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Texel Inlet Dynamics and Shoreline Management

By Jan Mulder, Filipe Galiforni-Silva, Floortje d'Hont, Kathelijne Wijnberg, Ad van der Spek, Mick van der Wegen and Jill Slinger

2.1. Introduction

Texel Inlet represents a case study in Dutch coastal management. The imperative to protect the Dutch coast from flooding has been the central issue in coastal management for centuries. The damming in 1932 of the Zuiderzee, a major salt water branch of the Dutch Wadden Sea, formed a fresh water lake –the IJsselmeer – and initiated a process of coastal sedimentary readjustment of which the Texel Inlet and adjacent coasts are parts. However, since 1990 Dutch coastal policy is aimed at preventing structural erosion by maintaining the Dutch coastline at the 1990 position through sand nourishments. This objectives-based policy and associated sand nourishment strategy now ensures that south west Texel receives a large portion of the national sand nourishment budget as it is an erosion hotspot. In this case study, we focus on the evolution of integrated flood risk management at Texel Island, showing how scientific insights into coastal dynamics have influenced coastal policy in the past (section 2.4), and how recent advancements in knowledge on the natural dynamics of the system (section 2.3) and on the importance of stakeholder involvement in environmental management, may play a role in a potential adaptation of the policy (section 2.5). In essence, the Texel Inlet case study highlights how a single issue – flood risk management – can dominate in determining the objectives for coastal management, and highlights the role that new scientific insights can potentially play in influencing coastal management into the future.

2.2. Study area

Texel island, Texel Inlet and the adjacent North Sea and Wadden Sea represent a coherent system of high natural value, largely protected under the European environmental law Natura2000. The Texel Inlet is a mixed-energy inlet system connecting the Wadden sea tidal basin to the North Sea (Figure 2.1). It is located in the north-western part of the Netherlands and is the largest inlet system of the Dutch Wadden sea. To the south, it is bordered by the city of Den Helder where the coastline is fixed by the use of groins and dikes (Figure 2.2). To the north lies the island of Texel, characterised by an eroding sandy shore with a dynamic sand flat at its southern tip - De Hors – covering an area of roughly 3 km. Over the past 18 years a dune field has been establishing at De Hors. Just north of De Hors, the coast is protected by groins for 9 km (Figure 2.2).

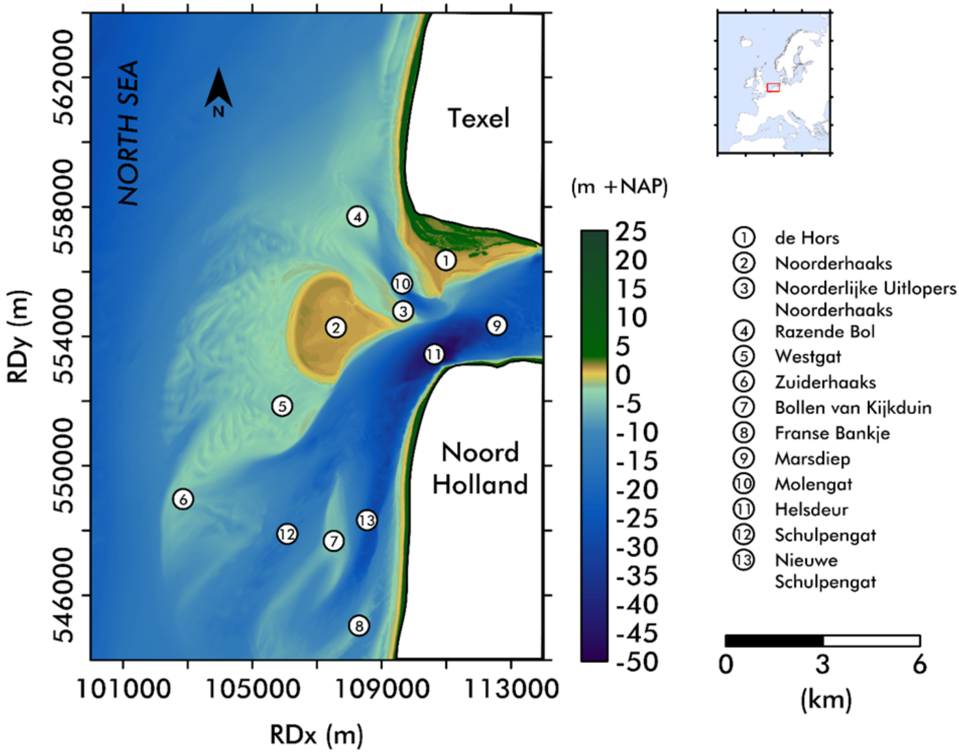

Figure 2.1. The Texel Inlet study area, showing the channel, ebb-tidal delta and shoals and the affected parts of the adjacent shorelines (after Elias et al., 2014)

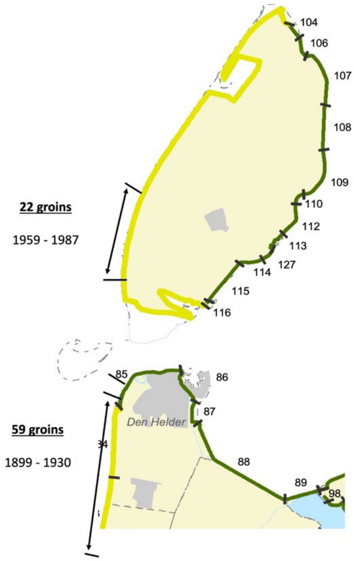

Figure 2.2. Characteristics of the shoreline along the Texel Inlet indicating dunes in yellow, dikes in green, and groins together with year of construction (after HHNK, 2008 and Verhagen and van Rossum, 1990)

2.3. Natural dynamics of the inlet

2.3.1. Hydrodynamics

According to Hayes (1979), the Texel Inlet can be classified as a mixed-energy, wave dominated inlet, although some tide-dominated characteristics such as a large ebb-tidal delta are evident. The tide-dominated features derive from the large tidal prism relative to wave energy (Elias and Van der Spek, 2017). The tide is semi-diurnal with a mean tidal range of 1.4 m, mean high tide level of 0.65 m NAP and a mean high spring tide level of 0.84 m NAP (Wijnberg et al., 2017). The average tidal prism is 990 x 10^9 m^3, with a seaward directed residual prism of 17 x 10^9 m^3 and peak ebb and flood velocities ranging from 1 to 2 $m.s^{-1}$ (Duran-Matute et. al., 2014, Buijsman & Ridderinkhof, 2007). The system is influenced by meteorological distortion of the water levels due to air pressure and wind set-up or set-down, which can reach values of up to 2 m during major storm events (Elias and Van der Spek, 2017). Daily maximum water levels show median values of 0.69 m (Figure 2.3). Data from 1997 up to 2015 show a maximum water level of 2.71 m with values above 2 m occurring less than 0.37 % of the time. The wave climate in the area is dominated by wind-generated waves coming from the North Sea. The mean significant wave height is 1.3 m, with a corresponding period of 5 seconds and a mean direction of west-southwest (Elias and van der Spek, 2006). The largest waves are associated with energetic events coming from the west and northwest owing to the longer wind fetch of the North Sea over these stretches (Sha, 1989; Van der Vegt & Hoekstra, 2012).

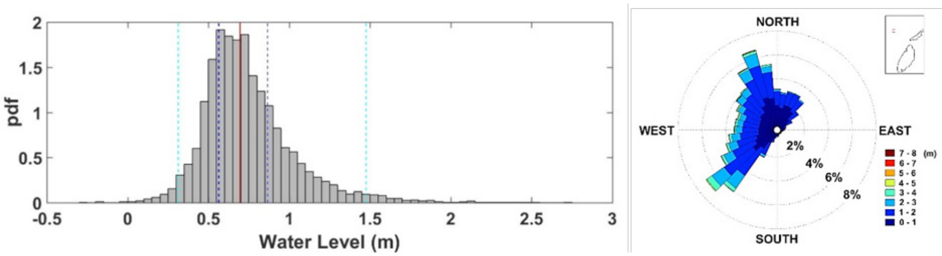

Figure 2.3. Left: Histogram of water level measured over the past 18 years. The median is located at 0.7 m to NAP. The 25 and 75 percentiles are at 0.56 m and 0.87 m, and the 2.5 and 97.5 percentiles are 0.31 m and 1.47 m respectively.
Right: Wave rose based on Eierlandse Gat buoy, near Texel.

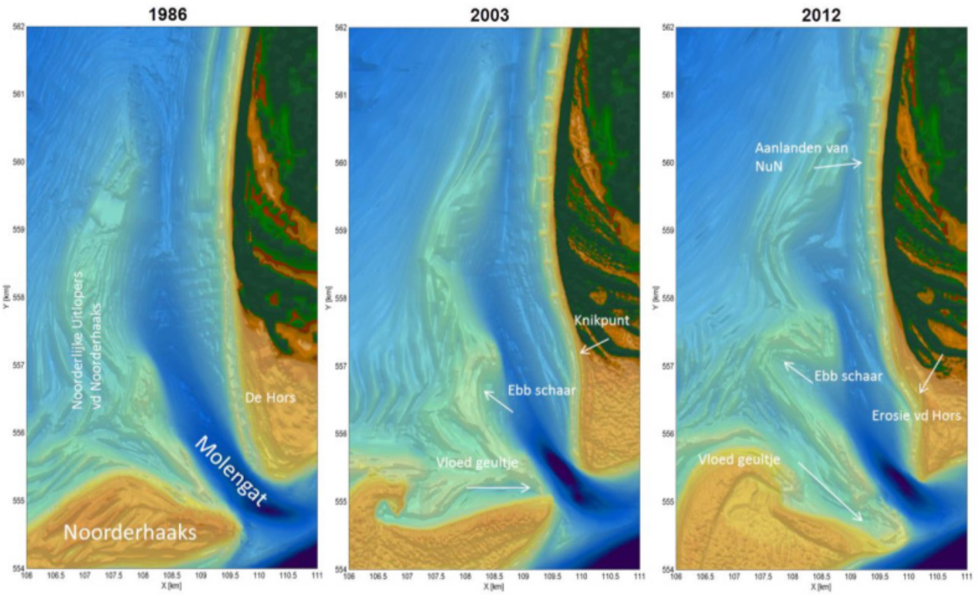

Figure 2.4. The northern parts of the sandy shoal Noorderhaaks in 1986, 2003 and 2012 exhibit a landward movement (from: Elias et al., 2014)

2.3.2. Morphodynamics

Regarding the ebb-tidal delta and the bed sedimentology, average surface grain size varies from 150 μm to 450 μm, depending on the location. Shoals present the smallest average grain size, ranging from 150 to 200 μm, whereas coarser sediments can be found in the Marsdiep area (Elias and van der Spek, 2017). The system presents an asymmetric ebb-tidal delta (Figure 2.1). The closure of the Zuiderzee in 1932 changed overall characteristics of the area by increasing the tidal range and consequently the tidal prism. This led to morphological responses in both the channel and the ebb-tidal delta (Elias and Hansen, 2013). The main channel of the ebb-tidal delta switched southward and developed into two southerly directed channels: Schulpengat and Nieuwe Schulpengat, whereas the delta extended towards the south and north (Elias and Van der Spek, 2006).

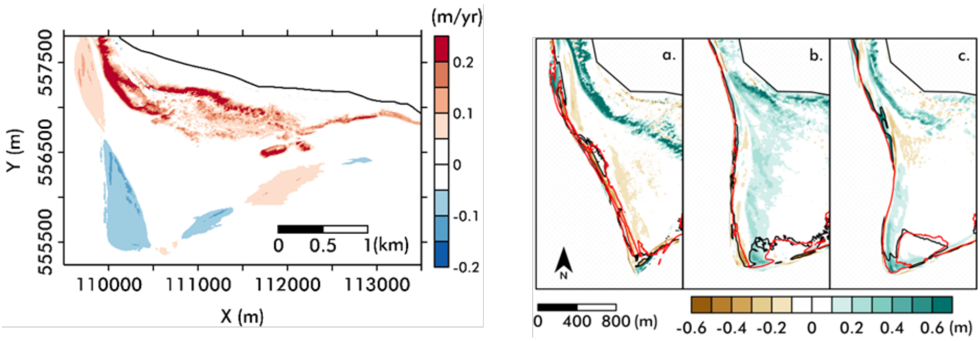

Figure 2.5. Average rate of change between 1997-2015, highlighting subtidal patterns of accretion and erosion, as well as dune growth on the northern end of the sand flat (left) with examples of yearly sand flat elevation changes observed on the west side of the sand flat (right). In each subplot, black and red contours represent the mean spring high tide level (MSHTL) of the first and second year, respectively. Subplot a (2014-2015) shows no deposition above MSHTL, whereas subplots b (2003-2004) and c (2009-2010) highlight deposition onto the flat in regions above MSHTL (Adapted from Wijnberg et.al., 2017)

The sandy shoal Noorderhaaks altered dramatically on the seaward side with the concave southerly directed spit changing to a more northward direction. In contrast, the landward side remained relatively stable due to the high flows and sediment redistribution related to the Molengat channel (Figure 2.4).

In previous centuries, parts of the Noorderhaaks periodically merged with the island extending the southern tip of Texel, De Hors. The closure of the Zuiderzee has affected this process, but recent interaction between Molengat and the adjacent coastline can be seen as an indication of a restoration of this bypassing mechanism. According to Elias and Van der Spek (2017), erosion of the southwest coastline of Texel can be attributed to a lack of sediment bypassing because of spit and channel migration.

The sand flat De Hors exhibits a steady dune growth, with a net accretion of 1.2 x 10^6 m^3 of sand over the last 18 years. The plain is stable in height, with more variation in shoreline movement in the west and the dune growth in the north. The average height of 0.89 (± 0.4) m between the waterline and the dune foot means that it is only flooded during energetic events. Since the east side of the plain is lower than the average height of the rest of the plain, thus being more prone to inundation. Morphologically, the dunes can be categorised in three zones: a western zone, with a high continuous foredune; a central zone, with a field of coppice-like dunes; and the eastern zone, with a continuous foredune that is lower than that in the west. The western zone accounts for around 60% of the total dune growth, followed by the central zone with around 30 percent and the eastern zone with only 10%. The observed spatial variability may be attributed to sediment supply limitations due to high groundwater levels and higher inundation frequency. Wijnberg et. al. (2017) hypothesise that two mechanisms are responsible for linking subtidal and subaerial sediment transfer and determining abundant dune growth regardless of beach plain stability. One mechanism is related to deposition of sand in the intertidal zone and consecutive transport by aeolian processes during lower tide levels. The second is related to deposition of sediment above spring high tide during flooding events. The sediment deposited during storm surge flooding, then is available for aeolian transport during non-energetic periods (Figure 2.5).

2.3.3. Biodiversity

The dynamics of the Wadden system are critical to the ecological functioning of Texel Island and its surroundings. In particular, the hydro- and morphodynamics, and the accompanying gradients in salinity and nutrients within the system, are responsible for mudflat, salt marsh- and dune development (Baptist et al., 2016; Van Puijenbroek et al., 2017) as well as the rich biology and vast diversity of flora and fauna (IJsseldijk et. al., 2015; Hoekendijk et al., 2015). Tidal effects have been observed on primary production, larval distribution and shellfish development (Cadée and Hegeman, 2002; Beukema and Vlas, 1989; Capelle et al., 2017). The area is an important breeding ground for juvenile fish and shellfish, an essential feeding ground for numerous migratory birds, and home to the largest population of seals in the Netherlands (Min. LNV, 2018). The dynamic dune development on SW Texel is rare in the Netherlands. This means that the sandy shoal of De Hors itself, the salt marshes along the Mokbaai just north of De Hors and the Texel Inlet including the dynamic shoal of Noorderhaaks are of high biological importance.

2.4. Evolution of coastal policy in response to new scientific insights

2.4.1. Early policies

For centuries, coastal protection in the Netherlands has been mainly a matter of 'trial and error' (Bijker, 1996). The first written notice in the country Holland dates from 1105 and refers to a Zanddijk (sand dike) near Egmond. The construction of primitive dikes using local materials like sand, clay sods and kelp reinforced by wooden piles, became common practice at locations where dunes were absent or very weak. The planting of marram grass from 1650 on, offered a first opportunity to stabilise and enhance growth of dunes and sand dykes. Up until the second half of the 18th century the use of stones for coastal protection was very rare. In 1776, the first stone groin was constructed at the coast

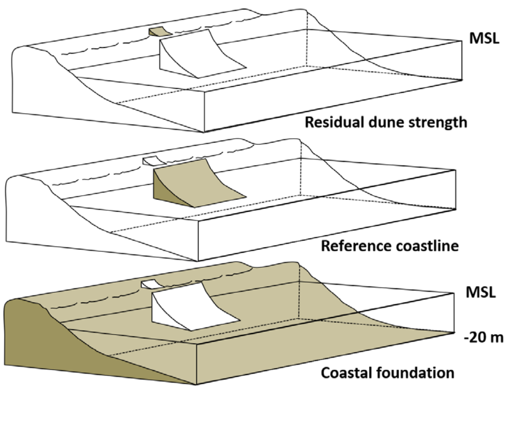

Figure 2.6. Schematic representation of the Dutch coast, indicating management objectives at three different scales (Mulder et al., 2011)

of South Holland, to counteract erosion. More were built until 1890 and more groins followed at the coast of Zeeland, North Holland, Texel (see Figure 2.2) and the island of Vlieland.

It is most likely that originally individual landowners were responsible for the construction and maintenance of dikes. Very soon however, the complicated character of water management led to the development of Water Boards where all inhabitants shared equal responsibility for flood safety. Management of the dunes, for centuries mainly hunting grounds, has been very limited for very long. This changed in the early 19th century when the national government (Rijkswaterstaat, founded in 1798) took increased responsibility. At Texel for instance, the dunes largely became state property. Rijkswaterstaat is responsible for maintenance of the most seaward dunes, and the State Forest Authority (SBB) is responsible for maintenance of the rest of the dune area. SBB plants marram grass and deciduous and pine forests, to prevent dune blow outs and to produce wood (RWS, 1950).

The knowledge and experience of the Water Boards has been documented. The 'Tractaat van Dyckagie' (Discussion on Dikes) by Andries Vierlingh (1507-1579) formed the state-of-the-art at the beginning of the 20th century (Bijker, 1996). The practice of flood protection gradually changed to accommodate learning from large engineering projects like the damming of the Zuiderzee (Afsluitdijk Project) and the inlets of the south-western Netherlands (Delta Project). This led to the establishment of safety standards of flood defence in the Delta Act (1958). However, the maintenance of the sandy coast and dunes as flood defence barriers still rested on experiential knowledge.

2.4.2. Start of a nourishment policy

Things gradually changed around 1965 with the start of a yearly monitoring programme of the Dutch coast, measuring coastal profiles at intervals of 250 m. Between 1985 and 1990,

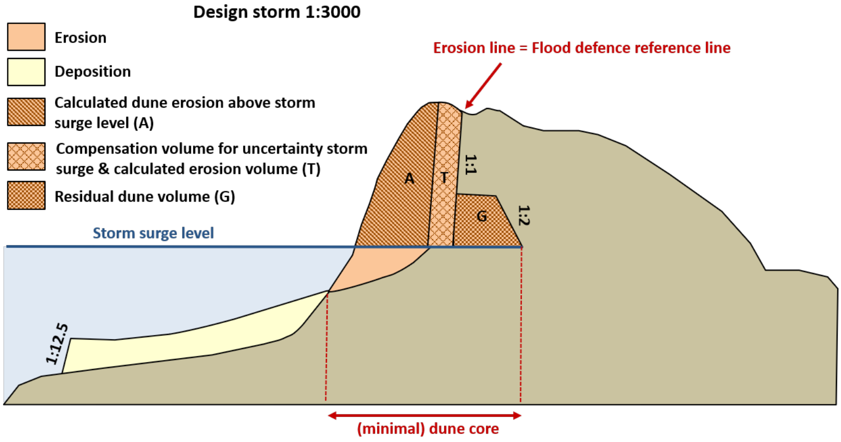

Figure 2.7. Definition sketch of dune strength calculation (after Technische Adviescommissie Waterkeringen [TAW], 2002)

scientific research undertaken as part of the Coastal Genesis Programme (Kustgenese) put forward significant new insights (e.g., Bijker, 1996, van Koningsveld et al., 2003) on flood protection based on a geologically-informed, large scale understanding of coastal processes. The Coastal Genesis Programme represented the first multidisciplinary coastal research programme of the Dutch government, involving engineers, geologists, physical- and historical geographers. For instance, at Texel, hard structures like groins proved to be ineffective in preventing erosion (Verhagen and van Rossum, 1990). The underlying cause of coastal erosion appears to be a structural sand deficit in the wider coastal system.

Following a severe coastal storm in 1990, the government adopted a new coastal policy called 'Dynamic Preservation' (Hermans et al., 2013). This policy identified three different scales to be considered in coastal protection, namely the small-scale residual dune strength ('reststerkte'), the medium-scale 1990 reference coastline ('Basiskustlijn') and the large-scale active coastal system concept ('kustfundament') (Mulder et al., 2011) (Figure 2.6).

The test procedure to determine the actual strength of a dune is based on a model calculation of dune erosion under design conditions, i.e., a storm with a probability of occurrence of 1 in 3000 years (Figure 2.7).

The model provides information to define the geographical characteristics of the dune water defence (the so called 'legger') which is then laid down in a legal document. The position of the flood defence reference line ('waterkering referentielijn') coincides with the erosion line under design conditions. The dune core ('kernzone') is the minimum volume required to meet the standard. In turn, the core comprises three components,

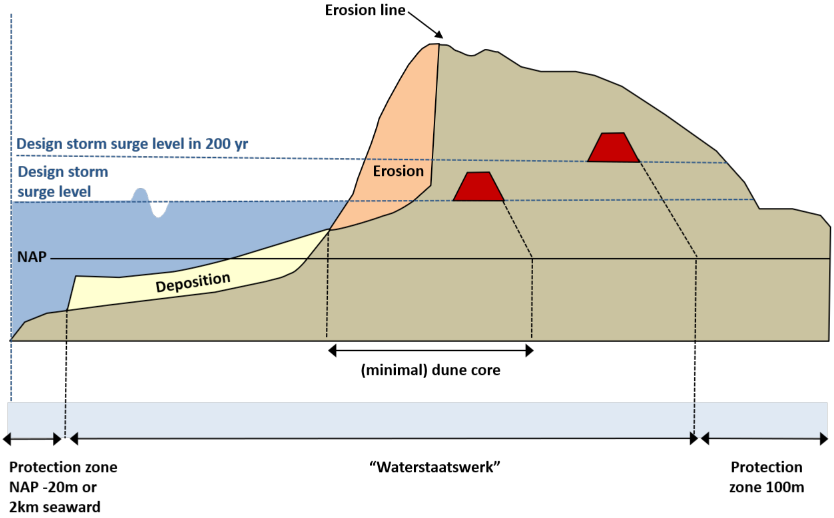

Figure 2.8. The different zones within a dune water defence (TAW, 2002).

namely the erosion zone (A), a small zone to compensate for uncertainties (T), and a zone comprising the required residual dune volume (G) (Figure 2.7). Next, the total spatial extent of the existing dune water defence (‘waterstaatswerk’) is defined by extending the core zone to include the deposition zone at its seaward side and at its landward side, a reservation zone to account for developments in hydrodynamic conditions over the next 200 years. Finally, summing up all zones that are subject to restrictions in use, two protection zones are defined: landward of the ‘waterstaatswerk’ a 100 m wide zone, and a seaward zone down to a depth of 20 m or extending 2 km offshore (Figure 2.8).

The dune strength is determined using this procedure every 5 years. The standard for safety against flooding of Texel has been redefined in 2014 as a probability of flooding of 1:3000 (Delta Programme, 2014). The standard applied in coastline management is the position of the coastline in 1990, referred to as the Base Coastline (Basiskustlijn [BKL]), based on principles as depicted in Figure 2.9. It relates the position of the momentary coastline to a volume around the Mean Low Water Level.

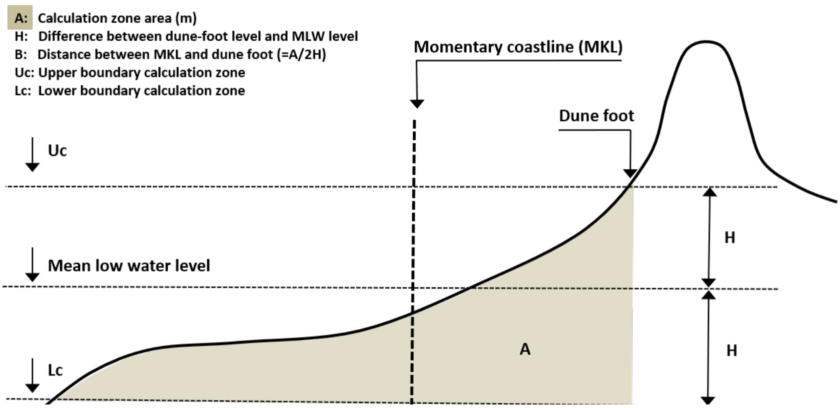

Figure 2.9. Definition sketch of momentary coastline (adapted from TAW, 2002)

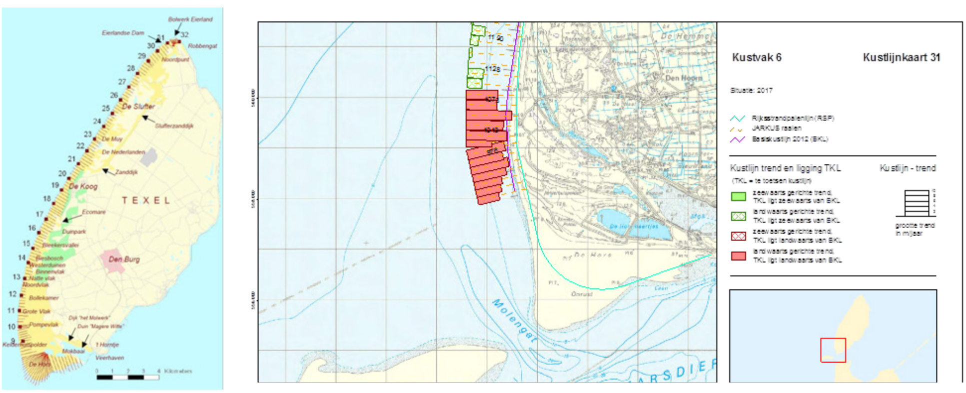

Figure 2.10. Position of all transects on Texel in the JARKUS monitoring programme (left; RWS, 2005). Right: results of coastline testing in 2017, indicating an erosive trend between km 9 and km 11 (right; RWS, 2016)

Based on the realisation that any momentary coastline only represents a snapshot and is not fully representative of the dynamic behaviour of the coastline, the standard 'basiskustijn' (BKL) was defined as the average momentary coastline position derived from its trend over the period 1981 – 1990. The coastline position is determined analytically on a yearly basis by comparing the BKL position with a predicted trend coastline position (TKL) as derived at that time from the momentary coastline trend over the preceding decade (Figure 2.10).

Coastline positions have been established and laid down in an appendix to the Water Law, at 250 m intervals along the entire sandy coast. An exception applies for SW Texel. To allow for natural dynamics at the southern tip of the island (De Hors) no BKL has been defined. The legal obligation to maintain the coastline only applies from Km9 northward (see Figure 2.10). This approach relies upon the yearly monitoring programme JARKUS that has been operational since 1965, and provides bathymetric transect data up to the 5 m contour of transects along the coast at 250 m intervals (Figure 2.10)

In 2000, the total sand volume of the active coastal zone between a depth of 20 m and the dune body massive has been defined as the 'kustfundament' or coastal foundation (Figure 2.6). This concept arose from research showing that maintenance of the BKL would be insufficient to meet the policy objective of sustainably maintaining coastal safety and other dune functions (e.g., Mulder et al., 2011). To comply with the objective of sustainability and maintain the sand volume of the coastal foundation, the yearly total nourishment volume of the Dutch coast was raised from 6 to 12 million m^3, from 2001 onwards.

2.4.3. Current legislative, organisational and social context

Currently, safety standards for all flood defences in the Netherlands, including the dunes, have been established by law (Delta Act, 1958; Flood Defence Act, 1996; Water Act, 2009). The Flood Defence Act and the Water Act define the need to preserve the coastline, in terms of the policy of 'Dynamic Preservation' (MIN V&W, 1990). In addition, natural values of the area, including the tidal inlet, adjacent dunes and sandy shoals such as De Hors, are protected under the European legislation Natura 2000 (Bird- and Habitat Directives apply here), and related national and regional legislation (e.g., Wet Natuurbescherming, 2017). Preservation of flood defences of the sandy coast of Texel involves three governance levels: a) the State or national level, Ministry of Infrastructure & Water management, Rijkswaterstaat (RWS); b) at regional level the province of North Holland and the water board Hoogheemraadschap Hollands Noorderkwartier (HHNK); and c) at local level, the municipality of Texel. In the case of Texel, the state (RWS) is responsible for the design and implementation of nourishments. At regional level, the province is responsible for co-ordination of spatial, economic and nature developments. The regional office of the State Forest Authority (SBB) is responsible for the protection of the natural environment (Figure 2.12). The Water Board (HHNK) is tasked with ensuring coastal safety against flooding. At local level, the municipality of Texel is responsible for maintenance of local infrastructure and economic development.

In implementing the coastal policy, repeated sand nourishments totalling 48×10^6 m^3 have been applied along the entire Texel coast between 1990 and 2015, with some 9×10^6 m^3

being applied between the transects 9 and 13 in the south-western part (Figure 2.11). The current coastal policy is successful in maintaining the coastline, but consideration of other aspects such as the natural environment and local economic development lags behind (Lubbers et al., 2007; Mulder et al., 2011). Indeed, where in other countries natural protection legislation generally constrains human interventions in the environment that affect protected habitats or species, Dutch legislation offers explicit exceptions for water safety objectives. The vital importance of flood protection in the Netherlands – where 59% of the country is prone to flooding (Pieterse et al., 2009) – means that the natural environment and local economic development often are secondary to the primary objective of flood protection.

Because Texel's dune system and intertidal area have significant ecological value, changes in nourishments and maintenance of the dunes affect the delivery of ecosystem services. The water board tries to align flood protection measures and water quality management actions with nature conservation. Indeed, many stakeholders have an interest in, responsibility for, or are affected by management decisions regarding the Texel coast (Figure 2.12). These include nature managers, tourists, environmental organisations, and people living on Texel. Tourism is a main contributor to the Texel local economy, and Texel's rich nature is what attracts tourist and recreants to the island. Also, visitors and owners of beach restaurants and beach houses have an interest in the width of the south-western Texel beach. A specific stakeholder is the Ministry of Defence, exploiting a training centre and small harbour at the north-eastern fringe of the sandy shoal De Hors. Additionally, the navy Harbour of Den Helder and local fisheries frequently uses the channel Molengat for navigation purposes.

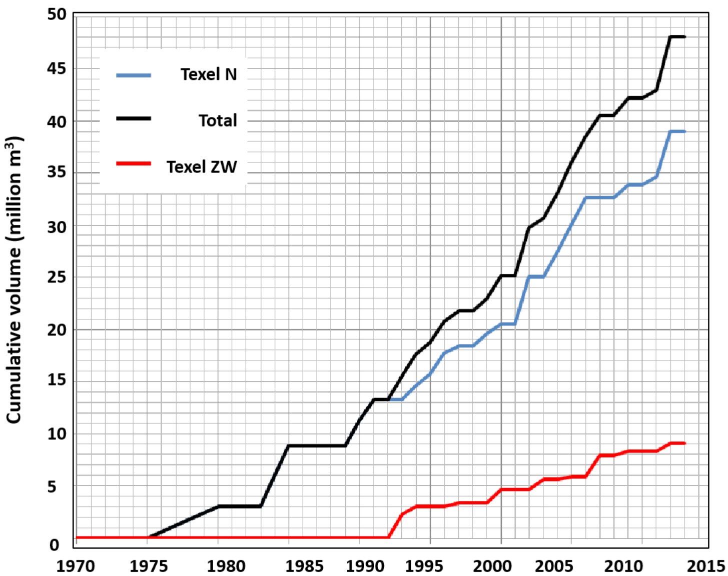

Figure 2.11. Total nourishment amounts (million m³) on Texel between 1990 and 2013, divided between the northern and south western part of the island (after Elias et al., 2014)

2.5. System understanding and insights gained

A structural sand deficit is determining the long-term evolution of the coastline of Texel. Recurring sand nourishments form an effective counter measure, as the coastline position has been maintained and safety against flooding from the sea has been guaranteed over a long period. However, the recurrence interval of nourishments and the associated costs are rather high, recreational beach widths are constantly under pressure and the lack of dynamics in the dune area has led to a deterioration of the natural environment. The latter is in strong contrast to the dynamic and highly valued area of De Hors where there is no legal obligation to maintain the coastline and no nourishments are applied.

New scientific insights shed more light on the relation between shoreline and dune development at De Hors (Section 2.3) and in general, on the link between inlet dynamics and ecological functioning. Present understanding is that the long-term, coastline movement at Texel may be regarded as a component of inlet dynamics (Elias and van der Spek, 2014, Van Heteren et al., 2006). In future, migration of the sandy shoal Noorderhaaks may have a significant effect on shoreline development (Cleveringa, 2001; Van Heteren et. al, 2006; Elias and Van der Spek, 2006). All in all, this challenges existing management approaches to take the (long-term) natural dynamics of the inlet into account. Questions that would need to be addressed include how channel-shoal dynamics in the inlet affect shoreline development, and whether manipulation of inlet dynamics is a feasible alternative to existing nourishment practices. Issues to be considered in addition to the sediment dynamics include flood safety, the status of Texel as part of a UNESCO world heritage area, biodiversity, tourism, navigation and fisheries.

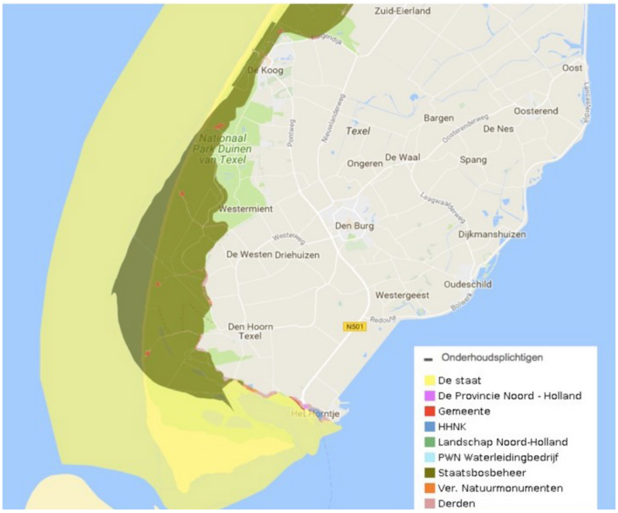

Figure 2.12. Indication of the main actors responsible for maintenance of different parts of SW Texel: state (yellow), municipality (red), state forest authority (dark green). Another main actor, not indicated in the map, is the Water Board, responsible for maintenance of the dune water defence (HHNK, n.d.)

A coastal system is perceived differently by different stakeholders (Costanza et al., 1997; Farber et al., 2002), and the interests of these stakeholders are affected by changing policies and management strategies (Hermans et al., 2013). Accordingly, active stakeholder engagement is considered necessary for effectively managing the environment (Ostrom, 2009). Since the single issue of flood protection has dominated the management of the Texel coast and inlet over time, different types and sources of knowledge (e.g., model-based, technical design knowledge and local community knowledge) will be needed in expanding to address the full range of objectives held by local inhabitants and other relevant stakeholders. The south-western part of Texel provides a wide range of ecosystem services, such as flood protection, biodiversity, recreational opportunities, navigation. As such, the interests of different stakeholders will be affected, highlighting the need for a collaborative exchange of perceptions, knowledge and understanding of the coastal system for the purpose of designing new strategies for managing this part of the Dutch coast.

2.6. Concluding remarks

The present coastal policy is effective in maintaining the coastline and ensuring safety from flooding. It requires frequent and costly sediment nourishments, particularly at south-western Texel. Scientific insights regarding large scale inlet dynamics indicate a future merging of the sandy shoal Noorderhaaks with the south-western tip of Texel. This holds implications for management approaches, implying that they should also take the (long-term) natural dynamics of the inlet into account. Perhaps, nourishments can be replaced by other methods aimed at steering large scale inlet dynamics. Scientific understanding of the sediment dynamics is essential in determining how alternative approaches could affect the natural dynamics of the coastal system. Similarly, governance knowledge is necessary to determine what is possible under existing regulations and what modifications to regulations might be necessary. Critical considerations involve balancing natural sediment dynamics, the long-term effects of climate change on the dynamic Wadden Sea system, and the envisaged human interventions. The south-western part of Texel provides a wide range of ecosystem services, such as flood protection, biodiversity, recreational opportunities, navigation, all of which dependent to some extent on the sediment cycle. The interests of different stakeholders will be affected by any changes in management approach. As such, the need for collaborative, participatory approaches in designing alternative multi-functional coastal management strategies into the future becomes apparent.

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