Reliability of HEC-RAS in Steady Flow Modeling: A Case Study on a Representative River Reach

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***Abstract*—This study uses the River Analysis System (HEC-RAS) from the Hydrologic Engineering Center to assess how well steady flow analysis simulates river hydraulics. Through the development of geometric configuration, downstream and upstream cross sections, and the interpolation of intermediate sections for increased accuracy, a realistic river reach was modeled. Water surface profiles, velocity distributions, and stage-discharge relationships were among the hydraulic metrics that were produced from steady flow simulations conducted for a range of discharge values. The reliability of the model was then evaluated by comparing its outputs with field data that was observed. Good agreement between the simulated and actual values was shown in the results, indicating that HEC-RAS can accurately forecast the conditions of constant flow in natural rivers. Results demonstrate HEC-RAS's potential as a useful and effective tool for river management, flood risk assessment, and hydraulic analysis applications**

***Index Terms*—HEC-RAS, steady flow analysis, hydraulic modeling, water surface profile, river engineering**

I. INTRODUCTION

The design of infrastructure, flood risk assessment, and water resource management all heavily rely on river hydraulics. Engineers can evaluate floodplain interactions, hydraulic structures, and channel behavior by accurately predicting water surface profiles under steady flow circumstances. Since it can support both steady and unsteady flow calculations, HEC-RAS is well known for being a flexible tool for these kinds of investigations. Because stable flow analysis is straightforward, requires little data, and has a wide range of applications in engineering practice, it is still crucial even when unsteady flow simulations offer dynamic solutions.

The River Analysis System (HEC-RAS) was developed by the US Army Corps of Engineers at the Hydraulic Engineering Center in 1995 and is publicly available. It can perform one- and two-dimensional hydraulic computations for a full network of purely natural and artificial channels (Lima et al., 2020). The HEC-RAS model (Sholichin et al., 2019) is one of the most popular flood modeling programs in hydrodynamic simulation, designed to perform simulations of 1D steady flow and 2D unsteady flow for a river flow study, sediment transport, and water quality modeling (Traore et al., 2015). It is based on geometric data representation and uses geometric and hydraulic computation routines for a network of natural and constructed river channels (Agrawal and Regulwar, 2016). Water surface profiles can be calculated by HEC-RAS for subcritical, supercritical, mixed, and continuous flows, as well as for flows with a gradual volume change (Uday Kumar and Jayakumar, 2020)

Numerous studies have highlighted the applicability of HEC-RAS for river system analysis. Brunner (2016) emphasized the role of steady flow computations in hydraulic design and floodplain mapping. Patel and Sinha (2020) demonstrated the use of HEC-RAS in bridge hydraulics and found that steady flow simulations provided adequate approximations for peak flood assessments. Similarly, Singh et al. (2022) applied steady flow analysis to evaluate channel modifications, concluding that HEC-RAS effectively captured variations in water surface elevations under varying flow conditions. Despite the increasing preference for unsteady simulations, steady flow models remain valuable due to their efficiency and practicality, particularly in data-scarce regions.

Using the peak flood data as inputs into the HEC RAS model, the anticipated flood levels were determined. The model's findings show an overflow at the highest points of the river under consideration for more than 50 years and after the return period. This objective is to assist planners, insurers, and decision-makers in developing a sound plan for flood mitigation and plans to lower disaster-related losses in the area under study. Limitations include: Only 1D modeling; No support for users other than the US Army Corps of Engineers; Model code is not publicly available; Only 30-degree skews of hydraulic structures may be modeled; and the model is currently unable to account for steep slopes greater than 10%. Ahmad et al. (2016) used HEC-RAS and one-dimensional steady flow analysis to study the Jhelum River in Jammu and Kashmir.

HEC-RAS offers several boundary conditions for steady flow computations. For each cross section, HEC-RAS required a variety of input parameters to define the shape, altitude, and relative placement of the fallows along the river stream.

Number of river stations (cross-sections); Lower levels at each terrain point the positions of the left and right bank stations The reach lengths of neighboring cross-sections between the left floodway, stream center line, and right floodway The geometric characteristics of any hydraulic structure, such as bridges, culverts, weirs, etc.; Manning's roughness coefficients; channel contraction and expansion coefficients; and the maximum stream discharge.

The purpose of this research is to assess the effectiveness of steady flow analysis for a representative river reach using HEC-RAS. (i) creating a HEC-RAS model for the chosen river geometry; (ii) simulating steady flow for several discharges; and (iii) evaluating model correctness by contrasting calculated outcomes with observed field data

II. METHODOLOGY

Methodology was identified for complete analysis after many trials and errors and many literatures review, which is mentioned as below in figure 1. Different parameters are required in modeling in HEC-RAS as per objective of study.

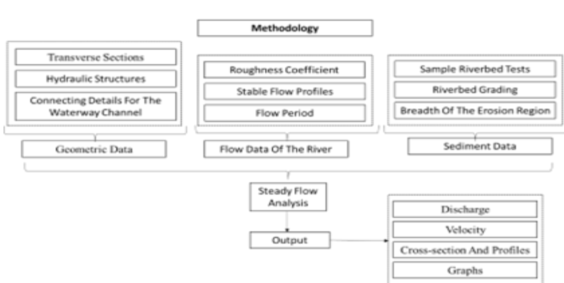


Figure 1- Methodology followed in Modeling

III. HEC-RAS MODEL SETUP

The model was developed in HEC-RAS 6.5. Geometric data including river centerline, cross-sections, bank stations, and structures were prepared using geometric data manually to compare the results with at actual. Boundary conditions were defined using normal depth at the downstream end and known discharge hydrographs at the upstream end. Multiple steady discharges corresponding to low, medium, and high flow conditions were simulated.

The river has been deteriorated by several human activity nearby, turning it into a sewer. In order to assess the river water's fitness for drinking and other uses, it is crucial to look into its quantity and quality. The HEC-RAS model uses a direct numerical method to solve the one-dimensional advection-dispersion equation in order to simulate the river's hydrodynamics and water quality.

The simulated data and the real data agreed well after being verified using samples taken at various points along the river. According to the simulation results, further technological solutions are recommended to enhance the river's water quality, particularly for contaminated sections and drains that contribute to river contamination. These include decentralized sewage and wastewater treatment, in-stream treatment, etc.

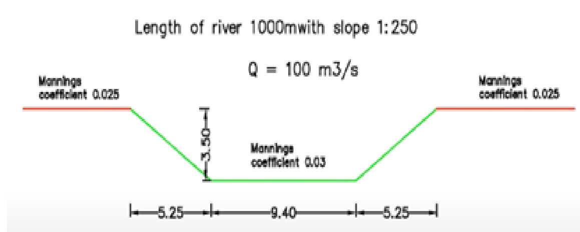


Figure 2: River Channel Cross-Section for Hydraulic Calculation

Figure 2 presents the geometry and hydraulic parameters of a compound open channel consisting of a deep, central main channel and adjoining shallower floodplains. Each section is characterized by a distinct Manning's roughness coefficient (n), allowing for accurate estimation of hydraulic performance. The discharge for the reach is prescribed as (Q=100 m3/s), over a river segment with a length of 1000 m and a longitudinal bed slope of 1:250.

For hydraulic computations, the divided channel method is typically employed to account for the heterogeneous flow resistance between the main channel and floodplains. In this case, the main channel, with (n = 0.030), exhibits higher roughness relative to the adjoining floodplains ((n = 0.025)). This differential in roughness coefficients is a critical factor in evaluating the overall conveyance capacity of the river reach, as it governs the distribution of velocity and discharge between the channel components.

Steps-

I. Open the HEC-RAS software, there will be a "file" tab in the top of the software in that, there will be an option of "New project"
II. Create a file of your new project as 'River'. After creating new project. Figure 3, is observed on screen.
III. Go to the "edit" and select "geometric data", then make a river reach by using option in the geometric data tab as shown in figure 4.
IV. Navigate to the Cross Section Data window and input the required parameters for the downstream side of the river, including station positions, elevations, reach lengths, and Manning's roughness values. After applying the data, the cross-sectional geometry of the downstream side is obtained (Figure 5).
V. From the Edit menu, select the Copy Cross Section option to generate the upstream cross section. Modify the lengths and elevations to reflect the bed slope variations, then apply the updated data to obtain the cross-sectional geometry of the upstream side (Figure 6).
VI. Open the Tools menu and select XS Interpolation. Choose the Constant Distance option, enter the desired spacing value, and perform the interpolation to generate intermediate cross sections along the river reach (Figure 7).
VII. After this we'll get the Geometric data as shown in the figure 8 below,
VIII. Now go to "Steady Flow Data" put the design discharge as specified (Figure 9).
IX. Select the boundary conditions as "critical depth" for downstream side of river (Figure 10).
X. After this perform a steady flow analysis simulation as below in figure 11.

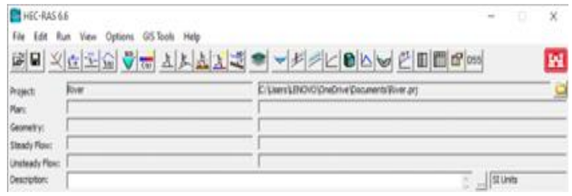


Figure 3: new project screen

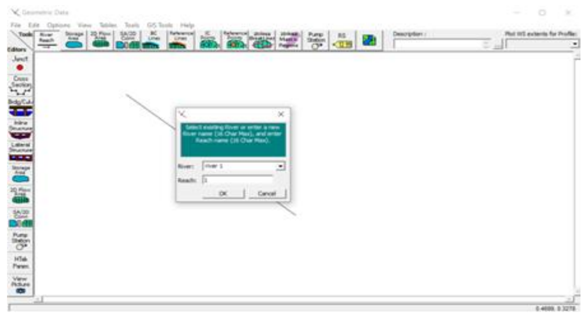


Figure 4: geometric data editor

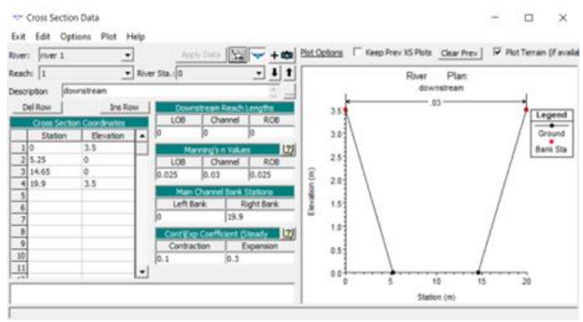


Figure 5: cross section data (downstream)

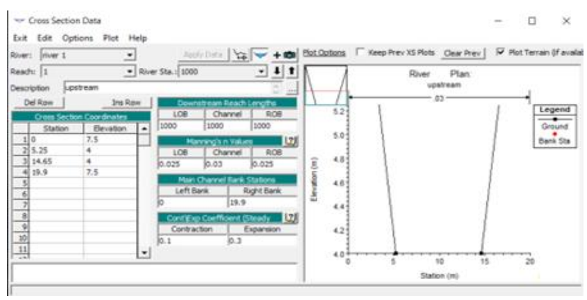


Figure 6: cross section data (upstream)

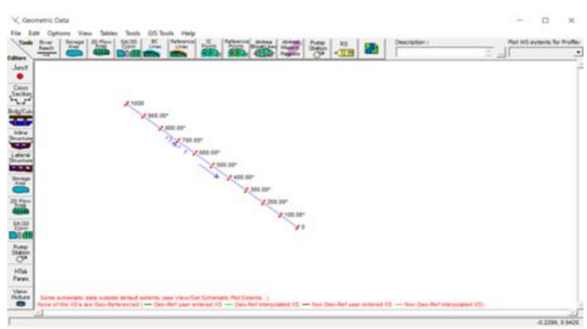


Figure 8: Geometric Data after interpolation

Calibration and Validation

Calibration was performed by adjusting Manning's n-values within acceptable limits to minimize discrepancies between observed and simulated water surface elevations. Validation was carried out using independent discharge events recorded during the 2023 monsoon season.

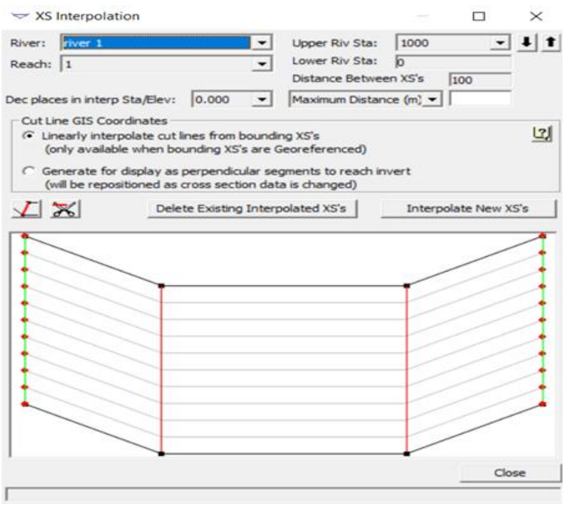


Figure 7: XS interpolation

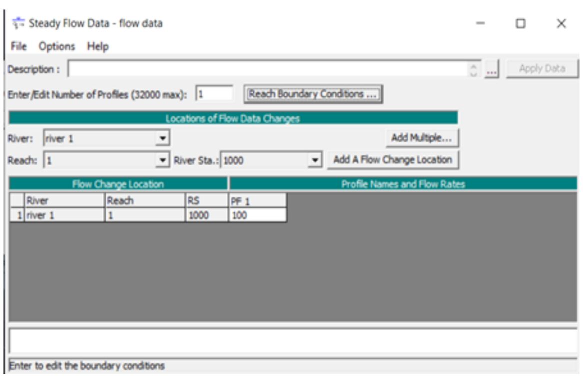


Figure 9: Modelling with steady flow analysis

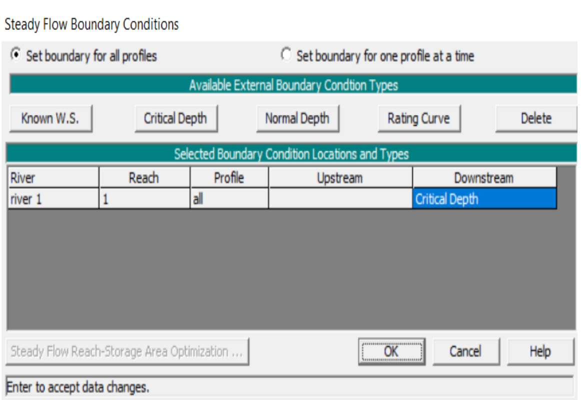


Figure 10: Modelling boundary flow conditions

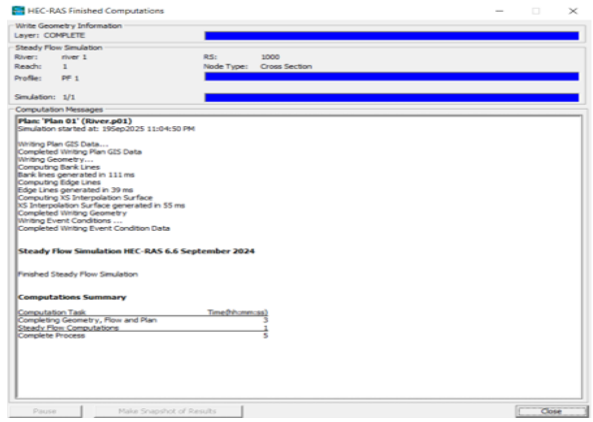


Figure 11: Modelling finalized computation statistics

IV. RESULTS AND DISCUSSION

The model geometry was established by defining the river reach within the Geometric Data Editor (Figure 12). Cross-sectional information for the downstream boundary was then incorporated through the Cross Section Data window. This included the specification of station positions, elevation points, reach lengths, and Manning's roughness coefficients. These inputs enabled the generation of the geometric profile of the downstream section (Figure 12).

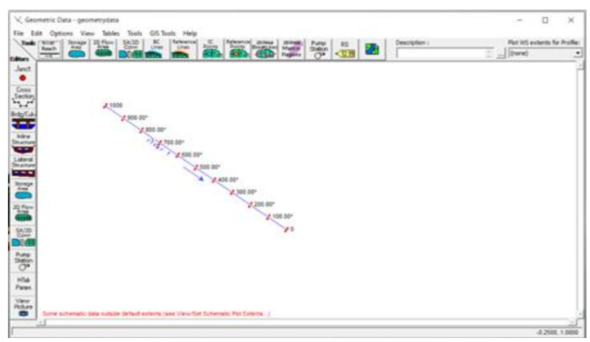


Figure 12: Modelling Geometric Data

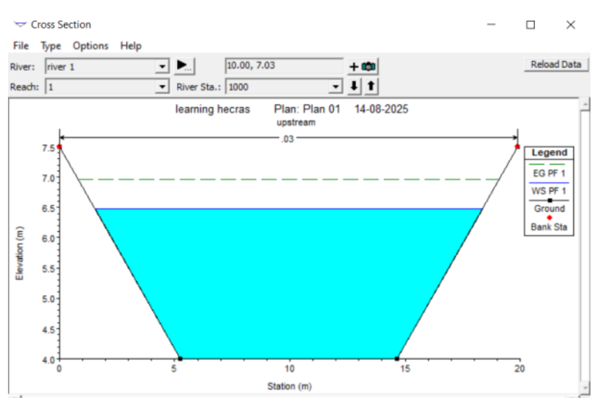


Figure 12: Modelling cross section

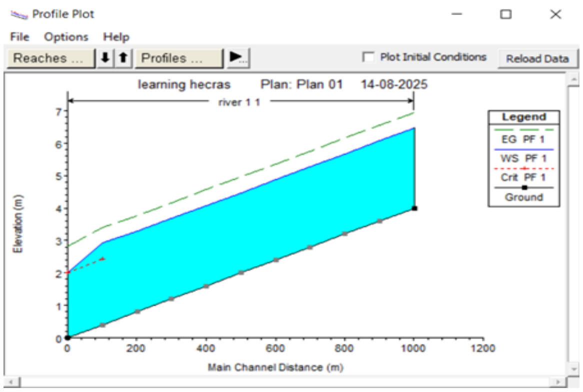


Figure 13: Modelling profiles results

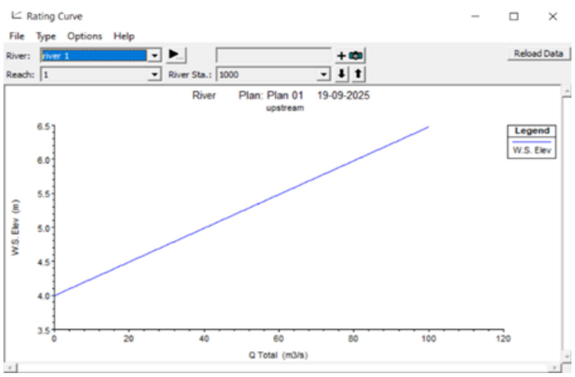


Figure 15: Modelling Rating Curve results

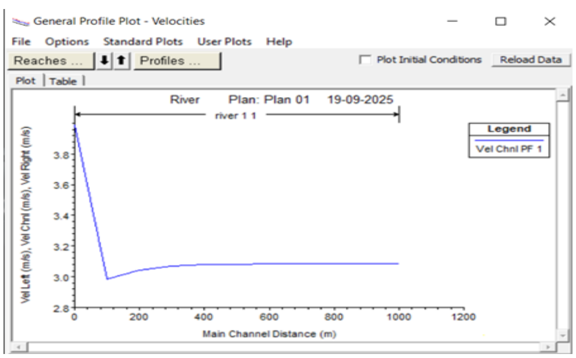
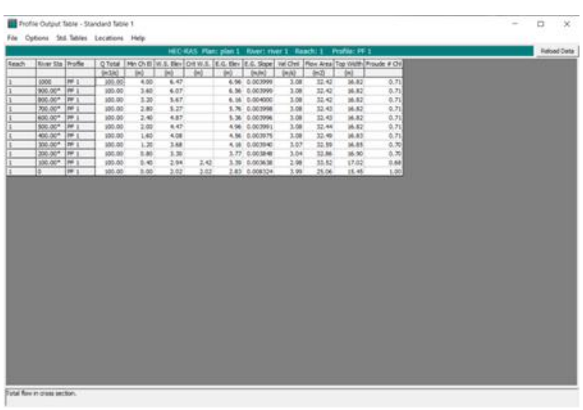


Figure 14: Modelling Profile Plot- Velocities



Profile Output Table - Standard Table 1

HEC-RAS Plan: plan 1 River: river 1 Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	1000	PF 1	100.00	4.00	6.47		6.96	0.003999	3.08	32.42	16.82	0.71
1	900.00*	PF 1	100.00	3.60	6.07		6.56	0.003999	3.08	32.42	16.82	0.71
1	800.00*	PF 1	100.00	3.20	5.67		6.16	0.004000	3.08	32.42	16.82	0.71
1	700.00*	PF 1	100.00	2.80	5.27		5.76	0.003998	3.08	32.43	16.82	0.71
1	600.00*	PF 1	100.00	2.40	4.87		5.36	0.003996	3.08	32.43	16.82	0.71
1	500.00*	PF 1	100.00	2.00	4.47		4.96	0.003991	3.08	32.44	16.82	0.71
1	400.00*	PF 1	100.00	1.60	4.08		4.56	0.003975	3.08	32.49	16.83	0.71
1	300.00*	PF 1	100.00	1.20	3.68		4.16	0.003940	3.07	32.59	16.85	0.70
1	200.00*	PF 1	100.00	0.80	3.30		3.77	0.003848	3.04	32.86	16.90	0.70
1	100.00*	PF 1	100.00	0.40	2.94	2.42	3.39	0.003638	2.98	33.52	17.02	0.68
1	0	PF 1	100.00	0.00	2.02	2.02	2.83	0.008124	3.99	25.06	15.45	1.00

Total flow in cross section.

Figure 16: Modelling tabular format results

Figure 13, illustrate the variation of flow depth along the river reach under the specified discharge conditions. These profiles enable the visualization of hydraulic gradients, backwater effects, and energy losses across cross sections. Velocity distribution along the modeled reach was obtained through profile plots are displayed in figure 14. These plots highlight zones of higher and lower velocities, which are critical for assessing flow efficiency, sediment transport potential, and possible erosion-prone areas.

The model generated rating curves that describe the stage–discharge relationship at selected cross sections are shown in figure 15. These curves are essential for flood forecasting, hydraulic structure design, and operational decision-making in river engineering. Figure 16 shows the table for Standard output provided detailed numerical results, including flow depths, velocities, energy grade lines, and hydraulic head losses for each cross section. These tabulated results facilitate a comprehensive comparison between different cross sections and flow conditions. The model exhibited moderate sensitivity to Manning's roughness coefficients. A ±10% variation in n-values resulted in water surface elevation changes up to 0.15 m. This highlights the importance of accurate field estimation of channel roughness.

V CONCLUSION

The usefulness of HEC-RAS for steady flow analysis in a sample river reach was shown in this study. In order to create a hydraulic model, comprehensive geometric data was incorporated, constant flow conditions for many discharges were simulated, and the accuracy of the findings was compared to field observations. The investigation verified that hydraulic parameters, such as water surface profiles, velocity distributions, and stage–discharge relationships, can be reliably predicted by HEC-RAS. Results show that river engineering studies can benefit greatly from the use of steady flow simulations in HEC-RAS, especially when it comes to comprehending flow behavior, locating crucial hydraulic zones, and assisting with design and management choices. Even though the model worked well in the conditions that were tested, more research is advised to expand the technique to unsteady flow simulations, include sediment transport, and examine extreme hydrological events for all-encompassing river system management.

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