How stable are multiple channels in a delta?

Avulsion and bifurcation in the late Holocene Rhine-Meuse delta, the Netherlands

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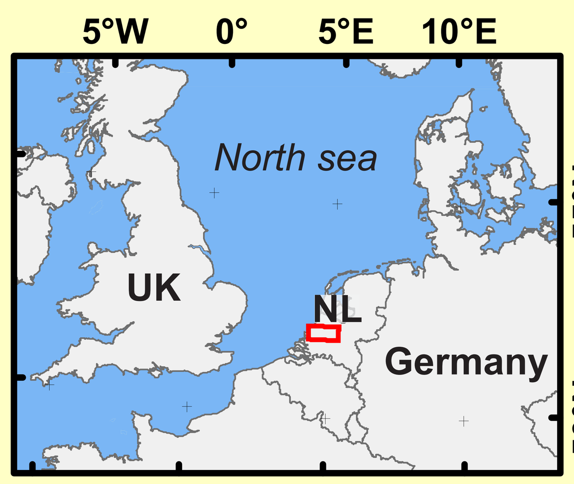
Introduction

Deltas have multiple bifurcating channels, that change their position over time (avulsion), to follow the path of the steepest downstream gradient. Gradients are for example affected by sedimentation, subsidence, changing backwater effects, and tidal incursion. In addition, also local meander bend radius at the avulsion point determines which branch is favoured.



Hypothesis

Given the difference in total hydraulic friction in the channels, a network with multiple channels would be less stable than a single channel. **This suggests that evolution towards a single main channel in a delta is most favourable.**

Human influence increased over the last 2500 years, changing gradients and sediment supply. As a result, avulsions took place that took several centuries to mature. **Before a possible stable single channel situation was reached, however, new avulsions were triggered and multiple branches remained.**

Method

To test these hypotheses, we focus on late Holocene avulsions in the Rhine-Meuse delta, the Netherlands. We use **detailed reconstructions of its avulsion history**. These have been compiled from >100k boreholes, over 1000 ^{14}C dates over the last decades (e.g. Cohen et al., 2012). We **compared avulsion history to human activities**, such as historical dam construction, lower delta peatland reclamation, catchment deforestation leading to enhanced erosion and sediment supply (Erkens, 2009; Pierik et al., 2018).

Outlook and implications

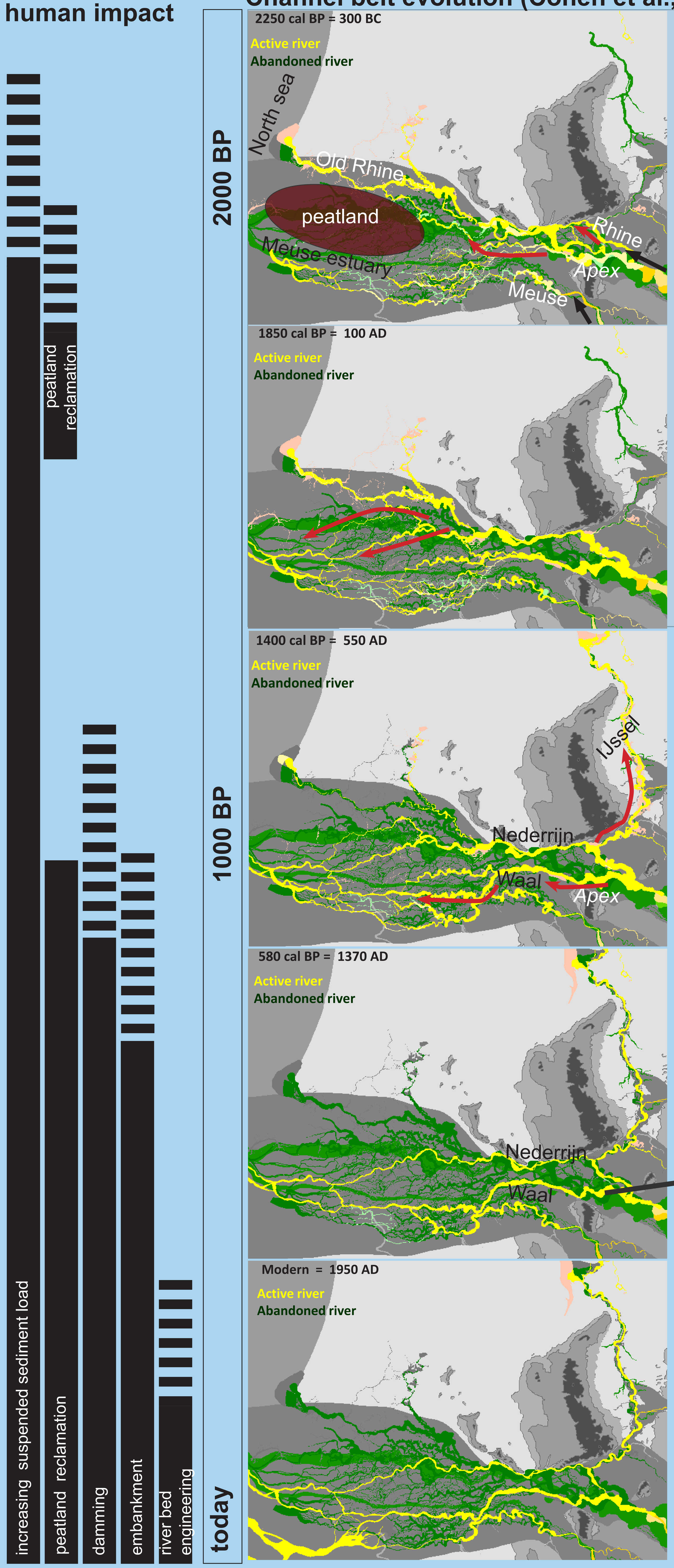
A 1-D bifurcation model (Kleinhans et al., 2011) will be used to further explore the controls on the stability of these river branches. To test the most favourable pathway and the time required to form a new equillibrium configuration.

These results help to understand the configuration and time control of channel belts in ancient fluvial deposits. They will also shed light on how human impact effects long-term avulsion behaviour.

Avulsion stages in the Rhine-Meuse delta

Increasing human impact

Channel belt evolution (Cohen et al., 2012)



Avulsion type I: local human-enhanced apex
Apex: local avulsions
Downstream: relatively stable situation; Rhine in north, Meuse in south, crevassing into peatlands.

Avulsion type II: early human-induced

First Rhine branches crossing peatland to Meuse estuary in Roman period. Aided by peatland reclamation, susp. load increase (Pierik et al., 2018).

Avulsion type III: regional human-enhanced apex

After these anthropogenically enhanced avulsions in the downstream part, two apex avulsions took place from 1500 BP onwards, of which the Waal gradually developed into the main channel.

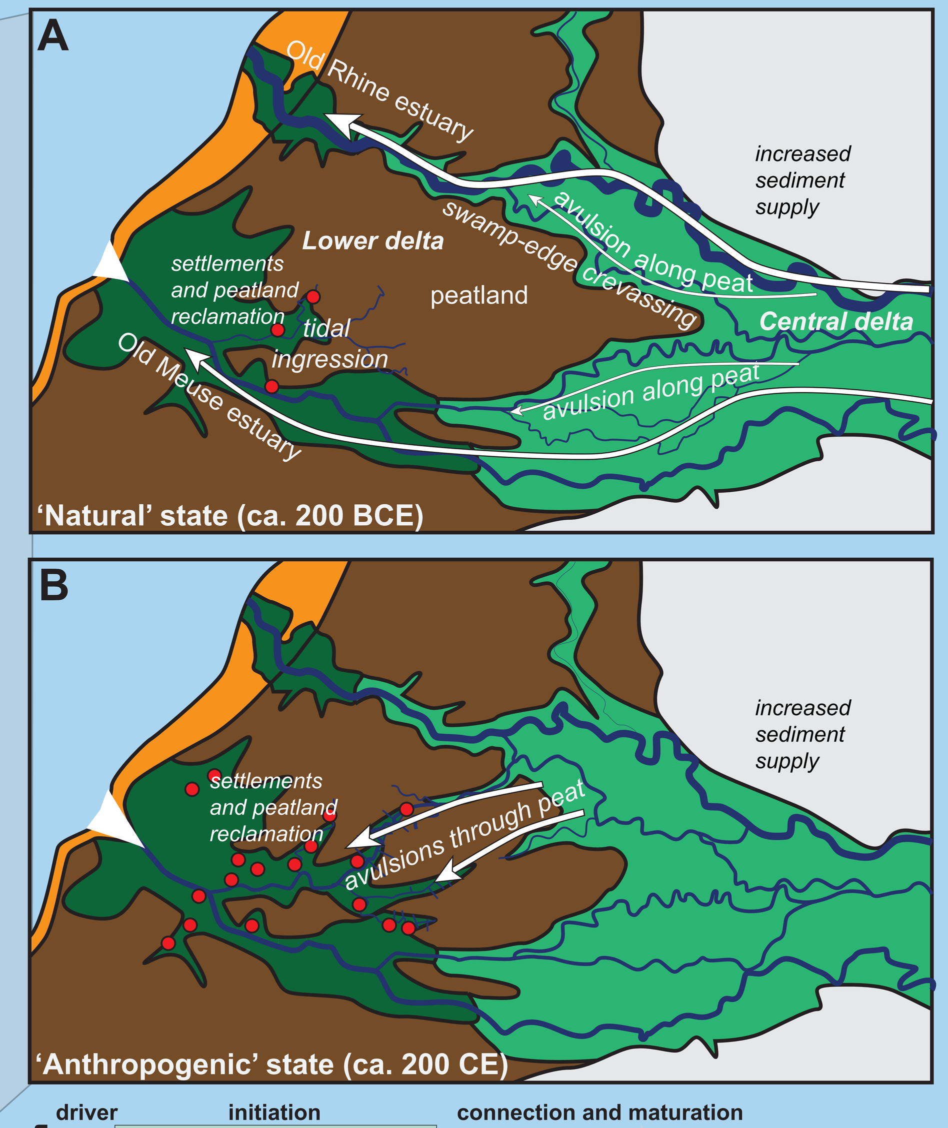
Avulsion type IV: modestly engineered

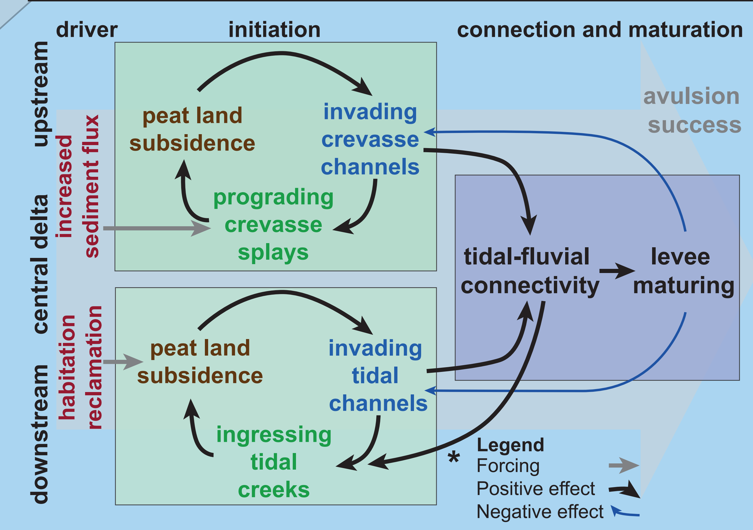
Humans prevented secondary branches to close for navigational purposes and a multi-branch delta remained.

Avulsion type V: fully engineered

New channels were dug, rivers dredged and secondary channels kept open.

Early human-induced avulsion

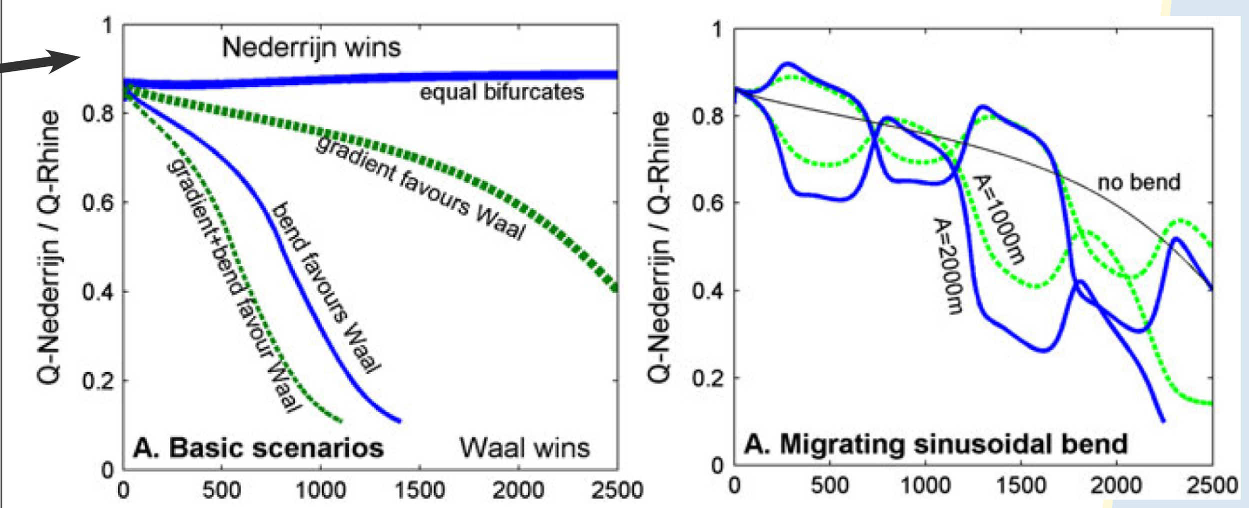




Feedback loops that caused early human-induced avulsion (Pierik et al., 2018).

Bifurcation model

- Evolution of discharge and sediment division on bifurcation points
- Role of gradient advantage, meander bend migration
- Can local bifurcation processes explain avulsion style on a delta scale?



Examples of the bifurcation model scenarios from Kleinhans et al. (2011) for the Waal-Nederrijn bifurcation, including the effects of bend configurations and dynamic meander migration.

References

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