# Responses to the first reviewer about: "Quantifying uncertainty in flood predictions due to river bathymetry estimation"

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Dear editorial support team and reviewer,

We thank you so much for the opportunity to reply to the reviewer about "Quantifying uncertainty in flood predictions due to river bathymetry estimation". Please see below, in green, for our responses.

***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 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 question we are trying to fill in. Finally, we have shown the difference between two formulas with explanation.

## 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:*** 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 time-consuming, expensive, and sometimes unable 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 18-24. In that, more information has been added between lines 22-23: *"Multi-beam sonar is effective but time-consuming, while blue-green LiDAR is faster but unable to obtain measurements in sediment-laden or deep water, and both of them are expensive."*.

Due to the inability to capture thoroughly the randomness of the river systems, these estimations contain uncertainties. If these estimated river bathymetric data are used to calculate the riverbed elevations to represent the river in topographic data like DEM and Manning's n (converted from roughness length) and use these data in a flood modelling, the flood 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 roughness length/Manning's n) generated by riverbed elevations and LiDAR data → inputs to a flood model (LISFLOOD-FP in this study) → affects flood model outputs

This information was written between lines 52-55 in the Introduction section, but it has been rewritten for clarification: *"Regardless of any approaches, due to the inability to capture the randomness of the river systems, errors in the measurements or estimations can introduce uncertainties that significantly deviate the simulated river bathymetries from the actual ones. Consequently, using these modelled river bathymetries to represent the river in flood modelling can affect the flood predictions. Currently, only limited studies concentrate on how these errors in bathymetry estimation can have impacts on the flood model outputs (Durand et al., 2008; Lee et al., 2018; Moramarco et al.,2019; Kechnit et al., 2024)."*.

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) (rather than forecasting streamflow or peak timing) are selected to analyse how they are influenced by the uncertainties in the estimated river bathymetric data. This flood model output was chosen because its 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. This whole information was mentioned between lines 163-169. As to the flood extents, thank you so much for helping us to point this out, its information has been added at line 169: *"The flood extents were then 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 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:*** The information about LISFLOOD-FP model was shortly mentioned between lines 105-106: *"These DEM and Manning's n were then applied to the LISFLOOD-FP flood model (Bates et al., 2010; Neal et al., 2018), which was calibrated for this site in Nguyen et al. (2024b), to run the flood simulations."*. However, for clarification, more information have already been added from line 105: *"In this study, LISFLOOD-FP model, a 2D hydrodynamic model, is chosen to simulate the January-2005 flood event because it is well known for its computational efficiency and highly accurate flood model outputs (Nguyen et al., 2025). In this flood model, the formula to compute the water flow $Qcell$ between cells at index $i$ 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 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):

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

This flood model was calibrated for the Waikanae River site in Nguyen et al. (2025).".

The main inputs for the LISFLOOD-FP model to simulate the January-2005 flood event are the river flow data, tidal data, topographical data that include the estimated river bathymetry - DEM and Manning's n converted from roughness length using the equation 1 mentioned in the paper. The main outputs of the model are water surface elevation and water depth across the time series and their maximum values. Among them, the study chose the MWDs to analyse as mentioned in question 1. The information about these inputs and outputs was mentioned in the paper but has been rewritten between lines 163-164 for clarification: *"These DEMs and Manning's n maps that include the simulated river bathymetric data, along with January-2005 flow and tidal data, were then used in the LISFLOOD-FP flood model to produce 50 maximum water depths (MWDs) for further statistical analysis."*. In this, Nguyen et al. (2024b) is now published as Nguyen et al. (2025).

To expand the flow of logic mentioned in the question 1, here we 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) → inputs to the LISFLOOD-FP flood model → affects maximum water depth.

According to the above chain, we assumed the uncertainties in the estimated river bathymetric data arising from the estimated parameters (river slope, flow, and width) used in two chosen formulas - Conceptual Multivariate Regression (CMR) and Uniform Flow (UF) (mentioned between lines 119-120). These river bathymetric data were then subtracted from the LiDAR-estimated water surface elevation to obtain the riverbed elevations (mentioned lines 158-160). 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 like DEM and roughness length/Manning's n (mentioned lines 96-101, 161-163). The roughness length/Manning's n was then used in the LISFLOOD-FP flood model to produce flood model outputs. As mentioned before, we selected the MWDs among these outputs for uncertainty analysis for easy data manipulation.

## 3 Question 3

As this question includes a lot of small queries, we divided it 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 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 question: "How significant is the uncertainty in the flood predictions arising from the errors in the estimated river bathymetric data?". There have been some papers that tried to answer this question, but there are certain gaps in their methodologies. This idea was written between lines 52-55 and lines 75-78. In that, lines 52-55 have been rewritten for clarification: *"Regardless of any approaches, due to the inability to capture the randomness of the river systems, errors in the measurements or estimations can introduce uncertainties that significantly deviate the simulated river bathymetries from the actual ones. Consequently, using these modelled river bathymetries to represent the river in flood modelling can affect the flood predictions. Currently, only limited studies concentrate on how these errors in bathymetry estimation can have impacts on the flood model outputs (Durand et al., 2008; Lee et al., 2018; Moramarco et al.,2019; Kechnit et al., 2024)."*.

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. (2021). Due to the time intensity and complexity, we selected three parameters - river slope, flow, and width - and examined how their errors propagate through the flood modelling and affect the outputs. This idea was written between lines 79-82, and have been rewritten for clarification: *"In this paper, 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). These two methods were validated by Pearson et al. (2021). Within the Monte Carlo framework, we generated multiple realisations of river bathymetry, then used this to perform a sensitivity analysis to evaluate the impacts of each parameter on flood predictions, individually, and collectively.”*.

The errors of each parameter were drawn from a normal distribution with zero mean and a standard deviation set to 10% of the best estimate of that parameter. We chose that 10% for all parameters because: (i) several observed cross-sectional riverbed elevations fall within the area of simulated riverbed elevations - calculated from the simulated river bathymetric data as seen in Figure 1 of this answer sheet; (ii) with the same amount of errors, we can then compare the impacts of those errors, between datasets, on the flood predictions. Generally, this helps us to see, with this small amount of errors, how they propagate through the flood modelling and affect the flood model outputs. Higher levels of errors such as 20%, 30%, etc. should also be considered, but due to the time intensity and complexity, another research would be a better fit. This information and the Figure 1 in this answer sheet will be added into the paper.

The main results have shown that the errors in the estimated river bathymetric affect at some level to the flood model outputs. In particular, between two formulas, the errors in the parameters using the UF formula are associated with greater uncertainty in flood predictions than the CMR formula. However, when we validated them with the observed flood data, their RMSEs are not much different. This 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 has also been mentioned between lines 335-337, but it has been rewritten for clarification: *“... However, because we have only compared the UF formula with the CMR developed for coarse-grained rivers, other comparisons with other formulas still need further research to confirm the applicability of the UF formula.”*.

Between parameters, 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 the resources are limited. Specifically, we can focus on measuring the parameters that have the greatest impacts (river flow and width) and deprioritize the one 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 friction as well as $\alpha$ and $\beta$ coefficients. This has been shown in Section 3.3, 3.4, and 3.5. This point was also mentioned between lines 338-341 and has been rewritten for clarification: *“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 friction 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. Hence, future studies should investigate the errors associated with these factors and perform a thorough sensitivity analysis to support the data collection process better.”*.

Generally, our focus is to find out how the errors in estimated river bathymetric data can affect the flood 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

(a)

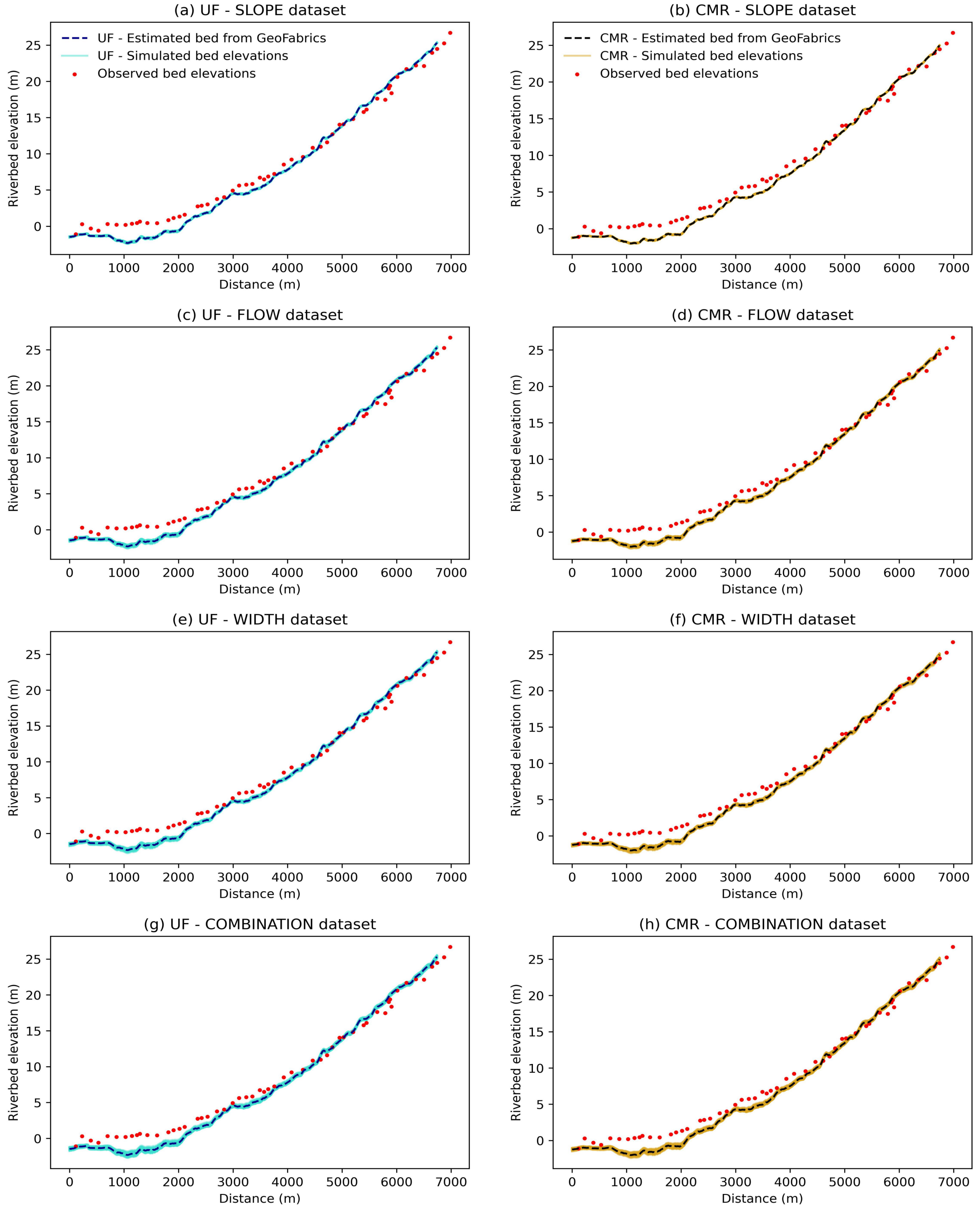


**Figure 1.** Observed cross-sections, best estimates, and simulations of riverbed elevations at the Waikanae River: the Uniform Flow formula - (a) slope, (c) bank-full flow, (e) width, and (g) combined; the Conceptual Multivariate Regression formula - (b) slope, (d) bank-full flow, (f) width, and (h) combined.

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 will support the data collection process to focus on these parameters if the resources are limited and also suggest future investigations to research on 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. (2021). As mentioned above, the errors for each parameter were selected from a normal distribution with zero mean and a standard deviation set to 10% of the best estimate of that parameter. Based on this and to also consider the spatial variability along the river, the Gaussian variograms were applied to generate unconditional simulations for each parameter. This idea has been written and explained in Section 2.4 between lines 138-155. 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 extent 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 model outputs.

## 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 117-118 can be rewritten: *"For the $\alpha$ and $\beta$ coefficients, the UF formula used two constant values of 2/3 and 1/2, while the CMR formula, designed for coarse-grained rivers, applied 0.745 and 0.305 respectively with another constant value of 0.162 for Manning's n."*.