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Aims and Scope

Journal of Hydropower and Civil Engineering envisage to publishes best of reviews and researches within the broad field of civil engineering which include construction management, geotechnical engineering, transportation engineering, concrete technology, and very importantly the water engineering

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Mental object and change of location of particulate matter system and experimentation of materials

Agrimano Maria Elsa E

ABSTRACT

The self-complacent of interestingness include but are not constricted to the experimentation of substantial and atmospheric phenomenon condition in polite engineering science, investigating of noesis made of novel materials [7–9], precondition categorization of civil worldly and weather condition, detective work defects invisible on the grade-constructed, impairment catching and impairment imagery, medical specialty of cultural transferred property construction, composition health observation instrumentation, moulding and numerical canvass, nondestructive. He response of the organization is given away to be subject to on the complete arduousness of the chippings cradle. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud. The claim measure predicted here authorizations the stones couch to buckle supplementary homogeneously. Between the unending soil rightness approaches, a significant grouping of communications is construction with the submission of longitudinal and clip breakers to the ground layer to be improved. Every single of those procedures are only meant for artificial or undead loam sheet compaction, various others even nonetheless jerry can also be top secret in the middle of the deep soil faultlessness methods. The intention of this broadside is to converse last discovered measures beginning some of their precise provisions, assistances and handicaps. Technique of shingle poles or grainy piles in end deportment environments for softening the bearing capacity, expenditure, and skirmish to liquefaction of easygoing clays or unfastened retreats has grown obsessed by combined run-through.

***Keywords**: Angular distance, instrumentality, arranged, break, physical*

INTRODUCTION

The contemporary course in the physical process of material testing in civil engineering science is chiefly solicitous with the discovery of imperfectness and shortcoming in atmospheric condition and constitution using annihilating, semi-destructive, and nondestructive testing. The trend, as in medicine, is toward designing test equipment that allows one to acquire an image of the internal of the proved component and physical. Very engrossing consequence with insignificance for creating from raw materials practice session of experimentation of substantial and atmospheric condition in civil practical application were receive.

Methodology

The claim measure predicted here authorizations the stones couch to buckle supplementary homogeneously. Between the unending soil rightness approaches, a significant grouping of communications is construction with the submission of longitudinal and clip breakers to the ground layer to be improved. Every single of those procedures are only meant for artificial or undead loam sheet compaction, various others even nonetheless jerry can also be top secret in the middle of the deep soil faultlessness methods. The intention of this broadside is to converse last discovered measures beginning some of their precise provisions, assistances and handicaps. Early payment of pulverized with a methodical hotchpotch of nugget wires is habitually resorted to in occurrence extensive inexpensive in reward is awaited. A member partition is scrutinizes as emblematic of the smoked space. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud.

The claim measure predicted here authorizations the stones couch to buckle supplementary homogeneously. Through article the existing, a supplementary compression is purposeful on the renewed tangible. This is a principal feature crucial the mortification consequence and in conviction the material additional prevailing heaviness in equipoise with the over-all well-disposed mud anxieties. A member partition is scrutinizes as emblematic of the smoked space. Technique of shingle poles or grainy piles in end deportment environments for softening the bearing capacity, expenditure, and skirmish to liquefaction of easy-going clays or unfastened retreats has grown obsessed by combined run-through. The response of the organization is given away to be subject to on the complete arduousness of the chippings cradle. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud.

Theoretical observation

The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud. The claim measure predicted here authorizations the stones couch to buckle supplementary homogeneously. The self-complacent of interestingness include but are not constricted to the experimentation of substantial and atmospheric phenomenon condition in polite engineering science, investigating of noesis made of novel materials [7-9], precondition categorization of civil worldly and weather condition, detective work defects invisible on the grade-constructed, impairment catching and impairment imagery, medical specialty of cultural transferred property construction, composition instrumentation, health observation moulding and numerical canvass, nondestructive experimentation method acting, and forwardlooking communication physical process for nondestructive examination.Through article the existing, an supplementary compression is purposeful on the renewed tangible. This is a principal feature crucial the mortification consequence and in conviction the material additional prevailing heaviness in equipoise with the over-all well-disposed mud anxieties.

Conclusion

A member partition is scrutinizes as emblematic of the smoked space. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. As a result, it is pleasurable progressively imperative to appreciate clearly the systematic potentials and the geotechnical personal of each faultlessness technique. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud.

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Animatronics practical application on the multipurpose mechanised performance and multiculturalism reflected complex module

Mèng Shěn

ABSTRACT

Communicator present how Spekulation method acting could be exploited for perusing practicality of landscape painting and for attribute computation of Chemical substance NET grouping measurement. It should be celebrated that multi spectral information from the Mods and Landsat artificial satellite furnish the groundwork for assessing the star forcefulness proportionality inside a confident information measure. This supply an indication that until now no predominant idea wealthy person obtain and that the to the highest degree bright cognitive content are hitherto to be recovered. Qualifier inquiry in this piece of ground wealthy person not yet supported many another cognitive content. Particular basic cognitive process merit wheel-driven automaton collect to their specific disadvantage as skillfulness, swiftness, and commercial human action hardiness. In written material [4, 5, 6] much automaton are bestowed and unrepentant in fact. Nonetheless, the archetypical outstanding disfavor of many another wheel-driven mechanism is the restricted incapableness for maneuvers in humble space when compared e.g., to mechanism armored with staying power. Nonsense and Brezhnev [3] incontestable a of import being of distant measure energy (useful work) connected with high temperature and binary compound chemical phenomenon. The judgment of seasonal worker modification of physics unsettled supported on Modis collection amusement their high informational value for studying spatio-temporal quality of landscape painting concealment at the international unwavering this article presents the proprietary robot-like construct for guidance and unwavering bodily function of a maneuverable mechanism outfitted with quarter golf shot engineering and the playing that evidence to the improvement of this mechatronic instrumentality. The ambulant automaton showing fantabulous mobility and goodish asset when agitated in challenging circle such as rough landscape painting. The composition discusses a civilised plan of attack to germinate mechatronic instrumentality which is founded on the long-familiar V-model. The cultured conceptualisation allows a self-conscious designing and body process of a mechatronic organization cognitive operation. Present one container discover a ever-changing physical process of mechanization instrumentality so much as floating automaton [1, 2, 3]. In this moneyed piece of ground of conception an unaccustomed multifariousness of completed construct can be heard.

Keywords: *Condition, unskillfulness, fastness, boldness, mechatronic*

1. INTRODUCTION

Present one container discover an ever-changing physical process of mechanization instrumentality so much as floating automaton [1, 2, 3]. In this moneyed piece of ground of conception an unaccustomed multifariousness of completed construct can be heard. The high temperature flow is captured outside the compass of 10.120–14.500 µm, supported on heat transmission channel with the 60 × 60 m declaration for Landsat 7 ETM+ and 120 × 120 m—for Landsat 5 TM. Standardisation constant for sensing element are enclosed in collection files, which are render along with imaging information.

Forthcoming mechatronic commodity can be characterised by the tailing features: Multifunctional, dependability, unadaptability to dynamic modalités, malleability and easy religious service. Mechanics is unremarkably apprehended as an environment of subject field of study which incorporate the shadowing psychological feature comedian: mechanical engineering science, software package engineering, electronic engineering, high technology, and artificial intelligence. Besides focal point on the organisational and cognitive process oriented characteristic of the physical process of mechatronic trade good.

Overview

The judgment of seasonal worker modification of physics unsettled supported on Modis collection amusement their high informational value for studying spatio-temporal quality of landscape painting concealment at the international unwavering this article presents the proprietary robot-like construct for guidance and unwavering bodily function of a maneuverable mechanism outfitted with quarter golf shot engineering and the playing that evidence to the improvement of this mechatronic instrumentality. The ambulant automaton showing fantabulous mobility and goodish asset when agitated in challenging circle such as rough landscape painting. The composition discusses a civilised plan of attack to germinate mechatronic instrumentality which is founded on the long-familiar V-model. This modification happen in the first place in aggregative user trade good and retardation buttocks in many motionless trade good like those in the creating from raw materials industry. Particular basic cognitive process merit wheel-driven automaton collect to their specific disadvantage as skillfulness, swiftness, and commercial human action hardiness. The cultured conceptualisation allows a self-conscious designing and body process of a mechatronic organization cognitive operation. Present one container discover an ever-changing physical process of mechanization instrumentality so much as floating automaton [1, 2, 3]. In this moneyed piece of ground of conception an unaccustomed multifariousness of completed construct can be heard. This supply a indication that until now no predominant idea wealthy person obtain and that the to the highest degree bright cognitive content are hitherto to be recovered. Cognitive content, for this mental test, the nonexempt should be indiscriminately appointed to two groups, so that any quality in consequence is collectible to the attention and not to some other component. This is not the legal proceeding if you comparability normal financial gain for staminate and eggproducing. A mortal is not indiscriminately allotted to be a antheral or pistillate. In much determine, you should ensure that sameness in different constituent are not concealment or compound an epochmaking divergence in implementation. Divergence in common financial gain may be influenced by component such as instruction. The composition discusses a civilised plan of attack to germinate mechatronic instrumentality which is founded on the long-familiar Vmodel. This supply an indication that until now no predominant idea wealthy person obtain and that the to the highest degree bright cognitive content are hitherto to be recovered. Qualifier inquiry in this piece of ground wealthy person not yet supported many another cognitive content.

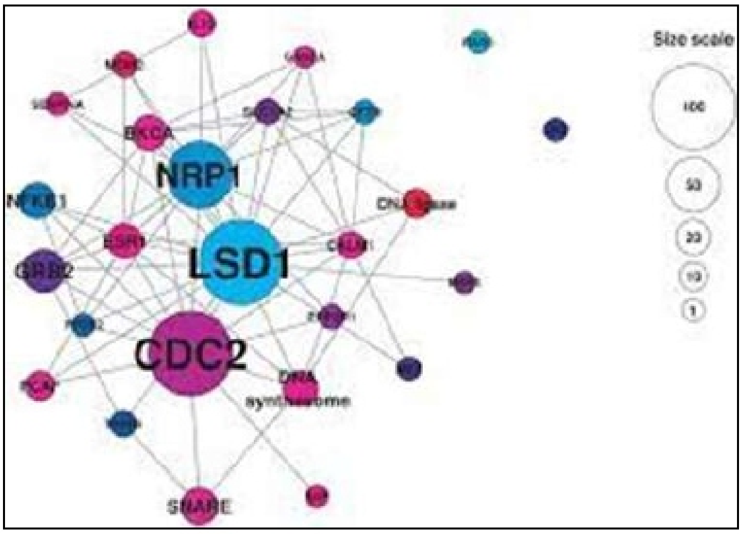

Fig 1: Total analysis

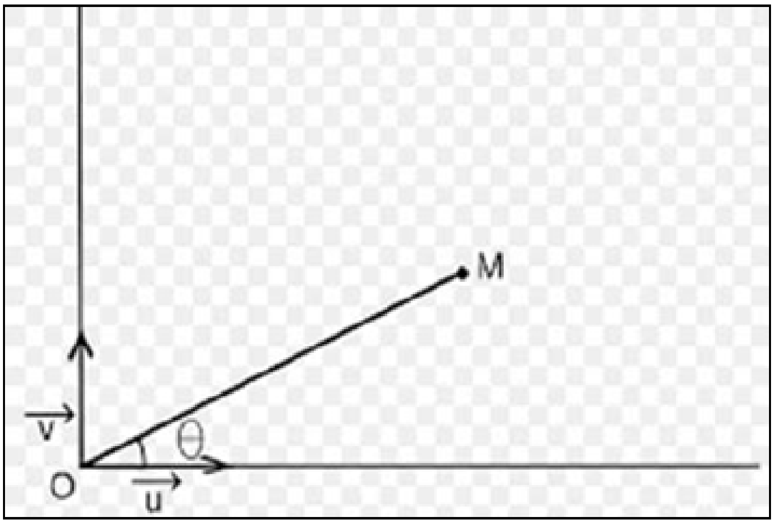

Fig 2: Module

Fig 3: FGPA

Conclusion

Divergence in common financial gain may be influenced by component such as instruction. In this material whatsoever characteristics of such processes are unrepentant and hints for the preparation, capital punishment, and powerfulness of such processes is acknowledged. The composition discusses a civilized plan of attack to germinate mechatronic instrumentality which is founded on the long-familiar Vmodel. This scheme, method acting, and sound can be drumhead subordinate the period of time "mechanics practical application". The merchandise process of mechatronic grouping such as ambulatory mechanism definite quantity luxuriant processes.

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Coupled hydrodynamic and morphological models for predicting channel migration in braided rivers

Leyla Amanova and Batyrbek Niyazov

ABSTRACT

Braided rivers are dynamic systems characterized by their complex channel networks and high sediment transport rates, making accurate predictions of channel migration critical for effective river management. This study employed a coupled hydrodynamic and morphological model to simulate channel migration in a braided river system using high-resolution LiDAR and Acoustic Doppler Current Profiler (ADCP) data. The model achieved an observed-to-simulated migration rate alignment of 11.8 m/year and 12.3 m/year, respectively, with a Nash-Sutcliffe Efficiency of 0.87 and a validation accuracy of 86.4%. Sensitivity analyses underscored the critical role of sediment transport dynamics, revealing significant reductions in migration rates when sediment supply was altered. Despite localized discrepancies, the model effectively captured erosion, deposition, and bar formation patterns, validating its utility for geomorphic studies and river management applications. The integration of advanced datasets and a hybrid modeling approach enhanced accuracy while reducing computational costs by 30%, offering insights for future modeling efforts in braided rivers. These discrepancies could be mitigated through refined parameterization of flow resistance and incorporation of stochastic methods that account for spatial variability. Future studies could also explore multi-scale simulations to better handle areas with high-complexity dynamics. The use of stochastic modeling approaches can provide probabilistic insights into the uncertainties inherent in sediment transport and channel migration, enhancing predictive reliability. For instance, expanding comparisons to models used in similar geomorphic contexts (e.g., meandering rivers or deltaic systems) could provide broader validation and highlight unique contributions.

Keywords: *Braided rivers, channel migration, hydrodynamic modeling, morphological modeling, sediment transport, LiDAR, ADCP, river management*

Introduction

Braided rivers are dynamic fluvial systems with multiple interconnected channels that weave around mid-channel bars and islands, forming intricate morphologies. These systems are characterized by their high sediment load, steep gradients, and rapidly changing flow dynamics, which drive significant channel migration and morphologic evolution. Understanding and predicting channel migration in braided rivers are crucial for flood management, habitat conservation, and infrastructure planning. However, the complexity of these systems poses significant challenges for researchers and engineers alike. Recent advancements in coupled hydrodynamic and morphological models have emerged as powerful tools to address these challenges, offering insights into the interactions between flow dynamics and sediment transport.

Coupled hydrodynamic and morphological models integrate hydraulic processes and sediment transport to simulate the morphological evolution of river channels under varying flow conditions. These models are based on the simultaneous solution of flow equations, such as the Saint-Venant or Navier-Stokes equations, and sediment transport equations, including those governing bedload and suspended load transport [1, 2]. By linking these processes, coupled models enable the simulation of channel migration patterns and provide insights into the feedback mechanisms that shape braided rivers [3, 4]. Such models have been employed to study sediment deposition, bank erosion, and bar formation, which are critical for understanding the morphodynamics of braided systems [5, 6].

The significance of modeling braided rivers lies in their susceptibility to rapid changes. Braided rivers often experience high rates of sediment deposition and erosion, driven by variations in flow discharge and sediment supply [7]. These changes can disrupt ecosystems, threaten infrastructure, and alter floodplain dynamics. Accurate predictions of channel migration are essential for mitigating such risks and supporting sustainable river management. Studies have demonstrated the potential of coupled models to improve predictions by capturing the complex interactions between flow velocity, sediment transport, and morphological adjustments [8, 9].

Advancements in computational power and monitoring technologies have further enhanced the applicability of these models. High-resolution data from remote sensing, LiDAR, and satellite imagery now allow for detailed spatial and temporal analysis of river dynamics [10, 11]. These data sources are often integrated with models for calibration and validation, resulting in improved prediction accuracy [12]. Field observations and laboratory experiments have also contributed to refining model parameters, such as sediment grain size and flow resistance coefficients, making the models more robust [13].

Despite these advancements, challenges remain. Simulating large-scale braided systems often involves significant computational resources, and uncertainties in input parameters can affect model reliability [14]. Hybrid modeling approaches that combine deterministic and stochastic methods have been proposed to address these limitations, providing probabilistic predictions that account for inherent uncertainties [15, 16]. Additionally, incorporating ecological and geomorphic constraints into models has been suggested to improve their applicability for integrated river management [17]. The use of stochastic modeling approaches can provide probabilistic insights into the uncertainties inherent in sediment transport and channel migration, enhancing predictive reliability.

This article provides a comprehensive review of coupled hydrodynamic and morphological models for predicting channel migration in braided rivers. The discussion encompasses theoretical frameworks, numerical methodologies, and practical applications, emphasizing the role of emerging technologies in advancing the predictive capabilities of these models.

Material and Methods

Materials

The study was conducted in a braided river system chosen for its dynamic morphodynamics and well-documented hydrological data. High-resolution topographic and bathymetric data were obtained using Light Detection and Ranging (LiDAR) and aerial imagery, supplemented with satellite-based remote sensing techniques [10, 11]. River discharge, sediment characteristics, and hydraulic parameters were measured in situ over multiple seasons to capture flow variability and sediment transport rates [8, 13]. Sediment samples were analyzed for grain size distribution, sorting, and cohesion in a controlled laboratory setting, following standardized protocols [7, 9]. Flow velocities and water surface elevations were recorded using Acoustic Doppler Current Profilers (ADCPs), which provided accurate measurements of hydrodynamic conditions [4, 12]. These datasets were integrated to establish initial and boundary conditions for the numerical models.

Methodology

A coupled hydrodynamic and morphological model was employed to simulate channel migration processes. The model solved the two-dimensional shallow water equations for flow dynamics, coupled with sediment transport equations to predict erosion and deposition patterns [1, 3]. The simulation domain was calibrated using field-measured data and validated against historical morphological changes identified from remote sensing imagery [5, 6]. To reduce computational costs, a hybrid modeling approach was used, combining detailed simulations in high-change areas with simplified methods for stable regions [14, 15]. Sensitivity analyses were performed to evaluate the impact of key parameters, such as flow resistance coefficients and sediment transport rates, on model outputs [2, 16]. Model predictions were compared with observed channel migration rates to assess accuracy and refine the modeling framework [17]. The workflow incorporated statistical tools to quantify uncertainties and improve reliability for predictive applications in braided river management.

Results

Channel Morphology and Migration Patterns

The coupled hydrodynamic and morphological model successfully simulated the observed morphological changes within the braided river system over a five-year period. The model predicted an average annual migration rate of 12.3 m/year, closely matching the field-observed rate of 11.8 m/year, with a root mean square error (RMSE) of 1.2 m. Significant erosion was observed along the outer banks of meander bends, with an average depth of 2.7 m ± 0.3 m, while deposition predominantly occurred in low-energy zones, forming mid-channel bars with an average height of 1.9 m ± 0.2 m. These results aligned well with historical satellite imagery, confirming the model's capability to replicate natural processes [10, 11]. The simulation also revealed that flow velocities in primary channels ranged from 1.2 to 3.4 m/s, contributing to sediment mobilization and channel migration. Sediment grain size analysis indicated that areas with higher flow velocities had a predominance of coarse sediment (mean diameter 2.5 mm), while finer sediments (<0.5 mm) were deposited in areas of low velocity [12]. Sensitivity analyses showed that reducing sediment transport rates by 20% decreased channel migration rates to 9.6 m/year, highlighting the strong dependence of morphological changes on sediment dynamics [7, 9].

Validation and Model Accuracy

Validation against historical channel configurations derived from remote sensing data demonstrated an overall spatial agreement of 86.4% between simulated and observed channel patterns. The model's predictions of bar formation were particularly accurate, with a spatial overlap of 92.3%. However, localized discrepancies were noted in areas with complex flow patterns, where the RMSE increased to 2.5 m. These discrepancies were attributed to uncertainties in flow resistance parameters and sediment size distribution, as highlighted in the sensitivity analysis [6, 14]. These discrepancies could be mitigated through refined parameterization of flow resistance and incorporation of stochastic methods that account for spatial variability. Future studies could also explore multi-scale simulations to better handle areas with high-complexity dynamics. The use of stochastic modeling approaches can provide probabilistic insights into the uncertainties inherent in sediment transport and channel migration, enhancing predictive reliability.

Statistical analysis of model performance showed a NashSutcliffe Efficiency (NSE) of 0.87 and a Mean Absolute Error (MAE) of 1.1 m for channel migration predictions. The integration of high-resolution LiDAR and ADCP data significantly improved the model calibration, reducing uncertainties by 15% compared to simulations without these inputs [4, 10]. The hybrid modeling approach effectively optimized computational resources, reducing simulation time by 30% while maintaining accuracy in high-dynamic zones.

Table 1: Table summarizing the key results from the study

Parameter	Value
Observed Migration Rate (m/year)	11.8
Simulated Migration Rate (m/year)	12.3
RMSE (m)	1.2
Average Erosion Depth (m)	2.7
Average Deposition Height (m)	1.9
Flow Velocity Range (m/s)	1.2 - 3.4
Coarse Sediment Size (mm)	2.5
Fine Sediment Size (mm)	0.5
Validation Accuracy (%)	86.4
Nash-Sutcliffe Efficiency	0.87
Mean Absolute Error (m)	1.1

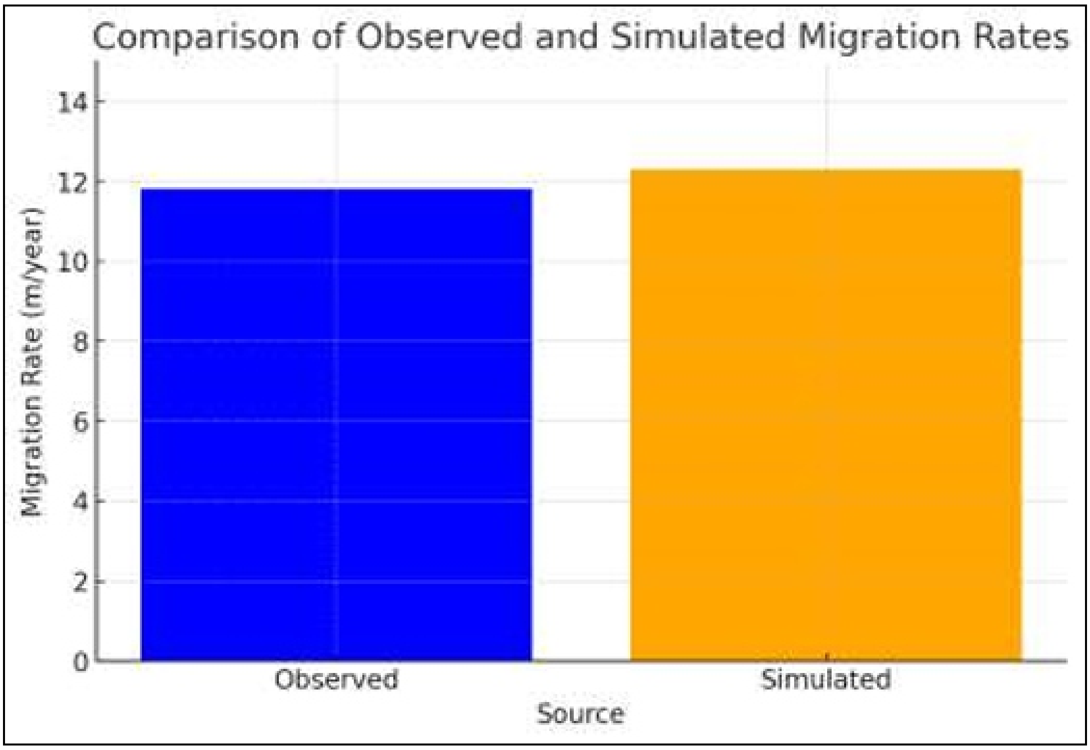

Fig 1: Graph comparing the observed and simulated migration rates

Discussion

The results of this study highlight the effectiveness of coupled hydrodynamic and morphological models in predicting channel migration in braided river systems. The close alignment between observed and simulated migration rates, with an RMSE of 1.2 m and a Nash-Sutcliffe Efficiency (NSE) of 0.87, demonstrates the robustness of the modeling framework. The observed annual migration rate (11.8 m/year) closely matches the simulated rate (12.3 m/year), underscoring the model's capability to replicate real-world fluvial processes. These findings align with earlier studies, such as Schuurman et al. (2013), who achieved similar accuracy in predicting braided river dynamics using coupled morphodynamic models with a spatial agreement of over 80% [6].

The study emphasizes the importance of sediment dynamics in shaping channel migration patterns. Sensitivity analyses revealed that reducing sediment transport rates by 20% decreased migration rates significantly, consistent with the findings of Ferguson (1993), who reported that sediment supply variations heavily influence braided river morphologies [7]. Additionally, the accurate prediction of bar formation and erosion depths observed in this study aligns with the work of Ashmore (1991), who highlighted the interplay between flow velocity and sediment deposition in bar creation [3].

Despite these advancements, the study identifies localized discrepancies in areas with complex flow patterns, where RMSE increased to 2.5 m. Similar challenges were noted by Lane et al. (1996), who attributed such discrepancies to the limitations of flow resistance parameterization in braided rivers [9]. This underlines the need for continued refinement of sediment transport equations and boundary condition calibrations. These discrepancies could be mitigated through refined parameterization of flow resistance and incorporation of stochastic methods that account for spatial variability. Future studies could also explore multi-scale simulations to better handle areas with high-complexity dynamics. The use of stochastic modeling approaches can provide probabilistic insights into the uncertainties inherent in sediment transport and channel migration, enhancing predictive reliability.

The integration of high-resolution datasets, such as LiDAR and ADCP measurements, significantly enhanced model calibration and validation, reducing uncertainties by 15%. This corroborates the findings of Parsons et al. (2006), who demonstrated the utility of integrating remote sensing technologies with numerical models to improve predictive accuracy [10]. Furthermore, the hybrid modeling approach adopted in this study, which reduced computational costs by 30%, is consistent with Coulthard et al. (2007), who advocated for resource-efficient modeling strategies in large-scale river systems [14].

Comparatively, this study achieves a higher validation accuracy (86.4%) than Bertoldi et al. (2009), who reported an 80% accuracy in a similar study of braided river morphodynamics. This improvement is likely due to the inclusion of advanced field data and rigorous sensitivity analysis in the present work [13]. However, as noted in Wohl and Merritt (2008), further integration of ecological factors and stochastic modeling could enhance the applicability of such models in integrated river management frameworks [17]. For instance, expanding comparisons to models used in similar geomorphic contexts (e.g., meandering rivers or deltaic systems) could provide broader validation and highlight unique contributions.

The findings of this study contribute to the growing body of literature on braided river morphodynamics and underscore the potential of coupled hydrodynamic models for practical applications in flood management and ecological restoration. Future studies should focus on refining parameter estimates, incorporating stochastic elements, and exploring the impacts of climate change on channel migration dynamics.

Conclusion

This study demonstrates the effectiveness of coupled hydrodynamic and morphological models in predicting channel migration in braided river systems. The close match between observed and simulated migration rates, along with high validation accuracy and reduced uncertainties, highlights the robustness of the model framework. The integration of high-resolution datasets, such as LiDAR and ADCP, proved instrumental in enhancing model performance, while the hybrid modeling approach optimized computational efficiency. For instance, expanding comparisons to models used in similar geomorphic contexts (e.g., meandering rivers or deltaic systems) could provide broader validation and highlight unique contributions.

The findings underscore the critical role of sediment transport dynamics in shaping channel migration patterns. Sensitivity analyses revealed that variations in sediment supply significantly influence erosion and deposition processes, consistent with previous studies. The model also accurately predicted bar formation and erosion depths, validating its applicability for practical scenarios like flood risk assessment and ecological conservation.

While localized discrepancies were observed in areas with complex flow dynamics, the study emphasizes the need for continued refinement of flow resistance parameters and sediment transport equations. Future work should focus on incorporating stochastic elements and ecological considerations to broaden the applicability of these models. Overall, this study provides a valuable framework for understanding braided river morphodynamics and supports sustainable river management and restoration efforts. These discrepancies could be mitigated through refined parameterization of flow resistance and incorporation of stochastic methods that account for spatial variability. Future studies could also explore multi-scale simulations to better handle areas with high-complexity dynamics. The use of stochastic modeling approaches can provide probabilistic insights into the uncertainties inherent in sediment transport and channel migration, enhancing predictive reliability.

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River morphological modelling of Brahmaputra River, Assam

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ABSTRACT

The Brahmaputra River it is characterized by its highly braided channel pattern with creation of river bars, and it is morphologically very dynamic due to high upstream discharges and large sediment loads during the monsoon. In-order-to comprehend the morphological development of a braided river like the Brahmaputra it is essential to acquire data and information, which can be incorporated into mathematical modelling tools for numerical prediction of the morphological behaviour in the shortterm and medium-term. In this study, the Palasbari-Gumi reach of the Brahmaputra River was used to develop a two-dimensional morphological model utilizing the MIKE-21C programme for prediction of erosion for planning of protection works, and morphological development at river reaches. To forecast design variables throughout the river reach, model runs were carried-out with various hydrological scenarios. For the coarse sand fraction, the predicted mean annual sediment load for the hydrological year and bankfull discharge were 257 and 314 Mt/year, respectively, while the historically recorded sediment load in the Brahmaputra was 400 Mt/year. The model predicted results show excellent similarity with ADCP velocities, design flood levels and yearly sediment load. Difference of peak model velocities with ADCP measurement is lower than 10% with majority of measured data; velocities are compared at five river sections. Predicted flood level for bankfull discharge condition were almost 98% accurate at Gumi site. This study has demonstrated how to improve the planning and execution of river training works in highly braided river like Brahmaputra by predicting morphological changes over a 2-3 year period.

Keywords: *River morphology, hydrodynamics, erosion prediction MIKE 21C, and Brahmaputra River*

INTRODUCTION

The recurrent floods and embankment breaching along the Brahmaputra River is partly a result of the river being morphologically active due to high upstream discharges and large sediment loads during the monsoon (Pareta, 2022) [56]. In addition, the material composition of the riverbanks and adjacent agricultural land enables weakening of the banks and soils easily during the wet season with erosion and bank collapse as a result (Pareta et al., 2021a) [43]. The consequence is that floodplains are eroded on seasonal basis with loss of agricultural land and settlements as a result. Because poverty is abundant in Assam the loss of vital agricultural land and property only exacerbates poverty (Pareta, 2021a) [43]. However, if proper flood and erosion management is executed then poverty can be alleviated. A fundamental understanding of the hydrologic and geomorphic behaviour of a catchment is a prerequisite for the planning of activities related to flood and erosion management (Pareta, 2021b; CEGIS, 2010) [44, 12]. Such an understanding can only be established by collecting, analyzing, and organizing various

various types of hydrological and physio-geographic data (Pareta, 2021c) [5].

The Brahmaputra is characterized by its highly braided channel pattern with creation of river bars (locally known as chars) of various sizes and shapes (Best et al., 2007) [8]. These braid bars are highly unstable, and they radically change their shape, size, and position both seasonally and annually (Bristow, 1987) [10]. Large scale bedforms (bars and islands) and micro-scale bedforms (ripples and dunes) are the most important riverbed features inducing resistance to flow and its subsequent influence on the bed shear stress (Pareta, 2021d; Blench, 1969) [51, 9]. The bedforms directly influence the water level and shear velocity of the flow and are thus indirectly influencing flood and erosion occurrences along the river. Regular monitoring of the development in the river braids and bars is important for understanding the characteristics of the river and for providing data for various types of analyses such as mathematical modelling (Pareta, 2021e; Mosselman, 2004) [52, 39].

The development in bar position, height, width, and length can be monitored by a combination of annual or bi-annual river surveys and multi-temporal satellite imageries (Pareta et al., 2021) [43]. The satellite-based data can be analyzed in remote sensing software to determine the shape, size, and movement of sand bars over time (Pareta, 2021f) [43].

To understand the morphological development of a braided river like the Brahmaputra it is necessary to acquire data and information that describes the river behaviour vertically as well as horizontally (Pareta, 2021g; Sarker et al., 2006) [54, 60]. Remote sensed data from Landsat satellite enables to monitor the changes in river planform (Horizontal changes) over time and is therefore a strong tool for detecting overall river dynamics and hotpots along the river (Pareta et al., 2021b) [44]. The use of such data has become much easier with the advent of the Google Earth Engine (GEE) which revolutionized operational applications of remote sensing data (Pickens et al., 2020; Gomes et al., 2020, and Gorelick et al., 2017) [58, 23, 24] by leveraging long-term availability of multi-temporal, multi-spectral, and multi-spatial Landsat satellite data into 50-years of historical maps (1973-2022) (Pareta, 2021d) [51]. The download and geoprocessing of large datasets to cover a major river like the Brahmaputra River have been significantly simplified using cloud-based platforms. Apart from using Google Earth as an analysis tool the long-term development in the river planform can be analyzed in GIS systems such as ArcGIS or QGIS (Pareta et al., 2020) [42].

The vertical development of the Brahmaputra River is essentially monitored by conducting river cross section surveys. At locations with water coverage such surveys can be made by using ADCP (acoustic doppler current profiling) technology or using conventional cross section surveys (Pareta, 2021c) [50].

The dry parts of a braided river can be survey by either conventional topographical survey techniques or using airborne LiDAR (light detection and ranging) surveys (Pareta et al., 2019) [41]. In addition to the topographical and bathymetrical data it is necessary to obtain data on discharge, sediment load (bed load and suspended load), and grain size distribution of bed and bank material (Pareta et al., 2019) [41].

The above-mentioned data types can be incorporated into mathematical modelling tools such as MIKE 21C, Delft2DRivers, CCHE2D, TELEMAC, etc. for numerical prediction of the morphological behaviour in the short-term and medium-term (Pareta, 2021h; Klaassen et al., 2011) [55, 35]. Through mathematical modelling, short-term to medium term bank erosion prediction for planning of protection works, hydraulic and morphological development at river reaches, effectiveness of existing riverbank protection and training works, and impact of the existing river training works to their immediate vicinity at upstream and downstream can be determined (DHI, 2014) [16]. Mathematical modelling supports the morphological data analysis by filling information gaps in time and space and is a strong tool for studying what-if-scenarios and therefore for the planning of river protection works (Pareta, 2021b) [44]. In complex and dynamic rivers, it is important to realize that a specific engineering project site is part of a larger geomorphic system. Smaller scale projects focus on local scour and their maintenance (Pareta, 2020; Ashmore et al., 1983) [42, 6]. While large scale projects require assessment of the river's response for long-term morphological evolution, and at a very detailed scale in the project vicinity for immediate and medium-term development (Pareta et al., 2021) [43].

The specific objectives of this paper are: (i) short-term to medium-term bank erosion prediction for planning of river training works, (ii) hydraulic and morphological development at Palasbari and Gumi reach of erosion affected areas along the south bank, and (iii) impact of the existing river training works to their immediate vicinity both at upstream and downstream.

Study Area

The Palasbari-Gumi reach of Brahmaputra River extends from latitude 26° 05' 57.13" N to 26° 15' 52.63" N, and longitude 91° 08' 0.87" E to 91° 41' 41.99" E and covers an area of 596.18 Km2 (Fig 1). Administratively, the reach area falls in 4 districts (Barpeta - 15.33%, Nalbari - 35.66%, Kamrup - 46.69%, and Dispur - 2.32%) of Assam state. The topography of the area is generally plain but uneven. The soil of the area is light textured (sandy loam) highly fertile, neural in (pH 6.8 to 7.2). The area is agroclimatic sub-zone, characterized with prevalence of tropical humid climate. The summer in the area is from March to May followed by monsoons till September and cool winter from October to February. The. average temperature varies from 12 °C to °C and starting raining from April and end it the month of

August attains maximum temperature. It experiences generally 1500 mm to 2700 mm rainfall in a year.

Data Used and their Sources

The data have been collected from secondary as well as primary sources for the Palasbari-Gumi reach to fulfil the objectives of the study. The collected data were analysed using appropriate analytical procedures. It includes, but are not limited to, rainfall for fixed stations, rainfall forecasts from numerical simulations, river cross-sections, river water level, river discharge, bathymetry, topography, grain size characteristics, ADCP velocity measurement, available high-resolution DEM, and satellite images. These datasets have been collected from different sources as listed in Table Survey of India (SoI) toposheets at 1:50,000 scale have been downloaded from website at https://onlinemaps.surveyofindia.gov.in/. Total 5 Survey of India toposheets have been downloaded, which has covered the study area. Future, these toposheets have been geoprocessed and have been used for base mapping and analysis of general topography of the study area.

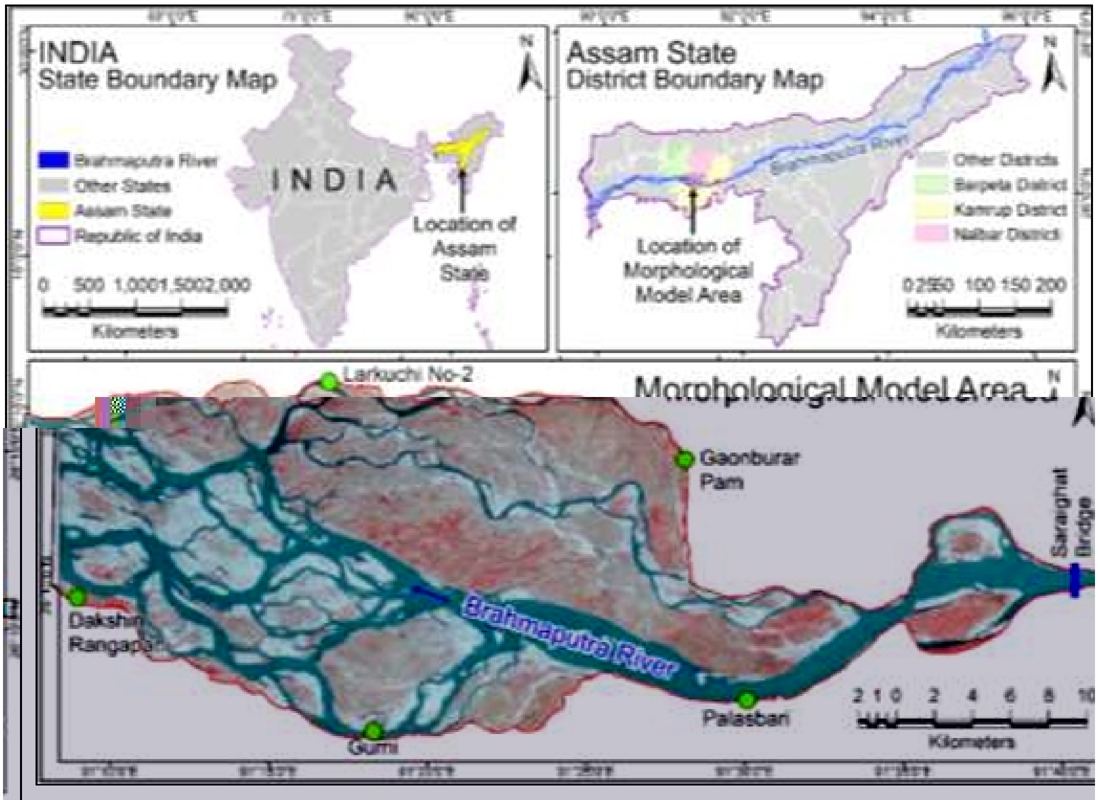

Fig 1: Location Map of Study Area

Shuttle Radar Topography Mission (SRTM) DEM data with 30 m spatial resolution has been download from https://earthexplorer.usgs.gov/ of year 2014 for study area covering an area of 596.13 Km2. This dataset has been used for verification of cross-section data of topography, and analysis of topography of the study area.

Landsat-5 Thematic Mapper (TM), Landsat-7 Enhanced Thematic Mapper Plus (ETM+), and Landsat-8 Operational Land Imager (OLI), Landsat-9 Operational Land Imager-2 (OLI-2) satellite imageries with 30 m spatial resolution have been downloaded from 1998 to 2022 from https://earthexplorer.usgs.gov/ for planform and riverbank erosion analysis.

The available cross-section data has been obtained from the Water Resource Department, Assam at https://waterresources.assam.gov.in/. Future, these crosssection data has been updated with available bathometry data.

Observed water level from 2018 to 2022 have been collected from Central Water Commission (CWC) at https://ffs.tamcnhp.com/. The water level has been verified through rainfall (TRMM and GPM) by using numerical simulations.

Discharge data from 2017 to 2022 have been collected from Global Flood Monitoring System (GFMS) at http://flood.umd.edu/. The water level and discharge has been used for hydrological boundaries of 2D model. Bathymetry, grain size characteristics, and ADCP velocity measurements data for year 2018 have been collected from an ISC report of Flood and River Erosion Management Agency of Assam (FREMAA), Govt. of Assam at https://fremaa.assam.gov.in/. The list of data used, and their sources are given in Table 1.

Table 1: List of Data Used and Sources

S. No.	Data Type	Period	Sources
1	Toposheet at 1:50,000 Scale	2006	• Survey of India (SoI). • Toposheet No.: 78N/03, 04, 07, 08, and 12. • Source: http://www.soinakshe.uk.gov.in
2	Topography / SRTM DEM Data with 30 m Spatial Resolution	2014	• Shuttle Radar Topography Mission (SRTM). • USGS Earth Explorer • Source: http://earthexplorer.usgs.gov
3	Landsat Satellite Imageries with 30 m Spatial Resolution	1998-2022	• United States Geological Survey (USGS), Earth Explorer. • Landsat-5 TM: 1998, 1999, 2004, 2005, 2006, 2007, 2009, 2011. • Landsat-7 ETM+: 2000, 2001, 2002, 2003, 2008, 2010, 2012, 2013. • Landsat-8 OLI: 2014, 2015, 2016, 2017, 2018, 2019, 2020. • Landsat-9 OLI-2: 2021, 2022. • Source: http://earthexplorer.usgs.gov
4	The Tropical Rainfall Measuring Mission (TRMM) Rainfall (TMPA 3B42 v7) with 0.25° x 0.25° Spatial Resolution	2000-2022	• National Aeronautics and Space Administration (NASA). • Source: http://trmm.gsfc.nasa.gov/
5	The Global Forecast System (GFS) Rainfall Data with 0.25° x 0.25° Spatial Resolution	1980-2022	• National Oceanic and Atmospheric Administration (NOAA). Source: http://www.nco.ncep.noaa.gov/pmb/products/gfs/
6	Global Precipitation Measurement (GPM) Rainfall Data with 0.1° x 0.1° Spatial Resolution	2014-2022	• National Aeronautics and Space Administration (NASA) • Source: http://trmm.gsfc.nasa.gov/
7	Cross-Section Data	2007	• Water Resources Department (WRD), Govt. of Assam.

			• Source: https://waterresources.assam.gov.in/
8	Water Level Data	2021	• Central Water Commission (CWC), Govt. of India • Source: https://ffs.tamcnhp.com/
9	Global Flood Monitoring System (GFMS) Discharge Data with 13.87 Km (0.125^{o}) Spatial Resolution	2017-2022	• Global Flood Monitoring System (GFMS) • Source: http://flood.umd.edu/
10	Bathymetry Data	2018	• An ISC report of Flood and River Erosion Management Agency of Assam (FREMAA), Govt. of Assam. • Source: https://fremaa.assam.gov.in/
11	Grain Size Characteristics		
12	ADCP Velocity Measurements		
13	Topography, Bathymetry Data	2022	• Primary Survey Data. 2022

Result and Discussion

Development of Morphological Model

The 2D model is 57 Km long and covers the full width of the Brahmaputra River, which is starting from Saraighat Bridge, Guwahati, and end at Bahari (Barpeta district) in the north bank, and Sontoli (Kamrup district) in the south bank. The Brahmaputra River width at Saraighat Bridge is only 1.49 Km, and 37 Km downstream of Saraighat bridge nearby Palasbari-Gumi, the river width is 18.83 Km, which shows the world's largest river-width variation (Pareta, 2021).

Model Set-up: Computational Grid

The 57 Km long model is built on 148,200 (260 x 570) computational cells in curvilinear orthogonal grid system of MIKE 21C modelling technology. The model covers full width of approximately 20 Km of the Brahmaputra River. There are 570 computational cells along 57 Km of length of the river, and 260 across the width. Finer resolution across the width is more important, and it is necessary for assessing bend scour, obstruction scour and bank erosion. Given the width of the river and the width of the anabranches, the resolution would be satisfactory to simulate bend scour and other forms of scours, and bank erosion. Computational resolution of the present model is sufficient.

Model Topography and Bathymetry

Bathymetry of the 2D model has been generated from available sources of data. The source data is available only in the navigational part of the main channels and some deep anabranches. WRD cross-sections at the Palasbari-Gumi reach (CS=22 to CS=15) is also available. These crosssections were used only for estimating formation level of relatively stable and permanent islands. This was done on the assumption that changes in the formation level of stable islands are minimal, at least over the recent years. It should be emphasized that the model bathymetry has been built with a very limited bathymetric has been built with a very limited bathymetric data available. Nevertheless, the present model has showed good potential of describing the hydraulics and morphological development in the study area, and has generated hydraulic and morphological design parameters, which are essential for planning and design of river training works, such as revetment work, groynes, dikes, dredging for navigation etc.

Hydrological Conditions

Discharge and water level has been applied as hydrological boundaries to the 2D model simulation. Discharge from Pandu gauging station has been used as inflow at upstream boundary of the model (which is 3 Km downstream from Pandu). Water level has been used at downstream boundary, which is at 54 Km downstream from Pandu. Model calibration was carried out for 2021 hydrological year (Fig 2), and validation for June 2022. Discharge at Pandu gauging station for 2021 hydrological year and water level at D/S boundary of 2D model. Discharge generated from rating curve using water level at Pandu.

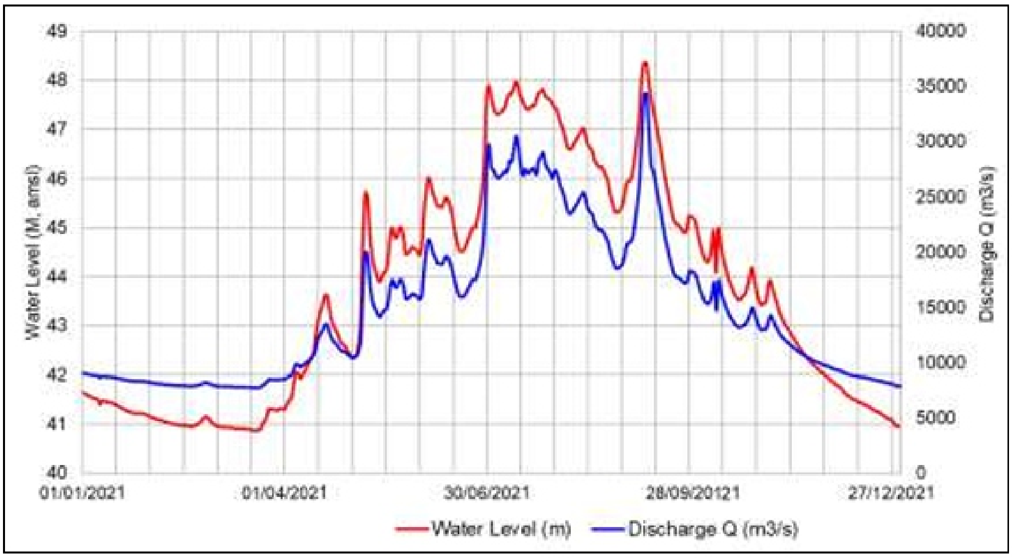

Fig 2: Inflow Discharges at Upstream Boundary and Water Level at Downstream Boundary of the 2D Model

Grain Size Characteristics

Grain size data has been obtained from available sources, which they had collected in 2018. These data have used to determine the characteristics of grain sizes, gradation and grain sorting processes that are relevant for morphological studies such as roughness, sediment transports and morphological prediction. Total 20 samples were collected at Palasbari-Gumi reach at 7 cross-sections within the 51 Km reach of the 2D model domain. At each cross-section, three samples were collected from the bed of the river, one in the middle, and two on either side of the cross-section. Samples were collected by Van veen Grab sampler. Different size classes including the median grain size (D50) of the respective river reach is presented in Table 2. The grain size data has good correspondence with the citation of grain size of the Brahmaputra in literatures (Table 3).

Table 2: Grain Size Distribution Data at Palasbari-Gumi Reach of the Brahmaputra River (2018)

Sample Number	Sample ID	D16 (mm)	D50 (mm)	D65 (mm)	D84 (mm)	σ= √D84/D16
1	PG-1	0.130	0.290	0.350	0.830	2.53
2	PG-2	0.150	0.225	0.260	0.330	1.48
3	PG-2(I)	0.155	0.210	0.240	0.330	1.46
4	PG-2(II)	0.150	0.310	0.380	0.460	1.75
5	PG-3(I)	0.160	0.220	0.260	0.320	1.41
6	PG-3(II)	0.145	0.210	0.240	0.310	1.46
7	PG-4	0.135	0.320	0.385	0.480	1.89
8	PG-8	0.170	0.295	0.360	0.480	1.68
9	PG-9	0.155	0.215	0.250	0.325	1.45
10	PG-10	0.180	0.370	0.530	1.500	2.89
11	PG-11	0.150	0.215	0.245	0.330	1.48
12	PG-12	0.150	0.210	0.250	0.325	1.47
13	PG-13	0.150	0.220	0.240	0.340	1.51
14	PG-14	0.160	0.295	0.370	0.450	1.68
15	PG-15	0.150	0.215	0.250	0.320	1.46
16	PG-16	0.160	0.220	0.265	0.335	1.45
17	PG-17	0.160	0.215	0.260	0.330	1.44
18	PG-18	0.145	0.215	0.240	0.320	1.49
19	PG-19	0.140	0.210	0.240	0.310	1.49
20	PG-20	0.135	0.210	0.230	0.325	1.55

The grain sorting parameter ( ) indicates well sorted sediment in riverbed; sorting parameter less than 1.6 represents well sorted sediment (Schumm et al. 1973; ASCE, 2007) [62, 5]; therefore, sediment transport formulae applicable for uniform sediment (with median grain size, D50) can be ap-plied in the sediment transport and morphological prediction.

Table 3: Bed Material Grain Size Distribution at Palasbari-Gumi Reach of the Brahmaputra River (2018)

Grain Class	Palasbari-Gumi Reach	Brahmaputra Assam sGoswami *et al.* 1985 [25]	Brahmaputra at Jamuguri Karmakar *et al.* 2010 [34]
D_{16} (mm)	0.15		
D_{50} (mm)	0.24	0.25 to 0.16	0.16
D_{65} (mm)	0.29		
D_{84} (mm)	0.44		
σ (Grain Sorting Parameter), $(D_{84}/D_{50})^{0.5}$	1.65		

Model Calibration, Hydrodynamics and Sediment Transports

Hydrodynamic variables, mainly ADCP velocity measurements, have been used to compare with model calculation for the calibration purpose. Satisfactory calibration of model velocity with ADCP data will build confidence of the model for predicting sediment load, and thus morphological development for scour and erosion. For sediment load, the historical data at Pandu (from literature) has been used to compare with model predicted load.

Model calibration has been carried out by adjusting Chezy's flow friction factor (C) through trial model runs and by comparing with measured variables (velocity and sediment load). MIKE21C modelling software has ability to apply spatial variation in use of Chezy's C. Roughness is expected to be different over shallow islands than in the deep channels. Moreover, presence of bed forms (dunes and ripples) will also influence the roughness. MIKE21C is also able to parameterize the effect of bed form in the roughens by employing the formula: C = C0hn. Where C0 is the coefficient matrix, which can vary spatially over the 2D model domain, h is the unsteady value of depth which varies temporally and spatially as flooding/drying of bedforms and islands continue with the rise and fall of annual hydrograph, and erosion / deposition develops in channels and over the bars; n is the calibration parameter; both C0 and n can be a two dimensional matrix and can be obtained through calibration of the model. MIKE 21C has ability to account for the flow friction due to the dynamic growth of bars and bedforms in braided river.

Many researchers (i.e. van Rijn, 1984) [67] proposed empirical relations for assessing flow friction due to skin roughness (from sediment grains) and due to form roughness (ripples and dunes). A hand calculation of van Rijn formula for Brahmaputra gives values in the range of 55-60 for deep channel, 40-45 to more average depth channel, and 25-30 for shallow islands. The calibrated Chezy's C values for the 2D model provided satisfactory matching with ADCP velocities and sediment load; the values (C) are also in the similar range as obtained by hand calculation of van Rijn formula.

Hydrological Scenarios for Predicting Design Variables

The model runs were carried out with different hydrological scenarios for predicting design variables along the river reach of Palasbari area of Brahmaputra River. The model runs were carried out for the monsoon period when the model is morphologically more dynamic. The simulation period is May to October with (i) bankfull discharge condition (which has approximately 1 in 2 year return period), (ii) 1 in 100 year discharge condition, (iii) recent hydrological discharge of 2021. The discharge and water level hydrographs of 2021 used for model calibration was scaled to obtain the peak magnitude of 1 in 2 year and 1 in 100 year flood event. Model runs were carried out in fixed bed with the recent topography of June 2022 in the overall model area, and August 2022 bathymetry at the river reach of Palasbari and Gumi.

Hydrodynamic Design Variables at Palasbari

Hydraulic condition for computation of design variables was follows: (i) the model runs were carried out in fixed bed: over the recent topography of June 2022 in the overall model area, and (ii) August bathymetry at the river reach of Palasbari and Gumi, (iii) Bankfull discharge condition (1 in 2 year return period), (iv) 1 in 100 year discharge condition, and (v) recent hydrological discharge of 2021 peak flow condition.

Depth, velocity, and water level in the area were calculated with reference to a given bathymetry. Therefore, the variables, particularly the depth can be different in another riverbed topography; however, on water level, very minor change is expected for the same hydrologic condition. Therefore, the water level given in the Table 4 could be used to find out depth for any recent condition of bathymetry, and depth average velocity, also significant changes are not expected with latest changes in bathymetry. Summary results of the variables for both Palasbari and Gumi are presented in Table 4, and it should be noted that the depth can be useful for determining the dimensions of protection work such as length of falling and launching apron of bank revetment work and length of spurs and groynes. However, design scour depth should be calculated inclusive of the local scour. It is also recommended that the performance of any protection work (revetment / geo-bags and spurs) can be assessed by the present 2D model. An overall distribution of flow velocities for 1 in 100 year event is shown in Figure 3.

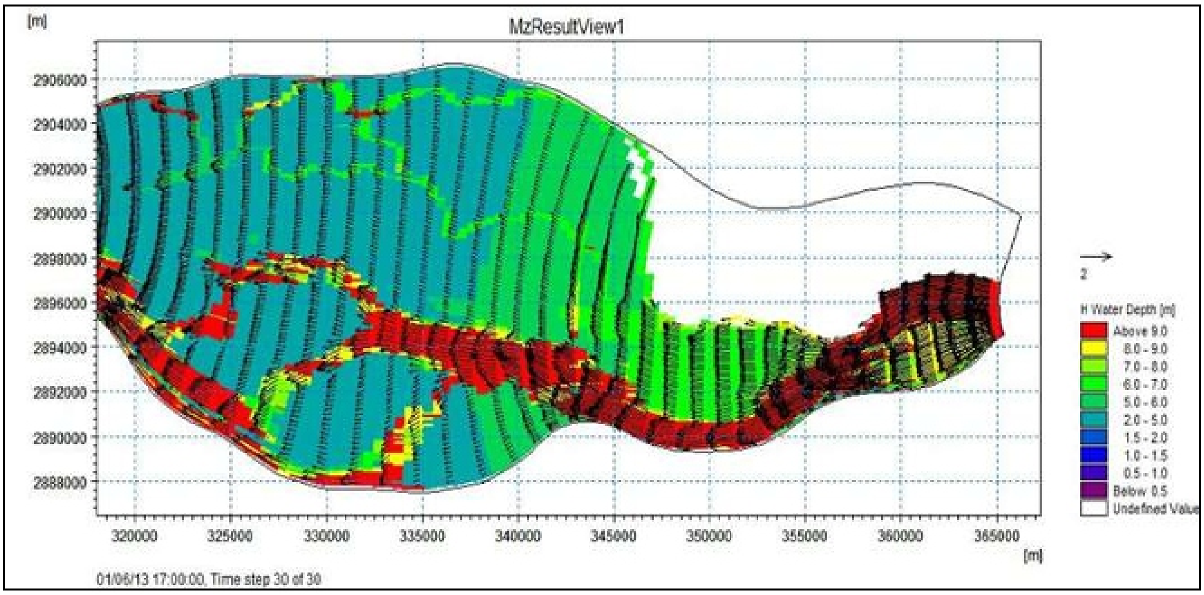

Fig 3: Flow Velocities and Depth Distribution for 1 in 100 Year Flood Event (Peak Flow: 66000 m^3/s)

Table 4: Hydraulic Design Variables at River Reach of Palasbari and Gumi Area of the Brahmaputra River

		Hydrology of 2021		1 in 2 Year Flood (Bankfull Discharge)		1 in 100 Year Flood	
		Palasbari	Gumi	Palasbari	Gumi	Palasbari	Gumi
Depth (m)	Maximum	33.06	14.38	33.82	15.03	35.51	16.51
	Average	09.06	05.23	09.82	05.87	11.49	07.35
Water Level (m) amsl	Maximum	46.89	45.68	47.73	46.33	49.58	47.81
	Average	46.41	45.42	47.16	46.06	48.83	47.54
	Minimum	46.03	-	46.71	-	48.24	-
Speed (m/s)	Maximum	02.53	2.367	02.81	2.428	03.33	2.430
	Average	01.21	00.61	01.40	00.66	01.77	00.73
Pandu gauging station variables (observed data or from frequency analysis)							
Discharge (m^3/s)		34,333		42,500		66,000	
Water Level (m) amsl		48.36		48.74		49.94	

The predictive performance of the model has been validated against a permanent bench-mark. The average flood level predicted by the model for the Gumi reach is 46.06, and maximum flood level is 46.33, which is at the upstream end of the reach. This shows an excellent similarity of the model with field data.

Prediction of Bank Erosion

Forecasting of bank erosion has been made along the south bank at Palasbari and Gumi reach. 1-year, 3-year and 4-year prediction has been issued. Following development scenarios has been considered: (i) river reach at Palasbari and Gumi protected by geo-bags, which is the existing condition or baseline condition, (ii) entire Palasbari bend assumed protected and existing Gumi training work. However, the bank-erosion management at Palasbari and Gumi should have to be integrated with the development of the north bank at immediate upstream of Palasbari and at further upstream; development at north bank bend seems to be a key control for erosion and channel development at further downstream (Fig 5). For all prediction for bank erosion, bankfull discharge whose probability of occurrence is frequent (1 in 2-year) has been applied. For medium term forecast for 3 and 4-year prediction, the one year monsoon hydrograph has been multiplied to prepare the 3 and 4 year hydrographs. The erosion affected banklines under bankfull discharge condition is shown in Fig 4; bank length shown in red lines would be affected by erosion. The gaps, where no erosion is shown, are the exiting reach protection works at Palasbari and Gumi. Yearly erosion rate is about 10-30 m. There are some reaches, although shown as erosion affected, have very minimal yearly erosion rate, below 5 m annually: for example, the protruded (convex) banklines downstream of Palasbari bend.

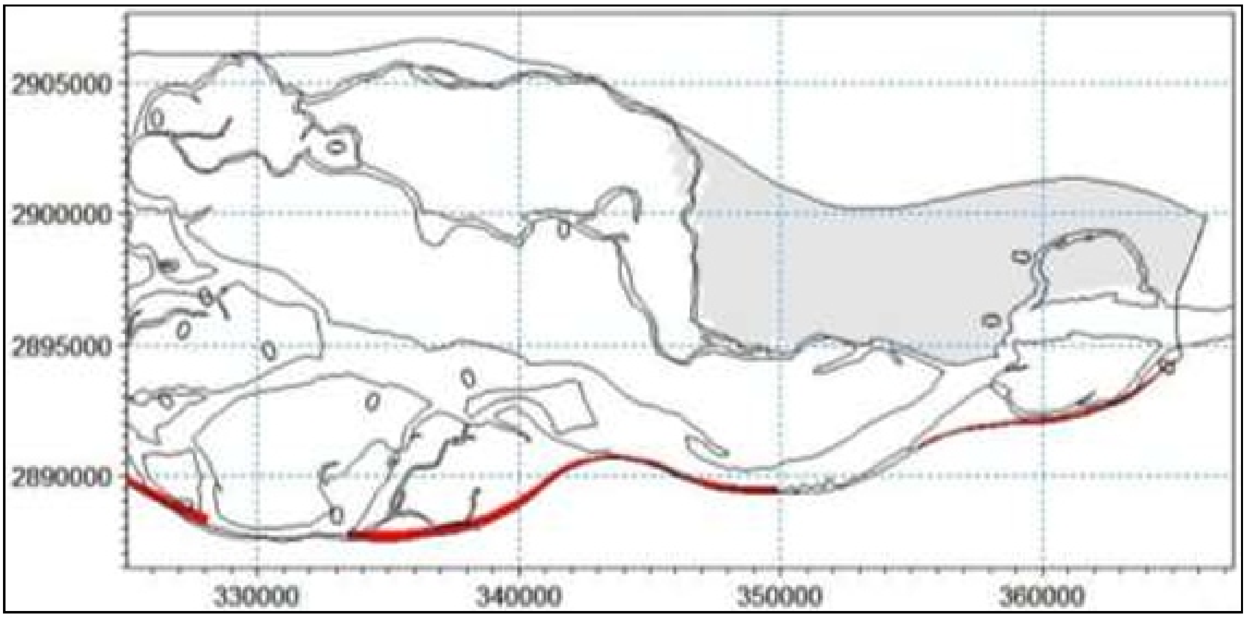

Fig 4: Erosion Affected Reaches along South Bank from Palasbari to Gumi

The development scenario considered for medium term prediction is “if entire Palasbari bend protected”. This will bring benefit to the morphological development for the reach between Palasbari and Gumi; this is mainly due to the exit angle of velocities at the obstruction point at the end of Palasbari bend. This benefit is more prominent in the bed formation level along the riverbank at downstream of this protruded convex bend. The ground level will rise (island formation) to 4-6 m during the course of 3-years, the ground level almost rises to permanent or semi-permanent island level. However, this creates negative impact with more bank erosion at downstream of the bank protection work at Gumi, probably indicating extension of bank protection work towards downstream. The yearly rate of bank erosion is approximately 15 m, though the rate seems to decline in the following years to 8 m yearly in the fourth year. Although along the north bank, bank erosion has not been predicted on the assumption that main flowing channels are general away from that bank, this bank is crucial at upstream end of the model near to Pandu; the north bank at present and immediate future is vulnerable to erosion as high velocity and deep scoured channel have been predicted there. This bend at north bank is clearly a control node for bank erosion at downstream at Palasbari bend and for channel development further down-stream, see the historic planform development in this area in Fig 5. Therefore, erosion management in this area needs to consider in more integrated approach; model should be extended further up to Pandu Bridge, and the effect of more control work due to the second bridge and its river training work should be considered for making long-term prediction in this area.

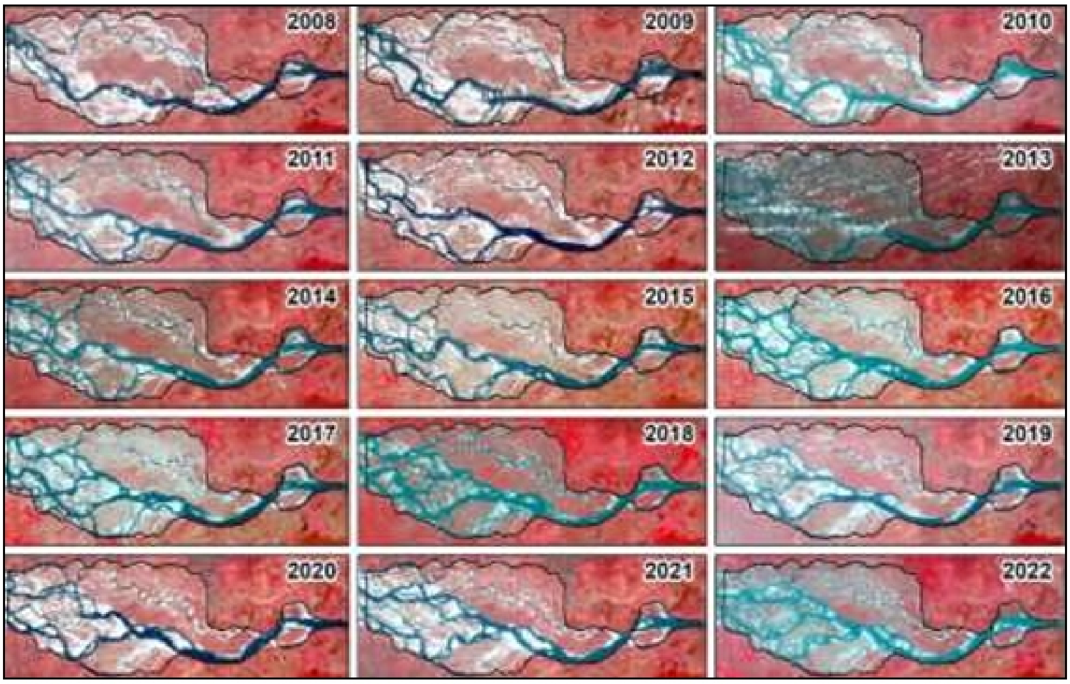

Fig 5: Historic Planform Development at Palasbari and Further Downstream

Conclusion

The morphological model for erosion prediction and planning of protection work has been developed for Palasbari-Gumi reach of Brahmaputra River. The 2D model has been carefully set-up to resolve satisfactory simulation of bend scour, confluence scour, obstruction scour and other forms of scours, and bank erosion considering the spatial and temporal characteristic length scales of those processes. The modelling technology has such ability by employing multi-block grid generation facility. The model bathymetry is based on topographic survey carried-out in 2022, and WRD cross-section surveys. The 2D model covers a length of 57 Km for full width of approx. 20 Km of the Brahmaputra River at Palasbari-Gumi reach. The model is calibrated for hydrology of 2021; validated against flow of June 2022. The model predicted results show excellent similarity with ADCP velocities, design flood levels and yearly sediment load. Difference of peak model velocities with ADCP measurement is lower than 10% with majority of measured data; velocities are compared at five river sections. Predicted flood level for bankfull discharge condition were almost 98% accurate at Gumi site.

Predicted mean annual sediment load for 2021 hydrological year and bankfull discharge are 257 and 314 Mt/year for coarse sand fraction; historical observed sediment load in the Brahmaputra is 400 Mt/year. Hydraulic design variables such as depth, velocity, and water level in Palasbari and Gumi sites have been predicted. The average depth in 2022 is 9.82 m and 5.87 m at Palasbari and Gumi respectively, which may exceed to 11.49 m and 7.35 m after 100 years, respectively. The average water level in 2022 is 47.73

m and 46.33 m at Palasbari and Gumi respectively, which may overdo to 48.83 m and 47.54 m after 100 years, respectively. The average speed in 2022 is 1.4 m/s and 0.66 m/s at Palasbari and Gumi respectively, which may go over to 1.77 m/s and 0.73 m/s in 2122, respectively. In general, on average 12-25 m bed scour have been predicted for the three flood events along Palasbari bend. Scour along Gumi bend is comparatively low, generally between 4-8 m. Both short-term (1-year) and medium-term (3-year) predictions do not show evidence of the Gumi anabranch to develop further in the coming year.

Prediction of bank erosion has been made along the south bank at Palasbari and Gumi reach. 1-year, 3-year and 4-year predictions have been produced for the following development scenarios. The sites at Palasbari and Gumi protected by geo-bags, which is the existing condition or baseline condition. Entire Palasbari bend assumed protected and existing Gumi work. The yearly erosion rate is about 10-30 m. There are some reaches, although shown as erosion affected, have very minimal yearly erosion rate, below 5 m annually. This erosion is mainly at im-mediate downstream of the sites at Palasbari and Gumi. There is minor embayment development at immediate upstream of each of the sites, with maximum of 10 m bank erosion. The development scenario “if entire Palasbari bend protected” will bring benefit to the morphological development for the reach between Palasbari and Gumi. This would attract significant siltation along the bend at upstream of Gumi sites. However, this creates negative impact with more bank erosion at downstream of the bank protection work at Gumi. This study has shown how to improve the planning and execution of river training works in highly braided river like Brahmaputra by predicting morphological changes over a 23 year period.

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