

# Influence of the Assembly of Coastal Defense Systems on their Safety

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## Abstract

Coastal defense systems are composed of different coastal protection elements. At the North Sea coast of Germany the protection elements are bars, groins, shore, dunes, islands, mud-flats, foreland, summer dikes, and main dikes.

The traditional design approach to these coastal defense systems is essentially deterministic and does not take into account the assembly of the whole system. The determination of the required dike height along the Lower Saxonian North Sea coast of Germany is for example based on the accumulation of maximum historically recorded deviations of the high water levels due to spring tides, wind effects and the expected wave-run-up taking into account the maximum wave-height in front of the main dike disregarding a possible increase of the safety due to the existence of other coastal protection elements. Therefore a probabilistic design approach is applied to selected coastal areas in order to determine the contribution of different coastal defense elements to the safety of the complete system. Besides that the influence of long term changes of tide levels und wave climate, e.g. caused by climate changes, on the effectiveness of the protection elements is examined.

As a standard of safety the probability of wave-overtopping at the dike and of the overtopping rate is deduced from the probability density functions (pdf) of the water-level and the wind-velocity and -direction far offshore. For each parameter combination of water-level, wind-velocity and -direction a numerical simulation of the wave propagation within the area of the coastal protection system has been performed so that the input parameters - water level and wind - are related to significant wave parameters, i.e. significant wave height and period - at every location of the coastal protection system. Figure 1 shows an example of the numerical wave modeling.

Using these relations the pdf of significant wave height and wave period at each location of the modeled coastal protection system is calculated from the pdfs of the input parameters. The pdf of wave height and wave period directly in front of the main dike is transformed into a pdf of wave run-up and

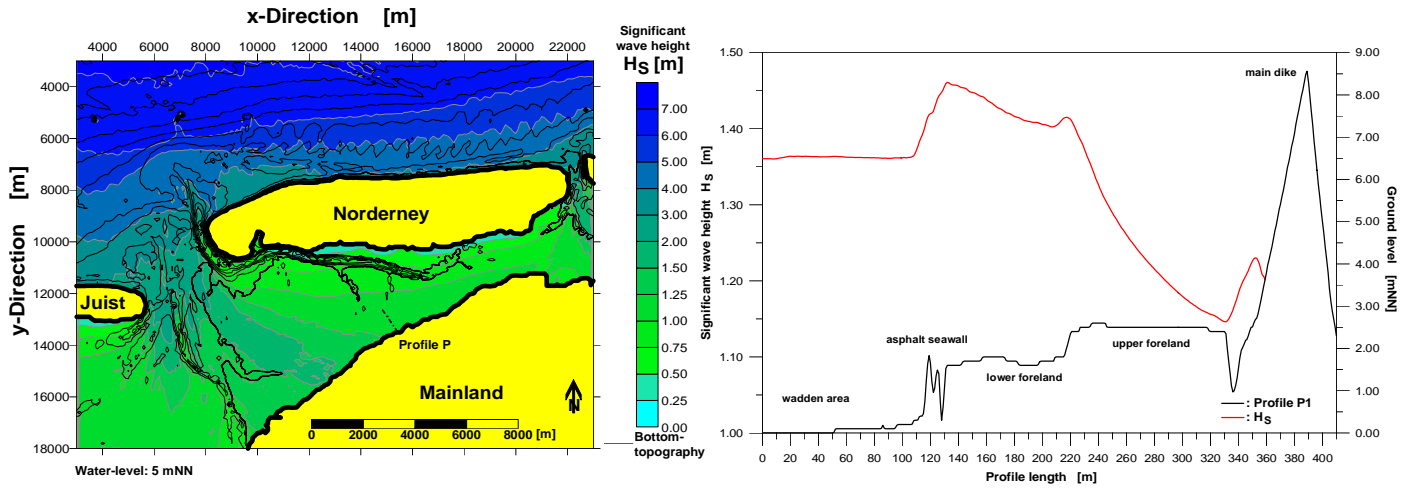


Figure 1: Coastal Protection System (Island, Wadden Sea, Foreland, Dike) and Wave Propagation.

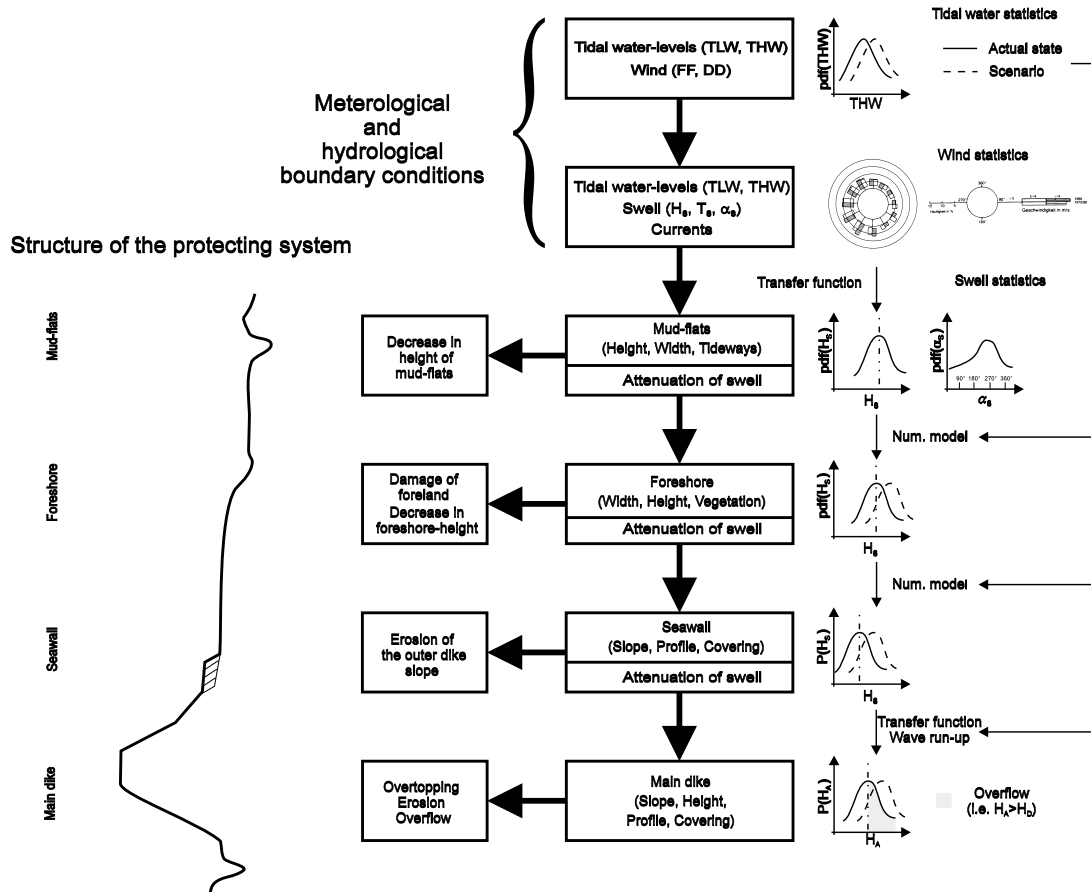


Figure 2: Probabilistic Evaluation Scheme applied to a Coastal Defense System.

wave-overtopping respectively.

Figure 2 shows the applied probabilistic evaluation scheme.

The probability of wave overtopping, i.e. the safety standard, equals the integral over the pdf of wave run-up for all situations which result in wave

overtopping, i.e. the sum of water level and wave run-up is larger than the construction height of the dike.

The probability-based concept used is a so called level III concept which describes that all of the mentioned the probability distributions do have their true shape and are not approximated by e.g. Gaussian distributions.

The effectiveness of a coastal protection element is determined by comparing the pdfs of wave parameters at locations on the seaward side of the protection element with those on the landward side.

The contribution of a protection element to the safety of the whole defense system is determined by the difference of the probability of wave-overtopping at the main dike with and without the element in scope.

By changing charakteristic parameters of the coastal defense element and using the described analysing scheme for each modification the dependency of safety on the design parameters of the defense element is revealed.

The contribution and effectiveness of particular coastal protection elements strongly depend on the probability distributions of the input parameters. This effect is examined by applying different scenario for altered pdfs of the input parameter and calculating the change in safety of the whole system and the effectiveness of each element. The results can especially be used in order to give first estimates of the effect of climate changes on the safety of the existing protection systems and on probably necessary reactions for design criteria.

Figure 3 shows an example of the pdf of the input parameter water-level and the calculated probability distributions of the significant wave height at different locations of the coastal protection system.

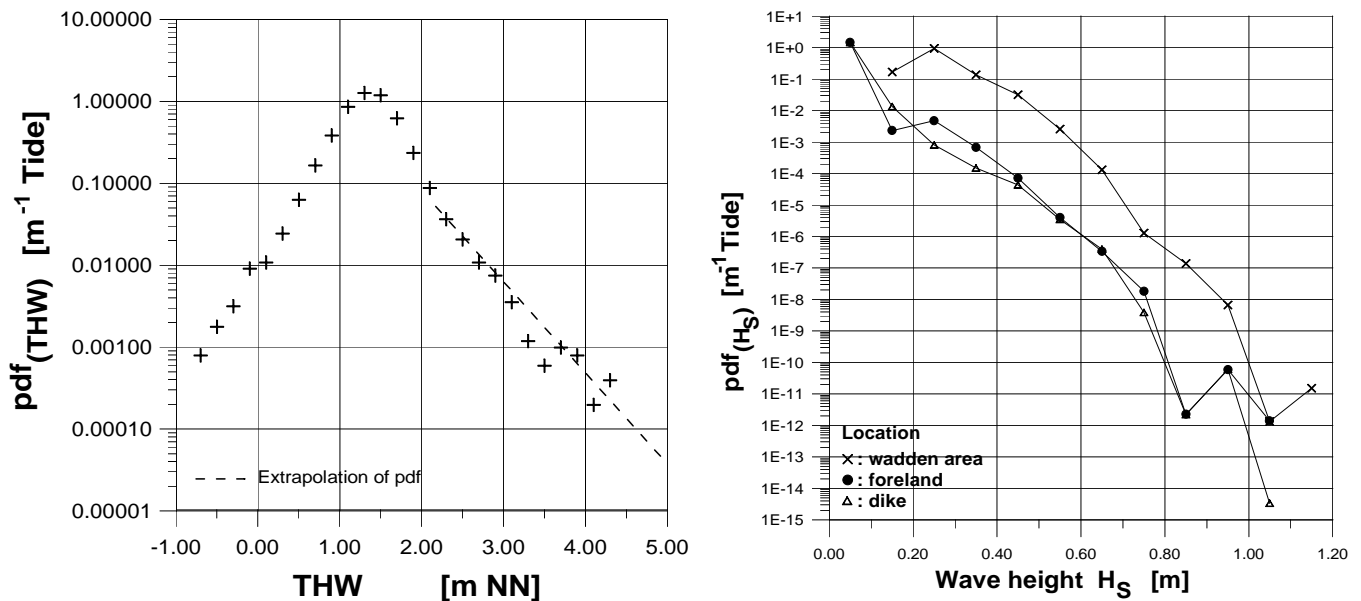


Figure 3: Relation of Pdfs of the Input Parameter High Water Level (left) and of the Calculated Significant Wave Height at Different Locations within the Coastal Defense System (right).

Preliminary results show that the protection elements, dune islands, wadden areas and forelands, increase the safety of the whole protection system more than the defense systems summer dikes and brush wood groynes. With rising mean sea level the importance of summer dikes increases in comparison to the foreland and wadden area. Nevertheless the safety of the whole coastal protection system is significantly reduced under rising water levels. First re-

sults show that the probability of wave overtopping will be quadrupled due to a rise of the mean sea level of 0.5 m and increase ten-fold due to a raise of 1.0 m.

Figure 4 shows the effect of varied input parameters on the safety of typical coastal protection systems.

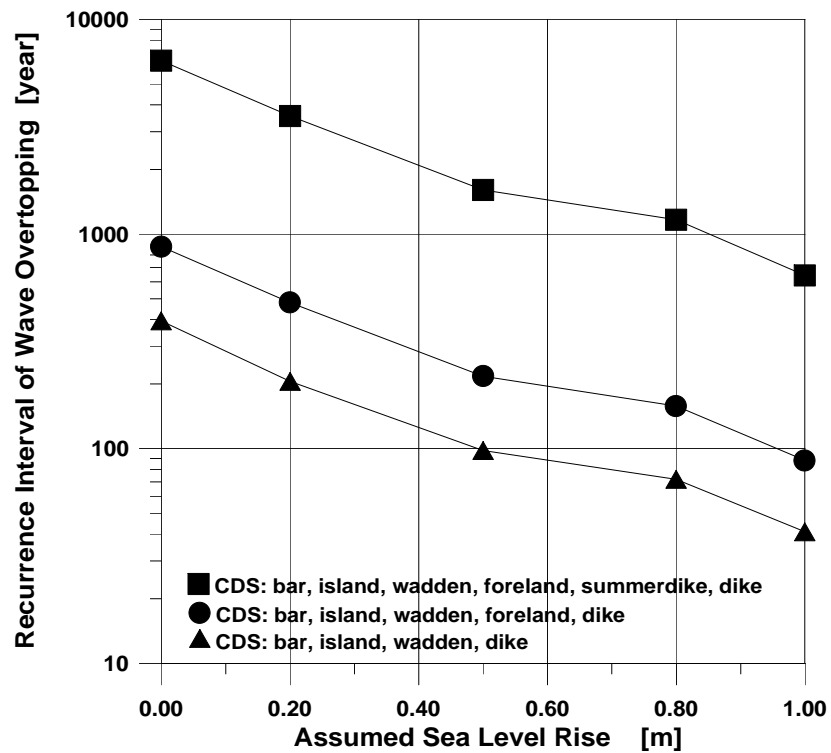


Figure 4: Recurrence Interval of Wave Overtopping as a Function of a Rise of Mean Sea Level for different Coastal Protection Systems (CDS).

The application of the probabilistic evaluation scheme show great differences in the recurrence period of wave overtopping for the different coastal areas even though the coastal protection systems were designed in the traditional way in order to guarantee the same safety. Future design of coastal protection systems and their adaption to changing environmental stresses should therefore take probabilistic methods into account in parallel to a purely deterministic design.