PART FOUR

Planning and Management

Conservation and Management of Cultural Heritage Sites on the Silk Road in Kyrgyzstan

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Abstract: *On the central Asian portion of the Silk Road, a number of historic and cultural monuments have attracted interest from people throughout the world. Kyrgyzstan (the Kyrgyz Republic) has not received much of this attention, however. This paper addresses the current situation in Kyrgyzstan regarding the state of preservation and restoration of these sites, many of which are located in the north in the Chui River valley and the Lake Issyk-Kul basin. Because of the increasing number of tourists to these sites, several measures have been taken by the government to preserve them. Researchers have studied a number of sites throughout Kyrgyzstan. Some of these are already open to the public, and state agencies are in place that formally control tourist flow. In addition, private tourism companies have been established.*

Despite these accomplishments, unresolved problems remain. Heritage sites are under exclusive state ownership and lack defined buffer zones and legal registration. Also, there is a lack of coordination among government bodies concerned with the preservation of heritage sites. A number of archaeological sites that are potentially attractive to visitors and have undergone extensive research have not received state financing or undergone exploratory surveys.

With regard to tourism, the major problem is the lack of adequately trained personnel and the absence of policies governing tourist flow. In addition, Kyrgyzstan does not currently have an educational institution that can provide specialized training in the protection of cultural heritage sites. Importantly, the lack of trained personnel extends to specialists in preservation and restoration and, to a lesser degree, researchers.

On the central Asian portion of the Silk Road, a number of historic and cultural monuments have attracted interest from people throughout the world. Although Kyrgyzstan (the Kyrgyz Republic) has not received much of this attention, it possesses important cultural heritage sites that are now gradually becoming better known internationally. This paper addresses the current situation in Kyrgyzstan regarding the state of preservation and restoration of its cultural heritage sites along the Silk Road.

The Silk Road in Kyrgyzstan

Starting in the second century C.E.,[1] transcontinental trade routes crossed the Tian Shan and Pamir Mountain ranges of southern Kyrgyzstan (Bernstam 1952), connecting the countries of the Mediterranean Sea with the Yellow and Yangtze River basins in China (fig. 1). The principal Silk Road routes passed through the Chui (or Chuy) River valley of northern Kyrgyzstan into the Lake Issyk-Kul basin,[2] then via the Bedel pass into Xinjiang in China. Another route led from the Lake Issyk-Kul basin, through the Kegen (Santash) pass, and into Siberia and Mongolia. This route was traversed between 629 and 645 C.E. by Xuan Zang,[3] in part by John of Plan Carpin between 1245 and 1247,[4] and by William of Rubruck between 1252 and 1256.[5]

These extensions of the Silk Road not only connected countries and peoples commercially; they also became a bridge between the cultures of many different civilizations. As such, they contributed to the intensive development of Krygyzstan's territory, culture, and economy and strengthened international relations. The influence of different civilizations on the cultural heritage of Kyrgyzstan is vividly

FIGURE 1 Principal Silk Road routes through Kyrgyzstan.

represented in the ancient monuments associated with the Silk Road, most of which are concentrated in the Lake Issyk-Kul basin in the northeast and in the Chui River valley in the north.

Lake Issyk-Kul Basin

The Lake Issyk-Kul basin is a unique combination of historical, cultural, and natural features (fig. 2). Among its archaeological attractions are petroglyphs, earthen rampart walls from medieval settlements, large barrows made by early nomads, epigraphic memorials, and ancient canals (Vinnik 1974). The basin's cultural heritage was influenced by the natural environment, as well as the primary needs of the ancient inhabitants and their responses to interlinking social, economic, administrative, and religious conditions. The Lake Issyk-Kul basin, which was nominated to the UNESCO World Heritage List in 2004, is a single geocultural region with distinctive cultural elements and, as such, falls within the UNESCO category of a cultural landscape. The physical boundaries of this cultural landscape are defined by the shoreline of Lake Issyk-Kul and by the Terskey Ala-Too Mountain range to the south and the Kungey Ala-Too range to the north.

FIGURE 2 Historical and cultural sites of the Issyk-Kul basin. Courtesy Scientific Research Institute "Kyrgyzrestoration"

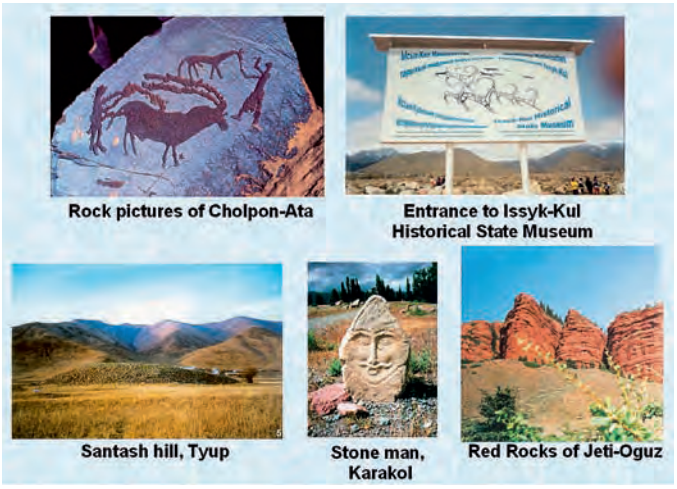

FIGURE 3 Important cultural and natural sites in the Issyk-Kul basin.

Figure 3 shows some of the many remarkable sites in the Lake Issyk-Kul basin. Sites include Jeti-Oguz, a picturesque canyon around the town of Karakol; Tamga-Tash, a rock carved with ancient Tibetan Buddhist inscriptions at the Tamga River gorge; Toru-Aighyr, a small village east of Balykchy, near where eleventh- to twelfth-century baths were discovered; Ak-Chunkur, a prehistoric cave near the Sary-Jazz River; and Cholpon-Ata, a resort center with petroglyphs of animals and hunting scenes dating from 500 B.C.E. to 100 C.E. Many of these sites have been strongly influenced by religious, artistic, and cultural associations with the natural world and therefore fall within the UNESCO category of associative cultural landscape.

The Issyk-Kul cultural landscape formed from the interaction between humans and nature over many millennia. Examples of this interaction are the barrows left by early cultures (e.g., Sak and Usun), the large stones bearing petroglyphs found among human settlements and on foothill terraces, and the ruins of ancient settlements in the form of earthen mounds. Scientific research has confirmed the authenticity of these archaeological sites, whose integrity has been preserved in the contemporary landscape and which are viewed by the Kyrgyz people as an integral part of their habitat. Most of the region's cultural sites still serve as sanctuaries and places of worship (*mazars*) for pilgrims, not only from the Lake Issyk-Kul basin but from other regions of Kyrgyzstan as well.

In 2002, by resolution of the Issyk-Kul State Administration, the Museum Association was established within the Issyk-Kul State Historical-Cultural Museum-Reserve, which consists of 100 hectares (1 km^2) set aside to house a museum and to protect outdoor immovable cultural heritage (e.g., the petroglyphs of Cholpon-Ata, Kara-Oi, Sary-Oi, and Chon-Sary-Oi, as well as the Karool-Debe ancient settlements). The Museum Association supervises both the museum collections and the immovable cultural heritage.

Existing data on the Lake Issyk-Kul basin identify it as one of the world's unique natural and cultural regions. Studies also reveal the alarming fact that the region's cultural sites are in danger of disappearing, despite their significance. Urgent measures are needed to safeguard them and to enhance public awareness of both their importance and their vulnerability.

Chui River Valley

The Chui River valley is the most advanced region in Kyrgyzstan and includes the country's capital, Bishkek. During the early Middle Ages, the area was a major trade, economic, and ethnocultural crossroads of Eurasia.

Archaeological excavations conducted in the Chui River valley between 1940 and 2000 identified cities and monumental architectural constructions dating from the fifth through seventh centuries C.E. (Kyzlasov 1959; Ziablin 1961). Researchers were able to trace cultural and artistic influences from Byzantium to the west, Iran to the south, and China to the east that were left by the peoples who had inhabited the territory. The culture and art of the Chui River valley's Semirechie (Seven Rivers) region from this period are most vividly in evidence at the ancient settlements of Krasnaya Rechka, Ak-Beshim, and Burana, known in antiquity as Navikat, Suyab, and Balasagun, respectively. These ancient settlements, as well as Bishkek, are situated on a branch of the ancient Silk Road that led to Lake Issyk-Kul and then to China.

Krasnaya Rechka, Ak-Beshim, and Burana became unique centers of symbiosis where various cultures came together. The settlements maintained a link with these civilizations by means of the Silk Road, through which passed Buddhist pilgrims and Syrian monks, Sogdian merchants, Turkic tribal leaders, and ambassadors from Byzantium, Iran, India, China, and Xinjiang.

Of special interest at the ancient settlements of Krasnaya Rechka, Ak-Beshim, and Burana—referred to as the Golden Triangle—are examples of early medieval temple architecture reflecting Buddhism, Zoroastrianism, Christianity, and Islam. These monuments are among the finest achievements

of art and material culture to be found in the East, and perhaps in the world.

Preservation Activities

At Krasnaya Rechka (Navikat), the remains of the second Buddhist temple are of particular archaeological interest (fig. 4).[6] The conservation and preparation for visitors of this monument, currently under way, will transform it into one of the most important sites not only at this ancient town, but in the Chui River valley as a whole. This work will involve advances in the field of physical and chemical preservation of earthen structures. Ideally, the most important exhibit of this temple would be the reinstallation of an 8-meter-tall sculpture of the Deceased Buddha. The sculpture now resides in the State Hermitage Museum in St. Petersburg, Russia, and would need to be returned to Kyrgyzstan in order to complete the temple. The safe display of this unique sculpture requires erecting a special shelter over the temple that is in harmony with the surrounding landscape. Additional historical, artistic, and technical investigations of this temple are prerequisites for its preservation.

The ancient settlement at Burana is popular among foreign tourists as well as the Kyrgyzstan people and is dominated by the oldest minaret found in central Asia and the ruins of mausoleums dating from the tenth to the twelfth century. The Burana minaret has become a symbol for the ancient Chui River valley, attracting increasing numbers of history lovers. The site is an open-air state museum of architecture and archaeology, known as a museum-reserve, and its valuable collections make Burana the center of the historical cities constituting the Golden Triangle.

At Ak-Beshim, the important conservation need is presentation and interpretation for visitors of a room in a Christian cult center in what was the ancient settlement of Suyab (fig. 5). The construction of a shelter made of modern materials for protection against atmospheric influences has been proposed. Through this shelter, tourists would be able to view the unique arch. The conservation needs of the Suyab complex at Ak-Beshim are the most urgent, due to both the extremely rainy spring seasons of recent years and unsupervised visits to the monuments by tourists and local inhabitants. The absence of a secure buffer zone is a serious threat to the safety of these archaeological sites.

The proximity of Bishkek, the capital of Kyrgyzstan, to the unique natural and cultural landscape of the Chui River valley makes it possible to turn the ancient settlements at Krasnaya Rechka, Ak-Beshim, and Burana into a center that highlights the area's historical and cultural resources for international tourists. To realize the conservation and tourist use of the monuments at these ancient settlements, it will be necessary to create an international team of experts to develop concepts, programs, and projects. With the financial support of the Japan Trust Fund and UNESCO, preservation of archaeological sites in the Chui River valley is proceeding. The project, known as Preservation of Silk Road Sites in the Upper Chui Valley in Kyrgyzstan: Navikat (Krasnaya

FIGURE 4 Remains of an eighth- to ninth-century Buddhist temple at the ancient site of Navikat in the Chui River valley.

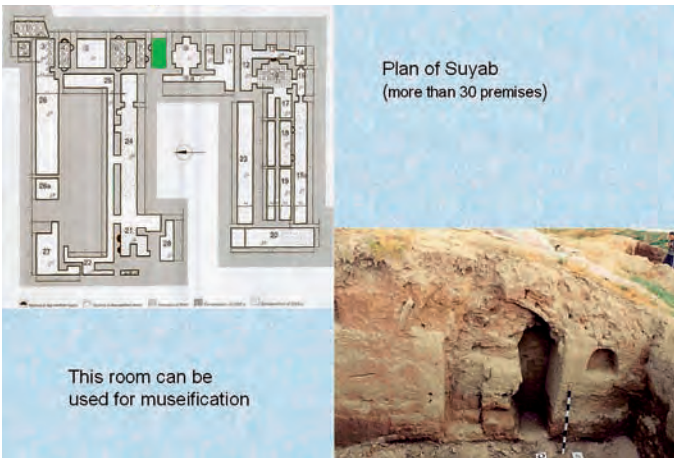

FIGURE 5 Plan of a Christian cult center in the ancient settlement of Suyab in the the Chui River valley. Green rectangle indicates room being readied for tourism.

Rechka), Suyab (Ak-Beshim) and Balasagyn (Burana), is allowing Kyrgyzstan to generate a local cultural tourism revolution, which, it is hoped, will revive awareness of the significance of the traditions of the Silk Road.

Protecting Kyrgyzstan's Cultural Heritage

Tourism and Preservation

The rich historical and cultural heritage and traditions of the Silk Road in combination with a unique natural environment make Kyrgyzstan an ideal place for tourism. Because of the potential economic benefits, the Kyrgyz Republic is developing a number of initiatives to expand tourism, especially international tourism, primarily in the Lake Issyk-Kul basin and the Chui River valley. These sites already have been attracting increasing numbers of tourists, and the volume is expected to grow appreciably as the area becomes more widely known in the tourist market, emphasizing the need to undertake preservation measures.

Today's visitors to archaeological sites want to experience culturally important structures and artifacts in as real a context as possible. Visitors want to experience the elements and forms of construction in ways that will permit them to imagine the former characteristics of a monument that is now a ruin. Informed preservation and effective interpretation have become basic principles in the management of architectural and archaeological monuments. What is required is not simply conservation, but conservation framed by appropriate aesthetic judgment so that sites are exhibited most effectively.

To meet the needs of the country's tourism industry, policies concerning the preservation and use of cultural property are being addressed at the national (state) level. In 1999 the Kyrgyz Republic passed the law On Protection and Use of Historical and Cultural Heritage, which describes the basic objectives and tasks of preserving cultural property in the country and the legislative norms and conditions on the protection and use of historical and cultural monuments. In 2002 the republic approved regulation of registration, research, restoration, and use of historical and cultural heritage properties. In 2003 the president of the republic issued an order strengthening sanctions against illegal archaeological work and research and accepting measures that strictly implement the 1999 law.

As described earlier, two projects aimed at protecting Kyrgyzstan's historical, cultural, and natural heritage are under way: nomination of the Lake Issyk-Kul basin to the UNESCO World Heritage List as a cultural landscape and the Japan/UNESCO-funded work to preserve the Silk Road sites in the Chui River valley.

FIGURE 6 Cultural heritage sites open to tourism in Kyrgyzstan.

Work on these two projects has identified the potential of these areas to create a national tourism industry, as well as the problems associated with their protection, preservation, and use. Over the past six years, a number of programs have been conducted to promote the Lake Issyk-Kul basin for tourist and recreational use. For example, the International Tourist Fair, an initiative of the government of Kyrgyzstan, is held annually at Cholpon-Ata. In addition, health-promotion organizations, travel companies, and relevant governmental bodies issue maps, brochures, booklets, and postcards featuring the area's most interesting sites.

The State Agency for Tourism, Sport, and Youth Policy along with local administrations organize annual meetings on the development of tourism and recreation and the protection and use of the region's historical-cultural and natural sites. International music festivals, including several weeks of activities aimed at children's musical creativity, are held in the recreational areas of the Issyk-Kul basin, and they have become a popular tradition.

Researchers have studied a number of monuments throughout Kyrgyzstan that are already being visited by tourists (fig. 6). In addition to the Lake Issyk-Kul basin and Chui River valley in northern Kyrgyzstan, cultural heritage areas of interest to the tourism industry are found in southern Kyrgyzstan, among them a twelfth-century architectural

complex in the Silk Road town of Ozgon (Uzgen) and the monuments around the sacred mountain known as Suleyman-Too in Osh, which has been nominated to the UNESCO World Heritage Tentative List.

Tourism Development Program

A number of governmental measures have been initiated to coordinate public- and private-sector activities in the development of tourism, to attract investment, to improve tour product quality, and to enable successful promotion in the international and domestic tourism markets. In 1999 the Kyrgyz Republic passed a law on tourism to address the needs of the industry. Subsequently, a ten-year program of development of the Tourism Branch in the Kyrgyz Republic was authorized (Government Resolution no. 33, 2001). This important document on tourism development determines the tasks on which the success of the industry depends. It also creates an opportunity to increase foreign investment, to create employment, and to retain and preserve unique archaeological finds and monuments of natural and cultural heritage. The program's principal elements are

- involving local administrations in tourism and promoting tourism; and
- cooperating with neighboring countries in tourism development on the Silk Road and in the development of visa regulations facilitating tourist travel among the countries concerned.

The Kyrgyzstan tourism development program is being implemented in three stages:

- Stage I, 2000–2002: During this stage, the Ministry of Education and Culture together with the Kyrgyz Republic National Academy of Science developed standards regarding the status of historical and cultural zones of the Silk Road and the preservation of unique archaeological monuments of cultural heritage. Research, restoration, and conservation work, together with enhanced security arrangements, at certain historical and cultural monuments has already begun. The State Committee for Tourism and Sport, working with travel agencies, has developed additional historical and cultural tourism routes. Itinerary sites include the Suleyman-Too historic-cultural and natural museum-reserve; Ozgon (Uzgen); Shakh-Fazil; Manas Ordo; the Burana historical and cultural complex; the Tash-Rabat caravansaray; and the Cholpon-Ata museum-reserve.
- Stage II, 2002–5: During this stage, programs were developed for specialized kinds of tourism (historic-archaeological, cultural-ethnographic, religious, ecological, etc.), and access roads to the country's principal tourist sites were constructed or reconstructed.
- Stage III, 2005–10: This stage envisions the completion of arrangements to create a tourism corridor among the countries located on the Silk Road. This is an extremely serious endeavor and is being studied in all central Asian republics of the Commonwealth of Independent States (CIS) through their Ministries of Foreign Affairs. We hope for a positive outcome such that all countries in the CIS will have a single Silk Road visa.

Administration and Management of Cultural Heritage Sites

The following official bodies in Kyrgyzstan are responsible for the administration and management of cultural heritage sites:

- State Commission under the government of the Kyrgyz Republic on the Development of Culture and State Language. The commission's functions include registration, identification, research, protection, restoration, and use of historical and cultural heritage sites. It is responsible for state museums, historical and cultural museum-reserves, and historical sites of national (state) significance.
- Regional boards of culture. Seven provincial administrative units have functions similar to those of the State Commission but are responsible for museums and sites of regional significance.
- District inspectors' offices. These administrative offices have functions similar to the above but operate on the district level.
- Rural administration. At this level, officials have responsibilities that include those of inspectors but within the limits of the territory of the particular rural administration.
- Museum and tourism associations.

State and local bodies charged with protecting the cultural heritage of Kyrgyzstan have the right to stop any type of economic development work that threatens cultural sites or fails to comply with regulations regarding their protection. If archaeological remains are discovered during the course of construction or roadwork, the company or organization involved must suspend its work, inform the relevant local authorities, and undertake all measures to ensure protection of the archaeological site. State bodies, legal entities, and individuals guilty of breaking the rules of protection or of misuse of cultural heritage sites are subject to administrative or criminal charges according to the laws of the Kyrgyz Republic.

Funds to support preservation activities come from the national budget, local budgets, and private investments. Seminars, courses, and workshops are organized to expand the country's expertise in conservation and management of culturally important sites.

National and World Heritage Sites

According to the Ministry of Culture, there are more than 2,000 historical monuments of local significance in the Kyrgyz Republic. As of January 2006, 583 historical and cultural sites of national significance have been identified. They are divided into the following categories:

Historic	55
Artistic	23
Architectural	101
Archaeological	402
Natural	2

Six of these sites have been submitted to the UNESCO World Heritage Tentative List. They are the Lake Issyk-Kul basin, Suleyman-Too, the Uzgen architectural complex, the Shakh-Fazil mausoleum, the Saimaly-Tash petroglyphs, and the Burana minaret.

According to the 1999 law on protection and use of historical and cultural heritage, the Kyrgyz Republic retains ownership of the country's sites that have been submitted to the World Heritage Tentative List. These sites cannot be privatized, and they have special legal status stipulating that they can be used only for scientific, educational, and tourism purposes. Furthermore, because the nominated sites represent the historical-cultural heritage of the Kyrgyz Republic, they are registered with the State List of historical-cultural sites of national significance.

Looking to the Future

Despite current social and economic difficulties, Kyrgyzstan is taking concrete steps toward the preservation and promotion of its rich cultural heritage. In this regard, Kyrgyzstan is interested in developing contacts for the exchange of experience in the areas of preservation, interpretation, and management of historically and culturally important sites. Kyrgyzstan especially needs help to develop conservation technologies and create computer-based scientific documentation systems, as well as to train national staff in the areas of maintenance, restoration, and preservation of cultural monuments.

Notes

1 This date comes from the account of the travels of Xuan Zang (602–64 C.E.), although other historical documents date the trade routes to the fourth century C.E.

2 The *National Geographic Atlas of the World* (8th ed.) gives the spellings *Shö* for Chui and *Ysyk-Köl* for Issyk-Kul.

3 Born into a poor family, Xuan Zang became a monk at the age of eleven. Since international travel was forbidden by the emperor, Xuan Zang disguised himself and joined a group of central Asian merchants heading west along the Silk Road between 627 and 643. His detailed travel accounts from the Silk Road provide reliable information about distant countries whose terrain and customs were known at that time in only the sketchiest way.

4 John of Plan Carpin (Giovanni da Pian del Carpini), a Franciscan monk, was sent on a papal mission to the Mongol Empire by Innocent IV. He journeyed to Karakorum and China in 1245 and returned in 1251.

5 William of Rubruck was a Franciscan monk sent by King Louis IX of France in 1255 to preach Christianity to the East and to establish contact with Nestorian Christians in the Mongol Empire. The account of his journey is considered the most authentic description of the empire before the conquest of China.

6 In 1961 a Kyrgyz archaeological expedition headed by P. N. Kozhemyako discovered a Buddhist temple complex at Krasnaya Rechka. It became known as the "first" Buddhist temple so as to distinguish it from the second temple discovered later that year.

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Visitor Surveys at Mogao: Pioneering the Process, 2002–2004

Li Ping, Sharon Sullivan, Kirsty Altenburg, and Peter Barker

Abstract: *One of the major problems facing the Mogao Grottoes is the rapid increase in visitors. This increase poses a number of problems: it may threaten the conservation of the fragile site, and overcrowding and pressure on available facilities may impair visitors' experiences at the site and their appreciation of its cultural value.*

Site conservation and visitor satisfaction and education are major objectives of the visitor management and interpretation subplans in the master plan for the Mogao Grottoes. To design strategies that effectively meet these objectives, the managers at Mogao decided that it was essential to systematize visitor information and to collect it regularly and in detail. Research into visitor origins, types, experience, and behavior at the site is as vital to successful management and conservation of values as is research into the physical condition of the cave paintings and sculptures. This paper describes the pioneering efforts of the staff at Mogao to design and conduct visitor surveys, and it reports and discusses some of the results obtained.

The rapid increase in the number of visitors to the Mogao Grottoes poses a number of problems for managing this World Heritage Site, which Altenburg and colleagues address in a related paper in this volume, "The Challenge of Managing Visitors at the Mogao Grottoes." Overcrowding threatens the fragile environment of the Mogao Grottoes and also puts pressure on site facilities and reduces visitors' experiences and their appreciation of the cultural values the site has to offer. The issue facing the Dunhuang Academy Reception Department, which is responsible for visitor management at the site, is how to effectively use the site to educate the public and allow more people to experience the outstanding culture at Dunhuang while at the same time improve conservation of the grottoes.

The Reception Department has been looking at these issues for some time, recognizing that detailed data were needed about visitors, including where they came from, flow patterns, expectations, their experiences at the site, their behavior, and the level of satisfaction and education they gained from their visit. The department had been receiving information on visitors from a number of sources, including the observations of Mogao staff guides,[1] data on visitor numbers, and feedback from tourism authorities and visitors themselves, but these data needed to be collected regularly and in more detail. Such visitor research is as vital to successfully managing the site and conserving its values as is research into the physical condition of the cave paintings and sculptures.

To obtain more detailed visitor information, the Reception Department has undertaken surveys to learn about visitors' experiences and obtain their evaluations of the management and services provided at the site. With this information, it hoped to uncover problems, improve management and the level of services provided, and improve implementation of the academy's general policies on conservation, research, and education. Specifically, the department hoped to apply this information to carry out the objectives outlined in the Mogao Grottoes Conservation Master Plan, 2005–2025, foremost among them site conservation, visitor satisfaction, and education.

Beginning in mid-April 2002, under the leadership of the Dunhuang Academy and with support from the General Office, the Research Institute, and the Grottoes Management Department, the Reception Department worked with colleagues from the Australian Heritage Commission to design

FIGURE 1 The Mogao guides who accompany visitors to the caves and provide commentary.

major visitor surveys that would be systematically administered. Five surveys were undertaken in which visitors filled out questionnaires: four surveys provided general data to assist visitor management; one survey asked visitors specific questions relating to conservation issues in the caves.[2] In addition to these surveys, Dunhuang Academy staff conducted an observational study of visitors during a national holiday week to examine their behavior under crowded conditions.

All visitors who enter the caves must be accompanied by a Mogao staff guide (fig. 1). Individuals who are not in tourist groups normally have to wait at the entrance to the Grottoes Zone for approximately fifteen minutes until enough visitors arrive to make up a group of about ten to twenty.[3] The visitor experience is affected by the length of the visit, the number of caves visited, the number of people in the group, and the style and content of the commentary provided by the guide.

Survey Design and Distribution

The questionnaires used in the five surveys were not identical. Four of the five surveys used general questionnaires that varied depending on whether visitors were surveyed during normal operating times between the low and high tourist seasons, when the flow of visitors is moderate; during the high tourist season; or during one of the national holiday weeks in May and October, when the cave visitation system changes to accommodate high visitor numbers and the visitor experience is qualitatively different.

Each of the four general questionnaires contained twenty-two questions. The first eight questions and the last question of these questionnaires were identical and designed to obtain information on gender, age, domicile (in China, this refers to residents of Hong Kong, Macao, and Taiwan) or nationality, whether the visit was in a group or individual, transportation to Dunhuang, percentage of first-time visitors to Mogao, sources of information on Mogao, reason for visiting Mogao, and visitors' comments on their experience at Mogao. Space is provided for suggestions and criticisms.

The fifth survey was designed to test what visitors learned on-site in the high season. In addition to the standard questions, ten specific questions were designed to determine how effectively the guides communicated basic knowledge and information about the site to visitors.

The surveys undertaken during the national holiday weeks contained specific questions on visitor experience at the site, reasons for visiting the site at that time, and, since visitors were not accompanied by staff guides, how much visitors had learned about the site. One question asked visitors for their "opinion of the conservation of the site." A separate survey focused on specific questions relating to conservation issues in the caves.

The questionnaires were designed to be short—visitors should be able to fill them out without reducing their visit time—yet obtain the specific information needed to improve management of the site. They were based on international examples and experience but also relied on the local knowledge of staff members and their view of the specific information needed. The questionnaires were in English, Chinese, and Japanese.

To encourage participation in the surveys, small souvenirs were provided to everyone who completed the questionnaires. The majority of visitors responded positively and supported the survey effort.

Visitor Surveys

April 17–29, 2002. The questionnaire for this survey was developed to collect standardized baseline information for visitor management use. It was designed to be conducted during normal operating times, such as late April, when visitation is moderate and visitors do not put too much pressure on the Mogao guides. Data collected from this questionnaire provided insight into the visitor experience, as well as

an overall evaluation of site management and services. The guides distributed the questionnaire after finishing their commentary in the caves. Visitors completed the survey at the site with the guide present.

August 1–6, 2002. This questionnaire focused on education and was designed to test what visitors learned on-site from the guides. The survey was undertaken in the high season to test the effectiveness of the guides' commentary when the site was crowded. The guides distributed the questionnaire after finishing their commentary in the caves. Visitors completed the survey at the site with the guide present.

May 1–5 and September 30–October 5, 2002. These two surveys were conducted during national holiday weeks. Because of the large number of visitors at this time (figs. 2, 3), the management system is changed, allowing access to fifteen open caves, with two or three staff guides stationed in each cave to provide continuous commentary. Because of these changed conditions, a different questionnaire was needed to seek feedback on visitor experience and level of satisfaction on the issues of overcrowding, noise, quality of guide commentary, and provision of other services. Also, a different method was used to distribute the questionnaires as the guides were fully occupied in the caves providing commentary. Staff distributed and collected the completed questionnaires at the entrance to and exits from the Mogao site (at the Nine-Storey Pagoda and the Small Archway). There was less opportunity for the Mogao guides to influence the visitors' comments, as the latter were not being guided in groups, as occurs at all other times. Data from these surveys provided information on visitors' experiences, their views on conservation, and their degree of satisfaction with visitor services. It should be noted that in April and May 2002 both domestic and international tourists were surveyed, whereas in August and October 2002 only domestic tourists were surveyed.

May 1–6, 2004. During the national holiday week in May 2004, the Reception Department surveyed visitors using questionnaires that focused on their perspectives on lighting and protective barriers in the caves (fig. 4). This provided useful information for the Visitor Carrying Capacity Study.

Visitor Observation Study

During the national holiday week of May 1–6, 2004, dedicated personnel also observed and recorded visitor behavior in cave 16 and logged visitor numbers (fig. 5). This cave was chosen because it is very large, with well-preserved Western Xia dynasty (1038–1227) paintings. It has some lighting and protective railings but no glass barriers, and it contains the entrance to the renowned Library Cave. As one of the caves that every visitor to Mogao wants to see, cave 16 provided an opportunity to study visitor behavior unobserved.

FIGURE 2 Vistors at the Mogao Grottoes during a national holiday week. At this time they are not accompanied by guides.

FIGURE 3 Crowded conditions during a national holiday week.

FIGURE 4 Visitors filling out survey questionnaires.

FIGURE 5 Mogao staff (left) observe visitor behavior in cave 16.

Survey Results

The Reception Department compiled and analyzed the survey data. Table 1 summarizes survey data on basic visitor information. Table 2 summarizes survey data on visitor satisfaction. Table 3 summarizes visitor behavior and numbers in cave 16.

Shortcomings

This was the first time the Reception Department of the Dunhuang Academy conducted formal visitor surveys at the Mogao Grottoes. Although considerable time was spent preparing the surveys and visitors actively participated in them, there were some areas that did not produce the hoped-for results. This was due to shortcomings in the survey process, as follows:

- Some people found the forms too long, which contributed to incomplete responses.
- Visitors to the site are often on a tight time schedule, particularly if they are part of a tour group, and this may also contribute to incomplete responses.
- Responses may have been influenced by the tour guides when they collected the forms. Also, visitors may not have experienced the full range of attractions at the site before filling out the forms. This problem resulted in a lack of good data on the Exhibition Center and the display on the history of the Library Cave and its artifacts in Abbot Wang's Temple.
- Methodological problems with the education questions resulted in a lack of convincing data on the information given to visitors and how they interpret it.
- Staff probably need more formal training in administering the questionnaires.

Improvements to the questionnaires have already been made, and their effectiveness and the survey methodology will be monitored and refined as needed.

Despite these shortcomings, the surveys provided a great deal of information that has important implications for management. They have also given the staff valuable experience in survey methodology. The results have been widely discussed and analyzed by site personnel, who are beginning to use them in day-to-day problem solving and in the further development of the Mogao master plan. The implications of some of the survey results are discussed below.

Basic Visitor Information

Gender. More men than women visit the site. This is explained by visits to the site by domestic business visitors, a great majority of whom are male. The guides have noticed that when groups comprise both men and women, it is common for the men in the groups to fill out the questionnaire.

Table 1 Basic Visitor Information

National origin	Foreign: From Asia, Europe, North America, Australia
	Domestic: From almost all of China's provinces, autonomous regions, and four municipalities under the control of the central government
Gender	Males exceeded females, especially in April.
Age range	Broadly representative, with the majority of visitors between 14 and 45 years old
Transportation to Dunhuang	Foreign visitors: commonly by air
	Domestic visitors: commonly by rail
Tour groups v. independent visitors	Foreign visitors*: 80% of 30,000 people surveyed visited in tour groups
	Domestic visitors*: 40% of 290,000 people surveyed visited in tour groups
First-time visitors	The percentage of first-time visitors to Mogao was seasonal:
	During the August 2002 survey, around 20% of people were repeat visitors.†
	During the April and October 2002 surveys, repeat visitors accounted for less than 15%.
Sources of information about Mogao	More than 50% of visitors learned about the site through radio, television, newspapers, or the Internet.
Reason for visiting	April 2002: 90% of visitors cited tourism; 10% academic study.
	August 2002: 15% of visitors cited academic study. (They were mainly high school students, heritage or museum professionals, academics, or scholars. This increase in academic study visitors also coincides with peak tourist numbers visiting the site.)
	May 2002: 90% cited tourism.
	October 2002: 82% cited tourism.

*2002 data. Foreign visitors only were included in April and May 2002 surveys. In August and October 2002, only domestic visitors were surveyed.

†In August 2002, the number of tourists from Gansu province increased. They came from companies in Lanzhou, Jiuquan, and Yumen that organized short-term summer holidays for their employees. This probably explains why there were so many repeat visitors to the site that month. August is also the month when tertiary institutions have their long summer break, and many teachers and students from fine arts tertiary institutions visit the site to carry out research, some of whom come for the second or third time.

First-Time Visitors. Most of the visitors had not been to the site previously. Information and services need to be provided that are suitable for both domestic and foreign tourists visiting for the first time. Tour guides need to engage especially first-time visitors; they need to use lively, vivid descriptions offering both general and in-depth knowledge to make visitors' experiences both enjoyable and educational.

Students and Scholars. While most visitors come to Mogao for tourism, a small but significant number are students and scholars wanting to learn about the caves in a more formal academic sense. This requires the ability on the part of site personnel to provide specialized guidance.

Time Pressure. Both domestic and foreign tourists visit a range of other attractions in the region. Most visits to the Mogao Grottoes are concentrated into a short time, which can lead to overcrowding and poor service.

Visitor Age Range. The majority of visitors are between the ages of fourteen and forty-five. They tend to be independent and active, which has implications for addressing their needs and understanding their behavior on-site.

Tour Groups versus Independent Visits. Forty percent of domestic tourists come in tour groups. Although foreign visitors did not participate in every survey, the data collected indicate that 80 percent traveled as part of a group. A professional guide from the tourist agency accompanies the agency's tour groups. The tourist agencies are quite familiar with the procedures and arrangements involved in visiting the site, and their guides work well with the site tour guides. Tourist agencies also provide advance information about the arrival of tourist groups. For these reasons, tourist groups are easier than independent vistors to manage and organize.

However, few tour groups visit the other exhibits on the site, such as the Exhibition Hall, which features cave replicas,

Table 2 Visitor Satisfaction

Satisfaction with services	April 2002: 96% of visitors were satisfied with or approved of the tour guide's commentary, and most visitors were satisfied with the car park and ticket office. (This high level of satisfaction appeared to be related to the degree with which the guide was present while questionnaires were being completed.) May and October (national holiday weeks) 2002: Only 65–70% were satisfied overall (during the holiday weeks, guides did not supervise visitors filling out the questionnaires). Dissatisfaction increased during the holiday weeks. Issues included flashlight rental, entrances, baggage checks. April, May, and October 2002: 33%, 25%, and 16% of respondents, respectively, were critical of the toilets; only 40% said they were satisfied. Exhibition Hall: Only 23.7% of respondents answered this question. More than 75% of the visitors who did visit the Exhibition Hall were extremely satisfied with it. Food purchases and shopping: The survey forms were collected before many visitors had purchased food or been shopping, which explains why only 13.4% and 17.2% of visitors completed these questions.
Satisfaction with the caves	20% of respondents would like more time to visit the caves and more free time to see the site. 30% would like to see more caves. 30% preferred that groups entering the caves be limited to 10 individuals. 17% of respondents wrote specific comments at the end of the questionnaires, most commonly identifying problems with lighting, air quality, and noise.
Site satisfaction during national holiday weeks (May and October 2002)	Visitors managed to see only 50% of the 15 open caves, citing difficulty in identifying the cave locations. 55% of May visitors, and 36% in October, complained that the large number of visitors negatively impacted their visit. Problems identified included overcrowding in the caves, visitors unwilling to line up, and the wait to get into caves.
Satisfaction with conservation efforts	More than 50% of respondents indicated that more should be done to conserve the caves and in a more comprehensive manner.
Satisfaction with cave lighting and protective barriers	47% believed that improved lighting in the caves would enhance viewing of the wall paintings (most caves are unlit and viewed with flashlights). 53% believed that electric lighting should not be installed because of its impact on conservation of the wall paintings. 53% believed that the protective glass barriers were an advantage to cave visitation and conservation. 47% believed thae barriers impinged on viewing the wall paintings.

Table 3 Visitor Observation Study in Cave 16

Visitor Origin	Total Visitors Counted	Visitors Touching Wall Paintings
China	16,683 (91.6%)	705 (4.2%)
Foreign	1,529 (8.4%)	3 (0.2%)
Total	18,212	708

FIGURE 6 Domestic visitors exploring Mogao independently.

and the Middle and Lower Temples, which cover the history of the Dunhuang Academy and conservation at the site. This is an issue that needs to be worked out with the tourism authorities. Some tour groups do visit the Exhibition Hall, but the vast majority are immediately returned to Dunhuang by tourist agency guides after visiting the caves and shopping.

The survey data show a growing trend among domestic visitors to visit independently, and this has important implications for site management (fig. 6). Independent visitors cannot be planned for as easily as tour groups. Although people taking part in group tours had the same general aims as individual travelers for their visits to Mogao, individual tourists tended to have a greater range of needs and expectations. For instance, individuals might have special research or academic interests in Chinese history, art, religion, or music. Especially difficult to organize and manage are independent visitors who require commentaries in foreign languages. The Reception Department is not well positioned to deal with the less common languages, such as Korean or Italian, and this is an area being worked on.

Source of Information about Mogao. More than half of the survey respondents learned about the site through the media—radio, television, newspapers—or on the Internet. This means that the media can be effectively used to tell visitors about the importance of the site, its management, and its services before they arrive.

Visitors' Basic Knowledge about Mogao. More than 95 percent of visitors correctly answered questions designed to test basic knowledge of the site. However, for various methodological reasons, this information is not always accurate; therefore, these questions need to be redesigned.

Satisfaction with Services. Visitor satisfaction with the provision of services varied. During the holiday weeks in May and October 2002, the number of dissatisfied visitors increased dramatically, peaking in October. There were some obvious problems identified with the entrances, baggage checks, flashlight rental, and toilets. Dissatisfaction with flashlight rental (most caves are unlit) was identified as a problem that urgently needed to be solved, as the poor quality of the flashlights has a direct impact on the quality of the visitor experience. This finding has implications for work under way as part of the Carrying Capacity Study to determine whether to provide more lighting for visitors in the caves.

Most visitors were basically satisfied with the car park arrangement and ticket office. However, visitors rated as only "average" the service received at the entrance, baggage check, and flashlight rental. The survey identified a very high level of dissatisfaction with the toilets, although this decreased to some extent in October 2002, probably as the direct result of no longer charging for their use. Accurate figures were not obtained on satisfaction with the Exhibition Hall and food and shopping. A more targeted survey is needed to obtain accurate figures on visitation to the Exhibition Hall and purchasing food and shopping.

These findings highlight the need to reorganize services to make them more efficient and to provide training to attendants in these areas to more effectively deal with visitors. Management is already taking steps to improve services. Providing average or sometimes below-average services is unsatisfactory at a World Heritage Site. Management is striving for excellence in all areas.

Satisfaction with Staff Tour Guides. Visitors appreciated the service they received from the staff tour guides. The high degree of satisfaction or approval of the guides' commentaries in April 2002 may represent some bias in the results because of the guides' involvement in distributing and collecting the questionnaires. Satisfaction fell 25 percent during the holiday weeks in May and October 2002, when completion of questionnaires was not supervised by the guides. The survey techniques should be refined to clarify this point. The survey results do suggest that the tour guides are well trained and consider dealing effectively with visitors among their major roles.

Satisfaction with Site Experience. Overall, visitors were satisfied with their experience at the site. Some

visitors would have liked to spend more time in the caves and hoped that tour group numbers at the caves could be limited. These suggestions are being considered, although they are difficult to resolve at the present time. The number of visitors to the caves and the length of the visits are limited by the number of tour guides; because of conservation concerns, visitors are not allowed to walk into any cave at will. The conservation of the site is given absolute priority, and tour guides are asked to inform visitors about the significance and importance of conserving the site to gain their understanding and support.

The national holiday weeks pose significant challenges to visitors' site experience. At other times, the majority of visitors felt they had benefited from their visit. However, in May and October 2002, when visitor numbers were high, only half the visitors managed to see all of the open caves,[4] and their satisfaction rating dropped significantly (only 55% were satisfied in May; 36% in October). Likewise during this period, visitors identified overcrowding in the caves and on the walkways, the level of noise, and deterioration in the quality of services as negative influences. It seems clear that the major influx of tourists during the holiday weeks has a significant deleterious effect on visitors' enjoyment and on their ability to appreciate the site.

With the recent expansion of the Dunhuang airport and the future completion of the railway line into the town of Dunhuang, visitor numbers can be expected to increase dramatically. Findings from the surveys about visitors' experiences at the site will be crucial in discussing with tourism authorities ways to mitigate crowding problems while also continuing to provide and *improve services to visitors.*

Satisfaction with Lighting. Poor lighting in the caves was identified by over 50 percent of visitors as the factor that influenced their experience most negatively. This confirmed that poor lighting significantly impedes visitors' appreciation and understanding of the site. But when asked whether they approved of the trial caves lighted by electricity, 53 percent of visitors were concerned about the possible negative effect on the wall paintings and felt that flashlights were more conservation-friendly. This information will be an important consideration in the experimental work under way to provide increased lighting in some caves while ensuring their ongoing conservation.

Satisfaction with Glass Barriers. Visitors were ambivalent about the use of glass barriers to protect the site. Many felt that the barriers impeded their view but that their removal might affect conservation. The tour guides' observations of the number of people touching the paintings in the unprotected areas was confirmed during informal observations of visitor behavior during the holiday week (May 2002) and during the visitor observation study in cave 16 (May 2004). This finding indicates that this issue requires careful consideration.

Satisfaction with Conservation. When asked about the conservation of the site, more than half the survey respondents said more should be done to conserve the caves and that both a comprehensive approach and more detailed conservation methods should be adopted. Visitors expressed concerns that the environment and crowding in the caves are endangering the paintings.

Some visitors even suggested limiting the number of caves that are open to the public in order to conserve the site better. The results show that the visitors' level of education is continuing to rise and that there is some awareness about the importance of conservation. From the specific comments visitors provided about the site and the conservation of the caves, they appear to be well educated and understand the conservation issues well. This feedback from visitors is encouraging as it indicates their appreciation for the site and the high value they place on it. It provides important information for site managers to use in their discussions with municipal and regional colleagues about the conservation of the site.

Visitor Behavior. The observational study conducted in cave 16 showed that only a small percentage of people touched the wall paintings, but extrapolated over time, this behavior will obviously have significant consequences. Touching is much more likely to occur during the peak season or during long holiday weeks when the caves are very crowded. This finding reinforces the need to improve the booking system and use other methods to reduce crowding and ensure adequate supervision. The observations also demonstrate the important role of the guides and managers in protecting the paintings when there are no glass barriers and the need to improve visitor education regarding the conservation of wall paintings.

Conclusion

The visitor surveys and the visitor observation study conducted in cave 16 have provided management with useful information about the experiences and behavior of visitors at the Mogao Grottoes. This information has already been used to improve visitor services.

The Reception Department plans to administer surveys on a regular basis to continue providing data for the visitor carrying capacity study and to assist in improving management's work at the site. The next tasks are to refine and readminister the surveys, design a manual for administering the surveys, and develop an appropriate training program that will ensure regular and consistent collection of data over time.

Notes

1 All visitors to the caves are accompanied by Mogao staff guides who provide information and commentary on the history, conservation, and use of the site. Tourist groups may also be accompanied by their own tour guide, but the guides referred to in this paper are Mogao staff members.

2 A similar survey, asking specific questions relating to visitors' experiences at the Exhibition Hall, was undertaken in 2005.

3 The Dunhuang Academy regulations state that each tour guide should take a group of about ten to twenty visitors; groups should be taken into about twelve caves over the morning or afternoon; and the total amount of time in the caves should be about two hours.

4 The site covers a large area, and although there is clear signage and colored flags at the entrance to the caves, many visitors have difficulty finding the exact location of the open caves.

The Challenge of Managing Visitors at the Mogao Grottoes

Kirsty Altenburg, Sharon Sullivan, Li Ping, and Peter Barker

Abstract: *Tourism in China has been increasing dramatically in recent years, and the exquisite paintings and sculptures of the Mogao Grottoes have become a major attraction for Chinese and foreign visitors. This paper presents information on the increase in and seasonal fluctuations of visitor numbers and the serious overcrowding during peak holiday periods. It describes the overall concept of visitor management with targets and strategies to improve the visitor environment and relieve the extreme pressure on the caves during peak seasons. These strategies include regular training for tour guides, multilingual tours, well-planned tour routes, and the rotation of caves that are open to visitors. In an effort to ensure that visitors enjoy and appreciate the artistic value of the caves, we conducted visitor surveys and incorporated their suggestions and comments into the visitor management program. Timely improvements have qualitatively enhanced the visitor experience. We conclude that effective conservation of the site must take into account sound visitor management to ease the growing conflict between tourism and preservation. We describe plans and proposals to enhance this effort.*

The Mogao Grottoes are a cultural resource of inestimable value to humanity. The grottoes are an irreplaceable and nonrenewable resource with unique historic, artistic, and scientific significance. Tourism, both domestic and international, has developed rapidly in China over the past few years. This paper discusses the specific challenges associated with the rapid development of tourism for the site managers at Mogao.

Conservation of the Mogao Grottoes

The work of the Dunhuang Academy commenced in 1944 with a focus on research and the conservation of the Mogao Grottoes. The site was inscribed in the World Heritage List in 1987, meeting all six criteria for cultural values. The Chinese government approved the formal opening of the Mogao Grottoes to the public in 1979.

Over the past two decades, tourism has increased at Mogao, making visitor management and interpretation an increasingly important aspect of site management. The director of the Dunhuang Academy, Fan Jinshi, has been central to this process, as related in other papers in this volume. She played a key role in the development of the China Principles, published as the *Principles for the Conservation of Heritage Sites in China* (Agnew and Demas 2004), and provided leadership in understanding the importance of identifying and clarifying cultural significance to managing the values of the site.

Mogao Grottoes Master Plan

Using the China Principles to guide the process, Fan Jinshi actively endorsed and contributed to the development of the Dunhuang Mogao Grottoes Conservation and Management Master Plan 2000–2010. The master plan identifies the cultural values of the site, assesses its opportunities and threats, and develops goals and objectives and subplans to realize these objectives. Visitor management and interpretation is one of the subplans.

Mogao Grottoes Values

The statement of significance in the master plan identifies the historic, artistic, scientific, and public values of the Mogao Grottoes, which are among the most important historic and cultural sites on the Silk Road. It provides extensive information on the official history of China, the Dunhuang region, and the construction of the grottoes at Mogao. It also provides information on Buddhism and the practice of other religions in China.

The wall paintings in the caves provide the oldest continuous, comprehensive, extant record of Buddhist art in the world, as well as an unparalleled record of every aspect of ancient Chinese lifestyles and early technological achievement, including agriculture and warfare. In addition to presenting a unique aesthetic experience, they also reveal the exchange, integration, and development of Chinese and foreign artistic styles and reflect the sinification of Buddhist art.

The Mogao Grottoes encompass important research values on traditional Chinese culture and arts and on the extent and magnitude of artistic categories and styles, in particular those predating the tenth century. In addition to their literary significance, works from the Library Cave, such as poems, essays, and Buddhist narratives and songs, which date from 400 to 1000 C.E., provide an important source of information for research on the linguistic transition from classical Chinese to vernacular Chinese literature.

In regard to public and social values, the Mogao Grottoes are a treasure house of traditional Chinese culture and a preeminent place to visit for Chinese and foreign Buddhists. Mogao is highly valued by the local population. It serves as a creative inspiration to contemporary artists and provides all visitors with a unique cultural experience in the appreciation of ancient art and culture. Moreover, visitation at the site provides economic benefits to the local community, as well as to the province and nation.

The richness, age, and importance of the site, and its consequent World Heritage listing, give us a potential management conflict. Large numbers of people want to visit the site, and it is important that they do so to understand and appreciate its values, but the overwhelming numbers pose a threat to the very existence of these outstanding values.

Tourism Pressures on Culturally Important Sites

China is now among the ten most visited tourist destinations in the world. The Chinese government's Western Regions Plan,[1] based on developing tourism as one strategy to grow the economy and raise living standards, exerts great pressure on sites such as Mogao to continue to expand tourist facilities and increase visitor numbers. The development of national infrastructure, including the recent expansion of the Dunhuang airport's facilities and the construction of the rail link, has enhanced the accessibility of Dunhuang and the Mogao Grottoes and other regional sites. This effort by the central government and the province to stimulate the economy is raising the standard of living of people in the region. However, unless this effort is carefully managed, with proper recognition of the heritage values of Mogao, the resulting rapid expansion of tourism can challenge the integrity of the site.

The development of the market economy and growing Chinese affluence is stimulating recreational tourism. Increasingly, large numbers of domestic tourists are traveling within China to places such as Dunhuang that were formerly considered remote. In addition, the number of international visitors to China is growing as tourists from the Chinese diaspora, Japan, and the West seek their traditional roots or an exciting new experience. Global cultural tourism promotes specialist visits to Silk Road sites and religious tours. Mogao is regarded as the spiritual home of Buddhism in East Asia and therefore attracts both domestic and international tourists, in particular from Japan.

Escalating visitor numbers are putting inexorable pressures on the Mogao site—its physical fabric; the caves, with their magnificent wall paintings and sculptures; and its fragile desert environment. Staff who are responsible for the long-term conservation of the site, its presentation and interpretation, and the enjoyment and safety of visitors are faced with intense management challenges. The rapid increase in the numbers of tourists, especially during the two national holidays—the first week of May and the first week of October (known as "Golden Weeks"), which have been heavily promoted by the government to stimulate the market economy—is causing loss of control, and effective management and monitoring at Mogao is inadequate.

Visitors at Mogao Grottoes

More than three million tourists from China and from more than eighty countries and regions have visited the Mogao Grottoes since it was opened to the public in 1979. Visitor numbers built up gradually through the late 1980s and 1990s to reach more than 200,000 in 1998, and by 2000 the number

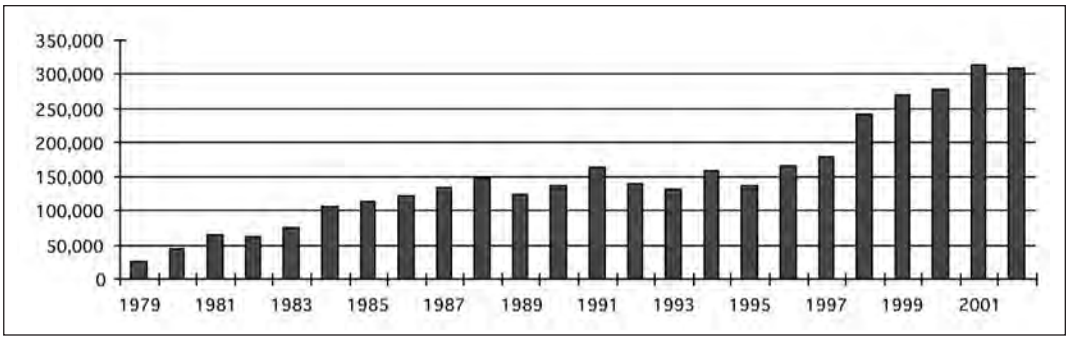


FIGURE 1 Increase in visitor numbers at Mogao, 1979–2002.

Credit: Dunhuang Academy

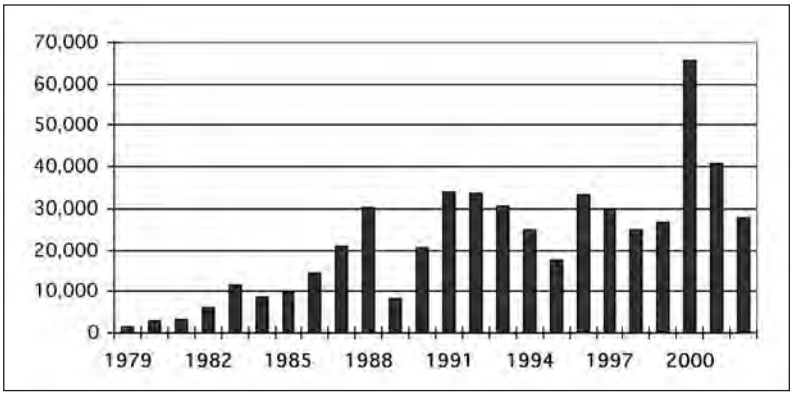


FIGURE 2 Increase in international visitors at Mogao, 1979–2002.

Credit: Dunhuang Academy

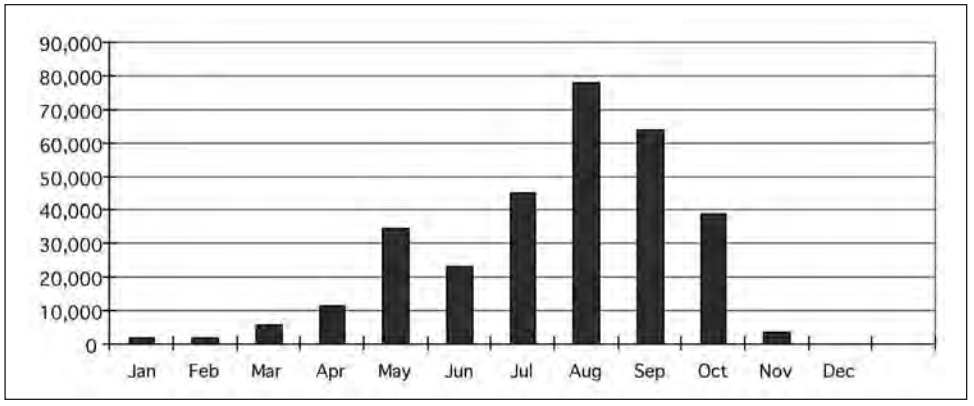


FIGURE 3 Number of visitors at Mogao each month in 2002.

Credit: Dunhuang Academy

exceeded 300,000 (fig. 1). For the past two decades, the number of overseas tourists visiting the Mogao Grottoes has grown steadily, reaching a peak in 2000 (fig. 2).

Visitors to the site are unevenly distributed throughout the year, as shown in figure 3. Visitors are mainly concentrated in the period from July through September. In 2002, of a total of 308,715 visitors, 187,934 (61 percent) visited during this three-month period. There are few visitors in winter.

Visitors are heavily concentrated in the peak season, and they are spending less time at the site. Before 2003, visits normally peaked in the morning, from 8:00 to 11:00, because of airline, railway, and other transportation schedules. Tourist companies typically adhere to tight schedules, with just one day in Dunhuang. Tourists are taken in the morning, when it is cooler, to sites close to the town, such as Crescent Moon Lake and Mingsha Mountain, and then in the early afternoon, to escape the heat, to the Mogao caves, before their departure on the evening train. These visits are restricted by transportation schedules as well as by the hot summer climate of Dunhuang. In 2003 most visitors were concentrated in the period from 1:00 to 3:00 P.M. This creates pressures for the visitor management staff.

FIGURE 4 The entrance to the Xia Temple, which houses the Library Cave exhibition. The exhibition provides valuable information on the history of the Library Cave and relieves visitor pressure on the caves.

Visitor Management

Visitor management at the Mogao Grottoes is organized into two branches: the Reception Department and guide-narrators and the Academy Office, which is responsible for ticket sales and cave management. Each branch is headed by the Dunhuang Academy director and deputy director, who chair joint meetings at which goals and strategies are developed.

Dunhuang Academy trains excellent guide-narrators who accompany all visitors. In addition to providing information in a number of languages, they supervise the safety of visitors and site security. The guides describe the richness of the arts and culture of Dunhuang to domestic and international visitors, playing a key role in the visitor experience of the site. They also play a role in the promotion of China's tourism industry and in the development of the local economy. While commercial guides may accompany tours to the site, each group must be led by a Dunhuang Academy narrator-guide.

The academy continually analyzes the visitor situation at Mogao, and it has taken a number of steps to improve visitor management, trying to keep pace with the rising visitor pressure and expectations. Forty caves and twelve visitor routes through the site have been carefully selected and developed to maximize visitor appreciation of Mogao. A systematic management regime is in place for these caves, and the infrastructure has been improved. An exhibition center with replica caves has been built to reduce the pressure on the caves. In 2003, to further ease visitor congestion, the Xia Temple, with displays about the Library Cave and its wealth of documentation and information, was opened to the public (fig. 4). The Library Cave, one of the richest finds in the world, was discovered walled up behind a hidden doorway in 1900 by Abbott Wang. The cave housed as many as fifty thousand documents: scrolls, printed books, paintings, textiles, and silken banners with mainly Buddhist texts and images. In the decades following Abbott Wang's discovery, the treasures of the Library Cave were scattered to institutions in many countries around the world.

Impact on the Caves

A total of 492 decorated caves exist at the Mogao Grottoes, most of which are quite small. Only a limited number of these caves are suitable for public access. In the peak season of July through September and during the two national holiday weeks, visitors put enormous strain on the staff and the site's resources. The caves become overcrowded, increasing

FIGURE 5 Overcrowding in the caves can damage the fragile wall paintings and diminish visitor experience.

FIGURE 6 A tourist guide pointing to a feature on the wall painting. Damage caused by touching the wall paintings increases during holiday periods.

the temperature and relative humidity inside the caves, causing damage to the wall paintings, and at times causing both guides and visitors to faint (fig. 5). Investigations are continuing to determine whether visitors have an impact on the physical fabric of the caves.

During peak visitation periods, large groups interfere with each other and make it difficult for guides to carry out their work. Noise levels become unacceptable, and the narrow access pathways become congested, inhibiting the flow of visitors.

The wall paintings and sculpture are extremely fragile, and damage is irreversible (fig. 6). The caves are highly susceptible to damage, as well as vandalism, so that, in addition to providing the narration, the guides are required to be vigilant and maintain security. The glass protective screens are intrusive and, if broken, pose a potential threat to the safety of fragile wall paintings and statues (fig. 7). Poor lighting hinders visitors' appreciation and understanding of the wall paintings.

Normally during the peak season, forty caves are open to the public, including the three special caves that all visitors want to see—the Library Cave (cave 17), the Standing Buddha in the Nine-Storey Pagoda (cave 96), and the Reclining Buddha (cave 130)—and ten caves that are used to regulate visitor traffic. However, as visitors often tend to be concentrated into one particular period of the day, there are often five hundred or six hundred visitors on-site each hour, so that each guided tour consists of twenty people. More than thirty guided tours take place at one time in the Grottoes Zone, the area on the western side of the Daquan River where the caves are located. In caves 428, 148, 61, and 96, for example, three to four groups may visit at the same

FIGURE 7 Inadequate lighting and intrusive glass screens diminish visitor appreciation and understanding of the wall paintings.

time, diminishing the visitor experience and the quality of the narration.

During times of high visitor numbers, some of the magnificent smaller caves, such as caves 328, 329, and 320, are opened frequently to help ease congestion. During the national holiday weeks, visitor numbers exceed the site's capacity to provide guides for regular conducted tours. Instead the guides are stationed in the open caves to provide ongoing narration, and there is a continuous flow of visitors, with the result that the entrance doors are left open for long periods.

Management

The unequal distribution of visitors to Mogao throughout the year and the large number of visitors during holiday weeks pose significant challenges for visitor management. During the national holiday week in May 2002, for example, the maximum number of visitors on one day was 5,225, exceeding the expected carrying capacity by 2,225.

Special strategies have been put into place to deal with high visitor numbers, such as opening fifteen caves rather than permitting visitors to be guided to ten caves. Visitors find their own way to the open caves, each of which has two or three guides permanently stationed to provide continuous narration. However, when the carrying capacity of the caves is exceeded, these measures are not successful, as was demonstrated in May 2002, when visitors expressed dissatisfaction with their experience at Mogao. (Visitor dissatisfaction is discussed in Li Ping et al., "Visitor Surveys at Mogao: Pioneering the Process, 2002–2004," this volume.)

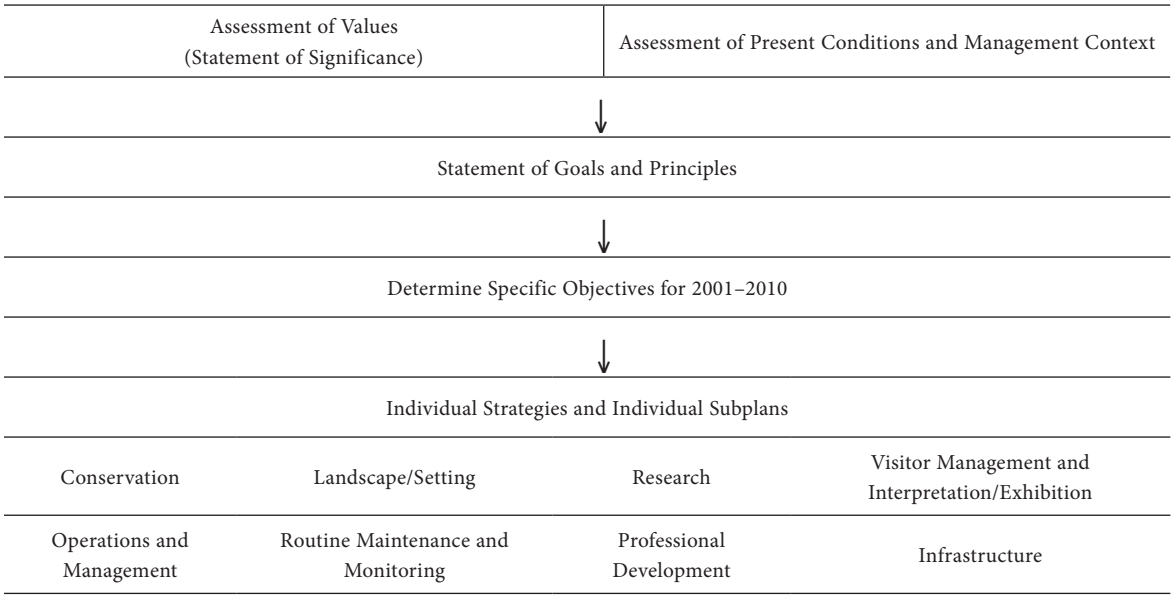
Challenges to Visitor Management

Visitors prefer to visit the actual caves, so there is not significant attendance at the replica caves in the exhibition center. Encouraging tourists to visit the exhibition center would reduce pressure on the caves. The distribution of guides for tour groups, individual travelers, and domestic and overseas visitors is another difficult area for site management, worsened by the lack of liaison with tourist agencies that bring visitors to Mogao. Site managers have little information on visitors and their needs, and they do not have the tools to measure and control visitor numbers.

Visitor Management Subplan

Managing visitors to Mogao, with the aim of providing an excellent visitor experience as well as protection for the caves' treasures, is addressed in the Visitor Management and Interpretation Subplan of the Mogao master plan. Both the subplan and the master plan have the same goals and principles. Figure 8 shows the relationship of the Visitor Management and Interpretation Subplan within the master plan.

The principles set forth in the master plan that are relevant for the subplan include the following:



Credit: Dunhuang Academy, *Mogao Grottoes Master Plan*

FIGURE 8 Flowchart of the Mogao Grottoes master plan.

- Physical intervention will be the minimum necessary to conserve the cultural significance of the site.
- All activities carried out at the site, including research and visitation, should not damage the site's cultural significance.
- No new structures that affect the cultural significance of the site should be built.
- Visitation of the caves must be supervised by a guide.
- No commercial activities whatsoever shall be carried out directly in front of the grottoes.
- Visitor numbers will be limited to the carrying capacity of the site.
- Use of the site must be in accordance with its cultural significance.
- Inappropriate use must be banned, including rock concerts, religious and wedding ceremonies, and the construction of new hotels.

Objectives and Strategies

Objectives and strategies have been developed to address the opportunities for and threats to visitor management and interpretation described in the master plan. Several key objectives and strategies are described below.

Carrying Capacity. The first and most important objective of the subplan is to determine the realistic carrying capacity of the site.[2] Determination of visitor capacity must be in accordance with the principles in the master plan, which emphasizes that when the carrying capacity is established, it will not be compromised by the desire to increase income to the site from visitors.

Once the visitor carrying capacity of the site has been established, visitor numbers and times of entry to the caves will be limited accordingly. This will ensure that visitor flow and time spent in the caves remain within appropriate limits and that the safety of the caves is guaranteed. Strategies to implement this objective include scientifically calculating the visitor carrying capacity of the caves, gradually instituting a booking system for visitors, enhancing the visitor experience in the caves by installing lighting if it is judged safe, and installing visually unobtrusive protective barriers.

Public Outreach. Other objectives and strategies are to establish a visitor's center, increase the number of new scenic spots to encourage exploration of the site, provide well-designed exhibitions about various parts of the site, and offer sufficient interpretation so that the visitor experience is both rich and enjoyable. Accurate information will be made available in a variety of formats to educate the public about the values of the site and to improve awareness of heritage conservation. Public participation in the conservation of historic and cultural heritage will be promoted. A degree and range of service commensurate with World Heritage Site standards will be offered. A range of quality souvenirs will be developed.

Tourism. Another strategy to manage visitor numbers is to work with tourism agencies to determine the number of visitors expected on any given day. An information network with thirty-two local travel agencies has already been set up to implement a booking system for tour groups, which was established in 2005. Other efforts aim to estimate the number of individual tourists who do not come in tour groups, achieve better distribution of visitors over the site, and undertake research on visitor behavior.

Implementing Objectives

Visitor Guides. To effectively disperse visitors across the Grotto Zone during the peak season, twelve visitor routes through the site have been developed that take into account the location of the caves that are open to the public, the three "must-see" caves, the art and artifacts they contain, and the dynastic period. When visitor numbers at the caves reach an unacceptable level, the Reception Department disperses visitors to the exhibition center.

Booking System. Department has instituted a more effective booking system. Tourism agencies planning to bring more than fifty visitors at a time to the site are required to book prior to arrival. Visitors staying all day are asked to visit the caves later in the day when there are fewer people in the Grotto Zone.

Special Requests. Overseas and domestic tour groups that have made special requests to visit specific caves may be taken to those caves on a secondary list of open caves before the more popular ones, thereby helping to relieve overcrowding in the caves that are open to the public.

Visitor Center. Planning is under way to establish a visitor center where all visitors will purchase tickets and other services and be provided with interpretation and orientation material before visiting the caves. The visitor center aims to educate people so that they will understand the significance of the caves and be aware of what the site has to offer, have their needs met, and have the best possible experience at the site. In this way visitors will be helped to comply with site rules and behavior expectations.

The visitor center will enable the site managers to minimize the time visitors actually spend in the caves, thus protecting their integrity. In this way, site managers will be able

to achieve the goals of the Carrying Capacity Plan. Further, it will ensure that the management staff are able to provide better and more comprehensive service to the tourism industry, which is very sensitive about access to and service at Mogao.

Additional Site Attractions. Several attractions at Mogao help to disperse visitors around the site and relieve pressure on the caves. They include the Xia Temple and the Library Cave exhibition. The completion in 2005 of the Shang and Zhong Temple museums with interpretive displays on the site's history and the history of the Dunhuang Academy will provide visitors with more attractions and encourage them to move around the site. After geologic stabilization, the Northern Grottoes Zone, the cliff-side caves north of the cave temples, which were once used by the resident monks as living quarters, may be opened to the public, providing another major attraction for visitors.

Sharing the Benefits of Tourism across the Western Region

Looking beyond the boundaries of Mogao Grottoes, there is a great challenge facing managers, planners, and the region's leadership. The authorities are strongly supporting development of the western region to stimulate the economy and provide employment opportunities, education, and training for local people. However, it is essential to ensure that the immense economic benefits that tourism can bring are used equitably to improve the social conditions of the local people and that tourism does not diminish their lives. An identified public value in the Mogao master plan is the economic benefit that the site can bring to the regional economy. It is important to ensure that strategies are developed and implemented to provide employment and training opportunities for local people to participate in and benefit from the rapidly expanding tourist economy.

Conclusion

The Mogao Grottoes have the potential to become an exemplary model for visitor management at a World Heritage Site. Site managers are grappling with the conflicting challenges of conserving a site of inestimable heritage value to the world and at the same time ensuring that the visitor experience remains rewarding and informative. The Visitor Management and Interpretation Subplan and the Carrying Capacity Plan for the site will provide site management with tools for decision making that will be tested by the mounting demands to increase visitor numbers.

Management planning is an iterative process: there can be no perfect *final* plan, since plans need to keep evolving to meet new challenges. Difficulties will arise in carrying out the objectives and strategies of the Visitor Management and Interpretation Subplan. One danger, of course, is that more attractions at the site will create more visitor demand. Other challenges include pressures from locals and visitors to use the fragile site for recreational and religious purposes.

Monitoring and adjusting the master plan and the subplan using tools such as the visitor management survey and ongoing assessment of the condition of the site will be crucial to ensuring that any new proposals for Mogao do not adversely affect the site and its values. For the long-term protection of this World Heritage Site, effective and proactive visitor management assumes an importance that is equal to the work of our colleagues who are implementing physical conservation measures in the grottoes.

Notes

1 China's western region encompasses eleven provinces, autonomous regions, and municipalities under the direct administration of the central government: Shaanxi, Qinghai, Sichuan, Yunnan, Guizhou, Ningxia, Xinjiang, Inner Mongolia, Gansu, Tibet, and Chongqing. The region covers 5.4 million square kilometers, possesses 57 percent of the country's land area, and has a population of 285 million, or 23 percent of the total Chinese population. More than half of China's identified natural resources are in the western region. In 1999 the Chinese government publicly announced its official plan to develop western China, as part of the tenth Five-Year Plan. Its goal is to achieve a satisfactory level of economic development in the western part of the country in a five- to ten-year time frame and to establish a "new western China" by the middle of the twenty-first century.

2 The paper by Demas et al. in this volume discusses the Carrying Capacity Plan. Objectives and strategies have been included in the subplan to ensure that data on visitor expectations and needs are collected to inform the cultural component of the Carrying Capacity Plan. The paper by Li Ping et al. in this volume details the surveys of visitor attitudes, expectations, and tourism needs at the site, as well as analysis of the survey results.

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Sustainable Visitation at the Mogao Grottoes: A Methodology for Visitor Carrying Capacity

Martha Demas, Shin Maekawa, Jonathan Bell, and Neville Agnew

Abstract: *At the Mogao Grottoes, visitor numbers have risen steadily since the 1980s while site managers have faced increasing pressure from local authorities and businesses to encourage more tourism. Although the direct and indirect impacts of visitation on the 492 painted caves were not known from systematic study, there was concern about irreparable damage from increased visitation. For this reason a carrying capacity study began in 2001 to determine the impact of visitation on the caves and visitor numbers such that, once implemented, visitors themselves would be safe and the caves and their art would not be damaged. The carrying capacity study, which addresses one of the principal objectives of the Mogao master plan, is a joint undertaking of the Getty Conservation Institute and the Dunhuang Academy and is part of a larger collaboration to apply the* Principles for the Conservation of Heritage Sites in China *at the site. The study required research into the mechanisms of deterioration, the impact of visitors and visitation on cave microenvironments, and visitor needs and levels of satisfaction. The study was based on the Visitor Experience and Resource Protection (VERP) methodology used by the U.S. National Park Service. The design and implementation of a research and assessment strategy includes investigations related to causes of deterioration and the impact of visitation. The results of these investigations are the basis for establishing the carrying capacity and, ultimately, the development of a long-term, adaptable management tool to respond to current and future challenges.*

As numbers of tourists at cultural sites around the world continue to grow, the need to understand the effects of visitation on cultural resources and on the visitors themselves has become paramount. Understanding the impact of visitation is integral to developing management practices capable of safeguarding the resources and ensuring the quality of the visitor experience, both of which are necessary for sustainable tourism and long-term economic, social, and educational benefits to the sites and their local communities.

At the Mogao Grottoes, visitor numbers have risen steadily since the 1980s,[1] and site managers have faced increasing pressure from local authorities and businesses to encourage more tourism. The direct and indirect impacts of visitation on the primary cultural resource of the site, the 492 painted caves, have not been determined previously, raising concerns for irreparable damage from increased visitation. For this reason, a carrying capacity study commenced in 2001 to determine the impact of visitation on the caves and inform management practices in order to prevent deterioration and ensure the quality of the visitor experience. The study, which addresses one of the principal objectives of the master plan for the site, is a joint undertaking of the Getty Conservation Institute (GCI) and the Dunhuang Academy (DA) and is part of a larger initiative to apply the China Principles at the Mogao Grottoes.[2]

Defining the Parameters of the Carrying Capacity Study

The carrying capacity for a heritage site is defined not as an immutable number of visitors that a site can safely accommodate but rather in terms of the parameters necessary to prevent deterioration of the resource while maintaining a predetermined threshold of visitor safety, satisfaction, and education. This involves consideration of a number of variables: management capabilities and limitations, including

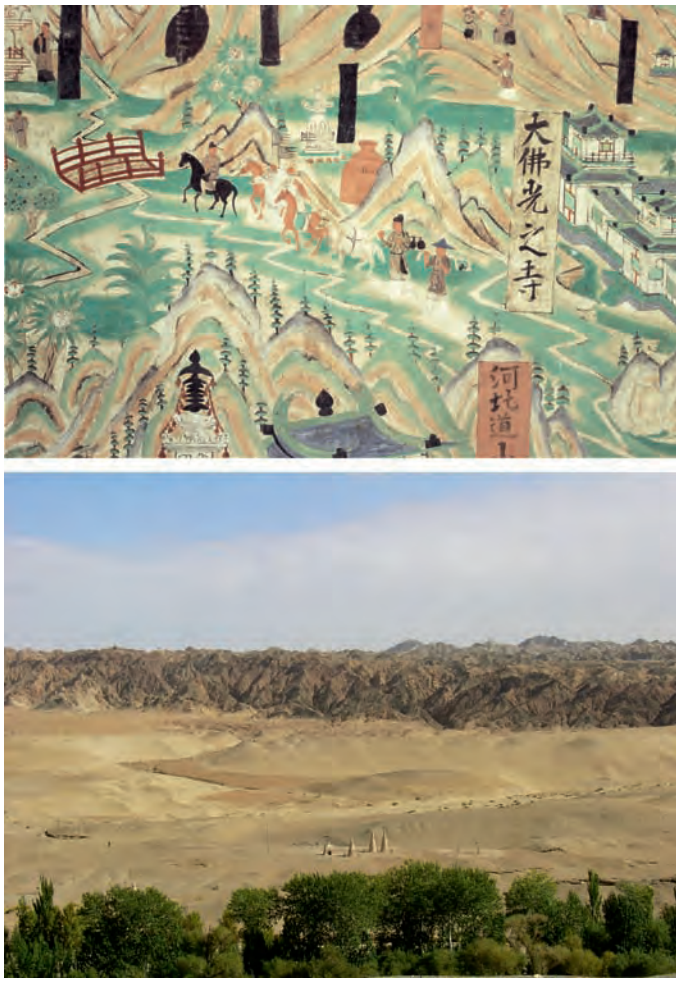

FIGURE 1 The visitor capacity study aims to protect the primary values of Mogao—the wall paintings (above, cave 61) and sculpture and the cultural and natural landscape (below). Photos: Wu Jian, courtesy Dunhuang Academy (top); J. Paul Getty Trust (bottom)

services and infrastructure; various impacts to a site, their relationship to visitation, and methods to monitor them; the degree of change or impact that is acceptable at a site; and the means by which a site's values will be protected and the quality of the visitor experience maintained while allowing flexibility to meet changing conditions. The complexities inherent in this undertaking required that clear parameters be established at the outset of the study. For Mogao, these parameters are as follows:

Values to be protected. The ultimate aim of establishing carrying capacity is to protect the primary cultural and natural values of the site (the wall paintings and sculpture of the grottoes and the landscape) (fig. 1), as well as the quality of the experience of visitors, who come to Mogao because of those values.

Limits of acceptable change. This concept defines the degree of change or impact that will be tolerated for the resource and the visitors. As the wall paintings and sculpture in the caves are the primary cultural resource of the site and are nonrenewable, no detectable change due to visitation is acceptable. Some level of impact to the landscape and to the quality of visitor experience during peak periods is unavoidable but can be mitigated or reversed through good planning and management.

Current management policies and use zones. Existing management policies and practices relevant to carrying capacity are the number of guides, tour size and numbers, opening hours, and so on. Current use zones are the Grotto Zone (fig. 2), where the decorated caves are excavated into the cliff face, and the Visitor Use Zone, where visitor facilities and exhibition buildings are located. This study is aimed primarily at the Grotto Zone.

Time of greatest threat. This is the summer peak period of visitation, from May through October, including the two national holiday weeks in May and October.[3] During this period, management and the grottoes themselves are often overwhelmed by visitors, and environmental conditions pose the greatest danger. The experience of visitors is also most heavily affected at this time.

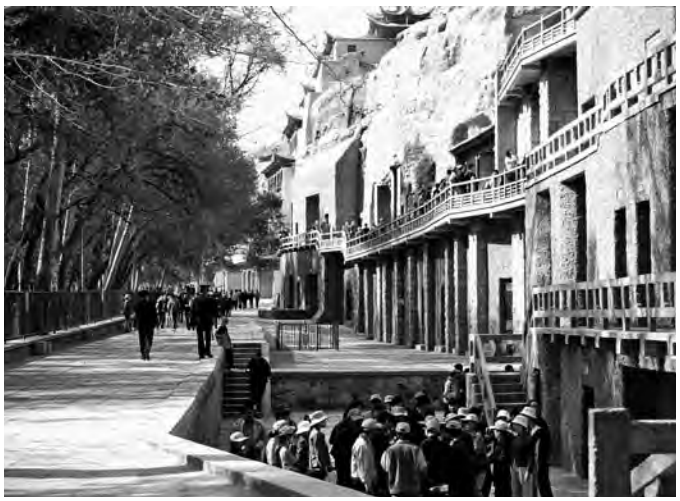

FIGURE 2 The Grotto Zone is the protected, narrow strip along the cliff face into which the caves were carved, many of which are open to public visitation. Photo: J. Paul Getty Trust

Based on the above parameters, the carrying capacity for the Mogao Grottoes site was defined as follows:

Daily maximum number of people who can visit the Grotto Zone without any resulting alteration or damage to the wall paintings and sculpture. Any damage or deterioration to the wall paintings due to visitation is irreversible and unacceptable. Determining a safe number of visitors to the caves and the conditions of visitation lies at the core of the carrying capacity study.

Maximum number of people who can be accommodated in the Visitor Use Zone without unacceptable change or intrusion to the landscape and setting of the site. The desert landscape setting of the grottoes includes the natural environment (mountains, sand dunes, trees, river) as well as cultural features (stupas, historic buildings, the cliff face with caves) (see figs. 1, 2), all of which contribute significantly to the values of the site and are integral to the experience of the visitor. The landscape and setting are affected mainly by visual intrusions (buildings and parking lots) related to visitor services, and there is a direct relationship between visitor numbers and the buildings needed to service them.

Maximum number of people who can use the site daily while maintaining the quality of the visitor experience, visitor safety, and the ability of management to effectively meet visitor requirements. The relationship of visitors to the primary cultural and natural values, to the staff, and to the information and services provided constitutes the visitor experience of the site. A temporary decline in visitor satisfaction may be tolerated because the condition is reversible with good management and adjustment of visitor numbers; however, there can be no tolerance for diminished visitor safety.

In sum, the carrying capacity for the Mogao Grottoes is the maximum number of visitors who can use the site daily over the six-month peak visitation period of May through October without risk of damage to the wall paintings and sculpture, without unacceptable change to the setting and natural environment, and while ensuring visitor safety and satisfaction. Establishing the carrying capacity for the Grotto Zone is the priority, as it constitutes the primary cultural resource and is the focus of this study. The capacity of the Visitor Use Zone is part of an ongoing comprehensive plan for visitor services, including a visitor center and exhibition spaces, being undertaken by the Dunhuang Academy.

Methodology of the Carrying Capacity Study

The methodology developed for this study is adapted from the Visitor Experience and Resource Protection (VERP) model developed by the U.S. National Park Service for natural sites.[4] It consists of two main stages, which are presented in the remainder of this paper.

Stage 1: Assessment and Analysis

The first stage of the methodology is assessment and analysis, which includes five distinct steps that progress from defining the problem to determining the conditions that will limit visitation. In the discussion that follows, the emphasis is on the research and assessment strategy in step 4.

1. *Identifying issues that have an impact on the site and visitors.* The most critical issue impacting the preservation of the wall paintings is active or ongoing deterioration. By this is meant that the mechanisms leading to decay are active or can be activated under certain conditions, one of which is elevated humidity, caused by the cave doors being open for visitation, allowing outside air to enter (fig. 3). For visitors, key issues to consider are acceptable carbon dioxide (CO_2) levels and comfortable physical space requirements.
2. *Identifying key indicators to monitor change.* Indicators measure the status or "health" of the resource. For the wall paintings, the main indicator of ongoing problems is evidence of hygroscopic salt-related deterioration (see fig. 3, right), but any detectable change in the wall paintings is indicative of undesired conditions and requires a management response. For visitors, the main indicators are a decline in satisfaction, as measured in surveys repeated over time, complaints to guides about crowding, and incidents of fainting due to bad air quality and high CO_2 levels.
3. *Defining desired conditions.* The desired condition for the wall paintings is stability, meaning no change in their current state. This requires a stable environment that does not activate the mechanisms of deterioration, namely deliquescent salts, and prevention of physical damage by visitors. For visitor safety and comfort, CO_2 concentrations must be maintained at or below internationally accepted levels, and the allocated space per person for visita-

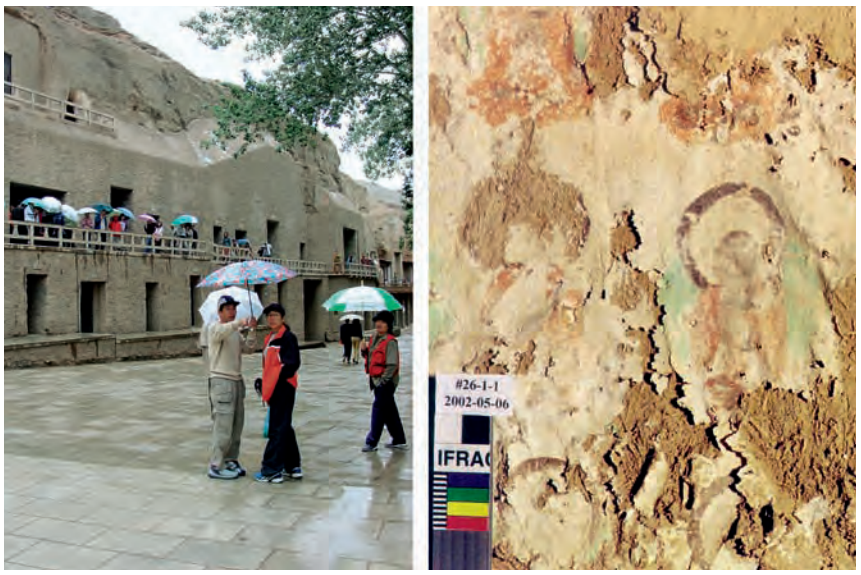

FIGURE 3 Ongoing deterioration of the wall paintings (a severe example, right) can be activated by elevated external humidity entering the caves, especially during periodic rain events in the summer months (left). Photos: J. Paul Getty Trust

tion should be sufficient to ensure that crowding is not a factor.

4. *Designing and implementing a research and assessment strategy.* The aim of the research and assessment strategy was to determine the mechanisms of deterioration, the link between deterioration and visitation, and the safety and comfort levels for visitors. This is the largest and most complex component of the carrying capacity study. The research strategy integrates analytical investigations in the laboratory, environmental monitoring and research, deterioration monitoring, assessment of condition and visitation potential for each cave, and visitor-related research and surveys. Together, these components of the study provide information on the following:

   - the presence, types, and distribution of active deterioration in the caves;
   - the conditions for activating this deterioration;
   - the role of natural (i.e., not mechanically driven) air exchange with the outside, as measured by number of air changes per hour (ACH), in accelerating or mitigating deterioration, rise of relative humidity (RH), and CO_2 buildup; and
   - the basis for determining risk to the wall paintings from visitation, to visitors themselves from CO_2 buildup, and to the visitor experience from crowding and other factors.

The six basic components of the research and assessment strategy are described in some detail below. These are the basis for determining the limiting conditions.

Analytical investigations. It was confirmed from the joint DA-GCI project in cave 85 that ongoing deterioration in the wall paintings is due mainly to hygroscopic salts and their response to fluctuations in humidity (i.e., deliquescence of salts as humidity rises and recrystallization as it falls).[5] This cycle of deliquescence-recrystallization occurs repeatedly over time as cave humidity changes and ultimately results in damage to the wall paintings. To understand this phenomenon, it was necessary to identify the salt species and the deliquescent relative humidity. Laboratory investigations showed that Mogao salts, primarily sodium chloride (NaCl) with minor amounts of other salt species, begin to absorb detectable amounts of water vapor at approximately 67 percent RH (pure NaCl deliquesces at 75% RH) (fig. 4). Practically, this means that 67 percent RH is the critical point at which deterioration is activated in susceptible caves, though time is also important: the longer cave RH remains above 67 percent, the more moisture is absorbed (depending on the amount of salts) and the greater the potential for damage. For purposes of managing the caves, the RH threshold for visitation has been conservatively set at 62 percent.

Salt concentrations in caves vary and thus have different rate responses to fluctuating RH. To understand the effect of salt concentration and the progression of deterioration, painted clay coupons that simulate the structure, composition, and pigments of the wall paintings and loaded with different

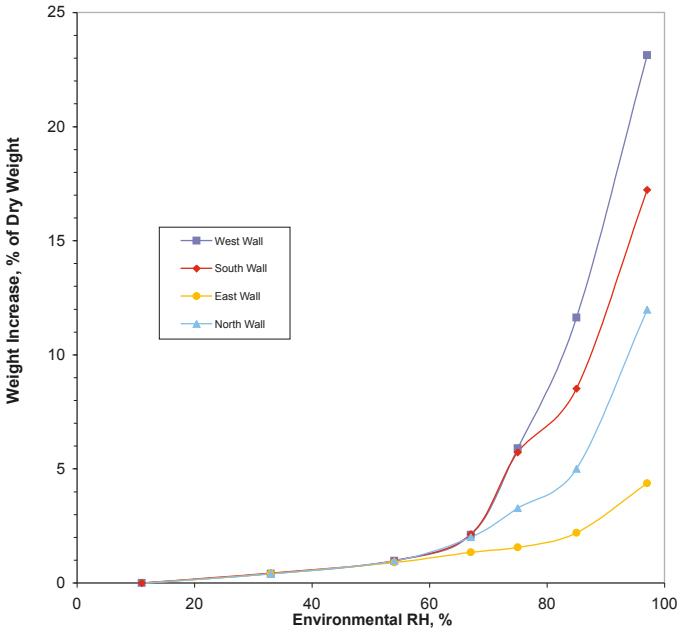

FIGURE 4 Laboratory investigations showed that salts identified in the wall plaster at Mogao (in this example, from cave 98) begin to absorb a large amount of water vapor at approximately 67 percent RH; note that the west wall—adjacent to the body of the rock—contains the highest percentage of salts in most caves and thus the quickest uptake of moisture.

amounts of salts were manufactured. Half of each coupon was also sprayed with a 2 percent solution of polyvinyl acetate (PVAC), previously used at Mogao as a treatment for flaking wall paintings. Once complete, the coupons were subjected to cycling at 25 and 85 percent RH in an environmental chamber to ensure thorough deliquescence and crystallization of the salts during each cycle. Coupons were examined after each drying cycle, that is, when recrystallization and any resulting damage occur (fig. 5), and changes were recorded photographically and through written description. Coupons representative of progressive deterioration were withdrawn and stored in a desiccator at a low RH to prevent further change.

An index of deterioration was then established that correlated with number of cycles and percentage of salt. The coupons that make up this index serve as a model for the development of salt-related deterioration in painted clay and exhibit many of the same patterns and types of conditions present in the wall paintings (e.g., cracking, flaking, plaster powdering). The coupons will also serve as reference for uncycled coupons placed in the caves as long-term deterioration monitors, as discussed in Deterioration Monitoring below.

Environmental research and modeling. Environmental monitoring is pivotal to making the link between visitation and mechanisms of deterioration in the caves. The objective is to determine the separate effects on the cave microenvironments of visitors (i.e., people in the caves) on the one hand and visitation (i.e., the opening and closing of cave doors) on the other, building on previous environmental monitoring and testing.

Since 1991, environmental monitoring has involved

- monitoring of the exterior climate (using a weather station established on top of the cliff in 1991 and temperature and relative humidity sensors placed outside the caves);
- installation of sensors recording air temperature, relative humidity, and surface temperature in four test caves, including visitor counters in the two open test caves;
- experiments to understand the effect of visitors on the microenvironment using varying-size groups occupying a cave for different periods of time;[6]
- experiments to determine the air exchange rate under varying conditions: doors opened, closed; visited, not visited; and the time required for the cave microenvironment to return to baseline; and
- spot monitoring in selected caves of CO_2, RH, and temperature during periods of peak visitation.

FIGURE 5 Clay coupon, simulating the structure, composition, and pigments of the wall paintings, showing typical salt-related deterioration after 26 cycles of high and low RH fluctuations in an environmental chamber. Photo: J. Paul Getty Trust

The air change rate, or ACH, is the number of times in one hour that the interior air is mixed with an equal volume of exterior air. Air change rate is measured by decay of a tracer gas released in the cave. There is no single, fixed value for a cave's ACH. The range of ACH values found for a particular cave depends on whether the doors are opened or closed, on the temperature difference between exterior and interior, on exterior wind speed and direction, and on cave characteristics such as size, architectural configuration, and area of door opening. ACH values drop markedly when cave doors are closed or when visitors block the entryway.

Air exchange with the exterior purges the cave of water vapor and CO_2 emitted by visitors and, likewise, may bring in high humidity from outside until the exchange process equilibrates interior and outside air. A continuously visited cave has its doors open throughout the visitation day (an eight-hour period) such that a return to the cave's environmental baseline (i.e., the situation without visitation and the door closed) is possible only during the closed period at night (sixteen hours). During the summer period, the external atmospheric humidity rises and experiences periodic spikes due to rain events (e.g., see fig. 3), typically reaching 85 percent. Elevated relative humidity may persist for several days depending on the duration of the rain and humid conditions, resulting in greater quantity of moisture absorbed by the salts and, consequently, greater damage upon drying.[7] The surface temperature of the cave walls, always substantially cooler than exterior air in summer, is also integral to determining the relative humidity at the surface of the paintings and the potential for salt deliquescence. As air temperature cools at the wall surface, relative humidity rises, meaning that exterior air does not need excessive humidity to create undesired conditions for the paintings.

Caves with high air exchange may be expected to override the influence of visitors on relative humidity (approximately 5%) and CO_2 buildup. However, in caves where air exchange is low, the increase in relative humidity and CO_2 can be significant during peak months. The lowest ACH values, either measured in situ or calculated from an empirical formula (based on measured ACH values as a function of cave volume and similar measured caves), are used to determine the potential for elevated CO_2 levels in each cave. Statistical values based on environmental data collected over a number of years indicate how many days per month over the summer period those caves with active deterioration will likely require closure because of infiltrating high ambient humidity. Table 1 illustrates that on the average over the monitored five-and-a-half-year period, 68 percent RH was exceeded less than 5 percent (36 hours) of the month of July; however, in any single year a relative humidity higher than 68 percent can occur for a longer period as the climate varies from year to year.

Deterioration monitoring. Methods of monitoring for visitor-induced deterioration were established and put in place in four environmentally monitored test caves in 2002. Areas of active deterioration are monitored photographically (e.g., fig. 3), through written observations, and by collection and weighing of fine particles of plaster and, rarely, paint flakes fallen from the walls. Two of these caves were closed to visitation as control caves, and two were subject to routine visitation, allowing for comparison in the rate of change of unvisited and visited caves.

Salt-laden clay coupons identical to those cycled in the lab were installed in the caves to determine their feasibility for use as long-term deterioration monitoring tools. If and when the coupons show signs of deterioration, they will be compared to the reference deterioration index produced in the lab and assigned a rank of severity. The coupons are intended to supplement in situ inspection and provide standardized monitors for deterioration, over the long term, in susceptible caves.

Visitor management research and assessment. Visitor-related research and assessment have focused on three areas: visitor behavior and satisfaction; appropriate physical capacity or occupancy (for the usable area of the main chamber of each open cave) (fig. 6) and CO_2 safety levels; and current visitor management policies and capacity.

Table 1 Summer Monthly Percentile Rank of Surface Relative Humidity at the West Wall of Cave 29 Based on Data Collected over a Five-and-a-Half-Year Period

Month	7.2 Hours per Month RH Exceeded	36 Hours per Month RH Exceeded	72 Hours per Month RH Exceeded
May	56%	43%	35%
June	83%	55%	43%
July	84%	68%	59%
August	81%	62%	52%
September	60%	47%	35%

FIGURE 6 The physical capacity of a cave, based on usable area of the main chamber, varies markedly, with many caves being too small to handle a group of twenty-five persons. Inevitably, groups tend to cluster close to the guides and the main focal points. Photo: Richard Ross © J. Paul Getty Trust

Since 2002 visitor surveys and observations have been conducted by the Dunhuang Academy and the Australian Department of the Environment and Heritage to assess visitor behavior and satisfaction.[8] Poor air quality and high CO_2 have long been a source of discomfort for visitors in the summer months. Acceptable limits for physical capacity (2 persons per square meter) and CO_2 levels (not to exceed 1,500 parts per million [ppm]) were established based on bibliographic research and industry standards.[9] These values become critical parameters for defining the limiting conditions (see below and table 2).

"Management capacity" refers to the ability of management to protect the caves and to service the visitors in the Grotto Zone; it is premised on existing policies, practices, and capabilities of management. While there are many management issues that affect the carrying capacity of the site (e.g., water resources, visitor service facilities, parking capacity), the principal policies and practices that have an impact on the visitor capacity of the Grotto Zone are those related to guiding, tour reservations, the number of qualified guides and their language capabilities, duration of visits, and routing pattern of groups along elevated, narrow walkways (see fig. 2).

Table 2 Summary of Limiting Conditions and Implications for Visitation

	Limiting Condition	Implications for Visitation
"Winnowing" Conditions	Significance	Only caves of significance rankings A (Highest) and B (High) are considered acceptable for visitation by the Dunhuang Academy.
	Safety and access	Only caves with no safety risks or access restrictions are acceptable for visitation.
	Physical capacity	Only caves that have a minimum physical capacity of 25 persons (the maximum allowable group size) are amenable to visitation.
	Unacceptable risk	Caves assessed as being at an unacceptable risk from visitation cannot be opened.
Restricting Conditions	CO_2 capacity	The CO_2 capacity may limit the number of visits per day for caves with low ACH. The method developed allows for a preset number of visits per hour based on projections of CO_2 (not to exceed 1,500 ppm) using ACH rates for caves with door left open. The resulting value is expressed as number of tours per hour @ 25 persons per tour that a cave can handle.
	Risk to wall paintings from humidity	High-risk caves are susceptible to deterioration from influx of humid air. A key limiting condition will thus be periods of high humidity outside (e.g., summer months, when ambient RH rises and rain events occur). This will require closing vulnerable caves during high humidity and monitoring for signs of change. It will not, however, have a great effect on daily carrying capacity if suitable "replacement" caves are identified for substitution when conditions require closure.
	Management capacity	The number of visitors who can be handled by management in the Grotto Zone is limited by guides available, tour group size, number of tours per guide, number of caves per tour, hours of opening, duration of cave visit, and routing constraints on the walkways of the grotto cliff face.

Assessment of cave physical condition and visitation potential. An assessment of physical condition and visitation potential is being undertaken for each of the 492 painted caves at Mogao. The principal objective is to determine which caves may be opened to visitation as a function of their physical condition (assessment of risk level to the wall paintings from visitation) and visitation potential (cultural significance, safety and access, physical capacity, and capacity set by the CO_2 limit). The CO_2 capacity of a cave is defined (for purposes of this study) as the number of visits of twenty-five persons that the cave can accommodate such that the CO_2 concentration does not exceed 1,500 ppm. In addition, the assessment will serve to plan for regular monitoring of the caves and periodic reevaluation of risk status.

A principal purpose of the risk assessment is to determine those caves that are at risk from visitation due to the salt-related mechanisms of deterioration. Those caves require careful monitoring and temporary closure under certain exterior environmental conditions. Other risks from visitation include the potential impact of humidity fluctuations or air movement on fragile paint layers (e.g., severe flaking) and mechanical damage from visitors touching the paintings. The risk assessment is used to establish a provisional carrying capacity and is the first stage in a process to ensure that there is no present or future impact from visitation. The preliminary ranking of risk will need to be confirmed and periodically reassessed as part of an ongoing monitoring program. The assessment process will result in a "portfolio" for each cave comprising a compilation of information on the date, location, size, dimensions, significance, visitation history, safety issues, and previous interventions, in addition to a record of its current physical condition. This information will become part of an integrated management system for both visitor management and conservation planning to be defined in Stage 2 of the carrying capacity study.

Defining the limiting conditions: The limiting conditions are the parameters that will restrict visitation to each cave and that may require management responses. They are derived from the research and assessment strategy discussed above and may be characterized as either "winnowing" or "restricting" conditions. The winnowers—principally significance, safety and access, and physical capacity but also including an unacceptable level of risk to the wall paintings—provide clear thresholds that must be met for caves to be open to visitors for purposes of establishing the initial carrying capacity. These conditions thus winnow, or separate out, the caves currently suitable for visitation from those that cannot be visited.

The restricting conditions, which are applied to the winnowed caves, are risk to wall paintings, CO_2 capacity, and management capacity. Risk to wall paintings and CO_2 capacity will restrict visitation in certain caves under specific conditions but will not prevent their use. Management capacity, limited by factors such as tour group size, number of guides, and hours of opening will also play a role in restricting the total number of visitors that can be accommodated in a single day.

All of these limiting conditions are potentially amenable to mitigation strategies, which might allow a higher threshold of visitation. Some of these strategies may be viable in the short term (e.g., the use of smaller tour group size to allow for visitation of smaller caves), but others may require a period of investigation, testing, and monitoring to determine their efficacy (e.g., the use of fans to increase air exchange, which may create new risks, or undertaking conservation of caves at unacceptable risk). The limiting conditions and their implications for visitation are summarized in table 2.

Stage 2: Response

In the response stage of the methodology the limiting conditions described above are used to establish the carrying capacity of the grottoes. Each open cave will have a maximum number of possible tour groups per hour, based on the CO_2 limit and natural air change rates. For a number of reasons, forced air exchange is not considered practicable or desirable. These numbers will be adjusted further due to periodic climatic events (e.g., rain), requiring open caves at risk to be temporarily closed. The carrying capacity of the Grotto Zone will therefore vary as a consequence of management responses to environmental changes or a change in visitor management capacities and policies (e.g., size of groups, opening hours, or number of guides).

Long-term monitoring and management tools are needed for sustainable visitor capacity. Ongoing monitoring of the wall paintings and cave microenvironments will be necessary to determine if and when change occurs. Methods of monitoring that will trigger management responses, such as real-time data capture and display of the environment within selected caves, are in development by the Dunhuang Academy. In addition to such sophisticated monitoring, simple tools are being tested for use. For instance, small paper

sachets of different dry deliquescent salts (NaBr at 59%, KI at 70%, and NaCl at 75% RH) mixed with water-soluble dyestuff (crystal violet) have proved effective as a relative humidity indicator. Placed inside a cave, these "sentinels" indicate, by staining the paper, that a particular relative humidity has occurred or has been exceeded. Portable CO_2 readers are also being utilized for spot measurement of CO_2 in selected caves. Condition monitoring, based on the risk assessment and assigned risk level, is designed to provide evidence of ongoing deterioration or damage. When the monitoring indicates change from desired conditions, specific actions need to be defined and set in motion. This will mean closing those caves with active salt-induced deterioration when exterior humidity rises above 62 percent, or reducing the number of daily tours or the period between visits (while keeping doors open to allow natural ventilation to flush the cave) if CO_2 limits are exceeded, or reassigning risk level if deterioration is shown to be continuing.

Concluding Remarks

The correlation and interpretation of all the generated data and observations are complex and represent a long-term effort to develop a comprehensive and rational visitor capacity for the open caves over the summer period of high visitation to the site. The initial carrying capacity for the Grotto Zone will need to be validated over time and adjusted as necessary. Management systems will need to be developed that will be responsive to changing conditions, on a daily basis, and staff trained to ensure the upkeep and efficient running of these systems. The Dunhuang Academy has already put some of these systems in place, such as a reservation system, which is critical for managing visitors to the site. Others are in development, such as a visitor flow simulation model, which will determine the most effective way to move visitors through the site,[10] and an off-site visitor orientation center, which will reduce the visual intrusions on the landscape, provide visitors with an introduction to the grottoes, and manage the flow of visitors to the site.

The strength of the carrying capacity study for the Grotto Zone is that it provides an objective, scientific basis for understanding and assessing the impact of visitation on the cultural resource at Mogao—the wall paintings. The difficulty of relating visitor use to impacts has been cited as the primary challenge to applying carrying capacity planning to cultural resources, as distinct from impacts to natural resources, which can be quantified (Valliere and Manning 2003: 237). Although we cannot yet quantify the impact of visitation on the wall paintings, we can use the theoretical model of deterioration to mitigate or prevent it. Continued research and monitoring will be needed to validate and refine our understanding of the causes of deterioration and their relationship to visitor use.

Like a living ecosystem, carrying capacity is an outcome of a complex system of relationships that function as an integrated unit. The carrying capacity study for the Grotto Zone described here is one essential component of that system that has as its central aim the preservation of the wall paintings for posterity rather than for the sole benefit of the present generation. The carrying capacity will not be sustainable, or effective, however, without constant vigilance and careful integration into the larger system of visitor management for the site.

Notes

1 For details of visitation, see Altenburg et al., this volume.

2 The *Principles for the Conservation of Heritage Sites in China*, developed through a collaboration between China's State Administration of Cultural Heritage, the Getty Conservation Institute, and the Australian Heritage Council, were issued by China ICOMOS in 2000. Available at www.getty.edu/conservation/publications/pdf_publications/china_prin_1chinese.pdf and www.getty.edu/conservation/publications/pdf_publications/china_prin_2english.pdf. See also Agnew et al. 2006 for application of the China Principles through the master planning process at the Mogao Grottoes and the Imperial Mountain Resort at Chengde.

3 Buddha's birthday, which takes place on the eighth day of the fourth month of the Chinese lunar calendar (usually in May), is also a time of excessive visitation but mainly involving people from the local community, who use the setting of the site for picnics and visit only a few selected caves.

4 Many examples of the methodology and application of VERP can be found on the Web. See, e.g., VERP 1997; Merced River Plan 2000.

5 The cave 85 project, a joint undertaking of the Dunhuang Academy and the Getty Conservation Institute, is described in numerous papers in this volume.

6 See Maekawa 1996 for early experimentation of the effect of visitation on the microenvironment.

7 This was demonstrated in cave 85 (see Maekawa et al., this volume).

8 See Li Ping et al., this volume.

9 Perceptions of crowding (encroachment on personal space) vary among cultural groups, with generally lower tolerance among Western tourists and higher tolerance among Asian visitors (for a discussion of crowding and analysis at the Glowworm cave site in New Zealand, see Doorne 2000). Visitor surveys at Mogao have shown that complaints about overcrowding during peak periods coincide with a general decline in satisfaction (see Li Ping et al., this volume).

CO_2 occurs as a component of the atmosphere, where its concentration is around 340 ppm. High levels in confined spaces are injurious to health. There are two aspects of CO_2 concentration relevant to Mogao visitation. Foremost is the comfort and safety limit. Industry standards for CO_2 are determined for commercial facilities and do not exist for exotic places such as caves; standards also vary among regions of the world, with European standards, for instance, being similar to or higher than U.S. standards (1,000 ppm), and are based on continuous exposure (ASHRAE 2007). In certain caves at Mogao, CO_2 levels frequently exceed 3,000 ppm in peak periods. Since visits are 5 to 8 minutes per cave and do not involve continuous exposure to the cave environment, the CO_2 limit has been set at 1,500 ppm.

The second equally important aspect is CO_2 as an air quality indicator. Heat stress on visitors, physical exertion, dehydration, and body odors combine with high CO_2 to result in degradation of visitor experience and instances of fainting, particularly among elderly or unfit visitors.

10 The Visitor Flow Simulation Model is being developed under contract to the Dunhuang Academy by Kiran Consulting Group, San Diego.

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Social and Environmental Monitoring as a Tool for Managing Visitor Impact at Jenolan Caves, Australia

Richard Mackay

Abstract: *The Jenolan Caves Reserve is a karst (limestone) landform within Australia's Greater Blue Mountains World Heritage Area. The reserve was set aside for the preservation of the caves in the 1860s—before the establishment of the world's first national park (Yellowstone, 1872). Of the 350 caves known in this ancient landform, sixteen are developed and open for public use, providing a major tourist destination and income for the reserve management. The reserve contains outstanding natural landforms and a fragile ecosystem that includes rare and endangered flora and fauna, as well as a rich cultural heritage comprising both indigenous sites and postcolonial structures with associative values related to the historic development of the caves for tourism.*

As part of the process for evaluating future management scenarios under increased visitation loads, the Jenolan Caves Reserve Trust (a management agency appointed by the government) commissioned a carrying capacity study in 1995. No finite carrying capacity was determined; instead, the study identified a complex interrelationship among visitor behavior, site management, and physical and biological impacts. Arising from this study, the trust put in place a social and environmental monitoring system that remains at the heart of conservation management for the reserve and forms a basis for balancing tourism pressures with conservation needs. This monitoring system examines a range of geophysical, biological, and social-experiential conditions. It seeks to determine relevant environmental and social factors, desired conditions, indicators to be monitored, methods for monitoring the indicators, causes of problems, priority of causal effects, and appropriate management responses. This paper showcases a small selection of the monitoring programs to illustrate how indicators and causal relationships with visitation are determined.

The Jenolan Caves Reserve encompasses a limestone valley studded with a system of caves set within a broader, dramatic, and heavily dissected sandstone plateau. The cave system includes more than 45 kilometers of known passageways, which are divided into 350 separately identified caves. Of these, sixteen caves are developed and open for public use. The 2,422-hectare (24 km^2) reserve is within Australia's Greater Blue Mountains World Heritage Area. It is one of the country's outstanding tourist destinations, boasting a spectacular but fragile natural environment and a rich cultural heritage. In the 1860s—before the establishment of the world's first national park, Yellowstone, designated in 1872—the Jenolan Caves Reserve was set aside for the preservation of its caves, nine of which are currently open to tourists. The reserve is located in eastern Australia, in New South Wales, approximately 200 kilometers west of Sydney.

The Jenolan Caves Reserve Trust, the management body responsible for the reserve, was established in 1989, following previous management by state agencies responsible for railways, tourism, and Crown lands. The trust's statutory role is to conserve Jenolan Caves and promote them as a leading tourist destination in a manner that is environmentally, culturally, and commercially sustainable.

The reserve contains outstanding natural limestone (karst) landforms and a fragile ecosystem that includes rare and endangered flora and fauna, as well as a rich cultural heritage comprising both indigenous sites and late-nineteenth- and early-twentieth-century historical structures with associative values related to the historic development of the caves for tourism. Visitors to the cave system are predominantly day trippers—a mix of inbound international visitors and residents of the greater Sydney area. Current

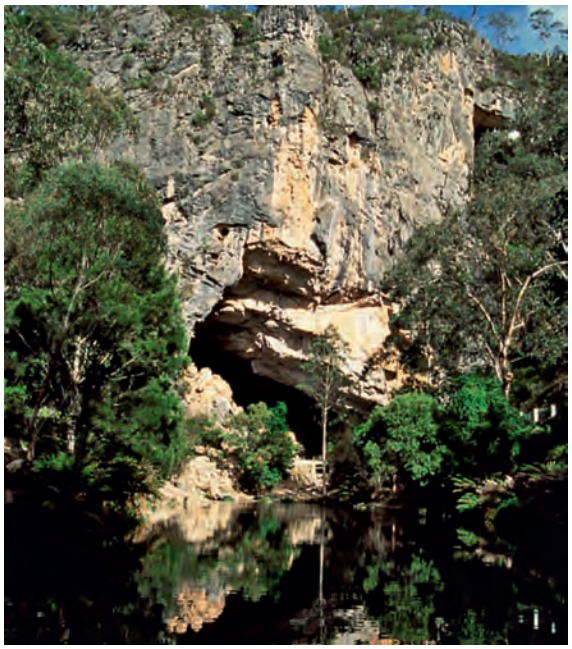


FIGURE 1 The Grand Arch, an outstanding karst formation at the Jenolan Caves Reserve, NSW, Australia.

visitation is around 250,000 visitors per year, although over the past decade, the number has reached almost 300,000. On busy days, visitation results in excessive pedestrian and vehicular congestion within the confined Jenolan valley.

The cave system is at the bottom of a narrow valley, and the main access road passes through the Grand Arch, a large, partially collapsed cave that is one of the major visual icons of the reserve (fig. 1).[1] In 1989 the management plan for the reserve identified the impact of vehicles on both visitor enjoyment of the caves and physical damage to the Grand Arch and the caves' ecosystem, perceiving that the nexus between transport, environment, and visitor numbers was the critical issue for effective natural and cultural heritage management.

The analysis of the situation at Jenolan Caves and the remedial approach adopted in the 1989 management plan fit well with the model recently espoused by the World Tourism Organization in its *Tourism Congestion Management at Natural and Cultural Sites: A Guidebook* (World Tourism Organization 2004: 4–5), prepared in conjunction with ICOMOS. The parameters of the situation at Jenolan Caves fall squarely within the guidebook's model,[2] in that both destination management (in particular, the process of arriving at this heritage site) and site management are recognized as critical to achieving the dual objective of care for the resource and a high-quality visitor experience.

Carrying Capacity Study

In 1995, as part of its process for evaluating future management scenarios for the reserve under increased visitation loads resulting from alternative access arrangements, the Jenolan Caves Reserve Trust commissioned a carrying capacity study. The results of this study have had far-reaching ramifications for management of the site as both an important heritage place and a major tourism destination.

The study was undertaken with a grant from the Australian Commonwealth Department of Tourism under the Sites of National Tourism Significance Program. The study was carried out by Manidis Roberts Consultants and was launched in 1995 by the minister for the environment.

The initial study brief required the development of a framework for determining the carrying capacity of the reserve, including the caves system. The study process quickly identified the need for a more complex understanding of the resources and issues involved. Therefore, the objectives were modified, requiring the study team to

- develop a clear understanding of the social, environmental, and infrastructure issues that face Jenolan Caves Reserve;
- apply the Visitor Impact Management process as a framework for determining carrying capacity at Jenolan Caves Reserve; and
- use the Visitor Impact Management process to develop an ongoing monitoring program and relate this to the management of the Jenolan Caves Reserve (Mackay 1995: 224).

A critical element of the study process was a three-day interactive workshop held at Jenolan Caves, involving staff and both national and international experts in visitor and karst management.

No finite carrying capacity was determined for the reserve; instead, the study identified a complex interrelationship among visitor behavior, site management, and physical and biological impacts. Using the results of this study, the trust put in place a program for social and environmental monitoring that remains at the heart of conservation management for the reserve and forms a basis for balancing tourism pressures with conservation needs.

The study identified the following major issues relating to managing the environment at the Jenolan Caves Reserve:

- overall objectives for the reserve
  - conservation of the resource
  - high-quality visitor experiences
- resource management and research
  - use of science and research in decision making
  - need for baseline data
  - environmental monitoring
- visitors and visitor experience
  - recognition of interpretation and education as crucial elements of visitor experience
  - need for information (what do they want/what do they get?)
  - relating Jenolan Caves to visitors' spectrum of recreational experiences
- infrastructure and transport
  - pedestrian/vehicle conflict (especially in the Grand Arch area)
  - vehicle parking capacity (which currently determines maximum visitor numbers)
  - access limits
  - impacts of emissions, runoff, and so on
  - need for further research

Visitor Impact Management

Application of a rigid carrying capacity limit at the reserve was rejected because it may have resulted in the oversimplification of a complex issue. Instead, two existing approaches were adopted for managing areas with high resource values and visitor use: *The Limits of Acceptable Change (LAC) System for Wilderness Planning* (Stankey et al. 1985) and *Management Process for Visitor Activities* (Parks Canada 1985).

A major premise of these methodologies is that management goals, which are qualitative in nature, must be translated into measurable (quantitative) management objectives through the use of indicators and standards. Environmental goals are therefore achieved by employing standards that are monitored through the use of suitable indicators. Monitoring programs are now in place at Jenolan Caves for a range of geophysical, biological, and social/experiential conditions.

The management approach for Jenolan Caves seeks to determine the following:

- relevant environmental and social factors/issues
- desired conditions
- indicators to be monitored
- methods for monitoring the indicators
- causes of problems
- priority of cause and effect
- appropriate management responses

The range of issues addressed through this process is broad and includes environmental considerations, physical impacts, biology, occupational health and safety concerns, and the visitor experience. Given the time and resources used to accumulate baseline data, the monitoring system remains at a relatively early stage. Even so, outputs are now directly influencing management decisions.

Operation of the monitoring program is the day-to-day responsibility of expert staff, assisted by cave guides and maintenance staff. From time to time, aspects of the monitoring work are included in the visitor program. For example, if personnel or equipment are observable during cave tours, the tours may pause to allow for explanations of the monitoring process. In addition, to provide a theoretical framework and a link with academic institutions and other relevant expertise, the Jenolan Caves Reserve Trust appointed an advisory group—the Social and Environmental Monitoring Committee—that has guided the program since 1996. The results of this structure have been excellent and have included an impressive array of graduate and undergraduate research projects and academic publications.

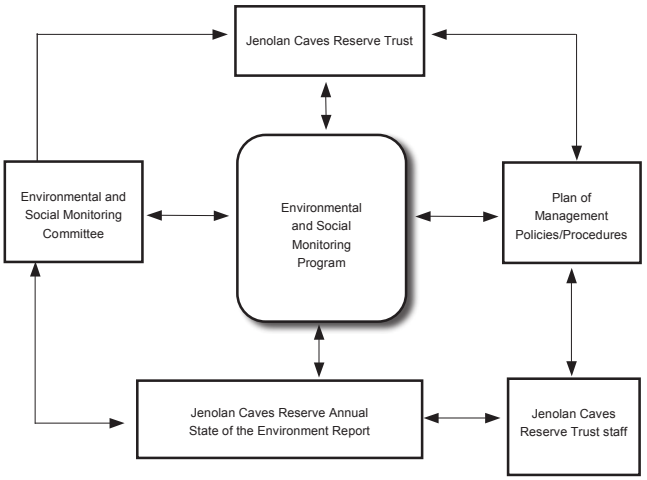
Table 1 describes the various components of the Jenolan Caves Reserve Visitor Impact Monitoring System.

Examples of the Monitoring Process for Jenolan Caves

Space does not permit a comprehensive discussion of the full range of issues monitored at Jenolan Caves and the entirety of the social and environmental monitoring process. Instead, the following eight monitoring issues are outlined briefly below:

- air quality (carbon dioxide)
- hydrology
- cave desiccation and humidity
- trail quality
- lampen flora

Table 1 Implementation and Evaluation of the Jenolan Caves Reserve Visitor Impact Monitoring System (Adapted from Manidis Roberts Consultants 1995)



- dust, lint, hair, skin flakes
- radon
- visitor experience

Table 2 summarizes how the social and environmental monitoring program applies to these examples. The information has been adapted from an internal report on the initial years of operation (Thurgate and Hamilton-Smith 1999).

Air Quality (Carbon Dioxide)

Air quality is measured both above- and belowground with the aim of achieving atmospheric conditions that are normal for a particular area or cave. Indicators for high carbon dioxide levels are increases in parts per million (ppm) above background level but, more significantly, corrosion of calcium carbonate (i.e., cave formations) and/or visitor distress. Michie (1997: 215–16) suggests that surrogate measures such as the design intention for ventilation of buildings offer appropriate guidance for permissible levels of carbon dioxide, as the national occupational health and safety standards suggest levels for short-term exposure (15 minutes) that could result in serious visitor discomfort or distress. A general level of 1,000 ppm (0.1%) is recommended, although a very short exposure of up to 5,000 ppm (0.5%) is acknowledged as being possible.

Air quality is monitored with a Dräger apparatus to obtain in situ infrared grab sampling and continuous sampling (fig. 2). These measurements are taken periodically and can be used to determine cave recovery times, that is, the time needed for the air quality in a particular area to return to a normal background level. Some of this information has been correlated with meteorological, microclimatic, and cave visitation data (e.g., Michie 1997: 181–215).

Periodically, carbon dioxide readings are significantly higher than normal in aboveground areas (no doubt, a result of high vehicle numbers). However, the current levels of pollution are relatively low, although concerns continue regarding the contribution of carbon dioxide to weathering of exposed limestone areas. Belowground the situation is more serious. Monitoring has established that the presence and frequency of visitors in the caves during the peak summer season raises the carbon dioxide levels such that they do not "relax" to the normal background level within the target time of twelve hours. While these levels are not currently a threat to visitor health, the desirability of ongoing monitoring in this area is self-evident.

Measuring of physical corrosion resulting from high levels of carbon dioxide will need to continue. The corrosion threshold appears to be site-specific, and active formations do not appear to be threatened (Thurgate and Hamilton-Smith 1999).

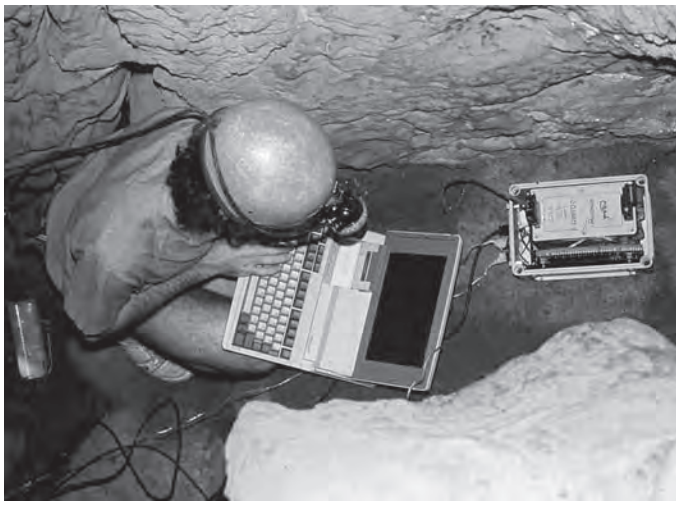


FIGURE 2 A scientist downloads information recorded during hydrological and water quality tests. Courtesy of Jenolan Caves Reserve Trust

Table 2 Monitoring Process at Jenolan Caves for Selected Social and Environmental Issues

Issue	Desired Condition	Indicators	Monitoring Methods	Causes of Problems	Priority	Management Response
Air quality (e.g., CO_2)	Normal levels for cave based on adequate characterization study	Visitor discomfort (as observed by cave guides) CO_2 levels above 1,000 ppm Corrosion of calcium carbonate	DRÄGER apparatus for in situ infrared grab sampling and continuous sampling to determine cave relaxation times; Meteorological and microclimate monitoring	Vehicles in Grand Arch and vicinity	High	Exclude vehicles from Grand Arch vicinity
				People	High	Monitor/modify visitation
				Microbial decay of organic material	Low	Reduce organic material
				Disruption of cave airflow patterns	Low	
Hydrology – Physical – Chemical – Biological	Near-natural conditions	Increased peak flows; poor water quality; low biodiversity	Historical records; stream gauging; water quality studies; biological surveys	Introduction of hard surfaces (such as concrete paths)	High	Increase and diffuse recharge areas
				Vegetation changes	High	Revegetate catchment
				Channeling of traffic and people	High	Relocate some structures, i.e., parking lots; traffic and people management
Unnatural cave desiccation	Near-natural conditions; Presence of indicator organisms at baseline levels	Dust dryness; Change in composition or decline in fauna	Temperature, evaporation/humidity; Indicator organisms	Paved surfaces and drainage systems	High	Reestablish natural drainage
				Unnatural air exchange	High	Install doors in caves to stop unnatural air exchange
				Stream diversion	High	Manage tour frequency
Trail quality	High safety levels; constructed to standards as outlined in manuals; trails providing a diversity of experience	Quality of surface; signage; trail width; amount of vegetation disturbed	Visual assessment by trained staff; relevancy to desired experience	Poor construction	Medium	Development of plan, brochures, and interpretation for trails
				Lack of maintenance; no policy for trails	Medium	
				Focus of staff and resources on high visitor use areas	Medium	Close trails at times of adverse weather and high visitation
Lampen flora (algae, moss, ferns, etc.)	Minimal growth; low treatment rate; no permanent physical damage by roots	Rate of treatment	Detailed records of treatment for each site	Exposure to light; use of unclean wash water; infection through introduction of spores	High, if significant growth on cave deposits	Reduce exposure time to light; infection control; develop new control techniques; studies on long-term effects of lampen flora
Lint (primarily hair, skin, and other organic materials)	Minimal level	Visible dulling of formation	Lint collection stations; petrie dish collection	Visitors	High	Require overalls to be worn; cyclical cleaning; remove wire netting from edge of cave paths; consider electrostatic removal systems
Radon	No health and safety issues for guides	Direct measure of emission	Radon badges/meters	Radioactive gravel deposits	High	Limit guide hours underground to safe level (1,000 hours per year)
Quality of visitor experience	High rating of experience; people going away wanting more; range of experiences achieved	Frequency of return visits; experiences achieved; ratings of experience	Visitor interviews, surveys, observation; guide feedback	Group size	High	Develop comprehensive visitor services plan using appropriate research
				Condition of cave	High	
				Number of visitors in cave at one time	Medium	
				Quality of interpretation	High	
				Program design	High	
				Vehicles in Grand Arch	High	
				Pricing	Low	

Source: Manidis Roberts Consultants 1995

FIGURE 3 Freshwater cave fauna like this tiny shrimplike crustacean known as a syncarid are good indicators of environmental change. Courtesy of Jenolan Caves Reserve Trust

Hydrology

Hydrological issues are at the heart of the health of the caves system. The desired condition is near-natural water conditions. Impacts are indicated by unseasonable peak flows, decline in water quality, or specific impacts on aquatic flora and fauna.

In the initial phases of implementing the monitoring program at the reserve, emphasis was placed on the physicochemical properties of the water (depth, pH, conductivity, temperature). Since these results were inconclusive, monitoring of freshwater invertebrates was added to the program in connection with a statewide project (fig. 3). Fecal coliform bacteria and other indicators of pollutants are also measured.

The hydrological studies are encouraging and suggest that although there is some pollution in the Grand Arch vicinity, water quality is generally good. Fecal contamination is present but at levels low enough to meet relevant standards for recreational water quality (although not for drinking water). It is therefore clear that ongoing monitoring is a major priority and that close attention must continue to be paid to bacteriological surveys.

Cave Desiccation/Humidity

Of the 350 identified caves at Jenolan, 16 are developed and open for public use. Physical modifications to the cave system to facilitate mass tourism have altered airflow and humidity. Although the desired condition is a near-natural state inside the cave system, the altered airflow and humidity and the introduction of particulates and vehicle emissions are unavoidably affecting what can be achieved.

Indicators monitored include particulates, dryness, and changes in the composition of flora or fauna. Over an extended period, weekly measures have been made of humidity, temperature, and evaporation, as well as particulate levels. The data indicate that metal-rich dust related to vehicle emissions is penetrating up to 50 meters inside some of the caves near the Grand Arch area and then is being disturbed and redistributed by visitors. The most obvious effect is increased dullness of some formations and consequent reduction in the visitors' aesthetic experience.

Data regarding the amount of water and humidity in the caves are gathered using some interesting techniques—including the attachment of rubber condoms to some formations (fig. 4). Desiccation and visitation frequency, rather than absolute visitor numbers, appear to be correlated. Management responses to desiccation include controlling the frequency of opening airtight doors that have been installed in the caves (fig. 5) rather than limiting the size of tour groups.

FIGURE 4 Rubber condoms are attached to some cave formations to measure the quantity of water entering the cave system. These data may be correlated with both external data (e.g., rainfall) and internal cave data (e.g., visitation numbers and frequency, desiccation). Courtesy of Jenolan Caves Reserve Trust

FIGURE 5 The opening and closing of airtight doors installed in the caves is used to stabilize humidity and manage desiccation. Courtesy of Jenolan Caves Reserve Trust

FIGURE 6 This specialized "track profile comb" was developed to measure and monitor trail degradation and erosion. Courtesy of Jenolan Caves Reserve Trust.

Trail Quality

The reserve features a network of scenic trails, many of which were constructed in the early twentieth century. The desired conditions for trails include high standards of safety, compliance with statutory controls, and a high-quality, diverse visitor experience. The impact on trail quality can be measured in a number of ways, including the quality of the surface and the amount of disturbance.

In view of the importance of trails to the total visitor experience at the reserve (not to mention obligations regarding public safety and potential liability), the trust has designed its own apparatus for measuring trail degradation and erosion using a "track profile comb" and photo monitoring (fig. 6).

This work reveals not only that the quality of some trails is substandard, but that trails are especially subject to erosion where they have existing soft substrate and during periods of wet weather and concurrent high visitation. These results are yet to be translated into management, but an obvious approach would be to consider closure of some susceptible trails after periods of inclement weather.

Lampen Flora

Lampen flora are algae, moss, ferns, and other plants that colonize new areas of the caves as a result of lighting introduced for visitation or management. The desired condition is minimal flora growth in the first place, with minimal need for treatment or management, and, of course, no permanent physical damage to the cave formations.

Although the presence of lampen flora is a highly visible impact to the caves, relatively little work has been done to date either on indicators or on monitoring, although staff currently keep detailed records of treatment at each site. (Treatments include manual removal and careful use of herbicide.) A number of management actions are possible, including relocating lighting, using herbicides, or cleaning; however, the problem is not considered sufficiently profound to warrant an active management response at this stage.

Dust, Lint, Hair, Skin Flakes

Visitors introduce dust, lint, and other organic particulates such as skin flakes and hair to the cave system. These organic particulates, in turn, may be the source of additional food for cave microbes and new bacteria. The desired condition is a dust- and lint-free cave system with pristine formations (rather than the discolored or "fuzzy" formations visible in the more heavily visited areas), as well as near-natural bacterial activity.

The accumulation of dust and lint can be measured directly, as has occurred at Jenolan Caves over an extended period using strategically placed Petri dishes as part of a doctoral thesis project (Michie 1997). The collection points were

located in both visited and wild (off-limits) caves. The presence of the Petri dishes provided opportunities for guides to explain the monitoring processes to interested visitors.

Not surprisingly, dust and lint accumulation correlates with visitor numbers; it is a cumulative, ongoing problem at Jenolan Caves. Cleaning cave formations with low-pressure plain water is possible, but the additional workload is not desirable. Although cleaning produces an aesthetically pleasing result, it does not fully address the implied introduction of an artificial bacterial food supply.

Significantly, Michie's work indicates that the impact of lint fibers on the cave ecosystem has been overstated relative to the subtler but longer-term physical change wrought by the mineral content of dust. Michie (1997: 179) attributes this to the high visibility of the lint fiber.

The current management regime is, therefore, minimal, comprising strategic placing of regularly cleaned mats on some pathways and periodic cleaning of limestone formations with water. Supplying lint-free overalls to visitors to fragile areas has been suggested as another control strategy, but it has not been implemented. There has also been discussion (but not implementation) of introducing lint pickers (small specialized implements to remove lint) and/or electrostatic devices at the entrance to some cave areas.

Radon

Radon, a radioactive element, has been identified in low concentrations in some of the mineral deposits within the cave system. While radon is of minimal danger per se, high cumulative doses may present health problems. Based on an extensive 1994–95 survey of Australian tourist caves (Solomon et al. 1996) and on national occupational health and safety standards, an action level, that is, a maximum level above which action must be taken, has been determined for radon. There is also the risk that visitors will perceive a health threat (e.g., through word of mouth, possibly leading to adverse publicity) and stay away from the caves. The desired condition with respect to radon is obviously that there be no health or safety issues. Radon concentrations are directly measured in the cave system using simple CR-39 detectors (Solomon et al. 1996: 4).

The trust is mindful that prolonged exposure to high concentrations of radon and its radioactive decay products is linked to an increased risk of cancer (Jenolan Caves Reserve Trust 1997). However, it is abundantly clear from the data gathered to date that visitors are not exposed to radon for long enough periods for this to be a problem. Nevertheless, radon exposure is an occupational health and safety issue for guides and other staff. The trust has therefore introduced a provisional policy that limits staff underground hours to a maximum of one thousand hours per year and requires routine monitoring of individual exposure with personal radon measuring devices.

Visitor Experience

Provision of an outstanding visitor experience to Jenolan Caves is one of the key statutory and corporate objectives of the trust. The caliber of visitor experience can be measured through a range of indicators, including visitor survey responses, the frequency of return visits, or observation of visitor behavior and the impact of crowding on people and services. A range of visitor surveys have been undertaken, including group discussions, personal interviews, and written surveys. External consultants, graduate students, and trust staff have conducted a number of observational activities, and there have been surveys of bus tour groups and independent travelers. The visitor surveys and monitoring conducted at the reserve are directly related to a range of other trust activities, including marketing and customer service.

Survey results suggest that visitors are generally satisfied with their experience but express dissatisfaction relating to crowding, access, and excessive time underground. It is clear that tour group size is a major issue. (Other visitor satisfaction issues arise from negative experiences with some of the accommodations and with food and beverage concessions operating at the reserve, but these are not addressed here.)

Results of monitoring visitor experiences at Jenolan Caves have been used by trust management in a number of ways, in particular, in the development of visitor services and interpretation plans.

Summary

The Jenolan Caves Reserve is one of Australia's great natural wonders, enhanced by a rich cultural history and a superb built environment. The challenge for managers of this extraordinary but increasingly popular attraction is to prevent it from being "loved to death." Implementation of the environmental and social monitoring program at Jenolan Caves is still in its infancy. The trust continues to allocate resources to gathering baseline data.

The Visitor Impact Management framework adopted by the trust provides a structured basis for dealing with

the potential for increased visitation while at the same time minimizing environmental impacts and enhancing visitor opportunities and experiences. The process enables the Jenolan Caves Reserve management to measure and understand the effects of actions on both visitors and the fragile ecosystem.

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Notes

1 Concerns about the impact of this road on the karst ecosystem and the visitor experience led, in the mid-1990s, to consideration of alternative access arrangements that included aerial (cable car or gondola) proposals that would have relied on a major increase in visitors. Government officials have decided not to proceed with any of these proposals at this stage.

2 This model offers an integrated approach to congestion management that recognizes that the congestion of sites cannot be solved by site managers alone and that site managers require the active support of other key stakeholders, including local authorities and other private-sector services that provide infrastructure allowing transport to and from the site. Congestion is minimized through destination management and demand management, issues linked by the experience of the visitor through three stages of demand: choosing a destination and time to travel (Demand Management) and the subsequent journey to the destination; the destination (Destination Management); and the site (Site Management).

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