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Climate Change Adaptation through Interventions in a River Bifurcation Region

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Introduction

The Rhine River system has been shaped by human interventions for centuries, making it one of the most engineered river networks in Europe. Issues such as ongoing channel bed incision and changes in hydrograph due to climate change (*Arbos et al.*, 2023) are anticipated to significantly affect future river functions, including flood safety, freshwater supply, and inland shipping. In recent decades, large-scale projects such as "Room for the River," the installation of longitudinal training walls, and sediment nourishments have helped preserve the Rhine's functionality.

At the Pannerdense Kop bifurcation, where the Dutch upper Rhine divides flow and sediment between the Waal and the Pannerden Canal, a gradual change in flow division between the branches is observed (*Chowdhury et al.*, 2023). This change appears to be linked to a series of peak flow events in the 1990s, which resulted in sediment deposition in one bifurcate, setting off a slow shift in flow partitioning ever since. More recently, *Blom et al.* (2024) proposed that the extreme flows in the 1990s might have pushed the system toward a tipping point and an emerging alternative equilibrium state.

Ensuring the anticipated flow partitioning is crucial not only for maintaining water supply and navigability during low-flow periods but also for controlling flood risk during peak events.

Objective and Method

This study aims to evaluate various interventions intended to maintain the desired flow partitioning and mitigate channel bed erosion over extended time scales (50–150 years). While earlier research has examined interventions such as floodplain lowering and sediment nourishment outside the context of a bifurcation, focused on modeling the bifurcation area without interventions, or studied climate change scenarios without morphological feedback, this study concentrates on both interventions and climate change adaptation within the Pannerdense Kop bifurcation region in a morphological context.

We will investigate two methods for evaluating the effectiveness of combining conventional engineering measures with (nature-based) solutions: (1) a one-dimensional modeling approach, and (2) a hybrid one/two-dimensional modeling approach. In the hybrid method, the boundary conditions for the two-dimensional domain of the bifurcation are dynamically connected to the one-dimensional model sections representing the river branches. This study will determine whether such dynamic coupling can accurately represent lateral flow exchanges between the main channel and the floodplain, as well as sediment transport and bed evolution processes within the bifurcation region, all while maintaining the computational efficiency typical of one-dimensional models for the larger system.

Expected Results

We expect that the effectiveness of interventions is significantly different in the presence of a bifurcation compared to single-channel conditions, with the specific design and location of interventions playing a crucial role. This analysis will provide insights into the relative effectiveness of a range of intervention strategies under various climate change scenarios, informing the development of adaptive management plans that enhance the long-term resilience of the Rhine River system.

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