IMPACTS OF CHANNEL DEEPENING ON SEDIMENT TRANSPORT MECHANISMS IN A MESOTIDAL ESTUARY

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INTRODUCTION

Carefully assessing the environmental impacts of human interventions in estuaries on sediment transport and morphodynamics has become increasingly important due to the high ecological importance of these systems. Man-made changes are typically quantified with numerical sediment transport models. However, setting up these models and more importantly interpreting their results requires a profound knowledge of the natural system and present-day transport processes.
This contribution focusses on the mechanisms of sediment transport in a mesotidal estuary and discusses possible impacts of a channel deepening on those mechanisms and their expected impact on long-term changes on sediment transport. The processes are described on the basis of field data and simulations.

STUDY AREA AND METHODS

The study area is the mesotidal and well- to partially mixed Weser estuary in the North Sea, Germany. The distance between the German Bight, where seawater salinity prevails, and the tidal weir upstream is about 120 km (Figure 1). The bathymetry is strongly influenced by river adaption measures of the last century involving extensive dredging and groin constructions to generate a sufficiently deep and stable navigation channel.

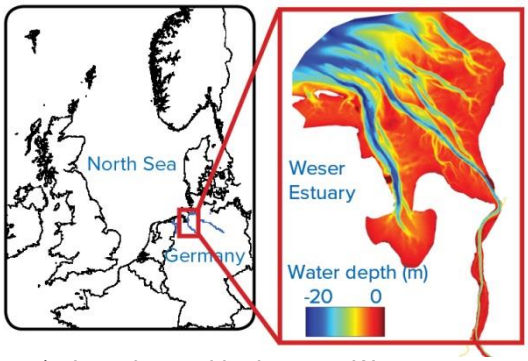

Figure 1 – Location and bathymetry Weser estuary.

The comprehensive data base includes a. o. digital terrain models, continuous stationary turbidity measurements and computed suspended sediment concentrations (ssc), a surface sediment distribution, data on maintenance dredging as well as tidal ADCP cross-section measurements providing current velocity and ssc values. Additionally, validated simulations of the hydrological year 2012 from a numerical sediment transport model of the Weser estuary are used.

RESULTS I: SEDIMENT TRANSPORT MECHANISMS IN THE PRESENT STATE

Regarding the mechanisms responsible for sediment transport, the estuary can be divided into two main parts in which different processes dominate:
The outer estuary is characterized by mostly fine sands in the main channels and sand- and mudflats on the shoals. Sediment transport here is dominated by tidal motions in the channels and locally generated wind-waves on the shoals.
In the inner estuary, an estuarine turbidity maximum (etm) zone develops. The surface sediment shows up to 50 % mud content and during flood and ebb, high ssc values are observed due to local erosion and advection. Fine sediment is trapped here due to the estuarine circulation, which in the Weser is assumed to be due to tidal straining processes mostly. In the baroclinic zone, simulations show an upstream-directed net current near-bottom and a downstream-directed net-current at the surface.

RESULTS II: IMPACTS OF CHANNEL DEEPENING ON SEDIMENT TRANSPORT MECHANISMS

The mechanisms responsible for sediment transport are affected by a channel deepening on different spatial and temporal scales.
Two local mechanisms govern the ssc changes. In some areas, the increase in cross sectional area leads to a decrease in current velocity, reduced local erosion and hence lower ssc values. In other areas, the deepening leads to a stronger concentration of the main flow to the channel, hence, the opposite effect occurs. Both are local effects, which however may show their impact far beyond the dredged river stretch due to resulting changes in advective sediment fluxes.
More important for the long-term ssc changes in the etm are two global mechanisms: In the baroclinic zone of the outer estuary, a deepening may result into a strengthening of the estuarine circulation and the net sediment transport into the etm.
In sediment transport simulations with a moderate fictional deepening of the outer Weser channel, both local and global mechanisms can be observed. In some areas, local effects lead to an immediate ssc reduction. However, net current and net sediment transport patterns in the outer estuary show a strengthening of the estuarine circulation and a net sediment import.

SUMMARY

The results illustrate the sediment transport processes in the present state of the Weser estuary and the mechanisms that may alter those processes in case of a channel deepening. In summary, both local and global mechanisms are important for the immediate and long-term response of the system. Residual current and sediment transport patterns may help to reveal indications for long-term changes.