Mixing and muddling: response of the lowermost Rhine and Meuse river branches to climate change and sea level rise

NKWK RIVERS2MORROW @ UNIVERSITEIT UTRECHT

Team

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Introduction and problem definition

The tidal river area is developing under the influence of changing flow statistics, sea level rise and human interventions such as closing sea arms and dredging navigation channels. Whilst navigability and safety from floodwaters are particularly important in the short term, the preservation of ecosystems and food chains, freshwater availability and liveability are important for the longer timescale of the 21st century (plan Living Rivers WWF). The most recent scenarios for accelerated sea level rise (KNMI, de Conto & Pollard 2016, de Winter et al., 2017) require a better understanding of the response of lowland rivers. All of these aspects are related to the balance of sand and mud, the flows and balances of which in the lower river are interrupted by ports, dredging and engineering works. To dynamically maintain ecological quality, safety and navigability through long-term sediment management and under changing conditions an integrated approach is needed. This forms the backbone for the NKWK-projects on the upstream and downstream rivers in the Netherlands for Rivers2Morrow.

Where sufficient sediment is present and usable, it can be used to counteract the negative effects of sea level rise. The Drowned Land of Saeftinghe/Saeftinghe marshes, the Groningen Salt Marshes and the Biesbosch are historical examples of the country's rise through natural processes. In the lower river it is not as obvious as in other parts of the Dutch Delta. Most of the sediment is trapped in the upper delta and sandy coast while vast peatlands developed between them due to the absence of sediment. The Dutch coast is raised by incoming sand from the North Sea, which offers protection against high water levels and saltwater penetration however, estuaries represent holes in the coastline where high water levels and saltwater can penetrate the peat landscape and rivers surroundings. Given the need for reliable river discharge, accessible shipping lanes and high water quality, shutting down all the estuaries using dams (as has been done with the Haringvliet, Grevelingen and Oosterschelde) is not an option.

This indicates that further understanding is required of the movement of sand and silt in the lower river area under the influence of changing river flow and sea levels in the coming century. On this timescale the availability and type of sediment determine the ability of the region to respond to potentially extreme sea level rise. In broad terms, the sand budget determines where sedimentation and deepening of the channels can occur and the sludge budget determines where unwanted harbour sedimentation will occur and where siltation on banks may be used as a natural barrier against high water from the sea and rivers. Shortage of sand in channels will not only lead to deepening but also to enhanced saltwater penetration and strengthening of the tide which leads to a morphodynamic feedback cycle. The uncertainties on this time scale are large due to uncertainties in projected boundary conditions and model formulations (e.g. van der Spek et al., 2015). Predictions of change for the Dutch coast rely largely on large datasets from the past and relatively well-known sediment supply volumes. For the lower rivers the required catch-up in knowledge and understanding can be achieved by combining existing sediment budgets from the upper rivers and the coast with echo data and dredging budgets in the low rivers.

Changing dynamics in the upper river and at the coast also affect the lower river. More sediment is available in the upper rivers but fine sediments are trapped on deepened floodplains and incisions occur in the channels due to upstream damming, groynes and sand extraction. Additionally, climate change will lead to more frequently occurring extreme low and high discharges on the Rhine and Meuse (Sperna Weiland et al., 2015) possibly with related effects on sediment dynamics. At the coast a lot of sediment is moving and the import and export of fine sediment and sand by the tides are boundary conditions for the lower river area. This project will therefore work closely with the upstream river project (Blom et al.,) with NKWK Rivers2Morrow, the Coastal Genesis 2.0 Project (van der Spek et al.) and the VICI and ERC projects on estuaries (Kleinhans). The involvement of Rijkswaterstaat, Deltares and the Port Authority will provide insights and data about dredging. Close collaboration with the builders of the Numerical RiverLab (Rijkswaterstaat, Deltares, HKV and RHDHV) will enable an efficient kick-start and provide insights and adjustments to the model for the entire community. This project also provides a launch platform for further research into sedimentation on banks and polders.

Project definition

1. Sediment in balance?

Movement of sand and mud under current conditions with upper rivers and the coast

The long-term development of the lower rivers is partially determined by water movement and sediment transport but also by dredging and anthropogenic movement of sand and by the subsidence of the western Rhine-Meuse delta. This require a better knowledge of the sediment budget of sand and mud for the network of river branches and estuaries and their connections with the upper rivers and the coast and the inclusion of dredging and dumping. In order to estimate where sediment may move in the future and where there is freedom to steer/alter plans (for example different dredging strategies), it is necessary to quantify the extent to which sand and mud transport are now coming from the sea and rivers and where this sediment is deposited within the lower river, what boundary conditions this defines and what proportion of the budget is determined by dredging work.

Contrary to what is intuitively expected at a delta there are several hard layers in the lower river and estuaries which reduce sediment availability in certain spots. On the basis of recent insights into estuaries it can be investigated what role these hard layers play on the sediment balance on the scale of the entire system or whether this is limited to local effects as the sediment migrates and accelerates over the hard layers (submitted papers UU).

This subproject will build on existing sediment balances for the upper river (ten Brinke et al. 2000, Frings et al. 2015) the lower river (van Dreumel 1995, Snippen, 2005, Becker 2015) and the coast (Coastal Genesis 2.0, van der Spek et al. 2015). This will also be complemented by sediment balances in the Western Scheldt. Meanwhile, new insights from researchers working on coastal zone sediment management will be taken into account (Lodder, 2016). On the basis of the integration with recent data needs for measurements can also be defined for other NKWK projects.

2. Sediment scenarios

Modelling with hydrodynamics, sand transport and mud transport for discharge and sea level scenarios and expected interventions

Channel depth develops in response to flow, sediment supply from both the rivers and the coast, the distribution of sediment at bifurcations and dredging. Although mud can play a large role in the sediment balance, sand is important as it determines the stability of bifurcations. For example, dredging in the Lower Merwede is necessary due to the unstable bifurcation at the Merwede bifurcation (Frings et al. 2008).

Water level variation, discharge and salt penetration are driven by rivers and tides and are strongly related to the depths of channels and the distribution of flow at nodes (bifurcations and confluences). Depending on tidal propagation and the presence of storage basins, a deepening of channels due to sea level rise can lead to a strengthening of the tide which causes even further channel deepening (Levy et al. 2014, Smolders et al. 2015). On the other hand, this also offers the possibility to strengthen sediment import through the tides.

In order to estimate the response to sea level rise and changing discharge, calculations are needed of both water movement and sediment transport of sand and mud under current conditions and for projections of future discharge and sea level rise. This is closely tied to the scenarios considered in the upstream river project (Blom) and in Coastal Genesis 2.0.

There are two models available that may be used: a 1D hydrodynamic model (SOBEK3) of the Dutch water systems and the Numerical RiverLab (http://www.riverlab.deltares.nl/). The latter is a 1D model schematization developed for the upper rivers for scenario calculations within the framework of NKWK and this should be extended by model builders to encompass the lower river on the basis of existing schematisations. The geometry and connections at junctions of the lower rivers are already schematized. The Deltares software also has the option for calculating sand transport and mud transport. This instrument will be used in close cooperation with the related NKWK upstream river project. The results under current conditions will be compared with the empirically determined sediment balance to identify differences between idealized model scenarios and the actual situation. By the end of this project, when the area is more clearly understood, the model can be calibrated more accurately to include new insights and scenarios.

3. Sod the dike:
Determining promising and desirable locations for natural sedimentation, deepening and bank building

Model scenarios will indicate places where the delta can grow (despite rising sea level), where adaptation and mitigation are needed and where needs attention, which can be achieved through a combination of sediment management, natural processes, deepening, supplementing etc. This involves, for example, combating siltation which can hinder shipping, counter channel deepening and undermine engineer works and therefore lead to flooding and salt intrusion. The manoeuvring room to tackle these problems is partly determined by the availability of moving sediment (Auerbach et al. 2015) and partly the response of water movement and sediment transport to any possible measures taken. This concerns also measures taken in the winterbed which function as room for high river discharge and in the estuaries as storage locations. In addition, this “spatial resilience” can be combined with nature (Beekers et al. 2017).

Not allowing natural sedimentation and silting up of the shores can have major negative consequence. Disasters in other deltas such as Hurricane Katrina in the Mississippi (Day et al. 2007) and Cyclone Aila in the Gange-Brahmaputra (Auerbach et al.2015) are partly caused by the man-made changes to these estuaries which are similar in many aspects to those actions which are ongoing in the Rhine-Meuse Delta. Additionally, species diversity is declining at an alarming rate, including diversity in river systems and estuaries, due to a lack of habitat area despite the slight improvement observed due to the Room for the River measures (Straatsma et al. 2017).

This subproject therefore combines sediment availability and the potential influence of high water and tidal asymmetry. We will learn from previous and ongoing experiments, measurements and model studies in the flood plains along the major rivers of the Netherlands the Biesbosch (Middelkoop et al., Staatsbosbeheer), the Westerschelde and Schelde River (VNSC and Sigmaplan) and the Ems-Dollard (ED2050 MIRT). Since the late Middle Ages, accretion has taken place on banks and in re-opened polders along the entire gradient from the upper river to the tidal dominated estuary. This not only forms new habitats but protects these habits from high water and improves the characteristics of tides and high waters due to the use of ponds. Nonetheless, the Rhine-Meuse delta is relatively low in sediment just like the Mississippi where it is questionable whether natural accretion will be sufficient to stop drowning (Blum & Roberts, 2012) and contrasting to the Ganges-Brahmaputra where a large amount of sediment in the delta is moving to the coastline (Auerbach et al. 2015).

The choices and development of activities in this project will depend partly on other NKWK projects (including Middelkoop and Blom), current research points with tides (Kleinhans, van der Vegt), connections with research projects in the estuaries (VNSC, Bouma, Van der Vegt, Kleinhans) the UU ‘Hub’ *Water, Climate and Future Deltas* (Middelkoop) and further plans of the Delta Committee. In view of the extreme sea level rise scenarios and climate related changes in river discharges, looking far ahead enough is a necessity, even if scenarios imply that the spatial planning, development and legislation should be changed. For this reason, for example, the principal possibilities of extreme measures such as depoldering or the use of exchange polders/Wisselpolders (such as the controlled embankment breaches in the Ganges-Brahmaputra, Auerbach et al.2015) are investigated. Perhaps the water movement and sediment dynamics of the area can be controlled with large-scale interventions so that potentially drowning areas can be maintained by natural sedimentation or can obtain high ecological value. For example, through controlled changes in tidal characteristics sediment import to low parts of the delta could be restored depending on upstream supply (Middelkoop, Blom). Model scenarios will provide insight into possibilities that, in consultation with the Delta Committtee (Delta Programme 2018) can be carefully connected to specific areas in the lower Rhine and Meuse.

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