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Identifying Probable Submergence Area of Surat City Using Digital Elevation Model and Geographical Information System

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Abstract: Today, the elevation information is represented in computers as elevation data in a digital format, which is called Digital Elevation Models (DEM). Thus a DEM is a computerized representation of the Earths relief. Different formats exists, among the most usual are Triangulated Irregular Networks (TIN), regular grids, contour lines and scattered data points. A DEM is usually described either by a wire frame model or an image matrix in which the value of each pixel is associated with a specific topographic height. Digital elevation models are in combination with other spatial data, an important database for topography-related analyses or 3D video animations (e.g. fly-through). Different georeferenced 3 dimensional products can be derived and complemented by a coordinate system and presented in a 2D-map projection or as a 3D perspective view In India, 12% land of the total geographical area is flood prone. Flood occurs typically during monsoon mainly due to heavy rain and less carrying capacity of the river sections. During August of 2006, Surat city of Gujarat state had experienced massive flood and that caused greater damage to personal and property. This single flood event had resulted more than 300 people being killed and damage worth US$ 4.5 billion. For presented work DEM of Surat city is generated by digitizing contour of the city at 0.5 m interval than Geographical Information system is used to identify probable submergence area of the various zones. In order to identify the probable submergence according to zone water level observed near Nehru Bridge during the flood of 2006 is taken as reference point. As outcome of the work we found that more than 85% of the area would be submerged if the flood of same frequency will occur in this flood plain.

Key words: TIN · GIS · Flood · LTB · Surat

INTRODUCTION

Environmental issues are of vital importance for human life on the earth. The question is how can 3D information of the topography of the earth surface can help us in understanding our vulnerable environment and secure a more sustainable management and use of our environmental resources. DEMs can be used together with other spatial data, image data in geographic information systems (GIS), for instance. A GIS is an information system designed to acquire, store, process and display data referenced by spatial or geographical coordinates [1]. In a sense, a GIS may be thought of as a higher-order map, being both a database system with specific capabilities for spatially referenced data as well as a set of operations for processing and analyzing the data [2]. The DEM provides a basic spatial reference system to the GIS spatial data set. Images or vector information can automatically be draped over and integrated with the DEM for more advanced analysis. Floods are an increasing problems for Surat city, situated at latitude 21° 06' to 21°15' N and longitude 72°45' to 72°54' E on the bank of river Tapi having coast line of the Arabian Sea is on its West. Surat has experienced a devastating flood which was generally described as the worst flood after the construction of Ukai dam. Although State government in association with Central Water Commission (CWC), Irrigation department, Surat Municipal Corporation (SMC) have invested large amount of resources in protecting Surat city and its surrounding area from recurrent flood events by constructing embankment, flood damage and flood affected areas have increased significantly in recent

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years. The paper describes the methods of preparing DEM by digitizing contours and how to find out probable submergence of different area according to increasing water surface in the river Tapi. Field measurement of river Tapi was carried out by agency in inspection of irrigation department and the detailed of more than 305 cross sections in Auto Cad format was collected to find out river carrying capacity of each section. After the exercise it was found that during the flood of 2006 caused due to release of 25768 m^3/s (9.1 Lakh Cusecs) water, the observed Gauge level was 12.5 m. near Nehru (Hope) Bridge.

The left and right hand side bank reduced level near this sections are 8.34 m and 7.59 m. As water keep its surface flat once it's get started spilling from any water body and hence in the present case it was found that West zone will be affected severely compare to East zone.

Study Area: The Tapi river, with its origin at Multai in Betul District of Madhya Pradesh, is located at Latitude 20°07'to 22°N and Longitude 72°41'to 78°12'E. The river has a total length of 724 km out of which last lap of the 214 km in state Gujarat and ultimately meets the Arabian Sea in the Gulf of Cambay approximately 19.2 km West of Surat. The portion between Ukai Dam to Arabian Sea is known as LTB, consisting of Surat city. The Tapi river basin in Gujarat, encompassing an area of about 65.95 x 10^9 m^2 [3] covers parts of Surat district. The topography in LTB comprises narrow valley and gently sloping ground [4]. The city Surat is situated at latitude 21°06' to 21°15' N and longitude 72°45' to 72°54' E on the bank of river Tapi having coastline of Arabian Sea is on its West. the Tapi, division of river basin, Ukai reservoir and surat city with zone boundary is shown in Figure 1.

Data Collection: For this work Geo-coded Indian Remote Sensing (IRS-1D) satellite image of April 2005 is used, (source BISAG), Topo-Sheets at 1:50,000 scale collected from SOI, High resolution Google-earth image (http://earth.google.com) down loaded through internet shown in Figure 2. Physical measurements for river hydraulic parameters obtained after monsoon of 2006 and Contour maps for various city zones at 0.5 m interval were collected from SMC. More than 305 river sections measured between Ukai dam to Arabian Sea at mean distance of 150 to 200 m were collected from Irrigation Department. The water level and river discharge data from hourly to daily scales for Nehru Bridge were collected from CWC, State Water Data Centre (SWDC) and Irrigation Department. Map showing zone boundaries collected from SMC.

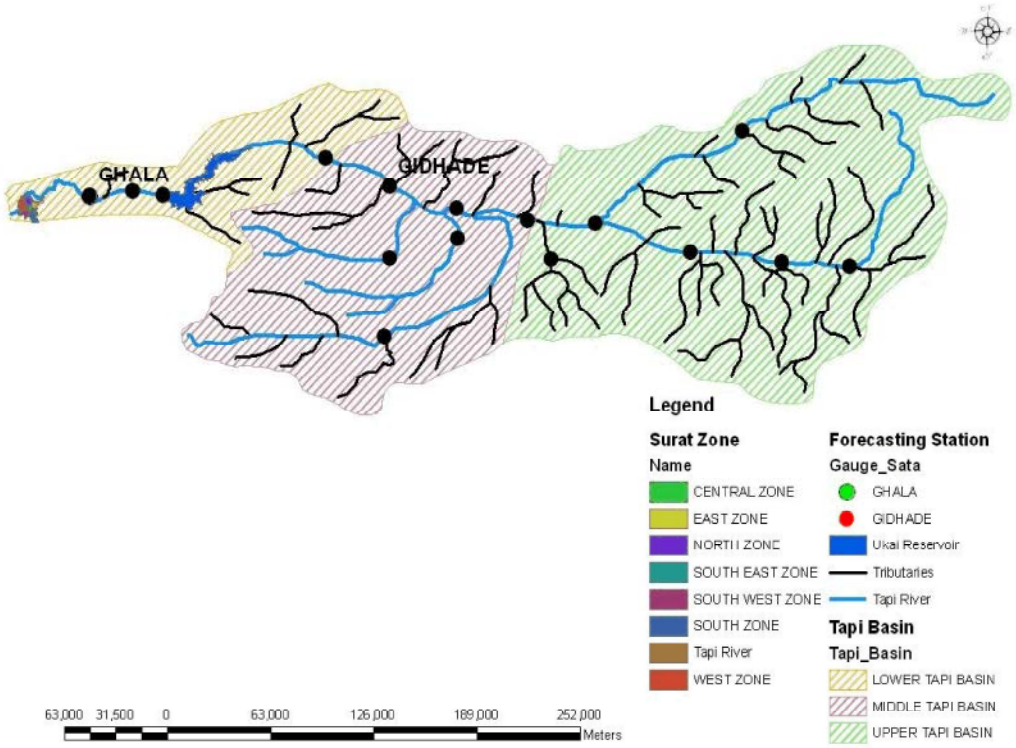

Fig. 1: Map showing Tapi Basin

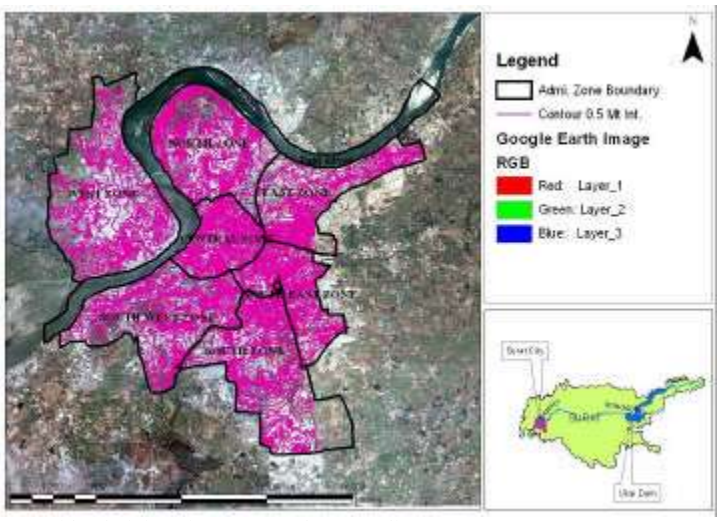

Fig. 2: Google earth image with administrative zones and contour lines

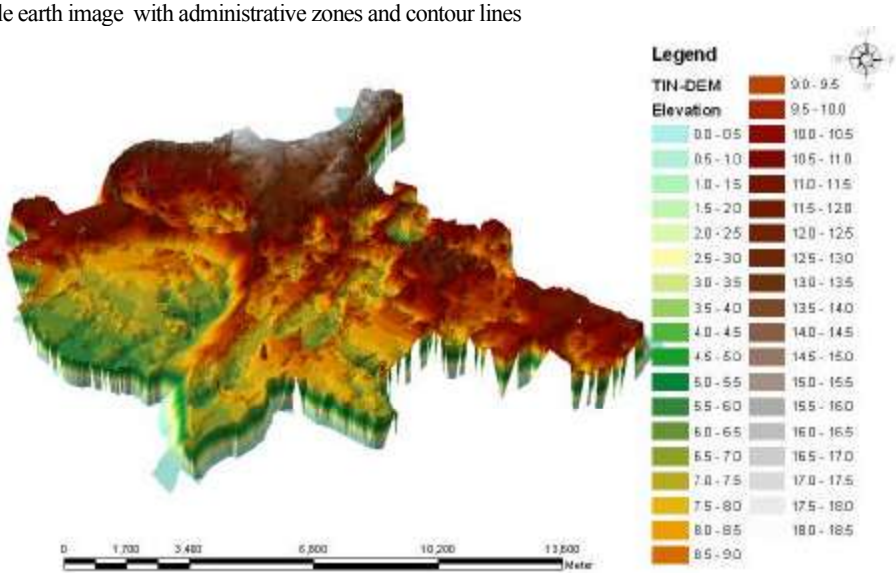

Fig. 3: TIN-DEM of Surat city

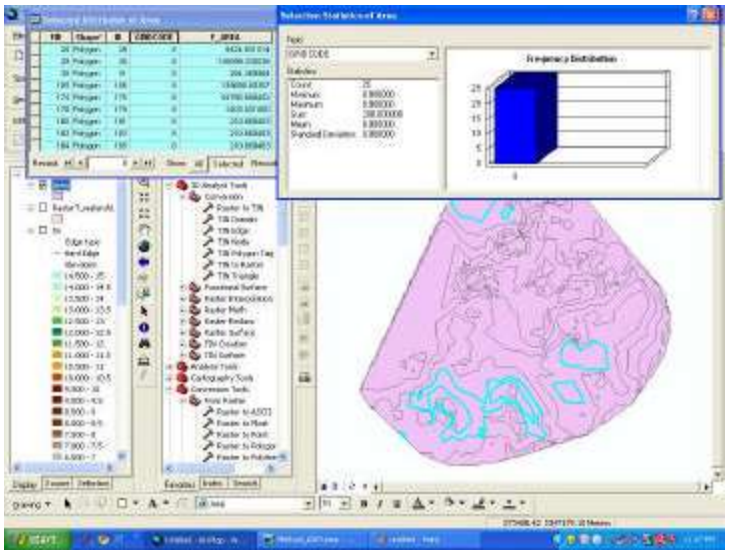

Fig. 4: Print screen showing area calculation

Methodology: In order to find out probable submergence area of the various zones of Surat city with help of ArcGIS, DEM of the city was generated by digitizing contours. Initially Google earth image of Surat city downloaded through internet and the toposheets are than scanned at 400 dots per inch (dpi) resolution, for georeferancing. In Using Arc editing contours of the city were digitized by option line file. Then digitized contour map was georeferanced over Google earth image and spatial adjustment was carried out for better accuracy. Then after spatial and temporal data are interlinked using GIS software and customized Data Base Management System (DBMs). 3D analyst is used to convert digitized Contours into TIN. Finally tool conversion used to convert TIN into DEM showing reduced level of the city at interval of 0.5 m and it is shown in Figure 3. For finding out probable submergence area of different zone, shape files of individual zone are prepared and following steps followed in ArcGIS 9.2 software.

- Arc Toolbox - Analysis tool - Extract-Clip-Area of interest/Contour
- Arc View- Toolbars-3DAnalyst Tools-Create / Modify TIN-Create TIN from feature.
- Arc Toolbox- 3DAnalyst Tools- Conversion- TIN to Raster.
- Arc Toolbox-Spatial Analysis Tool- Hydrology – Flow Direction
- Arc Toolbox – Spatial Analysis Tool- Hydrology-Watershed
- Arc Toolbox- Conversion Tools- from Raster choose Raster to Polygon.
- Arc Toolbox- Spatial Static Tool – Utilities-Calculated Areas
- After following all the steps in the end choose shape file of calculated area and use Query function. Through the function Query finds 'GRIDCODE' and 'F_ AREA'. In 'GRIDCODE' put the figure of desired contour (e.g. 6m, 7m). Finally 'GRIDCODE' indicate the area of contour, the worksheet for calculation of area according to contour is shown in Figure 4.

RESULT

Analysis: During the monsoon of 2006 water level in the Tapi was observed 12.5 m near Nehru Bridge due to release of discharge 25768 m^3/s (9.1 Lakh Cusecs).comparing observed Gauge level 12.5m and left hand side top bank R.L. 8.34 m, about 4.16 m depth of water could spilled the left hand side zone severely. Top bank R.L. of right hand side bank is 7.59 m, so the condition would be more serious in the West zone. Taking 12.5 m observed Gauge level near Nehru Bridge during last event. Flood hazard map of the city as shown in Figure 5 clearly indicates that most parts of the city would be under water by different amount. Analysis indicates that when water level starts increasing 8 m above surrounded area start submerge by different amount. DEM shows that West zone is low lying area of the city and the slope of the city is from East to West. Detailed calculation for probable submergence area of the different zone according to water level is given in Table 1. As seen in DEM West zone is low lying area and its topography varies from 4 m to 13 m. Major parts of Adajan area

Table 1: Calculated probable submerged area of different zone

	Central Zone	West Zone	East Zone	North Zone	South East Zone	South West Zone	South Zone
R.L. in m.	Area in m^2						
4	0	16459.8931	0	0	0	0	0
5	0	82685.7784	0	0	125204.4521	144157.84	0
6	35505.7137	3148877.841	0	0	309496.1909	733934.2222	10170.2584
7	218075.0861	10087669.98	0	23947.3616	932935.9305	5177583.488	340280.2013
8	909142.2165	15174263.9	4975.9088	724519.5648	2179847.015	12081565.46	1829098.736
9	2770571.703	19010774.62	69214.0399	3012504.379	5216316.875	16197165.4	4961610.873
10	4458378.64	20579900.4	1045504.081	6518841.898	7630186.822	17815792.9	10546086.5
11	5584819.726	22467947.47	1570872.928	10057721.87	9038917.745	17972520.79	15533632.09
12	6821422.009	23309406.67	2139519.887	11644490.98	9281470.812	17979211.44	17351842.98
13	7553971.397	23343323.55	4557964.053	13145141.06	9323525.22	0	17658427.94
14	7605169.701	0	7620681.004	14424795.18	9327802.941	0	17686694.4
15	7623753.748	0	10665881.83	15114343.94	0	0	0
16	0	0	12370449.75	15403339.84	0	0	0
17	0	0	12474629.8	15751534.07	0	0	0
18	0	0	12475711.15	15871592.54	0	0	0
19	0	0	0	15886591.83	0	0	0

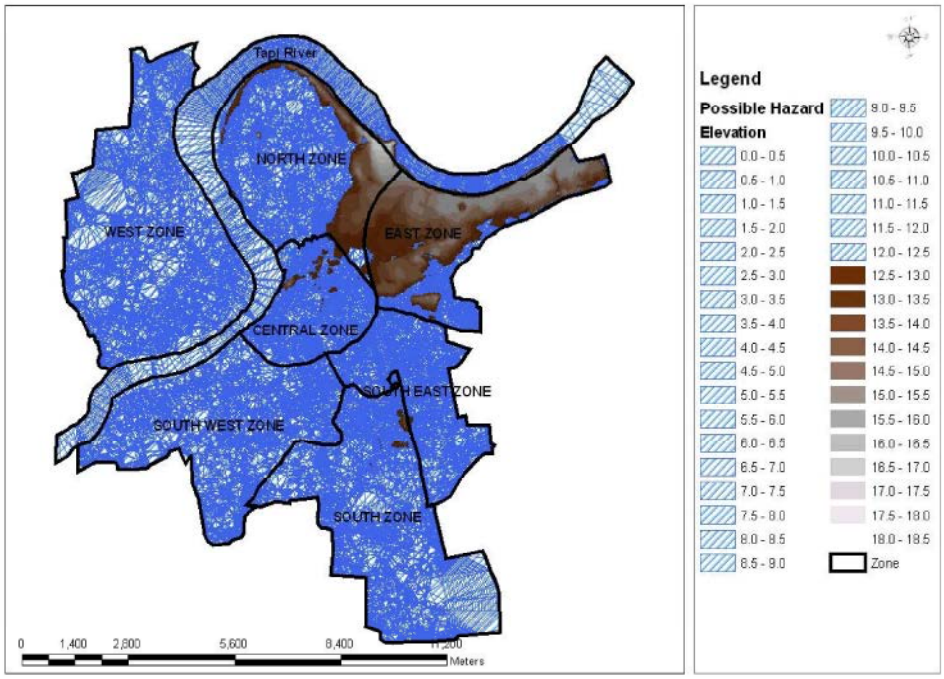

Fig. 5: Flood hazard map of Surat city (Flood 2006)

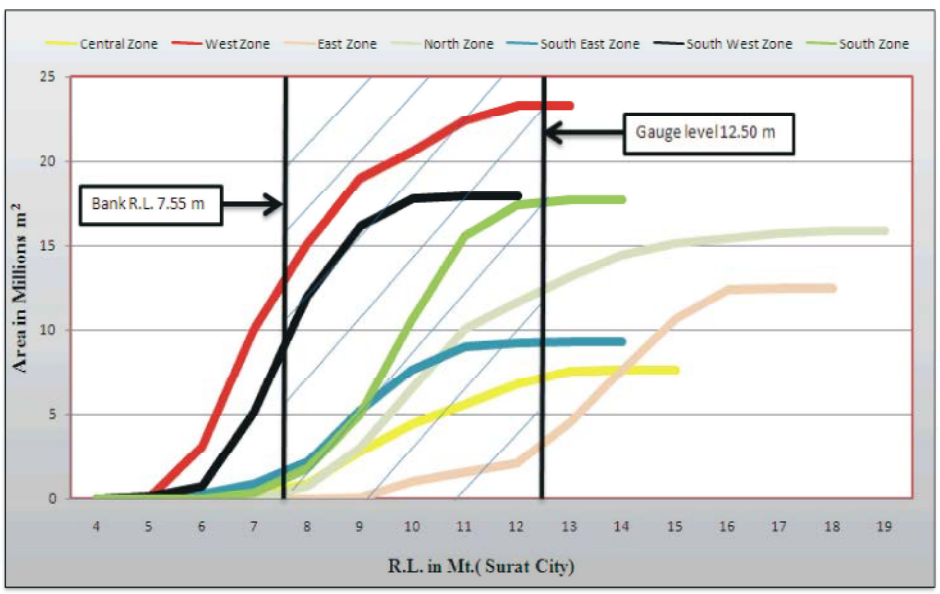

Fig. 6: Different zones of Surat city submerged in water

belongs to West Zone was under water, the depth of water in this area was 2 m to 4 m, [5], which demarcated in flood hazard map. Out of 23.34 km^2 area 23.30 km^2 would be under water in West zone if river reach to 12 m height near Nehru Bridge. South zone, South-West zone, South –East zone and Central zone are also low rise area of the city and all this zone would not survive longer for flood of equal frequency as 2006. North and East zone are high rise area of the city and most of its parts are settled at higher level than 12.5 m. Accordingly these two zones can survive against danger flood up to some extent compare to other zone of the city. The graph of submerge area versus water level of different zone is shown in Figure 6.

CONCLUSION

Forty years back the Tapi could carry flood of higher frequency than the last flood event of 2006. So modeling of river catchment areas necessitates are high-precision DEMs that to assess in advance the dangers in areas exposed to potential inundation and help governments in their task of shifting people. Use of GIS provides supplementary data in Hydrology for analysis and make easy to interpret and to understand flood phenomena and its characteristics. Digital Elevation Model (DEM) can be effectively used for simulation to get a complete model of the area. The generated DEM of Surat city has an accuracy of 0.5 m interval and has been used for analysis of delineation of flood prone areas. The analysis shows that West Zone and South West Zone is highly flood prone while East Zone is least.

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