UNCERTAINTY IN BATHYMETRY ESTIMATION

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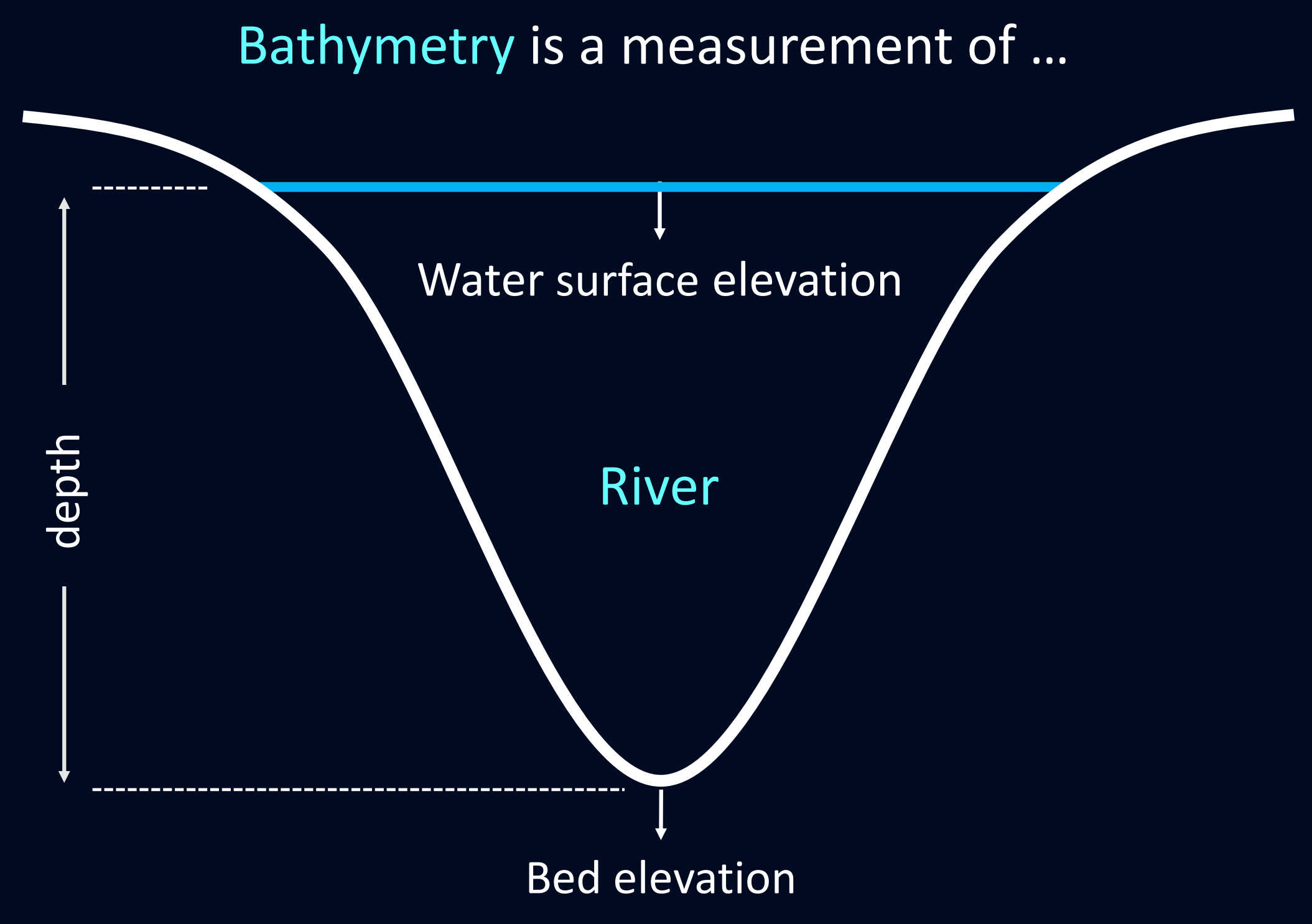
INTRODUCTION

River bathymetry plays a crucial role in flood modelling in the form of Digital Elevation Model (DEM). It increases the reliability, accuracy and continuity of the DEM. However, river bathymetry is not always available in data-scarce areas because of the time-intensive and expensive data collection process. This leads to the development of numerous conceptual models and interpolation algorithms for approximating river bathymetry (Neal et al., 2021). However, due to limitations in acquiring real-world data and in algorithms, these estimations can introduce implicit uncertainties which can propagate to the model results. These uncertainties will have a direct impact on the amount of flow discharge along the river, which in turn will impact the level of flood depths in the floodplain.

This research investigated the variation in the outputs of a flood model, where multiple DEMs were generated from topographic LiDAR and bathymetric data estimated by formula of Rupp and Smart (2007), and each was used to predict flood inundation. In that, the values of the flow discharge, the channel width, and the channel slope used to estimate the bathymetric data for Waikanae River area, New Zealand were adjusted to produce multiple DEMs. These DEMs containing different riverbed (bed) elevation information were then used in the hydraulic model LISFLOOD-FP to generate the flood maps. The variability in the results was then analysed statistically, allowing the sensitivity of model predictions to be assessed.



BATHYMETRY ESTIMATION FORMULA

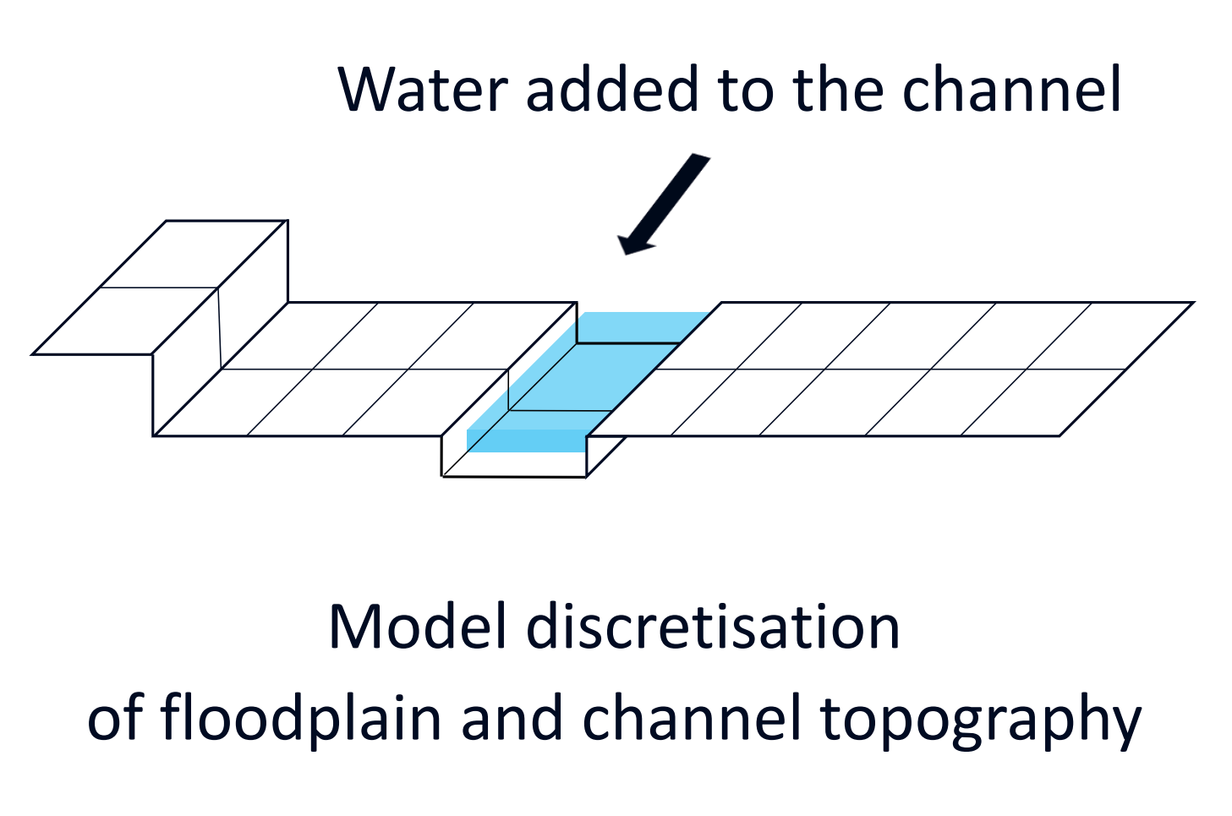
$$h = \left(\frac{Q}{6.16 * w * S^{0.305}}\right)^{\frac{1}{1.745}}$$

$$bed\ elevation = wse_{bankfull\ height} - h$$

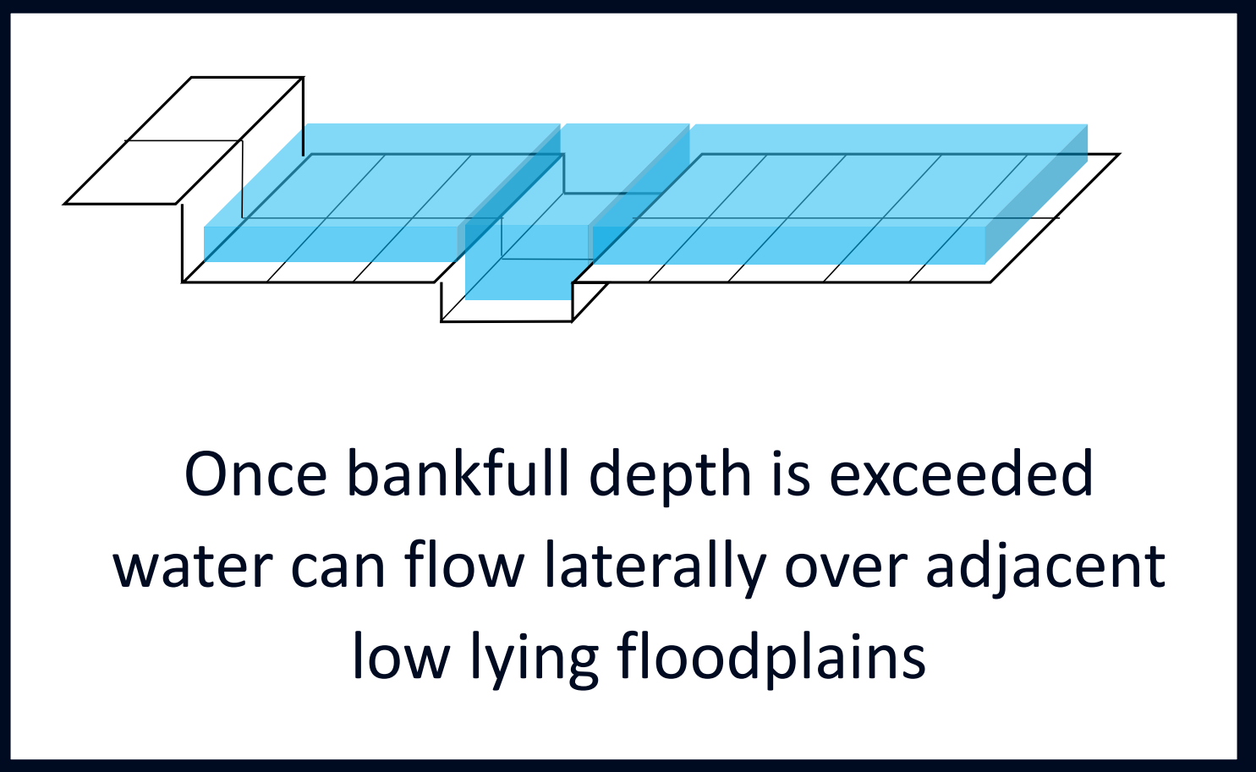
- h (m) : river channel depth estimated by Rupp and Smart's formula (2007)
- Q (m^3/s) : river flow discharge
- w (m) : river channel width
- S (m/m) : river channel slope
- wse (m) : river water surface elevation estimated at bankfull height

FLOOD MODEL – LISFLOOD-FP

A 2D hydrodynamic model developed specifically to simulate floodplain inundation



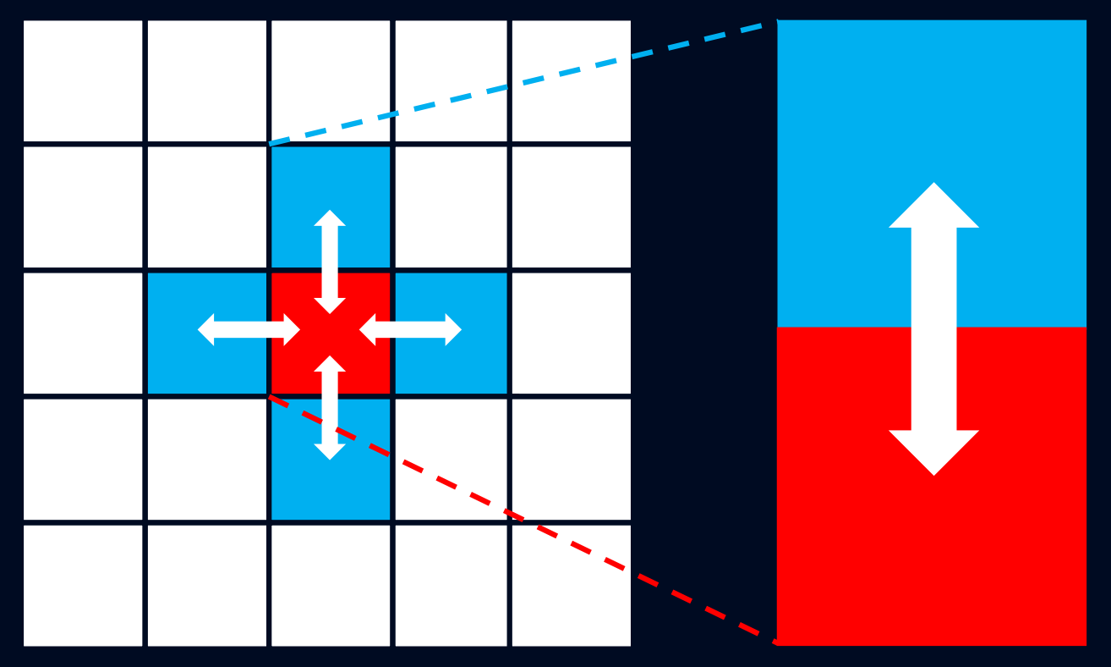
Model discretisation
of floodplain and channel topography



Once bankfull depth is exceeded
water can flow laterally over adjacent
low lying floodplains

CONTINUITY EQUATION

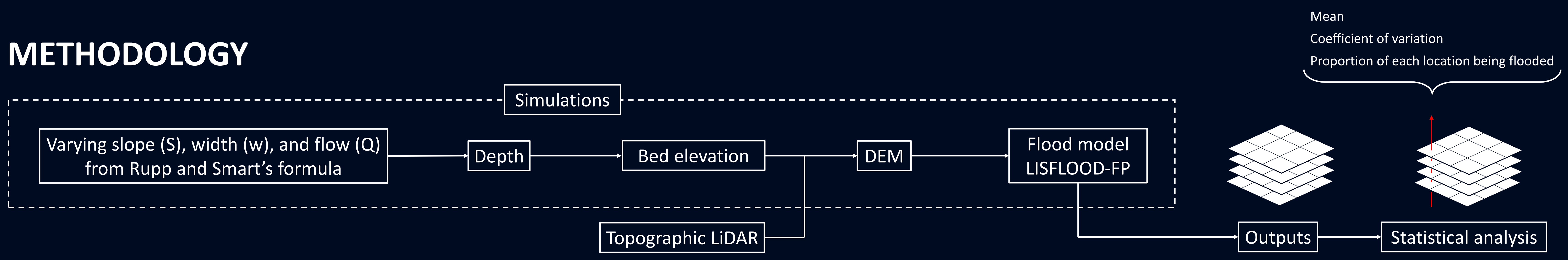
Change in cell depth is equal to the sum of water flow into the cell over each of the four cell boundaries



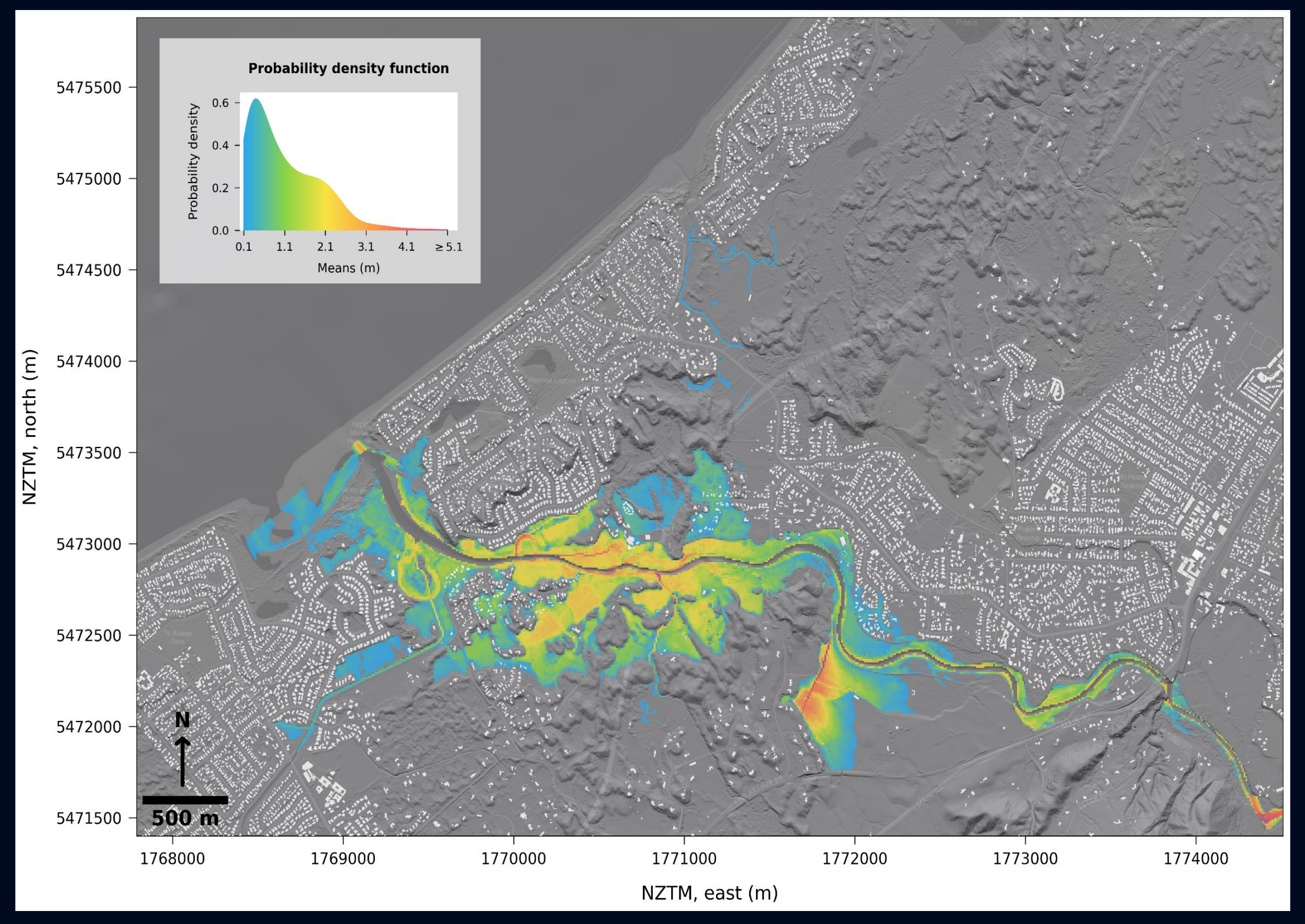
MOMENTUM EQUATION

To compute the water flow between two cells

METHODOLOGY

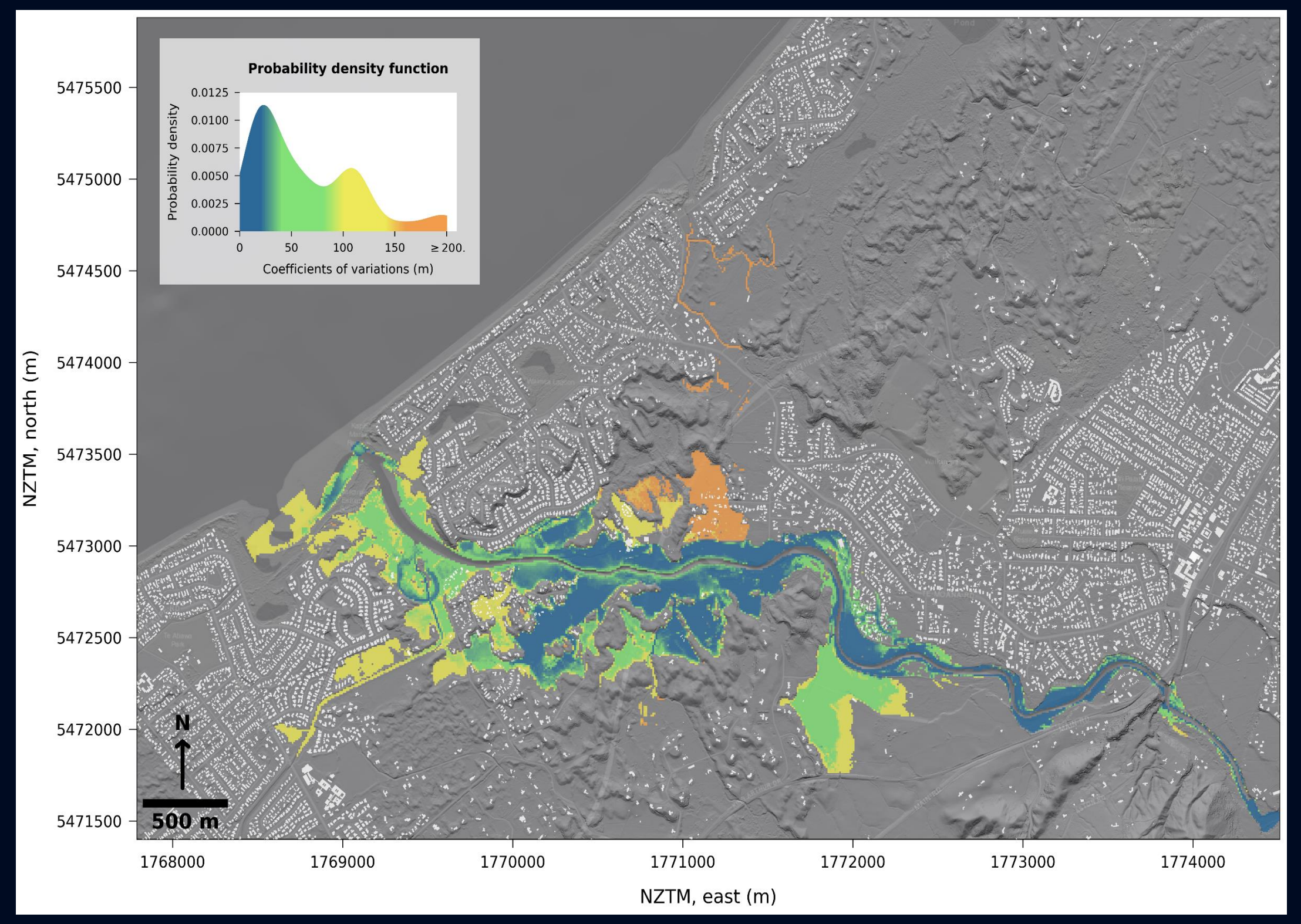


RESULTS



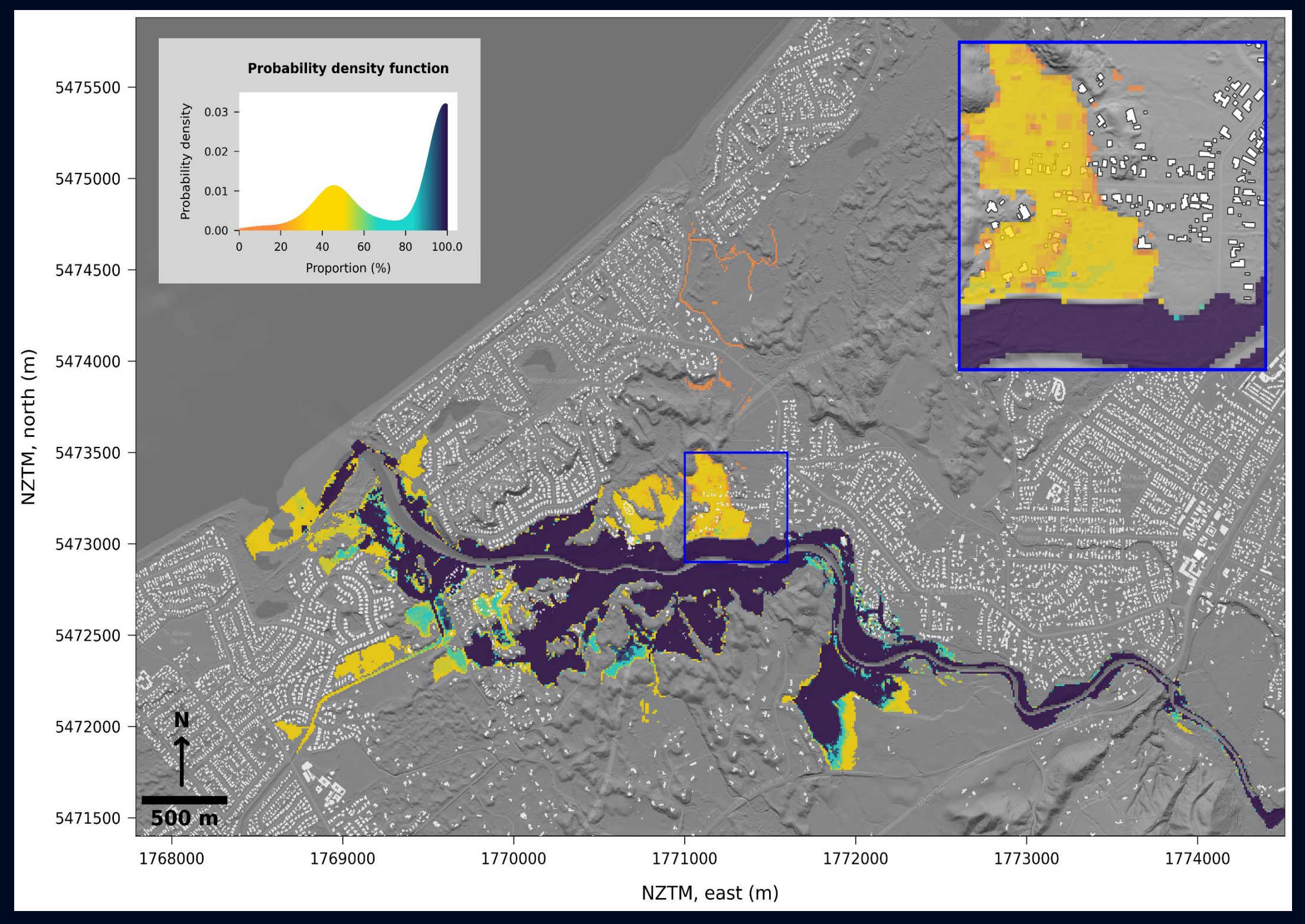
Means of water depths

Shallower flood water is towards the downstream of the river and at the edges of the flood extent (~ 0.1 m). Deeper flood water is more prevalent in the floodplain near the river and distributaries (≥ 1.1 m). The mean water depth distribution has a negative skew, indicating that the majority of flooded areas have depth values between 0.1 and ~ 1.1 m.



Coefficients of variation of water depths

The coefficient of variation expresses the standard deviation as a percentage of the mean. High variability (> ~ 50%) is readily visible at the flood extent boundaries, at some locations far away from the river, and in the floodplain near the end of downstream. Low variability (< ~ 20%) is in the floodplain near the river and towards the upstream of the river.



Proportions of each location being flooded

Locations along the edges of the flood extent, far away from the river, and in the floodplain near the end of the downstream were flooded in only ≤ 50% of the simulations, indicating a low confidence in predicted flooding. Most of locations near and along the river were flooded in ~ 100% of the simulations, indicating the highest confidence in predicted flooding.

CONCLUSION

Adjusting the values of flow discharge, channel width, and channel slope in Rupp and Smart's (2007) formula resulted in high uncertainty in flood predictions, particularly along the flood extent boundaries, far away from the river, and in the floodplain near the end of the downstream.

Further work is needed to examine the impact of changing individual values of flow discharge, channel width, and channel slope on flood predictions. In order to capture the most representative variability in flood predictions, this research should quantify the uncertainty in a more generalised bathymetry estimation formula that includes more estimated parameters.

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REFERENCES

Neal, J., Hawker, L., Savage, J., Durand, M., Bates, P., & Sampson, C. (coefficient for coarse-grained rivers" by Raul Lopez, Javier Barragan, and M. `Angels Colomer. Journal of Hydrology - J HYDROL, 346, 174–178. doi: 10.1016/j.jhydrol.2007.08.024

Pearson, R. (2021). Geofabrics. Retrieved June 13, 2022, from https://github.com/rosepearson/GeoFabrics2021). Estimating River Channel Bathymetry in Large Scale Flood Inundation Models. Water Resources Research, 57 (5). doi: 10.1029/2020WR028301

Rupp, D., & Smart, G. (2007). Comment on "Flow resistance equations without explicit estimation of the resistance coefficient for coarse-grained rivers" by Raul Lopez, Javier Barragan, and M. `Angels Colomer. Journal of Hydrology - J HYDROL, 346, 174–178. doi: 10.1016/j.jhydrol.2007.08.024