

Rainfall–Runoff Modelling for Urban Flood Analysis in Bhavanipuram Area, Vijayawada using SWMM 5.2

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Abstract— Urban flooding has become a major concern in rapidly urbanizing cities due to increased impervious surfaces, inadequate drainage systems, and high-intensity rainfall events. This study presents rainfall–runoff modelling and urban flood analysis for the Bhavanipuram area of Vijayawada using EPA SWMM 5.2 integrated with GIS techniques. Elevation and rainfall datasets were collected and processed to generate contour maps and Digital Elevation Model (DEM). Intensity–Duration–Frequency (IDF) curves were developed using the Gumbel distribution method to estimate rainfall intensity under different return periods. The study area was divided into sub-catchments and modelled in SWMM by defining conduits, junctions, outfalls, and rain gauges. Dynamic wave routing was used to simulate runoff and drainage behaviour during storm events. Results indicate that low-lying regions and highly urbanized sub-catchments experience higher runoff generation and water accumulation. Certain conduits showed surcharge conditions due to inadequate drainage capacity. The study demonstrates that GIS and SWMM integration provides an effective framework for urban flood modelling, flood-prone area identification, and sustainable storm water management planning.

Keywords— Urban Flooding, SWMM 5.2, Rainfall–Runoff Modelling, GIS, DEM, IDF Curve, Flood Risk Assessment.

I. INTRODUCTION

Urban flooding is one of the most severe natural hazards affecting rapidly developing urban regions. Population growth, land-use changes, and reduction in permeable surfaces significantly increase runoff generation during intense rainfall events. Vijayawada city has experienced severe flooding in recent years, particularly during the 2024 monsoon season due to heavy rainfall and overflow of the Budameru rivulet. Bhavanipuram, a densely populated low-lying region of Vijayawada, was severely affected by waterlogging and drainage failure. The Storm Water Management Model (SWMM), developed by the United States Environmental Protection Agency (US-EPA), is widely used for hydrological and hydraulic simulation of urban drainage systems. SWMM allows analysis of rainfall–runoff behaviour, drainage performance, and flood-prone regions under varying rainfall conditions. This study focuses on rainfall–runoff modelling and urban flood assessment in Bhavanipuram using SWMM 5.2 integrated with GIS-based spatial analysis.

II. RELATED WORK

Several researchers have used SWMM for urban flood modelling and stormwater analysis. Chang et al (2008) demonstrated the effectiveness of SWMM in urban stormwater management under varying rainfall conditions. Bisht et al. (2016) integrated SWMM with MIKE URBAN for urban drainage simulation and flood assessment. Banda and Kasitu (2018) used EPA-SWMM for runoff simulation in Zambia and identified flood-prone areas under different rainfall scenarios. Rangari et al. (2018) applied SWMM for urban drainage modelling and IDF curve development, while Agarwal (2019) evaluated SWMM performance for flood modelling in semi-urban catchments. Recent studies emphasize the importance of GIS integration, DEM analysis, and dynamic routing techniques for accurate urban flood prediction and drainage system evaluation.

III. STUDY AREA

Bhavanipuram is located in the western region of Vijayawada city in Andhra Pradesh, near the Krishna River and Eluru Canal. The area consists of mixed land-use patterns including residential, commercial, transportation, and institutional zones. The terrain is predominantly flat with several low-lying areas vulnerable to flooding during heavy rainfall. The region experiences a tropical climate with intense monsoon rainfall. Due to rapid urbanization and increasing impervious surfaces, infiltration capacity has reduced considerably, resulting in higher runoff generation and urban flood risk.

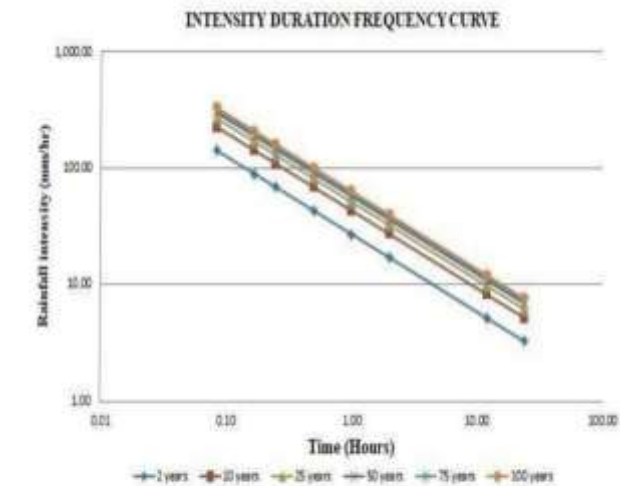
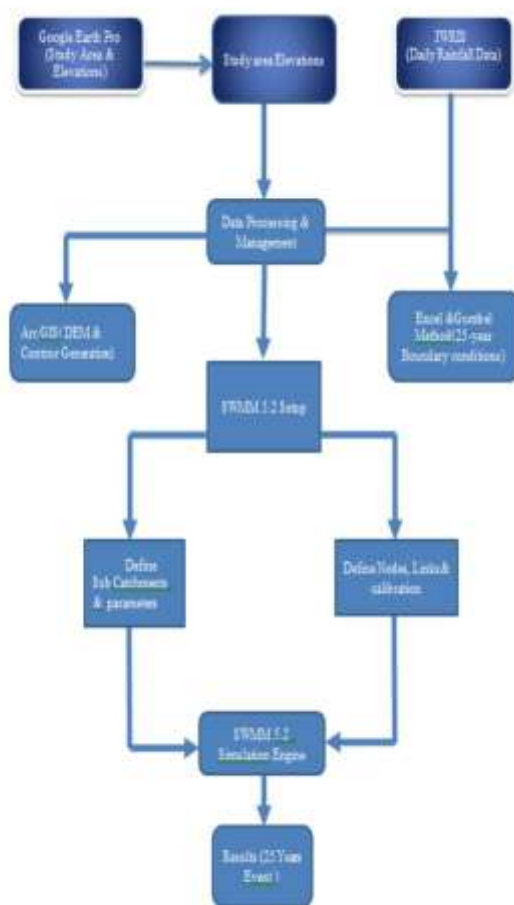


STUDY AREA OF BHAVANIPURAM

IV. METHODOLOGY

The methodology adopted in this study involves rainfall data collection, DEM preparation, IDF curve analysis, and SWMM simulation. Elevation coordinates were collected using Google Earth Pro and processed in ArcGIS to generate DEM and contour maps using the IDW interpolation technique. Historical rainfall data were analysed using the Gumbel distribution method to estimate rainfall intensities for different return periods. The generated IDF curves were then used as rainfall input in SWMM

5.2.



IDF CURVE



JUNCTIONS

The SWMM model was developed by defining sub-catchments, conduits, junctions, outfalls, and rain gauges. Dynamic wave routing was applied to simulate runoff and hydraulic flow behaviour within the drainage network.

V. RESULTS AND DISCUSSION

DEM and contour analysis identified several low-lying regions within Bhavanipuram that are highly vulnerable to water accumulation during heavy rainfall events. SWMM simulation results showed that runoff generation increased significantly in highly urbanized sub-catchments due to reduced infiltration and increased impervious surfaces. Node depth analysis revealed critical

Node	Type	Average Depth (Meters)	Maximum Depth (Meters)	Maximum HGL (Meters)	Day of Maximum Depth	Hour of Maximum Depth	Maximum Reported Depth (Meters)
J1	SWATCHMENT	0.00	0.23	2.73	1	00:18	0.23
J2	SWATCHMENT	0.00	0.22	2.68	3	02:18	0.22
J3	SWATCHMENT	0.00	0.22	2.52	1	04:27	0.22
J4	SWATCHMENT	0.00	0.23	2.50	1	05:42	0.23
J5	SWATCHMENT	0.00	0.23	2.38	1	06:11	0.23
J6	SWATCHMENT	0.00	0.26	1.98	1	06:11	0.26
J7	SWATCHMENT	0.00	0.78	1.93	1	03:23	0.78
J8	SWATCHMENT	0.00	0.78	1.83	1	03:08	0.78
J9	SWATCHMENT	0.00	0.78	1.93	1	03:40	0.78
J10	SWATCHMENT	0.00	0.25	1.93	1	00:15	0.25
J11	SWATCHMENT	0.00	0.25	2.23	1	00:23	0.25
J12	SWATCHMENT	0.00	0.25	1.83	1	00:23	0.25
J13	SWATCHMENT	0.00	0.25	1.78	1	00:08	0.25
J14	SWATCHMENT	0.00	0.33	1.83	1	01:40	0.33
J15	SWATCHMENT	0.00	0.43	1.83	1	00:02	0.43
J16	SWATCHMENT	0.00	0.73	1.83	1	00:40	0.73
J17	SWATCHMENT	0.00	0.33	1.93	1	00:23	0.33
J18	SWATCHMENT	0.00	0.83	1.83	1	01:08	0.83
OUT1	OUTFALL	0.00	0.17	0.17	1	00:12	0.17

NODE DEPTHS

Topic: Outfall Loading Click a column header to sort the column.

Outfall Node	Flow Frequency %	Average Flow CMS	Maximum Flow CMS	Total Volume 10 ⁶ lit
OUT1	0.59	0.002	0.002	3.477

OUTFALL LOADING

VI.CONCLUSION

This study presented rainfall–runoff modelling and urban flood assessment for the Bhavanipuram area of Vijayawada using SWMM 5.2 integrated with GIS techniques. The analysis demonstrated that inadequate drainage infrastructure, rapid urbanization, and low-lying terrain significantly contribute to urban flooding. SWMM simulation successfully identified flood-prone nodes, runoff behaviour, and conduit surcharge conditions under varying rainfall events. The integration of GIS and SWMM provided efficient spatial visualization and hydrological assessment of the study area. The study recommends improving drainage infrastructure, implementing sustainable stormwater management practices, and adopting proper urban planning strategies to reduce future flood risks and improve urban resilience.

VI. REFERENCES

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