# Responses to reviewers about: "Quantifying uncertainty in flood predictions due to river bathymetry estimation"

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Dear Prof. Lixin Wang and reviewers,

We thank you so much for the opportunity to reply to the reviewers about "Quantifying uncertainty in flood predictions due to river bathymetry estimation". We appreciate the time and effort that you and the reviewers spent on providing valuable comments to our paper. Please see below, in green, for our responses to the reviewers' questions. The sections and lines mentioned here are based on the track-changed manuscript version. Since some questions are about the same issue, we might provide similar answers. Apart from that, we added an extra section to list all of parts we edited to make the content more accurate, consistent, and concise. Additionally, please note that Nguyen et al. (2024b) is now published as Nguyen et al. (2025).

## 1 Editor report

Both reviewers think the topic is important. At the same time, both reviewers suggested that the lack of methodology details prevented a thorough evaluation of the novelty of this work, along with other major and minor concerns. I concur with the reviewers' assessment and would like to invite the authors for a thorough revision. Please keep the reviewers' comments in mind when carrying out the revision. The revised manuscript will be further reviewed.

We thank the editor again for this opportunity to revise our manuscript according to suggestions from the reviewers. Generally, in the revised manuscript, we adjusted the Introduction Section to highlight the main focus of our paper and expanded the methodology section by mainly adding a summary of the previous paper - Nguyen et al. (2025), further information about Waikanae River, LISFLOOD-FP flood model, and our assumption of errors of 10%. In this response, we explain in detail the relation between river bathymetry and flood model outputs, how these flood model outputs were analysed, and the robustness of our paper. Also, the corresponding contents in the revised manuscript were modified for consistency.

## 2 Reviewer 1

***Summary of reviewer's comments:*** The reviewer was asking for further information and clarification about the relation between the river bathymetry and flood predictions, the flood model used in the paper, the research question that the paper tries to answer, and the difference between two formulas used to estimate the river bathymetry.

***Summary of authors' responses:*** We thank you so much for helping us point out where we lack clarification and need improvement. In general, we summarised from the paper the relation between the river bathymetry and flood predictions through a simple chain in the response. We have added further information about LISFLOOD-FP - the flood model used in the paper. Also, we have clarified which research question we are trying to answer. Finally, we have shown the difference between the two formulas with explanation.

### 2.1 Question 1

***Question:*** The relation between flood predictions and river bathymetry estimation is not clear for me. When talking about flood prediction, I would expect the simulation or prediction of streamflow, the peak flow volume and peak time. However, reading the paper, I only find results of bathymetry and flood extents. The authors didn't provide many details about the calculation of flood extents, but it seems that the flood extents can be determined by the river bathymetry directly. Consequently, in my understanding, it seems that "flood prediction" and "bathymetry estimation" in this study is one thing to some extent.

***Answer:*** For clarification, in this paper, flood predictions and flood modelling refers to inundation modelling rather than flood flows. River bathymetry refers to the river depth measurement. It plays a crucial role in flood modelling because it determines when and where water leaves the river channel and starts to flood overland. Based on this, the flood extent and flood depth, controlled by the topography outside of the river and the amount of the water that leaves the river, can be affected. However, measuring the river bathymetric data using some current methods like swath beam sonar and blue-green LiDAR is either time-consuming or expensive, and sometimes unfeasible if the water is deep or sediment-laden. Hence, various approaches have been proposed to estimate these river bathymetric data. This information was mentioned between lines 20-28. In that, more information has been added between lines 24-26: *"Multi-beam sonar is effective but time-consuming, while blue-green LiDAR is faster but does not work in sediment-laden or deep water, and both of them are expensive (Bailly et al., 2010; Flener et al., 2012; Bures et al., 2019)."*.

If these estimated river bathymetric data are used to calculate the riverbed elevations and represent the river in topographic data and then used in flood modelling, the model predictions will be affected. The flow of logic for this paper is as below:

Estimated river bathymetric data → riverbed elevations → topographic data (DEM and Manning's n derived from roughness length) generated by riverbed elevations and LiDAR data → inputs to a flood inundation model (LISFLOOD-FP in this study) → affects flood model outputs (extents, depths, etc.).

This information was written between lines 55-63 in the Introduction Section, but has been rewritten for clarification: *"Regardless of any approaches to estimate the river bathymetric data, due to the inability to capture the randomness of the real-world river systems, these estimations still contain errors. These errors can cause the simulated river bathymetries to* *deviate significantly from the actual ones. Consequently, using these modelled river bathymetries to represent the rivers in food inundation modelling can affect the flood predictions. Currently, several studies have investigated the errors in the estimated river bathymetry (Durand et al., 2008; Lee et al., 2018; Moramarco et al.,2019; Kechnit et al., 2024), but they have not considered how these estimations with errors affect the flood model outputs. "*.

In our paper, we used the LISFLOOD-FP, a 2D hydrodynamic flood model, to model the flood map/flood extent forced by a hydrograph (as seen in Figure 1b in the paper). Its inputs include topographical data (DEMs and Manning's n maps) and January-2005 flow/hydrograph and tidal data (kept fixed throughout all simulations). In the topographical data, as mentioned above, the river is represented by the riverbed elevations calculated from the estimated river bathymetric data, and the surrounding land is represented by the LiDAR-derived topography.

Among the flood model outputs/flood predictions, the maximum water depths (MWDs) and maximum water surface elevations (MWSEs) (rather than forecasting streamflow or peak timing) were selected to analyse how they were influenced by the uncertainties in the estimated river bathymetric data. These flood model outputs were chosen because their variation through simulations can be easily manipulated and visualised. For each dataset of 50 MWDs, we calculated the mean (mMWDs), standard deviation (sdMWDs), and coefficient of variation (covMWDs) of MWDs. We also calculated proportion of simulations in which a given pixel was flooded (pFs) to distinguish where was always flooded, never flooded, and sometimes flooded throughout these realisations. In this study, the mMWDs and sdMWDs did not add insight, so we did not consider them. We also validated the flood simulations - MWSEs against observed flood levels using RMSE metric for the scenario modelled.

The whole above information was mentioned between lines 217-245. As to the flood extents, thank you so much for helping us to point this out, its information has been added between lines 234-237: *"Additionally, we computed expected flooded area or expected flood extent, a metric often employed by decision-makers, for each simulation for comparison. The expected flood extents were calculated based on these pFs by multiplying the area of one pixel (10 m x 10 m) with number of pixels that were always and sometimes flooded."*.

### 2.2 Question 2

***Question:*** Related to the first comment, I am also confused about the flood prediction model used in this study. The authors provide little descriptions on the LISFLOOD-FP model, missing some important issues. For example: what is the input and output of the model? What's the relationship between this model and the two formulas for river bathymetry estimation? Is the estimated river bathymetry used in this model?

***Answer:*** More information about LISFLOOD-FP model was added between lines 143-155:

*"In this study, LISFLOOD-FP (Bates et al., 2010; Neal et al., 2018), a 2D hydrodynamic model, was used to simulate the January-2005 flood event (which was calibrated for this site in Nguyen et al. (2025)) because it is well known for its computational efficiency and highly accurate flood model outputs (Nguyen et al., 2025). The DEM and Manning's n values, along with the flow information and tidal data mentioned above were used as input into this model.*

*In LISFLOOD-FP, the formula to compute the water flow $Qcell$ at the interface index $i+1/2$, between cells index $i$ and index $i+1$, over a time step $\Delta t$ is:*

$$Qcell_{i+1/2}^{t+\Delta t} = \frac{q_{i+1/2}^{t} - gh_{flow}^{t}\Delta t Scell_{i+1/2}^{t}}{[1+\frac{g\Delta t n^2 |q_{i+1/2}^{t}|}{(h_{flow}^{t})^{7/3}}]}\Delta x \quad (1)$$

*where $q^t$ represents the flux at time $t$, $\Delta x$ denotes the cell width, $Scell$ and $h_{flow}$ are the water surface slope and flow depth between cells (Bates et al., 2010). The flow formula here is displayed for the x direction, the y direction can be obtained analogously. The cell water depth $h_{flow}$ is updated based on the discharge through the four boundaries of that cell as below, where $i$ and $j$ denote the cell coordinates (Shustikova et al., 2019):*

$$\frac{\Delta h_{flow}^{i,j}}{\Delta t} = \frac{Qcell_x^{i-1,j} - Qcell_x^{i,j} + Qcell_y^{i,j-1} - Qcell_y^{i,j}}{\Delta x^2}." \quad (2)$$

As mentioned in question 1: The main inputs for the LISFLOOD-FP model to simulate the January-2005 flood event are the river flow data, tidal data, and topographical data that include the estimated river bathymetry - DEM and Manning's n converted from roughness length using the equation 1 mentioned in the Section 2.1. of the paper. The main outputs of the model are time series of water surface elevations and water depths and their maximum values. The study chose the MWDs and MWSEs to analyse. The information about these inputs and outputs is described in the paper between lines 217-245. In that, lines 217-226 were rewritten for clarification as below:

*"Similar to Durand et al. (2008); Moramarco et al. (2019); Kechnit et al. (2024), and especially Nguyen et al. (2025), our research also applied a Monte Carlo framework to generate 50 DEMs and 50 Manning's n maps from those 50 simulated rivebed elevations and LiDAR data from OpenTopography (2013) using the method described in Section 2.1 for each dataset. These 50 DEMs and 50 Manning's n maps are the same except for the river locations due to the use of 50 different simulated riverbed elevations. Hence, we only focus on analysing the variation in the simulated river bathymetric data used to generate these riverbed elevations instead of those simulated topographic data (see Section 3.2.). The DEMs and Manning's n maps that include the simulated river bathymetric data, along with the January-2005 flow and tidal data mentioned in Section 2.1, were then used in the LISFLOOD-FP flood model to produce 50 maximum water depths (MWDs) and 50 maximum water surface elevations (MWSEs) for further statistical analysis."*

To expand the flow of logic mentioned in question 1, we have added more details on how the uncertainties in the parameters used to estimate the river bathymetric data propagate through the LISFLOOD-FP flood model to the outputs as below:

Estimated parameters that include uncertainties (river slope, width, and flow) → two chosen formulas to estimate river bathymetric data → riverbed elevations → topographic data (DEM and Manning's n derived from roughness length) generated by riverbed elevations and LiDAR data → inputs to the LISFLOOD-FP flood model → affects flood extent and maximum water depth.

According to the above chain, we assumed uncertainties in the estimated river bathymetric data, in our case arising from the estimated parameters (river slope, flow, and width) and used these in two chosen formulas - Conceptual Multivariate

Regression (CMR) and Uniform Flow (UF) (mentioned at lines 168-169). The calculated river depths were then subtracted from the LiDAR-estimated water surface elevation to obtain the estimated riverbed elevations (mentioned at lines 135-138, 213-215). These riverbed elevations, along with the topographic LiDAR data collected from the OpenTopography, were then sampled and interpolated onto a square grid to obtain topographic data i.e., DEM and Manning's n (derived from roughness length) (mentioned at lines 146-147 and 223-226). These DEM and Manning's n were then used in the LISFLOOD-FP flood model to produce flood model outputs (mentioned at lines 137-139 and 212-216). As mentioned in question 1, we selected the MWDs and MWSEs among these outputs for uncertainty analysis.

### 2.3 Question 3

We divided this question into two sub-questions to answer as below:

***Question:*** The uncertainties in flood predictions come from several sources, including the accuracy of three parameters (S, Q and w), the accuracy of two formulas for bathymetry estimation, and the influence of bathymetry uncertainties on flood prediction. Unfortunately, the analysis conducted in this study is more likely a sensitivity analysis, without addressing these uncertainty sources clearly. The authors analyzed the uncertainty brought by a standard deviation of 10%, but the question should be what is the actual uncertainty in S, Q and w estimation themselves.

***Answer:*** Regardless of any approaches to estimate the river bathymetric data, due to the inability to capture the randomness of the real-world river systems, these estimations still contain errors. If they are used to represent the rivers in the topographic data like DEM which is an input for a flood modelling, the flood predictions will be affected. Based on this, our focus is to quantify the uncertainty in the flood model outputs due to such errors in the estimated river bathymetric data. This will help us to answer the research question: "How do the errors in the estimated river bathymetric data affect the flood model outputs?". Previous studies investigated the errors in river bathymetry estimations, but they did not evaluate how such errors could affect the flood model outputs. These whole ideas were mentioned in the Introduction Section lines 55-95 and rewritten for clarification as below:

- Lines 55-63: *"Regardless of any approaches to estimate the river bathymetric data, due to the inability to capture the randomness of the real-world river systems, these estimations still contain errors. These errors can cause the simulated river bathymetries to deviate significantly from the actual ones. Consequently, using these modelled river bathymetries to represent the rivers in food inundation modelling can affect the flood predictions. Currently, several studies have investigated the errors in the estimated river bathymetry (Durand et al., 2008; Lee et al., 2018; Moramarco et al.,2019; Kechnit et al., 2024), but they have not considered how these estimations with errors affect the flood model outputs."*
- Lines 64-73: *"For instance, Durand et al. (2018) developed an ensemble-based data assimilation approach for estimating river bathymetry from water surface elevation measurements and the LISFLOOD-FP hydrodynamic model. Using a Monte Carlo-based framework, they also performed a sensitivity analysis to assess how various error sources affected the estimated results. Their study found that errors in some input factors for their approach, such as river roughness and flow conditions, have greater influence than the water surface elevation measurement errors. However, this research did*

*not evaluate how the errors in these river bathymetric estimations can affect flood model outputs with consideration of spatial variability of input factors in the analysis."*

- Lines 79-83: *"Nevertheless, none of these studies investigated how uncertainties in such parameter estimations influence the river depths as well as the flood inundation model outputs, and they have not considered the spatial variability in their analysis."*
- Lines 87-89: *"Hence, their results might not be fully representative for such uncertainties in river bathymetry estimations. Also, their research did not consider how these uncertainties affect the flood inundation model outputs."*
- Lines 90-95: *"Generally, these previous studies have addressed certain gaps in quantifying uncertainties in estimated river bathymetry and show that errors can arise from various sources. However, they have not assessed how the flood inundation model outputs would be affected by errors or uncertainties in the river bathymetry. Additionally, their methods did not consider spatial variability in factors used to estimate river bathymetries and their results are not fully representative."*

In this paper, because we have no information about what the uncertainty is, we look into the sensitivity. Specifically, we developed a sensitivity analysis using Monte Carlo framework which can be used for different formulas and parameters. Within this framework, we chose two formulas that have been validated and used to estimate the river bathymetry at the Waikanae River - the UF and CMR - by Pearson et al. (2023). Due to the time intensity and complexity, we selected only three parameters - river slope, flow, and width - in these formulas and examined how their errors propagate through the flood modelling and affect the outputs. These ideas have been summarised and rewritten for clarity between lines 96-104 as below:

*"To fill these gaps, we quantified the uncertainty in flood predictions due to errors in the estimated parameters used in two formulas described in Rupp and Smart (2007) and Neal et al. (2021), and validated by Pearson et al. (2023). Within the Monte Carlo framework, we generated multiple realisations of river bathymetry, then used them to perform a sensitivity analysis to evaluate the impacts of each parameter on flood predictions, individually and collectively. We also considered the spatial variability in the analysis and whether our number of simulations is large enough to represent our results. This work can contribute to studies of other sources of uncertainty to adequately comprehend the uncertainty in flood model outputs. In the next section, we describe a method to explore relationships between the parameters within those two formulas and show a process to examine how errors in these parameters affect the flood predictions."*

As we do not have information about the sources or uncertainty, based on the observed riverbed elevations, we selected the errors for each parameters from a normal distribution with zero mean and standard deviation set to 10% of the best estimates of parameters. We added this information between lines 190-195 with Figure 3: *"Due to no information about the sources of errors, we assumed that their expected errors would be unbiased and normally distributed with zero mean and a standard deviation of 10% of the best-estimated values. This 10% was chosen because: (i) many observed cross-sectional riverbed elevations are within the simulated ensemble range (min-max) of simulated riverbed elevations - calculated from the simulated river bathymetric data (described in detail later in this Section) - as seen in Fig. 3; and (ii) with the same amount of errors, we* *can then compare the influences of those errors, between datasets, on the flood model outputs."*. This helps us to see how the errors propagate through the flood modelling and affect the flood predictions.

Different sources of errors should also be considered, but due to the time intensity and complexity, another research would be a better fit. This information is added in the Discussion Section between lines 419-423: *"Due to the lack of information about the sources of errors, the expected errors in our research were assumed to be unbiased and normally distributed with zero mean and a standard deviation of 10% of the best-estimated values. Hence, different realistic sources of errors should be considered to compare their impacts on the flood predictions. However, owing to the time intensity and complexity, this issue should be researched in another study."*

The main results have shown that between two formulas, the errors in the parameters using the UF formula are associated with greater uncertainty in flood predictions than the CMR formula. Apart from that, when validating the simulations with the observed flood data, the RMSEs between using two formulas are not much different. These key results demonstrate that the flood extent and flood depth are more sensitive to the UF formula than the CMR formula, but this did not translate to substantially reduced RMSEs in the validation. Moreover, the small difference in the RMSEs suggested the applicability of the UF formula to estimate the river without the need of river categorisation. Nevertheless, further research is needed to compare the UF formula with other approaches. This has been shown in Section 3.3, 3.4, and 3.5. It was also mentioned between lines 404-406 and rewritten for clarification: *"... However, because we have only compared the UF formula with the CMR developed for coarse-grained rivers, comparisons with other formulas and approaches are still needed to confirm the applicability of the UF formula."*.

Between the parameters considered in this study, the uncertainty in flood model outputs associated with the river slope parameter is the smallest, followed by the river flow and width. This information can support the data collection process when resources are limited. Specifically, we can focus on measuring the parameters that have the greatest impacts (river flow and width) and deprioritize the ones associated with the lowest influences (river slope). However, as mentioned above, due to the time intensity and complexity, we have not explored the errors in the river Manning's n as well as $\alpha$ and $\beta$ coefficients. This whole information was mentioned between lines 407-415 and was rewritten for clarification as below:

*"The results of our research can help the data collection process in which the parameters that have the greatest impact (specifically river flow and width) should be focused on measuring if resources are limited. Meanwhile, the parameter associated with the lowest influence (river slope) can be deprioritised. Nevertheless, due to the time-intensity and complexity, we have not explored the errors in the river Manning's n as well as $\alpha$ and $\beta$ coefficients. Furthermore, the Waikanae River bank-full flow is not strongly correlated with the variability of the bathymetry along the river as it nearly stays constant. This is based on the fact that the Waikanae River sections in our paper were not joined by major tributaries. Hence, future studies should investigate the errors associated with these factors and perform a thorough sensitivity analysis to better support the data collection process."*.

Generally, our focus is to find out how the errors in estimated river bathymetric data can affect the flood inundation model outputs. Since we have no information about what the uncertainty is, we look into the sensitivity. Furthermore, there are many sources of errors for such parameters and they would be different for different formulas. Hence, we developed this sensitivity analysis using the Monte Carlo framework that can be applicable to various formulas and parameters to assess which parameters that have errors can affect significantly on the flood model outputs. This also supports the data collection process, allowing it to focus on these parameters if the resources are limited and suggests future investigations to research errors in these parameters.

***Question:*** Besides, the study didn't use any measurement data to validate the estimated bathymetry, so the analysis actually only shows the range of estimated bathymetry caused by a 10% variation in S/Q/w, which, in my opinion, is a rather direct procedure from the viewpoint of mathematic, since the formulas for bathymetry (Eq.2) is a very simple equation.

The estimated river bathymetry for the Waikanae River was already validated by Pearson et al. (2023) (added at lines 97). Apart from that, as the reviewer said, this sensitivity of the 10% change on the equations is simple to compute, but understanding how that then affects the flood model ouptuts is not straightforward and that is what this manuscript investigates. In other words, this analysis provided information about how the errors in the estimated river bathymetric data can propagate and affect the flood inundation model outputs.

### 2.4 Question 4

***Question:*** Some questions about UF and CMR formulas. 1) According to section 2.2 the only difference in these two formulas is the different value of $\alpha$ and $\beta$, am I right? 2) Table 1: In my understanding, Manning's n should be a parameter reflecting the characteristics of riverbed. Why is it different in different formulas?

***Answer:*** The two formulas have different values of $\alpha$, $\beta$, and river Manning's n. The Conceptual Multivariate Regression formula has a constant river Manning's n because it is developed specifically for coarse-grained rivers. To highlight this idea, the information between lines 160-162: *"The CMR formula, designed for coarse-grained rivers, was selected to match with Waikanae River (Gyopari et al., 2014), and the UF formula was chosen for its simplicity (Neal et al., 2021) and can be widely applicable."*. Also, the information between lines 166-168 were rewritten: *"For the $\alpha$ and $\beta$ coefficients, the UF formula used constant values of 2/3 and 1/2 respectively, while the CMR formula, designed for coarse-grained rivers, applied 0.745 and 0.305 respectively with a constant value of 0.162 for Manning's n."*.

## 3 Reviewer 2

***Summary of reviewer's comments:*** The reviewer was asking for further information and clarification about the flood model used in the paper, adequate assessment of the uncertainty in flood model outputs, summary of previous publication - Nguyen et al. (2024b), context of this uncertainty analysis, and more case studies for robustness.

***Summary of authors' responses:*** We thank you so much for your help in pointing out where we lack clarification and need improvement. In general, we have added further information about LISFLOOD-FP - the flood model used in the paper. In this response, we have also indicated how we analysed the flood model outputs in the paper and summarised the previous publication - Nguyen et al. (2025). Finally, we have explained the robustness of our paper and suggested that another study would be better to investigate a wide range of rivers.

### 3.1 Question 1

***Question:*** Generally, the authors need to significantly improve the methods section to convey the methods used in this study. In particular, they did not provide enough explanation regarding the LISFLOOD modeling and the input data utilized. It is important to summarize the processes implemented by the model to understand the relationships presented in the results section. For example, processes such as, backwater effect, sediment processes, human regulations, etc.

***Answer:*** The information about LISFLOOD-FP model was rewritten for clarification and added more information between lines 143-155: *"In this study, LISFLOOD-FP (Bates et al., 2010; Neal et al., 2018), a 2D hydrodynamic model, was used to simulate the January-2005 flood event (which was calibrated for this site in Nguyen et al. (2025)) because it is well known for its computational efficiency and highly accurate flood model outputs (Nguyen et al., 2025). The DEM and Manning's n values, along with the flow information and tidal data mentioned above were used as input into this model.*

*In LISFLOOD-FP, the formula to compute the water flow $Qcell$ at the interface $i+1/2$ between cells $i$ and $i+1$ over a time step $\Delta t$ is:*

$$Qcell_{i+1/2}^{t+\Delta t} = \frac{q_{i+1/2}^{t} - gh_{flow}^{t}\Delta t Scell_{i+1/2}^{t}}{[1+\frac{g\Delta t n^2|q_{i+1/2}^{t}|}{(h_{flow}^{t})^{7/3}}]}\Delta x \tag{3}$$

*where $q^t$ represents the flux at time $t$, $\Delta x$ denotes the cell width, $Scell$ and $h_{flow}$ are the water surface slope and flow depth between cells (Bates et al., 2010). The flow formula here is displayed for the x direction, the y direction can be obtained analogously. The cell water depth $h_{flow}$ is updated based on the discharge through the four boundaries of that cell as below, where $i$ and $j$ denote the cell coordinates (Shustikova et al., 2019):*

$$\frac{\Delta h_{flow}^{i,j}}{\Delta t} = \frac{Qcell_{x}^{i-1,j} - Qcell_{x}^{i,j} + Qcell_{y}^{i,j-1} - Qcell_{y}^{i,j}}{\Delta x^2}." \tag{4}$$

The main inputs for the LISFLOOD-FP model to simulate the January-2005 flood event are the river flow data, tidal data, DEM, and Manning's n converted from roughness length. The main outputs of the model are the water surface elevation and water depth across the time series and their maximum values. Among them, the study chose the maximum water depths (MWDs) and maximum water surface elevations (MWSEs) to analyse. The information about these inputs and outputs was mentioned between lines 217-226:

*"Similar to Durand et al. (2008); Moramarco et al. (2019); Kechnit et al. (2024), and especially Nguyen et al. (2025), our research also applied a Monte Carlo framework to generate 50 DEMs and 50 Manning's n maps from those 50 simulated rivebed elevations and LiDAR data from OpenTopography (2013) using the method described in Section 2.1 for each dataset. These 50 DEMs and 50 Manning's n maps are the same except for the river locations due to the use of 50 different simulated riverbed elevations. Hence, we only focus on analysing the variation in the simulated river bathymetric data used to generate these riverbed elevations instead of those simulated topographic data (see Section 3.2.). The DEMs and Manning's n maps that include the simulated river bathymetric data, along with the January-2005 flow and tidal data mentioned in Section 2.1, were*

*then used in the LISFLOOD-FP flood model to produce 50 maximum water depths (MWDs) and 50 maximum water surface elevations (MWSEs) for further statistical analysis."*

According to Bates et al. (2010), the LISFLOOD-FP flood model does not assume uniform flow and includes the surface slope, $Scell$, which allows the model to simulate the situations like backwater effects - where the water flows uphill or slows down due to downstream resistance like tides. However, the flood model does not include sediment processes. Also, for human regulations, it partially supports by representing the levees/embankments, for example, through the DEM or manually inserted structures. In this study, the LISFLOOD-FP flood model and our research focuses on the pixel-level hydrodynamics and spatial water depth. Hence, the processes including backwater effect, sediment processes, and human regulations are not our main focus.

### 3.2 Question 2

We divided it into two sub-questions to answer as below:

***Question:*** I do not believe the authors adequately assess the uncertainty of floods, as they primarily evaluate the uncertainty of DEMs, bathymetry estimations, and roughness coefficients.

***Answer:*** The reviewer is correct, we do not assess all the uncertainties in floods as this would be an incredibly big task. Instead, we focus on this one particular aspect of uncertainty - the errors in river bathymetry estimation that can affect the flood predictions - to understand the bigger picture. To highlight this idea better, we have rewritten lines 55-104 as follows:

- Lines 55-63: *"Regardless of any approaches to estimate the river bathymetric data, due to the inability to capture the randomness of the real-world river systems, these estimations still contain errors. These errors can cause the simulated river bathymetries to deviate significantly from the actual ones. Consequently, using these modelled river bathymetries to represent the rivers in food inundation modelling can affect the flood predictions. Currently, several studies have investigated the errors in the estimated river bathymetry (Durand et al., 2008; Lee et al., 2018; Moramarco et al.,2019; Kechnit et al., 2024), but they have not considered how these estimations with errors affect the flood model outputs."*

- Lines 64-73: *"For instance, Durand et al. (2018) developed an ensemble-based data assimilation approach for estimating river bathymetry from water surface elevation measurements and the LISFLOOD-FP hydrodynamic model. Using a Monte Carlo-based framework, they also performed a sensitivity analysis to assess how various error sources affected the estimated results. Their study found that errors in some input factors for their approach, such as river roughness and flow conditions, have greater influence than the water surface elevation measurement errors. However, this research did not evaluate how the errors in these river bathymetric estimations can affect flood model outputs with consideration of spatial variability of input factors in the analysis."*

- Lines 79-83: *"Nevertheless, none of these studies investigated how uncertainties in such parameter estimations influence the river depths as well as the flood inundation model outputs, and they have not considered the spatial variability in their analysis."*

– Lines 87-89: *"Hence, their results might not be fully representative for such uncertainties in river bathymetry estimations. Also, their research did not consider how these uncertainties affect the flood inundation model outputs."*

– Lines 90-95: *"Generally, these previous studies have addressed certain gaps in quantifying uncertainties in estimated river bathymetry and show that errors can arise from various sources. However, they have not assessed how the flood inundation model outputs would be affected by errors or uncertainty in the river bathymetry. Additionally, their methods did not consider spatial variability in factors used to estimate river bathymetries and their results are not fully representative."*

– Lines 96-104: *"To fill those gaps, we quantified the uncertainty in flood predictions due to errors in estimated parameters used in two formulas described in Rupp and Smart (2007) and Neal et al. (2021), and validated by Pearson et al. (2023). Within the Monte Carlo framework, we generated multiple realisations of river bathymetry, then used them to perform a sensitivity analysis to evaluate the impacts of each parameter on flood predictions, individually and collectively. We also considered the spatial variability in the analysis and whether our number of simulations is large enough to represent our results. This work can contribute to studies of other sources of uncertainty to adequately comprehend the uncertainty in flood model outputs. In the next section, we describe a method to explore relationships between parameters within those two formulas and show a process to examine how errors in these parameters affect the flood predictions."*

Now, we briefly explain how we analyse this uncertainty in flood predictions arising from the estimated river bathymetry. The variability of simulations of the topographic data like DEM and roughness length/Manning's n gathers around the river due to the use of simulated river bathymetric data. Hence, we only focus on the variability of the simulated river bathymetric data (mentioned at lines 220-223) as analysed in Figures 5 and 6 in the paper.

After that, we analysed how the variability in the river bathymetric data can affect the flood model outputs based on MWDs and MWSEs. Specifically, for each of eight datasets of 50 MWDs, we computed their mean (mMWDs), standard deviation (sdMWDs), and coefficient of variation (covMWDs). Here, because the mMWDs and sdMWDs did not provide further insights, they are not considered in the paper. We also calculated proportion of simulations in which a given pixel was flooded (pFs) to distinguish where was always flooded, never flooded, and sometimes flooded throughout these realisations. These ideas were mentioned between lines 217-237.

For the flood extent, its calculation information was added between lines 234-237: *"Additionally, we computed expected flooded area or expected flood extent, a metric often employed by decision-makers, for each simulation for comparison. The expected flood extents were calculated based on these pFs by multiplying the area of one pixel (10 m x 10 m) with number of pixels that were always and sometimes flooded."*. Apart from this, we also validated each flood simulation - MWSE with the observed flood data - flood levels using the RMSE metric. This information was mentioned between lines 240-243: *"In our research, we went further than Nguyen et al. (2025) by validating each flood simulation - MWSE with the observed flood levels measured by Wallace (2010) for the January-2005 event. The Root Mean Square Error (RMSE) metric was harnessed for these validations."*

The results of covMWDs, flood extents, and RMSEs were shown in Figures 7-8, Figures 9-10, and Figure 11. This corresponds to the Sections 3.3, 3.4, and 3.5. In particular, we used boxplots (Figures 7, 9, 12) to compare the variations of eight datasets and maps (Figures 8 and 20) to visualise and explain. Here, our explanations linked with what we found in the variations of simulated river bathymetric data as shown in Figure 5 and mentioned in Section 3.2.

Generally, based on those Figures, we found that the variations in the MWDs based on covMWDs and flood extents correspond to the variations in the estimated river bathymetries. In particular, with the same amount of uncertainty added to each of eight datasets, the variation in the slope parameter corresponds to the smallest variation in the MWDs, followed by the flow and the width. Between two formulas, the errors in the parameters of the UF formula are associated with greater uncertainty in the MWDs than those of the CMR formula. We provided the explanation as below for each Section:

- For covMWDs, Section 3.3, lines 354-359: *"To explain, between parameter datasets, the small variability in the river bathymetry corresponding with the variation in the river slope does not significantly affect the water spreading into the floodplain, unlike the variations in the river bank-full flow and width. The impacts of all these variations become more apparent in floodplains farther from the river, especially at flood boundaries in midstream, where the water has less direct connection with the river. Between two formulas, because the variations in the UF-formula river bathymetries are higher than the CMR-formula ones as seen in Fig. 5, the variations in the flood depths of the UF-formula datasets are also higher than the CMR-formula datasets."*.

- For flood extents, Section 3.4, lines 371-376: *"Between the two formulas, the blue zoomed-in images highlight a location surrounding the river upstream to 1000 m downstream where the UF-formula river bathymetries are lower than the CMR-formula ones, resulting in greater flood extent here in the UF-formula datasets. This leads to that, in the UF-formula datasets, the flood extent variation appears not only in locations already totally flooded in the CMR-formula but also in new regions that are never flooded in the CMR-formula datasets. Consequently, there are more variations in flood extent in the UF-formula datasets compared to the CMR-formula datasets."*.

- For RMSEs, Section 3.5, lines 385-389: *"To explain, the CMR is developed for coarse-grained rivers like the Waikanae River, leading to lower RMSEs than the UF formula. In contrast, the UF formula was not developed for any specific river types, which may contribute to its slightly higher RMSE. However, these small differences in RMSEs between the two formulas highlight a broad applicability of the UF formula on rivers without categorising their types."*.

***Question:*** In addition, the authors did not indicate whether their sources of uncertainty are valid by referring to the ranges of DEM values, any reported roughness, etc.

***Answer:*** As we do not have information about the sources of uncertainty, based on the observed riverbed elevations, we selected the errors for each parameters from a normal distribution with zero mean and standard deviation set to 10% of the best estimates of that parameter. We added this information between lines 190-195 with Figure 3: *"Due to no information about the sources of errors, we assumed that their expected errors would be unbiased and normally distributed with zero mean and a standard deviation of 10% of the best-estimated values. This 10% was chosen because: (i) many observed cross-sectional* *riverbed elevations are within the simulated ensemble range (min-max) of simulated riverbed elevations - calculated from the simulated river bathymetric data (described in detail later in this Section) - as seen in Fig. 3; and (ii) with the same amount of errors, we can then compare the influences of those errors, between datasets, on the flood model outputs.*

Different realistic sources of errors should also be considered, but due to the time intensity and complexity, another research would be a better fit. This information is added in the Discussion Section between lines 419-423: *"Due to the lack of information about the sources of errors, the expected errors in our research were assumed to be unbiased and normally distributed with zero mean and a standard deviation of 10% of the best-estimated values. Hence, different realistic sources of errors should be considered to compare their impacts on the flood predictions. However, owing to the time intensity and complexity, this issue should be researched in another study."*

### 3.3 Question 3

***Question:*** In addition, they refer to a previous publication, Nguyen et al. (2024b), to get the key details for the methods used. For a smooth reading experience, the authors should summarize that key information in this manuscript as well.

***Answer:*** A summary of the key details of the methodology from Nguyen et al. (2025) pertinent to this work was added between lines 109-119 of Section 2: *"Our data and methodology were based on Nguyen et al. (2025) where the uncertainty in flood predictions due to arbitrary conventions in grid alignment was quantified. To explain, their research is also about how the uncertainty in the process of generating the topographic data like DEM and roughness length can propagate through the flood modelling to the outputs. Hence, their data and methodology can be applied in our research.*.

*Accordingly, we simulated the same flood event using the LISFLOOD-FP flood model and applied a similar method to generate topographic data. Moreover, a Monte Carlo framework was also designed in our research to observe how the uncertainty in estimated river bathymetries propagates through the flood modelling to the outputs. To assess the uncertainty, some similar measurements were used, some were not because they did not provide further information, and some were added to understand better the uncertainty. These similarities will be mentioned in details in the sections below."*.

### 3.4 Question 4

***Question:*** Moreover, the authors did not explain the context of this uncertainty analysis of the flood prediction. Also, they need to include the details about the flood event they used in this study to demonstrate what they want to establish from this study.

***Answer:*** The context of this uncertainty analysis of the flood was explained and rewritten for clarification as below:

- Lines 20-27: *"River bathymetry refers to the river depth measurement (Panigrahi, 20140). It plays a crucial role in flood modelling because it determines when and where water leaves the river channel and starts to flood overland (Cook and Merwade, 2009; Awadallah et al., 2022). Currently, hydrographic surveys and remote sensing methods, especially swath beam sonar and blue-green LiDAR, are prevalently employed to obtain these river bathymetric data (Coasta et al., 2009; Kinzel et al., 2013; Dey et al., 2019). Multi-beam sonar is effective but time-consuming, while blue-green LiDAR is faster but does not work in sediment-laden or deep water, and both of them are expensive (Bailly et al., 2010;*

*Flener et al., 2012; Bures et al., 2019). For these reasons, various approaches have been proposed to estimate these data (Ghorbanidehno et al., 2021; Araujo and Hedley, 2023).”*. We have changed "... unable to obtain measurements ..." to "... does not work ..." and added "... and both of them are expensive ...".

- Lines 55-63: *"Regardless of any approaches to estimate the river bathymetric data, due to the inability to capture the randomness of the real-world river systems, these estimations still contain errors. These errors can cause the simulated river bathymetries to deviate significantly from the actual ones. Consequently, using these modelled river bathymetries to represent the rivers in food inundation modelling can affect the flood predictions. Currently, several studies have investigated the errors in the estimated river bathymetry (Durand et al., 2008; Lee et al., 2018; Moramarco et al.,2019; Kechnit et al., 2024), but they have not considered how these estimations with errors affect the flood model outputs."*

- Lines 90-95: *"Generally, these previous studies have addressed certain gaps in quantifying uncertainties in estimated river bathymetry and show that errors can arise from various sources. However, they have not assessed how the flood inundation model outputs would be affected by errors or uncertainties in the river bathymetry. Additionally, their methods did not consider spatial variability in factors used to estimate river bathymetries and their results are not fully representative."*

- Lines 96-104: *"To fill those gaps, we quantified the uncertainty in flood predictions due to errors in estimated parameters used in two formulas described in Rupp and Smart (2007) and Neal et al. (2021), and validated by Pearson et al. (2023). Within the Monte Carlo framework, we generated multiple realisations of river bathymetry, then used them to perform a sensitivity analysis to evaluate the impacts of each parameter on flood predictions, individually and collectively. We also considered the spatial variability in the analysis and whether our number of simulations is large enough to represent our results. This work can contribute to studies of other sources of uncertainty to adequately comprehend the uncertainty in flood model outputs. In the next section, we describe a method to explore relationships between parameters within those two formulas and show a process to examine how errors in these parameters affect the flood predictions."*

We rewrote and added more information about the study site as well as the flood event between lines 121-130: *“Similar to Nguyen et al. (2025), the Waikanae River, located on the West Coast of the Wellington Region in New Zealand, was used in this paper. Its catchment covers around 149 km$^2$ and spans from the Tararua Ranges to the West Coast. There are recurring flooding issues at this study site that have influenced the regions around the river.*.

*In this study, we simulated a flood event with an 80-year return period that occurred in Waikanae from January $5^{th}$ to $7^{th}$, 2005 and reached its peak on 6th. Here, we focused on fluvial flooding from the Waikanae River. This allowed us to observe how the uncertainty in the estimated river bathymetric data can impact the flood inundation model outputs. Figure 1a depicts our site study extending about 7 km from the Waikanae Water Treatment Plant gauge to the coast. Figures 1b and 1c show the flow information recorded at the gauge by the Greater Wellington Regional Council (2005) and the tidal data estimated by the NIWA Tide Forecaster (2005) respectively.”*.

### 3.5 Question 5

***Question:*** The authors need to enhance their experimental methods to strengthen the robustness of their findings, such as applying these analyses to various case studies across a wide range of rivers.

***Answer:*** As we mentioned in the paper and in question 4, there are many approaches to estimate the river bathymetric data. However, due to the inability to capture the randomness of the river systems, errors in the estimations can introduce uncertainties that significantly deviate the simulated river bathymetries from the actual ones. Consequently, using these estimated river bathymetries to represent the river in the flood modelling can affect the flood predictions. Previous studies have investigated such errors in the river bathymetry estimations, but they did not evaluate how the flood model outputs would be affected if those estimations were used to represent the rivers in the flood modelling.

To contribute to this field, we quantify the uncertainty in flood predictions due to the estimated river bathymetries. In our case, we have investigated how the errors inherent in the estimated parameters (river slope, flow, and width) used in two formulas (CMR and UF) can propagate through the flood modelling to the flood predictions. These formulas were validated by Rupp and Smart (2007) and Neal et al. (2021), and validated for the Waikanae River and Buller River by Pearson et al. (2023).

Although our research was conducted at one study site, it helps raise the awareness of flood modellers who use estimated river bathymetries in their flood modelling. Furthermore, in this study, we provided a thorough Monte Carlo framework to capture the uncertainty in the flood model predictions arising from the estimated river bathymetry. We designed this framework including spatial variability which was not considered by previous studies (Durand et al., 2008; Lee et al., 2018; Moramarco et al., 2019; Kechnit et al., 2024) and using larger number of simulations than theirs. We also performed a sensitivity analysis collectively and individually. Hence, this framework can be applied to a wide range of formulas used to estimate river bathymetries.

Between lines 391-400, we rewrote for clarification: *"Our research went a step further than previous studies (Durand et al., 2008; Lee et al., 2018; Moramarco et al., 2019; Kechnit et al., 2024) to quantify the uncertainty in flood predictions due to the errors in the estimated river bathymetry. It helps raise the awareness of flood modellers who also use estimated river bathymetries in flood modelling. In this research, we applied the Monte Carlo method to generate a large number of simulations to capture the typical variability in the flood predictions and included spatial variability in our method. Moreover, we not only considered associated error distributions in parameters collectively, but we also performed a sensitivity analysis to assess the impact of each parameter. This analysis framework can then be applied to a wide range of formulas that are used to estimate river bathymetries to represent rivers in the flood modelling."*.

Based on our results, we found out some key points that can develop further research. Specifically, we have suggested the applicability of the UF formula without the need of river categorisation. However, we have only compared it with the CMR formula and this still needs further investigations with other equations. Between lines 404-406, we rewrote the idea for clarification: *"... However, because we have only compared the UF formula with the CMR developed for coarse-grained rivers, comparisons with other formulas and approaches are still needed to confirm the applicability of the UF formula."*.

We also observed that the uncertainty in flood predictions associated with the errors in the river slope parameter is the smallest, followed by the river flow, and width. This information can help the data collection process in which the parameters that have the greatest impact (specifically flow and width) should be focused on measuring if resources are limited. Meanwhile, the parameter associated with the lowest influence (river slope) can be deprioritised. However, due to the time-intensity and complexity, we have not explored the errors in the river Manning's n as well as $\alpha$ and $\beta$ coefficients. Hence, further research is necessary to perform a more thorough sensitivity analysis between these parameters and perhaps between formulas.

The above ideas were rewritten between lines 407-415: *"The results of our research can help the data collection process in which the parameters that have the greatest impact (specifically river flow and width) should be focused on measuring if resources are limited. Meanwhile, the parameter associated with the lowest influence (river slope) can be deprioritised. Nevertheless, due to the time-intensity and complexity, we have not explored the errors in the river Manning's n as well as $\alpha$ and $\beta$ coefficients. Furthermore, the Waikanae River bank-full flow is not strongly correlated with the variability of the bathymetry along the river as it nearly stays constant. This is based on the fact that the Waikanae River sections in our paper were not joined by major tributaries. Hence, future studies should investigate the errors associated with these factors and perform a thorough sensitivity analysis to better support the data collection process."*.

In practice, different rivers will have different characteristics, so we agree that the suggestion for applying our investigation to various case studies across a wide range of rivers is necessary. However, due to the amount of work, we leave this to future research. We have added this idea after line 416-418: *"In practice, different rivers will have different characteristics. Hence, it is necessary to generalise this study by considering a wide range of rivers for comparison and confirmation for the results found here. Accordingly, further research focusing on many rivers with diverse features is recommended."*.

## 4 Extra changes

### 4.1 Rewrite abstract

We rewrote the abstract to enhance the readability and consistency and also for clarification at lines 1-18 as below. In that the previous information - *"The results indicate that, between the two methods, the combined errors in the parameters using the Uniform Flow formula are associated with greater uncertainty in flood depths (median error: 3.89 m, quartile range: 2.36 to 7.78 m) and extents (208.72 ha, 206.59 to 209.58 ha), compared to Conceptual Multivariate Regression (depth: 3.61 m, 2.32 to 7.37 m; extent: 207.82 ha, 206.42 to 208.48 ha)"* - was removed because this belongs to intial analysis and we decided not to use this information anymore.

**Abstract:** *"River bathymetry is important for accurate flood inundation modelling but is often unavailable due to the time-intensive and expensive nature of its acquisition. This leads to several proposed and implemented approaches for its estimation. However, the errors in estimations inherent in these methods and how they affect the accuracy of the flood inundation modelling outputs, has not been extensively researched. Hence, to contribute, we investigate the sensitivity of flood predictions to the errors in river slope, width, and bank-full flow used in two formulas - the Uniform Flow and the Conceptual Multivariate Regression - for estimating river bathymetry. In this study, we employed a Monte Carlo framework to introduce random errors into these parameters drawn from a normal distribution with zero mean and a standard deviation set to 10% of their best estimates. Using this process, we generated 50 simulated river bathymetries for each parameter along with an additional 50 where the* *errors were applied to all parameters simultaneously. The riverbeds generated from these bathymetries were combined with topographic LiDAR data to create model grids. Each grid was used in the hydrodynamic model LISFLOOD-FP to simulate the 2005 flood event in the Waikanae River area of New Zealand. We assessed the resulting flood inundation predictions for their variability and sensitivity. The results indicate that between two methods, the errors in the parameters in the Uniform Flow formula are associated with greater uncertainty in flood inundation depths and extents compared to the Conceptual Multivariate Regression. Among the parameters, the width errors correspond to the highest uncertainty, while the slope errors correspond to the lowest."*.

### 4.2 Rewrite Section 2.1. Study site and data source

In Section 2.1., we also rewrote lines 131-139 for clarification: *"Following the approach of Nguyen et al. (2025), the topographic data - DEM and roughness length - in our paper were generated by an open-source Python package, GeoFabrics (version 0.9.4) developed by Pearson et al. (2023). Specifically, the package sampled and interpolated LiDAR point cloud data downloaded from OpenTopography (2013) onto a 10-metre square grid using Inverse Distance Weighted – an interpolation method has been commonly used in flood modelling (Ibrahim and Fritsch, 2022; Xing et al., 2022; Huang et al., 2023). To represent the river in this process, since the LiDAR only contains the water surface elevations, the estimated riverbed elevation data were then obtained to be included in the point cloud data by subtracting the estimated river bathymetric data or river depths (see Section 2.2) from these water surface elevations. The roughness length was converted to Manning's n using a conversion developed by Smart (2018)"*

### 4.3 Rewrite Conclusion

In the Conclusion Section, we rewrote between lines 441-457 to match with what we adjusted in the Discussion Section as below:

– Lines 451-461: *"Our analysis framework can be applied to various formulas used to estimate the river bathymetries to represent rivers in the flood modelling. The slight differences in RMSEs between the two formulas suggest a broad applicability of the UF formula across many river types without categorising them, but further study is still necessary to confirm this. Moreover, our results can support the data collection process by directing it to focus on measuring the parameters that have more significant impacts on the flood inundation model outputs if the resources are limited. Additionally, due to the time-intensity and complexity, the river Manning's n, and $\alpha$ and $\beta$ coefficients were not considered in our study, and thus further research about these parameters including a thorough sensitivity analysis are recommended."*

– Lines 462-468: *"Apart from that, since different rivers have different characteristics and our work only focuses on the Waikanae River, another study implemented on many rivers with different features is essential. In addition, further investigation should consider how different realistic sources of errors affect the flood predictions. Another future topic of interest is the impact of grid resolution on the estimated river bathymetry, which then influences the flood inundation* *predictions. Currently, to cover such uncertainty, a freeboard is often used, but it fails to cover the variation in the flood extent, and thus a further study is needed to improve its effectiveness. Lastly, there is a need for simpler and faster method than Monte Carlo framework such as machine learning approaches."*

### 4.4 Correct some grammars and vocabularies

There are some grammar and vocabulary mistakes we would like to edit for accuracy and consistency as below:

- Changed "categorize" to "categorise" at lines 28, 40, 389, 404, and 453.
- Changed "minimize" to "minimise" at line 76.
- Changed "visualize" to "visualise" at lines 181, 238, 244, 364.
- Rewrite lines 215-216: "Eight datasets of these simulated river data were organised and presented in the Table 2

### 4.5 Changing styles of Figures and Tables

We re-styled all the Figures and Tables for readibility as below:

- Figure 1: We combined the hydrograph and tidal graph into one (b) and changed the caption: *"Study site and data source (adapted from Nguyen et al., 2025): (a) Waikanae River flow discharge recorded by the (Greater Wellington Regional Council, 2005) and tidal data recorded by the (NIWA Tide Forecaster, 2005) for the flood event from $5^{th}$ to $7^{th}$ January, 2005."*
- Figure 8 and 10: We combined all subfigures into one figure.
- Table 1 and 2: We created these tables directly in Latex rather than added them as pictures.