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WAVE AND WAVE OVERTOPPING MEASUREMENTS IN A COMPLEX AREA AND AT A REAL DIKE

PATRICK OOSTERLO[1], JENTSJE VAN DER MEER[2] AND MAARTEN OVERDUIN[3]

1 Rijkswaterstaat, The Netherlands, patrick.oosterlo@rws.nl
2 Van der Meer Consulting BV, The Netherlands, jm@vandermeerconsulting.nl
3 Infram Hydren, The Netherlands, maarten.overduin@infram-hydren.nl

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1 INTRODUCTION

Wave overtopping is not easy to measure in real field situations. A 12-years long program started in 2018 to measure wind, wave and water level conditions in a complex estuary, together with wave overtopping measurements at dikes. The first winter storm was measured on 8 January 2019 and first results were described in Van der Meer *et al.* (2019). Wave and water level conditions are measured directly in front of the dike. Overtopping is measured with two identical overtopping boxes that were placed in the dike, but at different levels, see Figure 1. A measuring pole in front of the dike has measured wave and water level conditions for 10 years already and the design of the overtopping boxes was based on those data. In recent years, a system was invented that measures wave run-up and wave overtopping with two parallel lasers, see Figure 2. The laser scanner system was placed next to the overtopping boxes to enable a proper validation. First results were presented in Oosterlo *et al.* (2021a; 2021b). This paper describes the further storms that have been measured up to now, including new measurement devices, improvements to measurement devices and new analysis methods. This all brings new insights, but more storms and improvements of measurements are needed to come to a full understanding of this complex estuary.

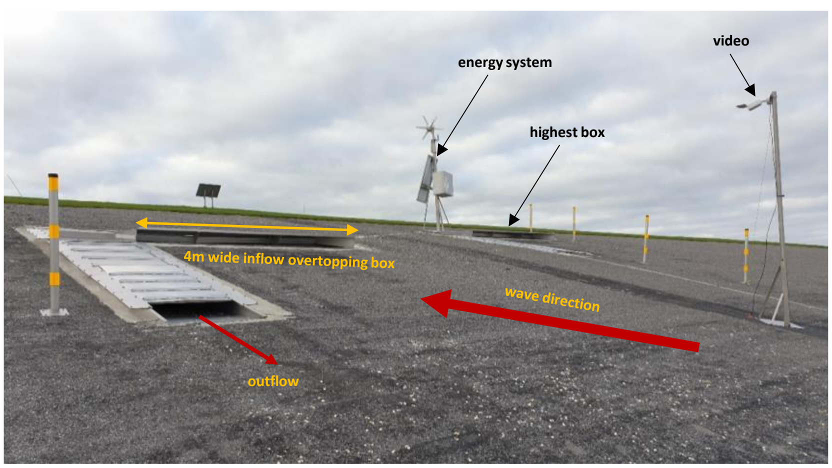

Figure 1. Two 4 m-wide overtopping boxes in the dike to catch wave overtopping volumes during storms.

The considered highly complex estuary is the Eems-Dollard estuary in the north of the Netherlands, with several barrier islands, deep tidal channels, shallow tidal flats and wetlands. The estuary is part of the Wadden Sea. The focus of this paper lies on a dike section near the Eemshaven (the main port in the area). A particular aspect for this area is that the design conditions for dikes are characterized by obliquely incident waves, up to 80° relative to the dike normal, mostly generated in the shallow Wadden Sea. Extreme storms in the area tend to start out in the southwest and then turn to the northwest, but they never cross north to become eastward directed. Moreover, waves from the North Sea may enter the tidal channel, break to some extent and then arrive at the measurement site with longer wave periods and from another direction than the local wind waves. Finally, infragravity waves may reach the measurement site, although it is yet unclear from where these waves originate mainly: reflected from offshore coasts, generated in the North Sea or in the Wadden Sea by short wave breaking.

The storms and wave overtopping are measured with the measuring pole, ADCPs, WaveDroids (small wave buoys), overtopping boxes and lasers and then numerically hindcasted, giving validation and/or improvements to existing prediction models. The measurements on wave overtopping will be compared to guidance as available in EurOtop (2018). The final objective after 12 years is to derive improved methods for dike crest level assessments and dike designs, with reduced uncertainties of design parameters, especially for these kinds of complex areas.

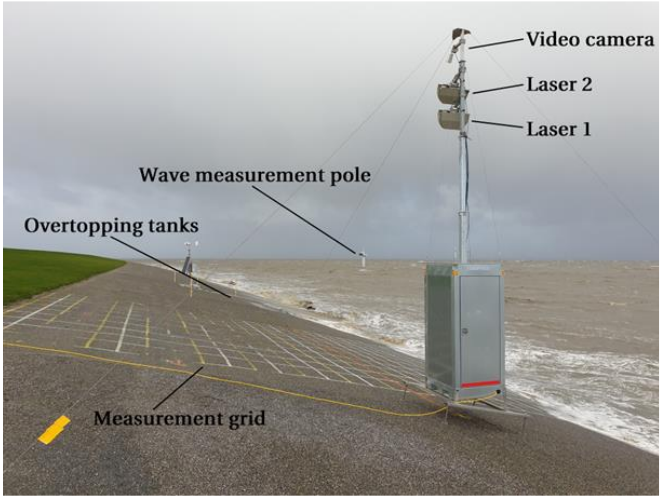

Figure 2. The double laser system next to the overtopping boxes with the measuring pole in the background.

This paper will present:

- The improvements to the overtopping boxes;
- Improvements of fitting individual overtopping volumes according to EurOtop (2018);
- Results of extra measurement devices such as ADCP and WaveDroid, which provide the 2D wave spectra;
- Measurements of wave run-up heights, layer thicknesses and velocities by a system of two lasers;
- Estimation of wave overtopping volumes and discharges by a system of two lasers and validated by the overtopping boxes;
- A novel improvement to get wave heights and periods from the laser system, as well as the 1D and 2D wave spectra;
- Results of all storms measured, including the winters of 2023 and 2024.

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