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## On the border of water and land

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**Prof. dr. ir. S.G.J. Aarninkhof**

# On the border of water and land





# On the border of Water and Land

Inaugural speech

Spoken at the occasion of acceptance of the  
position of full professor of Coastal Engineering  
at Delft University of Technology

On Wednesday May 10 (2017)

by

**Prof.dr.ir. S.G.J. Aarninkhof**

Translation by MSc Mariette van Tilburg

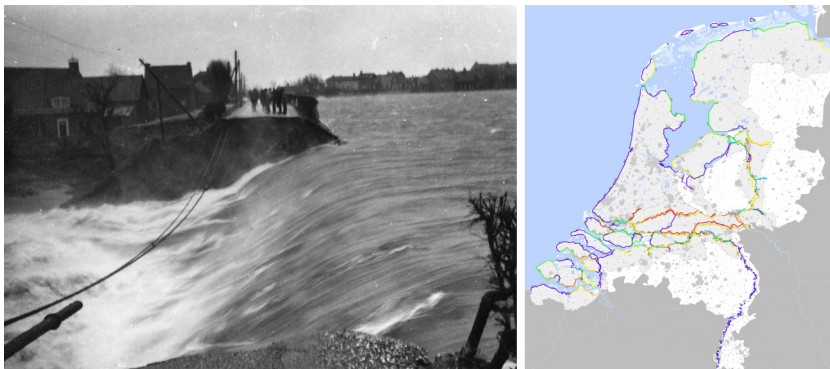
*Rector Magnificus, Members of the Executive Board, Fellow professors and other members of the academic community, dear family and friends, esteemed audience, ladies and gentlemen,*

The coast leaves few people untouched. Many of you will remember with nostalgia the family summer outings to the beach, or cherish the space and peace of a walk in the evening light. Proposals for construction, economic activities or other interventions in the coastal zone can invariably count on a serious debate between advocates and opponents. Dutch hydraulic engineers feel a tingling of pride when they bring new land above water in remote, exotic places - and thus, literally, expand the horizon of a country. However, this very sea has a much more grim face during a storm surge with waves crashing on its shores and the security of the country at stake<sup>1</sup>. All of these aspects - protection against flooding, infrastructure, nature conservation, recreation, environmental planning - play a role in the field of coastal engineering.

According to the Coastal Engineering Manual of the U.S. Army Corps of Engineers (USACE, 2002), the history of coastal engineering begins in classical antiquity in the Mediterranean countries. The driving force behind this is the rise of shipping, around 3500 BC. Initially the engineering concerned the construction of berths, breakwaters and other harbour infrastructure. The port of Alexandria, built around 1800 BC with a capacity for 400 ships, was probably the most advanced of its time. In later times the Romans implemented numerous innovations in port design, including the construction of walls under water. A combination of increasing prosperity and excellent infrastructure gave rise to a new phenomenon: beach recreation. This led to an unprecedented growth of the seaside resort of Baiae in the Gulf of Naples

With growing populations in coastal areas and the need for land for agriculture, flood protection became an increasingly important driver for the development of coastal engineering. Large floods, like the 1953 *Watersnoodramp* in the Netherlands (Fig. 1), but also the tsunami in South-East Asia and Hurricane Katrina in the United States, have permanently changed the coastline. They form the prelude to major investments in coastal protection schemes, giving an enormous boost to coastal research.

<sup>1</sup> To experience what this means to people I recommend a visit to the impressive 'Watersnoodmuseum' in Ouwerkerk, Zeeland.



*Fig. 1: Dike breach during 1953 Watersnoodramp (Source: Beeldbank Rijkswaterstaat, left) en scope of Dutch High Water Safety Program 2017-2022 (right)*

This is particularly the case in Netherlands, where the coast with its dunes, dams and dikes protects the low-lying polders against flooding. Most of the population lives and works in the so-called *Randstad*, the urban agglomeration of cities in the low-lying west of the country and economic engine of the Netherlands. Protection against flooding has the highest priority in Dutch coastal management. Yet, at the same time, the management has an integral character: in addition to coastal safety it aims to serve additional goals such as housing, nature and recreation. In order to secure coastal safety, every six years the government evaluates the strength of dikes and dunes for benchmark storm conditions.

In the period 2011-2016 all primary defenses have been reviewed. This has defined the scope of the High Water Safety Program 2017-2022 (Fig. 1b). The scope is based on the application of new safety standards, which not only account for the probability of failure of a barrier, but also its consequences. All defenses in blue are judged as safe. Inadvertently the question arises: Are we done with the coast?

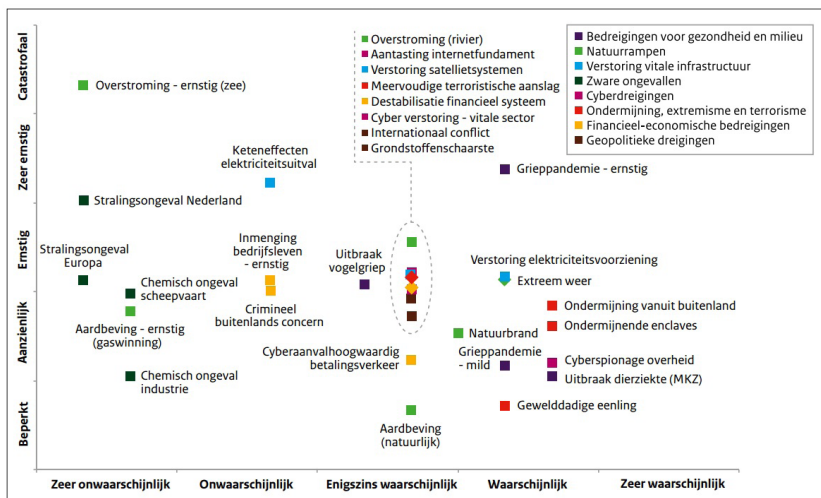


Fig.2: Risk map for different disaster scenarios (Ministry of Security and Justice (NL), 2017)

One can guess the answer to this question: on the contrary! A recent analysis by the National Coordinator Counter-terrorism and Security shows that of all possible disaster scenarios that may occur in our country, a flood from the sea will have the greatest catastrophic consequences (Fig. 2). Considering the disruptive effect of such a disaster on society, such event should be avoided at all costs. It deserves our constant attention, especially as our coast is erosive by nature, hence needs continuous maintenance in the form of sand nourishments (Fig. 3). Currently, approximately 12 million cubic meters of sand per year are added to the nearshore, but this volume is expected to increase. All things considered, enough reason not to lessen our guard to the coast, I will come back to this later on in my speech.



Fig. 3: Beach nourishment Zoutelande (NL, left) en land reclamation Bahrain (right)

Worldwide, there is a concentration of populations in vulnerable, low-lying areas. This puts great pressure on the available space and the use of natural resources. Climate change and human interventions further increase the pressure on deltas. A city like Jakarta experiences bottom subsidence in the order of 10 cm per year due to ground water extraction, which dramatically increases flood impacts. Besides safety, there is a permanent global need for new hydraulic engineering infrastructure such as ports, waterways and large-scale land reclamations. Design and implementation of this infrastructure is subject to increasingly strict societal and environmental requirements, and as a result complexity increases. The great challenges of the future include the development and implementation of modern, sustainable solutions for hydraulic engineering challenges.

This speech tells the story of the border between water and land. Of the fascinating dynamics in the zone where waves, tide and sediment meet to create the conditions for the development of breathtaking coastal landscapes. And of the work of engineers who develop and build hydraulic engineering infrastructures to provide for all kinds of societal needs. In short, a story about the challenges and opportunities for the chair of coastal engineering at the Delft University of Technology, now and in the future.

### **The context of the modern coastal engineer**

Recently I was on the island of Terschelling with five colleagues of various backgrounds to visit the *Bosplaat*. A track of 10 km brings you to one of the most remote places of Netherlands. Bouncing on our bikes a breathtaking landscape of almost non-Dutch natural wilderness unfolded. The area contains all the elements that are characteristic of our West Frisian Islands (Waddeneilanden): sand dunes, an impressive wash-over complex, wide beaches, large sandbanks in the delta, a strong erosion on the eastern tip and vast mud flats becoming vegetated as a consequence of the construction of the Sand dike in the 30s of the last century. These kind of dynamic systems challenge coastal engineers to perform their work in a responsible way.

Traditionally engineers tend to think in a mono-functional way. The primary function was leading in the design of hydraulic infrastructure, for example safety or navigation. There was little attention to environmental effects. Increasing environmental awareness in the 70s and 80s of the last century gave rise to discussions on the impact of hydraulic engineering works. These discussions were very defensive, and led to lengthy procedures and delays. Gradually a shared awareness arose in the public sector, among contractors, knowledge institutions and in environmental groups, that we were too much



preoccupied with mitigating adverse effects and too little with exploiting opportunities offered by the infrastructure development. A new, proactive approach was born: *Building with Nature*.

The concept of *Building with Nature* has already been introduced in the 80s of the last century by Waterman and Svašek (Waterman, 2008). The last ten years it has reached maturity in a number of large-scale knowledge and innovation programmes, including the *Building with Nature* program of the Foundation EcoShape (De Vriend et al, 2014) and the Engineering with Nature program of the U.S. Army Corps of Engineers (Bridges et al, 2014). The underlying concepts are very identical: all take the natural system as a starting point for the design and construction of hydraulic engineering works. In doing so, natural processes are ingeniously used to create added value for humans and the environment. The name suggests perhaps a focus on engineering and ecology, but in practice *Building with Nature* goes much further and, in particular, integrates socio-economic components as part of the approach.

A good example of a successful *Building with Nature* approach is the Cliffe Pools project along the Thames in the UK (Fig. 4). As a result of sand mining for the British cement industry, a large number of lakes was created over the years with a depth of about 8 metres. The lakes were separated by bunds, which restricted flow circulation and caused poor water quality. At the same time, there was a surplus of dredged material in the area due to river deepening and maintenance of the shipping channel. Traditionally this was disposed at the North Sea, but due to increasingly stringent regulation the costs associated with this strategy became a burden.



Fig. 4: Cliffe Pools wetland restoration project (UK)

The key to success was found in combining the interests of the dredging industry and the British Society for the protection of the birds. Both saw added

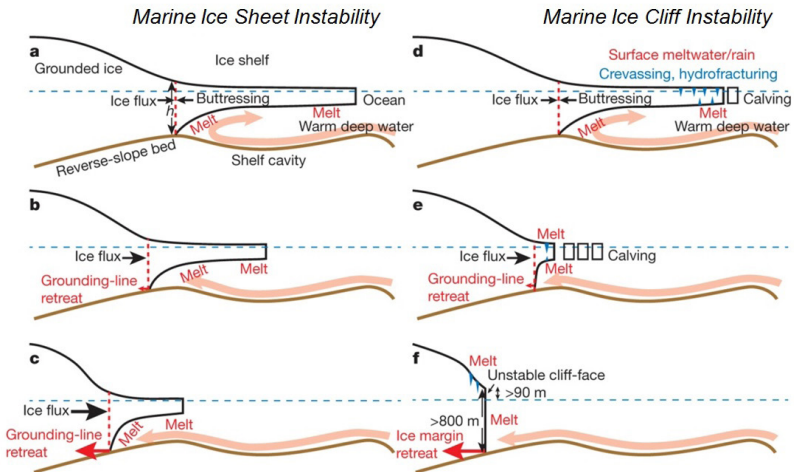


Fig. 5: Mechanisms for ice sheet collapse (after Pollard en De Conto, 2016)

value in the use of the dredged material to fill the former sand mining pits. While the puddles became shallow and salinity increased, the water quality improved, marine life returned and wetlands were formed. Today it is a protected area where wading birds breed and hibernate.

This example shows that a successful application of *Building with Nature* starts with a thorough understanding of the functioning of the natural system. In addition, there are other factors that are important for successful development and implementation of *Building with Nature* solutions (Aarninkhof and Bridges, 2015). This includes the availability of tools and guidelines for design, suitability of solutions within pertaining laws and regulations and a willingness to think across institutional boundaries. Crucial for the longer term is to train young professionals who embrace this rationale early on and bring it into practice.

A second driver that increasingly affects the research agenda of coastal engineering is climate change. A variety of natural processes drives a continuous change of the climate. Humans also played a large role during the past century by the emission of greenhouse gases, such as carbon dioxide and methane. The combination of these effects leads to global warming of the earth, which translates, amongst others into a rise in sea level. Of course, regional differences do exist. The sea level rise in the Netherlands is at this time about 3 mm/year. The last 30 years have undeniably shown an acceleration in the rate of sea-level rise. In its so-called 'KNMI 14-climate scenarios

([www.climatescenarios.nl](http://www.climatescenarios.nl)) the KNMI (Royal Dutch Meteorological Institute) predicts a sea level rise up to 80 cm in 2085, depending on the temperature increase in this period.

The question is whether the observed acceleration in the rate of sea level rise is the beginning of an exponential increase. Based on new insights in the processes behind sea-level rise (Fig. 5), a recent publication in *Nature* (Pollard and De Conto, 2016) suggest an *additional* sea level rise of 0.7 up to 1 meter in 2100. One of the processes is the intrusion of ice water through cracks in the ice mass in Antarctica. When the ice water freezes again it expands, causing ice shelves to break up, crack and drift towards the open sea. High ice cliffs form, which collapse under their own weight. This process of the breaking up and collapse of ice shelves will cause ice sheets to become unstable and melt much faster than assumed so far. Building on the study by Pollard and De Conto, the KNMI (Le Bars et al, 2017) arrives at systematically higher values for sea level rise for the Netherlands; in the most extreme case up 2.5 to 3 meters in 2100. This is based on the highest CO<sub>2</sub> emission scenario and maximum global warming, without accounting for the positive effects of the Paris 2015 climate agreement.

Modern observations with aircraft and satellites are invaluable for developing new insights into the processes behind sea-level rise. Recent measurements from 2016 show a gigantic, fast growing crack in the Larsen C ice shelf in Antarctica, with a width up to 100 m and a depth of up to 500 m. The fact that this happens is strictly speaking not worrisome, as the caving of ice shelves is, after all, a natural process. However, the pace and scale in which all this unfolds is alarming. It is not to us hydraulic engineers to determine whether and when this is going to happen, but we have to face the moment and time, and be prepared when hydraulic engineering is needed. In the long term the impact of climate change is governing the design of deltas. In addition, climate change may be associated with a regime shift in the response of coastal systems, for instance the drowning of tidal flats. Such regime shift may manifest itself at much shorter notice. The occurrence of such regime shifts can only be avoided by taking timely measures, based on thorough understanding of the natural dynamics.

Given the pace of climate change in relation to the long life time and preparation time of hydraulic infrastructure, we cannot allow ourselves to remain silent. For this very reason, the exploration of adaptation strategies for coastal systems impacted by climate change is one of the focal points of my research.

### Integrated management of sandy coasts

We return to the time of the here and now. As already said, coasts serve a multitude of functions including safety against flooding, housing, nature conservation, recreation and food supply. Integrated coastal zone management aims to fulfil this variety of functions in a balanced way. Depending on local conditions, different strategies exist. For example, in countries around the Mediterranean Sea, breakwaters and jetties are frequently used to create wide beaches for tourism (Fig. 6a). The Dutch coastal zone management aims at 'sustainable conservation of functions and values in the coastal zone', to be realized through dynamic maintenance of the coastline (Van Koningsveld and Mulder, 2004). This policy aims to maintain the shoreline at its 1990 position. Later, in 2001, it was decided to expand this preservation policy to the deeper part of the coastal zone, up to the 20m depth contour. Both goals, 1990 and the 2001, require maintenance of the coast, preferably through application of sand nourishments.



Fig. 6: Engineered shoreline with breakwaters and groins (Sitges, Spanje, left) en Pilot Sand Motor Delfland dd. February 16, 2016 (right)

Over the years, we have seen a shift in nourishment strategies. The location changed from the beach to foreshore, while the volume per nourishment increased. This eventually culminated in the construction of the pilot Sand Engine Delfland, an icon of *Building with Nature* (Fig. 6b). The Sand Engine Delfland is in essence a hook shaped mega-nourishment of over 20 million cubic meters, which is meant to feed the coastal stretch from the Hook of Holland to Scheveningen for the next 20 years with sand. Waves, wind and tide spread the sand along the coast. In addition, the Sand Engine is intended to promote dune growth and stimulate recreation.

Five years of intense monitoring have shown that the Sand Engine is developing successfully, although the dune growth was less than expected (Deltares,

2016). In addition, an international audit committee recommended to quantify the integral benefits of the Sand Engine, other than coastal safety, to improve the financeability of integral projects like the Sand Engine.

This touches on a very important point: integral solutions usually rely on integral financing. In other words, the necessary funding comes from different sources. By the very nature of integral projects, the distribution of cost among the various funding partners is an important topic of discussion. This becomes even more complex if the funding scheme, project objectives and design are interlinked. Joining the necessary monetary resources is one of the most important challenges in the light of successful implementation of *Building with Nature* solutions. In my position as professor of Coastal Engineering, I will contribute to this by carrying out quantitative research on the integral benefits of sandy solutions, including solutions on smaller spatiotemporal scales. New models and monitoring techniques will enable progress. An inspiring example is the EU CoastView project at the beginning of this century (Davidson et al, 2007). This project took advantage of high-resolution video observations for the development of new innovative indicators for (amongst others) swimming safety and recreation. Availability of such information allows for the justification of integral benefits, which can serve as a basis for the desired integral financial arrangements.

In view of accelerated sea-level rise it is also important to further explore the feasibility of extreme increases in the annual nourishment volume. The second Delta Committee (2008) foresaw an increase in the annual volume up to 85 million cubic meters per year for a sea level rise of 120 cm in 2100. New insights into the processes behind sea-level rise make this scenario more likely than assumed at the time. It is important to determine whether our nourishment strategy also sustains for such large volumes and whether the Wadden Sea and the Westerschelde basins can adjust accordingly. The Dutch Ministry of Infrastructure and Environment Rijkswaterstaat is planning for an outer delta pilot nourishment in the framework of its research programme 'Kustgenese 2.0'. This experiment will play an important role in the development of knowledge in this field.

In addition to the evaluation of integral benefits, I advocate optimization of coastal maintenance on the scale of the entire Dutch coast. I hereby foresee long-term programming of nourishment programs, potentially in good cooperation between public and private parties. It is important that the monetary evaluation of mega-nourishments as the Sand Engine takes place at the level of the coast as a whole, not a single coastal segment. At the scale of single

coastal segment, a mega nourishment of say 20 million m<sup>3</sup> with a return period of 20 years will not be cost-competitive to a more gradual strategy with a 5 million m<sup>3</sup> nourishment every four years. The benefits, to the extent that they can be quantified, simply do not outweigh the cost savings by delayed construction. On the larger scale of the entire Dutch coast this may be different though: Authorities can deliberately chose for a strategy based on a limited number of mega nourishments at strategic locations, thus combining the full, integral benefits of mega nourishments with the advantage of low construction costs. If accelerated sea level rise continues and induces an increase in annual maintenance volumes, I am convinced that such large-scale, long-term approach will lead to significant optimizations in coastal maintenance.

### Data and monitoring

Field measurements have traditionally played an important role in the development of our field. Since 1963 Rijkswaterstaat has carried out annual surveys of bathymetry along the entire Dutch coast. The so-called JARKUS dataset contains a wealth of information about the morphodynamics of the coast and the effectiveness of nourishments. Large-scale measuring campaigns in Duck (NC, USA), Egmond and on the Sand Engine have contributed to a detailed understanding of the action of waves, currents and sediment transport. Satellite observations and fully automatic Argus video stations make it possible to monitor the behavior of coasts on time scales of hours up to decades, often in combination with ever better radar, laser and LIDAR systems. The power of this kind of monitoring is in the systematic and continuous collection of data. In our profession, we have a responsibility to find smart modi operandi to continue this type of monitoring.

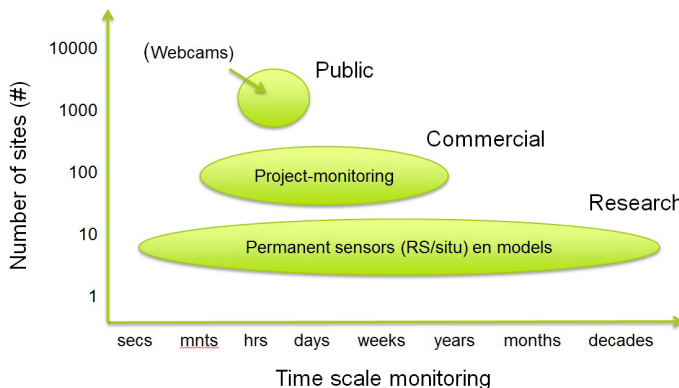


Fig. 7: Vision on monitoring and incentive for ICON: International Network of Coastline Observatories

Fig. 7 shows how this could be achieved. The horizontal axis shows the time scales covered by a monitoring effort, while the vertical axis gives the number of sampling sites worldwide. For research monitoring purposes, it is important to bridge a variety of time scales, ranging from hour-to-hour water motion and storms up to large-scale morphological developments. For research monitoring, completeness in measurement scope is more important than the number of sampling sites. Such Coastline Observatory offers, in addition to in-depth knowledge development on coastal processes, unique opportunities as a high-resolution test lab for new sensors, monitoring techniques and numerical models. Ultimately, this will lead to integrated facilities for the permanent prediction of coastal evolution based on the combined use of data and models. In a modern world Coastline Observatories will preferably be internationally organized. I will get back to this later on in this speech.

Project monitoring takes place in the planning phase, during construction and in the years after implementation during operation of the infrastructure. New technologies unprecedented opportunities. I foresee, among others, the deployment of drones equipped with LIDAR and video technology to map unknown coastal areas in a few days' time, by measuring the topography of dunes, beach and sea bed, vegetation cover, flow circulation and other parameters. Ongoing monitoring during and after project construction can add importantly to knowledge development in hydraulic engineering. While planning for such monitoring effort, it is important to account for the knowledge questions of the next project. Each project thus becomes an opportunity to learn for the next, thus enabling the Dutch hydraulic engineering sector to continuously improve.

At the highest level, we use the power of the crowd for data acquisition. Think for example of webcams that are installed along shorelines worldwide and increasingly deliver high quality imagery. Application of image analysis software – developed and tested in a Coastline Observatory – will provide instantaneous information on, for example, swimmer safety or surfing conditions. The information will be disseminated through websites and mobile apps, including the associated business models. For startups and other companies there is an interesting opportunity to develop and offer innovative products, ultimately contributing to a broad societal impact of our coastal research.

Another great opportunity forms the retrieval and analysis of over 30 years of satellite data. The volume of available data enforces extremely high demands on data storage, computational power and operational tools for data processing.



The availability of cloud platforms such as ‘Google Earth Engine’ (<http://earthengine.google.com/>) largely removes these restrictions and brings the use of satellite data within reach scientists and engineers. As a result, researchers at Deltares have been inspired to develop the AquaMonitor (Donchyts et al, 2016) and derived applications, such as MI-SAFE<sup>2</sup>. MI-SAFE uses advanced data-mining techniques to quantify coastal parameters such as the position of the coast line, the elevation of tidal flats and vegetation density. In addition, MI-SAFE offers links to other global data sets and the X-Beach model, for running real time dune erosion calculations.

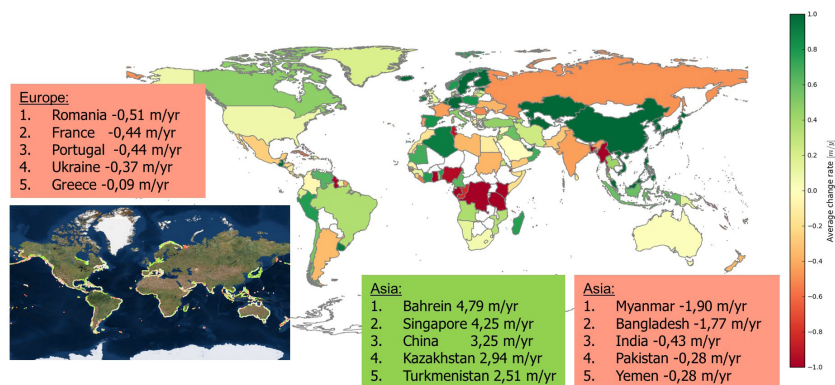


Fig. 8: Global Shoreline Dynamics. Analysis of annual average change per country coastline, over a period of 33 years (Luijendijk et al, in prep.)

Another application provides for the automated mapping of global coastline development from 1984 to present, along every sandy beach worldwide (Luijendijk et al, 2017, *in prep.*). Depending on the number of images available and their quality, the analysis software yields about 25 shoreline estimates per year. The coastline position is validated against long-term data from four different beaches on three continents, with a stunning sub-pixel accuracy in the order of 5-10 m. The tool is used to calculate the yearly average coastline change over 33 years for every country in the world (Luijendijk et al, in prep.). Fig. 8 shows the top-5 countries with the highest annual coastal erosion rates in Europe and Asia. The top-5 countries with the largest coastal growth is dominated by Asian countries with a rich tradition in land reclamation.

Although most routine analysis needs further validation I dare to say that the possibilities are endless. Where traditionally the choice of a specific case



governed both the scope and outcomes of the research, these modern techniques now allow for worldwide generation of time series of relevant coastal indicators and formulate the envisaged research on the basis of those. This opens the door to more generic research and commercial exploration of, for example, the applicability of nature-based solutions worldwide. This radical new approach, from case specific to the global, is expected to result in entirely new insights on for instance regime shifts in coastal dynamics, and will be a driver for coastal research in the years to come.

### To sustainable coastal development worldwide

In the above, I have sketched a picture of the importance of *Building with Nature* and climate change as drivers for current and future coastal research. I have also highlighted opportunities in relation to integrated coastal zone management and the use of data and monitoring. This all occurs with the ambition in mind to achieve sustainable coastal development worldwide.

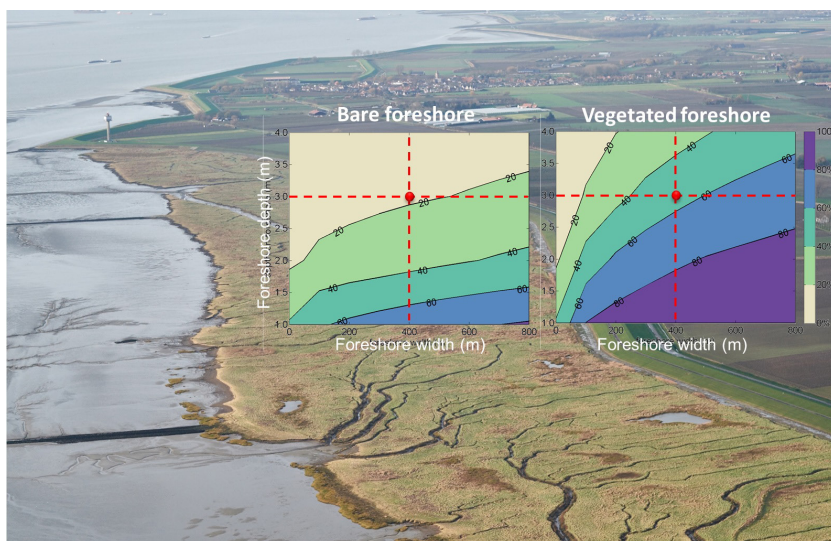
In 2050 more than 80% of the world population is expected to live in vulnerable delta regions. The combination of sea-level rise, land subsidence and decreased sediment supply will induce frequent flooding and structural erosion in many low-lying, densely populated areas. Especially in third world countries this leads to major problems caused by a lack of financial resources and administrative effectiveness to cope with complex problems of this kind. Hard measures, such as dikes and dams, often do not result in the envisaged effect (Fig. 9a). As a consequence erosion persists, agriculture lands disappear and poverty increases.



Fig. 9: Erosion near coastal revetment Indonesia (left) and Building with Nature pilot for mangrove development (Demak, Indonesia, right)

Under these conditions the solution can be found in the development of low-tech measures that induce natural siltation of the coast (Winterwerp et al, 2013). This requires thorough understanding of the physical and ecological processes of such deltas and intensive cooperation and support of local parties

(Wesenbeeck et al, 2015). Good examples are found in Indonesia and Viet Nam, where consortia of Dutch and local parties, led by respectively Han Winterwerp and Marcel Stive, work on natural methods to restore mangrove habitats. In Indonesia, this is done by placing permeable, brushwood dams (Fig. 9b). The dams provide sheltered areas for sediment trapping, thus creating the conditions for young mangroves to settle. The pilot project in Indonesia shows a sedimentation of about 50 cm in the first year after construction. At this moment, research is carried out for the upscaling of this approach to larger coastal regions. This requires improved understanding of the effect of mangroves on the stability of muddy coasts and the development of eco-morphological models for large-scale sediment dynamics. The work is still in its infancy.



*Fig. 10: Vegetated foreshores, and their effect on wave attenuation (after Vuik et al., 2016)*

Also in The Netherlands, nature-based solutions become increasingly popular. Within the High Water Safety program, nature-based solutions have been identified as serious alternatives for traditional approaches. For instance vegetated foreshores in front of a dike. Vegetated foreshores are associated with wave attenuation, hence a reduction of the wave load on the dike (VuiK et al, 2016). This principle is used as a starting point for the design of the northern half of the Houtribdijk reinforcement project (Enkhuizen-Lelystad, the Netherlands). A monitoring program will enable quantitative assessment of the vegetation and sand losses, as well as the behaviour of the defense during storm conditions.

Understanding these dynamics is of decisive importance for further application in the context of future high water safety projects. The Houtribdijk reinforcement project shows that *Building with Nature* solutions gradually grow beyond the pilot level to become mature solutions for full-scale use in practice.

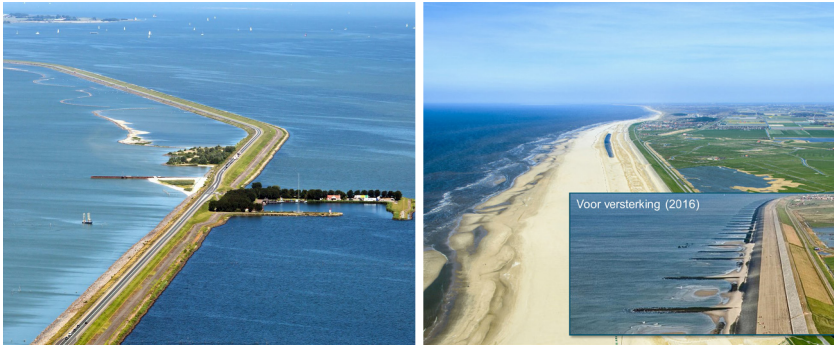


Fig. 11: Nature-based solutions in The Netherlands: Houtribdijk reinforcement (left) and Hondsbossche Dunes (right)

The sandy reinforcement of the Hondsbossche- and Pettemer Seawall (Petten, the Netherlands) is another example of *Building with Nature*. Since its construction in 2016 the sea wall is no longer an obstacle, but part of the dynamic, sandy coast. Crucial to the success of this type of interventions is the availability of reliable design instruments for the assessment of the expected sand losses after construction. The development of such instruments will be one of the priorities of my chair, amongst others through a probabilistic approach (Kroon et al, 2017). In addition, the link between foreshore, beach and dunes – including interaction with vegetation – is becoming increasingly important. A project like the Sand Engine has the explicit objective of the development of 35 hectares of dune area *after 20 years*. Such a question can only be addressed on the basis of sound understanding of wind-driven sediment transport at the interface of wet and dry. This has led to the development of a new wind-driven sediment transport model called AeoliS (Hoonhout and De Vries, 2016). Other than existing models, AeoliS explicitly takes the sediment availability on the beach into account. The new model allows for better estimates of the variation in dune growth along the coast. Currently work is done to merge AeoliS with the Delft3D morphological process model, indeed linking foreshore, beach and dunes. This allows us to literally calculate across the border of water and land.

These kinds of solutions and techniques are the ones that will enable sustainable coastal development, now and in future.

## The engineer of the future

This brings me to the engineer of the future. Perhaps the most important responsibility of our department is the training of hydraulic engineers and researchers. We do so for a wide range of parties. Currently the Department of Hydraulic Engineering delivers over 100 graduates each year, 60% of whom start working at a contracting or consulting firm. About 20% starts a career in academia or at a research institution. This means that in our education we in permanent search for a good balance between teaching research skills on the one hand, and design and engineering skills on the other. To this end, we apply different educational concepts, ranging from classical knowledge transfer in lectures to interactive knowledge development in a 'flipped-classroom setting'<sup>3</sup>. It is this combination of science and engineering that sets us apart from other curricula, and which is therefore essential for us as a department.

The engineer of the future is supposed to put his/her experience to practice in a world that demands integrated solutions for sustainable coastal development. Technical design is still a crucial part of a project, but the time that the engineer's word is law is already far behind us. To operate effectively, a modern engineer must be aware of the broader project perspective, including the requirements and wishes of local residents, environmental groups, politicians and others involved. This aspect is of particular importance for engineers who take the lead in the development and implementation of *Building with Nature* solutions. They must have a solid knowledge of the natural system, experience with the design of hydraulic infrastructure and have a talent to work with ecologists, public administrators, social scientists and other specialists. The well-known T-profile for engineers who operate from a sound technical basis to address a broad spectrum of solutions, is a good fit here: Open-minded engineers who can truly look beyond the boundary of water and land.

Practice shows that our youngest generations of students and engineers are intrinsically motivated to work on sustainable engineering solutions. *Building with Nature* offers an appealing framework to involve young engineers longer with our field. We, as an academic community, carry the responsibility to offer these students a challenging curriculum to realize their ambitions, hence to further build the movement from the basis.

3 *Flipped classroom is an instructional strategy and a type of blended learning that reverses the traditional learning environment by delivering instructional content, often online, outside of the classroom.*

### Boundless collaboration

I am getting close to the end of my inaugural address. I have talked about the complex context of hydraulic engineering works and the need for integrated, sustainable solutions. For that reason alone multidisciplinary cooperation is an absolute must. As a product of the Netherlands Centre Coastal Research NCK, this has been passed on to me with the (Dutch) proverbial spoon. I advocate boundless cooperation starting from the strengths and complementary nature of the parties involved. This goes way beyond the exchange of knowledge. Spending time together on one table, carrying out shared research and co-creating solutions for complex engineering problems helps to develop mutual understanding and the shared drive to come up with truly innovative solutions. The public-private collaborations in the context of EcoShape's *Building with Nature* form an excellent example of this approach.

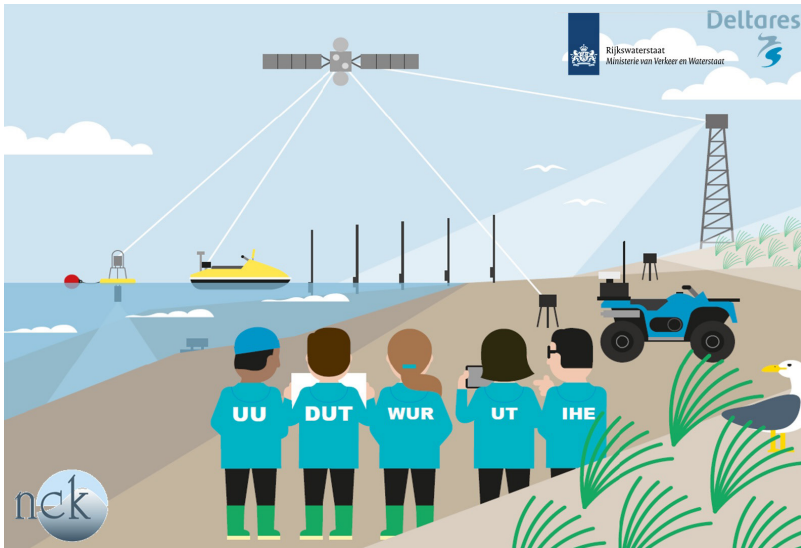


Fig. 12: Research collaboration around Dutch Coastline Observatory

Specifically, I strive for the establishment of a Dutch Coastline Observatory as a basis for joint coastal research by the NCK institutes. The goal is to embed the Dutch Coastal Observatory in a newly established international network called ICON, the International Coastline Observatories Network. ICON sites are selected on mutual diversity, data availability and associated research groups. All measuring and monitoring data will be publicly available according to mutually agreed data formats. This will allow researchers to rapidly test

new model concepts for a variety of environmental conditions, with an eye for effectiveness and reliability. At the moment, we are exploring the feasibility of ICON with Australian and American partners, on the basis of Narrabeen (NSW, Australia), Duck (NC, USA) and Delfland / Sand Engine coast (NL). The philosophy behind ICON seamlessly fits with that of DigiShape, a public-private initiative that aims to facilitate (open) access to relevant data sources within and outside the Netherlands.

In addition, there are opportunities for knowledge development during and after the realization of infrastructural projects. The implementation of hydraulic infrastructure usually comes with a large monitoring efforts. To my opinion, the scope of such monitoring should ideally be determined from a perspective that goes the objectives of the project at hand, and with the ambition to thoroughly understand the underlying processes. Such data sets lend themselves for the implementation of cutting-edge research. In this way, continuous improvements engage into innovation for the next project. Time is there to initiate large-scale project-related research collaboration, starting with, as far as I am concerned, *Building with nature* projects in the Netherlands and the United States.

The long history of intensive research collaboration between government, knowledge institutions and industry has given the Netherlands a unique and leading position in the international hydraulic engineering world. The Top-Sector Water (<http://www.topsectorwater.nl/>), amongst others, aims to expand this leading position. The Chair of Coastal Engineering at Delft University of Technology is prepared to contribute to this ambition.

### Closing words

I am about to conclude this speech. This speech has talked about the boundary of water and land. About the fascinating dynamics of the coastal zone, about the complex interplay of functions and interests, and about the infrastructure works hydraulic engineers design to meet the needs of society. About climate change that calls for attention and about the unparalleled opportunities provided by large data sets and international coastline observatories. I am committed to sustainable coastline development worldwide by contributing to the development and implementation of *Building with Nature* solutions. This requires research into eco-morphological processes in a wide coastal zone, the development of models for design and engineering, and the training of open-minded engineers who literally look further, beyond the boundary of water and land. Here are the challenges and opportunities for my chair, now and in the future.



With my appointment to this chair I follow in the footsteps of my predecessor, Professor Marcel Stive. A long time ago, in 1996, I was his first graduate student, and eventually his first PhD student.

Dear Marcel, from the first day on we had a connection and over the years we have developed a special relationship. With admiration, I have watched how you have continuously developed yourself - and with it your field: from wave dissipation and sediment transport in the surf zone, to nourishments, tidal inlets, and via the Sand Engine finally to the mangrove shorelines in Vietnam. I am impressed by your profound knowledge and involvement, as well as your charming personality that has inspired many colleagues worldwide to get things done. You have offered me a head start in the field, not in the last place by introducing me to everyone everywhere.

Thank you for the collaboration; it is an honour to build on your great work in this chair.

I would like to thank my former employers, WL | Delft Hydraulics (now Deltares) and Boskalis, both prominent parties in the international hydraulic engineering sector. I look back with pride and great pleasure to the time I worked with you. You have given me room to maintain a relationship with the research community and the opportunity to view the field from different perspectives. Especially this last experience will be of crucial importance for my new role in this chair. I look forward to maintaining the good working relationships that are so important for our sector.

I would like to thank the TU Delft for the trust they put in me with my appointment to the chair in Coastal Engineering.

And finally, my immediate colleagues and students in the Faculty of Civil Engineering and Geosciences and, specifically, the Department of Hydraulic Engineering. After 20 years outside academia, my return to TU Delft feels as a homecoming. I look forward to work with you to strengthen the position of our group in the international hydraulic engineering community and to further shape the future of our fascinating field.

I have spoken.

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