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Reproduction of Storm Surges and Evaluation of Design Water Levels at the Ems-Dollard Estuary by Mathematical Modelling

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The requirement of the German federal state of Lower Saxony with respect to a new safety margin for sea level rise acceleration has been increased of formerly 25 to now 50 centimetres as by the evaluation of design water levels. At open coastlines this supplement can be added to previously investigated design water levels, but in estuaries being subject to complex interactions a revaluation of design levels is necessary. Furthermore, the upstream part of the Ems-Dollard estuary at the southern North Sea coast is protected from flooding by a storm surge barrier. At the closing of the barrier the storm surge wave is partly reflected. Deterministic-mathematical modelling is applied with respect to both technical state of the art and legal boundary conditions to evaluate design water levels and design wave run-up in order to verify the design height of the dykes along the outer Ems-Dollard estuary.

Storm surge modelling requires a hierarchical cascade of models starting far out of the area of interest with decreasing spatial dimension and increasing numerical resolution. The largest model with a resolution of 8 km covers the Continental Shelf and parts of the North Atlantic Ocean, embedded the German-Bight-Model with average grid sizes of 600 meters that, in turn, generates water level time series at the sea boundary of the Ems-Dollard-Model (resolutions of 150 m offshore to 30 m upstream). All models apply the same meteorological boundary conditions, i.e. non-stationary and spatially differentiated model data of atmospherical pressure, wind velocity and direction being provided by the German Weather Service (DWD).

The model is verified against observed water levels of three storm events. The observed storm surge peak of “Britta” (Nov. 01, 2006) is one centimetre below the highest ever measured surge level at the gauge of Emden in 1906. After verification of the model, simulations for the evaluation of the design water levels under consideration of the design upstream discharges and increased wind velocities have been undertaken. In compliance with the Lower Saxon Dyke-Law, the design water level of Emden is determined by the single-value-method (LÜDERS & LEIS, 1963). The model boundary conditions are modified for each storm surge scenario respectively, i.e. the wind velocities in the wind fields are increased with the aim to achieve agreement with the predetermined design water level at Emden for the model state with an initially opened storm surge barrier. In a following state, the barrier is continuously closed. The design water level is a combination of the overall maximal peak water levels: in the outer estuary the peak water levels of the scenario “Tilo” (modified) are maximal; while upstream of Knock the scenario of “Britta” (modified) is significant.

Modelled water levels and current velocities are applied as non-stationary boundary conditions to run the spectral wave model SWAN (BOOIJ et al, 1999). Based on the modelled wave parameters at the dykes, the design wave-run-up is computed by empirical formula. The sum of the design water level and the design wave-run-up determines the new datum of the dykes.

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