Rhine Estuary Closable but Open

An integrated systems approach to floodproofing the Rhine and Meuse estuaries in the 21st century

Rijcken, Ties; Kok, Matthijs

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RHINE ESTUARY CLOSABLE BUT OPEN - AN INTEGRATED SYSTEMS APPROACH TO FLOODPROOFING THE RHINE AND MEUSE ESTUARIES IN THE 21ST CENTURY

Ties Rijcken is an Associate Professor of Integrated Water Infrastructure Development at the Faculty of Civil Engineering and Geosciences, Delft University of Technology.

In the spring of 2008, Delft University of Technology wrote a report for the Second Delta Committee, a body set up to advise the Dutch government and parliament on the Netherlands' long-term flood risk policy. The Delft report included a colourful drawing of a solution for Rotterdam and the Drecht Cities, and the Delta Committee used this image to illustrate their 'closable-but-open' recommendation for the Rhine-Meuse estuary and explicitly recommended further research.

Research information

RHINE ESTUARY CLOSABLE BUT OPEN RHINE ESTUARY WATERFRONT

PROJECT MANAGER: Matthijs Kok
INSTITUTE: TU Delft
EMAIL: matthijs.kok@tudelft.nl
CONSORTIUM PARTNERS:
RIVM, City of Rotterdam, Rotterdam Climate Proof
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As a response to this recommendation, the study 'Rhine estuary closable but open – a multidisciplinary exploration' was carried out for Rotterdam Climate Proof and Knowledge for Climate, led by the same researchers that made the initial drawing for the Delta committee. This resulted in six specialized reports and an integration report, which are available on www.aor.tudelft.nl.
The exploration had two objectives. The first was to study the effectiveness of the idea in the Delta Committee report, the second was to gain insight in the influence of new movable flood barriers on the interaction between the components of the Rhine-Meuse estuary as an 'integrated hydraulic-spatial system'. These different components consisted of the flood risks of the areas inside the dikes (embanked areas) and the areas outside the dikes (unembanked areas), shipping, ecological

Additional 'means' could be added to this geometry. These could include movable flood barriers, such as the existing barriers in the Europoort and the new barriers proposed by the Delta Committee. These objects can direct the water in desired directions under different hydraulic conditions.
It was also possible to alter the existing geometry by connecting it to an adjacent system like the basins in Zeeland or creating an entirely new waterway outside the dikes in the area currently inside the dikes. Both these additions ('control devices' and 'system expansions') are called 'means' in the systems approach used in this research. They are defined by their location and geometry, failure probabilities and operating regimes.
Design water levels (extremely high water levels that the dikes have to be able to withstand according to national law) throughout the system follow from the definition

flows, and the spatial development of the levees and the unembanked areas (focusing on the Rhine estuary and Drecht cities region). The method chosen to achieve these goals utilized five specific alternatives. These alternatives are all variations on the initial idea of a 'Rhine estuary closable but open', from the point of view of the sea, or both the sea and the river. Researching these alternatives was to address the first goal, but, ultimately, primarily served the second goal, which was to develop a systematic approach to the situation.

THE RHINE-MEUSE ESTUARY AS A HYDRAULIC-SPATIAL SYSTEM The starting point of the systems approach was the existing geometry of the entire unembanked area (wet and dry) together with the adjacent dikes (levees).

of the alternatives, national flood protection standards and climate change scenarios. These water levels, and also the closing frequencies of the barriers, are the crucial link between the alternatives and the consequences of the alternatives on the levees, the unembanked area and shipping. Just as shipping can be seen as a network of 'flows' of ships through the system, ecological flows such as fish migration and nutrient flows also play a part in the system. Lastly, related goals such as freshwater supplies and the transportation infrastructure had to be considered for a complete systems approach.
An integrated image of the various consequences offers two important 'feedback loops'. The first comprises suggestions for other alternatives, such as an additional system expansion or to relocate, add, or omit a movable barrier.

The second comprises altering the closing regime for one or more of the movable barriers. These closing regimes deserve special attention since they are an influential, as well as the most flexible, parameter of the alternatives.

CONCLUSIONS ABOUT THE IDEA IN THE DELTA COMMITTEE REPORT Was the idea proposed in the Delta Committee report a good one? The main questions are where and to what extent the 'design water levels' will rise throughout the region, and what this means for the adjacent dikes. The consequences for the unembanked region, shipping, ecological flows and 'synergy' opportunities were the next issues to be looked at.

Hydraulic calculations show that under the Delta Committee 2008 climate scenario (which includes a 1.30-meter sea level rise in 2100), all four of the river barriers, together with the 'New Lek', will reduce the increase in the design water levels by 30 centimeter in Dordrecht and 10 centimeter in Rotterdam. In addition, reducing the failure probability of the existing Europoort storm surge barriers will lower the increase by 10 centimeter in Dordrecht and 50 centimeter in Rotterdam. Measures such as additional water storage in Zeeland, lower probabilities of failure, less leakage and smarter control of the movable barriers can further decrease the rising design water levels by up to 30 to 50 centimeter. In this way, the moment when design water levels will start to rise along with the sea level can be delayed significantly. Nevertheless, in a closable-open system, they will eventually start to rise, due to the probability that movable barriers will close too late or fail in some other way.

Increasing design water levels will not necessarily require reinforcements of the levees because substantial (though fragmented) sections of the levee-system in the western part of the Rhine estuary are currently higher than required. Higher water levels will, however, result in higher overall maintenance costs for the levees, while lower water levels can transform a normal levee into an attractive, unbreachable 'Delta Dike'. If reinforcement of levees becomes necessary, it will be expensive along the more urbanized sections. This can, however, be realized by, for example, moving the levees in the direction of the river, as has been done several times in the past. Closer research will need to focus not only on sections with or without 'redundant height' but also those that are 'over-dimensioned'.

Under the 'KNMI-G+'-climate scenario (0.60-meter sea level rise in 2100), the current design water levels in Rotterdam and Dordrecht can most probably be maintained until 2100, with the addition of extra water storage capacity in the South Western Delta, a Maeslant arrier with a low failure probability and an additional 'Merwede Barrier' (it should be noted that these measures and their interaction need more detailed research). In the longer term, many solutions are possible; all will, however, combine movable barriers or dams at strategic locations, system expansions and/or levee reinforcements. Conceiving these using 'road maps', along 'timelines', or with a 'serious game' will provide the necessary insight in the wide range of measures that are possible. Understandable visual communication will contribute to foreign confidence that the Netherlands is in full control of its long-term flood risk.

MAINTAINING A DELICATE BALANCE OF INTERESTS THROUGHOUT THE COMING CENTURIES Flood risk measures for embanked areas influence related interests, such as shipping. Under the current closing regime of the Europoort barrier, a sea level rise of 1.30 meter would result in a closing frequency of 30 times every winter. This would lead to an unreliable shipping connection to the hinterland and unacceptable financial damage to the shipping sector. A sea level rise of 60 centimeter would necessitate a closing frequency of about once every year, which would probably be acceptable to the Port of Rotterdam and the shipping industry.

If current closing regimes are maintained (which is unlikely), at a sea level rise of 1.30 meter, the movable barriers will not prevent an increase in the flooding of areas outside the dikes by a factor 5 to 10, costing several million euros a year. These unembanked areas could cope with more frequent flooding with the aid of adaptive measures on different levels: buildings, building blocks or enclosing an entire area with a new levee construction. Shipping can use routes along the southern branches of the system. This would enable lower closing levels for potential barriers in the Lower Merwede, the Noord or the Old Meuse.

Unless a radical solution in favour of one of the interests is adopted sometime during the next two centuries, the Rhine-Meuse estuary system will have to implement customised 'step-by-step' measures in an ongoing manner. Safeguarding the region from flooding will mean maintaining a delicate balance between complicated fortification of the lowest urbanized levees, the flood risks for the embanked and unembanked areas, reliability for inland shipping, and ecological flows through the region. The movable barriers will be able to coordinate this balance since their closing regimes can easily be altered at any given moment, for the benefit of either shipping or the unembanked areas. In the current situation, for example, the closing frequency of the Europoort barrier could still go up, as the average closing rate is still only once every 12 years. Control measures like this provide the time for unembanked areas to adjust to higher water levels.

The objects that currently control water flows in the Rhine-Meuse estuary are either dams with gates (the Haringvliet dam and the Volkerak dam), or movable barriers like the Maeslant Barrier. A new design that combines these two types of barriers could be a promising alternative. This would be a barrier with a low probability of failure but a high capacity for shipping passage, river discharge and ecological flows. When designed with care, water engineering works of this nature can blend in well with their urban or rural surroundings and provide additional value as they connect the opposite shores, create attractive public space and serve as a landmark.

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ROTTERDAM CLIMATE PROOF

The Rotterdam Climate-Proof programme will ensure that Rotterdam will be climate-proof by 2025. Permanent protection and accessibility of the city and the port are the key elements. The full focus of the programme is on creating additional opportunities to enhance the attractiveness of the city in terms of living, recreation, working and investments. Trendsetting research, innovative knowledge development and decisive implementation will result in strong economic impulses. Together with prominent partners, Rotterdam will become the innovative water knowledge city of the world and an inspiring example for other delta cities. Rotterdam Climate-Proof participates in the Rotterdam Climate Initiative.

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