REPORT OF THE UIS MISSION OF EXPERTISE IN THREE SHOW CAVES AT THE REQUEST OF HIS EXCELLENCY THE MINISTER OF TOURISM OF LEBANON

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I. INTRODUCTION

Lebanon has one of the most beautiful show caves in the world: Jeita. Such a majestic but fragile world patrimony, many thousands of years old, must be kept for future generations in its natural state.

This cave—and the other caves visited during this mission—must be protected and special care must be paid by the show caves’ management, local and foreign visitors, as well as other public organizations and individuals (e.g. relevant governmental ministries, public administrations, municipalities, and politicians charged with the development of the environment, conservation of nature, underground waters, prevention of pollution, planning of roads and tourism). The careful vigilance of local and foreign cavers is also necessary because without them these caves would be still unknown.

II. WHY A UIS MISSION OF EXPERTISE?

Since its origin in 1965, the UIS (Union Internationale de Spéléologie) has had strong ties with the Lebanese speleological community when the Lebanese cavers representing their country participated in the foundation of the Union and the Union’s first Secretary General was Lebanese. This year the UIS was approached by the Spéléo-Club du Liban on a joint initiative they launched with the Lebanese Ministry of Tourism and the manager of Jeita Cave concerning the protection of Jeita and other Lebanese show caves.

His Excellency, the Minister of Tourism Mr. Michel Pharaon, invited two experts from the UIS for a five-day visit to Lebanon to investigate Jeita and two other caves: Qadisha and Rihane. His Excellency, Mr. Pharaon, requested the UIS prepare an expert report that details means to further protect these caves.

The UIS Bureau received the request, responded positively, and sent two experts: Dr. Arrigo Cigna (UIS past-President and Secretary General) and Jean-Pierre Bartholeyns (UIS Adjunct Secretary and President of the UIS Department of Karst Protection). A third UIS expert, José Labegalini (UIS past-President), came at his own expense to optimize the team’s efforts in providing the Lebanese Government an effective technical evaluation.
The UIS has witnessed and encouraged excellent relationships between show cave managing boards and public authorities with local speleologists around the world. Such win-win relationships help to promote tourist attractions, public awareness, and protection of national karst assets. We hope that our Mission of Expertise in Lebanon will encourage Lebanese stakeholders to work together for the sake of preserving their natural patrimony.

III. DISCLAIMER

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IV. JEITA CAVE

Visited on 10 and 11 June 2014.

General remarks

Jeita Cave, with its wonderful upper cave and its lower underground river is surely one of the most beautiful caves in the world. This great but fragile patrimony must absolutely be kept in its natural state for future generations.

The whole cave, both sections open and closed to tourists, deserves the protection and care of everyone involved. First, government ministries, administrations, municipalities, and politicians. They develop regulations, policies, and plans for sustainable development of the environment, conservation of nature, protection of underground waters, prevention of pollution, and planning of roads and tourism, all which should be designed to protect the cave and the areas that may impact the cave. Second, the cave’s management and NGOs, which carry out those regulations, policies, and plans, and which monitor the condition of the cave and surrounding areas daily. Third, the visitors to the cave and residents of the surrounding area who, when educated about the value of the cave, take extra care when visiting and in their activities near the cave, and support the above governmental and management authorities. In addition, the UIS recognizes the local speleologists who discover such natural jewels and promoted their study and protection for the good of the Lebanese nation.

Recommendations

1. Microclimatological monitoring system: An important show cave like Jeita, which receives several hundred thousand visitors every year, has to be equipped with a modern microclimatological monitoring system able to record the cave’s environment conditions. The resulting records should be saved for future investigations and to evaluate natural and artificial changes in the cave. They will be a significant asset for the cave’s management, scientific research, and assurance to public authorities that their policies are met.
Jeita Cave has an upper and lower level. The upper level is a hydrologically low-energy system dominated by drip water and airflow processes. The lower level contains a hydrologically active, high energy underground river. Changes in the river do not directly affect the upper levels, but do affect airflow, humidity, and the general microclimatological of the upper levels. Therefore, microclimatological monitoring is not suggested for the lower level. However, we advise continued monitoring of electrical conductivity, water levels, and other parameters of the river as conducted by the water purifying water station and to have those results available to the Jeita Cave monitoring network.

An adequate microclimatological monitoring system will measure continuously (each 6 hours) at least temperature, humidity, and CO₂ concentrations in Jeita Cave. In addition to their scientific and management value, the results will be of public interest and should be published on the cave’s internet website.

One of the most important uses of the microclimatological monitoring will be to test the effectiveness of the door seals, which have been renovated and in place in the artificial tunnel entrance of the upper cave since some months¹. The recommended monitoring network, discussed in detail in the appendix, consists of four (4) stations:

a. Outside, at the entrance of the tunnel that leads to the upper gallery;
b. Inside, at the natural cave entrance to the upper gallery;
c. In the middle of the length of the tour trail, where the descriptive panels are installed, or at the end of the trail.
d. Beyond the end of the trail at the stone quarry for the old steps.

At present the measurement of temperature and relative humidity only is recommended while few spot measurements of CO₂ by a Dräger detector, which is quite economical, could give an indication if there is large variation of the concentration. In case of the presence of such large increases more sophisticated detectors (infrared system) could be implemented.

2. Doors of upper Jeita Cave: Visitor access to upper Jeita Cave is through an artificial tunnel. It is crucial that this artificial entrance remain sealed by door that allow as little air circulation as possible and to minimize impacts on the cave’s interior. The current doors may serve this purpose but need to be maintained, upgraded, and submitted to a heavy-duty careful maintenance program to avoid possible failures. In no case should both sets of doors be open at the same time.

In addition, a couple of air curtain doors (such as those used in supermarkets) could be installed in the tunnel. Such devices consist of a fan installed in the side of the tunnel blowing air from the ceiling and recovering it through a grid and filter in the floor. In this way the visitors have an “air shower” which washes small particles from them, decreasing the problem of lint deposited inside the cave. This “air curtain” will also reduce the airflow through the tunnel, enhancing the effect of the doors.

3. Protection zones above the cave: Construction without adequate measures (karstic areas) to protect the cave, as well as the dumping of trash by trucks (sometimes belonging to the local municipality and/or private; see picture), will change the flow of water into the cave and degrade the

¹ The artificial access tunnel to the upper gallery was excavated and opened in 1969. To protect the cave, the tunnel was sealed throughout the war, from 1975 to 1982. After a few weeks of opening to the public, the tunnel was sealed again until 1990 when it was opened to serve as a munitions depot. Public access to the cave was re-established in 1993.
quality of the water, resulting in damage to the cave environment, its speleothems, and possibly to the health of people drinking water from the water purification station.

Debris that is dumped on the foothills of the valley is unstable and may create landslides after heavy storms. Construction and other activities could cause a collapse of the cave’s ceiling where the rock overburden is relatively thin.

Therefore, the relevant ministries, municipalities, public administrations and authorities should collaborate with the cave’s management and speleologists to identify the areas from which water enters the cave. These areas should be designated as protective zones, to protect the cave’s environment and groundwater, with strict regulations on what activities may and may not occur in those zones.

4. Cave trails: The trails inside the cave are in good order. In some places below the surface of the trails the iron in the concrete has rusted, resulting in small cracks. Such iron, if still structurally stable, should be chemically treated to transform the iron oxide into a stable compound and then covered again with concrete.

We suggest the use of adequate floor-washing machines (or even dry-cleaning), instead of limit the flow of the water (even eliminate) used for washing the pathways on the underlying formations.
5. Speleothems: Avoid spraying water on speleothems. The process of speleothem development is complicated, with exchanges of water and carbon dioxide that cannot be artificially created; spraying water could damage the speleothems.

Similarly, rimstone pools (i.e. gours) in the upper cave should not be filled with water pumped from the underlying Jeita River. The natural source of the water in those pools deposits calcite to create the rimstone dams. However, water in the river is dissolving limestone and calcite, and will slowly dissolve and destroy the rimstone dams and pools. Aesthetically, we recommend leaving the pools empty when they dry naturally. This cave area would then have different equally beautiful aspects at different times of the year.

The presence of coins in the cave’s pools is a source of pollution, and should be prohibited.

6. Safety on boats: In order to best assure the safety of the visitors, each boat in the lower cave should include ropes and a floatation vest for each visitor. The vests should be worn or be easily available in case of an emergency.

7. Iron handrails: The lateral protection of the stairways and trails are made of painted iron (not stainless steel). The upper bars, which serve as handrails, are covered with adhesive yellow tape to protect the hands of visitors from the rust. In some areas this tape is damaged. To improve the cave’s appearance, the covering of all handrails in the cave should be checked and repaired; any broken tape on the floor should be removed.

8. Surface attractions at Jeita Cave: We noticed very good management of the surface facilities by the show cave personnel (parking, ticketing, cable cars, etc.). Nevertheless, we have a few comments that would improve surface conditions.

First, the access road to Jeita Cave clearly lacks maintenance and is dangerous in some places. Efforts should be spent in order to improve this road and provide safety for the visiting busses and cars.

The cages with animals between Jeita Cave’s two entrances are not in line with the current attitude regarding the geological aspects and nature of a karstic feature like Jeita Cave. They could be conveniently substituted by panels with nice pictures describing the cave fauna, such as insects and bats, and fossil animals, such as cave bears, lions, etc. Public awareness of the fragile environment of caves and their formation could also be promoted there. Hence, the magnificent Jeita Cave would also become educational, leaving a bigger impact on the visitors of all ages and cultures.

9. Management: Management of the cave will be improved by implementation of the Recommended Management Guidelines for Show Caves (see appendix).
V. RIHANE CAVE

Visited on 12 June 2014.

General remarks

This is a small cave located in a remote area that could be developed into a show cave. We found the local people very motivated to support such a development.

Special remarks

1. This cave is located in a region without an important tourist attraction. On the other hand, it is situated in a quiet area with vistas of a relaxing landscape. Its development for tourism could improve the local economy through restaurants and handicraft shops of local products.

2. The already existing facilities must be maintained. They could be conveniently modified in the future.

2.1. The access road and other facilities provide a suitable entrance hall built with local stone.

2.2. The concrete structure at the entrance of the cave, once covered with local stone, would be quite acceptable from an aesthetic point of view. Such a facility could be used for ticket counters, toilets, souvenirs shops, and a small cafeteria looking on the nice view on the valley.

2.3. The existing trail in the cave is conveniently placed and allows a suitable view of the speleothems, which are nicely preserved.

2.4. A lighting system already exists. Its small size and the short time of operation do not seem to give problems with lampenflora at the moment. Nevertheless, it can be improved in order to eliminate any risk in the future.

3. It is possible to extend the tourist trail. A careful clearing of the left side of the final gallery with the existing trail would allow access to two rooms (10m x 5m) decorated with beautiful speleothems, perhaps the nicest sections of the cave. Explosives should not be used to gain access to these rooms. Expansion cement (see appendix) and the assistance of speleologists are safer for the cave.

4. Temperature measurements outside and inside the cave confirm that the artificial widening of the entrance has not changed the original cave temperature.

Recommendations

1. Visitor Information Center: The entrance artificial hall may easily provide space for a small booth for providing information to the visitors. Public awareness about the importance of this cave and caves in general could be promoted with information on the cave, its ancient speleothems, fragile environment that require respect and protection, origin, geology, history of discovery, and development.
2. Septic tank and WC: A septic tank for toilets should be installed in the vicinity of the Visitor Center building but at an elevation lower than that of the cave. Otherwise, the effluent released by the septic tank would percolate into and pollute the cave.

3. Entrance door: The sheet in the left side of the entrance door at minimum should be substituted by horizontal bars, 20 cm wide, to leave access for the bats and other living species that live in the cave. Otherwise, the cave’s eco-environment will deteriorate.

4. Trails and handrails: The trails are raised above the cave floor by a structure of iron and concrete. Unfortunately, the iron is easily corroded by humidity and water flowing in the cave during wet periods. The structure could be left as it is until it is unsafe to use. Once the iron is too severely damaged, the entire trail could be removed and substituted by a concrete trail placed directly on the natural floor, with the advantage of avoiding a low space for visitors who, in some places, must be careful to avoid stalactites. In this case, the handrails should be substituted by plastic ones, which are not damaged by humidity, are light, and can be easily worked.

5. Reuse of broken speleothems: Pieces of broken speleothems were reused in the cave to create walls in narrow passages. Others were used to replace natural speleothems, in which case care is needed to not put them in inverted positions. The position of these speleothems should be checked for correct orientation. Incorrectly oriented speleothems gives wrong information to visitors and demonstrates an embarrassing low knowledge of caves by the cave’s managers.
6. **Lamps**: Lamps should be directed toward speleothems and walls without being visible to visitors when entering and exiting the cave. Only white light (colour temperature 4000 K) should be used and LED lights should be used to substitute out-of-use lamps. To avoid the development of lampenflora, the lamps should be switched on only when necessary and placed not too close to speleothems and walls.

7. **Cleaning**: Graffiti was found in the cave in four different places. It should be carefully removed with nylon or stainless steel brushes and water sprayers. Care is necessary, especially if stainless steel brushes are used, to avoid grooves and marks.

8. **Speleological exploration**: The hill above the cave and the end of the cave should be examined for a possible secondary entrance. If one is found, the tour could be changed into one starting at the present entrance and exiting from the new entrance. If this is done, it is crucial that the new entrance include two air-tight doors as described for Jeita Cave. Further speleological investigation on the surface, searches of possible new underground branches, and the taking of good photographs in the cave should be undertaken by local Lebanese speleologists.

9. **Microclimatological monitoring system**: In order to control the environmental conditions inside the cave, temperature and humidity measurements should be made once a day and maintained to make sure that the cave conditions are not affected by access to the public. We recommend the installation of a simple monitoring network, consisting of two stations:
   1 – Outside, at the cave’s entrance.
   2 – Inside, midway along the length of the trail.
10. Management: Management of the cave will be improved by implementation of the *Recommended Management Guidelines for Show Caves* (see appendix).

11. Map
Survey of Rihane Cave by the SCL (Spéléo Club du Liban).
IV. QADISHA CAVE

Visited on 13 June 2014.

General remark

This cave has a notable tourist interest justifying its development as a regional show cave. The cave, as well as the whole valley and the nearby cedar forest, are listed as UNESCO World Heritage sites.

Special remarks

1. The cave is located in a large, beautiful, and quiet valley.

2. The path to the cave meanders almost horizontally along the valley wall through fragrant and floral vegetation, and offers visitors stunning views that overlook the surrounding mountains, Qadisha valley, and even the Mediterranean Sea.

Recommendations

1. General Recommendation: A maximum respect of the natural site must be kept and without any development that may threaten it. Cableway installation or widening the access path for small cars—even if electric—is strongly not recommended.

2. Cave Access Path: The 800-m long, open access path to the cave entrance should be kept only for pedestrians. In some places handrails should be provided for safety.

3. Information Signs: Signs should be installed along the trail to the cave that would give visitors useful information about the plants and landscape.

4. Lamps: A lighting system already exists in the cave. Although the cave is small, with a short period of operation, the problem of lampenflora is already present. The first step in correcting this problem is to move the lamps away from the speleothems. The second and more crucial step is to redesign the cave’s electrical and lighting system to eliminate or greatly reduce the actual problem.
5. Proposed Development Project: After careful study, we support the project proposed by Architect Johnny Tawk. It is excellent, original, respects the original development, suggests creative solutions to problems, and gives emphasis to special speleothems.

6. Microclimatological monitoring system: In order to control the environmental conditions inside the cave, temperature and humidity measurements should be made once a day and maintained to make sure that the cave conditions are not affected by access to the public. We recommend the installation of a simple monitoring network, consisting of two stations:
   1 – Outside, at the cave’s entrance.
   2 – Inside, midway along the length of the trail.

7. Management: Management of the cave will be improved by implementation of the Recommended Management Guidelines for Show Caves (see appendix).

VI. APPENDIX

1. The development of show caves: New materials and methods Arrigo A. CIGNA
   Proceedings 16th International Congress of Speleology, Vol.1: 215-218
   This document can be downloaded from http://www.karstportal.org/node/8370, but it is enclosed below.

2. UIS Recommended Management Guidelines for Show Caves
   UIS Department of Karst and Cave Protection
   This document can be downloaded from http://uis.caves.org/index.php?option=com_content&view=article&layout=edit&id=78&Itemid=404, but it is enclosed below.

3. Lamps LED
   CAVE LIGHTING
   GermTec GmbH & Co. KG - Hohe Strasse 700 Geb. 5B - 35745 Herborn – Germany
   Alexander Chrapko
   E-mail: ac@germtec.de
   Phone: +49 (0)2772 575218
   Fax: +49 (0)2772 575220
   Mobile: +49 171 7228201
   Web: www.germtec.de and http://www.cavelighting.com/
4. Plastic and other materials
Plastic materials that can be substituted for stainless steel are sold in Europe by Fibrolux GmbH, see http://fibrolux.com/fr/footer/contact/
Similar materials are also produced in US, see www.fibergrate.com

5. Excavation
For the widening of passages, as at the end of the Qadisha Cave, non-explosive products might be used, as found at http://www.dynacem.pl/de (Betonamit Non-Explosive Cracking Agent), www.nonex.it, or www.betonamit.net

4. Microclimate monitoring system
4.1. Microclimate monitoring system operation: The heart of a good monitoring system is an autonomous data logger what can be downloaded once a month to a laptop computer, is very rugged, reliable, not damaged by electric discharges due to thunderstorms, and can work well in humid cave atmospheres. ONSET, for example, has equipment with a temperature accuracy of +/- 0.5°C with a resolution of 0.1°C in a range from 0° to 50°C, and relative humidity (RH) measurements accurate to 5% to 95% RH and a resolution of 1% in the same range. Such devices often cost less than about $200 USD.

For CO₂, the Draeger Company offers simple devices which measure atmospheric carbon dioxide concentrations by the change of colour of a detector. A cartridge is used for each measurement. The system is inexpensive and provides a general idea if CO₂ concentrations are unnaturally changing. If such changes are detected, then a continuous monitoring infrared detector system could be installed.

4.2. Monitoring system placement: The management of each cave will ensure the placement and maintenance of the monitoring system equipment. It will also take care of the data collection and maintenance of those records.

4.3. Measurement evaluation: A small group (e.g. 3 or 4 maximum) of experts, collectively recognized by Lebanese cavers and scientists, competent in cave microclimatology would analyze the data collected. This group should be used to evaluation monitoring data for all show caves in Lebanon. UIS can provide, if requested, supervision and/or equipment advice.

5. Photos
Illustrative photos of this rapport can be provided on request in high resolution.
INTRODUCTION
The concept of establishing guidelines to be used as general parameters for good show cave management, originated during informal discussions between members of the International Show Caves Association at the time of the inaugural meeting of ISCA in Genga, Italy, in November 1990. These discussions continued over time and were first drafted for consideration at an ISCA meeting held on 17th September 2004 during the 30th Anniversary of the opening of Frasassi Cave, in Italy, to the public. The idea of creating guidelines, received strong recommendations from the UIS Department of Protection and Management at the 14th International Congress of Speleology held in Kalamos, Greece, in August 2005.

These management guidelines are the result of wide cooperation between the International Show Caves Association (ISCA), the Union Internationale de Spéléologie (UIS) and the International Union for Conservation of Nature and Natural Resources (IUCN). The intention was to create commonly accepted guidelines that all show cave managers can work toward, taking into account both the protection of the environment and socio-economical constraints. Many recommendations and suggestions have been received in the course of nearly twenty years, and therefore the document reported here can be considered as the result of an active cooperation among specialists involved in this matter.

1 DEVELOPMENT OF A WILD CAVE INTO A SHOW CAVE
The development of a show cave can be seen as a positive financial benefit to not only itself, but also the area surrounding the cave. The pursuit of these anticipated benefits can sometimes cause pressure to be applied to hasten the development of the cave.

Before a proposal to develop a wild cave into a show cave becomes a physical project, it is necessary to carry out a careful and detailed study to evaluate the benefits and risks, by taking
into account all pertinent factors such as the access, the synergy and possible conflict with other tourism related activities in the surrounding area, the availability of funds and many other related factors. The conversion should only take place if the results of the studies are positive. A wild cave that is developed into a show cave, and is subsequently abandoned, will inevitably become unprotected and be subject to vandalism in a very short time. A well managed show cave assures the protection of the cave itself, is a source of income for the local economy and also may contribute to a number of scientific studies.

1-1 A careful study of the suitability of a cave for development, taking into account all factors influencing it, must be carried out, and must be carefully evaluated, before physical development work commences.

2 ACCESS AND PATHWAYS WITHIN CAVES

In many caves it has been found to be desirable to provide an easier access into the cave for visitors through a tunnel, or a new entrance, excavated into the cave. Such an artificial entrance could change the air circulation in the cave causing a disruption of the ecosystem. To avoid this, an air lock should be installed in any new entrance into a cave. On the other hand it must be mentioned that in some very exceptional cases a change in the air circulation could revitalize the growth of formations. A decision not to install an air lock must be only taken after a special study.

2-1 Any new access into a cave must be fitted with an efficient air lock system, such as a double set of doors, to avoid creating changes in the air circulation within the cave.

Caves are natural databases, wherein an incredible amount of information about the characteristics of the environment, and the climate of the cave, are stored. Therefore any intervention in the cave must be carried out with great care to avoid the destruction of these natural databases.

2-2 As much as possible, any development work carried out inside a cave should avoid disturbing the structure, the deposits, and the formations of the cave.

When a wild cave is developed into a show cave, pathways and other features must be installed. This invariably requires materials to be brought into the cave. These materials
should have the least possible impact on both the aesthetics of the cave and its underground environment. Concrete is generally the closest substance to the rock that the cave is formed in, but once concrete is cast it is extremely expensive and difficult to modify or decommission. Stainless steel has the distinct advantage that it lasts for a long time and requires little, to no, maintenance but it is expensive and requires special techniques to assemble and install. Some recently developed plastic materials have the advantage of a very long life, are easy to install and are relatively easy to modify.

2-3 Only materials that are compatible with the cave, and have the least impact on the cave, should be used in a cave. Cement, concrete, stainless steel and plastics that do not emit volatile organic chemical are examples of such materials.

The environment of a cave is usually isolated from the outside and therefore the introduction of energy from the outside will change the equilibrium balance of the cave. Such changes can be caused by the release of heat from the lighting system and the visitors and also by the decay of organic material brought into the cave, which introduces other substances into the food chain of the cave ecosystem. In ice caves, the environmental characteristics are compatible with wood, which is frequently used for the construction of pathways, as it is not slippery.

2-4 Organic material, such as wood, should never be used in a cave unless it is an ice cave where, if necessary, it can be used for pathways.

3 LIGHTING

The energy balance of a cave should not be modified beyond its natural variations. Electric lighting releases both light and heat inside the cave. Therefore high efficiency lamps are preferred. Discharge lamps are efficient, as most of the energy is transformed into light, but only cold cathode lamps can be frequently switched on and off without inconvenience. Light-emitting diode (LED) lighting is also very promising. As far as possible, the electric network of a cave should be divided into zones to enable only the parts that visitors are in to be lit. Where possible a non-interruptible power supply should be provided to avoid problems for the visitors in the event of a failure of an external power supply.
It is essential to ensure the safety of the visitors in the cave, particularly in the event of a failure of the main power supply. Emergency lighting should always be available whether it is a complete non-interruptible power supply or an emergency lighting system with an independent power supply. Local code requirements may be applicable and these may permit battery lamps or a network of LEDs or similar devices.

3-1 **Electric lighting should be provided in safe, well-balanced networks. The power supply should preferably be non-interruptible. Adequate emergency lighting should be available in the event of a power outage.**

Lampenflora is a fairly common consequence of the introduction of an artificial light supply into a cave. Many kinds of algae, and other superior plants, may develop as a result of the introduction of artificial light. An important method to avoid the growth of green plant life is to use lamps that do not release a light spectrum that can be absorbed by chlorophyll.

3-2 **Lighting should have an emission spectrum with the lowest contribution to the absorption spectrum of chlorophyll (around 440 nm and around 650 nm) to minimize lampenflora.**

Another way to prevent the growth of lampenflora is the reduction of the energy reaching any surface where the plants may live. The safe distance between the lamp and the cave surface depends on the intensity of the lamp. As a rough indication, a distance of one meter should be safe. Special care should also be paid to avoid heating the formations and any rock paintings that may exist.

3-3 **Lighting sources should be installed at a distance from any component of the cave to prevent the growth of lampenflora and damaging the formations and any rock paintings.**

The lighting system should be installed in such a way that only the portions of the cave occupied by visitors are switched on, leaving the lighting in the portions of the cave that are not occupied switched off. This is important from the aspects of reducing the heating of the cave environment and preventing the growth of lampenflora, as well as decreasing the amount of energy required and its financial cost.

3-4 **Lighting should be installed to illuminate only the portions of the cave that are occupied by visitors.**
4 FREQUENCY OF VISITS AND NUMBER OF VISITORS

The energy balance of a cave environment can be modified by the release of heat by visitors. A human being, moving in a cave, releases about 150 watts – approximately the same as a good incandescent lamp. Consequently, there is also a limit on the number of visitors that can be brought into a cave without causing an irreversible effect on the climate of the cave.

4-1 A cave visitor capacity, per a defined time period, should be determined and this capacity should not be exceeded. Visitor capacity is defined as the number of visitors to a given cave over a given time period, which does not permanently change the environmental parameters beyond their natural fluctuation range. A continuous tour, utilizing an entrance and another exit, can reduce the time that visitors spend in a cave, compared to the use of a single entrance/exit.

In addition to the normal tours for visitors, many show caves have special activities, sometimes called “adventure tours,” where visitors are provided with speleological equipment for use in wild sections of the cave. If such a practice is not properly planned, it may cause serious damage to the cave.

4-2 When visits to wild parts of a cave are arranged, they must be carefully planned. In addition to providing the participants with the necessary speleological safety equipment, the visitors must always be guided by a guide with good experience in wild caves. The pathway, where visitors are to travel along, must be clearly defined, for example with red and white tape, and the visitors should not be allowed to walk beyond this pathway. Special care must be taken to avoid any damage to the cave environment, and the parts beyond the pathway must be maintained in a clean condition.

5 PRESERVATION OF THE SURFACE ECOSYSTEM WHEN DEVELOPING BUILDINGS, PARKING, AND THE REMOVAL OF SURFACE VEGETATION AND WASTE RECOVERY

It is important that the siting of the above ground facilities, such as the buildings, parking and waste recovery, be well planned. There is a natural tendency to try and place these development features as close as possible to the cave entrance. Sometimes these features are built over the cave itself, or relevant parts of it. The hydrogeology above the cave must not be modified by any intervention such as the watertight surface of a parking area. Any change
in the rainwater seepage into a cave can have a negative influence on the cave and the growth of its formations. Care should be exercised also when making any change to the land above the cave, including the removal of the vegetation and disturbance of the soils above the bedrock.

5-1 Any siting of buildings, parking areas, and any other intervention directly above the cave, must be avoided in order to keep the natural seepage of rainwater from the surface in its original condition.

6 MONITORING

After the environmental impact evaluation of the development, including any other study of the cave environment, it is necessary to monitor the relevant parameters to ensure that there is no deviation outside acceptable limits. Show caves should maintain a monitoring network of the cave environment to ensure that it remains within acceptable limits.

6-1 Monitoring of the cave climate should be undertaken. The air temperature, carbon dioxide, humidity, radon (if its concentration is close to or above the level prescribed by the law) and water temperature (if applicable) should be monitored. Airflow in and out of the cave could also be monitored.

When selecting scientists to undertake studies in a cave, it is very important that only scientists who have good experience with cave environments be engaged for cave related matters. Many, otherwise competent scientists, may not be fully aware of cave environments. If incorrect advice is given to the cave management, then this could result in endangerment of the cave environment. Cave science is a highly specialized field.

6-2 Specialized cave scientists should be consulted when there is a situation that warrants research in a cave.

7 CAVE MANAGERS

The managers of a show cave must never forget that the cave itself is “the golden goose” and that it must be preserved with great care. It is necessary that persons involved in the management of a show cave receive a suitable education, not only in the economic
management of a show cave, but also about the environmental issues concerning the protection of the environment at large.

7-1 Cave managers should be competent in both the management of the economics of the show cave and its environmental protection.

8 TRAINING OF THE GUIDES

The guides in a show cave have a very important role, as they are the “connection” between the cave and the visitor. Unfortunately, in many instances the guides have not been trained properly and, not withstanding that they are doing their best, the overall result will not be very good. It is very important that the guides receive proper instructions about the environmental aspects of the cave as well as dealing with the public. It is important that guides are skilled in tactfully avoiding entering into discussions, which can have a detrimental effect on the overall tour. The guides are the guardians of the cave and they must be ready to stop any misbehaviour by the visitors, which could endanger the cave environment.

8-1 Cave guides should be trained to correctly inform the visitors about the cave and its environment.

9 HEIGHTEN PUBLIC AWARENESS

The visitors' impact on the environmental state of the cave can be very detrimental. It is thus essential to provide the visitors with clear and simple information on their behaviour at the time of the visit. It should appear at the entrance of each tourist cave. Use quite visible and pleasant pictograms by personalizing them with your mascot to invite them not to touch concretions, to remain on the paths, not to eat/drink/smoke, not to throw anything, not to use flashlights/not to take photographs…

9-1 Clear, pleasant and quite visible pictograms should appear at the entrance to inform the visitors about their behaviour in the cave.
THE DEVELOPMENT OF SHOW CAVES: NEW MATERIALS AND METHODS

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1. Introduction

The development of a wild cave in order to obtain an easier way started many tens of thousands of years ago when our ancestors decided to use the caves for their ceremonies. Obviously at that time the main scope was to obtain a reliable result with the simplest intervention. Probably some steps carved into a steep soil are one of the earliest examples (Fig. 1). If the consequence to the environment was negligible the step life was acceptable only if their use was limited to a small number of people.

Excavations, demolition of some formations, construction of pathways became widespread and the advantage for the visitors prevailed to the protection of the environment. Only in the last tens of years the protection of the environment was taken into due account to make a choice among different solutions.

This paper has the scope to describe the up-to-date solutions provided by the most advanced technology.

2. The development of a show cave

The fundamental criteria presently adopted are the protection of the cave environment, the safety of the visitors and a correct profit from the cave management. All such criteria must be taken into account otherwise the development would have very negative effects.

As David Summers (2012) stated, the worst fate that can befall a cave is for it to be developed as a show cave, then for it to fail as a business entity, and be closed. The cave becomes very vulnerable to misuse. Therefore the show cave must not be profitable for the short term, but perpetually.

The view that a show cave is a golden goose laying golden eggs implies that the goose must be properly fed and protected. This means that is necessary to having all of the knowledge and awareness regarding the physical needs of the cave to ensure that its environment is preserved and conserved.

Recent years have seen a veritable plethora of innovations and concepts relating to the best cave management, which are here pointed out.

3. Materials

3.1. Conventional materials

3.1.1. Surface infrastructures

Buildings, with the ticket office, direction, guides, souvenirs, etc., were built as close as possible to the cave entrance. The same criteria were followed for the car and bus parking, which were asphalted. Often these areas were close to the cave and, in particular, above the cave itself, with the consequence of avoiding the rainwater percolation.
3.1.2. Pathways

The first developments of show caves had a minor impact on the environment because in general the pathways were obtained by carving some steps into the rock in order to decrease to a minimum the displacement of material into or out the cave. Also formations, mainly flowstone, were excavated to allow an easy transit of visitors.

A further improvement was obtained with concrete (reinforced when necessary) for steps and floor. This material has no adverse effects on the cave environment because from a chemical point of view has the same composition of limestone. The iron or steel used to reinforce the cement could sometimes cause breaks when got rusty.

The handrails in stainless steel were also a convenient solution, particularly when they were also used as pipes to provide water in different parts of the cave to wash out the pathways. The higher cost of stainless steel was justified by a lack of any maintenance also after many years of operation (Cigna et al. 2000).

Sometimes zinc plated iron structures solved the problem of providing pathways in difficult situations as overcoming cave passages at a level higher than the lower floor or negotiating upwards or downwards a pothole or a big hall (Fig. 2). It must be stressed that zinc is toxic for cave fauna and therefore it is acceptable only in caves with an important water flow that assures a good dilution of any zinc release.

![Figure 2. Zinc plated iron pathways in the Su Munnau Cave, Sardinia, Italy (Photo Cigna).](image)

Occasionally only, wood was used for bridges and staircases because of its decay in a wet environment (Fig. 3). Its use in ice caves was frequently adopted because it is less slippery and the organic decay is absent in this special environment. In temperate temperature caves wood becomes an important food source altering the cave biota.

3.1.3. Lighting

The lighting candles, torches and oil lamp were successfully substituted by electric lamps in the XX\textsuperscript{th} Century. Unfortunately the overall luminous efficiency of incandescent lamps is no higher than 5% the rest of the energy being released as heat. This fact implies an unwanted release of energy to the environment and a higher cost of the power supply.

![Figure 3. Wooden staircase in Grotta di Trebiacino, Trieste, Italy. These staircases have been initially installed in 1994 during the investigation for providing water for Trieste. The platforms (top in the photo) were installed one century ago in pitchpine treated with copper sulfate and charcoalite (Photo Masiun/SAS).](image)

3.2. Modern materials

3.2.1. Surface infrastructures

The siting of the above ground facilities must be well planned by avoiding that these features be built over the cave itself, or relevant parts of it. In particular any intervention such as the watertight surface of a parking area must be avoided. Any change in the rainwater seepage into a cave as well any change to the land above the cave may have a negative influence on the cave and the growth of its formations.

3.2.2. Pathways

In the last ten years new material were developed with incredible advantages with respect to the past. In particular the pathways can be built entirely with plastics. The material used for the pathways, including the railing and kickplate, are manufactured by a pultrusion process. It is in a continuous molding process whereby reinforcing fibres are saturated with a liquid polymer resin and then carefully formed and pulled through a heated die to form a part. Pultrusion results in straight constant cross section parts of virtually any shippable length where continuous fibreglass roving and mat is covered by resin. The resin used for handrails is, e.g., isotropic polyester and the resin used for other components is vinyl ester. Both have a low flame spread rating of 25 or less. These materials are delivered in various colours, avoiding, e.g., the brightness of the stainless steel that is not aesthetically agreeable.
Protection and Management of Karst, Education – oral

2013 ICS Proceedings

These components have abut one-third the weight of steel allowing easy installation using standard circular or sabre saws. Stainless steel bolts connect the different parts. Such pathways may be easily repaired or modified to adapt to new layout if necessary.

Since the mechanical properties of this materials are very close to steel’s properties it is evident the advantage because also long sections can be easily transported inside a cave, while the different parts can be easily worked out with simple instruments.

3.2.3. Lighting

Nowadays very efficient light sources have been developed. The most useful in caves are the LEDs and the cold cathode lamps (CCL). Both are characterized by a very long life of 50,000 hours and longer. The LEDs cost from 20% to 100% more than CCLs for the same results.

Table 1. Indicative comparison of the overall luminous efficiency per input power for different lamps (lm/W).

<table>
<thead>
<tr>
<th>Lamp</th>
<th>lm/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent (IL)</td>
<td>15</td>
</tr>
<tr>
<td>Light emitting diodes</td>
<td>45</td>
</tr>
<tr>
<td>Light emitting diodes</td>
<td>67</td>
</tr>
</tbody>
</table>

In Table 1 a comparison among the overall luminous efficiency (as lumen/watt) per input power for incandescent lamps (ILs), LEDs and CCLs.

The advantage of the new light sources is evident both for the cost of lighting and the long life of the lamps. But these new sources have specific qualities of their own. LEDs are point sources while CCLs are linear. LEDs may be chosen with different temperature colour, i.e. warm (with a red component) or cold (more white). CCLs may be produced with a negligible contribution of their emission spectrum in the regions (around 430-490 nm and 640-900 nm), which mostly contribute to the chlorophyllian process. In this way the proliferation of lampe fleura is reduced.

The emergency lighting can be obtained at a very low cost with the “rope light” i.e. a flexible plastic polymer rope with lights in inside that can be cut at a convenient length and placed along the pathways (Fig. 4). In particular such emergency lights can be divided into two sections distributed alternatively and connected to two different power lines in order that, in case of a failure of one section, there will always be another one in operation.

Such a kind of lighting can also supply enough light to the pathways in normal conditions, and special features only must have additional light sources.

3.2.4. Environmental monitoring

In the past a complete network to supply environmental data to a central computer was considered a best solution data to a central computer was considered a best solution to be achieved. But it was experienced that such a network might be convenient for larger caves only. The main problems being a relatively high cost (installation and maintenance) and the danger of damages due to lightning, which may discharge high tension peaks on the line connecting the sensors with the main computer.

4. Methods

4.1. Conventional methods

4.1.1. Pathways

In the past the layout of the passages was simply obtained on the spot according a procedure quite similar to that adopted for the staircase of Fig. 1. Later, the use of concrete and the excavation into the rock of formations required a more detailed preparation.

4.1.2. Lighting

The layout of the lighting network was often left to local electricians, resulting in a bundle of cables close to the passages, with the lamp sometimes attached to cave walls or formations.

4.2. Modern methods

4.2.1. Pathways

The design of fibreglass pathways needs a detailed survey of the strip where the pathway itself will be installed, because each element can be prepared in advance according
Protection and Management of Karst, Education – oral

2013 ICS Proceedings

the design. During the assembly of the pathway the legs require only small adjustment that can be easily obtained with sliding feet.

4.2.2. Lighting

The power supply must comply with both the country rules, which at present are in general rather severe and the aesthetic requirements. The plastic pathways may host below the platform and along the legs, pipes with the cables of the power supply. The cable network may be somewhat more complex than in the past because in general only the parts of the cave occupied by visitors should be switched on. The power supply of the emergency light should be split into at least two independent sections as reported above.

4.2.3. Other networks

In case of a complete network to supply environmental data to a central computer, as well as the telephone, cables run into other pipes. To improve visitors’ safety, a special network enabling a guide to talk with the outside office from any point of the cave would be strongly advisable.

4.2.4. Visitors carrying capacity

As it is well known, caves may be classified caves into widely different energetic categories. Heaton (1986) proposed three categories: high-energy, moderate-energy, and low-energy levels. In order to avoid any permanent change in the environment equilibria it is necessary to avoid the introduction of energy beyond the intrinsic cave capacity. Such a constraint implies a limitation of both electric power supply for the cave lighting and the visitors’ flow, i.e. the visitors carrying capacity.

This limit may be evaluated according different methods and specialists only are entrusted to carry out the whole procedure according the best choice to be applied to each local situation (e.g.: Mangin et d’Hulst 1996; Lobo et al. 2013).

5. Conclusions

The UIS Management Guidelines for Show Caves are very useful recommendations, if not a list of the least requirements, for a good development and management of a show cave. But such guidelines do not include the principle that it is imperative to keep oneself always up-to-date with the advancement of technology. But it is also important to have an open mind and not to stick to old solutions when something new and more reliable becomes available.

Since technology is evolving so fast, it is often impossible to suggest or recommend the best solutions because in the meantime an important improvement has already occurred.

In addition to the new materials and methods reported above, any data collection might be of little or no use at all in the absence of persons who have the capacity to take advantage of the data themselves. Probably a good Scientific Committee abreast of the management is the most important tool to assure a good development of a show cave. In any case the members of such a committee must obviously have a deep competence in their specific fields of interest but also a good knowledge of the cave environment is instrumental.

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References


