Assessment of Peak Flood Discharge in Thampanoor, Thiruvananthapuram, India: A GIS Approach

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Abstract— The peak flood discharge is the maximum volume flow rate passing a particular location during a storm event. It is a primary design variable for the design of stormwater runoff facilities such as pipe systems, storm inlets and culverts, and small open channels. The present study is an attempt to assess the peak flood discharge in Thampanoor , a high flood risk area in Kerala, India using Rational method integrating GIS and Remote sensing.
Key words: GIS, stormwater, pipe systems, culverts

I. Introduction

The Thiruvananthapuram City, the capital city of Kerala is facing serious problems of flooding and water logging even after a short spell of rain. The main problem area in the city that was identified from past experience and various studies is Thampanoor. The main reason for this situation is the lack of sufficient system to drain the storm water. The culverts and the available drainage system became insufficient to accumulate the water during rainy season. To solve the problem sufficient drainage system that can hold the peak flood discharge of the area is necessary. Rational method integrated with GIS and RS is a simple method for assessing the peak flood flow for small watersheds like Thampanoor.

II. Assessment Of Peak Flood Discharge

A. Objective

The main objective of the study is to assess the peak flood discharge in Thampanoor using Rational method integrating GIS and Remote sensing**.**

B. Study area

The delineated watershed of Thampanoor was the study area for the analysis. It located at 8°29′ 0.32" N 76°56′ 27" E / 8°30′ 40.49" N 76°57′46.09"E and has an area of 4.216 km^2. The study area is a highly urbanized area. Most of the area is covered with commercial centres. It has heavy and constant pedestrian and vehicular traffic as bus and railway station of the city is located in the study area. The average elevation of the city is 16 ft (4.9 m) above sea level. The mean maximum temperature is 34 °C and the mean minimum temperature is 21 °C. The humidity is high and rises to about 90% during the monsoon season**.** The area gets heavy rainfall of around 1800 mm per year.

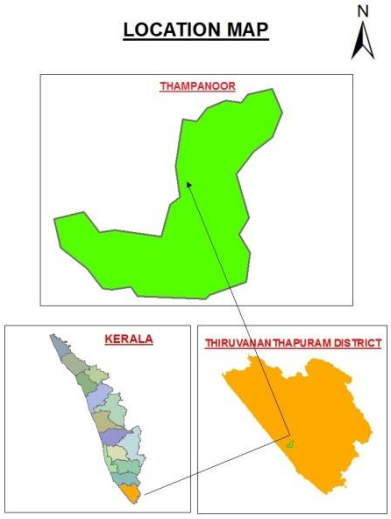

Fig. 1: Thampanoor watershed

C. Data Acquisition and data base creation

1) Data Sources

The main data sources used for the study are:

- SRTM Data 90m DEM version 4 Latitude 5^0 to 10^0 N and Longitude 75^0 to 80^0 E
- IKONOS Image of Thampanoor area
- The latest Google Earth Image of the area (2003)
- The Runoff coefficient values for urban watershed from 'Design and construction of Sanitary and Storm sewers' by American society of civil Engineers
- The Rainfall data by Dr.E.K Sreedharan, Centre for Water Resources Development and Management(CWRDM), India

2) Creation of Geodatabase

A geodatabase is a modern container for GIS data. The Geodatabase used for this project is 'Flood discharge', which is created in Arc Catalog. Feature datasets exists in the Geodatabase to define a scope for a particular spatial reference is 'Thampanoor'. Feature classes are collections of features of the same type. The feature classes created were boundary, landuse, road, Thampanoor and remote points and are projected to WGS 1984 UTM Zone 43N (World Geodetic System 1984) using the WGS 1984 spheroid.

III. Analysis

A. Delineation of the study area

Study area is the delineated watershed of Thampanoor. Delineation of Thampanoor watershed from the elevation data of Thiruvananthapuram City was done using the 'Hydrology tools' under 'Spatial analyst tool' in Arc GIS. Elevation data was used to determine the hydrological parameters of the watershed such as slope, flow accumulation, flow direction and drainage area. With the aid of the flow accumulations, the location of the watershed

outlet was determined and an outlet feature point was created. The watershed of this outlet is determined using the 'watershed delineation tool' of 'Hydrology tools'.

B. Preparation of Land use map

Initially a feature class 'Landuse' was created dividing different landuses based on landuse homogeneity. The Landuse map was prepared by vectorizing the study area in Arc GIS by identifying various land uses from IKONOS data. As Thampanoor is a metropolitan area, landuses are classified as commercial, residential, open area, rail yard and road yard. The end product was a landuse map showing different landuses in the study area . The area of each of these polygons is calculated. The main roads and railways are also digitized to prepare road and railway map

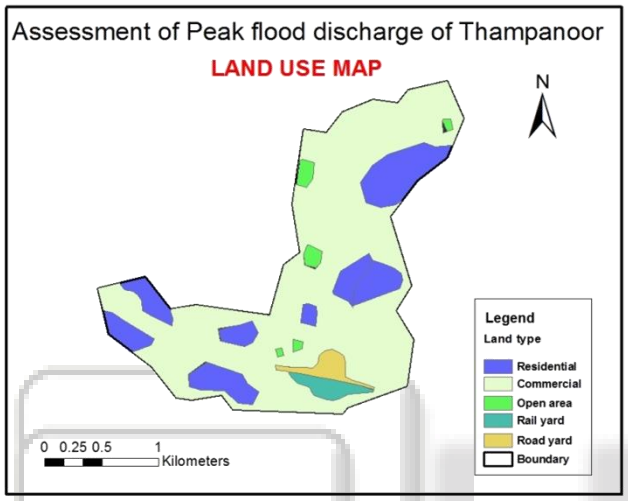

Fig. 4: Land use map of study area

D. Preparation of Elevation map

The Elevation map of the area was prepared from the *SRTM Data 90m DEM* version 4 Latitude 5^0 to 10^0 N and Longitude 75^0 to 80^0 E. Extract the required area from the SRTM data by the tool 'Extract by mask' in 'spatial analyst tool' box and elevation map can be generated. Then using 'Contour' tool of 'Surface Analysis' under 'Spatial Analyst' toolbar, a contour map is prepared with interval of 10 m using input as the extracted SRTM data. Then this contour map is given as the input for the creation of TIN. It is created using the 'Create Tin from Features' from '3D Analyst' toolbar by triangulating as mass points. Then to clip the TIN created within the areal extent of the study area, the 'Enable clip to shape 'option of the 'data frame properties' under 'Layer' Properties.

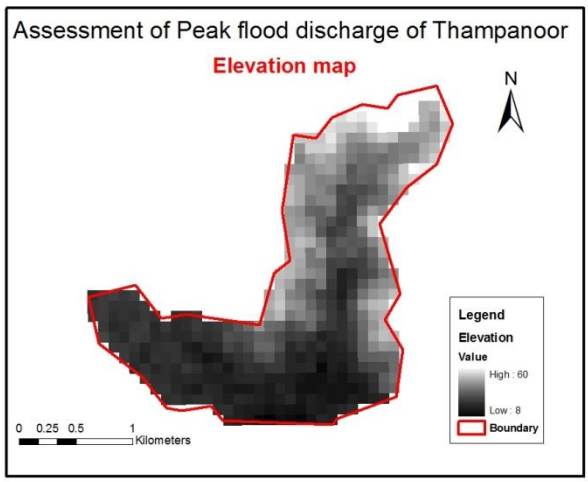

Fig. 2: Elevation map of Thampanoor

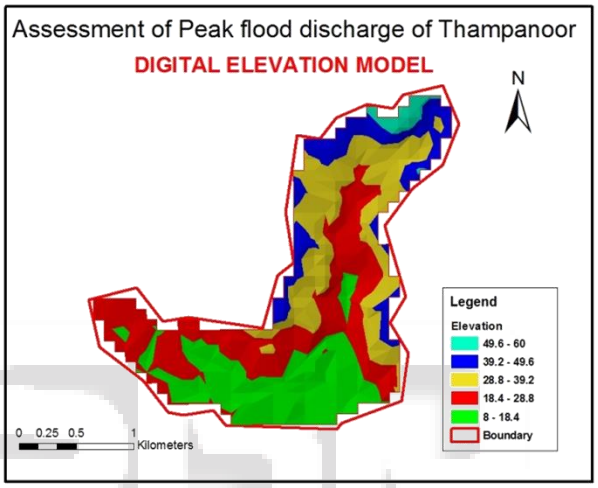

Fig. 3: DEM of Thampanoor

D. Estimation of peak flood discharge

The peak flood discharge is adequate for design of the conveyance systems such as storm drains, open channels, culverts and bridges. Countless hydrological methods are available for estimating peak discharges and runoff hydrographs The Rational Method is a simple method that provides estimate of peak runoff rate for small urban and rural watersheds in which natural or man-made storage is small. It is best suited to the design of urban storm drain systems, small side ditches and median ditches, and driveway pipes.

The Rational formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for duration equal to the time of concentration. The rational formula is expressed as

$$Q = CIA/360 \quad (1.1)$$

Where,

Q = maximum rate of runoff (m^3/s)

C= runoff coefficient

I=average rainfall intensity(mm/hr)

A= drainage area(ac or ha)

360=conversion factor for use only with metric measurements

1) Estimation of Runoff Coefficient (Ci)

From the Runoff Coefficient values of urban watershed data by **American Society of Civil Engineers**, the Runoff Coefficient values of various landuses are fixed as shown below. The maximum possible values are taken considering the worse condition and the future characteristics of the watershed. Landuse map was classified based on its runoff coefficient value and runoff coefficient map was prepared.

Land use	Runoff Coefficient
Rail yard	0.4
Road yard	0.95
Commercial area	0.95
Residential area	0.75
Open area	0.4

Table 1: Runoff Coefficient Values For Different Landuses Of Urban Watershed

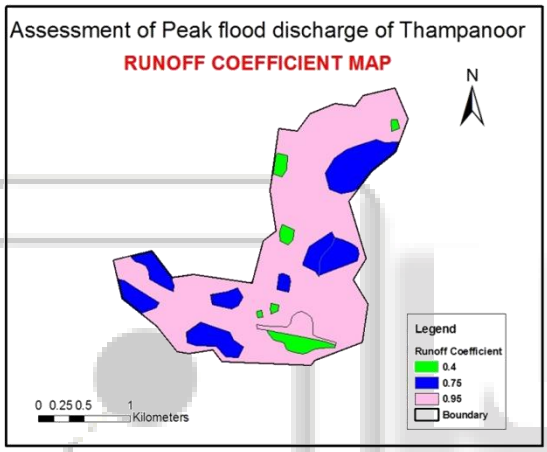

Fig. 5: Runoff Coefficient map of Thampanoor

As the study area has more than one land use type the average runoff coefficient of total area was determined using the formula,

$$\mathbf{C}= \frac{\sum CiAi}{\sum Ai} \qquad (1.2)$$

Using ∑Statistics in the attribute table of runoff coefficient map, ∑CiAi and ∑Ai are calculated as given below

Object ID	Landtype	Ai	Ci	CiAi
1	Commercial	3.002157	0.95	2.852049
2	Residential	1.003705	0.75	0.752778
3	Open area	0.036838	0.4	0.0128933
4	Rail yard	0.085485	0.4	.02991975
5	Road yard	0.087867	0.95	0.083474
		∑Ai = 4.216		∑CiAi = 3.73111375

Table 2: Attribute Table For Runoff Coefficient

Thus the average runoff coefficient for the study area,

$$C = \frac{3.73111375}{4.216} = 0.884 \qquad (1.3)$$

B. Estimation of Time of concentration, Tc

Nine remote points were selected at the farthest regions of the watershed. The distance and elevation difference of these points from the pour point Thampanoor was determined. The distance from Thampanoor to remote points was found by using 'measure tool' in Arc Map and depicted as L and elevation difference was found from elevation data and depicted as H. Using the field calculator in Arc Map, time of concentration values are obtained as shown below. The elevation of Thampanoor is 14 m

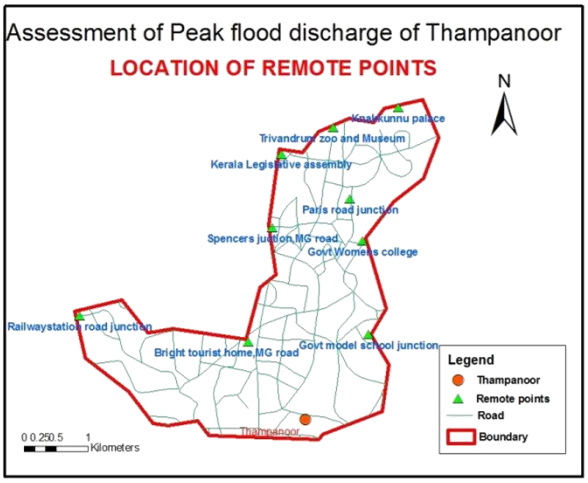

Fig. 6: Location of Remote points

Object ID	Location	Distance L(m)	Elevation Difference H(m)	Time of Concentration Tc (hrs)
11	Railwaystationroad Jn, Pettah	2172.037	7	1.096
2	Bright tourist home, MG road	840.3774	23.00305	0.2315
3	Spencers Jn, MG road	1697.52	24.0061	0.513
4	Kerala Legislative assembly	2321.165	30.0061	0.675667
5	Trivandrum zoo and museum	2572.698	35.0061	0.717167
6	Paris road junction	1697.52	24.0061	0.513
7	Kanakakkunnu palace	2840.399	40.00915	0.763667
8	Govt Womens college	1629.674	30.0061	0.449167
9	Govt Model school Jn	936.1555	27.0061	0.2465

Table 3: Time Of Concentration

Of these nine time of concentration values, the remote point at Railway station road Jn, Pettah gives the maximum value that is 1.096. So the time of concentration value,Tc is fixed as 1.096 hrs

C. Estimation of rainfall intensity

In our study 5 year and 50 years return period was taken for short term and long term planning respectively. The annual maximum rainfall depths of 1,2,3,7 and 10 days for a return period of 5 years and 50 years were taken from the work of Sreedharan (1989). The intensity of rainfall was calculated from these data. The values are as follows

Day	Rainfall depth (cm)		Intensity (cm/hr)	
	5 year	50 year	5 year	50 year
1	15.88	24.60	0.6616	1.0250
2	20.29	30.81	0.4227	0.6418
3	23.79	35.80	0.3304	0.4972
7	35.28	53.21	0.2100	0.3167
10	40.35	59.86	0.1681	0.2494

Table 4: Rainfall Intensity Calculated For 5 Years And 50 Years Return Periods

Graphs are plotted for 5 years and 50 years return period with the logarithmic values of intensity on y axis and duration on x axis. The points are found to follow straight lines, approximately and they are extended to get intensities for shorter durations as shown in the graph

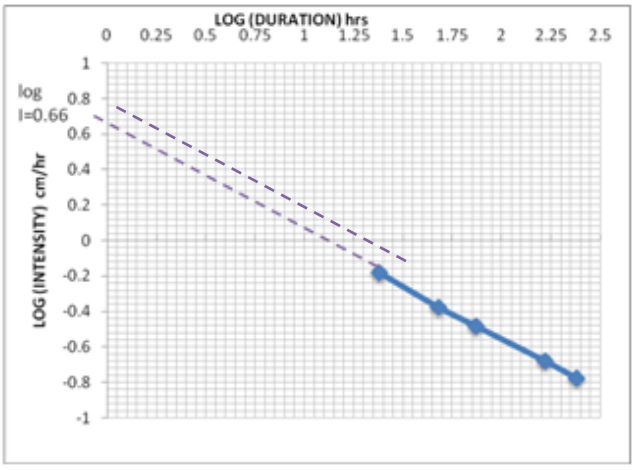

Fig. 7: Log (Intensity) - Log (Duration) Curve for 5years return period

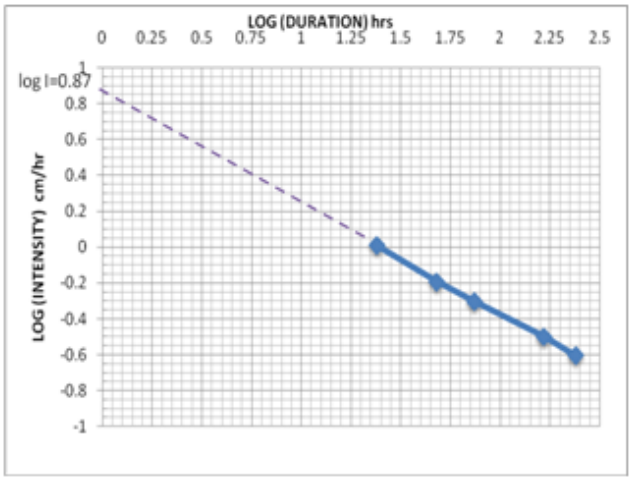

Fig. 8: Log (Intensity) - Log (Duration) Curve for 50 years return period

Gumbels distribution was fitted to the annual maximum series for estimating rainfall of different durations and return periods. Intensity was denoted as I and duration as t.

From graph, we get

$\log I = m \times \log t + C$ (1.4)

From 5 year return period graph, when log t=0 ; log I=0.66

Substituting the values in (1.4), we get the value of C

That is, 0.66 = m x 0 + C; C = 0.66

From graph, when log t= 1; log I=0.05

Substituting the value of C in (1.4), we get the value of m

That is, 0.05 = m x 1+ 0.66 ; m = -0.61

The slope of the graph is -0.61

Substituting the value of C and m in (1.4) we get

$\text{Log } I_5 = -0.61 \log t + 0.66.$ (1.5)

Similarly,

From 50 year return period graph, when log t=0 ; log I=0.87

Substituting the values in (1.4), we get the value of C

That is, 0.87 = m x 0 + C ; C = 0.87

From graph, when log t= 1; log I=0.25

Substituting the value of C in (1.4), we get the value of m

That is, 0.25 = m x 1+ 0.87; m = -0.62

The slope of the graph is -0.62

Substituting the value of C and m in (1.4), we get

$\text{Log } I_{50} = -0.62 \log t + 0.87$ (1.6)

After removing the logarithms, the equations becomes

$I_5 = 4.571 / T^{0.61} = 4.571 / 1.096^{0.61} = 4.322$ cm/hr

$I_{50} = 7.413 / T^{0.62} = 7.413 / 1.096^{0.62} = 7.003$ cm/hr

D. Estimation of peak flood discharge

By Rational formula , the peak flood discharge,

Q = CIA/360

Where,

Q = maximum rate of runoff (m^3/s)

C= runoff coefficient

I=average rainfall intensity (mm/hr)

A= drainage area (ac or ha)

The values of the variables obtained from the study are,

C =0.884

I_5 = 4.322 cm/hr = 43.2 mm/hr

I_{50}= 7.003 cm/hr = 70.03 mm/hr

A = 4.216 km^2 = 421.6 ha

By substituting the values,

The peak flood discharge for 5 year return period,

Q_5= 44.72 m^3/s

The peak flood discharge for 50 year return period,

Q_{50}= 72.50 m^3/s

IV. Results And Discussion

A) Preparation of thematic maps

A thematic map is a type of map or chart especially designed to show a particular theme connected with a specific geographic area whereas in a general map the variety of phenomena geological, geographical, and political regularly appear together. Thematic maps serve primary purposes such as they provide specific information about particular locations and general information about spatial patterns. They can be used to compare patterns on two or more maps. The various thematic maps prepared for the study are:

- Elevation map
- DEM
- Land use map
- Runoff Coefficient map
- Map showing location of remote point

B) Peak flood discharge assessment

The peak flood discharge of Thampanoor from a 5 year return period storm was estimated to be 44.72 m^3/s and a 50 year storm as 72.50 m^3/s. 5 year return period flood flow can be used for short term or urgent flood mitigation measures and 50 year storm flood flow for long term plannings. Due to the heavy and constant pedestrian and vehicular traffic as a result of the bus and the railway stations located in this area, , it is suggested to consider 50 year storm flood flow for the design of drainages and culverts to eliminate property damage and inconvenience to the minimum. The flood flow can be routed to the nearby drainages. Draining water to Killi river flowing at a proximity of 1.5 km is a good option. Recognizing the frequency and increased severity of flooding in this city, structural and non structural mitigation measures needs to be promoted to reduce the flood. An integrated planning taking into consideration various aspects like the cost, land acquisition, public perception etc and also involving all the concerned stakeholders is required before finalizing the action plan

V. Conclusion

The Thiruvananthapuram City is facing serious problem of flooding and Thampanoor is a main problem areas in the city identified from past experience and various studies. To solve the problem sufficient drainage system that can hold the peak flood discharge of the area is necessary. The basic objective of this study was to assess the peak flood discharge of Thampanoor using rational equation integrated with GIS and RS. The peak flood discharge of Thampanoor from a 5 year return period storm was estimated to be 44.72 m^3/s and a 50 year storm as 72.50 m^3/s. 5 year return period flood flow can be used for short term or urgent flood mitigation measures and 50 year storm flood flow for long term plannings. Owing to the constant increase in the urbanization, it is suggested to consider 50 year storm flood flow for the design of drainages and culverts to eliminate property damage and inconvenience to the minimum.

Acknowledgments

I express my sincere thanks to Center for Environment and Development (CED) and all the staffs there, for their support and cooperation. I hope that this study will help to further the progress of flood management in Thiruvananthapuram City

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