

Flood Modeling of the Budameru Catchment by Using HEC RAS

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Abstract:

Flood disasters continue to pose serious risks to human life, livelihoods, and the economy across Asia, with densely populated regions particularly exposed to extreme hydrological events. These hazards damage infrastructure, disrupt agriculture, and slow sustainable development. In recent years, geospatial technologies and satellite-based remote sensing have proven effective in assessing flood hazards, monitoring inundation patterns, and guiding disaster management efforts. The Budameru rivulet, which flows through Vijayawada in Andhra Pradesh, India, has a history of frequent urban flooding. This problem is intensified by rapid urbanization, floodplain encroachments, and the inadequate conveyance capacity of the Budameru Diversion Canal (BDC). To evaluate these risks, this study develops a one and two-dimensional (1D/2D) unsteady HEC-RAS model of the Budameru catchment. The model simulates the late-August to early-September 2024 flood, validates inundation extents against satellite-derived flood maps, and explores structural and non-structural mitigation measures. Calibration with observed water levels and reported high-water marks shows that the model captures flood peaks and depths with acceptable accuracy. The results reveal that low-lying localities such as Arjith Singh Nagar, Vombay Colony, Bhavani Puram, Rajarajeswaripeta, Payakapuram, Ramakrishna Puram, and Kandrika were most severely affected, with flood depths reaching up to 14.67ft. Targeted channel improvements and removal of encroachments significantly reduce inundation impacts in these vulnerable wards.

Keywords: Flood modeling, HEC-RAS 1D/2D, GIS-based flood assessment, Budameru rivulet.

Introduction:

Flash floods and boat capsize incidents are frequent in India, posing recurring threats to lives and livelihoods. These disasters are often aggravated by the absence of robust early warning systems, resulting in high mortality rates every year. In Andhra Pradesh, recent statistics reveal a particularly alarming trend of flash floods and boat accidents. The “Diviseema Uppena” tragedy of 1977, in which more than 10,000 people drowned in the Krishna River, remains one of the deadliest flood-related disasters in the state’s history. In addition, recurrent boat capsizing incidents in the Godavari and Krishna Rivers (The Hindu, 2016) highlight systemic weaknesses in preparedness and response mechanisms. Such events emphasize the urgent need for improved flood risk management and disaster mitigation strategies in the region. Globally, floods are recognized as one of the most destructive natural hazards, accounting for nearly half of all disaster-related damages and affecting billions of people each decade (Shah et al., 2017; UNDRR, 2020). Their impacts extend well beyond immediate inundation. Floods not only cause

loss of life but also damage critical infrastructure, disrupt transportation and communication networks, destroy crops, erode fertile soils, and trigger outbreaks of waterborne diseases (Hirabayashi et al., 2013). Climate change is further intensifying these risks by increasing the frequency of extreme rainfall events, accelerating glacial melt in upstream catchments, and contributing to sea-level rise in coastal zones (IPCC, 2021). In this context, flood disasters represent not just a hydrological phenomenon but a multi-dimensional socio-economic challenge.

Effective disaster risk reduction depends heavily on social preparedness and early warning systems. Community-based preparedness initiatives are recognized as cost-effective approaches for mitigating flood impacts (Lopez et al., 2017). At the same time, information and communications technology (ICT) has emerged as a transformative tool in disaster prevention, mitigation, and management (Choudhary et al., 2019). Satellite-based flood early warning systems have proven highly efficient for global-scale monitoring, but delays in information dissemination often limit their usefulness at the community level. Bridging this gap between technology and local preparedness remains a critical challenge for flood-prone regions such as India. Within this context, the Budameru rivulet is one of the most problematic tributaries in the Krishna basin. Flowing through Vijayawada city, Budameru has a history of repeated flooding events. These floods are primarily driven by the rivulet's limited channel capacity, widespread encroachments along its banks, and the insufficient diversion capacity of the Budameru Diversion Canal (BDC) (APSAC, 2024). Historical events illustrate the severity of the problem: the September 2005 flood inundated several wards of Vijayawada, while the August–September 2024 flood once again displaced thousands of residents, causing widespread disruption and prompting renewed calls for long-term mitigation measures (Times of India, 2024).

Despite the severity of Budameru flooding, systematic hydrodynamic studies of this catchment remain limited. Previous assessments have primarily relied on historical flood records, hydrological statistics, or simplified one-dimensional models, which provide only partial insights into the spatial dynamics of inundation. High-resolution two-dimensional modeling combined with satellite-derived flood mapping has rarely been applied to Vijayawada, resulting in gaps in understanding flood depths, flow velocities, and the effectiveness of mitigation interventions. Given these challenges, accurate hydrodynamic modeling of Budameru is essential for both scientific understanding and practical disaster management. Hydraulic models not only enable the reproduction of past flood events but also serve as decision-support tools for testing engineering interventions and land-use planning strategies. Among the available modeling platforms, the Hydrologic Engineering Center's River Analysis System (HEC-RAS) has become widely adopted because of its ability to simulate one-dimensional (1D) and two-dimensional (2D) unsteady flows, integrate rainfall–runoff dynamics, and produce high-resolution inundation maps for urban environments (Brunner, 2021). These features make HEC-RAS particularly suitable for modeling Budameru complex flood dynamics in Vijayawada.

This study, therefore develops a coupled 1D/2D unsteady HEC-RAS model of the Budameru catchment to simulate the August–September 2024 flood, validate inundation extents against satellite-derived flood maps, and explore a range of structural and non-structural mitigation measures. The findings are expected to support improved flood forecasting, inform engineering

interventions, and guide sustainable urban planning to reduce the vulnerability of Vijayawada's residents to future flood hazards.

Study Area:

The Budameru Rivulet is located between 16°30'N and 16°57'N latitude and 80°28'E to 80°48'E longitude in Andhra Pradesh, India. This geographical setting places the study area in a fertile alluvial plain that is strongly influenced by the Krishna River system. The land resources of the study area are primarily distributed among four major categories: Agricultural land, Built-up areas, Water bodies, and Forests. The analysis reveals that agricultural land continues to be the dominant land use, occupying 975.261 km² (69.7%). Built-up areas cover 165.033 km², and Water bodies cover 38.223 km² (2.7%), indicating a marginal decrease, while forest land remains relatively stable with 221.012 km² (15.8%) of the total study area, as shown in Fig.1.

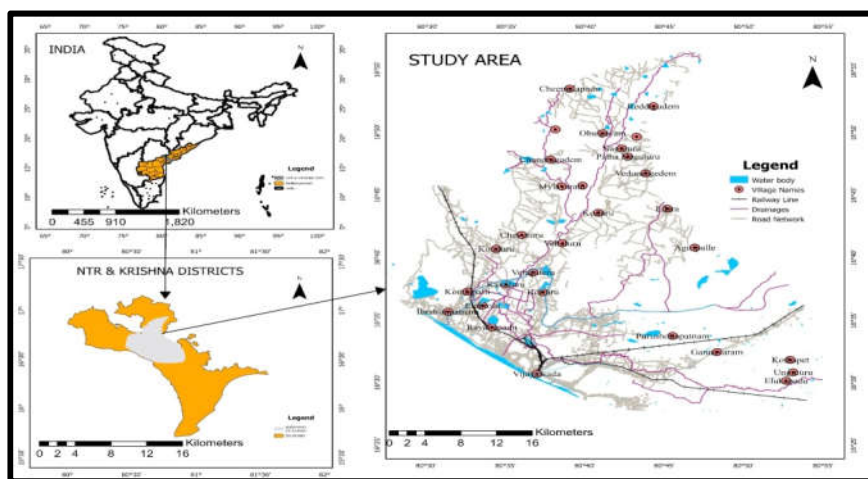


Fig.1 Location Map for the Study Area

Results & Analysis:

The study integrated remote sensing, GIS, and HEC-RAS hydraulic modeling to assess flood risk in August 2024. DEM data and river networks supported terrain and flow analysis, while rainfall inputs generated inflow hydrographs. Outputs produced inundation maps, highlighting rainfall, slope, catchment morphology, and hydraulic parameters as key flood-controlling factors. These findings demonstrate that the region, particularly within NTR and Krishna districts, is experiencing conversion of agricultural land into urban land uses, with only minor variations in water bodies. Such land use transformations have direct implications for flood risk, as the reduction of agricultural land and increase in impervious built-up surfaces decrease natural infiltration and enhance surface runoff. Even the slight reduction in water bodies may further reduce the storage and buffering capacity of the landscape. The generated LULC maps and statistics, therefore, provide crucial inputs for understanding flood vulnerability, hydrological responses, and watershed behavior and serve as valuable tools for planning flood mitigation measures, sustainable drainage systems, and disaster risk management strategies in the study area. Addressing these research gaps is essential for developing accurate flood forecasts,

designing effective engineering measures, and improving disaster preparedness at the community level, as shown in Fig.2.

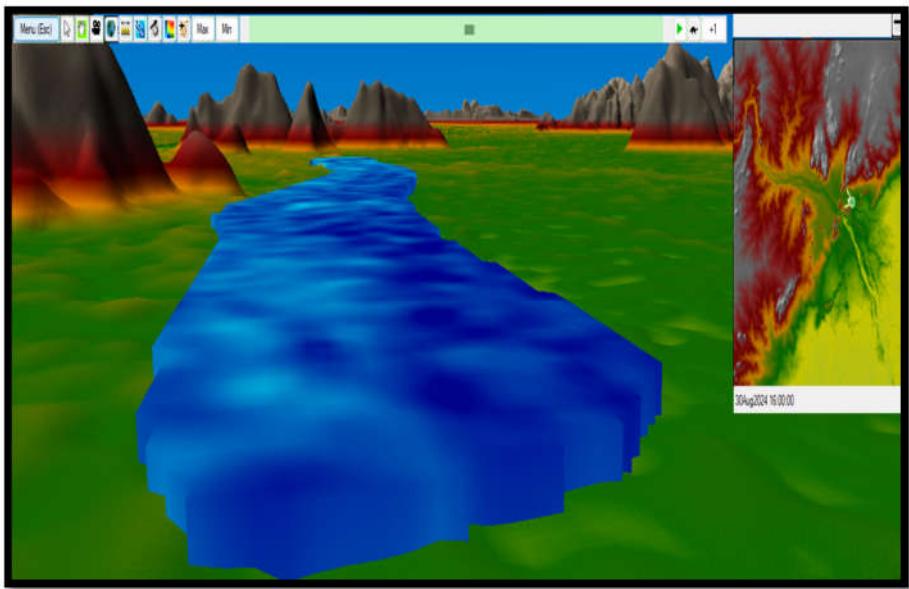


Fig.2 Flood Model Representation

Depth:

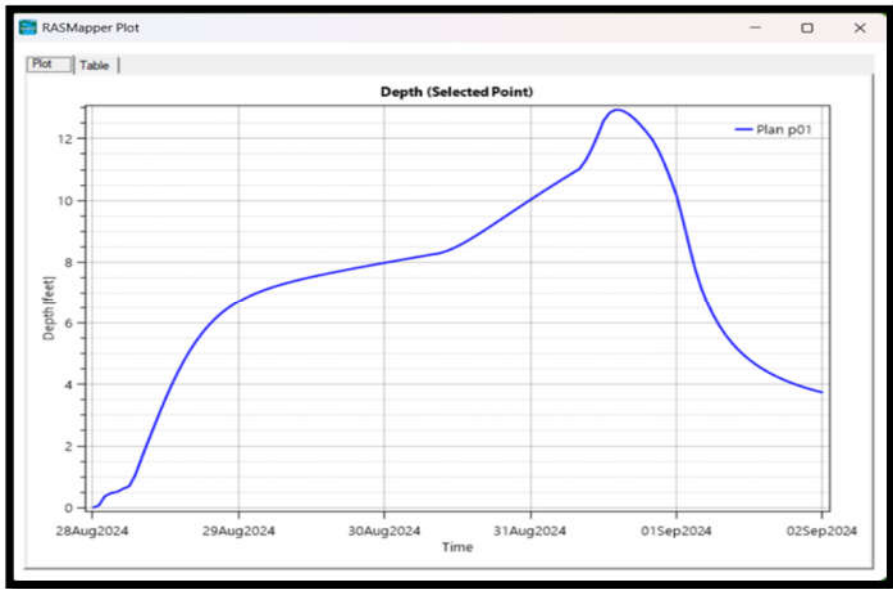


Fig.3 Critical depth

The hydrograph shows the simulated flood depth at a selected point in Budameru, with water levels peaking at 14.67 ft on 1st September 2024 in Fig.3. The areas revealed that low-lying localities such as Arjith Singh Nagar, Vombay Colony, Bhavanipuram, Rajarajeswaripeta, Payakapuram, Ramakrishna Puram, and Kandrika were most severely affected, with flood depths. The sharp rise and fall indicate intense flooding followed by rapid recession within a short duration.

WSE:

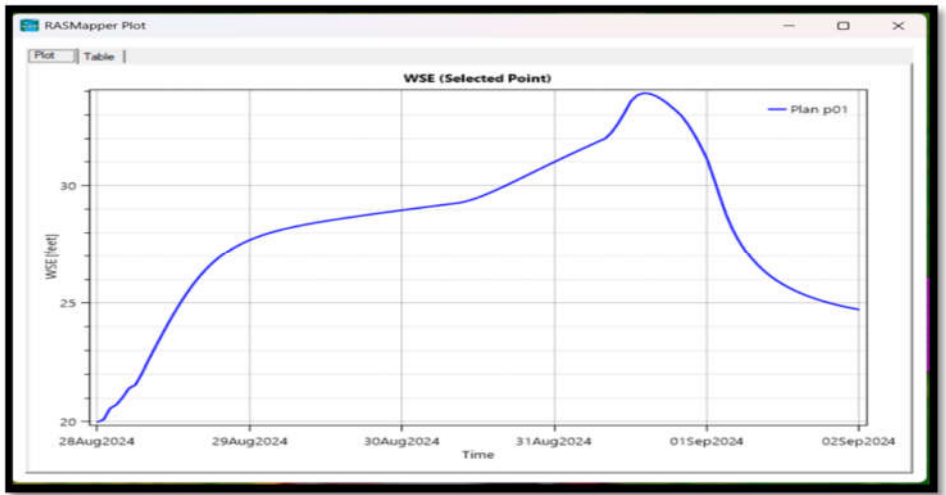


Fig.4 Waster Surface Elevation

The Water Surface Elevation (WSE) plot indicates levels rising steadily from 28th August, peaking above 34 feet on 1st September 2024 in Fig.4. The sharp decline afterward reflects the flood’s recession phase.

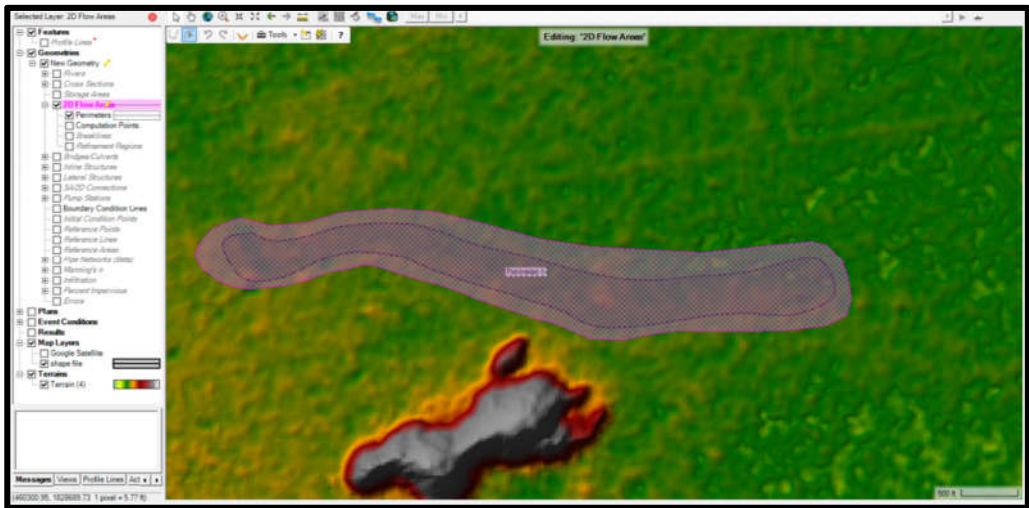


Fig 5. 2D-Model of Budameru Flooded Area

Fig 5. Represents the setup of a 2D Flow Area in HEC-RAS, which is used to simulate flood behavior across the floodplain. The shaded mesh region is divided into small computational cells where the model calculates how water flows, spreads, and recedes over time. Unlike a 1D model that only follows the river channel, the 2D approach accounts for overbank flooding, flow direction changes, and variations in depth and velocity across the terrain. This makes it especially useful for urban or complex floodplains like Budameru, where encroachments and terrain features strongly influence flood dynamics.

Conclusion:

This study applied HEC-RAS (1D/2D) hydraulic modeling integrated with GIS analysis to assess flood risk in the Budameru catchment during the August–September 2024 event, and the results highlight how rapid urbanization, channel encroachments, and limited diversion capacity have amplified flood hazards in Vijayawada. Model outputs validated against satellite-derived flood extents and observed high-water marks revealed inundation depths exceeding 15ft in several vulnerable wards, underscoring the urgent need for structural measures such as widening the Budameru Diversion Canal and removing encroachments, as well as non-structural approaches including early warning systems, community preparedness, and land-use regulation. The flood risk maps generated provide practical tools for disaster management and urban planning authorities, while the methodology demonstrates the value of coupling hydrodynamic modeling with remote sensing for improving flood resilience in rapidly urbanizing river basins.

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