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Simulation of Urban Drainage System Using a Storm Water Management Model (SWMM)

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***Abstract* - Urban floods are caused due to increase in population density, development of urban infrastructure without paying due consideration to drainage aspects and increase in paved surfaces. Storm water modelling plays an important role in checking issues such as flash floods and urban water-quality problems. The SWMM (Storm Water Management Model) has been an effective tool for simulating floods in urban areas. In this study a SWMM model is developed to analyze drainage network for the campus of National Institute of Technology, Warangal in the city of Warangal, Telangana, India. The model is simulated for one real storm event and 2-year return period of interval 1-hour design storm intensity. Frequency analysis is performed using best fitted distribution i.e., Gumbel's distribution for different return periods and the frequency values are used for development of IDF (intensity-duration-frequency) curves. Design storm intensity derived from IDF curves for different return periods is used to estimate peak runoff from each sub catchment which is used as input parameter in simulation of runoff in SWMM. GIS methodology is employed for handling spatial data simultaneously. From results, it is observed that some part of campus are commonly affected with flooding, when analysis is performed for two design storms and one day continuous rainfall/precipitation values.**
***Keywords*: Urban Flood, Storm water, SWMM, GIS, NIT Warangal, Rainfall–Runoff Simulation**

I. INTRODUCTION

Most of the cities in India are facing the problem of urban flooding lately. Unplanned growth of urban areas is affecting the natural drainage surface (Ahmed *et al.,* 2013). Moreover urbanisation is responsible for sealing of ground. Thus short duration intense rainfall is resulting in high flood peak flows form altered catchments of urban areas (Suriya *et al.,* 2012). Storm water drains play an important role in conveying the rainfall from the urban areas to the outlet point mostly a water body like river or lake (Zameer *et al.,* 2013). The drainage network in the country is old and deteriorated and thus do not have sufficient capacity to carry excess runoff due to extreme flooding events and hence flash floods occur almost in events of short duration rainfall with high intensity (Schmitt *et al.*, 2004). Unlike other types of flooding, urban flooding is a direct, quick and localized consequence of rainfall (Awakimjan, 2015). It often occurs with minute warning and affects areas not evidently prone to flooding which makes unpredictable and uncontrollable (NDMA Guidelines, 2010). This kind of flooding leads to heavy economic losses and disturbing social and environmental impacts (Rodriguez *et al.*, 2005). To avoid this type of situations, it is essential to dispose of the excess water economically and efficiently in the quickest possible time. One of the ways to reduce its intensity is proper designing and maintenance of drainage system. The notable examples of urban flooding in India which caused huge loss in terms of money and human life are Hyderabad (2016), Chennai (2015), Srinagar (2014), Mumbai and Kolkata (2013) (Rafiq *et al.*, 2016, Rangari *et al.,* 2016). Such happenings cannot be sopped but its influence can be minimized through modeling of flood events and preparing action plans an alert system (Tate, 1999, Knebl *et al.*, 2005).

A number of softwares are available which are capable of simulating urban floods. The first computerized models of urban storm drainage were developed during the late 1960s, and since that time a multitude of models have been in utilization (Zoppou, 2001; Mitchell, 2001). These models can be classified as design models, flow prediction models, and planning models (Rangari et al, 2015, Hunter *et al.*, 2007). With the advent of Graphical User Interface (GUI) software like SWMM, HEC-HMS, HEC-RAS, MIKE FLOOD etc. modelling of the urban flood became easy and easily understandable outputs have been generated by these software. Geographical Information System (GIS) software like ArcGIS, QGIS etc., has made the work still simpler for extracting data for direct inputs to the model (Hasheyman et al., 2015). The availability of DEM has made the simulation to more extensive simplification of reality when data availability is less (Magesh *et al.*, 2012).

The main aspect of flood modelling is to understand the characteristics of flood in the urban area and the impacts of heavy rainfall on the runoff of the urban catchments and the various socio-economic aspects of flood (Guangtao *et al.*, 2011). In this study, stormwater drainage system of NIT Warangal campus is examined using environmental protection agency's (EPA) storm water management model (SWMM). The SWMM is a dynamic rainfall-runoff simulation model based on momentum, mass and energy conservation laws. This model is used in the design, analysis and planning of drainage systems and for the simulation of runoff quality and quantity in urban areas (Rossman, 2010).

A. Study Area and Data Used

Area chosen for the present study is a small campus of NIT (National Institute Technology), Warangal. The Geographic location of the campus is 17° 59′ N latitude, 79° 31′ E longitude. The location map of the NIT, Warangal is shown in the figure 1. NIT Warangal is located in the city of Hanamkonda, Warangal which is in turn located in the northern region (slightly to east) of Telangana. The 256-acre (1.04 km^2) residential campus is situated on either side of National Highway 202 (Hyderabad to Warangal) at a distance of 3 km from Kazipet Railway Station and 12 km from Warangal Railway Station.

Data of the study area is collected from different agencies. Most of the data regarding DEM (Digital Elevation Model) map, landuse-landcover map were extracted from Cartosat 30 m DEM obtained from Bhuvan. Hourly rainfall data for 33 years is procured from WMC (Warangal Municipal Corporation), while 10 years rainfall data is taken from NIT Warangal campus weather station. The drainage details and present drainage network drawings are collected from NIT campus project office.

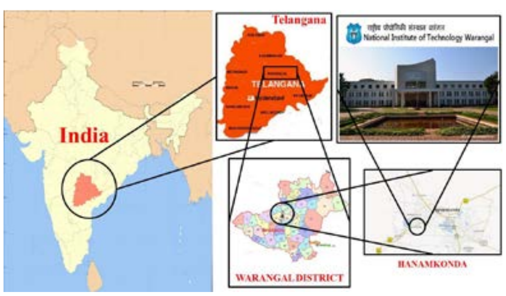


Fig. 1 Geographic Location of NIT Warangal

Fig. 2 Image of NIT Warangal Campus showing its boundary

B. The Problem Statement

NIT Warangal is one of India's reputed colleges. There has been development in the drainage systems corresponding to the sewage network but storms which causes surface runoff follows open drain system. A lot of construction activities and developments are taking place in the campus. Thus available permeable land is reducing. As a result, more and more runoff joining the open drains resulting in overflows at many locations. Due to heavy rainfall, lots of places get inundated in campus (especially in the low lying regions). Less maintenance of drain is also a reason for flood inundation as the capacity of the drain to carry storm has reduced over period of time. This causing many environmental problems like flooding, spreading of waterborne diseases and mosquitoes in the campus. Thus there is a need analyze and modify the drainage network of campus to carry excess of rain water and reduce the inundation.

II. METHODOLOGY

The Methodology consists of three parts: 1, Developing Intensity Duration Frequency (IDF) curves for the available rainfall data using best fitted distribution; 2, finding out the maximum discharge from the catchment using rational formula; and 3, carrying out capacity analysis of existing drainage system for design storm intensity considered from IDF curves.

Capacity analysis of existing drainage network for the chosen study area is carried out using well-known software SWMM (Storm Water Management Model). The models were set up using Cartosat 30 m DEM, LULC maps extracted from DEM and other drainage details collected from WMC. The total catchment area is divided into sub-basins using ArcGIS tool. Time of concentration is estimated using Kirpich formula for each sub-basin. Design rainfall intensity is obtained from IDF curves.

A. Generation of Intensity Duration Frequency (IDF)Curves

The annual maximum daily rainfall data of 33 years collected from WMC (Warangal Municipal Corporation) and institute rain gauge is used for development of IDF curves. For the rainfall data Gumbel's distribution provided a better fit than the Log normal distribution based on Kolmogorov-Smirnov test of goodness of fit. Frequency analysis is performed using best fitted distribution i.e., Gumbel's distribution for different return periods 2year and 5year, and the frequency values are used for development of IDF Curves, which is shown in figure 3. IDF relationship is developed for all return periods from IDF curves. Design storm intensity derived for different return periods is used to estimate peak runoff from each sub catchment and input parameter in simulation of runoff from each sub catchment in SWMM.

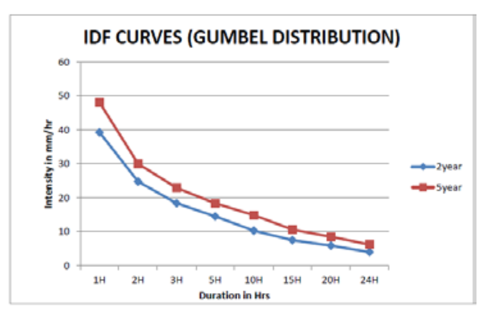


Fig. 3 Intensity-duration-frequency curves

B. Capacity Analysis of Existing Drainage System

The SWMM model is developed for the study area as shown in below figure 4. The total study area is divided into nine sub basins by considering the drainage line in arc GIS 10.2. Land use land cover pattern for the study area is extracted from 30 m Cartosat DEM. Area of each sub basin is calculated and provided as input in storm water management model (SWMM) to define the runoff from each sub catchment (sub basins are considered as sub catchments in SWMM). Overland flow from each sub catchment is calculated using rational formula and SWMM model (figure 4) is simulated for the calculated flow values and flooding junctions are identified.

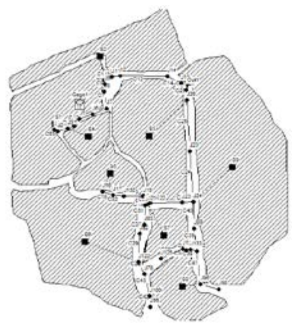
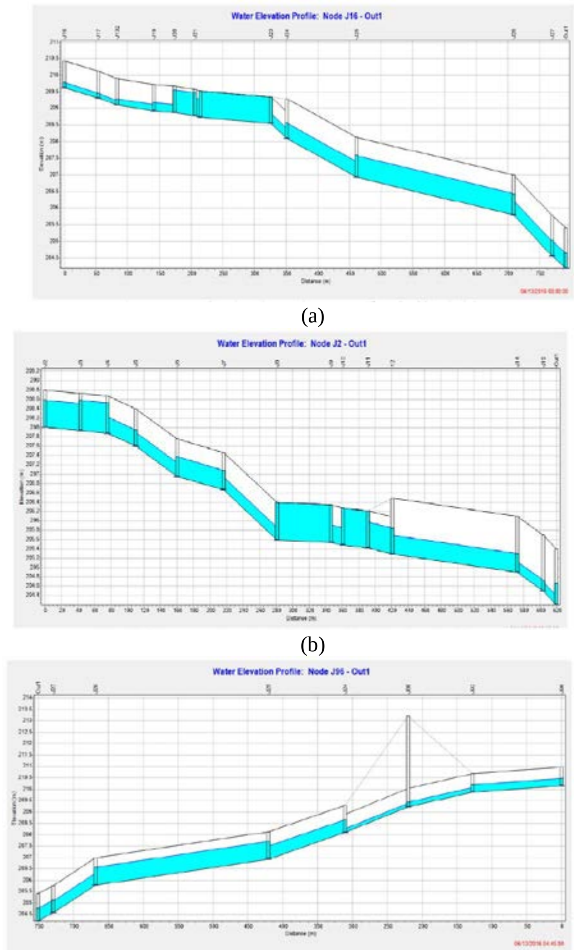


Fig. 4 SWMM model for study area

III. RESULTS AND DISCUSSION

Intensity of 2 year return period of 1 hour duration is considered as design intensity. The value of intensity is 39.251 mm/hr. Peak runoff for every subcatchment is calculated using rational formulae and given as input at each node/ junction from corresponding subcatchment. SWMM model is simulated for two conditions viz. design storm of 2 year return period and 1 day historical rainfall and overall simulation results are presented in table II and table III respectively. The flooding junctions are identified and presented in table 3 and table 4. Simulation results of 2 year return period design storm shows that maximum flooding occurring at J8, J20, J22. Some conduits C3, C8, C20, C22 have attained maximum/ full depth. Flow in the channels is dependent on the conduit slope and dimensions and roughness are the factors.



(a)

(b)

(c)

Fig. 5 Water Surface Profile at Different Junction Points

TABLE I SWMM MODEL CALCULATIONS FOR 1-HOUR DESIGN STORM INTENSITY WITH 2YEAR RETURN PERIOD

Return period	Flow Frequency percentage	Average Flow CMS	Maximum Flow CMS	Total volume 10^6 ltr
2yr	100.00	0.492	4.222	1.799

TABLE II DESCRIPTION OF STORM EVENTS RESULTING IN FLOODING FOR ONE DAY HISTORICAL RAINFALL DATA

Return period	Flow Frequency percentage	Average Flow CMS	Maximum Flow CMS	Total volume 10^6 ltr
1Day	7.08	0.434	3.163	79.649

TABLE III SUMMARY OF FLOODING AT JUNCTIONS FOR 1 DAY HISTORICAL DATA

Node	Hours Flooded	Maximum Rate CMS	Hour of Maximum Flooding	Total Flood Volume 10^6 ltr
J10	0.08	0.005	4:00	0.001
J22	0.85	0.217	4:00	0.34
J8	0.76	0.138	4:01	0.235

TABLE IV SUMMARY OF FLOODING AT JUNCTIONS FOR 2 YEAR RETURN PERIOD DESIGN STORM INTENSITY

Node	Hours Flooded	Maximum Rate CMS	Hour of Maximum Flooding	Total Flood Volume 10^6 ltr
J20	0.03	0.003	00:05	0.000
J22	0.07	0.174	00:06	0.028
J8	0.08	0.151	00:08	0.026

IV. CONCLUSION

In the present study a storm water drainage network for NIT Warangal campus has been analyzed using the well-known Storm water Management model. The data required for this model has been met by sources like Warangal Municipal Corporation and institute development project office. Simulation results for different design storms shows the J8, J0, J22 are commonly affected with flooding. Water surcharge conditions at junctions can be reduced by increasing the dimensions of the drainage system.

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