FLOOD HAZARD AND RISK ASSESSMENT IN MID-EASTERN PART OF DHAKA, BANGLADESH

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ABSTRACT

An inundation simulation has been done for the mid-eastern Dhaka (37.16 km^2) on the basis of Digital Elevation Model (DEM) data from Shuttle Radar Topography Mission (SRTM) and the observed flood data for 32 years (1972-2004). The topography of the project area has been considerably changed due to rapid land-filling by land developers. So, collected DEM data has been modified according to the recent satellite image. The inundation simulation has been conducted using HEC-RAS program for 100 year flood. Both present natural condition and condition after construction of proposed levee (top elevation ranges from 8.60 m to 9.00 m) have been considered for simulation. The simulation has revealed that the maximum depth is 7.55 m at the south-eastern part of that area and affected area is more than 50%.
Finally, according to the simulation result, a Flood Hazard Map has been prepared using the software ArcGIS. And risk assessment has been done and a Risk Map has been prepared for this area.

Keywords: Inundation simulation, Flood Hazard, Risk Map

INTRODUCTION

Dhaka is the largest and densely populated city in Bangladesh. The main natural hazards affecting Dhaka include floods, which are associated with river water overflow and rain water stagnation. In fact it is observed that some 60% of the Greater Dhaka East area regularly goes under water every year between June and October due to lack of flood protection in that area.
In 1991, JICA and ADB conducted feasibility study on this area. And in 2006, Halcrow Group Limited, UK, have done a study for updating/upgrading the Feasibility Study of Dhaka Integrated Flood Control Embankment. They divided the whole eastern part of Dhaka into three compartments. They proposed some structural measures which includes construction of embankment, flood wall, pump station and buildup of some pond area. But non-structural measures like preparation of Flood hazard map has not included. In this paper, middle part (compartment-2) is selected as study area and the main objective of this study is to do Flood hazard and risk assessment of that area.

DATA

For this study two types of data have been used. Topographic data which includes DEM (Fig. 1), satellite image (Fig. 2) and river cross-section and hydrologic data covering rainfall, discharge and water level etc. And two software are used; ArcGIS (ESRI, 1999) for DEM data processing & mapping and HEC-RAS (Hydrologic Engineering Center, 2002) for hydrologic simulation.

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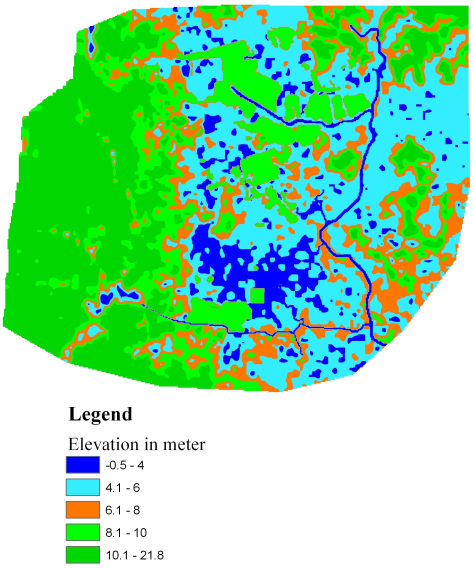


Fig. 1 Digital Elevation Model (DEM) of study area

Fig. 2 Satellite Image of the study area

METHODOLOGY

The methodology can be divided into three phases: Preparation Phase, Execution Phase and Verification & Flood Hazard Mapping Phase (Flow chart shown in Fig. 3). Some important steps of these phases have been briefly described below.

Geo-referencing and Projection

Collected Satellite image has been Geo-referenced according to the geographic coordinate system (GCS_WGS_1984). DEM was also in geographical coordinate system. Geographic coordinate systems indicate location using longitude and latitude based on a sphere (or spheroid) while projected coordinate systems use X and Y based on a plane. Projections manage the distortion that is inevitable when a spherical earth is viewed as a flat map. Projected coordinate system used for this study is WGS_1984_UTM_Zone_45N which is suitable for Bangladesh.

DEM Modification

Grid resolution of collected DEM data is 90 m. The average width of the Balu river (passes through the study area) is around 100 m. So it is difficult to find elevation value on the river path line in that 90 m resolution DEM data. Another problem I faced was that the obtained DEM data was based on satellite image of year 2000. After that, a lot of land development work have been completed in this area which is observed in recent satellite image. So the DEM has been modified according to current topography. The steps are briefly described below.

1. In DEM, elevation values are integer format. So the DEM has been converted to float format.
2. The 90 m DEM has been re-sampled to 30 m resolution DEM using Bilinear interpolation method.

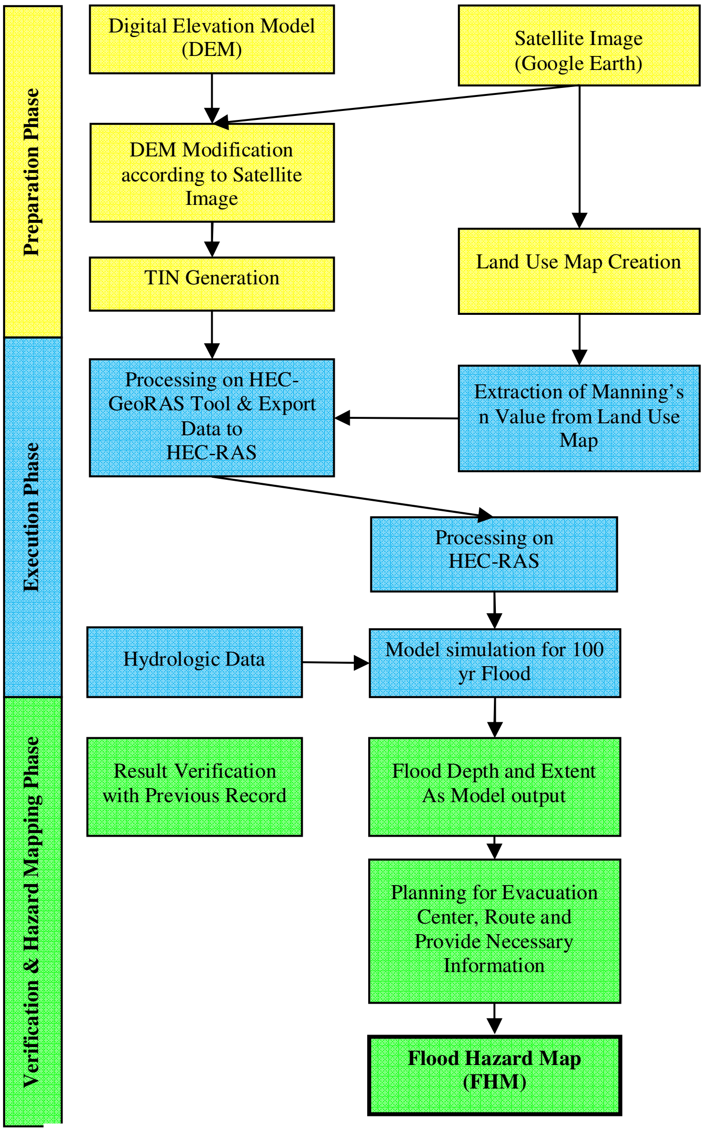
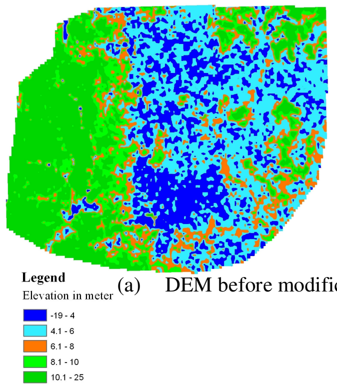


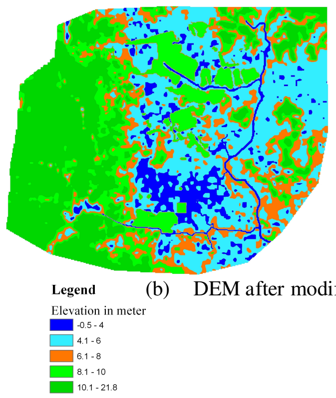
Fig. 3 Flow Chart of Methodology

3. Then the DEM data through the river path has been extracted and converted into ASCII format and finally modified the elevation according to actual cross-section of the river in Microsoft Excel.
4. The DEM data of land filled area has also been extracted by observing recent satellite image and then raised the elevation.
5. Finally the modified DEM has been merged with the original DEM.

The DEM both before modification and after modification is shown in Fig. 4.



(a) DEM before modification.



(b) DEM after modification.

Fig. 4 DEM for both before and after modification

Processing on HEC-RAS

In HEC-RAS the geometric data has been imported which was exported from ArcGIS by HEC-GeoRAS tool. Main job in HEC-RAS is giving hydrologic data and assigning boundary condition and initial condition. From historical record it is observed that water level in this area reached maximum in 1988. The maximum water level has been input here as boundary condition. At upstream given water level is 7.2 m and at downstream it is 7.05 m. Initial flow 100 m^3/s is given as initial condition. According to this condition a maximum inundation depth in every 20 m has been calculated for this area. Then this data has been exported to the ArcGIS.

SIMULATION RESULT AND OBSERVATIONS

Obtained simulation result (shown in Fig. 5) has been verified with observed inundation depth of 1988 flood and satellite image of just after cyclone "Sidr". It is observed that inundation depth ranges from 1 to 3 m covers most of the area (64 % with respect to total inundated area). But southern part of the study area is relatively low-lying where inundation depth is more than 3 m. However, buildup area located in western part is mostly unaffected due to higher topography. Percentage inundated area in the study area (compartment-2 shown in encircled by red line) is 54.5 %. Result obtained from this analysis is presented in Table 1.

Table 1 Percentage area inundated according to varying inundation depth

Inundation Depth	Inundated area (sq. km)	% with respect to total inundated area	% with respect to whole area
4 m or higher	1.09	5	3
3 to less than 4 m	3.33	16	9
2 to less than 3 m	7.01	35	19
1 to less than 2 m	5.84	29	16
Less than 1 m	2.97	15	8
Total	**20.24**	**100**	**54.5**

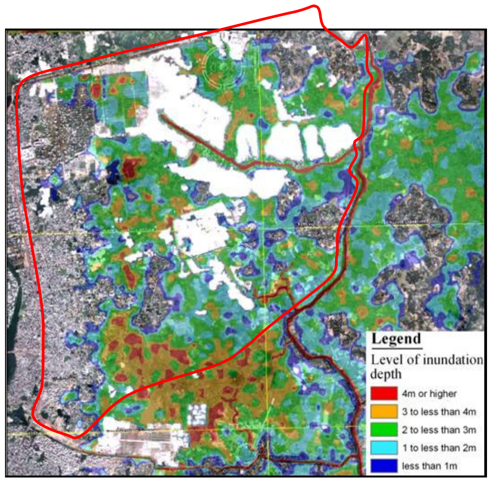


Fig. 5 Inundation status obtained from Simulation

FLOOD HAZARD MAPPING AND RISK ASSESSMENT

Preparation of Flood Hazard Map

A Flood Hazard Map has been prepared using the inundation status which was found from hydrologic simulation, as shown in Fig. 6. According to inundation depth the whole area has been divided into five categories. Some evacuation centers have been proposed in the high area. Some important places such as hospital and police box have been marked in this map which are identified from satellite image.

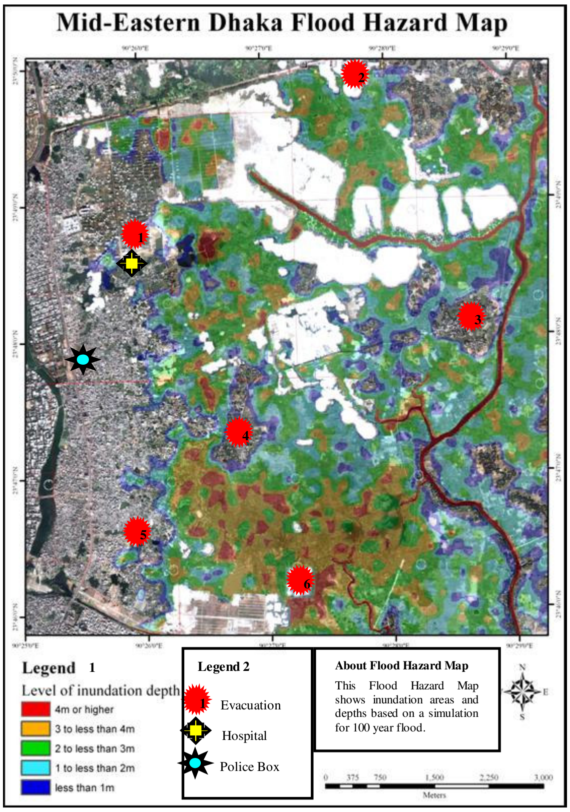


Fig. 6 Flood Hazard Map of Mid-eastern part of Dhaka

Risk Assessment

The risk faced by people must be seen as a cross-cutting combination of vulnerability and hazard. Disasters are a result of the interaction of both; there cannot be a disaster if there are hazards but vulnerability is (theoretically) nil, or if there is a vulnerable population but no hazard event (Wisner B. ; Blaikie P. ; Cannon T. and Davis I., 2004).
These three elements: risk (R), vulnerability (V), and hazard (H), can be written in a simple form:

$$R = H \times V \quad (1)$$

Risk Map

In this study an attempt has been taken to make a Risk Map. Risk index has been calculated by multiplying vulnerability and hazard index. Average depth of inundation has been assigned as hazard index. And for calculating vulnerability index, percentage of area covered with house/living place and agricultural land have been considered. The followed steps are described below:

1. The whole study area has been divided into 300m - 300m block. Total number of block is 624.
2. For calculating average inundation depth in each block, obtained 20m-20m resolution inundation map has been re-sampled to 300m resolution using Bilinear interpolation method.
3. For each block an integer value ranging from 0 to 5 has been assigned as a Hazard index according to inundation depth (shown in (Table 2).
4. For Vulnerability index, a value ranging from 0 to 10 has been calculated for each block. Weight factor 10 and 2 used for area covered by house and agricultural land respectively. Equation 2 has been used for calculating Vulnerability Index.

Table 2 Assigned Hazard Index (H) for varying inundation depth

Inundation Depth	Hazard Index (H)
No inundation	0
Less than 1 m	1
1 to less than 2 m	2
2 to less than 3 m	3
3 to less than 4 m	4
4 m or more	5

5. A Risk index for each block has been calculated by multiplying Hazard and Vulnerability index (Equation 3).
6. Then these Risk values have been converted to raster format and imported to ArcGIS.

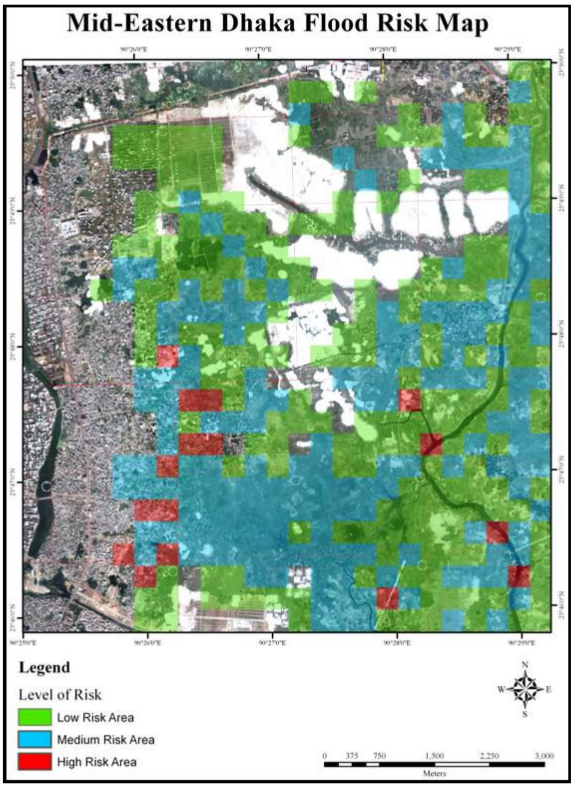


Fig 7 Risk Map of Mid-eastern part of Dhaka

$$\mathbf{V}_{\text{Index}} = \frac{\mathbf{10} \times \mathbf{A}_{\text{House}} + \mathbf{2} \times \mathbf{A}_{\text{Agriculture}} + \mathbf{0} \times \mathbf{A}_{\text{No Use}}}{\mathbf{A}_{\text{Total}}} \quad (2)$$

Where
$\mathbf{V}_{\text{Index}}$ = Vulnerability Index (ranging from 0 to 10)
$\mathbf{A}_{\text{House}}$ = Area Covered by House/Living Place
$\mathbf{A}_{\text{Agriculture}}$ = Area Covered by Agricultural Land
$\mathbf{A}_{\text{No Use}}$ = Area used for neither Living nor Agricultural
$\mathbf{A}_{\text{Total}}$ = Total Area of each Block

$$\mathbf{R}_{\text{Index}} = \mathbf{H}_{\text{Index}} \times \mathbf{V}_{\text{Index}} \quad (3)$$

Where
$\mathbf{R}_{\text{Index}}$ = Risk Index (ranging from 0 to 50)
$\mathbf{H}_{\text{Index}}$ = Hazard Index (ranging from 0 to 5)
$\mathbf{V}_{\text{Index}}$ = Vulnerability Index (ranging from 0 to 10)

Table 3 Area classification according to Risk Index

Risk Index	Level of Risk
1 to less than 5	Low risk area
5 to less than 10	Medium risk area
More than 10	High risk area

7. A Risk Map (Fig. 7) has been prepared by classifying into three categories: Low, Medium and High risk area according to Risk index (Table 3).

CONCLUSION

It is observed in Risk Map that high risk zone covers very few areas and it is located mostly near river bank and in transitional zone between western built up area and low-lying area. In this area risk is high because, area coverage with houses is high this means population density is also high in the area. High risk area represents the area where people are more exposed to hazard than those living in other locations.
It is observed that western built up area is completely risk-free though the area is densely populated. There is no inundation in this area and it means risk index is zero. Southern area where inundation depth is maximum, falls in medium risk category though no people living there. Because this area mostly covered by agricultural field.

RECOMMENDATION

The objective of Flood Hazard Map is to provide residents with the information on the range of possible damage and the disaster prevention activities. The effective use of Hazard Map can decrease the magnitude of disasters. From the resident point of view, it is an effective tool to reduce flood damage. On the other hand, Flood Risk Map represents the current scenario of that area according to degree of risk. This is very much useful for government. By using it government can prioritize some area according to degree of risk. In emergency, government can take necessary steps as soon as possible according to priority basis. As land development and urbanization is going on that area both maps should be updated regularly. The following recommendations are made for upgrading these maps:

1. Rainfall, evaporation, percolation which are ignored in current study can be included for further studies.
2. Town watching, conversation with local people and survey are very important work for making an effective Flood Hazard Map. But this work could not be performed for this study. For future studies this should be conducted.
3. For risk mapping, Hazard index has been assigned according to inundation depth. But other factors such as frequency of flood, duration of flood, etc. should be considered. For assigning Vulnerability index, two factors such as percentage of area covered with house and agricultural field have been considered. But there are lots of factors other than that responsible for degree of vulnerability which should be considered for future studies.

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