Impact Assessment of Urban Flood in Surat City using HEC-HMS and GIS

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A B S T R A C T

Flood is natural disaster which is occurring in almost every part of the country. Total of 30 years (1985-2016) hydrological data has been given as an input to the model study. In order to run HEC-HMS model for assessment of flood at Surat outlet of Tapi river basin the input such as Rainfall, soil map and land use/land cover map required are extracted from soil. The hydrology of the area is characterised by high interaction between ground water and surface water. Input files were prepared using HEC-GeoHMS and later imported to HEC-HMS along with the meteorological and hydrological data to calculate run-off at the watershed outlet. Analysis was carried out in HEC-HMS to determine peak stream flow and occurrence time. SCS (Soil Conservation service) method can be used for flood stimulation in HEC-HMS. From the values of R2 (coefficient of determination) and from stimulated Q_{peak} (discharge) and observed Q_{peak} the flood model can be derived in HEC-HMS. Satellite image of area near Tapi region is selected and with the help of software we could analyse the flood prone areas. Parameters like population Density, resources availability, Elevation of geographical area, etc. database can be collected using GIS. Software like ArcGIS can be used to get the data of flood. From the data obtained using HEC-HMS and GIS the area of surat are divided into High risk and Low risk zones. Based on this study it will be helpful in identification of low lying & flood prone areas in Surat city and also helpful in Surat urban planning near Tapi River.

Keywords: River; HEC-HMS;HEC-GeoHMS; Rainfall; Runoff; Modelling

1. INTRODUCTION

Surat is blessed with abundance of rainfall that contributes to an average of 1000-1200 mm a year. With the exception of extreme events, the annual average may exceed the above average. The consequences are several areas are inundated during the monsoon periods.

The cause of flooding in Surat is the incidences of heavy rainfall and large concentration of runoffs. Various flood forecasting and warning systems using advanced hydraulic and hydrological models were used in Surat, but were proved to be inadequate in terms of their ability to predict impending floods . In recent years, impacts of extreme events in Surat have been very much highlighted. For example, in 2006, some parts of Surat were badly hit by flooding which caused most of the areas under water. Flooding is the most commonly occurring form of natural disaster and it includes both river flooding and coastal flooding. Floods often cause tremendous damage to agricultural land and infrastructure such as roads, bridges and buildings.

The flood estimation that involves the development of hydrologic models is one of the non-structural measures that may help to reduce the amount of damages incurred. Hydrologists are continuously improving the capability of hydrologic models to predict accurately the frequency of flood events in a changing climate.

In view of the above and severity of the damages caused by extreme events, it is therefore necessary to establish a hydrologic model to simulate flood levels. This is very much necessary for the identification of possible inundated areas, so that a timely warning can be issued to the people in the affected areas. Therefore, it is timely to have more comprehensive scientific understanding of the effects of this ecosystem on the environment, particularly the hydrological regimes. Such information is crucial for the effective and improved management of water and other catchment resources.

As a means of evaluating this approach, a feasibility study has been completed on the Tapi river at Surat city. Input in HEC- GeoHMS is later imported in HEC-HMS and then output to be obtained. GIS software like ArcGIS or QGIS used to obtained some parameters related to flood event. HEC-HMS was run with the rainfall data in order to provide a flood level evaluation entering a catchment on the Tapi River. The results of this study are presented in this study, which starts with an overview of the methodology used in HEC-HMS rainfall-runoff studies. After describing the computer models HEC-HMS that are used in the study, a description of the Tapi river watershed used in the case study is presented, including its representation in HEC-HMS. Results of the study are then presented and discussed. The study presents the flood level characteristics and results of hydrograph modeling for a catchment in Surat City.

2. STUDY AREA

The study area deals with Tapi Catchment which is located in Surat City. The catchment area of Tapi is about 3837 km2 in Surat in Gujarat.Annual precipitation of about 1000-1200 mm and temperature of 27.2 degree Celsius. The below figure 1 represents the portion of Tapi river in all states. It represents the area of Lower and Upper Tapi river region in Surat city. The DEM of surat city was generated from the data obtained by the U.S.Geological Survey (USGS), from the website. The figure 2 is the image which represents the portion where work to be done a using tools such as Hec-GeoHMS and ArcGIS 10.1.The hourly data of rainfall runoff were downloaded from National Centre for Environmental Information website. Hourly data was used because as flood occurs the discharge can increase in very short time.

The figure 1 indicates the map of tapi basin in Gujarat, Madhya Pradesh and Maharastra state. Thus it indicates the whole region of Tapi basin while figure 2 indicates the region from figure 1 where flood estimation need to be done using ArcGIS, HEC-GeoHMS and HEC-HMS. The figure2 indicates the study area in which using DEM image of Surat City, we will carry out the analysis using rainfall runoff model and find its peak discharge.

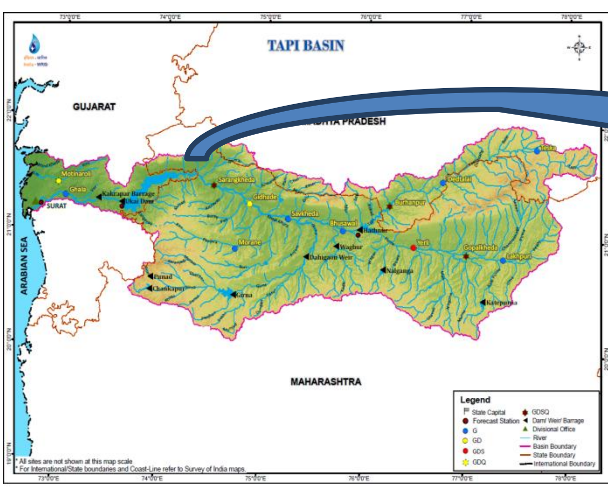


Figure 1:Location of Tapi Basin

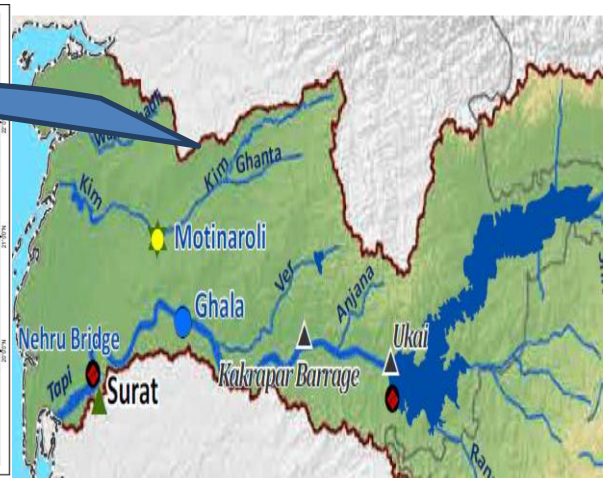


Figure 2: Tapi Basin in Surat city

3. METHODOLOGY

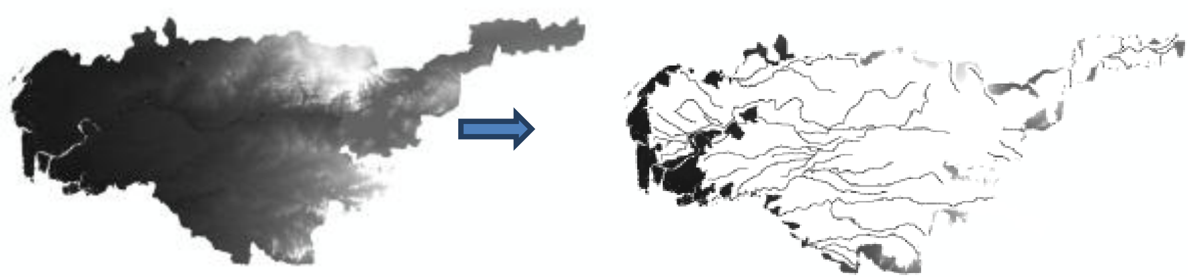
The hydrological model was generated using ArcGIS, Hec-GeoHMS, HEC-HMS using DEMs of study areas. DEM image of Surat along with its tributaries were inserted then terrain data was inserted, parameters of HEC-GeoHMS were inserted and later it was imported to HEC-HMS,the parameters of rainfall-runoff were given using HEC-HMS and the project output was generated.

3.1 ArcGIS Toolkit

In ArcGIS 10.1 ,DEM image was inserted of Surat city along with its tributaries.The sinks are filled in DEM using ArcHydro Tool box. Fill sinks, Flow direction, Flow accumulation, Stream definition, Stream segmentation, Catchment grid, Catchment polygon processing, Drainage line and Drainage point parameters were given. After that batch point was given as a outlet near drainage point. Different watershed characteristics are given are estimated and stored as attribute table for further need. After that HEC-GeoHMS tool is inserted and parameters are given accordingly.

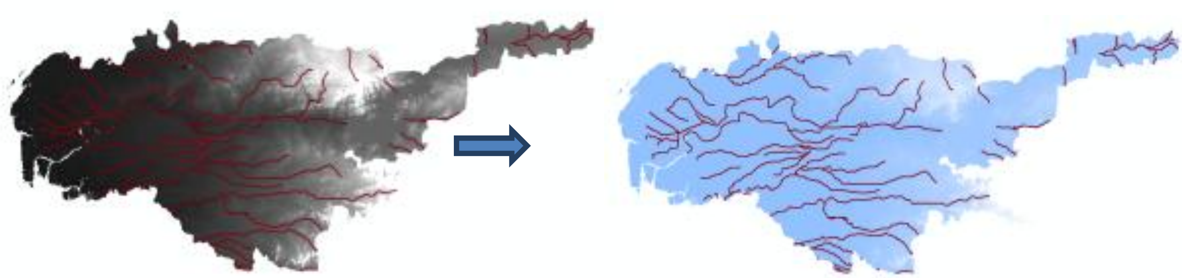
3.2 HEC-GeoHMS Toolkit

HEC-GeoHMS allows users to delineate sub basins and streamsto prepare inputs to hydrological model and help in preparing the report. HEC-GeoHMS 10.1 for ArcGIS10.1 is used here. We will generate the project by data management and generate project parameter. So project point and project area will be selected. The project area will be of Tapi river only as because the Surat city has tributaries of other river also. Futher the parameters of basin and river are given to selected area only and the project area will then become our DEM for the model. Parameters like basin merge, basin slope, river length, river slope, longest flowpath, centroid of flowpath, basin autoname, river autoname ,etc. were generated in subbasin and will get an output which is to be imported in HEC-HMS.



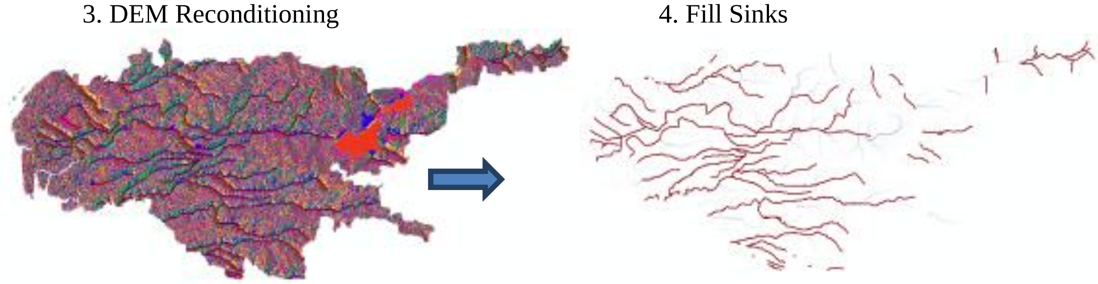
1. Raw DEM

2. Tributaries DEM



3. DEM Reconditioning

4. Fill Sinks



5. Flow Direction   6. Flow accumulation

7. Stream Defination   8. Stream Segmentation

9. Drainage line   10. Drainage Point

Figure 3: Pre-processing of data

3.3 Parameter Estimation

In HMS there are various loss estimation method, various rainfall-runoff transformation methods and routing methods from which SCS-CN (Soil Conservation system) method, clark unit hydrograph and muskingum method were selected for finding various parameters. Here we will consider Base-flow considered as zero because it has insignificant effect on flood events. Two paramters can be found using soil conservation method which are Curve number (CN) and initial abstraction (Ia). Where Initial abstraction means all losses expect runoff loss. While Curve number is function of land use, soil type and antecedent watershed moisture. CN values were estimated using HEC-GeoHMS toolkit in ArcGIS 10.1.

Following formulas can be used to estimate the curve number for each basin-

$$CN=\frac{\Sigma A_i CN_i}{\Sigma A_i} \quad (1)$$

$$S=\frac{1000-10CN}{CN} \quad (2)$$

$$Tc=\frac{1.67(L\times3.28)^{0.8}(1000/CN-9)^{0.7}}{1000y^{0.5}} \quad (3)$$

$$R=\frac{CsTc}{1-Cs} \quad (4)$$

$$K=\frac{L}{V_w} \quad (5)$$

Here, CN is the Curve Number, Ia can be found by multiplying the potential Abstraction(S) by loss coefficient of 0.2. Tc is the Time of Concentration (T_c) and storage coefficient(R) two parameters of clark unit hydrograph method. L is the main channel length in meter and y is the base slope. R is storage coefficient, Cs is constant value between 0.2 to 0.6. K is parameter of Muskingam routing method which is time for flood routing. X is dimensionless weight which is factor representing relative influence of flow and it is assumed as 0.3.

Table 1: Initial values calculation for each sub-basin

Sub-basin	Curve Number	Initial Abstraction(mm)	Time of concentration(Tc)	Storage Coefficient
5C1A1	74	18.01	1.95	1.3
5C1A2	66	26.4	1.53	1.05
5C1A3	71	20.5	1.62	2.7
5C1A4	74	18.01	2.45	1.4
5C1B1	73	18.78	4.07	1.2
5C1B2	73	18.78	1.72	1.56

Table 2: Initial calculation for Reaches in using Muskingum method

Reach	Length(m)	Slope	Muskingum K	X
5C10	4810	0.0012	4.30	0.3
5C20	4800	0.0013	4.20	0.3

Thus above table represents the calculation of parameters for the method such as Muskingum method, Clark Unit Hydrograph method and SCS (soil conservation system) Curve Number method. Thus from this calculation we can run the HMS model and can get the desire result.

4. HEC-HMS Model Development

The Rainfall-Runoff processes in surat city are stimulated by Hydrological Modelling Systems. HEC-HMS indirectly combines the flow near surface and overland flow and stimulates the direct runoff discharge at outlet. We can choose numerous infiltration loss parameters using HEC-HMS.

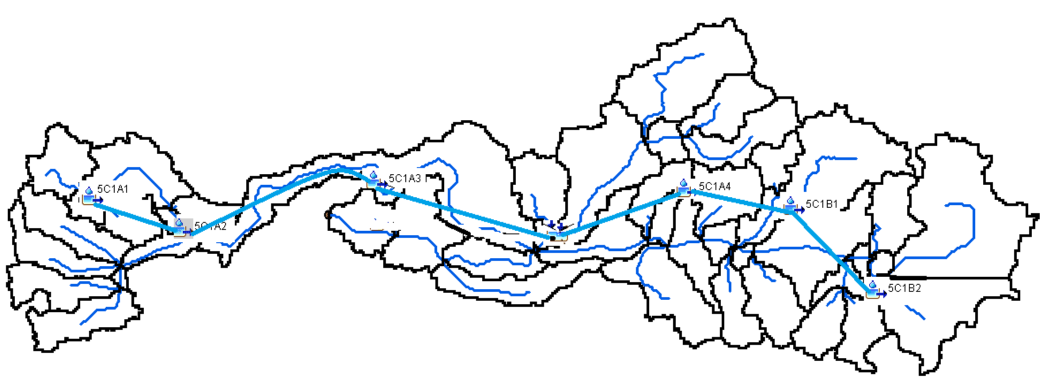


Figure 4: Generated project in HEC-HMS

After pre-processing in HEC-GeoHMS and ArcGIS the file is imported to HEC-HMS software as a basin file. The above figure shows basin model file and background map opened in HEC-HMS that was created in ArcGIS. The calculated parameter has to be added to the sub basins. Then we have to insert components of HEC-HMS in the imported model. In Time series data manager option we have to add the precipitation and discharge data of surat city. The data then has to be divided into five flood events which were held during the span of 30 years. Then simulation of purpose data has to be done. Then Metrological model option has been used for defining and giving control specification for five major flood events. Then the simulation of final model obtained has to done of each five flood events and the results will be obtained. Finally comparison of results to be done.

5. RESULTS AND DISCUSSION

In HEC-HMS after using all the components required the result of that inserted parameter will be obtained and stimulation of five flood events from the data will be obtained. Information regarding peak discharge with the date and time will be obtained. Along with that we could get the absolute error and RMS error in our project which suggest that we have this much error in discharge that is obtained using software and the manually obtained data. Below figure shows the the stimulation process and the graph shows the hydrograph obtained for observed and stimulated discharge at oulet.

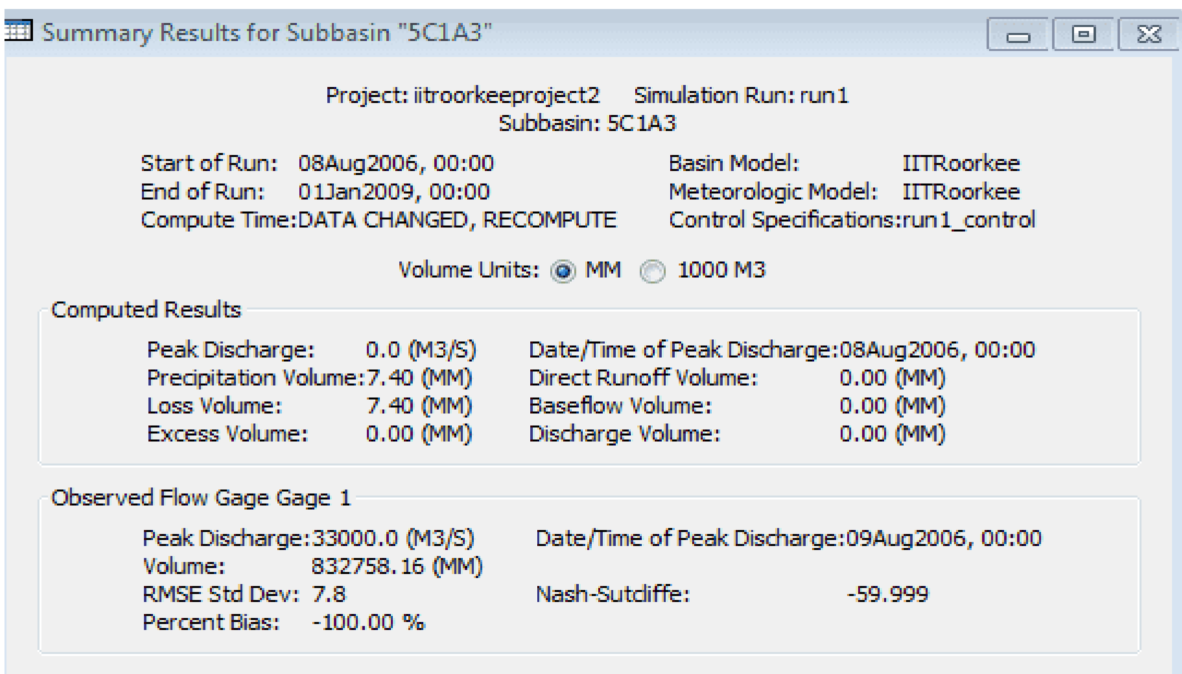


Figure 5: Result of Stimulation in HEC-HMS

Table 4: Showing comparison of observed and stimulated

	Observed Results	**Computed Results**
Peak Discharge(m^3/s)	25768	30000
Volume	832500	832758
Date and Time of Peak	08Aug2006,00:00	09Aug2006,00:00
Mean Absolute Error	14%	-
RMS Error	-	7.8

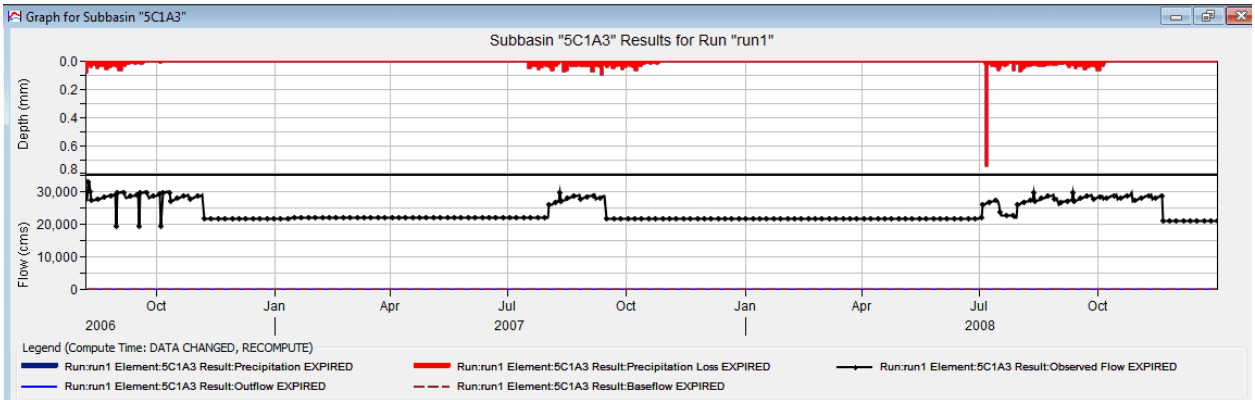


Figure 6: Result showing Graph of precipitation (mm) versus Time (Days) and Discharge (m^3s) versus Time (Days)

5.1 DISCUSSION

Therefore the results obtained has some dissimilarities in observed and stimulated discharge hydrograph which is due to following reasons: 1. Measurement of rainfall and runoff is done at same location that is at outlet point therefore there can be effect of rainfall in upper catchment. 2. It clear from results that there is bad correlation between rainfall-runoff data at the station. 3. There can the effect of cold climate and frozen grounds. 4.There may be any human error which can be either manually or in software due which we could not get precise results.

Thus it clearly states that due to poor correlation in rainfall runoff stimulation there were few errors which took place due to which stimulated result was more than observed. Thus if more data is available then better stimulation of the model can be done. Therefore if this inconsistency between observed and stimulated hydrograph is removed, then this software can be used for flood prediction.

CONCLUSION

From this model development of flood warning measures and importance of flood forecasting methods can be understood. The results obtained needs less calculation for forecasting flood than forecasting the flood by manual method. The main objective of using this software is that we could obtain better results in less time and cost. There various parameters to be calculated in manual flood forecasting but here we have to only insert the options and rest will be done by software. The applicability of HEC-HMS as hydrological modelling software and HEC-GeoHMS as a DEM pre-processing toolkit is clear. The flood forecasting model was developed in HEC-HMS and stimulated for five flood events. The results show high dissimilarity and reasons for that were identified. Therefore this method can be merged with data driven techniques when the errors are properly rectified.

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