SIMULATING FAILURE OF INDRAVATI DAM USING MIKE 11 AND THE PROPAGATION OF BREACHED OUTFLOW

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ABSTRACT

Dams are invariably used for multipurpose benefits to the society such as generation of hydropower, irrigation, water supply, flood control and others, but with associated high risk. As it retains huge amount of water, there is always a risk of formation of breach. There is a need to study the breaching aspects of a dam. In this paper a hydraulic model named MIKE11 developed by Danish Hydraulic Institute (DHI) is used to carry out simulation of flood resulting from the failure of Indravati multipurpose dam in the Odisha state. Propagation of the flood wave at its downstream reaches is studied and the consequent inundation map of the downstream submersed areas is prepared. Digital Elevation Map of the study area is obtained from USGS site and is converted into ARCII with the help of Arc-GIS software. Simulations carried out posed a challenge due to the availability of low resolution topographic data, stiff slope of the channel, obstructions at the downstream side of dam and other factors.

Keywords*: Arc-GIS, Indravati dam, Dam breach, Flood, MIKE11.*

1 INTRODUCTION

Dams are the basic piece of frameworks to the general public that add to social advancement and success. They serve too many beneficial purposes that are essential for the growth of the society, at the same time; dams hold a potential danger of disappointment because of numerous specialized security issues and threats. Disappointments are viewed as one of the real "low-likelihood" occasions. The surges coming due to dam failures can prompt catastrophes with gigantic death toll and property, particularly in thickly populated territories.

Past calamities resulting from dam disappointments are specifically identified with the clearing time when a dam failure happens (Wahl, T.L, 1998). It is along these lines critical to comprehend the procedure of dam rupturing, and if conceivable, to consider key breaking parameters required to display the dam rupturing process. Be that as it may, many existing dams still posture expanding risks to the downstream territories because of basic crumbling, lacking outline, defective development, and poor activity and upkeep. These dams are alluded to as upset dams.

Hanson et al. (2005) clarified that the breach development rate has a critical effect on the pinnacle release from a dam failure. In order to understand the breach development rate one has to keep a check on the breach initiation and formation times.

Wahl (1998) had given a clear cut explanation about two types of times associated with dam breach. The breach initiation time, which can be utilized to start an early cautioning, is the span from the beginning of overtopping stream over the dam dissolving downstream slope to the beginning of bringing down of the peak of the dam interfacing stored water to the broke outpouring. Breach development time is the span beginning from the bringing down of the bank peak and consummation with the total draw off the reservoir water.

For successful running of any software model, it requires a correct representation of channel of the downstream corresponding floodplains and other data as accurately as possible to predict the flood magnitude and level of water along the channel after the dam break (Gichamo**,** 2012).

In this paper a numerical simulation of the failure of Indravati dam is carried out by employing Danish hydraulic Institute's (DHI) - Mike 11. In this study, the effect of overtopping failure is given attention through Saint-Venant equations. A reliable and accurate mathematical model needs to be developed for breach evolution and for analysing the impact of dam break floods on downstream regions (Dhiman S, 2018).

2 STUDY AREA

2.1 Salient Features of Indravati dam

River Indravati originates in the eastern mountainous regions of India in the state of Odisha. It is an east flowing river that enters into Chhattisgarh state, finally joining the Godavari River. Indravati river basin lies between latitudes 18°43'25" N to 19°26'46" N and longitudes 80°16'19" E to 83°07'10" E. Major tributaries of this river are Bhaskal, Narangi, Nibra, Kotri, Bandia and Nandiraj rivers. Figure 1 shows the Indravati basin and dam while the other features of Indravati dam is given in Table 1. Figure 2 depicts a schematic diagram of the Indravati river

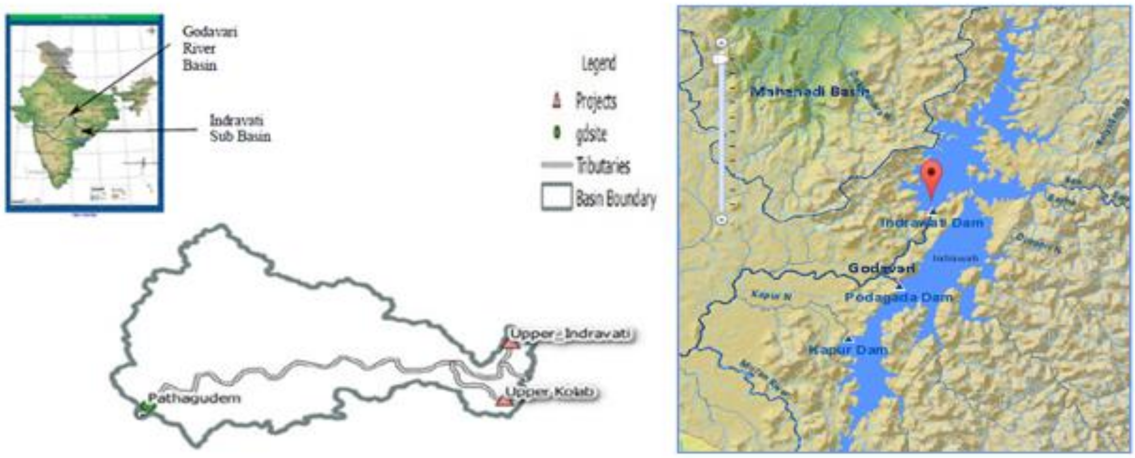

Fig 1: Map showing Indravati River Basin and the dam

system.

Table 1: Salient features Indravati dam

Dam Location and Properties		Reservoir Capacity	
River	Indravati	Gross Storage Capacity at F.R.L	2307 M Cumec
State	Odisha	Dead Storage Capacity	851.94 M Cumec
Latitude & Longitude	19°16’34.8” N & 82°49’42.4” E	Live Storage Capacity	1455.76 M Cumec
Catchment Area	2630 Sq. Km	Full Reservoir Level	R.L. 642 m
Length	539 m	Maximum Water level	R.L. 643 m
Height	45 m	Min Draw Down level	R.L. 625 m
Dam Top Crest Level	R.L. 645 m	Maximum Flood Discharge	23030 Cumec
Deepest Bed Level	R.L. 600 m		

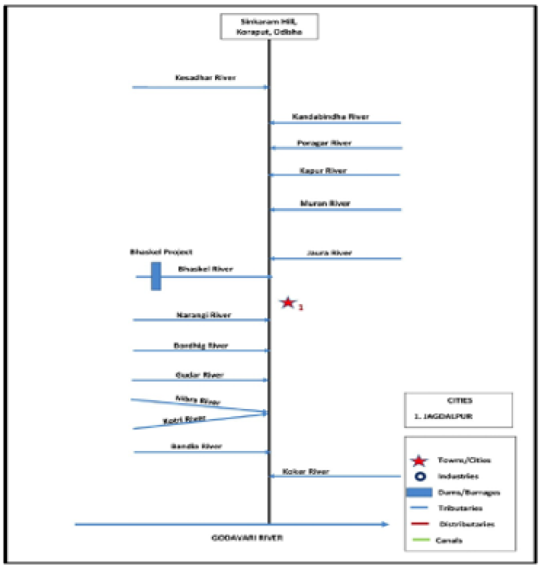

Fig 2: Schematic Diagram of Indravati River basin

3 DAM BREACH PARAMETERS

It is one of the most important inputs which have to be carefully considered in a dam break analysis. Usually earthen dams take more time for its complete failure as compared to a masonry dam. The failure time of earthen dam is 0.1 to 1 hour and that of masonry dam is 0.1 to 0.2 hrs (Fread, D.L, 2006). Table 2 shows the guidelines followed during dam break analysis as recommended by the UK and the Federal Energy Regulatory Commission (FERC) of the USA.

Table 2: Guidelines followed during dam break by UK and Federal Energy Regulatory Commission (FERC) of US

Dam Type	Average Breach width	Failure Time hrs	Breach Side Slope H:1V	Agency
Earthen/ Rockfill	(0.5 to5.0) x HD (1.0 to 5.0) x HD (2.0 to 5.0) x HD	0.5 to 4.0 0.1 to 1.0 0.1 to 1.0	0 to 1.0 0 to 1.0 0 to 1.0	USACE (2007) FERC (1988) NWS(Fread, 2006)
Concrete Gravity	Multiple Monoliths Usually ≤ 0.5 L Usually ≤ 0.5 L	0.1 to 0.5 0.1 to 0.3 0.1 to 0.2	Vertical Vertical Vertical	USACE (2007) FERC NWS (Fread, 2006

There are various ways in which breaches can be formed on embankment dams and it is pretty difficult to find out the extent of the erosion with the help of stringent mathematical formulas. Breach formation in embankment dams due to overtopping floodwaters has been counterfeit using complex 2D depth averaged flow models connected with slope failure method and soil erosion (Froehlich, D. C, 2004; Faeh, R., 2007)**.** Usually in practice, breach is presumed to take the shape of a trapezium as shown in Figure 3 (Fread, D. L, 1984; USACE, 1978).

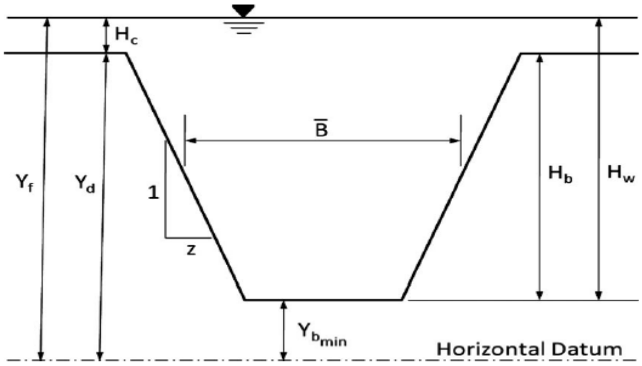

Fig 3: Dimensions of a trapezoidal dam breach approximation,
(height H_b, width $\overline{B}$ and ratio of side slope z (H:V), water in the reservoir Y_f)

4 METHODOLOGY

The DEM file of the study area is converted into ARCII format to import it into the MIKE HYDRO setup. The first step in MIKE HYDRO is to create a simulation file to save the progress of the work. In most of the dam break cases there is a single or multiple channels, a reservoir, the dam and its structures like spillways and others. At first, the network file is created, then the branches of the reservoir and downstream river is created. While creating / giving the cross-section, it is mandatory to give the first chainage section in of the reservoir to mark it as the storage. After that the boundary file is created inflow at the upstream is required for the simulation. Time series for water level and discharge is to be made. After which HD parameters is to be created. The HD module makes use of an implicit method for the calculation of unsteady flow in rivers. After all this procedure the setup is run and for this a simulation editor is created. While considering the dam-breach modelling, one of the greatest uncertainties is the simulation of the breach (Wurbs, 1987). Depending upon the size of the reservoir the parameters importance varies. The dam breach parameters used is shown in Table 3.

Table 3: Dam breach parameters

Dam crest elevation	645 m	Breach width at end	250 m
Reservoir level at breach	644.3 m	Breach slope	0:1 (vertical)
Breach width at start	10 m		

5 MODEL SETUP

The first step is the creation of Indravati River in the network editor. The river extends up to a stretch of 138.9 km at its downstream. Up to a length of 50000 m the river cross sections are provided at spacing of 500 m and after that and till 138900 m it is provided at a spacing of 1000 m. The dam break arrangement is defined at 130 m chainage from the starting point. At chainage “0” the reservoir is modelled. The PMF is considered as the inflow to the reservoir. At chainage point of 138900 m boundary conditions are applied. The *Q / h* values are generated automatically from Manning’s formula. Table 4 gives the *Q/h* values and Fig 4 shows the

Rating curve obtained from MIKE 11. Manning's roughness coefficient for the whole river is taken as 0.022 following chows (1959) guidelines.

Table 4: Stage discharge values

Stage (h) in m	Discharge (Q) in m^3/s	Stage (h) in m	Discharge (Q) in m^3/s
537.6	0	541.7	6069
538	22	542	7636
539	335.6	545.7	29791.3
540	1879.4	550	61702.7
541	3765.7		

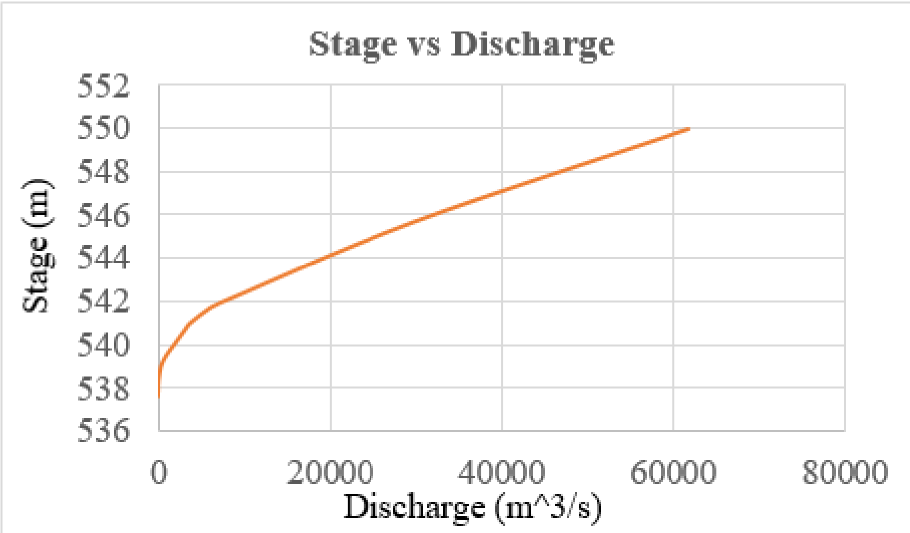

Fig 4: Rating Curve

6 RESULTS AND ANALYSIS

During dam break analysis, the most critical state is when the water in the reservoir is at FRL (Full Reservoir Level) and a PMF infringe the reservoir. The value of PMF considered is 23030 cumec. Dam breach is initiated at 25.3 hrs from the beginning of PMF, the maximum water level attained at that time is 645.201 m. The maximum value of discharge flowing out of the dam is 33218.4 cumec which is 1.44 times more than the PMF. This maximum discharge is attained at 6 hrs from the beginning of the dam break. Velocity of water coming out at this point is 10.6 m/s. The corresponding value of breach parameters are given in Table 5, while Table 6 shows the statistics of dam breach.

Table 5: Breach parameters at Maximum discharge

Level of Breach (m)	620
Depth in breach (m)	11.97
Breach bottom width (m)	250
Breach width at crest (m)	300

Table 6: Statistics of Dam breach

Time (h)	Q in breach (m^3/s)	V in breach (m/s)	Reservoir water level (m)	Level of breach (m)	Depth in breach (m)	Breach bottom width (m)	Breach width at crest (m)
25.3	12.2	2.215	645.201	644.3	0.525	10	11.4
25.5	38.4	2.806	645.205	643.7	0.844	15.3	17.8
26	332.1	4.355	645.217	641.7	2.038	35.3	41.9
26.5	1034.2	5.474	645.211	639.6	3.221	55.4	66.0
27	2237.3	6.387	645.174	637.67	4.386	75.4	90.1
27.5	3999.5	7.168	645.09	635.64	5.522	95.5	114.2
28	6346.9	7.849	644.938	633.6	6.618	115.5	138.3
28.5	9272.3	8.447	644.697	631.5	7.661	135.6	162.4
29	12736.7	8.974	644.346	629.51	8.638	155.6	186.5
29.5	16669.3	9.434	643.864	627.51	9.538	175.7	210.67
30	20968.2	9.833	643.229	625.41	10.347	195.7	234.7
30.5	25503.2	10.17	642.423	623.42	11.054	215.8	258.6
31	30112.8	10.447	641.422	621.42	11.646	235.8	282.9
31.3	33218.4	10.597	640.551	620	11.967	250	300
31.4	33008.8	10.576	640.468	620	11.917	250	300.0

6.1 Flood Routing

For the purpose of flood routing at its downstream reaches, 8 chainage points are considered at locations of 1.5 km, 5 km, 7.5 km, 10.5 km, 25 km, 55 km, 100 km and 120 km d/s of the reservoir. At the dam the value of peak discharge coming out after breaching process commences is 33218.4 cumec. This discharge comes out from the dam after a time of 6 hrs from the start of the breach. At 1.5 km d/s the value of maximum discharge is 33067.48 cumec. The time of arrival of flood is just 1 min from the beginning of flood. At 5 km d/s the value of maximum discharge is 32899.44 cumec, while the arrival time of peak value of flood is 9 min. At 7.5 km d/s the value of maximum discharge is 32704.8 cumecs, while the arrival time of peak value of flood is 12 min. At 10.5 km d/s the value of maximum discharge is 32453.44 cumecs, and its arrival time is 17 min. At 25 km d/s the value of maximum discharge is 29239.14 cumecs, while its arrival time is 1 hr 3 min. At 55 km d/s the value of maximum discharge is 23895.56 cumecs, while its arrival time is 3 hr 23 min. At 100 km d/s the value of maximum discharge is 16526.59 cumecs, and its arrival time is 8 hrs 30 min. At 120 km d/s the value of maximum discharge is 13693.69 cumecs, and its arrival time is 11 hr 3 min.

6.2 Longitudinal profile of the bed

Fig 7 depicts the longitudinal profile of the bed of river Indravati after dam break along with the water level attained at different downstream locations resulting from the dam break. Fig 8 represents the time series discharge of the river at midpoint of selected sections.

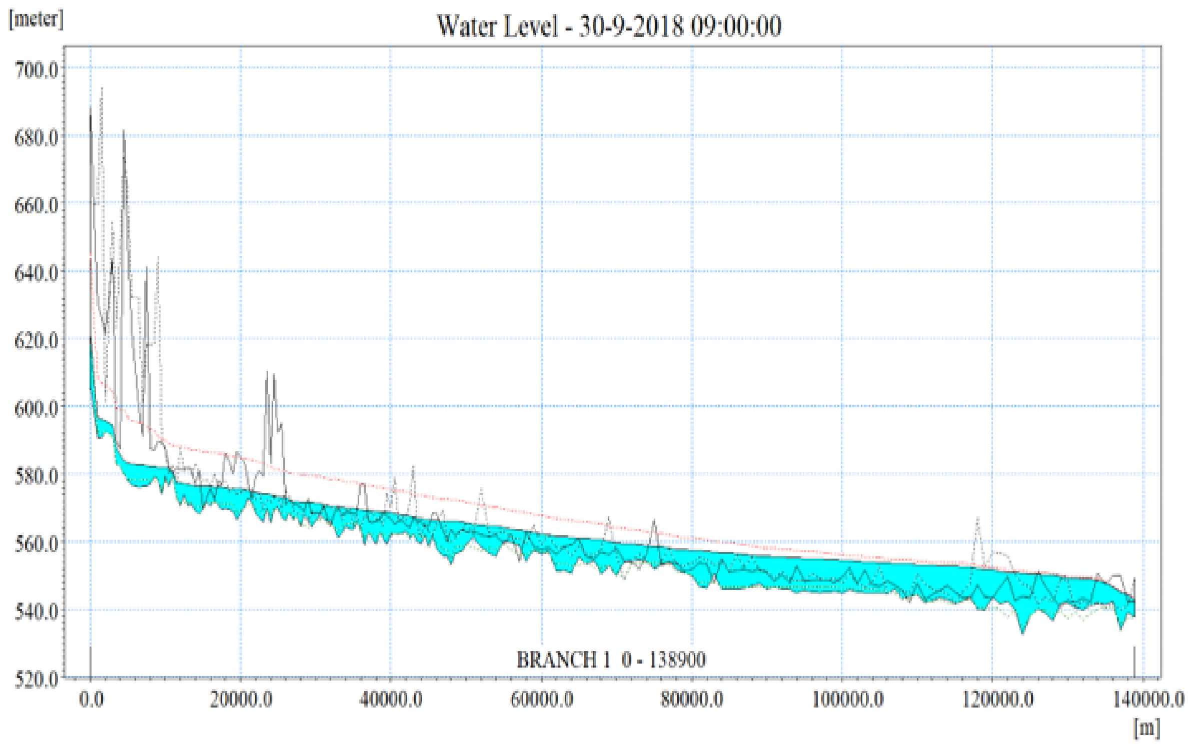

Fig 7: Longitudinal profile of the bed of river Indravati after dambreak.

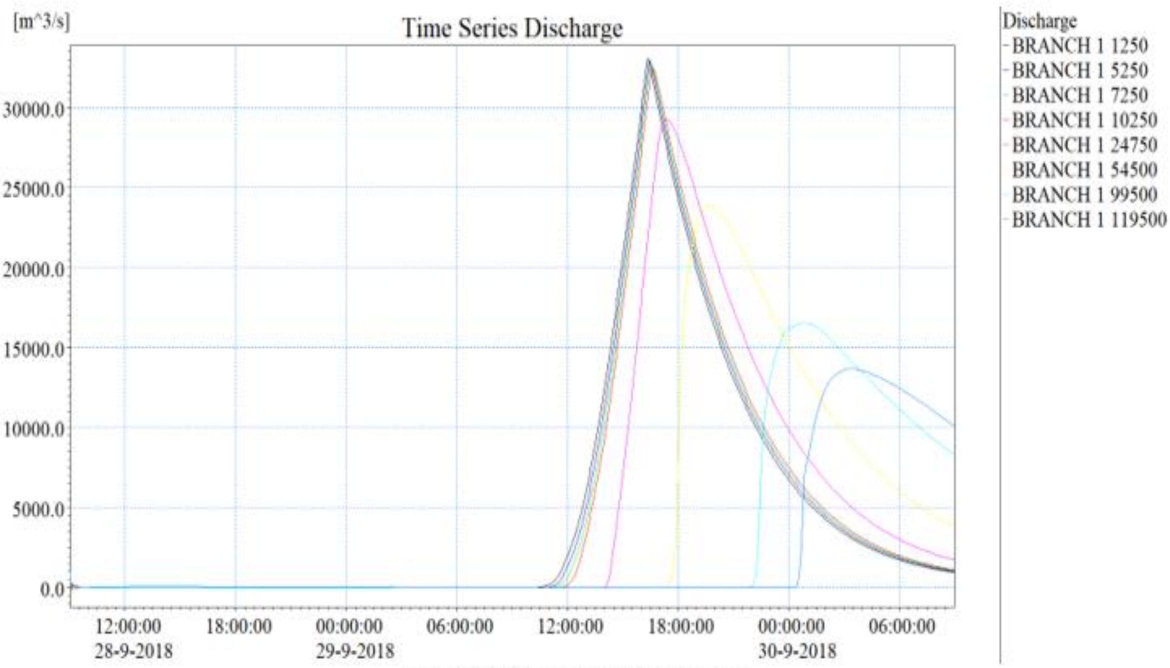

Fig 8: Time series discharge

Level of water at all the 8 chainages is shown in Table 7. Figure 9 depicts the time series water level of all the 8 chainages.

Table 7: Level of water along with the time of occurrence at each chainages

Distance d/s(km)	W.L. (m)	Max. W.L. time	Distance d/s(km)	W.L. (m)	Max. W.L. time
1.5	606.87	29/09/2018 16:24:0	55	569.67	29/09/2018 20:31:5
5	596.69	29/09/2018 16:30:0	100	556.34	30/09/2018 02:24:0
7.5	593.94	29/09/2018 16:33:5	120	552.69	30/09/2018 04:51:5
10.5	589.08	29/09/2018 16:45:5			
25	581.45	29/09/2018 17:51:5			

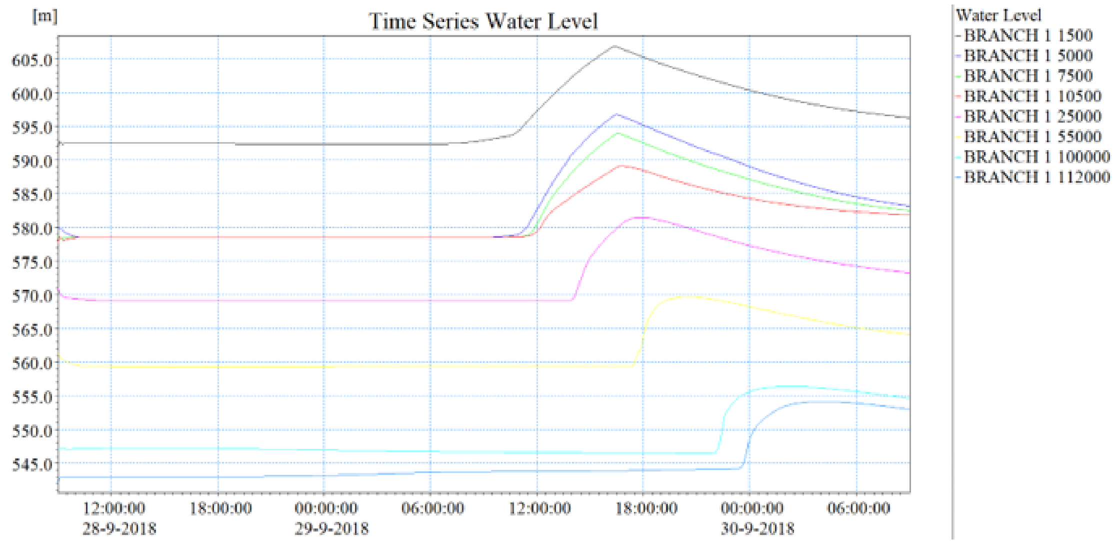

Fig 9: Time series water level

7 CONCLUSIONS

Here in this paper a hypothetical failure of Indravati reservoir is simulated using MIKE 11. The dam has a height of 45 m with gross storage capacity of 2300 M cumecs. Effects of dam break at the downstream side of the dam are studied with the help of flood hydrograph, duration of the flood, water level and velocity of propagation of flood wave. From the modelling, the following conclusions can be drawn.

- Maximum flood discharge from the failure of the Indravati dam is 33218.4 cumec which is 1.44 times more than the PMF.
- The dam break results can be utilized to prepare maps for an emergency action plan that can help communities in arranging future improvements in zones that are flooding prone.
- The time series water level and discharge at different c/s (1.5 km, 5 km, 7.5 km, 10.5 km, 25 km, 55 km, 100 km and 120 km) are obtained that suggests the flood prone areas resulting from the dam breach.

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