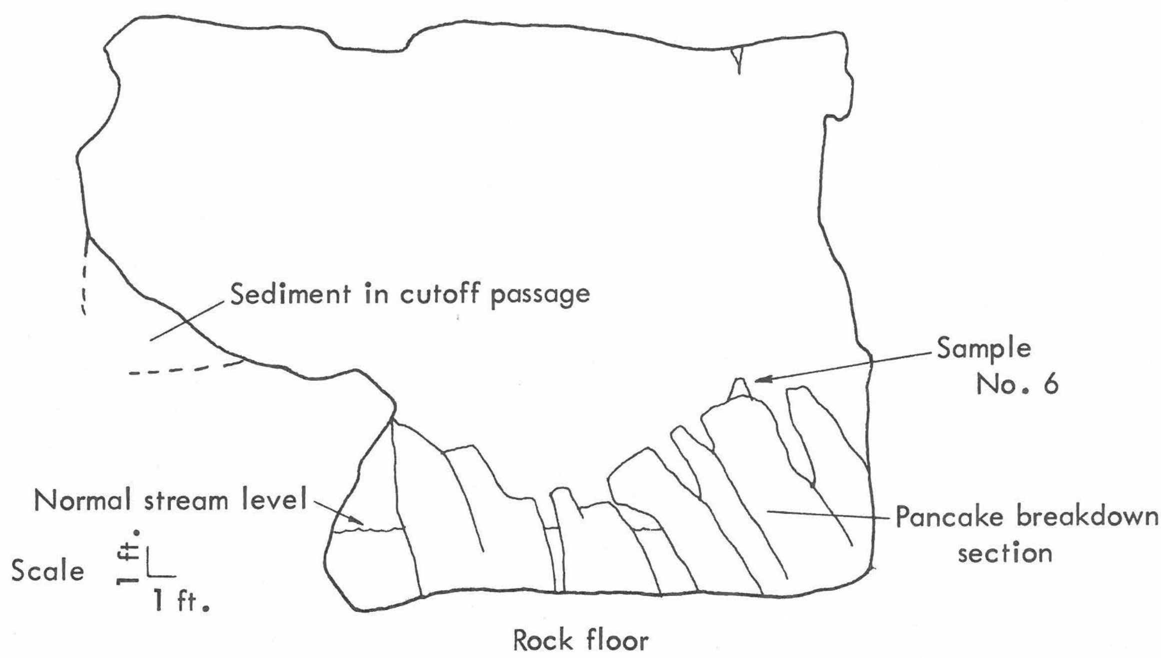
Figure 9. Speleothem Sample No. 5, 5a (collected 8-27-74)

Stalagmite: height, $7\frac{1}{4}$ inches; maximum base, $6\frac{1}{2}$ inches; weight, about 5 pounds.

Stratigraphic position: on breakdown slab.

Location reference: at "pancake" breakdown section across stream, 2,310 feet downstream from shaft.

Remarks: sample is in two pieces; sample was broken perpendicular to growth direction while removing from breakdown slab.



Cross-section of cave; view is looking downstream

Figure 10. Speleothem Sample No. 10 (collected 8-27-74)

chronologic events. Hopefully, the samples would provide significant information on at least Late Pleistocene chronology and climatology.

The age determinations obtained to date are listed in table 5 . Field sample number six provided the oldest date (80,000 years B.P.). According to Dr. Schwarcz, the likelihood is low that the oldest speleothem will be collected during random sampling. The ages obtained from CWC speleothems are stratigraphically correct, that is, a deposit which is known to be younger than another provides a younger age (table 5; field numbers 5--5a, fig. 9). If no speleothem is older than 80,000 years, CWC is a relatively young cave system. The oldest age is just into the last interglacial and it is likely that the cave is no more than 200,000 years old, and probably younger.

Climatic History

The CWC speleothems also provide a means of estimating former temperatures (paleotemperature). Here, as with age dating, isotopic geochemistry is used ($Oxygen^{18}$ / $Oxygen^{16}$ ratios). The results of analyses show that the ages and stable isotope behavior are internally consistant for samples on which more than one age was determined (fig. 11). Stable isotope (O^{18}) profiles for three samples analyzed are comparable and consistent with other oxygen isotope profiles for the period 5,000-80,000 years B.P. The O^{18} profiles for these three samples show that the speleothems were deposited in isotopic equilibrium, and analysis of drip-waters entering the cave fall on the well established meteoric water line (fig. 12). This indicates there is no process of isotopic fractionation that would place the results in question.

Table 5

AGES OF COLD WATER CAVE SPELEOTHEMS

Lab #	Field #	Dist. Above Base (cm)	U Conc. (ppm)	$[\frac{Th^{230}}{U^{234}}]$	$[\frac{U^{234}}{U^{238}}]$	$[\frac{U^{234}}{U^{238}}]_o$	$[\frac{Th^{230}}{Th^{232}}]$	Age (Years B.P)
74014:12	2	84	3.76	.050 ± .009	1.31 ± .02	1.32 ± .02	1,000	5,600 ± 1,000
74014:11	2	17	4.89	.176 ± .013	1.16 ± .01	1.17 ± .02	48	21,100 ± 1,700
74015:4	3	12.6	3.02	.171 ± .020	1.31 ± .12	1.33 ± .13	12	20,000 ± 2,500
74015:7	3	1.0	1.05	.280 ± .039	2.42 ± .35	2.58 ± .44	50	34,400 ± 5,500
74016:7	4	0.5	3.34	.087 ± .008	1.06 ± .02	1.06 ± .02	49	9,800 ± 1,000
74017:1	5	63.0	7.85	.098 ± .007	1.18 ± .09	1.18 ± .09	29	11,100 ± 900
74017:	5	2.0						40,500 ± 1,600
74018:3	5a	10.0	0.69	.054 ± .008	1.37 ± .02	1.38 ± .02	1,000	6,000 ± 900
74019:7	6	18.5	0.25	.087 ± 0.14	1.691± .04	1.71 ± .05	1,000	9,800 ± 1,600
74019:8	6	11.3	1.60	.170 ± .010	1.71 ± .03	1.77 ± .04	28	20,000 ± 1,300
74019:9	6	1.0	0.51	.550 ± .010	1.74 ± .03	1.92 ± .04	60	80,000 ± 2,100

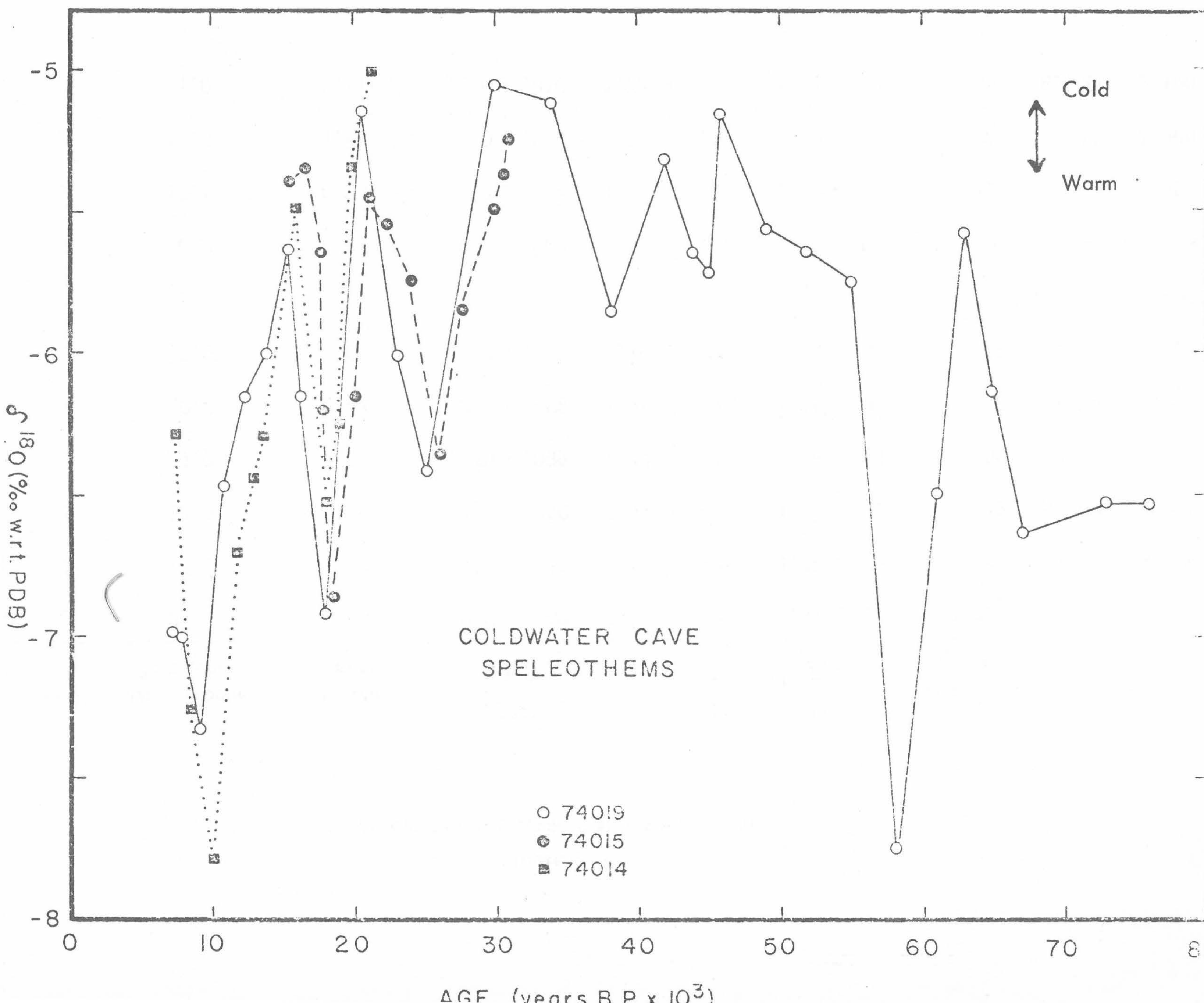


Figure 11. Temperature fluctuations through time.

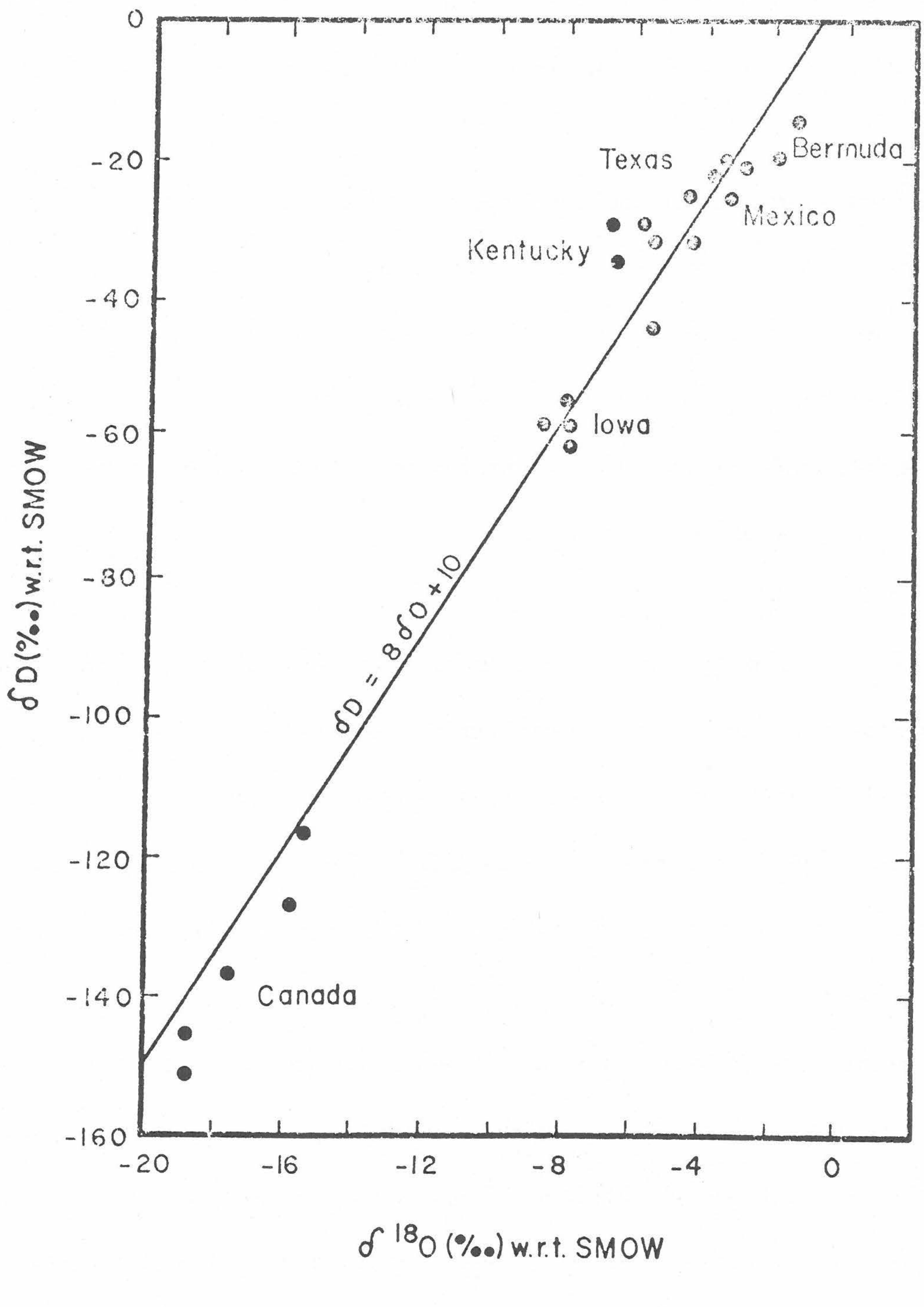


Figure 12. Meteoric water line.

Later analysis of soda straws and their associated dripwater will permit a temperature interpretation of the oxygen isotope data. Analysis of fluid inclusions in the calcium carbonate of the speleothems will provide additional temperature data.

Final information on additional age determinations, O^{18} profiles and fluid inclusion analyses is forthcoming. Any publication(s) by Mssrs. Schwarcz and Harmon will include acknowledgment to the Iowa Geological Survey. Their interest is spurred by the fact that the CWC speleothems are providing extremely valuable data on the chronology and climatology of the Late Pleistocene. The quality of this data seldom is attained.

Growth and Dissolution

The rate of precipitation or dissolution of calcium carbonate in any environment is dependent upon a critical relationship between several parameters. In a cavern environment the parameters include temperature, acidity or alkalinity (pH), and the partial pressure of carbon dioxide (CO_2). Both precipitation and dissolution of calcium carbonate occur on speleothems in CWC, possibly simultaneously at different locations.

A hole was drilled into the base of several stalactities at different locations in the cave and gold tubes were inserted to monitor any accretion of calcium carbonate. Stalactites were selected that showed different rates of dripping water. A thin film of calcium carbonate developed on the upper portion of the gold tubes inserted in fast-dripping stalactites within about five months. The film extended only about one-quarter inch and continued to grow thicker throughout the period of observation.

Calcium carbonate accreted more slowly on stalactites with moderate to slow drip rates and in some cases no accretion was apparent.

Speleothems are undergoing dissolution in some areas of the cave. Minor dissolution was observed on flowstone along the walls, but only at a few locations. Major dissolution was observed on flowstone beneath some dome pits (chimneys formed by solution of limestone). Corrosive waters are etching the flowstone and the layered structure of the flowstone is exposed on edges.

REPORT ON COLD WATER CAVE

APPENDIX X

RECOMMENDATIONS OF CONSULTANTS

RECOMMENDATIONS OF CONSULTANTS

Introduction

The charge to Dr. Samuel J. Tuthill and to Mr. Fred A. Priewert by Governor Ray in February, 1970 was to do those things necessary to advise the Governor and the General Assembly as to the merits of acquiring the property of Cold Water Cave for (1) a recreational facility and/or (2) a scientific preserve. Documentary information presented in preceding sections of this report relates principally to item (2) above and was derived by utilizing the particular expertise of personnel from universities, colleges, the U. S. Forest Service and the Iowa Geological Survey. The attributes of CWC for development as a recreational-educational facility relate to a more subjective process. That is, what parameters should be considered to arrive at a judicious decision? Is the size of the cavern system significant? Are the speleothems spectacular? Will people visit CWC in sufficient numbers to justify large expenditures for development? Would a private developer invest in CWC if the State of Iowa has no further interest? Because these questions can be answered better by individuals involved in the commerical development of caves, the IGS contracted three such people to visit CWC and present their conclusions. Besides operating their own caves, they are familiar with the most successful of the approximately 200 commercial caves in the United States. These people were shown only that portion of CWC beneath the Kenneth Flatland property. Their opinion is that CWC can and should be developed as a recreational-educational facility. Summary statements and recommendations from their reports follow.

RECOMMENDATIONS OF CONSULTANTS

1. Mr. Jack Burch, commercial cave consultant: Caverns of Sonora, Sonora, Texas.

The cave should be acquisitioned in its known entirety because:

1. It is unique to the area, and probably no cave within 200 miles could match it.
2. It is large for the latitude, both in size of the main passageway and in length of the cavern system.
3. Speleothems are active and well preserved.
4. It would be a valuable asset as a recreational site; a trip into a natural cave is an educational experience.

2. Mr. Roy Davis, commercial cave consultant: Cumberland Caverns, McMinnville, Tennessee.

Cold Water Cave ranks high with most of the commercial caves of the United States, far surpassing many. The series of siphons at the natural entrance has protected the cave from vandalism, exploitation and deterioration. Such a superb cave presents a rare opportunity for man to advance his understanding of the underground environment. Development of CWC by the State for public viewing as a recreational-educational facility is an ideal way to ensure protection of this unique environment. Whatever threat is posed to the cave environment by artificial entrances or lighting, abandonment of the cave to vandals or misinformed, under-capitalized private ventures is a far greater threat.

3. Mr. Jack Herschend: Silver Dollar Cave, Missouri.

The businessman's standard measurement of potential return on investment is inappropriate to evaluate the potential of CWC as a recreational facility to be developed by the State. A "yardstick" based upon dollar investment per annual visitor can be used to compare CWC with three broad categories of successful commercial caves.

The first category includes caves which are distant from high population centers, but because of their large size and beauty, people travel many miles out of their way to visit them. Examples are Carlsbad Caverns in New Mexico and Blanchard Springs Caverns in Arkansas. Capital investment for caves in this category approximates $60.00 per annual visitor. Although CWC has great beauty, its relatively small size would not justify an investment of $60.00 per annual visitor.

The second category of successful caves includes those located near high population centers or located along high traffic arteries. Examples in this category are Meramec Caverns in Missouri and Inner Space Caverns in Texas. These caves seem to be successful whether or not they possess intrinsic value. Private developers generally invest from $5.00 to $10.00 per annual visitor. The location of CWC with respect to population centers is average. Although no major traffic artery is nearby, there are approximately one million people living within a hundred miles. If we consider CWC within this category of successful caves, approximately 20,000 school children and 30,000 vacation and weekend visitors might visit the cave. Using our "yardstick" of $5.00 to $10.00 per annual visitor, a prudent investment would be $250,000 to $500,000.

The third category of successful caves includes those located within a vacation-recreation complex. Examples are Marvel Cave in Missouri and Cave of the Mounds in Wisconsin. Here again, the investment per annual visitor is $5.00 to $10.00.

The location of CWC with respect to a vacation-recreation complex would be rated below average at the present time. However, the ingredients for a tourist recreation area certainly are present in northeast Iowa. If the State or a private enterprise would develop a recreation complex with CWC as one of several attractions, approximately 100,000 visitors per year might be expected. Again, using our "yardstick," a prudent investment would be $500,000 to $1,000,000 for land acquisition and cave development.

In summary, CWC could be developed in a modest way to serve approximately 50,000 visitors annually, or on a larger scale as part of a recreation complex. In the first approach, a maximum investment of $500,000 could be justified. In the second approach, a maximum investment of $1,000,000 could be justified.

REPORT ON COLD WATER CAVE

APPENDIX XI

ESTIMATED VISITOR ATTENDANCE

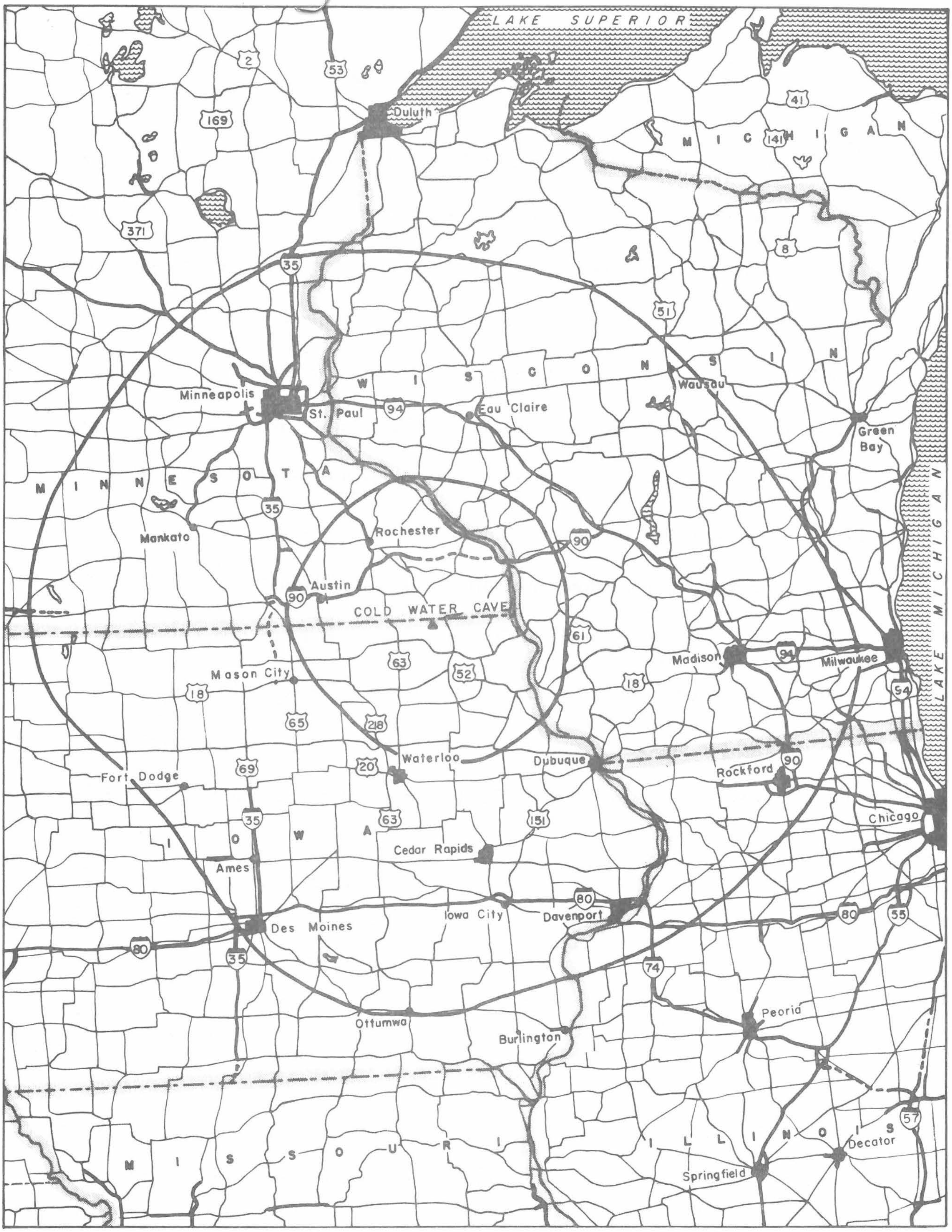
ESTIMATED VISITOR ATTENDANCE

The straight line demand projections of estimated visitor attendance are presented in this section. An analysis of estimated visitor attendance is desirable in order to compare the potential use of a cavern recreational facility with the cost of development. The projections are based upon participation rates and population growth. Participation rates were obtained from the U.S. Outdoor Recreation Resources Review Commission (ORRRC Study Reports No. 19 and 20, 1962). The analysis format was derived from A Feasibility Study--Blanchard Springs Cavern, Manes and Assoc., Inc., Little Rock, Ark.

Two major service areas are defined for Cold Water Cave (fig. 13). The primary service area is located within approximately one and one-half hours driving time (about 75 miles) of Cold Water Cave. The secondary service area is located within approximately one and one-half to four hours driving time (about 75-200 miles) of the cave. The 1970 populations for each area are presented below:

	1970 Population Primary Service Area	1970 Population Secondary Service Area
Iowa	169,240	1,850,841
Minnesota	261,029	2,415,527
Wisconsin	110,896	1,792,863
Illinois	0	696,013

Projected population figures for 1975 are used in this study, and visitation estimates are made to the year 1990. Percentage increase in population figures



Inside Circle 75 Highway Miles from Cold Water Cave

Outer Circle 200 Highway Miles from Cold Water Cave

Figure 13. Primary (75 miles) and secondary (200 miles) service areas.

were obtained from Population Estimates and Projections, U. S. Dept. of Commerce Series P-25, No. 477. Projected populations for the primary (P) and secondary (S) service areas are listed below:

		1975	1980	1985	1990
Iowa	(P)	171,440	174,148	177,533	180,409
	(S)	1,874,901	1,904,575	1,941,532	1,972,996
Minnesota	(P)	275,646	291,308	307,492	332,631
	(S)	2,550,797	2,695,728	2,845,490	2,985,591
Wisconsin	(P)	117,217	123,760	130,746	137,178
	(S)	1,895,056	2,000,835	2,113,785	2,217,771
Illinois	(P)	0	0	0	0
	(S)	730,118	767,702	806,679	842,871

Total service area population is not used in determining final attendance figures. Instead, percentages of the population are used to derive an estimated effective population. Percentages used for Iowa are 80 percent of the primary service area and 9.5 percent of the secondary service area. In the Blanchard Springs study, it was shown that for every 100 visitors, 60 are from in-state and 40 are out-of-state. That is, one-third again as many visitors resided in-state. In keeping with this ratio, the service area populations for states outside of Iowa are reduced 47 percent and 93.7 percent respectively, for primary and secondary effective populations. Estimated effective populations for 1975 are listed below:

Effective Populations--1975

	Primary	Secondary
Iowa	137,157	178,115
Minnesota	146,092	160,700
Wisconsin	62,125	119,388
Illinois	0	45,997

Participation rates for various recreational activities and localities have been established by both the ORRRC and the Iowa Conservation Commission (ICC). Cave tours are classified as a sight-seeing activity. The ORRRC sight-seeing rate for the north-central region of the United States is 6.64 times annually per person. The ICC sight-seeing rate is 3.8 times annually per person for Iowa. In using the ORRRC figure, it is assumed that the 6.64 rate is applicable to a 200-mile radius of Cold Water Cave. In using the ICC figure, it is assumed that the 3.8 rate for Iowa also can be applied to the portions of Minnesota, Wisconsin, and Illinois that are within that radius. Consequently, two sets of data can be generated, with a resultant high-low range of visitation estimates.

An estimate of gross effective demand in terms of activity occasions is obtained by multiplying the estimated effective population by the ORRRC and ICC participation rates. Figures for gross effective demand are listed below:

Gross Effective Demand
Activity Occasions

	ORRRC Yearly--1975		ICC Yearly--1975	
	Primary	Secondary	Primary	Secondary
Iowa	910,690	1,182,683	520,914	676,494
Minnesota	970,050	1,067,048	554,868	610,351
Wisconsin	412,510	792,736	235,955	453,444
Illinois	0	305,420	0	174,700

Another figure, the net effective demand, is calculated by subtracting the demand that is satisfied by existing facilities from the gross effective demand. When, as in this case, it is difficult to quantify the existing supply of facilities for sight-seeing activities, the gross effective demand equals the net effective demand.

An estimate of the percentage of the net effective demand that might be expected to be drawn to a new recreational facility was used in the Blanchard Springs study. The percentage estimate used for sight-seeing was 10 percent. The same percentage was applied to the figures for Cold Water Cave. The units derived from multiplying the net effective demand by the percentage draw are activity occasions. Calculated activity occasions are listed below:

Expected Draw
Activity Occasions

	ORRRC Yearly--1975		ICC Yearly--1975	
	Primary	Secondary	Primary	Secondary
Iowa	91,069	118,268	52,091	67,649
Minnesota	97,005	106,705	55,486	61,035
Wisconsin	41,251	79,274	23,595	45,344
Illinois	0	30,542	0	17,470

The units of measurement have been activity occasions. A single visitor to an area might participate in more than one recreational activity. Therefore, a single visit might generate two, three, or more activity occasions. In order to derive an estimate for the number of visitors to Cold Water Cave, a visitor participation factor must be applied to the estimated activity occasions. A visitor participation factor of 2.33, used in the Blanchard Springs study, can be applied to Cold Water Cave. An estimate of the number of visitors is obtained when expected draw is divided by the 2.33 factor. The range of estimated visitors for 1975 is shown on the following page, along with visitation projections to 1990.

Estimated Number of Visitors
Cold Water Cave

	ORRRC Yearly--1975		ICC Yearly--1975	
	Primary	Secondary	Primary	Secondary
Iowa	39,085	50,759	22,356	29,033
Minnesota	41,633	45,796	23,813	26,195
Wisconsin	17,704	34,023	10,126	19,460
Illinois	0	13,108	0	7,497
	98,422	143,686	56,295	82,185

Total -	1975	242,108 (high estimate)	138,480 (low estimate)
	1980	249,000	142,000
	1985	263,000	150,000
	1990	273,000	156,000

The 1975 annual visitation estimate ranges from approximately 138,000 to 242,000. These figures compare well with actual attendance figures at various state parks in Iowa (fig. 14), especially those parks located within the primary service area for Cold Water Cave. The 1972 attendance at Pikes Peak was 201,429. The larger attendance at Backbone State Park (413,433) is indicative of greater use that results when more recreational activities are available. Visitation figures for Cold Water Cave might increase significantly if adequate facilities are available that would attract campers, fishermen and hunters in addition to sight-seers.

A. A. Call	76,600	Lewis and Clark	223,960
Backbone	413,433	Maquoketa Caves	139,155
Beeds Lake	127,340	Margo Frankel	165,925
Bellevue	111,140	McIntosh Woods	270,665
Black Hawk	297,970	Mill Creek	20,284
Bob White	20,175	Mini-Wakan	13,945
Clear Lake	324,360	Nine Eagles	86,012
Dolliver	134,025	Palisades-Kepler	199,364
Elk Rock	45,850	Pammel	55,661
Ft. Defiance	119,395	Pikes Peak	201,429
Galland School	200	Pikes Point	56,232
Geode	597,570	Pilot Knob	98,725
George Wyth	187,695	Pine Lake	358,040
Green Valley	224,030	Plum Grove	4,474
Gull Point	106,115	Prairie Rose	152,765
Heery Woods	67,000	Red Haw	193,800
Honey Creek	228,830	Rock Creek	639,645
Lacey-Keosauqua	250,965	Springbrook	157,787
Lake Ahquabi	345,837	Stone Park	253,395
Lake Anita	203,190	Twin Lakes	32,390
Lake Darling	333,320	Union Grove	146,332
Lake Keomah	165,912	Viking Lake	190,411
Lake Macbride	1,079,483	Volga River	78,500
Lake Manawa	315,600	Walnut Woods	322,836
Lake of Three Fires	212,970	Wapsipinicon	428,200
Lake Wapello	269,255	Waubonsie	115,992
Ledges	484,961	Wild Cat Den	94,407

GRAND TOTAL ATTENDANCE - ALL PARKS - 11,443,552

Figure 14. Iowa state parks--1972 attendance.

REPORT ON COLD WATER CAVE

APPENDIX XII

ESTIMATED DEVELOPMENT COSTS

ESTIMATED DEVELOPMENT COSTS

Introduction

Development of Cold Water Cave as a recreational facility by the State of Iowa could ensure an operational program that would protect and preserve the ecosystem of the cavern. Any development proposal must include consideration of both the cost of underground construction and construction costs for surface facilities, such as an information center, campsite, and parking facilities. An estimate of the cost for surface facilities is presented first in this section of the report (table 6), followed by a discussion of underground construction costs. A summary of total cost estimates which includes both surface and underground construction costs is shown on the last page of this section (table 8).

I. Preliminary Estimated Development Cost--Surface Facilities

Source

Cost figures in table 6 were prepared by the Engineering Section, Iowa Conservation Commission, December 1974.

Table 6

Land acquisition 100 acres @ $1,000	$100,000 *
Information center	60,000
Water supply system	40,000
Sewage disposal system	30,000
Camp sites 30 @ $4,000	120,000
Bathhouse	40,000
Parking lot 30,000 sq. ft. @ $2.00	60,000
Roads 1 mile	80,000
Subtotal	$530,000
Engineering and overhead 20%	$106,000
Total estimated development costs	$636,000

*Land acquisition for surface facilities only.

II. Preliminary Estimated Development Cost--Underground Construction

Information Sources

The cost estimate for underground construction was derived after consultation with operators of several commercial caves and after visiting selected commercial caves. The principal objective was to compare the different entry-exit systems, types of walkway construction, and lighting techniques, and to select from these a construction program that is best suited to the unique characteristics of Cold Water Cave. Information was obtained from the following sources:

1. Blanchard Springs Cavern, United States Forest Service, Mountain View, Arkansas; Mr. Donald E. Williams
2. Marvel Cave, Silver Dollar City, Missouri; Mr. Jack Herschend.
3. Cumberland Caverns Park, McMinnville, Tennessee; Mr. Roy Davis
4. Caverns of Sonora, Sonora, Texas; Mr. Jack Burch
5. Onandaga Cave, Leasburg, Missouri

Entry-Exit System

The major cost will involve construction of an entry-exit system. Because the portion of the cave that is most suitable for development is located about two and one-half miles upstream from the natural spring entrance, access to the cave will require construction of a vertical shaft(s) with an elevator and/or staircase. The several options are:

1. A shaft with a spiral staircase for both entry and exit.
2. A shaft with an elevator and manway (emergency exit) for both entry and exit.

3. A shaft with a spiral staircase for entry, and a second shaft with an elevator for exit at the end of the tour.

4. A shaft with an elevator and manway (emergency exit) for entry, and a second shaft with an elevator for exit at the end of the tour.

Construction of a single shaft for both entry and exit would seriously limit the number of people that could be accommodated, especially during the heaviest tourism period. In addition, lights in the cave would have to be on during all operating hours. If separate shafts are constructed for entry and exit, there would be no necessity for retracing the tour path, and lights could be turned off to minimize algal growth as tour groups pass different segments of the tour.

The shaft(s) should be offset about fifty feet from the cave so that a tunnel(s) can be excavated between the bottom of the shaft(s) and the cave opening. This will permit construction of an airlock system to minimize exchange of large volumes of air between the cave and the surface atmosphere. Cost estimates for shaft options 1-4 and tunnel construction are shown in table 7.

Table 7

Cost Estimates for Shaft and Tunnel Construction

Option 1: 100-foot shaft with staircase to be used for entry and exit.

Excavation and lining	$ 60,000
Stairway construction:	
Aluminum beams	9,000
Aluminum plate	9,000
Concrete forms	1,000
Concrete	1,500
Tunnel	27,000
	$107,500

Option 2: 100-foot shaft with elevator and emergency manway for entry and exit.

Excavation and lining	$ 60,000
Elevator (15 capacity)	75,000
Manway	20,000
Tunnel	27,000
	$182,000

Option 3: 100-foot shaft with staircase for entry, and a second 120-foot shaft with an elevator for exit at end of tour.

	Entry Shaft	Exit Shaft
Excavation and lining	$ 60,000	$ 72,000
Stairway construction:		
Aluminum beams	9,000	------
Aluminum plate	9,000	------
Concrete forms	1,000	------
Concrete	1,500	------
Elevator	------	75,000
Manway	------	24,000
Tunnel	27,000	27,000
	$107,500	$198,000

Combined cost: $305,500

Option 4: 100-foot shaft with elevator and manway for entry, and a 120-foot shaft with elevator and manway for exit at end of tour.

	Entry Shaft	Exit Shaft
Excavation and lining	$ 60,000	$ 72,000
Elevator	75,000	75,000
Manway	20,000	24,000
Tunnel	27,000	27,000

Combined cost: $380,000

Tour Walkway

Because the stream in the cave is subject to flooding during periods of high surface runoff, a tour walkway must be constructed above flood level. The maximum flood stage observed during the study was three feet above normal stream level. The walkway must be constructed above this level. Most of the walkway should be cantilevered from the cavern walls. This construction will hide most of the structural supports from view and will maintain a more natural setting. Vertical supports can be used for some segments of the walkway where construction is on rock benches or where cantilevered construction is less practical. The walkway should be constructed with concrete laid upon an aluminum plate and surfaced with aluminum-oxide grit to prevent slipping. Aluminum handrails should be used. A sketch of walkway construction is shown in figure 15, and a cross-sectional diagram with estimated walkway construction-equipment costs is shown in figure 16.

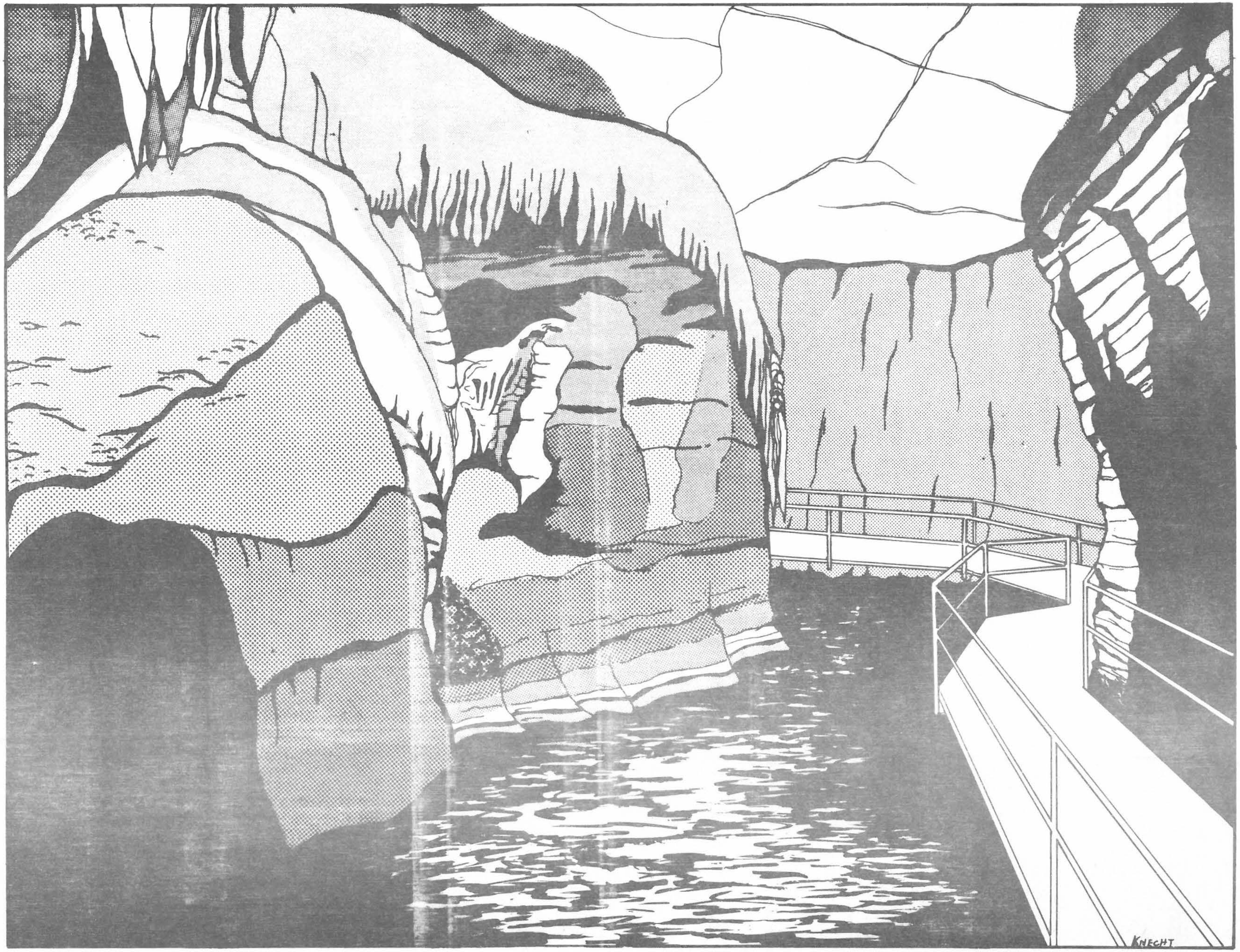


Figure 15. View of Proposed Walkway

WALKWAY MATERIALS COSTS

Material	Cost
Hand Rail	$ 9,000.
Aluminum Oxide Grit	2,500.
Concrete (60 cu. yds.)	1,700.
Aluminum Plate (1/2" x 4' x 2400')	53,100.
300 Aluminum Beams (8" x 6.38" x 6')	11,700.
Epoxy	1 240.
Subtotal 1	$79,240.
Equipment	
Stoper Drill	$ 5,000.
Air Compresser	3,000.
Scaffolding	300.
2 Cement Trail Buggies	3,000.
Subtotal 2	$11,300.
TOTAL WALKWAY–EQUIPMENT COST	$ 90,540.

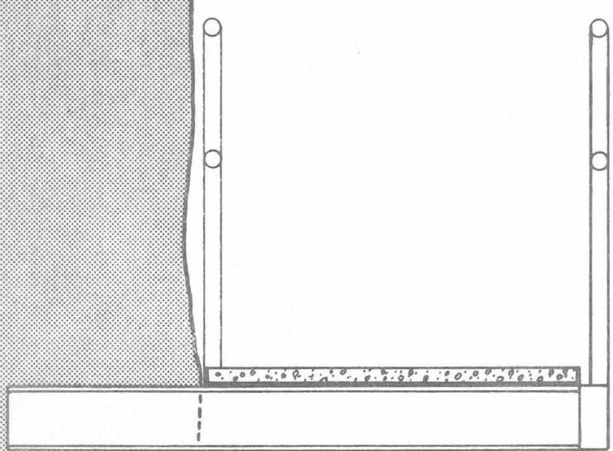


Figure 16. Cross-section of walkway; estimated construction-equipment costs.

Lighting

Proper lighting of the cave is critical. Lighting must be placed to most effectively show the natural beauty of the cave and to prevent or minimize the growth of algae on the rock walls and on dripstone formations. An adequate number of transformers and remote panels are required. Experience in the operation of Blanchard Springs Cavern has demonstrated that stainless steel fixtures are the most practical light fixtures to use. Electrical wiring should consist of aluminum wire encased in PVC (polyvinyl chloride) and should be hidden from view wherever possible. The primary wire can be placed beneath the walkway, and secondary lines can be camouflaged. Estimated lighting costs are listed below:

Estimated Lighting Costs

Transformers	$12,000
Remote panels	8,000
Light fixtures	10,000
Electric wire	22,000
Switches, light shields	13,000
	$65,000

III. Total Estimated Development Costs for Surface and Underground Construction

Development costs for surface and underground construction are presented in table 8. Costs for a lighting consultant and installation of an emergency generator are not included.

Table 8

Estimated Development Costs for Surface and Underground Construction

	Option 1	Option 2	Option 3	Option 4
Surface facilities	$ 530,000	$ 530,000	$ 530,000	$ 530,000
Entry-exit system	107,500	182,000	305,500	380,000
Walkway	90,540	90,540	90,540	90,540
Lighting	65,000	65,000	65,000	65,000
Subtotal	$ 793,040	$ 867,540	$ 991,040	$1,065,540
Engineering and overhead 20%	158,608	173,508	198,208	213,108
Labor	50,000	45,000	75,000	60,000
Total*	$1,001,648	$1,086,048	$1,264,248	$1,338,648

*Totals include land acquisition for surface facilities only; land costs for control of the complete cavern system are not included.

REPORT ON COLD WATER CAVE

APPENDIX XIII

MISCELLANEOUS ITEMS: GEOLOGIC-HYDROLOGIC SETTING

GRAVITY STUDY

PALYNOLOGY

COATINGS

PUBLICITY

TOTAL EXPENDITURES

MISCELLANEOUS ITEMS

Geologic-Hydrologic Setting

Cold Water Cave is formed within the Galena limestone (Ordovician System) which was deposited in shallow seas that covered the region about 450 million years ago. Prior to and/or during the various glacial and interglacial stages, a "karst topography" has developed that is characterized by caves, underground drainage, and sinkholes (closed depressions in the ground). Dissolution and mechanical abrasion of the Galena limestone is aided by the relatively steep gradient of the stream in CWC. The stream gradient is about 15 feet per mile compared to about seven feet per mile for the Upper Iowa River.

Gravity Study

Dr. Richard Kellogg, Luther College used the gravimetric technique of geophysical investigation in an attempt to define the location and depth of the cave. A LaCoste-Romberg geodetic gravity meter was used to obtain gravity data. Successful application of this technique could permit mapping of other segments of the main passage and perhaps some of the larger side passages from the land surface.

Gravity profiles were obtained along five north-south traverse lines and one east-west traverse line in the vicinity of the shaft site. Although extremely minor gravity anomalies were recorded, the spatial relationships of the known position and depth of the cave did not coincide with the interpretation of the gravity data. Apparently, the cross-section dimensions of the cave are too small to yield a gravity anomaly that is significantly different from background noise.

Palynology

Palynology is the study of pollen and spores and their dispersal. Pollen grains are useful microfossils, for they represent assemblages of plants that existed in the vicinity of the deposit at the time of deposition. Pollen recovered from CWC sediments might provide information on past plant assemblages that lived in the upland area over the cave. Also, qualitative inferences might be made about former climates.

Fine-grained sediments in CWC occur along the banks of the stream and on high rock benches above flood level. Core and trench samples were recovered and were forwarded to Dr. Leslie A. Sirkin (Department of Earth Science, Adelphi University) for extraction and identification of spores and pollen grains. The assemblage recovered and the number of specimens of one species were too meager to develop a pollen profile. Species of pine, cedar, spruce, alder, birch and maple were recovered. No oak pollen was recovered, even though oak is a dominant species in the region today. As with the invertebrate fauna, it might be possible to recover a more meaningful assemblage, but this would require processing a very large volume of sediments, or the fortunate discovery of a site that is unusually rich in organic remains.

Coatings

Large surface areas of the cavern walls are covered with a grayish-black coating or encrustration. This coating also occurs on many speleothems, on the surfaces of pebbles in gravel deposits and, locally, on the surface of some fine-grained sediment deposits. Samples of this coating were subjected to X-ray analysis by Mr. Erick Opstad (Geology Department, University of Iowa), and were identified as an amorphous (noncrystalline) substance composed of mixed organic material and iron-manganese oxides.

Publicity

Cold Water Cave has generated a great amount of enthusiastic interest from the public. On 23 January 1973 a television-press team was conducted on an eight-hour tour of the cave. A documented account of their experience was presented on most Iowa television stations and in nearly all weekly and daily newspapers. Later, a one-half hour special program on the discovery and exploration of CWC was presented on television. Local radio stations and newspapers continue to request an updating on research projects and ask when the public might be able to visit the cave.

In addition to the several public presentations on CWC by members of the Iowa Grotto, National Speleological Society, more than twenty presentations were given by IGS personnel. Groups that requested these presentations primarily include schools and civic organizations. Color slides and a 16mm colored film were used in the presentations. A set of 24 color slides with an accompanying description sheet is available from IGS at a cost of $7.00.

An article entitled Cold Water Cave--Beauty, Origin, Research was published in the December, 1973 winter issue of The Iowan.

Total Expenditures

The list of expenditures on CWC (table 9) is exclusive of wages for IGS personnel who worked on the project. The mobile home and laboratory trailer will be utilized elsewhere by the Iowa Conservation Commission. Much

Table 9

Construction, Equipment and Operating Costs
Cold Water Cave

	1971-72	1972-73	1973-74	1974-75	Totals 1971-75
Land lease	$2,000.00	$ 1,500.00	$1,500.00	$--------	$ 5,000.00
Exploration drilling	3,496.54	--------	--------	--------	3,496.54
Down-hole camera	1,091.25	--------	--------	--------	1,091.25
Shaft-ladder-winch	--------	23,409.16	--------	--------	23,409.16
Pole-shed and wiring	--------	1,742.85	--------	--------	1,742.85
Road, culverts, septic tanks	--------	10,832.14	--------	--------	10,832.14
Fencing	--------	4,881.30	--------	--------	4,881.30
Mobile home and laboratory trailer	--------	8,450.98	--------	--------	8,450.98
SCUBA equipment	--------	1,183.52	--------	150.00	1,333.52
Underground safety equipment	--------	1,921.98	--------	--------	1,921.98
Consulting services	325.00	358.26	2,072.35	385.00	3,140.61
Hardware-miscellaneous supplies	72.58	207.17	463.88	110.18	853.81
Photography-reprints	--------	1,040.11	958.04	6.81	2,004.96
Travel	1,800.47	805.27	645.63	338.04	3,589.41
Utilities	81.30	546.07	927.30	474.41	2,029.08
Miscellaneous rentals	--------	113.50	29.00	--------	142.50
On-site meals	--------	34.19	469.35	515.73	1,019.27
Miscellaneous expenses	96.59	72.84	52.96	3.67	226.06
	$8,963.73	$57,099.34	$7,118.51	1,983.84	
					75,165.42

of the underground safety equipment, such as the oxygen meter, methanometer, gas tester, resuscitator, oxygen administrator, and Scuba equipment can be used by other agencies.