Coastal engineering benefits of sand nourishments at the shores of Walcheren (SW Netherlands)

J. Stronkhorst, M. Boyall and Wietse van de Lageweg

HZ University of Applied Sciences, Research group Building with Nature, Het Groene Woud 1-3, Middelburg, the Netherlands

1. INTRODUCTION

Sand nourishments have become an important part of the solution for coastline retreat of sandy shores caused by erosion and sea level rise (Stronkhorst *et al.*, 2017). For decades sand nourishments have been executed throughout the coastline of peninsula Walcheren (SW Netherlands) with the goal of improving coastal safety, widening beaches for recreation and reducing the impact of coastal erosion on dune habitats and the landscape. While the coastal engineering benefits of sand nourishments have become clear, it remains challenging to understand the economic rationale of these nourishments compared to the alternative coastal defense strategy of dike construction and reinforcement. There is demand for direct comparisons between 'soft' *building with nature* methods like sand nourishments and traditional 'hard' coastal engineering methods such as dike construction. This demand is only heightened by the expectation of rising costs due to sea level rise.

2. METHOD

Data on beach and dune development at Walcheren were derived from the JARKUS database (https://publicwiki.deltares.nl/display/OET/Dataset+documentation+JarKus).

The database contains coastal elevations since 1965 for 150 cross sections corresponding with a beach-pole grid spaced 250 m apart. The MorphAn coastal modelling tool (Lodder & van Geer, 2012; Deltares, 2016) was applied to the coastline movement. First, the historical trends were determined in volume and position of individual coastal transects over the pre-sand nourishment period 1965-1978. Second, the estimated erosion or accretion trends were applied to the coastline (MKL) to model a 'what-if' scenario in which the sand nourishments had not occurred over the period 1979-2019. Two models were applied for coastline movement over the last 40 years using these historical trends: a linear trend model and natural log trend model. The modeled MKL was then compared with actual observed coastline MKL in 2019. Third, dune safety was assessed with weak points identified, using Dutch flood risk standards in MorphAn (Figure 1). Finally, a comparison was made between on the one hand the costs of 'hard' coastal defences at these weak points and on the other hand the costs of the conducted sand nourishments. Reference data on cost for the 'hard' coastal defences and sand nourishments originated from regional Waterboard Scheldestromen dike/dune reinforcement project Dishoek in 2008 and national agency Rijkswaterstaat Sand nourishment program in the period 2000-2020, respectively.

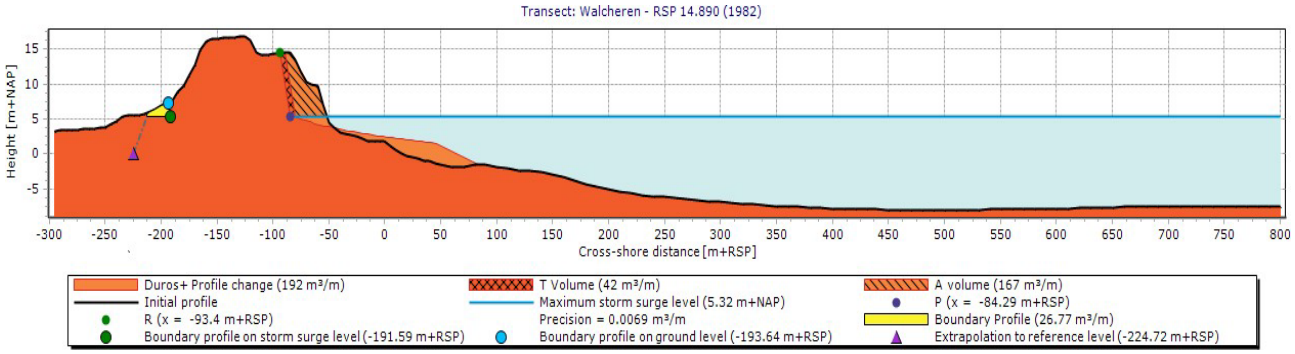

Figure 1: Dune safety assessment module in MorphAn. The hatched area indicates volume loss due to erosion

3. RESULTS AND DISCUSSION

Over the period 1979-2019 some 70 separate nourishments have been executed on the shores of Walcheren at a cumulative estimated cost of €180 million. Table 1 shows a comparison between the observed coastline in 2019 and the modeled coastline (linear and natural log model) in a scenario without sand nourishments. The sand nourishments resulted in coastal advance along 70% of the 33 km long coastline with an average gain of 48-66 m. This indicates that not only are sand nourishments preventing erosion but are meaningfully expanding the dunes and beaches.

Actual MKL (2019) Compared to Modelled Coastline Position (2019)					
Status	Number	Coastline Movement (m)			
		Linear Model		Natural Log Model	
		Average	Standard Dev.	Average	Standard Dev.
Advanced	107	66.2	67.4	47.9	47.2
Retreated	28	-12.2	71.1	-5.4	46.3
Unable to Determine	15	-0.5	N/A	0.6	N/A

Table 1: Comparison of actual coastline position (2019) to modelled position

The model simulations suggest that in the absence of sand nourishments over 40 years, volume trends result in a decrease in dune safety and a growing length of the coastline would require dike reinforcement. Given a unit price of approx. € 13 million per km dike reinforcement, the reinforcement costs are estimated at € 132-155 million (Table 2). The additional cost of coastal maintenance without sand nourishments of € 0.78 million/y was added to the reinforcement costs over the model period. This total compares to an expenditure on sand nourishments.

Total Costs w/o Sand Nourishments by 2019		
	Linear Model (millions)	Natural Log Model (millions)
Reinforcement Costs	€ 155	€ 132
Coastal Maintenance Costs	€ 31	€ 31
Total	€ 186	€ 163

Table 2: Alternative coastal defence costs in a scenario without sand nourishments

In conclusion, the overall value of the sand nourishments looks to be very positive as they advanced most of the coastline substantially, reduced reactive maintenance and increased beach area for recreation.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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