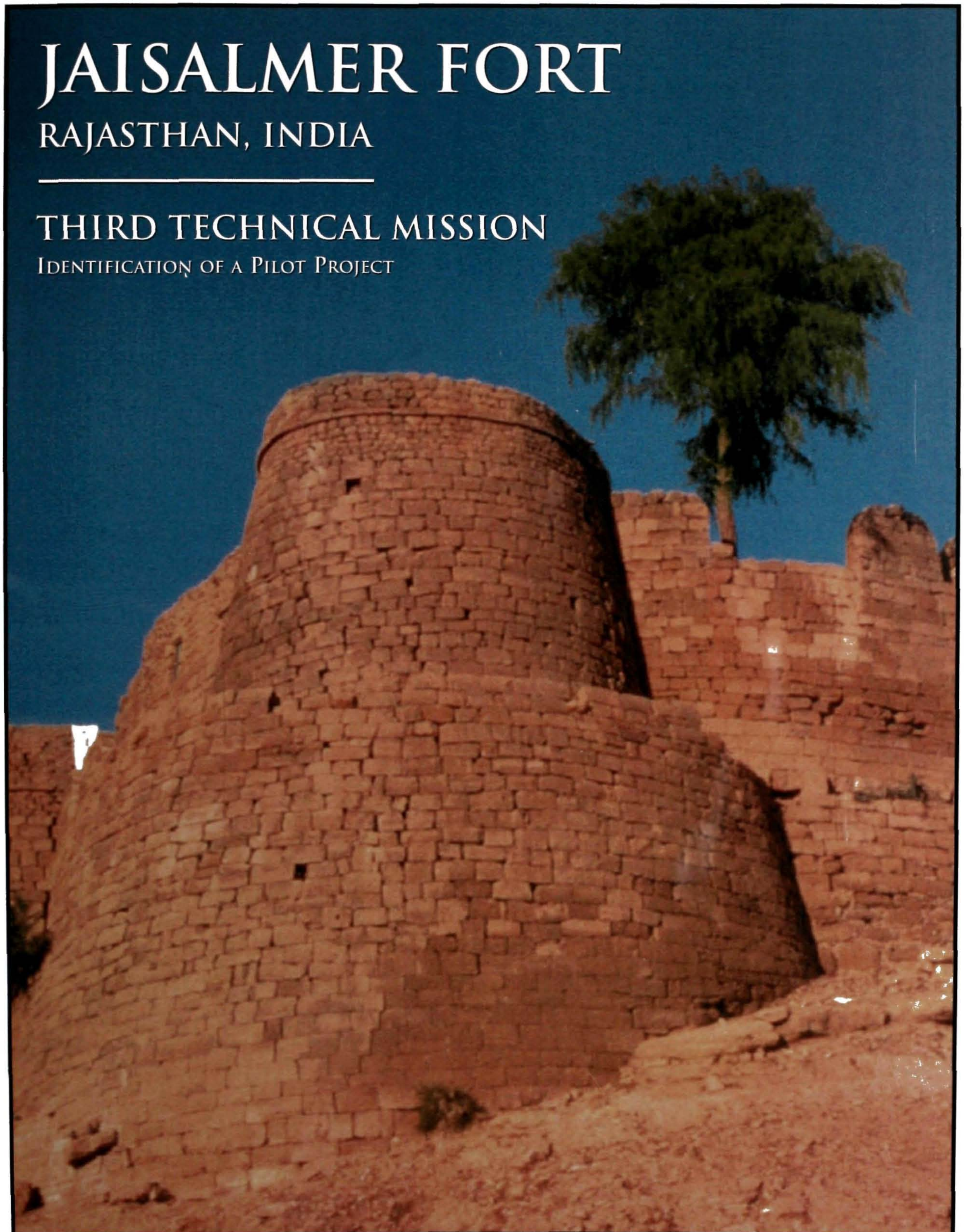
JAISALMER FORT

RAJASTHAN, INDIA

THIRD TECHNICAL MISSION

IDENTIFICATION OF A PILOT PROJECT



WORLD MONUMENTS FUND

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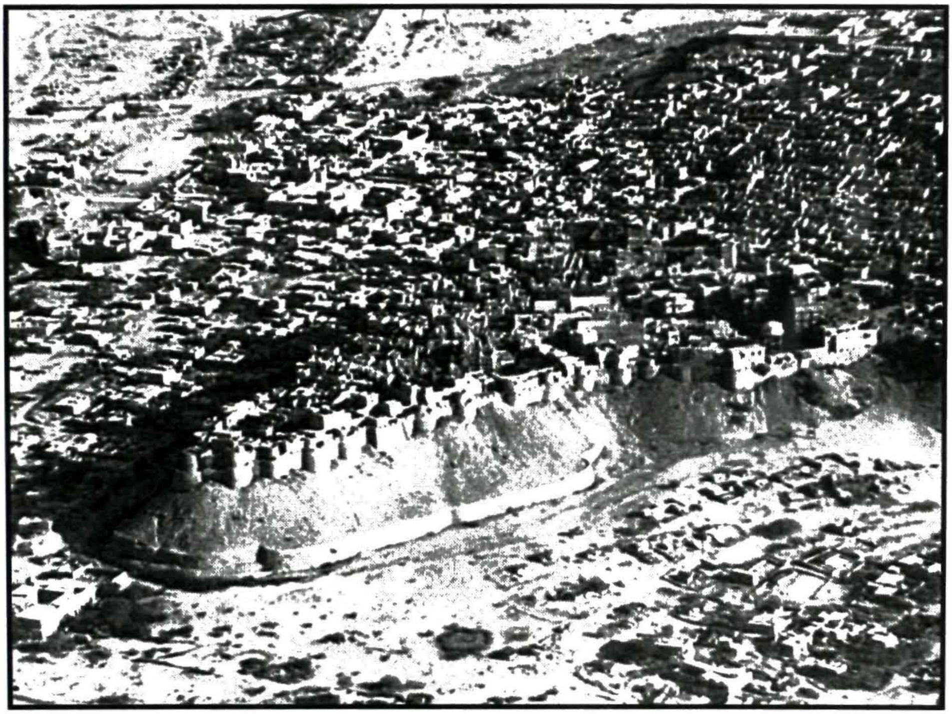
January 8–17, 2001



THE WORLD MONUMENTS FUND

with

SWECO INTERNATIONAL

New York—June 2001

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Cover Image: Mark A. Weber
Inside Cover Image: Kulbhushan Jain

ACKNOWLEDGEMENTS

The World Monuments Fund's third technical mission to Jaisalmer in January 2001 was made possible through the generous support of The Selz Foundation. The Foundation's commitment to preserving Jaisalmer Fort allowed WMF to investigate the complex array of problems confronting the Golden City and prepare the action plan presented in this report. The continued support of Mr. Robert W. Wilson, whose challenge grant will be used to implement the first phase of the stabilization work with the Indian government, is deeply appreciated.

In Delhi, the WMF team was warmly received on two occasions by Mrs. Komal Anand, Director General, and Mr. S.B. Mathur, Additional Director General, of the Archaeological Survey of India (ASI). They were most helpful in coordinating the mission's work program and helping to craft the Memorandum of Understanding which will guide the future collaborative project to survey and stabilize the outer fort walls.

INTACH (Indian National Trust for Architecture and Cultural Heritage) Director General Dr. O.P. Agrawal reaffirmed thier committment to Jaisalmer and willingness to work with WMF. Bindu Manchanda, INTACH's Jaisalmer project director, accompanied WMF to Jaisalmer, where she was most helpful in providing up-to-date account of recently completed work at the Rani Ka Mahal and Jaisalmer in Jeopordy's Streetscapes paving project.

Mr. Kuldeep Ranka, Collector, District of Jaisalmer, and Dr. Lalit Panwar, Secretary, Tourism, Art & Culture, State Government of Rajasthan, were instrumental in convening and leading a productive first meeting of the Jaisalmer Fort Task Force that was created for oversight of the WMF/Government of India collaborative project.

Gratitute goes to Maharawal Shri Brijraj Singh of Jaisalmer and his staff for graciously hosting the WMF team at the Jawahar Niwas Palace hotel and for a memorable dinner under the stars at the royal family's desert retreat Moolraj Sagar.

The principal authors of this report are Amitabh Verma, consulting architect and rapporteur, Mark Weber, WMF Mission Team leader, and Bjorn Holgersson, Hydrogeologist, and Lars Engvall, Civil engineer, of SWECO ABB, Stockholm, Sweden, the principal consultants for the mission. Keith Porteous and Angela Schuster of WMF were instrumental in the preparation of this report for publication. Finally, special thanks to architect Kulbhushan Jain, whose dedicated work to preserve Jaisalmer Fort over the last twenty years is recognized and appreciated by all who have had the pleasure to work with and learn from him. His many reports and graphic materials, some of which were kindly loaned for use in this report, have greatly assisted WMF's efforts in documenting and understanding the Fort's complex array of physical conditions and conservation issues.

PHOTO 1
A general view of Jaisalmer Fort from the east.

The World Monuments Fund (WMF) is a New York-based nonprofit organization that safeguards the heritage of mankind by supporting the conservation and preservation of art and architecture worldwide. Founded in 1965, WMF has brought international attention and funding to more than 165 conservation projects in 52 countries, including the Temple of Preah Khan, Angkor, Cambodia; Tintoretto's paintings for the Scuola Grande di San Rocco, Venice; the Tower of Belem, Lisbon, Portugal, and the Paradesi Synagogue, Cochin, India.

In 1995, WMF launched the World Monuments Watch List of 100 Most Endangered Sites, to identify and help save historic sites around the world in significant peril. Every two years, a panel of international experts chooses from nominations submitted by governments, non-governmental organizations and qualified specialists. Sites on the 2002 list include the Gothic cathedral in Beauvais, France, the Great Wall of China Cultural Landscape, Beijing, and Historic Lower Manhattan, New York City, listed as the 101st site following the devastating destruction of the World Trade Center on September 11, 2001.

The six sites on the 2002 list in India include Anagundi Historic Settlement, Karnataka; Maitreya Temples of Basgo, Leh, Ladakh; Dwarka Dheesh Mandir Temple, Ahmedabad; Lutyens Bungalow Zone, Delhi; Nako Temples, Nako; and the Osmania Women's College, Hyderabad. Jaisalmer Fort, Jaisalmer, was removed from the Watch List as a result of the progress made over the last five years. Since the Fort's first listing in 1996, WMF has undertaken three technical missions that have resulted in the restoration of the Queen's Palace and the development of a conservation plan and proposed pilot project to stabilize and conserve a section of the outer fort walls, the subject of this report.

The World Monument Fund's Third Technical Mission to Jaisalmer took place in January 2001. Following the previous two fact-finding missions, it is the most recent step in WMF's increasing involvement with the conservation of Jaisalmer Fort. The purpose of this mission was threefold: completing the technical assessment of the hydrological and geo-physical aspects of the fort; establishing a formal partnership with the Archaeological Survey of India (ASI) under the provisions of the Robert W. Wilson Challenge Grant; and, identifying a specific area of the fort for a Pilot Project.

The preceding missions had identified the cause of the most severe problems as an inadequate drainage system, coupled with increasing levels of sub-surface moisture in the soil below the Fort. With this information, this mission was able to direct its efforts toward a focused study of these phenomena. This knowledge also made possible the participation of experts from the geotechnical firm SWECO International, who studied and provided valuable testimony on these issues. SWECO's findings and recommendations for further investigations and interventions are presented in the second half of this report.

Observations during this mission again underscored the complex nature of the problems present in Jaisalmer. The historic fort and buildings still form a base for the growing and rapidly diversifying community. Subsequently, conservation here takes on a social, cultural, environmental and economic dimension, in addition to the archaeological. This in turn creates a very delicate situation, in which all restorative measures and solutions must be carefully considered in light of their implications for these diverse factors. This necessitates a close partnership between WMF, ASI, and local administrative bodies. To achieve satisfactory results, it is critical that this relationship be one of cooperation and easy interchange of ideas and information.

Conservation efforts in Jaisalmer must be directed on two fronts. Most urgent is the implementation of emergency measures in order to arrest deterioration and prevent further damage. Geared towards addressing the most pressing concerns, these would include:

- Facilitating the proper drainage of water away from the Fort
- Stabilizing the structures that are unstable and/or damaged
- Enabling efficient garbage disposal from all areas of the Fort

These steps should be undertaken before the onset of the next monsoon season.

Simultaneously, it is imperative to begin the process of data collection. Accurate data is a prerequisite to proposing sustainable solutions, and must be compiled as soon as possible. Funding for a part of the data collection would be available through the Robert W. Wilson Challenge Grant Program, which would also finance the Pilot Project. This grant of up to $500,000 is a matching fund that requires an equal amount to be raised from non-USA based private donors, corporations or NGOs, and a 1:2 match toward local and national government contributions.

Following the Pilot Project, the next stage will be the development of a long-term Conservation Action Plan, that would broaden the scope of conservation work to include the city, in addition to the Fort. Upon successful completion of the Pilot Project, WMF could act as a facilitator between all stakeholders in an effort to coordinate the conservation efforts in Jaisalmer Fort.

The Fort in Jaisalmer occupies a unique place in the Indian tradition. In addition to being of unequalled architectural and aesthetic significance, it is also an invaluable cultural treasure, being the only living fort in India today. Built of the very same golden-bronze rock on which it stands, it is known colloquially as *Sonar Kila*, or the Golden Fort. It is a national asset whose urgent conservation is necessitated by the fact that a monument that has endured for almost a thousand years has been brought to the brink of destruction in the short span of only a few decades.

Recent years have seen an alarming degradation of the Fort and the remarkable palaces, *havelis* and neighborhoods contained within. Stemming from a variety of environmental, social and natural causes, the magnitude of the damage is such, that if steps towards sustainable conservation are not initiated immediately, it is a real possibility that in the coming years this treasure will be beyond rescue and be lost forever.

To a visitor today, the Fort and the buildings present a distressing spectacle, one that juxtaposes glimpses of past beauty and glory with those of contemporary decay and disrepair. Many parts of the outer wall, along with several of the bastions, show signs of serious structural failure, some having collapsed completely. The facades of the beautiful *havelis* and mansions are marred by billboards, vandalism and unauthorized construction. The structural integrity of many of them, as that of the fort walls and bastions, has been jeopardized by reckless additions to houses. An inordinate amount of garbage is generated daily by residents and visitors, and in the absence of a comprehensive garbage disposal system, is deposited in the streets, where it is scattered by scavenging animals. The *Mori*, a once pleasant walkway circling the Fort, is marred by several collapsed sections, ubiquitous piles of rubble and heaps of accumulated trash, besides being used by residents as a public latrine. Everywhere inside the Fort, one sees a rapidly degenerating community that is losing the coherence, order and beauty that have characterized it for close to a millenium.

It was the above scenario that led to an awareness of the threat facing Jaisalmer Fort, an awareness that resulted in it finding a place on the WMF list of 100 Most Endangered Sites, first in 1996, and then again in 1998 and 2000. The need for immediate action was underscored by the collapse in 2000 of two bastions and a large section of the pitching wall during the rains. The involvement of the WMF with Jaisalmer began with a visit to the Fort in January 1997 by John Stubbs, Vice-President for Programs, which was succeeded by the Second Technical Mission to the site by a team of experts in December 1999.

The Second Technical Mission headed to India with the intention of assessing the situation and also interacting with the concerned stakeholders and key participants. The team attended several meetings with the many individuals and institutions that would be associated with a project of this magnitude. These included the Collector of Jaisalmer, the Archaeological Survey of India (ASI), the Public Works Department (PWD), and local residents, who would be participants in the process and the ultimate beneficiaries of its success.

1. Introduction:

The Third Technical Mission to Jaisalmer consisted of team leader and WMF Technical Director Mark Weber, civil engineer Lars Engvall and hydrogeologist Bjorn Holgersson representing SWECO International, rapporteur and architect Amitabh Verma, and WMF's India representative Amita Baig. The mission lasted from January 8 to 17, and involved on-site work in Jaisalmer, along with visits to New Delhi and Jodhpur.

2. Mission Objectives:

The primary focus of the mission was to build upon the excellent groundwork done by the preceding two missions. Following the extremely positive response to the its initiative by concerned citizens as well as organizations, WMF sought to formalize and define a program for the project to be funded by the Robert W. Wilson grant. The primary goals of this mission were the following:

1. Setting up of a framework for long-term involvement with conservation in Jaisalmer:
   The Mission intended to conduct a comprehensive study of the existing situation in Jaisalmer, as relevant to the undertaking of future conservation efforts for the Fort, the buildings and neighborhoods within. The desire was to obtain an overview of the critical issues and potential problems that would need to be examined before any effort could begin. An attempt was also made to identify the key organizations and players that have been involved with developments inside the Fort, including municipal and governmental bodies in charge of maintenance, as also non-governmental organizations, or NGOs. It would be important to set up a dialog with these bodies, so that the various works to be undertaken in the future can all proceed smoothly without conflict or repetition. Also, these projects could benefit greatly from the experience and knowledge of these players who have already been active in the improvement of Jaisalmer.

2. Finalizing of agreements with the primary agencies relating to the Fort:
   While in India, the WMF team participated in several meetings with governmental and administrative organizations, seeking to establish active partnerships that can contribute to the restorative effort in Jaisalmer. Primary among these were meetings in New Delhi with officials of the Archeological Survey of India (ASI), the government organization that has been entrusted with safeguarding all historic treasures in India, including Jaisalmer Fort.

   The first meeting with the ASI was held at the Directorate Office, New Delhi, and was attended by several ASI officials, including the Assistant Director General, Mr. S.B. Mathur, and Dr. Lalit Panwar, Secretary, Tourism, Art & Culture. It was a forum for the WMF to express its sincere concern about the deterioration of Jaisalmer Fort, and also its desire to assist the situation to the greatest degree possible under the Wilson grant. The team expressed the hope that the funds so made available will provide a much needed reprieve at this critical juncture. The parties also discussed the Memorandum of Understanding that would set forth the specific conditions and roles of the players, the scope of the intended work, and the desired timeline. Alternate methods of raising the additional funds required were also explored.

   The WMF initiative was returned in kind when the ASI expressed its wholehearted support of the proposed partnership, and its desire to contribute all possible resources to the effort. Although the ASI has the monumental responsibility of safeguarding close to 5000 of India's monuments, it agreed to make a special effort toward Jaisalmer, both in recognition of the unique nature of the Fort, and also to enable the WMF contribution to achieve its fullest potential.

The first step taken by the ASI during the meeting was the decision to set up a Task Force, comprising of officials and representatives who can most aid the restoration effort. The creation of this Task Force is a positive development that serves to highlight both the seriousness of the threat facing the Fort as well as the resolve of the associated groups to take timely action to forestall it.

3. Collection of data on the Fort, background and environmental factors:

   On site, the team sought to collect as much pertinent and specific data as possible. It conducted several surveys of the Fort and buildings, recorded information, and also researched existing documentation on the subject. The INTACH library in New Delhi proved to be a valuable resource in this respect. Unfortunately, attempts to locate a recent and accurate plan of the Fort proved unsuccessful. The team also discovered that some of the information about the Fort was inaccurate. For example, a visual survey indicated that the number of bastions, universally accepted as 99, was actually 89. Similarly, the stated height of the hill as 240 feet above the surrounding plain was also called into question. A visual inspection by the team suggested that the actual elevation is significantly lower.

   To collect data on civic services and infrastructure for the Fort, the team held several meetings with the government agencies responsible, both in Jaisalmer and Jodhpur. These were the PHED (Public Health and Education Department) and the GWD (Ground Water Department), in addition to the ASI. These meetings were extremely fruitful in providing the team with information on the existing and proposed infrastructural services for the area. To investigate options for obtaining the necessary surveys and maps in the future, the team visited two organizations in Jodhpur. These were the SRSAC (State Remote Sensing Application Center) and the RRSSC (Regional Remote Sensing Service Center), and it was felt that both had the necessary technological capacity, as well as the experience, to generate the information that will be desired by the WMF.

4. Diagnosis of geophysical and hydrological conditions and problems:

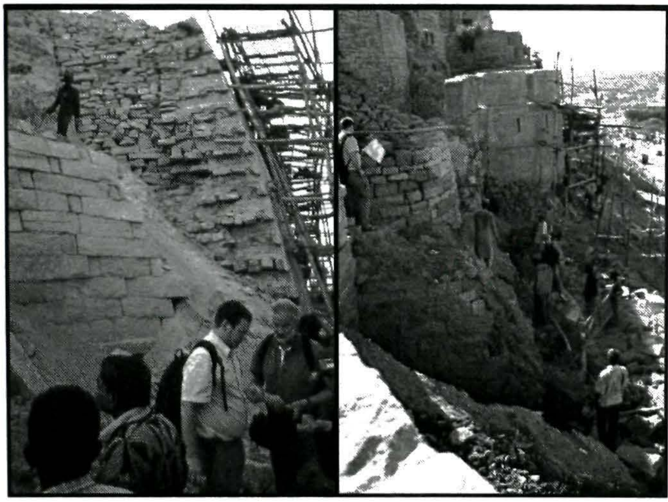
   Recognizing that the most serious problems in this case are related to the water and sewage services inside the Fort, WMF invited the reputed engineering firm SWECO International to examine and assess the factors that are adding to the process of deterioration. SWECO International has had many years of experience in dealing with problems of this nature in all parts of the world, including areas with social and physical structures similar to those of Jaisalmer. In addition to previous work in India, they have undertaken projects several other countries, including Egypt, the Philippines and Pakistan. It was felt important to incorporate their input early in the process, so that conservation efforts could be initiated with the most background information possible, thereby allowing for the selection of the most appropriate approach to the problems.

5. Defining the scope of a Pilot Project and identification of a potential site:

   The first step of the long-term restoration effort for the entire Fort, a Pilot Project would be an illustration of the ultimate improvements intended for the entire complex, but applied to a small sample area. For this, a site was desired that would be a microcosm of the Fort, possessing all of the constituent features, along with the characteristic problems. By initially addressing the entire spectrum of issues present but on a limited scale, conservation strategies can be most effectively tailored to achieve maximum impact when applied to the entire Fort. Similarly, project costing for the entire Fort perimeter can also be extrapolated from the results obtained from this exercise.

6. Observation of ongoing projects and works underway:
Progress on the work currently being executed was observed and documented by the team. This included:
The restoration of the *Rani-ka-Mahal*, including the construction of the new exhibition spaces that are being added on to the palace, the restoration of the living quarters of the King's and Queen's palaces, and the clean up work of the lower portion of the palace.
The repair work presently being completed at several locations around the Fort by the ASI. At different locations, it includes rebuilding of the collapsed or failing sections of the Pitching Wall (on the west face of the Fort wall), and the complete reconstruction of the two Bastions (also on the westernwall) that had collapsed during the monsoon in August 2000.

A visit was also made to *Chaughan Pada* neighborhood (several hundred feet northwest of the main square) where problems have arisen from the work undertaken recently by the Telephone and Electricity Departments. Due to a lack of coordination between the various municipal agencies, the paving stones of the lanes in this neighborhood were repeatedly dug up, first by the crew installing telephone cables, and then by workers laying new electrical connections. In each instance, the paving stones were relaid in a haphazard manner, without any regard to the original condition. Consequently, the pavers have now come loose or settled unevenly, making the lanes and alleys difficult and even dangerous to traverse. Naturally, the aesthetic appearance of the lanes has also been severely compromised. Such cases reiterate the need for coordination among the various players and it becomes imperative that all future works in an area be planned and appropriately scheduled, so that the residents are spared any such avoidable inconvenience.

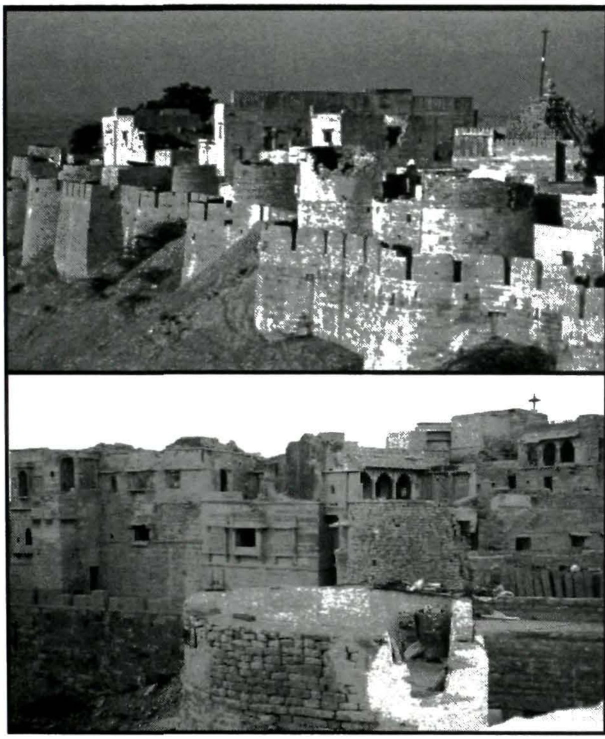


PHOTOS 2 & 3
WMF mission team engineers from SWECO International, left, inspect rock samples in front of the ASI pitching wall repair site. Excavations for the reconstruction of the west upper bastion, right, reveal wall foundation details.

The team studied the condition of the various components of the Fort, and examined the different items individually and extensively. The existing conditions, problems and extent of deterioration were observed and documented. The general analysis of the items is as follows:

1. Bastions/Inner Fort Walls:

The present state of the sandstone bastions circumscribing the Fort ranges from well preserved to seriously endangered. While a few on the eastern face are in fairly good condition, most others show signs of severe damage. As mentioned earlier, two bastions collapsed entirely during the rains in 1999. Some others are showing signs of imminent failure, with bulging base walls and crumbling stone blocks. Several bastions have been illegally occupied and converted into residences, thereby subjecting them to loads they were not intended to sustain. In some places, the crenellations have been incorporated into extended walls, which, in addition to being visually inappropriate, create a potentially dangerous situation for the residents and the people in the surrounding areas. A few bastions are disintegrating, partly due to weathering and partly due to the removal of their stone blocks for use as building material by the residents.

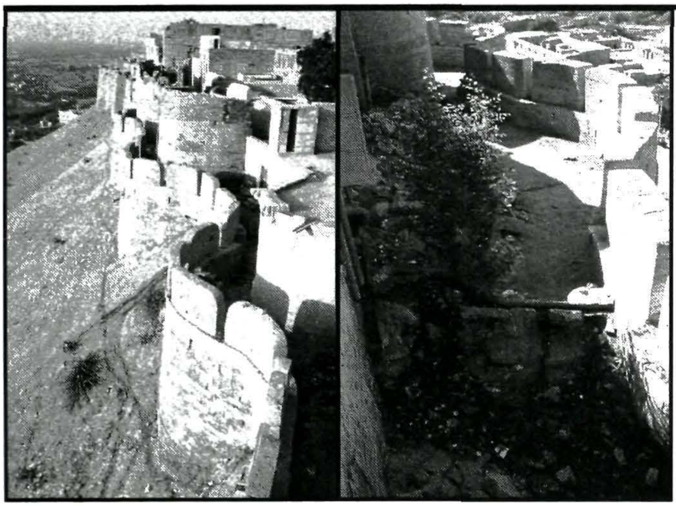


PHOTOS 4 & 5

A general view of the east range of the fort's upper slope and bastion walls, top. Additions made to the inner bastion walls during hotel construction, below, have compromised the fort's profile and increased pressure on wall foundations.

2. *Mori*:

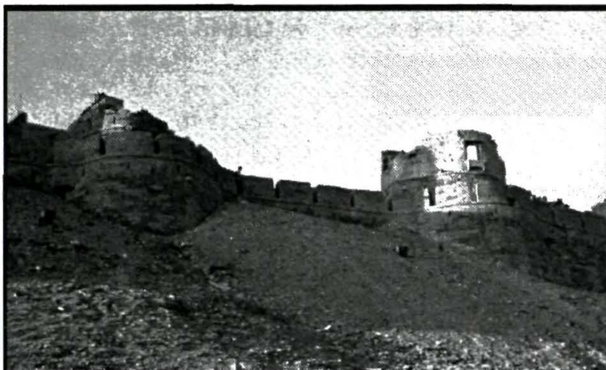
The *Mori* is the narrow passageway between the inner and outer bastions walls that meanders around the perimeter of the fort. Designed primarily for defensive purposes, the *mori* also functioned as the fort's main drainage conduit for storm-water during monsoons. Today, the most serious concerns relating to the *Mori* 's condition is its use as a latrine by residents without toilet facilities and the widespread habit of using it for the disposal of household garbage. This has had a severe impact on its condition, keeping it from serving its original drainage function. The paving in the Mori is uneven or missing altogether, with no signs remaining of the original outward pitch for effective drainage. There are innumerable mounds of rubble and discarded building material, which further obstruct the flow of water to the outer wall, thus forcing it into the ground below. The increasing moisture in the Mori has also encouraged the growth of vegetation, whose weight and root structure will, over time, lead to total disintegration of large sections.



PHOTOS 6 & 7
A view down into a section of the Mori's passageway, left, which was originally designed for defensive and drainage purposes. Drainage outlets, right, are blocked by household refuse and unchecked vegetation.

3. Outer Fort Wall:

Several sections have failed due to the uneven settling of the soil underneath, caused by moisture percolation. Due to the dumping of garbage over the slope, the outer wall has become buried under the accumulation, in several places almost entirely. Conversely, in other locations, the base of the wall, which was intended to be covered, has been exposed due to the erosion of the slope. The rough-hewn, unfinished stone so uncovered has failed in many places from contact with the elements. There are many instances where entire blocks of stone have disintegrated or dissolved, leaving large holes in the wall. The outer wall is also under serious threat by the rampant growth of vegetation, particularly the *Peepal* tree (*Ficus religiosa*), which tends to have an extremely invasive and damaging root system. Some bastions, especially on the eastern side, are buried under years of accumulating garbage.

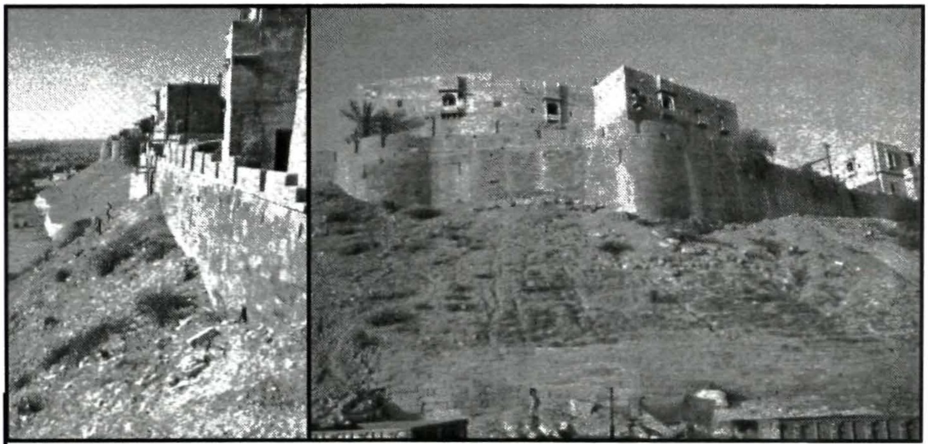


PHOTOS 8 & 9
Sections of the outer bastion wall, top, are covered by garbage and sandstone constuction debris dumped over the years. Foundations of the circular bastions, below, have been eroded by wind and rain.

4. SLOPE:

On all sides of the fort, the slope has suffered considerably from erosion and the continuous dumping of trash over the years. Although it is likely that this had been the practice throughout history, until recently the amount generated by the residents tended to be small and entirely organic. Lately, however, both the amount and nature of the refuse have changed, with non-biodegradable materials (plastics, metal, styrofoam, etc.) forming a large part of the debris. These tend to remain in place for extended periods of time, a process exacerbated by the greatly reduced occurrence of sandstorms, which would previously disperse the debris over a larger area. Significantly, much of the garbage today appears to be generated by tourists or tourism-related industries, such as plastic bags, film canisters, mineral-water bottles, etc.

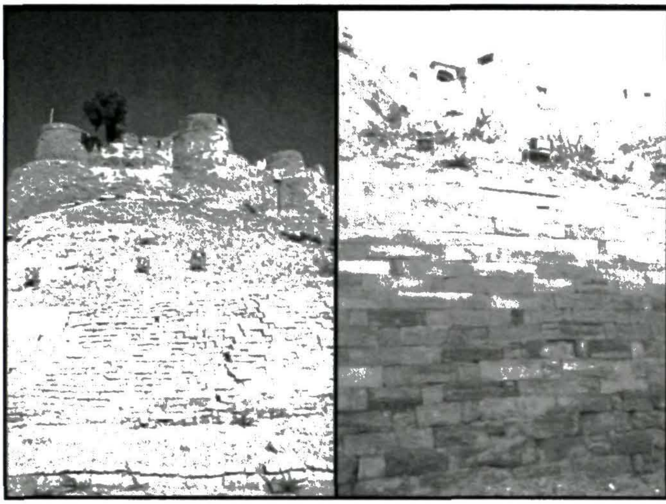
The condition of the slope has also been seriously compromised by erosion caused by wind and water. As mentioned earlier, this has exposed the base of the wall in many places. The increasing precipitation has washed away much of the upper layer of the slope, while facilitating vegetation growth. This fact is doubly destructive, since plants tend to further retain water within their roots, beginning a cycle of deterioration. The erosion is exacerbated by the animals and rag pickers who climb the slopes several times a day to forage amongst the garbage dumps.



PHOTOS 10 & 11
An increasing amount of non-recyclable material has been dumped over the bastion walls, left. Monsoon rains have carved gullies that funnel water down the slope, some of which collects behind the pitching wall.

5. Pitching Wall:

Due to its exposed position and considerable length, the Pitching Wall has seen much damage to its original form. It is of dry masonry construction, and ranges in height from 6 meters to 10 meters. Since it was originally intended merely to maintain the slope above it, it was not designed to withstand any lateral loads. The erosion of the slope, however, along with the seepage of water into the subsoil, subjects the wall to tremendous outward pressure, which it has been unable to withstand. It has collapsed in several places, and the rebuilding of the Pitching Wall is an ongoing work for the ASI. Often, the stones of the Pitching Wall are seen bulging or shifting, and some sections are visibly moist and wet. As in other parts of the Fort, the moisture has led to a complete dissolution of some blocks. In recognition of the changed situation and function of the wall, the portions being rebuilt by the ASI are provided with concrete footings and are designed to serve as retaining walls.



PHOTOS 12 & 13
As the clay absorbs water, the increased weight exerts pressure on the pitching wall, left, resulting in shifting and cracking. Dark sections of the pitching wall, right, attest the presence of moisture in the sandstone veneer and claystone behind it.

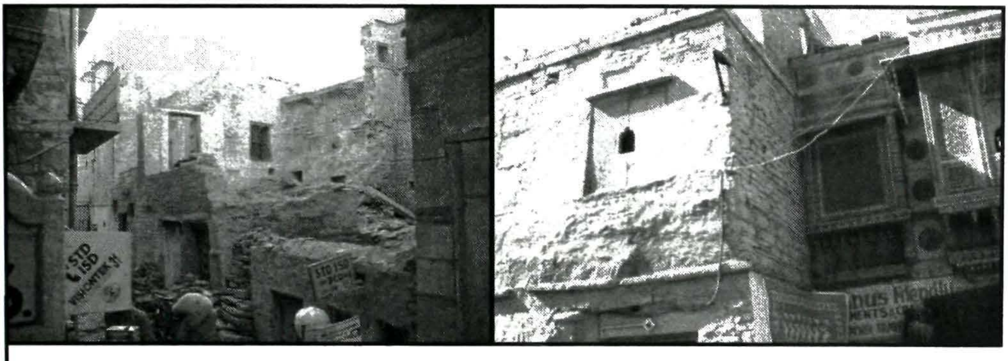
6. Structures and Buildings:

Most of the historic buildings inside the Fort are in need of immediate restorative measures. To date, 87 out of the 469 buildings have collapsed, and this rather large proportion gives some indication of the seriousness of the problem. Many of the houses have been built upon or added to, and converted into hotels or tourist accommodations. Some of the protected sites have been occupied by encroachers and are being used to house shops and retail businesses.

a. The most pressing concern about the historic monuments is structural failure, brought on by the settling of the subsoil caused by water seepage. Since the buildings were traditionally built of dry-masonry construction and without foundations, they have been unable to withstand lateral loads of even the smallest degree. The instances of building collapses have shown a marked increase during and immediately following the rains every year.

b. In some of the smaller private houses, the structural failure is often caused by unauthorized construction, with the residents building upon existing walls indiscriminately. Much of this additional construction has been to cater to the growing tourism industry, and is in violation of ASI guidelines for protected monuments.

c. The aesthetic value of the buildings is also being compromised rapidly. The new construction is of mediocre quality and substandard in materials and workmanship. There is an increasing tendency to use brick and cement for construction, instead of the sandstone blocks traditionally used. There are large, unsightly hoardings and billboards all over the city. Not only are they visually offensive, they also conceal the elegant facades of the buildings, in some cases even disfiguring them. The grand and ceremonial identity of spaces such as *Dassehra Chowk* has been completely overwhelmed by the riot of signs promoting hotels, restaurants, souvenir stores and lately, e-mail services.



PHOTOS 14 & 15
Collapsed buildings, left, collect rainwater, which migrates to and undermines adjacent foundations. Traditional facades are marred by the use of inappropriate construction materials such as concrete block and portland cement.

7. Streets and Lanes:

Most of the original paving in the streets throughout the Fort is in a greatly compromised condition. The stones have come loose and are generally uneven; they show signs of erosion after centuries of use. In some areas, an effort is being made to improve the condition of the streets by the laying of new dressed pavers that replicate the original configuration. The team visited Vyaasa Pada, a square within the Fort, where a project is underway to pave the street and alleyways, after incorporating new sewage and water disposal systems. This work is an undertaking of Jaisalmer in Jeopardy, a non-governmental organization that has been actively supporting the restoration of the Fort and the town.

PHOTOS 16 & 17
Ad-hoc repairs to municipal water and sewage connectons and telephone lines, left, have damaged paving stones. Workers, right, install paving stones using a traditional lime mortar mix.

Having established a very satisfying rapport with the various actors in the conservation effort, the WMF is looking forward to the beginning of an extended partnership in the restoration and improvement of the condition of the Fort. This section proposes the immediate steps to be taken towards the achievement of this objective, to be applied in the form of an Implementation Plan. This plan will guide the initial and subsequent steps to be taken by the players over the next few stages.

There will be two phases in the application of this plan. Phase I will constitute urgent preventive measures and data collection, while Phase II would be the Pilot Project.

PHASE I

A. Undertaking of Emergency Measures:

In view of the continued deterioration of all parts of the Fort, several steps need to be taken immediately to prevent further damage. These should preferably be in place before the advent of the next monsoon in the year 2001. It is evident that the size and complexity of Jaisalmer Fort make any conservation an immeasurably difficult undertaking. It must be mentioned that even with resources that are inadequate for the task, the ASI has been doing a commendable job of addressing issues as they arise, in a timely and thorough manner. Although there are several issues of concern, emergency repairs and prevention are of the greatest priority, and the main efforts of the ASI are best directed towards that end. There are a few measures that should be initiated simultaneously, in order to prevent serious problems in the future. These are as follows:

1. Cleaning and repair of Mori: In order to restore structural stability and prevent water accumulation, the Mori and its drain outlets should be cleaned of debris and the collapsed portions rebuilt as soon as possible.

2. Covering of collapsed buildings: Collapsed buildings present a grave danger to the Fort by allowing the collection and slow percolation of water into the soil. All such structures inside the Fort should be covered with an appropriate temporary roof, preferably of metal, adequately sloped to drain the rainwater away and prevent ponding.

3. Monitoring of structural movement: Until comprehensive data on the structure and formation of the hill becomes available, a preliminary monitoring system should be installed in areas of likely settling and movement to gauge the exact magnitude of the shift over a period of time.

4. Cleaning of disposal pipes: Both the storm water removal and sewage disposal pipes should be thoroughly cleaned. There is much refuse that is presently blocking the pipes and traps, thus preventing optimal performance. Its removal will allow the systems to function to their fullest and make a significant contribution toward the reduction of some of the existing problems.

5. Repairing of the slope: Efforts should begin to reclaim the original character of the surrounding slope by restoring the correct profile and pitch. Although this is not a goal that can be accomplished in a short period of time, work should be initiated nevertheless on the worst affected areas. These would include sections with the most severe erosion as

well as those with the most debris accumulation. This is important because the correct gradient of the soil (greater than 32°) will significantly increase water runoff from the slope and minimize seepage into the soil, thereby forestalling much damage in the future, most notably to the already suffering Pitching Wall.

B. Collection of Accurate Data:

The World Monuments Fund strongly feels that any serious effort toward the long-lasting conservation of Jaisalmer Fort must be grounded in comprehensive and thorough background data and information. Not only will this allow for the accurate prioritization of issues in the most efficient way, it will also enable the selection of the most suitable remedies. It will make it possible for all players to streamline their resources in an effort to achieve the optimal results. This fact is of paramount importance in a situation where a large and complex task is to be addressed with a limited supply of funds, and the only option is to exploit every single resource to its fullest.

In Jaisalmer's case, there is an almost total lack of reliable documentation of any kind, a situation that must be rectified immediately. It is recommended that this process begin with the assimilation or generation of reliable, comprehensive and current maps, for the relevant areas and fields. The documents and activities required are as follows:

1. Base Map: A detailed and accurate base map must be generated, which can then be used to overlay other pertinent data. This map should have a precisely indicated outline of the Fort, including all features such as the Bastions, the inner and outer walls, the Pitching Wall, the Mori, etc. Also required would be building footprints, streets, lanes and the community *Chowks* (public squares) showing the spatial organization inside the Fort.

   Due to Jaisalmer lying close to the national border, it is a restricted and sensitive area. Conventional methods of acquiring the necessary information, such as aerial surveys, are therefore not feasible. The most promising solution appears to be the use of satellite imagery, which can provide a preliminary map on which other specific information collected can be overlaid. SWECO International has researched this possibility, and has included a specific recommendation in its analysis.

2. Survey of the Slope: A comprehensive survey of the topographical layout and elevational change is absolutely essential for any analysis of the water problems. A contour map should be generated by conducting spot surveys, with a contour interval of no greater than 1 meter. This survey must include the slope surrounding the Fort, as well as the changing grade and elevations within the Fort.

3. Geotechnical research: The most serious problems afflicting the Fort have been tied to the strength and structure of the hill it stands on. It is important that the inherent strength and make-up of the landmass be examined and thoroughly understood. An investigation into the structure of the hill is to be undertaken as soon as possible, to explain its composition as well as its constituent elements. The different methods available to attain this result (core drilling, seismic testing, etc.) must be further explored and weighed for logistical and financial feasibility. The historical nature of the Fort, as well as its physical form, place extraordinary constraints on the execution of this task, and they must be duly considered in this regard.

   Simultaneously, tests must be carried out on the different types of rock constituting the various strata, to determine their integral strength and load-bearing capacity. These tests will reveal the extent to which the subsoil has been adversely affected by the recent changes and how much capacity, if any, still remains (see SWECO report).

4. Mapping of the Water Supply system: To minimize and prevent further damage to the Fort and the hill from water seepage, it is imperative that the existing water supply lines and storage tanks be surveyed and mapped. This will allow for the identification of problem spots and areas of likely future trouble. Along with plotting every single supply line in the Fort, the survey should also contain information on pipe size and capacity, material, number and location of joints, the condition of the pipes, existing slopes and the observed points of water leakage.

5. Mapping of the Storm Water Drainage system: The *naali*, or open channels edging the streets that had previously drained away the water during the rains are proving incapable of handling the greatly increased precipitation in recent years. However, there has been no new stormwater drainage system installed. Instead, the open drains have been connected at intervals to the sewage disposal pipes, which has compounded the problem instead of solving it. Not only is the stormwater drain still incapable of handling the load, the rainwater now overwhelms the sewage disposal pipes as well.
   Utilizing a contour map of the topography inside the Fort, a systematic drainage plan must be drawn up to show the existing patterns of water flow and drainage and can be used to design an efficient and effective sewage disposal scheme.

6. Mapping of the Sewage Disposal system: There is no real system in effect for the removal of sewage from the houses in the Fort. The few plumbing connections that exist are fairly new and function piecemeal. Some of the houses have added indoor toilets in the recent past, and these have been connected to one of four sewage lines serving the Fort. These are from a sewage disposal scheme drawn up by a local NGO, called *Aavaas Vikaas Sanstha*, or AVS. This system is very recent, dating to the mid-90s, and has been only partially implemented. An inclusive scheme of providing residents with private and plumbed toilet facilities should be drawn up. The scheme must provide individual connections to every household, along with an effective and clean method of disposal, to counter any resistance that the residents may have towards this change. Previous attempts to improve the sanitation facilities have met with opposition from residents who see them as a source for additional problems in the future. There were some problems encountered with the toilets initially installed, from factors such as obstructed drains, improperly sloped pipes, and clogged toilets, which led to complaints of noxious fumes and smells inside the houses. However, the adequate venting of the connections of each toilet will solve the problem, and is something that was not done earlier. In fact, only one toilet was provided with a ventpipe, and there have been no problems encountered in its functioning. The new proposal should take maximum advantage of the natural gradient, while remaining strictly separate from the storm water lines, to avoid the problems that are currently affecting the performance of both systems.

7. Assimilation of meteorological data: Although detailed and extensive climatic data exists in relation to the Jaisalmer area, it is scattered amongst several government and private agencies. In order to derive a holistic image of the environment of the area, it is necessary for this data to be collected from the diverse agencies and systematically analyzed. This process will generate a true picture of the past, present and future trends of environmental change. This will enable a better understanding of the actual impact of the weather, while explaining the causes of recent changes, such as increased rainfall, that have greatly impacted the situation and will have a significant bearing on the future condition of the structures, as well as the greater Jaisalmer environs.

PHASE II — THE PILOT PROJECT

A. Rationale for the Pilot Project:

Following the emergency preventive measures and the process of data collection, Phase Two of the Implementation Plan would take effect in the form of the Pilot Project. This would call for an integrated and 'hands-on' approach involving all major stakeholders. Before a comprehensive program for the protection of all of Jaisalmer Fort is developed, a smaller area is proposed to be studied and treated, from which, after a performance evaluation, solutions pertaining to the whole Fort will be derived. The Project is important for the following reasons:

It will aid in gaining a complete and thorough understanding of the context of the issues that are to be addressed in Jaisalmer. The task is one of complexity, with multiple aspects to be considered and addressed for the achievement of lasting solutions. As highlighted by the first meeting of the Task Force, the situation inside the Fort, besides having physical and historical aspects, also has social, cultural, economic and environmental implications. These aspects need to be given due consideration if a valid solution to the conservation problem is to be found. The Pilot Project will allow for the observation and study of the problems at all levels – from their role in the overall picture down to the smallest detail.

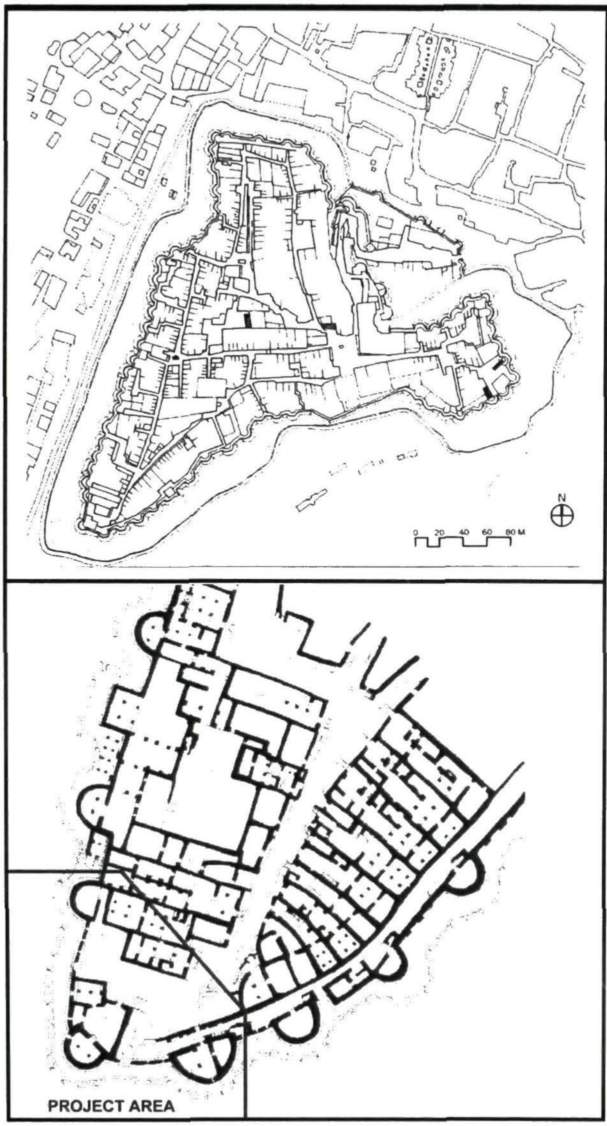
The Pilot Project will serve as a testing ground for the efficacy of the measures that will be proposed as part of the conservation process. Their initial application to a limited area will allow the players to observe the effectiveness and applicability of these solutions, and the degree of success that is attained by them. After observing their performance, the solutions can then be modified or enhanced to obtain the desired result, before they are applied to other similar situations in the Fort. This approach will also allow the teams to test multiple solutions, in an effort to select the one most suitable for a specific circumstance.

A similar advantage is gained in the estimation of financial and time requirements for the various projects. Their application on a small scale will create a true picture of the final costs of each type of project, as well as the time required for completion. This will aid the WMF in the setting of realistic goals and allocation of funds, in light of the resources available. Also, it will enable a systematic prioritization of remedies, based on the cost/ time required in relation to the results obtained. This information can then be extrapolated to estimate the budget for the work covering the entire Fort, and therefore, focus fund-raising activities by the players towards a reasonable goal.

It has tremendous potential to become an informational tool about the need for conservation in Jaisalmer. By presenting an observer with a real image of how the situation can be improved, it becomes a powerful vision of what can be possible. This easily comprehended symbol will be a great asset to raising awareness of the threat to the Fort, as well as generating more enthusiasm and interest among the residents than is seen today. It is clear that most of the resident population sees the situation either with apathy or hopelessness. In these circumstances, being able to present to them an example of successful improvement will go a long way in changing existing attitudes and fostering a desire to contribute – ideas that are ultimately essential for the continued protection and maintenance of Jaisalmer Fort in the future.

B. Site Description:

The area selected by the WMF team and ASI is located on the southwestern extremity of Jaisalmer Fort, forming the very tip of the lower flank that juts into the city below. It is located just south of the *Dhundh Pada* neighborhood, and is entirely residential. There are several small houses clustered together atop the hill, along with a few community spaces of varying sizes that can also be incorporated for treatment in the project. The environment and character are fairly representative of the general aspect of the Fort, although the residents in this particular area come from a lower-income group and their houses tend to be modest in size and of average condition, as compared to the rest of the Fort.



DRAWINGS 1 & 2
Overall plan of Jaisalmer Fort, top. Inset with proposed pilot project area detail, below.

C. Selection Criteria:

Characteristic Physical Structure: This site possesses all of the structural elements seen in the Fort, and so is a representative section of the general built form. Present are several Bastions, a large stretch of the Mori, and the slope and Pitching Wall below. Significantly, this area includes one of the four original large storm-water outlets, which were designed to drain water from the Fort. Recently, these openings, which historically only disposed of water, were incorporated into a sewage disposal system. While this has altered the purpose and character of the openings, the benefits of this change are debatable and need to be reevaluated.

PHOTO 18
One of the original four storm drains is visible in the west bastion wall above modern concrete sewage chambers.

Representative Conditions: The area exhibits a general level of deterioration evident throughout the fort, including a structural failure of the bastions, inappropriate use of the Mori and degradation of the slope, although garbage dumping here has been much more limited than elsewhere. The sanitary problems in the Mori, however, are of greater magnitude as the westernmost section has been designated a communal toilet. Several sections of the outer walls have collapsed and must be rebuilt. The Pitching Wall in this part has suffered numerous instances of collapse and failure over time and different sections have been repaired and'or rebuilt. The two bastions at the south end have been occupied and incorporated into houses by the local people, introducing an encroachment issue into the proposed pilot project area. This site was also chosen because conditions can be improved easily with a moderate investment of funds, time, and manpower.

PHOTO 19
Houses have been built inside the south-west bastion corners within the WMF proposed pilot project area.

Location of Sewage Disposal Line: The choice was also influenced by the presence nearby of one of the four sewage disposal lines serving the Fort. The pipeline exits the Fort at a point close to the southern tip, using one of the original openings provided in the Fort walls and the Mori as water outlets. This line is to be included in the site, since the possibility of addressing one of the most serious and complex problems in the Fort as part of the Pilot Project will be a tremendous advantage to the overall conservation effort. The existence of a sewage disposal pipe adjacent to several houses without plumbing or toilet facilities will allow for the prompt resolution of a complicated issue with a fairly reasonable investment of resources.

PHOTO 20
Open street drain within the proposed pilot area feeds into an original storm drain outlet in the bastion wall.

Visual Appeal: This site is an asset due to its siting and location. Being a visually prominent part of the Fort, it stands out from the rest, visible from all parts of the city. In contrast to other linear, two-dimensional sections, the curving, three-dimensional corner site benefits from a more interesting spatial organization. In addition, this site benefits from the presence at the foot of the hill of a large unoccupied and undeveloped area, which can potentially be used for an Interpretive Center or similar function in the future. As an excellent vantage point encompassing the full extent of the proposed pilot project, as well as dramatic views of the Fort, it could be the ideal location for arranging public-awareness programs and other conservation related educational activities.

PHOTO 21
View of the east side of the fort's south corner.

CONCLUSION

The role of the WMF in the conservation of Jaisalmer Fort has increased manifold since its initial involvement. The Technical Missions have all met with much success, and have led to a greater understanding of the issues and problems present, along with a clarification of the complex environment they exist in. The third Mission, in particular, has been a significant development in the process. Not only did it incorporate the systematic study of specific problem areas and concerns, it also included site-selection for the Pilot Project, which will begin the long-term commitment by the WMF to safeguard this historic treasure. More importantly, this mission resulted in the WMF establishing concrete partnerships with the various players in India who share its concerns and can make contributions of tremendous significance to this cause.

WMF is extremely encouraged by the recent developments in this project. Thanks to the funding provided by the Wilson Challenge Grant, it has become possible to realize a viable plan for conservation of and within the Fort. The funds so available will enable the generation and collection of much needed background data, in addition to the implementation of restoration projects of gradually increasing scope and complexity.

WMF seeks to play a diverse and multifaceted role in this process. Aside from making financial contributions, it can draw on its experience in conservation around the world and offer technical assistance to issues. In can also be a partner in the fundraising programs that will be necessary for future endeavors. In cooperation with other concerned organizations and individuals, it hopes to make a contribution that will help restore Jaisalmer Fort, and then protect this magnificent specimen of India's heritage for years to come.

PHOTO 22
A new day dawns on Jaisalmer Fort.

Amita Baig

Amita Baig is the WMF representative in India. In addition, she is also a founding trustee of the Jaisalmer Heritage Trust. She joined the Indian National Trust for Art and Cultural Heritage (INTACH) at its inception in 1984, and was the Director General of the Architectural Heritage Division from 1993 to 1999. At INTACH, she was involved with the restoration of major civic and historic buildings and monuments, the development of conservation plans for historic cities, socioeconomic studies, and theater workshops.

Lars Engvall

Lars Engvall is a Civil engineer with SWECO International in Stockholm, Sweden. One of the leading geotechnicians in Sweden, he specializes in soil mechanics and foundation engineering. He has been with SWECO for the last 35 years, and is currently involved with many of the major geotechnical projects in Stockholm and throughout Sweden. His diverse professional experience includes planning of field surveys, interpretation of results, evaluating existing geo-technical material, and assessing capacity of potential contractors.

Björn Holgersson

Björn Holgersson is a hydrogeologist with SWECO International in Stockholm, Sweden. He has been involved with numerous groundwater and environmental projects internationally, and has recently completed a long-term assignment as senior hydrogeologist in the Philippines. His experience includes assignments in India, Pakistan, the Philippines, Zimbabwe, and Latvia, in addition to Sweden. His work has included the use of computer-based databases, map production and geographical data analysis using remote sensing and GIS, and groundwater modeling.

Amitabh Verma

Amitabh Verma is an architect working in Atlanta, Georgia. His professional experience includes several preservation projects, including conservation and restoration of historic structures, as well as adaptive reuse of existing buildings. He has also been involved in urban design workshops and community planning projects. He has worked and studied in the United States as well as in India, obtaining a bachelor's degree in architecture from the University of Bombay, and a master's degree in landscape architecture from the University of Georgia.

Mark Weber

Mark Weber is the technical director of the WMF, based in New York. He is responsible for the review and management of various WMF projects across the globe, in addition to being the team leader of the WMF projects in India. He also provides technical assistance to the WMF's World Monuments Watch. Prior to joining the WMF in 1998, he was the director of technical services at the New York Landmarks Conservancy for 12 years. He graduated from the Boston University Preservation Studies Program in 1983.

PART II

WORLD MONUMENTS FUND

JAISALMER FORT

TECHNICAL MISSION REPORT

SWECO

SWECO INTERNATIONAL

Stockholm 10 May 2001

Project No. 1154275

TABLE OF CONTENTS:

1 SUMMARY

The following is a summary of findings and issues that have been investigated during the third technical mission to Jaisalmer, led by the World Monuments Fund. Issues have been identified for action or further studies.

- Rainfall and climate
  Natural rainfall has increased and the temporal distribution is more even. This trend remains to be verified with statistical analyses. The climatic effect of the Indira Gandhi canal is however believed to be local and there is no significant effect on a distance as far off as Jaisalmer.

- Supply systems
  A combined effect of misuse and poor design of the technical supply systems (water, sewerage and solid waste) leads to stagnant water, increased infiltration and erosion.

- Foundations
  The structures within the Fort are probably founded and built on the cap of hard sandstone which is believed to cover most of the plateau of the Fort. The thickness of this sandstone layer is said to be 2-3 m as an average, but is in many places suspected to be less. The bearing pressure on the stone under the bastions and the walls has increased due to recent additional structures that have been built in the Fort. These additional loads in connection with the processes that are weakening the rock are a threat to the stability of the Fort. It is of great importance to know the actual thickness of the sandstone layer beneath the foundation walls.

- Rock mechanics
  Through observations and investigations it has been concluded that:
  - the sandstone can be classified as a "moderately strong to strong" rock
  - the claystone can be classified as a "weak to moderately weak" rock, and
  - the clay shows swelling and shrinking properties with varying soil moisture and can therefore be classified as an "active clay"

- Base map
  There is no reliable base map of the Fort. Such a map is believed best to be produced using satellite imagery. The map can be used as a base for all further surveying and design within the Fort.

- Recommended actions
  A tentative workplan for documentation and fieldwork is presented in the final section of this report. This workplan shows prioritized areas for further investigations and indicates what measures are considered on short and long-term basis respectively.

2 INTRODUCTION

A third technical mission to Jaisalmer, lead by the World Monuments Fund, took place in January 2001. During the time 6 through 18 January Lars Engvall (Civil engineer, Soil Mechanics and Foundation Engineering) and Björn Holgersson (Hydrogeologist) from SWECO participated.

3 BACKGROUND

During the last decades there is evidence of an accelerating deterioration of the Fort. This has led to the collapse of many of the buildings within the Fort and also of two bastions. There is also damage to the pitching wall and other walls inside and around the Fort.

Already during the second technical mission (Dec. 1999) problems related to uncontrolled infiltration of water were identified as the major threat to the Fort. Infiltrated water - from rainfall and from leakage from malfunctioning water supply and sewerage lines within the Fort area - had led to an accelerated decay of the Fort. SWECO got the opportunity to give our views on the second mission report and to participate with two members on the third technical mission as mentioned above.

PHOTO 3.1

A view of the eastern part of the Fort with the pitching wall at the bottom, the sloe, the outer wall, the Mori, and the upper wall.

4 This Report

The following are the technical findings and recommendations that resulted from the third mission. Some of the findings can be seen as verifications of what was identified already in earlier missions but it has nevertheless been brought to focus in our report. Also, the observations that were made during the mission are listed below under specific headings followed by a brief discussion.

The report is concluded by a thorough discussion on the causal factors of the ongoing deterioration of the Fort. We have summarized our report with recommendations for actions or further studies. Whenever applicable we have identified these actions/studies (in total or as part of respective item) to be tried out in the form of a baseline study or pilot project.

5 Rainfall and Climate

Natural rainfall is said to have increased during the last decades. Sandstorms are said to be less common as compared to old days. Vegetation patterns seem to have changed. In the second technical report, monthly records of rainfall were presented, confirming this trend for Jaisalmer.

One aim of this mission was to try to verify this information and to examine the temporal distribution of the rainfall. Weather data for Jaisalmer on daily basis are available with the India Meteorological Department. These data are also distributed to several other governmental departments, such as the Groundwater Department. During our mission we looked at these data for the last ten years or so. The data did not contradict the previous findings, even though there are still examples of years when rainfall has been lower than average (i.e. the year 2000, with only 131 mm as compared to the average about 200 mm). However, daily rainfall data still have to be treated statistically in order to examine a longer period (usually a minimum of 30 years).

To put further emphasis on this issue, the question was discussed with personnel at the Regional Remote Sensing Service Centre in Jodhpur, which has a long tradition of research on climatic changes in the Thar Desert. They have confirmed through vegetation studies using remote sensing that rainfall is in fact increasing and that the temporal distribution is more even - meaning that the increased rainfall falls on a greater number of occasions.

The climatic effect of the Indira Gandhi canal was believed to be local and there is no significant effect on a distance as far off as Jaisalmer.

6 JAISALMER SUPPLY SYSTEMS

To give a background of the technical supply systems of Jaisalmer they are hereby presented in brief:

6.1 WATER SUPPLY

6.1.1 General description

Water supply to the Fort commenced in 1964. Before that the inhabitants had to fetch water from the Gadi Sagar Lake 2 km from the Fort.

Groundwater is being pumped from a well-field consisting of 12 tube wells a few kilometres outside the town. Presently 80 % of the water supply comes from this source. This water is being pumped to a separate tank after rather simple treatment with chloride. The groundwater quality is rather hard and slightly brackish. Static water levels at the well field are declining.

PHOTO 6.1
The water supply pipes to the Fort

Surface water is being brought from Indira Gandhi Canal (connected in 1991) through a combination of gravity flow and pumping. Close to Jaisalmer there is a storage pond with the capacity of 21 days of storage. Excess raw water can also be temporarily stored in Gadi Sagar Lake.

A newly constructed sand filter plant treats the raw water from the Indira Gandhi Canal before distribution to tanks and further into the town system. Projected future need has been catered for to the year 2031. The ratio will soon change with 80 % of water supply being taken from the canal and 20 % from groundwater.

Water is brought to the Fort area via a main pipe to a receiving tank.
The quantity of delivered water is not measured other than the registration of approximate number of times the tank is filled (approximated by the running time of the distribution pumps).

Water is further distributed, either directly from the receiving tank to household connections inside the Fort, or to two secondary water tanks inside the Fort. One of these secondary tanks is specifically for distribution to household connections within the Fort area.

The other one of these secondary tanks is specifically for distributing water to the foothill areas outside the actual Fort. This means that this tank is of no benefit to the residents of the Fort, but merely a liability with potential for problems or leakage.

Households inside the Fort are supplied by house connections. At present there are 300 connections within the Fort. Connections are generally not metered and the water is supplied free of charge.

6.1.2 Actors—Water Supply

Design and operation of the water supply system is the responsibility of Jaisalmer PHED (Public Health and Engineering Department).

6.1.3 Existing documentation

We did not come across any specific documentation and maps regarding the water supply system within the Fort area. However, PHED seems to be rather well aware of the construction and existing pipe materials.

6.1.4 Future Plans

PHED presented plans and cost estimates for replacing the entire water supply network with modern pipes. Disconnecting the water tank that was for the supply to the foothill area and replacing it with a tank outside the Fort was discussed. This however, has not been cost estimated in detail but it was said that it could be feasible. At present no funds are available with PHED to undertake any of the proposed projects. The future plans that were presented did not include metering of every house connection. The reason was a shortage of personnel for maintenance and registration. It was also their view that people have a right to get water free of charge.

6.2 Storm water and Sewerage

6.2.1 Definition

Sewerage is defined as used water that is being discharged from household water closets, washing sinks and bathtubs.

Storm water is defined as the part of the rainwater that is not evaporated or infiltrated. Furthermore, the storm water in reality also includes any spill of water onto the paved streets. This water originates from various activities, such as outdoor washing of laundry or washing of house facades.

6.2.2 General description

The storm water is led through open lined channels in the streets. The open drains were originally directed to four outlet locations, three through the Bastions and the Mori on the western and northern side of the Fort and one through the main gate. The drainage system for storm water is also meant to function as drainage for water spill, occurring in the streets from washing et cetera. The drainage system however is not completed for the whole Fort area and it is not functioning very well. In many streets there are no drainage canals.

PHOTO 6.2.2.1
Leakage from the water supply system and malfunctioning drainage systems leads to stagnant water in many streets.

Plastic bags, bottles and other garbage also often plug the drainage system. At regular intervals the existing channels are connected to the sewerage line. The idea is probably to flush the sewerage system in times of rain but the sewerage system is not well designed to take the load from storm water.

Original storm water outlets are likely to have been paved down the slope to the outer side of the pitching wall. The stone paving was to minimise the risk of erosion of the slope after heavy rainfall. The dimensions of the openings through the outer walls have been considerable to cater for the occasional downpour and flushes of water from the Fort area. The original design is to some degree still evident on the northern side of the Fort, at the outlet closest to the main gate. One of the original paved storm channels in the slope is shown on the photos below. As can be seen the channel is now blocked by vegetation. How the outlet was constructed through the Mori before it was converted to incorporate also the sewerage, is however unknown.

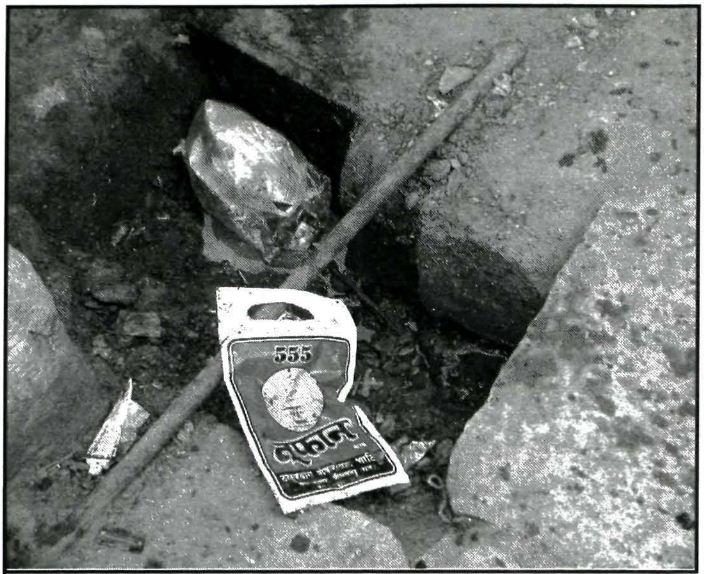
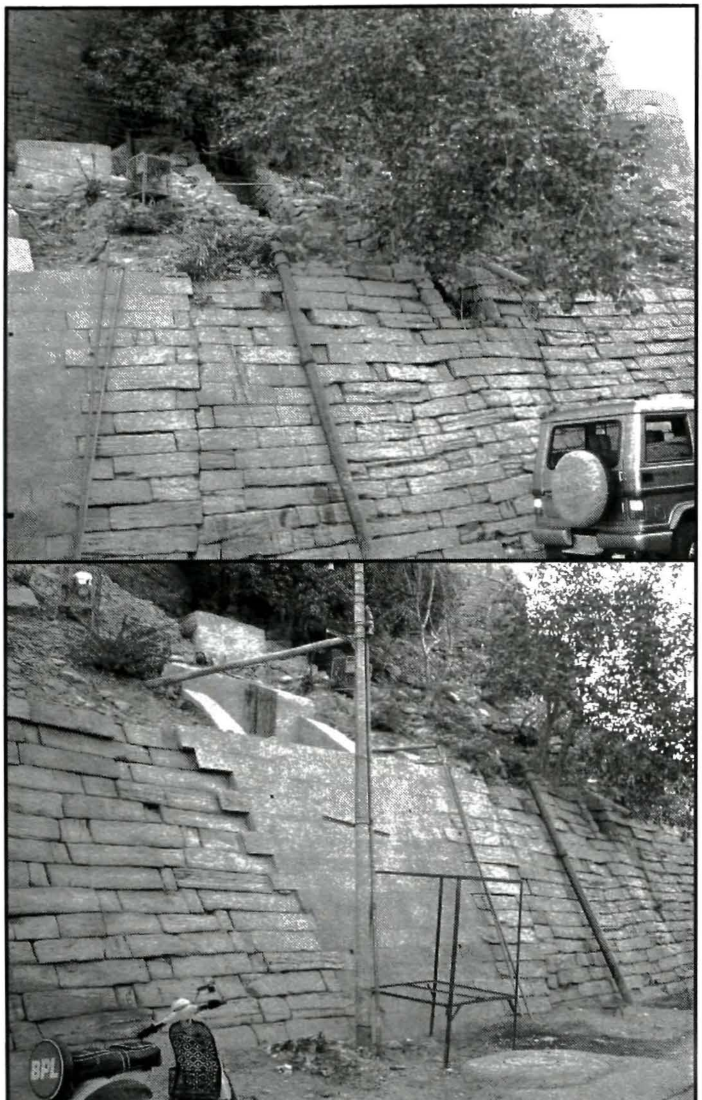


PHOTO 6.2.2.2
Garbage and plastic bags clogging the drainage system.

The original outlets have now been redesigned and a series of new, dull looking, concrete sewerage chambers, built on the slopes above the pitching walls have been added, incorporating both the sewerage and storm water. The sequences of chambers at each outlet are interconnected through a sewerage pipe that is obviously too small for the combined flow of sewerage and storm water in case of heavy rains.



PHOTOS 6.2.2.3 & 6.2.2.4

Original storm channel opening in pitching wall above vehicle on the slope and the new chambers for sewarage and storm water.

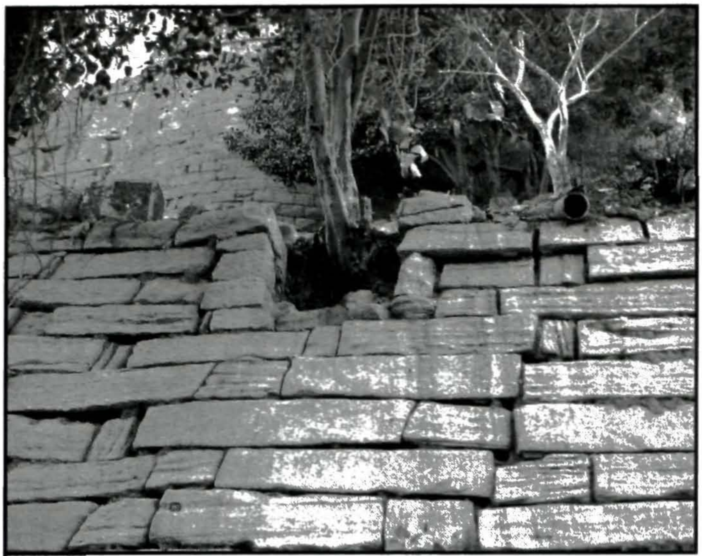


PHOTO 6.2.2.5
Original storm channel on the slope. Vegetation and garbage now block the channel.

The sewerage system is not as old as the water supply system. It was designed by AVS (Avas Vikas Sansthan) during mid 1990s and built soon after that. The pipes in the sewerage system are made of clay stoneware with open joints. There is a lot of leakage from the system due to broken pipes and joints that are not tight. Plastic bags, bottles and other garbage entering into the system also often clog the sewerage system.

Not all houses are connected to the sewerage system, specifically not the houses and hotels along the bastions above the Mori. Very few houses have water closets. There is a hesitance to connect to the sewerage system due to the fact that ventilation pipes have not been designed at every connection which leads to bad smell inside the connected house. In fact, only one ventilation pipe was installed that we saw. The house owners even had removed some toilets for the reason of bad smell.

Generally, the sewerage lines follow the flow directions of the original storm water drainage system, using the same four outlet locations (three through the Bastions and the Mori on the western and northern side of the Fort and one through the main gate as mentioned above). The storm water from the open lined channels in the streets is drained into the sewerage line at regular intervals. The connecting points of storm water to the sewerage lines are throughout the Fort protected from garbage entering the sewerage system at the street level by grilles that must be cleaned regularly. Even though this is done, the grilles are clogged again very soon after cleaning by further garbage. Furthermore, at some points the grilles are missing.

6.2.3 Actors—Storm water and Sewerage

PHED is responsible for the design and modification of the storm water and sewerage systems. Cleaning and operation of the system is however the responsibility of the municipality in addition to garbage collection. The protecting grilles at the connecting points are cleaned every morning. However, since the system of garbage collection is not functioning efficiently the grilles will be blocked again before the next morning.

6.2.4 Existing documentation

The report "Jaisalmer Fort, Sewerage Scheme, Technical Report" by AVS is available with the PHED. However, a detailed map of the system as-built, showing the present connected (and unconnected) households is not available.

6.2.5 Future Plans

PHED presented plans and cost estimates in relation to the existing sewerage system. These include separating storm water and waste water systems, connecting households close to the bastions and the Mori and re-design of the sewerage and storm water outlets (through the bastions and down the slope to the pitching wall).

The difficulties concerning connections close to the Mori were discussed where bathrooms often are facing away from the streets. Also the delicate matter of designing and re-building the outlets through the bastion walls, where PHED admits that they will need some structural engineering consulting in order not to interfere with the stability and design of the historic walls. PHED currently does not have any plans to rebuild the entire sewerage system.

6.3 Solid waste management

6.3.1 General Description

The problems concerning the solid waste system of the Fort area have previously been described. A large portion is connected to the lack of participation of the people living within the Fort, but also that an efficient system of stations for waste disposal and collection seems to be non-existing. What is presently undertaken gives the impression that it is conducted in an "ad hoc" or hasty manner.

The garbage is collected and transported in small wheelbarrows to the main square. Every day one small truck is filled with garbage (from the 2500 inhabitants of the Fort!). The garbage is sorted for recycable items (plastic, paper, metal etc.) and transported outside the Fort. All garbage that does not end up on the truck is thrown into the Mori or over the bastion wall or enters into the sewerage system (if it is not stuck in the storm water grids where it should be cleaned out every morning).

On the slopes surrounding the Fort there are numerous scavengers looking for recycle items.

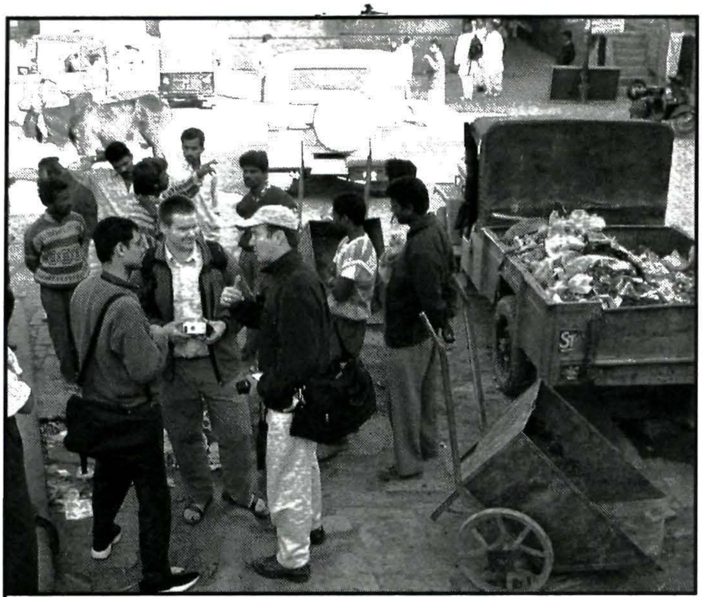


PHOTO 6.3.1.1
Daily garbage collection on the main square.

6.3.2 Actors—Operation

The municipality is responsible for garbage collection and cleaning of the sewerage and storm water systems as well as for the transportation of the garbage away from the Fort. We did not hear of any responsibilities of the Fort inhabitants.

6.3.3 Existing documentation

We did not come across any documentation concerning the present waste management.

6.3.4. Future Plans

We did not come across any plans concerning changes of the present waste management system.

7 Systems Effect on Fort Stability

It is quite evident that the different technical supply systems have a considerable effect on the stability of the Fort—either direct or indirect.

Some examples of relationships are as follows:

- Inefficient garbage collection leads to garbage clogging the storm water channels and sewerage systems which in turn leads to stagnant water.
- Stagnant water will inevitably lead to infiltration, which in turn effects the foundations.
- Storm water being led into the sewerage system leads to an added risk of leaking connection and infiltration.
- During heavy rains the sewerage system will not have enough capacity which leads to ponds and infiltration, erosion and possibly water pressure on the outer walls.
- Garbage being thrown into the Mori will block original drainage systems.
- Non-existing toilets and failing connections close to the bastions lead to the use of the Mori, either directly as a toilet or as a recipient of sewerage outlets from the houses, which further blocks the original drainage systems and contributes to infiltration.
- Garbage being thrown onto the slopes will lead to heavy erosion and wear of vegetation, not least by scavengers that come climbing the hills in search of recycle items.

8 Geology

Sedimentary rocks dominate the geology of the Jaisalmer area. The highly consolidated sandstone is the best known, being the building material of all houses inside the Fort and the Fort itself. This rock is being brought to the Fort from different quarries some kilometres away. Shale and less consolidated clay-stone are also common sedimentary rocks in the region.

The unconsolidated sediments consist of both alluvial deposits (transported by rivers and deposited when the area was covered by sea) and aeolian deposits (wind transported). Furthermore the weathering process that deteriorates consolidated rocks into soil can reach considerable depths in arid climates. This means for the region that it is not uncommon with great depths of unconsolidated sediments before hard rock can be observed.

A general description of the lithology of the Jaisalmer area (according to Groundwater Department) is as follows:

A cap of sandstone with a typical depth of 2 - 3 meters is typically overlaying layers of clay and clay-stone imbedded with layers of shale, sandstone or limestone.

The hill on which the Fort is built most likely consists of a similar lithological set-up. The field observations confirm the existence of a cap of sandstone on the upper portion of the slope. During the repair of a section of the pitching wall we had the opportunity to make observations and take samples of a 6 - 8 meter high excavation into the slope. Here the material that was excavated consists of semi-consolidated clay—best characterised as clay-stone. The clay-stone is believed to be impermeable, however, imbedded in the clay-stone are thin layers of sand that are believed to carry water laterally. The formation could be dug out using only manual tools like shovels and pick-axes.

An assumed typical section of the geology of the fort hill. The assumptions however must be verified by investigations.

PHOTO 8.1
Outcropping sandstone and boulders of sandstone can be seen on the slope in some places.

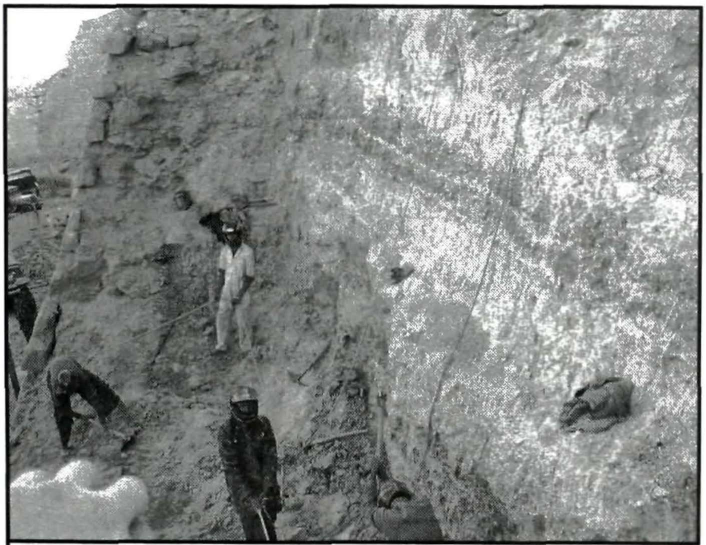


PHOTO 8.2
Repain of broken part of the pitching wall. The rock is a claystone, which can be excavated with pick-axes, The layers of sand can be seen inbedded in the claystone.

9 Hydrogeology

The most important hydrological issue for the Fort is to minimise infiltration of water. In order to give a better understanding of the different components they are discussed below:

The general natural groundwater recharge of the area is said to be < 10 % of rainfall according to the local officer of the Groundwater Department. The amount of infiltrated water is obviously an effect of rainfall amount, but also of rainfall intensity, evaporation, slope, vegetation cover and hydraulic conductivity of the geological formation (specifically of the topmost layer). It should be mentioned that the heavier the rainfall intensity is, the larger portion of it would run off on the surface. If, as an example, rain falls on 10 occasions with 10 mm each time the amount of infiltrated water will be more than if 100 mm falls on one occasion.

The general depth to groundwater in the region is usually very low below the ground surface. This is also the case within Jaisalmer Fort. Inside the Fort there are three dug wells, of which the one close to the main square still can be opened and monitored. During our mission we obtained a water sample from this well and registered the depth to the groundwater to be 85 meters. The total depth of the well was 97.3 meters (320 feet).

The whole Fort has been marvellously designed to minimize infiltration and lead away surface water. The only portions of the Fort that originally were not covered are the slopes between the outer bastion walls and the pitching wall. Here the general slopes are steep enough to rapidly lead away a majority of rainwater. When the Fort area is in a good condition it is therefore well prepared to cope with rainfall intensities that are normal for the region (usually in few but heavy showers). The regional climatic changes, as discussed above, resulting in increased rainfall amount and frequency, are not ideal for minimizing infiltration. This is however, not believed to be a major threat to the Fort unless the Fort is in decay and collapsed houses and eroded slopes create a potential for increased infiltration.

It was observed, at the excavation during the repair of the pitching wall, that the formation was considerably moist, even at great depth. Since this observation was made long after the monsoon, it leads to the conclusion that the moisture was the effect of infiltrated water from leaking water supply and sewerage systems. Therefore, it is our belief that infiltration caused by leakage from the water supply and sewerage systems is greater than the infiltration caused by natural rainfall.

10 Water quality

During our mission we took water samples from the dug well close to the main square as well as from the supplied water from a running tap. The water samples were analyzed in a laboratory. The results are presented in full in the separate report "Rock, Soil and Water Testing Report".

Well Water

The groundwater quality was dominated by the fact that the well has obviously not been used for a long time and a lot of organic material has intruded into the well. This has affected turbidity and sediment content of the sample and is also evident in the high Chemical Oxygen Demand (COD). One aspect of the water quality that is probably not affected by the organic material is the Chloride content that showed a rather high value (460 mg/l). The electric conductivity was measured to 293 mS/m. Also total hardness is rather high. As a conclusion, the water sample shows a chemical quality that is not entirely bad (not considering the quality issues that are connected to the organic matter) other than the high chloride content that is above the limit that is possible to detect by taste and indicates a saline water. The water quality shows no significant reasons for being corrosive or particularly bad for the consolidated rock of the foundation. Bacteriological testing has not been conducted.

Tap Water

The water of the supply system was also tested and showed a significantly better quality and is suitable as potable water. This was specifically due to the fact that the organic matter content was low, but also chloride content (170 mg/l) and electric conductivity (127 mS/m) was less, indicating only a slightly brackish water. This water quality does not show any significant reasons for being corrosive or particularly bad for the consolidated rock of the foundation. Bacteriological testing has not been conducted. The relatively high electric conductivity of the supplied water within the Fort indicates that this water also originates from groundwater. This was also the information given to us by PHED that the Fort is within a portion of the city that is serviced with water from the well field and not from Indira Gandhi Canal.

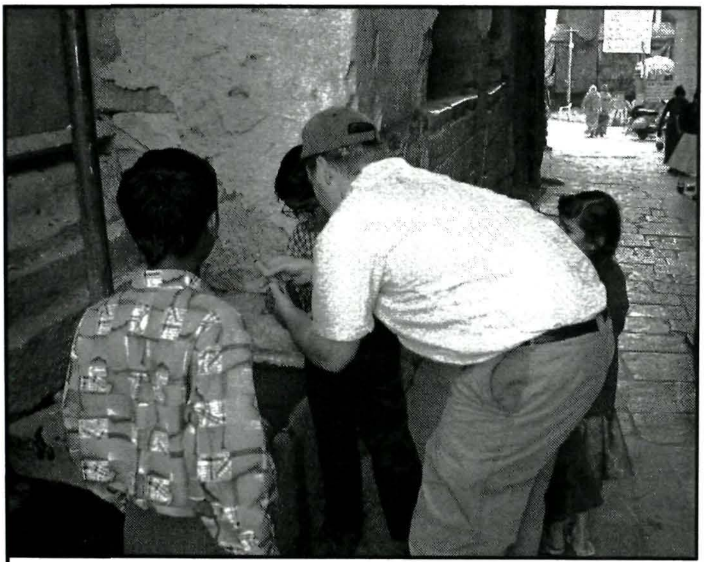


PHOTO 10.1
Collection of tap water sample for chemical analyses

11 Foundations

11.1 Bastions, Outer Wall, and Inner Wall

The bastions, the outer and the inner walls are probably founded and built on the cap of hard sandstone which is believed to cover most of the plateau of the fort. The thickness of the sandstone layer is said to be 2-3 m as an average, but in many places in the slope it is evident that the thickness of this hard cap is less – in some places there probably is no cap of sandstone at all. It is of great importance to know the thickness of the sandstone layer beneath the foundation walls.

The bearing pressure on the sandstone and clay stone under the bastions and the walls has increased due to the additional structures, mainly new hotels, that have been built in the Fort during the last decades. These additional loads in connection to the weakening factors described below are a threat to the stability of the Fort.

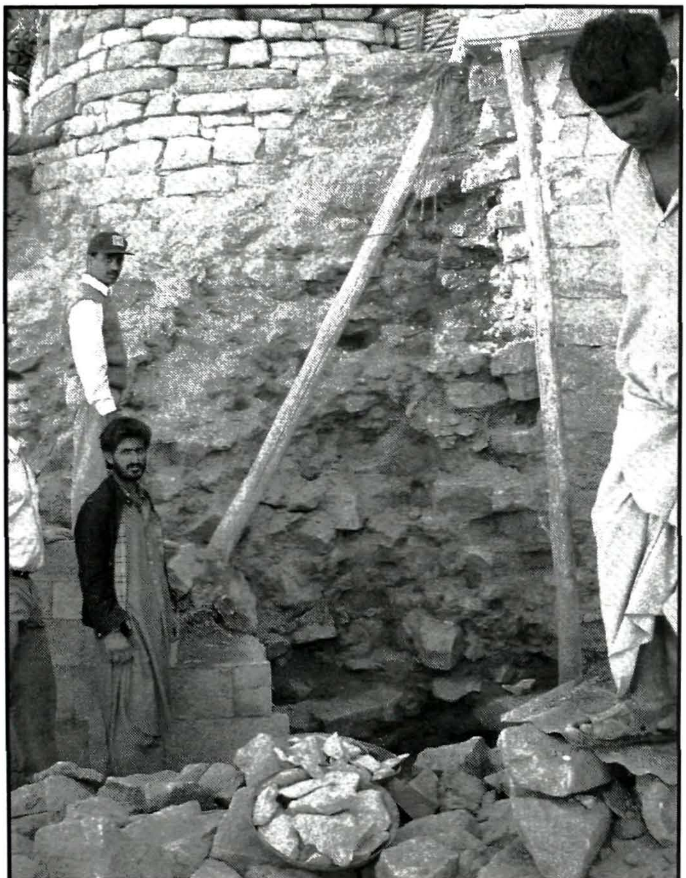


PHOTO 11.1.1
Repair of collapsed bastion

11.2 Pitching Wall

The purpose of the pitching wall is erosion protection of the steep slope comprising largely of clay-stone. The wall is 6-10 m high and is built as a dry masonry wall of sandstone on an excavated almost vertical slope made into the clay-stone.

11.3 Buildings within the Fort

There is no information about the foundations of the buildings within the Fort, but it can be assumed that they have been made mainly on sandstone. However, it might be possible that in some cases the foundation is made on clay-stone or on only a thin cap of hard sandstone. The ground surface inside the Fort is relatively horizontal but there are lower areas, where it is inevitable that some of the foundations will be water soaked for longer periods. In these places it is likely that the subsurface rock, if it consists of clay-stone, will have disintegrated to soil and there will be settlements or collapses of the buildings.

12 Rock Mechanics

The building stone used in the masonry is sandstone of a better quality than that found on the plateau. Tests presented in the report from the second technical mission show that the bearing capacity of the building stone is 42 MPa.

During our technical mission rock samples of the sandstone beneath the walls were obtained.

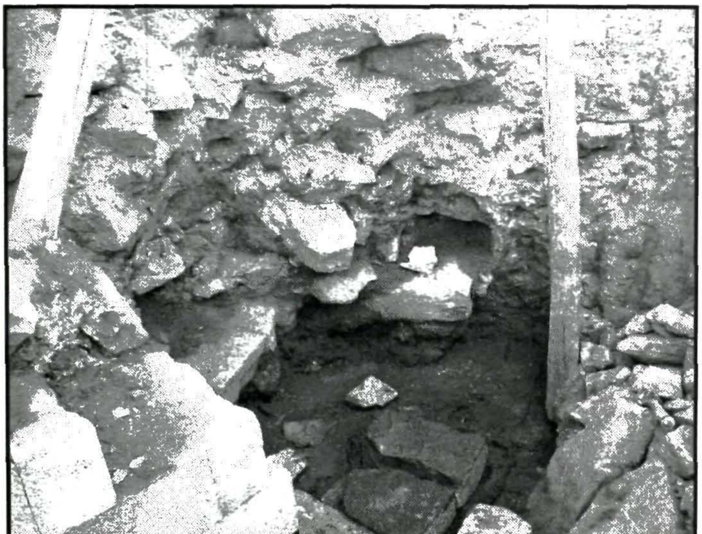


PHOTO 12.1
Rock samples from the original sandstone below the wall were obtained during the bastion repair.

Tests were made on two of these samples according to the method "Point load test". The tests show that the uniaxial compressive strength of the sandstone varies between 40 and 100 MPa. This means the sandstone can be classified as a "moderately strong" to "strong" rock.

The sandstone is a sedimentary rock and it often contains layers of coarser or finer materials. In some building stones of lesser quality these layers are more frequent and bigger than in others of better quality. It can be seen in the masonry walls that the stones of bad quality have been highly eroded. Sometimes entire stones are missing in the walls. The erosion is caused by water seepage and by wind. If one or more of these bad quality stones have been used near the bottom of the wall it causes settlements in the wall and may lead to failure of the wall.

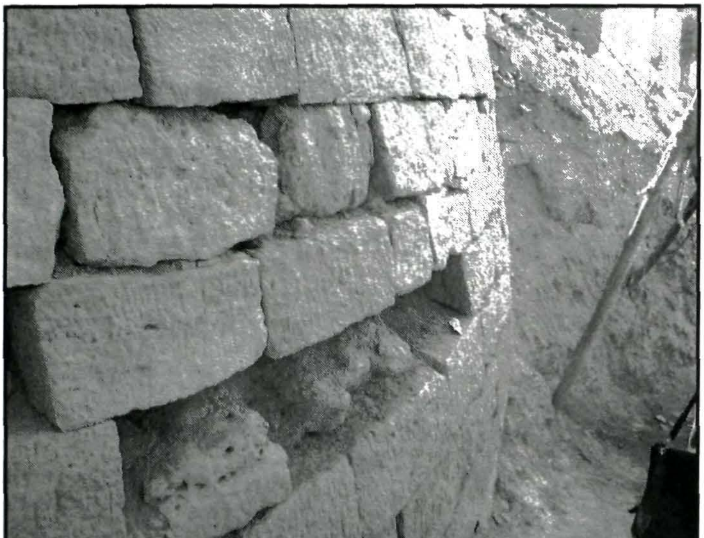


PHOTO 12.2
Example of masonry made of weathered, poor quality sandstone, which should be replaced.

Below the sandstone cap on which the bastions, front walls and upper walls are founded, there is believed to be a clay-stone. This is a weaker material and is also a material that becomes totally disintegrated when in contact with water.

During our technical mission rock samples of the claystone were obtained from the cut behind the pitching wall.

Tests on five of these samples were made according to the method "Point load test". The tests show that the "point load index" varies between 2 and 6, which means that the "uniaxial compressive strength" of the claystone varies between 5 and 10 MPa. This means the claystone can be classified as a "weak" to "moderately weak" rock.

In order to calculate the bearing pressure on the clay-stone it is important to know the thickness of the sandstone under the walls. A "pure" clay-stone is almost impermeable but the clay-stone observed contains thin layers of sand and silt, which can transport water horizontally. (see Photo 8.2). There is also a possibility for water to come in contact with the clay-stone in the intersection between the sandstone and the clay-stone. In the locations under the foundations of the structures, where the clay stone comes in contact with water, there will be settlements in the walls and eventually collapse of the structures. When the clay stone disintegrates it will be transformed into clay.

Swelling tests on the disintegrated claystone indicated that the material has swelling properties. The "free swelling" is measured as 175%-183% and the "free swell volume" is measured as 321%-438%, which means the material is classified as an "active clay".

The "swell pressure" was also tested. This was measured as 122 kPa, which means that the "swelling potential" is classified as "low".

These swelling properties of the clay imply that the swelling and shrinking due to the moisture content will not only effect the strength of the material but also create a risk for movements and settlements.

13 Causal factors of the ongoing deterioration of the Fort

13.1 Bastions, Front Wall, and Upper Wall

Water from the infiltration mentioned above causes seepage into the walls and into the sandstone beneath the walls. The sandstone is permeable and the water will evaporate from the walls. It is evident from the colour of the walls that many of the walls are dark in the lower parts due to moisture.

PHOTO 13.1
Stormwater outlets to the Mori are in many places blocked by new pipes, soil, and garbage.

A wet stone is somewhat weaker than a dry one, but the difference is not very big. So this process of water transport through the stone is not very severe as long as the water is fresh rainwater without contents of salt. However most of the available water has been infiltrated from leakage and spill from the water supply, which contains a certain amount of salt. When the salt water evaporates the salt will be concentrated and crystallised in the stone and eventually cause failures in the stone due to swelling of the salt in contact with water.

The weaker clay-stone that is likely to exist below the cap of sandstone will probably become totally disintegrated when in contact with water – it will become clay. When disintegrated there is a possibility of erosion of the soil and clay under the walls, which will cause settlements and eventually failures and collapse.

If the clay-stone has swelling properties the disintegration of the clay-stone will cause movements in the walls due to the swelling of the material in the ground.

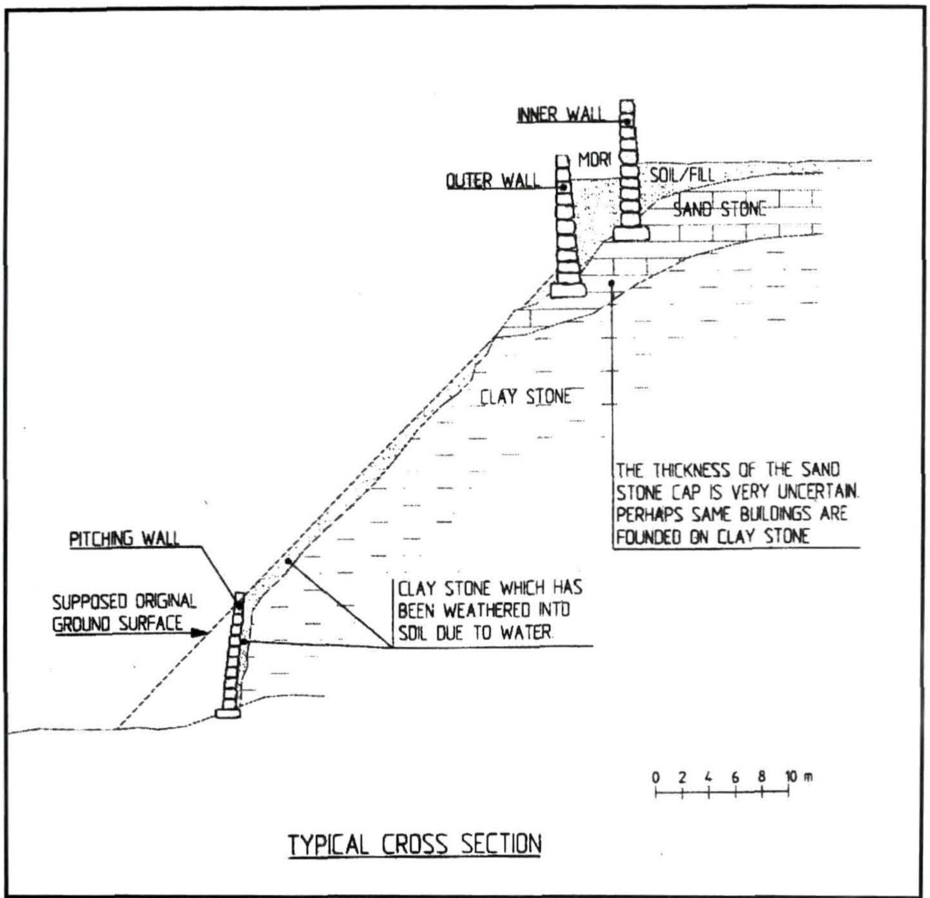
In connection to heavy rainfall there is a risk that the storm water outlets are not large enough to cater for the amount of water. This will cause a water pressure on the walls, which in connection with the weakening factors mentioned above will create a risk for collapse of the bastions and front wall. The resulting flush of storm water, taking other routes than through the storm water outlet will also increase the risk of erosion beneath the foundation of the walls.

13.2 Pitching Wall

The pitching wall is 6-10 m high and is built as a dry masonry wall of sandstone on an excavated almost vertical slope into a clay-stone.

PHOTO 13.2.1

The lower part of the pitching wall is dark due to moisture.



DRAWING 13.2.2

Typical cross-section showing, from top to bottom, upper bastions, mori, slope, and pitching wall construction.

The construction is stable as long as the clay-stone is intact. However, the stone material has been influenced by water from the above mentioned sources i.e. rain water along the slope, which has infiltrated behind the masonry, or from water transported horizontally in the sand-stone or in sand layers imbedded in the clay-stone. This water has lead to disintegration of the clay-stone into clay. Even weathering of the clay-stone may weaken the material.

When the transformation of clay-stone into soil has reached a certain level the pitching wall is no longer stable. There will be settlement in the clay material, which will pull down masonry.

13.3 Buildings within the Fort

The foundations of some buildings within the Fort are probably made directly on clay-stone or on an extremely thin cap the overlaying hard sandstone. Here there is a risk that the rock will have disintegrated into soil and there will be settlements or collapses of the structures. This risk is particularly high in lower areas where foundations will be water soaked for long periods.

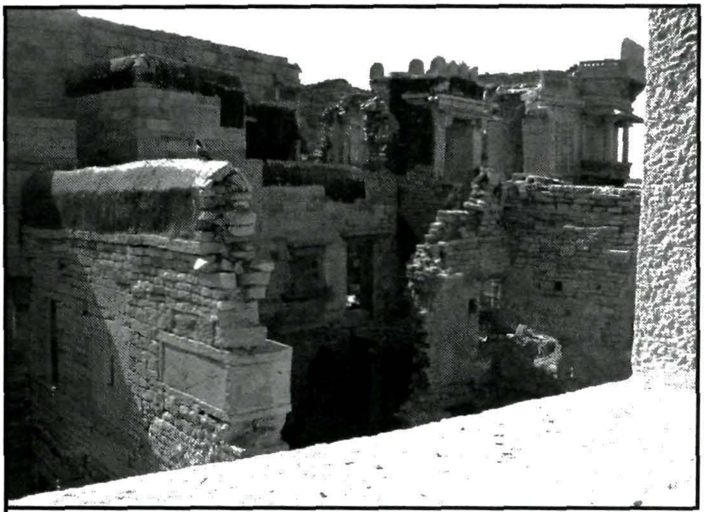


PHOTO 13.3
A large part of this building inside the Fort has collapsed.

14 Further Investigations

14.1 Statistical Verification of Rainfall Data

It is recommended that a brief statistical study be undertaken regarding daily records of rainfall for Jaisalmer over a minimum of 30 years. The aim should be to try to verify that the rainfall patterns really have changed. The study should focus in particular on temporal distribution over the year, during and after the monsoon seasons. The raw data is most likely available (digitally) with the Indian Meteorological Department. The priority of such a study is rather high. The effort is small and cost is low.

14.2 Base Map

An up-to-date and accurate base map for the Fort area is crucial. Aerial photos are not available due to the restricted military area close to the Pakistan border. Therefore satellite images with high-resolution turn out to be a feasible source of raw data. The satellite IKONOS with the resolution of 1 m is now available and is a good and cost effective way to proceed. The satellite images can be procured in Europe or USA since governmental agencies like State Remote Sensing Application Centre (SRSAC) or the Regional Remote Sensing Services Centre (RRSSC) have restrictions on procuring these types of images. However, as long as the images are procured and delivered to either of the centres in digital form, the base map can be processed in RRSSC or SRSASC. Processing involves projecting the images to a valid co-ordinate system, including a reference grid, printing hard-copies to scale (i.e. 1:5,000). It could also be possible to superimpose and enhance interpretations and other known information onto the map (i.e. vegetation cover, geological information like fracture zones, interpreted collapsed houses etc.) and to include a map legend. A detailed discussion with the remote sensing centre is necessary after having procured and delivered the images.

The priority of producing a base map is high. Of the two remote sensing centres mentioned we would like to recommend RRSSC. They gave a very professional and efficient impression. The services involves rather a big effort with a map readily produced within weeks or possibly up to a month or two after delivery of the images. As mentioned above "IKONOS-approach" is very cost efficient.

Furthermore it is recommended that the existing map developed by Professor Jain be digitized (or possibly scanned) and rectified using co-ordinates registered during the survey of elevations within the Fort area (see below) or from the IKONOS base map. It should be mentioned that Professor Jain, whom we met in Jaisalmer during the technical mission, promised arrange for the scanning of the original drawing, in order to minimize errors that may have occurred during the process of copying the map.

With Professor Jain's map at the same scale and orientation as an up-to-date map based on a satellite image, it will be easy to transfer any information that has over the years been plotted using the older map onto the new map, i.e. house numbers and the inventory of collapsed buildings.

14.3 Surveying of Slopes and Elevations

The Fort should be properly surveyed in respect to elevations within the Fort area and on the slopes surrounding the bastions. The aim is to be able to produce representative cross-sections through the slope and Fort area at regular intervals. Surveying teams are available within governmental departments like ASI or possibly within Department of Watersheds, both at Jaipur. These services are also available with private contractors and facilities could most likely be found in Jodhpur. The private firm Advanced Technologies and Engineering Services (ATES) that we met in Delhi during our mission can also assist with this service. This task has high priority.

Digital processing of the elevations of the slopes and Fort area, i.e. producing a digital terrain model and superimposing contours onto the base map can be done by RRSSC. The recommended contour interval should not be less than 1 m. The effort involved is not very big (2-3 months). Levelling equipment needed is not extremely advanced and cost should be moderate. Co-ordination between different departments will be needed if the survey should be conducted by a governmental department. The most efficient solution is to give the full responsibility to ATES, possibly with the aid of RRSSC for digital processing.

14.4 Geotechnical Field Investigation

One of the main difficulties with a geotechnical field investigation is the logistics of transporting the equipment through the gates of the Fort. The Groundwater Department (GWD) has the required equipment but its rigs are far too big to access the inner Fort. According to GWD there may be private contractors in Jodhpur, with smaller rigs. However, these firms are not likely to be able to make core drillings, where undisturbed samples can be retrieved, which leads to the need for secondary testing (logging) of the hole with different probes. Logging equipment is available at GWD at Jodhpur. Core drillings are far superior to logging since the core can be analyzed in several physical ways.

The private firm ATES in Delhi has a small rig for core drilling. The rig can be dismantled and brought to the Fort and be reassembled on site. According to ATES one core drilling to the depth of 30 - 40 meters should take 2 - 3 days/hole to complete. An investigation with about 20 - 30 holes is anticipated which should take 40 - 90 days to accomplish. This task has high priority. The effort is big (3-4 months) and cost is rather high.

The investigations should be core drilling to a depth of about 30 m in about 30 to 40 locations around the Fort. In each drill hole cores should be taken and a log made.

The task is recommended to be fulfilled by, or at least co-ordinated by ATES. It could start early in order not to lose time, possibly even before the above mentioned base map is finalised. The drillings should however, be finally mapped and plotted onto the newly developed base map.

According to GWD in Jodhpur there might be some difficulties to conduct geophysical investigations (seismic or resistivity) within the Fort due to difficulties of applying probes through the street paving and nuisance that the necessary blasting for the seismic survey might create. Instead investigations along the slopes at the foot of the bastion walls were recommended. GWD in Jodhpur has the equipment and skill of operation. We recommend that this investigation be carried out (seismic or resistivity) along the slopes as mentioned, with profiles around the entire Fort, possibly also including profiles at the bottom of the hill below and/or above the pitching wall. Inside the Fort area a resistivity survey should be carried out with profiles along the streets. Here the street paving must be temporarily removed. This task has the same priority as the drilling mentioned above. It is probably not very costly and should be seen as a complement to the drilling investigation.

Field investigations should be made mainly to determine the ground conditions below the bastions, the pitching wall and the inner and upper wall. Most important is to determine whether there is a cap of hard sandstone all over the plateau, the slopes and behind the pitching wall. If there is sandstone all over the place, it is important to determine the thickness of the sandstone.

14.5 Stratigraphical Interpretation and Geotechnical Laboratory Testing

Some of the rock cores should be tested in a laboratory with regard to the type of rock, the minerals, the bearing capacity of the rock material, permeability for water, the chemical properties and the reaction when in contact with water. Stratigraphical mapping of every borehole should be done. Cross sections should be designed. Geotechnical properties of selected core samples should be tested. This is probably best done by ATES.

14.6 Mapping of Existing Sewage System

Using the newly developed base map the existing sewerage system should be mapped in detail. All houses have to be identified on the new map (possibly using the previous base map developed by Professor Jain) and connections should be mapped. Houses that are not connected should be identified.

14.7 Metering all Household Connections

In order to have a possibility of quantifying losses from the water supply system we recommend that the system be divided in sections that are individually metered on the supply side. Furthermore, to be able to analyse in detail the water balance for the water supply of the entire Fort we also recommend that all household connections be metered. Obviously this is a big effort, knowing that PHED and/or the municipality at present lack personnel and funds to undertake the task of installing and monitoring these meters. There is also an obvious risk that people disconnect or destroy the meters for whatever reason. Nevertheless, we believe the issue to be so important that it is worthwhile to recommend the implementation. It could also be mentioned that a metering scheme could be a basis for a future costing or benefit system - which in time could help bring down the consumption of water within the Fort.

14.8 Monitoring system

We recommend that a monitoring system be set up for measuring movements of selected walls and bastions. This system is believed to be best kept rather simple in respect to instrumentation. Reference points should be set up in the foothill area of the slopes (points that are believed not to be effected by settlements). Measuring angles from these reference points on a regular basis to fixed points within the Fort, well marked and visible from below, will give answers with acceptable accuracy. The set-up of the monitoring system is believed to take a month to implement. After this we recommend monitoring four times per year.

15 Measures to Stop Further Deterioration of the Fort

The measures described below should be seen as preliminary recommendations until the results of further investigations are known.

15.1 Short term measures

15.1.1—Re-establishment of storm water outlets

Storm water outlets through the Mori and bastion walls have to be re-installed in a proper manner. The original outlets through the outermost houses and out to the Mori show impressive dimensions (approximately 3 by 4 feet). After entering the Mori the storm water channels presently "disappear" into the newly constructed series of sewerage chambers which are interconnected with obviously inadequately sized pipes. Re-establishing a proper design of these outlets will involve research for the original design. It is likely that the storm water channels along the slopes down to the pitching wall were originally lined with stone to minimise the risk of erosion. If this information can not be verified from old sources studies should be made of the northern outlet (closest to the main gate) where a previous design to some extent is still evident and has not altogether been altered during construction of the new sewerage outlet.

This measure is most urgent and it should be undertaken before the onset of the next monsoon. One of the outlets could make up an important part of a pilot project where all the interacting problems regarding the Bastions, Mori, Slope and Pitching wall can be studied in detail. It should be remembered though, that the rest of the storm water outlets are equally urgent to deal with and should be attended to, preferably before the monsoon - not waiting for the result of a pilot study.

15.1.2—Separation of sewage and storm water

The storm water drainage lines in the streets should be separated from the sewage system and the grilles should be removed. Previous "storm water openings" of the sewerage system should be thoroughly closed and cemented. When the open storm water channels reach the previous confluence points (usually in street crossings) they should be connected without interruptions. Channels should be thoroughly cleaned up and their lining should be checked. The storm water channels should finally be connected to the newly designed outlets through the Mori and bastion wall, see above.

A pilot project should, as has been mentioned earlier, include the outlet of storm water and sewerage. Our recommendation is that the entire section of drainage that is connecting to that specific outlet should be dealt with in respect to separating sewerage and storm water.

15.1.3—Street paving

The street paving is in many streets in a very bad condition. In order to minimize infiltration (and avoid accidents) it is important to make new watertight pavements. This work has started in some streets and must continue and be expanded to cover all areas.

15.1.4—Covering collapsed building sites

Collapsed houses should be covered with temporary roofs to prevent the collection of rainwater on these sites. The ideal solution for the long term is rebuilding the houses with original roof coverage.

15.1.5—Cleaning up the Mori

Inside the Mori the paving and slopes towards the existing drainage holes in the bastion walls should be re-established in order to minimise infiltration. The first step is to clean all debris and garbage that has been collected over a long period of time. A further benefit of this is, as has been mentioned in earlier reports, to make it possible for people to use the Mori as a walkway, around the entire Fort. Ref. Professor Jain's detail for paving used in the Mori of Rani Ka Mahal.

This could be tried out in a pilot project for the section that is included in the project.

15.2 Long term measures

15.2.1—Replacing existing water supply system

We recommend that the water supply system be replaced with modern pipes according to plans and design of PHED. Furthermore, we recommend that the watertank that was only used for distributing water to the foothill area be replaced with another tank outside the Fort. This will ensure that all water handled within the Fort area is for distribution within the Fort as such and there will be no unnecessary risk of water leakage. The PHED also supports this idea, although it was not included in their recommendation.

15.2.2—Replacing existing sewerage system

We recommend that the sewerage supply system be replaced with modern high quality pipes that are leak proof. This work can only be done with proper planning over a long period of time. If it is possible to co-ordinate this work together with the abovementioned scheme of replacing the water supply system, the additional cost will not be that great. Further discussions will be necessary with PHED, since they have not prioritized this issue in their action plan.

15.2.3—Connecting all households to the sewerage system

All households should be connected to the sewerage system. Specific studies might be needed for each and every house close to the Mori (involving moving of existing bathrooms closer to the street, laying sewer lines through houses, installing small sewer pumps at selected sites etc.)

These issues could be tried out in a pilot project for households and hotels that are established close to the section of the Mori in question.

15.2.4—Establish a bastion drainage system

A drainage line should be established at the foot of the bastion wall, collecting water from the Mori outlets. This drain shall take the entire storm water that falls either on rooftops that drain out to the Mori or directly onto the Mori area itself. A drainage line could be led down the slopes at regular intervals (must be concealed) and end above the pitching wall, letting out the Mori storm water on the outside of the pitching wall.

This concept could be tried out in a pilot project.

15.2.5—Establishing a proper slope

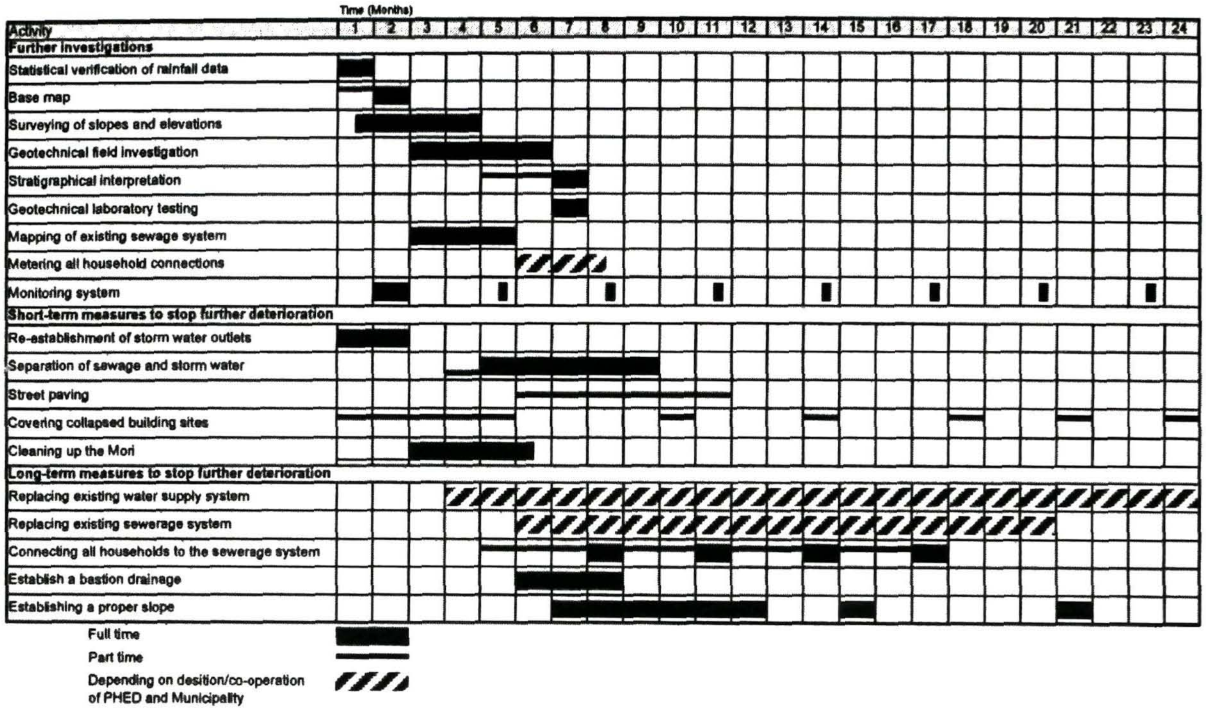
The general conditions of the slopes above the Pitching wall and below the outer bastion wall should be carefully surveyed. Convex slopes are preferred to concave slopes. Preferably the slope angles should be less steep than the internal friction of the soil masses (usually less than 32°-35°, depending on slope material).

These recommendations could be implemented in a pilot project, where emphasis would be on studying the effects of garbage deposition on the slopes, wear of vegetation cover and erosion caused by the scavengers walking up and down the slope several times a day.

16 Workplan for Documentation and Fieldwork

The following workplan presenting studies and actions concerning the Fort should be regarded as tentative.

Tentative Workplan for Studies and Actions Concerning Jaisalmer Fort



JAISALMER FORT

ROCK, SOIL AND WATER TESTING REPORT

Stockholm 2001-02-09
SWECO INTERNATIONAL
Stockholm

Project no: 1154275000

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Background

Samples of rock, soil and water were collected during the third technical mission to Jaisalmer in Jan 2001.

This report presents in brief the methods and results of the conducted tests

Rock

Point Load Strength Index test

Sample no: 1 (Claystone)


D = 65 mm, L = 100 mm, W = 60 mm

Point load pressure = 1,03 MPa

Point load index = 0,39 MPa

Sample No: 2 (Claystone)

D = 50 mm, L = 90 mm, W = 60 mm

Point load pressure = 0,82 MPa

Point load index = 0,45 MPa

Sample no: 3 (Claystone)

D = 65 mm, L = 75 mm, W = 40 mm

Point load pressure = 0,64 MPa

Point load index = 0,33 MPa

Sample no: 4 (Claystone)


D = 45 mm, L = 70 mm, W = 60 mm

Point load pressure = 0,64 MPa

Point load index = 0,43 MPa

Sample no: 5 (Claystone)

D = 50 mm, L = 60 mm, W = 40 mm

Point load pressure = 0,38 MPa

Point load index = 0,25 Mpa

Sample no: 6 (Sandstone)


D = 25 mm, L = 190 mm, W = 70 mm

Point load pressure = 3,6 MPa

Point load index = 6.07 MPa

Sample no: 7 (Sandstone)


D = 25 mm, L = 60 mm, W = 50 mm

Point load pressure = 1,4 Mpa

Point load index = 2,36 MPa

Soil

The swelling properties of the soil from disintegrated claystone have been tested regarding **swell pressure** and **free swell volume**.

The tests show that:

- Regarding to swell pressure, the soil is classified as a soil with low swell potential.
- Regarding to free swell volume, the soil is classified as active clay.

The test results are presented on the following page.

GEO- & TRÄDGÅRDSLAB

Soil / rock tests

Project **Jaisalmer Fort, India**		
Project no 115 4275-000	*Customer* VBB VIAK AB, Stockholm	*Table* *Reference no* 7676
Date of sampling	*Sampler*	*Date/Sign* 2001-02-28 *Date of testing* 2001-02-20 - 2001-02-28

Sample/ Location	Depth [m]	Soil / rock classification	Cone liquid limit [%]	Plastic limit [%]	Swell pressure 1) [kPa]	Free swell 2) [%]	Free swell volume 2) [%]	Notes
Claystone	-	Sandy clay	32	14	122	177 183 175	321 438 430	

1) A pressure preventing a specimen (grain size < 0,02 mm) in distilled water from swelling (after consolidation). The pressure is applied by using an oedometer test equipment (incremental loading).

Swell potential	Swell pressure [kPa]
None	< 100
Low	100-200
Medium	200-500
High	> 500

2) Percentage heave and volume change (according to Selmer-Olsen) of a small specimen (10 ml in a measuring glass; grain size < 0,02 mm; 3 different tests).

	Free swell [%]	Free swell volume [%]
Inactive clay	40-70	80-130
Active clay	100-170	160-500

P:\1152\UPPDRAG\2001\7676\[Page1Claystone.xls]

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Water

Two watersamples where collected:

- From a tap close to the square, representing normal supplied drinkingwater.

The water of the supply system was also tested and showed a significantly better quality and is suitable as potable water. This was specifically due to the fact that the organic matter content was low, but also chloride content (170 mg/l) and electric conductivity (127 mS/m) was less, indicating only a slightly brackish water. This water quality does not show any significant reasons for being corrosive or particularly bad for the consolidated rock of the foundation. Bacteriological testing has not been conducted. The relatively high electric conductivity of the supplied water within the Fort indicates that this water also originates from groundwater. This was also the information given to us by PHED that the Fort is within a portion of the city that is serviced with water from the well field and not from Indira Gandhi Canal.

- From a dug well close to the main square.

The groundwater quality was dominated by the fact that the well has obviously not been used for a long time and a lot of organic material has intruded into the well. This has affected turbidity and sediment content of the sample and is also evident in the high Chemical Oxygen Demand (COD). One aspect of the water quality that is probably not affected by the organic material is the Chloride content that showed a rather high value (460 mg/l). The electric conductivity was measured to 293 mS/m. Also total hardness is rather high. As a conclusion, the water sample shows a chemical quality that is not entirely bad (not considering the quality issues that are connected to the organic matter) other than the high chloride content that is above the limit that is possible to detect by taste and indicates a saline water. The water quality shows no significant reasons for being corrosive or particularly bad for the consolidated rock of the foundation. Bacteriological testing has not been conducted.

The laboratory analyses reports are presented on the following pages.

RAPPORT
utfärdad av ackrediterat laboratorium
REPORT issued by an Accredited Laboratory
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1 / 1

VBB VIAK AB, Stockholm
Geologi och grundvatten
Box 34044
100 26 STOCKHOLM
SWEDEN

Client	V1113
Proj. No	1154275000
Reference	
Date of Arrival	Jan 23, 2001
Station	Jaisalmer Fort
Site	
Sample Collector	B Holgersson

Sample No		**177509**
Sampling Date		Jan 11, 2001
Time		
Sample Label		Well
* Sampling Temperature	°C	------
Turbidity	FNU	1600
* Turbidity/acidified	FNU	850
Sediment		
pH		7.2
Conductivity	mS/m	293
COD-Mn	mg/l	240
Ammonium-Nitrogen	mg/l	0.32
Nitrate-Nitrogen	mg/l	<0.02
Nitrite-Nitrogen	mg/l	0.003
Phosphate-phosphorus	mg/l	1.1
Alkalinity	mg HCO3/l	850
Chloride	mg/l	460
Sulphate	mg/l	240
Fluoride	mg/l	0.48
Iron (ICP, B)	mg/l	54
Manganese (ICP, B)	mg/l	0.59
Calcium (ICP, B)	mg/l	250
Magnesium (ICP, B)	mg/l	57
Total Hardness °dH (B)	°dH	48
* Marble aggr. CO2 /calc.	mg/l	<1
Silicon (ICP, B)	mg/l	25
Potassium (ICP, B)	mg/l	18
Sodium (ICP, B)	mg/l	530
Aluminium (ICP, B)	mg/l	7.0
Copper (ICP, B)	mg/l	0.11
B: Digestion 0.34 M HNO3		------

* Ingår ej i ackrediteringen eller har ej utförts av VVL.
* Not included in VVL's accreditation

Stockholm Feb 2, 2001
VVL

Copy to:

Tommy Karlsson
vice Laboratory Manager

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RAPPORT

utfärdad av ackrediterat laboratorium

REPORT issued by an Accredited Laboratory

1 / 1

VBB VIAK AB, Stockholm
Geologi och grundvatten
Box 34044
100 26 STOCKHOLM
SWEDEN

Client	V1113
Proj. No	1154275000
Reference	
Date of Arrival	Jan 23, 2001
Station	Jaisalmer Fort
Site	
Sample Collector	B Holgersson

Sample No		**177510**
Sampling Date		Jan 11, 2001
Time		
Sample Label		Water supply
* Sampling Temperature	°C	------
Turbidity	FNU	1.7
* Turbidity/acidified	FNU	0.30
Sediment		None
pH		7.9
Conductivity	mS/m	127
COD-Mn	mg/l	<1.0
Ammonium-Nitrogen	mg/l	0.03
Nitrate-Nitrogen	mg/l	0.15
Nitrite-Nitrogen	mg/l	<0.002
Phosphate-phosphorus	mg/l	0.002
Alkalinity	mg HCO3/l	290
Chloride	mg/l	170
Sulphate	mg/l	100
Fluoride	mg/l	1.3
Iron (ICP, B)	mg/l	0.28
Manganese (ICP, B)	mg/l	0.003
Calcium (ICP, B)	mg/l	32
Magnesium (ICP, B)	mg/l	15
Total Hardness °dH (B)	°dH	7.9
* Marble aggr. CO2 /calc.	mg/l	<1
Silicon (ICP, B)	mg/l	5.4
Potassium (ICP, B)	mg/l	5.8
Sodium (ICP, B)	mg/l	250
Aluminium (ICP, B)	mg/l	<0.20
Copper (ICP, B)	mg/l	0.005
B: Digestion 0.34 M HNO3		------

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Stockholm Feb 2, 2001 | Copy to:

VVL

Tommy Karlsson
vice Laboratory Manager

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