Flood risk assessment for the Danish Wadden Sea - DK

1. Policy Objective & Theme

- ADAPTATION TO RISK: Preventing and managing natural hazards and technological (human-made) hazards

2. Key Approaches

- Ecosystems based approach
- Technical

3. Experiences that can be exchanged

The specific methodology aimed at an assessment of flood risk for a coastal area.

4. Overview of the case

A risk assessment was conducted for a part of the mainland of the Danish Wadden Sea area protected by a flood defence system comprising a dyke and sluice system. The methodology includes a hazard analysis and an analysis of vulnerability leading to an overall flooding probability. Seven different defence failure scenarios were analysed and took into account six different risk elements.

5. Context and Objectives

a) Context

There is a long tradition of coastal flood defence systems along the North Sea coast. The overall objective of flood defence systems is to protect low-lying coastal areas against flooding. However, throughout history many low-lying areas around the North Sea have been flooded during storm surges due to flood defence system failure.

The design of flood defence systems has undergone extensive development in the last decades. Traditionally, flood defence systems have been designed on the basis of deterministic approaches, normally referring to a design water level and wave overtopping. However, these approaches adopt simplistically fixed design values for the various parameters of hydro-dynamic and geo-technical processes taking place at a flood defence system during a storm surge. Hence, new design methods, including probabilistic approaches, have been subjected to constant development during the last years. The probabilistic approaches allow engineers to account for uncertainties in the input parameters and the models describing all possible versions of the various types of flood defence structures.

The area of the case is situated on the West Coast of Denmark about 50 km north of the German-Danish border and is mainly characterised by a large rural area of former marshland and by an urban area, Ribe town (population 9000). The flood defence system in has a flat sea dyke (18.4 km long) with a sand core, clay and grass cover. The standard profile shows a 1:10 seaward slope and a crown height of MSL +6,88 m. The system also comprises a sluice and three outlets. The flood-prone hinterland covers over 95 km².

b) Objectives

The main objective of this study has been the performance of a risk assessment of a flood defence system located in the Danish part of the Wadden Sea. As a pilot study area, the Ribe flood defence system and the accompanying flood-prone hinterland were chosen.

6. Implementation of the ICZM Approach (i.e. management, tools, resources)

a) Management

The Danish Coastal Authority (DCA) has been responsible for the completion of the study with the support of Ribe Municipality, Ribe County and the Ribe Tourist Office 'and Leichtweiß-Institute, Technical University of Braunschweig'

b) ICZM tools

The study in hand assessed the flood risk of this flood defence system. The flood risk of the Ribe defence system was defined as the product of the flooding probability and the subsequent consequences of flooding. The study was performed in two major steps comprising a hazard analysis, calculating the overall probability of flooding for the area, and an analysis of vulnerability determining the damage potential of the hinterland in the case of flooding.

The calculation of the overall flooding probability was based on six cross-sections of the Ribe dike. Information about a total number of 80 input parameters describing geo-metrical, geo-technical and hydro-dynamic boundary conditions were collected before carrying out the probabilistic calculations. The results of the deterministic calculation for all dike sections showed that “grass erosion” failure on the seaward slope may occur under design conditions. However, no overall failure of the sea defence system could be observed. However, the calculations for the sluice and the outlets result in a very high wave overtopping rate under design conditions such that wave overtopping is therefore assumed to be the governing failure mechanism for the sluice and the outlets.

Initially, the flood-prone area was de-limited (the 5.0 m altitude line) to enable the selection of the elements at risk. Within the de-limited flood-prone area six risk elements of direct, tangible damage were selected viz. buildings, movable property, agricultural acreage, livestock, electric installations and traffic systems. Additionally, four others - inhabitants, employees, vehicles, tourism - of intangible, direct/indirect damage were considered in a descriptive form. To determine the possible damage to the risk elements, seven scenarios were defined comprising different breach and overtopping scenarios. By means of these scenarios different inundation events, including inundation extension and inundation depth, were simulated and the damage caused by the inundation events was assessed. In order to assess the damage due to inundation, depth-damage functions were derived for risk elements where the damage depends on the inundation depth. The results showed that the flood-prone area is differently inundated depending on the location and the number of failure events. In general, this vulnerability analysis showed that the total damage calculated within each scenario depends on the definition of the scenarios, the considered risk elements, the determination of the inundation behaviour and the derived depth-damage functions. The economic consequences of a flood once in 400 years would be ca. €57 million in the worst case scenario (failure of the dyke, sluice and outlets) and this risk of €14,250/year is considered acceptably small.

7. Cost and resources

No costs are available.

8. Effectiveness (i.e. were the foreseen goals/objectives of the work reached?)

The risk analysis procedure conducted is considered to be a starting point of reliability based design of flood defence systems on a feasibility level. This study has shown that it is indeed possible to consider more stochastic parameters than just the water level and the wave run-up when analysing the safety of a flood defence system. Despite the fact that many questions are still open and problems regarding the feasibility remain unsolved, the risk analysis procedure applied has resulted in a considerable increase in information about the Ribe flood defence system and the protected hinterland, which should improve the decision-making basis.

9. Success and Fail factors

Considering the hazard of failure of the flood defence system, the study has contributed to a detailed description of all possible failure mechanisms at a sea dike. Furthermore, significant failure mechanisms and their limit state equations for a sluice and an outlet have been derived. First attempts of dividing the flood defence system into representative sections and considerations with respect to the length effect have been made. As part of an assessment of the consequences of failure of the defence system, the vulnerability analysis has shown that only a small number of all assets and the possible damage may be considered in full. For some damage types the tangible property is difficult to assess. The selection and definition of the inundation scenarios are only possible events marked by a chance order. The assessment of the inundation extension and thus the dimension of the damage is only possible to a certain degree of accuracy. However, to calculate the flood risk and to assess the importance of the flood defence system as a defence structure for the inhabitants and their assets, a vulnerability analysis is indispensable. The request of data about the risk elements from national registers, consultants and public administrations showed clear differences in the data quality and format. A prerequisite for carrying out this type of risk analysis is the availability of reliable information on the hydraulic design loads, and the structural properties of the flood defence system.

10. Unforeseen outcomes

None.

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13. Sources

- Risk assessment for the Wadden Sea (2004) Kystdirektoratet, Denmark
- www.kyst.dk (mainly in Danish)
- www.cabri-volga.org

Risk assessment for the Wadden Sea (12.71 MB)