Engineering: Building with Nature 101x MOOC

Hints and Information for Building with Nature Design

Case 4: Coastal Protection

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In 2003 an investigation into the coastal protection level along the Dutch coast over the next 50 years revealed that there were 10 weak links in the chain of defences. One of these is the 5 km long dike at the Hondsbossche Pettermer Zeewering between Camperduin and Petten. This is the first massive, stone dike ever constructed in the Netherlands. Construction of the dike began after the Sint-Elizabeth flood of 1421, but the sea broke through at times and the dike was repaired and reinforced repeatedly. In 1823, the stone dike was built and in 1977 the dike was raised to meet the safety standards of the time. The Petten of today shelters behind the sea wall, which together with dunes to the south and north, protects the hinterland from flooding. A nearby nuclear power plant, and areas of the province of North Holland, including large parts of the Dutch capital Amsterdam, may be flooded should this dike no longer be able to withstand the water levels, waves and winds associated with a severe storm of the magnitude that can occur on average once every 10,000 years. The question arises of how to strengthen this weak link.

You are required to design a nature-friendly solution to ensure the coastal protection of this stretch of coast. An additional requirement is that no maintenance nourishment may occur within the ten year period after construction, so that the ecosystem has time to recover.

Client and Stakeholders

The primary problem owners are the Dutch Ministry of Infrastructure and Environment, and their operational arm Rijkswaterstaat, and the district water board Hollands Noorderkwartier tasked with maintaining coastal safety levels. Other stakeholders include the Province of Noord-Holland, local residents, entrepreneurs, nature lovers, recreants, tourists and the nuclear facility. Nature organisations.

Legal issues

The dune area to the south of the Hondsbossche Pettermer Zeewiering is a protected nature area under both Dutch and European Law (Natura 2000 area).

Potential solutions such as managed retreat or raising of the dike (see Figure 1) would have consequences for properties on the coast with accompanying costly and lengthy procedures. Seaward there are very few legal issues. There is a strategic environmental decision regarding sand mining from the seabed on the Dutch continental shelf. Particular areas are designated for sand mining, and there are prescriptions on the manner in which this is undertaken. So there are no practical limitations on the availability of sand.

Potential Solutions

A number of potential solutions have been explored for strengthening the coast. Beach nourishment rather than reinforcing or raising the existing sea wall is seen as delivering more opportunities for recreation, tourism, nature and the economy. Similarly, high costs and delays are anticipated with managed retreat. Potential solutions could therefore involve reinforcing the coast with sand. The range of alternatives, depicted in Figure 1, includes:

- **Raising the dike**. This conventional solution would also require dike heightening and broadening of the base of the dike. Investigations of the strength of the dike core would also be

needed, given that it is a very old dike. High costs are associated with this approach. Some houses / properties would be affected.

— **Dike in dune**. Burying the dike in sand to create a broad dune encompassing the dike at its core. Investigations of the strength of the dike core would also be needed, given that it is a very old dike. Unlikely to contribute much ecologically, and some houses / properties would be affected.

— **Seaward extension.** This alternative involves seaward broadening of the dike with a dune field. With this measure the existing dike is retained, but the sharp transition from the dunes to the south to the Hondsbossche- Pettermer Zeewiering is smoothed. This smoothing of the coastline near the weak point is expected to address the problem of concentration of wave energy at the transition point, and so also reduce coastline maintenance requirements.

— **Broad seaward extension.** This alternative involves the creation of a broad dune field seaward of the dike. It means ignoring the contribution of the dike to coastal defence and using dunes to completely fulfil the safety requirement on their own. The strength of the existing dike then no longer has to be investigated. It leads to broader beaches and dunes, and improves the spatial quality of the area.

— **Managed retreat**. This involves the removal of (part of) the Hondsbossche Pettermer Zeewiering and the creation of a wetland and dune system behind the exiting dike. Properties would have to be expropriated and people would have to leave their homes. A new sea dike or alternative defence would have to be constructed further inland, around the wetland/dune system. Lengthy and costly legal proceedings are likely.

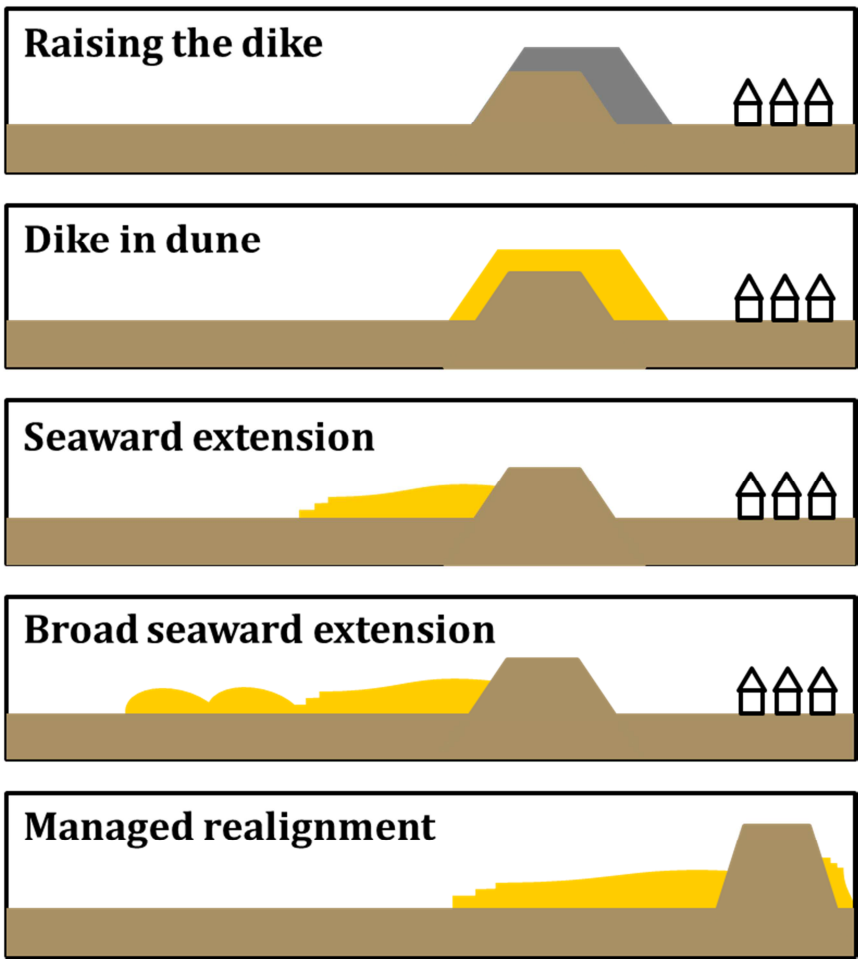

Figure 1: Potential coastal protection solutions

Ecological knowledge and expertise

Nature organisations, the Dutch Ministry of Infrastructure and Environment, universities and research institutes e.g. IMARES and Deltares, amongst others, have knowledge of the dune and sandy beach system.

The initial indications are that a mega sand nourishment (larger volume, for longer time perid) than the present shoreface nourishments at intervals of 3 to 5 years, may have a net positive effect for the ecosystem. However, research is in progress and evidence is still being collected regarding the ecological effects at the Sand Engine[1] on the South Holland coast.

At the Sand Engine, the lagoon is an interesting feature, providing a more diverse abiotic environment for colonisation by species tolerant of a brackish environment. The entrance channel is highly dynamic and the raised areas of the Sand Engine deliver wind-blown sand to the beach and dunes. Pioneer dune areas can start to form in front of established dunes. However, the small groundwater seeps and dune valleys characteristic of wide dune fields are not present, and the species characteristic of these zones are not offered opportunities. These include Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*). The landscape is also not as varied as that of the Schoorl dune field south of the Hondsbossche Zeewering, where dunes achieve heights of 58m above NAP and there is a wide variety of vegetation types.

Some useful engineering concepts and information

Characteristics of the North Holland coast:

- Sandy, wave dominated coast
- Microtidal, semi-diurnal tides with a mean tidal range 1,4 m to the north and 1,6 m to the south
- Mean annual wave height of 1,3 m, predominant from the SW and NNW (See wind rose, Figure 2)
- Median grain size (D_{50}) between 200 µm and 350 µm

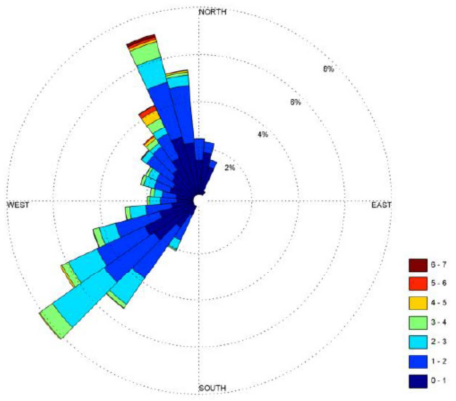

Figure 2: Wind rose for 1995 (Source: Giardino et al. 2012)

In Figure 3, the natural dynamics of a cross shore profile are shown. In winter, when storm and higher waves are common, the sand is eroded from the beach and deposited on a nearshore bar and in summer the low wave conditions move the sand back onto the beach. Of course, this conceptual model ignores processes such as longshore transport and loss of sand to deeper water, but it does provide the rationale for the shoreface nourishments used to maintain the coast. In a shoreface nourishment, the sediment is

[1] You are referred to the material on the Sand Engine and the Building with Nature Design Assignment example case for further information on the ecological consequences of a mega nourishment.

typically deposited immediately seaward of the outer bar and is transported to the beach under low wave conditions.

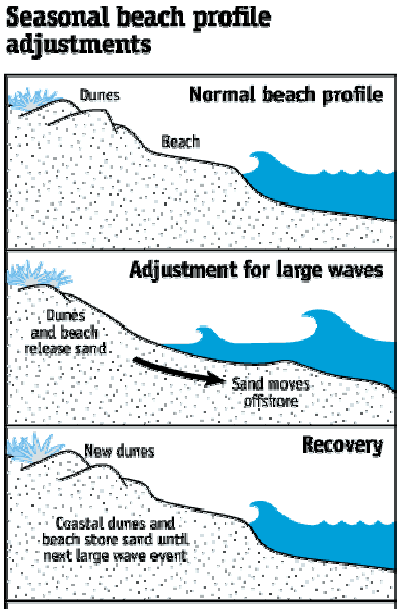

Figure 3: Natural dynamics of a cross shore profile Source: http://www.landforms.eu/lothian/beach.htm)

So, if you wish to design and undertake a seaward extension or nourishment, it is necessary to determine the length of coast over which this will occur, how much sand is needed for the extension, and how much sand needs to be added as a buffer. **The buffer is needed as no maintenance dredging is allowed within the first 10 years,** so that the ecosystem can start to recover from the initial major disturbance.

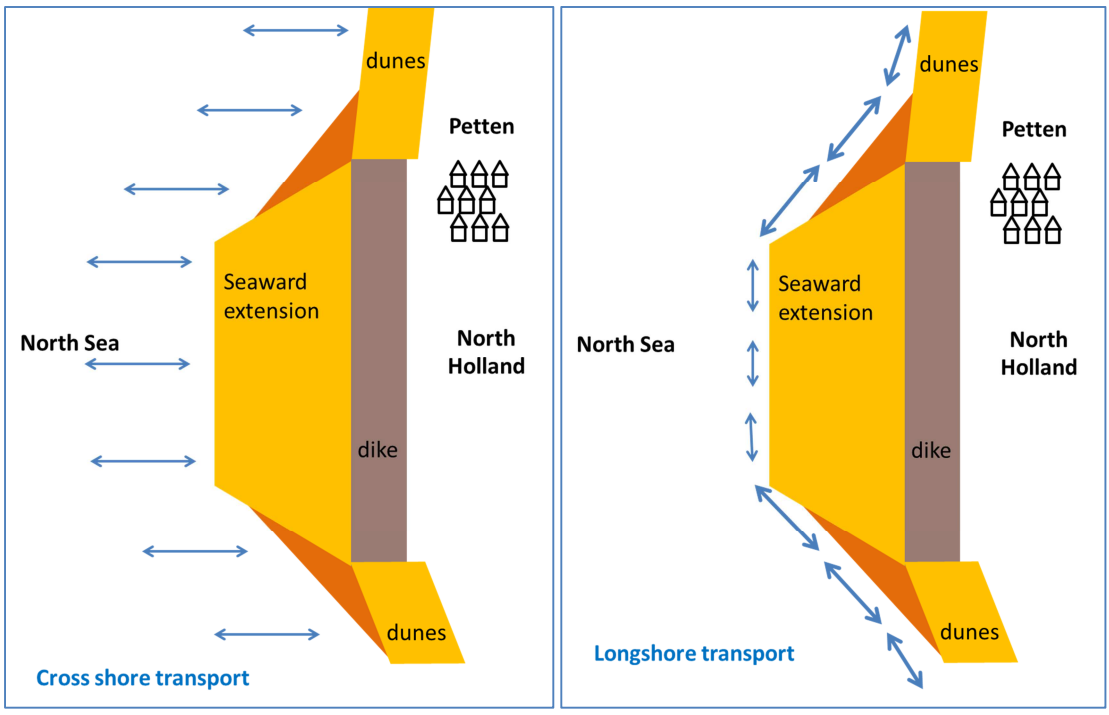

Figure 4: Plan view of the cross shore and longshore sediment transport processes operating on a seaward sandy extension in front of a dike

You may assume that the complex and site specific transport processes in the coastal zone mean that at this location the minimum sand volumes per meter of coast required to realise a 100 m or 300m seaward extension are **1000 m^3/m** and **2500 m^3/m**, respectively. However, the cross shore sediment profile of the mega nourishment will be steeper than the equilibrium profile (cf. Bruun 1954, Dean 2002). This means that the profile will adjust and that sand will be transported offshore, say a loss of **10 m^3/m per year**. You will need a buffer to compensate for these cross shore losses. Similarly, longshore processes are strongest where the longshore gradients are highest i.e. at the sides of the seaward extension. In this design, the gross longshore transports dominate over the net longshore transports. You may assume a loss of **0, 4 million m^3 sand /yr** owing to gross longshore transport gradients along the coast.

So, it is up to you to **choose the length of your project area** both seawards and along the coast and **how you will distribute the sand**. In designing your Building with Nature solution, you will need to take the longshore and cross shore processes into account. You will need to calculate how much additional sand you need in your buffer and where you will spread it: everywhere, only in the middle or on the sides of the nourishment? Remember, the buffer will need to see you through the **first 10 years**.

You are also advised to include a buffer to address sea level rise (Stive 2004), and to accommodate the uncertainty in the occurrence of storms (**between 0,3 and 0,5 million m^3/yr**).

Enjoy designing your Building with Nature solution!

References

Bruun, P. (1954) Coast erosion and the development of beach profiles. Beach Erosion Board Technical Memorandum. No. 44. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS.
Dean, R.G., Kriebel, D.L. and Walton, T.L. (2002). Cross-shore secdiment transport processes. Chapter 3 of Part III of the Coastal Engineering Manual, EM 1110-2-1100.
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Stive, M.J.F. (2004). How important is global warming for coastal erosion? *Climatic Change*. 64: 27 – 39.

Diagram retrieved from: http://www.landforms.eu/lothian/beach.htm