WATER MANAGEMENT OF TA PHROM TEMPLE COMPLEX, CAMBODIA FOR SUSTAINABLE ECOSYSTEM

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SYNOPSIS

Ta Phrom temple in the Siem Reap Province of Cambodia is one of the main tourist attractions. Built in the late 12^{th} and early 13^{th} Century AD by King Jayavarman, it is visited by over 1 million tourists every year. After the fall of the Khmer Empire in the 17^{th} Century the temple remained abandoned and neglected for several centuries. As a result, dense forest grew in and around the temple complex with roots of large trees finding their way though numerous cracks in various parts of the structure, some roots even extending spectacularly from the roof to the court yards down below spreading intricate networks on the walls. Though the entire temple complex is in a highly dilapidated condition, it has been deliberately left without major repairs for the tourists to have a physical feel of the “harmony between man and nature”.

The vast network of roots on the ground and dislodged stones from the crumbling structures have blocked most of the original drainage system. This causes extensive inundation of many parts of the complex during rainy season further endangering the structures. As part of conservation of this UNESCO Heritage Site, it is proposed to construct a sub-surface drainage system without disturbing the foundation of structures and the root system. Under the partnership project of Archaeological Survey of India and APSARA (Authority for Protection and Management of Ankor and the Region of Siem Reap) a Detailed Project Report (DPR) has been prepared after carrying out extensive GPR surveys to locate the location and depth of roots and underground structural elements.

The DPR envisages state-of-art trenchless technology of underground boring and simultaneous installation of drainage pipes together with construction of Sinks, Collection Chambers and Connecting links with the Moats outside the Complex for final disposal. The Project, to be implemented by WAPCOS Ltd. will meet the essential requirement of storm water management with sustainable ecosystem.

1.0 BACKGROUND

TA Phrom Temple in the Siem Reap province of Cambodia is one of the main tourist attractions. Built in the late 12th and early 13th Century AD by the Khmer King Jayavarman, it is visited by over 1 million tourists every year.

Ta Prohm is a series of long, low buildings at almost the same level, connected by passages and concentric galleries framing the main sanctuary. A rectangular wall made from laterite blocks surrounds it. It has entrance gates on all four sides but only the East and West entrance gates are in use. Inside the complex there is yet another boundary wall enclosing the main temple. A moat about 40m wide and 4m deep surrounds this boundary wall. Further inside, the main temple structure is surrounded on North and South side by two L-shaped inner moats of roughly the same dimensions.

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This causes extensive inundation of many parts of the complex during rainy season further endangering the structures. As part of conservation of this UNESCO Heritage Site, it is proposed to construct a drainage system without disturbing the foundation of structures and the root system. This work is to be done under the partnership project of Archaeological Survey of India (ASI) and APSARA (Authority for Protection and Management of Ankor and the Region of Siem Reap). The ASI has entrusted the entire work from concept-to-commissioning to WAPCOS Ltd, a Government of India Undertaking under the Ministry of Water Resources.

A multi-disciplinary team of experts of WAPCOS carried out extensive reconnaissance of the temple complex to make a preliminary assessment of the problems, their causes and the constraints in planning, design and implementation of the various feasible measures. Following major constraints were identified.

(i) Most of the original drainage system is not traceable
(ii) Due to extensive network of tree roots, both on ground surface and underground and piles of stone blocks from the crumbling structures construction of a surface drainage system is not feasible.
(iii) Where ever feasible, open excavation for surface drains would need to be done with extreme precaution.

In view of the above it was decided to carry out an extensive GPR survey to identify the location and depth of tree roots and underground structural elements so that a drainage system comprising of both surface and sub-surface drains may be planned and designed.

2.0 GPR SURVEY

A detailed topographical survey of the entire temple complex was carried out extending it upto the nearest natural drainages outside the complex. Based on the topographic maps, lines for GPR survey were marked on the ground. GPR equipment was then moved along these lines to record the location and depth of tree roots and underground components of the structures. It was found from this survey that 98% of the roots were at a depth of upto 1m below the ground and no roots were deeper than 2m.

3.0 DETAILED PROJECT REPORT

Based on the GPR survey a DPR has been prepared giving layout of sub-surface and surface drainage network together with all relevant technical details.

The drainage works would mainly consist of an underground piped drainage system within the temple enclosures. It is proposed to collect this water and drain it out into the inner moats from where it would be finally drained into the Outer Moats. This will be done by a combination of i) Sinks ii) Collection chambers and iii) Pipe lines installed utilizing the techniques of Trenchless technology.

The drainage mitigation works would be implemented in 2 phases viz Phase-I and II.

4.0 PHASE-I WORKS

These would mainly consist of:

(i) Blocking of surface drain entering the complex from the North-east corner by a Diversion Bund (DB) and the construction of a Outer Diversion Drain (ODD) to connect this existing drain to the Siem Reap river through a culvert.

(ii) Land drainage of the large ground area within the periphery wall, but outside the temple enclosures through a drain, two shafts and underground tunneling and a small connection from the second shaft to the existing stream.

(iii) Other drains for interconnecting the various low, swampy water bodies in this area to each other and to the outer moat.

(iv) Three connecting drains for connecting the inner moat, the in ner ponds and the outer moat.

(v) Reconstruction of a culvert for passing larger discharges, and remodeling of the existing stream upto the Siem Reap river.

(vi) Construction of an underground piped drainage system within the temple enclosures to collect the water and drain it out into the inner moat. This will be done by a combination of i) Sinks ii) Perforated pipe line installed by cut and cover method iii) Collection chambers and iv) Pipe lines installed using the Trenchless Technology.

Sinks

About 26 sinks will be provided at the selected low-lying areas. The surface water will enter into the network of pipes through these sinks. They will be circular in shape and will allow the clear water to go into the pipeline below, trapping the silt, which will be collected in a trap and removed from time to time.

Perforated Pipeline installed by cut and cover method

An open trench about 442 m long, 0.5m wide and of required depth will be excavated manually along the lines connecting sinks. Care will be taken to see that tree roots are not damaged in the process of excavation. Once the excavated trenches reach the required level, steel pipes of 200mm dia with perforations in the top half portion will be installed in the trench. A geo-textile filter will be provided on top of perforations. Proper connection of vertical shafts acting as sinks and pipeline has been designed. After the entire work of installing pipes and sinks is over, the trench will be filled back and the passage will be restored to its original condition.

Collection Chambers

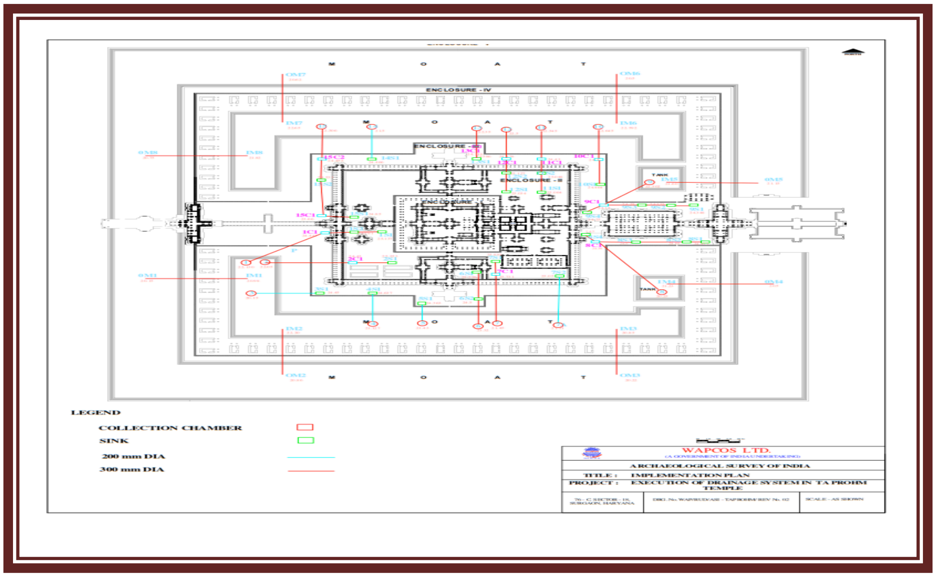
These chambers will collect all the water from the pipelines. The chambers will be constructed with local brick and a concrete floor. The slopes of the bed over which the pipeline is laid will be designed accordingly. The chambers will have dimensions of 2m x 1m x depth (varies).

4.1 Pipe line Installation by Technique of Trenchless Technology

The total Pipe length of 760 m will be used for connecting sinks and collection chambers with the outlets in Inner Moat. The additional length of 400 m will be used for connecting the inner moat with outer Moats. Care will be taken to see that tree roots are not damaged in the process. Mild steel pipes of 200 mm and 300 mm dia with inside coating of Epoxy Paint will be installed. The 200 mm pipes shall generally be laid at 1/150 slope whereas 300 mm pipes shall be laid at 1/250 slope. In order to avoid the backflow of water in the Pipelines and over flow of the inner moat, the excess water from inner moat will be drained into the outer moat with Mild Steel Pipes.

4.2 General Layout

The drainage system comprises of 15 main lines comprising the lines connecting sinks to chambers and chambers to Inner Moat, laid by Trenchless Technology. The Drainage System also envisages 8 mainlines from Inner Moat to Outer Moat. The complete network comprises of 27 sinks and 11 collection chambers. The detailed layout of the drainage pipeline system from temple to moats/tank is as under:



Complex Drainage System Layout

4.3 Details of Proposed Pipelines

The diameter and length of the 15 pipelines upto the inner moats and those of 8 pipelines from the inner moats to outer moats are given in Table 1 and Table 2.

Table 1: Length and Diameter of Steel Pipelines Proposed upto Inner Moat

	Length of 200mm Dia Pipe	Length of 300 mm Dia Pipe
Mainline 1	0	61
Mainline 2	0	53
Mainline 3	28	0
Mainline 4	25	0
Mainline 5	15	0
Mainline 6	0	44
Mainline 7	0	50
Mainline 7A	43	0
Mainline 8	0	92
Mainline 9	0	68
Mainline 10	0	48
Mainline 11	0	51
Mainline 12	0	49
Mainline 13	0	23
Mainline 14	26	0
Mainline 15	0	84
Total	**137**	**623**

Table 2: Length and Diameter of Steel Pipelines from Inner Moat to Outer Moat

From	To	Length (m)	Dia (mm)
IM 1	OM 1	50	300
IM 2	OM 2	50	300
IM 3	OM 3	50	300
IM 4	OM 4	50	300
IM 5	OM 5	50	300
IM 6	OM 6	50	300

IM 7	OM 7	50	300
IM 8	OM 8	50	300
	Total	400	

Note: IM = Inner Moat, OM = Outer Moat

5.4 Connection of Inner Moat to Outer Moat

All these connections are made by 300 mm steel pipes laid by Trenchless Technology. These connecting pipes shall be laid out at a depth of 0.5 BGL from the top of inner moat.

6.0 Phase II Works

These would be as follows:

(i) Construction of pump house on Siem Reap River bank and laying of pipeline from the river to the outer moat for maintaining the minimum water level in the moat system during the summer months.

(ii) Capacity increase of the stream in its lower reaches upto Siem Reap river.

7.0 Execution of Trenchless Technology

For the Implementation of Trenchless Technology following challenges are expected:

(i) The maximum road width available does not allow the large sized drilling rigs. Hence the entry and exit of trenchless equipment in the Ta Prohm complex is going to be challenging.

(ii) Since small width is available due to narrow gates/doors in most of the Enclosure II & III locations, the drilling rigs cannot enter the temple complex.

(iii) Due to unavailability of space for string placement, improvement in trenchless technique is required.

(iv) At the time of Implementation, removal of some bushes/vegetation in inner and outer moat is required for the mobilization of machine, man and material.

Keeping in view the above mentioned challenges the best option for implementation of trenchless technology as per the site condition and constraints is Horizontal Ager Boring (HAB) method.

Auger Boring Machine

The following are the advantages of Horizontal Auger Boring (HAB):

- Speeds up work by 5-10%
- There shall be no likely vibrations
- There is no chance of failure of bore as pipe is laid simultaneously

8.0 Silting Issues

In order to address the problem of silting following measures have been suggested.

(i) Sink – Geo-textile filters with traps have been proposed on the top of sink to reduce silting in sink. Sink may require cleaning once a while annually.

(ii) Collection Chamber – Though no silt is expected to travel into these chambers still some of those chambers may require annual cleaning.

(iii) Pipes – The slopes have been provided in such a way that minimum velocity is not less than 0.9m/sec so that no silting takes place during transfer of water. Any silt entering through sink or collection chamber shall flow into the inner moat. The depth of pipes entering into inner moat has also been so designed, to avoid any silting. But some silting may take place during heavy rains and during submergence of pipes, when water level rises beyond 2 m in the inner moat. This may require annual cleaning and maintenance. The total design of drainage system has been designed to have zero silting but annual upkeep and maintenance of asset is definitely required.

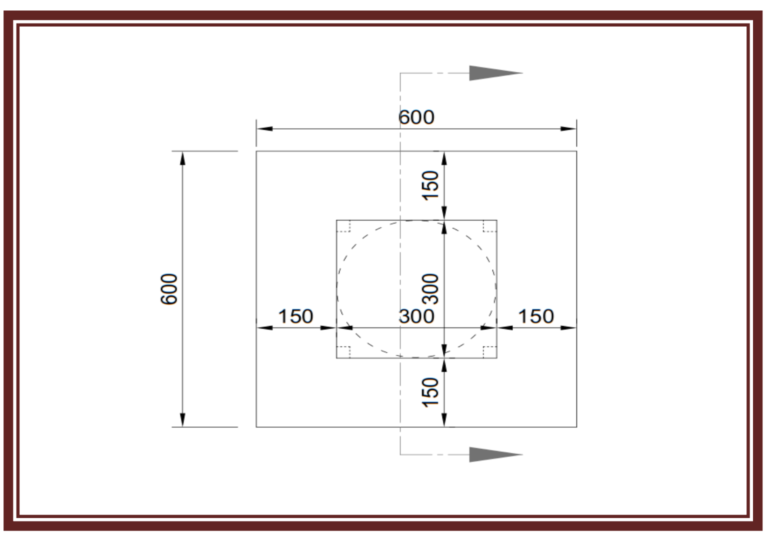
9.0 Specifications of Sinks & Collection Chambers

9.1 Sinks

The sinks are the places where the rainwater will first enter the drainage system. The minimum size of sink would be a section of size 600 mm x 600 mm x 1500 mm. the wall of the sink will be made of RCC. These walls will support the Cover, Silt trap and marginal length of pipe, which will carry water from sink. It will have the following components:

9.1.1 Cover

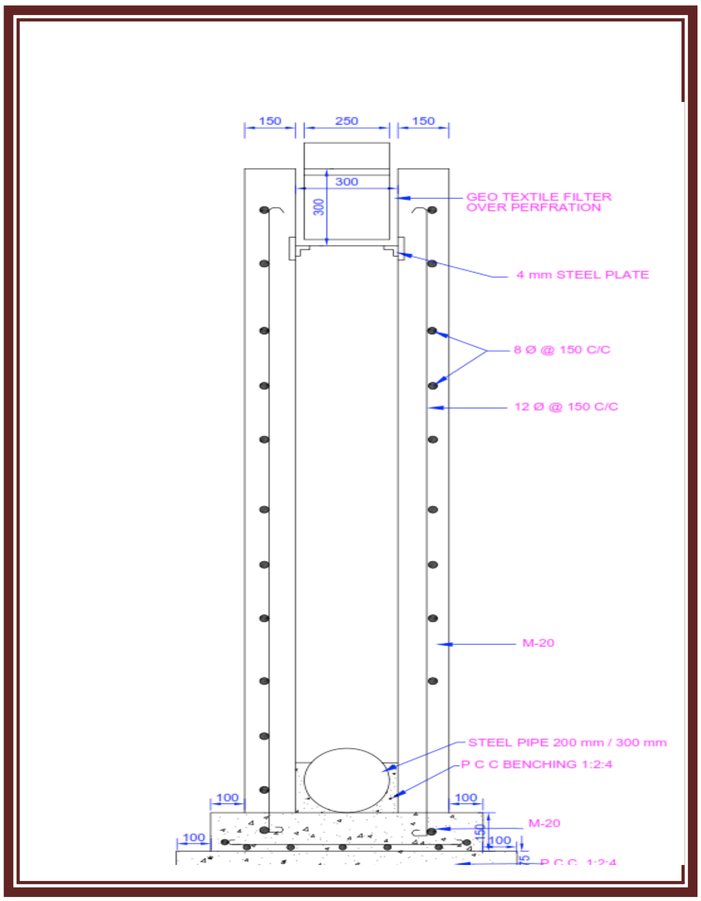
9.1.2 Silt Trap and arrangement for its sealing



Plan of Sink

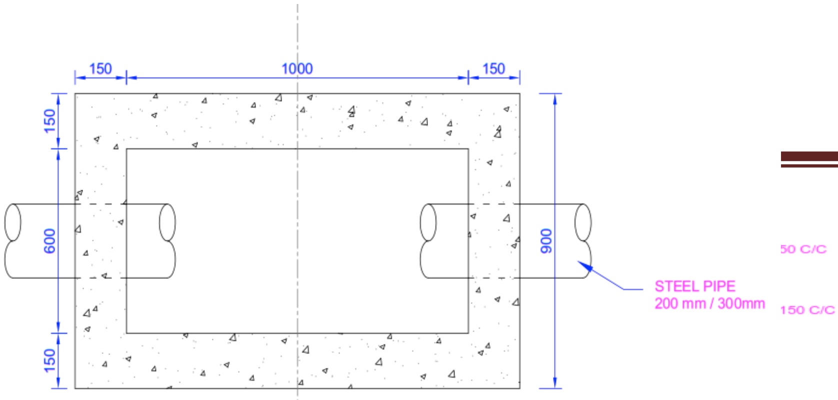
Cover
The cover shall be made of a mild steel plate, diameter 250 mm, thickness 5 mm. the cover will be painted with epoxy and while the paint is tacky, the sand from the surrounding area will be sprinkled over it, so that it acquires the same texture and colour. Suitable Number of pins shall be embedded in the well all around so that the over can sit on it.

Silt trap and arrangement for its seating
The silt trap shall be made of stainless steel in the form of cylindrical box of diameter 300 mm and height 300 mm. the trap will have perforations at the bottom, which will be covered by a geo-textile filter. The arrangement on which the silt trap sits will be made of mild steel with an angle welded all around.

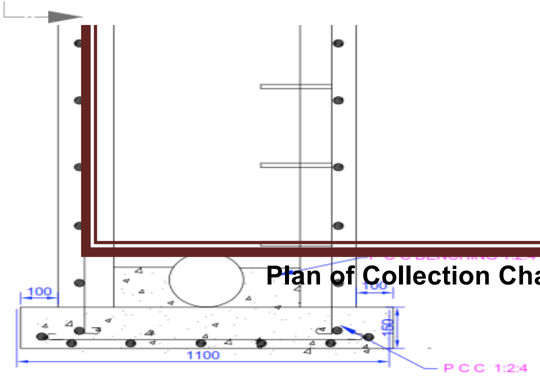


Section of Sink

The water from the sinks will get collected into the collection chambers through a pipe driven by Trenchless Technology. The minimum internal dimensions of the collection chamber will be 1mx0.6mx1.5m deep. It will have a floor of PCC and the walls of reinforced cement concrete. The drawings below show the details of the collection chamber.



Plan of Collection Chamber



Section of Collection Chamber

10.0 CONCLUSIONS

The project, to be implemented by WAPCOS Ltd. will meet the essential requirement of storm water management ensuring long term sustainability of the eco-system and thereby conserve the heritage value of this tourist attraction.