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# Flow Structure at the Pannerdense Kop Bifurcation

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**Keywords —** Flow structure, River bifurcations, Long term morphological change

## Introduction

The upper Dutch Rhine bifurcations- Pannerdense Kop and IJsselkop are of utmost importance for the river management authority for both flood mitigation and navigation in the Netherlands. The riverbed of the Rhine has been degrading as a result of narrowing and other interventions of the river channel (*Arbós et al.*, 2020), which often creates problems for navigation. Now climate change has added more concerns for the river managers as the rising sea level and changing rate of precipitation influence the stability and partitioning ratio of the bifurcations (*Edmonds*, 2012; *Wang et al.*, 1995) and current proportion of water and sediment received by the branches may change with them. How large that effect will be, is still an open question. There are several characteristics in the bifurcation neighborhood that control the partitioning, for example: transverse bed slope , variable width, backwater effect (*Edmonds*, 2012), secondary current, upstream meanders and downstream slope advantage, tides, width-depth ratio (*Kleinhans et al.*, 2012), and mixed size character of the sediment (*Schielen and Blom*, 2018). Flow structure provides useful information regarding these by detailing the three- dimensional features of flow. This abstract mainly focuses on some of the observations from the ADCP surveys performed between November 2019 and February 2020 at the Pannerdense Kop.

## Method

Six surveys conducted from November 2019 to February 2020 by Rijkswaterstaat at several discharges were selected for this study with one transect at each branch. Selected transects are located 1700m upstream from the bifurcation at Lobith, 800m downstream of the bifurcation into the Pannerdensch Kanaal, and 920m downstream into the Waal river. All three transects have a thalweg close to the outer bank due to the meandering pattern. A $600kHz$ Rio Grande ADCP was used for these surveys with a bin size of 25cm. Each transect was repeated at least ten times. The Velocity Mapping Toolbox (VMT), a suite of Matlab routines, was used for the flow structure analysis.

## Results

The Pannerdensch Kanaal (PK) in these surveys was observed to receive $20$ to $31\%$ of the flow at Lobith and the fraction percentage increased with higher discharge. However, the depth-averaged velocity at PK, follows a different approach. At lower values of water discharge ($< 2540m^3/s$), the depth-averaged velocity at the Kanaal is significantly lower than the Waal (Fig.1).

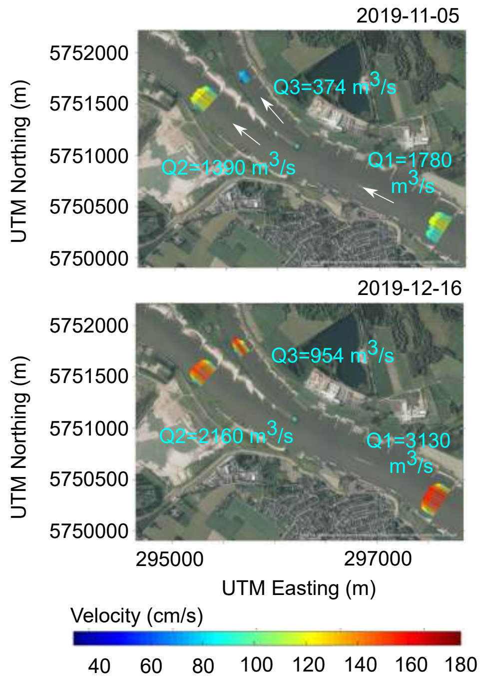


*Figure 1: Depth-averaged velocity at Pannerdense Kop at two discharge conditions*

However, the depth averaged velocity at PK gets almost as high as that in the Waal at water discharge values greater than $2540m^3/s$ (Fig.1). As the velocity, bed shear stress at PK also increases compared to low discharge conditions. Despite the fact that the water discharge partitioning into the branches remains below the agreed ratio, sediment discharge ratio would be influenced differently due to this velocity characteristics along with the sorting effect caused by the approach condition.

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Out of the six surveys at Lobith, five of them clearly show a large coherent clockwise circulation induced by the meandering pattern. Several other smaller cells were also found close to the left bank. At the Pannerdensch Kanaal transect (riverkm 868), the branch is narrower with a steeper transverse slope than Lobith. The typical helical flow direction due to meandering for this transect should be counter-clockwise (looking downstream), and the hint of this circulation is apparent from the surveys (5 out of 6 times) (Fig.2b). The circulation velocity increases with the increasing value of water discharge, but the variation is small. The location of the cell along the width also varies with different discharge conditions. Apart from this cell, different other coherent cells of similar size were also observed at this transect that were not always fully developed. Further downstream (riverkm 870) (Fig.2a), well developed circulation cells were observed. We hypothesize that it occurred because the transect was located inside the separation zone downstream of the bifurcation point. Further away from this zone, the cells can develop fully.

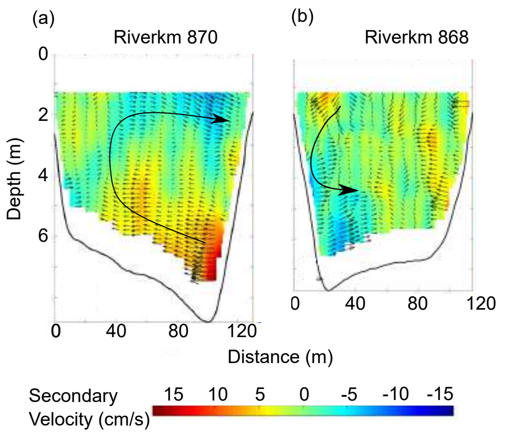


*Figure 2: Flow structure at Pannerdensch Kanaal at different discharge, contour and vectors both indicate secondary velocity in Rozovskii frame of reference.*

The transect at the Waal (riverkm 868) located 920m downstream of the bifurcation point, shows a coherent channel-wide counter-clockwise circulation (Fig.3a) similar to the Pannerdensch Kanaal transect. It was most apparent at discharge $1610$ to $1840 m^3/s$ and at higher discharge, more cells appear (Fig.3b). The same hypothesis may explain such occurrence. To confirm that, more ADCP surveys are required closer to the bifurcation point. The flow structure results discussed here show how flow behaves at these transects at a range of discharge conditions. The coherent structures induced by the meandering pattern is apparent from almost all the transects. However, the transects sometimes also show a number of coherent cells existing simultaneously. Why that occurs and how that may influence the partitioning of sediment requires further study.

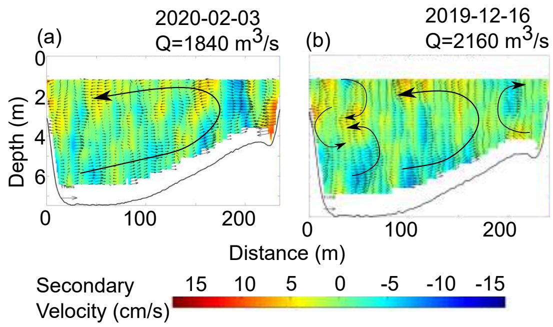


*Figure 3: Flow structure at a transect at the Waal (riverkm 868) at different discharge, contour and vectors both indicate secondary velocity in Rozovskii frame of reference.*

## Future works and Acknowledgements

Future research will contain survey and analysis of flow structure closer to the bifurcation and incorporate them results into the bed surface grain size and bed elevation dataset to draw a more complete picture of the dynamics and long term morphological evolution of a bifurcation system. This study is part of the research program Rivers2Morrow, financed by the Dutch Ministry of Infrastructure and Water Management. We thank the technical staff of Rijkswaterstaat for collecting and sharing the data used in this study.

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