REVIEW OF APPLICATION OF OPEN SOURCE HEC-RAS FOR 1 DIMENSIONAL HYDRODYNAMIC MODELING - GLOBAL AND INDIAN SCENARIO

[1]Ujas Pandya, [2]Dhruvesh Patel

[1]Assistant Professor, [2]Assistant Professor
[1]Civil Engineering,
[1]Government Engineering College, Gandhinagar, Gujarat, India

Abstract : Among all the types of flood, fluvial floods are most common over the entire globe. Hydrodynamic modeling technique is very useful for the development of 1 dimensional and two-dimensional models which can be further utilized for flood mapping. Among various available software, open source software HEC-RAS is most popular and widely used across the globe. This review aims for exploring the various application of HEC-RAS software for development of 1 dimensional hydrodynamic model for various rivers across the world and in the Indian context. The main objective of this review is to study the effectiveness and scope of HEC-RAS software along with GIS techniques to develop hydrodynamic modeling for open channel flow. Various studies across the globe concluded and confirmed the suitability of HEC RAS for development of steady and unsteady hydrodynamic models for an open channel.

***IndexTerms* - 1-D model, fluvial flood, HEC-RAS, Hydrodynamic model, Indian scenario**

1. INTRODUCTION

Flood is a natural disaster in which a large amount of water covers a nearby area which usually remains dry. Among many types of flooding like, coastal, pluvial, fluvial, ground water, sewer the fluvial floods are the most common across the globe. The Fluvial floods occur when, excess water in the river overtops the banks and it is generally caused by extensive and prolonged rainfall. The major consequences of floods are losses of human and animal lives, the devastation of infrastructure, damages to properties and the environment and negative impact on socio-economic growth (Bellos, 2012). Floods can result in structural damage in bridge abutments, bank lines, sewer lines, and other structures within the floodway. Waterway navigation and hydroelectric power are often impaired. Financial losses due to floods are typically very in terms of dead stock and live stock.

Flood management strategies generally involve multiple engineering projects that can fall under one of two categories. Hard engineering projects are ones that involve the construction of artificial structures like dam, levees, diversion spillways which prevent a river from flooding. Soft engineering projects are the opposite, which uses natural resources and local people's knowledge of the river to reduce the risk posed by a flood. Flood plain zoning, Afforestation, wetland restoration and river restoration are some of the soft engineering techniques for flood management. Hydrological modeling is one of the effective tools for flood mapping and management. Nowadays various software like MIKE-11, HEC-RAS, SOBEK, TUFLOW, Infoworks-2D, RiverFLO-2D and many more are used to develop hydrologic models in a combination of GIS techniques.

2. MODELING TOOLS

a. Geographic Information System (GIS)

Geographical information systems (GIS) are a technology for stacking, analyzing, and retrieving large amounts of data. The term GIS means x, y and z coordinates of the land surface defined in a coordinate system. GIS is a data processing tool, which provides and record information, such as digital elevation model (DEM), topographic surveys, land use and land cover maps etc (Singh, 2018). These days, global positioning systems (GPS) and GIS can be combined to offer more absolute information. The use of GIS permits integration of spatial, non-spatial, and supplementary data into hydrologic models and thus significantly strengthens hydrologic modeling capability. For development hydrologic model, data preparation and model interpretation are time-consuming tasks that can be simplified using a GIS for data processing and display. For the task of river analysis, specific features of a GIS may be made available to the hydraulic engineer through an interface.

b. HEC RAS

The U.S. Army Corps of Engineer's River Analysis System (HEC-RAS) is an integrated system of software comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The software was developed at Hydraulic Engineering Center (HEC), which is a division of the Institute for Water Resources (IWR), U.S Army Corps of Engineer (*HEC-RAS River Analysis System Hydraulic Reference Manual*, 2016). The first version of HEC-RAS was released in July 1995 and since that time many changes and updates are included until latest version 5.0 in 2015.

The HEC-RAS is freely available software designed to perform one dimensional, two-dimensional and combined 1D and 2D hydraulic calculations for a full network of channels. The latest version of HEC-RAS supports steady and unsteady flow water surface profile calculations, combined 1D and 2D hydrodynamics, sediment transport/mobile bed computation, water temperature analysis, water quality analysis and spatial mapping of many computed parameters. The major advantage is that all components use a common geometric data representation and common geometric and hydraulic computation routines (*HEC-RAS River Analysis System Hydraulic Reference Manual*, 2016).

3. APPLICATION OF HEC-RAS SOFTWARE FOR HYDRODYNAMIC MODELING

3.1. GLOBAL SCENARIO

3.1.1. Pahang River, Malaysia (Ghani, Kashfy and Kashfy Zainalfikry, 2018)

In this research, 1 dimensional hydrodynamic model of Pahang River, has been simulated using HEC RAS software. Geometric data like river cross sections, structures and flood plain area details of the study area has been collected through various departments and field surveys. Total 99 cross sections were produced by field survey and rest of the cross sections were generated using freely available DEM on USGS (the United States Geological Survey) website. Total 450 cross sections were used to prepare geometry along Pahang River by combining data of field survey and DEM extraction. Model is simulated for specific Manning's roughness coefficient and flow hydrograph at Kuala Tembeling was considered as upstream boundary and normal depth is assigned as a downstream boundary. Flow is simulated in unsteady condition for the year 2007 and 2014 and validated with observed values of respective years. The model predicts food output agreement with R^2 = 0.96 and R^2 = 0.82 for year 2007 and 2014 floods respectively. The researcher suggested considering channel and floodplain morphological changes for further improvements.

3.1.2. Martil River, Northern Morocco (Azouagh et al., 2018)

This study describes flood mapping and classification of risk areas integrating both HEC-RAS 4.1.0 and HEC GeoRAS 4.1.0 for Martil River crossing the city of Tetuan. For this research use of aerial photographs with a 2 meter resolution has been done for the elaboration of available DEMs of 30, 12 or 10 m resolutions from NASA. The geometry of channel is defined by 146 cross sections for the entire study area of 30 km. Data of maximum discharge from the year 1970 to 2013 for three stations; Amzal, Ben Karrich and Torreta have been used in the study. As per available data highest flow was observed for the year 1990 and 2000. Considering, geology and vegetation cover the Manning's roughness coefficient has been selected in a range of 0.04 to 0.045. Model is simulated for maximum discharge and study has been concentrated on three zones where the overflow appears to be significant. The results generated through model seems to be reliable and consistent with morphology of the field and allowed to locate flood zones, velocities and water levels to be useful for flood mapping.

3.1.3. Al-Kahlaa , Iraq (Awad, 2015)

In this study, researchers developed 1 dimensional unsteady hydraulic model of Al-Kahlaa river located in South of Iraq using HEC-RAS software. The river geometry is defined by the main channel and three reach and total 57 cross sections for the study area. The HEC RAS model is calibrated using recorded weekly stage and discharge data. The results show good agreement between predicted and actual value by considering Manning's value 0.04 for overbank and 0.027 for the main channel and using time weighting factor (ϴ) equal to 1. Researchers concluded that flow simulation in a channel highly depends upon the accuracy of estimated roughness and it is best evaluated through calibration using accurate field data. Result analysis of study also shows that simulated water surface profile is higher that the longitudinal bank elevation everywhere along the river reaches in case of high flow discharge, which indicates the existing cross sections are not capable to hold such high flows and must be modified by increasing the width or depth of the channel.

3.1.4. Lighvan Chai River, Iran (Khaleghi, Mahmoodi and Karimzadeh, 2015)

In this study, flood-prone area with different return periods was determined in 16 km length of the Lighvan Chai River using GIS and HEC-RAS model and land use changes of 10 years (2000-2010) was extracted using satellite images. The 1:1000 topographic maps of 16 km of Lighvan Chai River has been used for study area after georeferencing it in ArcGIS software and then converted to UTM and local height above mean sea level. This map is digitizing using Arc GIS and Auto CAD software and further used to extract geometric data of river cross sections for study reach. Maximum flood for an area with different return periods has been calculated using Fuller formula and entered in HEC RAS to run steady flow. Normal depth was considered as boundary conditions and mixed flow regime was considered for simulation.HEC GeoRAS has been used to extract water surface profile data from HEC RAS and incorporate it into a floodplain map in GIS. Flood zone maps were prepared by delineating water surface data and DEM created for the basin. Mapping for flood zone map with land use map in Arc GIS has been done to calculate the flooded area for different return period for different land use. Findings of this study show that with the use of the satellite images and flood simulations it is possible to show flood zoning maps, return periods and the effects of the flood on land use of flood plains.

3.1.5. Kalu River, Sri Lanka (Nandalal, 2009)

Kalu river is the 3rd longest river in Sri Lanka originating from the most upstream major town, Ratnapura and causing floods along its route to the most downstream town, Kalutara. In this research, the model has been developed to determine water levels along the entire patch of 79 km from Ratnapura to Kalutara using HEC-RAS hydrodynamic model. The model was calibrated and verified for both steady and unsteady flow conditions. The HEC RAS model uses the channel geometry data in terms of 86 field surveyed cross sections and elevations obtained from the 1:10,000 topo-sheets. The simulated model provides water levels and inundation on both banks along the river for different discharges. The model also provides three-dimensional view of the inundation area along the river which is a very useful result. Using results generated through the model, a set of tables were prepared to predict flood levels at downstream locations based on observed water levels at upstream locations which could be used by people with less technical knowledge.

3.2. INDIAN SCENARIO

3.2.1. Yamuna River, Uttar Pradesh (Kumar *et al.*, 2017)

In this study, researchers modelled the water surface elevation of Yamuna River at Allahabad district in Uttar Pradesh, India by using latest flood monitoring tool, GFMS, which provides near real-time discharge value of various streams across the world. Along the river reach considered for the study, three stations were selected for calibration of the model. In this study, HEC-RAS model was developed to determine water surface elevation of the year 1978 and 2001-2014. Also, water surface elevation for upcoming 100,500 and 1000 years was estimated by using Gumbel's distribution method. The modelled output data has been compared with actual data and found to be almost similar. The results obtained from HEC RAS modeling indicate that application of this model can play an effective role to predict flood potential and identify the water surface elevation in future for making the plan for any city situated near the river. This study suggests that a larger area nearby study reach falls in the highly risky zone and plan for safety management is needed.

3.2.2. Wainganga River, Maharashtra (Ingale and Shetkar, 2017)

The floods of Wainganga River affects the normal life in the Bhandara city located in north eastern part of Maharashtra, India very frequently. In the present study, the HEC-RAS 5.0.3 model is developed for 14 km long patch of Wainganga river for analysis of the flood. Total 19 cross sections along the river near the city are considered for the steady and unsteady flow simulations. The water surface elevation is computed for various flood discharges and return periods of 25 years, 50 years and 100 years. The flow hydrograph which is generated from previously available data is used for unsteady flow simulation. Critical cross sections from the simulated model have been identified for both steady and unsteady analysis and suggested to take protective measures to reduce losses.

3.2.3. Purna River, Gujarat (Azazkhan I.Pathan, Prof.B.M Vadher, 2017)

In this study, 1 dimensional model of Purna river in Navsari district of Gujarat has been developed using ArcGIS, HEC-RAS and HEC-GeoRAS software. Various layers in terms of stream centreline, bank lines, flow path and cross section cut lines are created through HEC GeoRAS and Arc GIS using existing digital elevation model and complimentary data sets. All geometric data created in GIS has been exported in HEC RAS for steady flow simulation. After applying appropriate Manning's n, boundary condition and peak discharge, the water surface elevation is directly obtained by steady flow simulation. This research demonstrates the utility of Arc GIS and HEC RAS and concluded that combined use of both Arc GIS and HEC RAS is effective for quantification of flooding at different cross-section and predict the chances of flooding at the particular cross section. Also, in future floodplain mapping of the river can be done to develop a flood risk map under varying scenarios.

3.2.4. Jhelum River, Jammu & Kashmir (Ahmad et al., 2016)

This study describes the application of HEC RAS model to study flood in Jhelum river in the valley of Kashmir. Recorded high flood data were used as input into HEC RAS to calculate expected flood levels. The hydrological modeling for the Jhelum river was performed using HEC RAS 4.1.0 for 1 dimensional steady state for computation of water surface profile of river. The main aim of this study was to check the fitness of HEC RAS model in simulating water surface profiles of river Jhelum. The consequential output generated by the model shows an overflow at maximum locations of the river under study for return periods of 50 and 100 years. This rationale is to give a hand to policy makers, planners and insurers, to develop a robust strategy for the development of flood mitigation measures and plans to minimize the losses associated with the disaster in the study area. The author concluded that HEC RAS models can be effectively utilized to improve and simplify the forecasts of areas likely to be inundated under a given flood.

3.2.5. Tapi River, Gujarat (Timbadiya, Patel and Porey, 2011)

In this study, one dimensional unsteady hydrodynamic model has been developed for the lower Tapi river using HEC RAS software. The reach of about 103.5 km of lower Tapi River from Ukai dam to Surat city has been considered for model simulation. Field surveyed geometric data retrieved from contour map has been used to create river geometry and flood flows of years 1998, 2003 and 2006 have been used for model simulation with Manning's n as appropriate boundary conditions at upstream and downstream. Simulated stage and flood hydrographs are compared with observed values at different stations on the river and found in close agreement with actual values of flood flows. Authors concluded that in all trends simulation flood values were found to be similar with observed floods it has further observed that one-dimensional model is not capable to predict the flood stages well in plain areas due to its inability to simulate two-dimensional flow situation.

REFERENCES

[1] Ahmad, H. F. et al. (2016) 'One Dimensional Steady Flow Analysis Using HECRAS – A case of River Jhelum, Jammu and Kashmir', European Scientific Journal, ESJ, 12(32), p. 340. doi: 10.19044/esj.2016.v12n32p340.

[2] Awad, A. M. (2015) 'Mathematical Modeling of Unsteady Flow for AL- Kahlaa Regulator River', 05(02), pp. 9–20.

[3] Azazkhan I.Pathan, Prof.B.M Vadher, D. P. . A. (2017) 'River Flood Modeling Using GIS, HEC-GeoRAS And HEC-', 2(3), pp. 216–222.

[4] Azouagh, A. et al. (2018) 'Integration of GIS and HEC-RAS in Floods Modeling of Martil River (Northern Morocco)', (April). doi: 10.19044/esj.2018.v14n12p130.

[5] Bellos, V. (2012) 'Ways for flood hazard mapping in urbanised environments : A short literature review', pp. 25–31.

[6] Ghani, A. A., Kashfy, M. and Kashfy Zainalfikry, M. (2018) HEC-RAS One-Dimensional Hydrodynamic Modelling for Recent Major Flood Events in Pahang River Innovative designs of sustainable agro-hydro-health systems View project Scour in Hydraulic Structures View project HEC-RAS One-Dimensional Hydrodynamic Modelling. Available at: https://www.researchgate.net/publication/327019531.

[7] HEC-RAS River Analysis System Hydraulic Reference Manual (2016). Available at: www.hec.usace.army.mil (Accessed: 12 January 2019).

[8] Ingale, H. and Shetkar, R. V. (2017) 'Flood analysis of Wainganga River by using HEC-RAS model', International Journal of Scientific Engineering and Technology, 6(7), p. 211. doi: 10.5958/2277-1581.2017.00022.5.

[9] Khaleghi, S., Mahmoodi, M. and Karimzadeh, S. (2015) 'Integrated application of HEC-RAS and GIS and RS for flood risk assessment in Lighvan Chai River', International Journal of Engineering Science Invention, 4(4), pp. 38–45.

[10] Kumar, N. et al. (2017) 'Applicability of HEC-RAS & GFMS tool for 1D water surface elevation/flood modeling of the river: a Case Study of River Yamuna at Allahabad (Sangam), India', Modeling Earth Systems and Environment. doi: 10.1007/s40808-017-0390-0.

[11] Nandalal, K. D. W. (2009) 'Use of a hydrodynamic model to forecast floods of Kalu River in Sri Lanka', Journal of Flood Risk Management, 2(3), pp. 151–158. doi: 10.1111/j.1753-318X.2009.01032.x.

[12] Singh, V. P. (2018) 'Hydrologic modeling: progress and future directions', Geoscience Letters. Springer International Publishing, 5(1). doi: 10.1186/s40562-018-0113-z.

[13] Timbadiya, P. V., Patel, P. L. and Porey, P. D. (2011) 'Hec-ras based hydrodynamic model in prediction of stages of lower tapi river', ISH Journal of Hydraulic Engineering, 17(2), pp. 110–117. doi: 10.1080/09715010.2011.10515050.