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Risk Analysis within Coastal Zone Management

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Summary

Natural hazards and human activities in the coastal zone are threatening the coastal system. Conflicts of interest between economic benefits, coastal defence or ecologic assets should be identified and solved by a Coastal Zone Management approach. Today`s design of coastal defences does not take into account the inundation of the hinterland in case of failure of the defence system, while the risk analysis takes into account the damage in case of inundation. In comparison to the traditional design the risk analysis needs a wider data basis, especially regarding the economic value of the hinterland. In order to provide an interface to the coastal zone management the different steps of a risk analysis were integrated into a Geographic Information System of the Jade-Weser estuary using ARCVIEW. With this information system called RISC (Risk Information System Coast) a tool for the decision making process in coastal zone management supported by risk analysis is provided.

1 Introduction

The coastal zone is essentially a natural resource system, which provides space, living and non-living resources for human activities. Being easily accessible the coastal zone has been inhabited by man from the early days of civilisation. The coastal zone is now a focal point as a large number of social and economic activities are concentrated in this area. The importance of the coastal zone will further increase in future due to the conflict between short term economic benefits, long term ecological assets and the need of coastal defence (EUROPEAN COMMISSION, 1999).

The aim of the Coastal Zone Management is to mediate between the different demands like nature conservation, fishery and agriculture, settlement and tourism or commercial respectively industrial uses within the coastal area. The latter uses require a sufficient coastal defence system to prevent damages due to natural hazards. The design of these coastal defences hat to be optimised with respect to socio-economic and ecological impact. Therefore in many European countries (see e. g. PURNELL (1999) or REEVE (1998)) risk analysis is introduced into coastal zone management.

2 Method of Risk Analysis

Within the method of risk analysis risk is defined as the failure probability of the coastal defence system and the losses to be expected in case of failure. The failure of coastal protection systems at the German coast is related to dike breaches. The main cause for dike breaching is wave overtopping as former storm events revealed. The risk is defined as

(PLATE & DUCKSTEIN, 1988) the product of the probability of failure and the loss in case of failure. The probability respectively the recurrence interval of breaching can be calculated taking into account the statistics of tidal high water levels and wave run-up. The statistics of wave run-up are in general deduced numerically from the statistics of wind and wave climate. The loss determines the part of all values in the hinterland being destroyed in case of failure of the defence system. It equals the product of the total property and a damage factor being a function of the inundation characteristics (MAI & VON LIEBERMAN, 2000).

Since Geographical Information Systems support especially the decision making process and may be extended to so-called decision support systems an example of an information system developed for the coastal zone between the two cities Wilhelmshaven and Bremerhaven with a special focus on risk analysis is presented in the following. It was realised within the framework of the GIS ArcView 3.1 of ESRI and extensions of the standard functionality with its included programming language Avenue (MAI & VON LIEBERMAN, 2002a).

3 The Risk Information System Coast – RISC

The system RISC has been developed at the Franzius-Institut for Hydraulic, Waterways and Coastal Engineering of the University of Hannover as an example for the coastal region between the estuaries Jade and Weser (VON LIEBERMAN ET AL., 2001). The RISC includes information on coastal defences and their relevant design parameters as well as an inventory of the economic values in the hinterland.

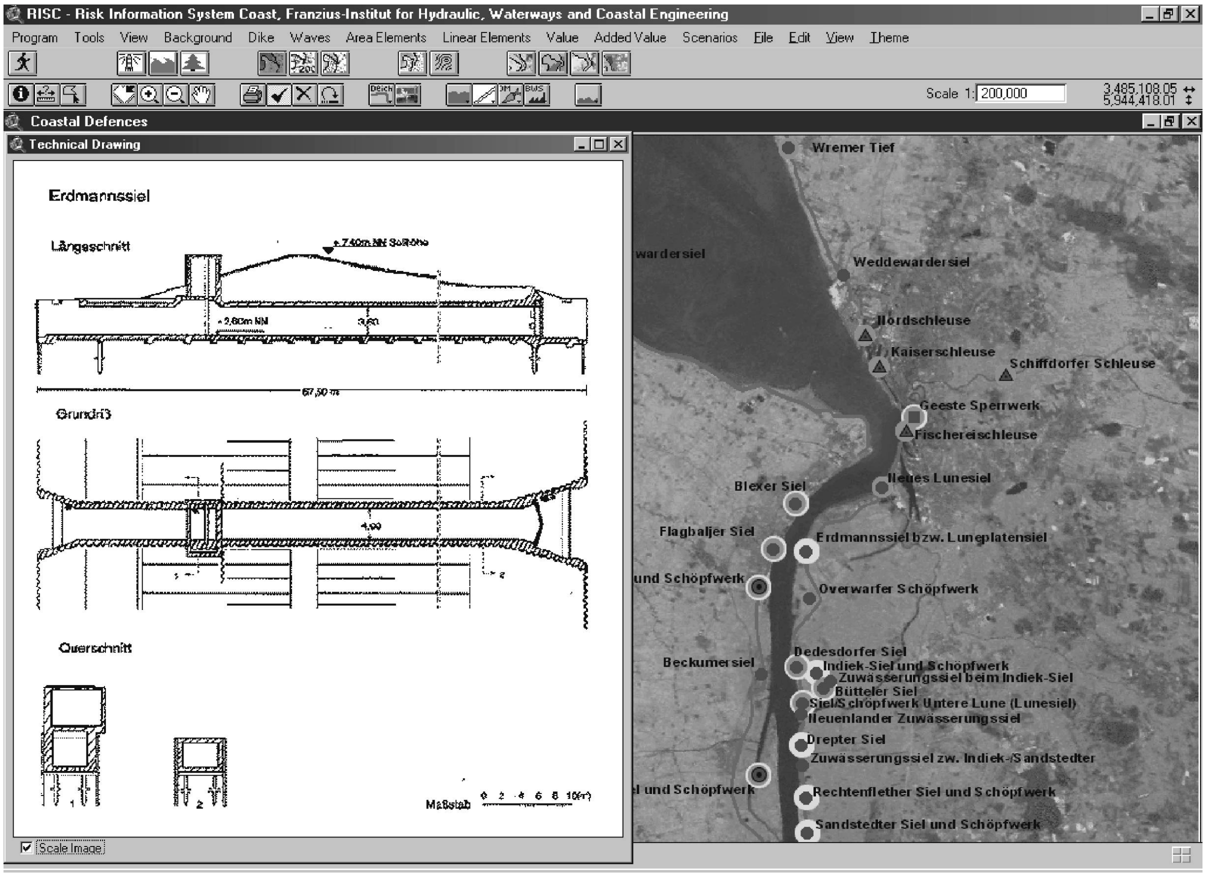

Figure 3.1 Information on Coastal defences within RISC (MAI & VON LIEBERMAN, 2002a)

Thus RISC allows a comparison of today`s safety standards and those in case of an increase of the tidal high water level due to climate change. Furthermore the consequences of adaptations in the coastal defences can be estimated.

Among others the failure analysis presented in chapter 2 requires the knowledge of the statistics of the tidal high water level and the design parameters of the dike. Thus these parameters were collected and included into RISC. Figure 3.1 shows a screenshot of the RISC, which provides information on dikes and other coastal defences like sluices, locks and storm surge barriers. The height of the dike and statistics of tidal high water being necessary to calculate the reliability are also presented. Because of missing long-term statistics on wave climate wave statistics are derived from wind and water level statistics using the numerical model SWAN (figure 3.2), which was calibrated with data of wave buoys (MAI ET AL., 2000).

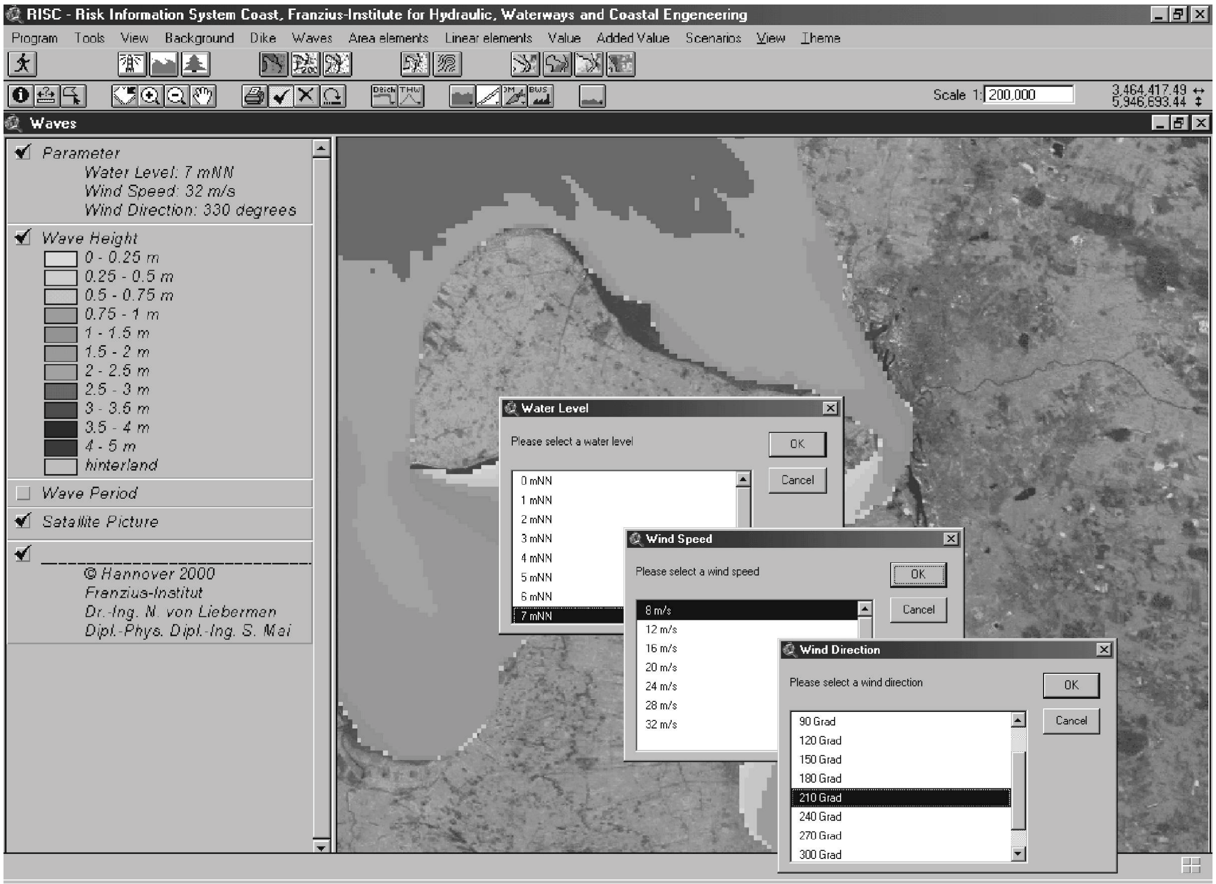

Figure 3.2 Wave forecasting in the estuary Weser within RISC (MAI & VON LIEBERMAN, 2002a)

In case of a failure of the coastal defence systems the values in the hinterland are damaged. In order to estimate the maximum damage mapping of the flood zones is necessary. Within RISC results of a depth-averaged solution of the Navier-Stokes equations with the numerical model MIKE 21 HD, developed by the Danish Hydraulic Institute DHI, for inundation after dike breaches at different locations (VON LIEBERMAN & MAI, 2001). As an example for a failure of the coastal defence system in Bremerhaven during the storm surge of the 29th of October 1976 figure 3.3 demonstrates the functionality of RISC in mapping the dynamic flooding process. Besides of maps animated videos of the inundation process are included in RISC (MAI & VON LIEBERMAN, 2002a).

Besides the inundated area RISC provides information on the spatial distribution of the total economic value, i. e. the maximum possible loss. The total economic value within the area of inundation is derived from official statistics including number of inhabitants, gross value, residential, industrial, and agricultural areas for the municipalities affected. The distribution of the parameters within the municipalities is derived by a top-down approach analysing topographical maps with respect to housing, traffic (railroad, autobahn, highway, waterway), communication and power lines, agriculture (grassland, field), and defence works, like dikes or sluices (von Lieberman and Mai, 2000). In order to calculate the loss in case of failure from the maximum possible loss typical dependences of the damage factor on the inundation depth are based on field surveys in the Netherlands during the storm surge in 1953. Unfortunately comparable data is not available for the latest storm surge in Germany in 1962.

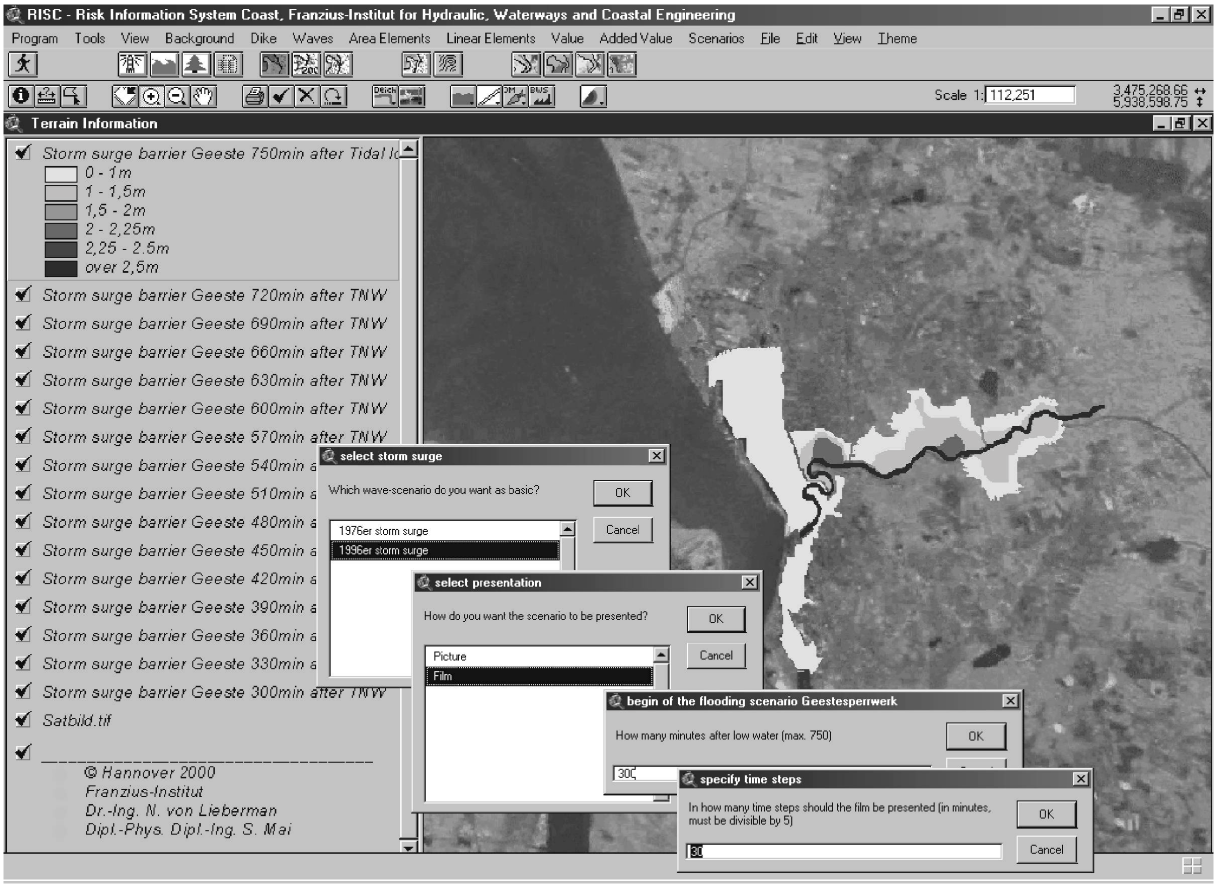

Figure 3.3 Flood zone in case of failure of the coastal defence system in Bremerhaven (MAI & VON LIEBERMAN, 2002a)

Besides the analysis of today's coastal defences under sea-level rise caused by climate changes different actions improving the coastal defence, like the heightening of dikes, the construction of storm surge barriers and the set-up of a second dike line were compared on the basis of risk maps with RISC (MAI & VON LIEBERMAN, 2002b).

4 Conclusions

The developed decision support system RISC helps to analyse the reliability of today’s coastal defences. Thus it can help decision-makers and stakeholders to optimise the allocation of investment in coastal defences and therefore in coastal zone management in order to get the same standard of risk along tidal coasts.

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