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The influence of floodplain geometry on riverbed elevation change within and between flood events

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Introduction

Flood events can cause abrupt changes to river channel morphology over short time scales. The spatial variation in patterns of erosion and deposition can also be high, making it challenging to predict morphodynamic response from a given discharge. Back-to-back floods can additionally cause adjustments to bed elevation that do not recover between events and can affect future flood hazards; intra-flood erosion can reduce channel-floodplain connectivity (e.g. Guan et al., 2016), and in-channel deposition can reduce overall conveyance for floodwaves (e.g. Stover & Montgomery, 2001). Understanding where and why different regions are prone to high degrees of bed elevation changes during floods is thus important for forecasting flood hazards in subsequent events. Previous work suggests that spatial changes in local river geometry can affect river bed elevation change during floods (Van Denderen, 2014). Channel confinement has also been shown to be a predictor of reach-scale channel response to floods (Sholtes et al., 2018). Here, we analyze relationships between longitudinal gradients in river channel width and bed elevation change in the Waal River. This work seeks to broadly understand the degree to which along-channel variation in river channel and floodplain geometry can be leveraged to predict bed elevation change during floods.

Floodplain variation hypotheses

Gradients in floodplain width are expected to be an important control on erosion and deposition patterns during high discharge events because they can generate gradients in flow velocity and sediment transport capacity. An abrupt spatial widening of the floodplain causes a backwater effect during peak flows as flow depth adjusts to the longitudinal change in planform geometry (Fig 1a). The resultant gradients in both flow velocity and sediment transport capacity can cause abrupt deposition where the floodplain widens and abrupt erosion where the floodplain narrows (Fig 1b). This behavior differs from low-flows where the discharge is confined within a main channel with constant width. Thus, we hypothesize that peak changes in main-channel bed elevation during floods will correspond with peak gradients in floodplain width, with the direction of bed elevation change (i.e. erosion or deposition) dependent on whether the floodplain widens or narrows.

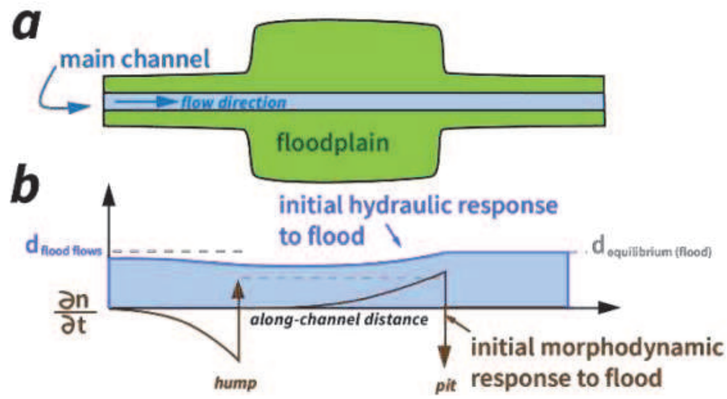

Figure 1. Example hypothesis of along-channel changes in floodplain width causing a backwater effect during flood events and initial morphodynamic response. ***a)*** *A planform channel schematic where the main channel has a constant width and the floodplain has relatively wide and narrow segments. Flow is from left to right.* ***b)*** *An expected hydraulic response for a flood which spills onto the floodplain is shown in light blue. The expected initial bed elevation change (∂n/∂t) is shown in brown. A hump forms where the floodplain rapidly widens and a pit is expected to occur where the floodplain rapidly narrows.*

Discharge & bed elevation analyses

We use high-resolution, biweekly bathymetry measurements from the Waal River in the Netherlands over the last 20 years to analyze bed elevation changes. A wavelet analysis proposed in Van Denderen et al. (2022) is used to isolate bed elevation changes on spatial scales of 300m-4km, those that are typically affected by discharge conditions on the Waal River. River bed variation as a function of discharge is analyzed at each location, and a linear fit is used to characterize the degree of difference in bed elevation changes between high and low flows (Fig 2b & c). The slope of this line is used to quantify bed elevation variation between high and low flows along-channel (Fig 2a). It is expected that the large differences in bed elevation change between high and low flows shown in Fig 2a will correlate with large gradients in local floodplain width.

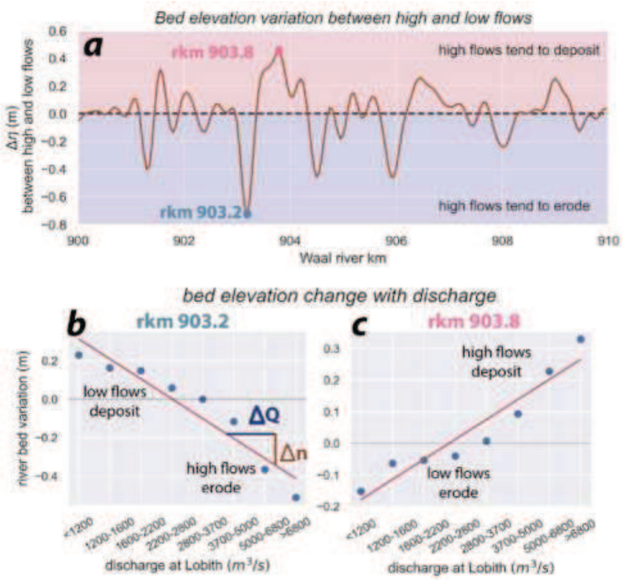

*Figure 2. **a)** An example section of the Waal River (river km 900-910) showing differences in bed elevation change between high and low flows (Δη) which vary along the channel. **b & c)** show example calculations of (Δη) for rkm 903.2 where high flows tend to erode and low flows tend to deposit and 903.8 where high flows tend to deposit and low flows tend to erode. Each plot shows river bed variation as a function of discharge at Lobith, where each data point represents bed elevation change for a range of mean daily discharge values obtained from flow duration curves for the data period, 2005-2021.*

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