The Waters of Mystery Cave

Forestville State Park, Minnesota

Mystery Cave Resource Evaluation (Groundwater)

MANAGEMENT REPORT

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INTRODUCTION

This is the management portion of the final report for the LCMR project **Mystery Cave Resources Evaluation (Groundwater)** and is one part of the Mystery Cave Resource Evaluation. Funding for this project was approved by the Minnesota Legislature M. L. 91, Chapter 254, Article 1, Section 14, Subd. 3(1), as recommended by the Legislative Commission on Minnesota Resources, from the Future Resources Fund. This project concerns the waters and geohydrology of Mystery Cave in Forestville State Park. A summary of these topics in non-technical terms is given in a separate Interpretive Report, and technical aspects are covered in a separate Technical Report. This Management Report contains recommendations meant to protect and improve the water quality in Mystery Cave, as well as recommendations for education and future research.

PROTECTION AND IMPROVEMENT OF CAVE WATER QUALITY

Water is of central importance to any cave in limestone or dolomite. Water forms the caves, decorates, and then ultimately destroys them. Mystery Cave was formed and shaped by the dissolution of the carbonate bedrock by water. Water carried sediments into Mystery and deposited the speleothems that decorate the cave's interior. Most of the biology in the cave is dependent on the water flowing into and through the cave. Caves allow unique access to the flow of water in the subsurface. Visitors to a cave can directly and personally observe, enjoy, study, and learn about how groundwater moves in the unsaturated zone of karst aquifers. A fundamental goal of the management of Mystery Cave is to protect and improve the quality of that water. The management, protection and improvement of water quality in Mystery Cave will be a complicated and challenging task.

As documented in the Technical Report, water quality in Mystery Cave reflects a variety of natural processes. In many cases, water quality is being significantly impacted by human activities both inside and outside of the cave. The current management philosophy and policies are directed at maintaining and improving the water quality in Mystery Cave and its surface environs. In general, those policies are working well. The following recommendations are meant to reinforce and strengthen those management practices.

Management policies need to reflect an understanding of the natural hydrologic and chemical processes at Mystery Cave. Policies should minimize changes to natural processes, whether in the cave or on the surface. Management practices further need to be based on the knowledge that some human impacts to the water quality result from activities well removed from the cave proper. There are three different scales at which to manage water quality in Mystery Cave: The first is in the cave itself. At this level, we consider the direct impact of human visitation and in-cave management practices on water quality. The second scale includes the cave and the areas above the cave and immediately adjacent to it. At this level, we are concerned with human activities on the surface which primarily affect water quality in the upper levels of Mystery Cave. The third scale includes the cave, the nearby surface, and the rest of the Mystery Cave surface basins. At this level, we are concerned with the impact of distant human activities which primarily affect the water quality in the lower stream levels; these streams are directly fed by the South Branch of the Root River. The following management recommendations are discussed within the context of these three different scales.

Activities inside Mystery Cave

The policies of cave management already emphasize minimizing the impact of the public, management, sport, and scientific visitation on water quality in the cave. All visitors are forbidden to discard anything in the cave. We recommend that these policies be maintained and strengthened.

We recommend that the disposal of anything in the cave continue to be forbidden. Anything artificial that is installed or placed in the cave should be viewed as temporary. Plans for its ultimate removal should be an integral part of the installation permits. The current policy of removing obsolete wiring and other artificial material from the earlier show-cave phase should be continued. The chemical and physical interactions of all activities with the cave waters should continue to be a management consideration.

The waters in the cave are moving *through* the cave. Very little of the water remains in the cave for very long. Removal of modest amounts of the water for management or scientific purposes will not significantly impact the cave (see Education and Research Recommendations below). The current policy of allowing water sampling for scientific, management, and educational purposes should be continued.

The bedrock, sediments, and speleothems in the cave should be protected. However, the Mystery Cave System contains a important and unique record of the speleogenesis of the cave and a detailed, regional climate record that extends back at least 150,000 years. We recommend that a carefully controlled and monitored permit system for sampling of the bedrock, sediments and speleothems for scientific research purposes be established. A scientific research advisory committee might be a good mechanism to allow the Park Managers access to expert advice to help evaluate permit applications.

The full extent of the Mystery Cave System is not known. A complete map of the known cave does not exist. A *complete* working map of the cave at a scale suitable for most scientific work does not exist. Although we never know just how much of the real extent of a cave is known or surveyed, it is usually desirable to have as complete a map as possible. Exceptions occur; some caves have passages so well decorated and fragile that complete exploration and mapping would result in unwarranted degradations. Nonetheless, for Mystery Cave we recommend additional surveying to increase our knowledge of the cave's extent. That knowledge is essential if we are to have a chance of protecting the entire cave system. Thus, we recommend that policies designed to encourage exploration and mapping of the cave system be implemented. The sport caving community represents a significant source of volunteer expertise and should be utilized in the exploration and mapping efforts.

Low but elevated concentrations of zinc in Frozen Falls Pool, which is directly below a major bridge, are up to eight times the background values measured in Frozen Falls Drips and other sources feeding the pool. Some leaching of zinc from the galvanized steel bridges and railings is indicated. We recommend that zinc should be monitored on an infrequent but periodic basis at any sites where zinc concentrations might build up and significantly impact water quality.

The zinc sampling has been relatively modest to date due to budgetary constraints. We recommend that zinc sampling be extended to previously unsampled sites as well as the sampled sites. Frozen Falls Pool and Turquoise Lake are reservoirs with short residence times. They are flushed during recharge events (mostly associated with storms) sufficiently often that zinc is unlikely to build up to significant concentrations, at least for the present time, while the railings and bridges are young and the galvanized coatings are intact. Frozen Falls Pool and Turquoise Lake also are flushed infrequently when the Root River floods into Mystery I, as happened in late March, 1993. Sites at small flowstone pools along the Mystery I tour route where zinc might build up have not yet been sampled. These pools are adjacent to galvanized steel railings used to separate visitors from flowstone and other speleothems. These pools appear to have low fluxes and long residence times for the water recharging them, but zinc may enter via splash processes off the railings. We plan to sample these areas for zinc during the 1993-1994 Mystery Cave Geochemistry project. The small flowstone pools are reported to occasionally harbor springtails, so the zinc concentrations there may be of biological significance.

No sediment samples or biological materials were checked for zinc during this study. Zinc can be adsorbed on sediment, accumulate, and then be released at later times. Zinc can also build up to detrimental concentrations in organisms. We recommend that the zinc sampling be extended to include sediments and biological materials.

We recommend that modifications of the tourist trails in Mystery II be limited to the removal of objectionable existing artificial material and limited restoration efforts to reverse the effects of past commercialization. The "wilder" caving experience with hand held lights in Mystery II is popular with the tourists, is an appropriate tour experience, and minimizes the potential impact of massive modification associated with accessible trails and lighting.

One necessary modification of the Mystery II tourist trail involves the bridge over Blue Lake. During periods of high stage at Blue Lake, most of the wood bridge support piling is inundated. At low stage, during some of the fall and winter of a typical year, the wood piling may be completely dry. If the water level is sufficiently high, a set of seeps and springs in the tourist trail are active. Blue Lake Springs are about 60 ft east of the lake. Similarities in chemistry, and the correlation of flow with high stage, indicate that Blue Lake Springs water is derived from Blue Lake. That water seeps and flows out of the gravel in the middle of the trail, spreads out as a thin sheet, and then collects in a ditch on the north side of the passage. The water flows about 100 ft downslope before disappearing into a hole between the breakdown and gravel along the north wall. Blue Lake Springs are usually active in the winter or spring, but may become active anytime water level is sufficiently high. Blue Lake Springs were active most of the spring and summer of 1993, a particularly wet period.

When the water level in Blue Lake is high, there is a distinct odor of creosote around the Lake and to the east in the passage leading to Diamond Caverns. The wood bridge piling has a similar smell, as does a black sticky substance that can be scraped from the wood. The odor is strongest when Blue Lake Springs are active and is objectionable to many visitors. We believe the odor derives from semivolatile organic compounds in the impregnated bridge piling. The compounds dissolve in the lake water and are volatilized as the water flows down the trail and ditch from Blue Lake Springs. During dry years the odor may be detectable only in the late winter and spring, but during wet years it can be expected throughout the summer tourist season. Volatile compounds were not detected in the single sampling for volatile organic compounds at Blue Lake,

but a careful resampling for the appropriate semivolatile compounds may detect them. We recommend an additional sampling at both Blue Lake and Blue Lake Springs for organic compounds associated with creosote. Such sampling could be conducted during the spring of 1994, when recharge refills Blue Lake.

Regardless of the results of the sampling, we recommend that all impregnated wood pilings be replaced. This will require significant reconfiguration of the bridge, but may entail little modifications to the support systems at the ends of the bridge. If possible the replacement bridge should not use pilings. If such a bridge is not feasible for engineering, economic, or management reasons, we recommend that replacement pilings should be chosen that are compatible with the hydrogeochemistry of Blue Lake.

Blue Lake and Blue Lake Springs have a significant educational value as hydrologic features. Blue Lake is also important because it has excellent examples of raft cones; indeed it has the only ones visible along the Mystery II commercial trails. Although the springs wet the trail and constitute an occasional annoyance, they do not present a major management problem. Minor modifications could be made to better direct the water to the side, leaving the seeps and springs intact as hydrologic features. These seeps and springs could be labeled and identified as part of the interpretative program. Water level, water and air temperature, and conductivity data acquired at Blue Lake (see the Technical and Interpretative Reports) could be worked up into an in-cave display that illustrates (1) cave meteorology, and (2) the hydrology and chemistry of Blue Lake and Blue Lake Springs.

Additional modifications of the Mystery II trail system may be necessary. The hydraulics of the entrance area are a problem. During recharge events, water sprays out of the retaining walls, runs a short distance down the tourist trail, and erodes a small sinkhole in the trail. This pit is a hazard to anyone entering the Mystery II entrance. We recommend that engineering solutions to this problem be investigated.

About 80 ft west of 17 Layer Rock in 5th Avenue of Mystery II there is a side passage that leads toward a surface valley. During major recharge events, a small stream flows down the passage and spreads out over the trail of 5th Avenue. At times, the water forms one or more pools up to five inches deep. The pools can cover the entire width of the passage, as occurred during the wet summer of 1993. The pools impede tours. We recommend that engineering solutions to the problem be investigated.

Activities on the Surface above Mystery Cave

Groundwater in the upper parts of Mystery Cave, including all of the tourist trails, flows primarily downward to the horizontal streams in the lower levels of the cave. These lower level streams locally represent the top of the water table and mark the transition from predominantly vertical to horizontal groundwater flow. Horizontal movements of groundwater in the upper portions of Mystery Cave certainly exist but are limited by the major vertical joints. Water flowing horizontally may be diverted down smaller joints, but cannot flow far without intersecting a major joint. The major joints are spaced about every 30 to 100 meters. This spacing is evident in the cave itself and is visible in local limestone quarries. Examples illustrating downward vertical flow in the upper levels can be seen at Enigma Pit, the Smoking Chamber, Frozen Falls, and at the waterfall in Old Mystery Cave. The primary management implication of this downward flow pattern is that *the land surface directly above the cave is the source of most of the water in the upper parts of the cave*. The major exception to this is water flowing on the surface for some distance before sinking over the cave. Most of the land over Mystery is not owned by the State of Minnesota or managed by the Department of Natural Resources and Forestville State Park. This limits the management options available to protect the water quality in Mystery Cave.

Forestville State Park does manage the critical surface areas around both entrances to the cave. Human activities in these areas directly affect water quality in the cave. Management policies adopted by Forestville Park will, by example, set an upper limit on practices the DNR may hope the surface landowners will adopt. We will make recommendations mainly on the policies that the DNR can adopt for its own property over the cave. We hope these will illustrate the principles that should guide the DNR managers in their negotiations with the other surface land owners.

A major potential source of water pollution in the cave is from human sewage generated by visitors at the cave. Although perhaps not the most aesthetically pleasing solution, the current use of self-contained "port-a-potties" is an excellent solution to the problem and may be the most economically viable approach for the foreseeable future. The important hydrogeologic characteristic of these facilities is that no waste water is injected into the subsurface over the cave. We recommend that sewage treatment at any new visitor or management facilities at Mystery Cave or as a replacement for the existing "port-a-potties" should not involve any type of drain fields or technology over the cave that will inject effluent into the subsurface. Such injected water may be in the cave on a time-scale of minutes and will almost certainly be in the cave in hours to days. A closed system that is periodically pumped and transported or a sewer system that moves the waste to a treatment facility hydraulically downstream from the cave is necessary.

Use of the previously existing cesspool outhouses were very correctly abandoned as soon as Forestville Park began to manage the cave. However, those old cesspools remain in at least three locations over the cave. They may develop into a source of groundwater pollution as the geochemical changes in the wastes progress. We recommend that the feasibility of excavating and removing those old cesspools be investigated.

Dye tracing has documented that the septic system at the DNR residence at Mystery I impacts the water quality in some lower stream passages of Mystery I. About 1% of the effluent going into the drain field reaches the lower stream levels as fast as does the water which sinks in the river in front of the cave. There is little documentation of the construction of that drain field. We recommend that the existing drain field be replaced with some type of closed system. The trailer dump facility at the campground in Forestville Park is well downstream from the cave and does not threaten water quality in the cave. That facility is one possible place to treat waste from the residence over the cave.

The DNR does not maintain any animals or agricultural activities in their land over Mystery. One management practice that might arise is the use of herbicides to control plant growth around the cave entrances or over the cave. Any such practice is not recommended and if necessary should be monitored very carefully. If the cave area is tied into the trail system of Forestville Park and those trails are to be used by horses, the stable areas and hitching areas should not be over or upstream of the cave.

Parking lots for visitors are an ongoing challenge. To the maximum extent possible, such facilities should not be over the cave. The water quality associated with runoff from parking lots contains hydrocarbons, heavy metals, antifreeze, etc. Parking lot runoff is not a desirable addition to the cave's waters. Many National Parks that manage caves are currently struggling with this problem. Off-site parking is the ultimate goal. Roads over the cave should in general be viewed as a necessary evil and whenever possible should be routed away from the cave.

The land over the cave that is in private ownership is a major challenge. The atrazine, nitrates, chlorides, and coliform bacteria observed in water from the upper levels of Mystery Cave probably came in large part from the agricultural and domestic activities over the cave. Several private homes over the cave have septic systems that probably impact the cave. The nutrients and agricultural chemicals applied to the fields are impacting the cave's waters. The animal wastes

from barn yards, feed lots and manure applications to the fields are impacting the cave's waters. We can only recommend that the DNR work creatively and innovatively with the local landowners to limit these inputs.

Activities in the Surface and Groundwater Basin of the Root River

Water quality in the lower stream levels of Mystery Cave is largely determined by the water quality in the South Branch of the Root River which sinks at the cave and forms the lower level streams. That water resurges at the Rise of the South Branch of the Root River in Crayfish, Seven, and Saxifrage Springs. The water from the South Branch that sinks north of Mystery Cave resurges at Moth and Grabau Springs. Moth and Grabau springs are the headwaters of North Branch or Forestville Creek, which flows for most of its length in Forestville State Park. The water quality in the South Branch upstream from Mystery Cave, therefore, directly affects the water quality in major parts of the cave and park. Elevated levels of nitrate, coliform bacteria, and atrazine are ubiquitous in the river water and the lower level streams in Mystery Cave. We recommend that the DNR examine its regional management policies to look for ways to improve the water quality in the South Branch upstream of Mystery Cave. We recommend that the classification of this stretch of the South Branch be upgraded to reflect its impact on Mystery Cave and the trout streams in Forestville State Park.

The summer of 1993 proved to be exceptionally wet. The South Branch of the Root River covered all of the flood plain at the ticket building at Mystery I and flooded parts of the Mystery I tourist trail twice. Major log jams formed on the upstream side of the new bridge to the Mystery I picnic area. The log jams partially blocked flow, causing ponding upstream. This may have exacerbated the flooding of Mystery I. We recommend that the impact of these recurring log jams on the local flooding be investigated and necessary corrective measures be developed.

Routine practices that can impact the water quality in the South Branch include the agricultural and domestic activities of everyone who lives, works, plays, or visits the basin. The City of Ostrander is in the basin. The Ironwood Sanitary Landfill with its industrial waste pollution is in the basin. The American Oil Company pipeline crosses the South Branch of the Root River's basin about a mile upstream from Mystery. This is an old pipeline. Spills and leakage have occurred as close as the Amoco tank farm just east of Spring Valley. A variety of hazardous materials are transported on the roads in the basin and are stored on farms, businesses, and residences.

Scenarios for the impact of events in the surface basin on the cave range from minimal up to life threatening. A gasoline spill, for example from a tank truck or the pipeline, would move down the South Branch and flow into the lower stream levels of Mystery. The turbulence of the cave streams would vaporize part of the gasoline. Explosive mixtures of gasoline vapors could then rise from the lower levels into the tourist portions of the cave. If this occurred during the summer tour season, an entire tour group might be lost to an underground explosion. We hasten to add that this is a worst-case scenario. However, explosions and fires from fuel spills have occurred in caves, sewers, and houses in karst areas, under circumstances in which the spilled materials originated outside the explosion sites. We recommend that the DNR cave management coordinate with all local, county (Fillmore *and* Mower), regional, and state emergency response authorities. Notification of the cave management of any report of a spill or release of pollutants anywhere in the basin of the South Branch of the Root River should be a high priority. We recommend that contingency plans be created to deal with such an emergency.

RECOMMENDATIONS FOR EDUCATION

Mystery is the largest and most accessible cave in the state. Minnesota has invested millions of dollars in upgrading the tourist access in Mystery I. The new, state-of-the-art Mystery I facilities are outstanding and a testament to the vision, skills, dedication, and hard work of the Park staff. Mystery Cave has an immense educational potential. We recommend that the educational use of Mystery Cave be significantly upgraded and expanded.

Public Education

Forestville Park staff has made a concerted effort to include preliminary results of this project and all other available scientific into the visitor experience during summer tours. This public educational effort is already excellent and should be strengthened and expanded. The Park has a strong program of training of the summer interpretive staff. This project will supply much additional material to enhance the training and information available to the staff. Many of the summer visitors spend a significant amount of time waiting for their cave tour. We recommend that audio-visual material which gives background information on the cave and the cave tour be developed. Such material could simultaneously enhance the experience for the visitor and simplify the task of the interpretive staff on the tours.

K-12 Education

Mystery Cave historically had a strong component of K-12 educational visits before and after the summer tourist season. The other commercial caves in the region continue such programs and their experience indicates a strong interest in, and demand for, such educational opportunities. We recommend that Forestville State Park develop a program, including pre- and post-visit curricular materials, to encourage various grade levels of school groups to visit the cave. The opportunity to begin educating K-12 students about karst hydrogeology is unsurpassed. Such an effort will require significant new resources but is directly in line with the current LCMR priorities. K-12 visitation of Mystery will increase the use of the cave during the off season.

College and University Classes, Professional Education

Individual faculty members at regional colleges and universities routinely include visits to the cave as part of field trips in various earth and environmental science courses. Visits to Mystery are also routinely included in field trips associated with professional and scientific meetings and short courses. The staff of Forestville State Park have encouraged and facilitated such usage. Such visits, however, are largely at the initiative of the individual faculty or meeting staff and are not coordinated. Other faculty and meeting staff may not realize that such visits are possible. Various educational materials have been generated in connection with these field trips, but little of it has been accessible to or used by the Park staff. This usage should be encouraged as part of the educational effort. The educational materials generated for these field trips should be assembled and coordinated. We recommend that policies designed to encourage and facilitate such educational usage be developed.

RECOMMENDATIONS FOR FURTHER STUDY

The research in this program has demonstrated that Mystery Cave is indeed a world class cave. The assembled information base should form the basis for a whole series of ongoing research efforts. New and additional information generated in such work will only enhance the stature and value of the cave and will assist in the ongoing management challenges. We recommend that management policies explicitly encourage the use of Mystery Cave for scientific

research.

A particularly new and exciting development in paleoclimatology is the recent discovery of annual banding in speleothems. This discovery, coupled with new advances in the precision of speleothem dating and isotope geochemistry, raises the possibility that the speleothems and sediments in Mystery contain a unique record of climate change in the upper midwest for the last 150,000 years. We recommend that carefully selected speleothem and sediment materials be available for such research.

Much work has been done on zinc leaching from galvanized steel and other building materials. Zinc initially weathers rapidly, forming zinc carbonate and other surface coatings that tend to protect the lower layers of zinc as well as the steel. Later weathering can be slower, but varies greatly according to the environment. Weathering environments that allow zinc coatings to dry tend to have lower leaching rates, but many factors are involved. Knowledge of long-term zinc leaching rates in a variety of surface environments has allowed engineers to predict the expected lifetimes of galvanized steel structures on the surface, out of doors as well as indoors in such settings as chemical factories. We cannot at present predict expected lifetimes of the galvanization of Mystery Cave bridges. We do not have useful long-term data on leaching in cave environments, nor is it clear what effects local environmental and chemical factors will exert in Mystery Cave. The cave is humid, and most bridges and railings are never fully dry in Mystery I, so leaching rates could be high. At some locations, the galvanization could be protected, if waters supersaturated with respect to calcite deposit calcite crusts directly onto the metal. Because the railings and bridges are essential to operation of the cave tours, we recommend additional work directed at estimations of zinc leaching rates. If those rates turn out to be high, zinc concentrations of waters, sediments, or organisms might rise to unacceptable levels. Mystery Cave provides an excellent opportunity to investigate zinc removal from galvanized steel and its possible accumulation within the subsurface. Such an opportunity should be seized, if for no other reason than that galvanized steel definitely does have a limited useful lifetime. When the time (hopefully many years from now) eventually does come to replace or upgrade the bridges, it will be helpful to know as much as possible about the performance of the existing materials.

Mystery Cave is one of the best possible locations for long-term monitoring of water quality trends in southeastern Minnesota's karst region. Management of the cave will require some level of routine water-quality monitoring. There are several programs within Minnesota State environmental management efforts that monitor Minnesota's ambient groundwater quality. We recommend that the DNR work to include some of the waters in Mystery Cave and Forestville Park in these ongoing groundwater-quality monitoring efforts. There is a real opportunity to avoid duplication and to conserve financial resources here.

We recommend that specific research and monitoring of the cumulative impact of various types of visitation on the cave and its waters be initiated. Does the cave have carrying capacities for specific types of visitations? The water-quality data generated in this project will serve as the baseline for such future work.