PREAH KHAN CONSERVATION PROJECT
HISTORIC CITY OF ANGKOR

Siem Reap, Cambodia

REPORT III
CONSERVATION PLAN

WORLD MONUMENTS FUND

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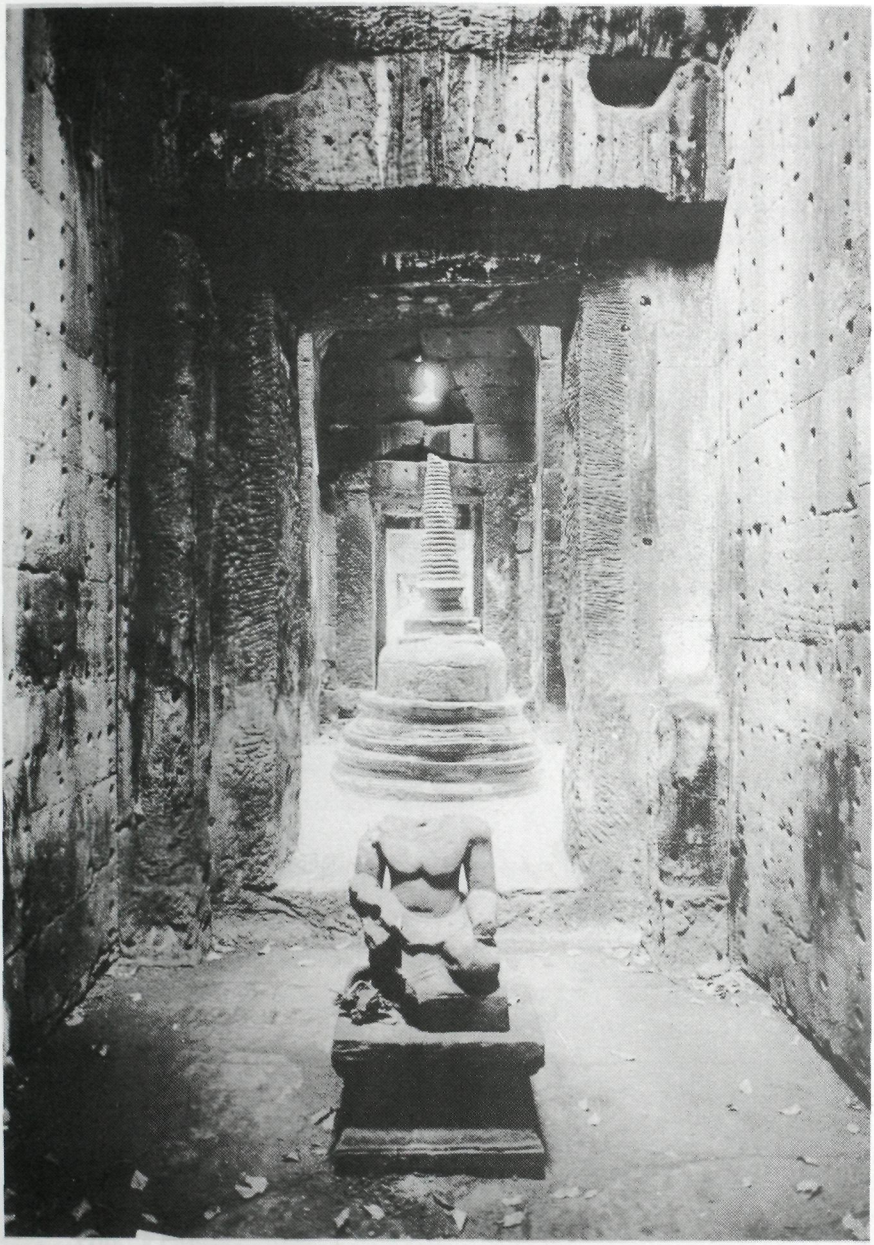
New York

September 1992

Revised



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INTRODUCTION

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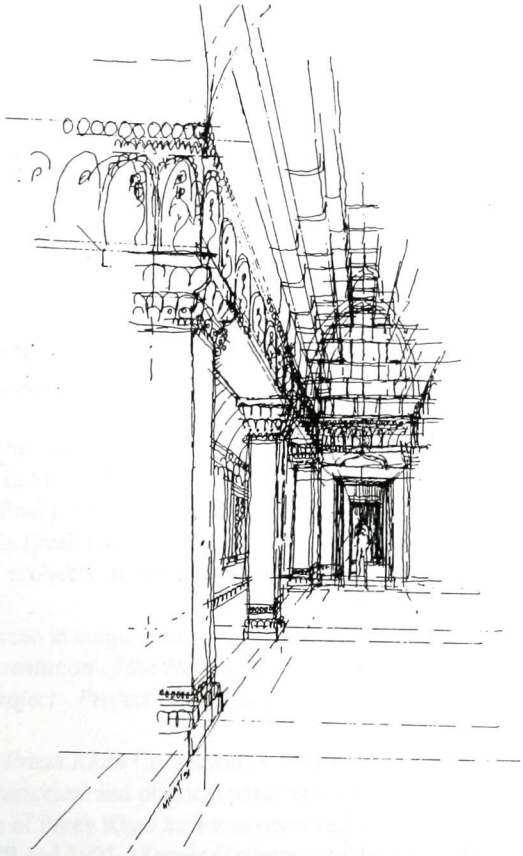


1. INTRODUCTION

FOREWORD

During its first mission to Angkor in 1989, the World Monuments Fund team spent approximately two days at Preah Khan. This allowed initial observations of the extent of the site and the scope of the conservation challenge. The second mission in 1991 permitted a total of ten days on site and, with the assistance of a team of eight students, the WMF team undertook a more thorough analysis of the condition of Preah Khan and an assessment of the work required to conserve and present the site. The information derived from the second mission is recorded in *Report II: Preah Khan Conservation Project - Project Identification* which serves as a basis for the present *Report III: Preah Khan Conservation Project - Conservation Plan for Preah Khan.*

Following a request from the Cambodian Government at the end of its first mission, the World Monuments Fund team has since undertaken a comprehensive conservation research program for the monastic complex of Preah Khan, one of the largest historic sites at the Historic City of Angkor. This report documents information gathered during the second World Monument Fund mission in March 1991 and a subsequent March 1992 mission, and proposes recommendations for the conservation and presentation of Preah Khan to the Committee for the Rehabilitation of the Monuments and Museums of Cambodia.

Representatives from the World Monuments Fund have discussed the proposed conservation program in Preah Khan with the Cambodian Government and it has been agreed, pending final permission and successful fund raising, that a conservation and training program in Preah Khan will be initiated, following the recommendations outlined in this report, probably in November 1992.

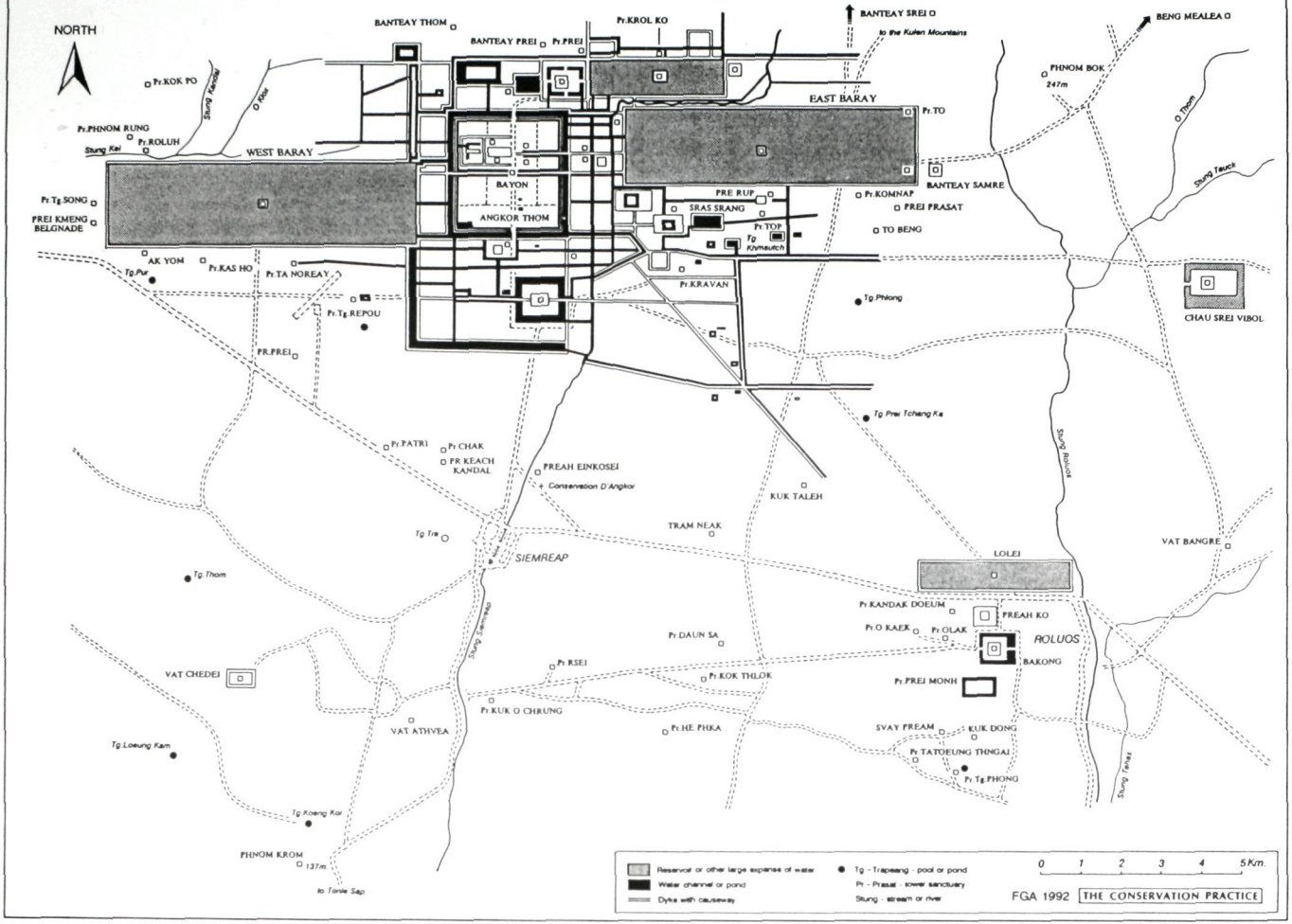
This report should be read in conjunction with *Report I: Considerations for the Conservation and Presentation of the Historic City of Angkor* and *Report II: Preah Khan Conservation Project - Project Identification.*

The WMF *Report II: Preah Khan Conservation Project - Project Identification* defined the physical, historical and physical parameters of the conservation challenge posed by the large site of Preah Khan as it was observed and analysed by the WMF team of experts in 1989 and 1991. *Report II* attempts to define the framework for both a holistic and an integrated conservation analysis of the site, with regard to its

past, present and future states of existence. *Report II* also defines the conservation "philosophy" to be adopted at Preah Khan which entails a conservative approach. Upon completion of the conservation project, Preah Khan will continue to appear as a "partial ruin" but will be stabilized to guard against structural collapse for the next several decades and made more intelligible from the standpoint of visitor interpretation. The rationale and procedures for implementing this type of intervention are further articulated in this Report.

This *Report III - Conservation Plan* further defines various conservation issues at Preah Khan as well as the methods being considered to address these issues. The report discusses problems and methods in relation to a series of test programs, and also within the context of a defined overall site conservation and interpretation program. Its purpose is further described in "Project Application and Review Process" (Section 4 of this Report) and in Section 5, "Work Plan." All specific conservation analyses and other researches will follow the orthodox scientific method of research, analysis and hypothesis and, in this case, will stress restoration technique, testing, and careful documentation. Many, but not all, of these methodologies are standard in the field. Where possible, the simplest, safest, and most efficient methods will be used. Methods that respect the local building traditions and technologies will always be given first consideration for use. After all, the conservation work at Angkor should be, as much as possible, by, for, and about the Cambodian people.

A MAP OF ANGKOR



REPORT PURPOSE

Report I: Angkor Considerations and *Reports II* and *III* which specifically propose a *Conservation Plan for Preah Khan* have been produced for the following purposes:

- to document architectural conservation issues and make recommendations appropriate to the Historic City of Angkor, in particular for the representative site of Preah Khan;

- to provide an application describing methodologies proposed by WMF for a conservation program at Preah Khan to the National Heritage Protection Authority of Cambodia (NHPAC) as well as to national and regional offices of the Cambodian Ministry of Culture; and

- to describe the proposed conservation to UNESCO and other such organizations as well as to potential financial supporters who, it is hoped, will view the Preah Khan conservation effort as a "pilot project" in which they are invited to participate.

ACKNOWLEDGMENTS

WMF is grateful to the individuals who have served as members of its three Angkor research missions, and to the experts who have reviewed and made the suggestions for improvement of these reports. WMF hopes that, in their presently revised form, these reports will prove useful in formulating a *Conservation Plan for the Historic City of Angkor.*

Specialists who have contributed in various ways to the production of these reports include: John Sanday, Dr. Corneille Jest, Dr. Claude Jacques, Bonnie Burnham, John Stubbs, Sam Heath, Rebecca Anderson, Daniel Burke, Gini Dofflemeyer, Bruno Bruguier, Christine Hawixbrock, Dr. Frank Preusser, Fred Aldsworth, Stan Armington, Dominique Lajoux, Norma Joseph, Lori Anglin, Scott Cunliffe and Robertson Collins.

Special gratitude is expressed to WMF's hosts in Cambodia, in particular, Prime Minister Hun Sen; members of the Ministry of Culture including Minister Hang Chuon, Ouk Chea and Pich Keo; Uong Von; members of the University of Beaux Arts in Phnom Penh, including Deans Chuch Phoeurn, Hem Bun Tong and Hor Lat.

Colleagues and collaborators from other governmental organizations who have been of particular assistance include Professor Yoshiaki Ishizawa of Sophia University and his colleagues; Minja Yang, Matthias Dermitzel, Richard Englehardt and Véronique Dauge of UNESCO; and Dr. Leon Vandermeesch and Dr. Bruno Dagens of the Ecole Francaise d'Extreme Orient.

WMF's efforts have also been aided by important contributions from concerned individuals acting on their own initiative, both in Cambodia and throughout the world. WMF thanks these individuals, who are too numerous to specify, for their interest in the conserving and presenting the Historic City of Angkor.

WMF also expresses profound gratitude to its sponsors, without whose financial support these missions would not have been possible.

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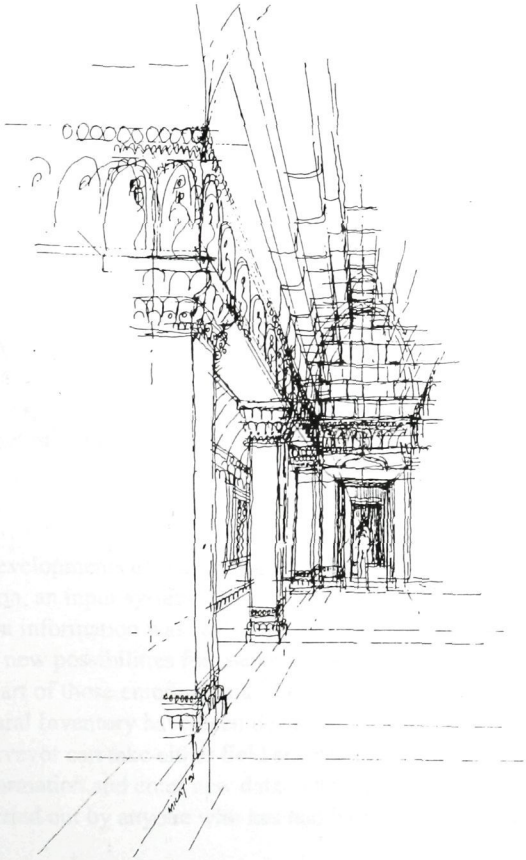
CHAPTER 2

MISSION III DEVELOPMENTS

The Computerized Architectural Inventory

Research and Documentation

A Conservation Philosophy for Preah Khan



2. MISSION III DEVELOPMENTS

THE COMPUTERIZED ARCHITECTURAL INVENTORY

Purpose

As outlined in *Report II - Preah Khan Project Identification,* the Computerized Architectural Inventory is an inventory recording information about an architectural structure, or component thereof, compiled and maintained from a specific point in time using consistent criteria. The principal purpose of conducting an inventory is to assist in the evaluation and planning of the building conservation program, an essential part of every cultural management plan. Such an inventory should be designed to be a dynamic chronicle of the architectural site and should be continually updated.

Standard database computerized inventories are generally repositories for information alone. Due to the complexity of the Preah Khan site, it was decided to design a more versatile and easily used inventory which would assist the WMF team with both documentation and conservation planning for the site.

During the second WMF Angkor Mission in March 1991, the team set up some basic parameters for the design of the Computerized Architectural Inventory and prepared a provisional field record sheet which recorded basic information on over 120 architectural spaces and components. This survey covered all structures within Enclosure II and a number of structures within Enclosure III of the complex.

Operation in the Field

Based upon the initial developments of the Computerized Architectural Inventory during the second mission, an input system for collecting and editing architectural description and condition information was revised and expanded in March 1992. This system provides several new possibilities for use and will require a minimum of computer skills on the part of those entering data. The entry screens for the Conservation Architectural Inventory have been designed to replicate the actual field evaluation forms. A surveyor can take either field sheets or a laptop computer to the site and view extant information and enter new data. Other specialized data accessing or processing can be carried out by anyone who has had basic computer training.

An important consideration in the design and development of a Computerized Architectural Inventory System for Preah Khan was the possibility of using the system, with minimal modification, at other Khmer monument conservation projects, especially elsewhere at Angkor.

Design Criteria

Since the computer-based inventory system will be used by many people, often with little or no knowledge of computer operations, the system has been developed with the following objectives in mind. The program had to be:

- portable and easy to use;
- "user friendly," with on-line help, accessible upon request or when inconsistent data are entered; and
- visually intelligible so that users may readily transfer their understanding of the data collection sheets to the computer screen.

Members of the Computerized Architectural Inventory design development team were encouraged to create a format that met a variety of foreseeable needs. New features include the possibility of effecting quantity surveys, storage and retrieval of basic graphic and photographic reference data and the presentation of various statistical analyses. For purposes of conservation design decision-making and for construction estimation these new computer functions should prove invaluable. As new needs arise, the program can be easily expanded.

Hardware

The computer inventory system requires the following equipment:

- an IBM-compatible computer with 640k of RAM,
- a hard disk, minimum 20 megabytes, preferably larger, in order to store an extensive photo library,
- any kind of screen for text entry, but a VGA screen will be needed for the proper display of photographs.

The system has been written on a Taiwan-made notebook computer and has been tested on Toshiba 1200 laptops as well as standard desktop IBM clones. The program is network-compatible. Data can be entered in the field on inexpensive notebook or laptop computers and eventually transferred to a central facility where many people can access the same data simultaneously. The data are stored in a standard database

Item EC Entrance Central | Enclosure 1 | WMF_Ref GE1/3
Group GE Gopura East | Grid Coord N000W034 | File No: 923/33
Alt Name(s) Central Tower | EFEO Ref

Description

Plan
- Rectilinear
- Square
- √ Cruciform
- Other

Architectural Features
- Columns
- √ Colonettes
- √ Pediment
- √ Cornices
- √ Architraves
- √ Scribed Reveals
- √ Scribed Walls
- √ Exterior Bas Relief
- Interior Bas Relief
- Other

Roof
- √ Crude Vault
- Dressed Vault
- √ Tower

Walls
- Coursed
- √ Keyed

Building

	LA	SS	BR	TI	ST	OT
Roof		√				
Wall		√				
Floor		√				

Openings (Qty)
- 4 Doors
- Windows

Inscription
N S √ E W

Movable Artistic Features

'In Situ' or nearby
- Sculpture. Type:
- √ Base

'Ex Situ'
Type:
Location:

Prior Interventions

Late Angkorean	Modification to Building	Partial Reconstruction
15th 16th Cent	Modification to Finishes	Total Reconstruction
EFEO	Stabilization	Other _____

As Found Condition

Gen. Assessment

Good			Destroyed
√ 1	2	3	4

Principal Structure
Roof: 25 % Covered
Floor: 80 % Intact

Walls

	N	S	E	W
% Intact	100	100	100	100

Threats to Building Fabric

Trees	√ Biological Growth	Visitor Wear	Thiobacilus
√ Vines/Sm. Plants	Adj Structures	√ Poor Drainage	Settlement
Intervention	√ Moisture	√ Stone Delamination	Other

Threat of Collapse
√ Low Medium High
Area(s): Tower

Conservation Urgency
Low Medium √ High
Area(s): Tower

Dimension (Meters)
Floor ns 10.00
Floor ew 8.00
Wall hgt 4.00

Notes

Trial cleaning of Biological growth on interior walls undertaken by Dr F. Preusser. Simple cleaning using water and soft brush with excellent results. Samples on NE wall; NE door reveal; SE wall.

It is strongly recopmmended that the tower roof is capped or completed to prevent water penetration which causes biological growth.

Possible site for interpretation center?

Replicate original sculpture and place on existing base?

Bibliographical Reference(s)

Recorded by
Name Sanday | Photo Neg No:
Date 30/03/92

Field Recording Form, The Preah Khan Computerized Architectural Inventory, 1992

Item EC Entrance Central	Enclosure 1	WMF_Ref GE1/3
Group GE Gopura East	Grid Coord N000W034	File No: 923/33
Alt Name(s) Central Tower		EFEO Ref

=Recommendations=

- Debris Clearance (Non Archeol.)
- √ Vine/Plant Removal
- Tree/Stump Removal
- Specialty Tree Pruning
- Emergency Structural Stabilization
- Remove Interventions
- Monitor for Structural Movement
- Minor Resetting of Dislodged Stones
- Minor Stone Reattachment
- Resetting of Dislodged Stones
- √ Major Stone Reassembly
- Structural Pinning
- Foundation Underpinning
- Complete Reconstruction
- Precast Unit Repairs
- New Stone Carving
- Composite Stone Repair
- New Wall Capping
- Joint Weatherproofing
- √ Reset Floor Paving Stones
- √ Improve Drainage
- √ Minimal Stone Cleaning
- Thorough Stone Cleaning
- Application of Biocide
- Application of Stone Consolidant
- Plaster Finish Conservation
- Sculpture Conservation
- √ Sculpture Replication
- √ Wire Mesh Protection
- Other _____

=Building Technologies=

- Minor Scaffold
- √ Major Scaffold
- Movable Crane
- √ Hoist
- Stone Centering/Cradling
- Temporary Access Ramps
- √ Simple Jacks
- √ Extension Jacks
- √ Stone Cleaning
- Special Stone Treatment
- Injection Grouting
- Other _____

=Photos=

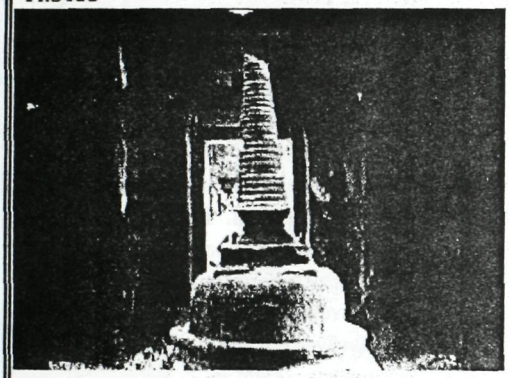
No photos for this structure

World Monuments Fund

Field Recording Form (page 2 of 3)

Item CC Central Cell	Enclosure 3	WMF_Ref GE3/1
Group GE Gopura East	Grid Coord N000E122	File No: 923/10
Alt Name(s) Central Gate, Gopura.		EFEO Ref

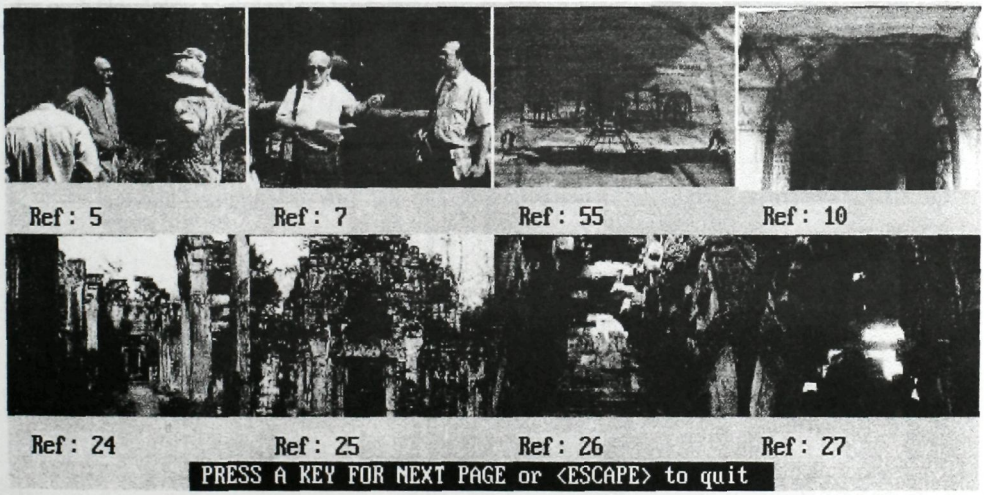
Photos



Caption: Central Shrine Int: Stu

Reference: 18, File PK_WE18.PCX

Inventory Form (page 3 of 3): Digitized Image of Architectural Element



format that is compatible with all xBase systems including DBase III and IV, Foxbase, Foxpro and Clipper. This format allows free-form memo fields and is the worldwide standard for database formats. Any other computer system or program (including Apple) can read, write and manipulate Database format files either directly or indirectly. Any computer-literate person can modify files and fields, extract data and prepare reports from database files.

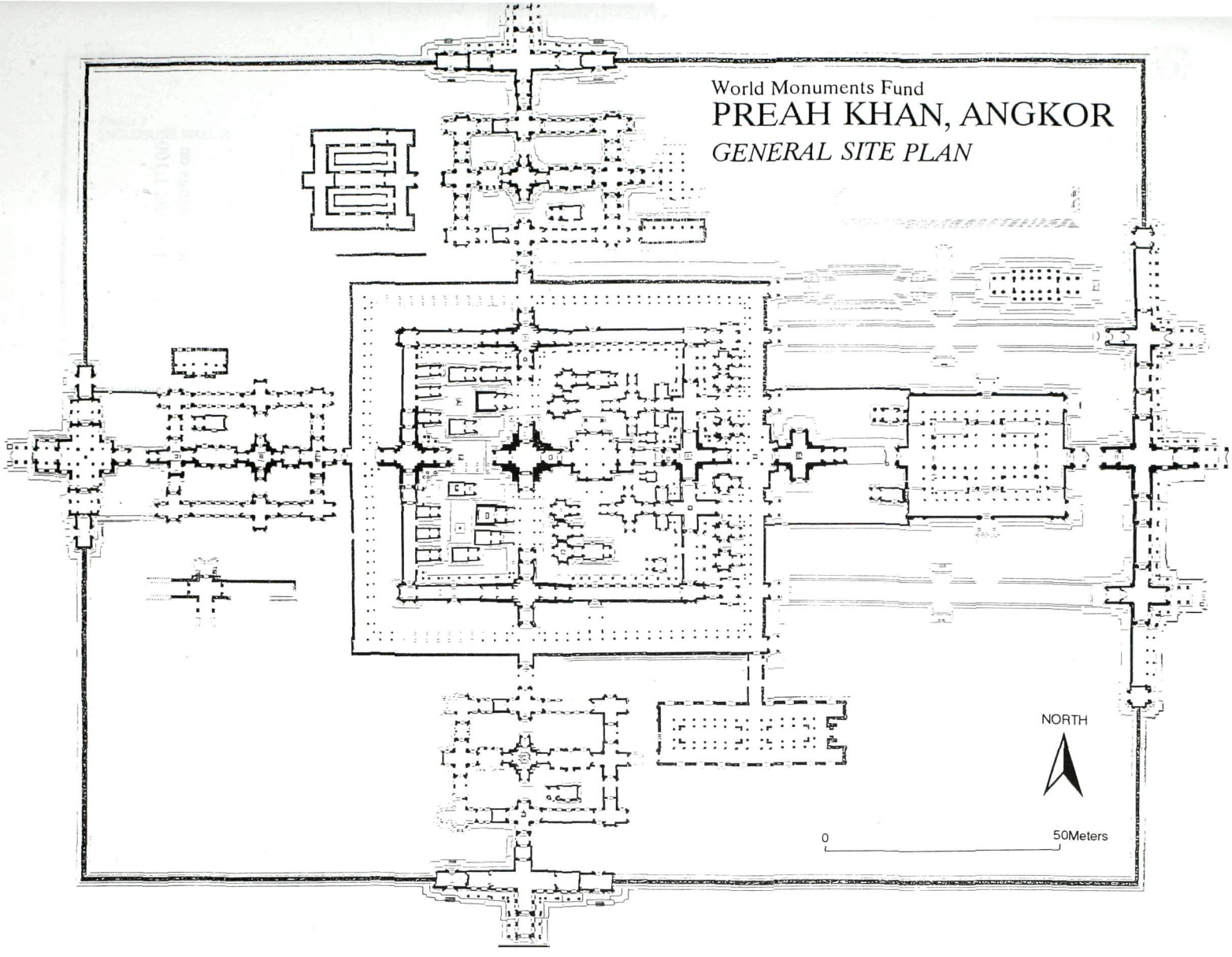
Visual Images

The system has been designed so that video or photographic images can be stored on computer disks and incorporated into the database. Capturing the images requires some additional hardware (a computer interface card and a VGA monitor) that may not be available in Siem Reap. However, this equipment is presently available for WMF team use in Bangkok, Hong Kong and Kathmandu. Images, therefore, can be converted off-site and incorporated into the database when completed. Each image at present requires about 70k of disk space. There is no limit to the number or complexity of graphic images, other than the fact that they must be stored in the industry-standard "PCX" format. Once the images are converted to "PCX" files, the inventory program can display them without additional hardware if the computer is equipped with a VGA or EGA display.

Technical Data

The data entry program is written in Clipper 5.01 under MS-DOS. It is supplied in compiled form and is a complete executable (.EXE) file that requires no other drivers or sub-systems. The program works on IBM based machines only; there is no facility at this time to convert it to Apple or Macintosh.

In its initial stages the computer inventory can be maintained on laptop or notebook computers. Eventually, as other sites are inventoried and additional photographic images are incorporated, and as more researchers use data from the inventory, a larger more permanent facility will be required. It is envisioned that the inventory will be maintained on networked PCs in the World Monuments Fund office in New York with a sub-system in Asia. Information for specific sites could be transferred from the master system to portable computers for field use and then re-integrated into the master system. (See also Appendices A & B)


World Monuments Fund
PREAH KHAN, ANGKOR
GENERAL SITE PLAN
NORTH
0
50Meters

RESEARCH AND DOCUMENTATION

Historical Research

Several architectural drawings exist describing Preah Khan, the most recent of which was prepared by J. Dumarcay in 1988. There are 74 drawings (plans, sections and elevations) catalogued in the archives of the Ecole Française d'Extreme Orient in Paris. These and many other drawings from the EFEO collection have been microfilmed and a set has been given to the National Museum, Phnom Penh where they are available for study. WMF plans further to research these drawings and to obtain copies of each from the EFEO in Paris.

Photographic Survey The EFEO has an extensive and remarkable photographic record of Preah Khan dating from the early 1930s up to 1975. During Mission II, in March 1991, it was possible to compare the condition of many structures today with early photographs from the EFEO collection. The early photographs will be invaluable in helping to evaluate the deterioration of the structures of Preah Khan and in understanding the well documented interventions undertaken by the EFEO between 1932 and 1960.

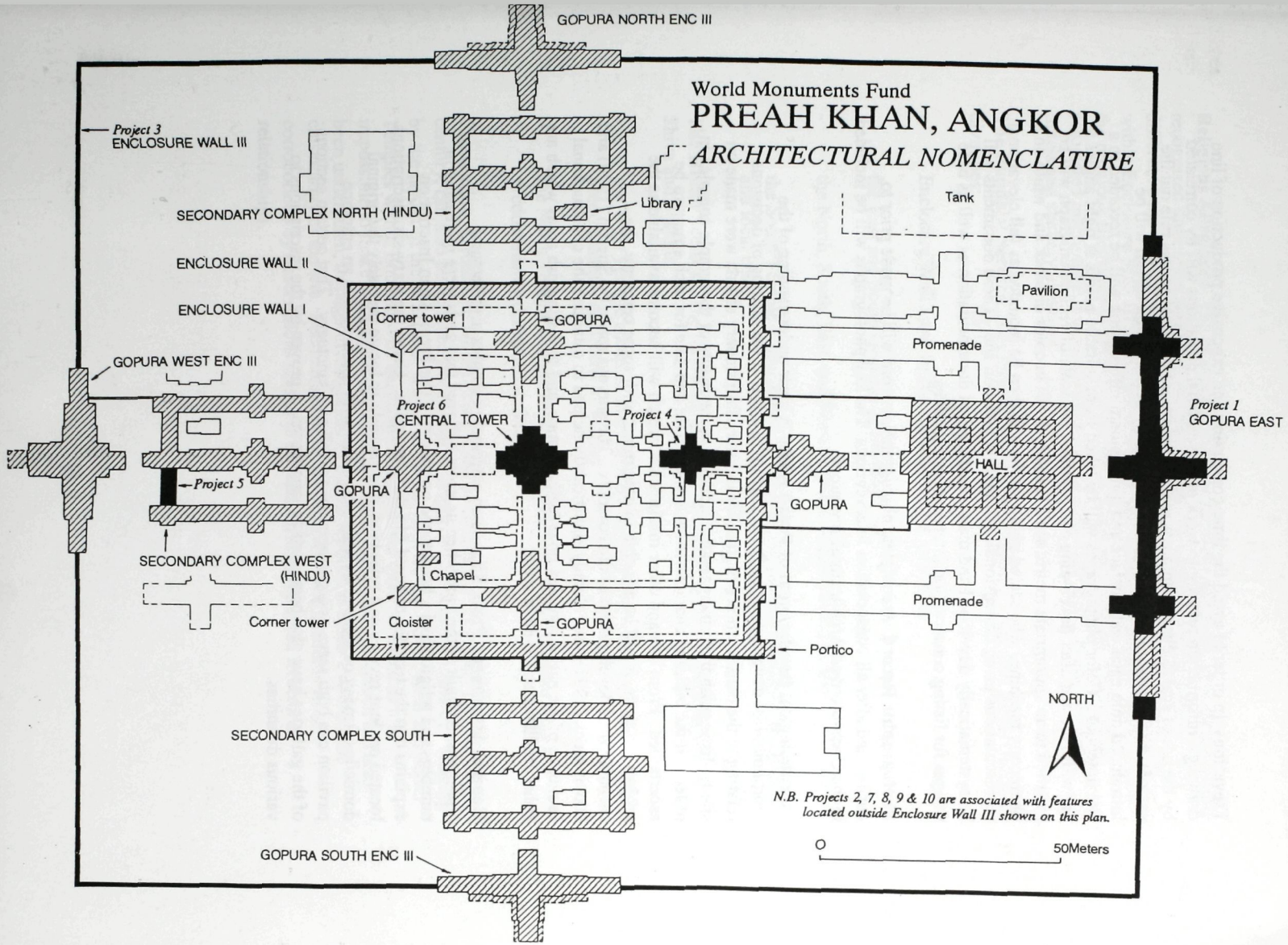
Since its first mission in 1989, WMF has developed an extensive photographic archive which will be expanded and included in the Computerized Architectural Inventory.

Measured Drawing Survey For a full discussion of survey methodologies and accomplishments during Mission III see Appendices A & F.

General Documentation As part of the research for the WMF Preah Khan Conservation Project it will be necessary further to collect and prepare information in the form of photographs and line drawings to assist the team to:

- document "as found" conditions,
- undertake historical research,
- prepare conservation specifications, and
- record conservation interventions.

Plans and Sections Plans and sections will be prepared as inked line drawings on drawing transparencies to appropriate metric scales e.g., 1:10, 1:20, 1:50 and 1:100.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PREAH KHAN, ANGKOR
ARCHITECTURAL NOMENCLATURE
GOPURA NORTH ENC III
Project 3
ENCLOSURE WALL III
SECONDARY COMPLEX NORTH (HINDU)
Library
Tank
ENCLOSURE WALL II
ENCLOSURE WALL I
Corner tower
GOPURA
Pavilion
Promenade
GOPURA WEST ENC III
Project 6
CENTRAL TOWER
Project 4
Project 1
GOPURA EAST
HALL
Project 5
GOPURA
GOPURA
SECONDARY COMPLEX WEST
(HINDU)
Chapel
Promenade
Corner tower
Cloister
GOPURA
Portico
NORTH
SECONDARY COMPLEX SOUTH
N.B. Projects 2, 7, 8, 9 & 10 are associated with features located outside Enclosure Wall III shown on this plan.
0
50Meters
GOPURA SOUTH ENC III

Elevations In order to avoid the time-consuming and expensive production of line drawings, information relating to work on the external elevations will by correlated by the use of scaled photographic prints. (Problems of physical access rule out the use of orthodox photogrammetry at Preah Khan.) A horizontal datum will be introduced onto each wall surface and dimensional information will be recorded in a site notebook. Color photographs will be taken from suitable points at right angles to the wall face and after developing and printing, the scale of each photograph will be rectified to an appropriate metric scale (usually 1:50) in color or black and white on a photocopy machine. The scaled photographs will then be mounted as full elevational representations using dimensional information taken on site. These documents will be systematically developed and maintained as filed documentation as well as base images for listing conservation intervention directives.

Photographic Record A complete photographic record will be made prior to, during, and after all conservation interventions. The key photographs will be included in the Computerized Architectural Inventory.

Morphological Development of Preah Khan A clear understanding of the morphological development of Preah Khan will assist in the making of decisions relating to the conservation program for the site. Preliminary efforts were made on site to distinguish the principal constructional components of the temple complex in order that the building characteristics, artistic style and date for each structure be ascertained. From this and other information, which will become available as the project proceeds, it will be possible to determine, with some certainty, the chronological development of the complex. The surveys made by Stierlin (1970) and Hawixbrock (1991) have already significantly helped to establish the constructional sequence of the entire complex on artistic grounds, and to distinguish areas which are either Buddhist or Hindu in style.

General Assessment Preah Khan is an extremely complex architectural configuration built at the time when its users believed that gods were increasing in numbers and religion had a heightened popularity. The Preah Khan Inscription explains that the temple sheltered 515 different gods. Using the sixty-six inscriptions located on door reveals as a reference, it is possible to locate precisely the original domicile of many of these gods and to establish with certainty that an entrance pavilion can both serve as a passageway as well as a sanctuary. That certain sections of the galleries have also been used as sanctuaries, is proven by the inscriptions to various divinities.

Religious Allegiance The increase in the number of divinities which were apparently recognized during the period of construction greatly complicates the attribution of different parts of Preah Khan. For example, the function of the laterite structures within Enclosure Wall III is still unknown. Nevertheless, it is possible to determine the religious allegiance of several of the Preah Khan structures by reading their associated inscriptions and following a careful study of the decorated pediments, lintels and statuary locations.

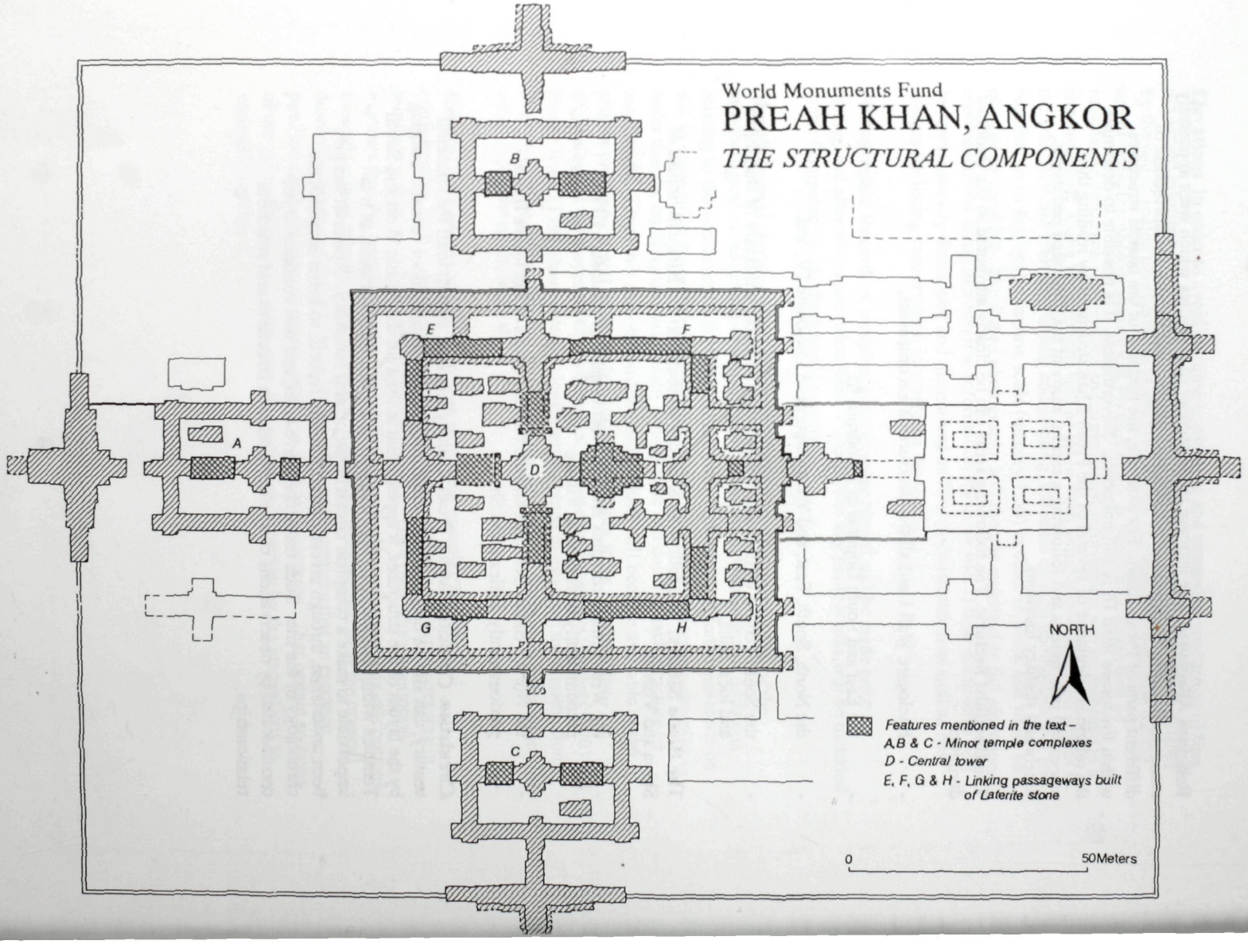
The Buddhist Sectors: The following areas can be clearly attributed to the Buddhist divinities:

- Enclosure Wall I and all the structures it encompasses,
- the East and South Gopuras of Enclosure III,
- the North, South, East, and West Gopuras of Enclosure IV, and
- the South Temple of Enclosure III which is probably a mixture of Buddhism and local cults.

The Hindu Sectors: The following areas are attributed to the Hindu divinities of Shiva and Vishnu:

- the West Temple complex and the West Gopura of Enclosure III are predominantly dedicated to Vishnu
- the North Temple Complex and the North Gopura of Enclosure III are predominantly dedicated to Shiva.

Circulation Circulation within Preah Khan by its users, at least until the sixteenth century, can also be deduced from small inscriptions on many door reveals. Judging by the layout of the structures, it appears that at least for the North, West and South Temples within Enclosure III the circumambulatories were not used, as it is impossible to make a complete circuit of the central sanctuary. Research has also been undertaken, through investigation of earlier reports, to better establish the chronology of the site. Such researches have been, and will continue to be, corroborated by observations on site of foundation structures and structural relationships.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PREAH KHAN, ANGKOR
THE STRUCTURAL COMPONENTS
A
B
C
D
E
F
G
H
NORTH
Features mentioned in the text –
A,B & C - Minor temple complexes
D - Central tower
E, F, G & H - Linking passageways built of Laterite stone
0
50Meters

Aspects of Preah Khan's Building Chronology

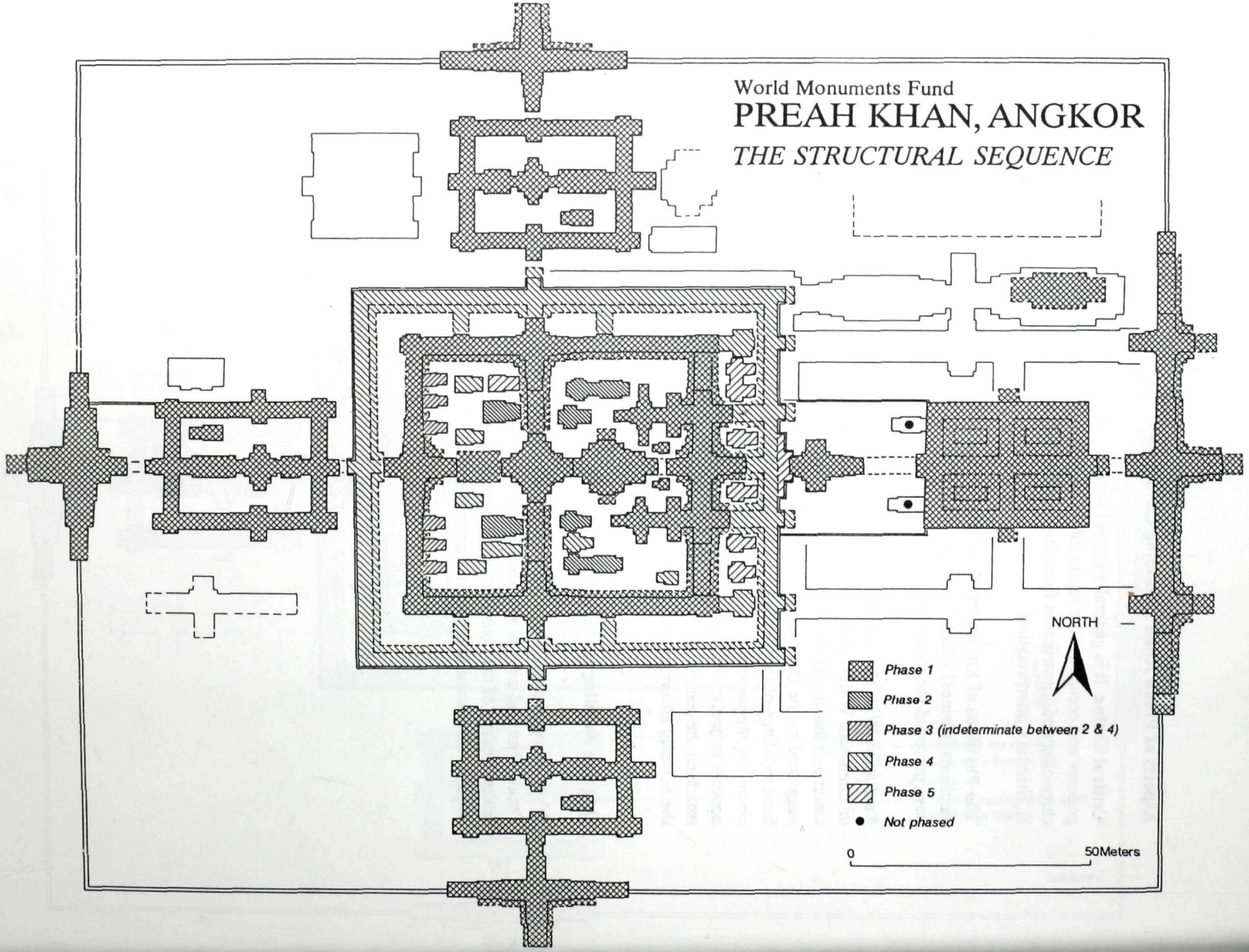
Central Shrine It is generally agreed that the Central Shrine, Enclosure Wall I, its gopuras and corner towers represent the original period of construction and the chronology of construction from this original development is illustrated in H. Stierlin's interpretation.

The Pavilions of Enclosure II Within Enclosure II there is a similar group of pavilions (shrines) which have been added later. The outer square shrines appear to have preceded the rectangular structures between them.

Enclosure Wall II Despite earlier contentions relating to the period of construction of Enclosure Wall II, it is apparent from close examination of the foundation structures that it was built later than the North and South access corridors. This is suggested by the fact that the base moldings of the corridors are interrupted by the base moldings of the enclosure wall. Despite it being difficult to determine by observing the joints, the section of the passage from the Northeast laterite terrace appears to precede Enclosure Wall II. It also seems that the link construction attaching the eastern cruciform pavilion to the enclosure wall was the final addition in the building chronology of this section.

Ongoing Building History Research

WMF recognizes the importance of ongoing research of the architectural history of Preah Khan and intends to ensure that further research is undertaken to secure a full understanding of the constructional sequence of the complex. See Section 7 of this Report, "Recommendations for Future Study."


World Monuments Fund
PREAH KHAN, ANGKOR
THE STRUCTURAL SEQUENCE
NORTH
Phase 1
Phase 2
Phase 3 (indeterminate between 2 & 4)
Phase 4
Phase 5
Not phased
0
50Meters

Stabilization of West Gopura III, Preah Khan, c. 1942.

A CONSERVATION PHILOSOPHY FOR PREAH KHAN

Approaches to Conservation and Repair Recommendations

Before a detailed set of recommendations or specifications can be drawn up, several decisions regarding the philosophical approach to the conservation of the temple complexes of Angkor must be undertaken. Listed below are some of the basic issues that must be considered before any major interventions are made. Standard techniques for repair are being developed which are referred to in this Report and in the Computerized Architectural Inventory. It is anticipated that new conservation technology developed on site for Preah Khan will, with further analysis, be useful elsewhere at Angkor. All recommendations can only be finalized after careful experimentation on site.

Conservation Guidelines

The Preah Khan Conservation Project should follow the set of guidelines for conservation and repair set out in the WMF's *Report I: Considerations for the Conservation and Presentation of the Historic City of Angkor.* Further to these guidelines, the following more general modalities should be taken into consideration:

- The conservation of architectural monuments involves working on materials in an open and uncontrollable environment. The conservation team must anticipate the effects of time and weather.

- Architectural conservation is always a team effort involving historians, architects, technicians, craftsmen and administrators all of whom are required to work closely together. Good communication and supervision are essential to the success of a project.

- When undertaking the repair and conservation of a structure, the structure should not be viewed as an isolated element. Its ancillary structures and ambiance must also be duly protected and preserved.

Types of Conservation Intervention

The following definitions broadly cover conservation work anticipated at Preah Khan:

Anastylosis The process of reconstructing a collapsed structure, or the careful dismantling and rebuilding of a structure using modern technology. Anastylosis, or reconstruction, is dependent upon craftsmen experienced in stone construction and upon the knowledge and skills of the conservation team. In the case of Preah Khan, it may be possible to reconstruct some of the sections suffering from partial collapse and structurally to rectify the cause of failure. The use of cranes and gantries is essential to this work and the means of obtaining access to this equipment in what are often physically constricted areas of the site needs to be carefully planned.

Conservation Architectural conservation generally refers to the combined actions exerted in the protection, stabilization, repair and restoration of a monument or part thereof. The conservation of specific building materials is a major aspect of architectural conservation. Documentation and planning for the conservation methodology are also important aspects of Architectural Conservation. The present effort to preserve and present Preah Khan could be called Architectural (or Archaeological Site) Conservation.

Consolidation Consolidation refers to minimal strengthening and supporting of structures and building fabrics which are about to fail. Generally it implies the use of new material. The term consolidation can be applied to the conservation of a specific material such as stucco or stone, or to work on a larger scale such as structural consolidation.

No Intervention For various reasons, the wisest course of action in a conservation project may be to do nothing at all. Occasionally, it is best to leave a site or part of a site undisturbed for a future generation, at which time conservation technologies and other abilities may have improved. WMF proposes to leave parts of the Preah Khan complex in its "as found" condition. This will also serve as a good illustration for site interpretation.

Restoration The term restoration usually implies returning a building or site to what is understood to be its earlier or original appearance. Restoration often implies major intervention to the surviving architectural fabric of a structure, in order to recreate original finishes and appearances. The quality of a restoration is usually critically dependent upon a thorough understanding of a monument through detailed historical research and both above- and below-ground archaeological investigation. Practically none of the fragile finishes and fittings that would have been experienced by its early users survive today at Preah Khan. Accurate "restoration" as defined above is, therefore, not warranted at Preah Khan, except perhaps for purposes of interpretation and then only when the display is clearly justified and labeled.

Stabilization Stabilization refers to minimal repair and conservation, avoiding the use of visible new materials when possible. In the case of Preah Khan, this term will most be used in connection with structural stabilization.

CHAPTER 3

SPECIAL ANALYSES

Conditions Survey
Inaccessible Areas
Conservation Threats and Defects
Conservation Recommendations
Recommendations for Archeological Activities
Visitor Access and Site Development

3. SPECIAL ANALYSES

CONDITIONS SURVEY

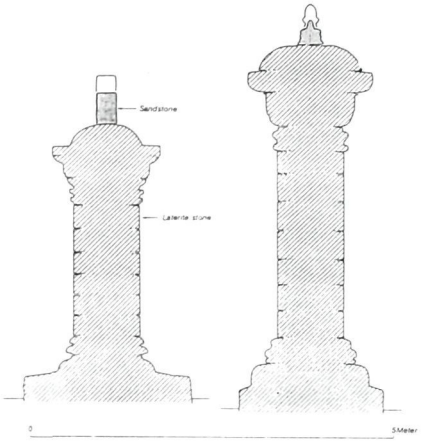
Building Materials in Use at Preah Khan

Sandstone Most of the original structures at Preah Khan have been constructed and faced in the pinkish-grey sandstone that is quarried near the Kulen Hills, 35 km to the northeast of Angkor. The fine-medium grained stone has been classified as feldspathic litharenite or lithic greywacke and is composed of approximately 65% quartz grains, 10% rock fragments, 5% biotite and 20% feldspar. (See Appendix C: Getty Conservation Institute's Analytical Report - 1992.) Exploitation of the original or nearby quarries has been hindered in modern times as access to them from Angkor was difficult. It is reported that the quarries are still workable and that there is an abundance of quarried stone ready for immediate transportation, if the present problems of access and transportation can be resolved.

Laterite Local knowledge and sample testing indicates that there is a bed of laterite close to the surface at, and around, Preah Khan (see Appendix D: Sophia University Geological Test Report, 1992). It is, therefore, likely that much of the stone needed for the structures was quarried from both the surrounding moat and the tanks within the compound. At the time of quarrying, this very coarse grained yellowish stone is soft, but once exposed to the atmosphere it hardens. Despite its weight, (it weighs approximately twice as much as an equivalent volume of Kulen sandstone), its load-bearing characteristics are very poor. However, being locally available and easy to quarry it was considered a logical material for foundations and walls. Due to its coarse-grained nature, laterite has been used in simple block form but often it has been dressed to form overlapping joints and moldings for plinths and cornices, especially where it has been used in later construction such as in the insertion of Enclosure Wall II and its associated gallery.

Wall Structures and Types Wall construction throughout Preah Khan is of excellent quality and the method of construction is very precise. The following is a typology of construction methods and their inherent defects.

Sandstone Wall Construction The walls of Preah Khan were constructed using dressed stones and laid with no mortar. After careful and precise cutting and rubbing to form tight joints, weight and friction kept the stones in place. In some cases a bonding agent made from tree sap is said to have been employed. Stratification in the stone is very apparent and if the stones are laid with the natural stratification or bedding plane set vertically instead of horizontally, there is weakness in the structural integrity of the stone. All the square section vertical columns ranging in height from 2.5 meters to 4 meters have been set with vertical beds and pose a variety of conservation problems today. In many instances, stones used in the walls have also been vertically bedded and show deterioration.



Sections Through the Outer (left) and Inner (right) Boundary Walls at Preah Khan

In most instances, the dry laid sandstone masonry at Preah Khan is tightly joined and is occasionally tied by stones cut in wedge or butterfly shapes. Some of these unusual details appear to be later insertions. It appears that the walls are set on minimal foundations set directly onto laterite bedrock. More often than not, the sandstone veneer is backed by a laterite structure. The methods of bonding structurally distinct wall surfaces, as found in two faces of the stone wall, appear to be somewhat arbitrary. There is occasional through-linkage using stone keys from the outer sandstone skin.

Sandstone Walls - Structural Failure For the most part, the load-bearing sandstone walls at Preah Khan are standing and are in reasonably good condition. Most of the damage to walls has been caused by masonry falling from towers above that have been destabilized by tree roots. There are some alarming fractures through various lintels. These conditions were also largely the result of the impact of falling stones. In some instances incorrectly bedded or poor quality stone has caused failures. In some cases lintels and columns have split vertically, thus greatly reducing the bearing capacity of the structural system. Lintels were usually finely carved and presented as exterior building surface. Such fragile finishes eventually deteriorate and, in the

process, form significant water collecting surfaces. Increased moisture movement cycles in structural lintels can, and often does, contribute to structural collapse.

Laterite Wall Construction Although a cruder and less durable material than sandstone, laterite was used in wall construction at Preah Khan. Such construction usually involved simple coursed bonding. There appears to be no mortar matrix used for bedding the stones. Laterite was predominantly used in the construction of the enclosure walls between the gopuras and in building many of the later structures. Laterite blocks were also used to create the core of wall structures which were faced with sandstone.

Laterite Walls - Structural Failure As laterite is a very soft and porous stone, it is subject to damage caused by moisture intrusion. This, in turn, eventually results in a loss of structural integrity. This problem has resulted in foundation and wall surface separation at Preah Khan, causing sizeable areas to collapse. The enclosure walls especially, as well as a number of regular building walls, have been badly damaged by tree roots.

Roof Structures and Types

Roof structures are formed by corbelling either to form vaults or towers. Both sandstone and laterite are used as materials.

Roof Construction - Vaults In the typical cross section taken on the west side of the inner enclosure, just to the south of the main east-west axis, large sandstone lintels span between pillars to provide support for the corbelled vaults above. These lintels are frequently linked with interlocking joints along their edges. Roofs over the galleries are formed by the corbelling of massive stones which project one third of their width until the opening is finally capped with a large sandstone bridging stone. Each stone is structurally keyed to provide lateral stability and specially lipped and grooved to shed precipitation from the upper to the lower stone courses.

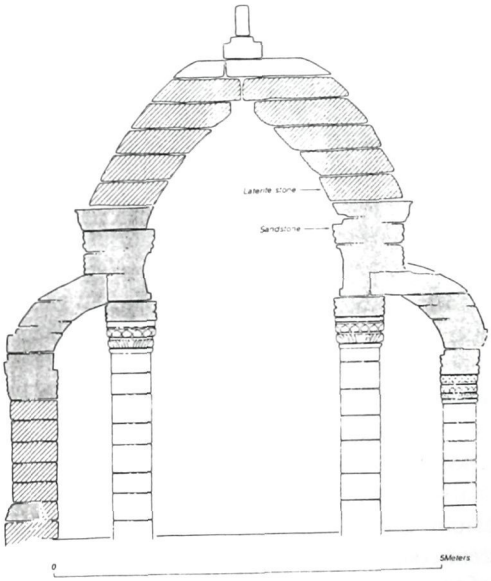
Detail of Quarter Vault

Vaults - Structural Failure A vaulted structure is completely stable only when it is intact. Stones used in construction are dependent upon one another for structural support. In the event of partial collapse or failure, there usually is little to prevent the entire structure from falling to the ground. The loss of structural integrity of a vault can also occur due to the collapse of adjacent structures.

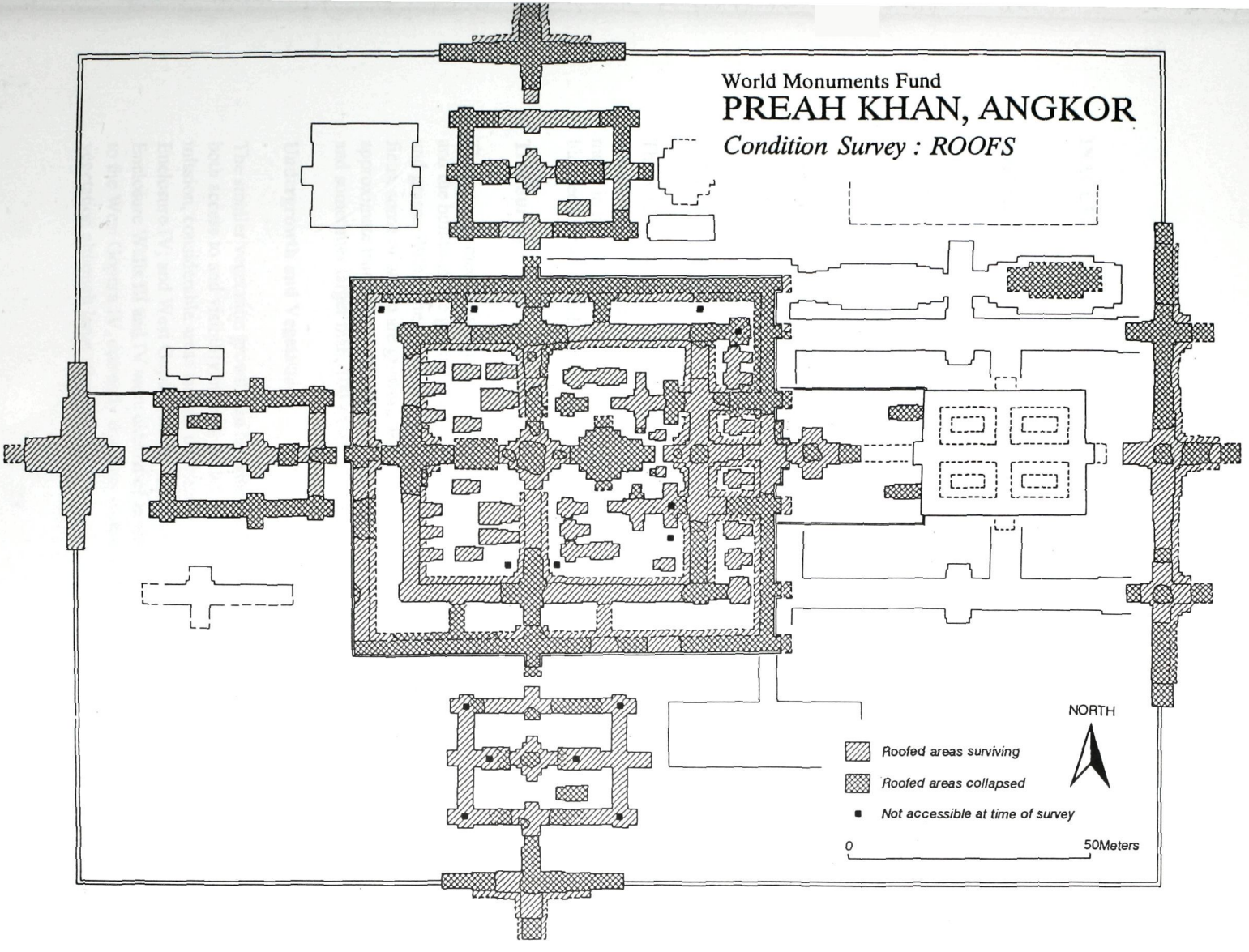
Tower Construction Failure Tower roof structures over gopuras and temples are formed by simple corbelling of stones. Inherent structural problems evident in Angkorian tower construction include dry laid joints (no adhesive bonding), minimal or no joint staggering and the lack of horizontal stone bonding to tie the tower structures together. When sizable plants take root in tower stone crevasses, the towers tend to split open vertically with stones falling into piles of rubble on the four sides of the tower base. The impact of masonry falling from the collapsed towers almost invariably causes the collapse of corridor vaults below. The collapse also causes considerable stress to the squinch stones in the more complicated construction of the gopura tower vaults.

Roofs - Condition Survey

During the March 1992 mission, a preliminary survey was made of the condition of the roofed structures throughout Preah Khan. It is presented here in diagrammatic form in the illustration on the following page. The plan distinguishes areas where the roofs survive intact (hatched diagonally) from the areas where they have collapsed (shown solid). The survival rate of vaulted roof construction at Preah Khan depends essentially upon the original method of construction.



Section Through East Gallery, Preah Khan


World Monuments Fund
PREAH KHAN, ANGKOR
Condition Survey : ROOFS
NORTH
Roofed areas surviving
Roofed areas collapsed
Not accessible at time of survey
0
50Meters

INACCESSIBLE AREAS

Field Survey of Inaccessible Areas

During the March 1992 mission, a preliminary survey was completed of the distribution of collapsed masonry as well as of the mature trees within the main building complex. The results presented in diagrammatic form incorporate evidence gathered for the entire temple complex. The plan distinguishes information pertaining to collapsed masonry and information on trees. In order to indicate how these features inhibit access, the main passages have been highlighted. The long-term preservation and presentation of the site require that collapsed and unstable *in situ* masonry will have to be structurally consolidated and some mature trees may have to be removed.

Collapsed Masonry

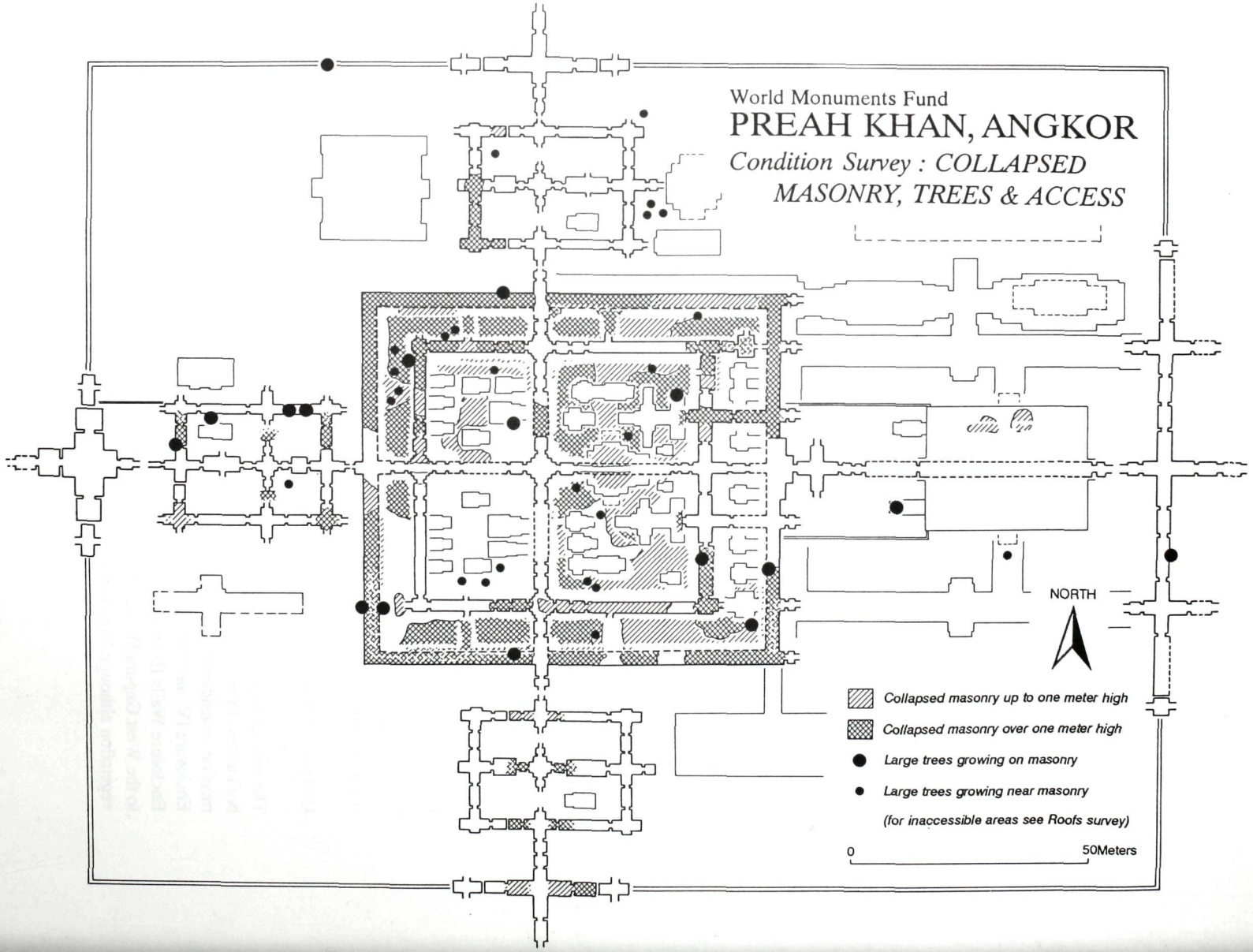
The volume of collapsed masonry in any particular area has been roughly classified as being either up to one meter in height (shown diagonally hatched black) or over one meter in height (shown cross-hatched black). Access routes are for the most part blocked along the gallery and the main passages.

Tree Survey

The areas immediately outside Enclosure Wall III and between Enclosure Wall IV and the buildings are generally covered in vegetation comprising small trees, bushes and grass. Within the entire complex there are a number of mature trees, mostly ficus, some of which are growing on walls, roofs and within passageways. Their approximate trunk sizes are indicated as being either up to 50 cm in diameter or up to, and sometimes larger than, 100 cm in diameter.

Undergrowth and Vegetation

The smaller vegetation growth can be removed easily and inexpensively to improve both access to and visibility of parts of the architectural complex. During the 1992 mission, considerable areas around the North Gopura, Enclosure IV; East Gopura, Enclosure IV; and West Gopura, Enclosure IV and along the both sides of the Enclosure Walls III and IV were cleared of minor vegetation growth. The approach to the West Gopura IV, currently the main visitor access, was also cleared of vegetation although large trees remain.


World Monuments Fund
PREAH KHAN, ANGKOR
Condition Survey : COLLAPSED MASONRY, TREES & ACCESS
NORTH
Collapsed masonry up to one meter high
Collapsed masonry over one meter high
Large trees growing on masonry
Large trees growing near masonry
(for inaccessible areas see Roofs survey)
0
50Meters

CONSERVATION THREATS AND DEFECTS

Failure of Building Materials and Structural Systems

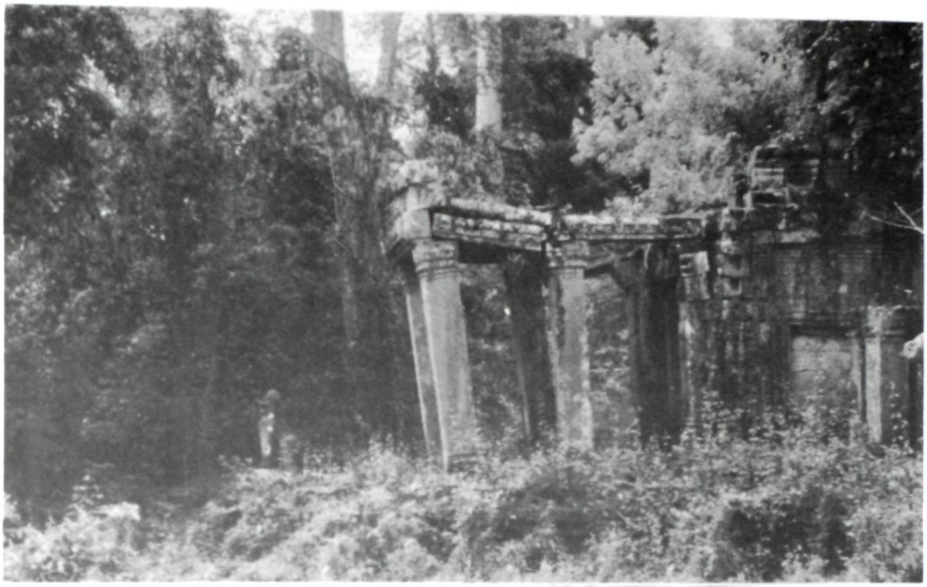
Preah Khan exhibits stone damage and deterioration of all types and stages, including total and partial collapse, severe erosion and disruption by vegetation. Preah Khan may have been completely abandoned as early as the 16th century. Over the centuries the temple structures have been exposed to harsh conditions due to the tropical climate. The break in regular maintenance and the ensuing problems of water penetration eventually started a pattern of deterioration resulting in a range of conservation problems observed at the site today.

Problems Relating to Access

It is likely that the construction of Preah Khan commenced from the main temple structure in the center of the complex and developed towards the outer enclosure walls. This would have greatly simplified the placement of the large masonry blocks used in construction which were then brought directly to the building site and placed in position for final carving. With regard to the present conservation/restoration task, the difficulty of access raises a combination of problems. On the one hand the work force has the unusual problem of site access to implement the conservation program, and on the other hand, the free access to Preah Khan from the park perimeter permits the site to be pillaged.

Planning for Access The longitudinal plan of Preah Khan creates an unusual set of physical constraints that must be considered when planning conservation procedures. Due to the density of construction and the nature of the design of the temple compound, access is extremely limited. Today, to reach the central structures it is necessary to pass through narrow doorways, each with a raised threshold, and along low galleries. Once in the inner compound, there is little space for maneuvering equipment such as cranes to move or replace the large stone blocks, which often weigh over four tons. Construction material storage and work areas must also be accommodated.

Damage Relating to Free Access Preah Khan is freely accessible through all of its four entrances and the site is a popular thoroughfare for the villagers living nearby. Influential members of the community are apparently felling many of the mature trees within Enclosure Wall IV, preparing the timber on the spot for building and transporting it from the complex by truck and cart. The removal of the mature trees which are part of the character of the site and the physical damage, especially to the gopuras which is caused by the trucks and carts, must cease. Uncontrolled vehicular access also encourages looting as it provides ready transport for the large-scale sculptures.



Structural Failure at
West Gopura III, South Porch

Vertical Fissure in Column,
West Gopura III

Theft and Vandalism Because of its remote location Preah Khan has been subjected to frequent and bold attacks by looters. More damage has been caused by efforts to decapitate or separate bas-reliefs from their stone supports than warfare. Photographs from WMF's 1991 mission provide evidence of sculptures having been decapitated within the last 12 months. Size appears to be no deterrent, as can be seen from an attempt to remove the large head of one of the demons formerly protecting the southern causeway. Due to the diligence of the temple guards during one incident this year, four vandals were caught - two were reported to have been shot dead and two imprisoned.

Stolen Bas Relief

Damage Caused by Natural Phenomena

The tropical monsoon climate of Cambodia subjects the structures of Preah Khan to considerable stress from heavy rainfall and fast growing vegetation.

Sulphate Attack Caused by Humidity A common intrinsic problem in the stonework of Preah Khan is the presence of sulphates (salts) and chlorides within the sandstone. Moisture dilutes and activates salts present in the material and the salt-laden dampness migrates within the stonework due to capillary action. During the drier months the salts crystallize under the outer surfaces of the stone and cause surface spalling or powdering. Such action can destroy finely sculpted finishes and decorations in a matter of a few years.

Basal Erosion One of the major reasons for stone decay at Angkor is basal erosion, caused by the presence of moisture (often standing rainwater), which is drawn into the stone by capillary attraction. This is especially noticeable in stones which contain relatively high amounts of feldspar or clay deposits which form a constituent part of the sandstone used at Angkor. High moisture levels can create a chemical reaction within feldspar which reverts it to clay, increasing in volume and possibly causing stone surface delamination. Building stone is not used to its best advantage when it is bedded with its natural laminations placed vertically and thus parallel to the exposed surface. In this position, not only is the bearing capacity of the stone reduced but the potential for moisture penetration is greater, resulting in the feldspar breakdown

described above. Examples of this type of delamination are common throughout Angkor but have been noticed to a lesser degree at Preah Khan.

Drainage Problems Like many of the other temple complexes in Angkor, Preah Khan is surrounded by a wide moat and has several large water tanks within its boundaries. Over the centuries the moats and tanks have silted up and the original storm water drainage system within the enclosure walls has fallen into disuse. The partial destruction of the structures due to natural causes has also blocked the original storm water drainage system. The prime cause for the basal erosion of stonework at Preah Khan is standing water. At present, rainwater is prevented from draining away from the exterior of the structures. With the numerous open roofs at the site, water is often trapped inside the various structures because of the high thresholds found at all doorways. There are a few instances where standing water may have caused foundation settlement.

Defects Caused by Biological Growths The stone structures throughout Preah Khan are covered with a variety of cryptogamous organisms such as mosses, lichens and algae. Different types of moss are abundant in the damp and dark interiors. The extent of damage caused by these growths is minimal save for the growths that harbor quantities of moisture. Attempting to remove or control them may be more destructive than leaving them untouched. A testing program for biological growth removal will be conducted.

Defects Caused by Thiobacilli Thiobacillus is a microorganism that develops in bat excreta which, when it comes into contact with stonework laden with moisture, attacks and degrades sandstone. This defect has an appearance similar to that of salt action. An analysis of the stone deterioration has been undertaken at The Getty Conservation Institute laboratories. The analysis showed a stone that was thought to be contaminated with thiobacilli to be deteriorating more as a result of the chemical breakdown of the feldspar present in the sample (See Appendix C).

Weather Damage A hurricane that swept through the historic city of Angkor on September 1, 1989, caused relatively minor damage and disturbance to Preah Khan, toppling large trees within the area and causing some disturbance to Enclosure Walls III and IV. Minor damage also occurred at some of the smaller structures in the southern sector.

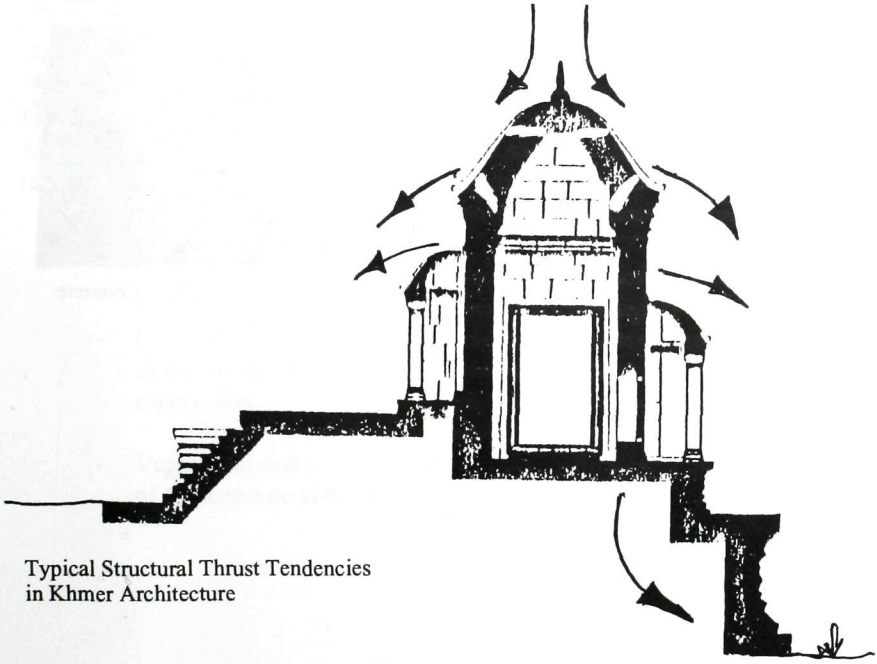
Effects of Vegetation As a result of decades of abandonment Preah Khan provides some remarkable instances in which bombax and ficus trees have grown on and around a number of the structures, creating an amazing blend of nature and architecture. Over the last twenty years, through force of circumstance, little effort had been made to keep the site clear. Vegetation, previously kept under control, has flourished in and around the temple precincts making it almost impossible to obtain a clear impression of the expanse and grandeur of the temple structures.

Structural Defects

Preah Khan, like a number of the other stone structures at Angkor, suffers from inherent flaws in design and construction. Excessive weight often causes eccentric loading on columns and walls and has, in many cases, resulted in serious movement in wall and roof structures.

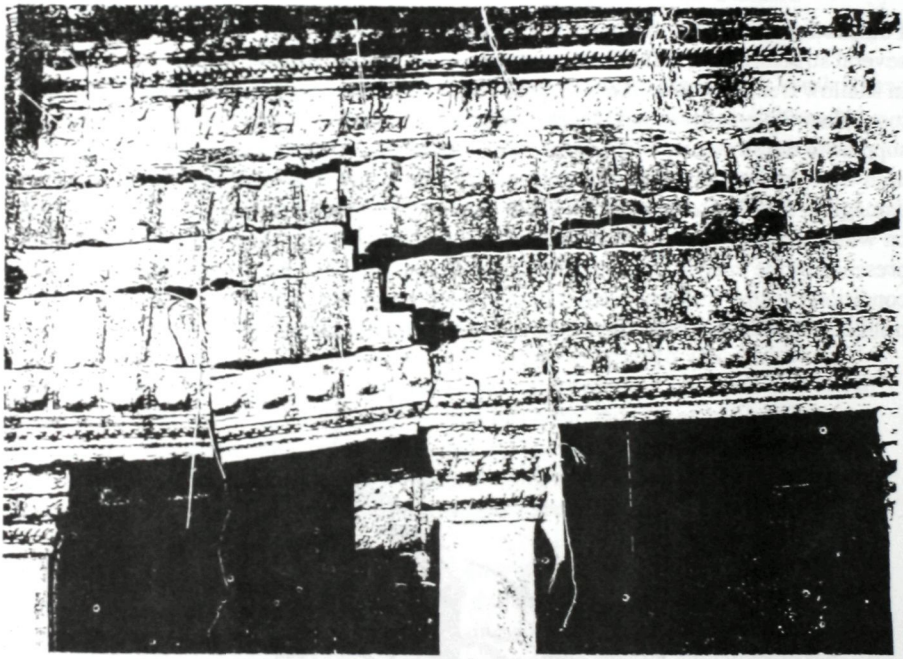
Defects in Design The lack of horizontal ties that bind courses in the stone structures has caused a number of the heavy corbelled roofs, especially at the towers, to spread - thereby placing uneven loads on walls and columns. This eccentric loading is transmitted to the bases or plinths of structures and often results in structural failure. The effects of such stresses upon columns and wall piers are even more threatening.

Foundations Failures Archaeological probes have shown that the foundations of several structures in Preah Khan are shallow and usually built of laterite blocks placed in shallow trenches. It is likely that the whole complex rests on a laterite bed located just below the present ground level. Often this laterite bed forms the foundation support to the structures themselves. Because of the laterite's porous nature, it has a high water absorption and drainage capacity which may explain the apparent minimal damage to the structures in Preah Khan due to excessive standing water. As the earth on which the foundations are laid is mostly undisturbed ground and because of the presence of the laterite stratum, foundations appear to be in reasonably stable condition causing little movement to the structures above. Structural settlement problems caused by ground water have been noted infrequently.



Typical Structural Thrust Tendencies
in Khmer Architecture

Failure Due to Poor Structural Integrity Laterite is a poor quality building material, lacking compressive strength and cohesiveness. These failings are evident in essentially all structures at Angkor that are partly or wholly constructed of this material. Its stability and strength varies, depending upon the amount of moisture that is present. Laterite has been used widely as a foundation material and in wall cores supporting a veneer of lighter sandstone. The condition of the laterite used in wall construction can only be assessed by failures noticed in hard stone outer surfaces. Failure of laterite wall cores is often accompanied by the crushing tendency of collapsing outer sandstone veneers.



East Gopura III (Northern Section) Collapsing Vault Stabilized with Cast-in-Place Concrete

CONSERVATION RECOMMENDATIONS

Site Clearance - General Assessment

Before conservation work commences in or around the Preah Khan temple complex, it is recommended that the site be carefully cleared of underbrush and any recent tree growth on the structures. Before deciding whether to remove the larger trees, it is best to balance their value - they are, after all, part of the site's history - against any potential danger they pose to the structure. It is recommended, for the time being, that the southern sector of Preah Khan be left in its overgrown state as a jungle ruin. To walk along the north/south axis and witness the symbiosis of manmade structures interwoven with those of nature is a spiritual experience. Elsewhere at Preah Khan this unusual presentation of the works of time, man and nature will greatly enhance the visitor's experience. Special care should be taken during clearance of vegetation not to disturb this special relationship.

Vegetation Clearance It is recommended that two teams of casual laborers (*flottants*) be engaged for eight months of the year to continue with site clearance and to control the jungle around the structures. Recognizing the romantic qualities of overgrown jungle ruins, the WMF team proposes to leave part of the southern sector of Preah Khan in its "as found" overgrown state as an interpretative feature for visitors.

Proposed Summary of Botanical Interventions Consultant botanists visiting Angkor and Preah Khan from Sophia University have provided the following recommendations:

- After a careful survey all distinctive trees should be identified and retained between Enclosure Walls III and IV.

- During the clearance activities, all trees with a girth of more than 12 cm should be left *in situ*. Brushwood should be cleared with careful supervision.

- Vegetation, except for selected large trees, should be cleared to a distance of 50 meters on both sides of Enclosure Walls III and IV.

- Except in special circumstances, vegetation should be removed from all structures. Initially the growth should be cut back and later treated with a suitable herbicide.

- Special observations should be made of newly created micro-climates in spaces which have been influenced by the presence of vegetation, especially on walls where there are micro-organic growths.

- Once cleared, regrowth in selected areas should be controlled using a suitable herbicide.

- All tree roots, both in the temple complex and around the enclosure walls, should be treated with a suitable stump remover and removed once they are dead.

- Vines should be treated with a suitable biocide and once they have withered they should only then be carefully removed.

- The tapping of the large *dipterocarpus* trees for sap by local people should be strongly discouraged as it shortens tree life.

Means of Access

It is essential to plan the most efficient access routes for all repair and conservation activities and to devise a work plan to suit this means of access. Access requirements to areas of the site will vary depending upon present site conditions and the different levels of intervention – conservation, consolidation and reconstruction – that are anticipated.

Access to Work Site Bearing in mind the limited access to the densely built temple structures, it is important to plan for equipment and facilities that can easily be maneuvered or adapted to the tight spaces within Enclosure III. It is recommended that an access road be formed on the west side through the northern breach in Enclosure Wall III and also through Enclosure Wall IV. Access to the East Gopura should be also from the west along the outside of the northern side of Enclosure Wall III. Within Enclosure Wall III the only direct approaches are along the north/south and east/west axes. Subject to the means of transportation devised for the stone blocks, it may be necessary to construct temporary access ramps and raised floors along the main corridors ensuring that the door jambs, thresholds and lintels are properly protected during the repair and conservation process.

Giant Ficus at Preah Khan, East Gopura III, 1968

Structural Repairs

Most of the structural repairs will be directed towards minimal intervention. During the initial stages of work on site, experiments will be undertaken to improve and perfect the techniques outlined below.

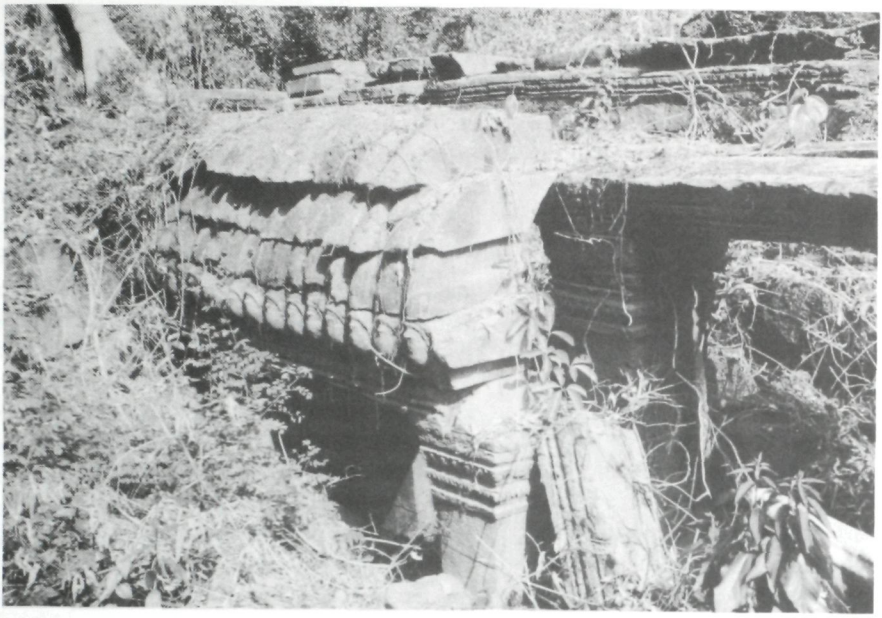
Emergency Stabilization Following the completion of the Computerized Architectural Inventory for all structures, a program can be prepared to undertake the careful conservation of structures or parts of structures that are threatened with imminent collapse. The careful replacement of missing blocks or the temporary support of failing structural elements using steel props and jacks will help save extant building fabric and reduce costs at a later date. This work will involve minimal intervention and cost.

Monitoring for Structural Movement Several structures were noted as being subject to active structural movement. It is recommended that all structures that are considered dangerous should be carefully monitored with simple technology. To detect movement, three fixed points can be established across a fracture line. These points can then be examined and measured with a micrometer at suitable intervals.

Structural Consolidation Structures threatened by collapse may require a series of gradual interventions administered as stages in a long term special project. Once such a structure is identified, an appropriate repair and consolidation program should be developed. It is essential that, before and during any partial dismantling, an accurate record be made of the structure and the location of each stone using detailed drawings and photographs. (See Appendices A and B.) Often this type of repair involves considerable intervention as it requires the careful dismantling of sections of the structure, the insertion of new structural steel or reinforced concrete supports and the resetting of dismantled or dislodged stones.

Structural Pinning Stones that are delaminating can be stitched back together *in situ* using stainless steel or high strength non-ferrous dowels and resin glues. In instances where lintels have fractured and are held in position with temporary supports, they can be structurally consolidated by doweling and gluing with epoxy resins.

Resetting Vaults Using Centering/Cradling In many instances the main vaults and side vaults of corridors, arcades and porticos have collapsed or threaten to collapse. Some were structurally stabilized by the EFEO in the 1930s and 1950s in a manner that preserves their dislodged and misaligned "as found" appearance. It is planned to develop suitable techniques to reset the more precarious vaults and lintels using jacks and specially constructed cradles that will raise the vaults sufficiently to permit the repair of broken beams as well as the vertical resetting of columns.



Typical Failure at a Quarter Vault

Foundation Consolidation The cursory geological studies undertaken in Preah Khan in March 1992 reveal little evidence of clays in the soil. (See Appendix D.) Therefore, there is relatively little indication of failure in foundations below ground. It is speculated that Preah Khan is built on a stratum of laterite providing rapid drainage and well-compacted foundations. Examples of deformation of foundations can be seen in the plinths of the gopuras at Enclosure Wall III. (This is especially noticed at the East Gopura.) Other examples of distorted foundations can be seen where tree roots have undermined structures. In such cases recommendations for consolidation and repair can only be ascertained on a case by case basis and with the guidance of a structural engineer.

The Conservation of Stone

A short visit by a specialist in stone conservation from The Getty Conservation Institute determined many of the issues relating to the cleaning and consolidation of the Kulen sandstone, which was used for nearly all exposed building surfaces and sculpture at Preah Khan. An analysis of the stone has been undertaken in the GCI Laboratories and a summary of their findings is contained in Appendix C.

Advisability of Stone Cleaning Following the premise that Preah Khan is to be conserved and presented as a partial ruin, it is questionable whether the stonework should be thoroughly cleaned. Analyses have been made of the possible damage that

was being caused by the micro-organic growths on the sandstone and it was determined that these growths were causing minimal degradation. On the whole, their presence is primarily an aesthetic issue. A preliminary analysis showed that some of the inscribed interiors are obscured by mosses and algae. However, the process for cleaning these walls is very simple. Biological growth on external stonework appears generally to be neither harmful nor particularly disfiguring. Given that a minimum of harm is caused and that the biological growth inevitably returns within a matter of months, it is recommended that all external stonework be left "as is." On exterior building surfaces it is recommended to clean only where the growths are obliterating decoration. If and when a suitable long lasting protective solution becomes available (a formula using copper sulphate is presently undergoing laboratory tests) selected external stone cleaning may be considered feasible.

Stone Cleaning - Interiors Initial tests, in which interior decorated sandstone walls were cleaned of mosses and algae, proved that simple brushing with a soft bristle brush removed micro-organisms from the stone and caused only imperceptible surface damage. Treatment of the surface with a very dilute solution of copper sulphate would be sufficient to control further growth as long as the solution is not washed out of the stone by improper rainwater drainage.

Stone Cleaning - Exteriors Tests to remove lichen growth using water and soft bristle brushes showed that particles of the stone's surface were being removed along with the lichens. Further tests are recommended using a stone consolidant prior to the cleaning process.

Stone Consolidation Based on an initial survey by stone conservation specialists, it appears that there is little need for extensive stone consolidation at Preah Khan, except in some cases where stonework near ground level is delaminating and on some of the exposed decorative stonework such as lintels. In such situations, water is the chief culprit for the stone deterioration and, where possible, its effects should first be minimized by improved drainage. Where necessary, the judicious application of a well-tested and appropriate stone consolidant may prove to be an inexpensive yet appropriate solution.

Cast Stone Repairs Collapses have occurred in many places where the vaults of corridors have been constructed in laterite, which for the same volume is approximately twice the weight of sandstone. Many of the remaining vaults have stones which are badly deteriorated and which, if left unrepaired could lead to collapse. It is proposed that experiments be undertaken to precast the different slab sections that make up the vaults in air entrained lightweight concrete using crushed laterite as an aggregate to obtain a similar color. Such cast stone could be used to reconstruct some of the corridor vaults, thereby enabling safe access to the other areas of the monastic complex that are now inaccessible.

Composite Stone Patching Where cornices or moldings are damaged and can be returned to working order by simple stone repairs, composite stone patching is appropriate. Such work has been satisfactorily carried out, elsewhere at Angkor, but there are many examples of both new and old work that is both physically and visually incompatible. The latter result must be avoided in all future stone conservation work at Angkor. Before patching is undertaken anywhere at Preah Khan, samples should be prepared of different strength, porosity, color and texture for comparison and carefully tested under laboratory conditions and in the field. Composite stone repairs should be kept to a minimum and if used, they should be carefully detailed to avoid feather edges and unsuitable joints.

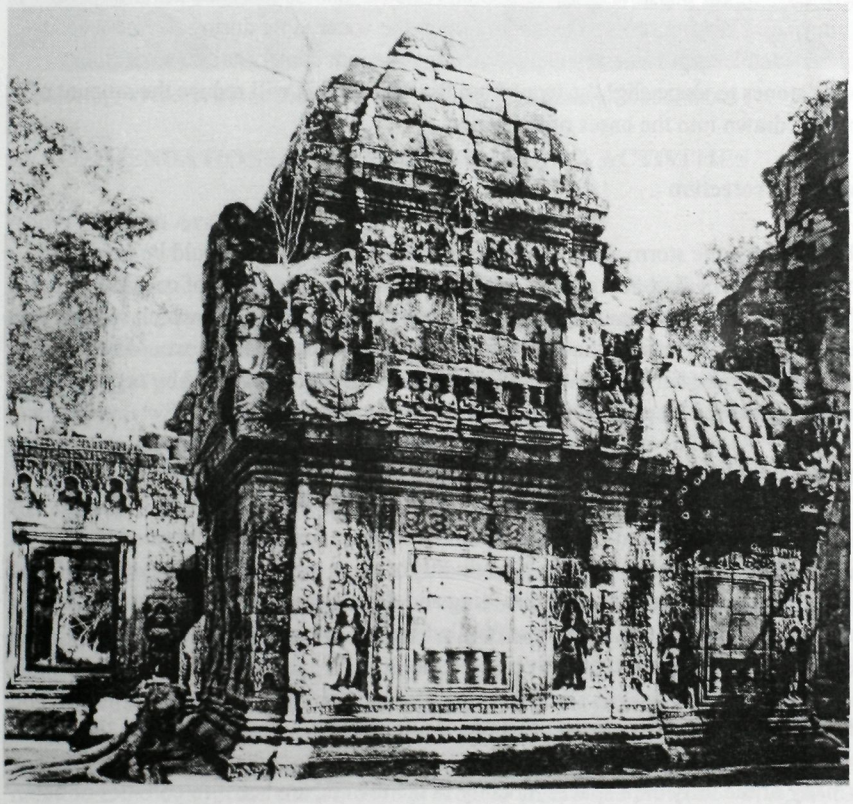
Minor Stone Reattachment Where there has been partial collapse, many of the stones have fractured and become separated. It is still possible to identify the location of missing stone sections and it is feasible to reattach these dislocated pieces using a stone adhesive and non-ferrous dowels. Minor stone reattachment can play a significant role in preserving stone sculpture which can still be repaired.

Cleaned Sandstone Sculpture, Angkor Wat

Protection Against Moisture

Moisture is almost always the most serious threat to historic structures, and its common sources being from above (precipitation), below (ground water) or within (condensation). Special methods must be devised to minimize the deleterious effects of water upon the exposed architectural remains of Angkor.

Weatherproofing of Joints A special study will be undertaken to ascertain the best alternatives for weatherproofing joints, especially in the roof vaults. The stone slabs were originally dry laid and their careful detailing effectively channelled rainwater off the roofs. Today many of the roofs display problems of leakage. A system using joint seals may be preferable to the standard remedy of mortar filling, which contravenes the original design principles and can cause stonework discoloration.



Open Stone Joints in Detached Shrine, Enclosure I

New Wall Capping

To prevent rain water percolation, it may be necessary to cap open wall tops with a water-shedding surface. The intervention must not be visible from the ground. The careful creation of recessed joints set to a gentle slope to drain water away from the wall center using a carefully selected cement aggregate, sand mix, is preferable to contoured mortar capping.

Drainage

A careful study is required of the movement of storm water around the site during the monsoon period. Following this visual inspection, efforts should be made to respect the natural lie of the land in and around the site and to use existing falls and drainage patterns wherever possible. A careful study should also be made of water trapped within spaces lacking roofs. Depending upon the water table during the monsoon, it may be feasible to provide dry wells or sumps in room centers and to reset floor paving stones to slope slightly away from the walls. This will reduce the amount of moisture drawn into the bases of the walls.

Weather Protection

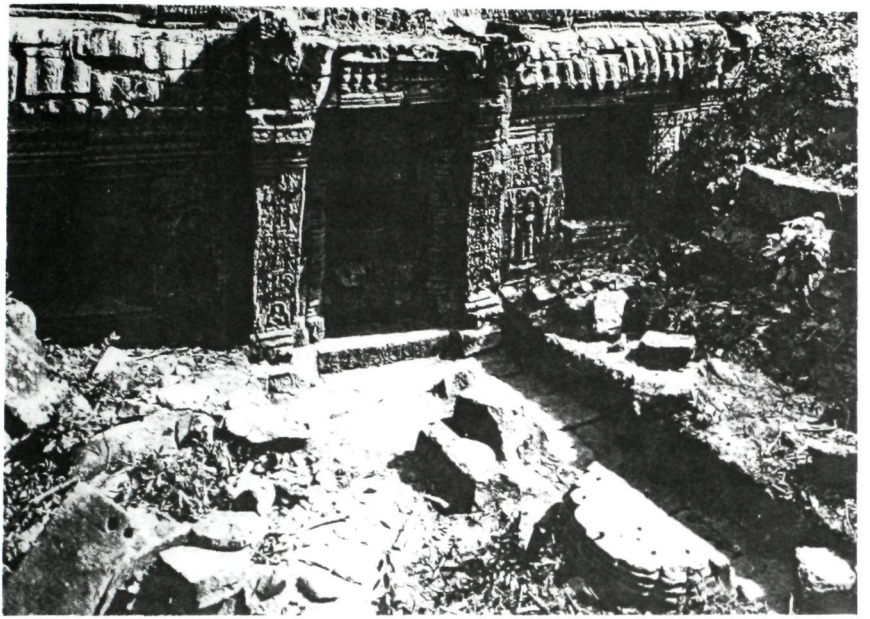
After checking the storm water drainage pattern, consideration should be given to occasionally providing new roof systems, either by reconstruction of original vaults or by the placement of carefully designed provisional roof systems which will prevent the percolation of rain into the structures. This type of intervention would be especially useful where decorated wall surfaces are being obliterated by organic growths supported by precipitation.

Interior Interventions

It is apparent that the crude vaults at Preah Khan were originally concealed by ceilings formed of timber panels. No remains of these wood ceilings have been found to date. The same is true of wall panelling and door surrounds. No plans exist at present to reconstruct any of the lost fragile finishes, except perhaps on paper as conjectural studies for interpretative purposes.

Wire Mesh Protection

As many of the lofty dark spaces, notably in the towers, are home to colonies of bats, it is recommended that some of the more intact structures from these colonies be protected by placing panels of heavy wire mesh screen at original ceiling levels. The placement of these screens should be selective and as visually discrete as possible.



Archaeological Excavation, Courtyard in Enclosure III, Location S0005-W065 (1991)

RECOMMENDATIONS FOR ARCHAEOLOGICAL ACTIVITIES

Above Ground Archaeology

As part of its concern for the historic fabric of Preah Kahn, WMF intends to ensure that, wherever possible, features are preserved *in situ* without disturbance. Only where *in situ* preservation is not a viable course of action will structures be reinstated using the best possible methods based upon available evidence. In any case, all interventions will be fully documented and an archive of information relating to work on the temple complex will be maintained.

Recommendations for Implementation

Prior to commencement of any repairs, an architectural survey and an archaeological study of the area will be undertaken under the direction of the project architect as a basis for all possible interventions. (See Appendices F, I & J) Features of significance, including historic alterations or additions, will be recorded and specially noted to ensure that they are not adversely affected in the conservation process. The exact methods of aboveground archaeology will include, as part of its research and analysis method, a chronology for structural components. All work will be carefully monitored throughout the conservation process to ensure the protection of significant features not previously identified. A record will be made of all interventions using drawings and photographs.

Below Ground Archaeology

WMF recognizes the historical importance of the ground on which the Preah Khan temple complex stands, which could contain archaeological evidence relating to the site for which there are no other sources of information.

Proposed Interventions

During the conservation process every attempt will be made to ensure that the ground surface is not disturbed unnecessarily by, for example, the passage of heavy vehicles or by the mechanical removal of large tree stumps. In the longer term, attempts may be made to establish the extent and nature of buried deposits and, if funding permits, a program of research excavations may be proposed. (See "Section 7: Future Studies")

Recommendations for Implementation

During conservation work, the ground will not be disturbed other than on a limited scale. If, however, a need to excavate arises as, for example during work related to drainage, all excavation work will be carefully monitored and any features of interest disturbed during the operation will be recorded. In the longer term, selected areas will be cleared of minor vegetation and, where possible, laid to grass. *Sondages* (trial excavations) may be undertaken to establish the nature of the topsoil and stone strata.

VISITOR ACCESS AND SITE DEVELOPMENT

An important component of Preah Khan's appeal for the visitor is its remarkable jungle setting. The integration of the architectural remains into the natural surroundings, and the often surprising manner in which plant life has encroached upon the monuments create a spectacle of unique beauty.

Visitor Access - the Present Situation

The lack of adequate roads limits access to the site. On arriving at Preah Khan's presently used west entrance, the visitor must walk some 500 meters along the east/west axis to pass through the complex. Access is also possible from the northern gateway. Access beyond those means described above is restricted by stone rubble and undergrowth. Vistas are few, with existing views greatly limited by the jungle. There is therefore a need to open additional vistas for interpretative purposes and to provide a more varied access for visitors.

Recommendations for Immediate Visitor Access

It is recommended that an established route be developed for visitors to provide safe access to Preah Khan without disrupting the building conservation activities. All visitors are potential donors and therefore information and display boards should be erected along the route providing historical information, as well as a description of the conservation work. Visitor safety can be improved considerably by simple measures such as debris removal and the careful resetting of floor paving stones to minimize tripping hazards. Unsafe areas of the site should be marked accordingly.

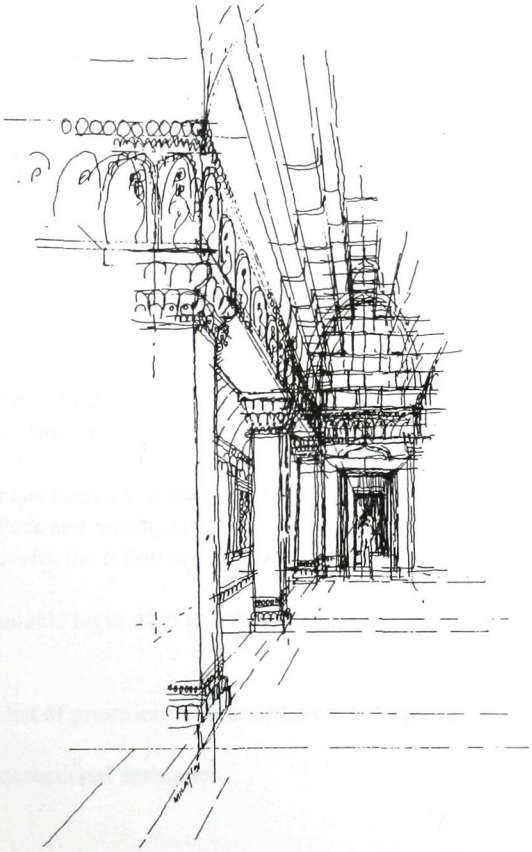
Long Term Recommendations for Visitor Access and Accommodation

The various enclosure walls of Preah Khan still provide effective limited access and therefore are key site control elements which favor preservation of the complex. It would be possible to limit the number of visitors through the main entrance to the Enclosure Wall IV. It is recommended that any new required structures such as guard houses, visitors' facilities, and even new religious shrines be strictly controlled. New construction should not be allowed to compromise the present undisturbed quality of the site.

CHAPTER 4

ADMINISTRATIVE DEVELOPMENTS

A National Committee for Conservation
Project Application Review Process
Conservation d'Angkor/WMF Relations
EFEO/WMF Relations
Preah Khan Project Administrative Structures
Planning for Conservation



4. ADMINISTRATIVE DEVELOPMENTS

A NATIONAL COMMITTEE FOR CONSERVATION*

Under the Presidency of His Highness Prince Norodom Sihanouk, the National Committee for the Rehabilitation of the Monuments and Museums of Cambodia was established on February 3, 1992 following the signing of an Aide Memoire for the safeguarding and development of Angkor on 28th November 1991 between UNESCO and the Supreme National Council of Cambodia (SNC).

Under the Vice Presidency of the Minister of Culture, the National Committee is made up of the following fourteen members:

- Six members of the Secretariat of the SNC
- The Governor of Siem Reap,
- The Governor of Battambang,
- The Director of Conservation d'Angkor,
- The Director of the National Museum at Phnom Penh,
- The Director of Vat Poveal Museum,
- The Rector of University of Beaux Arts and Deans of the five Faculties
- The Director of Cultural Relations, and
- The Director of the Academy of Cultural Activities.

The National Committee has the authority to invite observers, specialists and representatives from different agencies. During the first few meetings several delegates from diplomatic missions were in attendance.

The National Committee has been given the tasks of safeguarding and developing the Angkor Archaeological Park and rehabilitating the Museums of Cambodia. The Committee was provided with the following mandates:

- to establish suitable legislation and the necessary procedures for its enforcement,

- to establish a list of priorities to be undertaken in Angkor, and

- to evaluate international assistance.

The National Committee is also responsible for ensuring assistance with the administration of project development as well as implementation of _conservation activities at all sites at Angkor and elsewhere in Cambodia. Their mandate with regard to the Angkor projects will be to coordinate the national roles of Conservation d'Angkor, the Museums of Cambodia and the Faculties of the University of Beaux Arts.

Over the next two years, the National Committee has been asked to coordinate the nomination of Angkor to the World Heritage List which is maintained by UNESCO, and to investigate the possibilities of revitalizing the Conservation d'Angkor. The Committee has also been requested to oversee the necessary studies for the consolidation of the foundations of Angkor Wat and the Bayon, as well as the stabilization of the structures of Bayon.

The National Committee plans initially to meet once a month to discuss progress relating to project developments and to receive formal applications and offers for project support.

[*The above-mentioned National Committee was eliminated in April 1992 and replaced with the National Heritage Protection Authority of Cambodia (NHPAC) established by the Supreme National Council of Cambodia at its meeting on 20 October 1992.]

PROJECT APPLICATION AND REVIEW PROCESS

This report, outlining WMF's proposals for the conservation and presentation of Preah Khan, can be considered as its formal application to the National Committee for the Rehabilitation of the Monuments and Museums of Cambodia. It is intended that *Preah Khan Project Identification (Report II)* and the present *Conservation Plan (Report III)* serve as a compilation of basic research done on or at the site of Preah Khan, to date. Together, the three reports deal with the past, present and future of the site in as much detail as is possible for a conservation project in its preliminary stage of development.

These reports indicate that the parameters of the conservation challenge at Preah Khan have been determined and that a conservation philosophy and methodology have been carefully considered. The articulation of the conservation issues and solutions recorded in sections of the reports constitute the intentions of WMF for the site.

WMF proposes submitting *Reports I, II, and III* to the National Heritage Protection Authority of Cambodia for review and approval in October 1992. The reports will also be circulated for comment at the Ministry of Culture in Phnom Penh and at other departments and institutions involved in the Angkor Conservation Project. In addition, WMF will present the reports to UNESCO's Division of Physical Heritage in Paris and to its office in Phnom Penh for information and comment, and to the board of directors of the World Monuments Fund (U.S.A.)

The proposals at the end of this report include an implementation plan which is scheduled to occur over a period of approximately ten years. As the site work must be planned on a seasonal basis, the Preah Khan conservation project is envisioned as a series of work campaigns, occurring between the months of October and April on an annual basis. Other important administrative, research, documentation and fund raising activities would be carried out during the remainder of the year.

Perhaps the best analogy for WMF's vision of the Preah Khan Conservation Project is the system used internationally in most archaeology expeditions, in which a work permit is granted to the applicant by the government for an agreed number of years based upon an overall work plan, with each year's campaign being proposed and approved as the project progresses.

Assistance provided in any given year will be contingent upon the following factors:

- successful procurement of project funding;
- approval of Cambodian state and local government administration; and
- safe working conditions.

Annual reports will be prepared following the format of Reports I-III.

CONSERVATION D'ANGKOR/WMF RELATIONS

The WMF team has discussed all aspects of the proposed Preah Khan Conservation Project with the members of the Ministry of Culture and with the Directorate of the Department of Archaeology. At Preah Khan, the WMF team was regularly joined by the staff of Conservation d'Angkor due to the Director's continuous interest in the project and support. In order to develop a close working relationship with the Conservation d'Angkor, WMF has requested and been granted space for a project office in the same block as that of the Directorate of the Conservation d'Angkor. This office will serve as WMF's mission headquarters and work facility in Cambodia.

The WMF project director has also met with the directors of the British Volunteer Service in Phnom Penh which is providing the Conservation d'Angkor with a young British architect to assist in the reorganization of the Conservation d'Angkor's permanent staff, and to help establish and coordinate a work force of labor and crafts people to service the projects planned throughout Angkor. WMF has offered to collaborate in developing this support by using Preah Khan as a prototype, and hopes that the British architect will assist WMF in establishing, supervising and coordinating the planned work force for the Preah Khan Project.

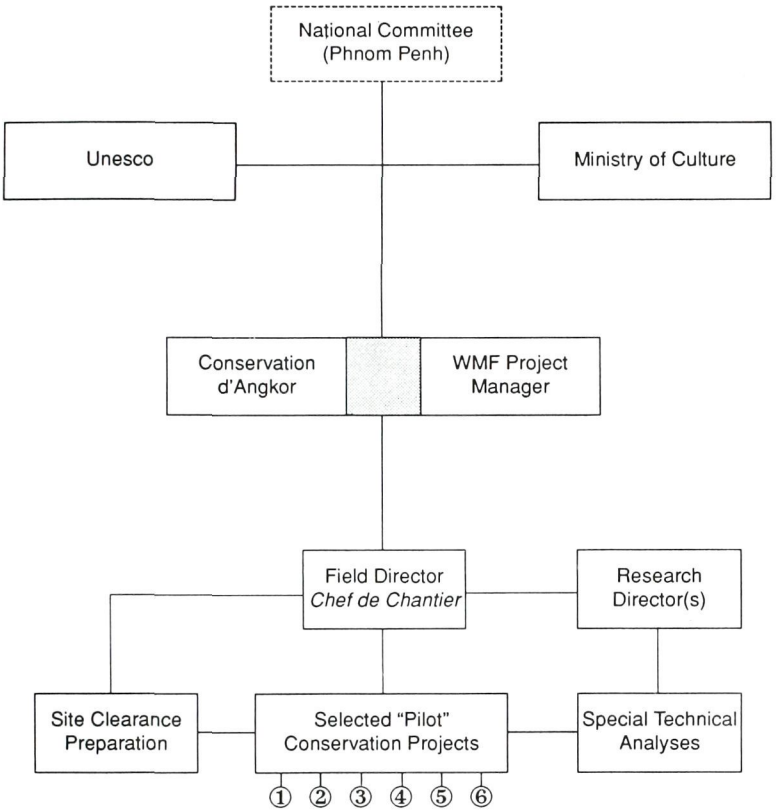
EFEO/WMF RELATIONS

The Ecole Française d'Extreme Orient (EFEO) in Paris, the organization which serves as the principal research and education facility for the study of Cambodian history. EFEO served as a clearing house and base of operations for research and conservation activities from 1902 until 1975, when its activities were interrupted by civil strife within the country. Archives pertaining to the numerous research activities at Angkor over the years were removed to Paris where they are accessible today. (Some copies remain in the National Museum Library in Phnom Penh.) A computerized index of many of the archival holdings of EFEO has recently been developed and is available today in both Paris and Phnom Penh. After a hiatus of approximately twelve years caused by war, additional inventories and continuing research and publication activities are again underway.

WMF Angkor Missions II and III benefitted from the participation of EFEO researchers Bruno Bruguier and Christine Hawixbrook. Both were responsible for preparing an inventory of all available data in the form of reports, plans and photographic material. Their contribution to WMF's efforts to identify the parameters of the proposed Preah Khan Conservation Project was invaluable. Ms. Hawixbrook's specific contribution focused on the morphological and stylistic developments of the Preah Khan complex, with particular reference to religious iconography. Mr. Bruguier worked on an inventory of archival documentation and a bibliographic index for the site. Each of these scholars, and indeed the EFEO institution, is considered vital to the success of the proposed conservation project.

PREAH KHAN PROJECT ADMINISTRATIVE STRUCTURE

WMF expects the Preah Khan Conservation Project to conform with the Government of Cambodia's administrative structure following the directives established by the National Committee for the Rehabilitation of Monuments and Museums of Cambodia, as described in the following diagram.



Project Management for Conservation Field Campaign I

PLANNING FOR CONSERVATION

Project Office and Staff

With the assistance of the Department of Archaeology, WMF hopes to set up an office at Conservation d'Angkor and to recruit staff to work on the Preah Khan Conservation Project.

Establishment of WMF Project Office

Following discussions with the Ministry of Culture, the Department of Archaeology and the Conservation d'Angkor, WMF has been offered space for a small project office in the Conservation d'Angkor compound. The room measures 9m x 5m and was the former "Bureau of Design" of the EFEO. It is adjacent both to the Director's office and the administrative office of the Conservation d'Angkor. WMF proposes to establish this office and equip it with the necessary office furniture, drafting equipment and supplies at the start of the Preah Khan Conservation Project in November 1992.

Availability of Project Staff

Once there is a formal agreement for WMF to commence the Preah Khan Conservation Project, recruitment of technical and administrative staff will begin and an initial work force for the conservation program will be established. The Cambodian Government has indicated its willingness to designate administrative staff from the Department of Conservation, Ministry of Culture as well as from the Conservation d'Angkor. The University of Beaux Arts, Phnom Penh plans to select students from the Departments of Architecture and Archaeology for the Preah Khan Conservation Project. It is intended that this training on site will provide credit for the students' degrees, and it is hoped that the future staff for the office of the Conservation d'Angkor will be selected from among these students.

Administrative and Technical Staff

It is anticipated that a team of national staff, students and international consultants will be required to set up, plan and supervise Preah Khan conservation campaigns each year which follow the present Conservation Plan. It is hoped that the UBA students will be active members of this team.

Khmer Work Force That Helped at Preah Khan (1991)

	International Consultants	National Staff and Students
Research and Inventory		
- Architectural Historians	[1 x 1mth]	(2 x 4mths)
- Archaeologists/Surveyor	[1 x 3mths]	(2 x 4mths)
- Art Historian	[1 x 1mth]	(2 x 4mths)
- Research Assistant		(1 x 12mths)*
Survey - Recording		
- Computer Programmer	[1 x 2mths]	(2 x 12mths)*
- Draftsmen		(4 x 12mths)*
Condition Survey/Supervision		
- Architect Conservator	[1 x 6mths]	(1 x 12mths)*
- Civil Engineer	[1 x 2mths]	(1 x 12mths)*
- Materials Conservationist	[1 x 1mth]	(1 x 12mths)*
- Store Keeper		(1 x 12mths)*
- Accountant		(1 x 12mths)*

* One staff member provided by Conservation d'Angkor; his work load would range from part time to full time.

The above-mentioned team will be responsible for the following broad based activities :

- to undertake the preparatory research and analysis for the Preah Khan Conservation Project,

- to develop and maintain the annual conservation management plan for Preah Khan, and

- to guide the repair, conservation and interpretation of Preah Khan.

Consultants

WMF plans to augment its present team with a civil engineer experienced in the repair of historic buildings. An even closer relationship will be developed with the EFEO especially concerning the historical development of Preah Khan. WMF hopes to further utilize the expertise of scholars from both EFEO and other institutions to assist with archival and field research. WMF will also continue to identify Khmer professionals who will join the team to help with site supervision and administration, as well as with the training of UBA students.

The Conservation Work Force

It is proposed that a work force be set up to commence conservation activities at Preah Khan in November 1992. The work force will be developed over time and in accordance with site mobilization needs, the approved work plan and funding limitations.

Skilled Work Force

It is considered best to establish one group of people under a single head foreman who will be responsible for supervision under the guidance of the national and international members of the WMF team. During the third mission, staff from the Conservation d'Angkor assisted in planning the work force for Preah Khan. A former Head Foreman (*Chef de Chantier*) has been asked to draw up the skills required for the work force and a list of names to make up the work force. It will be necessary to train or retrain stone masons to cut, dress and carve sandstone and laterite and it will also be necessary to reestablish the skills of the laborers in locating, identifying and moving the stone blocks scattered around the site. Optimally the team will consist of the following:

SKILLS	(French Trans.)	TOTAL	DAILY RATES (Riels)	($US)
Head Foreman	*Chef de Chantier*	1	3,000	6.00
Supervisors	*Caporal*	5	2,000	3.25
Stonemasons	*Macon*	5	1,800	3.00
Carpenters	*Charpentier*	5	1,800	3.00
Stonecutters	*Tailleurs de pierre*	10	1,800	3.00
Stone Laborers	*Ouvrier*	150	1,500	2.5
Metalworkers	*Forgeron*	3	1,800	3.00
		179	$US	428.50

The cost (1992) of running this 179-strong work force is:

Per month	$US 10,284
Per year	$US 123,408

Labor Force

A casual labor force of 50 *"flottants"* should be recruited to selectively clear the site of vegetation, for a period of up to eight months per year. Their responsibilities, under the control of the two guardians posted to Preah Khan and under the supervision of the WMF team, will be to clear the site as directed of underbrush, to remove some of the larger trees threatening the structures and generally to maintain the clearance of the site throughout the year.

SKILL	(French Trans.)	TOTAL	DAILY RATES (Riels)	($US)
Laborer	*Flottant*	50	1,000	1.5
		50	$US	75.00

The cost of running this 50-strong work force is:

Per month (24 Days)	$US 1,800
Per year (8mths)	$US 14,400

CHAPTER 5

WORK PLAN

Project Summary
Action Plan 1991 - 1992
Administration
On-Site Training at Preah Khan
Facilities and Equipment
Urgent Site Activities
WMF Fall 1992 - Spring 1993 Field Project
Priority Project Profiles
Project Schedule & Budgets

5. WORK PLAN

PROJECT SUMMARY

The World Monuments Fund is prepared to collaborate with the State Government of Cambodia in the initiation of the Preah Khan Conservation Project. Provided that approval is given, a WMF office in Siem Reap will be established as a base of operations to coordinate and support the field work for this project.

The WMF 1992-1993 program centers on the formulation of a conservation plan for Preah Khan and final concurrence on its implementation by all interested parties. Throughout this process, inventory and site analysis work as well as training program activities will continue.

With the commencement of conservation activities on site, a program will be initiated to retrain members of the original Conservation d'Angkor work force in conservation technology. A team of approximately 150-170 skilled workers will be placed under the control of an experienced *Chef de Chantier*. A group of students from Departments of Architecture and Archaeology at the University of Beaux Arts in Phnom Penh is being selected to assist with the planning and supervision of work on site and to continue their on site training. It is anticipated that these students will eventually become the leaders for the campaign to conserve Angkor and the other Khmer sites in Cambodia.

With the assistance of staff members of the Department of Conservation, Ministry of Culture and of the University of Beaux Arts, it is proposed that an ongoing program of conservation activities will be established at Preah Khan to develop and implement appropriate procedures for use in the conservation of the site. An on-site temporary facility will be established and equipment will be obtained to aid in the provision of the highest quality of conservation workmanship.

ACTION PLAN 1991 - 1993

ADMINISTRATION

Conservation Office The Cambodian government has indicated that it can provide administrative staff from the Department of Conservation, the Ministry of Culture and Information as well as the Conservation d'Angkor to operate a conservation office at Siem Reap. Several office personnel will be required, including a Cambodian office administrator. In this regard, one objective is to help restore both the facilities and the pre-1975 operational capacities of the Conservation d'Angkor in Siem Reap so that it can again effectively serve *Parc d'Angkor.*

Project Team After official approval, the WMF project team will be responsible for the co-ordination of a work force for the Preah Khan Conservation Project. The team will be managed by an experienced conservation architect and will include a team of international consultants who will visit the site, as required, for the duration of the project. The project team members will also assume responsibility for training activities and for coordinating the work of the following subgroups:

Planning Team The planning team will oversee the ongoing refinement and maintenance of the Preah Khan Conservation Plan, and will be responsible for site inventories, determinations of significance, the implementation of conservation policy and documentation of these developments.

Crafts Teams The crafts and masons teams will conduct the stone inventory, learn basic masonry techniques, and assist in emergency stabilization work. This interdisciplinary team will consist of international consultants supported by trainees and students.

Labor Teams The labor teams will support the project team in site clearance and stabilization measures.

Administrative Team This team will consist of the support staff at the Conservation d'Angkor, coordinated by a Cambodian administrator.

PLANNING

During the forthcoming campaigns the Preah Khan Conservation Plan will be further developed and followed, based upon work accomplished to date. The Conservation Plan will articulate in detail the specific conservation program and will contain information on:

Historical and/or Bibliographical Research

- Architectural historical research
- Facsimiles and summaries of EFEO archives
- Botanical research
- Religious histories
- Documentation of stone inscriptions and translations
- Materials conservation research
- An inventory of sculpture both *in situ* and *ex situ*
- Geological/hydrological research

Physical Investigations

– Computerized Architectural Inventory	Refine and continue to develop the basic Computerized Architectural Inventory of the Preah Khan site and collate the information using the process designed during the 1991-1992 Missions.
- Stone Inventory	Initiate an inventory of stonework at Preah Khan in its "as found" position before any on-site interventions are undertaken.

- Botanical Inventory	Further identify major plant species and growth patterns and make recommendations regarding future removal and protection of plant material at Preah Khan.
- Graphic Documentation	Verify existing plans and drawings of selected areas of the complex. Supplement extant drawings as required.
- Excavation	Perform minimum excavation for the purpose of verifying above-ground documentation and conservation work only.
- Chronology	Undertake comparative analyses with other sites and further investigate morphological development of the site across time.
- Geological/hydrological Sampling	Continue borings and establish water table monitoring stations.
- Structural Assessment	Analyze building failures and document various structural systems.

Ongoing Analyses In selected priority areas of Preah Khan, the assessment of the structure and materials will be undertaken by the multidisciplinary project team. Some analyses and investigations should continue over the course of several campaigns of work.

Computerization of Inventories All investigations will be recorded using the Computerized Architectural Inventory, which is capable of facilitating relational comparison, quantitative analysis, scheduling and other aspects of management for the conservation project.

Adherence to Policy Subsequent parts of the present Preah Khan Conservation Plan will provide specific recommendations for short and long-term site work and its management. The recommendations will follow the policies, principles and procedures previously set out in *Angkor Considerations Report (Report I), Preah Khan Project Identification (Report II)* and the present Report.

ON-SITE TRAINING AT PREAH KHAN

Student Team The University of Beaux Arts in Phnom Penh has indicated that selected students from the Departments of Architecture and Archaeology can continue to be associated with the Preah Khan Conservation Project as part of their practical professional training. Site training and off-location seminars are proposed for the team. The training program will be aligned to the planning and investigation and conservation planning requirements, so that the students participate in a real conservation project.

Each year there will be a core group of approximately twelve students that will represent a constant in the conservation training process at Preah Khan. New students will be replacing the graduates as required. All special consultants used by WMF in Cambodia will be expected to spend a portion of their time within the country assisting with training.

Training University of Phnom Penh Students

Other Training The staff hired to work in the project office or on site will also receive skills training in required areas. (See *Report II* for general training proposals.)

FACILITIES AND EQUIPMENT

Project Offices In addition to the year round project office which will be established at Conservation d'Angkor in Siem Reap, basic facilities will be put in place at Preah Khan to support the field team and perhaps a site guard. A sensitively designed and located new facility (very modest and organic in construction) might be erected. Its design would anticipate the possible future need for a site interpretation facility.

Equipment A list of equipment requirements for the Conservation d'Angkor office and the site activities is in preparation. The needs will be confirmed with further analysis of site conditions and after more careful construction planning and budgeting is done, prior to the commencement of work on site. Determinaton of equipment requirements, its delivery and storage is a principal objective of the Fall 1992 - Spring 1993 field campaign, or project *mobilization phase*.

URGENT SITE ACTIVITIES

The preliminary inventory established in 1991 identified the following tasks for the 1992 site program at Preah Khan:

- specific identification and conservation planning for areas of imminent collapse,
- determination of security requirements and implementation, and
- vegetation control.

The following Priority Project Profiles are based on the above concepts and have been selected as representative projects from Preah Khan. Work on any or all of these ten proposed projects will provide a valuable exposure to construction procedures and costs, which will prove useful in planning future work. As the WMF program in Preah Khan progresses, a more detailed work plan will be developed annually for presentation to the National Committee for the Rehabilitation of the Monuments and Museums of Cambodia.

WMF FALL 1992 - SPRING 1993 FIELD PROGRAM

The proposed conservation activity program for fall 1992 through spring 1993 (Conservation Campaign I) is intended to expand upon the reconnaissance and feasibility work done to date. WMF Mission IV can generally be characterized as "mobilization" activity, where the following management systems and field activities are brought into existence:

- establishment of a project office at Conservation d'Angkor,
- development of a core staff of Cambodians and others to manage the WMF Mission IV in the field,
- commencement of selected and relatively small scale field activities (tests) for the purpose of better understanding actual conservation procedures in the field, costs, construction logistics, procurement and payment systems, etc.,

- determination of available local skills for addressing the conservation problems at Preah Khan, and

- advancement in training of graduate students from the Université des Beaux Arts in Phnom Penh, as well as local craftsmen in Siem Reap, in the skills necessary for conservation efforts at the site.

Field Campaign I is planned to occur between November 1992 and March 1993 with peak periods of activity projected for November, January and March. During these peak periods an increased number of experts will visit the mission and participate in training duties. Peak periods within an extended mission such as the present one reflect the limited time availability of specialty consultants, and the special arrangements which must be made by Deans in the Departments of architecture and Archaeology in Phnom Penh for the proposed on-site training of selected students at Angkor.

Activities throughout the five-month Mission IV will be continuously maintained by WMF-sponsored management personnel under the direction of the designated WMF project manager. (See WMF Mission IV Project Management Diagram.)

Pending funding availability and WMF's initial effort at mobilizing men and material at the site, specific pilot conservation projects at Preah Khan will focus on Projects 5,8,9 & 10 from the following list of priority works:

Project 1. East Gopura, Enclosure Wall III - General structural stabilization and selected reconstruction.

Project 2. Enclosure Wall IV - Reconstruction of fallen sections.

Project 3. Enclosure Wall III - Reconstruction of fallen sections.

Project 4. East Gopura. Enclosure Wall I - Partial reconstruction of tower and side vaults; cleaning of inscribed walls and protection of Preah Khan stele, installation of bat-proofing measures.

Project 5. Tower and galleries of the Vishnu Temple Complex (West) - Structural consolidation and repair of vaults.

Project 6. Central Temple tower and adjacent structures - partial reconstruction of tower and repair of adjacent vaults.

Project 7. West Gopura, Enclosure Wall IV. General consolidation/repair and partial reconstruction.

Project 8. West Causeway - General cleaning, re-laying of dislodged paving stones.

Project 9. Processional Way and Lanterns, West Entrance - General cleaning of the west processional way, re-erection and repair of stone stelae along processional pathway.

Project 10. Site clearance and maintenance - Undergrowth removal near architectural remains, selected tree cutting, stump and dead tree removals.

In addition to all or some combination of the above pilot conservation projects, a number of less site-specific special conservation analyses and related activities will be conducted such as:

- additional stone cleaning tests,
- stone repair tests,
- stone carving and casting tests,
- drainage installations,
- continued botanical/ecological surveys,
- continued structural surveys,
- continued historical researches,
- hydrological surveys,
- specialty engineering analyses,
- and, possibly, certain archaeological probes.

Ongoing during Field Campaign I will be administrative support, material procurement, transport activities, field documentation and fund raising activities, including site visits to Preah Khan by potential donors in November, 1992.

PRIORITY PROJECT PROFILES

INTRODUCTION

In order to commence a conservation project for Preah Khan, it is necessary to clearly identify a series of representative projects in order to start a fund raising program. Of almost equal importance is the need for the conservation work force to familiarize itself with successful work procedures to be actually carried out in the field. The following ten pilot projects have been selected as appropriate and representative tasks for the proposed work force. As the project gains momentum, further projects will be identified and, if possible, a large work force will be employed.

The pilot projects range from Project 1 - The East Gopura, Enclosure III, which is the largest in terms of scope and complexity to the smallest, Project 9 - the Resetting of the Lantern Stones on the West Processional Path. The projects were selected with the assistance of the staff of the Conservation d'Angkor and a preliminary budget has been prepared with assistance from a former *Chef de Chantier* who worked for the EFEO team in the 1960s.

The successful completion of most or all of these representative projects will allow for a final determination of exactly what is required to complete the estimated ten year program to conserve and present the site of Preah Khan.

PROJECT 1

EAST GOPURA, ENCLOSURE WALL III

Location

The major entrance through Enclosure Wall III from the east to the religious complex.

Present Condition

This extensive and complex gateway structure demonstrates all the problems associated with the repair and conservation of structures in Preah Khan and elsewhere at Angkor. There are sections threatening to collapse - South East Portico; structures engulfed in trees - South East Gallery; structural settlement/displacement - South Vestibule; structures in need of consolidation due to unsuitable previous interventions - North East Gallery; stonework requiring realignment and consolidation - pediments to gopura; problems of drainage - beneath the Central Tower; sections presenting opportunities for simple reconstruction - North Portico; and wall tops requiring weatherproofing - practically throughout.

Repair Recommendations

This structural group presents a composite program for recording (See Appendices A & G) for repair and for conservation. Each of the problems identified should be carefully resolved and used as a model for future activities.

Portico Reconstruction

After recording of the entire structure, the stone columns and lintels should be carefully dismantled. The load bearing capacity beneath columns should be analysed and strengthened as necessary. Fractured lintels and columns should be repaired using non-ferrous metal dowels and then re-erected. After reassembly, the water shedding elements should be put back into working order.

Restrict Further Tree Growth

The gigantic tree that has taken root in the South East Gallery is a monument itself and should be conserved. Efforts should be made to restrict its future growth and specialist advice should be sought on trimming dangerous branches. Moisture

penetration into the stone structure which is affected by the tree should be prevented by the filling of misaligned stone joins with an appropriate mortar mix, using recessed joints.

Structural Settlement

Major settlement at the threshold of the southern vestibule should be further analyzed and corrected.

Consolidation of Previously Repaired Structures

The North East Gallery which was consolidated circa 1952, requires further structural stabilization. It is recommended that the original structure be cradled and raised off its concrete supports. Subsequently, its damaged lintels could then be repaired and realigned, followed by the lowering and realignment of roof corbels. This "cradling" technique should avoid excessive handling and damaging of stonework.

Waterproofing of Wall Tops

It is recommended that all exposed wall tops that are vulnerable to rainwater be made to drain by re-setting stones at gentle slopes, using an appropriate mortar mix and painting ingredients. Consideration should also be given to the use of both organic and inorganic sealants for these types of repairs. This intervention must not be visible from ground level.

Drainage within Confined Spaces

The building group provides opportunities for testing various methods of surface drainage within confined spaces following recommendations set out in Section 3, "Special Analyses."

Simple Reconstruction

Sections of the North Portico of the East Gopura are easily recognizable in the piles of stones stacked close by. It is recommended that partial reconstruction be undertaken so the stones can be replaced to their original position while it remains relatively easy to do so.

Stone Cleaning and Consolidation

There are many places in this structure where stone cleaning and consolidation can be discretely tested and implemented. Techniques for simple cleaning of the interior wall faces can be undertaken and methods of stone consolidation can be tested on the *fronton* or other fragile bas-reliefs.

Work Force and Budget (For East Gopura, Enclosure Wall III)

Team	Time Required
Supervisor	
Chef de Chantier	
5 Caporals	800 Days
Work Force	
80 Laborers	800 Days
10 Stonecutters	600 Days
10 Stonemasons	600 Days
3 Blacksmiths	300 Days

Budget (in U.S. $)	
Supervision	17,800
Labor	198,700
	216,500
Contingency	21,650
SUBTOTAL	238,150

Project 1 - East Gopura III

PROJECT 2

ENCLOSURE WALL IV

Location

Enclosure Wall IV delineates the perimeter of the former city of Preah Khan and is bordered by the moat.

Present Condition

The total length of Enclosure Wall IV measures approximately 3,160 meters. The wall, which is built of laterite and has a crenelated capping of sandstone, is on average, 5 meters high and 90 cm thick and is constructed on a solid plinth. The form of its foundations is not presently known. Throughout its southern length, which is in dense jungle, the wall has been disturbed by tree growth and vegetation. Trees felled during the severe storm in 1989 have also breached the wall in several places. An approximate total of 335 meters, or 10% of the total wall length, has been damaged. At least 75% of the fallen stones can be reused.

Repair Recommendations

As this structure clearly delineates and serves as the outermost protective barrier for the Preah Khan complex, it is recommended that it be repaired and reconstructed. Once the wall is reinstated and guards are posted at each of is gateways, access to Preah Khan can again be effectively controlled. The fallen stones need to be identified, cleaned and reset into their original position. Where necessary, some strengthening should be incorporated with concealed concrete bonders. Missing stones should be replaced with new carved laterite or cast stone using crushed laterite for aggregate. Some of the present wall breaches should be temporarily used for construction access.

Work Force and Budget (For 335 meters of Enclosure Wall IV)

Team	Time Required
Supervisor	
2 Caporal	650 Days
Work Force	
70 Laborers	650 Days
Budget (in U.S. $)	
Supervision	4,225
Labor	113,750
	117,975
Contingency	11,798
SUBTOTAL	129,773

PROJECT 3

ENCLOSURE WALL III

Location

The Enclosure Wall III delineates the perimeter of the religious structures within the Preah Khan complex.

Present Condition

The length of Enclosure Wall III, including the gopuras, measures approximately 750 meters. The actual wall, which is built of laterite and has a crenelated capping of sandstone, measures approximately 540 meters in total length. The wall is on average 5 meters high and 90 cm thick and is constructed on a solid plinth. Little is known about the form of its foundations. Throughout its length, the wall has been greatly disturbed by tree growth and vegetation both on the wall and adjacent to it. Tree roots have undermined the foundations and the trees felled during the severe storm in 1989 have breached the wall in several places. As a result approximately 310 meters, or 60% of the wall length, has been damaged. Most of the stones have fallen close by and only about 25% of them cannot be reused.

Repair Recommendations

For the sake of security and for the well-being of the site, it is recommended that a work force be engaged to repair and reconstruct the Enclosure Wall III. The stones need to be identified, cleaned and reset into position. Where necessary, some strengthening should be incorporated with carefully concealed concrete bonders. The missing stones will need to be replaced with new laterite or with cast stone that simulates laterite.

Work Force and Budget (For 310 meters of Enclosure Wall III)

Team	Time Required
Supervisor	
2 Caporal	625 Days
Work Force	
70 Laborers	625 Days
Budget (in U.S. $)	
Supervision	4,063
Labor	109,375
	113,438
Contingency	11,344
SUBTOTAL	124,781

PROJECT 4

EAST GOPURA - ENCLOSURE WALL I

Location

The gopura complex directly to the east of the Central Temple in which the Preah Khan Inscription is located.

Present Condition

The tower over the gopura has partially collapsed causing extensive damage to adjacent structures. The stones are in piles to the west of the structure. The interiors which have delicate inscribed decoration are open to the elements. The condition admits dampness and provides a micro-climate within the tower, which supports an accumulation of biological growth on the walls. The priceless Preah Khan inscribed stele is also exposed to rain and humidity causing avoidable degradation to the stone.

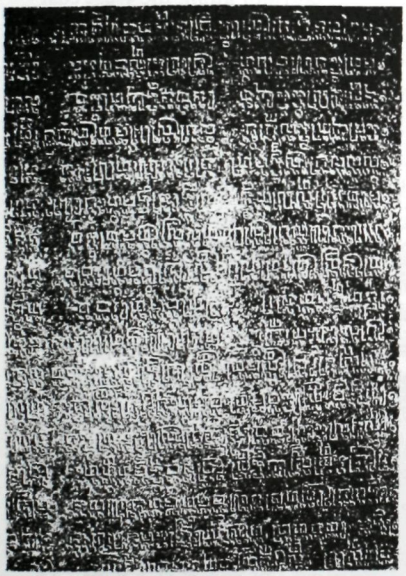
Repair Recommendations

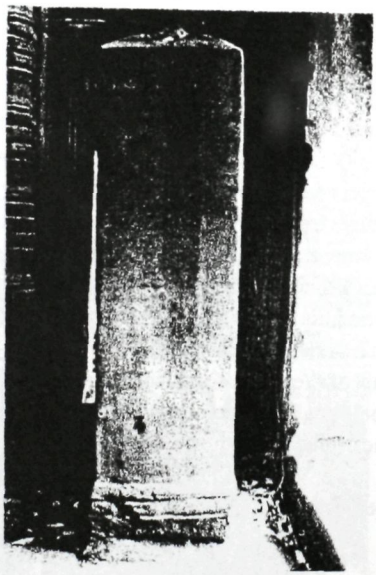
As an important means of protection to the inscribed interiors and to the vestibule containing the inscribed stele, it is recommended that the roofs of the tower and vestibules be carefully reconstructed, possibly by placing concrete ring beams to bond the vault structures. The problems of identifying the fallen stones to be reused will be further complicated by the restriction in working space. Once the roofs and towers have been made watertight, the interior stone surfaces can be cleaned and treated. The conservation of the inscription stele will require more detailed study followed by recommendations for its cleaning and consolidation. In the meantime, it is recommended that an appropriately designed plexiglass screen be placed over the inscription allowing for visibility and ventilation, but blocking precipitation and the touch of visitors.

Workforce and Budget (East Gopura - Enclosure I)

Team	Time Required
Supervisor	
Chef de Chantier	450 Days
3 Caporal	450 Days
Work Force	
70 Laborers	450 Days
10 Stonemasons	300 Days
10 Stonecutters	350 Days
3 Metalworkers	150 Days

Budget: (in U.S. $)	
Supervision	7,090
Labor	99,600
	106,690
Contingency	10,670
SUBTOTAL	117,360





Preah Khan Stele (1992)

PROJECT 5

TOWER AND GALLERIES OF THE VISHNU TEMPLE COMPLEX (WEST)

Location

The temple tower and the two adjacent north/south galleries flanking the western temple of the Vishnu Complex.

Present Condition

The temple tower has fallen outward causing the adjacent north and south galleries to collapse. This has caused major displacement to the east gallery which has a composite vaulted roof now threatening to collapse. The fallen stones remaining *in situ* in the flanking galleries are not secure and are a hazard to visitors. The remains of a large tree, damaged in the 1989 storm, hang precariously over the Northern Gallery and is a threat to the remaining structures. The corridor along the west/east axis exhibits clear evidence of severe structural movement and collapse appears imminent.

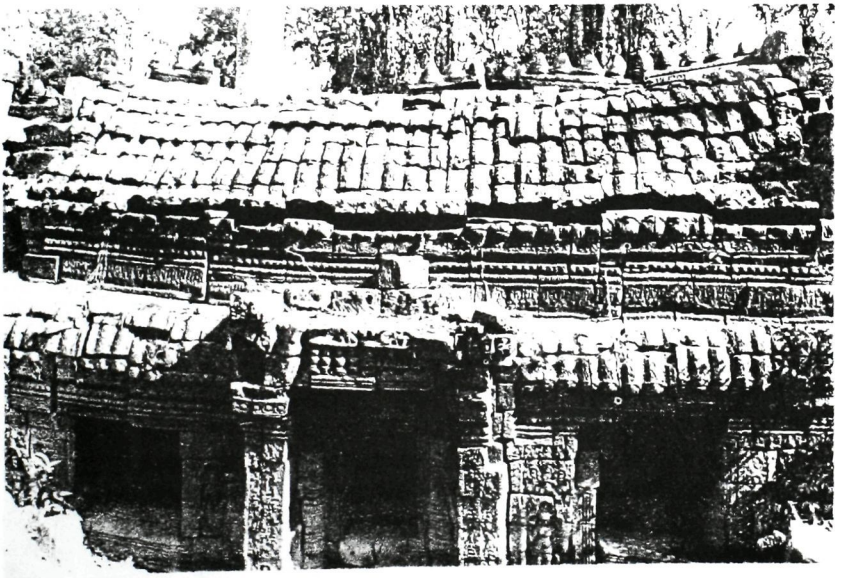
Repair Recommendations

As every visitor passes beneath the tower and along the eastern corridor, the various fractures and open joints should be monitored to ascertain whether there is still "live" movement. As this corridor represents a significant architectural development at Preah Khan, the dismantling and reconstruction of the composite vault should be avoided. It is recommended that the structure be analysed by a specialist engineer with a view to consolidating the corridor in its present form. Reconstruction and repair of the north/south corridors should also be considered as many of the vault corbels are in dangerous condition. A skilled team should be able to identify the stones lying to the north and south of the tower base, and substantially reconstruct that tower in its original form. Concrete rings should be judiciously placed within the tower structure.

Work Force and Budget (Tower and Galleries of Vishnu Complex, West)

Team	Time Required
Supervisor	
2 Caporal	280 Days
Work Force	
30 Laborers	280 Days
10 Stonecutters	150 Days
5 Stonemasons	100 Days
3 Blacksmiths	100 Days

Budget (in U.S. $)	
Supervision	1,960
Labor	28,650
	30,610
Contingency	3,061
SUBTOTAL	33,671



Project 5, Gallery of Vishnu Temple Complex (West)

PROJECT 6

CENTRAL TEMPLE TOWER AND ADJACENT STRUCTURES

Location

The center of the Preah Khan complex where the main north/south and east/west axes intersect and where the main divinity was originally placed.

Present Condition

The tower has undergone several changes in its history, the last being during the EFEO program in the 1950s. Much of the central tower collapsed, probably several hundred years ago, and with it several of the adjacent structures also fell. What remains appears to be in reasonably sound condition. The internal walls of the tower are heavily obscured by biological growth supported by rainwater through the open vaults. At present, there is a persistently damp micro-climate within the tower.

Repair Recommendations

It is recommended that the tower be partially reconstructed and capped to prevent rainwater from entering the structure. This will entail the careful sorting, identification and reconstruction of the upper part of the tower. This procedure will make possible the removal of stones and debris blocking the northern axis corridor adjacent to the Tower.

It is recommended that the interior inscribed stone wall be cleaned according to approved *in situ* cleaning tests.

Workforce and Budget (Central Temple Tower, etc.)

Team	Time Required
Supervisor	
1 Caporal	144 Days
Work Force	
30 Laborers	144 Days
5 Stonecutters	100 Days
1 Mason	100 Days

Budget (in U.S. $)	
Supervision	468
Labor	12,450
	12,918.
Contingency	1,292
SUBTOTAL	14,210

Central Tower, Shrine Interior

PROJECT 7

WEST GOPURA - ENCLOSURE WALL IV

Location

The West Gopura is the present main entrance to Preah Khan for all visitors. After crossing the causeway over the moat, this structure forms the first impression of the monumental remains of the Preah Khan complex.

Present Condition

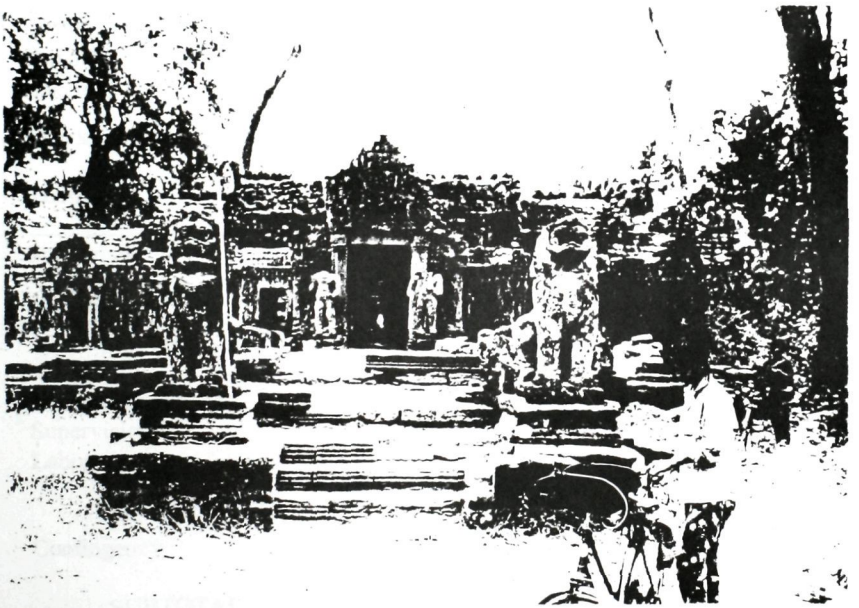
The gopura underwent considerable repairs by the EFEO during the 1950s. The porticos, on the eastern facade, and some other structures have already fallen down and other sections are at the point of collapse. Some previously collapsed stonework was neatly stacked adjacent to the gopura. Some visitors have etched their names in the mosses growing on the stone walls of this structure.

Repair Recommendations

The West Gopura is threatened by the destructive actions of visitors who climb over the delicate sculpted pediments lying on the ground and who inscribe their names on the walls. It is recommended that a small training program for administrators and craftsmen be established for this gopura. A relatively small work force could be assigned to this structure and a wide range of useful procedures could easily be demonstrated here. The process of locating and identifying fallen stones can be established; techniques for moving and repositioning stones can be developed; and various methods of stone cleaning and consolidation can be implemented.

Workforce and Budget (West Gopura)

Team	Time Required
Supervisor	
1 Caporal	192 Days
Work Force	
30 Laborers	192 Days
Budget (in U.S. $)	
Supervision	624
Labor	14,400
	15,024
Contingency	1,502
SUBTOTAL	16,526



Project 7, West Gopura

PROJECT 8

WEST CAUSEWAY

Location

The West Causeway crosses the moat between the Processional Way and the West Gopura of Enclosure Wall IV.

Present Condition

The West Causeway is bordered by a sculpted railing composed of images of demons and divinities holding the Naga. Many of the heads of these mighty images are missing and those that remain are often loosely set and covered with biological growth. The sandstone paving of the causeway is often loose and displaced by vegetation. The main structure of the causeway rests upon laterite piers set into the moat. Due to constant moisture in this location, there is abundant vegetation.

Repair Recommendations

Due to the causeway's prominence as part of the principal entrance sequence to Preah Khan, as well as its relatively good state of preservation, it is recommended that the causeway be rather fully repaired and cleaned. Dislocated slabs should be realigned, vegetation should be removed and the sculptures should be cleaned and consolidated as necessary. The laterite base of the causeway should also be repaired and kept clear of vegetation.

Workforce and Budget (For the West Causeway)

Team	Time Required
1 Caporal	35 Days
Work Force	
20 Laborers	35 Days
Budget (in U.S. $)	
Supervision	114
Labor	1,750
	1,864
Contingency	186
SUBTOTAL	2,050

PROJECT 9

PROCESSIONAL WAY AND LANTERNS - WEST ENTRANCE

Location

The western extremity of the site bordering the presently used main access route for visitors.

Present Condition

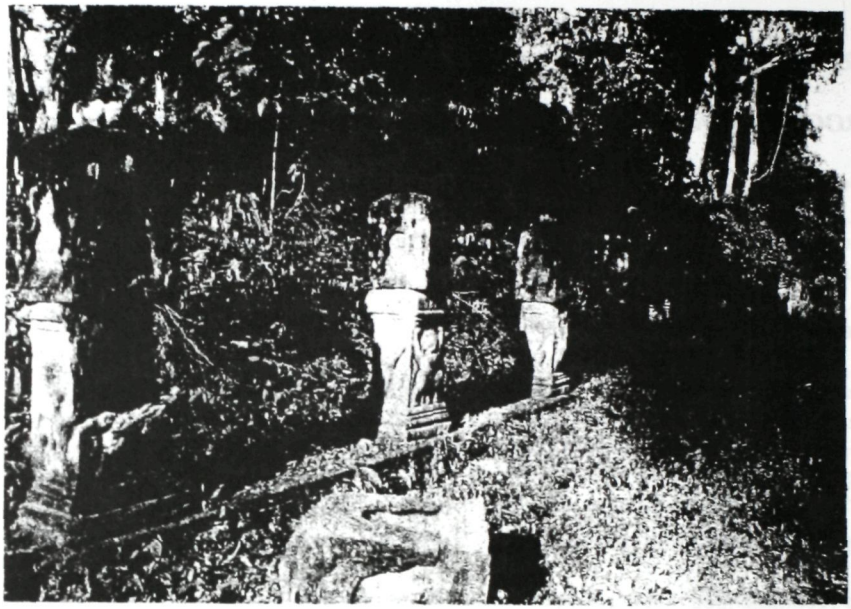
The sandstone lanterns lining the Processional Way are in various stages of repair. Many have fallen, some are broken, and some are missing. The original laterite surface of the Processional Way is buried up to 20 cm in depth. Many of the paving slabs are misaligned.

Repair Recommendations

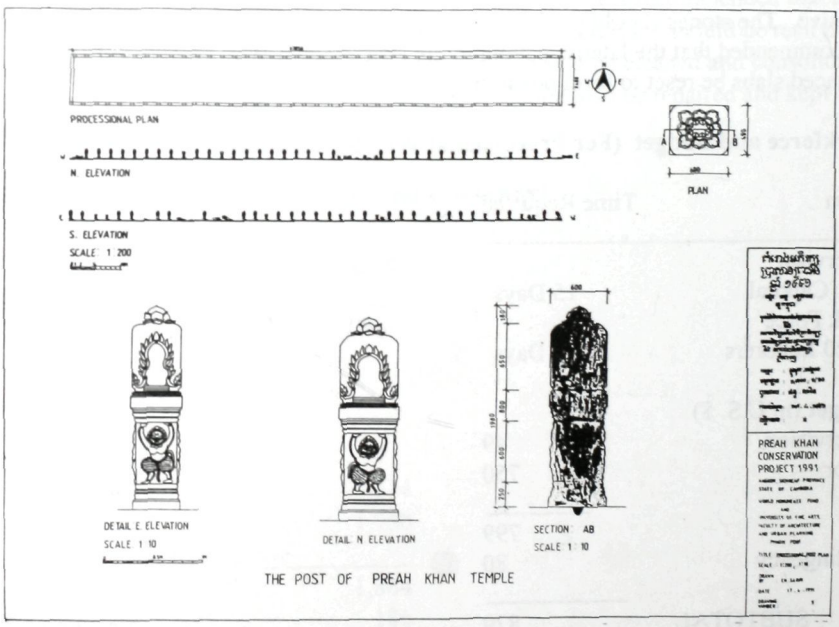
It is recommended that the lantern stones be identified and recorded. Verification of the original positions of the various displaced elements can be aided by careful examination of materials and breakage patterns. Each stone requiring repair should be drilled to receive non-ferrous dowels and re-joined using an appropriate stone adhesive. The stones should be lightly cleaned and reset in their original position. It is recommended that the laterite paving to the Processional Way be exposed and the displaced slabs be reset to level positions.

Workforce and Budget (For Processional Way Restoration)

Team	Time Required
Supervisor	
1 Caporal	15 Days
Work Force	
20 Laborers	15 Days
Budget (in U.S. $)	
Supervision	49
Labor	750
	799
Contingency	80
SUBTOTAL	879



Milestones at West Entrance to Preah Khan (1992)



Drawing by UBA Students of Milestones (1991)

PROJECT 10

SITE CLEARANCE AND MAINTENANCE

Location

The whole of the Preah Khan site within Enclosure Wall IV to the outer extremity of the moat.

Present Condition

Totally overgrown with underbrush, vines, and small to medium size trees, blocking access to most parts of the temple complex.

Recommendations

General clearance of undergrowth and trees up to a 20 cm caliper in designated areas under strict supervision and annual maintenance of site.

Workforce and Budget (Site Clearance and Maintenance)
Assumes 8 Months Work per Year

Team	**Time Required**
Supervisor	
2 Caporals	192 Days
Work Force	
48 Laborers	192 Days

Budget (in U.S. $)

Supervision	1,248	
Labor	13,824	
	15,072	
Contingency	1,507	
SUBTOTAL	16,579	(per 8 month work year) *

*It is estimated that it would require three years of work, as described above, to clear the designated areas of Preah Khan at a total cost of $49,740.

PROJECT BUDGETS & SCHEDULE

Short Term Budget

A Budget Analysis has been prepared for a short term, three year project which amounts to a total cost of approximately $1.5 million. This budget has been realized on the budget costing of a series of ten priority project profiles which are considered representative of the work required to conserve the whole site of Preah Khan as a partial ruin. Completion of the ten represented projects contained herein would represent some 20% of the total effort needed to conserve and present Preah Khan.

Long Term Budget

The three year budget has been projected for a period of ten years, which is a fair assessment of the time required for a single conservation team of 170 workers to complete a major program for the repair, conservation and presentation of Preah Khan. The total budget for ten years amounts to approximately $5.5 million

Future Maintenance

Once the major work of repair and conservation is completed, it is hoped that revenues earned from entrance fees to the site will be sufficient to properly maintain the site in accordance with the conservation management plan.

This global budget is only a rough estimate that is intended to provide an order of magnitude of the funds required to preserve and present the site. It should also serve the purpose of providing a target for fund raising campaigns.

1992/1993 MISSION SCHEDULE

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PREAH KHAN CONSERVATION PROJECT - WORKPLAN FOR END OF MISSION III & MISSION IV 1992/1993     WORLD MONUMENTS FUND   NEW YORK
-------------------------------------------------------------------------------------------------------------------------------------
NO       A C T I V I T Y                AUG  I  SEPT  I  OCT   I  NOV   I  DEC   I  JAN   I  FEB   I  MAR   I  APR   I  MAY   I  JUNE  I  JULY
---------------------------------I--------I--------I--------I--------I--------I--------I--------I--------I--------I--------I--------I--------
APPROVALS                        I        I        I        I        I        I        I        I        I        I        I        I
1.  Project Submission to NationalIxxxxxxxxI        I        I        I        I        I        I        I        I        I        I
    Committee & Approval         I        I        I        I        I        I        I        I        I        I        I        I
                                 I        I        I        I        I        I        I        I        I        I        I        I
ADMINISTRATION                   I        I        I        I        I        I        I        I        I        I        I        I
1.  Selection of WMF Project Team I........IxxxxxxxxI        I        I        I        I        I        I        I        I        I
2.  Establish Project Office     I........I........I........IxxxxxxxxI        I        I        I        I        I        I        I
3.  Hire Administrator           IxxxxxxxxI        I        I        I        I        I        I        I        I        I        I
4.  Identify Crafts/Labour Teams IxxxxxxxxI        I        I        I        I        I        I        I        I        I        I
                                 I        I        I        I        I        I        I        IxxxxxxxxI        I        I        I
PROJECT ACTIVITIES               I        I        I        I        I        I        I        I        I        I        I        I
    Project 1                    I........I........I........Ixxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      East Gopura - Enclosure III I        I        I        I        I        I        I        I        I        I        I        I
    Project 2                    I        I        I        I        I        I        I        I        I        I        I        I
      Enclosure Wall IV          I        I        I        I        I        I        I        I        I        I        I        I
    Project 3                    I        I        I        I        I        I        I        I        I        I        I        I
      Enclosure Wall III         I........I........I........Ixxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
    Project 4                    I        I        I        I        I        I        I        I        I        I        I        I
      East Gopura - Enclosure I  I........I........I........I........I........I........I........IxxxxxxxxxxxxxxxxxxxxxxxxxxI        I
    Project 5                    I        I        I        I        I        I        I        I        I        I        I        I
      Vishnu West Temple Complex I        I        I        I        I        I        I        I        I        I        I        I
    Project 6                    I        I        I        I        I        I        I        I        I        I        I        I
      Central Temple Tower       I        I        I        I        I        I        I        I        I        I        I        I
    Project 7                    I        I        I        I        I        I        I        I        I        I        I        I
      West Gopura Enclosure IV   I        I        I        I        I        I        I        I        I        I        I        I
    Project 8                    I        I        I        I        I        I        I        I        I        I        I        I
      West Causeway              I........I........I........I........IxxxxxxxxI        I        I        I        I        I        I
    Project 9                    I        I        I        I        I        I        I        I        I        I        I        I
      Processional Way - West    I........I........I........IxxxxxxxxI        I        I        I        I        I        I        I
    Project 10                   I        I        I        I        I        I        I        I        I        I        I        I
      Site Clearance             I........IxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxI        I
                                 I        I        I        I        I        I        I        I        I        I        I        I
TRAINING ACTIVITIES              I        I        I        I        I        I        I        I        I        I        I        I
1.  Site Training Preah Khan Team IxxxxxxxxI........I........IxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxI
                                 I        I        I        I        I        I        I        I        I        I        I        I
DOCUMENTARY/PHYSICAL STUDY       I        I        I        I        I        I        I        I        I        I        I        I
1.  Architectural Research       I        I        I        I        I        I        I        I        I        I        I        I
    and Technology               IxxxxxxxxI........I........IxxxxxxxxI........I........I........IxxxxxxxxI........I........I........IxxxxxxxxI
2.  Archaeological Research and  I        I        I        I        I        I        I        I        I        I        I        I
    Selection of Excavation      I........I........I........IxxxxxxxxI........I........I........Ixxxxxxxxx         I        I        I
3.  Botanical Research and       I        I        I        I        I        I        I        I                  I        I        I
    Field Inventory              I........I........I........I........I........I........I........IxxxxxxxxI        I        I        I
4.  Stone Stacks Inventory       I        I        I        I        I        I        I        I        I        I        I        I
    and Analysis                 I........I........I........I........I........I........I........IxxxxxxxxxxxxxxxxxI        I        I
5.  Research on Materials (Stone) I        I        I        I        I        I        I        I        I        I        I        I
    Conservation                 I........I........I........IxxxxxxxxI........I........I........I........I........I........I........I........I
6.  Structural Assessment        I        I        I        I        I        I        I        I        I        I        I        I
    General                      I........I........I........I........I........I........I........IxxxxxxxxI        I        I        I
7.  Hydrological and Geological  I        I        I        I        I        I        I        I        I        I        I        I
    Survey/Sampling/Monitoring   I........I........I........I........I........I........I........IxxxxxxxxI        I        I        I
8.  Historical and Inscriptional I        I        I        I        I        I        I        I        I        I        I        I
    Research on Chronology       I........I........I........IxxxxxxxxI........I........I........IxxxxxxxxI        I        I        I
9.  Compile & Maintain Computer  I        I        I        I        I        I        I        I        I        I        I        I
    Inventory Programme (CAR)    I........I........I........I........I........I........I........I....xxxxI        I        I        I
                                 I        I        I        I        I        I        I        I        I        I        I        I
PUBLICATION & PROMOTION          I        I        I        I        I        I        I        I        I        I        I        I
1.  Publication of Preah Khan    I        I        I        I        I        I        I        I        I        I        I        I
    Conservation Management Plan I........I........I........I........I........I........I........I........I........I........I........IxxxxxxxxI
                                 I        I        I        I        I        I        I        I        I        I        I        I
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PREAH KHAN MISSION PLAN BUDGET — ACTIVITIES - AUGUST 1992 - JULY 1993 — WORLD MONUMENTS FUND - NEW YORK

NO A	ACTIVITY	AUG/92	SEP/92	OCT/92	NOV/92	DEC	JAN/93	FEB/93	MAR/93	APR/93	MAY/93	JUN/93	JUL/93	TOTAL
		<--<--MISSION III-->-->			|<--<--<--<-MISSION IV->-->				<--<--<--<--<-MISSION IV->-->					
	LOCAL SUPPORT													
	Establish Project Office				4000									$4,000
	Local Staff (X2) Salaries				250	250	250	250	250	250	250	250	250	$2,250
B	CONSULTANTS (Fees, Travel, Expenses)											SUB TOTAL		$6,250
	Building Conservation (PJS) (Project Coordinator)	5000			9000		5000		5000		5000		9000	$38,000
	Environmental Specialist (CJ)				5600									$5,600
	History - Epigraphy(BB/CJQ)				4000				4000					$8,000
	Archaeologist (FA)				8500				8500				8500	$25,500
	Structural Engineer (PG)				8500				8500					$17,000
	Computer Programmer (SA)								5600					$5,600
	National Advisers (2 Nos)								3000	3000	3000	3000	3000	$15,000
C	SITE ACTIVITIES - (Inclusive of Labor & Materials) (See Project Profile - Details)											SUB TOTAL		$114,700
	Project 1 - East Gopura Enc 3				7000	7000	7000	7000	7000	7000	7000	7000	7000	$63,000
	Project 2 - Enclosure Wall 4													$0
	Project 3 - Enclosure Wall 3				3000	3000	3000	3000	3000	3000	3000	3000	3000	$27,000
	Project 4 - East Gopura Enc 1								2000	2000	2000			$6,000
	Project 5 - Vishnu Complex													$0
	Project 6 - Central Tower													$0
	Project 7 - West Gopura Enc 4													$0
	Project 8 - West Causeway					2050								$2,050
	Project 9 - Processional Way				810									$810
	Project 10 - Site Clearance			2070	2070	2070	2070	2070	2070	2070	2090			$16,580
D	TRAINING ACTIVITIES (Travel & Subsistence $250 per head)											SUB TOTAL		$115,440
	Continue Site Training of Preah Khan Team	700			1500	1000	1000	1000	1000			1500	1000	$8,700
E	DOCUMENTATION/PHYSICAL STUDIES											SUB TOTAL		$8,700
	Architectural Research						3000						3000	$6,000
	Development of Stone Inventory						5000							$5,000
	Research on Materials (Stone)								5000					$5,000
	Compile & Maintain Computer											10000		$10,000
F	PUBLICATIONS & PROMOTIONS											SUB TOTAL		$26,000
	Preparation Annual Report												15000	$15,000
												SUB TOTAL		$15,000
	MONTHLY TOTALS	5700	0	2070	54230	15370	26320	13320	54920	17320	22340	24750	49750	========
												GRAND TOTAL		$286,090

DIAGRAM ***

PREAH KHAN CONSERVATION PROJECT
PROJECTED GLOBAL BUDGET TO COMPLETE STRUCTURAL REPAIRS
THE 10 YEAR CYCLE

THE WORLD MONUMENTS FUND
NEW YORK

Budget Item	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
Consultancy	120950	150650	150650	60000	60000	60000	60000	60000	60000	60000	$842,250
Training/research	49700	49700	49700	25000	25000	25000	25000	25000	25000	25000	$324,100
Labor/Materials	115440	280988	321644	369891	400000	400000	400000	400000	400000	400000	$3,487,963
Equipment	50000	100000	25000	25000	10000	10000	10000	10000	10000	10000	$260,000
Inflation (15%)	0	87201	82049	71984	74250	74250	74250	74250	74250	74250	$686,733
TOTAL	336090	668539	629043	551874	569250	569250	569250	569250	569250	569250	$5,601,046
CUMULATIVE TOTAL	336090	$1,004,629	$1,633,672	$2,185,546	$2,754,796	$3,324,046	$3,893,296	$4,462,546	$5,031,796	$5,601,046	

NOTES:

The Budgets for Years 1 to 3 are based on Project Profile Budgets and International Consultancy Inputs up to and including Year 3.

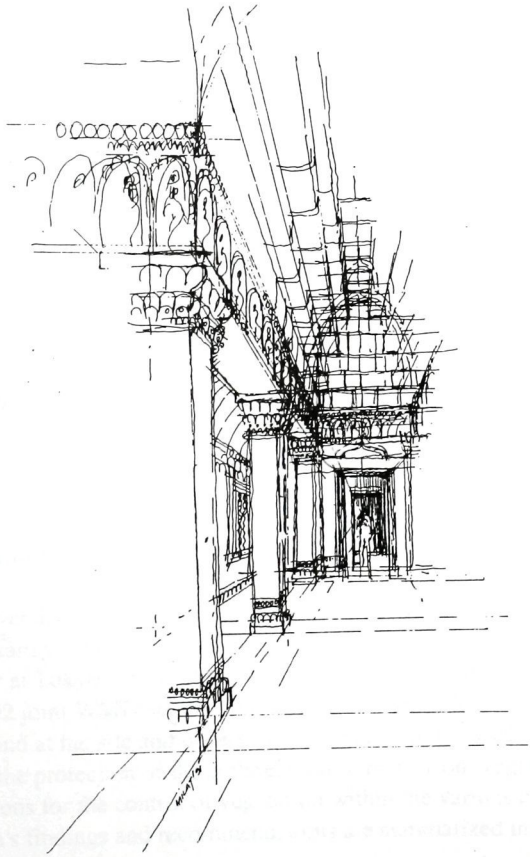
Project Costs are extrapolated from the Project Profiles and are based on an assumption that 2 Project Teams (Chantiers) will take 10 years to complete general structural repairs in Preah Khan.

The Budget for Year 4 to Year 10 allows for limited international supervision and relies on the employment of National professionals.

Inflation has been calculated at 15% per Annum.

CHAPTER 6

SUPPLEMENTAL TECHNICAL ANALYSES



6. SUPPLEMENTAL TECHNICAL ANALYSES

Stone Pathologies and Recommendations

During WMF's third mission to Angkor in March 1992, Dr. Frank Preusser, Associate Director of The Getty Conservation Institute, California visited Preah Khan and advised on the problems related to the cleaning and conservation of the Kulen sandstone. His recommendations have been incorporated in the various technical sections of this Report. The GCI's analytical report on a stone sample from Preah Rup (constructed of the same sandstone as that of Preah Khan), providing details of the stone's composition, is found in Appendix C.

Geological Sampling

As part of Sophia University's research activities at Angkor, and in accordance with the collaborative program established between WMF and Sophia University, Dr. Tomio Moriai, Professor at the Tohoku Institute of Technology, Tokyo, has undertaken investigations at two locations at Preah Khan. The first boring was made just north of the terrace to the West Gopura of Enclosure III in March 1991. The second boring was to the north of the Terrace outside the East Gopura of Enclosure III in March 1992. A third boring was attempted in the courtyard to the North West of the Central Shrine but the augers were unable to penetrate a layer of laterite thought to have been placed as part of the foundations. Both borings were taken at the same time of the year and revealed similar information. Dr Moriai's report is attached, providing a preliminary geological analysis of soil conditions around Preah Khan (See Appendix D).

Botanical Sampling and Recommendations

As part of Sophia University's research program for Angkor and in accordance with the collaborative program established between WMF and Sophia University, Mr. Jun Yokoyama, researcher at Tokyo University, spent several days in Preah Khan during both the 1991 and 1992 joint WMF/Sophia University Missions. He collected specimens of flora found at the site and observed patterns of plant growth in the area. Advice was given on the protection of the architectural remains from vegetation as well as recommendations for the control of vegetation within the various enclosure walls. Mr. Yokoyama's findings and recommendations are summarized in Appendix E of this report.

CHAPTER 7

RECOMMENDATIONS FOR FUTURE STUDY

7. RECOMMENDATIONS FOR FUTURE STUDIES

Continuing the Search for and Compilation of Archival Material Concerning the History of Preah Khan

Of particular importance will be the transcription and analysis of accounts of the restoration history of Preah Khan contained in the archives at the EFEO in Paris. Drawings and photographs of Angkor from the earliest scientific study of the site through today, are of major importance to the present conservation team. The development of a master index of these materials and a compilation of facsimile images of each is considered a priority.

An Illustrated Inventory of Sculptural Elements With Preah Khan Associations

Considerable work on the compilation of a general inventory of known Angkor sculptures has already been undertaken by Dr. Bruno Dagens for EFEO and Conservation d'Angkor. WMF plans to develop a sculpture inventory specific to Preah Khan, and expand it as necessary by further checking inventories of various museum collections. Such an inventory will prove critical to any interpretative plan for Preah Khan.

Archaeological Research

Only samples of below ground archaeology have been made to date at Preah Khan. Although extensive archaeology may not presently be considered a priority, a carefully planned archaeological program for the site should be formulated to address the following:

- the overall archaeological parameters of Preah Khan based on historical and archival research,

- a *sondage* program which attempts to verify suppositions made as a result of the above steps, and

- a series of archaeological campaigns intended to
  a) further aid the architectural conservation process,
  b) expand the present knowledge on the use of the site, and
  c) search for elements which have been lost over time.

A particularly promising idea for archaeological investigation at Preah Khan would be to investigate areas where the average inhabitants lived, whose structures were presumably built of the more perishable materials of wood, thatch and mud brick.

Investigation of the Hydrological System

Preah Khan is surrounded by a rather clearly defined moat which in parts still contains water. This moat and the sources (past and present) of its water supply should be studied by qualified hydrological experts for the following reasons in particular:

- to fully understand the role water played at Preah Khan and its environs when the system functioned;

- to try and understand the effect of the moat and nearby *barays* on the ground water level at Preah Khan, and its various structural implications, (e.g., load-bearing capacity); and

- to investigate the feasibility and desirability of reactivating at least parts of the moat system for ecological and/or site interpretative purposes.

Conducting a Comprehensive Study of Flora and Fauna

Preah Khan is located near the edge of the Historic City of Angkor and is more remote to visitors than the more frequently visited sites of Angkor Wat and Angkor Thom. It is an advantage for Preah Khan that its surrounding forests are almost completely intact, thus making it an ideal area for the study of indigenous flora and fauna. Unfortunately, nearly all forms of wildlife have been killed off in the area in recent years, but comparative studies of other regions and historical accounts would still make a formal study possible. Only the most preliminary observations of the plant history of the site and its present condition have been made to date (see Appendix E). Such a study should be systematic and scientific for the purpose of both documentation and for its potential use in the envisioned interpretative program for the site. Experts from the ecological research laboratories of the University of Toulouse (France) have been proposed for conducting this research.

Plans for the future conservation and interpretation of Preah Khan should definitely take into account its special ecological situation and the potential for reintroducing and protecting certain types of wildlife (i.e., gibbon, parrot) indigenous to the area.

A Site Interpretation Plan

On-site interpretative aids are completely absent from Angkor today. The conservation program for Preah Khan should have, as an integral part, plans for site interpretation including:

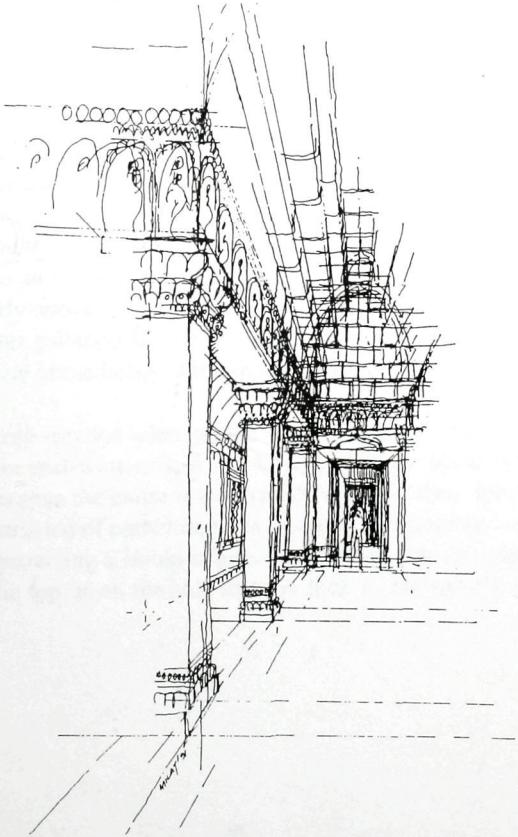
- Plans of Preah Khan which effectively show its overall form, historical evolution, special points of interest. In addition, a recommended visitors walking route would do much to heighten appreciation of the monumental remains of Preah Khan. Lists and diagrams could explain artistic, architectural and environmental aspects of the site.

- Architectural drawing reconstructions. Both the interior and exterior appearances of at least parts of Preah Khan should be reconstructed on paper by qualified researchers and capable illustrators. These conjectural diagrams should then be made available for site interpretation purposes.

- An appropriately designed and placed interpretative building should be considered. Its design should be as simple and unobtrusive as possible. Interpretive displays could eventually be placed in shelters which initially will be necessary to protect building equipment used in the conservation/restoration program. Alternately, the enclosure could be provided by parts of the actual ruins such as the end of a corridor or an entire gopura. In any case, exhibitry would need to be durable e.g., baked enamel or glazed tile panels for illustrations, and sculptural facsimiles in cast stone.

APPENDICES

A. Conditions Survey
B. Building Materials Analytical Report
C. Soil Composition Analyses at Preah Khan
D. Botanical Observations
F. Field Documentation Systems
G. Constructional Sequence
H. Structural Components
I. Survey of East Gopura
J. Photographic Recording Methodology



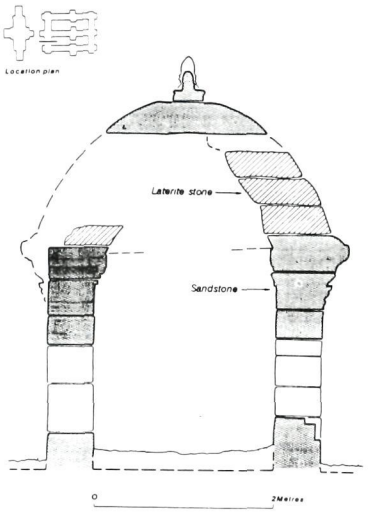
APPENDIX A

PREAH KHAN CONDITIONS SURVEY

by Fred Aldsworth

Roofs

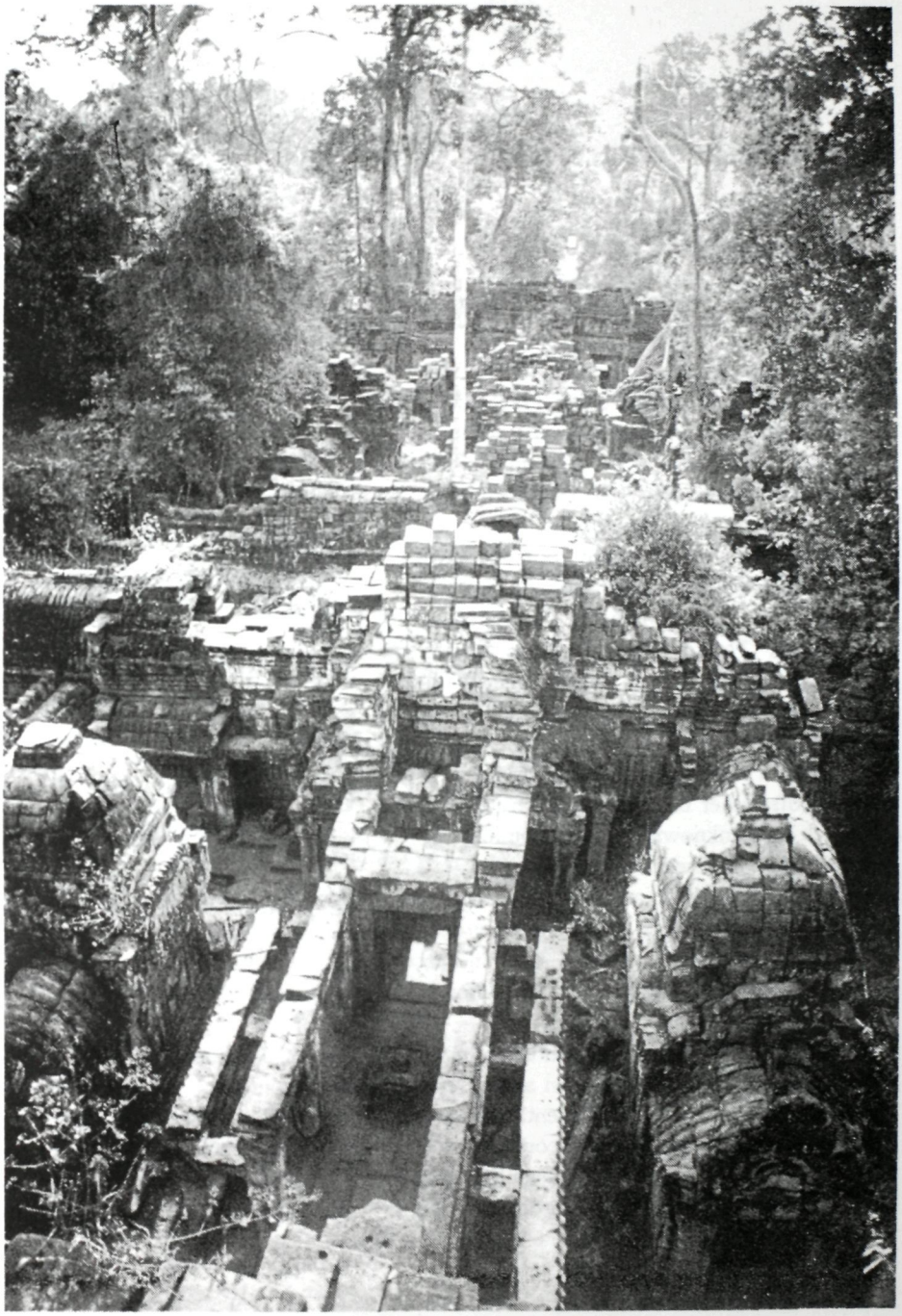
A survey was made of the condition of the roofed structures of the entire Preah Khan temple complex within the inner Enclosure Wall I. The results of this survey are shown in the Research and Documentation Section of this Report. The plan distinguishes areas where roofs survive intact (hatched diagonally) from those areas where they have collapsed (shown cross hatched). The few areas not accessible at the time of the survey are indicated with black squares.



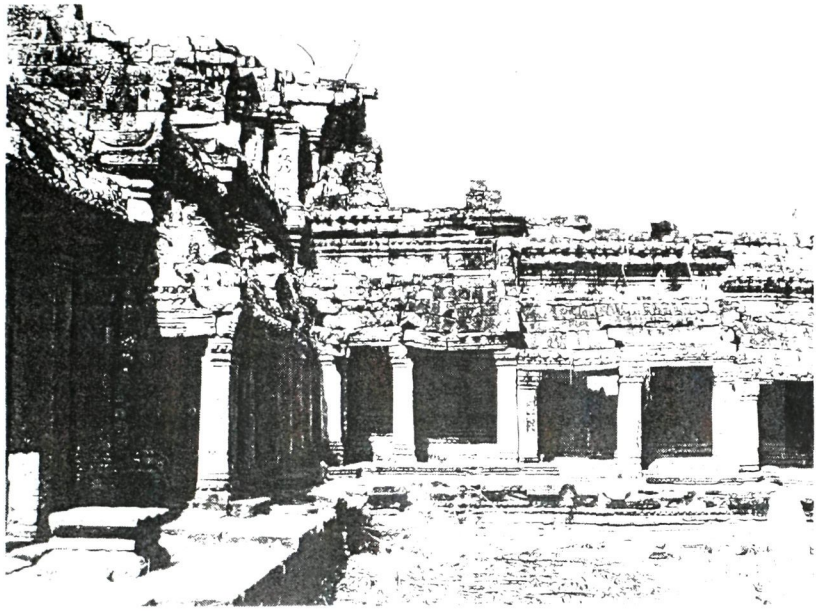
Diagrammatic Section, Through the West Minor Temple Complex

The use of corbelling for the construction of the roofs rather than use of the true arch, which was unknown to Khmer builders at this period, has meant that the entire complex is subject to an inherent weakness due to this sub-optimal vault construction technique, particularly above the larger openings. It is significant that while virtually the whole of the outer gallery added in Phase IV has collapsed, the narrower gallery added at the same time immediately adjoining it on the inside is substantially intact.

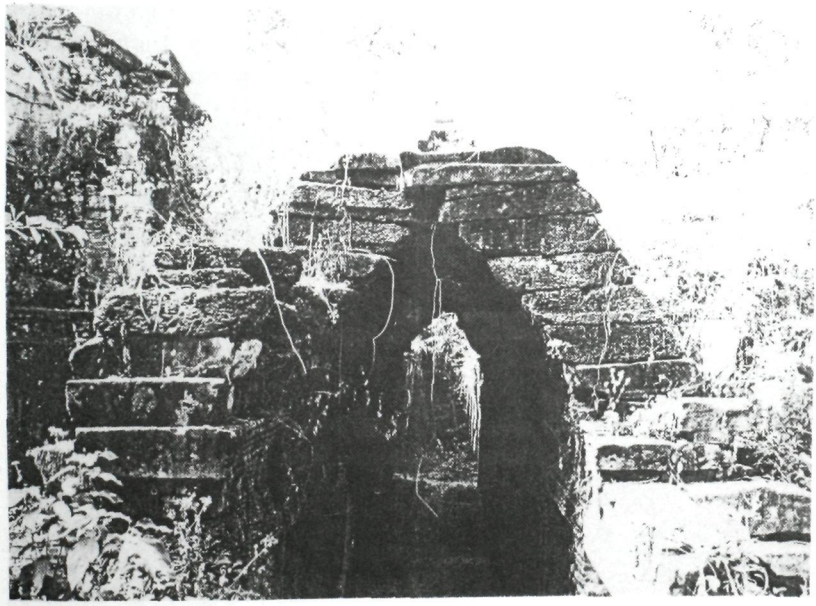
In the generalized cross-section taken on the west side of the inner enclosure, just to the north of the main east-west axis, it can be seen that the stone slabs capping the smaller side galleries span the entire space beneath them, whereas the roof of the high outer gallery is constructed of corbelled slabs which to some extent interlock laterally with rebated joints providing a stable structure only when it is complete. As soon as damage occurs at the top or on the side there is little to prevent the entire structure from falling.



Roof Conditions Along East-West Axis of Preah Khan, (March 1991)



Roof Conditions at East Gopura



Roof of East Gallery

Collapsed Masonry, Trees and Access

A survey was made of the distribution of the collapsed masonry and the mature trees within the main building complex and the results are presented here in diagrammatic form. (See Section 2: "Documentation.")

The plan distinguishes *collapsed masonry* (hatched) and *trees* (black dots) affecting the structure. In order to indicate how these features inhibit access, the main routes through the buildings have been highlighted.

The volume of collapsed masonry in any particular area has been classified as being either up to one meter in height (hatched diagonally) or over one meter in height (cross hatched). Access routes are, for the most part, blocked along the outer gallery and the main passages.

The areas both immediately outside the outer enclosing wall and between the outer and inner walls, are covered in vegetation consisting of small trees, bushes and grass. Within the entire complex there are a number of mature trees, mostly fig, and some of these are growing on the walls, roofs, and within passageways (large dots) while the roots of others (small dots) may be adversely affecting the structure.

Since it limits visual enjoyment of the structure, the smaller vegetation growth can easily and cheaply be removed to improve both access and visibility. During Mission III considerable areas around the east and west gopuras and along the inside and outside of the Enclosure Wall I were cleared of minor vegetation growth. The approach to the west gopura - currently the main visitor access - was also cleared of vegetation.

The long term conservation and presentation of the site require that insecure *in-situ* masonry be made safe; collapsed masonry be cleared; and possibly that some mature trees be removed.

Ficus Tree on East Gopura, 1991.

APPENDIX B

COMPUTERIZED ARCHITECTURAL INVENTORY DEVELOPMENT

Sophia University/World Monuments Fund Joint Efforts - Progress Meeting Notes

by Yoshiaki Fujiki

The purpose of the Building Inventory Division of the "Seventh Sophia University International Survey Mission for the Study and Preservation of the Angkor Monuments" was to further develop a field recording form for the inventory, and to survey the front colonnaded hall of Banteay Kdei. The field recording form was studied and discussed before the Fifth Survey and two major issues arose: the purpose of the inventory, and the terms to be used. In connection with these issues, the Sophia University team received many helpful suggestions from three members; John Sanday, Lori Anglin and Scott Cunliffe, at the time of the fifth Survey. In addition, Mr. John Sanday visited Japan before the start of the Seventh International Survey and presented a revised set of forms based on those prepared by WMF during the Sophia Fifth Survey. These forms were most helpful in the formulation of a revised inventory form made by the Sophia University team. Based on this process, during the Seventh Survey, the Sophia University team performed the survey of the front colonnaded hall of Banteay Kdei and discussed it with WMF during the March 1992 joint mission.

During the course of the meeting, the Sophia University team presented its own field recording form and tried to combine its contribution with WMF's latest computerized architectural record inventory form. The Sophia University team pointed out that, for some time, the WMF's form had given too much weight to conservation, that it was insufficient for the study of the architectural style and history. Furthermore, WMF's form did not seem to adequately take into account architectural details such as the shapes of reveals and free-standing columns.

The Sophia University team's field recording form divides the inventory into three sections: *Total Complex, Each Building within the Complex* and *Elements of the Building*, expecting that it will be useful for both the study of architecture and history *and* conservation.

Complete concurrence on the two inventory systems being developed could not be attained during the March 1992 mission; however, significant progress was made in completing the building inventory. It should be noted that valuable suggestions were given by Mr. John H. Stubbs from WMF, regarding the terminological problems of architectural style and structural forms.

APPENDIX C

Building Materials Analytical Report

Analytical Report

Requester: Frank Preusser/Corneille Jest

Reference Number: ED/AW-1

Sample Number: AW-1

Sample Information: Sandstone sample collected at the temple of Pre Rup, Angkor, Cambodia by Mr. Jean Michel André. Sample given to Frank Preusser for analysis at The GCI by Corneille Jest.

Problem/Request:
Determine if *Thiobacilli* are causing extensive deterioration of the sandstone used in the temples at Angkor.

Background:
Thiobacilli are a group of bacteria that use SO_2 in the air as an energy source. Some researchers believe that they are important in the development of gypsum crusts on limestone and marble monuments in polluted environments (Hansen, 1980).

Analytical Strategy:
Samples of the weathered surface of the sandstone sample AW-1 were put in a damp atmosphere for 24 hours to allow dry organic materials to assume their normal shapes. The weathered surfaces of these samples were then examined using the binocular microscope and the Environmental SEM (see attached paper). No further preparation was needed for samples imaged in the E-SEM. Weathered surfaces were studied for evidence of extensive microbial growth. If *Thiobacilli* are playing a major role in the deterioration of the Angkor sandstone they should be present in substantial numbers on the sample surface.

Two standard petrographic thin sections of the weathered face were also prepared. One cross section was examined using a standard petrographic microscope for mineralogy and texture. The other section was coated with

carbon and analyzed in the electron microprobe to document fine-grained components and features that are not easily studied with the optical microscope. The uncoated section was examined using the UV microscope to search for the presence of fluorescent organic compounds that might indicate concentrations of organic material. The hand specimen was also examined under short and long wavelength UV radiation for the same purpose. Previous experience has shown that UV fluorescence is useful in discriminating some types of organic residues on weathered stone.

Results

No fluorescent compounds were found on the weathered sandstone surface or in the cross section sample. A dark surface was noted on one of the sandstone samples that appears to be the result of fungal growth (Figures 1-8). The species of the fungi were not identified, but appear to be similar to those studied by other researchers. Occasional rod-shaped bacteria were found associated with the fungi (Figure 7). No large concentrations of *Thiobacilli* were found in any sample. No sulfur containing minerals or organic material were found.

The biological growth found on the sandstone suggests that some biodeterioration is taking place by the action of fungi. However, part of the overall deterioration appears to be due to the chemical weathering of unstable minerals within the sandstone.

Sandstone composition, texture and name:
This sandstone is a Feldspathic Litharenite (Folk, 1968) or Lithic Greywacke (Pettijohn, 1957) composed of approximately 65% quartz grains, 10% rock fragments, 5% biotite and 20% feldspar (Figures 9-20). It is composed of fine to medium sized sand particles, 100-500 microns in diameter. The porosity is moderate and variable at 8-16%. The biotite grains are responsible for the green color (Figures 17 and 19). Several different types of feldspar are present in the sandstone, including plagioclase, microperthite, albite (unstable sodium feldspar), microcline and potassium feldspar (Figures 10 and 20). The grain sorting is good and the grains are angular to sub-rounded in shape. The main cement phase is quartz, with overgrowths joining the abundant detrital quartz grains (Figure 11). Among the accessory minerals present are zircon, ilmenite, magnetite, and hornblende. Fine-grained goethite (hydrated iron oxide) is common in the interstices of the stone as a weathering product of more

unstable minerals such as feldspar and rock fragments (Figure 14). Some feldspar grains have altered to illite (Figure 15) or are in the process of dissolution (Figures 13 and 14).

Interpretation

There does not appear to be any evidence for large colonies of *Thiobacilli* in this sandstone sample from the Pre Rup temple at Angkor, Cambodia. The lack of any sulfur also suggests that *Thiobacilli* are not present in this sample. However, there is evidence for biodeterioration by fungi and chemical weathering of unstable minerals.

Discussion

Biodeterioration has received a great deal of attention over the last decade (Koestler, 1991; Hansen, 1980). Krumbein and others (1991) have shown that bio-pitting by lichen and fungi are important stone deterioration mechanisms. However, other studies of microbial communities in stone have not been able to link important changes in the stone to the action of microorganisms (Pentecost and Terry, 1988; Saiz-Jimenez and others, 1990). Therefore, we must better understand the impact of biology on the physical and chemical processes that lead to deterioration before we place great emphasis on the elimination of microbial communities from stone monuments. Slowing the chemical weathering of the stone, which affects its mechanical stability, may be more important than the elimination of the surface fungi and organic layers.

Suggested additional analyses:

It would be useful to transfer some of the fungi to organic media in order to grow enough for positive identification.

Analyst:

Eric Doehne

Eric Doehne

Date: March 18, 1992

APPENDIX D

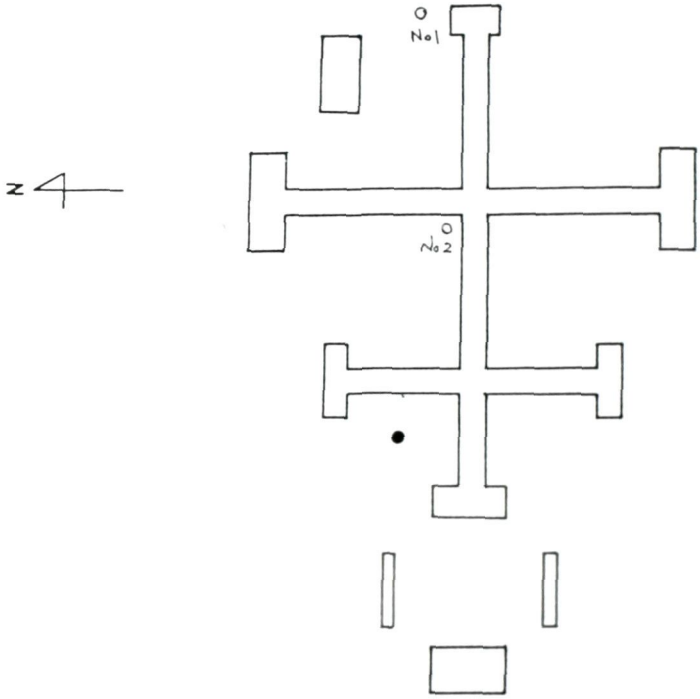
SOIL COMPOSITION ANALYSES AT PREAH KHAN

by Tomio Moriai

After a first auger boring at Preah Khan in March 1991, the soils engineering team from Sophia University decided to bore the ground in the following two places in March 1992: the north side of the east gopura and the southwest courtyard of the central tower (See illus.). The results of the borings are as show below:

1992 No. 1 Auger (unit: cm.)

0 - 40	Conglomerate, sandy soil and surface soil
40 - 80	White gray sandy soil
80 - 200	White-gray sandy soil containing laterite reddish soil
140	pH 6.1
150	pH 6.1
160	pH 6.2
170	pH 6.2
200 - 240	White-gray sandy soil containing a small quantity of laterite reddish soil
200	pH 6.1
220	(Note 1) -- Quartz, kaoline
240 - 280	White-gray sandy soil containing laterite reddish soil
240	pH 6.6
250	pH 5.8
280	(Note 2) Quartz, kaoline pH 4.7
280 - 310	White-gray sandy soil
280	pH 4.6
310 - 350	White-gray sandy soil containing laterite reddish soil
310	pH 5.0 (ground water, PH 4.6 (soil)
320	pH 4.7 (fine gravel containing breccia medium-grained sandstone)
330	pH 5.8
350	pH 5.6
350 - 430	Laterite reddish soil containing white-gray sandy soil
370	(Note 3) Goethite, kaoline and quartz, pH 6.0 (Reddish soil), pH 5.7 (white-gray soil)
380	pH 6.5
410	pH 6.5
430	pH 6.5



オーガー位置図（プリヤ・カーン）

● 1991.3月
○ 1992.3月

Auger Boring Points in Preah Khan, 1991 & 1992

1992 No. 2 Auger

0 - 50	Laterite reddish sandy soil and sand
50 or more	Laterite pavement (further boring was impossible)

The Results of X-ray Analysis

The major results of the X-ray analysis at each depth of 2.20 m, 2.80 m and 3.70 m in the first boring in March 1992 are as shown below. (Unit: cm)

220: White-gray sandy soil. The majority is composed of quartz (about 90%) and kaoline (about 5%)

280: White-gray sandy soil containing quartz (about 75%) and a larger amount of kaoline (about 20%) when compared to the above.

370: Laterite reddish soil containing quartz (about 70%), goethite (about 15%) and kaoline (about 15%). It also contains a small quantity of goethite and iron hydroxide which reddens the soil.

For further details on the results of the first auger boring in 1991 and the x-ray analysis, refer to pages 50 and 291 of "Renaissance Culturelle du Cambodge (5)." The results of the x-ray analysis are shown in the attached data. From this X-ray analysis, it was found that in the white part of the ground Fe and Al are elluviated, a large amount of quartz kaoline exists, and in the red part, goethite and hematite have been generated.

Since there is concern about consolidation settlement in areas of Preah Khan, it was desirable to carry out soil tests.

From the results of No 1 and No. 2 borings, the ground can be classified into three layers; A, B and C. (Unit: cm)

Layer A	0 - 40 (50)	Surface soil and upper sand/red soil layer
Layer B	40 - 350	White gray sandy soil layer containing laterite reddish soil
Layer C	350 - 430	Laterite reddish soil layer containing white-gray sandy soil

When compared to the results of the auger boring performed at the west side of the monument in March 1991, nearly the same soil composition can be seen.

The ground water level found in the No. 1 boring in 1992 was relatively narrow, 3.10 m from the ground surface, because the boring was carried out in the dry season. It is expected to rise to levels approaching the ground surface, although no measurement has been carried out in the rainy season. At the time of the auger boring in 1991, the measuring result was 4.10m which was deeper than that found this year, however the ground water level is expected to rise considerably.

The measured pH values of soil samples collected during the survey in Marcy 1992 are included in the range from 4.6 to 6.5, proving acid soil. The pH value of the ground water was 5.0. Based upon these values and upon the analyses which were performed, the following inferences can be drawn:

1. The white-gray sandy soil layer was possibly whitened by the acid water, and as a result Fe and Al are elluviated. To find more definitive causes for the acidification of the soil and water, further survey work will be required.

2. The white-gray sandy soil layer has been formed as mentioned above, and it is hoped that such a formation may provide some indication to the reason for the rise and fall of the ground water level, which can be estimated to be in the vicinity of 3m.

3. The laterite reddish soil layer other than the surface soil is supposed to have been formed as a result of elluviation of Fe and Al.

4. Due to the repeated rise and fall of the ground water level in the range of 3 to 4m over a long period of time, soil particles have turned to clay and have whitened (x-ray analysis found a large quantity of kaoline clay). Parts saturated by ground water tend to be drier than their dry counterparts. Relatively soft foundation stones can destroy the monuments due to poor load-bearing capacity and ensuring differential settlement. Differential settlement was observed in several places at the periphery of the monuments.

5. A strong correlation between pH values and the growth of plants can be assumed, thus it is also important to continue the soil survey as an environmental issue.

Note 1: X-ray analysis in 1992 Preah Khan 2.2m
Note 2: X-ray analysis in 1992 Preah Khan 2.8m
Note 3: X-ray analysis in 1992 Preah Khan 3.7m

The following documents are on file in the WMF offices in New York:
Fig. 1 Location of auger borings; Fig. 2 Columnar section; X-ray diffraction charts, 1 chart in 1991 and 2 charts in 1992.

APPENDIX E

INITIAL OBSERVATIONS ON THE BOTANICAL ENVIRONMENT AT PREAH KHAN

by Jun Yokoyama

General Observations

Although most of the Historic City of Angkor has been deforested, the forest remains at Preah Khan are in relatively good condition. The canopy consists of six major species such as *Dipterocarpus alatus* and about 250 species of other tall plants. Three layers were recognized in this forest: a tree layer (30-40m), a shrub layer (less than 10m), and a herbaceous layer. Epiphytic plants were also observed relatively frequently compared to what is found at other parts in the Angkor complex. Owing to partial cutting of the forest at Preah Khan , however, the canopy was discontinuous . Trees, the height of which was between the tree layer and the shrub layer ,were scarcely observed. Furthermore, weedy plants such as *Chromolaena odorata* exist in the areas of relatively recent tree cutting, resulting in a remarkable simplification of forest structure.

Effects of Plants on the Monument

Plants of various growth forms were observed on the remains of the Preah Khan monument. Among these, trees have had the most serious effect on the buildings. Their direct effects, such as the destruction of parts of the stone complex by growing roots, are obvious. Indirect effects such as providing epiphytic plants and linane with fallen foliage, which turns into nutrients, is also important to consider from the standpoint of monuments conservation. Many seedlings of the species constituting the canopy of forest were observed on the monument. *Tetrameles nudiflora* is one of several species which seems to have a serious effect on the monument. These trees grow up to 30m in height and probably have extremely high growth rates compared to other tree species. About thirty examples of this species were observed inside the inner wall of Preah Khan. However, all of them are mature and, in fact, some may have died. The number of young trees or seedlings of this species could not be determined during this investigation. The monument will not suffer further direct effects from these trees except perhaps from those which have died, which may cause damage when falling. Lichens and algae have had certain effects on the monuments which would require a separate survey.

Considering the great quantity and increasing rate of biomass, it is very important to consider the higher plant community around the monuments in all future conservation plans for the site.

Suggested Conservation Policy for Forest at Preah Khan

As described above, deforestation of the Angkor complex is very extensive. Forest remains should be conserved from the viewpoint of protection of the environment and wildlife. The best condition for protecting the forest is to remove all artificial effects, i.e., cut nothing. This however, is impracticable since the monuments would soon be buried again in deep forest. In order for both natural forest and man-made monuments to coexist, the areas of forest brought under control should be kept at an absolute minimum. Since it is very difficult to keep such a large area as Preah Khan free from any plants, it is appropriate that removal of vegetation and maintenance of this condition be largely restricted to the inside portion of the temple walls. Although the size of this area will vary with the scale of the proposed restoration, this area within the conserved monuments should have weeds and seedlings of trees removed periodically.

The vegetation outside the innermost enclosure walls should be conserved as much as possible, although the hazards of live trees falling as a result of natural factors should be considered. Therefore, a buffer zone should be established of intermediate height between the tree layer and the shrub layer. The height of vegetation, including trees, should gradually increase in relation to their distance from the architectural remains. Such types of forests can be maintained also by selective pruning. The other parts of the forest should be kept free from any artificial effects such as selective cutting.

People live near Preah Khan and use its forest in various ways to survive. Their actions should be allowed except for the cutting of large trees. Tropical forests such as those found at Angkor are very complicated and are scarcely understood. Therefore, ecological studies must be continued from various points of view. These studies should include an analysis of wildlife that exists ,or that was known to have existed, and its role in the ecosystem of Preah Khan's surrounding forests.

APPENDIX F

by Fred Aldsworth

FIELD DOCUMENTATION SYSTEMS

The Preah Khan Conservation Project will require field documentation of various types of information, both for repair purposes and academic research.

The Graphic Record

With help from students of the Department of Architecture and Archaeology, University of Beaux Arts, Phnom Penh, the WMF team ran field trials and were able to agree on a system for the production of graphic records of components of the temple complex which can be used as a basis for further documentation as may be required by architects, historian s and archaeologists.

Levels

Commencing at an arbitrary datum of 10 meters on the east gopura, a series of levels were taken throughout the length of the main east-west corridor and individual spot height values were marked on the ground. A ground level profile along this axis was prepared. This survey will provide the basis for all future work on the site.

Levels were also taken at three points to compare their relative heights in association with trial boreholes made for soil sampling purposes. (See Appendix D). The results were as follows:

Ground level in possible pond area to north-east of east gopura - 7.05m
Ground level in possible pond area to north-west of west gopura - 7.14m
Ground level north-west of central tower - 9.07m

Elevations

The 10 meter datum was marked as a continuous line in white chalk on all the external elevations of the east gopura and a series of photographs were taken with a 35mm camera giving minimal vertical distortion wherever possible.

The building was carefully measured with a steel tape from center lines established on the ground and at the level of the 10 meter datum. The dimensions derived are used to provide scaled enlargements of the photographs in both color and black and white using a photocopy machine with percentage enlargement and reduction facility. The photographs provide a record of the structure prior to any intervention and the enlargements provide the basis for specifying repairs and documenting alterations, without the need for time consuming and expensive full elevation drawings.

Plans and Section

The almost consistently rectangular form and symmetry of the temple structures renders the need for further overall survey almost superfluous. Individual structures and special details should be drawn in the detail where the above mentioned scale-rectified photographic survey method is not possible. Scales of 1:100 for plans and 1:20 and 1:50 for sections seem appropriate.

APPENDIX G

by Fred Aldsworth

THE CONSTRUCTIONAL SEQUENCE OF PREAH KHAN

Preliminary attempts have been made by Stierlin (1970) and Hawixbrock (1991) to establish the constructional sequence (morphological growth) of the entire complex on artistic grounds and to distinguish areas where the decoration is either Buddhist or Hindu in style. See also *Report 2 – Preah Khan Project Identification.*

The constructional sequence, as currently understood, is presented here in diagrammatic form in Section 2: "Documentation" of this Report but it is obvious by comparing this with some of the structural components identified in this Mission that a full understanding of the development of the temple complex has yet to be achieved.

The two "library" structures immediately adjoining the west wall of the "Hall of Dancers," for example, have yet to be firmly placed in the architectural development of the site, but the one to the north appears to predate the west wall of the hall which itself is thought to have been constructed in Phase 1.

Statement of Intent

WMF recognizes the importance of this aspect of its work at Preah Khan and intends to ensure that further research is undertaken in order to secure a full understanding of the architectural evolution of the site. See Section 7: "Recommendations for Future Studies" section of this Report. WMF proposes that any conservation work which is undertaken not involve any interventions to the architectural fabric which could adversely affect the historical integrity of the buildings.

APPENDIX H

THE STRUCTURAL COMPONENTS

A preliminary attempt has been made to distinguish the principal structural components of the temple complex in order that the building characteristics, artistic style and date for each may be ascertained. From this and other information which will become available as the project proceeds, it will be possible to determine with some certainty the chronological development of the complex. A preliminary attempt to do this has already been made on artistic grounds.

However, a preliminary study of the temple during the Mission identified a number of important structural alterations which appear not to have been previously noted See Section 2: "Documentation" of this Report.

The minor temple complexes to the north, south, and west of the central area have previously been considered each to belong to Phase 1 of the construction sequence, but each includes linking structures which were clearly added at a later date. This suggests that the central component of each was originally free-standing.

A similar arrangement may originally have existed with a free-standing tower at the center of the main temple. The mortise holes around it were clearly intended for much larger pillars than those presently used and which now form part of the present linking covered ways .

Linking passageways on all four sides of the central area are constructed, unlike the towers, of laterite stone and may also be later additions.

Statement of Intent

The WMF conservation program will recognize and respect the evidence of previous building alterations and additions as they are considered changes over time which should be part of the overall site interpretation.

APPENDIX I

SURVEY OF THE EAST GOPURA

During Mission III the East Gopura at Preah Khan was surveyed in some detail with the assistance of students from the Department of Architecture and Archaeology, Phnom Penh.

A ground plan was prepared at a scale of 1:100, two sections were measured and drawn at 1:20 and the external elevations were photographically documented as a record of the condition of the building and for the production of scaled photographs to be used as conservation plan documents instead of full elevation drawings.

Based upon above-grade observation, there is no evidence to indicate that the gopura was constructed in phases.

APPENDIX J

PHOTOGRAPHIC RECORDING METHODOLOGY

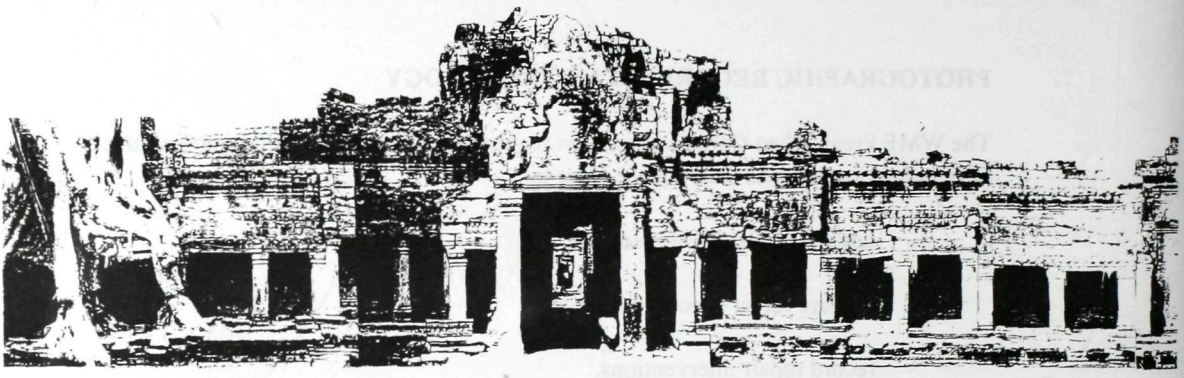
The WMF Preah Khan Conservation Plan requires the use of information in the form of photographs and line drawings in order to:

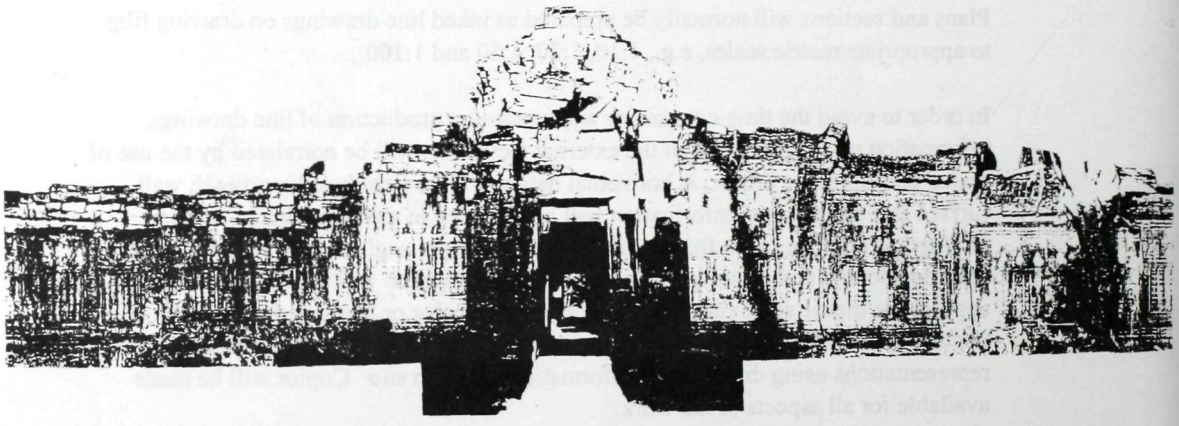
- undertake historical research,
- prepare repair specifications, and
- record repair interventions.

Plans and sections will normally be prepared as inked line drawings on drawing film to appropriate metric scales, e.g., 1:10, 1:20, 1:50 and 1:100.

In order to avoid the time-consuming and expensive production of line drawings, information relating to work on the external elevations will be correlated by the use of scaled photographic prints. A horizontal datum will be introduced onto each wall surface and dimensional information will be recorded in a site notebook. Color photographs will be taken from a suitable point at right angles to the wall face and after developing and printing the scale of each photograph will be rectified to an appropriate metric scale (usually 1:50), as either a color or black and white print on a photocopy machine. The scaled photographs will then be mounted as full elevational representations using dimensional information taken on site. Copies will be made available for all aspects of the work.

A full photographic record will be made prior to, during, and after repairs.





Composition of Scale Rectified Photographs Depicting East & West Elevations of East Gopura III (1992)

The WMF Mission III Team (March 1992)