DAM BREAK ANALYSIS OF KRISHNARAJASAGARA DAM DUE TO OVERTOPPING FAILURE BY HEC-RAS

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Abstract - *Dams being a hydraulic structure are beneficial for society in many a ways, but sometimes it proves to be a bane. During catastrophic disastrous event such as floods, they tend to break or overtop causing serious damage to the downstream end resulting in loss of lives, property, damage of economy etc., In order to reduce the threats posed by the dam due to its breakage, one must take precautionary measures in designing or evaluating its aftermath effects prior to the disastrous event. This paper provides an overview of the application of 2-D Hydraulic model, HEC-RAS for the analysis of dam break of Krishnarajasagara dam located at Mandya district, Karnataka. The Dam breaks are analyzed for failure with comparison of the hydrographs at different downstream locations by changing its breach parameter using HEC-RAS. The analysis helps in developing flood inundation levels, time of arrival of flood, velocity of flood and extent of flooding in downstream areas, whose information can be used by loyal authorities and decision makers in preparing emergency action plan (EAP) and designing early warning system.*

***Key Words**: Dam break, Catastrophic, Hydraulic Model, HEC-RAS, Hydrograph, Inundation maps.*

1. INTRODUCTION

Flood is most familiar natural catastrophe that takes place frequently. By far accounting for 67% of all recorded events. India witnesses flood due to excessive rain which then results in overflow of rivers, lakes and dams, causing irremediable damage to people's livelihood, wealth and pivotal infrastructure. Many factor ascendancy the flood disaster besides triggered factor- precipitation, the internal factors, like river density and topographic relief, are also indispensable conditions .Out of the total geographical area of 329 million hectares (mha), more than 40 mha is flood prone every year. [5]

Dams are the storage structure constructed across the river to store water in the upstream and release it to downstream as and when the demand arises and it plays a vital role in the economy of the country. The water retained is generally used for irrigation, aquaculture, industrial use, human consumption, etc. Flood generated from the dam break is much higher than flood generated from the heavy precipitation.

A dam can break because of many reasons, of which seepage failure, failure due to overtopping, foundation failure, construction failures and failure due to bad quality materials are the most common ones. Hence it is necessary to carry out dam break analysis to study the behavior of the flood wave generated from the dam break and to prepare the inundation maps as a part of emergency action plan to evacuate the population during the flooding event.

In the present paper, a detailed analysis is being made on the Krishnarajasagara dam for the Dam break analysis using a reliable tool, HEC-RAS (Hydrologic Engineering Center River Analysis System) by adopting 2D approach modelling, developed by the U.S. Army Corps of Engineers to study the downstream effects and to prepare the inundation maps if the dam breaches due to overtopping. Such an analysis of dam failures and its inundation maps, would help in providing adequate warnings to the public in prior to the catastrophic event.

2. STUDY AREA AND DATA USED

Krishnarajasagara dam also known as Kannambadi katte is a barrier constructed across the river Kaveri which is also known by the other name 'Dakshina Ganga' (Ganges of the south) proves to be the life savior of the southern part of Karnataka. The dam was built around 1924 under the able leadership of Krishna Raja Wadiyar IV with the help of eminent chief architect of the dam Sir M. Visvesvaraya to cater the needs of drinking water supply and irrigation purposes of Mysore and Mandya region initially. Later on, it became the chief source of water for the Bangalore residents also. The dam lies between Latitude 12º 24'58" North and Longitude 76º34'26" East. The location details of the study area is depicted in the Figure 1.

KRS dam is a type of Gravity dam constructed with stone masonry along with surki mortar having a length of 2621 m and has a maximum height of 44.66 m reckoned between top of the dam and the foundation in the lowest river bed portion and the bottom width of the dam at this level is 33.88 m covering a catchment area of 10961 km^2. The Gross storage capacity of the dam is 1400 MCum. The design flood discharge is estimated to be 9911 cumecs. A total number of 152 gates have been installed to dispose off the surplus as well as water stored in the KRS dam which are situated at different levels of the dam having varying capacities.
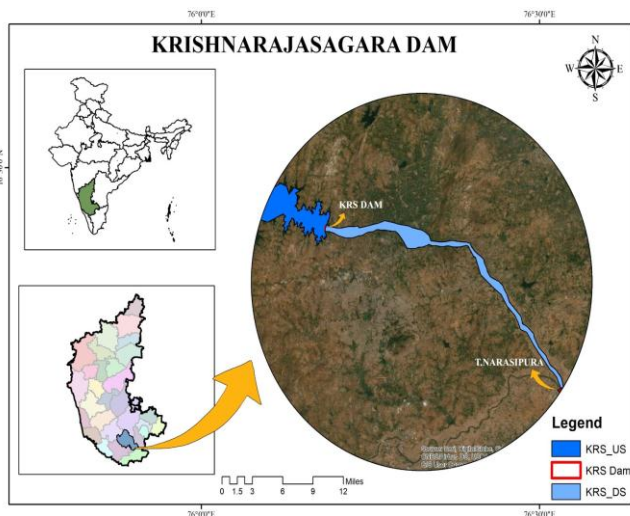
Fig -1: Location map of the Study area

Following data are used in the present study for the analysis purpose:

- SRTM –DEM of 30m resolution from USGS, NASA (https://dwtkns.com/srtm30m).
- Dam Gate details from CNNL (Cauvery Neeravari Nigam Limited) department, Mandya.
- Dam Breach parameters calculated from Froehlich formula 2017(b)
- Flow hydrograph was obtained from the KERS (Karnataka Engineering Research Station) at dam site location, Mandya.
- The characteristics of dam and river relative to topography are also collected from dam authority, like Full supply level, catchment area and design flood etc.
- The HEC-RAS software developed by the US Army corps of Engineers.

3. METHODOLOGY

A hydraulic model developed by U.S Army Corps of Engineers, HEC-RAS software has been used to model the dam break analysis due to overtopping of Krishnarajasagara dam to develop and visualise the flood inundation maps. Numerous models are available in the present market to study the dam break analysis both free and proprietary. They have contrasts in their user interface, input information necessities, exactness and different qualities. Be that as it may, all principle dam break models utilize the equivalent or comparative calculations for greatest outpouring computation and flood inundation mapping.

The present work consists of various steps in developing required inundation maps. Fig 2 represents the work flow process adopted in achieving the requisite objective through HEC-RAS software.
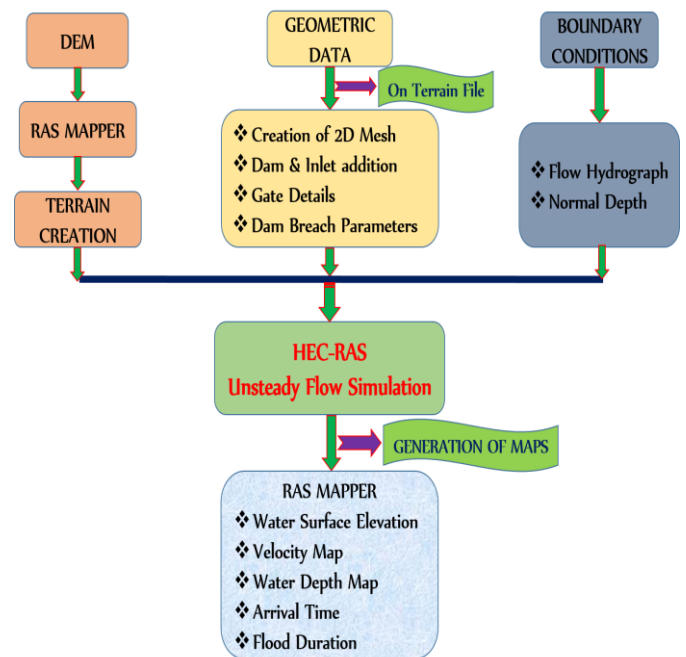

Fig -2: Workflow Process adopted using HEC-RAS

4. HEC-RAS MODEL SETUP AND EXECUTION

4.1 Background

HEC-RAS is a hydraulic model developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers. HEC-RAS is a widely accepted tool for the floodplain determination due to its user-friendly credibility also assists in performing various other operations such as Dam break analysis, water quality analysis, sediment transport analysis, etc. Recent advancement in HEC-RAS had resulted in performing 2-D Hydrodynamic flow routing within the unsteady flow analysis.[2]

4.2 Geometric file and Hydraulic input

HEC-RAS needs several data to perform dam break analysis under unsteady flow routing conditions. The SRTM DEM of 30 m resolution was downloaded and terrain of the study area was created in RAS-Mapper platform. The geometrical properties are defined in the same platform along with the development of 2-D computational mesh by defining a 2-D flow area of cell dimensions 100mx100m. Manning's roughness coefficient (N) was assigned within the 2D flow areas.

A hydraulic structure such as Dam along with the inlet is created by providing the required hydraulic inputs. The total number of gates provided in this case accounts for 152 numbers. There are 4 groups of gates having different dimensions and are placed at different elevations.

4.3 Breach Parameters

The breach parameters were estimated by using the formulae suggested by Froehlich, in which centre station, final bottom elevation, bottom width, left and right slope of breach, type of failure, etc are provided. Depending upon the type of breach selected, the model will simulate and yield the results. The present study focuses on overtopping of the KRS dam.

Estimation of Breach parameter as suggested by Froehlich, 2017 (b) for concrete and masonry dams is given by:

$$B_{avg} = 0.12 * 1.5^{TYPE} * \left(\frac{V_w}{H_b^3}\right) * \left(\frac{L_a}{H_b}\right) * H_b$$

Where,

B_{avg} = average breach width in m.

$TYPE$ = 1 for Concrete dams and 0 for Masonry dams

V_w = volume of water above breach bottom in m³.

L_a = approach flow width in m.

H_b = height of breach in m.

The analysis done by the various agencies like USACE, FERC and NWS (USACE 2014) shows that, the failure of a masonry / concrete dam is almost instantaneous and the breach formation time is narrowed in between 6 minutes to 30 minutes. The breach type was selected as overtopping and the breach trigger was selected at the water surface elevation level, i.e., at 754.32 m. By taking all the above stated points into consideration for the analysis purpose, the breach parameters used in the study is depicted in the Table 1 as below:

Table -1: Breach Parameters used in the Model

Breach Parameters	Values
Final Bottom elevation	714.45 m
Breach width (B_{avg})	729.6 m
Side slope (H : V)	1 : 1
Breach weir co-efficient	1.44
Formation time	0.25 hrs

After adding all the hydraulic inputs such as dam, gates, etc., the boundary condition lines are assigned to the model and then the geometric file is saved for further processing. Figure 3 represents the prepared geometric file.
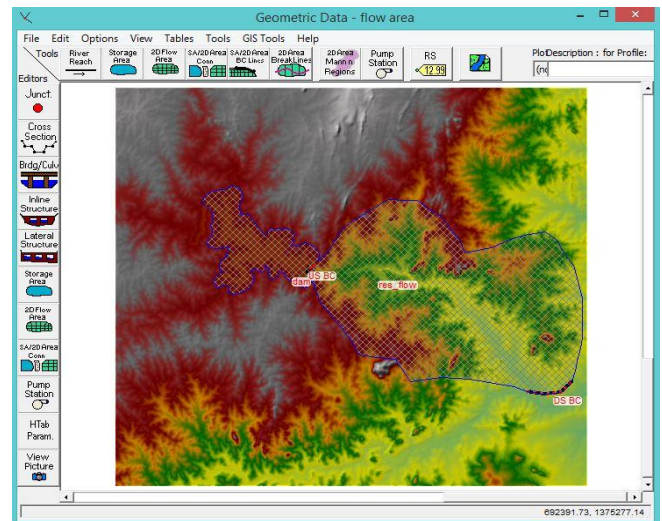

Fig -3: Geometric File

4.4 Boundary Conditions

Upstream (U/S) and Downstream (D/S) boundary condition are required in order to perform the necessary calculations for running the model under unsteady flow simulation. In the present study, Flow hydrograph has been used as the upstream boundary condition for the analysis, whereas for downstream boundary condition, normal depth of 0.001 is being used. The flow hydrograph used for the study was collected from the CNNL and is as shown in the Figure 4.
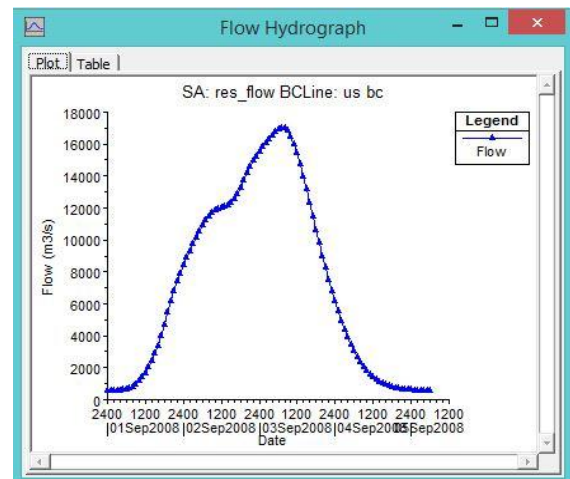

Fig -4: Flow Hydrograph

4.5 Unsteady Flow Simulation

After defining the required boundary condition, plan, geometry data files are saved and the unsteady flow simulation is carried out. For the present study, Hourly discharge data was used. Diffusion wave equation was used to simulate the 2D flow with a warm up period of 1 hr. The computational interval chosen was for 1 minute and the hydrograph and mapping output interval was set for 1 hour.

5. RESULTS AND DISCUSSIONS

Generation of Inundation maps plays a vital role in preparation of Emergency Action Plans (EAP's), peril moderation, flood hazard management, etc. These will in turn helps the dam authorities to take suitable measures in developing basic framework which aids locales with populace in danger that may require defensive measures during the catastrophic event. These plans ought to be created before the event of an occurrence, in light of most pessimistic scenario situations.

The output of dam breach modelling due to overtopping failure from HEC-RAS software includes various inundation maps such as; depth map, velocity map, water surface elevation map, Flood arrival time maps which contributes to the assessment of the flood hazard. The maps portraying the inundation due to overtopping failure with respect to the above said parameters are shown in below figures.
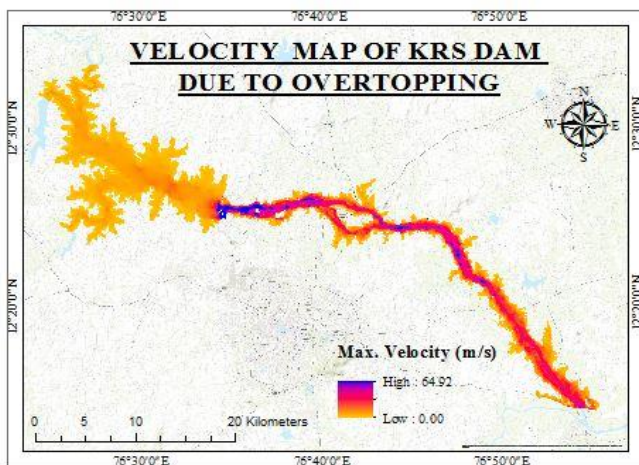
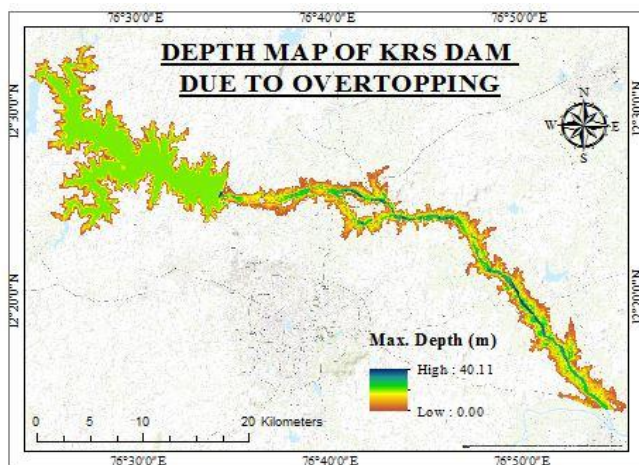**Fig -5**: Velocity map of KRS dam breach due to Overtopping

Fig -6: Depth map of KRS dam breach due to Overtopping

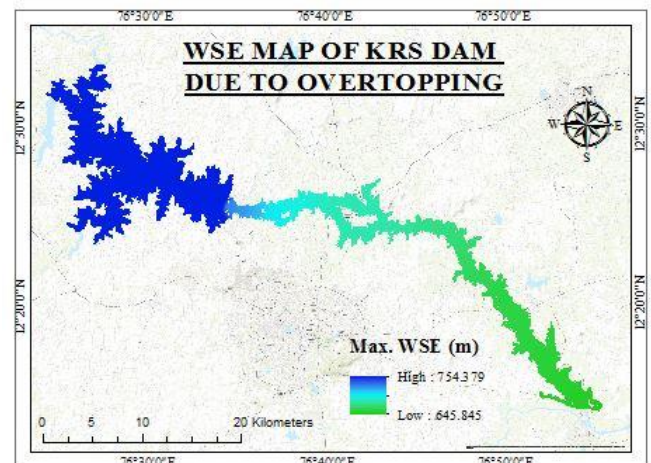**Fig -7**: Water Surface Elevation map of KRS dam breach due to Overtopping
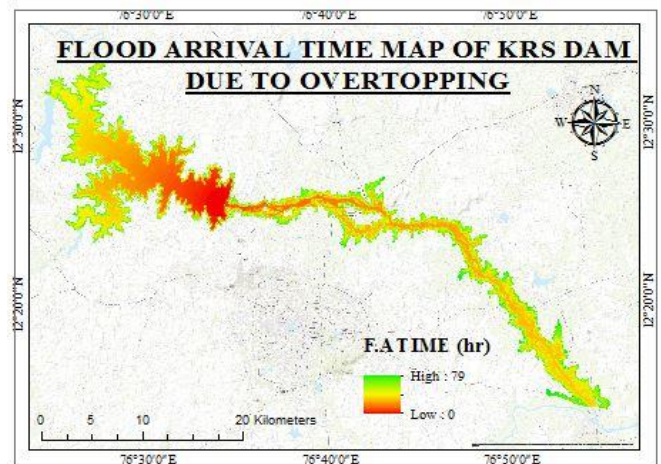

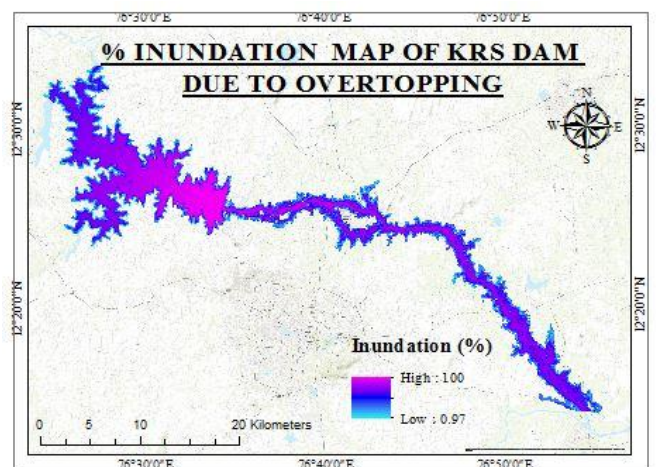**Fig -8**: Flood Arrival time map of KRS dam breach due to Overtopping

Fig -9: Percentage Inundation map of KRS dam breach due to Overtopping

6. CONCLUSIONS

Failure of dams is inevitable, but its management in reduction of loss of lives and property is definitely in cards with suitable measures. One such measure was demonstrated in the present paper, i.e., with the use of hydraulic model, HEC-RAS in analyzing the dam breach of high hazard potential dam – Krishnarajasagara located at Mandya. Due to its huge storage capacity and significant habitation in the downstream part of the dam, it was necessary to conduct the research and estimate the possible inundation due to overtopping failure.

The present study demonstrates the use of HEC-RAS model in achieving the above stated objectives and with the generated flood inundation maps it is possible to take suitable measures by the dam authority, owners, stakeholders, engineers, etc. From the overlay analysis on the google maps, it was seen that more than 50 villages were tend to be affected due to the dam breach of KRS dam till T. Narasipura which was the last point of interest due to time constraint. From the results obtained, it can also be concluded that, a few more villages may submerge until it reaches the Mettur dam located at Tamilnadu state. The dam break study helps in enhancing the commuters resilience towards such catastrophic event and also to reduce the possible impacts with speedy recovery following the disaster.
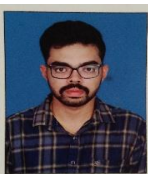
ACKNOWLEDGEMENT

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