KERALA FLOODS – RISK ASSESSMENT IN KUTTANAD REGION AND NEED FOR FLOOD CONTROL DAMS- A PERSPECTIVE

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ABSTRACT

In the wake of recent 2018 major flood in Kerala and the consequents losses suffered by the state, it is imperative to ponder over the risk assessment as well as flood control of potentially risk prone dams in the state. Back tracking from the devastating afflux of floods in various regions, it was observed that major river basins which require a study in aforementioned direction are the Periyar river basin of middle Kerala, Chaliyar river basin of Nilambur area as well as cluster of river basin in Kuttanad region. Of this, Kuttanad region was studied in detail with respect to risk assessment and the need for flood control regulators/dams in the opening rivers to Kuttanad like Achankovil, Pamba, Manimala and Meenachil. From this risk assessment, it is observed that flood in the component which causes highest risk related to dams. Need for the flood control dams were assessed using CWC 2010 guidelines, part 2, for DPR preparation of flood control dams. Accordingly, the ratio of damage assessment in yearly terms shall be more than 1.5 times the yearly deduced value of construction of dam. Approximate assessment was made and found that flood control dam can be of the order 18 Mm^3 for the upper regions of rivers joining Kuttanad region. This is capable of absorbing 5 hours of peak flood. Absorption and release (routing) so as to keep the levels in downstream below the alarming levels is the objective of such flood control dams. In the Kuttanad region, floods from connected rivers can be alleviated by allowing water to impound in the lower Kuttanad region by about 0.15 m average, so that the flood levels will not increase above alarming levels. This also is capable of absorbing a full peak flood discharge by 5 hours. Again the route to absorb and release shall have sufficient cross section to accommodate this flood discharge. Absorption is from the rivers joining Kuttanad and release is through the openings to the sea at Thanneermukkam barrage and through Thottappilly spillway.

1. INTRODUCTION

Kerala floods in 2018 mark the occasion of yet another flood event after devastating floods in 2018. Highest levels marked for 2018 floods is found to compare with similar big flood occurred one century back. Hence, this event can be approximately grouped as an event which has an occurrence of 1 in 100. There will be one peak flood event occurring every year in Kerala and highest among this occurred, one in 2018 and another a century back. However, there was a repetition of flood in 2019 also, where the highest levels were in par with that of 2018 floods. Hence, extreme alert is required in future considering the unpredictable flood events likely to hit Kerala in future. In order to combat this event, an assessment is made on the approximate design flood in the region considering the similar values elsewhere in Kerala with the similar influencing parameters, evaluated by critical sequencing method of CWC. In order to mitigate this flood, it is required to absorb this value and release at controlled intervals asflood levels will not increase beyond permissible higher levels. For this reservoir routing and flood routing need to be done. Such studies reveal that flood control dams of capacity 16 Mm^3 is required for each of the outlets of rivers joining to Kuttanad region. This will absorb the maximum possible design flood calculated value of 1100 m^3/s for a maximum of 4 days so that by this time flood will be over. In order to create similar situation in Kuttanad region, the lower Kuttanad is allowed to impound water to absorb a design flood of maximum of 2000 m^3/s for 5 days. Hence, the level of water will not increase above alarming levels. In order to facilitate this, pumping out water in Kuttanad region shall be initiated once the rain starts which causes high floods. Otherwise, required absorbing capacity of floods will not be available.

Flood control regulating dams on upstream, with about 5 spillways of 9 × 7 m, need to be opened initially to release water in a controlled way to prevent rise of water, above alarming levels. Thus, by release and closing spillways flood can be controlled during high rains controlled by hydraulic hoist mechanisms coupled with PLC SCADA system,. As it is difficult and dangerous to approach the dam using floods, remote operation with PLC SCADA system is a requirement for the effective operation of regulating mechanisms in dams.

It is also important to collect data for the expenditure incurred in the previous floods. This is to evaluate the average yearly flood damage. This value need to be more than yearly cost incurred by the construction of flood controlled dams as per CWC 2010 norms.

2. RISK ASSESSMENT FOR FLOODS

2.1 Risk assessment and management

The Government of India (GOI), in recognition of the importance of Disaster Management as a national priority, set up a High-Powered Committee (HPC) in August 1999 and a National Committee after the Gujarat earthquake, for making recommendations on the preparation of Disaster Management plans and suggested effective mitigation mechanisms (www.ndma.gov.in). The Tenth Five-Year Plan document also had, for the first time, a detailed chapter on Disaster Management and Twelfth Finance Commission mandated review of Disaster Management financial arrangements. On 23 December 2005, the Government of India enacted the Disaster Management Act, which envisaged the creation of National Disaster Management Authority (NDMA), headed by the Prime Minister, and State Disaster Management Authorities (SDMAs) headed by respective Chief Ministers, to spearhead and implement a holistic and integrated approach to Disaster Management in India. Refer www.ndma.gov.in for details including warnings for disaster etc.

Section 23 of the Disaster Management (DM) act 2005 provides that there shall be a DM plan for every state. Following this, first KSDMA (Kerala State Disaster Management Authority) was constituted vide S.R.O No. 395/2007 dated 4th May 2007. Present composition of KSDMA is notified vide S.R.O No. 583/2013 dated 17th July 2013. (Refer www.sdma.kerala.gov.in). As per this, the risk aspects of dams in Kerala are entrusted to Irrigation department and K.S.E.B.

2.2 Risk assessment evaluation for various components

Risk assessment was calculated as per no. of occurrence of events given in Wikipedia of dam failures. Various risks are proposed in table 1 below, with probability of occurrence of events and proposed remedial action.

Table 1 : Proposed typical risk register for dams

Sl. No.	Description of risk based on importance	Probability of occurrence of failure	Proposed remedial action
1	Inadequate estimation of Reservoir flooding.	0.494	Refer subsequent sections
2	Poor maintenance	0.066	Refer subsequent sections
3	Insufficient initial design	0.066	Refer subsequent sections
4	Defective construction	0.055	Refer subsequent sections
5	Excessive seepage	0.055	Refer subsequent sections
6	Geological instability	0.044	Periodic yearly inspection from GSI department is important to check any new faults formed due to recent earth quake or other tectonic movements.
7	Mining near dam	0.044	No mining to be permitted near dam
8	Failure due to earthquake	0.022	Refer subsequent sections
9	Failure due to attacks	0.022	Refer to section 6
10	Failure due to outlets closed by debris	0.022	Yearly maintenance of outlets
11	Failure due to landslides	0.022	Check for slope stability
12	Failure due to lightening	0.022	Put lightening arrestor
13	Instrumentation error	0.011	Yearly calibration
14	Tunnel collapse	0.011	Yearly maintenance
15	Death of aquatic life in reservoir	Not reported so far	Check for phosphorus content in water
16	Contamination of reservoir due to tanker truck overturning to reservoir water or to the streams joining reservoir water	One incident reported at Peechi dam, Kerala	Design of guard rails as per BS 8110

17	Caving of earthen dam body by rats and other similar animals	Not reported so far	Periodic visual checking and corrections
18	Too much boring operations on top of dams due to various investigations	Not reported so far	Model the dam with max. bore and limit as per bore register of dams
19	Falling of vehicle from road on top of dam after thrashing parapet	Not reported so far	Design of guard rail as per BS 8110
20	Boat capsizing	One incident reported in Thekkady of Mullapperiyar reservoir	Limiting passengers and periodic maintenance of boats

2.3 Inadequate estimation of design flooding

Spillway shall be designed to accommodate the flash flooding in reservoir. Flooding details after the commissioning of dam shall be compared with spillway openings and if spillways are insufficient, gate modifications need to be proposed. As the probability of dam failure due to insufficient estimation of flooding is the most (0.494), all dams need to be checked for dam safety again for the up to date flooding details.

2.4 Effect of poor maintenance on dam safety

Maintenance action plan need to be developed and need to be maintained. Otherwise, there are following possibilities of disaster.

(a) Absence of periodic application of grease in the rails of spillway gates may cause jamming of gates at rails. Application of more pressure for opening may cause break of gates or rails and can cause sudden flooding due to failure of gates.

(b) Complete corrosion of certain bars of canal opening gates may cause passing of debris to openings and the flow may be reduced at the necked portion. This will results in excessive flooding and overtopping of water on top of dam.

2.5 Control of excessive seepage in dams

Conduct engineering seismograph survey for earthen dams and tomographic survey for concrete or masonry gravity dams. Electrical resistivity method also needs to be performed. Thus, the state of cavities or low density spots in dam body can be obtained. Based on this, a rectification measure can be initiated, such as grouting, external concrete low permeable zone, bitumen or other suitable layer on outer surfaces or combination of these methods, etc. After the completion of the remedial measure, once again aforementioned studies need to be conducted to assess the internal states of the material of the dam. Obviously, the comparison of seepage records before and after the rectification work will also give conclusive results.

2.6 Design checks of dams for seismic forces

There are 58 dams in Kerala as per the listing of water resources details commissioning of many such dams occurred quarter century back, for which, the design basis dates back to more than 30 years old. While checking the designs, the following shall be noted. Referring to the loads, it may be noted that seismic loads have changed over a period of time and still earthquake loading as per Indian standards is in the coefficient application stage over a zone when comparing the peak ground acceleration (PGA) contours for each place as per international standards like ASCE 7-05, International building codes etc. Countries like UAE have adopted these standards of contour mapping of PGA which are specific to location. As per cl. 1.2 of the guidelines for preparation and submission of site specific seismic study report of river valley project to National Committee on seismic design parameters, site specific seismic studies are mandatory for majority of dams in Kerala. Also, it needs to be checked that old dams meet with the requirements of new codes.

2.7 Evaluation of peak ground acceleration

One such old dam as mentioned in previous para is the Malankara dam, where the coefficient used for earthquake design was 0.05 (Project report, Kerala Engineering Research Institute, Peechi, 1984). Now, the design codes were revised and the structures need to be checked for the revised loads and load combinations. Design of masonry and gravity dams shall be carried out as per IS: 6512: 1984 (reaffirmed 1998) [6] considering all the seven load combinations enlisted. This includes the earthquake loads also. As per the guidelines given in the document of dam by CWC site specific investigation shall be carried out in order to determine peak ground acceleration (pga) for use in design. Hence, for majority of cases of dams, it is imperative to determine the site specific peak ground acceleration to be used in design. Relevant consultants shall be contacted to evaluate this parameter for all of the required dams for design checks.

2.8 Evaluation of compressive strength of masonry in masonry dam

For such seismic forces as described above, the dam need to be checked for strength, safety and serviceability. For this, the compressive strength of masonry needs to be evaluated. As per IS 6512-1984(reaffirmed 1990), 75×75×75 cm prisms or 45 cm dia and 90 cm cylinder cores shall be tested for evaluating compressive strength of masonry. The compressive strength obtained from this test shall be more than five times induced compressive stress in dam or 12 MPa whichever is more. Similar provision is given in the guidelines for safety inspection of dams by Central Water Commission.

It is not advisable to take such big cores aforementioned, due to the additional stresses induced in the dam on account of vibrations and the equivalent static load of the machinery involved. Moreover, the machinery involved in taking such cores is not readily available which need to be made for this single purpose, and hence will make a negative impact on cost and time of the project at this stage. Moreover, the failure load in this case normally exceeds the capacity of normal compression testing machines.

Hence, it is proposed to adopt the following method for assessing the compressive strength of masonry.

1. Compressive strength of building stone (fb) comprising dam masonry may be found from 50 mm bore samples from dam. It is proposed to make at least six test pieces of diameter 50 mm and length 50 mm from every 3 m of coring operation. Coring operation shall be carried with diamond drilling bit and double barrel pipe with core lift. Test piece shall be identified by putting name containing the reference of block of dam and the depth from top.
2. Compressive strength of masonry(fm) for each level of 3 m of dam shall be found as fm= 0.30×fb , where fb is the lowest compressive strength of building stone obtained as given in step 1, with the condition that this compressive strength shall be more than lowest 5% of test results. Design shall be performed for each block and for each level as mentioned in point no.1, for economy.

This compressive strength obtained from above method is also fairly in agreement with the range of basic compressive stress in masonry values (0.25 N/mm^2 for lowest strength mortar and 3.05 N/mm^2 for highest strength mortar) given in IS 1905: 1987. Note that dams are also having the similar slenderness limits. Hence, the masonry compressive strength obtained from aforementioned method is reasonable and on safer side.

2.9 Proposed blast loading on dams

Blast loads are produced from the detonation of explosive materials. Detonation is a chemical reaction which proceeds through the explosive material at supersonic speed and converts the material into high pressure gas. Due to this, a pressure wave is formed which travels in all directions and has got a pushing and pulling action on air.

While this incident pressure hits on the building (shall be treated as dam with calculations on fundamental time period etc.), it gets increased and is called reflected pressure. Thus, blast load is a uniformly distributed load which acts on the structure which is a function of time. Data for reflected pressure for various explosives placed at various distances is given in the literature when solid explosives are considered (ASCE 1997). These values range from 21 to 69 kPa on the exposed surfaces. Procedures for the design of blast resistant buildings (shall be applied to dams with calculated dynamic parameters) are given in literature (Naval facilities command, 1986, ASCE, 1997, Venkatesh, Marchand, 2004). Refer IS 4991-1968(reaffirmed 2003) also for the blast resistant design procedures.

3. CONCLUSION FROM RISK ASSESSMENT & SCOPE FOR FLOOD CONTROL DAMS

From section 2, it is clear that flooding is the component which has the highest risk associated with dams. In order to curb this flooding, it is required to check whether such possibility exists as per CWC norms, as discussed in introduction.

Design flood value was found to be of the order of 1100 m^3/s for the location in Manimala 30 m from its origin. This was found based on the similar values in identical conditions. However, this value keeps on increasing along the downstream. In order to release this flood, 5 nos. of gates of size 9 m X 7 m is required assuming one shutter to be in operational. So, a 50 m long and 10 m deep flood regulating structure satisfying the above outlet requirements in each of the above joining rivers to Kuttanad region can release and alleviate flood to a great extent in the upper regions of the river. This is because the above impounding arrangement can absorb aforementioned design flood for 5 hours, whereas the peak flood duration is less than this as observed in the past. Corresponding capacity of such formulated reservoirs shall be around 16 Mm3 capacity. However, in the lower regions, as the discharge will be of the order of 2000 m3/s, the cross section perpendicular to flow need to be increased and also, some floods need to be stored in one place with controlled release to ocean. For this cushion, lower Kuttanad region of around 230 km2 is adequate, which can store water up to a depth of 0.15 m average so that the volume of water which can be accumulated for 5 hours of flood corresponding to peak discharge is around 36 Mm3. As the peak rain duration causing flood was found to be less than 5 hours, certainly, this region can contain the floods without increase in water levels in the region provided, sufficient evacuation measures in the region is mooted as per emergency control plan and cultivation is not planned in the peak flood forecast period and recently Government is initiating Room for River concept as in Netherlands.

So, by utilizing the flood control dams one each for each of the tributary rivers joining to the estuary of Vembanad as well as by utilizing the lower regions of Kuttanad, the problems of floods in the river basins leading to Kuttanad can be resolved without increase in levels and leading to flood hazards. For storing this water, it is imperative to keep the levels lower than the hazard level of floods by 0.15 m by means of special pumps in the region called 'petti and para' by pumping to the artificial made channels draining to river and estuary regions. In fact, it may be noted that cultivation in lower Kuttanad was initiated way back by transforming the Vembanad estuary. It is to be noted that land reclaimed from estuary is called lower Kuttanad of area 257 sq. km. and upper Kuttanad is land reclaimed from floodplain marshes extending to 293 sq.km.

Details of design flood estimated as per critical sequencing method of CWC is given below with routing procedures of 1 m cushion of water in the proposed flood control dam.

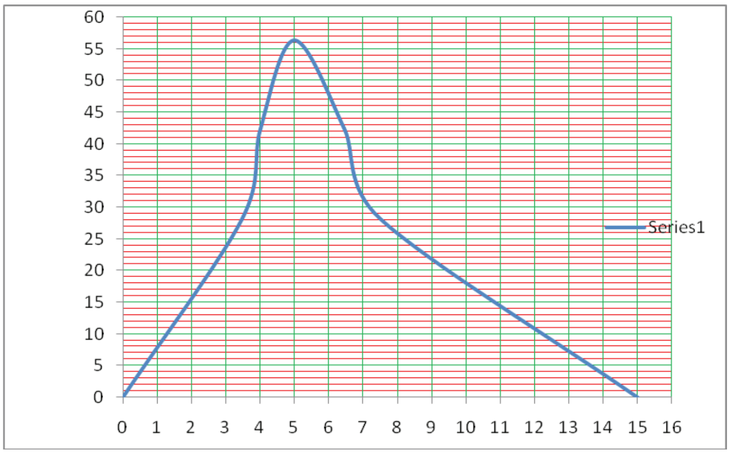

Fig. 1 : Smoothened synthetic unit hydrograph

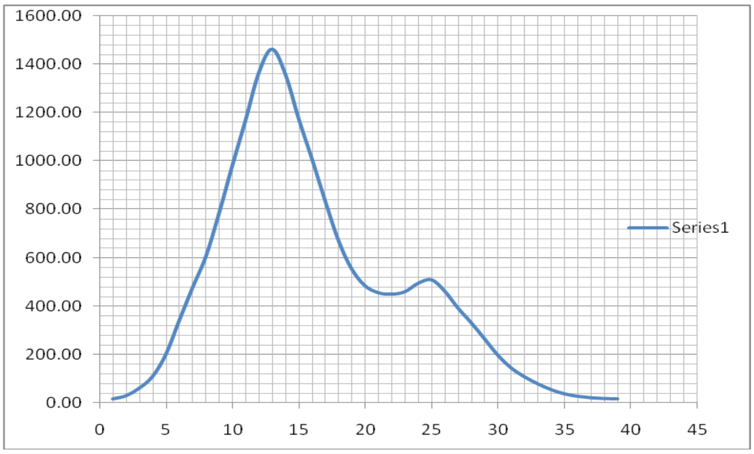

Fig. 2 : Critically sequenced flood hydrograph in B1-B2 convolution

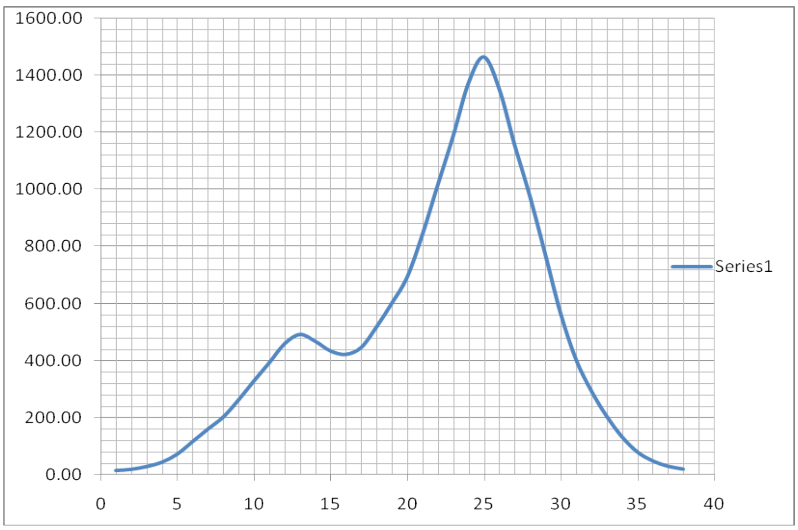

Fig. 3 : Critically sequenced flood hydrograph in B2-B1 convolution

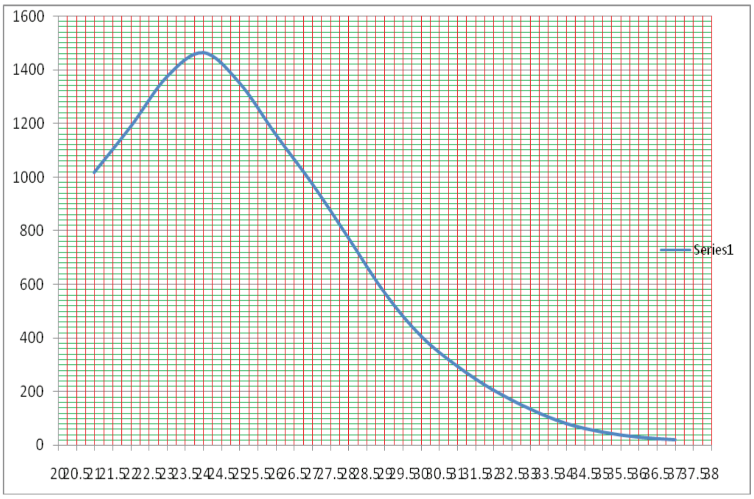

Fig. 4 : Reservoir routing graph

A total loss in 2018 floods in Kerala was declared to by 8316 crores. Out of this, cost in the Kuttanad region is approximately 4000 crores. So, four interventions at four rivers of impounding water of 18 Mm^3 which costs a total estimate of around 400 crores is justifiable and currently Manimala and Achenkovil rivers are not having any Reservoir with Dams.

4. CONCLUSIONS

From sections 1 to 3, risk assessment related to floods as well as need for flood control dams are given in detail. It is shown that flood control dam of the order of discharge of 16 Mm^3 is required for each river joining Kuttanad. In the Kuttanad region, the lower Kuttanad portion can be used to store water for the flood period. By these measures, the rise in level above the hazard levels of floods in Kuttanad region can be eliminated.

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