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A Field Study on Groyne Field Nourishments

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Introduction

Over the past century, the main channel of the Waal has experienced erosion of approximately 1-2 metres (Ylla Arbós et al., 2021; Chowdhury et al., 2023). This erosion leads to various problems such as instability of structures or disruption to shipping. To address this ongoing degradation, a potential solution is the implementation of sediment nourishments.

Recent pilot studies have been conducted in 2016 and 2019 to investigate the feasibility of using sediment nourishments in the main channel of the Dutch Rhine (Becker, 2023). Another possibility of nourishing is to add sediment to the groyne fields. Under the influence of currents and ship waves, sediment is expected to be transported to the main channel, causing a groyne field to act as a *sand motor*. To explore this concept, Rijkswaterstaat initiated a pilot project with sediment nourishments in three groyne field clusters along the Waal during the fall of 2023. The pilot includes an extensive measurement campaign.

Dynamics of Groyne Fields

Studies on groyne fields have explored their hydrodynamics, sediment exchange and flow patterns. Uijttewaal et al. (2001) employed flume experiments, investigating exchange processes between rivers and groyne fields. They concluded that the overall exchange of matter can be described as a first-order process. The significance of the three-dimensionality of the flow was highlighted by Sukhodolov (2014) as they demonstrated high variability of the flow characteristics both across and along the flow depth for both emerged and submerged conditions. Yossef and De Vriend (2011) explored the differences in turbulence nature regarding submerged and emerged conditions. This offers insights into flow patterns near groynes, mixing layer characteristics at different flow stages, and dynamic velocity behaviour along the mixing layer between the main channel and groyne fields. Yossef and De Vriend (2010) found that under all flow conditions, a net sediment import occurs in groyne fields in straight reaches. For emerged groynes, aggradation is dominated by advection by the primary circulation cell, whereas during submerged conditions it is rather residual advection by large-scale coherent flow structures.

Ten Brinke et al. (2004) investigated groyne fields along the Waal, using in situ measurements, aerial photographs, and bed level timeseries to grasp the dynamics equilibrium of groyne fields. They concluded that there is a balance between erosion due to increased flow velocities induced by navigation and sedimentation due to high flows. Brouwers (2022) explored the effects of vessel characteristics on water level and flow velocity from field measurements in the Waal near Nijmegen, finding significant variance for all characteristics and concluded that is difficult to predict the impact of a single vessel.

Furthermore, Kok (2020) used a numerical modelling approach to investigate groyne fields as nourishment locations. She demonstrated that for emerged groynes, nourishments can effectively release sediment into the main channel. She underscores the limitations of the modelling approach used and the need for further exploration regarding nourishment compositions, extended simulation periods, and practical tests to optimise the effectiveness of groyne field nourishments.

New Field Study

The pilot study area includes three groyne field clusters along the Waal shown in Fig. 1. These clusters were chosen so that there is variability in the characteristics of the groyne fields. This includes clusters on the northern and southern banks and clusters along a straight part of the river as well as on a river bend. Each cluster consists of five groyne fields: four fields where nourishments are executed and one upstream field for reference.

Morphodynamic and hydrodynamic measurements were performed in situ using frames in both the shallow and deep parts of the groyne

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Figure 1: Locations of the three groyne field clusters.

fields (Fig. 2). These measurements included flow velocity, water depth, and turbidity. The influence of shipping on these properties will be investigated by analysing vessel tracking (AIS) data. This includes vessel velocity, draught and dimensions. In addition, measurements were taken of the bathymetry and velocity flow fields (Fig. 3).

The combined data sets may contribute to construct a 3D view of the dynamics of flows and sediment transport during a ship passage, as well during undisturbed conditions without ships passing. Regular velocities in the primary eddy are in the order of 0.3 m/s, whereas passage of ships can at least double these. Following the recent high flows, we will also explore whether additional sedimentation in the groyne fields has occurred and what this means for their dynamic equilibrium.

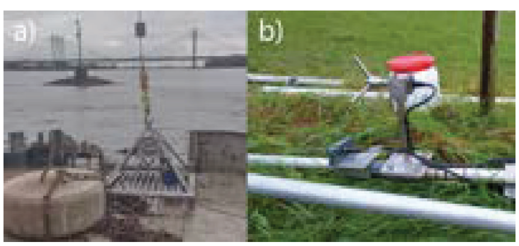

Figure 2: Measurement frames for both the a) deep and b) shallow parts of the groyne fields.

Future Work

Measurement data will be used both for a standalone analysis of inherent properties and for integration into numerical modelling processes. This approach aims to identify controlling processes at various spatial and temporal scales, particularly in the interactions between the main channel and the groyne fields.

If we understand the physical processes and we are able to model them, we will be able to design and upscale these sand motors in an optimal way that suits the location and targets of this measure.

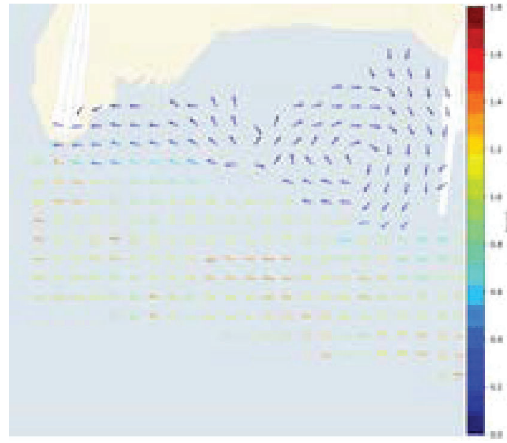

Figure 3: Velocity flow field within a groyne field.

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