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Manuscript Title: Experimental study on scour and turbulent flow characteristics around unsubmerged I-head and T-head groynes

Response to **Reviewer3**

Dear Reviewer,

We want to express our sincere gratitude for your dedicated time spent on reviewing our manuscript and providing us with invaluable feedback. Your insightful comments have played a pivotal role in shaping the current version of our paper, and we deeply appreciate your contributions to enhancing our work.

The authors have conscientiously examined each of your comments and made comprehensive efforts to address them. Our commitment remains steadfast in upholding the journal's rigorous standards, and we trust that the thoughtful revisions made to the manuscript are in line with your expectations.

We wholeheartedly welcome any further constructive comments or suggestions you may have, as they would greatly contribute to further improving the quality of our paper. Your expertise is highly esteemed, and your input is of immense value to us.

To assist you in reviewing our responses to your comments, we have provided a detailed point-by-point breakdown below. Additionally, for your convenience, all modifications made to the manuscript have been highlighted in yellow.

Comments and Suggestions for Authors:

The paper is about experimental study on scour and turbulent flow characteristics around unsubmerged I-head and T-head groynes. Overall, the paper needs some significant improvements/revisions before its possible publication. Below are some of my concerns to be addressed:

The literature review is somehow weak (Improvements needed). By reading through, it is difficult to grasp the key justification for the need of this research. The manuscript needs to clearly elaborate more and show, what are the problems with the existing works in the field either globally, regionally, or nationally? Without this, readers would have difficulties in seeing the merit of this paper. Toward the end of the introduction section, the author (s) are requested to show what is missing in these previous works to grasp the real limitations of these studies leading to the motivation of conducting this specific research. Otherwise, it is questionable/dubious when the novelty is considered, authors must underline and stress on the novelty of the paper.

Author response: Thank you for your constructive feedback. We have taken your suggestions seriously and made significant improvements to the literature review in the introduction section to better justify the need for our research and emphasize its novelty.

In our revised manuscript, we have incorporated recent literature reviews and discussions to provide a more comprehensive account of the research gaps in this field, as well as the limitations observed in previous research efforts (Page: 2-3; Line:91-125). This enhanced discussion serves to underscore the motivation behind conducting our experimental study. Specifically, we have elaborated on the fact that while previous research has highlighted the advantages of different head-shaped groynes over traditional

IHG structures [42-47], the existing body of experimental studies on T-head groynes (THG) remains somewhat limited in scope. Previous investigations have primarily focused on isolated aspects, such as local scour depth evaluation [44,46,48-51] or flow characteristics around these groynes [42,52-54].

Moreover, comprehensive research that delves into the 3-D mean and turbulent flow characteristics and their correlation with scouring around THG is notably sparse in the existing literature. Additionally, there is a significant gap in comparative studies between straight-head and T-head groynes [50,55]. This lack of comprehensive investigation hinders our understanding of the hydraulic performance of THG structures.

Furthermore, most of the THG investigations to date have been conducted in channel bend configurations, with limited exploration in straight channels featuring a mobile bed. Our research addresses these gaps by presenting experimental results and comparing scour patterns, mean and turbulent flow characteristics around a single IHG and THG, particularly under un-submerged clear-water conditions over a straight mobile bed channel.

To enhance the cost-effectiveness of groynes and optimize their configuration and dimensions, we have conducted a comprehensive cost-benefit optimization analysis for both IHG and THG structures (Annexure A) and (Page: 15-17; Line: 428-515). The findings from the presented cost-benefit analysis acts as a guidance in decision-making approach for selecting groyne shape and dimensions. We appreciate the reviewer's input in this regard.

In conclusion, the revised introduction section now provides a more comprehensive and clear justification for our research, highlighting its novelty and the valuable insights it can offer to the field. We believe these improvements align our manuscript more closely with the expectations of the journal and its readers.

State the specific objectives/Aims of your study; the novelty of the work and application of your work. The novelty of the work is not clear. The introduction section and literature review must improve. At the end of introduction section you must discuss about innovation of your work compared with previous works. Other country experience and other researcher study must review and discuss.

Author response: We greatly appreciate the reviewer's input and have taken steps to address these important points in our revised manuscript. In the introduction section, we have defined the specific objectives of our study, which are to comprehensively investigate the 3-D mean and turbulent flow characteristics around both IHG and THG structures and their correlation with scouring (Page: 3; Line: 118-123). To underscore the novelty of our work, we've provided a detailed explanation in our revised manuscript (Page: 3; Line:109-125). Previous research has indeed emphasized the advantages of different head-shaped groynes over traditional IHG structures [42-47]. However, there exists a limited scope of experimental studies on T-head groynes (THG). Prior investigations have primarily focused on specific aspects, such as evaluating local scour depth [44,46,48-51] or examining flow characteristics around these groynes [42,52-54].

Moreover, there's a notable gap in comprehensive research that explores the 3-D mean and turbulent flow characteristics and their correlation with scouring in the context of THG structures [50,55]. Comparative studies between straight-head and T-head groynes are evidently sparse in the existing literature [47]. This knowledge gap impedes a comprehensive understanding of the hydraulic performance of THG structures.

Furthermore, most THG investigations have centered on channel bend configurations, with limited exploration in straight channels featuring a mobile bed. Our research addresses these gaps by presenting experimental results and comparing scour patterns, mean and turbulent flow characteristics around both IHG and THG, particularly under un-submerged clear-water conditions over a straight mobile bed channel.

Additionally, we've undertaken a comprehensive cost-benefit optimization analysis for both IHG and THG structures to examine their cost-effectiveness and optimize their size (Page: 15-17; Line: 428-515). The findings from the presented cost-benefit analysis acts as a guidance in decision-making approach for selecting groyne shape and dimensions. We appreciate the reviewer's input in this regard. This holistic approach strengthens the contribution and relevance of our study.

Cost/ benefit analysis is not sufficient. Discussion about price and challenges of the method for commercial use in the rivers must discussed.

Author response: Thank you for your valuable suggestion regarding the economic analysis of various methods for river bank protection. We have taken your recommendation into consideration and have conducted a comprehensive cost-benefit analysis to thoroughly address this aspect.

In the revised manuscript, we have performed a detailed cost-benefit analysis for both IHG and THG, taking into account crucial parameters like groyne length, depth of flow, and groyne thickness as variables. Our aim was to establish cost expressions for constructing both types of groynes while considering the observed effective bank protection length from our experiments as the benefit.

To provide a comprehensive account of this analysis, we have included the derivation of the cost-benefit ratios as Annexure A in the revised manuscript. Additionally, we've incorporated the expressions, observed plots, and in-depth discussions resulting from the cost-benefit analysis within a dedicated sub-section in the Results and discussion section (Page: 15-17; Line: 428-515). The findings from the presented cost-benefit analysis serve as a valuable framework for making decisions regarding groyne configuration and dimensions. We greatly appreciate the reviewer's valuable input on this matter.

This addition not only enhances the depth of our research but also addresses your suggestion by providing a quantitative evaluation of the cost-effectiveness of different groyne configurations. We believe that these enhancements significantly contribute to the value and relevance of our study.

Economic analysis for comparing the method with alternate methods for river restoration is necessary. How much does it cost each method? Also, Scale analysis and economic analysis for execution of the proposed method must discussed.

Author response: Thank you for highlighting the importance of economic analysis in evaluating various river restoration methods. While we agree that economic considerations play a significant role in decision-making, we would like to clarify the scope of our study.

Our research primarily focuses on the hydraulic aspects of two groyne types, specifically investigating their hydraulic performance and flow characteristics (Page: 3; Line: 118-123). While we have conducted a comprehensive cost-benefit analysis to assess the cost-effectiveness of these groynes in the context of bank protection (Page: 15-17; Line: 428-515), our study does not extend to a detailed economic comparison with alternate river restoration methods.

Economic analyses involving alternate river restoration methods often require a broader study framework, including assessments of materials, labor costs, long-term maintenance, and environmental impacts. These analyses are indeed valuable but are typically carried out in dedicated studies with a specific focus on economic aspects.

We appreciate your suggestion and recognize the importance of economic considerations in river restoration projects. However, given the scope and objectives of our current study, conducting a comprehensive economic analysis for all possible river restoration methods falls beyond its intended scope. We hope that our research findings on the hydraulic and cost-effective aspects of groyne types provide valuable insights for the river engineering community.

Also, scale and economic analysis with previous work and alternate work for eutrophication reduction and control must compare.

Author response: We appreciate the suggestion to compare our study with previous work and alternate methods for eutrophication reduction and control. Eutrophication is indeed a critical issue in many river systems, and various methods have been proposed to address it. However, we would like to clarify the scope of our research and why this specific analysis was not included.

Our study primarily focuses on the hydraulic aspects of two groyne types, specifically investigating their hydraulic performance and flow characteristics around the groynes (Page: 3; Line: 118-123). While eutrophication is a significant concern in river systems, it often involves complex and multifaceted processes related to water quality, nutrient management, and ecological aspects. Comprehensive evaluations of eutrophication reduction methods typically require a specialized study with a specific focus on water quality parameters, nutrient loading, and ecological responses.

While our research contributes valuable insights to the field of hydraulic engineering and bank protection, it does not encompass the broader aspects of eutrophication control and water quality management. We recognize the importance of such studies and their relevance in addressing environmental challenges in rivers. However, given the scope and objectives of our current research, conducting a detailed comparative analysis with previous work and alternate methods for eutrophication reduction is beyond its intended focus.

We appreciate the reviewer's interest in the broader context of river management and environmental considerations. Our study aims to provide a specialized contribution to the field of hydraulic and river engineering, and we hope that our findings are valuable in this specific domain.

Quality of pictures are not good and must improve.

Author response: Thank you for your feedback regarding quality of pictures. In the revised manuscript, we have taken your comments into consideration and have made improvements to the quality of the figure. Additionally, we have corrected the size of the annotations in Figure 1(a) (Page: 4), to enhance clarity and make it easier for readers to understand the top-view and lateral-view sketches. We believe that these changes will significantly improve the visual presentation of the figures in the paper.

In experimental works, statistical analysis and validation of results are important. More discussion and sensitivity analysis on different parameters and concentration of water quality variables are necessary.

Author response: Thank you for emphasizing the significance of statistical analysis and validation in experimental studies. We have taken your feedback into consideration and made important additions and clarifications in our revised manuscript to address these aspects.

In our study, we have performed power spectral analysis, which is a valuable tool for calibrating and validating measurement instruments. By analyzing the frequency spectra of the measured velocity fluctuations, we have observed a clear trend of the data following the Kolmogorov's law with a spectral exponent of $-5/3$ in the inertial subrange (Figure 3). This observation suggests that turbulence structures and energy distribution maintain consistent patterns across different scales, reinforcing the universality of turbulence.

We have incorporated an explanation about these concepts in the revised manuscript (Page: 6; Line:188-194). Specifically, we mention that the Nyquist frequency, which represents the highest frequency accurately represented in digital signals or systems, is equal to half of the sampling frequency (Nyquist frequency = 25 Hz in our case, with a sampling frequency of 50 Hz) [63]. This information emphasizes the adequacy of our chosen sampling frequency, especially that the majority of kinetic energy in the flow falls within the frequency range of 0.1 to 1 Hz, rapidly diminishing beyond 10 Hz (Figure 3).

We have also presented experimental uncertainty statistics of the turbulent velocity fluctuations employed to analyze the data obtained from our experiments (Page: 6-7; Table 2). This includes measures such as mean values, standard deviations, skewness, kurtosis and standard error to quantify the uncertainty in mean velocity estimates due to sampling variations. We believe that these additions enhance the rigor and validity of our findings.

While we acknowledge the importance of sensitivity analysis on different parameters and the consideration of water quality variables in river studies, it is essential to clarify that our study's primary focus is on hydraulic and river engineering aspects related to groynes and bank protection (Page: 3; Line: 118-123). As such, the scope of our study does not encompass the assessment of water quality variables. These aspects are typically addressed in dedicated research efforts with distinct objectives and methodologies.

While the result section is well written, there is limited discussion about this study. This makes the whole part of the discussion weak and poor. Comparing your results to the previous studies is not just enough but also should consider providing the implication of your findings. The author (s) are requested to dig deep into the recent literature (Consulting recent publications) on the topic to discuss the overall results of the study.

Author response: Thank you for your feedback and valuable insights into the discussion section of our manuscript. We appreciate your guidance, and we have taken steps to enhance the depth and quality of our discussion.

In response to your comments, we have made significant improvements to our Results and Discussion section. Specifically, based on our experimental results, we concluded that the effective bank protection length for an un-submerged I-Head Groyne (IHG) in a straight channel is approximately two times its transverse length. In the case of a T-Head Groyne (THG), the effective length was found to be around three times the transverse length (Page: 13; Line: 384-388) (Page: 14-15; Line: 419-425) (Page: 18; Line: 575-581).

Cost-benefit optimization analysis for an IHG and THG and the important findings from this analysis have also been incorporated into the Results and Discussion section as a dedicated sub-section in the revised manuscript (Page: 15-17; Line: 428-515). From all the cases considered, the IHG was found to be more cost effective groyne in comparison to THG, when cost of constructions are compared along with the effective bank protection lengths (Page: 18; Line: 582-584). These additions provide readers with a more comprehensive understanding of our research outcomes.

In response to your suggestion to dig deeper into recent literature, we have made significant updates to the introduction section. We have incorporated reviews from several recent publications in the field, discussing their methods and key findings [45-54] (Page: 2-3; Line: 91-116). This addition not only provides a broader context for our study but also highlights the relevance of our research in the current scientific landscape.

The authors have succinctly summarized the major findings but toward the end, the significance of the research findings was not provided. The major weakness of this section is that there is a lack of concluding remarks based on your findings.

Author response: We appreciate your acknowledgment that we have succinctly summarized the major findings of our study. We have taken substantial measures to bolster the conclusion section of our paper. In addition to the previously outlined conclusions in the dedicated Conclusion section, we've introduced several significant additions.

Specifically, based on our experimental results, we've deduced that in the case of an un-submerged I-Head Groyne (IHG) situated in a straight channel, its effective bank protection length is approximately two times its transverse length. In case of a T-Head Groyne (THG), the effective bank protection length was found to be around three times its transverse length (Page: 13; Line: 384-388) (Page: 14-15; Line: 419-425) (Page: 18; Line: 575-581).

Furthermore, we've expanded upon the conclusion by incorporating insights derived from the cost-benefit analysis of both IHG and THG configurations. From the comprehensive analysis, it was concluded that IHG exhibits greater cost-effectiveness when compared to THG, considering construction costs alongside the effective bank protection lengths (Page: 18; Line: 582-584). This refined conclusion section provides a more comprehensive overview of our research findings and their implications.

Recommendations for future direction/orientation for further research based on the remaining gaps is highly encouraged.

Author response: We appreciate your suggestion in this regard. There are indeed valuable opportunities for further exploration in this field. We recommend that future researchers conduct experimental studies to investigate the scouring and 3-D turbulent flow characteristics around a series of different head groynes (Page: 18; Line: 585-589). Such research endeavors would significantly contribute to the existing literature, providing essential data for optimizing the spacing between consecutive groynes in series and offering a deeper understanding of the flow fields that develop between these groynes. This knowledge is crucial for effective river management and bank protection.

The English language usage should be checked by a fluent English speaker as the whole of the manuscript contain many grammatical and Syntax errors as well as typos. It is suggested to the authors take the assistance of someone with English as their mother tongue/or a professional language proofreader.

Author response: We would like to express our gratitude to the reviewer for their valuable feedback. We have taken their suggestions into careful consideration, and as a result, the entire manuscript has been revisited to rectify any grammatical errors, syntax issues, and typos, thereby enhancing the overall language quality (Page: 3; line:138, Table 1), (Page: 4; line:148), (Page: 9; line: 263/264,270, 281), (Page: 10; line: 287), (Page: 13; line: 357), (Page: 17; line: 541/542, 544/545).

Re-check the journal guidelines for authors to update their references (Cited sources).

Author response: We sincerely appreciate the reviewer's attention to detail and their valuable suggestion. As per their recommendation, we have thoroughly reviewed and updated the references in accordance with the journal's guidelines for authors. Thank you for bringing this to our attention (Page: 20-24).

Revisit long sentences and try to shorten them so that readers of the manuscript cannot get lost.

Author response: We are grateful to the reviewer for their insightful feedback. In response to their suggestion, we have revisited the manuscript, identified lengthy sentences, and subsequently broken them down into smaller, more digestible sentences (Page: 13-14; Line: 384-388) (Page: 14-15; Line: 419-425) (Page: 18; Line: 575-579). This modification aims to enhance the readability of the manuscript for our readers. Thank you for highlighting this aspect.

The paper must summarized. Based on journal guideline the introduction section.

Author response: We would like to express our gratitude to the reviewer for their feedback. We have made efforts to enhance the summarization of the paper. To achieve this, we have included additional key conclusions derived from our study. Notably, we have presented findings regarding the effective bank protection lengths of the two groyne types (Page: 13; Line: 384-388) (Page: 14-15; Line: 419-425) (Page: 18; Line: 575-582). Furthermore, we conducted a comprehensive cost-benefit analysis, considering both the construction costs of the individual groynes and their respective effective bank protection lengths (Page: 18; Line: 582-584). The observations from this analysis, which indicates that the IHG is more cost-effective than the THG, serves as a succinct summary of our study's key findings. Thank you for your valuable input in this regard.

Validation of experiment results and results must discuss.

Author response: We appreciate the reviewer's valuable input regarding the validation of experimental results. In our study, we have performed power spectral analysis, which is a valuable tool for calibrating and validating measurement instruments. By analyzing the frequency spectra of the measured velocity fluctuations, we have observed a clear trend of the data following the Kolmogorov's law with a spectral exponent of $-5/3$ in the inertial subrange(Figure 3) . This observation suggests that turbulence structures and energy distribution maintain consistent patterns across different scales, reinforcing the universality of turbulence.

We have incorporated an explanation about these concepts in the revised manuscript (Page: 6; Line:188-194). Specifically, we mention that the Nyquist frequency, which represents the highest frequency

accurately represented in digital signals or systems, is equal to half of the sampling frequency (Nyquist frequency = 25 Hz in our case, with a sampling frequency of 50 Hz) [63]. This information emphasizes the adequacy of our chosen sampling frequency, especially that the majority of kinetic energy in the flow falls within the frequency range of 0.1 to 1 Hz, rapidly diminishing beyond 10 Hz (Figure 3).

We have also presented experimental uncertainty statistics of the turbulent velocity fluctuations employed to analyze the data obtained from our experiments (Page: 6-7; Table 2). This includes measures such as mean values, standard deviations, skewness, kurtosis and standard error to quantify the uncertainty in mean velocity estimates due to sampling variations. We believe that these additions enhance the rigor and validity of our findings.

Abbreviation must presented at the end of paper.

Author response: We appreciate your observation regarding the presentation of abbreviations. Following your suggestion, we have included a comprehensive list of abbreviations and notations at the end of the revised manuscript for clarity and reference. Thank you for your valuable input (Page: 24-26).