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Rivers in an uncertain future

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Impact of Weir Location on Discharge Partitioning in Longitudinal Training Walls

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Introduction

A pilot project completed in 2015 replaced existing groynes with longitudinal training walls in the Dutch Waal River. The design seeks to mitigate river bed erosion and improve river function for navigation and ecology (*Havinga, et al.*, 2009). The change expanded the total flow width and separated the primary channel P_1 from three consecutive auxiliary channels A_1, A_2, and A_3 with longitudinal walls and fixed-elevation entrance side weirs. Figure 1a shows the field site spanning from Rhinekilometer (RK) 911 to 922, highlighting the location of channels, walls and entrance weirs. Water enters auxiliary channels via the weir at low flows and additionally via in-wall notches (broad-crested sections below the wall top), and wall over-topping at higher discharges.

This design seeks to increase low-flow depth and decrease both flood-flow depths and riverbed erosion in the primary channel. These factors relate to how discharge is partitioned between primary and auxiliary channels. Experimental results in a straight channel show that increasing discharge drives a larger proportion of flow into the auxiliary channel (*De Ruijsscher et al.*, 2019); a similar result is found at entrance A_3 in our field site (*De Ruijsscher et al.*, 2020). However, while discharge partitioning increases with depth over the weir at low flows, it is unaffected by weir design when the wall is inundated (*De Ruijsscher et al.*, 2019). We focus here on how discharge is partitioned to all three channels along a meandering river planform to determine how the position of the entrance weir affects discharge partitioning to auxiliary channels across a range of flow discharges.

Discharge Data

All weirs and walls were initially set relative to a reference water surface elevation, as to maintain equivalent relative elevations. In May 2018, weirs at A_1 and A_2 (Figure 1a) were raised by approximately 2 meters (*Sieben*, 2020). Discharge was measured at adjacent cross-sections along the primary channel and auxiliary channels over a range of flows from 632 m^3/s to 3482 m^3/s (approximately bankfull flow) during 2017 and 2018. The four largest discharge measurements (Q $\geq$ 1443 m^3/s) were collected before the weir change and the two lowest discharge measurements (Q $\leq$ 962 m^3/s) were collected after two weirs were raised. Flow in the auxiliary channel Q_A is normalized by the total discharge entering the domain Q_{tot} indicating the percentage of discharge shifted to auxiliary channels.

Results and Discussion

The discharge partitioning Q_A/Q_{tot} along the channel is plotted at six discrete total discharge values in Figure 1b. Line color shifts from red to blue as discharge increases and lines are segmented at the junction between walls. As total discharge increases, the percentage of flow shifted to auxiliary channel increases, but spatial trends vary among channels and at different discharge levels. The effect of weir height and position are entangled in our measurements at low-flow conditions, so this is omitted here.

At bankfull flow, all auxiliary channels convey about 25% of the total discharge on average (blue line in Figure 1b). However, the downchannel pattern in discharge varies among auxiliary channels and trends magnify as total discharge is increased. Channel A_2 gains discharge downstream, while A_3 loses discharge downstream, and A_1 shows a combination of these trends. Flows via the notches and wall over-topping, when active, tend to counterbalance weir flow as to maintain a common discharge value in all channels. As such, weir position does not affect the average discharge partitioning magnitude when the wall is overtopped, making the wall height a more relevant design parameter for these discharges.

These spatial patterns relate to how much flow can enter via the weir, so we consider the differences between weirs that leads to such opposite trends. Traditional factors controlling weir flow include the height, location, shape,

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and length. Relative weir depth is not a factor, as the high-flow data was collected pre-2018 when relative weir submergence (versus a select reference profile) was equal in all channels. All weirs are broad-crested side weirs, while the weir to A_2 also bends to connect to the adjacent bank (Figure 1). Regardless, the weir is still parallel to flow due to deflection from an upstream ferry quay, suggesting shape difference is not significant. All weirs are approximately the same length. All channels lie along an inside bank, but A_3 is positioned just downstream of a curvature crossover and collects the most flow at all discharge levels (Figure 1b). Therefore, weir position is the only relevant variable to explain these trends.

Conclusions and Future Work

Our analysis of a field experiment illustrates that side weir position in meandering river planform affects how water enters into the auxiliary channels, but does not strongly affect the average magnitude of partitioned discharge when the wall is over-topped

The former result will be expanded in future work as it implies important morphodynamic consequences. The way water enters an auxiliary channel directly affects the grainsize, magnitude, and regime of sediment transport leaving the primary channel. Additionally, spatial patterns of erosion and sedimentation will vary depending on weir position, which can affect how engineers maintain these channels from common problems such as sedimentation.

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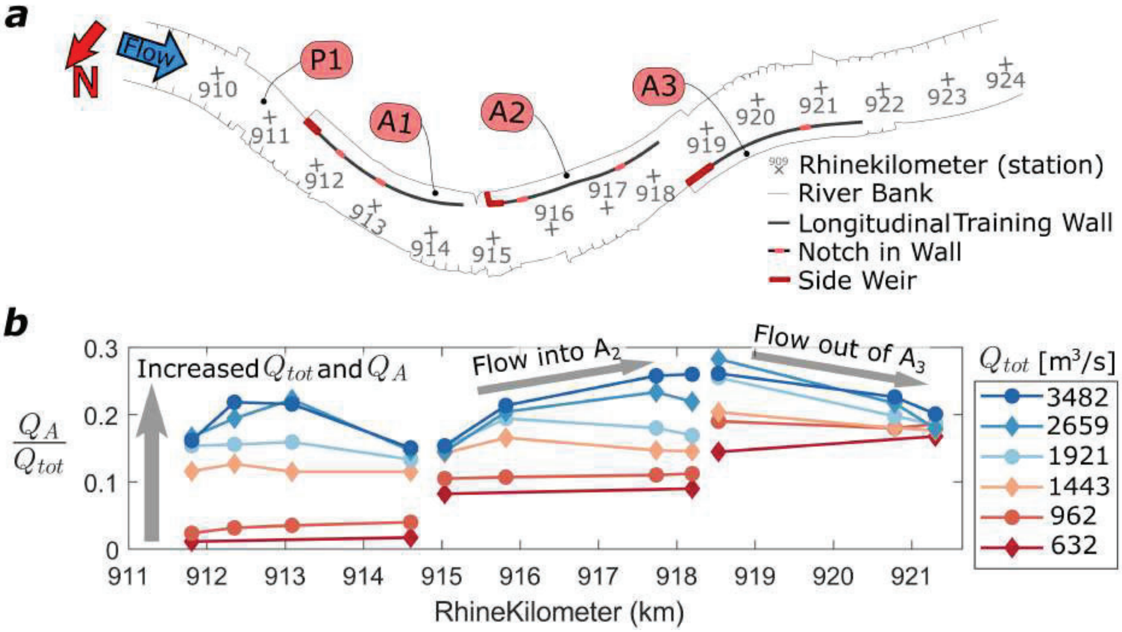

Figure 1: a) Plan view schematic of Longitudinal Training walls in the Waal River at Tiel, Netherlands. b) Proportion of measured discharge in the auxiliary channels Q_A relative to the total measured discharge upstream Q_{tot}.