1 Introduction

The East Frisian island of Juist is situated 10 km off the German North Sea Coast in the Wadden Sea (see Fig. 1). In recent years its municipal port has been complemented with a marina which is facing high siltation leading to dredging expenses and frequencies of about 9m³ per year. Mainly fine sands are transported into the basin and deposited behind the marina entrance. Silt is transported farther and aggregates in the marina basin leading to rapid siltation and limiting accessibility for shipping (see Fig. 2). In Fig. 1 poster for measurements, analysis and quantification of sediment transport mechanisms in the port of Juist are presented. Furthermore, numerical simulations based on the findings of the analysis of the status quo are carried out to evaluate different constructional options aiming for an optimization of the marina design.

2 Methods

2.1 Measurements

In order to determine the variation in hydro- and morphodynamic parameters throughout a spring-neap cycle, a long term monitoring station consisting of a pressure gauge, an electromagnetic current meter (EMC) and two optical backscatter sensors (OBS) was installed in the marina entrance. Water level, current velocity and suspended sediment concentrations were recorded over a period of 30 days. The OBSs were calibrated with water and sediment samples taken at the study site. Based on these measurements, flood and ebb duration were defined according to change in flow direction. Sediment fluxes for flood and ebb periods were calculated by integrating flow velocities and sediment concentration over the cross-sectional area of the marina entrance. Based on the sediment fluxes mass balances of sediment in- and outflow over individual tidal cycles were computed. To illustrate differences between spring, neap and normal tide, representative cycles for each state were computed. To illustrate differences between spring, neap and normal tide, representative cycles for each state were computed. The integrated sediment influx was found to be twice as high during spring tides as during neap tides or medium conditions.

2.2 Numerical Simulations

Following the evaluation of aforementioned measurements a numerical model of the municipal port and marina was set up to reproduce hydro- and morphodynamic phenomena in the port of Juist. A triangular unstructured mesh was generated based on high resolution bathymetric data obtained by airborne laser scanning and multibeam echo soundings. Hydrodynamical and morphological data obtained during the measuring campaigns were used for the calibration of the numerical model. Model runs were then carried out using the 3D finite-element circulation modeling tool SELFE (Zhang and Baptista, 2008). After the model had been set up and calibrated, different design options aiming at an improvement of the sedimentation problems were defined in consultation with local authorities as well as port and marina operators. The constructional alternatives were investigated numerically. The option favored by marina operators was a widening of the marina entrance at its current position as it does not involve any rearrangement of jetties or redesign of the overall marina. Model runs were set up to investigate the efficiency of the design alternatives in reducing sedimentation problems in the marina.

3 Results

3.1 Measurements

The evaluation of the long term measurements illustrates a strong tidal asymmetry exhibiting high velocities during a short flood phase and lower velocities during a longer ebb phase. Accordingly, high concentrations of suspended sediment are found during flood current, whereas SSC is reasonably lower during ebb current. Water level, flow velocity and sediment load for an average spring cycle are depicted in Fig. 3. It is obvious that low flow velocities and SSC integrated over the period of ebb current do not match the sediment volume transported into the basin during flood current. Therefore, the sediment mass balance over a full tidal cycle shows a net sediment influx into the marina basin. The integrated sediment influx was found to be twice as high during spring tides as during neap tides or medium conditions.

3.2 Numerical Model

The results from the numerical model runs show a good representation of the flow pattern as recorded by ADCP and drifter measurements. The differences between flood and ebb current as well as between spring and neap conditions are reflected in the model runs. Flow velocities during spring flood and ebb current can be found in Fig. 5. It can be seen that flow velocities and therefore suspension and transport capacities are reasonably higher during flood current. A certain drop in flow velocities at the end of the approach channel due to the sudden widening of the effective flow area leads to the aggregation of sandy material which is suspended in the approach channel and transported into the port.

The evaluation of the morphodynamic simulations for the favored design alternative with a widened marina entrance in comparison to the current state shows that it will supposedly not help to reduce sedimentation in the marina basin. Figure 6 shows a comparison between the current state and the design alternative from two morphodynamic model runs.

4 Summary and Outlook

The combination of long term stationary measurements of velocities and concentration and spatial velocity and concentration measurements helped to understand the overall flow pattern and sediment transport pathways in the port area. Fine sands suspended in the approach channel are transported to the marina entrance and deposited there due to the diminished transport capacity of the current. The deposited sandy material forms a sand bar at the marina entrance, making the marina basin act as a sediment trap for silt and silt/sand mixtures which may be re-suspended by the flow of the ebb current. The data collected during the long term measurement and vessel based campaigns were used to set up and calibrate a numerical model of the port area. The model was then used to evaluate the effects of a redesign or relocation of the marina entrance on sediment dynamics. It was found that a simple widening of the marina entrance will not help to reduce siltation problems. Other design options are currently being discussed among port and marina operators as they require a rearrangement of jetties and a complete redesign of the marina.

References