Proceedings of the Sixth Academic Sessions, University of Ruhuna 2009
Vol. 6 pgs 248 - 263

Dam breach analysis using HEC models: A case study for Samanalawawa and Udawalawe dams

N.D.P. Ransara[1], **G.H.A.C. Silva**[2]
[1]*Mahaweli Authority, Colombo. (No. 11, Dam safety division, Jawatta road, Colombo 05.)*
[2]*Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Galle.*
✉ *amila@yamanashi.ac.jp.ruh.ac.lk*

Abstract

Flood catastrophes have become frequent events around the world and the economic losses and threat to human life are more significant for developing nations than for developed nations. The disaster mitigation has become a popular theme in recent times to control the adverse effects due to all type of disasters. Generally, flood disaster studies are done for extreme weather conditions. However, it is becoming important to perform scenario analysis for dam breach which could lead to flash floods. Moreover, the threat of dam breach is considered to be significant due to both natural and manmade disasters in the region. Also a breach of an upstream dam could be a huge threat to a downstream reservoirs or dams. In this study two such dams are selected which are constructed in the same main river, Walawe. The two reservoirs are Samanala-wewa and Udawalawe where the dams are located about 30 km apart from each other along the river. Since the two reservoirs are closely located, it is very important to ensure that, in case of a dam break of upstream reservoir, the water can be discharged safely through the downstream dam. One dimensional river dynamic model HEC-RAS and GIS software Arc-GIS were used to simulate the flood and taking cross sections respectively. Due to the high amount of inflow, tributaries were ignored and only the main river flood plain was considered. The results showed that the damage due to flood is minimum in upstream and also the maximum flow can be safely conveyed through the downstream dam.

Keywords: Dam Breach, Flood modeling

Introduction

Generally, floods are one of the most common natural disasters to human beings because most of the populated areas in the world are vulnerable to flood disasters, whereas other natural hazards such as earthquakes, volcanic activities, landslides and avalanche are particular to certain regions only. In long-term analysis, flood disasters account for about one third of all natural catastrophes (evaluated by frequency of occurrence and economic losses induced), and cause more than half of the life losses due to huge flood-induced human cost in the developing and heavily populated countries such as China and Bangladesh. Fortunately, the number of deaths caused by floods has decreased drastically due to the progress in flood warning methods in recent years. However, world-wide, floods are likely to become increasingly severe and more frequent due to climate change, population growth, and change of land-use, irrigation, deforestation, and urban development of flood plains. Therefore flood disasters should attract more attention, and more work is needed on flood risk assessment and mitigation.

In general, it is observed that flood occur due to extreme wet weather conditions. However, dam breach could lead to a sever disaster especially when the dams are constructed in the same main river. In this study, a possible flood has been simulated in an unexpected dam breach of Samanala wewa reservoir which is located close to Belihul Oya. The overall catchment area of the Samanalawewa dam is 341.7km^2. In addition at normal full storage level the reservoir covers an area of approximately 10 km^2 and stores a gross volume of 274 Mm^3.

Here Hydraulic Engineering Center, River Analysis System (HEC-RAS) software and Arc-GIS (Geographic Information Systems software) have been used in order to simulate the flood and taking cross sections respectively.

to get accurate results, accurate input parameters must be found. Following list contains required input parameters for HEC-RAS model.

- Cross section data
    - Cross sectional coordinates
    - Down stream reach lengths
    - Main channel Bank stations
    - Manning's n values
- Boundary conditions
- Initial conditions

Cross section data

Cross section data can be obtained either doing a field survey or using Arc-GIS. In order to take cross sections of concerned Walawe river Arc-GIS software was used. By creating a TIN (triangulated irregular network) layer, required cross sections were obtained. Figure 1 shows that created tin layer and Figure 2 shows that a cross section generated from the tin layer. Though the accuracy of this method is less than that of direct survey method, the required cross section inputs can be obtained easily with the aid of Arc-GIS which is very much cost effective in comparison of surveys.

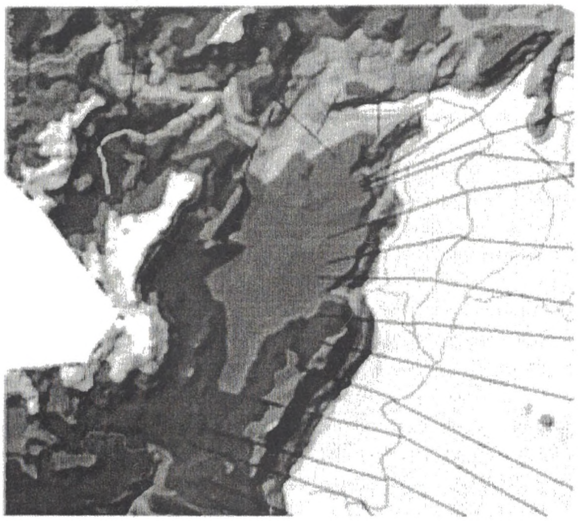


Figure 1. TIN layer

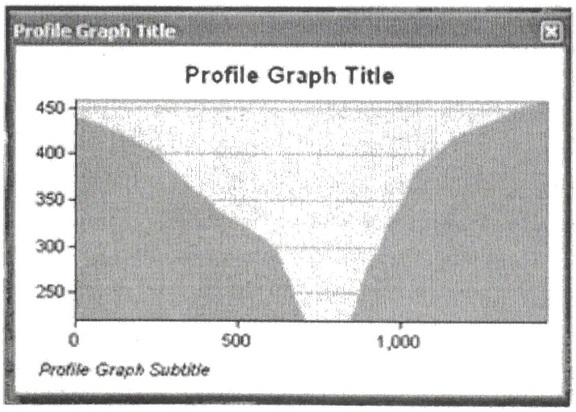


Figure 2. An interpolated cross section

Boundary conditions

There are two types of boundary conditions named as upstream and downstream boundary conditions. Several options are available for both boundary conditions and suitable boundary condition is selected upon the availability of historical data. For instance, stage hydrograph, flow hydrograph, etc. for upstream boundary conditions and rating curves, normal depth etc. stands in addition to that hydrographs for downstream boundary conditions.

It was considered flow hydrograph as upstream boundary condition calculated using CIRIA 542 (Construction Industry Research and Information Association) method (Risk management for UK reservoirs) that is given by equations 2.1 – 2.3.

$$Qp = 330(BEF)^{0.42} \tag{1}$$

where:

Qp is peak discharge (m^3/s), BEF is breach formation factor, BEF = VH (Mm^4), V is storage volume of the reservoir (Mm^3), and H is eight of peak reservoir water level above the base of the dam (m).

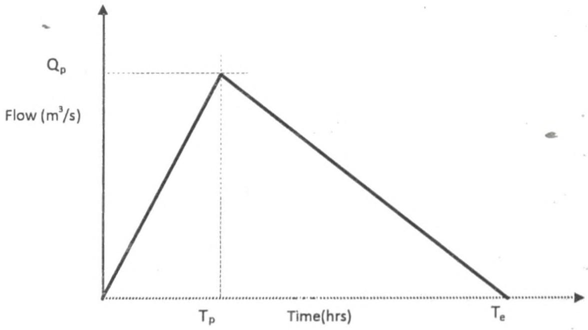
To predict the time of failure to peak discharge, apply:

Time to peak discharge, Tp (s) =120H (2)

where:

H is height of peak reservoir water level above the base of the dam (m)

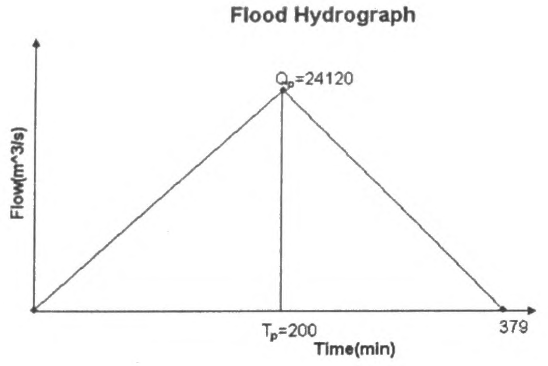
The flood hydrograph is estimated using following triangular profile approximation.



The inflow hydrograph that is calculated from the equations is shown below.

$$V = \frac{1}{2}(Q_p{}' \, T_p) + \frac{1}{2}(Q_p{}' \, (T_e - T_p) \qquad (2.3)$$

Te, may be calculated by ensuring that the volume under the hydrograph matches the reservoir volume, V.



For the downstream boundary condition normal depth option was selected and average bed slope was considered as the input parameter.

Initial conditions

Initial conditions consist of flow and stage inflow information at each of the cross sections, as well as elevations for any storage areas defined in the system at the beginning of the unsteady flow simulation. Acquisition of historical data is essential to full fill this requirement also. Here it was found initial flow for the simulation. However, initial flow is not a critical parameter of this kind of simulation, since the inflow is high.

Results

The model was setup with the initial conditions and boundary conditions and the simulated results were obtained. HEC-RAS is facilitated to view several types of results in a cross section such as variation of velocity, flow depth, hydrograph, etc. Figures 3 and 4 illustrate that the velocity variation and hydrograph of the most downstream cross section respectively.

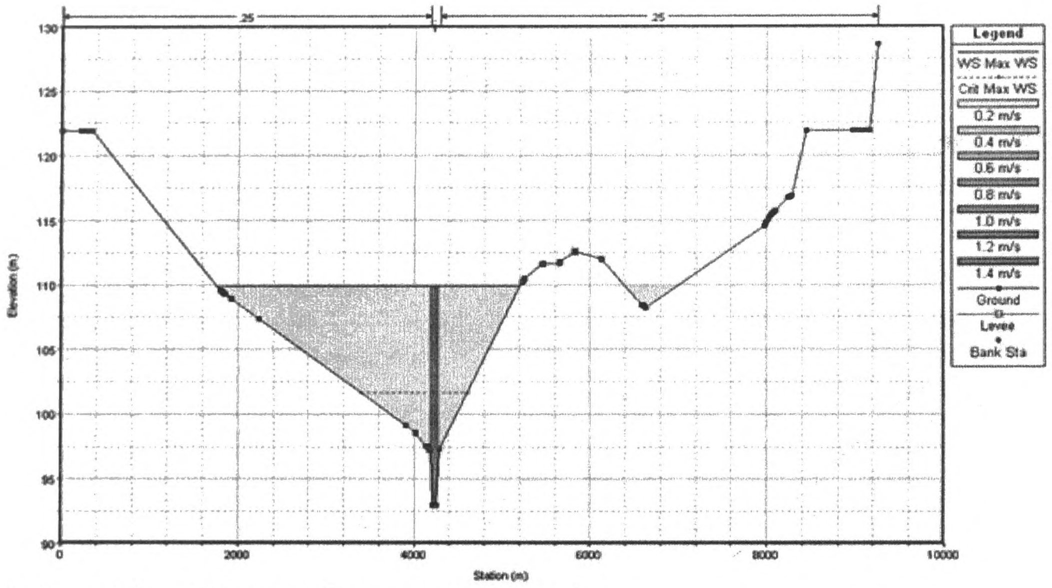


Figure 3. Velocity variation of the most downstream cross section

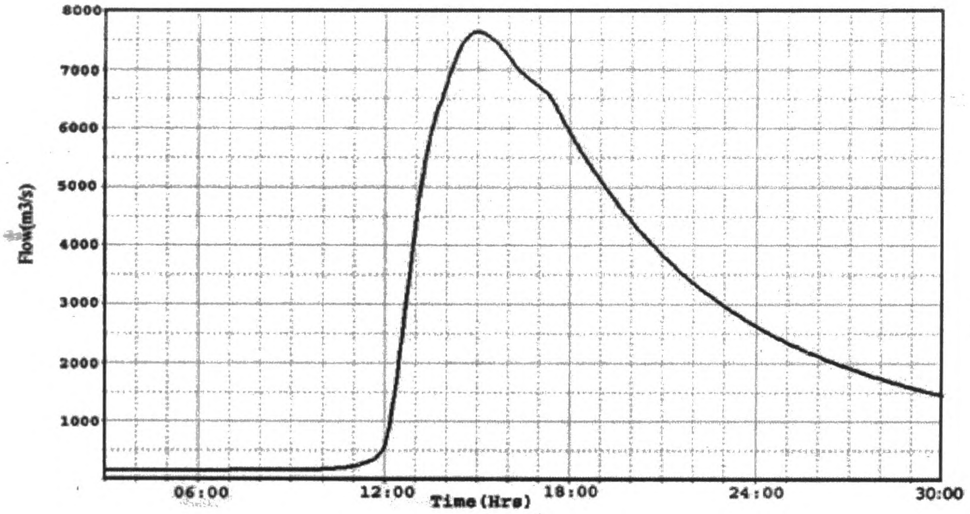


Figure 4. Flow Hydrograph at most downstream

According to the inflow and resultant hydrographs it can be seen that, discharge has been concentrated up to 7640.12m^3/s. This is a good achievement in order to ensure that the flow can be discharged safely from the Udawalawe dam. In addition to that following data is copied from final report developed for Udawalawe reservoir by JACOBS GIBB.

Table 1 Udawalawe Reservoir Discharge

Water surface elevation(m)	Storage (mcm)	Maximum discharge (m^3/s)
88.39	268.6	2527
89.00	294.3	3011
89.61	319.9	3829
90.22	345.6	4841
90.83	371.2	6004
91.44	396.9	7296
92.04	422.6	8702
92.65	448.2	10212

Figure 5 shows that the inundations map. Here different hatch patterns indicate that the condition of the flood. For instance, angled single line hatch pattern stands for total destruction area which means, flood can be threatened to lives as well as physical structures. In other words, flow carries high velocity of this area.

In order to break up the areas which varying types of flood damage, it was used a flood damage parameter of depth × velocity developed by Binnie and Partners and the Flood Hazard Research Centre (1991).

Greater than	7 m^2/s	total destruction
Between	3 m^2/s	partial structural damage
Below	3 m^2/s	inundation only

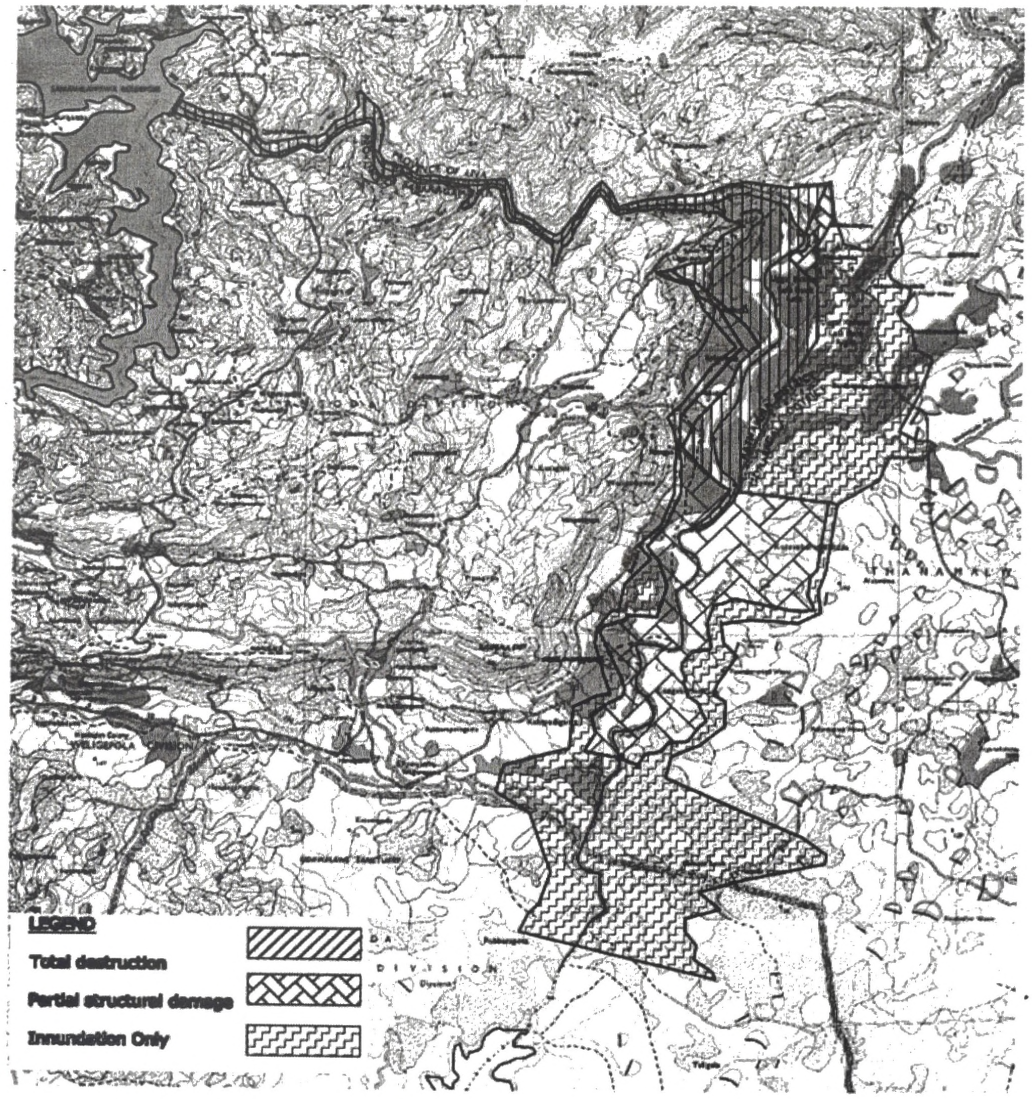


Figure 5 Inundation map

Conclusions

Cross section data can be subjected to changes time to time due to extreme weather conditions. Here, it was used contour maps developed some years ago and now it may be subjected to changes. In addition, it is important to find correct manning's n value over the river as well as flood plain. Therefore a detail field survey will enhance the accuracy of the simulation. Furthermore, it was unable to find out actual cross sections (depth) of the river. Therefore assumed values were used. However, when consider about the flood, the effect of the river cross sections cause minor differences for the simulation. The overall results of the simulation are a good approximation. The used methodology is cost effective and time saving. HEC RAS is an open source model and widely used all over the world and frequent upgrades of the model are also available to users and facilities are improved in order to get better results.

References

Hydraulic Reference Manual, Hydrologic Engineering Center

Risk management for UK reservoirs, A.Hughes, H.Hewlett, P.G.Samuels, M.Morris, P.Sayers, I.Moffat, A.Harding, P.Tedd

Samanalawewa final report, JACOBS GIBB Ltd

Udawalawe final report, JACOBS GIBB Ltd