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Delineation of the evacuation route plan, relief camp and prioritization using GIScience

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Abstract. Rising urban flood patterns are a universal phenomenon and a significant challenge for city government and urban planners worldwide. Urban flood problems range from relatively localized incidents to substantial incidents, which lead to cities being flooded for a few hours to several days. Therefore, the effect may be widespread, such as the temporary displacement of individuals, disruption to civic facilities, water quality degradation and the possibility of epidemics. The problems raised by urban flooding are highly challengeable and compound by ongoing climate change, with adverse implications for changes in rainfall and gaps in intra-urban rainfall distribution. Unplanned construction and invasions of large houses along rivers and watercourses have interfered in natural rivers and watercourses. As a result, the runoff has risen in proportion to the urbanization of the urban floods. The location of the relief camp and the priority for evacuation were determined, and the safest route to avoid floods were established. This method can be used for emergency planning in future flood incidents, and it will help plan disaster preparedness for Panchayat. This study will promote the flood plain's potential use for disaster management and land use planning virtually.

Keywords: GIScience; flood; evacuation prioritization; network analysis; settlement

1. Introduction

Many countries have been affected by the disasters caused by various weather conditions that have caused the loss of many lives; many properties have suffered damage, mainly economical activities (Ambastha *et al*. 2007). Weather-related disasters between 1995 and 2015, of which 47 percent were attributed to flooding from Asia involving 2.3 billion people. The significant floods occurred since the 21st century is 2000 Mozambique flood occurred in South Africa, followed by the successive heavy rainfall for several months, which caused some rivers to double the average water level. The Haiti flood occurred in 2004, which caused continuous rain for two days,

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resulting in about 600 casualties. Many people across south-eastern Europe suffered a lot due to flooding after 2006 as the Danube river was overflowed (Blaikie *et al*. 1994). In Asia, in developing countries like India, Bangladesh, China, Vietnam, Pakistan, and Indonesia, flooding is the biggest disaster affecting thousands of people. The regions primarily influenced by the flood are the large landmasses consisting of more than one river Basin and flood plains coupled with high population densities and flood affecting areas (Pandey *et al*. 2013, Meraj *et al*. 2013). The flood occurred due to the heavy monsoon rains in Bangladesh, which caused damage to thousands of houses and lives of not less than 3.7 million. The flood happened in Nepal due to above-average rainfall, resulting in a surge in 36 of the 75 districts. The floods reported in the report includes flood occurred in China, Myanmar and Sri-Lanka. Another flood in Thailand was the worst flood that affected 65 out of its 77 provinces (Nathawat *et al*. 2010). Kerala's state suffered the most significant surges in mid-August, killing 2/3 of its inhabitants and 504 people. More than 23 million people have lost their homes. The flash floods without notice or symptoms are the worst in the world since the 1920s and cost the US $2.85 trillion (Joy *et al*. 2020a). The world's most flood-affected country in Bangladesh, and floods cause India's place and one-fifth of the world's death rate. Twenty-three states in the nation are liable to floods and about 40 million hectares of land, about one-eighth of populated by topographical countries (Swaminathan 2001, Singh and Sontakke 2002, Meraj *et al*. 2018).

The Ganga and the Brahmaputra are the river basins under extreme flooding. These Himalayan flows down the slopes create flood problems in Uttar Pradesh, Orissa, Bihar, West Bengal and Assam because of the high monsoon from June to September (Singh *et al*. 2011). Around four kilometers or about one-eighth of the topographical Indian territory are inclined to flood. The Indian sub-continent has an explicit geological system that is prone to flood various parts of the world (Singh and Pandey 2014). The snow-capped Himalayan River in the North has one of the world's most massive glaciers, a source of numerous rivers (Pelling *et al*. 2004, Wilhite 2000). These vast fields are inclined to flood due to the rivers that swell in Monsoon due to heavy precipitation. India's average rainfall is 1150 mm, with some variation across the region (Singh 2017). Some of the terrible floods in the past that have crushed individual states and lives are listed below. The west coast, Western Ghats, Khasi paths, and Brahmaputra valley's main area add up to 2500 mm and more to the site. Other river flood explanations include massive flooding, glacial lakes bursting, cloud bursting, and tsunami.

The information about the location and extent of flooding in real-time is obtained utilizing Optical data and microwave data from the satellite ranges such as IRS, Radarsat, Landsat ERS. Data from the satellites, before or after the flood, are used to carry out a flood damage assessment using the ground details, topology data, hydrological data, land use of flood plains, or land cover data on a GIS network (Pandey *et al*. 2010, Altaf *et al*. 2013, 2014). The fluvial configuration is analyzed using spaceborne multispectral data. This data also helps examine infrastructure for flooding control and classify flood-prone areas, areas vulnerable to bank erosion, drainage congestion, etc. Remote sensing inputs such as satellite rainfall estimations, soil data, current hydrologic land use or land cover enhance flood forecasts (Pandey *et al*. 2012).

GIS is commonly used to store information and also to interconnect various databases and multi-theme layers. This data is presented in maps, and the relations between the layers are also analyzed (Meraj *et al*. 2015, 2016). GIS gathers data from many sources, including GPS, soil samples, environmental patterns, remote sensing, stream measurements, and censuses (Kanga and Singh 2017). Once the flooded area is again flooded, checking the flooded regions' history helps classify flood risk areas. The data collected is used to evaluate the effect and impact of each GIS factor. GIS provides technology through the provision of a viable solution. GIS helps to identify, prepare, mitigate, respond, and recovery management activities (Pratyush *et al*. 2018). Flood-prone areas can be identified by overlaying different space layers, and thus, additional mitigation can be given and the required response taken at the time. GIS offers maps to warn the public and government about floods, evacuation paths, etc. This data can be distributed through web technology; interactive maps with the query option can be created and updated in real-time linked to additional available data (Joy *et al*. 2019). Flood modeling and flood risk estimation along with different pandemics are also effectively conducted using remote sensing (Kanga *et al*. 2020a, b).

Because of its geography, Kerala is heavily affected by natural disasters and climate changes. Kerala's State Disaster Management Plan identifies the 39 dangers and categorizes them primarily into two hazards, naturally triggered and anthropogenically triggered. As Kerala is the most populated state (860 people per sq. kilometers), it offers more significant opportunities to be affected by damages and losses. Flood is the typical natural hazard to Kerala, as almost 14.5 percent of the state's land area has torrents and half of its land is prone to flooding in individual districts. The most common threat is in communities such as Wayanad, Kozhikode, Idukki, and Kottayam. Seasonal drought also poses a natural hazard during the summer. Between 1881 and 2000, Kerala had several years of drought, with 66 years. In urban and rural areas, water scarcity arose due to the lowering of water resources and the drying of 8 rivers. Fighting, high wind speed, coastal erosion of forest fires, and soil piping are other natural risks that affect Kerala. Kerala's major regions are in the seismic zone III. The average annual precipitation rate in Kerala is approximately 3000 mm. There are two main types of monsoons, south-western monsoon and north-eastern monsoons, which manage Kerala's precipitation. The rainfall storm leads to massive discharges in the Kerala rivers. The continuous rainfall leads to land flows across streams and water sources to significant streams (Fig. 1).

2. Materials and methods

Over time, the rise of the floodwater levels should be studied for planning purposes,

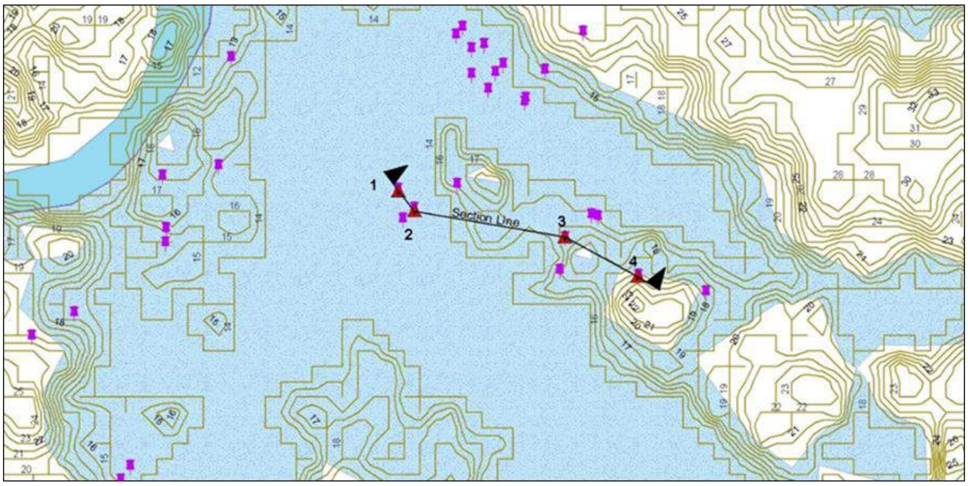

Fig. 1 Selected survey points and section line for cross-section to show temporal flood levels

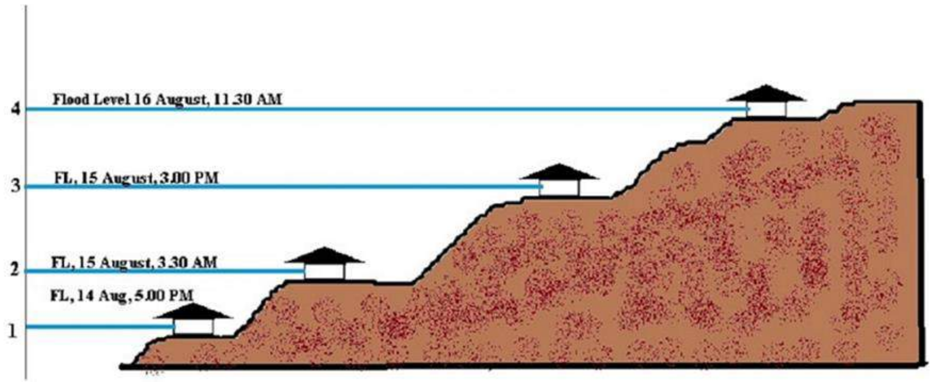

Fig. 2 Cross-section of survey points for tracking flood level at different times

Table 1 Flood levels at the time of evacuation and final level

No	Date of evacuation	Time of evacuation	Flood level during evacuation (meter)	Final flood level (meter)	Difference (meter)
1	14 August	5:00 PM	0.92	6.40	5.48
2	15 August	3:30 AM	1.52	5.49	3.97
3	15 August	3:00 PM	0.30	2.44	2.14
4	16 August	11.30 AM	0.91	0.91	0

evacuation, and finding out the first flood-affected regions. The temporal change was analyzed using the survey data. Survey data consist of evacuation time and flood depth during the evacuation; this data can be used to find out the flood level at different times. Four GPS points were selected out of 293 surveyed points, such that it lies from low lying area to higher elevation area, which enables us to track the flood levels at different times. The first point is in the low lying area, and the flood was affected early; they were evacuated on 14 August, 5:00 PM, and point four was flooded later, and they were evacuated on 16 August at 11.30 AM (Fig. 2). Flood levels during the evacuation were also collected, and the difference was calculated (Table 1).

The difference in flood level during evacuation and peak time can help find the flood inundated area during different times. The difference value (Table 1) is subtracted from flood inundated area raster to get the corresponding flood inundated raster of that time. Then further, cost distance raster was calculated, flood inundated area polygon was digitized and flooded areas on different days are mapped, and inundated areas are computed using the calculate geometry tool. This temporal change should be studied because of the spatial variation of floodwater; its path will determine the evacuation and response planning. This technique also predicts the time required to flood the specific areas, and priorities can also be set for evacuation (Fig. 3).

3. Results and discussion

3.1 Potential relief camp location identification

During the flood events of 2018, few relief camps were needed to change because

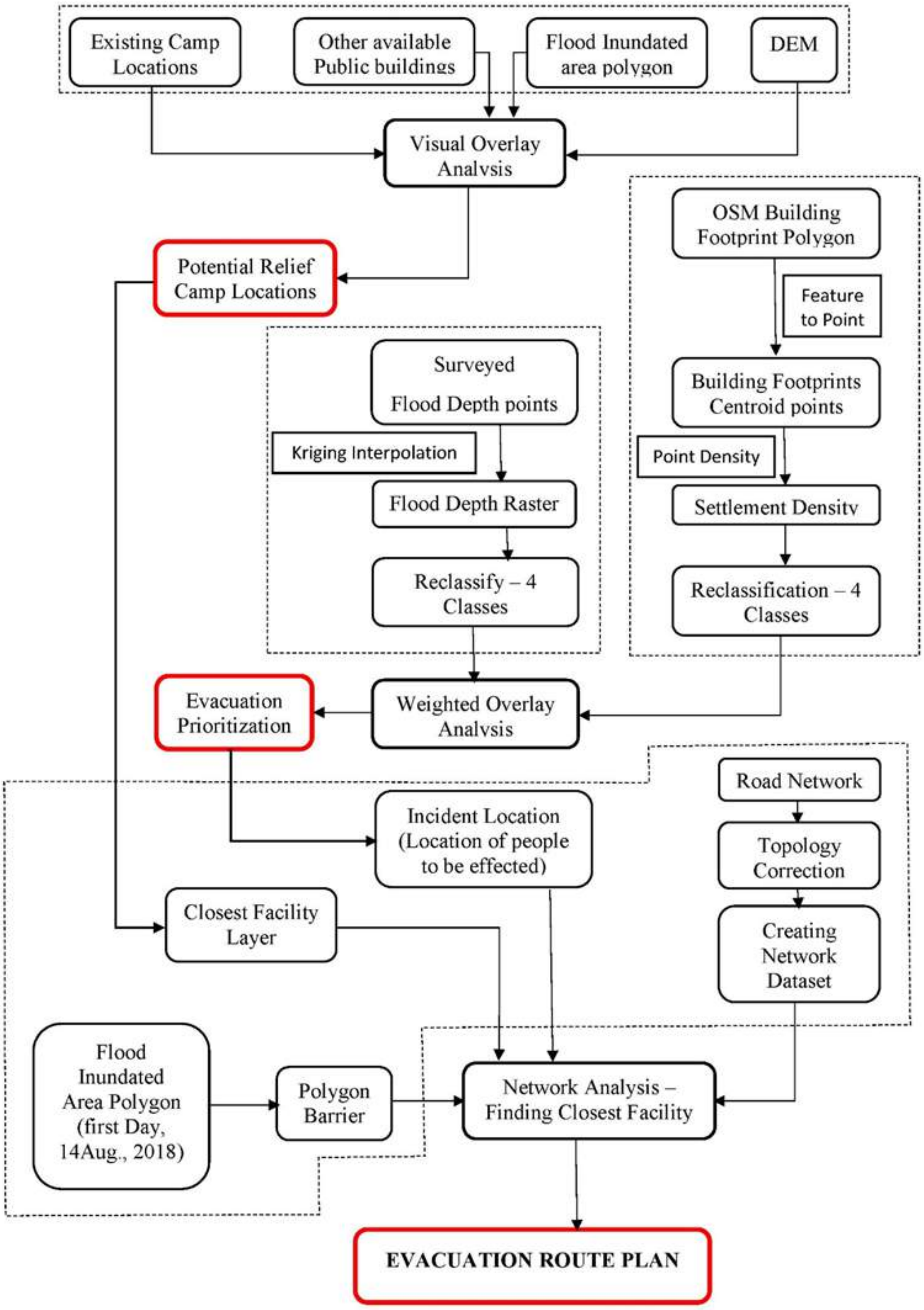

Fig. 3 Cross-section of survey points for tracking flood level at different times

water entered after some time. Which is a serious issue; the base should be in the safest place possible. In our study area, Meloor Panchayath, there is a big facility retreat center named Divine,

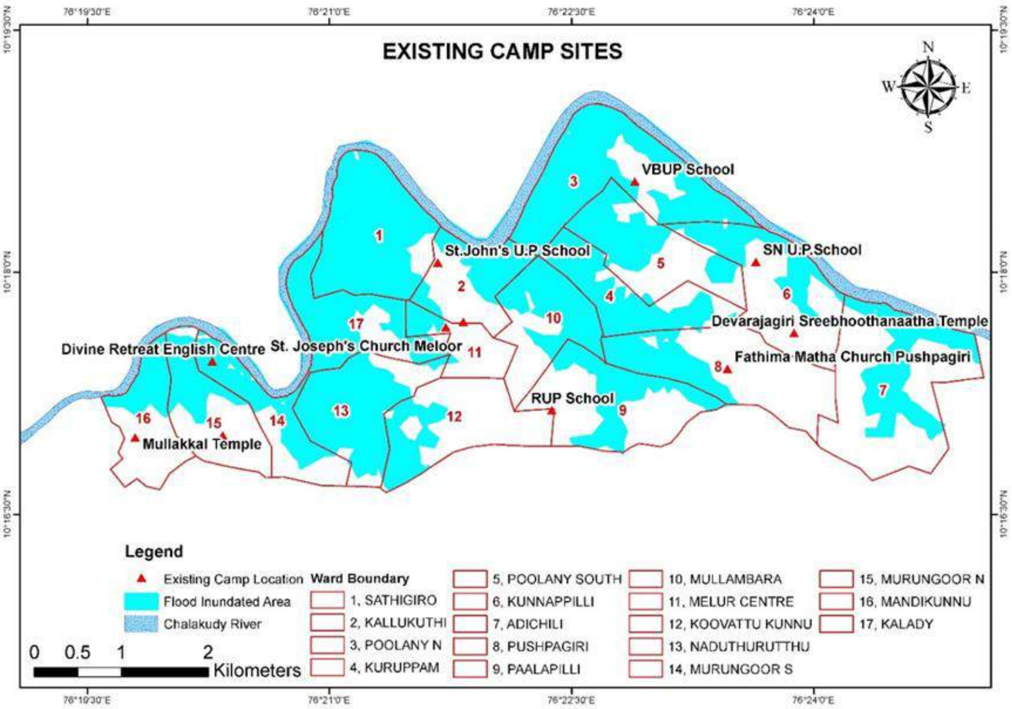

Fig. 4 Camp locations used during the recent flood

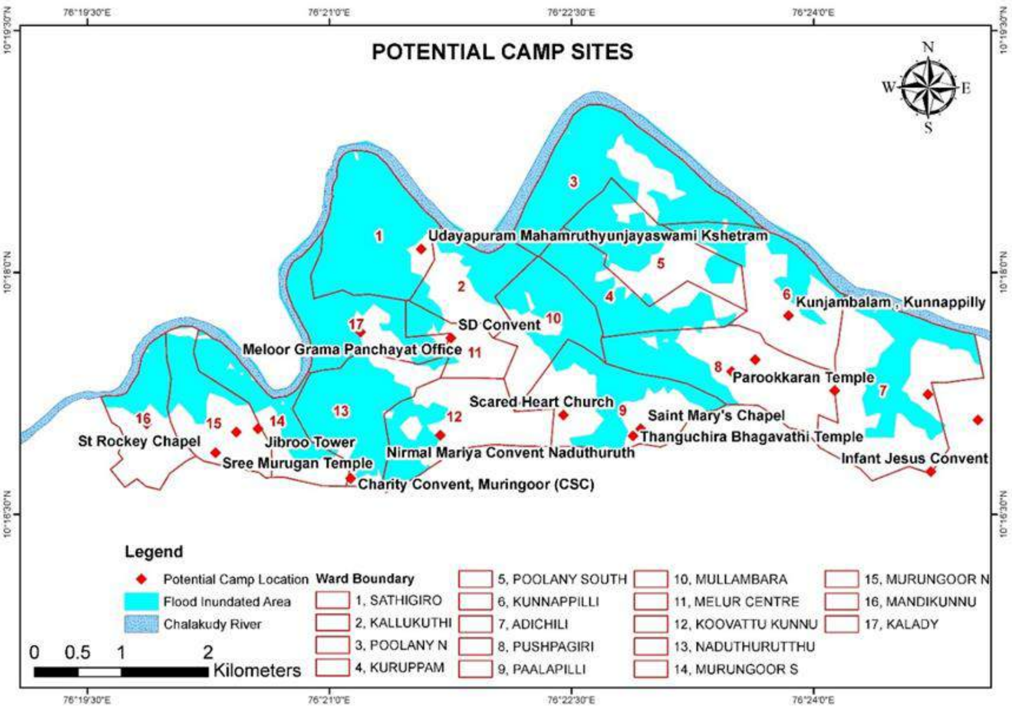

Fig. 5 Potential camp sites for future flood events

a relief camp during the flood's earlier stages. There were hundreds of people stranded with food and water during peak flood days. The importance of planning camp locations for future flood events comes; it is a dangerous situation to change the camp location during peak flood events.

Existing camps were mapped to study the situation. It was observed that two of the campsites were flooded or stranded due to surrounding floodwater. Camp location GPS coordinate was collected from google earth, and flood inundation area polygon was overlaid to see the situation (Fig. 4). For proposing safe camp locations, public buildings, schools, colleges and religious institution facilities were collected from google map, and those locations were discussed with the panchayat officials. Panchayat officials had the ground experience during the flood times and had good knowledge of the communicated facilities. A selected list of the facilities was made as a point feature class in ArcGIS using coordinates from Google map. Visual overlay analysis was done to select the best relief camp locations. The layers used were selected camp facilities, flood inundated polygon, and DEM. Each layer was overlaid above the other, and the suitable camp location where selected. Here the flooded area of the recent flood was taken as the benchmark, and every facility above the flooded area was selected. DEM was also used for reference; higher elevation points were considered for camp location. Thus, potential relief camp location was identified (Fig. 5). There were eleven major relief camps used for recent flood events, and out of that two of them were flooded during peak days. Flooded camps are Divine Retreat Centre and VB UP School, causing several people stranded (Fig. 4).

Other facilities like hotels and relative homes where some peoples stayed during the flood were not considered here. All camps are labelled on the map along with Ward boundaries and almost all wards have a camp location in their vicinity.

After visual overlay analysis, some of the potential camp locations were removed because of flooding and the remaining 9 camps with 17 camps where found, therefore total 26 relief camp location was found. All camps are spatially distributed all over the study area. The safest relief camps in the study area are Infant Jesus convent and Devarajagiri Temple, which lies 55M and 66M above MSL, which reduces the chance of worst flood scenarios.

3.2 Evacuation prioritization

It was essential to prioritize the areas which are required to respond faster during future flood events. It was done by analyzing the current flood scenario. It is necessary to learn from past situations to solve the same problems in the future, and it is essential for disaster preparedness. Evacuation priority areas were located on the basis of settlement density and flood depth. Where there are a higher flood depth and settlement density, that place should be evacuated firstly because more population means more damage, and it will be challenging to move a large number of people during the disaster time. So, we should be prepared, and planning should be done. Flood depth was collected during the participatory survey, and the collected flood depth points were used to create the flood depth raster. Kriging interpolation was used for flood depth raster creation. This raster was reclassified into four classes.

Then settlement density was found from the building footprint polygon from the Open street map. OSM building footprints can be easily downloadable using QGIS. Building footprint polygon was converted in to point feature using the feature to point tool. This creates points in the centroid position of each polygon. Points were made because point density was the better way to depict the settlement density. So, using the point density, a tool settlement density raster was found. The radius given in the point density tool is 142.21 m, and point density was calculated in Square

Table 2 Weighted overlay analysis parameter

Layer	% Influence	Classes	Scale
Settlement density (Sq.km)	60	0 – 200	Restricted
		200 – 850	2
		850 – 1000	3
		> 1000	5
Flood water depth (m)	40	0 – 0.60	Restricted
		0.60 – 1.80	2
		1.80 – 3.00	3
		> 3.00	5

kilometers; it ranged from 0 to 1684.068 Sq. km. Then density raster was reclassified into four classes to facilitate weighted overlay analysis.

Both reclassified flood depth and settlement density were used for weighted overlay analysis to determine the priority areas. Weighted overlay analysis is generally used for site selection or site suitability, which uses scale values and influence percentage to create integrated research, which will find out the best location for the specific phenomenon. During weighted overlay analysis, pixel values of each raster are multiplied by the given influence percentage and added together to obtain the result. Weighted scale values will also consider and bore when adding the raster. Here raster's are settlement density and flood depth, which were reclassified previously. The influence percentage and scale values for each class of layers are shown in Table 2. Here 60% influence percentage was given to settlement density because there are high flood depth areas where no people live, like paddy fields and agricultural land. So, more importance was given to settlement density, and 40% was given to flood depth raster. Scale value was out of 5, and higher values are assigned to classes where higher evacuation priority should be there, like places with higher settlement density and higher flood depth (Table 2).

The resultant raster of evacuation priority with five classes was given priority on the basis of increasing order, from No Priority to Very High Priority. Evacuation priority was found out using the weighted overlay method, and parameters used are floodwater depth and settlement density. Both of them are four classes, and each type is spatially distributed over the study area. As showed in the floodwater depth map (Fig. 6), (0 – 0.60) M class is only spread over 756.13 Sq. Km, then (0.60 – 1.80) M class is spread over 1.136 Sq. Km. (1.80 – 3.00) M class is spread over 7.78 Sq. Km and flood height, which is more than 3 M, is spread over 3.29 Sq. Km.

There is a large area which is flooded more than 3 M, which is devastating. Also, note that paddy fields and agricultural lands are more in this class. Settlement areas are also affected; see the map (Fig. 6). The settlement is also mapped along with it; settlement density is the settlement density per square kilometer. It was classified into four, as showed in Table 3 and Fig. 7, red-color regions with settlement polygons are the regions with massive destruction. But all of the settlement areas were not flooded, so after intersecting the flooded region with settlement density, the area in the flooded region was obtained (Table 3).

The percentage of each class flooded was found. The highest rate is for type (200-850), where 50.43% was flooded, and 47.54% flooded area luckily lies where settlement density is low i.e., (0-200). Higher settlement density classes like (850-1000) and (> 1000) were only flooded in 1.39% and 0.64%, which is indicating that settlement is concentrated in higher altitude regions.

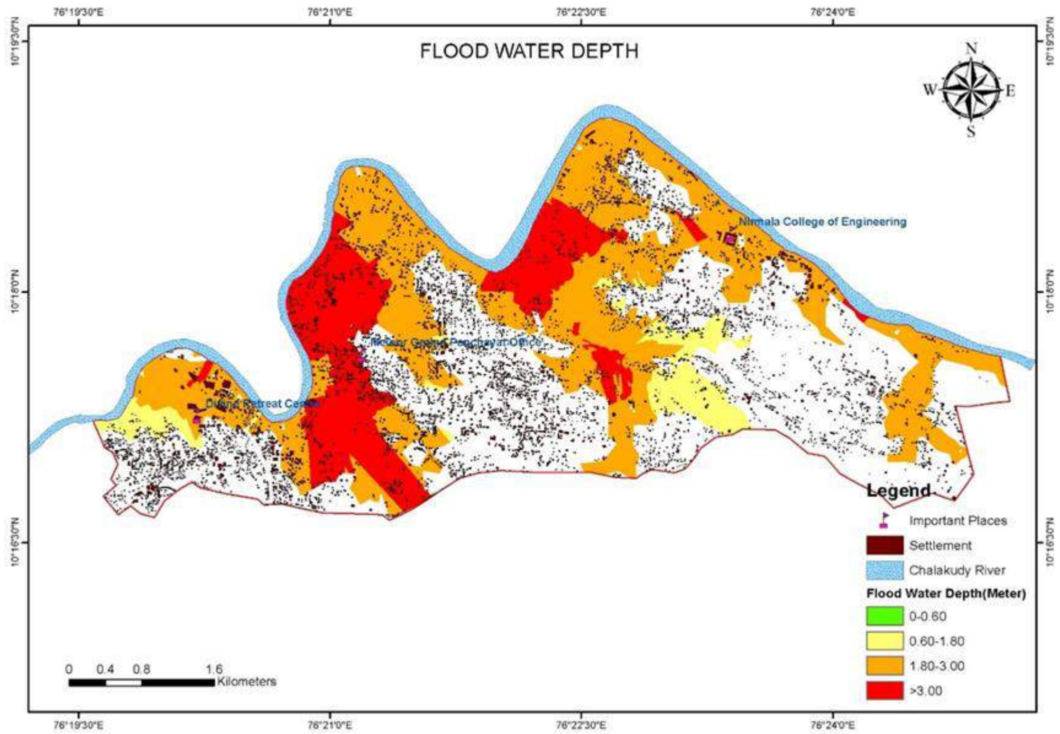

Fig. 6 Floodwater depth classification map

Table 3 Settlement density classes and area

Density classes (Per Sq. Km)	Area (Sq. Km)	The area in the floode region (Sq. Km)	% Area in flooded region
0 – 200	8.58	5.80	47.53
200 – 850	13.20	6.16	50.43
850 – 1000	0.66	0.17	1.39
> 1000	0.54	0.07	0.63

Then from a field visit, it was evaluated that some of the flooded settlements are newly built by landfilling low-lying paddy fields and agricultural lands. Then after weighted overlay, analysis evacuation priority zones were found. Priority zones are No priority, Low, High, Very high and First priority. Most flooded areas are in the priority zone because they have no settlements and agricultural land. Priority zones are minimal in size, which should be noted for future flood events because, in that area, settlement density and flood heights are more. It should be noted that several houses are isolated in flooded regions and should also be evacuated.

3.3 Evacuation route planning

The shortest and safest route, while evacuation is significant. The responders should know the roads which will be flooded while evacuation to avoid confusion. They should have a plan for

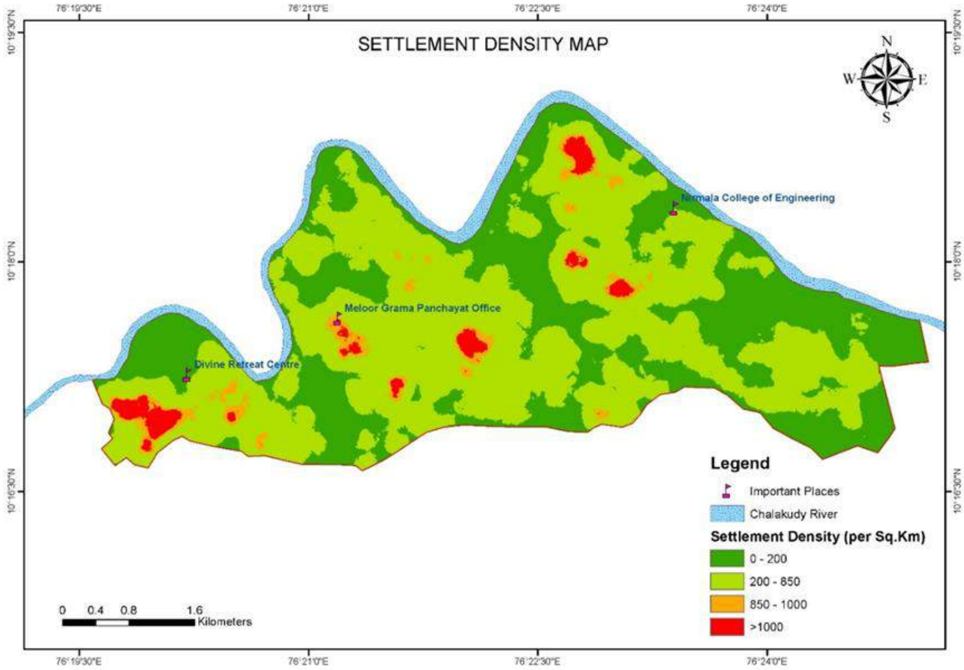

Fig. 7 Settlement density map

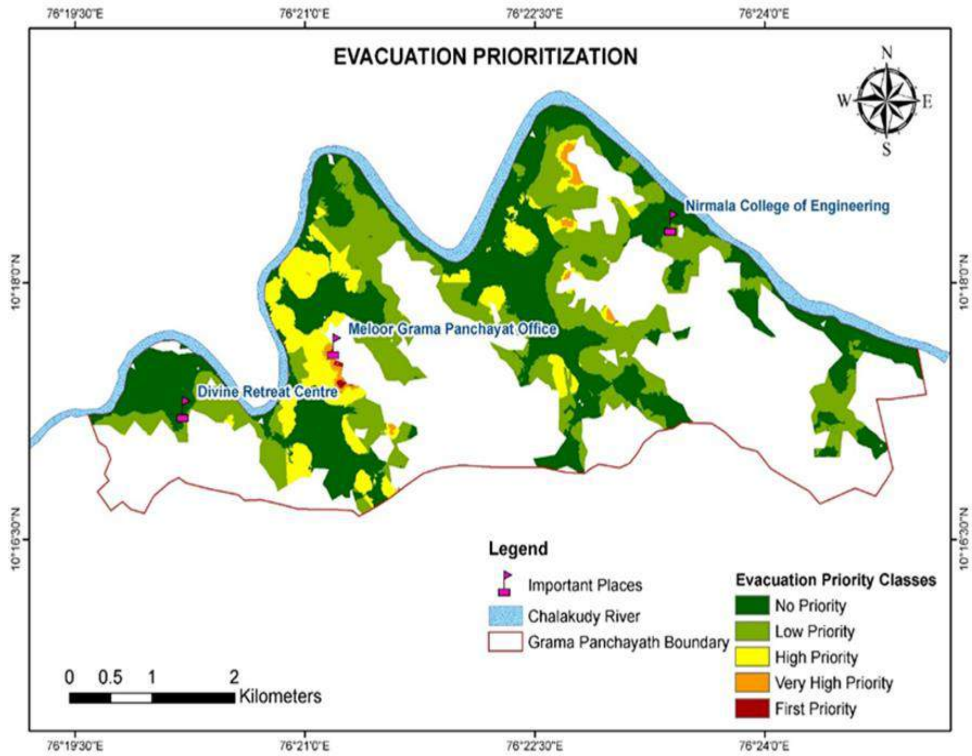

Fig. 8 Evacuation priority zones

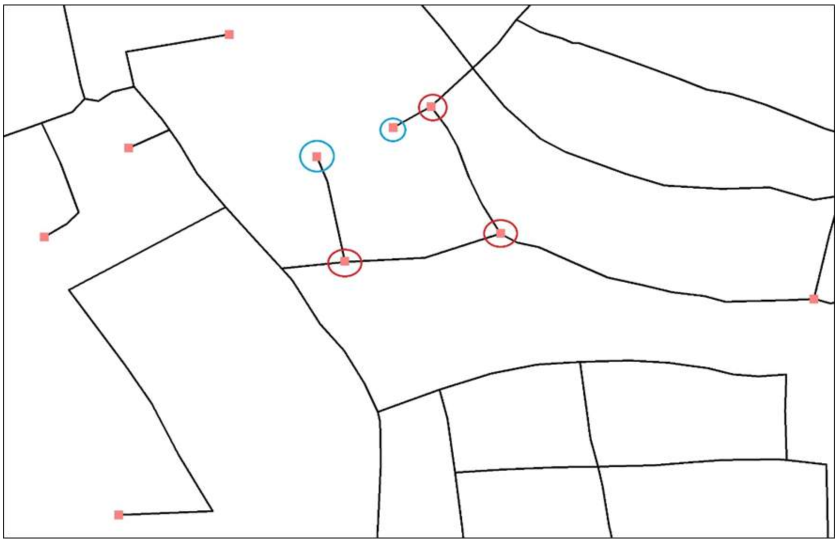

Fig. 9 Topology error inspector

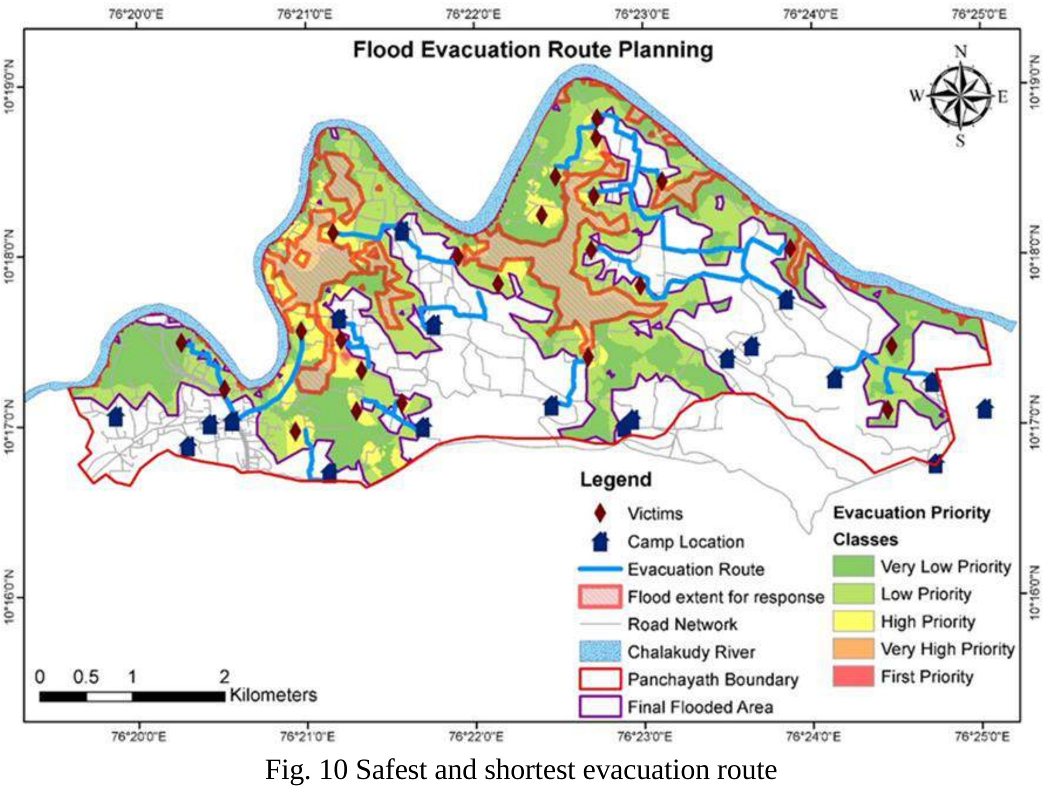

Fig. 10 Safest and shortest evacuation route

evacuation, and it should be the fastest and safest route from the incident location to the closest relief camp (Fig. 8). Several deaths were reported in history due to the chaos and confusion of emergency evacuation during unexpected natural disasters. This study is about developing a system for automatic route selection to closest relief camp and avoiding confusion and losses. ArcGIS network analyst tool was used for the purpose. The Network Analyst extension in ArcGIS is a great tool for creating a network dataset from transportation features and performing analysis on that network dataset. It can solve complex routing problems; the closest facility analysis in Network analyst was used to find out the shortest and safest route towards the nearest relief camp facility. Data required are road network and relief camp locations. Thus, entirely digitized data was checked for errors using topology correction (Romshoo *et al*. 2020). Topology error correction is significant in network analysis because road edges should be properly connected (Fig. 9). Otherwise, that route won't be considered in the analysis result. Topology was created in the dataset using ArcCatalog. The rule for road topology error checking is "Must not have dangles". According to this rule, every line segment of the road must touch any road layer lines at both endpoints. After creating the topology layer, it was added to the ArcMap and supporting layer; the road network was also added. Validation was done to solve the rule, and an error inspector was used to search the errors. The errors are shown in red colour dots (Fig. 10).

According to the rule, the errors were showed, but every error needed to be validated according to real-world conditions, the base map can be used for that purpose. According to the rule, every road ending at a street will be listed in errors because that line endpoint didn't connect to other lines at both ends, so we have to cross-check every mistake. Fig. 10 shows that red circled are real errors, and blue circled are not actual errors that should be exempted. After topology correction, the Network dataset was created inside the geodatabase. While creating the Network dataset, the connectivity policy was set to "Any vertex" because the road network was not split in every junction. Elevation of the road network was not considered; that is, under bridges and over bridges was not considered because of data unavailability. Attribute for network dataset was given, Road length was the only attribute given, and other attributes like travel time, traffic signals, etc., were not considered. The length value was calculated using the "Calculate Geometry" tool in the attribute table of the road network and was used in attributes of network datasets. Then the network dataset was added to ArcMap along with the corresponding layers. The closest facility analysis of the Network analyst tool was activated, and facilities were added. Facilities are the potential camp locations identified and the incident locations are given in high priority zones. Essentially, incident locations can be provided at any points inside the study area, and according to the future requirements in a flood event, this system can be shared with responders. It will be useful in evacuation planning.

Polygon barriers are given as the flood inundation area polygon. Peak flood level area polygon was not considered here because evacuation should be conducted at earlier stages of a flood event. So, flood the inundated area during the first day was regarded as the barrier, and this flood level is proposed to be used as the trigger for starting the evacuation in future flood events. This flood inundated area was found during the temporal change analysis, and the exact time is 14 August, 5.00 PM, which will be the benchmark for starting evacuation for the future deluge. After adding every parameter, the solve tool was used to calculate the result. Thus, evacuation route to nearby relief camp locations avoiding flooded areas was found. As part of proposing a disaster preparedness plan, an evacuation route plan was done. The evacuation was analyzed using the first-day flood extent as the trigger for the future flood evacuation response. Evacuation priority zonation was done using overlay analysis, and these zones were used in evacuation route planning. In any level of flood control, flood emergency management plays a critical role in preparedness and response to flood events and their recovery. The Emergency Plan should identify the distribution responsibilities, flood predictions, and alerts and recognize appropriate implementing activities. Mandated and responsible authorities shall conduct and coordinate in different emergency scenarios of floods. Planning of flood emergencies at different levels is required: national state, district, sub-district, and municipality depending on flood gravity and range. Emergency management includes knowledge of multiple flood situations, actions for adaptive situational control.

Furthermore, flood risk analysis is useful for local applications and resource building, including preparing and implementing exercises. To minimize the residual risk, losses due to property damage and economic interruption, and flood behavior should be moved, exchanged, or investigated for possible solutions. Risk-sharing mechanisms must be established to allocate financial and obligation flood management burden and clarification of mutual responsibility for each stakeholder

4. Conclusions

In recent years there has been a growing pattern of urban flood catastrophes in India, which have seriously affected large cities in India. The research focused on flood mapping and disaster preparedness and observed that the participatory GIS approach is advantageous in flood mapping despite a lack of time-resolution satellite imaging. Planning for flood incidents has been completed during emergency preparedness and the recent flood as a benchmark. We observed several landfills in low-lying paddy fields and agricultural land to construct homes, religious buildings, and commercial establishments, which would increase damage during the possible flood events. We prepared the evacuation road plan as part of the disaster preparedness plan to trigger a rapid flood evacuation response during an eventuality of any possible flood situation. We also identified relief camps' locations using overlay analysis. Finally, we determined the best escape route using GIS-based network analysis. Our study lays down a foundation of flood mitigation plans (fluvial, river basin and surface water) that must be incorporated into a city's overall land use strategy and master planning to control the threat of urban flooding. This study is supposed to serve as a blueprint for an organized and efficient response following urban floods that minimizes damage and losses and makes it possible for citizens to recover early.

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