Insight into the local bed-level dynamics to assist management of multi-functional rivers

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Introduction

River discharge fluctuations cause bed-level variations at various scales, resulting from spatial gradients in the river's geometry (Bolla Pittaluga et al., 2014), local interventions (Paarlberg et al., 2020) or backwater effects (Arkesteijn et al, 2019). These bed-level variations can affect river functions such as navigation. Insight into these bed-level variations and their relation to discharge fluctuations can help to predict and prevent the formation of local bottlenecks. In this paper, we use bi-weekly bed-level measurements of the river Waal to estimate the bed-level variations related to the river discharge, assuming that the river planform remains constant. We apply a wavelet transform to disentangle the relevant spatial scales from the measurements.

Method

The bed level in the navigation channel of the river Waal is measured bi-weekly from 2005 using multi-beam echo sounders. We average the bed level over the width of the navigation channel to estimate the bed-level variations over the river's longitudinal profile. After 2014, bed-level variations in the Waal are strongly affected by various 'Room for the River' interventions. Therefore, we focus on bed-level variations between 2005 and 2014 relative to the time-averaged bed level over this period.

Bed-level changes occur over various spatial scales. Large-scale (>4 km) changes are related to the long-term trends, i.e. bed degradation. Small-scale (<320 m) changes are related to dune-like bedforms and groynes. We apply a wavelet transform to isolate the bed-level variations over an intermediate (320 m–4 km) spatial scale. These variations are affected by a single discharge event.

We classify each bed-level measurement according to the maximum discharge between the measurement and the previous measurement using eight characteristic discharge categories (Paarlberg et al., 2020). The categories are chosen such that bankfull discharge (2,900 m^3/s), 2-year peak flow (4,000 m^3/s), and a 5-year peak flow (5,300 m^3/s) each fall into a different category. For each category, we will show the average deviation from the time-averaged bed-level profile.

Results

We present the bed-level variation as a function of the discharge for a segment in the lower part of the river Waal (rkm 933-940). Fig. 1A shows the time-averaged bed level and the time-averaged bed level after low and high discharge. The bed-level variation range is about 0.5 m and the largest deviation from the time-averaged profile occurs after high discharges. Fig. 1B shows the bed-level variation around the time-averaged bed level for the eight considered discharge categories. The red colour means that the bed level is higher than the time-averaged profile and blue means that the bed level is lower. Where deposition occurs during high discharges, scour occurs during low discharges and vice versa. These bed-level variations can, for example, result from fixed spatial gradients in the river's geometry. Just upstream of rkm 937, the right floodplain narrows, which means that at high discharge the fraction of the discharge conveyed by the main channel increases. This locally increases the sediment transport capacity and thereby causes local scour. The opposite occurs just downstream, where the floodplain widens. These gradients in sediment transport capacity only occur during high flow conditions, when the discharge is above bankfull and the floodplains convey water. During low flow conditions, the scour hole is filled and the sediment deposited at high flows is eroded.

We compare our results with so-called MGD (=Least Available Depth) locations to determine whether the local aggradation results in navigation bottlenecks. An MGD corresponds with the lowest navigable depth in a river trajectory. Fig. 1C shows three peaks at rkm 936, 936.6 and 937.4, where between 2005 and

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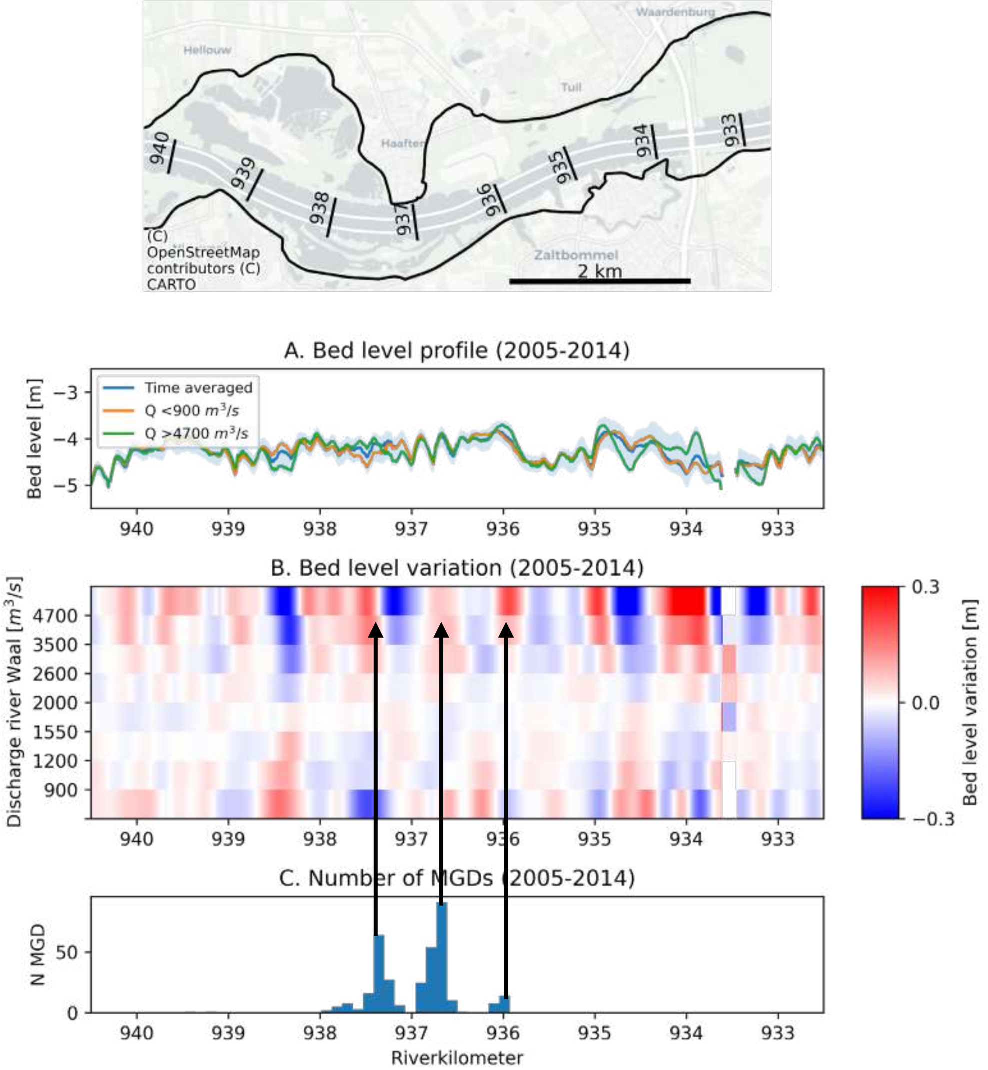

Figure 1. Considered river segment in the downstream part of the river Waal. (A) The time-averaged bed level, the average bed level during low and high discharges (filtered for wavelengths between 320 m and 4 km. The blue background gives the total range of the bed level between 2005 and 2014. (B) The bed-level variations around the time-averaged bed level for eight discharge categories. (C) The number of MGDs (Least Available Depth) in this segment, which shows where shipping bottlenecks occur.

2019 MGD occurred regularly. These peaks correspond with locations where, during high discharges, aggradation occurs. Note that we do not consider the migration of bed features such as bedforms, since we only include bed-level variations that occur over 320 m–4 km. These migrating features often determine the exact location of the MGDs.

Discussion

Insight into bed-level variations as a function of discharge fluctuations helps river managers to understand the river's dynamic behaviour. This can be used to determine the optimal type and location of river interventions such that existing bottlenecks disappear and new local bottlenecks are prevented. Fig. 1B can be used to optimize the location of, for example, a side channel. At the confluence of the side channel, scour is expected during peak flow and this scour could mitigate the deposition at rkm 934.

Here, we focus on a specific spatial scale (320 m–4 km) using a wavelet transform. This method can be used to distinguish between the spatial scales of bed-level changes. In rivers with less-frequent bed-level measurements, it is more difficult to relate these changes to the discharge. However, with fewer discharge categories a similar analysis could still be valuable in determining the trends and range of the river bed level dynamics.

References

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