Two-dimensional Modelling of Flood Inundation in Parts of Kundah River, The Nilgiris, Tamil Nadu

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ABSTRACT

The aim of this study is to understand the flood inundation situation based on two-dimensional model and identify the risk prone areas due to flooding. The part of Kundah river basin, the Nilgiris, Tamil Nadu, South India was selected for this study. The Kundah river is one of the important rivers in the Nilgiris. The entire river is flowing on steep slope hilly terrain. Some major reservoirs like Avalanche, Emarald and Kundah were constructed across Kundah river and mainly used for generating hydroelectric power to fulfill the local domestic needs. In this simulation study, a river length of 19.5 km was taken on the downstream side of Avalanche Reservoir in Kundah river. MIKE 21 flow model was used for generating water surface flow of the study area. River feature and bathymetry were extracted from CARTOSAT1 DEM. The result obtained from flood inundation model shows that the flooding has affected seven habitations situated along the close proximity of river bund and two more habitations located far from river bund.

Keywords:

CARTOSAT1 DEM; MIKE21; Two-dimensional model; Flood Inundation Study; Kundah River

1. INTRODUCTION

All over the world, cities and towns are mainly situated near the riverside. The main reason was to manage their daily needs like drinking water, agricultural usage and other purposes. However, during the rainy season, the overflow of water from the river bank causes flooding. Flood disaster is a regular phenomenon for almost all the settlements located on the riverside. Due to the lack of expertise on storing or diverting the flood water, many disasters have occured in the past. Nagesh Kumar, Falguni Baliarsingh & Srinivasa Raju (2011), Dhruv Sen Singh (2014) and Durga Rao et al. (2014) mentioned about the causes, its type and other parameters of floods. Construction of dams across the river to store the flood water has drastically reduced the floods in the downstream area. Nevertheless, it has a threat of a dam breaking and out flow of excess water from the dam. By developing a two-dimensional flood simulation model of a dam breaking situations, it is possible to take the necessary mitigation plan and hence the losses due to the flooding can be avoided. Geographic Information (GI) Technologies and two-dimensional flood numerical models such as MIKE, SOBEK, FIVFLOOD, Hydro2DE and ISIS were used to build 2D flood simulation models. Though many researchers reported the simulation studies (Andrea Defina (2000), McCowan, Rasmussen & Berg (2001), Angelo Leopardi, Elisa Oliveri & Massimo Greco (2002) and Morten Rung and Kim wium Olesen (2003)) on the plain terrain, studies on hilly terrain were limited.

2. STUDY AREA

The area selected for the present study is part of Kundah river in hilly terrain of the Nilgiris, India. The Nilgiris mountain is situated in the Western Ghats and is famously called as the Blue Mountain. Kundah River

originates from Avalanche and Emerald Reservoirs located in the southern part of the Nilgiris. The river flow southeastward and joined with the Bhavani river. In this 2D terrain is situated at an altitude of 2388 m in northeastern portion and sloped to a minimum altitude of 686 m in southeastern portion.

In the study area, 108 rural habitations were captured through GPS survey. Out of these 108 habitations, 24 habitations were identified within one km proximity of the center-line of the Kundah river. Among them, Bharathi Nagar, Inbasagar Nagar, Kuttimani Nagar, Nehru Kandy, Nehru Nagar, Periyar Nagar and Surendra Nagar were very closely situated along the river bund (Figure 1).

3. DATA USED

Ground Control Point (GCP) survey was conducted in the study area for georeferencing imagery, Village and Taluk maps. As many as 54 GCPs were captured in the field using single frequency Differential Global Positioning System (DGPS). Rober J. Connell, David J. Painter and Cornel Beffa (2001) were used GCP for their studies pertaining to two-dimensional floodplain flow on the Waiho river rural floodplain in New Zealand. These 54 GCPs, captured for the present study, were post-processed using trimple post-processing software for achieving high accuracy. The satellite imagery namely CARTOSAT1 panchromatic stereo data with 2.5 m resolution was rectified using the post-processed GCPs. Fine resolution Digital Elevation Model (DEM) was generated from CARTOSAT1 panchromatic stereo data. Apart from these, point features data with elevation values were extracted from fine resolution DEM data and used in this study. Srinivasa Rao et al. (2009) and Kiran Yarrakula et al. (2010) mentioned that the DEM is very much useful for flood simulation study. They have conducted flood simulation in Godavari river and Subernarekha river respectively.

simulation study, a river length of 19.5 km was considered for two-dimensional flood simulation from downstream side of the Avalanche and Emerald Reservoir. The hilly

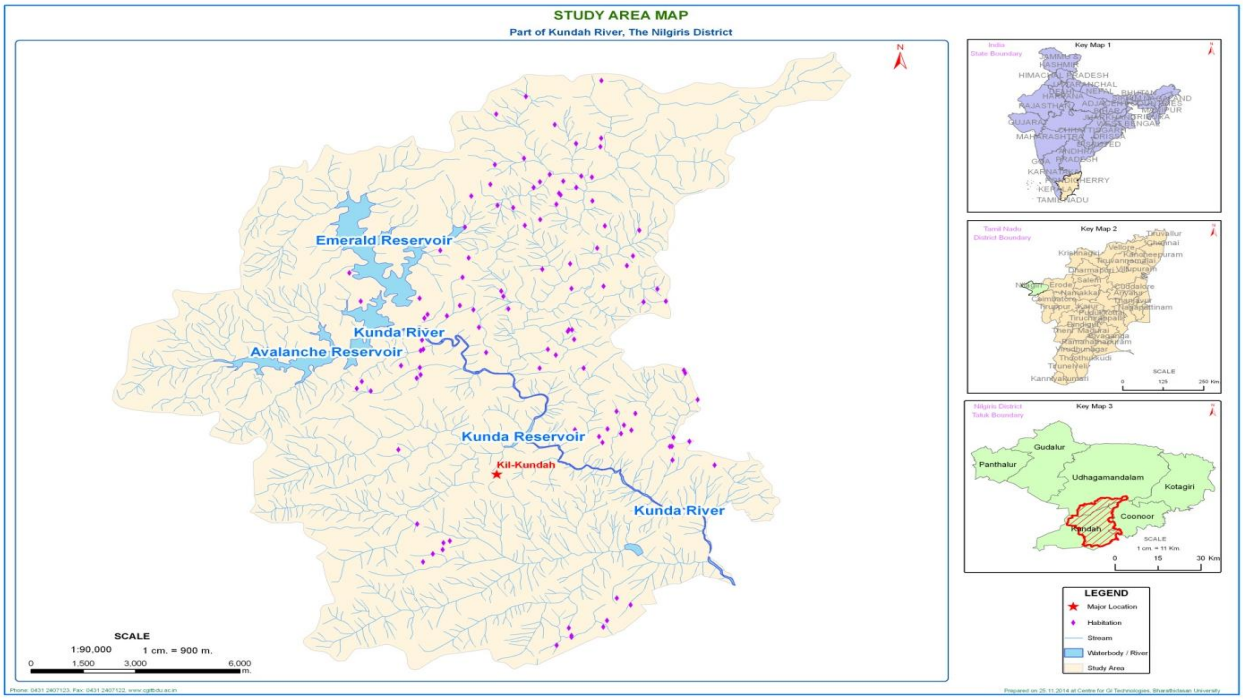

Fig. 1

4. METHODOLOGY

The methodology adopted for the present study is given below in Figure 2.

CARTOSAT1 stereo data from National Remote Sensing Centre (NRSC) was preprocessed and GCP surveyed. Subsequently, the Georeferencing of CARTOSAT1 imagery was carried out by post-processed GCPs. DTM editing for the entire study area was carried out. In the DTM editing work, values of Z parameter were identified and brought to fit onto a surface and DEM data was generated. Totally 2,79,421 point features with height values were generated from fine resolution DEM data for generating bathymetry data.

MIKE21 model developed by the Danish Hydraulic Institute (DHI) was used for the two-dimensional flood inundation in the hilly terrain of Kundah river. The model was executed based on depth averaged Saint-Venant equation method of two-dimensional model. To execute the MIKE21 flow model, the following steps were adopted:

Step 1: Generation of Bathymetry data through Point feature class DEM data.

Step 2: Specifying the Simulation period for the run model.

Step 3: Identifying the various sources for executing the model. In this study, three sources via: Source 1: Outlet of Avalanche Reservoir; Source 2: Outlet of Emerald Reservoir and Source 3: Tributary of Kundah was considered.

Step 4: Initializing the various hydrodynamic parameters required for the model like surface elevation, eddy viscosity, resistance, etc.

Step 5: Assigning the optimal time interval for the simulation based on bathymetry condition and time series data.

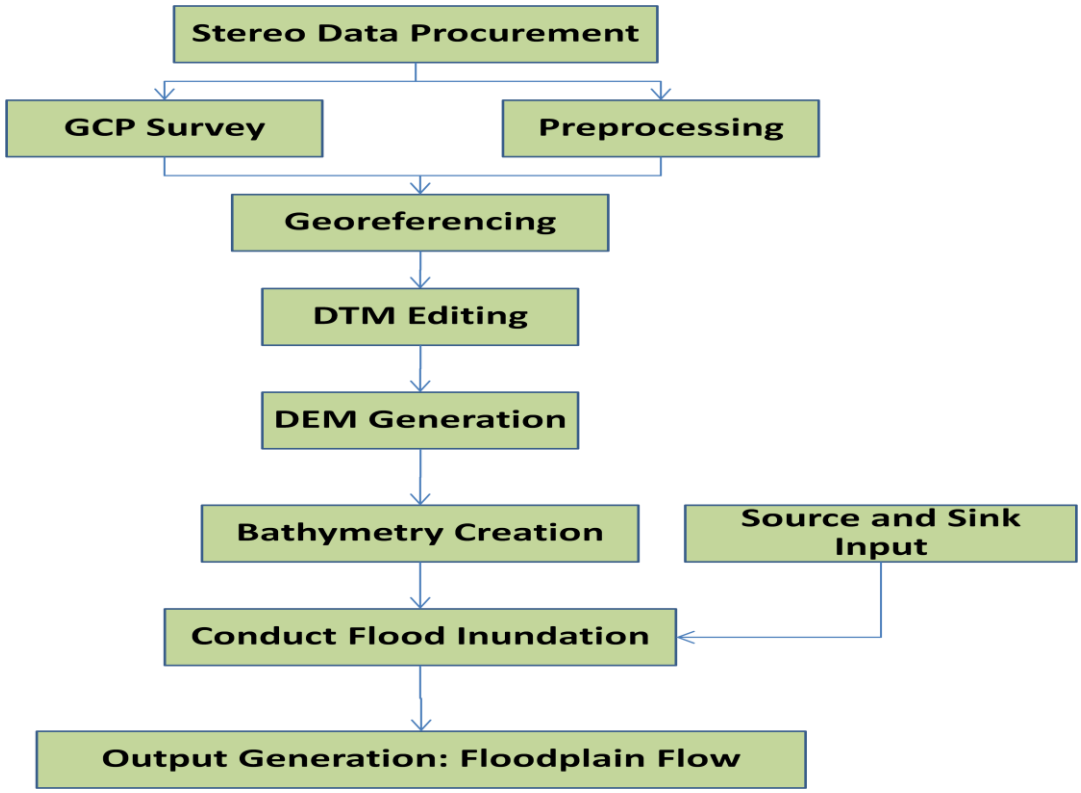

Fig. 2

5. RESULTS AND DISCUSSION

The results of water surface flow modeled through MIKE21 flow model during the starting time of first day is shown in Figure 3. The dam structures are represented in blue line symbology, the river stretches are marked in brown color line symbology and habitations are marked with red color point symbol. Figure 3A shows the three source locations in the study region.

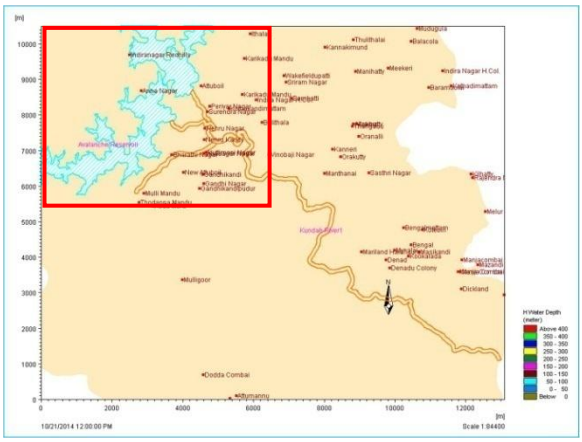

Fig. 3

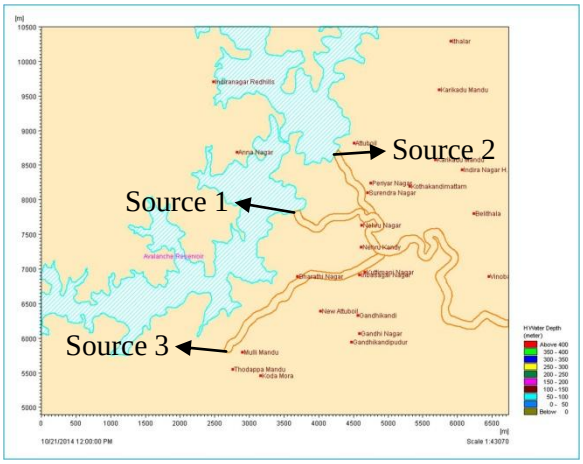

Fig. 3A

For the given conditions, it has been observed that the water flow from Avalanche (Source 1) and Emerald (Source 2) dams were converging on Kundah river at 16.50 hours on the first day (i.e. after 4 hours 50 minutes from the time of start). At this stage, the water depth in the river was found at the level of below 50 m and hence the Surendra Nagar situated on left side bank of the Emerald dam spillway channel and Bharathi Nagar situated on left side bank of the tributary were found to be inundated with flood water (Figure 4).

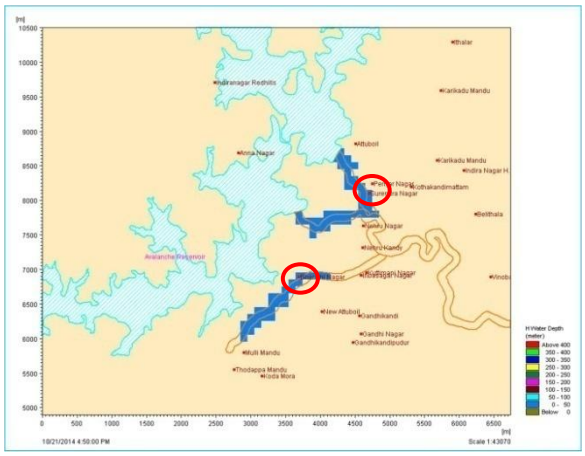

Fig. 4

Figure 5 shows that at the time duration of 22.00 hours on the first day (i.e. after 10 hours 00 minutes from the time of start), the water started flow from the tributary converge in Kundah river. At this stage, the water depth ranging between 50 and 100 m at the spillway channel of Avalanche dam was recorded. Due to this impact, three more habitations such as Periyar Nagar (left side of the river bund), Nehru Nagar and Nehru Kandy (right side of the river bund) were found inundated with flood water.

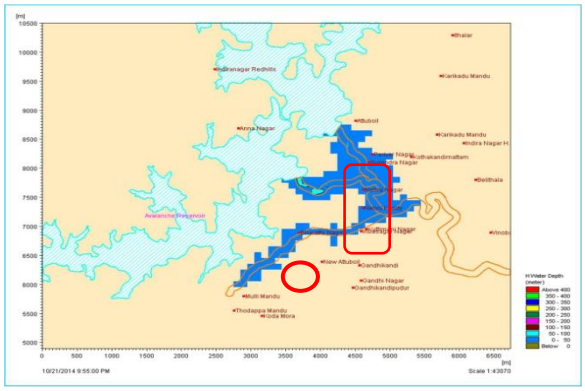

Fig. 5

Figure 6 shows that at 23.40 hours on the first day (i.e. after 11 hours 40 minutes from the time of start) river water crosses approximately more than 5 km of length. Now, additional two habitations situated on right

side bund of the tributary such as Inbasagar Nagar and Kuttimani Nagar was also inundated (Figure 6). At 3.30 hours on the second day (i.e. after 15 hours 30 minutes from the time of start), it was found that the Gandhikandi and Gandhi Nagar habitations were inundated (Figure 6) with flood water.

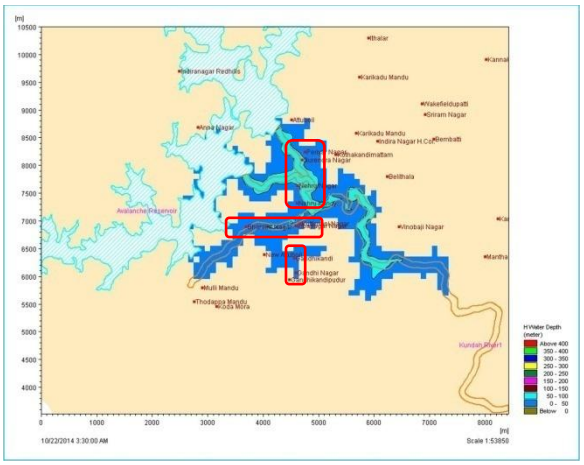

Fig. 6

The water continuously flown in the river and reached end of the river stretch (Figure 7) at 13.55 hours on the second day (i.e. after 25 hours 55 minutes from the time of start). In this stage, no other habitations have been inundated with floodwater, except the nine habitations which were already inundated. Now the water depth of the river stretch was more or less ranging between 50 and 100 m whereas the water depth at the floodplain was below 50 m (Figure 7).

Fig. 7

At 15.15 hours on the second day (i.e. after 27 hours 15 minutes from the time of start) the water was reaching the river end. Subsequently, the flood slowly drained at its origin place of the river. Figure 8 shows that at 08.05 hours on the third day (i.e. after 44 hours 05 minutes from the time of start), Nehru Nagar habitation was completely drained from flood water followed by complete drain at Gandhi Nagar habitation. At 13.45 hours on the third day (i.e. after 49 hours 45 minutes from the time of start), the water depth increased up to the range between 350 and 400 m at the end part of the river (Figure 8).

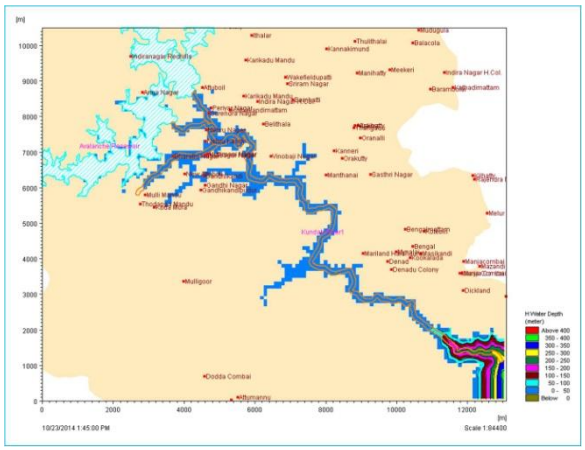

Fig. 8

It was noticed that the Nehru Kandy habitation was also completely drained from flood water at 20.05 hours on the third day (i.e. after 56 hours 05 minutes from the time of start). Then the Gandhikandy habitation was completely drained from flood water at 1.00 hours on the fourth day (i.e. after 61 hours 00 minutes from the time of start). Finally, five habitations such as Surendra Nagar, Bharathi Nagar, Periyar Nagar, Inbasagar Nagar and Kuttimani Nagar were not drained (Figure 9) from flood water even after the fourth day (i.e. after 72 hours 00 minutes from the time of start).

When executing the model, as many as nine habitations were affected by the flood and the flood duration details are given in Table1.

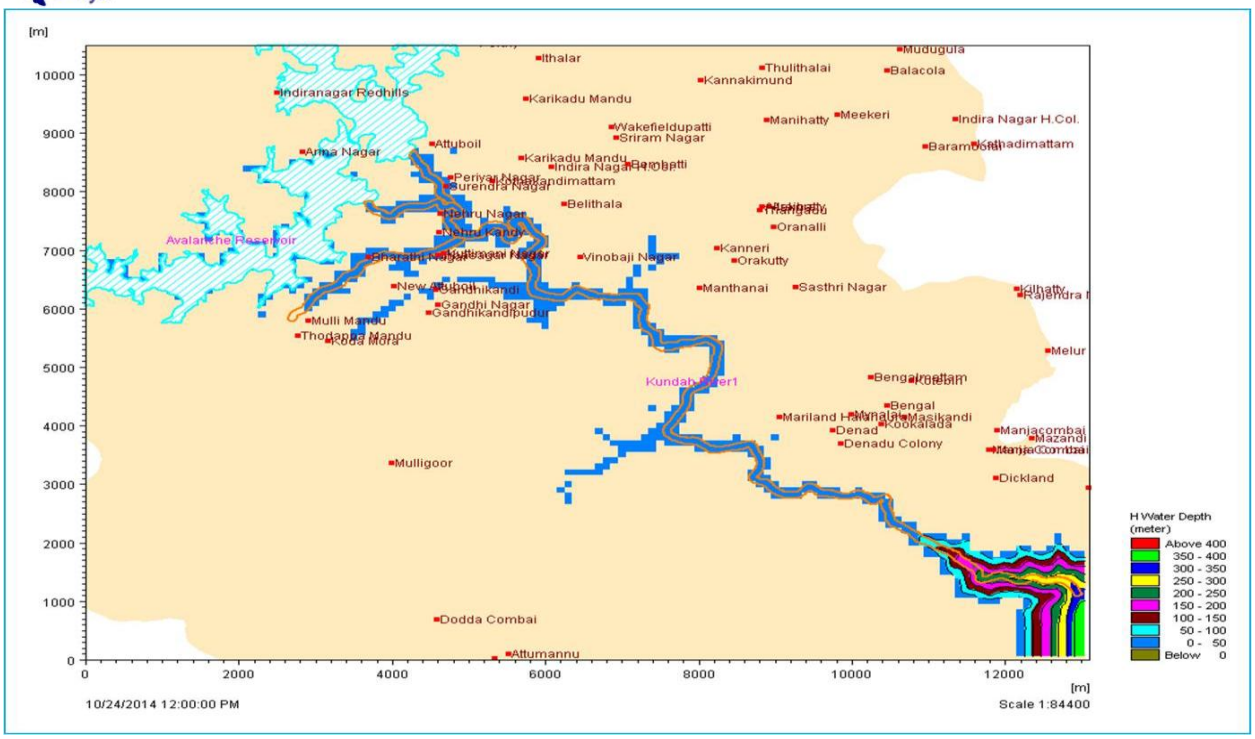

Fig. 9

Table 1

No.	Habitation	Time from starting of the Model (Hrs.)		Flood Duration (Hrs.)
		Flood Start	Flood End	
1	Surendra Nagar	4.50	-	Continued
2	Bharathi Nagar	4.50	-	Continued
3	Periyar Nagar	10.00	-	Continued
4	Nehru Nagar	10.00	44.05	34.05
5	Nehru Kandy	10.00	56.05	46.05
6	Inbasagar Nagar	11.40	-	Continued
7	Kuttimani Nagar	11.40	-	Continued
8	Gandhikandi	15.30	61.00	45.30
9	Gandhi Nagar	15.30	49.45	34.15

6. CONCLUSION

The results obtained from flood inundation study using MIKE21 flow model is giving clear picture about two-dimensional inundation scenario of flood water. The inundation scenario was examined for 4 days. In the present study, when water uncontrollably overflows or dam break occurs from Avalanche and Emerald Reservoirs and one tributary of Kundah river, flood affects

nine habitations such as Surendra Nagar, Bharathi Nagar, Periyar Nagar, Nehru Nagar, Nehru Kandy, Inbasagar Nagar, Kuttimani Nagar, Gandhikandi and Gandhi Nagar located both sides of the river bund. Even though Gandhikandi and Gandhi Nagar habitations were located far from river bund, still these habitations have also affected due to the flood. The two-dimensional model is found to be useful to analyze the flood inundation of floodplain in the Kundah River.

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