FLOOD CONTROL MANAGEMENT IN SIEM REAP RIVER BASIN IN CAMBODIA BY REVIVAL OF ANCIENT STRUCTURES OF 10TH CENTURY

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ABSTRACT

In this paper, an attempt has been made to analyse the ancient hydraulic networks of Angkor and to identify the potential area of development for flood control management in Siem Reap River Basin. During the Angkorian period, the Khmer rulers developed efficient techniques and methodology for optimum utilization of natural (water) resources towards the sustainable development of farmers, villagers by providing them adequate water for irrigation & drinking purpose. Water networks used to collect water from the North Kulen Mountain ranges and diverges water towards the capital Angkor through large scale networks of canals, reservoirs, Barays etc. which will further flow towards the Tonle Sap lake. Planning of their water networks is an indiscrete example of Water Engineering. Now-a-days, It is imperative requirement to restore the ancient hydraulic networks and extinguish infrastructure to tackle the problem of flooding. The study aims at quantifying the estimated flood discharge and identifying suitable approach and methodology to control the flood water and optimizing it to enhance the irrigation potential in the Basin

Keywords: Irrigation system, Canals, Ancient Hydraulic structure, Reservoirs, Flood Management

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1.0 BACKGROUND

Flooding is an frequent recurring problem in Siem Reap River Basin which comprises the area of Puok river, Siem Reap River and Rolous River network. Recently, Siem Reap City get affected with frequent flooding in the year 2009, 2010 and 2011. However, There was no inscription from the Khmer Empire mentions either flood or draught in Angkor region, and neither do the Khmer people have a memory of disaster transferred from one generation to other through legends. It would seem therefore that these flood problems did not occur in the past, indicating that the water management system in ancient times was capable of optimizing water resources.

The topography of Basin area shows three zone i.e. Upper Kulen mountain ranges, middle collector zone with various manmade and natural depression and lower discharge zone to Tonle Sap Lake as shown in figure 1. The middle zone and lower zone are more flood prone area. The deflection from natural course of river and redundant ancient hydraulic structure are the major cause of flooding the basin area.

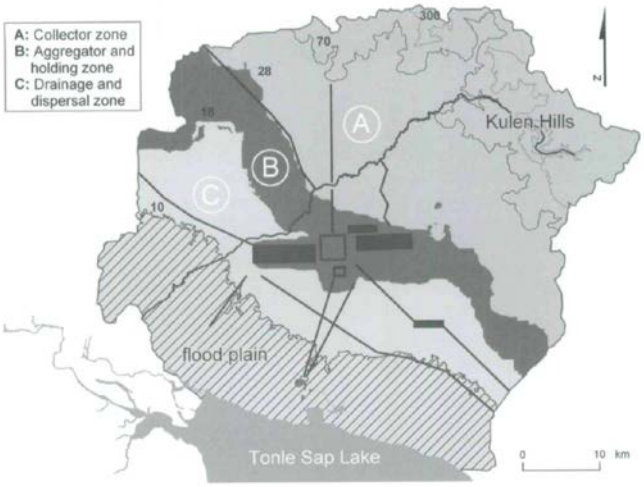

Fig. 1: Zoning of Siem Reap River Basin

2.0 HYPOTHESIS

To find out remedy of the problem of flooding, it is important to understand the ancient water network in Angkor and assess suitability of revival of ancient hydraulic structures / network for developing various sectors as irrigation, agriculture and drinking water supply.

3.0 WATER NETWORK IN ANCIENT ANGKOR (HISTORICAL DEVELOPMENTS)

In the early 8th Century, Siem Reap comprises of two major river system namely Puok River and Rolous River. Puok river flows from Phnom Kulen mountain ranges to the South West of Present West baray to the Tonle sap Lake whereas Rolous River flows from North East corner of Kulen Mountain ranges to the South West to lake. During the Early Angkor Period, Khmer Kings Make Bakong as their capital and develop the Rolous network system. The Rolous network as currently includes a Baray namely Indratataka, various channels and moats around the Bakong, a major N-S canal from Rolous river which feeds the intake of baray and flows towards South East to provide water to irrigation system to Lake. Indratataka Baray was 3.8 kilometres long and 800 metres wide. It was able to hold up to 7.5 million cubic metres of water. The complicated and complex irrigation systems of artificial canals and waterways were made up of the barays. They provided water for the crops so that the civilisation didn't need to depend on rainwater. The irrigation system estimated to have been able to harvest 480 ha Rice field during dry season and 2,400 ha during wet season. (Acker 1998.)

Later in the 9th Century, a massive East baray structure was constructed of 7.5 kilometres long and 1.8 km wide which takes intake from North east corner of embankments from the southwards flowing tributaries of Rolous river. To regulate the water inflow an earthen embankment was formed from the Phnom Bok mountain to the corner of East Baray as to restore the Tributaries flow and divert all flow to East Baray. Depth of baray varies from 5m to 8m and have water storing capacity of around 54 MCM, which have been estimated to provide irrigation to 3,162 ha rice field area in dry season and 5000 ha area in wet season. (Acker 1998.) However, Baray had the capacity to irrigate around 21,500 ha area during rainy season but it got constrained because of its location which reflects the Purpose of East baray was not only to provide support to irrigation but also as Flood controlling structure.

Later in 10th century, during the shifting of Khmer capital from Bakong to recent Angkor Park area an North- South canal was structured taking inflow from the ancient Puok river and provide the supply intake to East Baray at Northen Embankments. Excess water from East Baray outflows from South East embankments towards the N-S canal of Rolous River to supply water to Indratataka and various moats in Bakong.

In the Early 11th century the glory of Khmer empire spending around the Southeast Asia, During this period the Angkor rulers start developing the renounced "Hydraulic City of Angkor". Presently, West Baray is a huge reservoir of size 7.8 km long and 2.1 km wide having depth varies from 10 m to 13m from East to West. West Baray had an capacity of storing 156 MCM water and support water supply canals to Irrigation fields and drinking water supply. Earlier, West Baray is served by a second offtake from the ancient Puok River at North Eastern side of Embankments. Water was taken out of the baray through the middle of the East bank and South western corner of Baray to the Paddy fields for the development of Agriculture in the South western Part of Angkor. The irrigation system from Baray have been able to irrigate 10,500 ha of rice field in dry season and 14,000 ha in wet season.

Later during the construction of Angkor Wat in Early and Mid 12th Century, the East baray structure demolish due to redounding structure. The offtake for East baray extended to flows westwards to provide water intakes to moats of Angkor Wat and Angkor Thom. This offtake flows further southwards to lake and provide support to the Irrigation system and water supply to Angkor inhabitants. At present time, this offtake is named as Siem Reap River and also provide the intake to West Baray through the Ancient Eastern embankments of Baray from Angkor Thom moats. There was also excess outflow canal from SW corner of Angkor Wat moats and flows Southward to Tonle Sap providing supplementary support to irrigation and Flood management.

In early 13th Century, Jayatataka Baray was constructed 3.6 km long and 930 m wide with water storing capacity of around 10 MCM. The existing Great North canal acting as a tributary to Puok River was realigned to match the axis of Angkor Thom and a channel was built from the North Canal running eastwards through a series of right angle turns to an entry in the NE corner of the Baray. There was no evidence of Outlet canal to irrigation fields except one canal flowing westwards to West baray.

4.0 SIEM REAP RIVER BASIN

Siem Reap River Basin is bound by Tonle Sap Lake also known as great lake in the South and Kulen mountain in the north. Total area of Siem Reap Basin is 3619 km^2. Some of The topographic features of the basin are : (refer Fig. 1)

- Physically the area is divided into three zones: the Kulen Mountains, the alluvial plain and Tonle Sap lake surrounded by marshy land.
- The main feature is the 500 km^2 large mass of Kulen Mountains extending as a plateau in the northwest and south east direction and rising to elevations of 300m to 400m. The highest point is EL 487m in the southeastern part of the mountain, while in the northwestern part the highest point is EL 394m.
- The alluvial plain is sloping with the elevations ranging from 60m to 10m. In the south the area is bordered by the Tonle Sap lake in which the seasonal water level fluctuation is 7-8m.

The Siem Reap river basin consists of three main river catchments: Puok, Siem Reap and Rolous. Beside these catchments on eastern sides of basin; there are small river catchments O' Samraung, O' Anhchanh and O' Phnum Changha which drain directly into Tonle Sap. On the western side of basin there are number of small channels which contribute to the local ponds or directly to Tonle Sap lake. In the present study, the main river catchments Puok, Siem Reap, Rolous and O' Samraung group which contribute major part of basin area encompassing most of basin population and important sites of cultural heritage, National park and biosphere are covered.

5.0 PRSESNT SCENARIO OF WATER NETWORK

The past studies indicate that during Angkor period there was only two river system namely Puok and Rolous river system which still flows through their natural watercourse while Siem Reap River was an artificial waterway receiving water from kulen mountain diverging the flow of ancient Puok watercourse to an offtake canal. Over the centuries, the Siem Reap River get widened and form major watercourse.

Present, Puok river receive water from the intersection point with Siem Reap and ancient tributaries from North highlands. The massive East Baray got demolished in early 12th century due to failure of intake structure from the Earthen dyke as Phnom Bok Reservoir. Drying of East baray had affected the Angkorian agriculture growth and diminished the ancient irrigation system. Extinguishment of Great North Canal affected the inflow to the Jayatataka Baray which remain as a rainfed reservoir for Centuries. In year 2010, APSARA authority constructed the Weir at Kreang Kroch to diverge the Flood water to West Baray and Jayatataka Baray. Ancient Canal watercourse is reconstructed and dykes of Jayatataka baray are restored to restore the capacity to 5 MCM.

Water storage capacity of West Baray was also get affected due to excess siltation and sedimentation which reduces from 156 MCM to 56 MCM. But, West Baray still support irrigation system of around 7000 ha of rice field in dry season and 10,000 ha in wet season while the Indratataka Baray is on course to nearly dry due to redounded structure and water in baray is unable to support any irrigation network.

Presently, Siem Reap river feeds water to ancient storage structures West baray (Reservoir), Moats of Angkor Thom and Angkor wat and North Baray (Jayatataka) through a number of interconnecting channels and control structure like French Weir and American Gate. A line diagram showing the Siem Reap flow directions an interconnecting channel and structures is shown in figure 2.

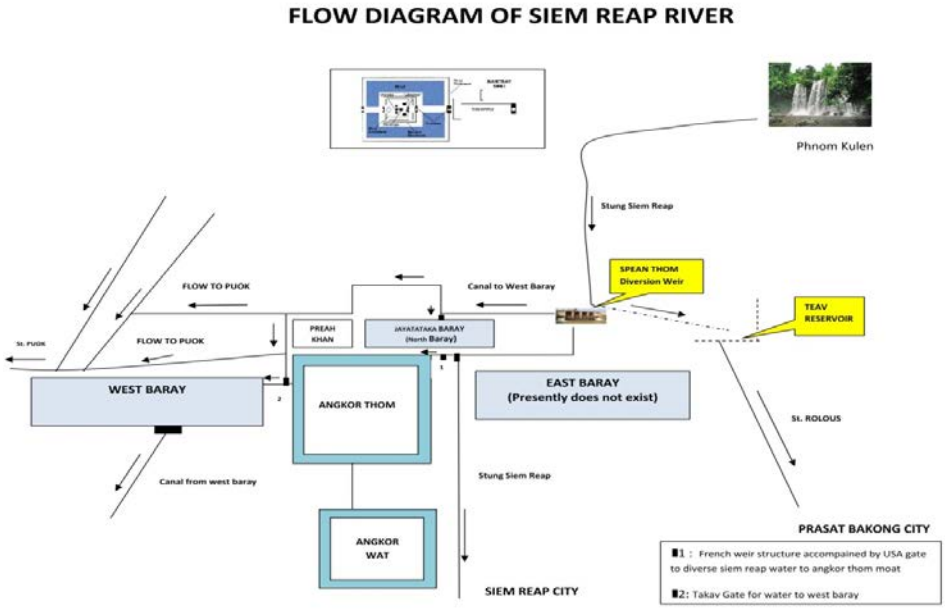

Fig 2: Flow Diagram of Siem Reap River

6.0 FLOOD MECHANISM IN THE BASIN

The main reason of Flooding in the Angkor area is the diminished water collector reservoirs and ancient canal network to diverge the excess flood water to either Tonle Sap or to the Barays. In year 2009, Siem reap city and angkor area get flooded due to excess water discharge from Kulen Mountains due to the absence of any diversion canal or structure in upstream to diverse water. All flood water discharge was diverted done from French weir (which itself located in Angkor Area) to Angkor Thom moat and finally to West Baray through takav Gate. The canal from Weir to moat have insufficient water carrying capacity which results into flooding of all Angkor area. Similarly in year 2010, Siem Reap City get flooded due to failure of takav gate to divert water to West Baray. Considering the above remedies, APSARA authority build Kreang Kroch weir in the upstream of Angkor area and reconstruct the ancient canal way to inflow water to Jayatataka and West baray.

Flooding is also majorly occur in the diverging area **Boeing Rumlich** of Siem reap River from ancient Puok river due to overflow of river banks and excess sedimentation in ancient Puok river water course. During flooding, Siem reap river overflows the right banks and forms wetland areas in the upstream of Angkor area which contribute to Phnom bok reservoir. In the present study, it is suggested to estimate the flood frequency at Kreang - Kroch before recommending the flood control measures.

6.1 FLOOD ESTIMATION

In order to carry out the detailed studies of flood control problem of the area, it was considered important to estimate the peak flood at Kreang Krunch. For this, the flood frequency analysis was carried out based on the available rainfall data at Phnom Kulen and Banteay Srei stations.

Due to the unavailability of concurrent rainfall runoff data the regional method for developing synthetic unit hydrograph (SUG) is adopted. For estimation of Peak discharge, the effective rainfall increments were re-arranged

against ordinates such that maximum effective rainfall is placed against the maximum U.G. ordinate, next lower value of effective rainfall against next lower value of U.G. ordinates. Sum of the product U.G. ordinate and effective rainfall increments to compute total direct surface runoff. Base flow is added to get total peak discharge.

Rainfall analysis of data collected for two stations be carried out using Gumbel's Type I - extreme value analysis for estimating the extreme rainfall for various Return period. Extreme rainfall computed for derivation of Flood Peak is selected for storm duration of 5 hr equivalent to 1.1times of time of peak discharge of SUG. Effective rainfall computed for storm duration of 5 hr is 95.15 mm inclusive of aerial reduction. Recurring interval of 50 year is adopted for estimating the design flood peak at Kreang Krunch.

Based on above studies, a peak flood of 2521.69 m^3/sec with a return period of 50 years is likely to strike the Siem reap river at Kreang Kroch.

7.0 CONCLUSION AND RECOMMENDATIONS

From the above studies, it can be seen that siltation & sedimentation and redundant structures of barays have affected not only affected the water carrying capacity of Baray to store excess water during flooding but also affect the irrigated system in Basin area reduces from 14,000 ha during Angkor period to presently 7000 ha area of rice field in dry season.

Further, the capacity of river Siem Reap in upstream of Kreang Kroch was assessed as 310 cumecs using Manning's formulae which shows that excess flood water to the tune of 2210 cumecs is likely to overflow the river banks and create wetlands. The topography shows that there is a vast land on the left and right banks of river which gets flooded and results in formation of number of ponds and marshy land. On right bank of river it overflow the banks near Boeing Rumlich to affect the area with flood water.

Also, the discharge reaching at Kreang Kroch of the order 310 cumecs needs to be diverted suitably to protect Angkor Temple complex as well as Siem Reap City. At present the flood water reaching at Kreang Kroch is diverted through a canal to West baray capacity (56 MCM), North baray (Jayatataka Baray - 5 MCM). On filling up of west baray and north baray the excess water is discharged to Puok through interconnecting canals. The assessed capacity of Siem reap river in downstream of Kreang Kroch is limited to about 70 cumecs. The capacity of canal to West Baray is 100 cumecs. In order to meet the situation created due to peak floods, a scheme is planned to divert water on eastern side of Kreang Kroch by construction of a channel leading to Phnom Bok reservoir on Rolous river.

It can therefore be concluded that it is appropriate to recommend revival of ancient hydraulic structures of East baray and channelization of ancient Puok river and water network.

7.1 RECOMMENDATIONS

From the above flood estimation, it seems important to divert Siem Reap river waters before the river reaches Kreang kroch. To divert the water during floods, it is considered appropriate to recommend construction of controlled gateway, to restore the ancient Puok river watercourse in the reach between Boeing Rumlich and Bampanh reach and channelize the excess flow of Siem Reap to Puok River. The restoration of earlier Puok River in this reach would reduce flood discharge in Siem Reap River.

During the flood, Left bank of Siem reap River overflows and contribute towards the catchment reservoir for Rolous river at Phnom Bok. Therefore, it is recommended to construct the retention basin and channelize all basin to reach Phnom Bok so as to discharge flood water to Lower Rolous River. It is also needed to plans to rehabilate East Baray (more than 36 MCM), which is now completely dry to gain the storage so as to absorb excess flood water to facilitate flood management and reduce the pressure on the prevailing system.

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