ABSTRACT

This study delves into the complex dynamics of braided rivers in low-land areas, focusing on the Jamuna River in Bangladesh. It aims to assess the effectiveness of newly constructed groynes and introduce innovative countermeasures for riverbank protection. Utilizing both 2D and advanced 3D numerical modeling, the research evaluates morphological changes, sediment transport, and erosion patterns associated with these structures. The initial phase involves a comprehensive evaluation of existing groyne-like structures near Sirajganj, employing a 2D model to observe sandbar movements and bed topography alterations. Subsequent efforts transition to a 3D modeling approach which provides detailed spatial and temporal insights into flow dynamics and sediment transport. The research aims to address the challenges posed by the dynamic nature of braided rivers like the Jamuna.

Firstly, the study begins with a thorough review of the historical context and previous riverbank protection measures implemented along the Jamuna River. It places a particular emphasis on the design, implementation, and performance of these measures over time. This detailed review provides a solid foundation for introducing novel countermeasures aimed at significantly enhancing riverbank protection. The research employs a systematic and methodical approach to model the river's behavior, which includes comprehensive data collection, meticulous calibration, and rigorous validation processes to ensure the level of accuracy and reliability in the findings and proposed solutions.

Second, shifting focus to the present, we evaluate four cross-bar structures near Sirajganj town using a 65-year record of peak flood data. 2D simulations with iRIC Nays2DH software are conducted for six critical flood scenarios for 50 km river reach of the Jamuna River as model domain. The simulations reveal the success of cross-bars 1, 2, and 4 under both normal and extreme flood conditions. However, a critical vulnerability is identified at the toe of cross-bar 3 for high-magnitude floods. Furthermore, a new erosion zone is discovered upstream of cross-bar 1, potentially caused by the structures themselves. This highlights the potential for unintended consequences arising from riverbank protection efforts. Therefore, the study emphasizes the need for a holistic approach to river management. This includes not only the effectiveness of structures but also anticipating and mitigating potential drawbacks. Ongoing monitoring and adaptive management strategies are crucial for the long-term success of these endeavors. By combining historical analysis with advanced modeling techniques, this study paves the way for robust and sustainable Jamuna Riverbank protection strategies.

Third, the river analysis procedure ensured accurate impact assessment, while this research proposes new controls using structures placed along the designated area. Tests are conducted to assess the effectiveness of these measures under various flood conditions, identifying a highly vulnerable erosion zone. The test scenarios included a baseline without structures, two sets of structures placed in separate zones, and a combined approach. Analysis of the four test cases, each encompassing three flood conditions, revealed that implementing two specifically shaped, perpendicular structures in series within the erosion-prone area effectively diverted angled flow. This approach proved optimal, reducing erosion risk by redirecting flow and shaping sediment deposits along the riverbank. This study improves river protection, highlighting the importance of these structures and promoting a comprehensive understanding of flow dynamics for future river management and effective controls.

Finally, this study explores the advantages of three-dimensional (3D) numerical modeling in analyzing riverbank protection strategies, particularly focusing on groynes in braided rivers. The limitations of traditional field studies and two-dimensional (2D) models are addressed, highlighting the need for more comprehensive approaches in the case of the Jamuna River. By employing the iRIC NaysCUBE software, a 3D numerical model was developed to simulate the effects of groynes with various head shapes (T-shaped, L-shaped, and I-shaped) on flow patterns, erosion, and deposition. The results demonstrate that 3D modeling offers a superior understanding of river dynamics compared to 2D models. The analysis reveals distinct flow patterns and erosion/deposition zones associated with each groyne head shape. Notably, the T-shaped groyne exhibited the most favorable performance, minimizing erosion at the head while facilitating early detection of potential damage. This part emphasizes the importance of considering local factors like hydrology, topography, and sediment characteristics when designing groynes. 3D models are instrumental in incorporating these aspects and optimizing groyne design for enhanced stability and effectiveness.

Although this study focused on the Jamuna River, it also addresses generalized braided rivers in low-land areas. A key finding is that constructing multiple hydraulic structures to train and narrow a braided river can create upstream vulnerable areas prone to bank erosion. This erosion can propagate further upstream over time. Effective management requires identifying precise locations for countermeasures to protect the vulnerable banks and prevent further erosion. Additionally, the shape and orientation of groyne heads and riverbanks are critical factors for stability and flow diversion.