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Discharge and location dependency of calibrated main channel roughness: case study on the River Waal

B.C.A. Domhof[a,*], K.D. Berends[a,b], A. Spruyt[b], J.J. Warmink[a], S.J.M.H. Hulscher[a]
[a]*University of Twente, Department of Water Engineering and Management, Faculty of Engineering Technology, P.O. Box 217, 7500 AE, Enschede, the Netherlands*
[b]*Deltares, P.O. Box 177, 2600 MH Delft, The Netherlands*

Introduction

Hydrodynamic river models are used to predict water levels along the river and support decision making in river management. Therefore, the model predictions need to be sufficiently accurate. To increase the accuracy of the predictions, hydrodynamic river models are calibrated and validated. Often the hydraulic roughness coefficient is calibrated because it is the most uncertain parameter in hydrodynamic river models (Pappenberger et al., 2005).

The physical bed roughness can vary along the longitudinal direction of the river due to differences in bed sediment. Moreover, as discharge increases, river dunes grow leading to an increasing bed roughness (Julien et al., 2002). Therefore, it is hypothesized that the calibrated main channel hydraulic roughness is mostly sensitive to the discharge and location in longitudinal direction of the river. The calibration study of Warmink et al. (2007) confirms this hypothesis but does not explain why the calibrated roughness varies.

Our objective is to explain why variations in the calibrated roughness parameter occur and whether its value depends on the location or discharge used for calibration. We use a case study on the River Waal in The Netherlands.

Method

In this study we calibrated the Manning coefficient of the main channel roughness of the 1D Waal SOBEK 3 model for the winter of 1995. The location dependency is investigated using a varying number of roughness trajectories of roughly equal length for a bankfull discharge peak and a flood stage discharge peak. A roughness trajectory is defined as a river section between two water level observation stations with a uniform roughness. The discharge dependency is investigated using a varying number of discharge levels and five roughness trajectories. A discharge level is defined as the discharge for which the roughness is calibrated. A window around the discharge level of the peaks for the location dependency was applied to limit the calibration time period. Calibration is performed automatically using OpenDA (OpenDA, 2015) with a weighted non-linear least squares objective function and the DuD optimization algorithm (Ralston and Jennricht, 1978). Validation using the calibrated roughness values is performed with the 1D Waal models of the winters of 1993 and 2011 using a slightly adapted RMSE criterion (Domhof et al., 2017). This criterion accounts for the more frequent low and less frequent high water levels such that each water level range is equally important.

Results: calibrated roughness

The calibrated roughness values for the location dependency case show little variation along the river length. The calibrated roughness values for the discharge dependency show an overall roughness increases with increasing discharge (Fig. 1). As more discharge levels are added, a roughness decrease around 4000 m^3/s and a roughness peak around 6000 m^3/s appear. The decrease is a result of the transition from bankfull to flood stage and the peak is a result of floodplain compartmentation.

Results: validation

Comparison of the RMSE for the location dependency (Fig. 2) and discharge dependency (Fig. 3) show that the discharge dependent cases overall has a lower RMSE than the location dependent cases. Therefore, the calibrated roughness is more sensitive to discharge than location. For the location dependent cases no clear mininimum RMSE is found. For the discharge dependent cases a minimum RMSE is found at six discharge levels, though the differences in RMSE between other number of discharge levels is 9

Discussion

In this study we also calibrated the 1995 IJssel and the 2011 Waal model. The resulting calibrated roughness functions are similar to the ones presented in this abstract. However, the inaccurate description of flow in sharp bends in the IJssel leads to decreasing cali-

*Corresponding author
Email address: boyan.domhof@gmail.com (B.C.A. Domhof)

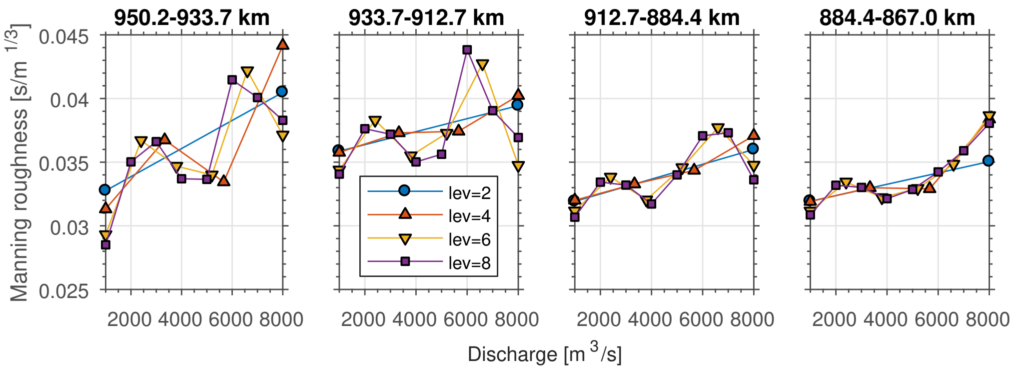

Figure 1: Calibrated roughness-discharge functions for varying number of discharge levels. From right to left plots show the functions from upstream to downstream sections between measurement stations. The most downstream section is not shown, because results are largely affected by the downstream boundary condition

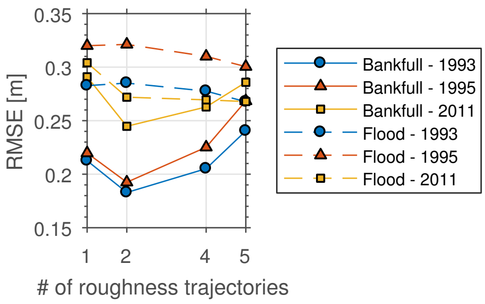

Figure 2: Validation of location dependent calibrations

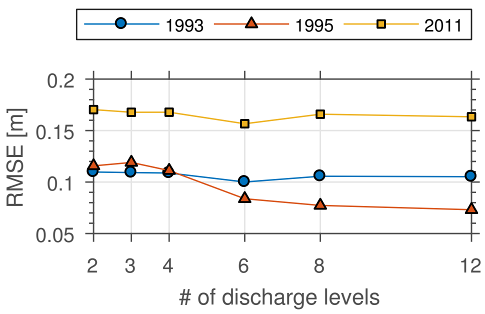

Figure 3: Validation of discharge dependent calibrations

brated roughness for increasing discharge. Additionally, a calibration of the 2D 1995 Waal model is performed. The resulting calibrated roughness-discharge functions lack the effect of the transition from bankfull to flood stage and the floodplain compartmentation. Therefore, these functions more closely resemble the expected increasing roughness due to river dune growth.

Conclusion

We conclude that in the calibration of 1D hydrodynamic river models the transition from bankfull to flood stage and floodplain compartmentation have a large effect on the calibrated main channel roughness. Furthermore, the calibrated roughness values and the validation show that calibrated main channel roughness is mostly sensitive to discharge compared to location. The calibrated roughness increases overall with increasing discharge as expected from river dune growth.

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