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M.Sc. Thesis

System-description Noord-Holland Coast

"a review of the nourishment strategy applied."

[Delft University of Technology]
[Faculty of Civil Engineering and Geo Sciences]
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A. Préface

This document entails a "System description of the Noord-Holland coast and a review of the current nourishment strategy." It serves as a M.Sc. Thesis of the writer and aims to gain better understanding of the Noord-Holland coastal system. This is of importance for the assessment of the current coastal maintenance strategy applied over the period 1990-2010. The study is made at Rijkswaterstaat, the department of waterways and public works of the Ministry of Infrastructure and Environment. On behalf and under supervision of the Waterdienst this thesis is made.

Working on this document enabled me not only to learn, but also experience coastal engineering challenges. To be supported by employees of both Rijkswaterstaat and knowledge institute Deltares enabled me to look towards issues in different ways. Being coached by Ruud Spanhoff and Quirijn Lodder has been a nice and interesting experience. I would like to thank them for their input, detailed feedback and the freedom they gave me to shape my M.Sc. thesis in the direction that I found interesting. It has been a true pleasure to work with them.

I am grateful towards those that made it possible to experience different perspectives of those involved in Dutch coastal engineering. In that light I would like to thank Gerben de Boer, Edwin Elias, Dirk-Jan Walstra, Ankie Bruens and the crew of the Ms. Zirfaea. The drive of Gerben to assure knowledge is shared within organizations and his enthusiasm towards Open Source data has been great inspiration. A special thank you goes out to Jim Denevan. Thanks for allowing me to use your monumental sand drawings. Furthermore, I would like to mention my professor Marcel Stive. Thank you for the many interesting lectures and sharing feedback and insights.

Furthermore, I need to thank Wim Visser. Without his input I would not have been able to document the steps needed to process coastal morphologic data. I have appreciated his extensive efforts to check and correct my work. I would like to thank Giorgio Santinelli and Fedor Baart for helping me out with Matlab when needed. The many conversations with Giorgio on my findings and coastal processes that influenced results were very pleasant and valuable.

The time spend at Deltares has been intense and inspiring. It was a joy to work in an atmosphere with so many other M.Sc. students, all with their own assets. Highlights were the Friday-afternoon gatherings and the many conversations in which both frustrations as well as motivation were shared. Deltares is a great environment to learn and excel.

Finally I would like to thank my parents for the unconditional support during my studies. A last thank goes out towards my other relatives, friends, fellow students and fellow delegates of the United Netherlands Harvard Delegation. Thanks for the motivation and support.

B. Summary

The safety of a large part of the Netherlands is dependent on the safety level of our flood protections. The shape of these protections varies from artificial dams and dykes to dunes. The height and volume of the dunes and the near shore zone influence this safety level. Robust dunes have provided natural safety against the sea for centuries. While floods have occurred numerous times, the large natural sand bodies remained present. In the last centuries, structural erosion of the coastline and the increase of the use of the hinterland have made coastal maintenance a necessity in order to provide this safety.

The Noord-Holland coast is one of the most extensively maintained coastal stretches of the Netherlands. In the last twenty years Rijkswaterstaat nourished this coastal stretch with a total volume of 44 million m3, in the shape of beach and foreshore nourishments.

To assess the need of such extensive maintenance and to map sedimentation and erosion trends a system description is made. Over the area from IJmuiden till Den Helder, the coas is divided into seven coastal cells (van Rijn, 1997). Per cell the near shore volume evolution is analysed. With the support of a description regarding the processes, morphologic features and an alongshore distributions of volume trends these cells are analysed.

To describe the Noord-Holland coast it is chosen to use the JARKUS database. Forty five year of coastal morphologic data is used, over the period 1965 to the year 2010. Each year along the Dutch coast transects with an average lateral distance of 250 m are monitored. The framework of this monitoring program is described. To analyse whether this database is valuable for the aforementioned system description an accuracy calculation led to the following results. The error with regards to the JARKUS data is found to be limited when a large number of profiles is analysed. This can be explained by the law of large numbers and a convergence of the systematic error. Accuracy in the order of 15 – 21 m^2 over the surface of a profile needs to be taken into account. Based on these results the JARKUS database can be considered to be valuable to describe the near shore volume evolution of the Noord-Holland coast.

To analyse the near shore volume two datasets are used. The first dataset consists of volume calculations with a landward boundary selected 100 meters landward of the RSP-reference line (RijksStrandPalen). Seawards a distance of 750 meters is selected. The second dataset reaches 1200 meters seaward of the RSP-reference.

The focus of the near shore volume evolution is partly based on the assessment of the coastal maintenance strategy applied. In the year 1990 a new coastal maintenance policy was introduced; "Dynamic Preservation". This policy had the strategic objective *"to guarantee a sustainable safety level and sustainable preservation of values and functions in the dune area"* (Min V&W 2001).

To reach the objective a coastal state indicator has been implemented. In the year 1990 the position of the coastline was established through a concept called the Basal Coast Line. Combined with a benchmarking principle a method was formulated to assess when coastal maintenance, in the form of nourishmens, is found to be necessary.

Since the implementation of this benchmarking principle and the "Dynamic Preservation" policy the nourishment volume increased vastly. The effects of extensive nourishing are analysed. By correcting for the artificially added volumes an autonomous volume evolution is presented for each cell. With the assumption that similar erosion rates would have been present without coastal maintenance, an indication of the state of the Noord-Holland coast is given.

In order to determine erosive hot-spots and to assess alongshore variations of the near shore volume, a distribution of volume trends in alongshore direction is made. The system description concludes the following:

+ The largest part of the Noord-Holland coastal stretch has been erosive over the last forty five years. The coastal stretch from Egmond aan Zee till Den Helder shows significant erosion.
+ Erosion hotspots are present adjacent to the coast near Den Helder. Landward migration and deepening of the "Nieuwe Schulpengat" cause erosion rates in the order of a million cubic meter per year. The influence of these processes due to the morphodynamic developments of the Texel tidal inlet and the outer delta (Noorderhaaks) are significant. Along the coast near towns of Egmond aan Zee and Bergen aan Zee erosion hotspots are also found.
+ Over the whole Noord-Holland coast the near shore volume decreased by about 20 million m^3 over the period 1965 – 1990. Over the last twenty years the near shore zone gained 20 million m^3. A total nourishment volume of 44 million m^3 was needed to achieve this.

The near shore volume corrected for nourishments over the period 1990 – 2010 shows an autonomous degradation of similar order compared to the years 1970 – 1990. This indicates that for the whole Noord-Holland coastal stretch, the concept of the autonomous behaviour as conservative indication of erosion / sedimentation rates holds plausible values.

The system description indicates that the coastal stretch of Noord-Holland received a significant larger nourishment volume than deemed necessary to reach the objective of the "Dynamic Preservation" policy.

The autonomous volume changes over the period 1965 to 2010 are used to calculate yearly sedimentation and erosion rates per coastal cell. By adopting alongshore transport rates over the + 3 to – 8 m zone proposed by Van de Rest (2004) a sand budget model is made. The results indicates that for the most northern cells Van de Rest underestimates the alongshore transport gradients. By adopting the calculated transport rates from Stive and Eysink (1989), better results are obtained. Although the sand budget model holds some limitations, the results are quite reasonable.

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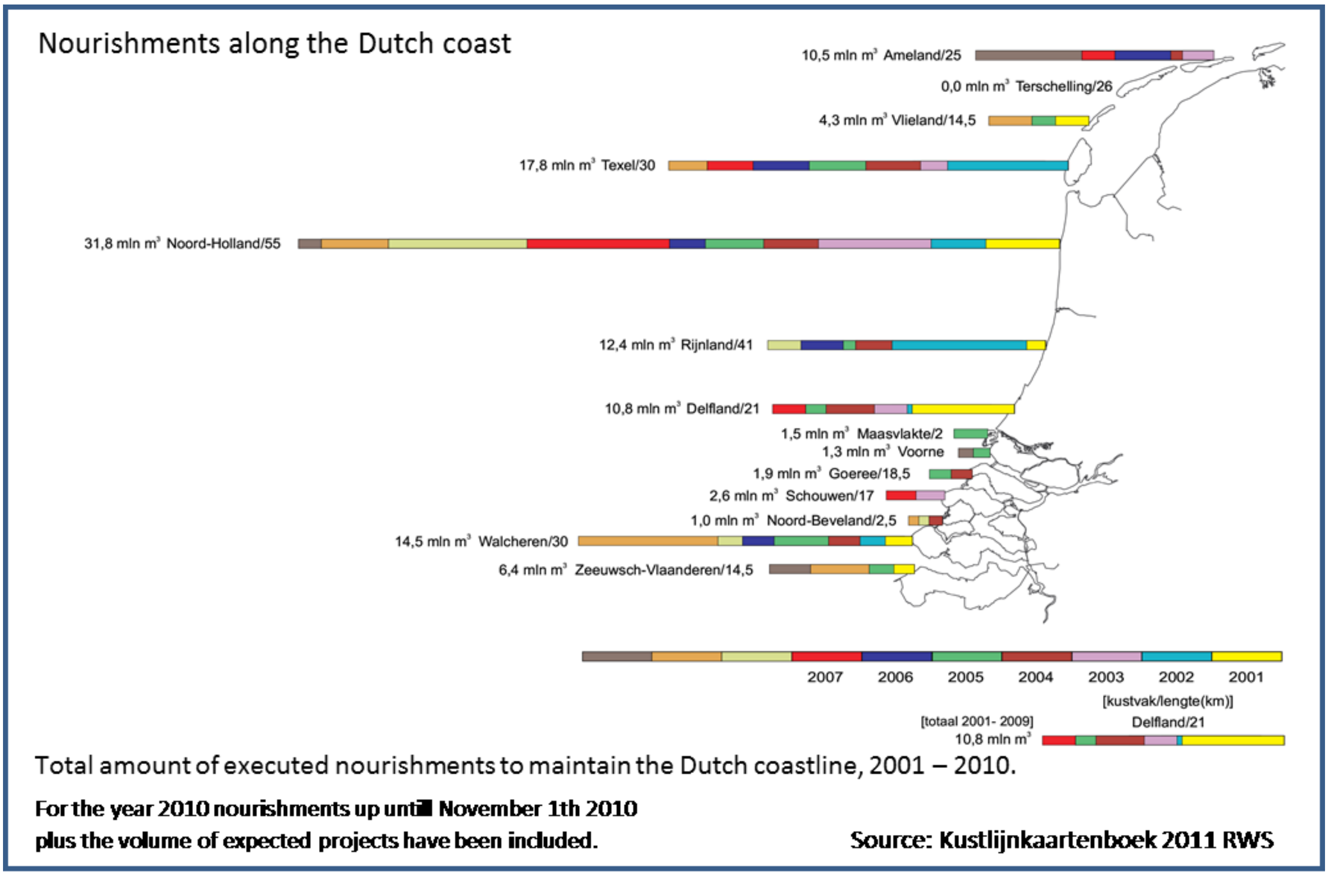


Figure 1.1 Nourishment volumes along the Dutch coast

1 The State of the Noord-Holland Coast

This document entails a “System description of the Noord-Holland coast and a review of the current nourishment strategy.” It serves as a M.Sc. Thesis of the writer and aims to serve as description of the morphodynamic processes present. By analyzing the available coastal morphologic data in the period 1965 – 2010, the evolution of the volume of the near shore coast is presented. With support of earlier acquired estimates of long shore sediment transport a sand budget model is made. These aspects should improve understanding of the Noord-Holland coastal system. Furthermore an assessment for the coastal maintenance strategy applied between 1990 and 2010 is made. The study is made at Rijkswaterstaat, the department of waterways and public works of the Ministry of Infrastructure and Environment.

1.1 Background

The safety of a large part of the Netherlands is dependent on the safety level of our flood protections. The shape of these protections varies from artificial dams and dykes to dunes. The height and volume of the dunes and the near shore zone influence this safety level. Robust dunes have provided natural safety against the sea for centuries. While floods have occurred numerous times, the large natural sand bodies remained present. In the last centuries, structural erosion of the coastline and the increase of the use of the hinterland have made coastal maintenance a necessity in order to provide this safety.

While first solutions were sought in artificial flood protections like the Hondsbossche and Pettemer Sea defence, nowadays, extra volumes of sand are brought into the coastal system to compensate erosion and prevent coastal retreat. Building with nature became the main paradigm within the field of coastal engineers in the Netherlands. The costs of this policy are in general thought to be lower compared to artificial flood protections and relocation of structural erosion problems seems to be avoided.

The background of this study was the request of Rijkswaterstaat for a system description of the Noord-Holland coast. This study area was chosen due to the fact that continuous coastal maintenance is far higher compared to other coastal areas along the Dutch coast. In the last ten years Rijkswaterstaat added over 30 million m^3 of sediment to the system in the shape of beach and foreshore nourishments (figure 1.1). The organization wonders if there are innovative long term solutions for coastal maintenance in this area. A new design for an update of the the Hondsbossche and Pettemer sea defence was included, since the current design is not up to safety standard (Min V&W, 2005). Within the scope there was an aim to formulate solutions for the structure to meet its requirements.

Furthermore, an interest existed for a feasibility study for a sand engine applied at the Noord-Holland coast. In the light of the developments of a similar project in the province of Zuid-Holland this research question formed an interesting thesis that combined both the assessment of the current methods used in maintenance and smart and innovative thinking.

During the description of the coastal system it turned out that interesting features and the complexity of the coastal system demanded further attention. Moreover, further detail towards coastal morphologic data was found to be both beneficial for the understanding of the available data and of importance for the framework in which it served.

1.2 Research questions

The approach chosen is to build this thesis based on four pillars. Firstly an introduction of the coastal system and its characteristics is described. Secondly an outline is given regarding coastal morphologic data. In the third pillar the current state of the Noord-Holland coast is evaluated. Finally strategy of coastal maintenance is discussed. Each pillar within this M.Sc. Thesis has its own specific objectives.

The first pillar provides the reader with the current insights in coastal processes; the physics of a coastal system build up by a summary of the hydrodynamic regime and morphodynamic processes. The processes described are the ones which have a substantial impact for coastal maintenance purposes on a human time scale. Processes which are not described are excluded from of the scope of this research. Secondly the evolution of the Noord-Holland coast is shared, as well as the interference of mankind on the coastal stretch.

The second pillar deals with coastal morphologic data. It encompasses five research questions in order to value the data that is used for to describe the state of the Noord-Holland coast. The following research questions are formulated:

+ What coastal data is available?
+ What is the value of this data and how is it acquired?
+ What steps are taken in order to process the acquired data and to fit it within the Jarkus-framework?
+ What is the accuracy of Jarkus-data?
+ Is this data suitable to describe the current state of the coast?

Based on these insights a system description is made. This entails the third pillar of this thesis and aims to answer what the current state of the Noord-Holland coastal system is. Through the following sub-questions the state of the Noord-Holland coast is described.

+ What kind of general volume trends can be found?
+ What are the dynamics in volume change?
+ Is the Noord-Holland coast an erosive coastal stretch?
+ How do we define erosion hotspots and are they present within this coastal area?
+ What is the influence of the Marsdiep / Waddenzee on the evolution of the Noord-Holland coast today?
+ What can we say regarding the term coastal foundation?

The system description aims at analyzing the processes and quantifying them. Firstly a methodology is presented. The system description is build out of seven coastal cells. Per cell a description is made. This is mainly done to understand in which environment coastal maintenance takes place. This is not only a logical step; it also reflects the current paradigm of coastal maintenance measures in the Netherlands. The observed processes give an overview on the current state of the coastal system.

With the Jarkus data the near shore volume is studied. With the data calculations are made and trends are presented. The results of the analysis are summarized by presenting the findings for the whole Noord-Holland coast. These results are used to set up a sand budget model. Sediment transport rates obtained from earlier studies and the sedimentation and erosion rates of different cells give insights of the near shore zone of the Noord-Holland coast.

In the final pillar an overview of the current coastal policy is shared. The pillar gives a review of the coastal maintenance program today. With the support of data and the assessment of the seven coastal cells the review of this program is made. The following research questions will be treated.

+ When does one speak of an effective coastal maintenance policy?
+ What goals and criteria should be set in order to assess effectiveness?
+ Is the current coastal maintenance policy effective?
+ How can coastal maintenance be improved?
+ Are there smart, long term solutions for coastal maintenance?

To conclude the work, a small summary and critical review of the steps being taken are made. Recommendations towards policy makers and engineers are set out and an overview concerning further steps is given.

As mentioned this thesis consists of four pillars. In chapter 2 a general background on the Noord-Holland coast is given. Its evolution and characteristics are described. In chapter 3 coastal morphologic data will be treated. In this chapter the reader finds an outline of the yearly coastal survey program, the Jarkus-framework.

The next chapter presents the analysis of the sand budget of the Noord-Holland coast. This entails chapter 4. The Noord-Holland coast is divided into seven sub-areas. The background of the analysis is described. Subsequently an analysis is made for each of the sub-areas. Chapter 5 entails the sand budget model. In Chapter 6 the reader will find an outline of the current coastal management strategy. It discusses the effectiveness of the strategy based upon the results obtained from the sand budget study. Conclusions, recommendations and a critical review are presented in chapter 7.

2 Morphologic description of the Noord-Holland Coast

2.1 Study area

The Dutch coast is part of a coastal stretch from northern France till Denmark. The coast is bound by the shape of the Noordzee. The Noordzee is a relatively shallow sea on Europe's continental flat. It is connected with the Atlantic Ocean between Norway, the United Kingdom and France. The Noordzee has an average depth of 90 to 50 meters.

The border between the Netherlands and the sea is a high laying sandy barrier on which dunes have developed. While this area seems a fixed, the shape of the beach and the position of the coastline is highly dynamic. Both on the short and long term changes of its position are found. The position of the coastline and the width of the near shore zone have an impact on the safety of the hinterland (Stolk 1989).

The Dutch coast can be divided into three main sections. Each of the sections forms a coastal system with its own characteristics. The Zeeland Delta is characterized by estuaries and (tidal) inlets. The delta works have a great impact on both the shape and the dynamics of the coast. Further north we find the Holland coast. The Holland coast is a relatively long coastal stretch with a clear beach profile that runs from Hoek van Holland till Den Helder.

From Den Helder north and eastwards the Waddenzee is found. The intertidal sea is formed by barrier islands. It has a large tidal basin composed of flats, gullies and several tidal inlets. The area holds great values for nature and recreation. The largest inlet is found between Den Helder and Texel. The inlet influences the morphology and hydrodynamics of both the Waddenzee and a part of the Holland coast. A spectacular outer delta is present seaward of the deep channels of the inlet.

Research of this M.Sc. Thesis focuses on the northern part of the Holland coast. The area entails the Noord-Holland coast. This coast stretches from Zandvoort to Den Helder. It is about 60 kilometers long. The study deals for practical reasons with the coastal stretch from IJmuiden (km 55) to Den Helder (km 2). Over the largest part of this coastline several natural dune rows protect the hinterland against the sea. In the mid-north of the coastal stretch, the Pettemer- and Hondsbossche Sea defence take over this function. This is necessary the since surface of Noord-Holland is below sea level. The hinterland consists of the province of Noord-Holland. About 2.8 million people live in this area, the economic activity is large.

On a regular basis it is needed to maintain the near shore zone of Noord-Holland. With nourishments, artificially sand is added to the beach and foreshore. The nourishments are needed in order to maintain the position of the coastline and to prevent large dune erosion. Thereby nourishments contribute to the safety of the coastal defence. Secondly, the dunes have an important function for the fresh water supply of the Netherlands. With a wider near shore zone, dune growth is stimulated and a larger capacity is generated. Another important reason is to provide wider beaches for recreation and tourism.

In figure 2.1 an overview is given of the study area. The study aims involve the influence of the Marsdiep and the Waddenzee, in combination with the outer delta between Noord-Holland and the island of Texel.

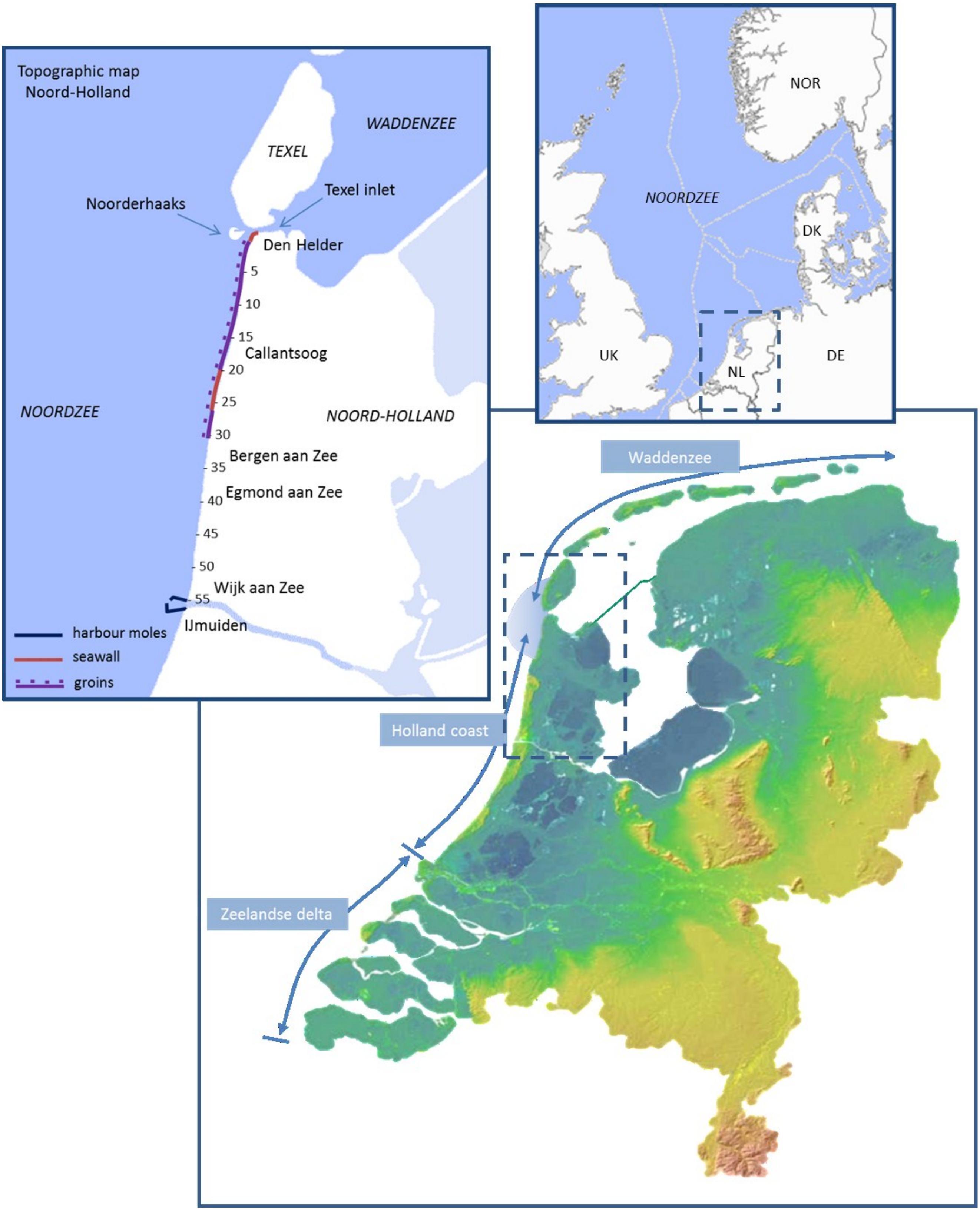


Figure 2.1 The study area and an overview of The Netherlands and its coastal systems.
(source: Actueel Hoogtebestand Nederland, 2010 - Maes et al, 2005)

2.2 The evolution of the (Noord)-Holland Coast

2.2.1 The Holocene evolution

In the late Pleistocene, about 10 - 20 thousand years ago the sea level was far lower compared to recent times. The mean sea level was about 30 to 20 meters below its current level. Due to this, the southern Noordzee was dry and formed a connection with England. Rising temperatures caused sea level rise, around 1 m per century and the coastline retreated rapidly.

At the start of the geological period Atlanticum (8000 years BP), the Dutch coastline was situated 25 kilometers west of its current position and still retreating. At the end of this period, coastline recession declined. Enough sediment was available to fill the tidal basins. With the formation of old dunes the closure of the Dutch coast, from the Zeeland Delta up to Alkmaar, took place. This period of coastal propagation took place in the Sub-Boreal period about 3000-5000 years before present. The coastal stretch was not completely closed by dunes. At that time the Oer-IJ, a large inlet located near Castricum, separated the two stretches (Beets et al., 1991).

During that time the north western part of the Netherlands was located higher due to ridges pushed up in the ice age. The “Texel High” as it is referred to in the literature dominated the coastal evolution in that area, including the northern part of what is now the province of Noord-Holland for a long time. The Texel High was a source of sediment for the tidal basins. The earlier formed glacial landscape had created valleys. Over the years they flooded and their depth ensured the right conditions for sediment to sink. The Dutch coast was shaped by many inlets, lagoons and coastal plains (shallows). One of the current processes in the Waddenzee played a substantive role in the evolution of these plains. Sand hunger, a popular expression for accumulation of sediment in a basin, allowed coastal plains to maintain a constant level of the shoals (Beets et al., 1991).

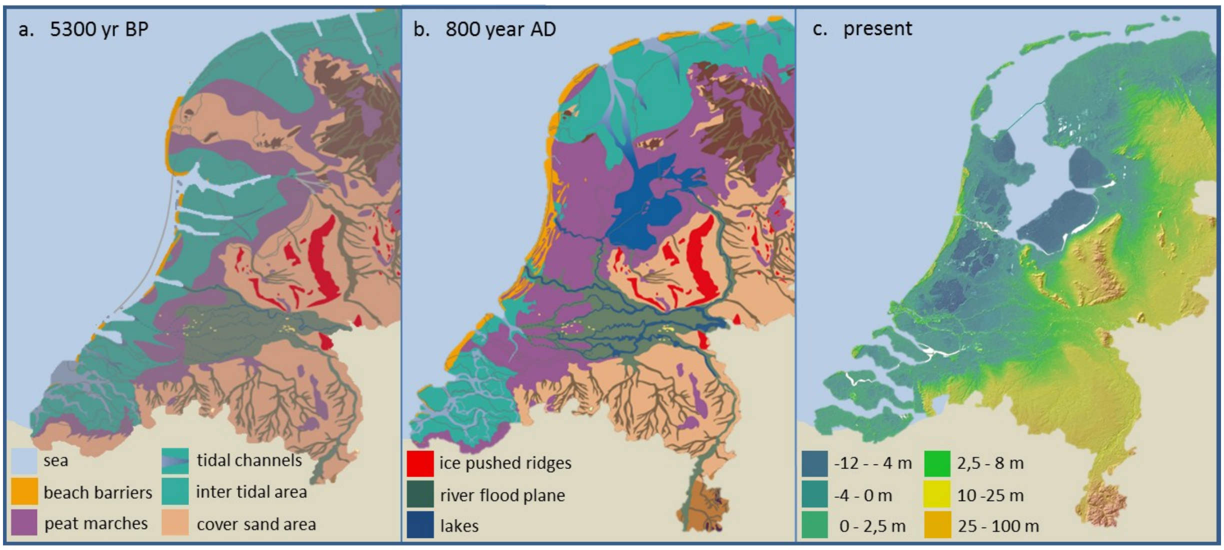


Figure 2.2 The evolution of the Holland-coast (Source: Berendse 2004, De Mulder 2005)

Approximately 3000 years before present, the Sub-Atlanticum period, was chartered by coastal retreat. Whilst sea level rise decreased, subsidence behind the formed coastal barrier led to inundation and breaches. The “Texel High” faced severe erosion and made way for the western Waddenzee. The Marsdiep breach became its largest tidal inlet, the Texel tidal inlet.

In the Roman age, due to the construction of dams in the main rivers and sea level rise sources of sediment became exhausted. The coastal barrier in the west remained intact; in the north the Wadenzee expanded by formed inlets and gullies, into the area what is now the IJselmeer.

From the 11th till the 14th century subsidence due to peat excavation and artificial drainage increased the vulnerability to flooding. In the middle ages floods often occurred. During the 14th century the Water Boards were founded in the threatened areas to work on protection against flooding. However, the establishment of the Water Boards and the construction of dikes and dams did not stop the ongoing natural process of erosion (Berendse and Zagwijn, 1984).

2.2.2 Coastal erosion

Coastal erosion continuously posed a threat and thereby a vital problem for the Dutch. Erosive coasts and problems due to coastline recession are found around the world. Coasts are part of a system that is kept in balance over long time scales by forces that are part of that same system. Equilibrium conditions, over a certain time can be established. When these conditions are not met the position of the coastline changes. Coastal areas are dynamic and the position of the coastline is always subject to change. When sedimentation occurs the coastline moves seawards. This process is called accretion. When a coastal stretch is erosive, the coastline propagates landward over time. Erosion in itself does not pose a problem. *"Erosion is the process of weathering and transport of solids (sediment, soil, rock and other particles) in the natural environment or their source and deposits them elsewhere." (OED, 2008)* The effects of an erosive coast can pose problems for humanity.

Often coastal zones are highly populated areas. Coastline recession can affects these areas. Valuable functions of the beach and hinterland can be threatened. Then coastal erosion is seen as a negative process. Over the past century the population in coastal areas has increased exponentially. Due to this coastal erosion is not just a process of nature, it is an issue with a societal and economic dimension.

Recession of the coastline over time does depend on the rate of erosion. The character of the coast, the material that builds up the coast, the sea level and the way in which the coast is maintained have a substantial impact on these erosion rates.

Many forces that act within the system play a role in causing erosion. Bruun (1989) outlines six different causes of erosion. Focused on the location of the coastal area being considered, five out of these six causes play a role.

+ The coastal zone of the Netherlands has to deal with Sea Level Rise and accelerated Sea level rise.
+ Subsidence of the hinterland strengthened by isostatic subsidence lowers the surface of the western part of the Netherlands.
+ The (Texel) tidal inlet combined with the Waddenzee influences the shape of the coast.
+ The local natural morphology in combination with the hydrodynamic climate enables sediment transport gradients.
+ Human induced erosion. Focused on the Coastal stretch between IJmuiden and Den Helder are interventions within the system, such as the harbor at IJmuiden or the completion of the Afsluitdijk. These projects have induced (local) erosion in the past. The effects of those structures have direct or indirect effect on the state of the coastal system.

2.2.3 Human interference

In the 19th century human interventions were taken aiming to stabilize erosion and coastal retreat. Groynes and earlier, the creation of the Hondsbossche Zeewering, are examples of this. Floods in the province of Noord-Holland in 1916 laid the political the base for the closure of the Zuiderzee, creating the IJselmeer. This has an ongoing influence on the Waddenzee and the Noord-Holland coastal system (Zagwijn, 1984).

The natural (equilibrium) profile of the Noord-Holland coast is treated in the next paragraph. Figure 2.3 shows the typical natural coastal profile of the Noord-Holland coast. To maintain this coastal profile, nourishments are often executed. Large volumes of sediment are needed on the beach or at the foreshore to compensate for losses due to erosion.

In table 2.1 the currently present man-made structures are summarized. Figure 2.1 indicates the location on a map of Noord-Holland. These man-made structures are not the only human intervention influencing the coastal system. Coastal maintenance in the form of beach and foreshore nourishments has a substantial impact on the physics and state of the coastal area. Dunes are at some locations artificially strengthened by eco-planning or dune nourishments. Eco-planning entails the creation of an environment in which the growth of particular vegetation is stimulated. Particular vegetation has a stabilizing effect on dunes. Nourishments are treated in chapter 6 of this thesis.

Structure	Location	Period	Spatial scale
Seawalls			
Sea defence Den Helder	0 – 0.4 km	Construction started in 1721	400 m alongshore
Seawall and shoreface defence	0,4 – 1.1 km	Construction in 1956	700 m alongshore
Pettemer	20,3 – 21,2 km	Constructed in 1969	1 km alongshore 200 m cross shore
Hondsbossche	21,2 – 25,8 km	Constructed in 1500 Restored in 1872	4 km alongshore 200 m cross shore
	25,8 – 26,2 km	Constructed in 1954	
Harbour jetties			
IJmuiden **Extension**	55 – 56 km Idem	1865 - 1879 1962 - 1967	1,5 km cross-shore south + 1,5 km north + 0,7 km
Groins			
North Noord-Holland	0,2 – 31,0 km	Construction 1838-1935	29 km alongshore 200 200 m cross-shore

Table 2.1 Man-made structures (After: Wijnberg et al, 2002)

At other locations the coastal area is sometimes used to execute projects that aim for innovative solutions for coastal maintenance. Eco-beach, an initiative of the Royal BAM group near the city of Egmond aan Zee is such an example.

In the province of Zuid-Holland, a large scale innovative nourishment project, called the Zand-motor has been executed in the spring of 2011. About 21.5 million m^3 of sediment has been added to the system as an extension of the beach. The nourished area should provide the adjacent coast with sediment to compensate for occurring erosion. It gives an idea of possible alternative coastal maintenance strategies.

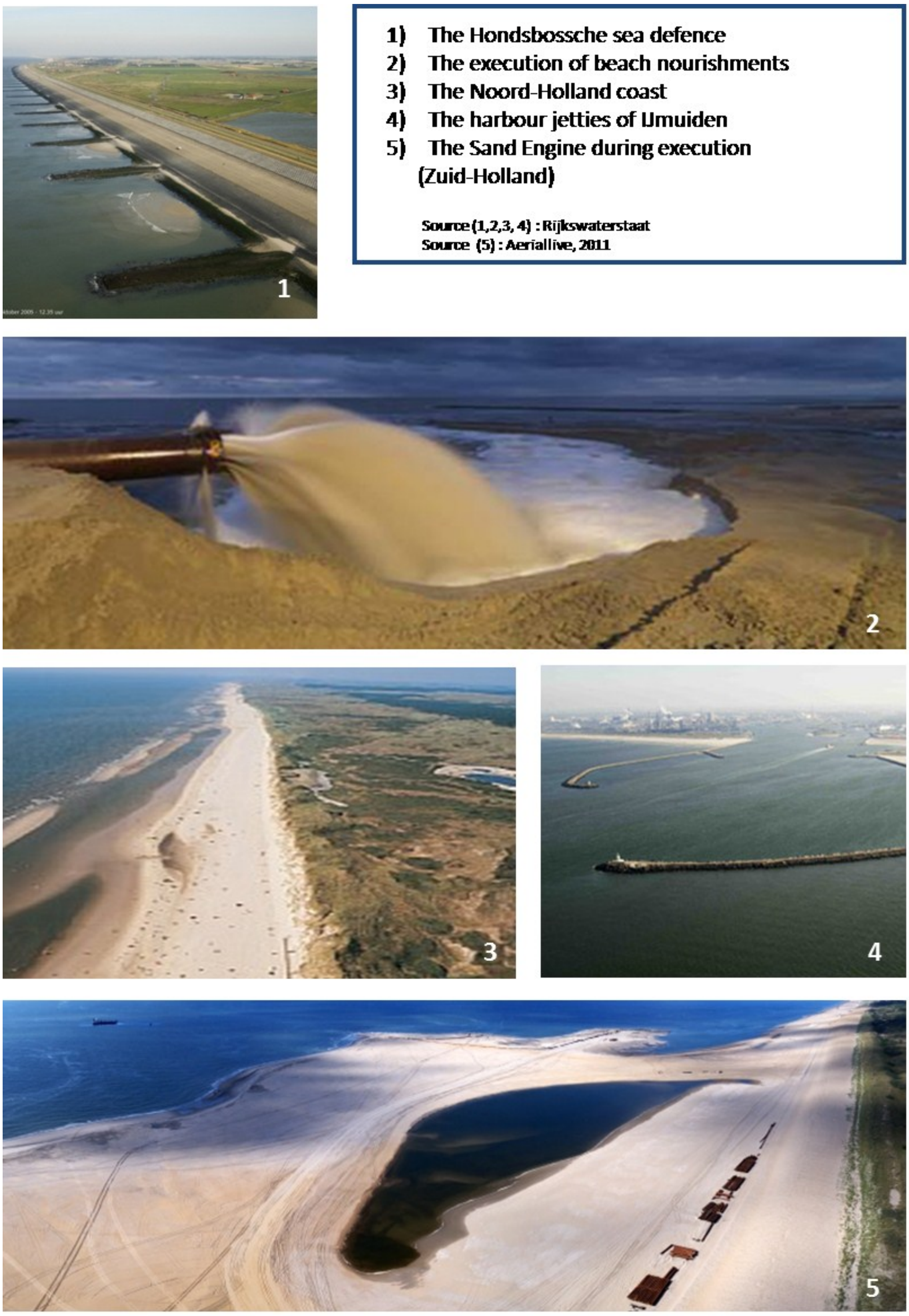


Figure 2.3 The (Noord) Holland coast and human interference in the coastal system

2.3 Characteristics of the Noord-Holland coast

2.3.1 The coastal profile

A typical coastal profile for the Noord-Holland coast is a multiple barred coast. The profile contains dune rows with a width between 150 m to a few kilometres. Seaward a beach and the near shore zone can be found. One to three shallows form (breaker) bars. After depth of closure a relatively large continental shelf is present. In the case of the Holland coast, the sea floor of the Noordzee. A typical depth of closure would be minus 8 to minus 10 meter. Seaward of the depth of closure, a milder morphodynamic climate is present. The average beach slope is in the order of 1:60. The near shore zone has an average slope of 1:60 – 1:150 (Knoester, 1990). The slopes can vary significantly in longshore direction. Near Den Helder the influence of the channels of the Texel tidal inlet cause steeper slopes. Near IJmuiden, the dry beach and the near shore zone have a larger width.

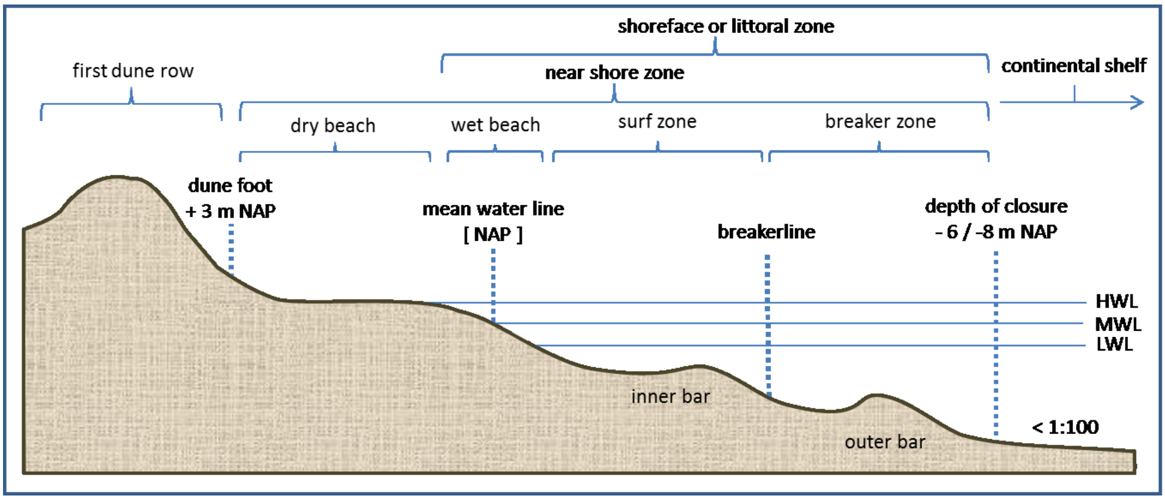


Figure 2.4 Typical profile of the Noord-Holland coast

In 1995 Wijnberg and Terwindt divided the Holland coast in five regions in which they described the morphologic behaviour. Their observations were based on high resolution bathymetric surveys and give an overview of the state of the coastal zone. The first three regions encompass the Noord-Holland coast. Taken from Wijnberg (2002):

Region 1 (3 – 8 km) is characterised by shoreline retreat, profile steepening, and the presence of a near shore bar which was located progressively closer to the shoreline over time.

Region 2 (8 -23 km), in this area the shoreline is also retreating but, in contrast to Region 1, the profile has mainly been flattening. In the last few years of observation, however, the tendency of flattening seems to change into profile steepening. One near shore bar with a stable position is present. Locally, some artificial shoreline progradation occurred due to a large beach nourishment. Near kilometer 15 two natural shallows are present. The Pettemer Polder is the one most profound.

Region 3 (23 – 55 km) is dominated by slow, temporally and spatially coherent fluctuations in shoreline position and profile shape. The shoreline moves onshore and offshore over a timespan of approximately 15 years but the direction of movement varies rhythmically alongshore on about a 2 km scale. This pattern tends to be longshore progressive towards the south. There is also periodic behaviour of the multiple bar system (2-3 bars). All bars move offshore (net) with the outer bar decaying offshore and with a new bar being generated near the shoreline; the typical time span of one such cycle is about 15 years. The mean profile steepness exhibits slow fluctuation over similar time spans.

2.3.2 Tidal characteristics

The water mass in the Noordzee undergoes a tidal cycle driven by the tide present in the Atlantic Ocean. This tide in combination with the geometry of the Noordzee basin creates an amphidromic system. The tide does progress around an amphidromic point located in the centre of this system. For the Holland coast this implies a semi-diurnal tide. The tidal range, defined as the vertical movement of the water level with respect to a reference, is presented in figure 2.5. The figure indicates that the tide is not fully symmetrical. The tidal cycles show a shorter rising period compared to the falling period. This phenomenon is called tidal asymmetry.

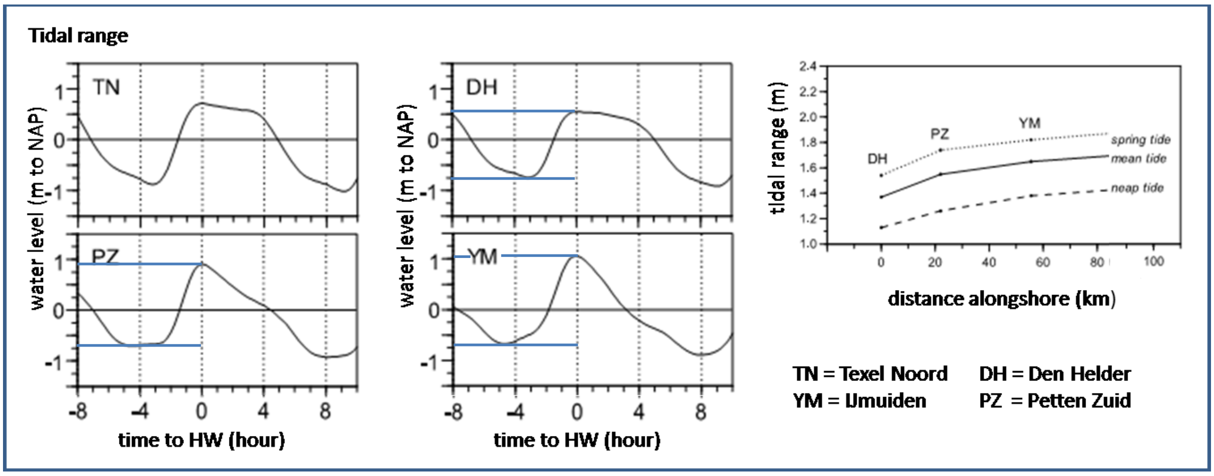


Figure 2.5 The tidal range at the Noord-Holland coast. [after Wijnberg, 2002]

The vertical tide causes currents and thereby movement of water mass. This movement is defined as the horizontal tide. In paragraph 2.5 the contribution of these currents on the long shore current are described.

2.3.3 Wave characteristics

For the Holland coast the wind direction that occurs most often is south-west. Twenty-three per cent of the time this is the cast. Winds from the west and north-west can be expected consequently 16 % and 12 % of the time. During extreme storm conditions, the dominant wave direction is west or north-west (Roskamp 1988).

The yearly mean wave height H_{m0} is about 1.2m. The yearly mean wave period is about 5 seconds. During the winter season the average wave height is 0,5 m higher, in summer the average wave height is about 1 m (Van de Rest, 2004). Wave from the West are in general lower compared to north western wave directions due to the shorter fetch length caused by the presence of the island of the United Kingdom.

Low frequency waves generated on the Atlantic Ocean can propagate towards the Dutch coast. These waves are called swell. Their wave direction is north – north-west (Wijnberg, 1995).

Swell is considered not to be of significant influence when it comes to dune erosion during storm events. Near Den Helder the outer delta in front of the Marsdiep reduces the attack from wind waves considerably between Den Helder and the Pettemer Polder, up until km 20. The bathymetry and shallows in front of the Noord-Holland coast form a protection against wave attack (Mus, 2003).

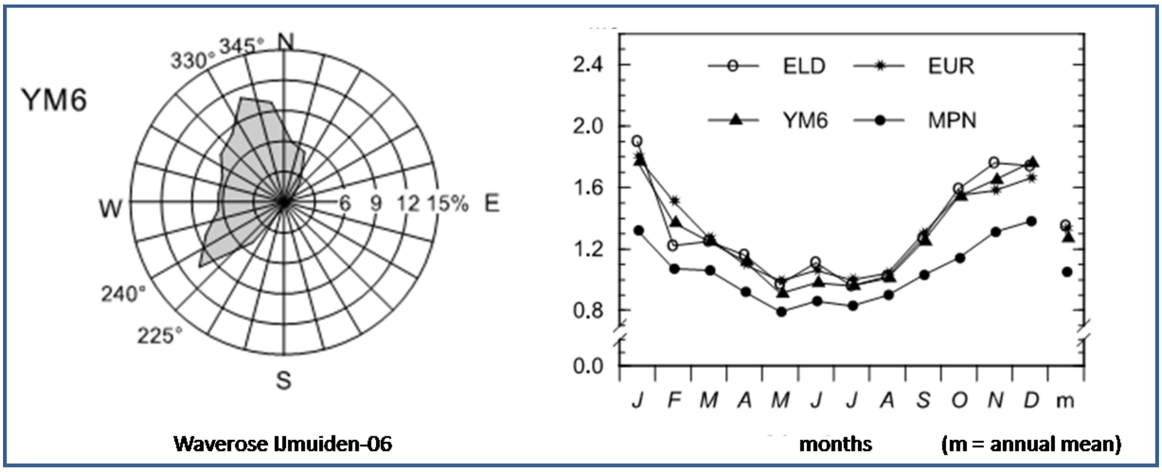


Figure 2.6 Mean monthly waveheight and mean annual waveheight and direction (waverose YM6) along the Holland coast. [modified from Wijnberg (2002), source: Rijkswaterstaat]

2.4 Morphodynamic processes

Morphodynamics is a field in one aims to describe the feedback between the hydrodynamic environment and the present morphology. Morphodynamic processes are complex and their physics depend on many factors. With the current knowledge of these processes one is able to distinct the most important transport processes that influence coastal morphology on a human time scale.

Stive et al (1991) described these processes by dividing the cross-shore profile in three different zones. This is indicated in figure 2.6. The first zone, i.e., the active zone, or upper shoreface, extends from the first dunes to minus 8 m water depth. This zone is bounded by the depth of closure. At this point waves can be influenced by the bathymetry of the bottom. From minus 8 meters to minus 20 meters, the middle and lower shoreface is defined. The inner shelf extends from minus 20 and deeper. The morphodynamic features that take place active zone and the middle and lower shoreface will be treated. Mostly due to the fact that the processes occur within these zones and that the time scale is considered to be one of 10 – 100 years. The geologic processes of the inner shelf fall have larger time scales. They are excluded from the scope of this thesis. One of the most important processes is the alongshore current and it's capability to transport sediment. This process takes place within the active coastal zone. This phenomenon is treated in paragraph 2.5.

2.4.1 Sand waves

Along the Holland coast periodic variation in shoreline position can be observed. These variations are not due to seasonal changes. It was found that some of these variations have periods between 50 and 150 years. Bruun was the first to describe these variations as migrating sand volumes along the Danish coast in 1954. Along several stretches, including the Noord-Holland coast similar features have been observed and described. Verhagen (1989) described the characteristics of the sand waves for the Holland coast as follows: "*The observed sand waves have celerity in the order of 65 m per year, a period of 75-100 years and amplitudes of 40-60 meter*".

These phenomena are called sand waves. Some caution when it comes to a definition is necessary. Scholars that have observed ripple like features in the Noordzee, further of the coast are also defined to be sand waves. McCave (1971) describes mega ripples offshore with similar wave like behaviour. He states that due to wave action sand waves are absent in the near shore of the Holland coast. However, various features, often with a shorter cycle can be observed along the Holland coast. These features influence the near shore volume on a temporal basis.

To illustrate sand waves in the active zone, the propagation of a sand wave near Walcheren (Zeeland) is used. This particular feature was subject of the study by Verhagen (1989) and further investigated by Rijkswaterstaat in 2011. Taken from a study on the island of Goeree (Zeeland) the image of figure shows a relatively large beachfront near A. As a consequence the volume within the beach profile in B is large. Near C the beach is considerably less wide, causing a smaller profile volume near D. It has been shown that these larger volumes propagate alongshore. Further to the right of the image similar features can be observed. With bathymetry images and the evolution of the dune foot, as well as the low and high waterline a celerity of 200 m per year has been determined (Rijkswaterstaat, 2011).

Figure 2.7 Coastal evolution Goeree (sand waves or "strandhaken")

These features have an impact on the analysis of the local sand budget, decisions on whether or not to execute nourishments and on analysis regarding shoreline movement and erosion studies. In chapter 4 attentions will be paid on the influence of sand waves.

2.4.2 Cross-shore variations and bar behaviour

As mentioned in paragraph 2.4.2 the shape of the profile varies over time. Therefore redistribution of sediment in cross-shore direction is needed. Cross-shore redistribution of sediment happens through sediment transport in cross-shore direction. In paragraph 2.5 will elaborate on the topic of (cross-shore) sediment transport. This paragraph will focus on temporal profile variations.

The coastal profile changes throughout the year. The influence of the seasons and thereby the wind and wave climate causes a difference in forcing over the seasons. The coastal profile reacts to this forcing. In winter, with a more severe wave climate, erosion takes place. Storm events enable large scale dune erosion. The sediment is transported offshore due to a larger undertow (paragraph 2.5.3). This volume is not lost; it is redistributed over the profile. During summer, a moderate wave climate enables the profile to restore. This is indicated in figure 2.8.

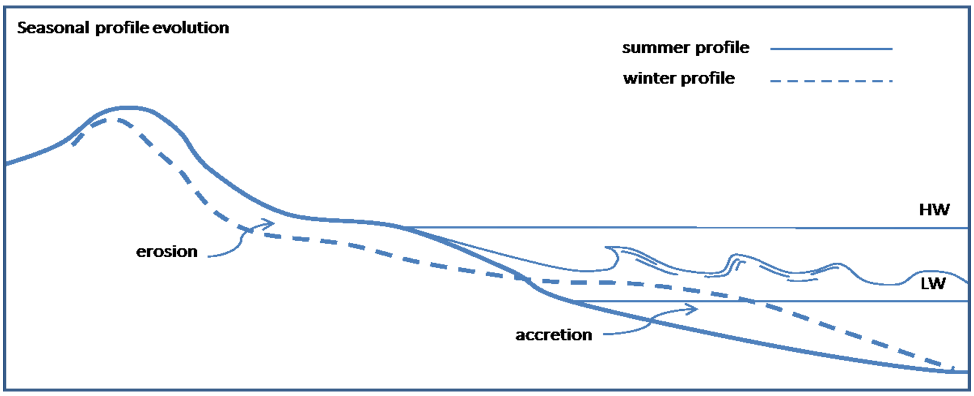


Figure 2.8 Profile evolution due to seasonal changes in wave climate

While these temporal morphologic changes take place in a yearly cycle, other processes have different time scales. The Holland coast is, for the most part a barred coast. In the near shore zone one, two or sometimes three shallow areas can be found. They are called bars. Bars can be characterized as elevations that extend above the average slope of the cross-shore profile. One can distinguish an intertidal bar close to the beach, an inner near shore bar and an outer near shore bar. Between these bars a trough can be recognized. In figure 2.4 a schematized coastal profile can be found. The inner and outer bars are indicated. As mentioned these bars are not static coastal morphologic features. Bars can grow, migrate and thereby their shape and location evolves. By monitoring the near shore coastal volume, the influence of bar behaviour cannot be ignored. By studying the coastal morphologic data of the Holland coast the multiple bar system can be recognized. Furthermore cyclic off-shore directed movement of the bars is observed. The time scale of this migration is in the order of years. Thereby this process can be characterized as medium-term (Ruessink and Terwindt, 2000).

In figure 2.14 coastal morphologic data is used to illustrate the cyclic behaviour of bars. Ruessink and Terwindt (2000) describe such a cycle in three steps by formulating a qualitative model. Firstly, a bar is generated. The bar can move onshore and offshore depending on wave conditions. In general, the bar will maintain its near shore position. When the outer bar decays, the inner bar is less sheltered. As a consequence, the inner bar starts moving offshore. Storm events seem to cause this offshore movement. This seems plausible since these events are characterized by seaward sediment transport due to a relatively large undertow. As a result the crest of the bar will be located at greater water depth. Less stirring of sediment due to wave action and weaker wave induced currents prevent significant landward movement of the bar. At a certain point, when the bar is located at its most offshore position it starts to decay. Ruessink and Terwindt (2000) argue that this *"may be due to a delicate balance between onshore and offshore transports during surf zone conditions"*. In figure 2.9 decay is clearly visible (1974-1976).

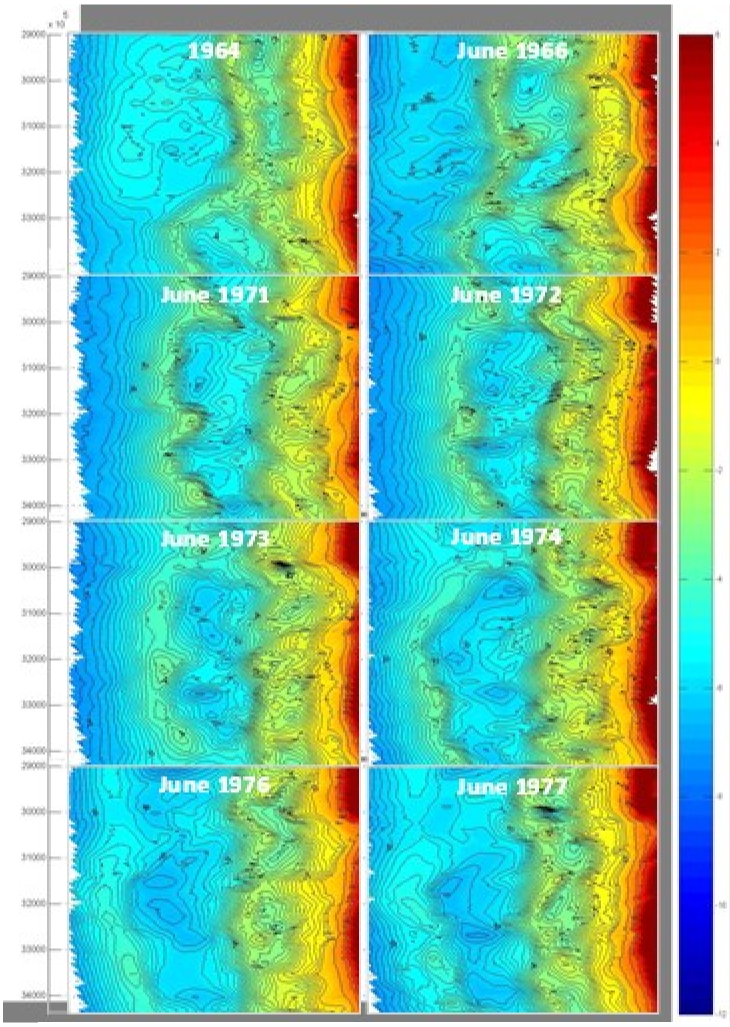


Figure 2.9 Bar behaviour near Egmond (Rijkswaterstaat, 2002)

For the Noord-Holland coast cycles in the order of 8-15 years can be observed. Molendijk (2008) calculated the cycle time of bars by analysing coastal morphologic data. He found bar cycles varying between 12 and 15 years for the area between Egmond aan Zee and IJmuiden. Bar behaviour can be influenced significantly when shoreface nourishment are executed. Spanhoff and de Graaff (2006) elaborate on this matter. They indicate that when designing a nourishment project: "*one should consider the status of the bar system to avoid adverse effects with neighbouring bars*". Good timing may lead to effective volume adaptations.

2.5 Sediment transport

In the coastal zone the hydrodynamic forces, wind, waves and the tide are able to move sediment particles. When sediment particles are moved, one can speak of sediment transport. If particles stay close to the bed, one speaks of bed load. Sediment can also be in suspension. This happens when a critical flow velocity is reached. The particles then are transported by the current. The movement of sediment particles in the coastal zone depends on two elements, namely on the availability of sediment and its characteristics and the presence of forcing.

The sediment of the near shore zone of Noord-Holland coast consists of sandy Holocene deposits. About 5% consists of fine silt (De Gans, 1991). The particles have an average diameter (D50) of 150-500 µm (Figure 2.10). Wijnberg (2002) concludes due to a lack of correlation between the found variation in sediment grains and coastal behaviour, that the '*role of sediments in explaining the observed alongshore changes in decadal coastal behaviour seems to be small*'. However, for sediment transport, the characteristics of particles play a large role.

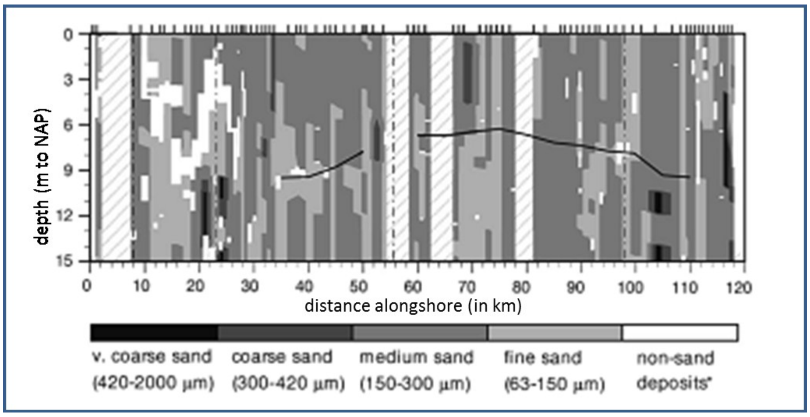


Figure 2.10 Lithology along the Holland coast (source: Wijnberg, 2002)

In order for sediment particles to move, a certain threshold of forcing is needed. Izbash formulated a relation in which a critical velocity u_c was chosen as force and d as a strength parameter. In 1936 Shields came forward with a relation between a mobility parameter ψ_c, in fact a hidden shear stress component combined with an introduced particle Reynolds number Re_*. The relation between forcing and strength was found to be evident. When $\psi_c > 0{,}06$ one can expect the initiation of sediment movement. It shows the relevance of the shape and the mass of the sediment particles.

$$\Delta d = 0{,}7\,\frac{u_c^2}{2g}$$

Izbash, 1930

$$\psi_c = \frac{\tau_c}{(\rho_s - \rho_w)gd} = \frac{u_{*c}^2}{\Delta g d}$$

Shields, 1936

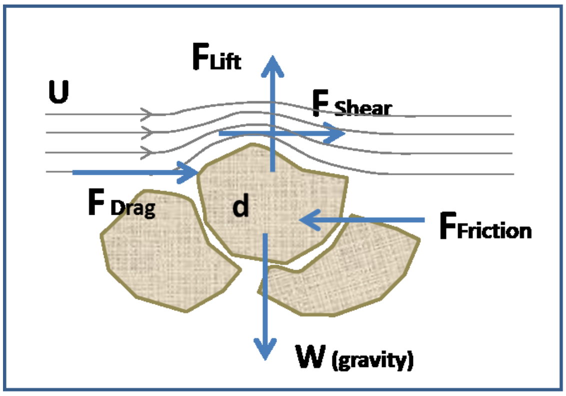


Figure 2.11 Forces on a sediment particle[1]

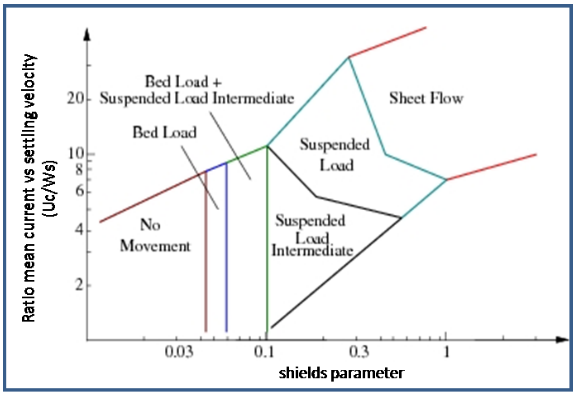


Figure 2.12 Shields parameter and modes of transport[2]

[1] after: Schiereck, 2001 [2] after: Shibayama and Horikawa, 1982

In the near shore coastal zone various forces to move sediment are present. Along the Holland-coast we can find both long and cross-shore sediment transport. These transports are (partly) induced by (oblique) wave impact. When waves are starting to be influenced by the bathymetry of the sea floor the orbital motion starts to become a-symmetric. This enables a net residual landward current in the upper layer of the water column. This nonlinear phenomenon is called the Stokes drift. It was described by Stokes in 1847. The mass balance is closed by another phenomenon, a seaward current called the undertow, in the mid-lower section of the water layer.

In order for sediment transport to happen, both a current and availability of sediment are a condition. Forces that are able to bring particles in suspension must be present (figure 2.11). Within the active zone the (breaking) waves are able to stir up sediment. Near the bed the largest concentrations of sediment are found. A variety of cross-shore currents play a role. They all have an effect on the shape of the profile. The rate of sediment transport depends on the current velocity and sediment concentration. Sediment transport is considered to be a function of u multiplied by a concentration c. Van Rijn (1997) lists the main transport components found in the (near) shore zone:

+ Stokes drift, a net onshore-directed transport is generated due to the asymmetry of the near-bed orbital velocity caused by the waves. Taken over a wave period; large onshore peak velocities under the crest of the wave and small velocities under the trough generate a net onshore transport.
+ The undertow generates an offshore-directed transport due to the generation of a return current caused by the waves propagating towards the shore. Thereby the waves transport mass. This mass is kept in balance, by the undertow. It is held responsible for beach erosion during storm periods.
+ Longuet-Higgins (1953) streaming is generating a net onshore directed transport near the bed.
+ Net offshore directed transport under bound long waves, due to the fact that the trough of the wave group coincides with the highest rate of stirring of the sediment (Deigaard et al, 1999).
+ Gravity induced transport due to the slope of the bed.

In figure 2.13 these currents have been sketched in a velocity profile over depth. The impact of the long bound wave (due to wave groups) is not taken into account.

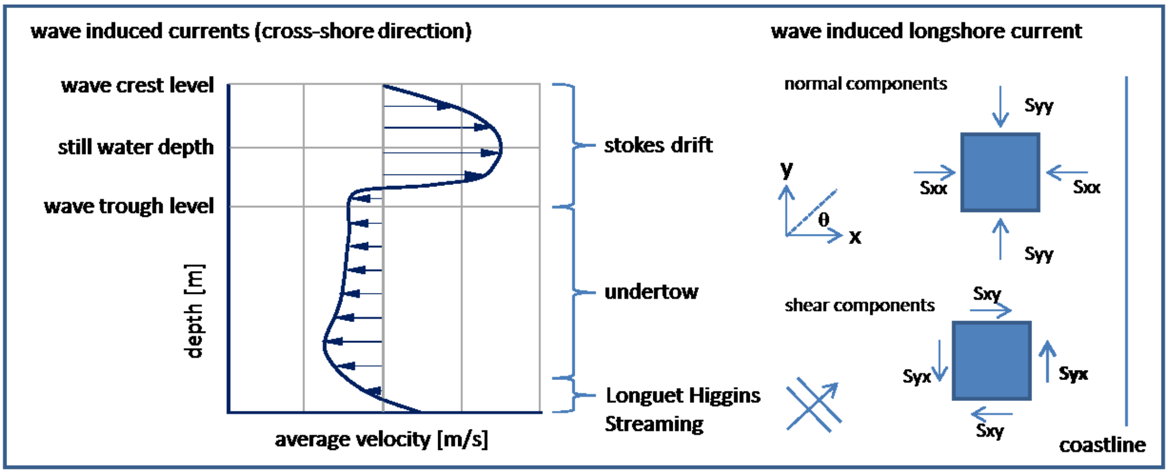


Figure 2.13 Wave induced currents

Due to the presence of a dominant wave direction, a net residual current in alongshore direction can exists. This residual current is caused by the shear component of the radiation stress. Radiation stress is the transport of momentum due to the presence of waves and the wave-induced pressure force. By taking the time average over the advection and pressure part this stress can be found.

The total radiation stress in wave propagation direction is composed out of pressure and advection.

$$S_{xx} = \underbrace{\int_{-h}^{\eta} (\rho u_x) u_x \, dz}_{\text{[advection]}} + \underbrace{\int_{-h}^{\eta} p_{wave} \, dz}_{\text{[pressure]}}$$ in which u_x represents the particle velocity in x-direction

With the linear wave theory (Airy, 1841) both surfaces can be approximated.

$$S_{xx} = S_{xx,pressure} + S_{xx,horizontal\ particle\ velocity} = \left(n - \frac{1}{2}\right) \times \frac{1}{8} \rho g H_{rms}^2 + n \times \frac{1}{8} \rho g H_{rms}^2$$

From this stress we can derive the shear stress in alongshore direction as follows:

$$S_{yx} = n \cos\theta \sin\theta \times \frac{1}{8} \rho g H_{rms}^2$$ in which θ represents the angle of incidence (wave direction) and H_{rms} the root-mean-square wave height

The formulation of the shear stress shows that it is dependent on the wave height, wave direction and the value n. The value of n expresses the ratio of group velocity and celerity (Holthuijsen, 2007). In figure 2.11 the shear component of the radiation stress is shown. Variation in this stress generates a force according to:

$$F_y = \left(\frac{\partial S_{yy}}{\partial y} + \frac{\partial S_{yx}}{\partial x}\right)$$

With the assumption of a uniform wave height over the y-axis (alongshore) the first term equals zero. The second term drives the alongshore current. Through the value n the wave induced longshore transport is confined to the surfzone (a). This is an important aspect. This is shown in figure 2.14. Turbulence quickly reduces the current seaward from the breakerline. Mixing effects of the two water masses generate this turbulence.

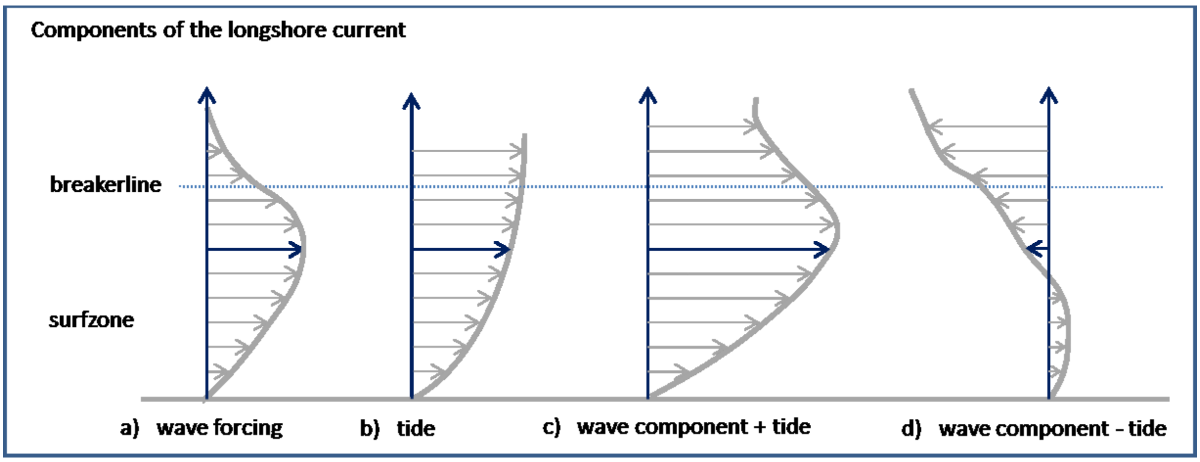


Figure 2.14 The longshore current and its components.

A second force acting on sediment particles is the tide. The tide is able to generate an alongshore current (figure 2.14 b). The tidal currents change with the tidal cycle and therefore change the long shore current over the tidal period. Figure 2.14 indicates the contributions of the two main components of the longshore current combined (c). The driving forces are of higher order; therefore one cannot add the two components directly. The tidal component does strengthen the longshore current and induces a current outside the surfzone.

Rijkswaterstaat determined longshore currents induced by the tide with the TRIWAQ-model. With a south western wind of 15 m/s maximum flood currents have been calculated.

Longshore tidal currents					
distance to Den Helder	**depth** [m NAP]	**max flood velocity** m/s		**max ebb velocity** m/s	
		no wind	wind	no wind	wind
14 km	20	0.65	0.81	-0.50	-0.30
Callantsoog	8	0.52	0.63	-0.40	-0.09
40 km	20	0.64	0.77	-0.53	-0.40
Egmond	8	0.52	0.69	-0.44	-0.20

Table 2.2 Maximum depth average currents in longshore direction (source: Rijkswaterstaat, 1993)

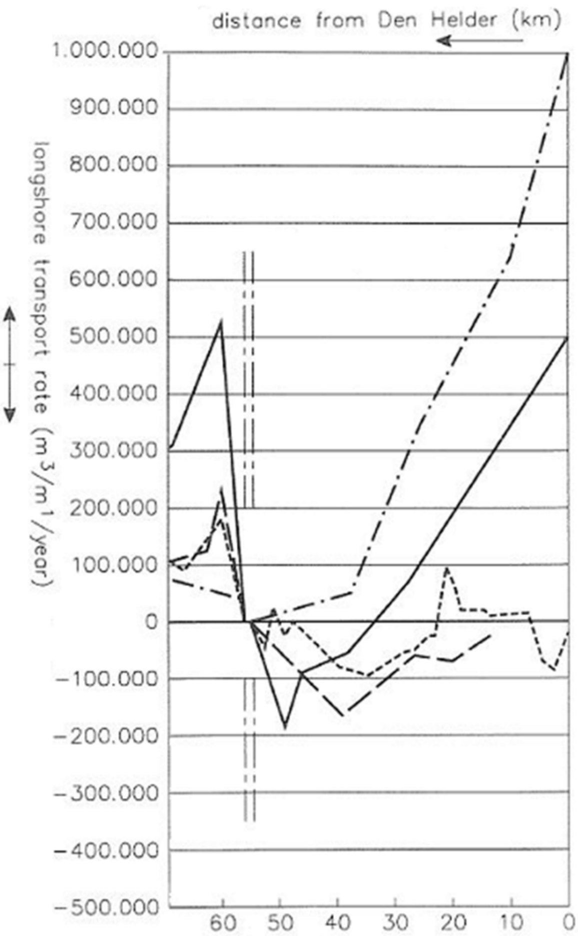
The tidal currents generated due to the propagation of the vertical tide have values ranging from 0,8 m/s to 0,7 m/s. Over the tidal cycle a net residual current is contributing to longshore current along the Holland coast. This results in a residual current velocity of 0,1 m /s (Van Rijn,1997). Yearly average wind induced currents account for velocities of 0,07-0,11 m/s in the upper layer of the water column (De Ruijter et al., 1992).

For Noord-Holland wave driven currents in the active zone have velocities between 0.5 and 0.8 m/s. During storm periods maximum velocities of 1.3 m/s have been documented (Van Rijn, 2002).

The currents depend on the variations of wind direction, wave height and the tidal cycle. They are able to induce sediment transport.

The availability and the stirring of sediment plays a role too. This determines the sediment concentration. The sediment concentration influences the transport. Insight in both these quantities is needed to predict sediment transport rates. Field campaigns to measure the transports are complex and expensive. Magnitudes are mostly determined through 3-d models and transport formula that aim to approach the real situation.

For the Noord-Holland coast net sediment transport rates have been studied, calculated and predicted often. Results of these studies are presented in figure 2.15. These findings can be used as indication of the order of sediment transport rates.



Bakker et al (1989) (till – 5 m NAP)
Van de Graaff-Stroo (1991) (till – 6 m NAP)
Stive and Eysink (1989) (till – 8 m NAP)
Van Rijn (1994) (till – 8 m NAP)

Figure 2.15 Alongshore sediment transport rates along the Noord-Holland coast (source: Van Rijn, (1995)) Van de Rest (2004) compared the sediment transport studies for the Holland coast. He adjusted sediment transport rates on the basis of including results of recent observations. By studying the approaches from Stive and Eysink (1989), Van Rijn (1995), PonTos (1999) and Roelvink (2001) he concluded:

+ The longshore dirft in the surfzone and the cross-shore transport over the minus 8 meter line are most important for the coastal evolution along the Holland coast.
+ Cross-shore transport is considered to cause the largest discrepancies within the studied sand budget models.
+ The accuracy of gradients of the longshore drift is higher for the the coastal stretch of Zuid-Holland. Near IJmuiden due to the harbour mole and near Den Helder the reliability of sediment transport rates is the lowest.
+ Sediment transport rates of the deeper part of the Holland coast are unknown.

An important remark is that Van de Rest (2004) concluded that within none the earlier studies the effects of nourishments on sediment transport rates have been studied. During the execution of nourishments large amounts of sediment are in suspension. It seems likely that dredging companies aim for the smallest losses possible. Therefore they might aim not to deposit sediment during high (tidal) currents. However, a short duration of the project leads to efficient use of equipment.

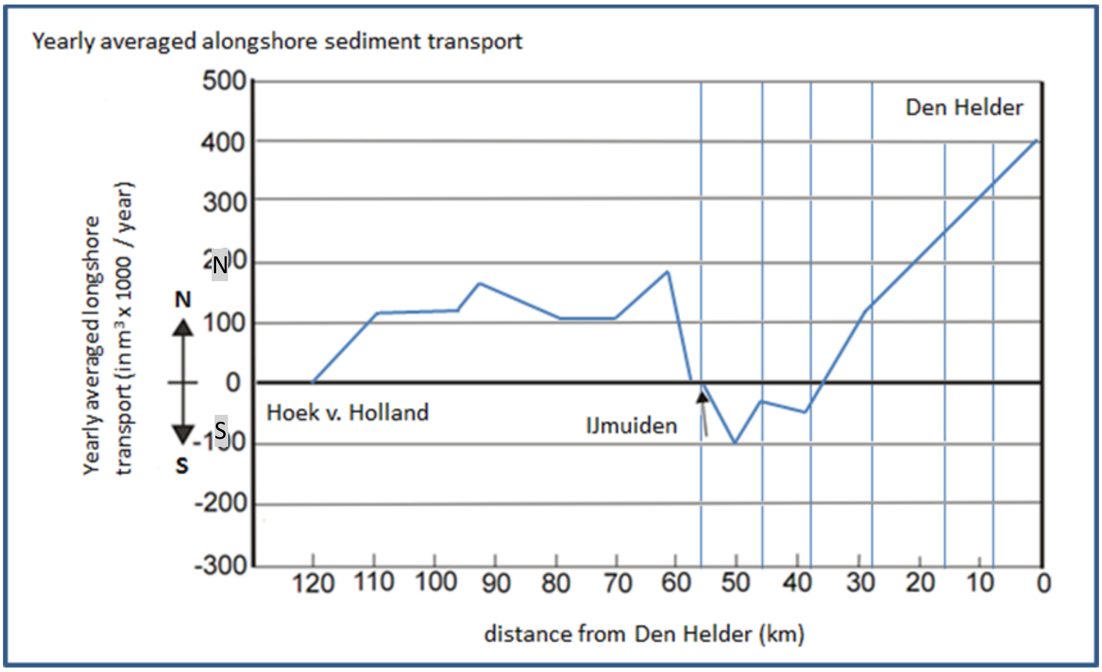


Figure 2.16 Yearly averaged alongshore transport in the zone NAP +3/-8m (source: Van de Rest, 2004).

In chapter 5 these sediment transport rates are used in the sand budget model. Some limitations need to be taken into account.

First of all, the transport rates cover only a limited surface of the cross-shore profile. Near Den Helder (0,2-12 km) the used Jarkus-profiles extend to larger depts. Secondly the reliability of the values near IJmuiden and Den Helder needs to be taken into account. The study of Elias (2006) gives additional insights and a more detailed view of possible sediment transport rates along the northern part of the Noord-Holland coast. The results obtained from Stive and Eysink (1989) and Van Rijn (1995) give an indication of the possible occurring transport rates in the active zone.

3 Coastal morphologic data

Coastal zone management in the Netherlands is for a substantial part based on morphologic data of the coastal zone. Since 1800 depth surveys have been executed. A few decades later (1843) it was decided to record the location of the coastline. The data available has been and can still be used for research on coastal processes and management decisions regarding the safety of the hinterland. Furthermore water quality surveys and environmental impact studies are conducted on numerous locations. Salinity, water levels, waves, tides and (relative) sea level rise are measured. Governmental bodies as Rijkswaterstaat and the waterboards as well as institutions like Deltares execute surveys and record information in databases like DONAR (Data Opslagsysteem voor de NAtte Rijkswaterstaat) and in the Open Earth repository. In Annex I information on the Open Earth database is shared.

In order to establish the dynamics of sediment volumes and to be able to build a sediment balance, a substantial amount of information needs to be gathered, valued and used in a framework suited for calculations and research. In general one can distinguish three ways in which information is gathered. One can describe them in terms of location, accuracy, survey method(s) and periodic time-frame. JARKUS data (**J**aa**R**lijkse **KUS**tmetingen, vakloding data and project surveys are the most important surveys executed to record the morphologic behaviour of the Dutch coast.

The most important sources are the Jarkus-data and vaklodingen-data, depth measurements of the coastal area. Both sets of data are part of the MWTL, Monitoring Waterstaatkundige Toestand des Lands. The MWTL encompasses a periodic monitoring of water depths of the Dutch coastal area in a standardized and systematic way. Frequencies of the Vakloding monitoring are once per three years of the outer Waddenzee, Zeeuwse Delta, Holland Coast and Westerschelde, and once per six years for the inner Waddenzee and Oosterschelde. The JARKUS surveys are being executed once a year, along the Dutch coast line. In the next chapters attention is paid to the different frameworks and surveys.

Choosing sources and selecting data suitable for setting up a sediment-balance needs to be done in an intelligent way. While extensive monitoring and multiple sources of data seem to contribute towards more accuracy, the opposite can be true. The coastal system is highly dynamic. On the scale of cross-shore profiles and in the cross-shore dimension, the natural dynamics are such, that profiles measurements can differ vastly within a period of months (storm season vs summer) or, during storm events over a period of days.

Due to this, a combination of vakloding-data and Jarkus surveys, taken from different periods, is on a certain space scale not always suitable for a comparison of the geomorphological state of part of the coastal zone. The natural dynamics of the system will almost certainly assure differences in depth and thereby differences in volume.

In order to describe the possible errors and difficulties, one needs to understand the process of data handling. Understanding of the processing of the survey data as well as how surveys are executed is vital in order to assign value to the available data. This chapter aims to do so.

The sediment balance presented in this thesis is based on Jarkus-data. For this reason its survey process and data processing is fully described. Afterwards an accuracy study is executed to sketch the flaws and errors that come when applying Jarkus-data as basis for a sediment balance.

3.1 Data availability

3.1.1 Vakloding data

The surveys that generate the vakloding data differ from the Jarkus surveys in the sense that the areas measured start at the end of the JARKUS surveys and reach to depths of about – 20 NAP. Therefore the Vakloding-surveys reaches further offshore. The Waddenzee and the estuaries are also part of the survey program. The vakloding-surveys differ both in space and in time, depending on the dynamics and topography of the surface within the area.

The Noord-Zee coast (Holland coast and the barrier islands adjacent to the Waddenzee) have reference transects with a lateral distance of one kilometre. The Waddenzee and the estuaries have a transect distance of 200 to 100 m. In the inlets between the barrier islands in the Waddenzee, a transect distance of 200 m is selected. The transects are used to generate a grid of a particular area. This grid is merged with Jarkus-grids. The two grids combined cover the entire coastal zone of the Netherlands. The cells are presented in blocks with a surface of 10 x 6,25km. They are stored in the DONAR database. Survey frequencies are relatively low, from once per three years to once per six years. (Wiegmann et al, 2002).

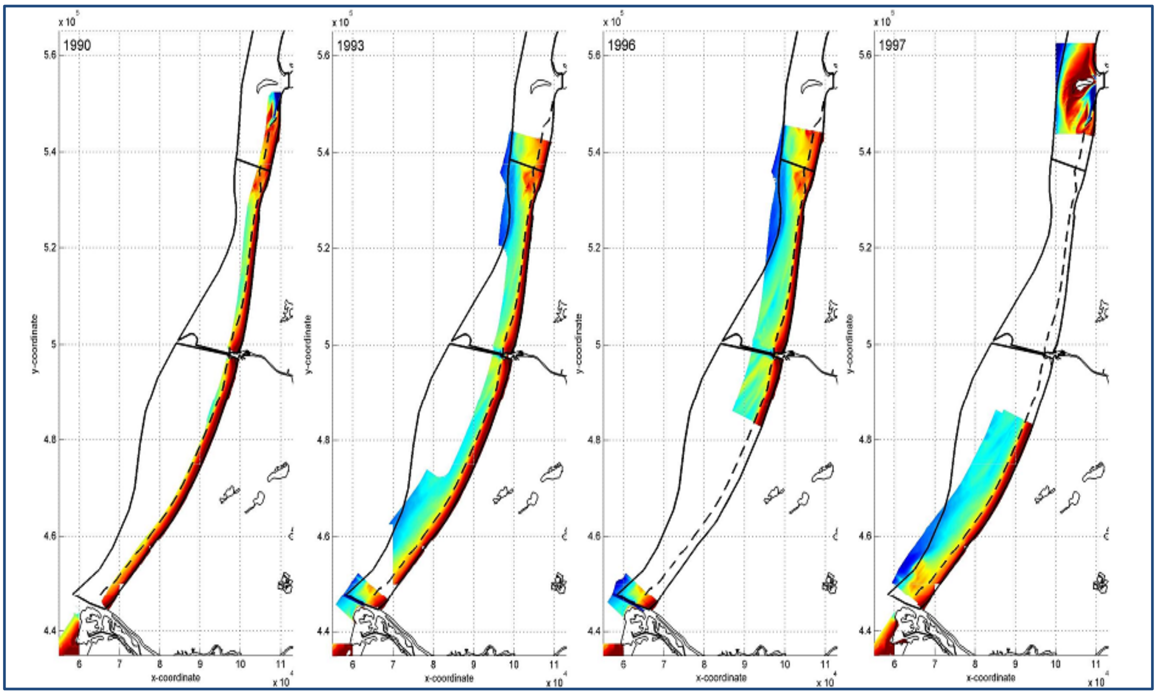


Figure 3.1 Vakloding data from the Holland Coast (single beam soundings) used in the VOP II-1.2 study (1995)

Grids with cell areas (kaartbladen) are merged in order to form larger areas that are updated with the same frequency. The areas in which survey data is being acquired are larger than the areas used in the database. The overlapping surface is used to smooth out rough edges and to create a natural grid. To avoid gaps in the data this overlapping contributes to a digital terrain model that aims to approximate the actual bathymetry. Vakloding data is processed and presented in 20x20 m grid cells, as a 3d surface. This digital terrain model is compiled out of transects and generated through an interpolation process similar to Jarkus-grids. This interpolation process is described in paragraph 3.1.3.

3.1.2 JARKUS profiles

JARKUS surveys (**JA**a**R**lijkse **KUS**tmetingen) are the yearly survey program for the Dutch coastal area. Since 1963 this framework enables the monitoring of the near shore coastal zone within the Netherlands. Within a fixed framework, each year the depths and heights of coastal profiles are measured. This framework has been created in order to be able to compare the state of coastal profiles from year to year and from location to location. The JARKUS data fit within a special reference frame. This allows for systematic monitoring.

The reference of the monitoring in space is the RSP-line (RijksStrandPalen) in the horizontal plane. The location of each data point is fixed in RD-Coordinates (Rijksdriehoeks-coördinaten) as well as in a local-axis system with the reference transect as guidance. For the measured Z-coordinate, the vertical plane, the reference NAP is used. All survey data is measured in centimetres. The measured values are surface-height positive (height) and negative (depth), both with NAP as a reference. All references in space are fixed.

The length of the Jarkus transects, with RSP as a reference, used to reach 800 m offshore until the year 1988. Since 1988, the surveys are executed till a depth of -8 m NAP / -10 m NAP, is reached. For most part of the Holland Coast this depth is reached at a distance between 800 m till about 1500 m. When locally channels are presents, transects should reach the other shallow.

Transects are stored in a database and numbered according to location. A fixed amount of transects with a distance of 200-250 m has been used. Each year transects are used as a reference for a survey. After the surveying, a process takes place that fits the surveys in the Jarkus-framework. The result is a depth profile, called a Jarkus profile.

Strict guidelines have been set with regards to the moment in which the surveys can take place. For a coastal stretch all surveys have to be completed within a month between March and June of each year.

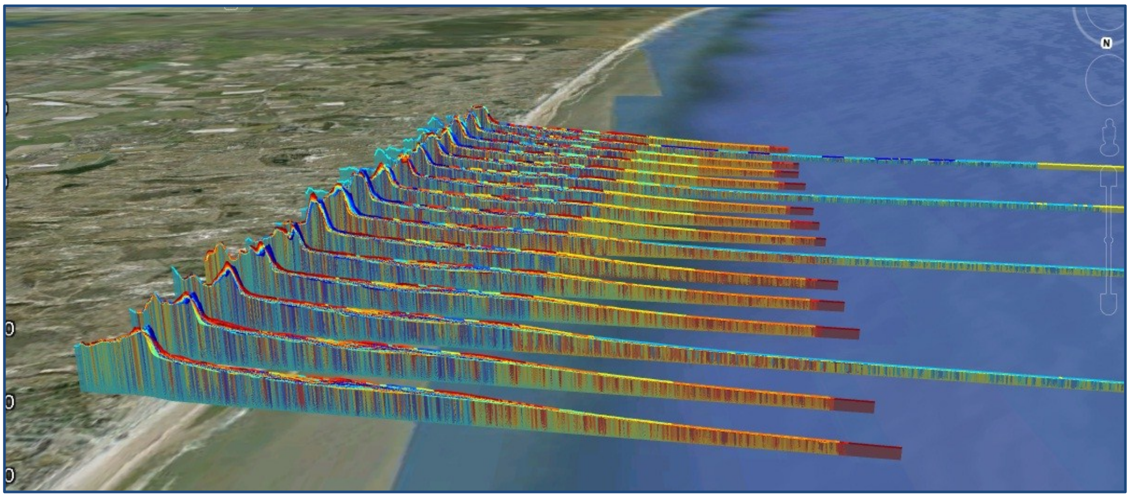


Figure 3.2 Jarkus profiles plotted in 3-d in Google Earth

The Jarkus profiles are primary used to inspect and monitor the position of the momentary coastline, to record volumes of beach profiles and to plan nourishments. The concept of the momentary coastline will be treated in chapter 6.2.

3.1.3 Jarkus-grids

Jarkus-data is also used to generate grids. These grids hold the 3-d bathymetry of the coastal zone, a digital terrain model that approximates the real bathymetry. This data can be used to analyse bar-behaviour, nourishments, sediment patterns and volume changes.

While the Jarkus-grids hold more extensive bathymetry information, one should realize that the grid is digitally generated. One cannot compare the Jarkus-grid with a digital terrain model that is compiled with observed data. The generation of the Jarkus-grids is a process in which Jarkus profile information is both interpolated and extrapolated to gain digital data points needed for the required resolution. Eijnsbergen (1993) elaborates on the accuracy of the interpolation process as used in Digibeeld, the predecessor of the currently available Digipol software. In their analysis of global accuracy (multiple profiles vs a grid) they found a deviation of the z-value in the order of 10 – 20 cm. Currently Digipol software is used to generate grids. Van Halderen (2005) describes the Digipol method. An estimation of the (systematic) error is not made.

Within Rijkswaterstaat the grid generation is described with the following principles. The acquired grid points are built with information of 64 points in the area of the point that is generated. This is shown in figure 3.3. When the points are generated they are connected. These lines are used to generate surfaces. These surfaces shape the 3-d digital terrain model.

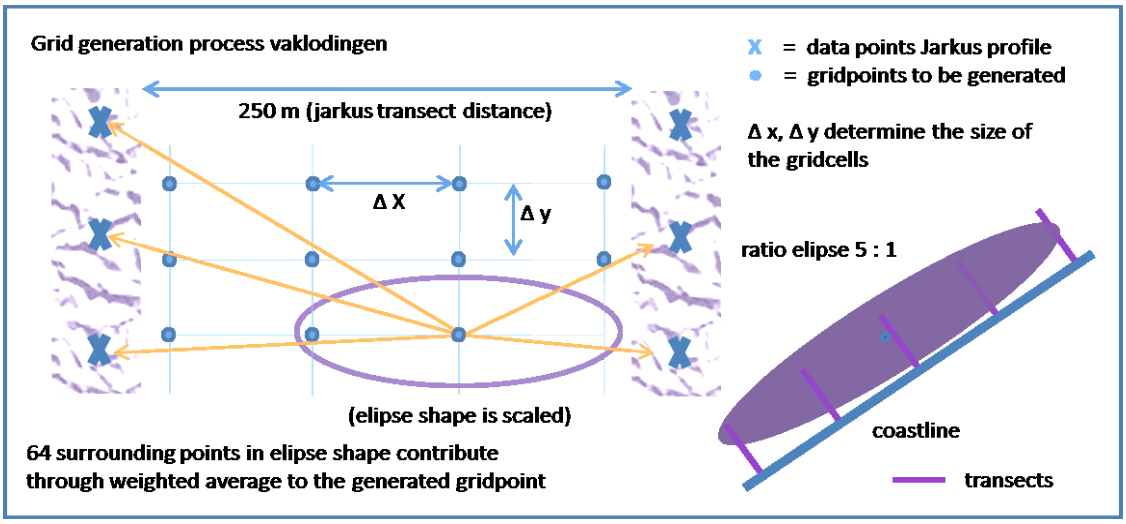


Figure 3.3 Jarkus-grid generation principles

3.1.4 Coastline data and other coastal data

In the year 1840 the Dutch hydraulic engineer Jan Blanken introduced a coastal survey framework in order to document coastal development. This became a reference line composed of **R**ijks **S**trand **P**alen (RSP). Since 1843 the High Water Line and the Low Water Line have been documented with respect to the RSP. Since 1900 the location of the dune foot is recorded (Otten, 1985). Today the records of the position of the coastline and its deratives are accessible and form a valuable tool for coastal engineers.

Complementary surveys, mostly project surveys, or surveys for academic research are often needed to study particular aspects of the behaviour of the coast. One could think of near shore wave action, bar-behaviour of an in depth study on the local and temporal effects of nourishments. These sources of data are not analysed in this thesis. Indirect results obtained from various earlier conducted studies are present.

3.2 The Jarkus survey process

Surveys of the coastal zone are compiled of depth-height surveys in combination with a coordinate both within a local axis system and the RD-system. The depth survey is executed each year from ships with on board single beam echo sounding equipment and automatic recording system, in combination with an automated positioning system. Height surveys are executed with laser altimetry technology. The terrain is recorded and with the data a three dimensional digital terrain model is made. From the digital terrain model, heights at transect location can be extracted.

The depth survey by survey ship is executed during high tide whilst the height surveys are executed during low tide. In this way an overlap is generated and a whole profile at each transect can ultimately be generated. When for some reason the survey vessel is unable to measure the full transect and through experience one suspects an error in the height surveys, transects can be measured by levelling (manual survey on the ground) or with a remote controlled vehicle (Kr-8 sessie RWS, 2011). Manual surveys have been executed over the years. The use of remote controlled vehicles has not been confirmed by Rijkswaterstaat. The application might be limited to the area covered by RWS Dienst Zeeland.

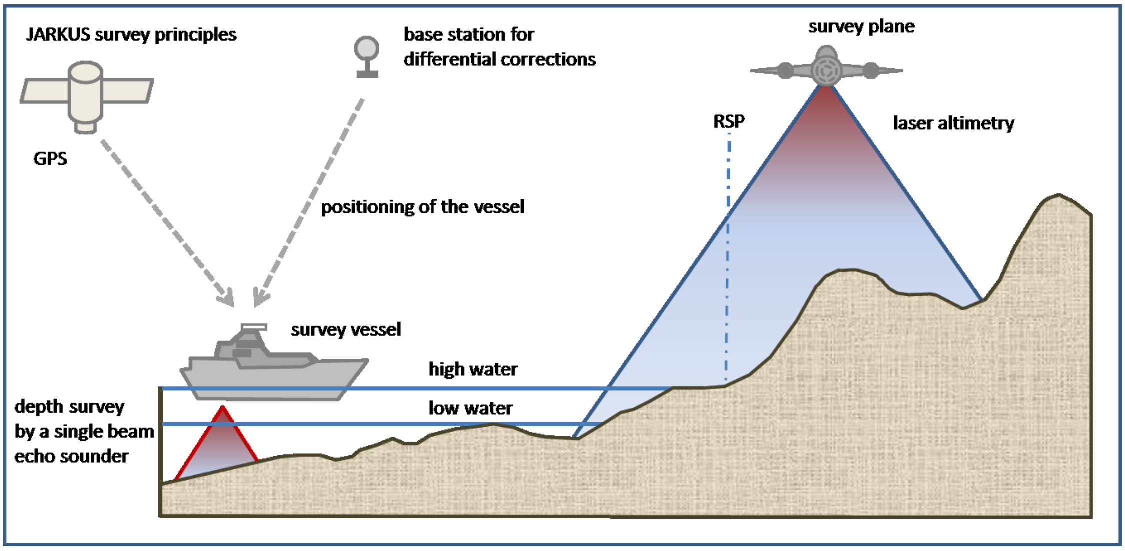


Figure 3.4 The principles of Jarkus-surveys.

To acquire the bathymetry of the seabed, a single beam echo sounder is used to measure the distance from the survey vessel to the sea bed. This principle is based on the production of sound by transmitting short pulses of acoustic energy to the bottom surface. The surface will reflect the transmitted energy and with a detection system the time between the transmitted and the reflected pulse can be measured. The distance between the vessel and the sea bed can be calculated through the travel time times the velocity of the acoustic pulse divided by two. Through global positioning satellite, a base station and GPS-receivers, the position of the vessel can be recorded. Accelerometers take into account the movement of the survey vessel. Through these three systems relatively accurate bathymetry data can be acquired (Minneboo, 1995, USGS, 2002).

To generate altimetry-data of an area a laser altimeter is used. The device is operated from a plane. A laser altimeter sends out infrared laser radiation. The radiation is reflected at the surface and a detection system can measure the time between an emitted pulse and its return pulse. The position of the plane and thereby the location of the measured elevation (in 3D coordinates) can be determined through GPS and an internal navigation system. The latest Lidar systems measure a range of points at a time. Between a few thousand up to 400.000 laser pulses are emitted. Each pulse reaches a different point on the surface (Geolas, 2004).

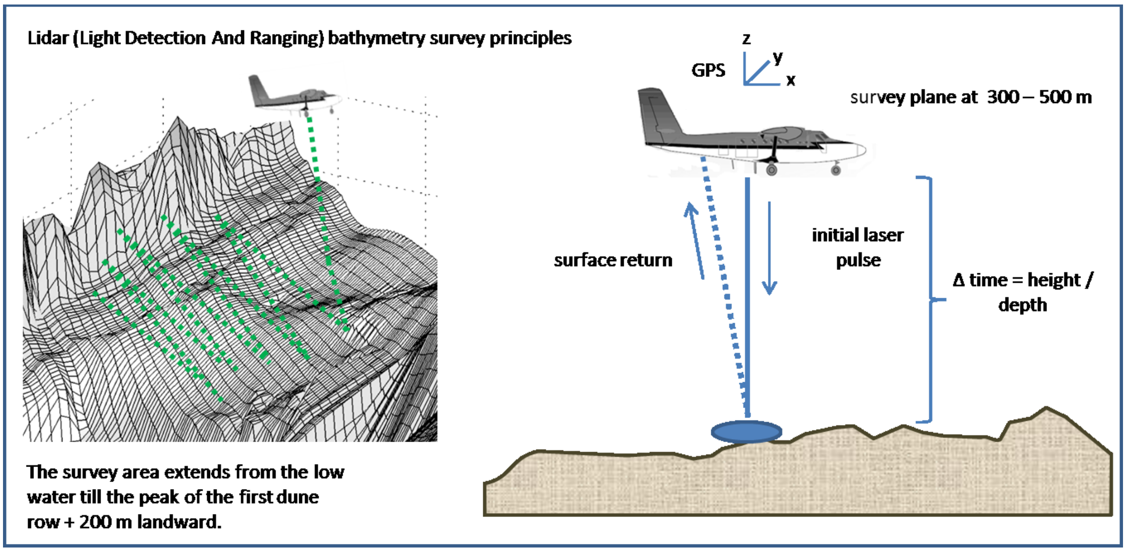


Figure 3.5 Lidar laser altimetry survey principles (source: DID, 2010)

Stereo-photogrammetry was used up until 1996 to obtain spatial measurements and to determine the terrain elevation of a part of the coastal zone through the JARKUS survey framework. The technique is able to construct 3D objects from 2D aerial photographs taken from a survey plane. To obtain elevation, the overlapping of the images is vital. The change in relative position of the objects cause a parallax effect that enables the calculation of 3D coordinates (Bernhardsen, 2002).

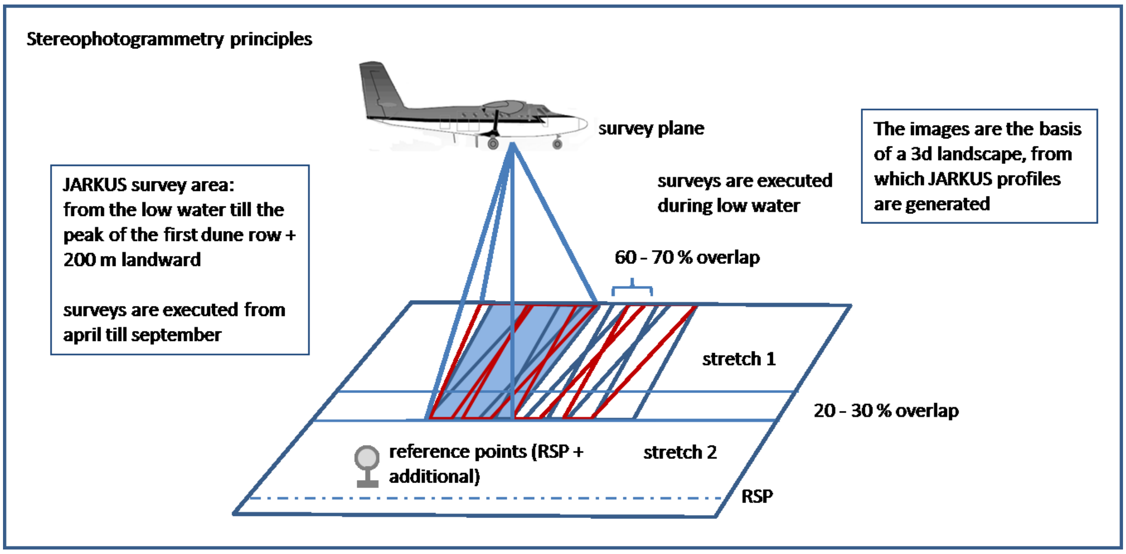


Figure 3.6 The principles of stereo-photogrammetry (source: Minneboo 1995)

3.3 From Jarkus survey to Jarkus profile

In order for the coastal manager to acquire morphologic data several steps have to be undertaken within the organisation of Rijkswaterstaat. Firstly a request for data has to be formulated. This entails an assignment including:

+ A description regarding the methodology (which technology and framework).
+ The required quality (accuracy, precision, confidence intervals).
+ The time frame of execution and the location.

A tending procedure follows after which the survey can take place. The final decision for the contractor when to execute the survey goes in close cooperation with the data specialist. The main reasons are the weather conditions in combination with the high dynamics of the coastal profile.

After the survey all date is reviewed and checked and spikes (strange outcomes of measured data) are removed by a specialist. The raw "clean" data can be considered as validated and is ready for processing. Several steps are made in order to filter and process the validated survey data towards data suited for research. This means that year to year surveys are documented and framed into the JARKUS framework and processed via a standard method. Without this process, coastal research over multiple years and a comparison between different profiles would be impossible.

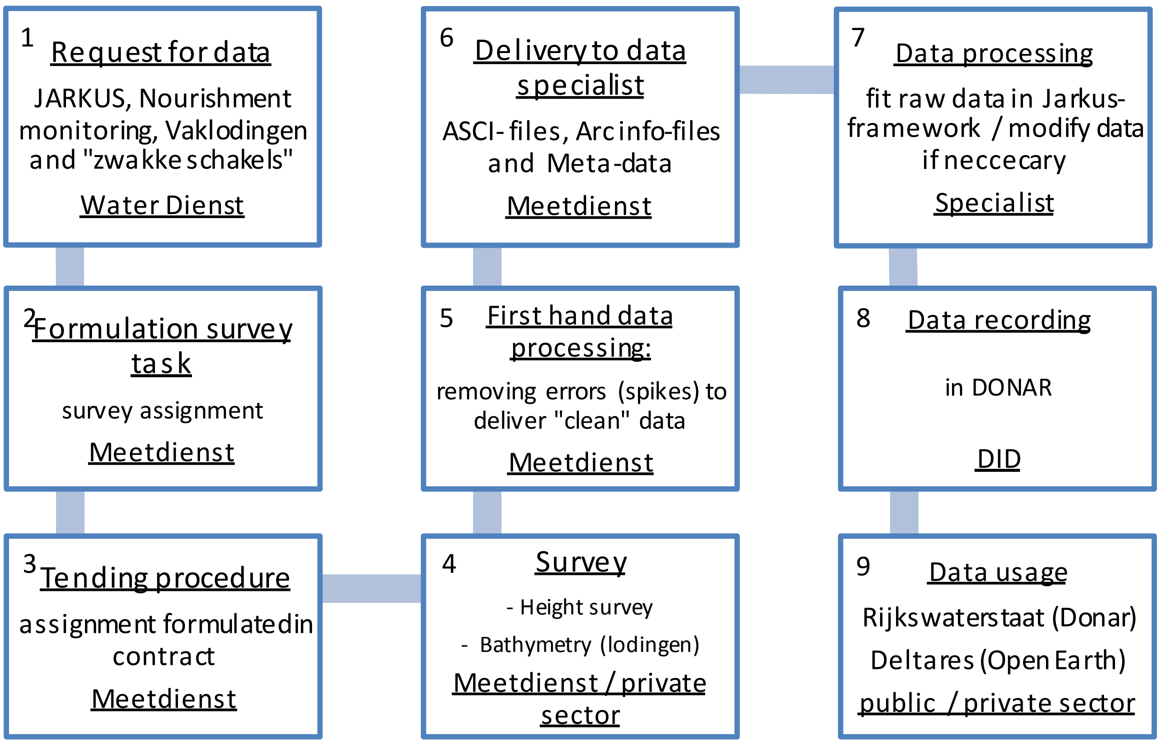


Figure 3.7 Management of coastal morphologic data at Rijkswaterstaat 2011

The last step consists of the documentation of the data in the DONAR database. After documentation the data is ready for usage. The data can be requested by institutions, the public and the private sector. Rijkswaterstaat, the Waterboards, Deltares, The Royal Netherlands Institute for Sea Research (NIOZ), Tennet and the Nederlandse Aardolie Maatschappij (NAM) frequently use the available datasets for studies, research and coastal related projects (Kr-8 sessie, 2011).

3.4 Jarkus-data processing

All delivered files are edited, merged, adjusted and processed within a software tool called Maria, (**M**orphologic **A**pplication for spatial (**R**uimtelijke) **I**nterpolation and **A**nalysis). The tool is built upon Matlab (mathworks) function files and serves as a façade / user interface to manage, transform and handle coastal survey data. Insight into the abilities and working method of its user (the data specialist at Rijkswaterstaat) is essential in order to value the outcomes. The application can be used for both vakloding data as well as JARKUS survey data and project survey data. The process is described for JARKUS survey-data in the following 11 steps.

1. **Delivered data loaded into processing software**
   1.1. The files with the validated clean data are loaded into “the Maria software package”. Files have.dia (donar) or ascii extention (corrected for spikes at Meetdienst).
   Spikes are extreme values that do not represent the true value. They can be caused by backscattered noise, steep slopes, submerged structures or objects and sudden movements of the survey vessel. Technical errors within the equipment can also cause spikes.
   1.2. The data consists of series of points. All with X-, Y- and Z- value, about 3-5 per m' in a transect path around the reference transect.
2. **Verification survey data**
   2.1. One prefers a survey in which all transects within a single coastal cell have been measured without interuption.
   2.2. Did the survey take place within the right timeframe? [reasonable time frame = 1 month]
   2.3. Did the *meetdienst* deliver a complete set of data?
3. **Profile Calculation**
   3.1. From discrete data points to continuous profile
   Discrete data points have an XY-coordinate, a height/depth (Z) and a time/date
   About 3-5 points per m' are the result of the single beam survey
   3.2. A continuous profile is established by connecting the data points.
   The continuous profile still has the shape of the route of the survey boat (not a straight line)
4. **Validation of the survey data (optical, geographic and spatial check)**
   4.1. One looks at the path of the survey vessel.
   4.2. Values should be within a bandwidth of 30 m measured from the reference transect. See figure 3.8. Values outside this bandwidth are deleted.
   4.3. The hiatus generated, are filled in later in the process (step 8). Hiatus are found in general 20 in profiles per year for the Noord-Holland area (about 350 profiles).
5. **Raw data exported to DONAR.**
   5.1. The clean, checked and validated data is available in DONAR.
   5.2. The file (.dia) can be seen as a general transect dataset with a name, date, time and xyz-coordinates.
   5.3. All information gathered by de Meetdienst can be reproduced through these files via GIS.

Jarkus transect definition

A Jarkus transect is defined as a theoretical line that extends perpendicular to the coast in most of the time offshore direction. This line is fixed within the RD-coordinate system and has been given a number. This number consists of the coastal area code and a transect number. This number combined with its geographic location is in fact a Jarkus transect definition. If over time a definition needs to be changed, this has to be done carefully. The data could lose its value if this does not happen with caution. The profile evolution at one particular location can only be studied if the definition of the transect is consistent over the years. Therefore, the aim is to change definition as little as possible.

6. **Schematizing survey data into Jarkus profile with transect definition**
   6.1. Survey transect information is transformed into Jarkus profile according to the Jarkus definition, generating one z-value each 10 m.
   6.2. Schematizing the curved continuous transect and the discrete values to a straight transect
   6.3. The reference transect is divided into cells (30 m width in alongshore direction and 10 m length in cross shore direction).
   6.4. All Z-values within each cell, regardless of their position, are averaged. The averaged Z-value serves as a virtual data point in the centre of the cell. This point is located on axis of the reference transect and becomes the formal depth within that cell. See figure 2.
   6.5. All averaged points from each cell (80 for a transect length of 800 m) form a representative cross shore depth profile called a Jarkus transect. Each transect has his own number.

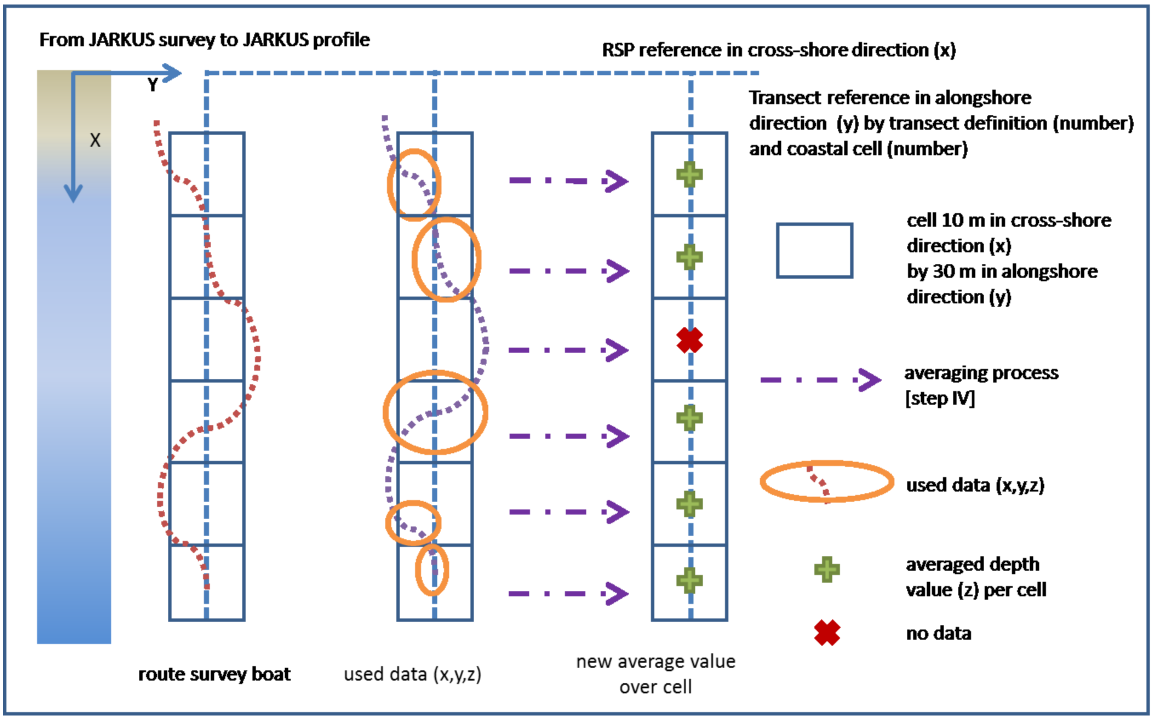


Figure 3.8 From survey-data to an average profile with Jarkus-definition

Outliers

Outliers are defined as points within a profile that do not seem to fit within the natural shape of the coastal profile. To check whether or not outliers are present they first must be defined. This is done by comparing the location of each data points with a generated smooth profile, the natural reference profile. If single or multiple points are located too far from the smooth profile, one speaks of outliers. Outliers can originate from errors during the survey process.

7. **Deleting (extreme) outliers and the generation of the natural reference profile**
   7.1. Firstly a natural reference profile is generated. A smooth line is calculated with an incremental interpolation method described by Eilers (1999). The implementation of this method is verified through studying the script files of the Maria Application.
   7.2. To apply the Eilers-method input of two parameters are needed. A smoothness parameter determines the amount of outliers present. A weighing factor assigns added value towards possible outliers. Thereby the natural reference is fit with more accuracy.
   7.3. Finally a threshold value (in general $\pm$ 15 cm deviation) is introduced to automatically delete outliers.
   7.4. For each profile a natural reference profile is made and checked upon outliers. To replace outliers the natural reference profile or manual modification (step 8) are used.

8. **Hiatus in the profile and manual modification**
   8.1. Transects with missing data points are selected. When missing data is found there are four solutions to replace the hiatus with generated data. Expert judgement plays a large role
   8.2. <u>1-d smoothing</u>
   This method makes uses of values within the measured transect, to interpolate between neighbouring data points.
   8.3. <u>2-d smoothing</u>
   When applying 2-d smoothing, neighbouring transects are used to fill in missing data points.
   8.4. <u>Historic transects</u>
   Historic transects can be used to fill in missing data points. The part of the profile that is missing can be borrowed from earlier profiles and fitted within the new profile.
   8.5. <u>Ad-Hoc</u>
   Points are replaced through expert judgement, by comparing 1-d smoothing, 2-d smoothing and historic transect.
9. **The processed transects (bathymetry survey and laser altimetry) are exported to DONAR.**
10. **Merging the "wet" and "dry" part of the survey**

The "dry" part of the survey (Laser altimetry through LIDAR) is processed with similar steps (4-8). There is an important difference. The profile data of the "dry" part of the survey originates from a generated digital terrain model (resolution 5x5 m), acquired through laser altimetry.

   10.1. The bathymetry profile and the laser altimetry profile are imported from DONAR.
   10.2. The bathymetry survey (water) and the laser survey (land) overlap. Due to the differences between these two surveys, the profiles need to be merged and sometimes adjusted to each other to create a smooth profile.
   10.3. Merging takes place through weighted averages according to the principles presented in figure 3.9.

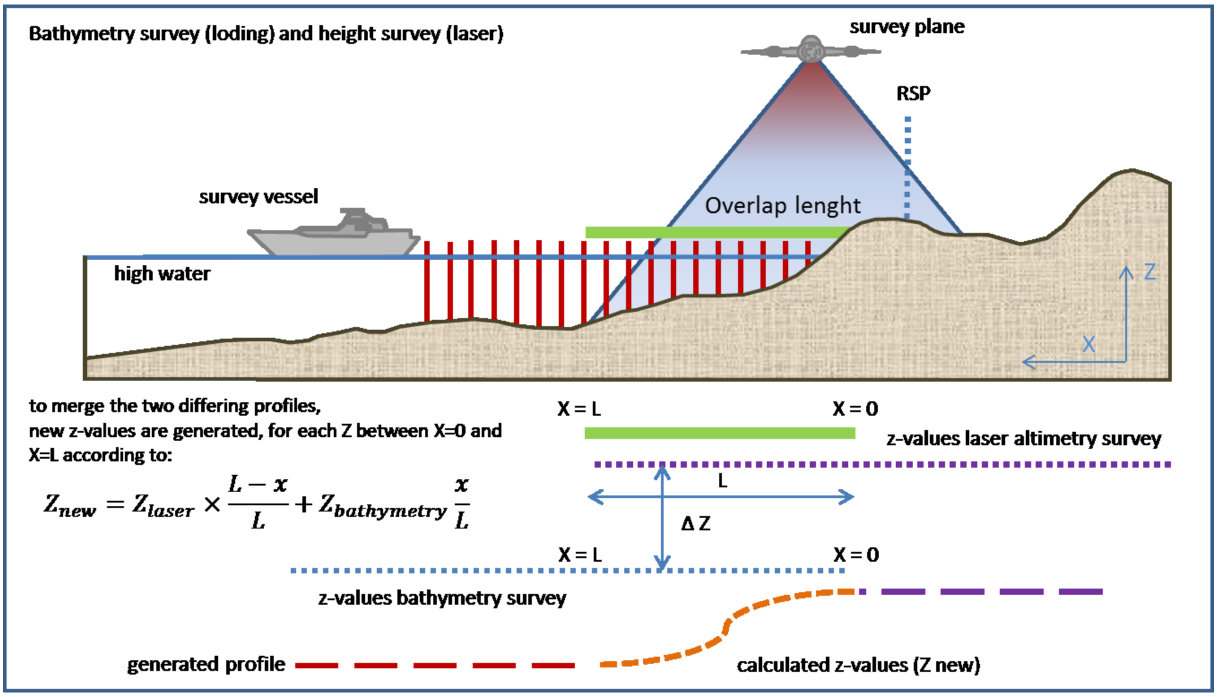


Figure 3.9 Merging between bathymetry and height data

11. **The merged file is transformed into .jrk extension and DONAR**

The .JRK extension holds the following data: Coastal cell, Year, Transect information and survey method. The .JRK files are made available in DONAR.

3.5 *Quality, usability and limitations of Jarkus data*

The usability of Jarkus-data for a sediment balance study depends on the quality of the data. Quality of survey data relies on the way in which the data is used. Short term events such as a storm surge would not be visible if one subtracts one Jarkus profile from another, since it is expected that the interval between the surveys is larger than the timeframe of recovery of the profile.

The quality of the data therefore relies on availability in time and space. To analyse a certain event (nourishments or a storm surge) one needs data acquired shortly before and after the event. The accuracy, precision (occurrence of random errors) and the reliability of data is important. Reliability depends on the level of professionalism during the survey campaign, on post processing of the data and on proper process management. Guidelines and process management should keep the consequences for users and errors within the data, to a minimum. In the following three paragraphs estimates on these errors will be made. Improper calibration of instruments (bias) is not considered.

Systematic errors

The accuracy of the survey process is influenced by five elements.

1. The recording of the position of the vessel (limitation of applied GPS).
2. Model of the salinity gradient over depth and thereby the velocity of the signal.
3. Errors produced in the echo sounding process.
4. Angle bias due to misalignment of the transducer during installation.
5. Squat, vessel movement (altitude) and the water-level (before GPS was applied).

These elements can be seen as a systematic error. The order of these errors can be calculated for a number of these elements. Therefore one is able to correct for most of these errors after the survey process has taken place. Corrections for the systematic errors can be made for (2, 3 and 4). Therefore we assume that they do not influence the result of the survey in a substantial way. However, the limitation of the positioning of the vessel introduces a spatial error for which one cannot correct. According to De Graaf et al. (2003) the accuracy of the positioning is dependent on the distance from the reference station to the rover. The accuracy is calculated to be 15 cm (2 σ) at a depth of 15 m.

The systematic error of the depth value z (wet) is the measured value minus the true value. Caused by the deviations due to (3, 5) this value is estimated to be 10 cm with a standard deviation < 20 cm (Eijnsberg, 1993, De Graaf et al., 2003). The accuracy of laser altimetry data (LiDAR), is calculated to be 5 cm on average with a standard deviation of 10 cm (DID, 2010).

Random errors

Random survey errors also occur. They are usually expressed in terms of standard deviation. They can relate to an unstable position of the vessel, noise (due to sound reflection effects) and the mostly unstable reflected signal. During processing these errors occur when data is missing and when modifications are made to “fit” the survey data into the Jarkus-framework. Human errors are observed too, for example due documenting the wrong transect. In (Kalf et al, 1993) the following examples were given:

+ A number of transects in Walcheren in the period 1973-1975 was given an incorrect definition.
+ Inaccurate correction of the water level due to the introduction of an incorrect tidal elevation has occurred multiple times.

They cannot be quantified since there is no record of human errors, nor can estimates be made regarding the consequences. When data is used, trained researchers / coastal engineers should be able to recognize most substantive errors. Depending on the character of error this is not always possible.

Accuracy of processing

As aforementioned in the paragraph on survey errors, many errors are systematic and therefore correctable. These corrections happen on the survey vessel and during processing by the Meetdienst. This department takes care of the reduction of spikes and survey errors (step 5, figure 3.7).

During the processing (paragraph 3.3, step 6) various steps influence the accuracy of the Jarkus profiles. The averaging over the survey path (figure 3.8), a deficiency of data, the influence and modification of outliers and the merging of the depth and height survey have an impact. The latter is causing a discrepancy due to the time interval between the two surveys due to the dynamics of coastal profiles (figure 3.8).

The systematic error and the Law of large numbers

Not all errors have the same impact on the accuracy of the framework. Errors that cannot be avoided and occur systematically are called systematic errors. These errors only have an impact when one compares the real situation with the observed situation. By comparing data with data systematic errors can even out. When a large amount of data is used the power of averaging will reduces the deviation from the real situation.

This can be explained as follows; $\bar{X}_n$ is the average of n independent random variables. The value n stands for the number of profiles. The average $\bar{X}_n$ represents the time of the signal or profile to profile deviation. This value has an expectation μ and variance σ^2. For any occurring error ($\epsilon > 0$) the following holds:

$\lim_{n\to\infty} P(|\bar{X}_n - \mu| > \epsilon) = 0$ *(the law of the large numbers)*

The Law of large numbers states that as one has a relatively large series of observations (n>400), the average of all deviations (ϵ) approaches zero.

In the case of the Jarkus-database of Noord-Holland, 330 Jarkus-profiles are present over a timeframe of 45 years. Each profile consists of about 4000 z-values. This leads roughly towards a value n in the order of 60 million. In case of the echo sounding process, in which many signals lead to one z-value similar numbers are reached.

For this reason all systematic errors will not affect trends extracted from the data, nor will it influence the accuracy of the profile. One simply has to live with the fact that the digital model is only an approximation of the real situation. When one analysis a single profile, the consequences of systematic errors have to be taken into account. This also holds when a small number of profiles n < 40 are studied.

Within the Jarkus-process many variables are a source of error. In general these errors do not influence the value of the Jarkus-database. However, to quantify possible occurring deviations from the true value, an analysis is made. In order to give an approximation of deviations to expect between the true value and the acquired digital profiles the most important deviations have been listed in table 3.1. The consequences have been calculated with the input from the processing specialist and written literature.

$$Total\ Error = Systematic\ error + Random\ Error$$

$$U_{total} \approx \sqrt{u_{systematic}^2 + u_{random}^2}$$

For the used sources and data the writer refers to Annex 3. The definitions of the undesirable observations and the calculation of the deviation can also be found in Annex 3 .

When one works with the Jarkus-data the deviation of the data compared to the real world needs to be taken into account. When one profile is used for precise calculations or when relatively small erosion/sedimentation rates occur, it is important to know the accuracy of the Jarkus-framework. The dynamics of coastal profiles are large. The Jarkus-framework only aims to approximate the real world. Through guidelines and a certain frequency of surveying, a certain confidence has been created.

In order to quantify this confidence an approximation for accuracy is made. For every deviation a consequence in significant unit is calculated. In this case the significant unit is cubical meters deviation from an integrated profile over one m^1.

Undesirable deviation due to	occurrence	process of error and modification	deviation z-value	consequence [significant unit]
positioning vessel	all profiles	**systematic during survey**	± 7,5 cm	-
accuracy single beam echo sounding	all profiles	**systematic during survey**	± 5 cm	80[1] m^3/m
averaging process	all profiles	**systematic due to framework** see fig 5.7	± 25 cm (estimate)	5 m^3
no data (hiatus)	95% confidence interval	**random during processing**		
		<u>solutions</u>		
		1-d interpolation		> 8 m^3
		2-d interpolation		8 m^3
		usage of historic transect data		3.5 m^3
		ad-hoc subjective modification		2 m^3
Outliers		**random during processing**		
> 15 cm		fully corrected	± 10 cm	2 m^3
< 15 cm		not corrected	± 7,5 cm	1,5 m^3
discrepancy due to survey “wet / dry”	all profiles	**systematic (survey program)**		unknown[1]
		processing		4,2 m^3
		Total deviation single profile		**95-100 m^3**
		Total deviation n profiles[2]		**15-21 m^3**

[1] this deviation only impacts single profiles, a profile length of 800 m is used.
[2] where n is the number of profiles and n > 40

Table 3.1 Jarkus accuracy estimation in significant unit

Which errors are acceptable depends on the use of the profile. With a large dataset, for example as source for a sediment budget calculation, a deviation in the order of 20-50 m^3 per profile can still lead to a credible outcome. For dune erosion calculations such deviations can be unacceptable.

The analysis leads to a deviation in the order of 15 to 21 m^3 assuming a confidence interval of 95 %. This means that in 95 % of the cases this number should be lower. This deviation only holds when a total number of at least 40 profiles are being studied with variations in space and time. For single profiles a deviation of at least 95 m^3 should be taken into account. The location of the presented profile varies ± 15 m in alongshore direction.

3.6 Conclusions

With regards to the availability of coastal morphologic data the Vakloding-data and the Jarkus-profiles, as well as the records of the position of the coastline are the most important datasets. The DONAR database and the Open Earth repository are the main sources from which coastal engineers can acquire records. The Open Earth repository increasingly provides more documents, records, tools and other useful sources regarding coastal engineering and flood risk management. In annex II a summary is made on the possibilities of Open Earth.

The value of those records depends on the understanding of the framework, the accuracy of the data and the quality framework itself. Survey frequency, processing and quality management determine this quality. Information regarding this is necessary in order to make analysis, validations and future predictions. For the Jarkus-profiles this framework is described. Vakloding-data have a similar framework. The accuracy of the Jarkus-framework depends on how the profiles are being used. For a single profile a larger error is present compared to the accuracy when large numbers of transects are used for analysis. The later one is less important for such an analysis. An important remark is that when one analysis volume changes in the order of million m^3 a deviation of the order of 10-100.000 m^3 can be expected. This deviation is quite acceptable given the highly dynamic environment.

With that in mind, the Jarkus-framework is considered to be extremely valuable for coastal research and for coastal managers to plan maintenance works.

3.7 Findings with regard to the use and processing of Jarkus-data

Through working with the Jarkus data, the sensitivity analysis and mapping of the Jarkus-process recommendations for the Jarkus-framework have been formulated. The writer recommends the following:

+ When using the Jarkus data one should be able to understand both its value and imperfections. A simple deviation from the real world situation is not enough.
+ Jarkus grids are of great value to generate a digital terrain model. However, the use of the grids would not lead to a higher resolution of the real world situation.
+ The current Jarkus-framework does not make optimal use of the survey data that is acquired.
+ The outcome of the height survey on the dry part of the coastal zone (coastal LIDAR data) is a grid with a resolution of 5 by 5 meters. This data is currently only used to extract profile information according the the Jarkus-transect definition. The use of this data can improve predictions and analysis on volume changes of the dry part of the coastal zone and dune strength.
+ A manual of the process from survey to useable data could prevent misjudgement of results. Chapter III of this thesis together with the manual of the MARIA application could serve as a start. When Jarkus-data is shared, such a manual should be provided.
+ Within the process the knowledge of the data specialist is of vital importance for continuation of the Jarkus-framework. Currently this knowledge is not shared within the organisation of Rijkswaterstaat. A back-up system in the form of a trained user of the Maria application and a manual can secure continuation of the framework. Such measures should be taken in order to safeguard knowledge of the Jarkus-framework.

4 Analysis of the Noord-Holland coast

4.1 Structure and background

Many studies of the (Noord) Holland coast have been conducted. Descriptions of sediment transport, coastline behaviour and sand-budgets have been made in the past. Studies by Stive and Eysink (1989), Van Rijn (1997), Wijnberg et al. (2002) and Elias et al. (2006) can listed as the ones that give a clear overview of (a part of) the Noord-Holland coastal system. All these studies showed considerable variability in the coastal volume over time. For the most part of the Noord-Holland coast decay in near shore volume has been observed. This indicates the Noord-Holland coast can be considered as an erosive coastal stretch. This could be related to the long term trend of sea level rise. Other (local) processes can also contribute to the (local) erosive state.

The erosive state in the largest part of the Noord-Holland coast leads to a perpetual loss of sediment in the (near shore) coastal zone. Consequences for the equilibrium coastal profile are substantive. Generally a smaller beach width and deepening of the near shore zone are found. Such circumstances enable waves to propagate closer to the first dune row. This has substantial impact on wave impact and dune erosion during storm events. In this way erosion of the coast directly relates to the safety level of the hinterland.

To counteract this process, coastal maintenance under supervision of Rijkswaterstaat has been significant over time. By supplying sediment to the system shaped in beach and foreshore nourishments, an artificial source of sediment was created. In the period 1965 - 2010 a volume of 48.8 million m^3 has been brought in the system (Rijkswaterstaat, 2011). Thereby the Noord-Holland coastal can be considered as the most extensively maintained coastal stretch of the Netherlands.

This sand budget study will encompass a description of the current state of the Noord-Holland coast by using Jarkus-data from 1965 to 2010. The description should lead to answering the following questions;

+ Can one extract main trends from the coastal data available?
+ What kind of general volume trends can be found?
+ What are the dynamics in volume change?
+ Is the current Noord-Holland coast an erosive coastal stretch?
+ How do we define erosion hotspots and are they present within this coastal area?
+ What is the influence of the Marsdiep / Waddenzee on the evolution of the Noord-Holland coast today?
+ What can we say regarding the term coastal foundation?

The system description aims at analysing the processes and quantifying them. Setting up a sand budget model and describing the observed processes should give an overview on the current state of the coastal system. This is mainly done get hold of the present coastal processes and their consequences. Furthermore, by describing the near shore volume evolution, understanding of the environment in which coastal maintenance projects are executed is gained. This is not only a logical step; it also reflects the current paradigm of coastal maintenance measures in the Netherlands.

In order to do this, first the methodology will be presented. Secondly, the boundaries of the area and the expected sources and sinks of sediment will be discussed. Hereafter this thesis will zoom in to morphologic processes within smaller areas, ie. the coastal cells used in the study by Van Rijn (1997). Finally the state of the entire Noord-Holland coast will be looked into and the term coastal fundament will be treated.

4.2 Methodology

To analyse the Noord-Holland coast various steps have been taken. In the schematics presented in figure 4.1 an overview of these steps is given. Per step Within the next paragraphs each of the steps undertaken are described.

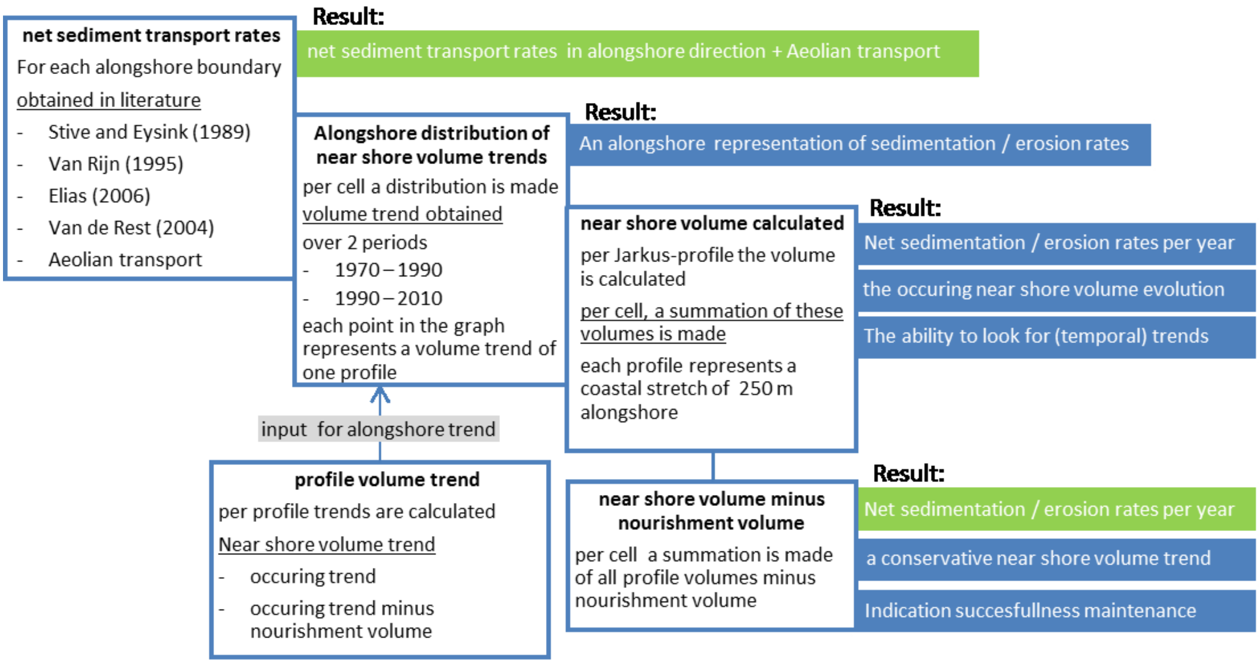


Figure 4.1 Schematics of the steps undertaken for the sand budget model and system description

The results indicated in blue are used to describe the volume evolution of seven coastal cells. This description is supported with single Jarkus-profiles, 2-d sedimentation and erosion patterns, written literature and coastal processes.

To obtain these results several calculations have been made. The calculations are made through Matlab-function files. In Annex IX these scripts can be found. To calculate the absolute volumes and to make plots suited to analyse the Noord-Holland coast a new script is made; others were checked and adjusted to obtain a presentation of the results as wanted. They originate from the Open Earth repository.

The results obtained presented in the green rectangles are used for the sand budget model will be treated more extensively in chapter 5.

4.2.1 Data

For the sand budget study the Jarkus-profile data is used as source of information. The data set consisting of profiles from 1965 to 2010 is being considered the most valuable source of coastal morphologic data for the near shore coastal zone, in particular when it comes to change of volume over time. In chapter 3 the framework of JARKUS was described. Jarkus-grid data and the use of vakloding-data have also been considered as source for the sand budget model. There are four main reasons why these sources have not been used:

+ The vakloding-data consists of surveys conducted once per six years. In order to evaluate coastal volumes and the nourishment strategy, year to year surveys could provide more detail.
+ Vakloding-data does not cover the near shore zone, nor the beach and therefore do not reach until the first dune row. When vaklodingen are presented this is not visible. The vaklodingen consist of a grid compiled out of single beam soundings of profiles of the deeper part of the coast. This is combined with a grid that encompasses the shallow, near shore zone. For this grid the Jarkus-profiles are used as source. The combined grid is presented as vakloding. Therefore the vaklodingen do not hold additional information when it comes to the near shore zone.
+ As mentioned in paragraph 3.1.3, the Jarkus-grids consist of Jarkus-profiles. Through an interpolation method a grid with fine resolution is generated. While the bathymetry looks natural, the end result of volume calculation depends on how the grid is interpolated.
+ The generation process of Jarkus-grids has changed over time. This could cause possible artificial volume variations. The accuracy of the grids is not known due to this variation. The Jarkus-profile framework does show continuation in processing methods. Moreover, the accuracy and possible errors can more or less be determined. For the accuracy of Jarkus-profiles the writer refers to paragraph 3.4.

For the Noord-Holland coast about 260 complete Jarkus-profiles datasets were available. The profiles have on average a lateral distance of 250 m. The assumption has been made that one profile represents the coast over an alongshore distance of 125 m on both sides of the profile. The Jarkus-profiles serve as source to evaluate the behaviour of a certain cross shore (beach) profiles, in particular, the volume of the near shore zone.

In about 30 cases, the profile data over the years had different transects definitions. The definitions were found near the original profile. The data of these profiles was merged manually in a copy of the original ascii-file. Otherwise these profiles could not have been used, thereby less accuracy. In annex 3, the redefinition of those profiles and the working method is documented. From this file a Net-CDF file has been made. The file was used as source for the different Matlab scripts and calculations.

Intermezzo

At Deltares, each year a Net-CDF file (transect.nc) is generated to work effectively with the large Jarkus-dataset and the Open Earth toolbox. The data itself does not change during the generation of a Net-CDF. The generation only repositions the profile information and saves it in an effective and structured way. As source the Jarkus-ascii files per coastal area are used. These files are produced by the data specialist.

4.2.2 Profile volume calculations

For the Noord-Holland coast a research area is selected. Over this area all Jarkus-profiles are gathered. By using the data it is possible to plot the volumes per profile for each year. For all transects the same RSP distance is selected. By taking the integral over this area the volume is calculated. For each year over the period 1965 to 2010 this volume is calculated (see figure 4.2). For each year the volume is documented. The aim is to extract trends of the near shore coastal volume.

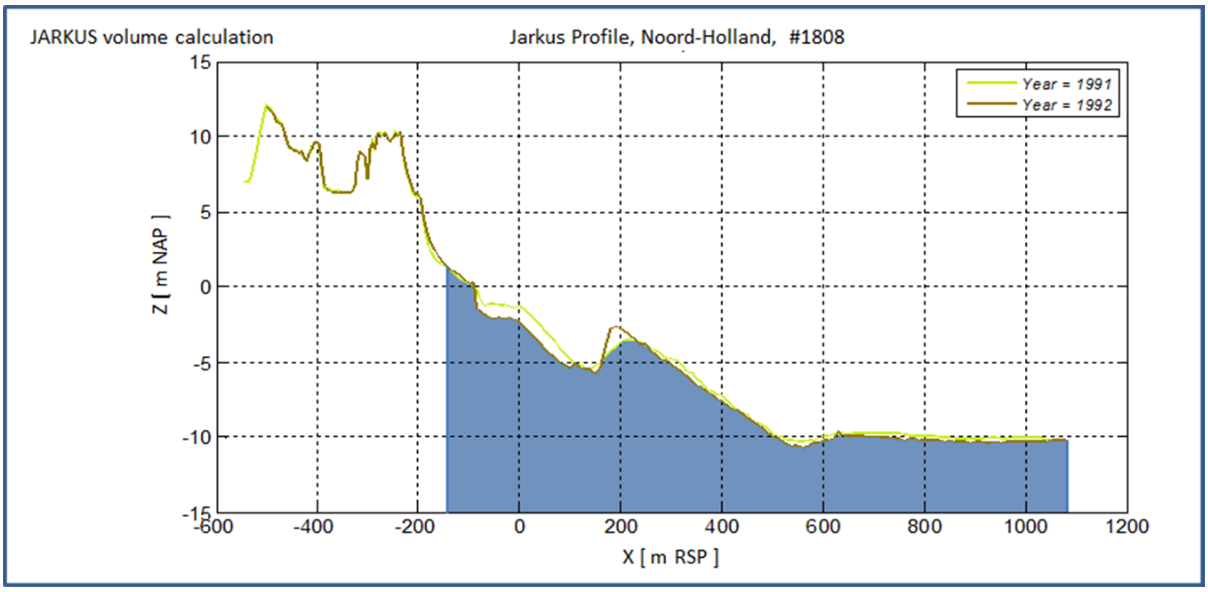


Figure 4.2 Jarkus-volume calculation

4.2.3 Profile volume trends

By plotting the volumes per year, volume trends are made. The black line is generated by linear regression through the black dots. These are the integrated Jarkus profiles. The result of the regression is the occurring trend. This is the trend of the maintained coastal profile. Per profile the nourishment volumes have been gathered (Annex 4). For each transect the added volume in m^3/m is calculated. By subtracting the nourishment volumes the blue dots represent the corrected volume. With a similar linear regression an indication of the autonomous volume trend is obtained. This trend is indicated in blue, presented in figure 4.3.

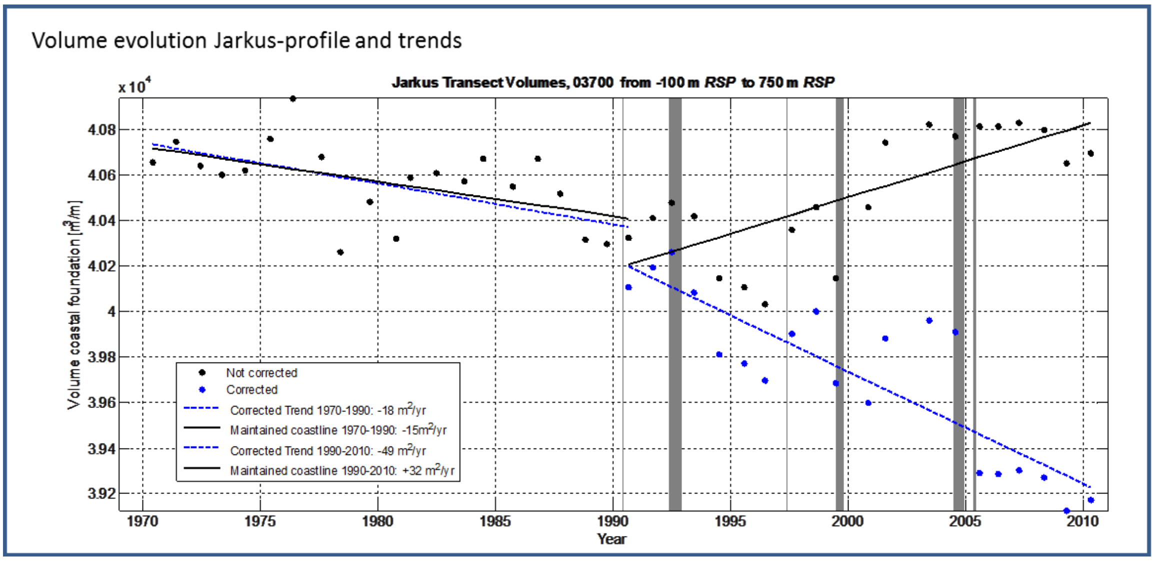


Figure 4.3 Volume evolution Jarkus-profile and trends.

For the corrections made for nourished volumes it is important to know whether the added nourishment volume has been added in calculated the area. In the data presented all nourishment volumes are fully subtracted. Initially this could lead to an over estimation of erosive trends. To avoid this, a reduction coefficient can be introduced. If (a part of) the nourishment falls outside the boundaries, the volume can be corrected. However, this method has not been applied. Often data with regards to the exact nourished location was not available. This makes it difficult to determine the right reduction coefficient. Alongshore variability of nourished areas could not be taken into account. Therefore it is chosen to checks afterwards if all nourishments were included within the selected boundaries. If not, such cases are stated.

4.2.4 Linear regression and a timeframe

For each profile volumes trends have been made by linear regression over the calculated volumes per year. Following Santinelli (2010) a range is introduced in which the trends can vary. By applying the standard deviation as range the slope is limited. An upper and lower boundary is introduced at a distance of each 1 σ. This prevents that trends are influenced by extreme values.

$$\sigma = \left[\frac{1}{N-1} \sum_{i=1}^{N} \left(f\left(Y_i\right) - V_{corr,i} \right)^2 \right]^{\frac{1}{2}}$$

in which N represents the number of years used for the regression $f(Y_i)_s$ the trend volume and $V_{corr,i}$ the corrected volume for *each year*

Two periods have been used to extract trends. Originally trends over 10 year periods were proposed. It was found that periodic features as bar behaviour and propagating sand waves lead to large volume fluctuations. This caused flat or steep regression lines per profile in which the actual trends were not visible (figure 4.4). Furthermore, the trends have a similar duration to avoid differences caused by cyclic behaviour and to keep the influence of long term changes, such as sea level rise, to a minimum.

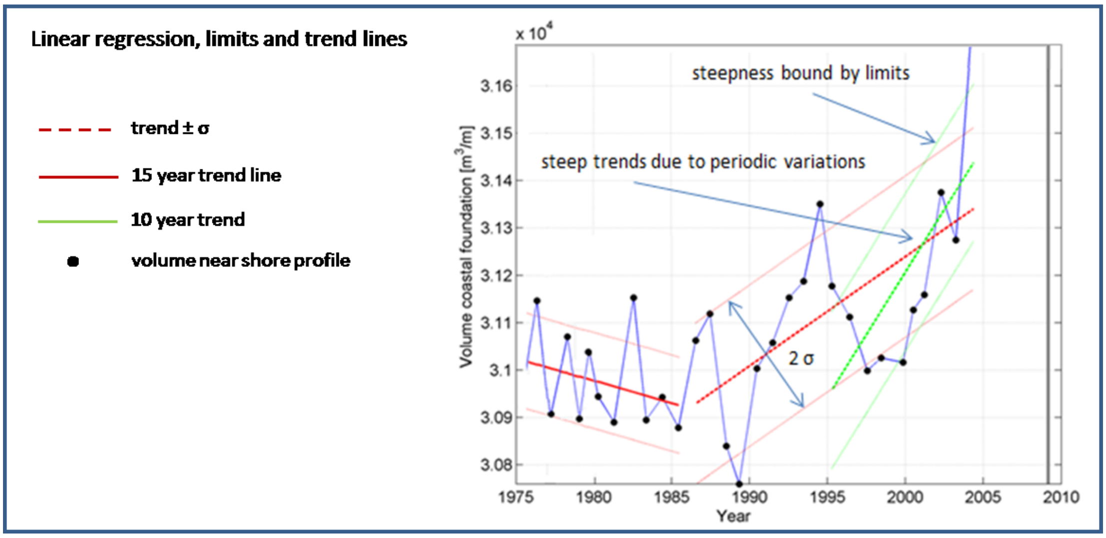


Figure 4.4 Jarkus-volume calculation

For these reason it is chosen to use two timeframes. The first period describes the evolution of the coastal volume from 1970 to 1990. The second trend describes this for the years 1990 to 2010. The length of the periods over which the linear regression was made has been adjusted several times before reliable results were obtained. The trends match reasonably with the occurring the volume evolution. All plots are added in Annex X.

4.2.5 Alongshore volume trends

Due to alongshore variability, through analysing one transect (1-d) one is unable to analyse volume changes and behaviour of a stretch of coast. For this analysis areas have been constructed by using a ray of transects, creating coastal cells. For each profile volume trends are gathered. The trends are combined and presented per coastal cell. This allows the description of change of volume over coastal areas. The profile volume trends are plotted in alongshore direction and analysed per coastal cell.

The alongshore plots consist of the following trend lines:

+ The occurring trend (maintained near shore volume) 1970-1990
+ The occurring trend (maintained near shore volume) 1990-2010
+ The corrected trend (maintained minus nourishments) 1970-1990
+ The corrected trend (maintained minus nourishments) 1990-2010

By looking at these trends insight is gained into the state of local coastal areas (figure 4.5).

After 1990 a new coastal maintenance policy was implemented. Due to this, the supplied amount of sediment has increased locally by a factor 10. At other locations hardly any nourishments have been executed. The alongshore trends should be able to provide us with information on the (local) effects of the nourishments. Moreover, from the trends erosion hot-spots could be detected. Final goal is to determine whether or not the nourishment policy has been effective. In chapter 6 and in the paragraphs that treat the analysis per cell, further elaboration on this matter takes place.

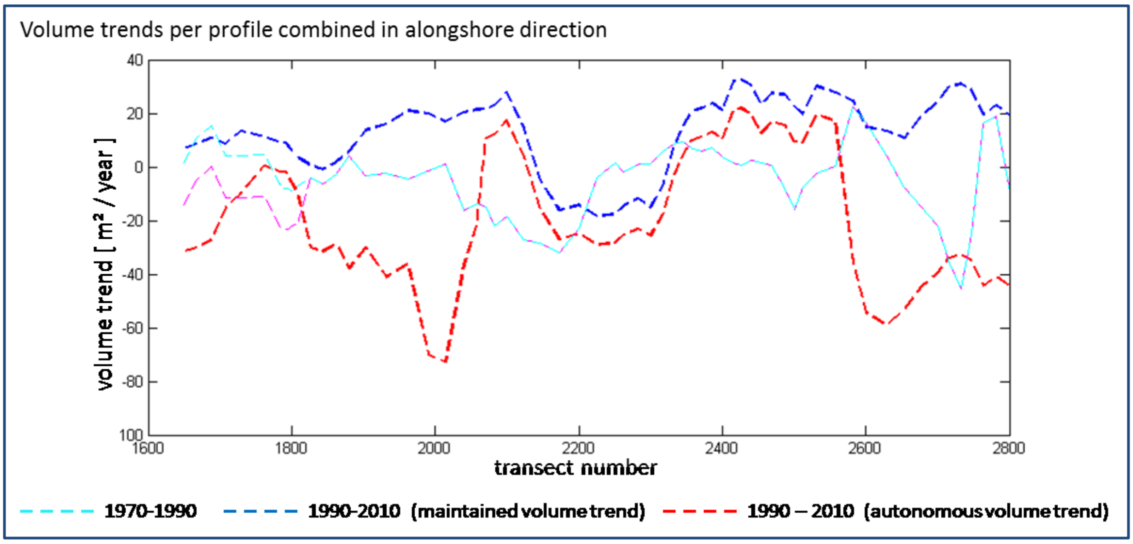


Figure 4.5 Volume trends distributed in alongshore direction, using a ray of transects

To gain further understanding in the morphodynamics of the particular cells, 3-d plots have been made. Vakloding data, the position of the coastline and individual profiles have been used to support and illustrate the volume evolution of the near shore zone.

4.2.6 The Noord-Holland coastal system

In order to analyse the whole Noord-Holland coast, the results of the coastal cells and the individual profile plots are presented. Information regarding sources and sinks over the boundaries of the area as well as sediment transport rates of earlier conducted studies is used for a sediment budget model. This model can be found in chapter 5.

4.3 Reference and boundaries

4.3.1 Reference and definitions

To calculate the profile volumes the RSP line is used as a reference. This reference line was established in the year 1840. It formed a general representation of the coastline. Since that time it acts as a reference for coastal profile surveys. To take into account major coastline changes the RSP has been locally redefined in the years 1963 – 1967 (Otten, 1985). It can be considered as a constant, fixed reference.

With respect to altitude / depth NAP, Normaal Amsterdams Peil is used. This reference level is used throughout the Netherlands to study long term movement of the surface, protection against flooding, water management and as level for the construction of buildings.

Within the description often the geographical term Noord-Holland coast is used. In the scope of this entails the area defined within the alongshore boundaries selected; the coastal stretch from Den Helder (km 0.9) to the northern harbour mole of IJmuiden (km 55).

The term "near shore zone" is used in a broader context. When used it refers to the area in between the + 3 m NAP line and the depth of closure.

To describe the volume trend corrected for nourishents often the term "natural behaviour" is used. This term is considered to be the natural volume evolution. One needs to note that this behaviour <u>does not represent</u> the occurring trend. <u>Only with the assumption</u> that similar erosion/sedimentation rates would have occurred without nourishing, one could speak of the natural behaviour.

4.3.2 Alongshore boundaries

The study area comprises the Noord-Holland coast from IJmuiden till Den Helder. The southern bound is the northern breakwater of the port of IJmuiden. Seaward of the breakwater the northern ridge of the IJ-channel takes over this function. The IJ-channel has a width of 450 meters, a depth of -19 m NAP and extends 23 kilometers offshore. This boundary does not only represent a geographic boundary, it also more or less acts as a physical boundary. The breakwater interrupts the wave induced alongshore current and redirects the tidal current.

The bathymetry of the IJ-channel acts as an area in which sediment is captured. A change in velocity profile due to the larger depth causes lower velocities in the alongshore current. The result: less transport capacity and settlement of (fine) sediment in suspension. The occurrence of this phenomenon is supported by the findings of Ribberink and Roelvink (1989). They found gradual northward movement of the channel due to sedimentation on the southern edge and erosion on the northern edge.

Near the breakwaters the theory of smaller current velocities does not apply. The influence of the hard structures on current and density currents cause three-dimensional effects and enhancement of current velocities locally. The aforementioned physical boundary cannot be seen as a completely closed boundary. Sediment transport from the southern Holland coast towards the study area can still occur. In paragraph 4.5.6.3 attention is paid to these transport rates and current patterns.

The most northern defined Jarkus-transect acts as boundary near Den Helder. Further north the Texel tidal inlet generates different hydraulic and coastal morphologic conditions. Moreover, the natural coast makes way for a constructed sea wall. The state of the coast of the island of Texel and the coast of Noord-Holland facing the Waddenzee are not included within of the scope of the study area. However attention is paid to the influence of the Texel tidal inlet on the northern part of the Noord-Holland coast.

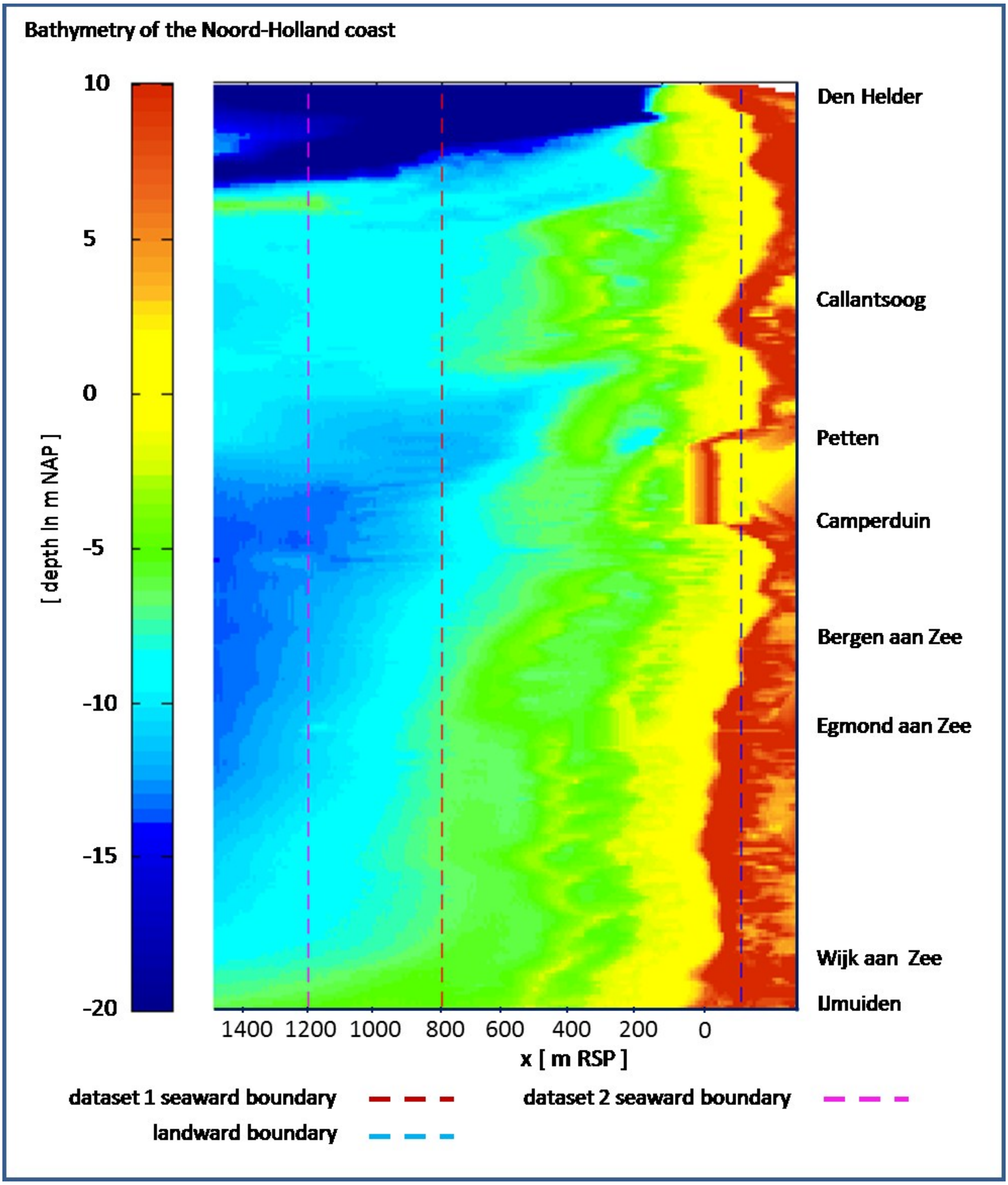


Fig 4.6 Surfplot of JARKUS profiles, Noord-Holland transects 20 - 5480, Year 1990

4.3.3 Cross-shore boundaries

The maximum cross-shore distance of the Jarkus profiles differs from year to year. Before 1990 the profiles on average extended 750 m offshore. To monitor the deeper part of the coast, each five year extended Jarkus surveys were conducted, up until 2000 m offshore. After 1990 the average extension differed between 800 m till 1400 m offshore.

To make optimal use of the available data, two data sets of profile volumes were generated, each with different boundaries. The first set consists of the Jarkus data with a transect length of 800 meters, reaching depths between minus 6 m NAP and minus 8 m NAP. The second set consists of Jarkus profile volumes with transect lengths of 1200 m offshore reaching minus 12 m NAP.

The notion of a certain depth as cross-shore boundary has not been used. From a physical point of view this boundary would give a better representation of similar behaviour between the coastal cells. However, the volume trends of the coastal cells are not compared with each other. The introduction of depth as a boundary would limit the use of the available data due to alongshore variation of the profile. With the change in volume, the depth over the years also changes. This could influence the near shore volume analysis negatively. For this reason a boundary is used in the shape of a fixed cross-shore distance with RSP as reference.

coastal cells	transect	landward boundary		seaward boundary		depth
Data set 1						
Cell 1	0020 – 0810	-	100	+	750	> -8 m
Cell 2	0810 – 1630	-	100	+	750	-7 m
Cell 3	1630 – 1880	-	100	+	750	-8 m
	1880 – 2600	+	100	+	750	
	2600 – 2800	-	100	+	750	
Cell 4	2800 – 3900	-	100	+	750	-6 m
Cell 5	3900 – 4700	-	100	+	750	-6 m
Cell 6	4700 – 5000	-	100	+	750	-6 m
Cell 7	5000 – 5500	-	100	+	750	-5 m
Data set 2						
Cell 1	0020 – 0810	-	100	+	1200	- 20 m
Cell 2	0810 – 1630	-	100	+	1200	- 10 m
Cell 3	1630 – 1880	-	100	+	1000	- 12 m
	1880 – 2600	+	100	+	1000	
	2600 – 2800	-	100	+	1000	
Cell 4	2800 – 3900	-	100	+	1200	- 12 m
Cell 5	3900 – 4700	-	100	+	1200	- 10 m
Cell 6	4700 – 5000	-	100	+	1200	- 8 m
Cell 7	5000 – 5500	-	100	+	1200	- 8 m

Table 4.1 Table of transect distance used, volume calculations near shore zone

Landward from the RSP, a profile boundary of minus 100 m is selected, except for the transects in coastal cell 3. Near the Pettemer and Hondsbossche sea defence, a landward boundary of +100 m with respect to RSP was used. Due to the fact that this sea defence does not consist of sediment that is able to move freely in the coastal zone, the adjustment of this boundary will not impact the sediment budget.

4.4 Sources and sinks

4.4.1.1 Nourishments

Nourishments can be considered as a major artificial source of sediment in the study area. For this reason nourishment volumes are used directly in the sand budget calculations. Per cell the effects of nourishments are treated.

In the Netherlands Rijkswaterstaat determines the nourishment program and manages each project. Nourishment data is available and being stored for each action in which sediment has been supplied to the system. In several areas in which nourishments are executed extra surveys allow coastal engineers to look at the effectiveness of their intervention.

The following data was used to take nourishments into account:

- the location in the form of km / transects
- the time of execution
- the added volume, following the nourishment database, Rijkswaterstaat 2010
- the type of nourishment design
- comments on the location

About 40 % of the obtained volumes are indicated to originate from survey in situ. When these volumes were unavailable, the gross volume is used. The gross volume is multiplied by a factor ranging from 0.95 to 0.85 to obtain a net value. In 60% of the cases a corrected gross volume is used.

Between the years 1965 and 2010 a total volume of 48 million cubical meter has been added to the system. The volume has had and still has a major impact on the current state of the Noord-Holland coast. Therefore nourishments will be treated extensively in both the description of the coastal cells as in chapter 6, on the effectiveness of nourishments. In annex IV an overview is given of each nourishment project in terms of volume and location.

4.4.1.2 Dredged sediment maintenance IJ-geul

For ships to enter the port of Amsterdam they have to make use of the IJ-channel. In order to keep this channel at the desired depth accumulated sand and fines need to be taken out. This is done with dredging equipment. About 25 % of the dredged sediment consists of sand, the other material are fines, called silt. Since the northern edge of the IJ-channel is used as southern boundary of the study area, no losses are present. The fines are dumped in the lower shore face zone between -12 and -20 NAP at a site 4 km north of the IJmuiden harbour. Within the sand budget study the dumping north of IJmuiden is not considered as a source of sediment. The lower shoreface near IJmuiden was not included in the available surveys. From 1990-2003 on average 200.000 m^3 per year was dumped at this site. On a year to year basis this volume varied between 40.000 m^3 and 1.7 million m^3 (Rijkswaterstaat DWW, 2005).

Most sediment is dredged 17-19 km out of the coast, near the entrance of the IJ-channel. This sand is used for nourishments. These volumes are taken into account as nourishment volumes. The greatest part of the dredged sand was used for the private sector. Before 1990 similar numbers have been shared in the study by Van Vessem (1994).

4.4.2 Sand mining

Various sand pits are present in the Noordzee. These sand pits are located offshore at a distance of 5-10 km out of the coast. Each year a volume of 35 million m^3 is used from these pits for nourishments and construction works like Maasvlakte 2. Along the Dutch coast the pits are located at depths at least minus 20 meters NAP.

In 2001 a report on the "physical effects of sand mining" (Hoogewoning et al., 2001) concluded the following: *"Large scale sand mining in the Noordzee does not have significant impact on coastal safety."* In the same study it was concluded that large scale sand mining close to the minus 20 depth line does influence the sand budget of the near shore.

The depth of minus 20 meter NAP is currently considered to be the boundary of the so called "coastal fundament". Many scholars and reports have indicated that no substantial volume loss below this depth is expected on the short term. Stive et al (1998) indicated that on the long term (centuries or longer) the morphologic development due to sand pits could influence the near shore zone and coastline position. This was under the condition that the sand pit area reaches in cross-shore direction till in the near shore zone. With the process-based model UNIBEST the impact of sand pits on the position of the momentary coastline has been studied for the Maasvlakte 2 project. The study of Steijn (1997) showed insignificant results. For this reason and despite the conclusions by Hoogewoning et al (2001) sand mining will not be considered to have an impact on the sand budget model presented.

4.4.2.1 Aeolian transport

Sediment transport by air, forced by the wind is called Aeolian transportation. In this way the wind is able to influence the sand budget. Sediment particles are able to be transported in suspension if upward flow velocities are large enough to support the weight of the lighter sediment particles. Transport of more heavy particles happens near the ground, through rolling and jumping. This is called saltation. The layer in which this transport occurs is about 1 centimetre high (Herrmann, 2006).

The process is important for dune growth and the formation of new dunes. This suggests that sand volumes are moved from the beach to the dunes. De Vriend and Roelvink (1989) describe this type of cross-shore transport as follows: "*Between the high active zone and the dunefront, sediment transport is caused mainly by aeolian processes and hydronamic processes. ".* Their findings suggest that the width of the beach (fetch) is an important parameter for the rate of aeolian transport. Wind induces both the initiation of motion as well as the movement of the air. The transport rates mainly dependent on the wind. Sediment characteristics (weight and shape) also influence aeolian transport; it needs more force to move heavier particles (Heindorn, K.C, 2002).

Since movement of sediment occurs, it is plausible that sediment particles move out of the boundaries of the studied area. Wind blown transport in offshore direction is not expected to lead to losses of sediment. Firstly, less wind force will be present due to sheltering effects of the first dune row. Secondly, vegetation in the dune area causes sheltering effects that will lead to decreasing direct forces on the particles. Moreover, the main wind direction is faced landwards. Finally, the seaward boundary is further away from the beach; one can expect aeolian transport to be limited in the near shore.

For these reasons losses are expected at the landward boundary. Therefore aeolian transport should be considered as a sink of sediment. Quantitative estimates regarding the transport rates have been made by Van Vessem and Stolk (1990). They estimate wind transport from the beach to the dunes to be 150.000 m^3 per year over the coastal stretch IJmuiden-Den Helder. Van der Wal (1999) estimates this volume to be three times larger. According to De Ruig (1989) variation alongshore can be quite large, mostly due to the aforementioned fetch length (beach width). Net wind induced transport can vary between 4-10 m^3/m/year. Taking the average of these values this leads to a net transport of 200-250.000 m^3 towards the first dune row.

4.5 Coastal cells

In order to study the Noord-Holland coast, the coastal stretch is divided into seven coastal cells. In the study of Van Rijn (1997) the Holland coast (both Noord-Holland and Zuid-Holland was divided into sixteen coastal cells. On the basis of "similar morphologic" behaviour and and hydrodynamic environment these cells were selected. Earlier, in the study of Stive and Eysink (1989) a similar approach was chosen. The cells adjacent to the Noord-Holland coast have been used in this study. Thereby the coast is divided into seven sub areas. The near shore zone south of the IJ-channel is excluded from this study. This is indicated in figure 4.7. Per area an analysis of the near shore volume is made.

Coastal cell 1 (km 0 to km 8.1) is located between near the city of Den Helder and in the vicinity of the Texel tidal inlet. Coastal cell 2 is located between Julianadorp and Callantsoog (km 8.1 to km 16.3). Both cells can be regarded as coastal stretches in which the morphologic behaviour is influenced by the Texel inlet and the hydrodynamics of the Waddenzee tidal basin.

Coastal cell 3 is composed out of the Jarkus-transects 1630 to 2800. The coast near the town of Petten and the Hondsbossche and Pettemer sea defence are included into this stretch.

The fourth cell consists of the near shore area from Camperduin to transect 3900 (km 39). Within this cell the artificial dune breach "de Kerf" is present. This project to enhance ecologic qualities and biologic diversity in the dune area has been topic debate since the concept was born. Local citizens are worried with regards to the risk of flooding. Coastal engineers have not found consensus on the effects of both the morphologic consequenses and possible increased risk of flooding. The coastline adjacent to Bergen aan Zee and Egmond aan Zee is one of the most heavily maintained parts of the Noord-Holland coast. Both in front of the towns of Egmond and Bergen the coast numerous nourishments are executed since the implementation of the "Dynamic Preservation" policy in the year 1990.

The fifth cell includes the area between transect 3900 (km 39) to transect 4700 (km 47) In contradiction to cell 4, cell 5 is less maintained. Hardly any nourishments have been executed in this area. Comparing the evolution of the near shore volume of cell 4 with cell 5 could lead to interesting results. The volume evolution of the near shore zone of cell 5 could give an indication of natural variability present.

The last two coastal cells that will be analysed are number 6 and 7. They lay in the vicinity of the harbour moles of IJmuiden. The morphologic consequences of the extension of the northern mole are expected to be found within the volume trends. The presence of a circulation zone and diverging currents, due to the harbour moles could have significant impact on the near shore zone.

In the following seven paragraphs per coastal cell the results of the volume calculations are presented. Per cell an analysis is made. Main trends are described and the applied nourishments are evaluated. Locally erosive hot-spots are determined and looked at closely. Hydrodynamic and morphodynamic boundary conditions have been described as background or explanation of the results.

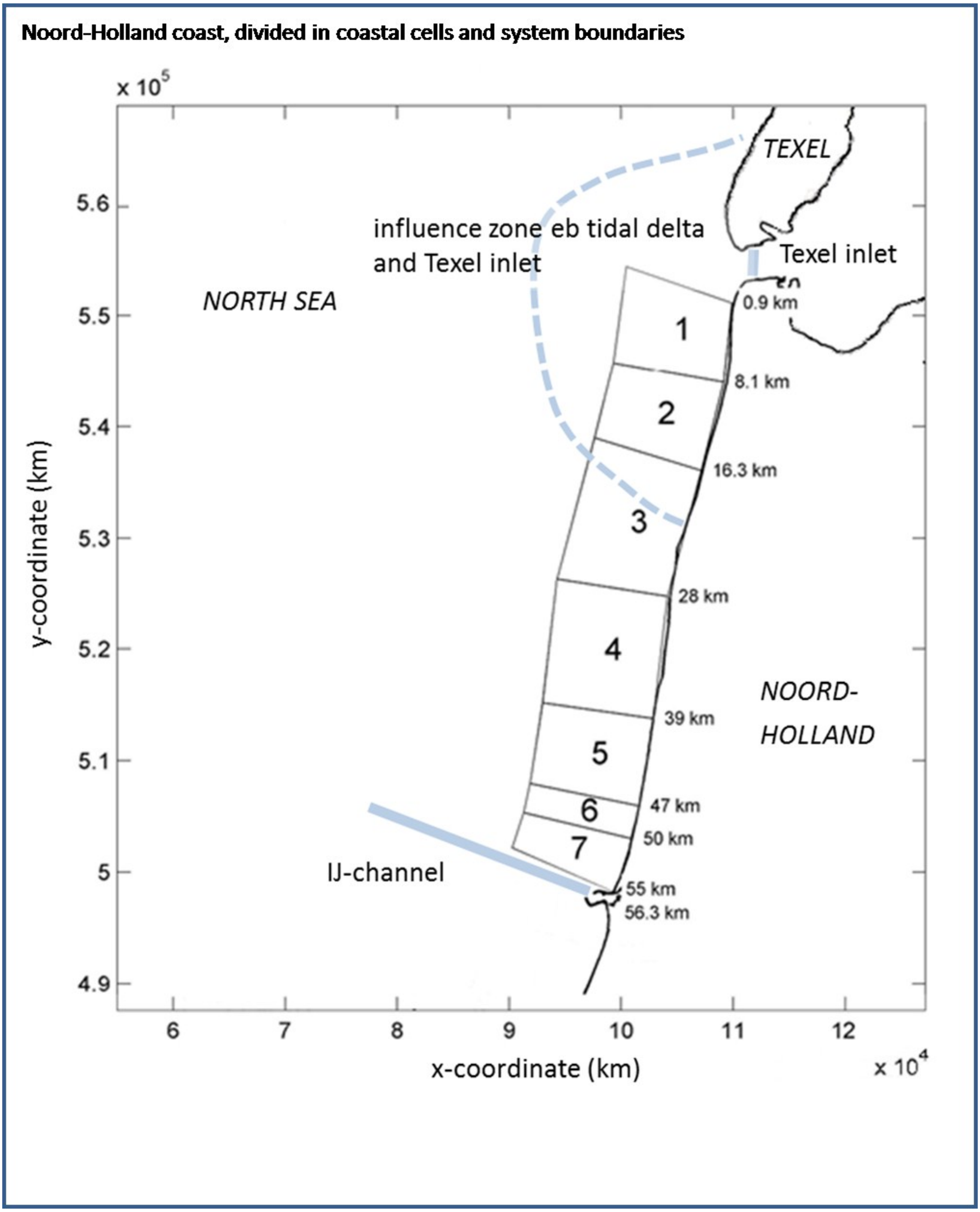


Fig 4.7 Overview Noord-Holland coast, divided in coastal cells (edited from: Van Rijn, 1997)

4.5.1 Coastal cell 1 (Den Helder, km 0 – km 8.1)

Over the period 1965 to 2010 the volume of the near shore zone (-100 m - + 800 m) has decreased by 10,8 million m^3. This considerable number shows clearly that this coastal stretch has been erosive over the last 45 years. This erosion took place between 1965 and 1990. From 1990 on the volume observed seems to be more or less stable. This is shown by the green striped line in figure 4.8. It describes the volumes calculated from the Jarkus-profiles. Fluctuations in the range of 1 to 1.5 million m^3 are present. Coastal maintenance increased significant after 1990. Nourishments played an important role in maintaining the near shore volume.

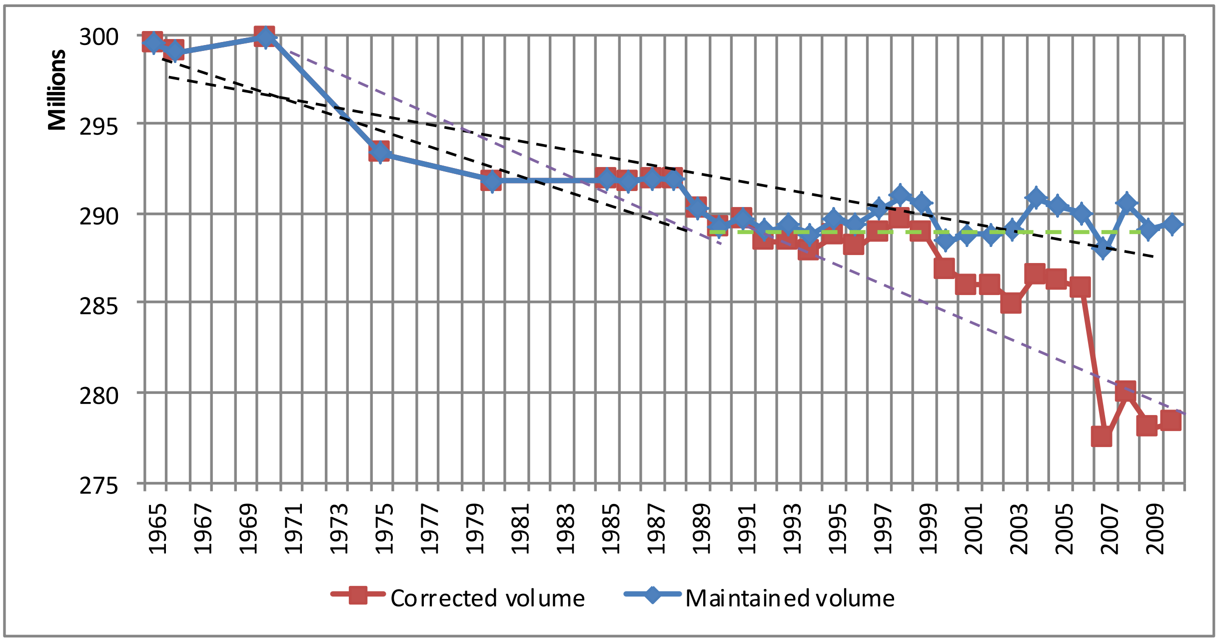


Fig 4.8 Near shore volume evolution cell 1 between -100 - + 750 RSP

In the dataset (2) bounded by a cross-shore distance of 1200 m a slightly larger loss was found. This graph is presented as figure A.5.1 in Annex 5. The profile volume decreased 14 million m^3 in the period 1965-1990. This indicates that erosion also took place in the deeper part of the profile. By observing the volume evolution a volume gain of 4 million m^3 is found over the years 1990 to 2010.

By correcting for the nourishment volumes it seems that the natural trend present before 1990 continues (purple striped). In the period 1990-2010 a loss of about 11 million m^3 was found. A notable negative jump is present between the years 2007 and 2008. This can be explained by three large nourishments executed in 2007. One of the nourishments was executed as shoreface nourishment. Furthermore sand was added to the system on the beach and a volume was added on the ridge of the Nieuwe Schulpengat. The channel is visible as the deeper part presented in figure (4.11) between transect 20-300. In the year 2007 a total of 6.3 million m^3 was nourished. The volume originates as dumped volume from the dredging vessels (gross minus 15 percent). Taking into account the hydrodynamic circumstances present in the area, an additional loss of 20 percent, during the execution of the nourishment is proposed. After this correction, a net volume of 5 million m^3 remains. After the year 2007 an increase in volume of about 2.5 million m^3 was found. By correcting for an assumed yearly loss of 0.55 million m^3, a loss of 2 million m^3 seems to have occurred.

There are a few ways in which one could explain these losses. The pressent alongshore sediment transport rates along the Noord-Holland coast described in paragraph 4.3.1.2 seem not high enough to transfer these amounts. Furthermore, these sediment transport gradients are not expected to increase temporally unless significant interference in the system occurr. This is not the case.

An occurring gradient in sediment transport rate caused by the influence of the Texel inlet can be an explanation. The area is highly dynamic. Large transport rates are present. The deep channel, Nieuwe Schulpengat is present in the vicinity. Cross-shore transport towards the western part of the channel could have moved nourished sediment out of the survey area. In the alongshore distribution of volume trends we can see where the largest discrepancy between the maintained trend and the corrected trend is found. In figure 4.9 it becomes clear that this coastal stretch has become increasingly erosive. The nourishment strategy applied has not lead to an increase in near shore volume along the whole stretch.

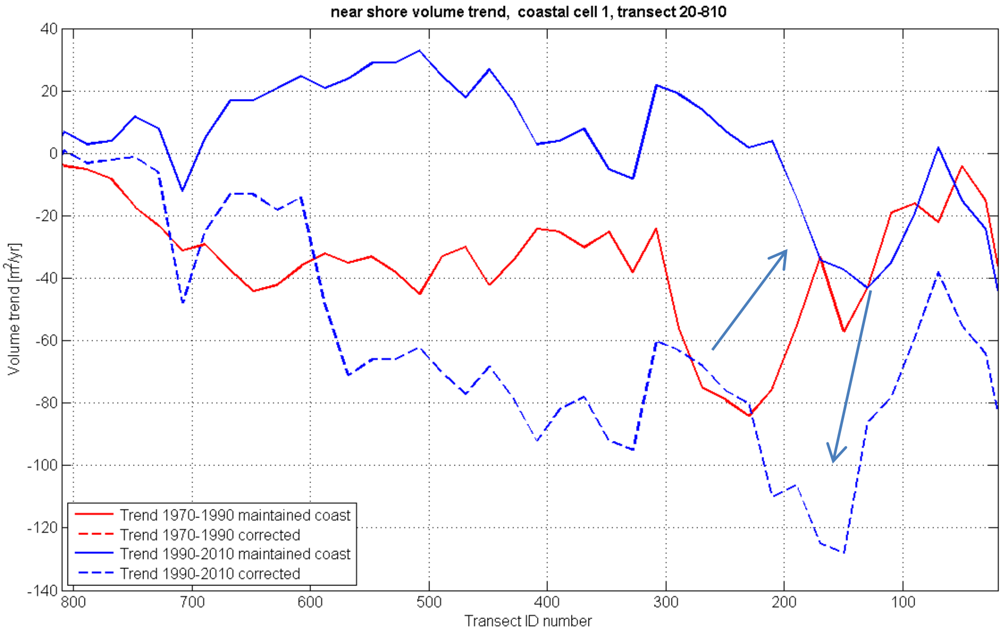


Fig 4.9 Near shore volume trend between -100 - + 750 RSP

By looking at the volume trends, the following remarks / observations can be made;

+ Locally an erosive hot-spot seems to be present, from transect 120 to transect 300 (figure 4.9).
+ Between the transect 60 - 300 a yearly erosive trend of on average -80 m^3/m is found.
+ In the volume plots the trend lines are influenced by the loss of volume between 2007 and 2008.
+ Between 1970 and 1990 a similar erosive spot southward (transects 200-300). Considerably lower erosion rates are observed. The relocation of this spot could possibly indicate mitigation of the "Nieuwe Schulpengat" channel. It is clear that morphodynamic changes are present.
+ The area further south, from transect 250 to transect 550 also shows a substantial erosive trend, (blue dotted line). This is in fact the result of the subtracted volume of the shore face nourishment. The occurring trend (blue) indicates that the added volume only compensated erosion. No significant increase of volume is found over the period 1990-2010.

The nourished volume in 2007 cannot be traced completely by looking at the Jarkus-profiles. Single profiles need to be assessed in order to describe the developments after the three nourishments took place. The three profiles in figure 4.10 all show a substantial increase in volume at the bottom of the channel. Profile 70 shows deepening of the channel between 2005 and 2006. In the years 2009 and 2010 erosion can be observed. The locations that gained volume in 2007 (profile 2008) now show losses. By following the trend it seems that the added sediment will be eroded completely by 2011. Seaward of the shown profiles no changes in volume / depth can be observed. Deepening of the channel seems to happen between the 150 m and 650 m line.

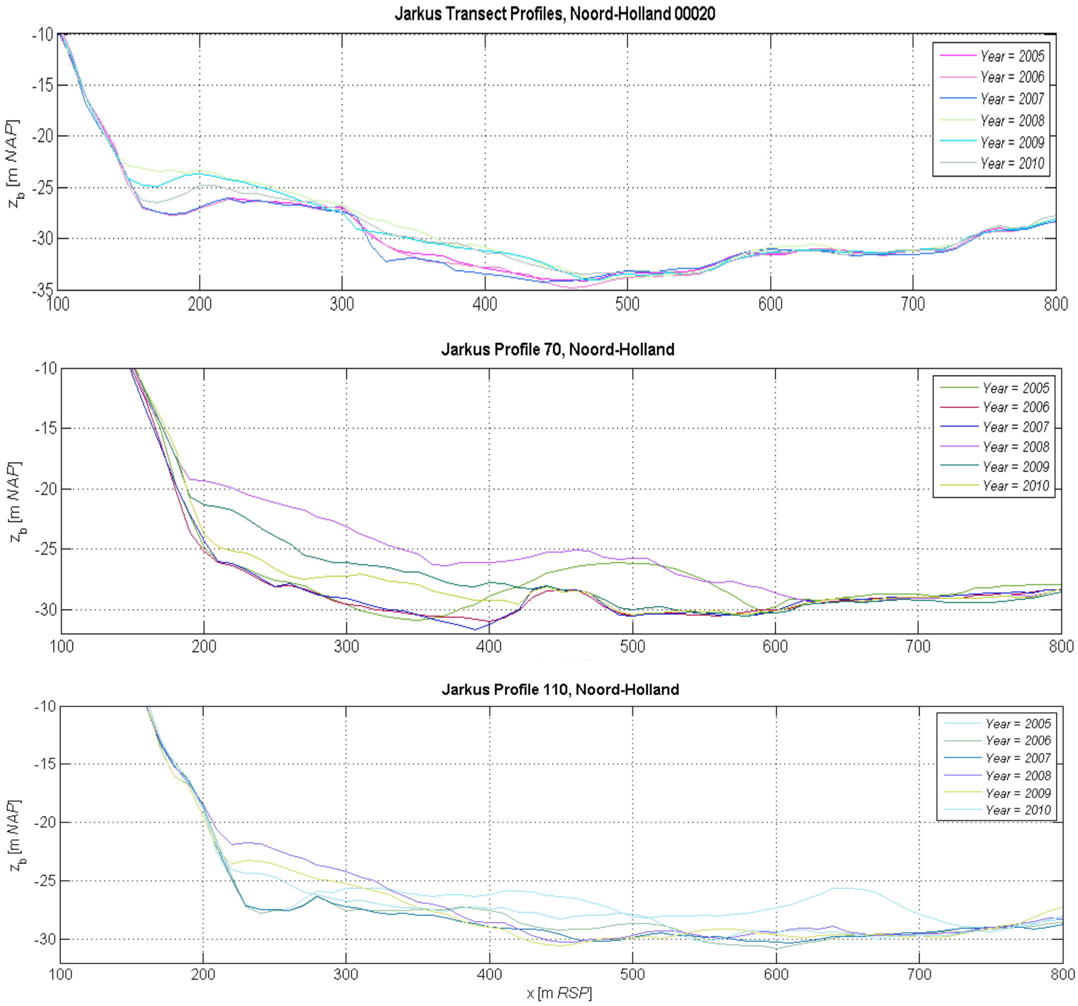


Fig. 4.10 Jarkus-profiles, nourishing the Nieuwe Schulpengat ridge

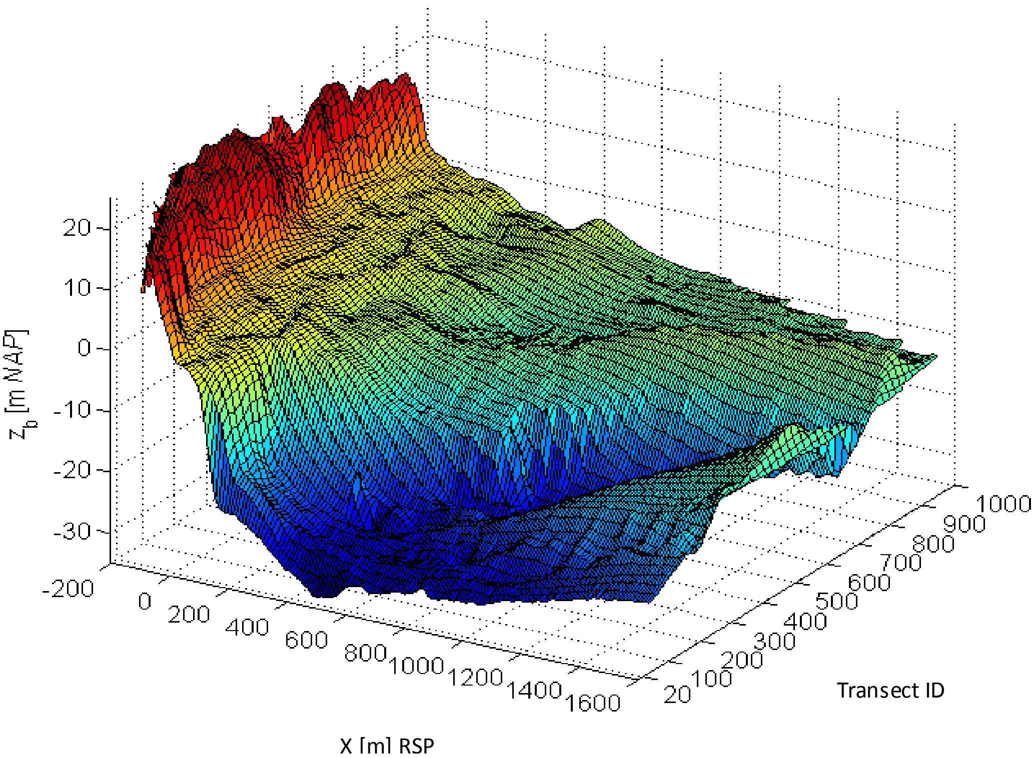


Fig. 4.11 Bathymetry of coastal cell 1, in the front, the Nieuwe Schulpengat channel

Southward of the shown profiles similar observations have been made. The profiles 210, 249, 308 and 449 all show deepening of the channel.

Elias (2006) concludes that the hydrodynamic boundary conditions present in the northern part of Noord-Holland are able to transfer sediment in the order of 1 to 2 million m^3 per year. Sediment transport rates alone are not able to induce erosion. Gradients in sediment transport rates can. When considering the fact that the adjacent cell is characterised by a sediment transport rate of 500.000 m^3 per year (van de Rest, 2004), erosion in the order of 1-2 million m^3 per year cannot be induced by an alongshore transport gradient alone. Other morphodynamic proceses of the Texel tidal inlet seem to play an important role.

Looking at year to year erosion following from the profiles, the following remarks can be made:

The high rate of erosion of the area before 2007 shows adjustment of the channel and a migration eastward. The migration causes even steeper slopes of the ridge. Steepening of the slope will eventually have an effect on the higher part of the shoreface.

After the nourishment at the ridge of the channel, one can observe an ongoing process of erosion. By analyzing the profiles indicated in figure 4.12, we can observe erosion rates in 2 million m^3 per year. An indication of these rates is supported with Jarkus-profiles in Annex VIII. These large numbers indicate a continuation of the process of migration or deepening of the "Nieuwe Schulpengat" channel.

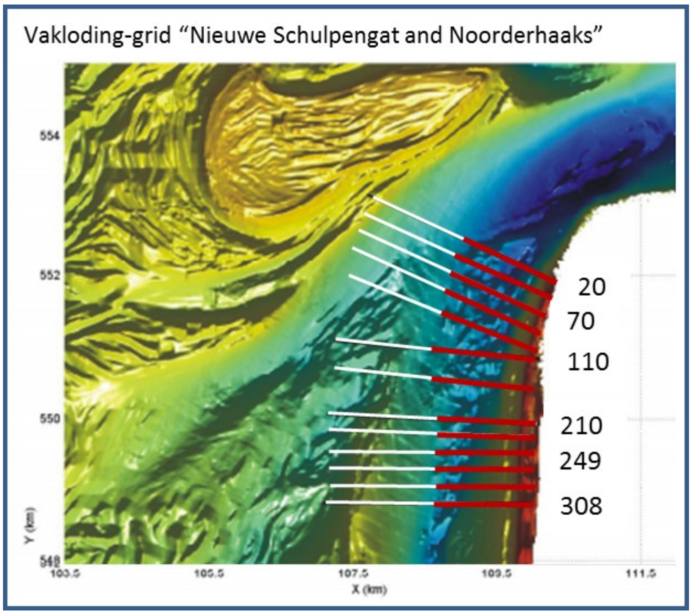


Fig. 4.12 Vakloding grid and used Jarkus-transects (after: Mus, 2003)

One cannot conclude that therefore the nourishment was not successful. Further losses in the years afterwards have been prevented. When one compares the volume change over a period of 20 years, the periods 1970-1990 and 1990-2010 (corrected for nourishments), one cannot extract an increase in erosion over time (figure 4.8). Local erosion due to migration and deepening of the Nieuwe Schulpengat is found (figure 4.9).

We can conclude that that the coastal maintenance strategy started from 1990, for this coastal cell, has not led to increasing erosion. Moreover, the strategy was able to maintain the coastal volume found in 1990. Landward migration of the channel is a process that cannot be prevented by nourishments. The area will shape itself until an equilibrium state is found. The area poses a threat with regards to coastal maintenance. Considering the steep slope and the large volumes involved, this area could lead to high maintenance costs and the need for substantial nourishment volumes.

Consequences of the observed changes in morphodynamics can be substantial for the state of the near shore zone. Therefore more understanding of the tidal inlet is important. A focus towards measures to counteract erosion, especially near the ridges of the deeper channels is required. The stability of the steep slope and the beach between transect 20 and 449 requires attention from coastal engineers and those involved in maintaining the coastline and safety.

4.5.1.1 Noorderhaaks, the Texel tidal inlet and the Waddenzee

Just north of coastal cell 1 the Texel tidal inlet is present. The inlet is located between the mainland of Noord-Holland and the island of Texel. The Texel tidal inlet consists of multiple channels and locally reaches a depth of more than 50 meters. The width of the channel is about 2.5 km. The Texel inlet connects the Noordzee with the Waddenzee. The Waddenzee is a large intertidal shallow sea with tidal flats and wetlands protected by barrier islands (Texel, Vlieland, Terschelling, Ameland and Schiermonikoog). The Waddenzee is listed on UNESCO's World Heritage list and is recognized as one as the most important wet-land area's in the world.

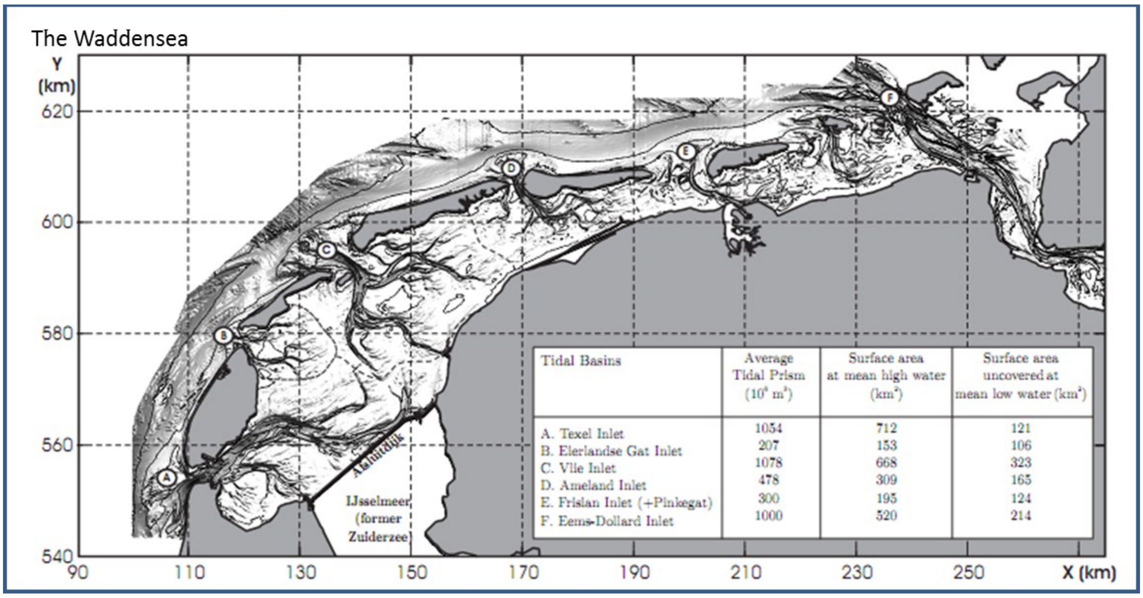


Fig. 4.13 The Waddenzee (Source: Elias et al. 2003)

In between the barrier islands inlets connect the Noordzee with the tidal basin. Tidal induced currents make exchange of sediment possible. The surface of the basin is about 720 km^2. Before 1932 the basin was 5 – 6 times larger. With the design of a large closure dam, (de Afsluitdijk) the Zuiderzee was closed. The closed basin is called the IJselmeer. Safety was provided for the hinterland. The closure had a major impact on the morphology of the Waddenzee, its tidal prism and hydrodynamic features.

The large scale effects of the closure have appeared up until 40 years after the closure. Observations regarding these effects are extensively made by Battjess in his study "Zeegat van Texel" (1962) and by Elias (2006). Despite of the reduction of the surface basin, the tidal amplitude near Den Helder increased. The presence of vakloding grid-data and satellite images are proved to be valuable to recognize the features of the tidal inlet. Taken from Elias et al. (2003) the Vakloding-grid shows the morphology (figure 4.14).

Morphologic behaviour of the adjacent coast and the sea floor is heavily influenced by the inlet. The inlet is the largest of the Waddenzee. According to Hayes (1979) the inlet is qualified as a mixed energy, wave dominated inlet. However, morphologic features such as a large ebb-tidal delta are found. Elias et al. (2006) argues that this is caused by the large tidal prism and relatively low wave energy. Features of the inlet reach about 10 km offshore and determine the alongshore bathymetry over a coastal stretch of about 25 km. Hayes (1975) came forward with a model of what features are generally observed in and around inlets.

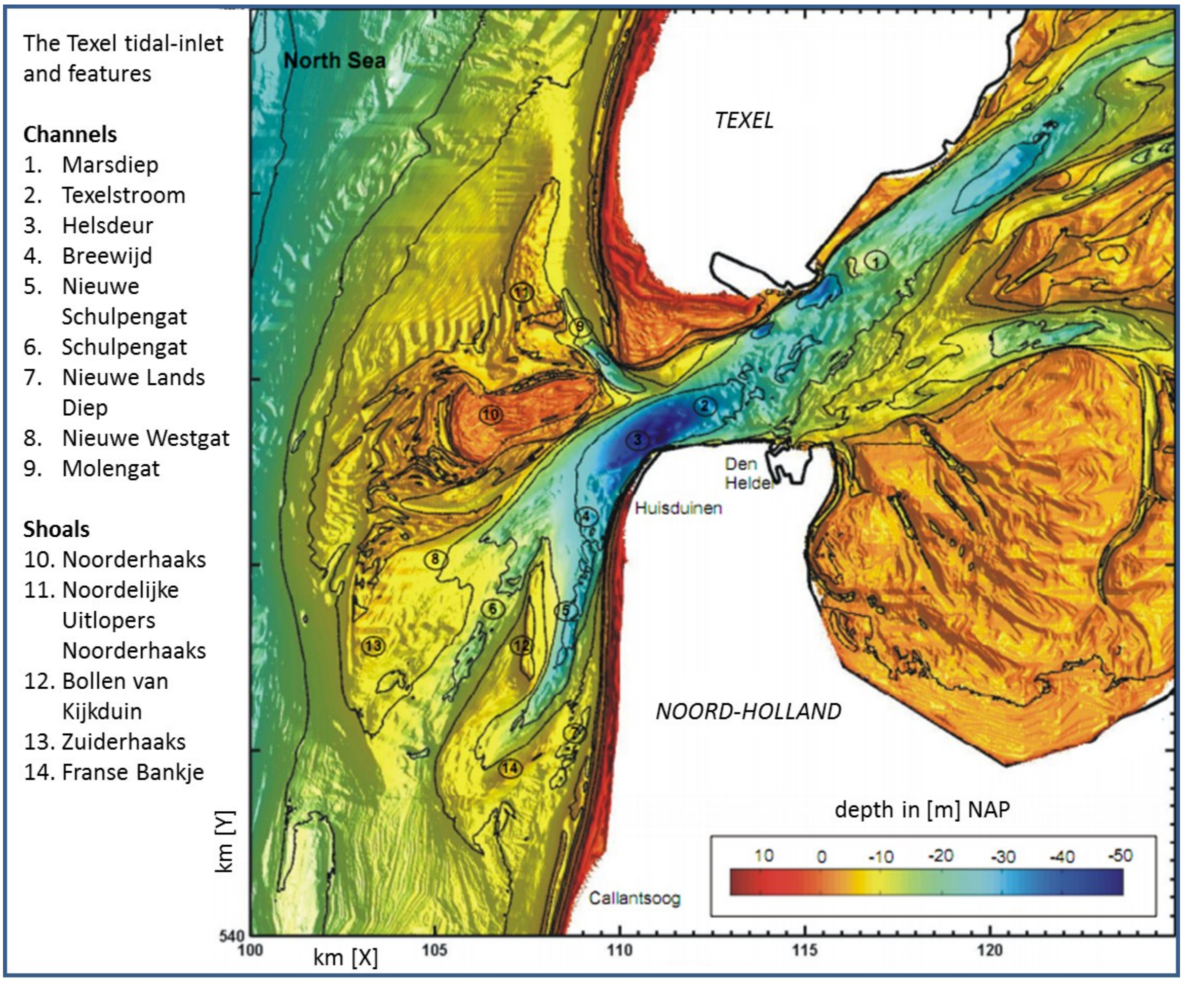


Fig. 4.14 The ebb-tidal dellta (Vakloding 1997) (Source Elias et al. 2003)

Firstly, he describes ebb tidal channels. For the Texel inlet the various channels can be recognized as such. The Marsdiep (1), Breewijd (6) and Helsdeur (5) are examples. The bathymetry of figure 4.10 shows near the delta multiple other channels. The Schulpengat (9) and the Nieuwe Schulpengat (7) are the main ones southward. Initially the Niewe Schulpengat (7) was not present. It evolved between 1930 and 1950 southwards as the "Schulpengat" along the Noord-Holland coast. Later on it diverged into two channels, the original channel and the "Nieuwe Schulpengat. They reach almost 20 km alongshore to the Noord-Holland coast.

The study of Elias and Cleveringa (2003) concluded that the growth of this channel caused severe erosion of the near shore zone. Jarkus-profiles pre-1990 confirm erosion due to evolution of this channel. The vakloding-grids (1986, 1994 and 2003) indicate that the channel no longer grows or migrates. However, the results of the Jarkus-volume analysis shows that erosion still occurs within this section (paragraph 4.5.1). Northward of the tidal delta the Molengat (13) is present. According to Cleveringa (2001) this channel plays an important role in the erosion of the southern Texel coast.

In between the channel arms, a large tidal shoal can be found. On the Noordzee side of the delta, a large sub-tidal shallow is present: "de Noorderhaaks" (14). The feature is a large accumulation of sand provided by sediment transport during ebb-tidal currents. The shape on the seaward side is influenced by wave action and the present alongshore (tidal) currents. The size of the delta is determined by the currents and the availability of sediment. The delta has a surface of a few km^2.

Over the years the shape of the Noorderhaaks evolved. Strong landward migration led to sheltering of the southern Texel coast. Furthermore, marginal flood channels can be observed; they are dominated by the flood tidal currents. Swash platforms, shallows on either side of the ebb channel are generally found. For the Texel-inlet one is present, on the north side of the channel, attached to the island of Texel. Several shoals can be found around in the inlet. The morphology of the Franse Bankje and the “Noorderhaaks uitlopers”, as well as the Zuiderhaaks shape the ebb-shield of the different channels. They are caused by the interaction between the hydrodynamic forces and the available (suspended) sediment.

According to Elias et al. (2003) since 1975 relative stability exists. Most channels and shoals seem to have a stable position. However the Schulpengat has been showing migration towards the coast. While this process induced erosion, sheltering due to the Noorderhaaks has decreasing effects on wave attack.

4.5.1.2 Sediment transport patterns and implications for the Noord-Holland coast

Sediment transport patterns through and around the Texel inlet have an impact on the sand budget. In order to analyse what the influence on the Noord-Holland coast could be, the work of Elias et al. (2006) on these matters is used as source. The following description entails a summary of this paper. Elias (et al.) compared a conceptual model (based on expert judgement) with the process-based model Delft3D Online Morphology. Based on this comparison he concluded that this model is capable of the identification of the main transport drivers.

After a qualitative description, a quantitative overview is made of the most important transport rates that possibly contribute to the erosive state of the northern part of the Noord-Holland coast.

Sediment transport rates in and around the Texel tidal inlet and the forces and mechanisms that play a role are a complex matter. However, the studies of many scholars under which Dronkers (1986), Sha (1989) and Ligtenberg (1998) all found that through the tidal inlet a net import of sediment takes place. They more or less agree on a transport rate of about 1 to 5 million m^3 / year. Forces behind this transport are considered not only to be flood-dominance.

Bonekamp et al. (2002) put forward other explanations such as wind and wave driven transport. Secondary fluctuations in the basin due to density differences caused by the discharge sluices in the Afsluitdijk are named, as are non-linearities regarding sediment transport and currents. A particular interesting remark is the idea of less stirring in the basin, compared to the seaward side of the basin, due to the sheltering effects of the barrier islands. He reasons that thereby the ebb-flow contains less sediment concentration compared to flood-flow.

The present interaction between the hydrodynamic forces and the morphology are lised by Elias and Cleveringa (2003). In their study they list the following morphologic developments in and near coastal cell 1:

- *An increasing depth of the channels Nieuwe Schulpengat, Schulpengat and Nieuwe Westgat.*
- *A seaward and southward outbuilding of the Zuiderhaaks.*
- *Changes in Nieuwe Schulpengat and associated ebb-shield due to small anti-cyclonic rotation and migration of the channel.*

They identified a net influx of sediment along the Noord-Holland coast into Marsdiep towards Texelstroom.

From a qualitative point Elias et al. (2006) sketches a sediment supply to the basin by a *"northward directed littoral drift along the Noord-Holland coastline, southward directed transport along the Texel coastline and from the abandoned ebb-tidal delta front."* Moreover, he concludes that erosion of the updrift and downdrift coastlines adds to this supply. A representation of these elements can be found in figure 4.15. For the Nieuwe Schulpengat system he concludes that ebb—tidal transport supplies the Franse Bankje. The flood dominant transport seems to be most important along the Noord-Holland coast.

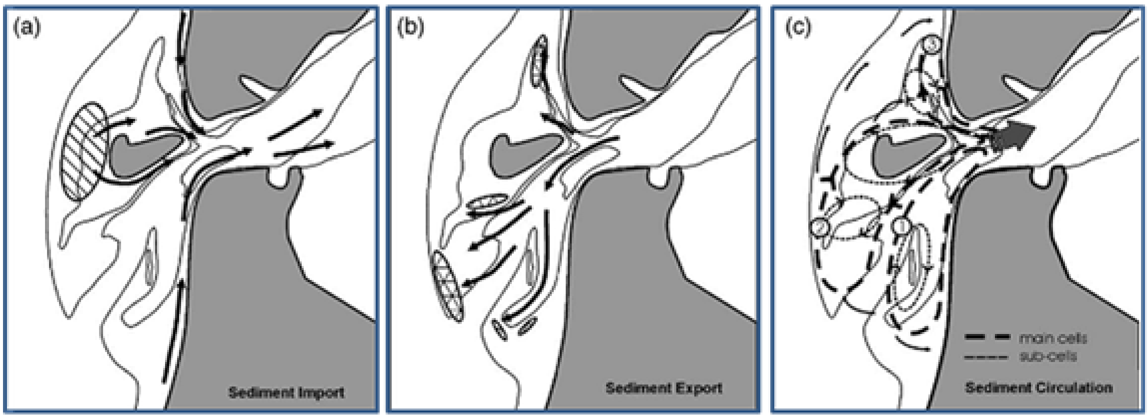


Fig. 4.15 Schematic representation transport patterns (Source Elias et al. 2006)

The qualitative sketch in figure 4.15 by Elias et al. as well as the conclusions from Batjes (1962), Dronkers (1986), Sha (1986) and Ligtenberg (1998) all show that the Waddenzee basin is inter-linked with the Noord-Holland and Texel coast. The morphodynamic system of the Texel tidal inlet has a clear effect on the Noord-Holland coast. Due to the complexity of its system of channels and shoals, not one distinct effect prevails over the other. While the Noorderhaaks limits wave attack, the demand for sediment, the gradient in littoral drift and migration of the Nieuwe Schulpengat all induce erosion of the adjacent coastline.

Some field data of with regards to tidal discharges and current patterns are available within the area. In 2004 Rijkswaterstaat published an extensive report of the currents present. Adequate sediment transport rates have never been acquired.

The fact that these are hard to obtain forces us to look at model results. The aforementioned Delft3D Online Morphology model was able to generate net sediment volume changes through sketched sub-cells in figure 4.16.

With the model a net sediment import through the Marsdiep into the Waddenzee basin of 5-6 million m^3 per year has been quantified. This result confirms the present demand for sediment in the basin. A phenomenon called "zandhonger".

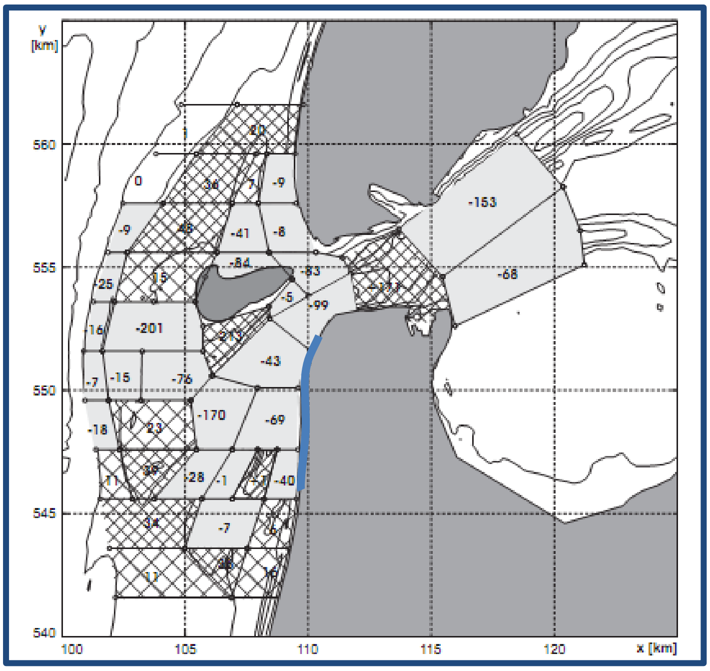


Fig. 4.16 Residual sediment volume change (in 0,01 Mm3/year)
(Source: Elias et al. 2006)

For the most northern section of the studied coast (highlighted in blue) the adjacent cells all show erosion. A total amount of 1.5 million m^3 per year can be found. An important remark is that Elias states that the model validation is rather limited. The large scale spatial changes correspond reasonably well with observations. The obtained sediment transport rates are not always consistent with the present sediment and erosion rates. Therefore the model is more valuable for qualitative understanding. Nonetheless, the magnitude of the erosion rates calculated is locally more or less consistent with the obtained results in paragraph 4.5.1 and the estimates made in Annex VIII. When one realizes that the Jarkus-profiles do not completely cover the cells of the model, the occurring erosion seems to be approximated closely.

4.5.2 Coastal cell 2 (km 8.1 – km 16.3)

The near shore morphology of coastal cell 2 is, just as cell 1 influenced by the ebb tidal delta. Along the coastline groins can be found. In coastal cell 1 similar structures are present. Each 250 m groynes extend seaward. They extend 200 m in the surf zone and were built to counteract erosion. In paragraph 4.5.3 more attention will be paid towards these strutures.

By examining the evolution of the near shore zone a volume of 1.5 million m^3 has eroded in the period 1965-1990. In this period 3 million m^3 of sediment was brought into the system to compensate for losses. The first thirty years of the dataset show a stable, slowly decreasing near shore volume. Since 1990 erosion made way for accumulation of sediment within the area. An increase in volume of 6 million m^3 can be observed. During the last twenty years twelve nourishments of which six shoreface nourishments have been completed; a total amount of 8.7 million m^3.

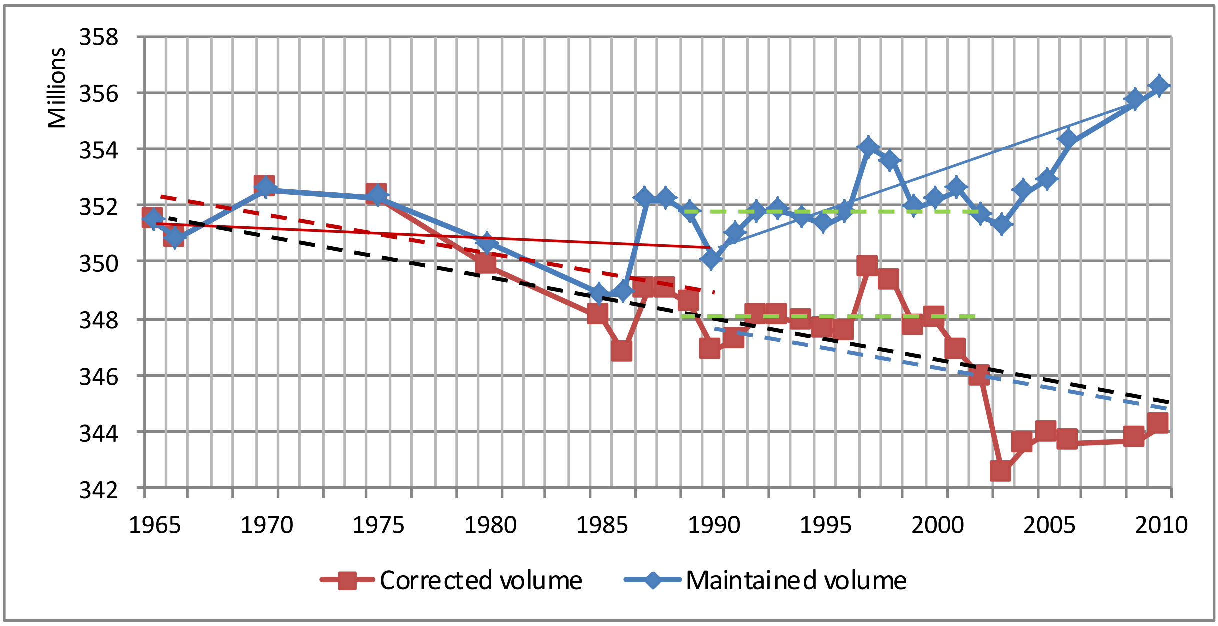


Fig 4.17 Near shore volume cell 2, -100 - +750 RSP

When one observes the volume evolution of the corrected volume as estimate of the autonomous behaviour, the trend line (blue dashed) shows a similar trend compared to 1970-1990. From the year 1990 to 2000 relative stability seems to be present. No losses can be observed. Since 2000 the nourishment volume increased to 7 million m^3. This led effectively to a volume increase of 5 million m^3 over the last ten years.

By observing the alongshore distribution of the volume trends (figure 4.18) the following observations can be made:

The volume trend 1970 - 1990 (red) shows no or little change volume change. By correcting for nourishments a loss of 2.4 million m^3 can be deduced assuming a trend of minus 20 m^3/ m per year. This approximates the absolute losses from figure 4.13. In between km 11.5 and km 14.0 (1150 – 1400) the largest increasing volume trend is present. The nourishments seem to be the least effective for the profiles 1300-1400. The coastal stretch from transect 810 to 1150 seems relatively stable. Between the years 1990 and 2010 this part gained more than was added. In cell 1 similar observations have been made for the are southwards of transect 700.

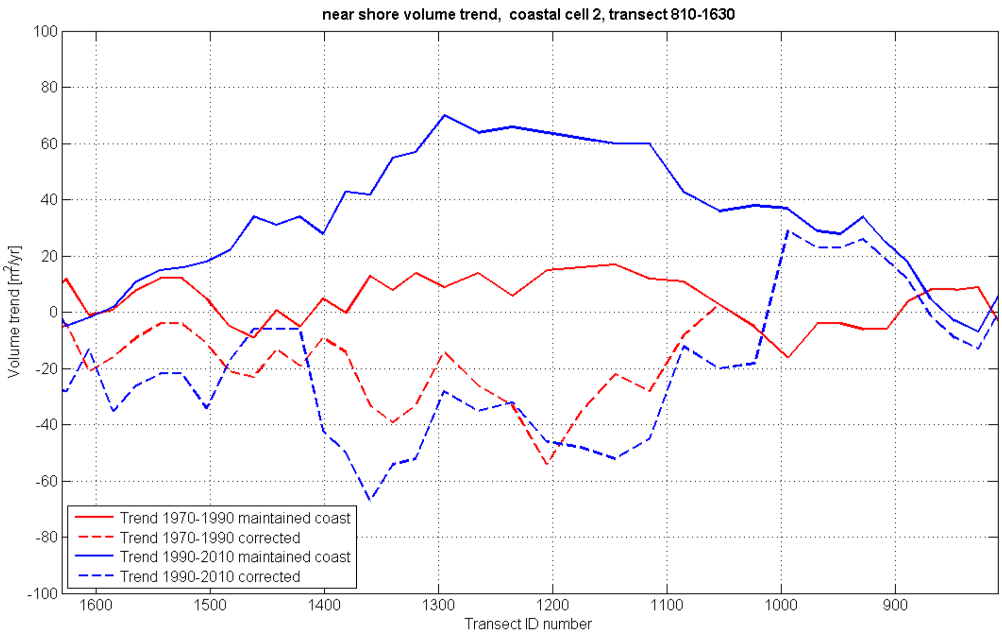


Fig 4.18 The near shore volume trend, coastal cell 2

4.5.2.1 The influence of groins

Beach groynes serve to counteract coastal erosion. They are structures that extend to a certain distance in the surf zone. The main goal is to disturb the wave driven longshore current. Secondly, the groynes push the tidal currents further seaward. As a result, the longshore transport rate locally decreases. If over a coastal stretch a gradient in longshore transport is present, groynes could, when designed correctly, take away this gradient. Often only a gradient reduction is reached. This directly leads to a decrease of erosion rates locally. Thereby groynes act as sand traps. After Prusak (2006) figure 4.19 shows the basic principles of a groyne field. The original sediment transport rate over the whole surfzone is reduced. The lateral distance between the groynes (X_b) , the seaward extension of the structure (L_b) and the permeability of the structure determine the reduction rate (R). If in between the groynes landward movement of the shoreline is prevented or seaward movement of the shoreline is accomplished, the desired result of the measure is reached.

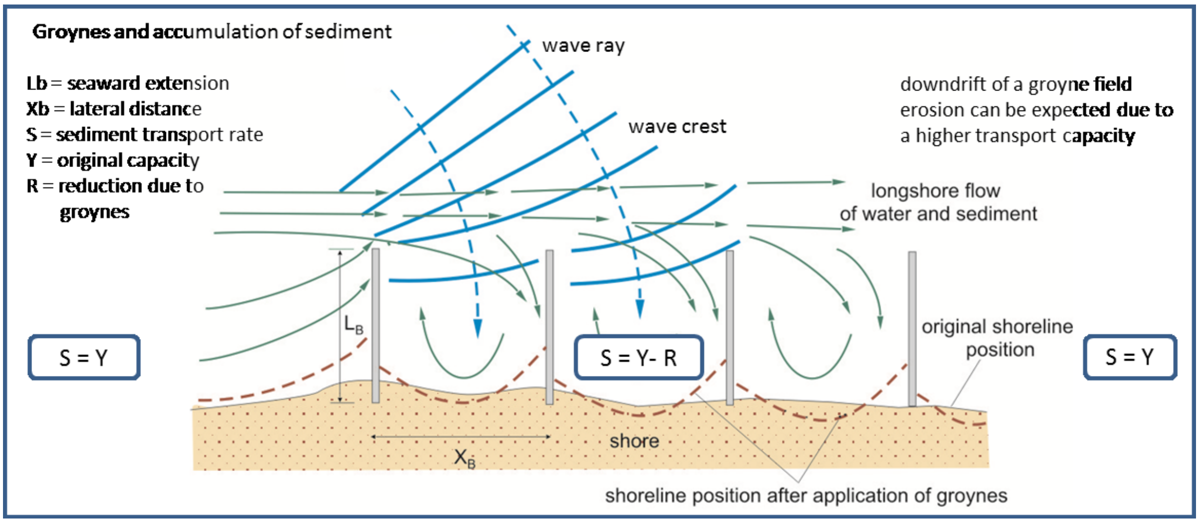


Fig 4.19 Groynes and the reduction of sediment transport rate

Along the Noord-Holland coast groynes can be found from 0,2 to 31 km from Den Helder. They extend along the northern part of the coastal stretch. They are also found along the Hondsbossche and Pettemer sea defence. Their lateral distance differs from 200 to 500 m. In general they extend about 100 -200 m seaward measured from the RSP. The groynes are constructed between 1838 and 1935.

The effects of the groyne fields present along the Noord-Holland coast have been described in a TAW study (1995). This study states: "*beach groynes that guide the tidal flows are effective, reduction of the wave induced longshore current is considered to be less effective*". As a consequence of this erosion seaward of the groynes is expected. The effectiveness with regards to the reduction of wave induced transport depends on the hydrodynamic conditions. Storm surges can influence the width of the surf zone and thereby the effectiveness of the groynes. According to Van Rijn (1998) groynes could reduce the alongshore transport with 25 per cent. He assumed a rate of effectiveness of 50 per cent during daily non-storm conditions.

Coastal maintenance along the Noord-Holland coast is affected by the presence of the groyne fields. Uitwaterende Sluizen (2001) studied the effects of the field on the autonomous behaviour of the coast. They put forward that the groyne field present in cell 1 and 2 (3 -18 km does not influence the autonomous behaviour of the coast. In contradiction to this, they do expect *"an increase in coastal maintenance of 50 to 100 per cent"* if the groynes would not be present.

Since no nearby reference area is present in coastal cell 2 and 3, it is difficult to estimate or observe the effectiveness of the groyne field in preventing erosion. Near coastal cell 4 such an area does exist, although the present alongshore sediment transport rate is considerably lower. This affects the sedimentation and erosion rates significantly. Therefore a comparison cannot be made.

4.5.2.2 Sedimentation and erosion patterns

With the Jarkus-data indicative (year to year) sedimentation and erosion patterns can be obtained through incremental volume changes. Interpolation between transects allows for a 2-d view of near shore volume changes. This method is rather limited due to the fact that temporal changes are not always captured. If morphologic changes are limited, it is still possible that large sediment volumes are moved. Dispite these limitations, the sedimentation and erosion patterns are analysed in the aim to gain more understanding of the local, medium term volume evolution.

By analysing the sedimentation and erosion patterns in front of the coastal stretch of cell 2 some distinct features can be observed. Firstly, a trough and an outer bar can be recognized (contourplot 1990). The incremental volume change between the years 1970 and 1990 shows no significant erosion / sedimentation in the vicinity of the bar. Between the bar and the beach, erosion can be observed between transect 1000 – 1400. The beach (-50 - +100 m) shows little erosion over the period 1970-1990. This seems to be consistent with the theory that a groynefield is able to prevent erosion locally. In theory, seaward of the groynes, erosion can be expected. In both sedimentation / erosion plots (1970-1990 and 1990-2010) the near shore zone, just seaward of the groynefield does show a significant loss of volume.

Since 2000 shoreface nourishments have been applied to fill the trough and to maintain the bar. In the years 2001, 2003, 2006, 2008 and in 2009 sand was added to the system. By comparing the contourplot of 1990/2010 with the incremental volume change, one can observe an erosive area near the trough. The contourplot of 2010 shows that the trough has deepened compared to 1990. The trough can be spotted in blue and is located about 200 to 400 m seaward of the RSP line. Further seaward and area of sedimentation is present. It is likely this is induced by the shoreface nourishments.

In the contourplot over the period 1970 1990 substantial losses are found near the dune foot. The height at which these losses occur indicates dune erosion. In the years 1976, 1979, 1986 and 1987 dune nourishments have been conducted. The nourishments are likely to contribute to the sedimentation patterns present in red. It seems that erosion caused the dune row to retreat landwards.

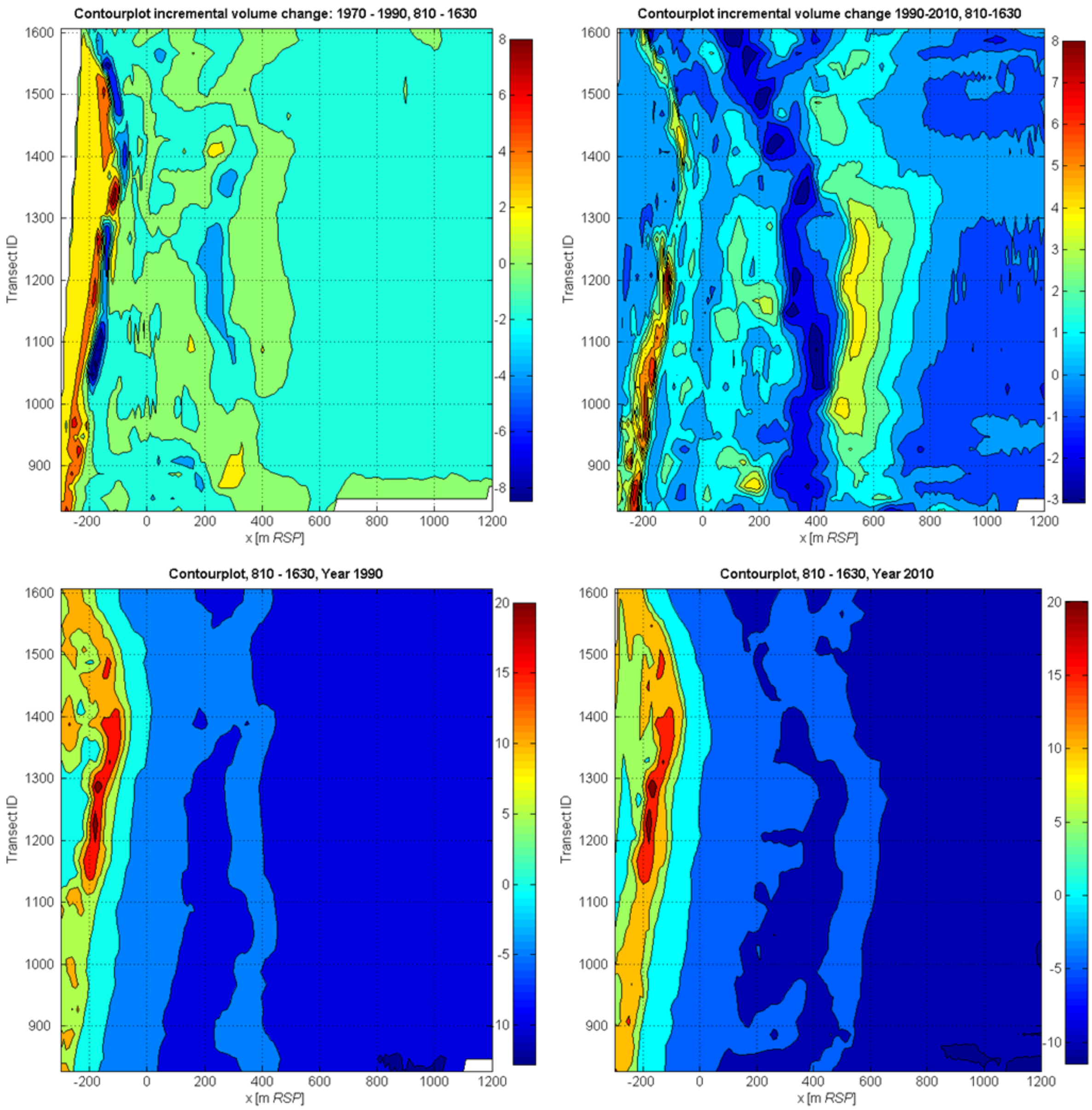


Fig 4.20 Sedimentation and erosion rates cell 2 and contourplots bathymetry
(Composed out of Jarkus-transects interpolated in alongshore direction)

4.5.3 Coastal cell 3 (Callantsoog – Petten, km 16.3 – km 28.0)

The evolution of the near shore volume of coastal cell 3 shows significant irregularities and fluctuations. The cell covers the coastal stretch from Callantsoog till Petten. From 1965 to 1970 the area gains a volume of 4 million m^3. After 1970 this volume seems to disperse with a similar rate. In the years 1984-1986 sedimentation occurs within the bounds of the cell. The successive four years are charachterized by losses of the same order of magnitude. The trend from 1970 to 1990 will not do justice towards the occurred volume evolution. Within a period of twenty years losses of 12 million m^3 have been observed. About fifty percent of the losses were temporal. In absolute terms the near shore zone was erosive. The trend taken over the years 1970 - 1990 indicates a loss of 6 million m^3 over a period of twenty years.

The period 1990 - 2010 can be characterized by a relative steady volume gain. The volume advanced 7.8 million m^3. Nourishments have been a source of sediment in those years. On a regular basis both shoreface nourishments and beach nourishments have been executed. To maintain the coastal stretch a total of 9.4 million m^3 was added. From 2002 to 2007 the area gains volume without nourishments present. It is assumed that this must originate from outside the bounds, possibly through net longshore transport. The corrected trend over the period 1990-2010 shows a rather similar erosive trend.

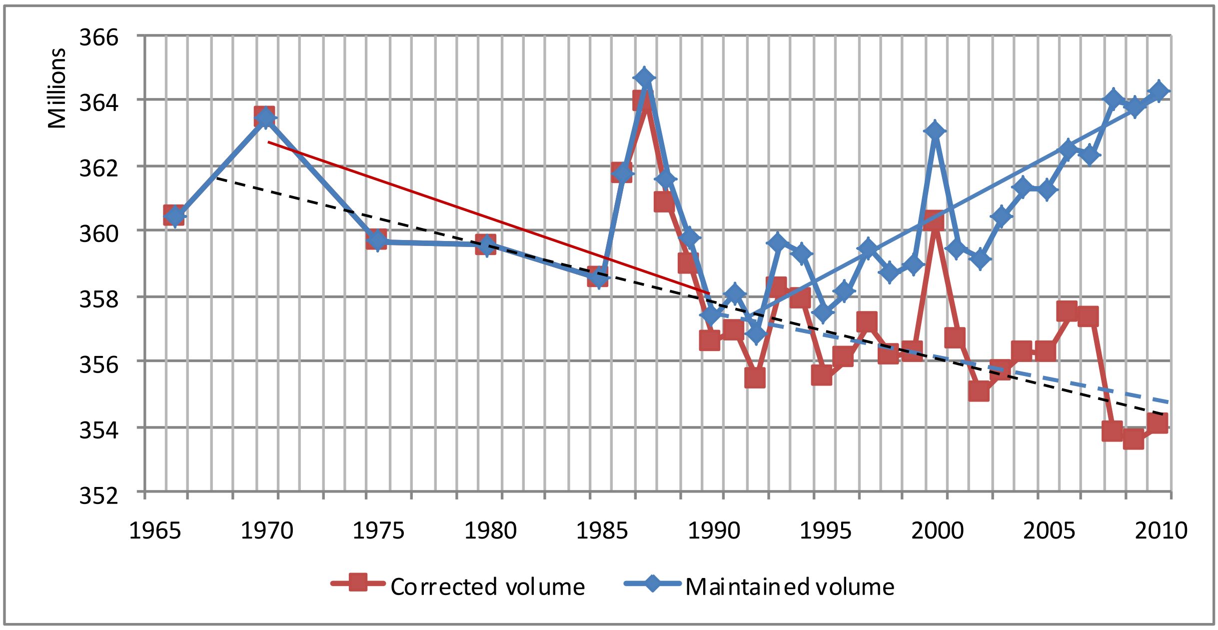


Fig 4.21 Near shore volume cell 3, -100 m - + 750 m

In 1970, 1986 and in 2000 jumps in volume evolution can be found. They seem to occur with a frequency of fifteen years. The temporal losses present in the years 1995, 2000, 2001 and 2008 are of the same order of magnitude of the losses found in the period 1965-1990. For an observation of the volume evolution of the deeper part of the coastal cell insufficient data is available. The Jarkus-surveys do not extend far enough frequently to analyse this part.

In paragraph 2.5.1 sand waves have been mentioned as plausible explanation for local temporal increase in near shore volume. Taking into account celerity in the order of hundred meters per year this phenomenon cannot explain the observed fluctuations. The behaviour of near shore bars at the edge of the cell could explain large volume fluctuations. Periods of similar order have been documented. This explanation can be excluded since no bar is present near the seaward boundary. Near the landward boundary, adjacent to the Pettemer and Hondsbossche sea defence the near shore dynamics do influence the volume. An illustration is presented in Annex VIII.

4.5.3.1 Alongshore volume trends and the Hondsbossche and Pettemer sea defence

The Hondsbossche and Pettermer sea defence comprises the coastal defence between transects 2000 and 2630. The sea wall consists of a sea dike with revetment. Groynes extend seaward. Since the reconstruction (1877) a locally stable coastline has been established. From the perspective of coastal morphology the solution had a significant negative impact. Over the last hundred years structural erosion caused coastal retreat on either side of the structure (de Graaff, 2002). Due to this process the seawall extends further seaward compared to the first dune rows on either side of the structure.

An alongshore distribution of the volume trends of cell 3 is presented in figure 4.22. The presence of the Pettemer and Hondsbossche sea defence forced the use of a different landward boundary. This is indicated in figure 4.22 and 4.23.

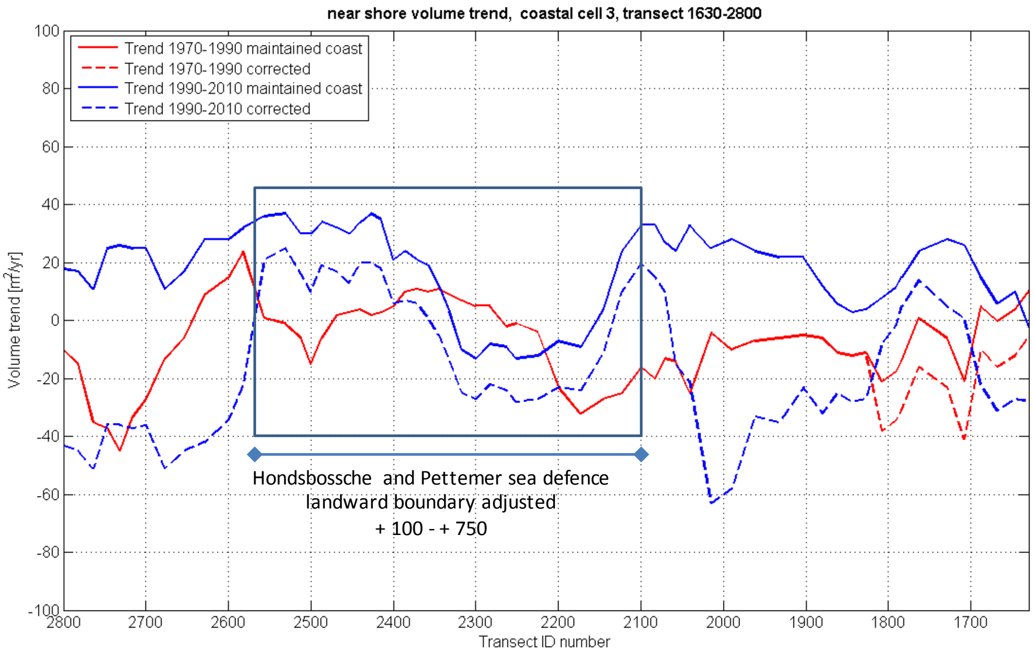


Fig 4.22 Near shore volume trends cell 3 between -100 - + 750

The volume trend of 1970 – 1990 shows little erosion. Local fluctuations are observed within transects. By observing the alongshore distribution a relative stable coastal stretch seems present. The largest erosion for the period 1970 – 1990 is found south of transect 2600 and northward of transect 2200. In the last twenty years a positive trend is present over the largest part. This is consistent with the absolute volumes shown in figure 4.21. In front of the Hondsbossche and Pettemer sea defence this positive trend is present as well. However, the near shore volume in front of the northern part the sea defence shows mild erosion. From transect 2100 to transect 2350 this can be observed.

The natural behaviour (corrected trend) shows on either side of the sea defence a negative trend. The nourishments might explain the positive trend on the ends of the structure. Southwards a larger number of nourishments is executed (transects 2550-2800). The positive trend in blue reflects the added volume. This indicates the nourishments were (temporally) effective locally. The structural volume gain from transect 2350 to 2800 cannot be completely explained by the nourishments. A plausible explanation would be a net inward sediment exchange with cell 4 or cross-shore exchange.

Figure 4.23 shows the landward boundaries used for the volume calculations. Due to unsufficient Jarkus data near the sea defence, the boundary is located 50 m seawards of the structure. By observing the sedimentation and erosion patterns (incremental volume change presented over 2 periods) some remarks can be made.

In front of the sea defence, clear sedimentation patterns are visible. Both over the period 1970-1990 and 1990-2010 an increase in volume can be recognized. These gains are limited between transects 2650 - 2300. Northward (transect 2000 – 2200) mild erosion is present. Further seaward, at a cross-shore distance of 300-500 mild erosion occurs. In the period 1990-2010 landward of this area, erosion patterns of similar order are found. Over this period a volume gain is found three to four hundred meter seawards. The profiles presented in Annex VIII indicate a bar is growing. This pattern is clearly visible in figure 4.23. An important remark is that the presented sedimentation patterns are strengthened by a shoreface nourishment executed in 2008.

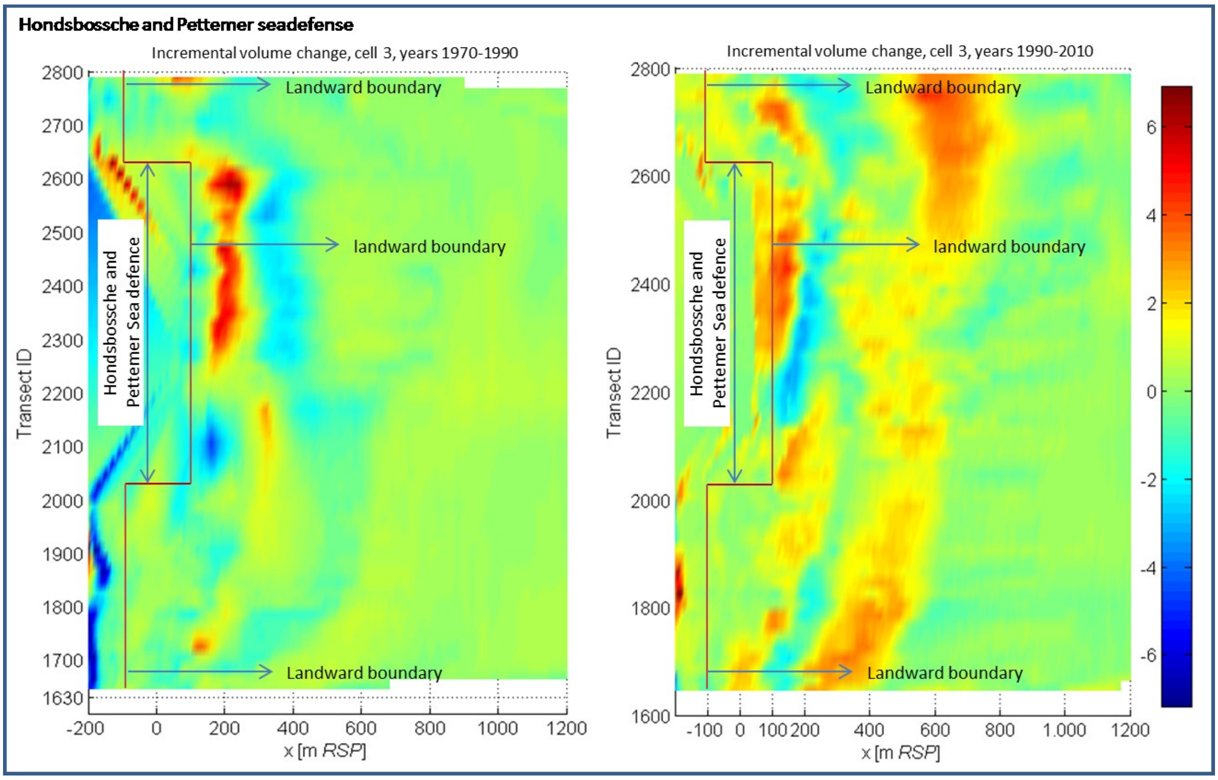


Fig 4.23 Erosion and sedimentation patterns and selected boundaries cell 3

Since the sea defence does not meet safety requirements measures are sought to strengthen the structure. Through an assessment the structure is found to be one of the weak links (Zwakke Schakels) in the Dutch flood defence system. An integral assessment of these links is made Arcadis/Alkyon (2005). They came forward with a large scale static equilibrium solution through the construction of a seaward extending non permeable element. Svasek Hydraulics (2008) explored solutions that take into account the morphodynamic environment around the structure.

In the summer of 2011 the first interviews with consultants and contractors have started to seek solutions and explore designs. An assessment with a morphological model on the possible consequences of such a design is expected to be made in the near future. Interesting solutions have been proposed already. Steetzel (2009) has put forward an abstract on the design of a hybrid solution. The current seawall combined with a sandy seaward extension, partly covering a sea wall with sand. Such a solution could be feasible for the Hondsbossche and Pettemer sea defence.

4.5.4 Coastal cell 4 (Bergen – Egmond, km 28.0 – km 39.0)

The volume evolution of coastal cell 4 can be characterized by extensive human interference. The near shore volume of the coastal cell received 12 million m^3 through beach and shoreface nourishments over the last twenty years. Before 1990 no nourishments were executed. The near shore volume is steady decreasing in the first twenty five years. Erosion in the order of 6 million m^3 over this period can be observed. This is an equivalent of 250.000 m^3 loss per year. In figure 4.24 this is indicated by the black dashed trend line.

Over the period 1990 – 2010 a substantial increase of volume can be observed. The near shore zone has gained a volume of 8.6 million m^3 (blue line). Between the years 1985 to 2000 a relative stable near shore volume seems present. This is shown by the green dashed line. The volume corrected for nourishments indicates 5.8 million m^3 was needed to maintain this stability. The nourishments have compenstated for erosion rates of on average 500.000 m^3 per year. A notable higher yearly erosion rate compared to the period 1965 - 1990.

Since 2000 the near shore volume increases. By comparing the red dotted line with the blue dotted line we can observe that the nourishments lead to an increase of volume. The volume of 7 million m^3 that was added led to a net gain of 5 million m^3. Looking at the volume evolution over the whole period (1965-2010) seems to indicate that the nourishment strategy started in the year 1990 does not impact the average erosion rate. This trend is indicated by the black and blue dashed lines .

Over the period 1990 -2010, the nourishments did compensate further erosion. Furthermore, the near shore zone has increased volume over the last twenty years. This indicates that the area is locally overnourished. About 2/3 of the nourished volume was not needed to compensate for the occurring erosion.

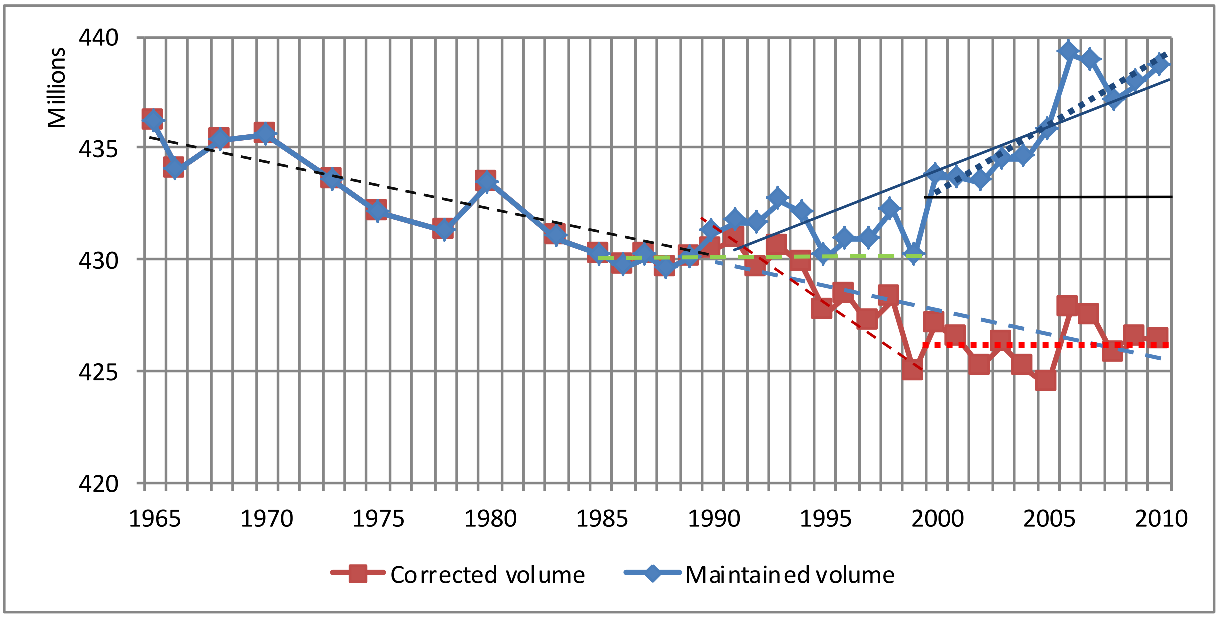


Fig 4.24 Near shore volume, cell 4 between -100 - +750 RSP

The second dataset provides us with data till + 1200 m RSP. It is presented in figure A.6.4. It can be studied in annex VI. A similar erosive rate for the years 1965 – 1990 is found. After 1990 the increase in volume found from dataset 1 has made way for a relative steady state, slightly increasing over the last twenty years. This indicates that losses in the deeper part of the cell are present. Taken over the whole dataset graph A.6.4 shows erosion in the order of 300.000 m^3 per year. This is 90.000 m^3 more compared to the volume bound by the + 750 RSP line. From 1965 to 1990 a loss of 180.000 m^3 per year was found. Since 1990 this rate has grown towards 500.000 m^3 per year.

In figure 4.25 an alongshore distribution of the four volume trends are presented. The trend 1970 – 1990 shows mild erosion from transect 3750 northwards. Furthermore the distribution shows local fluctuations in the order of 30 m^3 / m per year. This variation is partly caused by the generation of the trends. Natural variations in profile volume are of the same order. By studying the single profile trends this can be observed. They are presented in Annex 7.

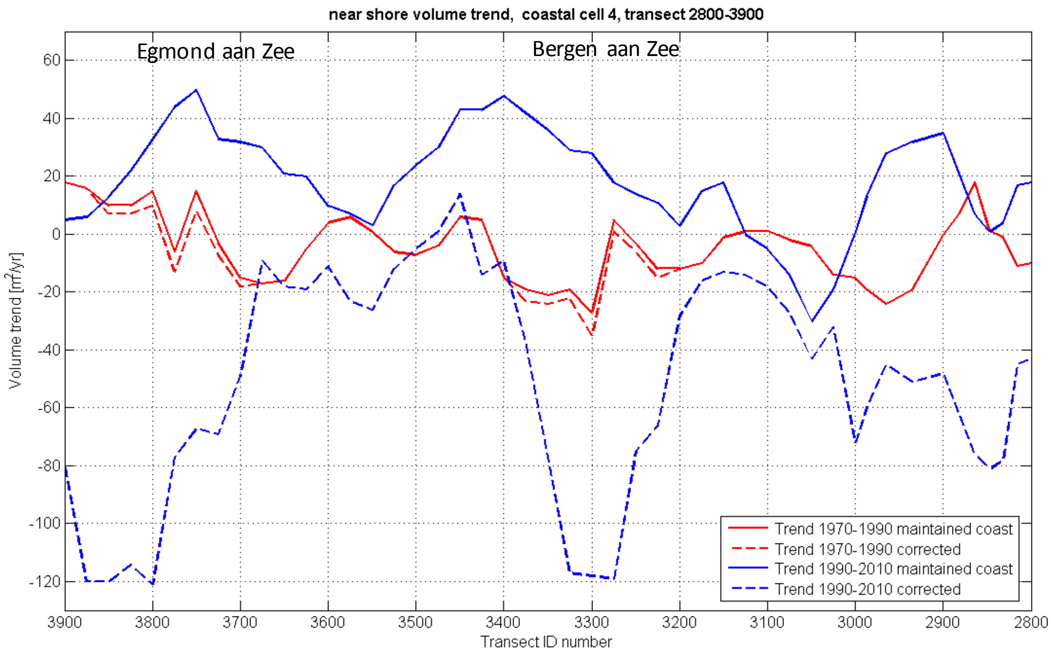


Fig 4.25 Near shore volume trends cell 4 between -100 - + 750

The trends of 1990 – 2010 show the impact of coastal maintenance in this area. The area between transect 3200 and 3400 near Bergen aan Zee has received numerous nourishments. Similar, southward of transect 3700 (the area in front of the town of Egmond aan Zee) a substantial amount of nourishments is executed. The blue dotted line indicates the maintained trend corrected for nourishment volumes. Considering the difference between the maintained (occurring) trend, these locations are subject to continuous erosion. The nourishments compensate for these losses.

The occurring near shore volume trend (blue trend in figure 4.25) shows accretion between transects 3600 and 3900. A similar trend can be observed from transect 3200 to transect 3600. In between these two areas a steady volume is found. It appears that the locally executed nourishments do not lead to sedimentation in this area. Furthermore, neighbouring cells do not show significant natural accretion. An exception seems the positive trend from transect 3000 to 2600.

By comparing the two blue trends in figure 4.25 a distinct shift between the accretive trends and the nourished spots is present. For Egmond aan Zee a trend indicating a volume gains is found northward. For Bergen aan Zee, the gains are found southwards of the nourished area. The bathymetry of the adjacent coast and complex current patterns found in the vicinity of Egmond and Bergen could possibly be an explanation for this phenomenon.

The higher erosion rates found in dataset 2 (an average of 500.000. m^3 per year compared to 250.000 m^3 over the period 1990-2010) point towards structural losses of the deeper part of the cell. The losses that occur at the deeper part of the cell could contribute to a plausible explanation why this coastal stretch requires extensive maintenance. Processes that cause the relatively low positive trends compared to far larger nourished volumes cannot be explained with year to year near shore volume data. To further explore this, a study including net cross-shore transport rates is necessary

4.5.4.1 *Influence of "De Kerf" on the coastal system*

In 1997 an artificial dune breach was established. The reason for this remarkable project was the limited ecologic diversity within the dune area. The breach is located near an old weak link of the Noord-Holland dunes. In the years 1928, 1953 and in 1974 the first dune row was unable to protect the valley behind it (Staatsbosbeheer, 2009). The breach is found between transects 3000 – 3100. The measure was taken in the light of the new paradigm / policy in coastal engineering called dynamic preservation of Rijkswaterstaat. The main goal for Rijkswaterstaat was to recover natural dynamics within the coastal zone.

The breach has a width of hundred meters of which the dunes have been lowered to + 1.5 m NAP. Behind the breach the "Parnassia valley" covers about 60.000 m^2. Since the breach the area has flooded about forty times. In the last ten years this number declined. Near the original dune row a small bar has grown due to aeolian transport.

Fig 4.26 The artificial dune breach "De Kerf"

After six years the project was evaluated. Arens (2003) studied the geomorphology of the area through an analysis of Jarkus-profiles and aerial images. The study led to the following conclusions:

+ Changes in the near shore volume are insignificant considering the normal volume variations.
+ Near the breach little dunes have started growing since 1999. Currently a bar with a height of + 2 - 3 m NAP can be observed.
+ The first dune row adjacent to the breach is strengthened by sediment originating from the beach, mainly due to aeolian transport.
+ During floods locally a gully is formed from the high water line towards the first dune row. The beach recovers relatively fast after floods (timescale in the order of months).

Despite the efforts and analysis by Arens (2003), the debate on the impact on safety and morphologic impact on the near shore zone is on-going. By examining the near shore volume evolution through the Jarkus-profiles, an additional analysis is made. The plots are added in Annex VIII.

Alongshore plots of near by Jarkus-profiles are used to generate “surfplots” of the area 2900-3200. A reference sedimentation erosion plot has been made in order to assess the state before the breach. The years 1990-1996 have been used. Before the breach mild beach erosion can be observed. Landward sedimentation patterns of similar order are found. The first dune row (along the – 200 m RSP line) seems to gain volume.

A second plot has been made for the years 1996 – 1998. This plot gives an overview of the effects just after the breach. At the sight the artificial breach can be recognized near the first dunerow (-600 m - -200 m RSP). Mild erosion patterns are visible. Adjacent to transects 3000 to 3150 losses are found, 50 to 200 m seaward from the RSP. With the data presented, it is not possible to ascribe these losses as consequences of the breach. During the first years, the valley behind the breach flooded several times. During those stages, channel formations can be recognized (figure 4.26). No other notable erosion patterns are observed in the vicinity of the breach.

The third plot shows the volume evolution from 1998 to 2004. In front of transects 3000 – 3200 erosion patterns are found at a distance 100 to 200 m seaward from the RSP. Local losses in front of the breach, at a distance of 100 to 150 m landward of the RSP can be observed. Losses are found, over a larger compared to the losses during the years 1996 – 1998. These losses have an order of about 100.000 m^3. This can be considered to be quite substantive. Two hundred meter seaward of the RSP other losses can be recognized. They stretch along the coastal stretch. Over the period 1990 - 1996 similar losses are observed, slightly seaward.

Over the period 2004 – 2010 no significant losses are observed. Near the breach, local substantial losses are found. Landward similar sedimentation rates are found. This could relate to landward movement of the new dunes described by Arens (2003).

From the analysis of both the absolute volumes and the sedimentation and erosion patterns no (long term) significant losses near the breach can be observed. By looking at the nearby coastal cells no negative effects, such as channel formation are recognized. The occurring erosion rates mentioned in the years 1998 – 2004 are not larger compared to local erosion rates of coastal stretches nearby. Therefore, apart from (temporal) local changes of the profiles that cover the breach, it can be concluded that based on the data available, “de Kerf” has not affected the near shore volume from 1998 to 2010 substantively.

4.5.5 Coastal cell 5 (Castricum, km 39.0 – km 47.0)

Cell 5 is characterized by the fact that this coastal stretch was not nourished until the year 2004. This gives the possibility to assess the natural variability and behaviour of the near shore volume. The development in terms of volume is presented in figure 4.27. In the period 1965 to 1972 significant accretion took place. The cell gained a volume of 7 million m^3. This is equivalent with a yearly sedimentation rate of 1 million m^3 per year. The years after 1972 show a yearly loss of 500 - 700.000 m^3. From 1980 these rates make way for relative steady accretion, although at a lower rate compared to the period 1965 - 1970. The temporal volume variations are indicated by the black dashed trend lines.

One can observe that in the period 1988 – 1998 a mild erosive trend is present. From 1998 to 2000 the near shore volume gained 5 million m^3. In the period 2000 – 2007 a relative steady volume is present. From the year 2007 to 2008 shows a significant increase. This could indicate that the volume changes over the period 1998 to 2007 are of a temporal nature. Over the whole dataset coastal cell 5 shows a clear increase of the near shore volume. The blue dotted trend indicates this.

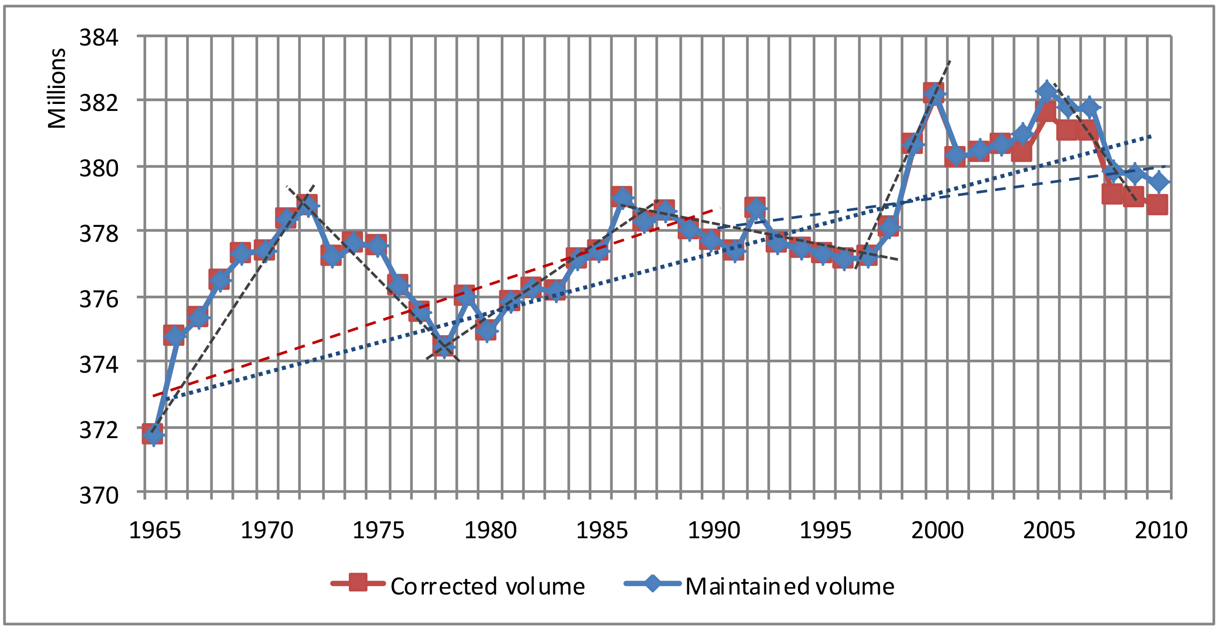


Fig 4.27 Near shore volume cell 5, -100 - + 750 m RSP

Over the period 1990 – 2010 coastal cell 4 has received a large number of nourishments. As stated in the description of cell 4, only a limited though substantial volume increase can be observed. The question whether a part of the volume of the nourishements from cell 4, had an impact on the near shore volume of cell 5 arises. In order to judge where the sediment originates from, exchange along the boundaries of this cell needs to be mapped.

Over three boundaries a sediment exchange can occur. At both alongshore boundaries, exchange could take place. Sediment from cell 4 and 6 could enter cell 5. For this to happen, a gradient in net alongshore transport needs to be present. Otherwise morphologic changes do not occur. According to Van de Rest (2004) such an alongshore gradient between the neighbouring cells is not present within the surfzone (figure 2.16). It must be realized that the sediment transport rates presented by Van de Rest (2004) are obtained through comparison of the transports presented by Van Rijn (1995) and Stive and Eyskink (1989). The studies conducted by Van de Graaff – Stroo (1991) and Bakker et al (1989) do indicate a net transport gradient. Sediment exchange can also occur along the cross-shore boundary. Sediment from the deeper near shore zone could enter the cell. The second dataset with a further extended seaward bound enables to study the near shore volume of the deeper area.

The second data set, with bounds of -100 - + 1200 m RSP does show a relative stable volume over the last twenty-five years. Significant temporal changes are not present. This leads to the idea that cross-shore volume variations are responsible for the temporal volume gains. Bar behaviour could explain these temporal changes. Over the period 1965 to 1975 dataset 2 does not provide enough data. Due to the coverage of the survey area we cannot analyse the volume changes.

To support bar behaviour as explanation for the temporal changes single profiles are analysed. By examining various profiles along the coastal stretch, land and seaward movement of an outer bar near the seaward boundary is present. Fluctuations of the near shore volume caused by bar behaviour are observed over the years 1965 – 1975 and 1998 – 2010. Profiles, serving as support for this explanation can be found in Annex VIII. The losses that occur due to seaward movement and degradation of the outerbar are clearly visualized. A detailed study that includes all profiles over both periods, including single volume calculations and the location of the present bars in recommended.

The alongshore distribution of volume trends are presented in figure 4.28. The trend 1970-1990 shows only mild accretion and alongshore variation. The trend 1990-2010 shows alongshore variation. Some profiles gain volume, others lose volume. The trend is in general similar to the trend of period 1. Near transect 3900 the corrected trends indicates the substantive nourishment volumes. It seems that the area 3900-4000 is far more erosive compared to the most part of coastal cell 5.

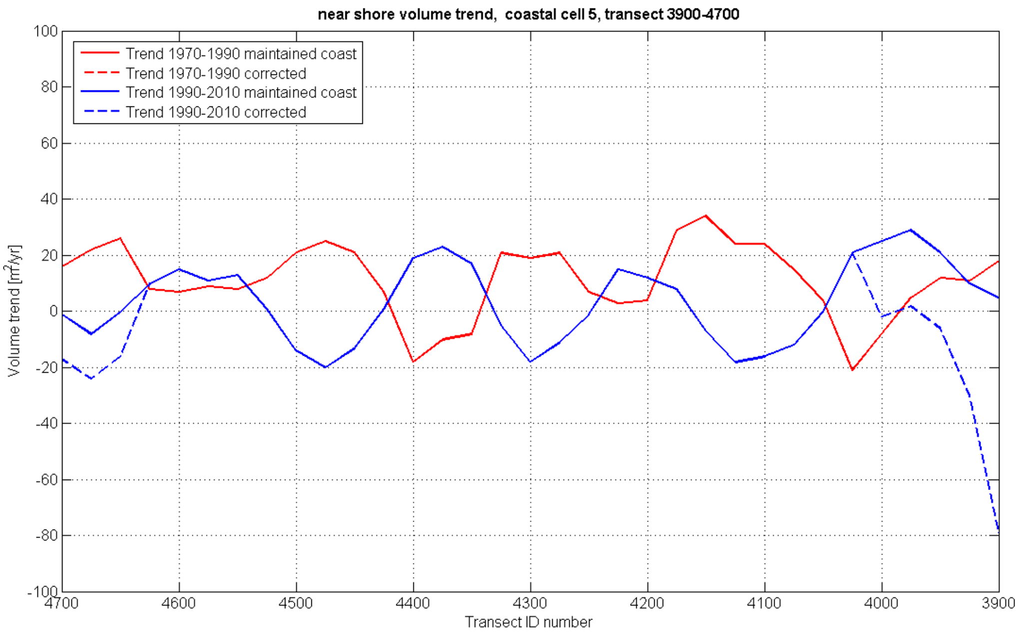


Fig 4.28 Near shore volume trends cell 5, -100 - + 750

The coastal stretch shows significant volume variations. It is unclear why these variations come about. When looking at the trends of individual profiles three important remarks can be made. Firstly, individual profiles always show variation in volume. Over the whole Noord-Holland coast year to year variations is in the order of 30 m^3/ m are observed. Furthermore, averaging plays an important role in the generation of trend lines. Due to this temporal variations are lost due to this process. Variability of the near shore volume also influences the trends. Cross-shore and local alongshore processes such as local deepening due to currents and small scale morphologic features induce additional temporal and local volume changes in these trends.

Although the variations cannot be explained completely, it is important to take them into account. When nourishment projects or small scale coastal features are studied, these variations are able to influence results significantly. This teaches that small volume trends in the order of 10 m^3 / m per year are difficul, or even impossible to extract.

4.5.6 Coastal cell 6 and 7 (Wijk aan Zee, km 47.0 to km 55.0)

Coastal cell 6 (transects 4700-5000) and coastal cell 7 (transects 5000-5500) will be treated in one paragraph. The first cell mentioned is relatively small. The cells are the most southward located cells. The harbour moles of IJmuiden are expected to play a role in the near shore volume evolution of both. The volume evolution is treated separately. In figure 4.29 the volumes of cell 6 are present, in figure 4.30 cell 7 is presented.

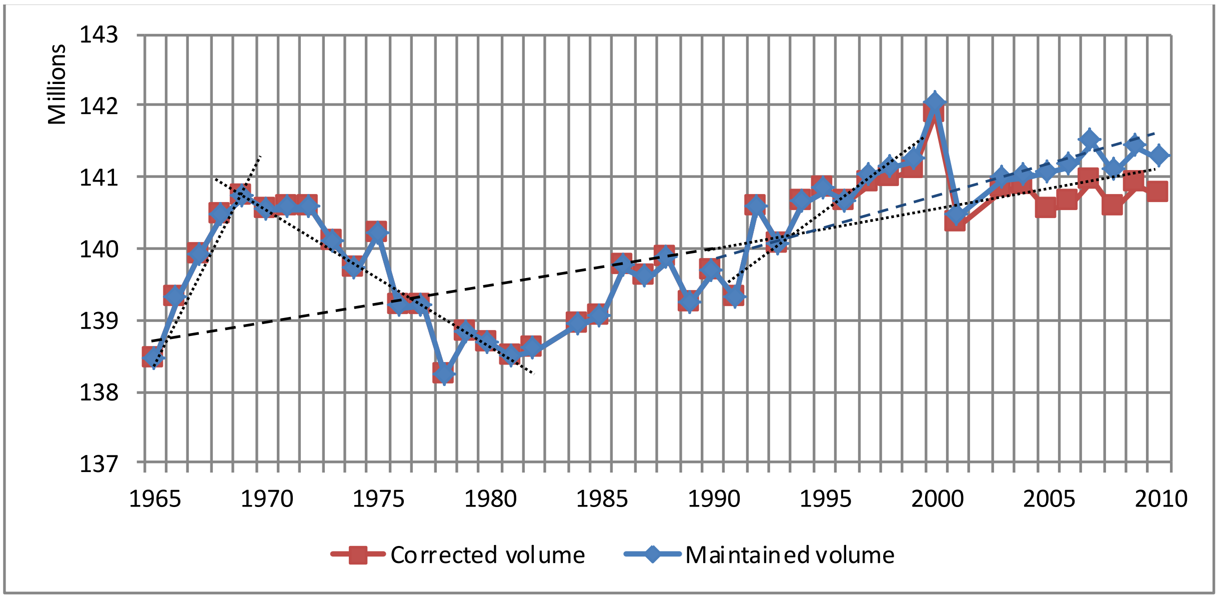


Fig 4.29 Near shore volume cell 6, -100 - + 750 m RSP

Coastal cell 6 shows over the period 1965-1990 mild accretion. The black dashed trend is not representative for the temporal volume changes in the first ten years. Over the period 1965 - 1970 the near shore volume increases yearly with 500.000 m^3. After 1971 an erosive trend can be observed. The trend shows yearly erosion in the order of 200-500.000 m^3. In the near shore volume evolution of cell 5, a similar volume gain, followed by a decreasing volume is found over the same years. In Annex VIII Jarkus profiles sketch qualitative way the influence of bar behaviour on the near shore volume. Bar behaviour seems to be at least partly responsible for the temporal volume changes.

Since 1990 a trend in the order of 200-300.000 m^3 sedimentation is found. By continuing the trend line over the first 25 years a fit can be made over the period 1990-2010 for the corrected volume. The blue stripped line indicates the maintained trend. The trend is steeper compared to the autonomous trend taken over the full surveyed period. This indicates that the effect of the nourishments on the volume is still notable, eventhough little nourishments have been executed.

Coastal cell 7 shows steady accretion in the period 1965-1990. The near shore volume gained 1.5 million m^3. From figure 4.30 temporal fluctuations in the order of 800.000 m^3 are present. These fluctuations are about three times smaller compared to the temporal fluctuations observed in coastal cell 6. Over the period 1990 - 2010 the near shore zone increases with a similar rate compared to the years 1965 to 1990. A notable fluctuation is present over the years 1998-2003. The studied Jarkus profiles (5200, 5300 and 5400) indicate they are caused by bar behaviour. For this phenomenom the writer refers to paragraph 2.4.2 and Annex VIII (examples cell 3, 5 and 6). In 1996 and 1997 two nourishments have been executed. Without the nourishments the trend line since 1965 would be considerably lower. This indicates that the nourishments were needed to maintain the near shore volume. The red dotted line in figure 4.25 shows this corrected trend.

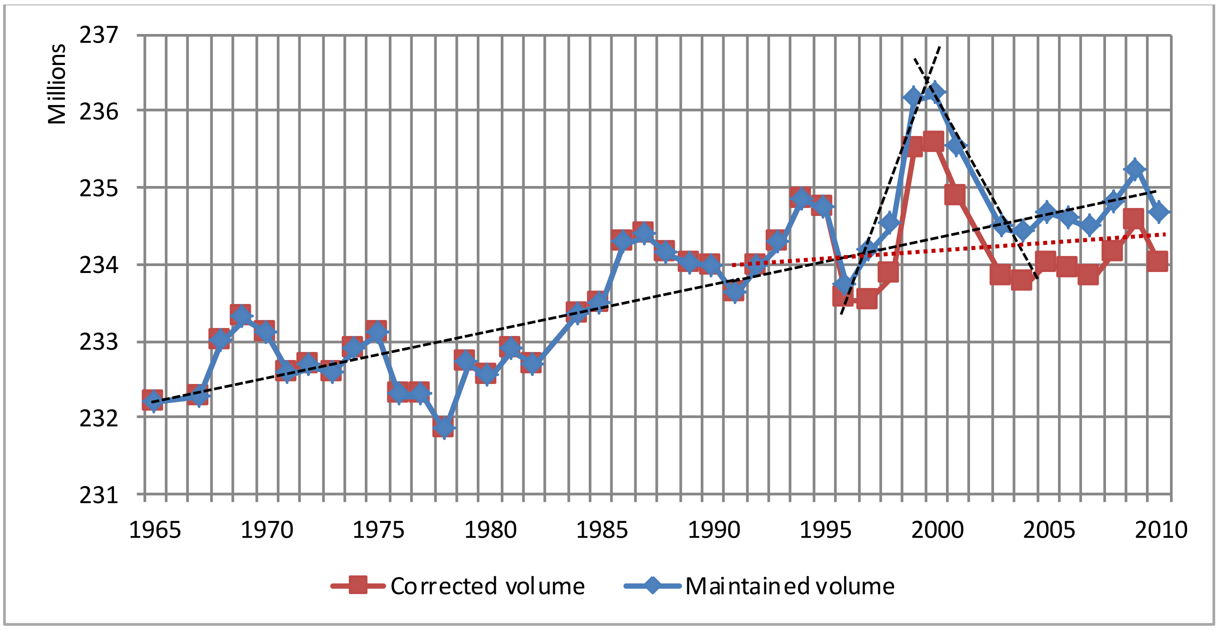


Fig 4.30 Near shore volume cell 7, -100 - + 750 m RSP

The alongshore distribution of volume trends is presented in figure 4.31. The period 1970-1990 shows accretion near the harbour mole. From transect 5000 northward a steady coastline is present. Little fluctuations are found and no erosion seems to occur. Looking at the trend 1990-2010 a few differences can be observed.

The volume trends in the area near the harbour mole a decreasing positive trend. The trend 1990 - 2010 still shows accretion, however less compared to 1970-1990. It indicates that a steady state after the impact of the extension of the harbour mole still is not reached. The decreasing trend does point towards an evolution to this state. From transect 5100 northward the steady trend made way for erosion in the order of -40 m^3/m year. Nourishments have partly compensated for the losses.

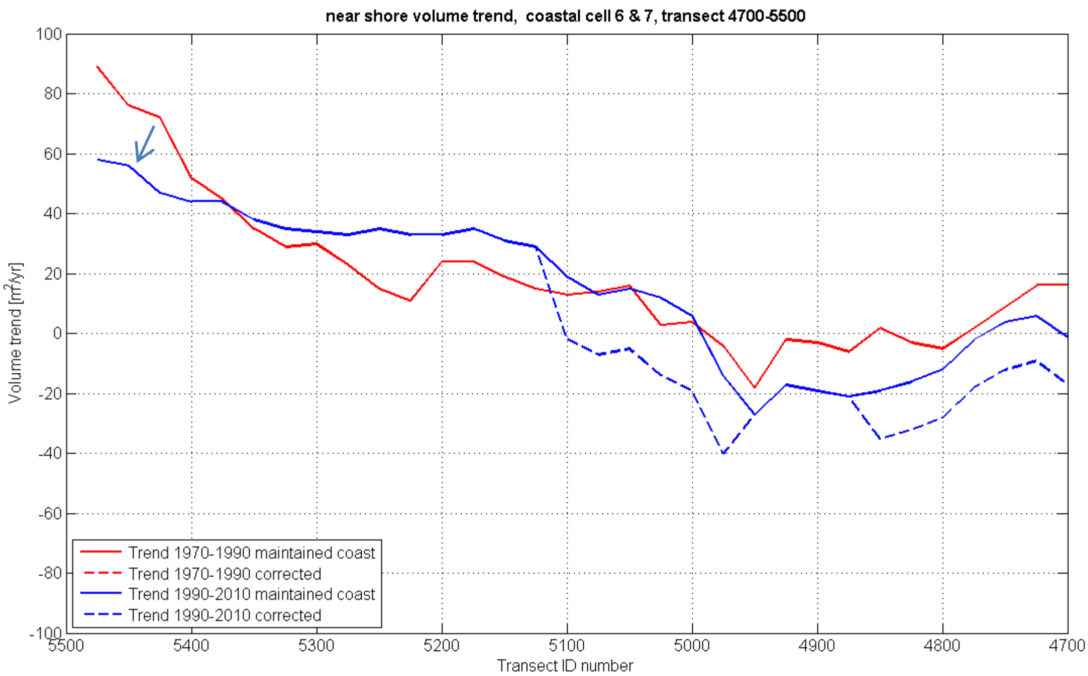


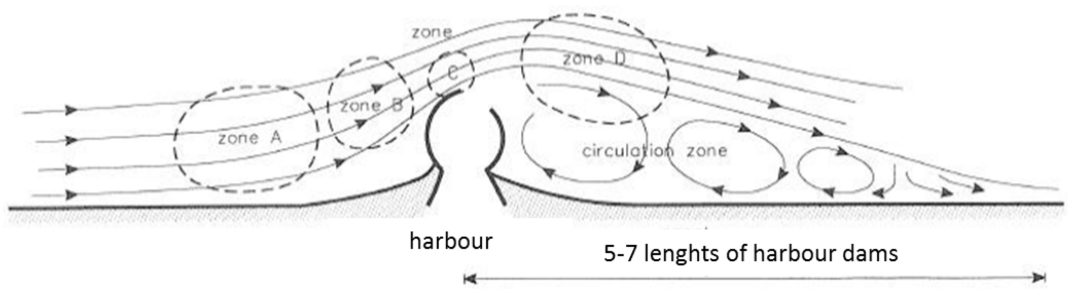
Fig 4.31 Near shore volume trends, cell 6 and 7, -100 - + 750

4.5.6.1 The impact of the constructed breakwater near IJmuiden

The breakwaters that protect the harbour of IJmuiden extend 1 – 2 km into the sea. Thereby they block the wave induced longshore current present in the surfzone and force the tidal current to more around the structures. This has substantial consequences for the morphologic character of the area. Direct volume changes of the nearby shore due to such a structure can be found 5-7 lenghts of the moles on either side. Often erosion is described The time-scale of the impact of the structure is in the order of a few decades to a century. After that time it is expected an equilibrium state is reached.

According to Van de Rest (2004) a net sediment transport is directed toward the harbour, both from northern and southern direction. The breakwaters also act as shelter zone. The southern side of the harbour faces less wave attack from storms surges from the north-west. Other hydrodynamic effects also play a role in shaping the nearby coast. Van Rijn (1995) puts forward a theory in which the convergence and divergence of the tidal current explain the morphologic behaviour of the adjacent coast.

The longshore (tidal) current near harbour moles



zone A : erosion by converging current
zone B : sedimentation due to reduced wave stirring effect (deeper water)
zone C : local scour by increased velocities
zone D : diffusive sedimentation in circulation zone generated by diverging current

Fig 4.32 The longshore (tidal) current near harbour moles (After: Van Rijn, 1995)

Van Rijn distinguishes four zones. Firstly, a converging current leads to higher velocities. Thereby a gradient in longshore transport comes about. This gradient leads to local erosion in zone A. For the case of IJmuiden this zone seems to 7-10 km south of the harbour. On the north side erosion is found 5-8 km north. In zone B sedimentation takes place due to the fact that waves at deep water are not able to stir up sediment as much as in shallow water. Zone C generates local erosion due to higher velocities and turbulence near the structure. In zone D sedimentation is found. The sediment transport capacity of the longshore current starts to become less.

The effects of mixing between the circulation zone and the tidal current down drift of the harbour are complex and not often studied. By observing the volume evolution of cell 7 (figure 4.30), year to year fluctuations in the order 200-700.000 m^3 can be found. These currents are likely to stir up sediment particles and transport them in and out of the study area. With the presented data it is difficult to link these fluctuations to the processes present.

4.6 Results analysis of the Noord-Holland coast

The description of the coastal cells leads to an overview of the whole Noord-Holland coast. The volume of the near shore zone, the nourishment volumes and sedimentation / erosion rates are used. The description has been made with the use of the Jarkus-data mentioned in paragraph 4.1. The timeframe over which the analysis is made is forty five years. The dataset provided information from the year 1965 to 2010.

Firstly the averaged sedimentation - erosion rates will be presented per cell. Secondly attention will be paid towards the alongshore and cross-shore variability. To support the system description the evolution of the coastline is discussed. While this evolution does not affect the sand budget model, it is of importance to assess a successful maintenance strategy. Finally a sand budget model will be presented.

The sedimentation and erosion rates have been derived from the trends indicated per coastal cell. The near shore volume trends with boundaries (-100 - +750) can be found in pagragraph 4.5. The trends calculated with the boundaries (-100 - +1200) are found in Annex VII.

The volume changes cover the coastal cells as described in paragraph 4.3 and are bounded by the cross-shore distances mentioned in table 4.1. To cover the whole cell, each Jarkus-profile represents an alongshore stretch with a width of the lateral profile.

For the period 1965-1990 the results of the near shore volume calculations are presented in table 4.2. The results of the volume change over the period 1965 to 1990 directly obtained from the Jarkus-profiles are firstly listed. It is reffered to as the maintained volume. The second column contains the "corrected near shore volume". The surveyed volumes are been corrected for the volume added through nourishments. By following these trends the autonomous change over this period is obtained. The volume changes are refered to as the autonomous behaviour. They represent an indication of the occurred volume changes without coastal maintenance.

Coastal cells	Boundaries	-100 - + 750	Boundaries	-100 - + 1200	
1965-1990	Maintained	Autonomous	Maintained	Autonomous	Nourishments
1	-10,23	-10,23	-14,33	-14,33	0,00
2	-3,81	-7,01	-5,73	-8,93	3,20
3	-3,05	-3,83	-6,12	-7,44	0,78
4	-4,95	-4,95	-3,48	-3,48	0,00
5	5,96	5,96	11,73	11,73	0,00
6	-1,62	-1,62	-1,59	-1,59	0,00
7	0,12	0,12	-	0,00	0,00
Total	-17,59	-21,56	-19,52	-24,04	3,98

Table 4.2 Volumes changes per cell 1965-1990 [x 10^6 in m^3]

From these volume it can be concluded that the near shore zone of all coastal cells except for coastal cell 5 have shown erosive behaviour over the period 1965 to 1990. Coastal cell 1 and coastal cell 4 show the largest losses. Dateset 2, with a seaward boundary of 1200 m with respect to RSP shows considerable larger losses. An exception is coastal cell 5. This section has gained 11 million m^3. The effects of the extension of the harbour mole near IJmuiden are expected to have contributed to this.

The effects of nourishments in coastal cell 2 are considerable. The other cells have not received sediment through nourishments. Therefore, the autonomous volume change and the maintained volume change are the same. By studying dataset 2 (-100 - + 1200) similar rates are observed. Slightly larger losses can be found, partly outside the surf zone.

In table 4.3 the volume changes over the period 1990 – 2010 are presented. Over this period, 44 million cubic meter sediment has been brought to the system artificially, in the shape of nourishments.

Coastal cells	Boundaries	-100 - + 750	Boundaries	-100 - + 1200	
1990-2010	Maintained	Autonomous	Maintained	Autonomous	Nourishments
1	0,15	-10,88	4,38	-6,65	11,03
2	6,44	-2,33	5,02	-3,75	8,77
3	6,87	-3,34	5,19	-5,01	10,21
4	7,48	-4,08	2,28	-9,28	11,55
5	1,78	0,41	0,87	-0,51	1,37
6	0,63	0,10	3,14	2,62	0,53
7	-0,41	-1,06	0,69	0,04	0,65
Total	23,35	-21,18	21,57	-22,54	44,11

Table 4.3 Volume changes per cell 1990-2010 [x 10^6 in m^3]

Looking at the total volume changes (data set 1, - 100 - + 750 m RSP), one can observe that the volume gain within this time interval is about half of the nourished sediment. With the assumption that the autonomous trend represents a conservative indication of the erosion present over this period, the following theory can be presented;

The nourishments have been able to compensate for the losses. Erosion caused the near shore volume to degrade with 22.5 million m^3. A nourished volume of 44 million m^3 has entered the system. As a result the volume of the near shore coastal zone has increased with 21.6 million m^3.

With this assumption a more or less closed balance can be found. The assumption can be supported by comparing the erosion rate over the period 1965 – 1990. Over this period a yearly loss of about 930.000 m^3 is present. Taking into account a period of similar duration, erosion caused a volume loss of 18.6 million m^3. A loss of similar order compared to the period 1990 – 2010. For dataset 2 similar results are obtained.

With these results it can be established that the Noord-Holland coast is an erosive coastal stretch. Over the last forty five years erosion has been established over almost the whole near shore zone. Due to the coastal maintenance strategy the near shore volume gained about 20 million m^3.

If the objective of the maintenance strategy was to maintain the volume present in the year 1990, one can conclude a significant smaller nourished volume would have been sufficient. About fifty percent of the nourished volume allowed the near shore zone to gain volume.

Alongshore variations

The alongshore differences of the near shore volumes, between coastal cells are quite significant. A representation of this is shared in figure 4.28. Per coastal cell the maintained and autonomous (corrected) near shore volume changes are presented.

Looking closer to the coastal cells, the four most northward cells show erosion. Cells 5, 6 and 7 show volume gain. By comparing the volume evolution per coastal cell one can observe that often volume losses present over the period 1970 – 1990, differ significantly with respect to the autonomous (corrected) volume over the years 1990 – 2010. This indicates that over the studied period local morphologic changes have occurred. With respect to cell 1, one can conclude that this area has become less erosive.

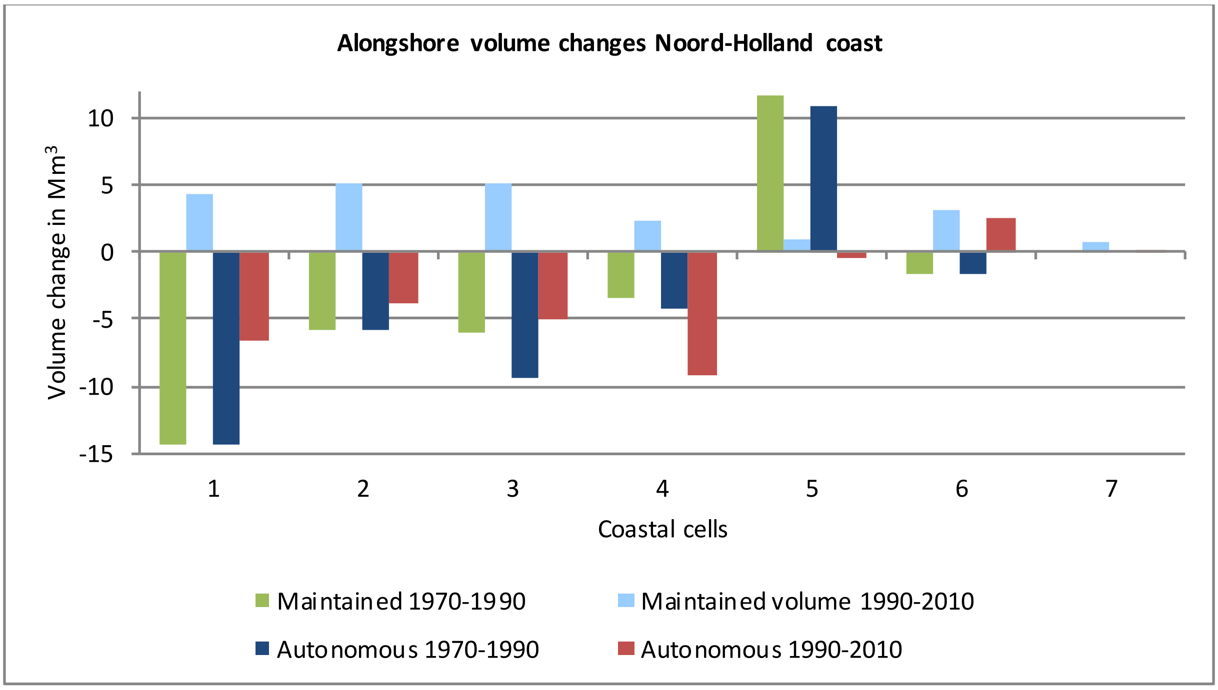


Figure 4.33 Near shore coastal volumes per cell (-100 - + 1200)

Yearly averaged erosion – sedimentation rates

The studied volume evolution allows us to calculate yearly averaged erosion – sedimentation rates per coastal cell. In figure 4.4 these rates are listed. The rates represent the slope of the trends presented in paragraph 4.5.

For two periods the sedimentation – erosion rates have been derived. Chosen is to select two periods, each with a duration of 20 years. Thereby an indication is given over the period 1970 – 1990 and 1990 – 2010.

Yearly averaged erosion / sedimentation rates Noord-Holland coast				(-100 - + 750 m RSP)		
Coastal cells	1970 – 1990 Maintained	1990-2010 Maintained	1965 – 2010 Maintained	1970-1990 Autonomous	1990-2010 Autonomous	1965-2010 Autonomous
1	- 480	- 45	- 224	- 570	- 610	- 470
2	- 125	+ 305	+ 100	- 270	- 135	- 160
3	- 340	380	+ 84	- 340	- 130	- 140
4	- 220	+ 375	+ 55	-260	-200	- 210
5	+ 15	+ 90	+ 170	+ 15	+ 55	+ 155
6	- 45	+ 80	+ 62	- 45	+ 55	+ 23
7	+ 45	+ 35	+ 55	+ 45	0	+ 40
Total	- 1150	+ 1220	+ 302	- 1425	- 965	- 826

Table 4.4 Yearly sedimentation / erosion rates per cell (in m^3 x 1000)

An important remark is that the average rate can differ strongly from temporal erosion rates. As the volume evolution presented in figures 4.21, 4.27, 4.29 and 4.30 indicate. Temporal rates are found to be significantly higher.

Cross-shore variations

Since 1990 the Jarkus-surveys extended further seaward. Therefore it seemed interesting to look closer to local cross-shore distribution of losses and gains for the period 1990 - 2010. Furthermore, data of the deeper part of the near shore zone could provide further information regarding the term coastal foundation. The coastal foundation is the area that is of vital importance for the protection against flooding and that carries all functions present in the coastal area. The coastal foundation includes the coastal sandy area, with a seaward boundary of – 20 m NAP. As landward boundary the whole dune area including the sea defence structures (Min V&W, Nota Ruimte, 2006). The second coastal policy (Kustnota 2, 1995) states that "*it is necessary to compensate for erosion of the deeper part of the coast in order to successfully apply the policy of dynamic preservation*". Apparently losses occur in the deeper part of the near shore zone. When realizing that the upper part of the profile is heaviliy maintained, steepening of the profile should occur, if this process is present.

To analysing the deeper part of the near shore zone, attempts have been made to confirm (long term) erosion of the area till + 1500 m with respect to the RSP. Alongshore the coastal cells proposed by van Rijn (1997) have been used. When alongshore variations of the profile were significant, the cells were divided into cells with similar morphology.

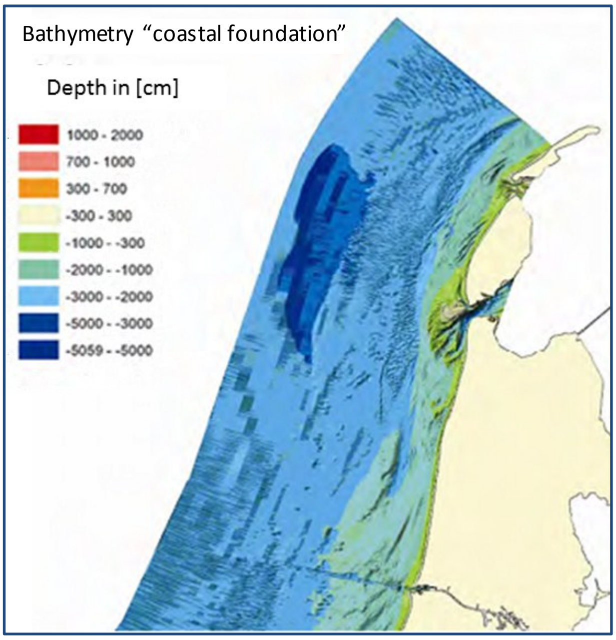


Fig. 4.29 The bathymetry of the coastal foundation adjacent to the province of Noord-Holland (After Deltares study "dynamic seaward growth dutch coast" 2010)

The crossshore profile was divided into into six parts. Per coastal cell the volumes of all Jarkus-profiles have been calculated for these parts. An important note is that the nourishment volumes are included in these numbers. Originally it seemed that losses seaward of the – 8 m line could be observed. Furthermore, the near shore zone landward of the – 8 m line gained volume. This could be explained by coastal maintenance (nourishments). The results however showed not to be very reliable. Selecting different cross-shore boundaries influenced the outcome of sedimentation and erosion trends significantly.

Local temporal processes play a significant role in the cross-shore profile evolution. Steepening, due to local changes such as bar behaviour interfere significantly with long term profile trends. The morphologic adaptation of coastal cells 5 -7 to a new equilibrium state due to the extension of the northern harbour mole also influence this process. By observing the volume evolution of such areas, it is difficult to come to conclusions or even to observe steepening or degradation of the deeper near shore zone.

To analyse this process volume trends with a high spatial resolution (small cells) both in alongshore and cross-shore direction is required. Furthermore, the application statistical operation to compensate for temporal volume fluctuations might be necessary.
A second remark with regards to maintenance of the coastal foundation relates to steepening of the profile. Near Den Helder steep profiles could pose a threat on medium term timescale towards the ability to protect the hinterland against flooding. Over the rest of the Noord-Holland coast mild profile slopes are present. Within the analyses of the volumes presented in this thesis there are no indications that similar situations are reached within decades.

4.7 Coastline evolution

In the previous chapters the near shore volume has been analysed and treated. However, the location of the coastline is just as much an indication of the state of a coastal stretch. Moreover, the evolution of the coastline position could indicate a possible successful nourishment strategy. Therefore for several locations the coastline evolution has been documented. For each coastal cell two locations have been selected as representation of their coastal cells. For these locations the average position of the Mean Low Water Line (MLWL) is documented. While two locations per cell seem rather limited, a general overview has given a clear indication of its evolution. In table 4.4 this is presented. A positive number represents seaward movement, a negative one coastal retreat.

Location	cell	1900-1965[1]	1965 – 1990	1990 – 2010	Total
Huisduinen 0,2 km	1	- 95	- 40	+ 10	- 125
Transect 808	1	- 120	- 25	+ 45	- 100
Callantsoog 13 km	2	- 50	- 10	-	- 60
Transect 1503	2	0	- 10	0	- 10
Transect 1791	3	- 40	- 10	-	- 50
Transect 3050 “de Kerf”	4	- 105	- 10	0	- 115
Bergen aan Zee 3300	4	+ 10	+ 10	0	+ 20
Transect 3600	4	- 30	+ 25	+ 15	+ 10
Egmond aan Zee 3800	4	+ 25	+ 15	+ 50	+ 90
Transect 4000	5	+ 25	- 40	+ 45	+ 20
Transect 4700	6	+ 20	- 50	+ 90	+ 60
Transect 5000	7	- 35	+ 20	+ 30	+ 15
Wijk aan Zee 5500	7	+ 40	+ 130	+ 80	+ 250

Table 4.5 Measured coastline evolution mean low water line (summer) 1900 – 2010

Over the last century the northern coastal cells have shown landward movement of the mean low water line. The southern cells have shown seaward movement. Alongshore a variation of 375 meter is present. Since 1990 no landward movement for these locations could be established. Most locations show a seaward movement in the order of ten to ninety meters.

In order to put these numbers in perspective, a table with an analysis far longer is presented. Taken from the Kustgenese project (1995) coastline retreat for the Noord-Holland coast is summarized. From table 4.4 it becomes clear that coastline retreat has been present over the last four hundred years. Towards the present time the landward movement decreased.

Location	1600 - 1700	1700 - 1800	1800 - 1900	1900 – 1990	Total
Huisduinen 0,2 km	450	300	150	100	1000
Callantsoog 13 km	250	150	80	70	550
Seawall Petten 23 km	400	300	100	100	900
Egmond 38 km	150	100	30	0	280

Table 4.6 Rough estimates of coastline retreat 1600 – 1990 (kustgenese, 1995)

The Basal Coast Line implemented in 1990 as part of the policy “Dynamic Preservation” was meant to prevent coastline retreat. This concept is discussed in chapter 6. With the presented results and by observing additional available coastline data[1] we can make conclude that over the last twenty years the current nourishment strategy has been successful in maintaining the position of the Basal Coast Line.

1 available through the OpenEarth repository, MLWL presented in Google Earth, with respect to the RSP

5 The sand budget model

Sedimentation and erosion rates

The sedimentation and erosion trends presented in chapter 4 and the net sediment transport rates presented in paragraph 2.5 enable the generation of a sand budget model. The net losses and gains of the near shore zone of the two datasets have been averaged. The results are the yearly sedimentation and erosion rates per coastal cell. They have been presented in paragraph 4.4. The rates originate from the volume changes minus the nourishments. This leads towards an overestimation of erosion rates of those cells that have gained volume over the last twenty years.

Alongshore transport

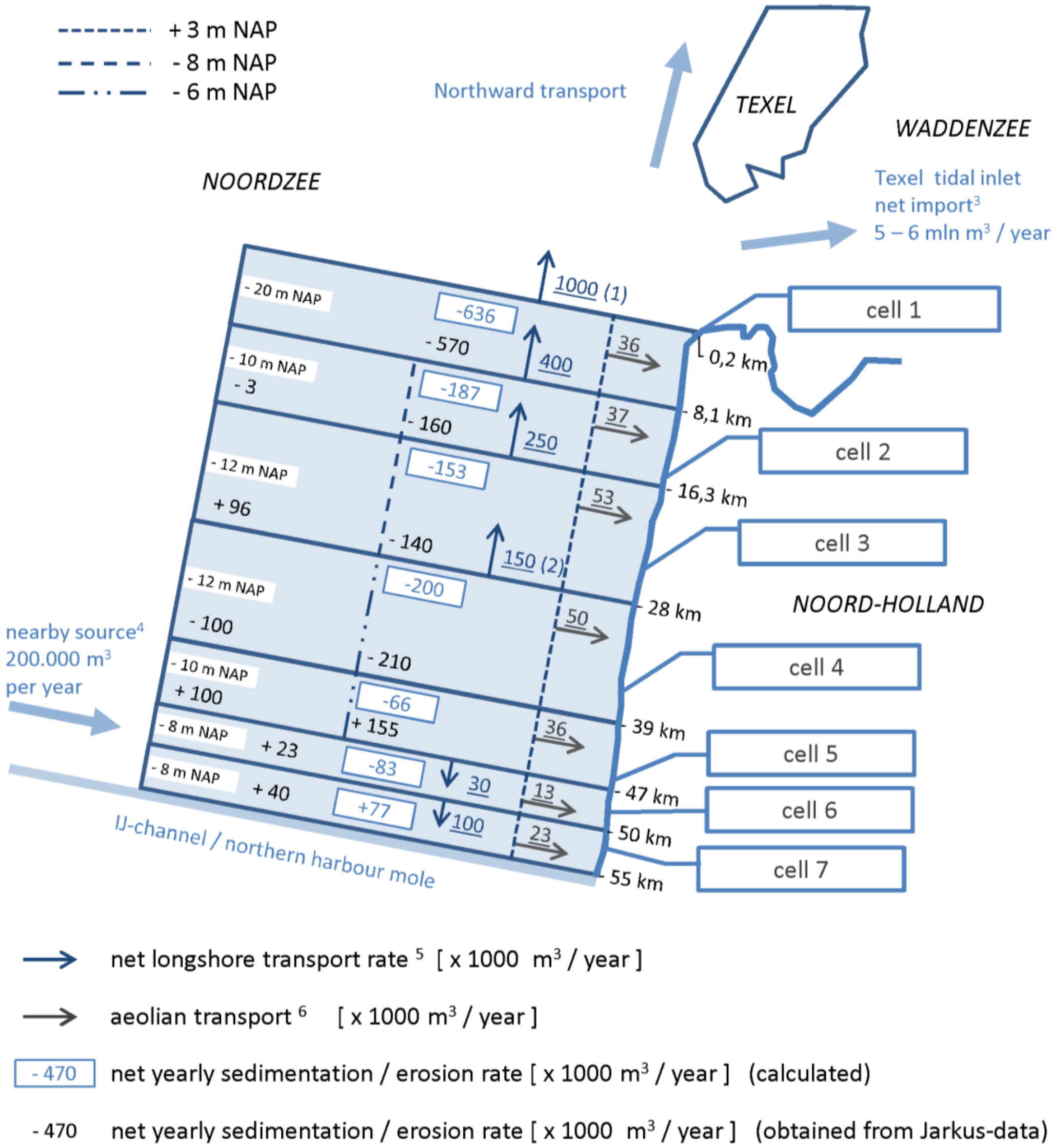
At the alongshore boundaries of each cell net sediment transport rates have been determined by obtaining the results from figure 2.14. The net transport rates presented by Van de Rest (2004) originate from this graph. By reading the net sediment transport rate at the boundary of each cell, gradients of the longshore transport over the surfzone are determined. Gradients in alongshore transport determine the transport capacity within an area. If the sediment transport rate at the northward boundary is higher compared to the southward boundary, a gradient exists. This gradient leads towards erosion within the cell. In table 5.1 the values of the longshore transport rates are presented. The values indicated in green have been used in the sand budget model

Net averaged longshore sediment transport rates per coastal cell [x 1000 m^3 / year]							
Study:	1	2	3	4	5	6	7
Stive and Eysink (1989)	1000	750	550	300	50	12	10
Van Rijn (1995)	500	370	240	50	-100	-150	-150
Van de Rest (2004)	500	400	250	150	0	- 30	-100
Boundaries + 3 m - – 8 m NAP							

Table 5.1 Net averaged longshore transport rates per coastal cell [x 1000 m^3 / year]
(Per cell the value of the northward bound is used)
(Positive values are northward directed, negative values represent southward transport)

The northward alongshore transport at the boundaries of coastal cell 1 have been adjusted. The occurring erosion could not be explained by the transport gradient estimated by Van de Rest (2004). The study of Stive and Eysink (1989) indicated a substantive larger transport near the most northward boundary. By obtaining this transport rate, the sinks and sources show consistency with the occurring losses. Van Rijn (1995) calculated a larger net averaged yearly transport rate for the northern boundary taking into account the deeper part of the near shore zone. He puts forward a transport of 500.000 m^3 / year over the + 3 - – 8 m NAP zone and an additional 900.000 m^3 / year for the zone – 8 - – 20m NAP.

Over the deeper part of the near shore zone, the reliability of the transport rates is lower compared to those contained in the surfzone. Less data is present to validate the model. Therefore it is chosen to confine the study to the transports present in the surfzone.



1) Adjusted net sediment transport rates following Stive and Eysink (1989)
2) not modified for used boundaries
3) Indicative net sediment transport rates according to Elias (2006)
4) According to Hoogewoning (2001) Inventory dredging and dumping RIKZ
5) Obtained from Van de Rest (2004)
6) Results from Van Vessem and Stolk (2004) and De Ruig (1989) (averaged)

Fig 5.1 The sand budget model

Each of the studied coastal cells contains the calculated sedimentation / erosion rate (black). The blue rates are obtained by adding and substracting the present the sources and sinks. Expected sources and sinks adjacent to the study area are indicated with the light blue arrows.

Aeolian transport

At the landward boundary losses due to landward Aeolian transport have been calculated from each cell. The presented transport rates by Van Vessem and Stolk (1990) and De Ruig (1989) are used. They concluded yearly average aeolian transport rates for the whole (Noord-) Holland coast. By correcting for the length of the cells, net averaged values per cells are presented. Aeolian transport rates can vary significanty. Within the studies of Van Vessem, De Ruig and Van der Wal, substantial different findings have been found. Therefore the average of two studies is taken.

Calculated average aeolian transport rates [x 1000 m^3 / year]							
Study	1 8.1 km	2 8.2 km	3 11.7 km	4 8 km	5 8 km	6 3 km	7 5 km
Van Vessem and Stolk (1990) (2.5 m^3/m)	22.1	22.3	31.9	21.8	21.8	8.2	13.6
De Ruig (1989) (6 m^3/m)	50	52	74.1	78.2	50	17.8	32.4
Averaged Aeolean transport (4.4 m^3/m)	36	37	53	50	36	13	23

Table 5.2 Aeolian transport rates [x 1000 m^3 / year]

Limitations

The sand budget model presented has a few limitations. Firstly, net cross-shore sediment transport rates have not been implemented. Within the scope of this thesis, the transport rates for the Noord-Holland coast have not been studied. A net onshore transport is often mentioned at the minus 8 m NAP line. Stive and Eysink (1989) and Van Rijn (1994) have both described these transports. General consensus on the occurring transports is not available. This makes it difficult to implement them.

Net sediment transport rates of the deeper part are left out of the balance. The main reason for this is the difference in seaward bounds for each cell. The sediment transport rate for coastal cell 4 and 6 occurs over the whole surfzone. The first dataset does not fully cover this zone.

Vital information of the deeper part of the Noord-Holland coast is necessary. The large yearly volume gain present in coastal cell 3 and the substantial losses in cell 4 cannot be explained by the analysis made in chapter 4. Improvements on the sand budget model can be made.

Results

In general the results of the sand budget model, the occurring losses and the assumed net sediment transport rates can be explained reasonably well. The sediment transport rate at the boundary of cell 1 is consistent with the model results from Elias (2006) (paragraph 4.3.1.2). The net gain of coastal cells 5, 6 and 7 seem to be consistent with the theory of Van Rijn with regards to the harbour moles. This is described in paragraph 4.3.6.1.

The large losses near Egmond aan Zee and Bergen aan Zee are currently explained by the gradient in net sediment transport rates. The large losses found over the deeper part of this cell (minus 12 m NAP to minus 6 m NAP) might be a plausible explanation.

6 Coastal management

6.1 Coastal Zone Management; the Dutch policy

In the previous chapters it is established that the Noord-Holland coast is subject to erosion. In the past several measures have been taken to counteract coastline retreat. The Dutch have a long history when it comes to counteracting floods and water management. The demographic development of the Netherlands has changed the way in which mankind dealt with this issue. The importance of a safe hinterland thereby increased. Population growth, an increasing economic value to protect and the paradigm of decreasing social and political acceptance of flooding have influenced this.

In the last century the population of the Netherlands has been growing from 5 million inhabitants to a population of 16 million. Since the year 2000 more than half of this number lives in an area below mean sea level. Each year, sixty per cent of the Gross Domestic Product is generated in this area. (CBS, 2000). For these reasons the ability to provide safety against flooding is an essential matter. Managing the coastal zone and mitigating occurring erosion plays an important role in providing his safety.

6.1.1 Coastal zone management pre 1990

About 500 years ago first actions were undertaken to systematically prevent flooding. The establishment of local water boards took place around the 15th century. The establishment enabled cooperation to provide safety against high water in a structured manner. In 1667 Hendrik Stevin came forward with a proposal to establish a system of levees to assure safety against the dangerous waters of the Noord-Zee. A few hundred years later, the closure of the Zuiderzee provided a safety level for the northern part of the Netherlands.

Providing safety was the main paradigm of coastal zone management. This paradigm was heavily influenced by large scale floods. After the storm surge disaster of 1953, the Delta-project started. The project aimed to assure safety on a system level. In the next three decades large scale structures closed tidal inlets. Dikes were strengthened and a delta-safety level was introduced.

The solutions presented were mostly focussed on the issue of safety. Some measures also led to degradation of area involved or relocation of problems. Examples are local erosion problems near the Hondsbossche sea defense and poor water quality in the closed basins. Halfway, during the execution of the Delta-project, attention was drawn towards the possible negative effects of seawalls, closure dams and hard measures. Ecology and other functions started to play a role. Stakeholders became involved in the decision making process.

After the completion of the Delta-program and the establishment of a prescribed safety level more attention was paid towards these negative effects. Structural erosion and sustainable measures became important aspects of the coastal policy. Before 1990 interference due to coastal erosion problems often meant the construction of hard defence structures. Often these structures are still part of the current coastal defence.

Since 1960 Rijkswaterstaat was gaining experience to solve coastal erosion problems with soft solutions. Volumes of sediment were added to dune rows, beaches and later on at the foreshore. The artificial way of adding sediment to the system was called a nourishing. In order to successfully add sediment to the system, further understanding of the coastal zone was needed. Due to these developments the Dutch government developed a new coastal policy at the end of the 80's.

6.1.2 A new paradigm (1990 – 1995)

Based on this research, the government adopted a national policy, in 1990, "dynamic preservation". The introduced policy had the strategic objective "to guarantee a sustainable safety level and sustainable preservation of values and functions in the dune area". (Min V&W 2001) The method to reach the prescribed safety levels and to preserve the values and functions of the coastal zone was focused on maintenance.

To guarantee a coastal state indicator was implemented. In the year 1990 the position of the coastline was established through the concept of the Basal Coast Line (Min V&W 1991). With an indicator that could determine whether or not to nourish a coastal stretch a second concept was born. Koningsveld and Mulder (2004) refer to this concept as: *"A quantitative concept of the actual state of the system, including procedures for objective benchmarking and preferred methods of intervention and maintenance."* This quantitative concept was shaped by the location of the Momentary Coast Line. In paragraph 6.2 more attention to this indicator is paid. Koningsveld and Mulder (2004) also described procedures on how to evaluate the new policy.

The adoption of the policy implied more artificial interference in the coastal system. However, an indirect basic safety level was assured. With the term "dynamic preservation" one implied to take into account the natural dynamics of the coastal system (Min V&W 2001).

6.1.3 Law enforcement and the coastal foundation

In 1995 a second policy report was formulated. It confirmed the policy started five years earlier. The coastal zone was described through a new concept; the coastal foundation. This foundation was described by the coastal sandy area, with a seaward boundary of – 20 m NAP and as landward boundary the whole dune area including the sea defence structures (Nota Ruimte, 2006). The policy states that "*It is necessary to compensate for erosion of the deeper part of the coast in order to successfully apply the policy of dynamic preservation and to avoid weakening of the coastal foundation."* (Kustbalans, 1995).

As a consequence of compensating for erosion of the deeper part of the coast further human interference within the system. An increase of the yearly nourishment volumes was needed for this compensation.

In 1996 an important law was approved. Responsibilities with regards to the coastal defence were enforced by law. Maintenance of the coastline and mitigating structural erosion was appointed to be the responsibility of the national government. Recovery of dune erosion and maintenance of primary water defences became the responsibility of water boards. In addition to these responsibilities safety levels against floods were established. A requirement to test primary water defences once per five years was introduced. The findings of these tests need to be presented to the responsible minister as well as the parliament and congress (de Ronde et al., 2003).

6.1.4 Dynamic Preservation evaluated and a long term perspective

(summary: 3e Kustnota, Min V&W 2000)

The third national coastal policy document (3e Kustnota, Min V&W 2000) was written with a long term perspective in mind. Long term developments such as sea level rise, climate change and demographic developments are treated. For short term (< 5 years) and mid long term perspective (< 30 years) policies are presented. Furthermore an evaluation of the "Dynamic preservation" policy adopted in 1990 is shared.

The evaluation of the “Dynamic Preservation” policy shared is based on six pillars.

- Providing safety against flooding
- Maintaining of the Basal Coast Line position through nourishments (including sustaining the functions of the coastal zone)
- Compensation through nourishments of erosion of the deeper part of the coast (stabilizing the coastal foundation)
- Nourishing the foreshore (the execution of nourishments below mean sea level)
- The performance of flood walls/structure that extend seawards with reference to the position of the Basal Coast Line
- Dynamic maintenance of the dune area

Since the “Dynamic Preservation” was implemented no structural losses have occurred. The average beach width has increased mildly over the period 1990-2000. The areal of dunes increased, young dunes have strengthened dune protection levels. The concept of the Basal Coast Line has proven to be an important coastal state indicator. Cyclic behaviour is not always been taken into account. To maintain the Basal Coast Line as indicator every ten years updates with regards to the position of the dune foot and sea level rise is needed. Expert judgement is necessary to use the concept of the Basal Coast Line in a proper way.

The experience gained with foreshore nourishments led towards positive results. Hindrance during execution towards recreation is limited compared to beach nourishments. Furthermore, foreshore nourishments are proven to be economical more attractive. A larger volume is nourished for a lower price compared to nourishing the beach.

The coastal foundation and thereby the deeper part of the system is found to be erosive (Min V&W, 2000). In order to analyse these losses the coverage monitoring program will be extended seaward. The performance of flood walls / structures is considered to be positive. Within the choice whether or not to apply these ‘hard’ structures the local costs should not be considered as the only criteria for a suitable solution. The added effect of nourishments, including local losses should also play a role.

The policy with regards to maintenance of the dune area was evaluated in Kustbalans (1995). This evaluation indicated room for improvement. Since 1995 steps have been taken to further implement and improve dynamic maintenance. Over seventy five per cent of the dune areas were maintained through these principles. The area has become more natural and the quality of the vegetation present has improved.

The evaluation (Min V&W, 2000) led to the following decisions:

+ The policy Dynamic Preservation will be continued in the next years.
+ Erosion of the deeper part of the coastal zone will be compensated starting in 2001.
+ Maintenance of the dunes with a dynamic mind-set will be continued and expanded.

6.1.5 A safety level vs economic and demographic developments

The adopted safety levels are based on the economic and demographic circumstances present in the year 1950. With the growing population, investments and economic value this safety levels have not been adapted. Therefore the safety level in place does represent the values it needs to protect. For this reason it is expected that in the near future these safety levels will be adjusted. Strengthening of coastal defences therefore needs to be executed in such a way, adaptation in the future is possible. The second Delta Committee (2008) proposed new safety levels. They have not been adopted yet.

6.2 Planning coastal maintenance

6.2.1 Coastal management tools and concepts

The planning of nourishments and the assessment of coastal stretches is led through a few principles or coastal management tools. With these principles a method is generated that allows coastal engineers to plan and analyse coastal stretches in a structured manner. With the Jarkus-data and these concepts the nourishments are planned. One has to acknowledge, that possible processes can take place that cannot be caught with these methods. Therefore expert judgement and awareness is essential in order to provide the hinterland with the required safety. With three basic concepts, in general one is able to explain the method, which is currently used in the Netherlands.

The Momentary Coast Line (MCL)   (Momentane Kust Lijn, MKL)

The assessment of a given profile takes place with the concept of the Momentary Coast Line (MCL). Through the calculation of the volume between two horizontal planes, the upper and lower plane its position can be determined.

The two planes, as indicated in figure 6.1 are located at a distance H of the Mean Low Water level (MLW). The distance H is the determined calculated by subtracting the Mean Low Water level from the level of the Dune Foot line (DF). The dune foot is considered to be at a level of + 3 m with reference to NAP. The Dune Foot line forms the landward boundary (TAW 2002).

Mean Low Water (MLW) is defined as the shore crossing of the local mean low water level. In paragraph 2.3.2 they are described for the Noord-Holland coast and indicated in blue for Texel, Den Helder, IJmuiden and Petten Zuid. On average this level is about 70 centimetres below NAP.

In figure 6.1 , A is the surface of the plane. The reference line represents the “Rijks Strand Palen” line (RSP).The position of the Momentary Coast Line is calculated through:

$$MCL\,(B) = \frac{Surface\ A}{2\ H} \qquad [\,X = MCL\,position\ B + Distance\ Dune\ foot\,to\,reference\,]$$

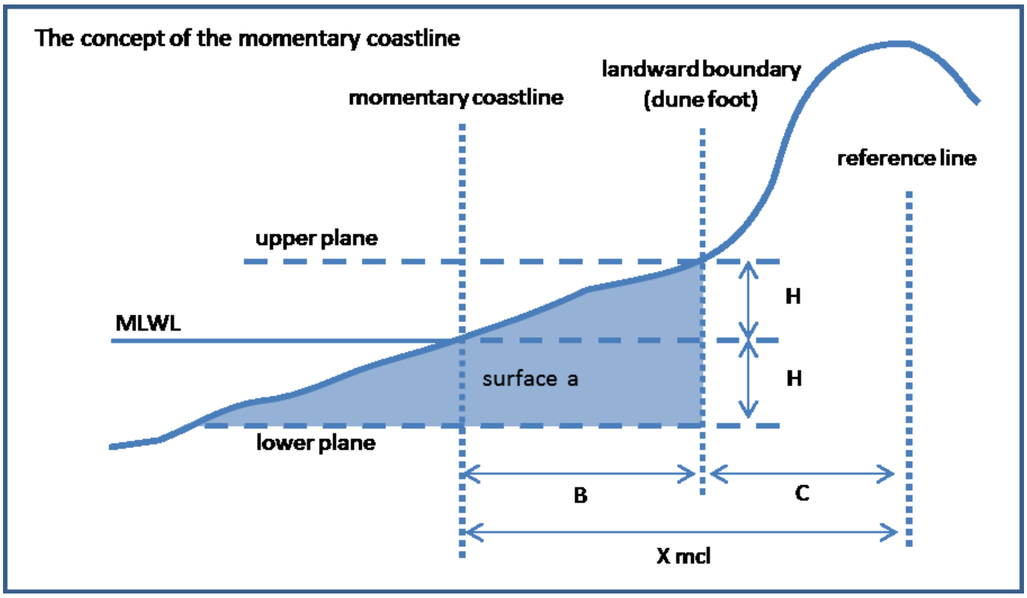


Fig 6.1 The Momentary Coast Line (Source: Min. V&W 1991, after Van Koningsveld and Mulder 2004)

The Basal Coast Line (BCL) (Basis Kust Lijn, BKL)

In practise the Basal Coast Line functions as a reference. When the policy “Dynamic Preservation” was introduced this reference was determined. It originates from the trend of the Momentary Coast Line (MCL) observed over the period 1980 -1990. Over the period of 10 years a trend has been established. The last survey included was executed six months before implementation. Over this period the average location of the momentary coastline was extrapolated. The influence of nourishments was taken into account. On January 1th, in the year 1990 the Basal Coast Line was established (de Ronde et al., 2003).

The Testing Coast Line (TCL) (de te Toetsen Kust Lijn, TKL)

The assessment of the position coastline takes place through the principle of the auditing coastline, or “Test Coast Line”. The various calculated positions of the Momentary Coast Line are interpolated over the period (T minus 10 years). An extrapolation is made till T plus 1 year. The position that is obtained is compared with the position of the Basal Coast Line. When the Basal Coast Line is crossed by this trend, nourishments should be considered. Thereby multiple Jarkus-profiles are assessed. If multiple of these profiles show a similar trend and cross the Basal Coast Line, a nourishment is planned (TAW, 2002).

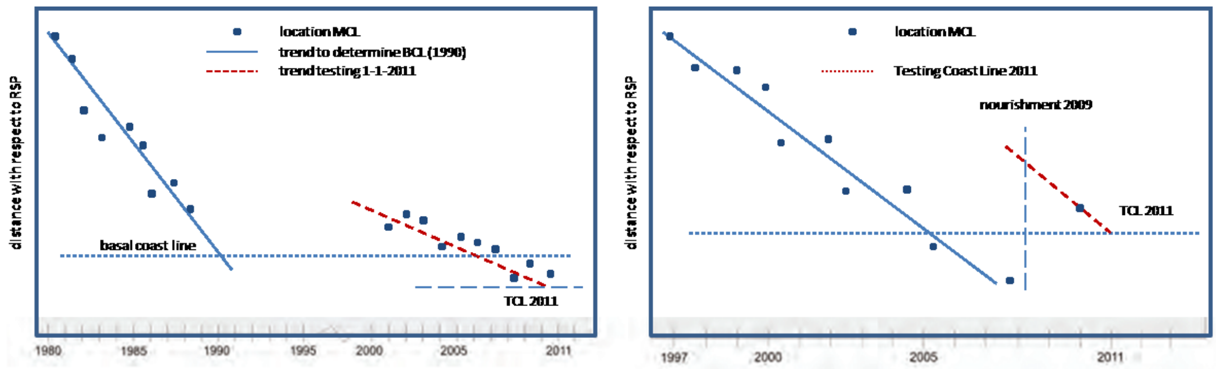


Fig 6.2 a. Example Testing coastline b. Calculation location TCL 2011 and trend (1 year after nourishment)
(Addopted from: Kustlijnkaartenboek 2011, Rijkswaterstaat)

Every year such an assessment takes place. An outcome of such an assessment is presented in figure 6.3. Local fluctuations or crossings are present. Through expert judgement the trends crossing the Basal Coastline are analysed. Based on the trends of all coastal stretches, a nourishment planning is made each year.

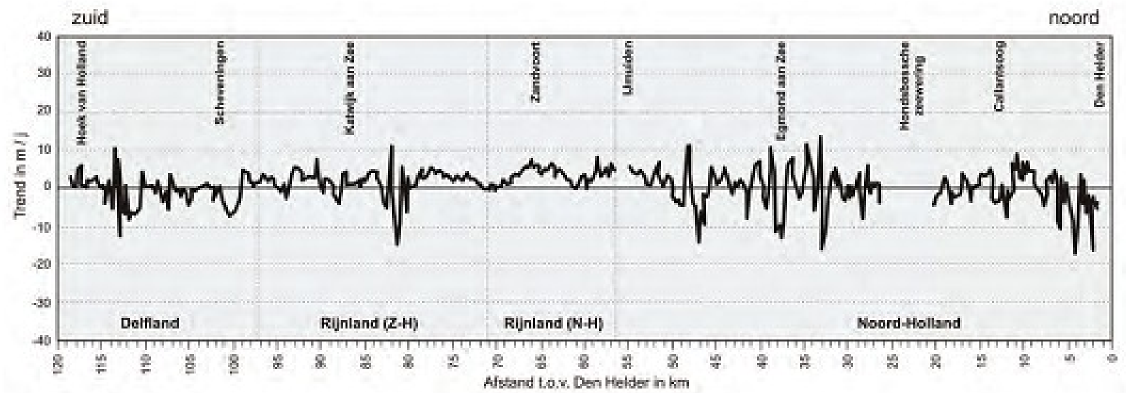


Fig 6.3 Trends for Noord-Holland and Zuid-Holland (Source: Kustlijnkaartenboek 2011, Rijkswaterstaat)

6.2.2 Nourishment program

Each year Rijkswaterstaat the momentary coastline is tested to obtain the state of a coastal stretch through a number of Jarkus-profiles. With the Jarkus-profiles the MCL position is calculated. After this process a number of steps need to be undertaken in order to realize the nourishment program.

In general this program is realized in a cycle of three years. This means that after the first indications which coastal areas to nourish, some time is needed to prepare the execution. Aspects that play an important role within this process is a consultation round with stakeholders, the application of a permit and the tending procedure. The process presented in figure 6.4 indicates that coastal maintenance is not only a technical exercise.

Year 0

- Survey coastline (May - August)
- Testing momentary coastline with reference to BCL (September)
- First indication nourishment locations (October)

Year 1

- Consults with stakeholders
- Adjustments nourishment design

Year 2

- Tending procedure
- Execution nourishments (year 2 + year 3)
- Monitoring nourishments

Fig 6.4 Realization nourishment program (Source: Rijkswaterstaat 2010)

In 2011 Rijkswaterstaat applied for the first time a different methodology. The indications of locations likely needed to be maintained have been determined for a period of 4 years. The aim is that through this approach the market can be made aware of upcoming projects in an early stage. By adopting a flexible timeframe in which the nourishments can be executed, a cost reduction is expected.

6.2.3 Nourishments design

Planning and the design of nourishments can differ for each location. As mentioned in paragraph 6.2.1 the execution is determined by assessing the position of the Momentary Coast Line with respect to the Basal Coastline. According to (TAW, 2002) a general formula is used as a guideline for the design of the nourishment. The required volume depends on the erosion rate and the expected duration in which the added volume is able to compensate for occurring losses. These values are multiplied by a factor that takes into account the uncertainty that comes with the predicted erosion rate.

$$Required\ volume\ =\ \alpha\ \cdot (e\ \times\ t - R)$$

In which e is the erosion rate in [m^3/year];
The factor α is a measure of uncertainty;
The duration is expressed by t [years];
The R stands for extra necessary volume.

The required volume can be considered as a net volume. During dumping of the sediment losses occur. Therefore an extra factor needs to be taken into account.

In general three possible nourishment designs are used. Firstly, sediment can be nourished directly on the beach. Secondly, shore face nourishments provide sediment under the waterline. Sand is nourished near the bars to influence bar behaviour and thereby aiming to counteract erosion of the beach. A thirds option is nourishing the ridge of a channel. This option is mostly chosen to mitigate shoreward movement of present channels.

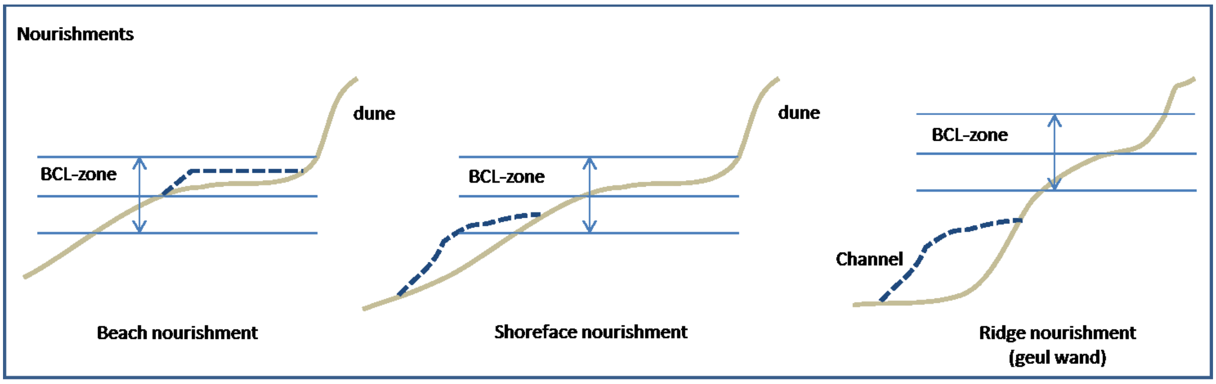


Fig 6.5 Applied nourishment designs (Source: Rijkswaterstaat 2010)

For the Noord-Holland coastal stretch all three designs have been applied. By adding volume the position of the momentary coastline will move landwards. Furthermore by adding sediment to the system one is able to compensate for expected losses. These basic principles hold for all three designs. The results and implications of the different designs however can differ considerably.

Beach nourishments assure a direct adjustment of the momentary coastline position. Foreshore nourishments do not have directly a positive effect on the position of the momentary coastline. Sediment is dumped underwater at the foreshore. Over time (a part of) this volume will influence the profile of the momentary coastline zone.

6.2.4 Policy guidelines and limitations of design

With regards to the effects of single nourishments towards the maintenance policy it is established that they cannot be fully predicted. Both in time and in space sedimentation and erosion patterns the effects depend on various processes. Knowledge about these processes is currently not sufficient. Due to this, pragmatism plays an important role in applying nourishments.

The choice between nourishment designs and location is one that depends on morphodynamic, ecologic and financial aspects. Furthermore the method of execution plays an important role (Min V&W 2000). The third coastal policy shares preferences for nourishment designs. When an immediate safety issue is present, beach nourishments (or dune strengthening) should be applied. If the Basal Coast Line is not yet crossed and time is available, the policy proposes the execution of foreshore nourishments. Hereby the policy shares a clear preference, for nourishments applied under the mean sea level and not at the beach, when this does not affect the issue of safety. When the Basal Coast Line is crossed and safety constrains do not play a role, foreshore nourishments should be executed as close to the beach as possible. An over dimension is preferred to maintain the coastal foundation. When safety is not an issue, foreshore nourishments should be executed at the deeper part of the shoreface (Min V&W 2000).

7 Review nourishment strategy

The current nourishment strategy has been in place since the year 1990. To assess the successfulness and effectiveness the analysis of the volume evolution of the seven coastal cells is used. The state of the Noord-Holland coast described in the preliminary two chapters is the main source on which this evaluation is made. This review does not aim to assess single nourishments. It rather looks at the effects of the application of nourishments in a certain area; in our case, the coastal cells. More specific attention will be paid towards "erosive hot-spots" and highly nourished areas.

In order to determine whether or not the applied maintenance strategy has been successful the goal of the strategy needs to be taken into account. The goal of "Dynamic Preservation" was formulated as follows. The policy should *"guarantee a sustainable safety level and sustainable preservation of values and functions in the dune area"* (Min V&W, 1990). To determine whether or not this objective was reached the following question was formulated:

Does the particular coastal area shows a neutral or positive development with regards towards volume and coastline position?

To make this question more tangible the coastal cells will be used to answer four sub-questions:

+ Is the current maintenance policy able to counteract coastal erosion?
+ If the maintenance policy is able to mitigate coastal erosion, is it able to prevent coastline retreat?
+ Are there areas in which the strategy induced a steady increase of the near shore volume?
+ Is the current applied maintenance strategy successful?

If all these questions can be answered with a firm *"Yes."* we can speak of an effective coastal maintenance policy.

Cells	State	Mitigation	Increase	Coastline position	Successful?
1	-	+	0	+	+
2	-	+	+	+	+
3	-	+	+	0	+
4	-	+	+	+	+
5	+	+	+	+	+
6	+	+	+	+	+
7	+	+	+	+	+
Total	-	+	+	+	+

Table 6.1 Assessment applied coastal maintenance strategy (1990-2010)

Reviewing the presented results per coastal cell one can conclude that the applied coastal maintenance strategy over the period 1990 – 2010 was able to compensate for losses, prevent coastal retreat and has led to a substantial increase of the near shore volume.

The assessment of the applied maintenance strategy requires some explanation. This, together with specific findings and aspects of the applied strategy as well as the effects of nourishments are treated in the next paragraphs. Firstly, the notion of effectiveness is discussed. Secondly, nourishment planning is treated. To round off, recommendations with regards to the policy are shared.

7.1.1 The notion of effectiveness

To assess the effectiveness of the coastal maintenance strategy one needs to take into account the objective of the underlying policy. While the assessment indicates that in the near shore coastal zone has been maintained successfully, a few remarks can be made.

The assessment of the effectiveness of the coastal maintenance strategy can be seen through various lenses. From an overall point of view, academic observations can be made. In the real world, the perspective of stakeholders determines for a large part whether or not a successful maintenance strategy has been applied. Meeting certain safety requirements and keeping the costs limited, is a different perspective compared to that of a municipality that aims to provide an attractive coastline.

7.1.2 Planning nourishments

The coastal stretch from IJmuiden till Den Helder received a significant larger nourishment volume than deemed neccesarry for the maintenance of the Basal Coast Line. One could also argue that the Basal Coast Line was selected in such a way, that the consequence would be an increase of maintenance, at least locally. In the year 1990 this reference line has been established. The location of this coastline is of significance when it comes to planning nourishments. A seaward Basal Coast Line will, due to the benchmarking procedure, lead automatically to an increase of coastal mainenace.

Furthermore it seems that this benchmarking procedure is more suitable to deal with structural rather than occasional erosion problems. As an example case the channel "Nieuwe Schulpengat" can be considered.

Deepening and landward migration of the channel does currently not influence the momentary coastline. Only the indirect consecuences for the near shore (shallow) zone have an effect on the position of the momentary coastline. Due to expert judgement and extensive monitoring, the negative effects of these developments can be mitigated. The nourishment volumes neccesarry for such measures do not directly lead to a better "performance" when it comes to avoiding crossings with the Basal Coast Line. Just applying the method based on coastal state indicators could lead to ineffectiveness of coastal maintenance.For this reason expert judgement and close monitoring of the developments of coastal zone are of vital importance.

7.1.3 Recommendations

As stated, different perspective allow subjectivity when it comes to the coastal maintenance policy. Currently the different perspectives are taken into account through consults with stakeholders. In the end no clear definition is available when it comes to assigning nourishment volumes to certain areas.

It is proposed to adopt a three-step approach of coastal state indicators. With this approach the concept of the Basal Coast Line can be extended. The introduction of a "Desired Coast Line" and the introduction of the Assured Safety Limit are proposed as two additional coastal state indicators

The introduction of the Assured Safety Limit to secure a minimum required near shore volume to assure safety. This concept should take into account the volume evolution of the near shore zone and the profile evolution over a period of ten years.

The "Desired Coast Line" could provide a tool in order to differ between required nourishments to maintain the near shore volume for safety requirements and secondary functions of the coastal zone, such as recreation, dynamic dune maintenance and nature.

The objective of a coastal maintenance policy can be made more explicit through this approach.

8 Conclusions

8.1 Conclusions

Coastal morphologic data

Vakloding data and Jarkus-data are the main sources of coastal morphologic data available to assess a coastal area. This data can be supported by written literature and data regarding the position of the coastline. The Jarkus profiles are best suited to study the near shore zone. Firstly, the Jarkus-database consists of forty five years of data. Therefore, the duration allows for a mid to long term analysis of the near shore volume. Secondly, the Jarkus profiles cover the Noord-Holland coast, with a lateral profile distance of 250 m quite well. Most importantly, the Jarkus framework allows for understanding its principles. Therefore estimations can be made with regards to its accuracy.

The value of the data depends on the context in which it is used. The accuracy of Jarkus profiles is found to be 15-21 m^2 (as deviation under the surface of a profile) if a large number of profiles is used. For single profiles a deviation in the order of 95 – 100 m^2 needs to be taken into account.

System description

It has been proven possible to find trends in the near shore volume evolution. The data allowed obtaining trends over periods of 20 – 45 years. Short term temporal volume changes, caused by processes such as bar behaviour and single nourishments have been recognized.

The largest part of the Noord-Holland coastal stretch has been erosive over the last forty five years. The coastal stretch from Egmond aan Zee till Den Helder shows significant erosion. The coastal cells near IJmuiden showed a stable volume or mild accretion. A significant erosion hotspot is present adjacent to the coast near Den Helder. Along the coast near towns of Egmond aan Zee and Bergen aan Zee erosion hotspots are also found.

Near Den Helder, landward migration and deepening of the “Nieuwe Schulpengat” cause erosion rates in the order of a million cubic meter per year. The influence of these processes due to the morphodynamic developments of the Texel tidal inlet and the outer delta (Noorderhaaks) are significant. Consequences of the observed changes in morphodynamics can be substantial for the state of the near shore zone. Therefore more understanding of the tidal inlet is important. A focus towards measures to counteract erosion, especially near the ridges of the deeper channels is required. The stability of the steep slope and the beach between transect 20 and 449 requires attention from coastal engineers and those involved in maintaining the coastline and safety.

With the Jarkus data and the methods applied, degradation of the deeper part of the coastal foundation could not be assessed. Therefore no conclusions can be drawn with regards to this. To analyse this process, volume trends with a high spatial resolution (small cells) both in alongshore and cross-shore direction are required. Furthermore, the application statistical operation to compensate for temporal volume fluctuations might be necessary.

Coastal maintenance strategy

Over the whole Noord-Holland coast the near shore volume decreased by about 20 million m^3 over the period 1965 – 1990. Over the last twenty years the near shore zone gained 20 million m^3. A total nourishment volume of 44 million m3 was needed to achieve this. Thereby the objective of the policy is reached. The system description indicates that the coastal stretch of Noord-Holland received a significant larger nourishment volume than deemed necessary to reach the objective of the “Dynamic Preservation” policy. It is proposed to adopt a three-step approach. Thereby the concept of the Basal Coast Line can be extended. The objective of a coastal maintenance policy can be made more explicit through this approach.

8.2 Recommendations (for further research)

Coastal morphologic data

+ The large amount of available and monitored coastal morphologic data needs to be described. An assessment should be made to optimize the use of this valuable source of information.
+ The underlying principles of Vakloding-data, Jarkus-grids and the dry part of the Jarkus-profiles (Lidar data) should be looked into. These data sources are extremely valueabe. The lack of an up to date description of these data sources leaves room for improvement.
+ A uniform way of documenting these principles and the availability of these descriptions needs to be taken care of.
+ Assessments with regards to the accuracy of these data sources should be made. The accuracy calculations of the Jarkus-profiles presented in this document can be extended and improved.
+ More information with regards to occurring errors is needed. Studies on this matter can be extremely valuable for users. A start should be made by analysing earlier conducted studies. Many of them are included with this thesis and can be obtained through Rijkswaterstaat.
+ The way in which coastal morphologic data is managed, used and processed should be optimized.

System description

+ In order to gain better understanding of the coastal system a n accurate sediment budget study including the deeper part of the coast needs to be made. Possibly statistical analysis are required in order capture the described processes of steepening and degradation of the (deeper part) of the coastal foundation.
+ This study should be supported with more accurate net sediment transport rates. To obtain these sediment transport rates state of the art (3D) morphologic models can play an important role. With a dataset of forty five years of Jarkus-profiles, enough data is available to validate the model.
+ Possible large scale erosion of the coastal stretch of Den Helder needs attention. A practical study towards the consequences and solutions for this erosive area is valuable for both fundamental understanding of occurring processes and for coastal zone managers.
+ Coastal cell 4 (Egmond aan Zee and Bergen aan Zee) shows complex erosion/sedimentation patterns. Not all occurring patterns could be explained by analysing volumes and volume trends. An in depth study on this area could provide information with regards to the state of the coast. Hydrodynamic and morphodynamic aspects should be combined. Field experiments on the topics of currents and sediment transport, conducted near Egmond in August and October of 2011 could provide possibly valuable information. They are performed by students of Delft University of Technology and Utrecht University.

Nourishments

+ A feasibility study that should explore the possibilities of extension of the concept of the Basal Coast Line through the introduction of two extra coastal state indicators.
+ The introduction of a “Desired Coast Line” could provide a tool in order to differ between required nourishments to maintain the near shore volume for safety requirements and secondary functions of the coastal zone, such as recreation, dynamic dune maintenance and nature.
+ The introduction of the Assured Safety Limit to secure a minimum required near shore volume to assure safety.

8.3 Review

With regards to the substance of this report there are a few remarks that need to be shared. The description of the Jarkus-data does not compile all knowledge that is available on this matter. Many documents have been found. They all have been analyzed; however it is not completely clear when certain changes have occurred within the process. Therefore, the description is not complete. Extensive simulative tests with the data and the Maria Morphologic application could have provided more insight. Due to the focus of this thesis, this has not been done.

When it comes to the system description of the Noord-Holland coast a few notes can be made. Firstly, for the assessment of the deeper part of the coast the Vakloding data has not been used. The choice to use only Jarkus-data has assured a realistic view of the nearshore zone. However, the data available could provide valuable information of the volume evolution from minus 10 meter and deeper. An assessment of the accuracy before using this data is needed. While the accuracy of the Jarkus-data is acceptable for the sand budget study, a more accurate analysis of the dry part of the beach is possible through the use of Lidar-grids.

The assessment of the effectiveness of the coastal maintenance strategy can be seen through various lenses. From an overall point of view, academic observations can be made. In the real world, the perspective of stakeholders determines for a large part whether or not a successful maintenance strategy has been applied. Meeting certain safety requirements and keeping the costs limited, is a different perspective compared to that of a municipality that aims to provide an attractive coastline.

Cross-shore sediment transport rates have not been included in the sand budget model. With the inclusion of those transport rates a better understanding of the Noord-Holland coast would be possible. However, the sediment transport rates in cross-shore direction are uncertain and no general consensus exists on this matter.

The used sediment transport rates in alongshore direction are a combination of various studies executed. The difference in calculated net transports is rather large. This affects the accuracy of the sand budget model.

Alongshore plots do not take into account the whole volume evolution. The linear interpolation does affect the outcome significant. The plots are a valuable source to present the alongshore distribution of sedimentation/erosion trends. Whilst being used with caution, the real situation can only be approximated roughly.

A final statement by Van Rijn (1997) applies fully to the work that has been presented in this thesis:

"A sediment budget analysis consists of two basic elements: volume changes in each compartment and exchanges of sediment between the compartments, both in cross-shore and in long shore direction. Understanding of the transport pathways requires the application of mathematical models, because synoptic and accurate field data of transport processes generally are not available. The application of transport models yields information of the relative importance of the various transport components and the net values and directions. Without modeling results the observed volume changes can only be evaluated in terms of gains and losses but the causes and possible remedial measures cannot be overseen."

9 Literature

Airy, G. B. (1841), "Tides and waves". In Hugh James Rose, et al.. Encyclopaedia Metropolitana. Mixed Sciences. 3. 1817–1845. Also: "Trigonometry, On the Figure of the Earth, Tides and Waves", 396 pp.

Alkyon/ Arcadis (2005), *Integrale beoordeling zwakke schakels Noord-Holland, basisrapport veiligheid*, Initiated by Provincie Noord-Holland

Arens, S.M. (2003), *De kerf bij Schoorl; evaluatie monitoring geomorfologie 1997-2002*. Rapport Arens Bureau voor Strand- en Duinonderzoek RAP2003.02, in opdracht van Staatsbosbeheer Regio Noord-Holland, 43 pp.

Battjes, J. A. (1962), *Studie Zeegat van Texel (in Dutch)*, M.Sc. Report. Delft University of Technology, Delft.

Beets, D.J., Van der Valk, L. and Stive, M.J.F. (1992). *Holocene Evolution of the Coast of Holland,* Marine Geology, 103: 423-443.

Berendsen, H.J.A. & W.H. Zagwijn eds. (1984), *Geological Changes in the Western Netherlands during the Period 1000-1300 AD*, Geologie en Mijnbouw 63, pp. 225-307.

Berendsen, H.J.A. (2004), *Rivers and the sea: how science went wrong explaining the formation of the Netherlands' coastal plain*. In: Dietz, T., P. Hoekstra & F. Thissen eds. The Netherlands and the North Sea. Dutch geography 2000-2004. KNAG: Netherlands Geographical Studies 325, p. 56-63.

Bernhardsen, T. (2002), *Geographic information systems: an introduction*, published by John Wiley & Sons, New York

Bonekamp, J. G., Ridderinkhof, H., Roelvink, J. A., and Luijendijk, A. (2002), *"Comparison modeled and observed water motion and sediment transport in the Texel tidal inlet"* Proc. 25th International Conference on Coastal Engineering, Cardiff, Wales.

Bruun P. (1989), *Coastal Engineering and the Use of the Littoral Zone,* Ocean & Shoreline Management, 12: 495-516.

Clieveringa, J. (2008), Morphodynamics of the Delta Coast, *Alkyon Hydraulic Consultancy and Research,* to WL Delft Hydraulics - *Rijkswaterstaat RIKZ/A1881*

Deltares (2010), *"Technische mogelijkheden voor een dynamische kustuitbreiding, een voorbereiding t.b.v. het Deltaprogramma"*, 1201993-004

Dronkers, J. (1986). *"Tidal asymmetry and estuarine morphology"* Netherlands Journal of Sea Research, 20, pages 117-131.

Data en ICT Dienst, Rijkswaterstaat (2010), *Kwaliteitdocument laser altimetry*, Data en ICT Dienst Rijkswaterstaat

De Mulder, E.F.J., Geluk, M.C., Ritsema, I., Westerhoff, W.E. & Wong, Th. E. (2003), *De ondergrond van Nederland.*, deel 7.Utrecht: Nederlands Instituut voor Toegepaste Geowetenschappen TNO.

De Vriend, H.J. and D. Roelvink. 1989. *Innovatie van kustverdediging :inspelen op op het kustsysteem. Kustverdedigin na1990*, techn rapport 19. WL | Delft Hydraulics (in dutch)

Deigaard, R., N. Drønen, J. Fredsøe, J. Hjelmager and M. P. Jørgensen (1999), *"A morphological stability analysis for a long straight barred coast."* Coastal Engineering 36: 171-195

Eijnsbergen, van, C. (1993), *Nauwkeurigheidsanalyse van dieptegegevens in de Westerschelde*. TU Delft: Delft. 73 pp.

Eilers, P.H.C. (1999), *A Perfect Smoother,* Analytical Chemistry 2003 75 (14), 3631-3636
Reformulated in *"Smoothing van Lodingen",* 1999, for RIKZ (document not found)

Elias, E.P. (2006), *Morphodynamics of Texel Inlet* PhD thesis Delft University of Technology / IOS (under the imprint of Delft University Press) ISBN 1-58603-676-9; DUP Science / Delft Hydraulics Select Series 9/2006

Elias, E.P.L., Van Koningsveld, M., Tonnon, P.K. and Wang, Z.B. (2006), *Sediment budget analysis and testing hypotheses for the Dutch coastal system : VOP II - 1.2 long term coastal management and DC05.20 North Sea and coast,* Report Z4100, WL|Delft Hydraulics.

Elias, E. P. L., and Cleveringa, J. (2003), *Morfologische analyse van de ontwikkeling van het Nieuwe Schulpengat en de aangrenzende kust (in Dutch)*, Report RIKZ-2003.040. Rijkswaterstaat RIKZ, The Hague.

Gans (de), W. (1991), *Kwartair geologie van West-Nederland*, Grondboor en Hamer, November 1991: 103-124

Geolas Consulting (2004), *Airborne Lidar Sensors*, GIM International, edited by Mathias Lemmens, Februari 2007

Graaf (de), H.J.C., Oude Elberink, S.J., Bollweg, A.E., Brügelmann, R. and Richardson, L.R.A. (2003), *Survey techniques for "Dry" Jarkus Profiles Along the Dutch Coast* (Inwinning "Droge" Jarkus Profielen Langs Nederlandse Kust), Rijkswaterstaat AGI-GAM-2003-40

Graaff, van de J. (2002), *Coastal protection, structures and (sea)dikes,* taken from "*Engineered Coasts",* edited by Chen, J., Eisma, D., Hotta, K. and Walker, H.J., published by Kluwer Academic Publishers, the Netherlands.

Hayes, M. O. (1975). *"Morphology of sand accumulation in estuaries."*, Estuarine Research, L. E. CRONIN, ed., Academic Press, New York, 3-22.

Herrmann, H.J. (2006), Almeida MP and Andrade JS, *Aeolian transportlayer*, Physical Review Letters, 96(1), 018001.

Heindorn, K.C. (2002), *Weather Phenomenon and Elements; Aeolian transport explained*, June 2002

Holthuijsen, L.H. (2007), *Waves in Oceanic and Coastal Waters,* Cambridge University Press, ISBN 978-0521860284.

Hoogewoning, S.E. and Boers, M. (2001), *Fysische effecten van zeezandwinning*, Rijkswaterstaat RIKZ Rapport RIKZ/2001.050 Den Haag. 96 p.

Hoogheemraadschap Uitwaterende Sluizen (2001), *De functie van strandhoofden langs de Noord-Hollande kust*, Hoogheemraadschap van Uitwaterende Sluizen In Hollands Noorderkwartier, februari 2001.

Kalf, R.B., Walburg, A.M. and Nijland, G.J.M. (1993), *Validatie Jarkus Gegevens in Het Kader Van Het Projekt Kustgense*. GWAO-93.133X, Rijksinstituut voor Kust en Zee, Den Haag.

Koningsveld M. and Mulder J.P.M. (2004), *Sustainable Coastal Policy Developments in The Netherlands. A Systematic Approach Revealed*. Journal of Coastal Research, 20, 375-385.

Knoester, D., (1990) *De morfologie van de Hollandse kustzone (analyse van het Jarkus-bestand 1964-1986)*. Nota GWAO-90.010, Rijkswaterstaat / Dienst Getijdewateren, Den Haag.

Ligtenberg, J. (1998), *De rol van het getij bij de aanzanding van het Marsdiep, voor en na de afsluiting van de Zuider Sea* (in Dutch), Report RIKZ-OS-98.106x. Rijkswaterstaat RIKZ, The Hague.

Longuet-Higgins, M.S. (1953), *"Mass transport in water waves"*. Philosophical Transactions of the Royal Society of London, Series A 245 (903): 535–581. Bibcode 1953RSPTA.245..535L.

McCave, I.N. (1971), *Sand waves in the North Sea off the coast of Holland*, Mar. Geol., Vol. 10, pp. 199-225

Min. V&W (1990), 1e Kustnota: Kustverdediging na 1990; beleidskeuze voor de kustlijnzorg, Ministerie van Verkeer en Waterstaat.

Min. V&W (1991), De basiskustlijn, een technisch / morfologische uitwerking. Ministerie van Verkeer en Waterstaat, Rijkswaterstaat

Min. V&W (1996), 2e Kustnota: Kustbalans - 1995, Ministerie van Verkeer en Waterstaat, Tweede Kamer.

Min. V&W (2000), 3e Kustnota: Traditie, Trends en Toekomst, Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat.

Min. V&W (2011), Kustlijnkaartenboek uitgave December 2010, Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat.

Minneboo, F.A.J. (1995), *Jaarlijkse Kustmetingen, richtlijnen voor de inwinning, bewerking en opslag van gegevens van jaarlijkse kustmetinge,* RIKZ-95.022, Ministerie van Verkeer en Waterstaat, RijksInstituut voor Kust en Zee.

Molendijk, E. (2008), *Research on the relation between breaker bar movement and volume fluctuations along the Holland coast,* Msc. Thesis Civil Engineering and Geosciences, 2008-12-03
Delft University of Technology

Mus, A.D., (2003). *Duinveiligheid van de kust van Noord-Holland, nabij het zeegat van Texel.* M.Sc Thesis Civiele Techniek en Geowetenschappen TUDelft.

Oxford English Dictionarry (2008), Oxford University Press, 2008

Otten, C.J. (1985), *Ontwikkelingen in de Jaarlijkse Kustmetingen en verwerkingssysteem 1977-1985, Ministerie van Verkeer en Waterstaat, Rijkswaterstaat, dienst getijdewateren,* NOTA GWIO-86.001

Prusak (2006), image groynes, Polish Academy of Sciences; Institute of Hydro-engineering, through Coastal Portal Encora.

Rest, vd P. (2004), *Morfodynamica en hydrodynamica van de Hollandse Kust*, Msc Thesis TU Delft, faculteit Civiele Techniek.

Ribberink, J.S. en Roelvink, J.A. (1989), *"Zeezandwinning. Onderbouwende notitie",* Rapport WL, H825.

Rijkswaterstaat (2011), *Kr-8 Sessie Coastal Morphologic Data*, meeting organised to map the present processes needed to aquire useable coastal morphologic data

Ruessink, B.G. and J.H.J. Terwindt (2000), *The behaviour of nearshore bars on the time scale of years: a conceptual model.* MarineGeology163, pp.289-302.

Ronde, de, J.G., Mulder, J.P.M. and Spanhoff, R. (2003), *Morphologic developments and coastal zone management in the Netherlands.* National Institute for Coastal and Marine Management / RIKZ Rijkswaterstaat; International Conference on Estuaries and Coasts, Nov 9-11, 2003

Roskam, A.P. (1988), *Golfklimaten voor de Nederlandse kust*, Nota GWAO-88.046, Rijkswaterstaat, Den Haag

Rijn (van), L.C. (1995), *Sand budget and coastline changes of the central coast of Holland between Den Helder and Hoek van Holland period 1964-2040*. WL rapport H2129- project Kustgenese, WL| Delft Hydraulics.

Rijn (van), L.C. (1997), *Sediment transport and budget of the central coastal zone of Holland*, Coastal Engineering, 32: 61-90.

Roelvink, J.A., Ruessink, B.G., van der Kraaij, T., Bos, K.J. (2001), *Inceptierapport perceel 2*. Mare. WL Delft.

Ruig (de), J. H. M. (1989*). The sediment balance of the closed Dutch Coast*, 1963-1986, Report GWAO 89.016. Rijkswaterstaat RIKZ, Den Haag.

RWS DWW, Van Heijst, M.W.I.M. (2005), *Vaargeulonderhoud, zandwinning & kustlijnzorg; Risico's en perspectieven voor Rijkswaterstaat*, Ministerie van Verkeer en Waterstaat; DWW-2005-050 Publicatiereeks Grondstoffen 2005/04 40 Vaargeulonderhoud, zandwinning & kustlijnzorg

Santinelli, G. (2010), *Trend analysis of nourishment volumes,* Deltares, project 1202344-000 for Ministerie van Verkeer en Waterstaat, Rijkswaterstaat

Schiereck, G.J., (2001), *Introduction to Bed, Bank and shore protection,* Delft University Press, ISBN 9789040716836 NUR 956, Delft.

Schwab, W.C., Danforth, W.W., *Sea Floor Mapping*, U.S. Geological Survey, Sea-Floor Mapping Facility at U.S. Geological Survey Woods Hole Field Center, Massachusetts

Sha, L. P. (1989), *"Sand transport patterns in the ebb-tidal delta of Texel inlet, Wadden Sea, the Netherlands."* Marine geology, 86, 137-154.

Shibayama, T. and Horikawa, K. (1982), *Sediment transport and beach transformation due to waves.* In: Proceedings, 18th International Conference on Coastal Engineering, Cape Town. ASCE, New York, Vol. 2, pp. 1439- 1458

Shields A. (1936), *Application of similarity principles and turbulence research to bed-load movement.* Mitteilunger der Preussischen Versuchsanstalt fur Wasserbau und Schiffbau 26: 5–24

Spanhoff, R. and Van De Graaff, J. (2006), *Towards a better understanding and design of shoreface nourishments*. Proceedings of 30th International Conference on Coastal Engineering, 4141-4153.

Staatsbosbeheer (2009), Wondergem, H., *De Kerf, Kust-special*, Staatsbosbeheer regio west, mei 2009

Steetzel, H.J., de Vroeg, J.H. (1999). *Update and validation of the PonTos-model.* Joint Venture Alkyon Hydraulic Consultancy & Research – Wl, Delft Hydraulics, Report A244/Z2559, Delft

Steetzel, H.J. (2009), *Background report design sandy protection of the Hondsbossche and Pettemer Sea Dike*, Alkyon/Arcadis. Report A2089

Steijn, R.C. (1997), *Morfodynamische berekeningen Beleidsanalyse Slijkgat; effecten van beheersmaatregelen op de onderhoudsbehoefte van de vaargeul.* Rapport A214, Alkyon.

Stive M.J.F., Nicholls R.J., de Vriend H.J. (1991), *Sea-level rise and shore nourishment: a discussion*, Coastal Engineering, 16, 147-163

Stive, M.J.F., Wang, Z.B., Capobianco, M., Ruol, P. and Buijsman, M.C. (1998), *Morphodynamics of a tidal lagoon and the adjacent coast, in: Physics of Estuaries and Coastal Seas*, Dronkers & Scheffers (eds), Balkema, Rotterdam, pp 397-407

Stive, M. J. F., and Eysink, W. D. (1989), *Voorspelling ontwikkeling kustlijn 1990-2090. fase3*. Deelrapport 3.1: Dynamisch model van het Nederlandse Kustsysteem (in Dutch), Report H825. WL, Delft.

Stokes, G.G. (1847), *"On the theory of oscillatory waves"*. Transactions of the Cambridge Philosophical Society 8: 441–455. Reprinted in: G.G. Stokes (1880). Mathematical and Physical Papers, Volume I. Cambridge University Press. pp. 197–229.

Stolk, A. (1989*), Zandsysteem Kust, een morfologische karakterisering,* Ministerie van Verkeer en Waterstaat, GEOPRO, 1989.02

Svasek Hydraulics (2008), *"Zand voor de Hondsbossche and Pettemer zeewering"*, Instructing party: The municipality of Zijpe, mkl/1464/07541/C.

Technische Adviescommissie voor de Waterkeringen (2002), *Leidraad Zandige kust,* DWW-2003-046, Ministerie van Verkeer en Waterstaat, ISBN 90-369-5541-6

Verhagen, H.J. (1989), *Sand Waves Along the Dutch Coast*. Coastal Engineering, 13(2): 129–147.

Van Vessem. P., Stolk. A. (1990), *Sand budget of the Dutch coast*, 22th Int. Conf. Coastal Eng. Delft, The Netherlands, ASCE. Pp. 1895-1908

Van der Wal, D. (1999), *Aeolian Transport of Nourishment Sand in Beach-Dune Environments*. Thesis, Universiteit van Utrecht.

Walstra, D.J.R., L.C. van Rijn en S.G.J. Aarninkhof (1998), *"Sand transport at the middle and lower shoreface of the Dutch coast"*, WL/Delft Hydraulics rapport Z2378.

Wiegmann N., Perluka R., Boogaard K. (2002), *Onderzoek naar efficiency verbetering kustlodingen,* AGI/110105.GAM010, Meetkundige Dienst Mariene Geodesie

Wiegmann, N., Perluka, R., Oude Elberink, S., Vogelzang, J. (2005), *Opnametechnieken vaklodingen, Vergelijking tussen verschillende inwintechnieken*, AGI-2005-GSMH-012 Ministerie van Verkeer en Waterstaat, RWS-Zeeland, Meet Adviesdienst

Wijnberg, K.M. (1995), *Morphologic Behaviour of a Barred Coast over a Period of Decades*. PhD Thesis, Universiteit Utrecht

Wijnberg, K.M. and Terwindt, J.H.J. (1995), *"Extracting decadal morphologic behaviour from high resolution, long term bathymetric surveys along the Holland coast using eigenfunction analysis"* , Marine Geology, 126, 301-330.

Wijnberg, K.M. (2002), *Environmental controls on decadal morphologic behaviour of the Holland coast.* Marine Geology, 189: 227-247

Zagwijn, W. H. (1986), *Nederland in het Holoceen*, Report. Geological Survey of the Netherlands, Haarlem.

Zijpp, van der, N.J. (2008), *Gebruikershandleiding Morfologie Applicatie version 1.06*, Model IT, opdrachtgever, RIKZ, Projectteam ModelIT

10 Supplements

Table of content:

10.1 Anex I Jarkus-data storage and availability

Available Jarkus-files

Validated “clean” data is the outcome of a successful survey. Four formats are delivered to the data process specialist. Together they form all the information as outcome of the survey.

1. Asci-files

In standardized ascii format the transect name ####, date/time, X, Y and the depth Z are recorded.

2. Arc GIS – files

In MBS extention extra information is stored that can be used within a Geographic Information System.

3. Metadata

Location specific information (source: Model IT, 2010):

+ observation type (WNS;4)
+ units of observation and area (EHD;I;cm)
+ the awarding authority (OGI; RIKZMON_MORF)
+ administrative and analysing organization (BHI/ANI;NHXXANMIJMDN)
+ coordinate type (LOC;xxxxxxRD)
+ code measurement device (VAT;RWSLOD05)
+ analyse method (ANA;F025)

4. Digipol grid data

Some survey services provide digipol grid data. This data provides an average interpolated depth-value Z, the coordinates X, Y of the cells, the size of the cells. Empty cells have a dummy value “zero”.

The data process specialist also generates these Digipol grids. Comparisons can be made between the generated grids and the delivered grids. When there are no or very few differences, processing of the Digipol grids can take place before delivery to the data specialist.

Data availability

When there is a request for coastal morphologic data in the Netherlands one can request data at the DONAR Database:

Storage insitute: Ministerie van Milieu en Infrastructuur; Rijkswaterstaat; Data-ICT-Dienst

Address:
Postbus 5023
2600GA Delft
Netherlands
Phone: +31-(0)15-2757575
Fax: +31-(0)15-2757576
Email: did-info@rws.nl
Link: **http://www.marbef.org/data/imis.php?module=dataset&dasid=26**

OpenEarth access

Open Earth provides digital access to coastal morphologic data. In the next section attention will be paid towards OpenEarth. http://public.deltares.nl/display/OET/OpenEarth

10.2 Anex II The OpenEarth initiative

OpenEarth is an open source initiative to deal with Data, Models and Tools. During this study the value of this initiative has been recognized. The use of this tool is highly valueable for data acquisition and to access and use calculation tools and to visualize data. Professional involved in marine and coastal engineering projects, from both the private as the public sector could benefit from this open source initiative.

Taken from public.deltares.nl:

A sustainable interaction between mankind and the dynamic natural system provides a great number of hydraulic and environmental engineering challenges. The paradigm to confront these challenges one-project-at-a-time, while attractive from a budget management perspective, results in grave inefficiencies in the development and maintenance of the basic elements that are invariably in volved: data, models and tools.

OpenEarth is a free and open source initiative to deal with Data, Models and Tools in marine & coastal engineering projects. In current practice, research, consultancy and construction projects commonly spend a significant part of their budget to setup some basic infrastructure for data and knowledge management.

Most of these efforts disappear again once the project is finished. As an alternative to these ad-hoc approaches, OpenEarth aims for a more continuous approach to data & knowledge management. It provides a platform to archive, host and disseminate high quality data, state-of-the-art model systems and well-tested tools for practical analysis. Through this project-superseding approach, marine & coastal engineers and scientists can learn from experiences in previous projects and each other. This may lead to considerable efficiency gains, both in terms of budget and time.

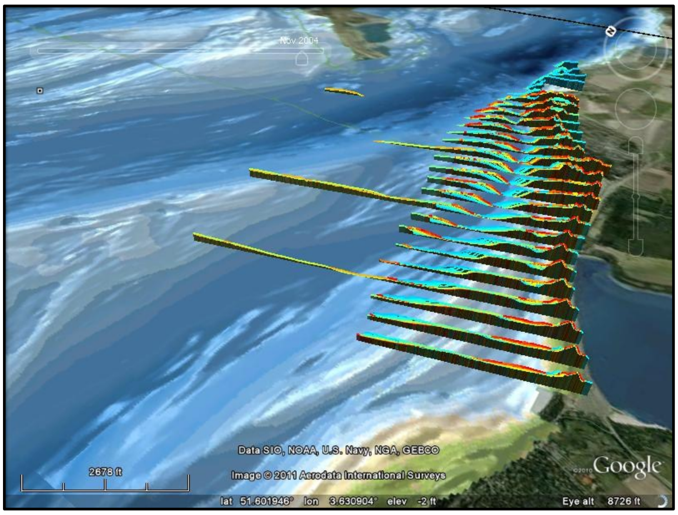


Fig. A.2.1 Rijkswaterstaat vaklodingen + JarKusdata visualised with OpenEarth tools in Google Earth

OpenEarth users are particularly interested in using data, models and tools that have become available through OpenEarth for project purposes. OpenEarth developers participate actively in the dissemination of new datasets and model systems and the development & improvement of all kinds of handy tools.

For access and information the writer refers to:

http://public.deltares.nl/display/OET/OpenEarth

10.3 Anex III Generated Net-CDF file with Jarkus-data

For the sand budget calculations all Jarkus-profiles were assessed. The length of the profile and the transect definitions were checked. It was found that for about 30 transects no complete dataset existed. Of these cases the transect was redefined after 1987 and therefore trend analyses from 1965 to 2010 were impossible to make. In order to make use of all the available data transects were merged. When the more than 10 years of data was missing, transects were deleted. This was all done within the most recent asci-file (2010) found in the DONAR database.

Coastal Cell 1	**Transects 0000 – 0810**					
Merged	-			Deleted	0000	0040
					0060	
Coastal Cell 2	Transects 0810 – 1630					
Merged	1047	to	1054	Deleted	1000	
	1078	to	1085		1062	
	1182	to	1175		1093	
	1197	to	1205		1152	
	1258	to	1265		1213	
	1228	to	1235	1123	1243	
	1016	to	1023		1273	
	0984	to	0994		1303	
Coastal Cell 3	Transects 1630 – 2800					
Merged	2023	To	2015	Deleted	1777	1896
	2606	To	2600		1910	1925
	1755	To	1763		1955	1983
	1940	To	1932		2009	2111
	1916	To	1903		2134	2158
	1969	To	1962		2187	2212
	1996	To	1990		2238	
	1777	To	1784			
Coastal Cell 4	Transects 2800 – 3900					
Merged	2923	To	2935	Deleted	2945	
Coastal Cell 7	Transects 5000 – 5500					
Merged	-			Deleted	5500	

Table A.3.1 Overview merged and deleted Jarkus-data

From this asci-file a new Net-CDF file was created. It contains about 300 transects of the Noord-Holland coastal area, each having a complete dataset, from 1965 to 2010. The Net-CDF file can be found on the enclosed dvd. An overview of the merged and deleted transects is given in table A.2.1.

The implications of merging transects with a different definition did not have a substantial impact on the year to year variation between the profiles. The mean reason for this is that transects merged were often located not more than 10 m from each other. Therefore adverse effects on the reliability of the data can be neglected.

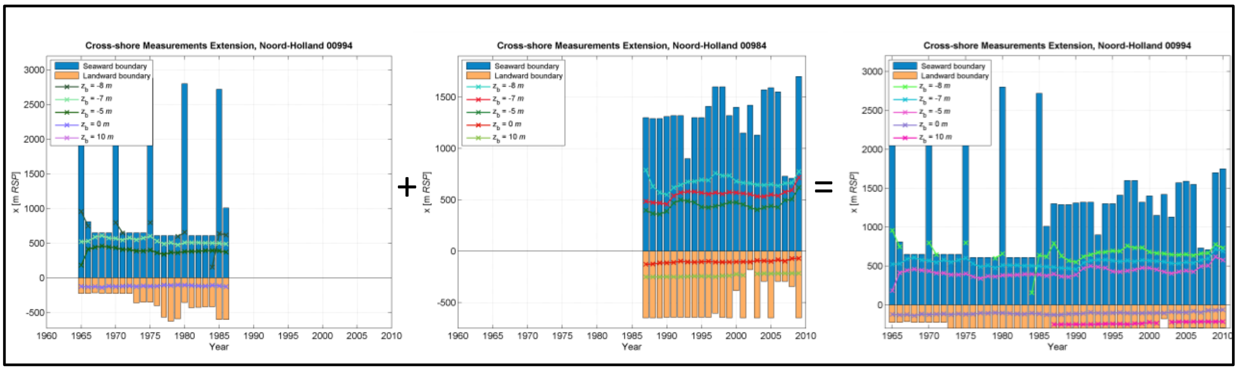


Figure A.3.1 Merging Jarkus-data

10.4 Anex IV Undesirable deviations / errors in the Jarkus database

Discrepancy depth and height survey

In (validatie Jarkus-gegevens tbv Kustgenese) the amount of incorrect profiles due to faults and large discrepancies between the survey data has been listed (table 3.1). In figure 3.9 the issue is sketched.

Yearly JARKUS surveys Number of cells with no data (z-value) recorded (with merging, an error occurs)				
coastal cell	**coastal cell**	**number of cells with no data**		
		number of profiles	patched profiles	partly modified
1	Rottum	-	-	-
2	Schiermonnikoog	7	3	4
3	Ameland	13	9	4
4	Terschelling	33	14	19
5	Vlieland	8	4	4
6	Texel	2	2	-
7	Noord-Holland	14	2	12
8	Rijnland	4	2	2
9	Delftland	7	-	7
10	Maasvlakte	7	1	2
11	Voorne	12	6	6
12	Goeree	27	18	9
13	Schouwen	1	1	-
14	Oosterschelde	-	-	-
15	Noord Beveland	8	8	-
16	Walgeren	3	3	-
17	Zeeuws Vlaanderen	-	-	-
	Total	146	73	69

Table A.4.1 Hiatus Jarkus-surveys (dry-wet) (Taken from: validatie Jarkus-gegevens tbv Kustgenese (1993))

Consequences for the accuracy of the Jarkus profiles

The year to year variation of the volume between two Jarkus profiles has been calculated to be on average 166 m^3.

With the assumption that this volume variation takes place in both the active zone of the profile, this number should be divided by the width of the active zone. An average width of 800 m is chosen. This number differs per location due to different equilibrium profiles and forcing. The chosen average is an assumption. Taking a normal distribution for hiatus in the Jarkus-database and the data from table A.4.1, one can determine that five per cent of the data shows a hiatus. Since it is unknown over which length there is no data available we must make an educated guess. In the Jarkus-framework one has determined to measure the dry beach during ebb. The execution of the echo-soundings takes place during high tide. Usually a large overlap (order 50 m') is present. Therefore the no-data area cannot be very large. A length of 20 m is chosen.

As estimate of the modifications of the error:

$$\frac{166\ m^3}{800\ m^1} \approx 0{,}21\ m^3\ per\ m^1 \text{ as expected variation} \qquad 0{,}21\, m^3 \times 20\ m = 4{,}2\ m^3\ deviation\ \ (upper\ limit)$$

No data (hiatus) after depth survey (echo sounding)

When no available survey data is present over a certain length within the profil e, still a profile is generated. This often occurs, mainly due to irregularities of path of the survey vessel (figure 3.8). The generation of a profile despite hiatus makes sense. Most of the times there is almost a complete profile present. It would be a wasteful not to use this data. As stated in paragraph 3.3, step seven, there are four ways to fill in the gaps. Each of these methods is treated and possible errors are calculated. In table A.4.2 an overview is given of the occurrence of hiatus.

Yearly JARKUS surveys
Number of cells with no data (z-value) recorded

coastal cell	coastal cell	number of cells with gaps in the profile			
		> 50 m	> 100 m	> 250 m	dataset
1	Rottum	-	-	-	-
2	Schiermonnikoog	317	161	84	2991
3	Ameland	571	325	125	4412
4	Terschelling	461	144	8	4959
5	Vlieland	283	77	8	3651
6	Texel	154	51	4	4331
7	Noord-Holland	417	91	8	7128
8	Rijnland	941	341	2	4788
9	Delftland	641	119	0	2129
10	Maasvlakte	163	98	24	1017
11	Voorne	263	108	11	1711
12	Goeree	460	257	76	2667
13	Schouwen	174	47	12	2845
14	Oosterschelde	15	7	1	275
15	Noord Beveland	55	31	3	708
16	Walgeren	427	133	20	4795
17	Zeeuws Vlaanderen	324	81	3	2145
	Total	5612	2072	390	50626

Table A.4.2 Hiatus Jarkus-surveys (Taken from: validatie Jarkus-gegevens tbv Kustgenese (1993))

<u>1-d interpolation</u>

When 1-d interpolation is applied the missing data in the profile is filled by the line that connects the closed measured points. Therefore the length between these points plays a large role in causing deviations from the actual profile. In table 1.1 both the number of gaps and the length of the gaps within the profile are listed.

Four missing data points occur in 9 % of the profiles for. If one takes a profile length of 800 m and a difference over z of 20 m we end up with a linear profile gradient of 1:40.

The error of the approximation through interpolation can be defined as:

$$R_T = f(x) - p(x) \cdot \alpha$$

In which p denotes the linear interpolation, f(x) the actual profile and α a scaling factor.

Since f(x) is dependent on the position of the missing data, on time and on alongshore location, it is unknown we cannot calculate the error.

We could approximate f(x) in the active zone as a hyperbolic function. This would lead directly to an over estimation of the actual profile. Such an assumption in itself leads to a much larger error than the investigated error at hand.

For this reason α is introduced as a scaling factor that takes into account both the difference in z-value and the amount of missing data points.

$$F(x, \bar{x}, \sigma)dx = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}} dx \quad \text{(see figure 10.3.1)}$$

<u>2-d interpolation</u>

2-d interpolation implied the use of neighbouring transects by fitting a part of the profile in the missing part of the original profile. The spatial variability of profiles is calculated to be 73 m^3.

$$\frac{73\ m^3}{800\ m^1} \approx 0{,}1\ m^3\ per\ m^1 \text{ as expected variation} \qquad 0{,}1\ m^3 \times 50\ m = 5\ m^3\ deviation\ \ (occurence{:}\ 9\ \%)$$

For a gap > 100 m: $0{,}1\ m^3 \times 100\ m = 10\ m^3\ deviation\ \ (occurence{:}\ 4\ \%)$

For a gap > 250 m: $0{,}1\ m^3 \times 250\ m = 25\ m^3\ deviation\ \ (occurence{:}\ 0{,}8\ \%)$

<u>use of historic transect data</u>

Historic data implies the use of data measured last year, from the same transect. Year to year volume variability is calculated to be 31 m^3. With the same assumptions this would lead to the following deviations: 2 m^3 in 9 % of the time, 4 m^3 occurring 4 % of the time and 9,7 m^3 deviation 0,8 % of the time.

<u>ad-hoc subjective modification</u>

Ad-hoc modification of the profile only happens when historic transect data and neighbouring profiles do not fit. Information of both is used to generate a “natural” profile. We can only assume that the modification generates a better outcome. An educated guess on the effects of this method cannot be made. With the aforementioned assumption, a reasonable deviation would be 2 m^2. However, this only holds for a limited gap width and solely due to this modification. Systematic errors in the order of ± 10 cm are not included.

Estimation of accuracy

With the aforementioned deviations one is not able to say something about the accuracy since the deviations only occur a certain percentage of the time. Therefore one needs to introduce a confidence interval. Thereby one is able to bound the error.

Assuming a Gaussian distribution (Standard Normal Distribution) :

$$F(x, \bar{x}, \sigma)dx = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}} dx \quad \text{(see figure 10.3.1)}$$

The distribution is symmetrical over the mean value $\bar{x}$. The width of the “bell”-like shaped figure is dependent on the standard deviation.

$$Standard\ Deviation\ (\sigma) = \sqrt{variance}$$

$$variance = \frac{\sum_{i=1}^{N} (X_i - \bar{X})^2}{N-1}$$

The distribution is used when n, the number of observations is relatively large. In the case where n > 40, this assumption seems valid.
For the estimation of errors, often a 95 % confidence interval is used, in statistics; two times the standard deviation (2σ):

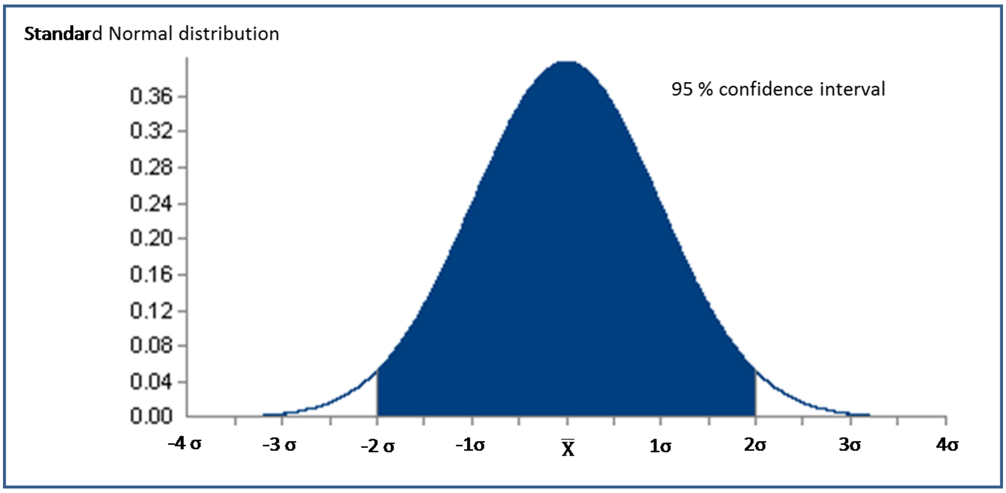


Figure A.4.1 (Standard Normal Distribution of the error)

Taking the 95 % confidence interval leads to the following results:

Deviations / errors due to:	Consequence:
1 – d interpolation	-
2 – d interpolation (space)	8 m^3
historic transect as source (time)	3,5 m^3
expert judgement	2 m^3

Table A.4.3 Undesirable deviations and consequences for accuracy

Outliers

In the Maria-software package profiles can be modified when they do not look as expected. Errors can be found by visually checking each profile. From time to time outliers, points that do not fit within a natural profile are found. They are edited when > 15 cm outside of the reference profile. A reference profile can be a neighbouring profile or a historic transect with the same definition.

A calculation of an outlier depends on the outlier itself. No information is available on how many show up within a normal dataset. Outliers with a substantial impact are always visible. This also holds for non-trained users of the dataset. They will, when carefully using the data, recognize them. Other profiles can be chosen for analysis or calculations. Smaller outliers (order 15 cm) will have an impact. Moreover, they are hard to recognize. For this reason, over a width of 1 cell a significant deviation needs to be taken into account. A width of 10 m and a deviation of ± 10 cm leads to 2 m^3 deviation per m'.

10.5 Anex V Overview nourishments

The nourishments are listed according to assigned project number. The Rijkswaterstaat record “suppletiedatabase_versie_20_april_2011.xls” is used as source. BA = Banket, D=Different / unknown, B=Beach nourishment, R=Ridge nourishment, U = Unknown, NE = Not Executed, NP = Not Processed, NIJ = Not in Jarkus Data yet (therefore not used in caclculations).

Coastal cell 1 **Transect** **0** **810**

#	Location	Transect S Transect E		Cell	Year	Kind	Volume m3	m'	Lenght
507	Den Helder	1	7,5	1	1992	B	615527	95	6500
510	Den Helder	3,28	5,68	1	1993	B	280000	117	2400
772	Den Helder	1,5	7,5	1	1996	B	400000	67	6000
742	Julianadorp	4,69	5,88	1	1998	NE	0	0	1190
714	Julianadorp	3,95	6,28	1	1999	B	287480	123	2330
758	Den Helder	1,5	5,68	1	2001	B	1290240	309	4180
784	Den Helder-Julianadorp	1,5	5,88	1	2003	B	1305458	298	4380
861	Den Helder-Julianadorp	2	7,1	1	2007	S	3239103,478	456	7100
862	Den Helder-Julianadorp	1,5	5,9	1	2007	B	1350447,826	307	4400
?	Den Helder	0,00	2,00	1	2007	R	1782262,609	891	2000
876	Den Helder - Julianadorp	7,00	10,00	12	2009	S	477400	434	1100
					Total nourished volume 1990-2010		11027918,91	11,03	Mln M3

Coastal cell 2 **Transect** **810** **1630**

#	Location	Transect S Transect E		Cell	Year	Kind	Volume m3	m'	Lenght
876	Den Helder - Julianadorp	7	10	12	2009	S	824600	434	1900
505	Callantsoog	11	14	2	1991	B	538404	179,468	3000
517	Zijpe / Callantsoog	10,01	14,1	2	1996	B	459000	117,3913	3910
518	see 517	0	0	2	1996	B			
759	Zijpe	11,08	14,01	2	2001	S	1499940	511,9249	2930
788	Callantsoog-Zwanenwater	10	16	2	2003	S	2572642	428,7737	6000
787	Callantsoog	11,1	13,75	2	2003	B	438155	165,3415	2650
809	Groote Keeten	9,13	9,43	2	2003	S	12243	40,81	300
820	Callantsoog	11,1	13,74	2	2004	B	216655	82,06629	2640
852	Callantsoog - Zwanenwater	10	15,2	2	2006	S	1668148	320,7977	5200
513	Zwanenwater	16,24	17,6	23	1995	B	13560	226	60
877	Hondsbossche- en Pettemer Zeewering	15	29,5	23	2008	S	510900	393	1300
749	Zwanenwater	16,26	16,88	23	2000	B	7760	194	40
760	Zwanenwater	16,26	16,88	23	2001	NE	0	0	0
					Total nourished volume 1990-2010		8762007	8,762007	Mln M3

Coastal cell 3		Transect	1630	2800					
#	Location	Transect S Transect E		Cell	Year	Kind	Volume m3	m'	Lenght
513	Zwanenwater	16,24	17,6	23	1995	B	306840	226	1300
877	Hondsbossche- en Pettemer Zeewering	15,00	29,50	23	2008	S	5187600	393	13200
749	Zwanenwater	16,26	16,88	23	2000	B	112520	194	580
760	Zwanenwater	16,26	16,88	23	2001	NE	0	0	0
506	Petten	18	20,18	3	1991	B	371418	170	2180
514	Petten	18,8	20,4	3	1995	B	361740	226	1600
522	Zijpe	19,25	20,5	3	1998	B	228901	183	1250
748	Callantsoog	13,2	14	3	1999	B	144000	180	800
775	Petten	18,27	20,35	3	2002	B	500561	241	2080
807	Petten	19,83	20,58	3	2003	B	230577	307	750
808	Camperduin	25,62	26,41	3	2003	B	357788	453	790
821	Aansluitconstructie Petten	19,83	20,58	3	2004	B	98953	132	750
822	Aansluitconstructie Camperduin	25,65	26,41	3	2004	B	194955	257	760
776	Camperduin	26,5	30	34	2002	S	846000	564	1500
508	Egmond-Camperduin	26,2	38,5	34	1992	B	216000	120	1800
520	Schoorl	26	30,05	34	1997	B	270000	135	2000
Total nourished volume 1990-2010							9427853	9,43	Mln M3

Coastal Cell 4 **Transect 2800 3900**

#	Location	Transect S Transect E		Cell	Year	Kind	Volume m3	m'	Lenght
?	Bergen	31,50	34,00	4	2010	B	501233	200	2500
?	Egmond	37,00	39,00	4	2010	B NIJ	0	0	
?	Bergen - Egmond	31,00	40,00	45	2010	S	384000	48	8000
829	Bergen	31,5	36,2	4	2005	S	1262364	269	4700
831	Bergen	32,25	33,75	4	2005	B	300435,6522	200	1500
832	Egmond	37	39,25	45	2005	B	432000	216	2000
814	Egmond aan Zee	36,2	40,2	45	2004	S	1125600	402	2800
776	Camperduin	26,5	30	34	2002	S	1128000	564	2000
795	Bergen	28,32	30	4	2001	B	511127	304	1680
731	Bergen aan Zee	32,25	34,25	4	2000	S	994000	497	2000
750	Egmond	38	39	4	2000	B	207445	259	800
730	Bergen aan Zee	32,75	33,25	4	2000	B	225000	450	500
716	Egmond	37,25	38,75	4	1999	B	214515	143	1500
715	Bergen aan Zee	32,5	33,75	4	1999	B	205793	165	1250
747	Egmond	36,9	39,1	45	1999	S	840000	400	2100
713	Egmond	37,5	38,75	4	1998	B	244442	196	1250
737	Egmond	36,25	38,8	4	1997	B	314000	123	2550
771	Bergen-Egmond	34,5	35,75	4	1997	B	158000	126	1250
773	Bergen aan Zee	31,05	33,5	4	1997	B	352000	144	2450
738	Bergen aan Zee	30,05	31,05	4	1997	D	132690	133	1000
520	Schoorl	26	30,05	34	1997	B	276750	135	2050
515	Egmond	37,25	38,75	4	1995	B	306000	204	1500
516	Bergen aan Zee	32,625	33,625	4	1995	B	306000	306	1000
512	Egmond	37,85	38,2	4	1994	B	106343	304	350
511	Bergen aan Zee	32,9	33,5	4	1994	B	100683	168	600
508	Egmond-Camperduin	26,2	38,5	34	1992	B	1260000	120	10500
509	Egmond	37,65	38,6	4	1992	B	69225	73	950
679	Bergen aan Zee	32,25	33,75	4	1990	BA	60000	40	1500
504	Egmond	37	38,5	4	1990	B	323318	216	1500
503	Bergen aan Zee	32,25	33,75	4	1990	B	385774	257	1500
					Total nourished volume 1990-2010		12726737,65	13	Mln M3

Coastal cell 5 **Transect 3900 4700**

#	Location	Transect S	Transect E	Cell	Year	Kind	Volume m3	m'	Lenght
747	Egmond	36,9	39,1	45	1999	S	40000	400	100
814	Egmond aan Zee	36,2	40,2	45	2004	S	482400	402	1200
832	Egmond	37	39,25	45	2005	B	54000	216	250
?	Bergen - Egmond	31,00	40,00	45	2010	S NPF	48000	48	1000
833a	Castricum	44,75	Unknown	5	2005	B	6000		
833	Castricum-Heemskerk	46,5	48,5	56	2005	B	130000	260	500
						Total nourished volume 1990-2010	760400	1	Mln M3

Coastal cell 6 **Transect 4700 5000**

#	Location	Transect S	Transect E	Cell	Year	Kind	Volume m3	m'	Lenght
833	Castricum-Heemskerk	46,5	48,5	56	2005	B	390000	260	1500
736	Heemskerk	49,65	51,2	67	1997	B	137550	393	350
						Total nourished volume 1990-2010	527550	0,53	Mln M3

Coastal cell 7 **Transect 5000 5500**

#	Location	Transect S	Transect E	Cell	Year	Kind	Volume m3	m'	Lenght
736	Heemskerk	49,65	51,2	67	1997	B	471600	393	1200
519	Heemskerk	50,425	51	7	1996	B	180050	313	575
						Total nourished volume 1990-2010	651650	0,65165	Mln M3

BEFORE 1990

Coastal cell 3 **Transect 1630 2800**

#	Location	Transect S Transect E		Cell	Year	Kind	Volume m3	m'	Lenght
502	Zwanenwater	13,755	18,1	23	1987	B	702000	390	1800
678	Zwanenwater	14,7	17,84	23	1987	D	75460	49	1540
						Total nourished volume pre-1990	777460	1	Mln M3

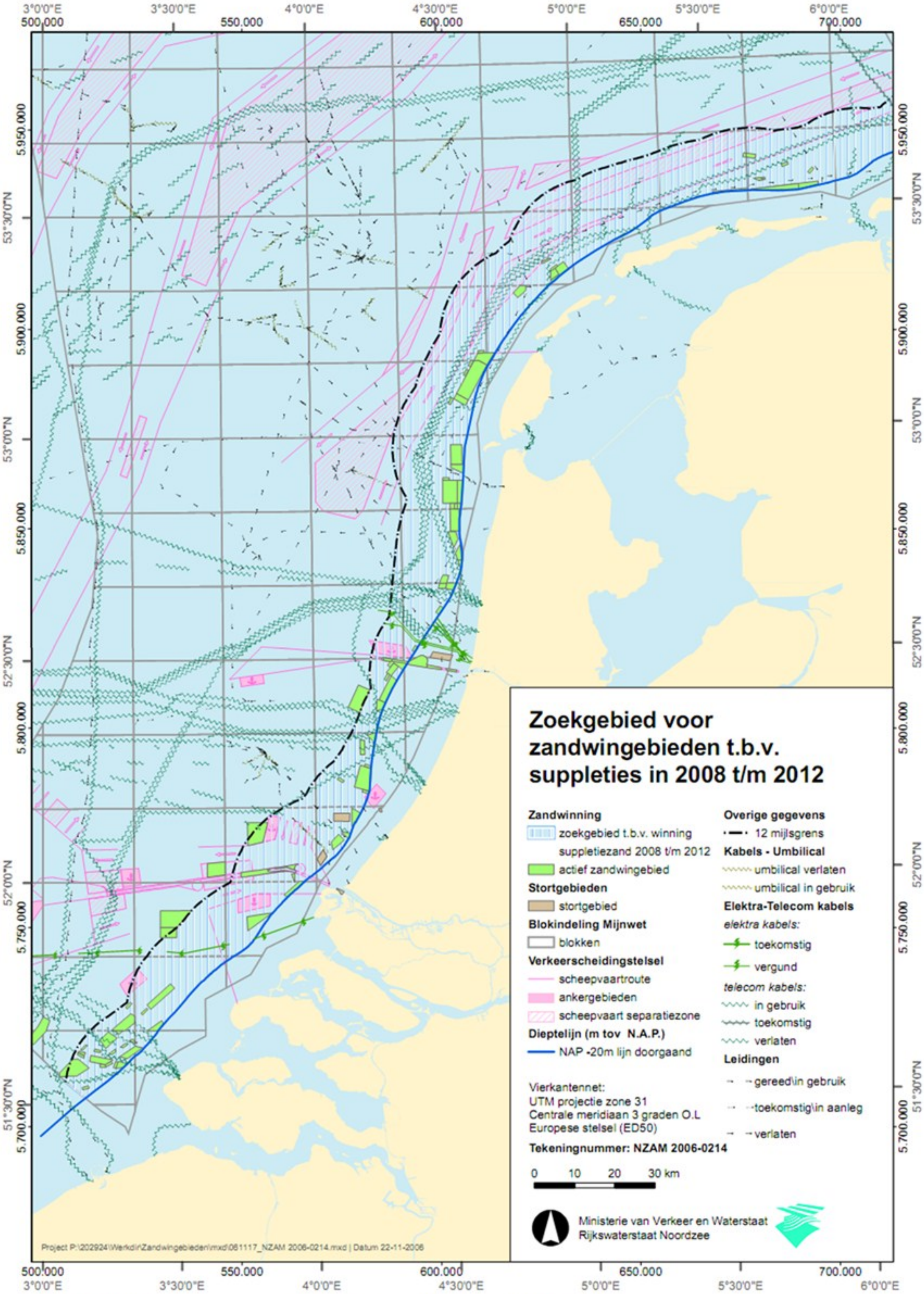
Coastal cell 2 **Transect 810 1630**

#	Location	Transect S Transect E		Cell	Year	Kind	Volume m3	m'	Lenght
502	Zwanenwater	13,755	18,1	23	1987	B	992550	390	2545
678	Zwanenwater	14,7	17,84	23	1987	D	78400	49	1600
500	Callantsoog	11,15	12,8	2	1979	D	470000	285	1650
499	Callantsoog	12,975	13,75	2	1976	D	342000	441	775
501	Callantsoog	10,825	13,725	2	1986	B	1242434	428	2900
677	Callantsoog	11,75	12,05	2	1986	D	77913	260	300
						Total nourished volume pre-1990	3203297	3	Mln M3

Note:

Only nourishments have been listed between 1965 and 2010. Before 1965 there does not exist a record with reliable nourished volumes, locations and methods.

10.6 Anex VI Sand-mining



Addendum bij startnotitie m.e.r. winning suppletiezand Noordzee 2008 t/m 2012

Fig A.6.1 Zoekgebied en actieve zandwingebieden tbv suppleties 2008-2012
(source: m.e.r. suppletiezand Noordzee 2008)

10.7 Anex VII Volumes per coastal cell, dataset 2 (-100 - +1200 m RSP)

Coastal cell 1

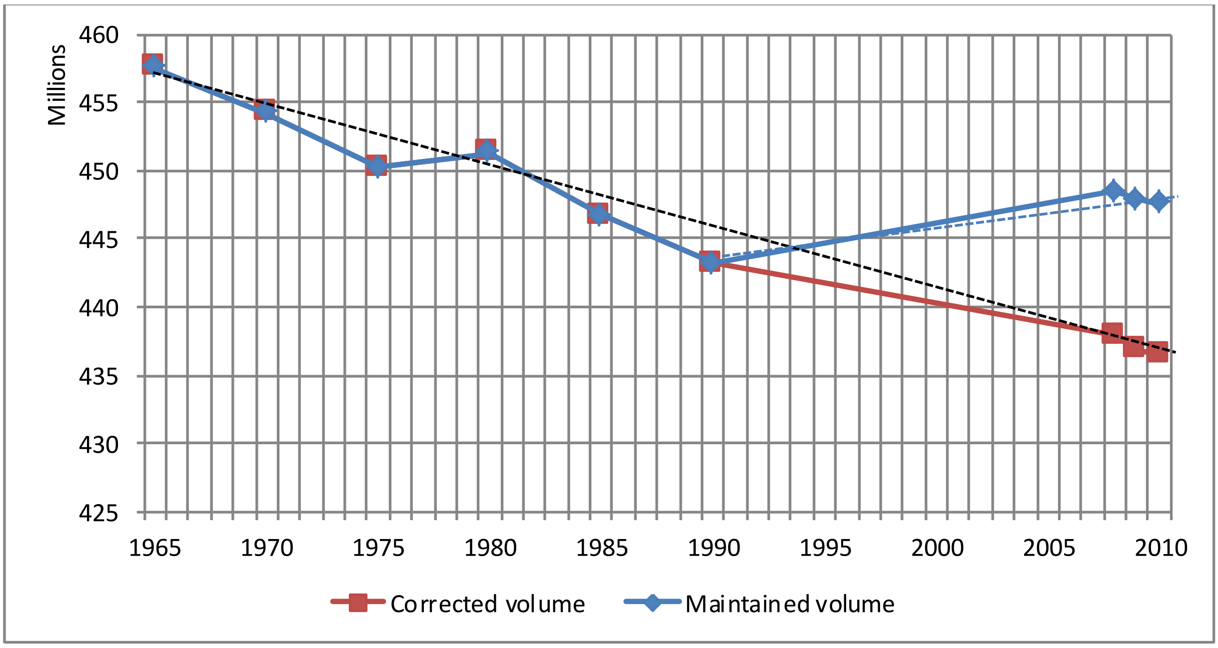


Fig A.7.1 Sediment volume cell 1 between -100 - + 1200 RSP

	1965 – 1990 : - 570.000 m^3 per year	1990 – 2010 : 220.000 m^3 per year
Corrected	1965 – 1990 : - 570.000 m^3 per year	1990 – 2010 : - 330.000 m^3 per year

Coastal cell 2

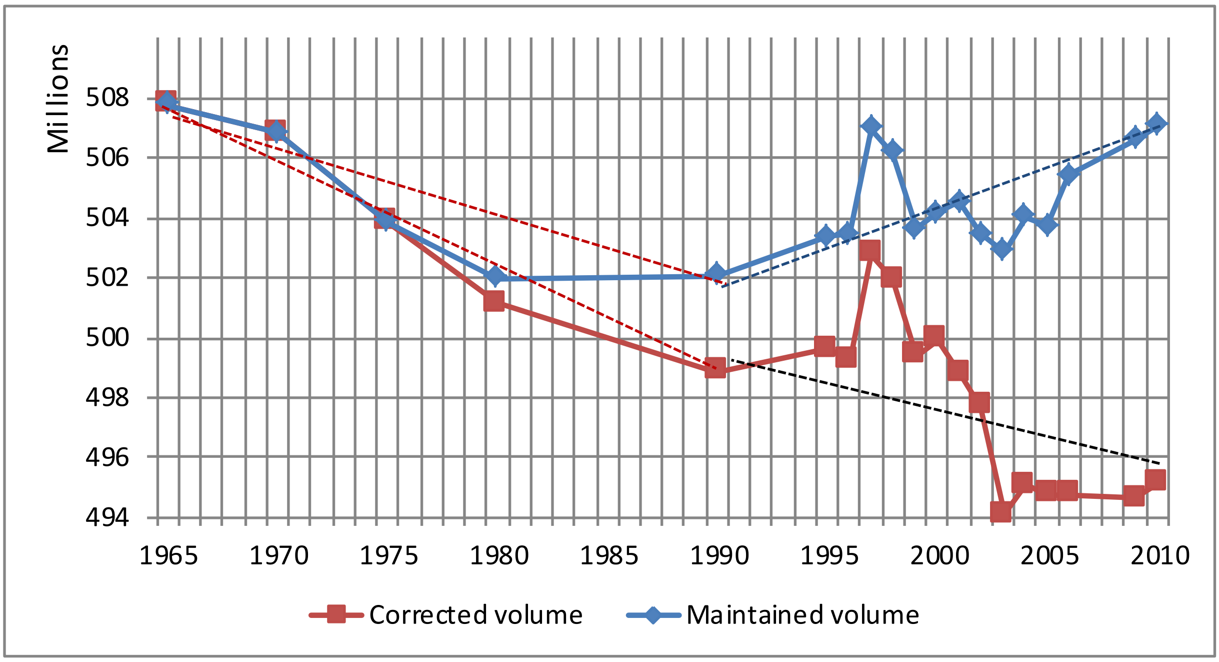


Fig A.7.2 Sediment volume cell 2 between -100 - + 1200 RSP

	1965 – 1990 : - 330.000 m^3 per year	1990 – 2010 : 250.000 m^3 per year
Corrected	1965 – 1990 : - 350.000 m^3 per year	1990 – 2010 : -180.000 m^3 per year

Coastal cell 3

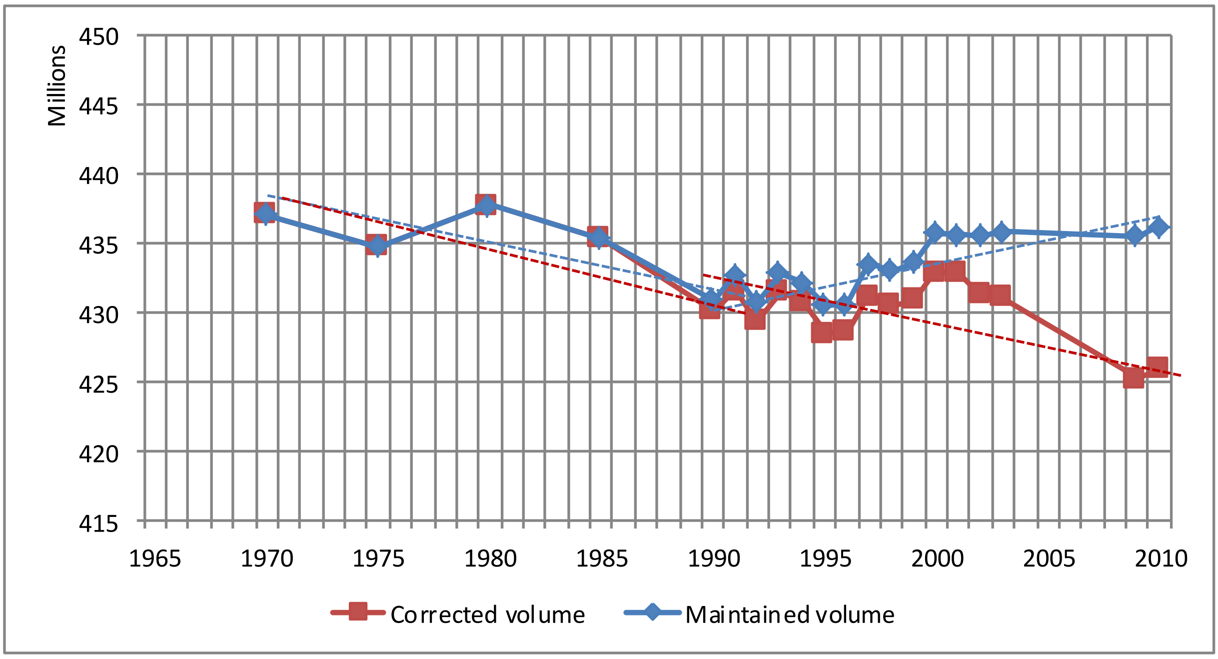


Fig A.7.3 Sediment volume cell 3 between -100 - + 1200 RSP

	1965 – 1990 : - 245.000 m^3 per year	1990 – 2010 : 260.000 m^3 per year
Corrected	1965 – 1990 : - 300.000 m^3 per year	1990 – 2010 : -250.000 m^3 per year

Coastal cell 4

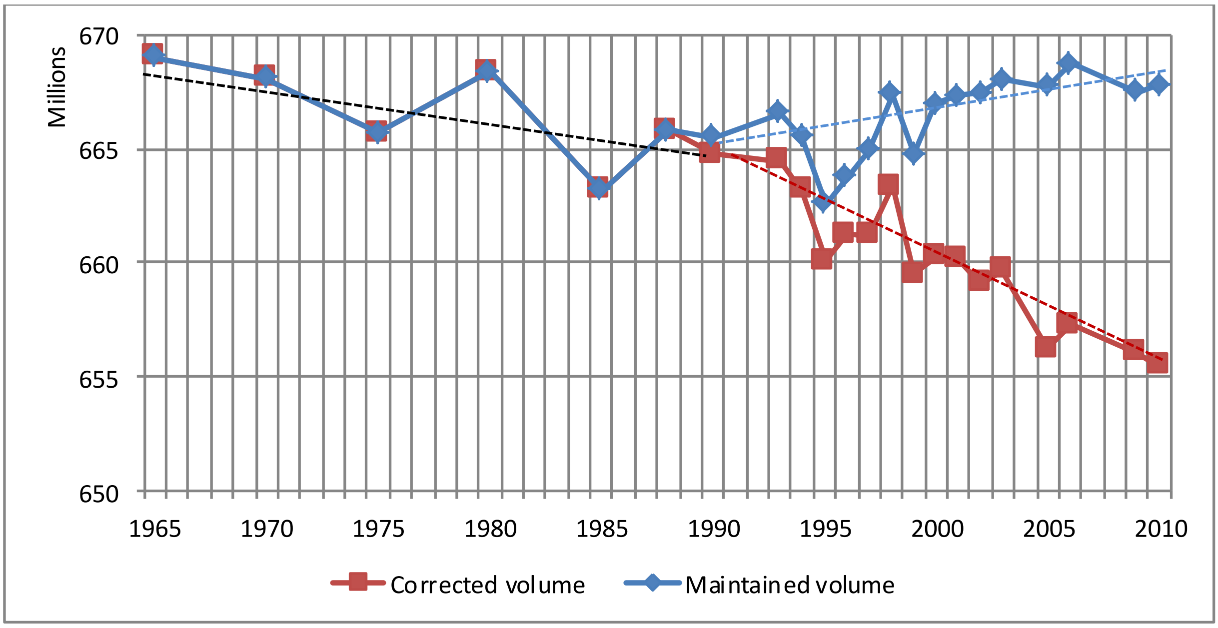


Fig A.7.4 Sediment volume cell 4 between -100 - + 1200 RSP

	1965 – 1990 : - 110.000 m^3 per year	1990 – 2010 : 115.000 m^3 per year
Corrected	1965 – 1990 : - 110.000 m^3 per year	1990 – 2010 : -460.000 m^3 per year

Coastal cell 5

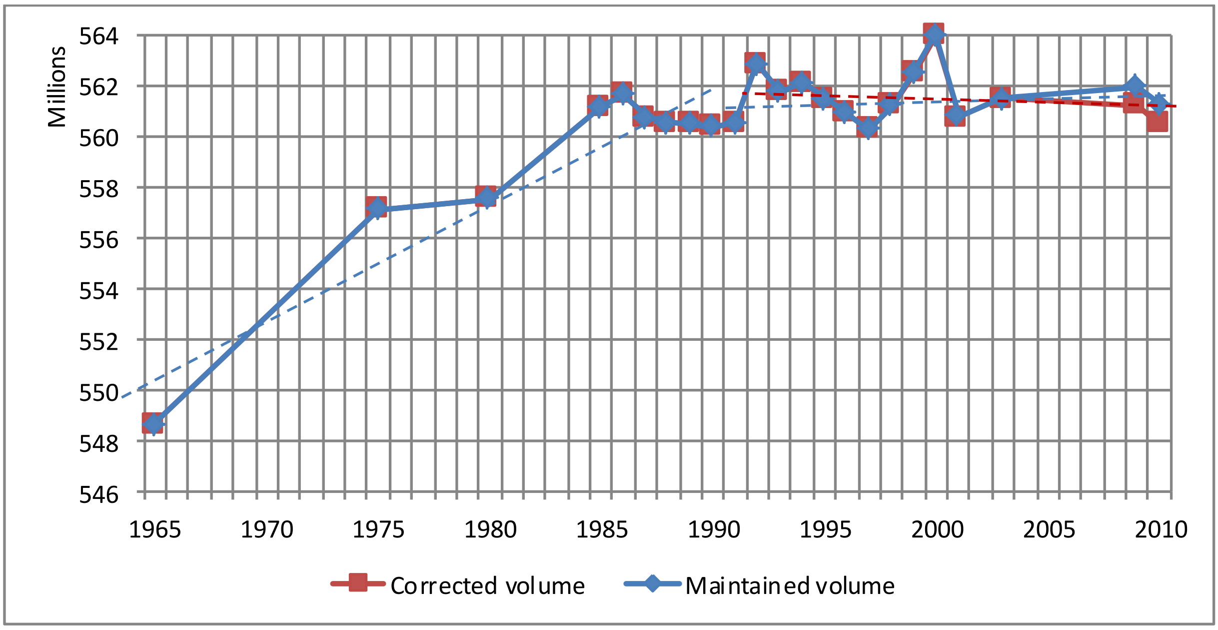


Fig A.7.5 Sediment volume cell 5 between -100 - + 1200 RSP

	1965 – 1990 : 470.000 m^3 per year	1990 – 2010 : 40.000 m^3 per year
Corrected	1965 – 1990 : 470.000 m^3 per year	1990 – 2010 : -25.000 m^3 per year

Coastal cell 6

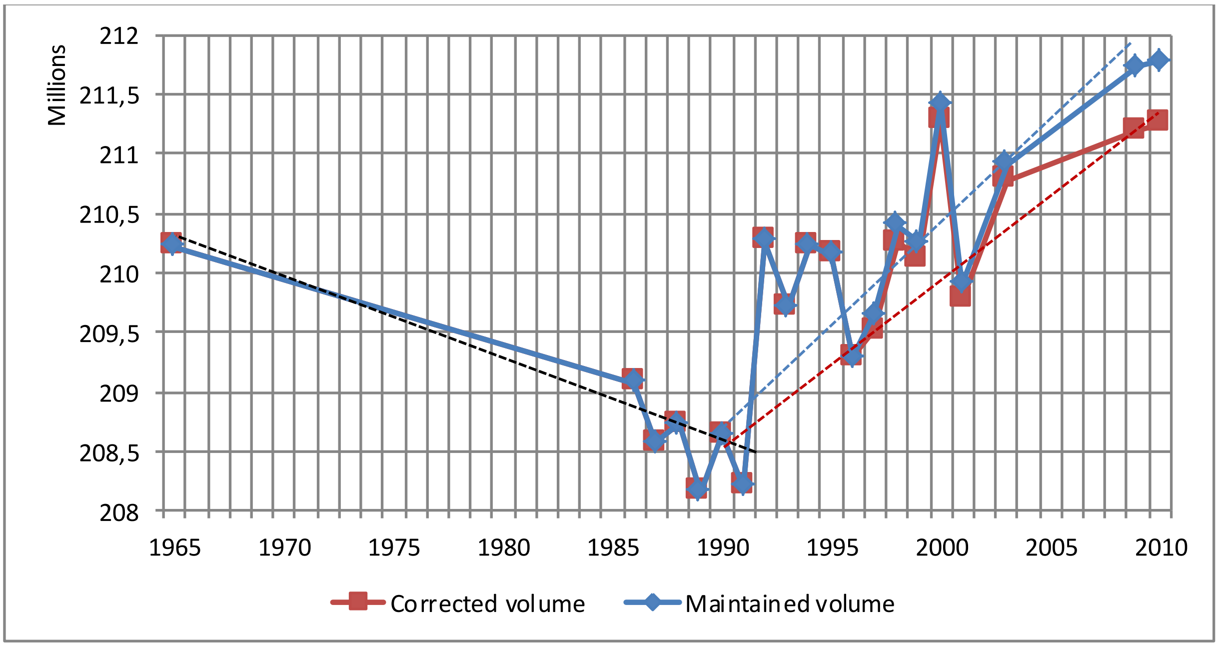


Fig A.7.6 Sediment volume cell 6 between -100 - + 1200 RSP

	1965 – 1990 : -60.000 m^3 per year	1990 – 2010 : 155.000 m^3 per year
Corrected	1965 – 1990 : -60.000 m^3 per year	1990 – 2010 : 130.000 m^3 per year

Coastal cell 7

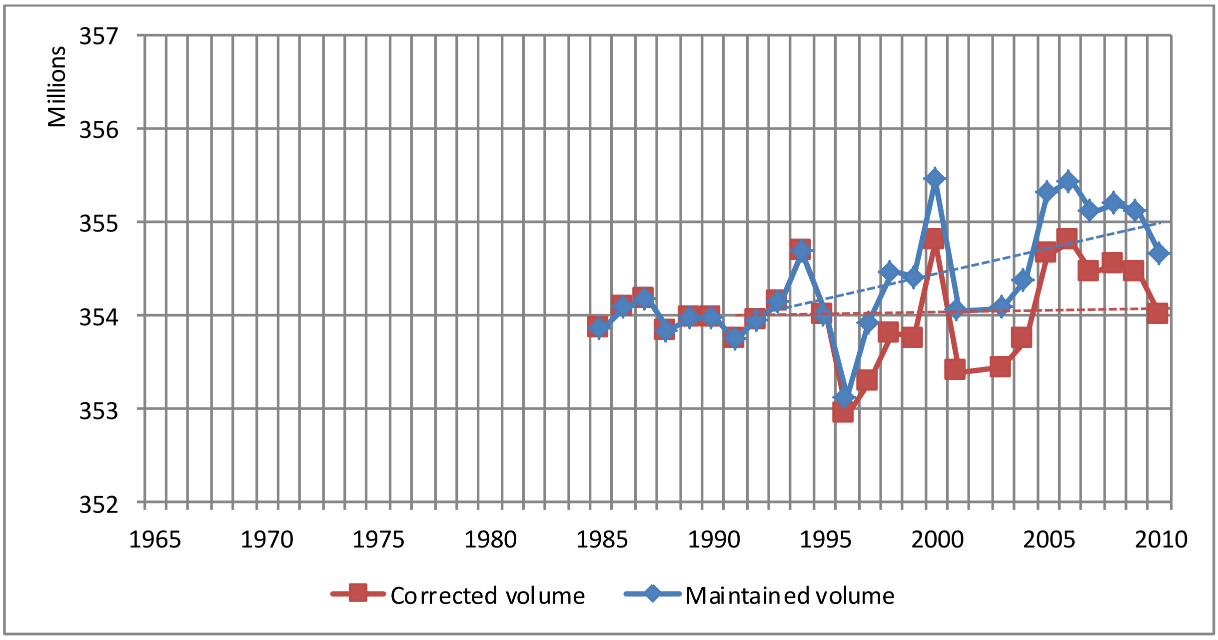


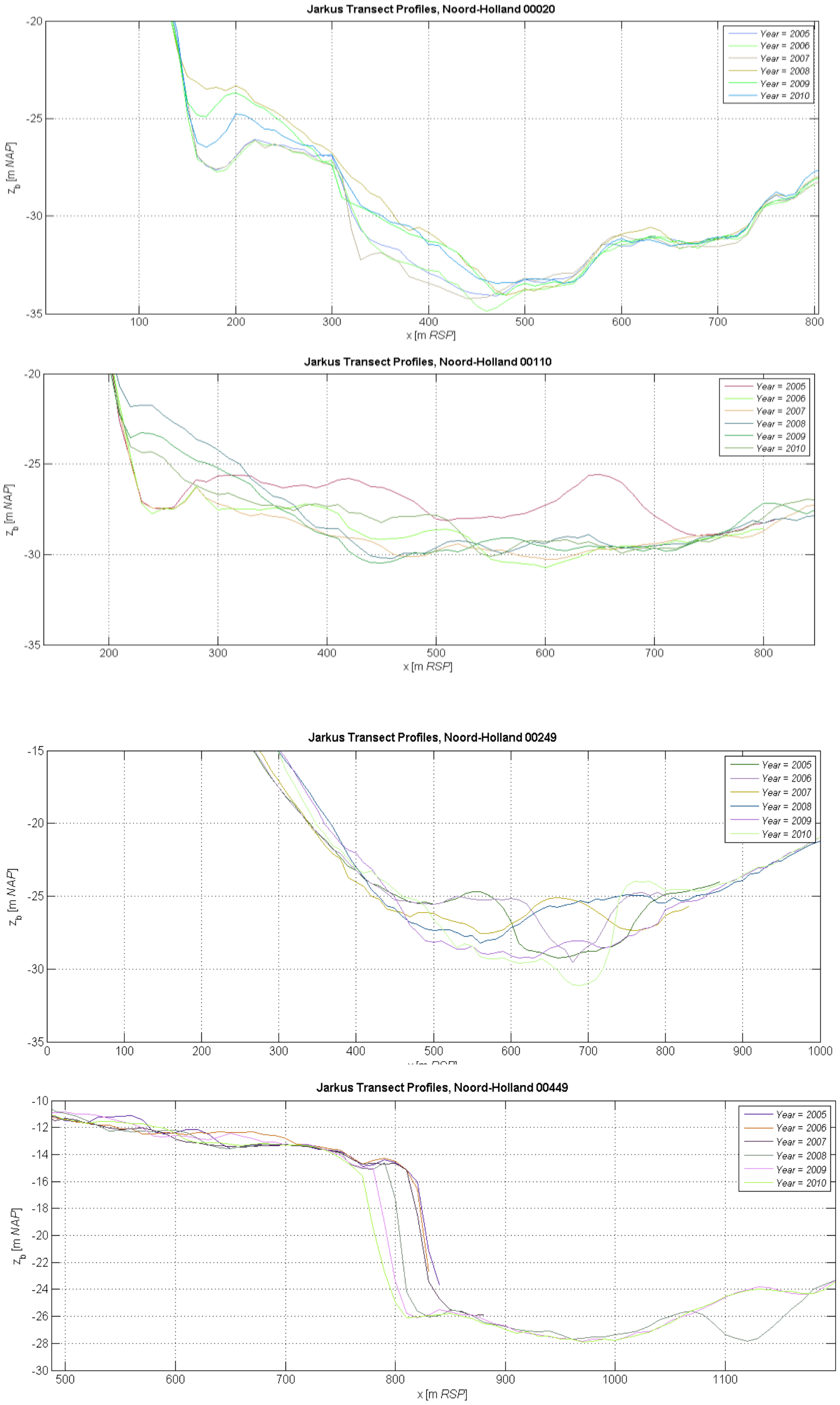
Fig A.7.7 Sediment volume cell 7 between -100 - + 1200 RSP

	1965 – 1990 : - m^3 per year	1990 – 2010 : 35.000 m^3 per year
Corrected	1965 – 1990 : - m^3 per year	1990 – 2010 : 2.000 m^3 per year

10.8 Anex VIII Additional data system description, per cell

Cell 1

In the description of coastal cell 1 the morphodynamics of the “Nieuwe Schulpengat” are discussed. To indicate occurring dynamics, Jarkus-profiles over the period 2005 to 2010 are presented. To give an idea of the occurring erosion rates a rough calculation is made.



Average deepening of over the period 2008-2010:
Transect 20-100:
1.5 m per year (150-300 m RSP)
Transect 110-200:
1 m per year (200-350 m RSP)
Transect 249 (200-300):
1.5 m per year (450-600 m RSP)
2.5 m per year (600-750 m RSP)
Transect 449 (300-449):
15 m landward migration of he channel per year over a depth of 10 m

Equivalent erosion rate:
Transect 20-100:
Order - 180.000 m^3/year
Transect 110-200:
Order - 140.000 m^3/year
Transect 249 (200-300):
Order - 500.000 m^3/year
Transect 449 (300-449):
Order - 250.000 m^3/year

Estimation total erosion rate due to migration and deepening of the channel:
Order – 1.000.000 m^3/year

Fig A.8.1 Erosion / deepening and migration “Nieuwe Schulpengat” channel

Cell 3

As indicated in the description of the nearshore volume evolution of cell 3, bar behaviour near the seaward boundary cannot be the cause of temporal volume changes. Over the coastal stretch such cycles are not found near the seaward boundary. By examining the profiles adjacent to the Hondsbossche and Pettemer sea defence it was found that temporal fluctuations occur near the structure. Alongshore differences are quite substantial and a particular pattern in profile evolution has not been found. Therefore, a complete theory with regards to the temporal volume changes has not been made. The fluctuations of the bed near the used boundary do indicate that possible losses due to these temporal variations are likely to influence the near shore volume significantl y.

Two plots have been added to sketch the local profile variations. Along the whole sea defence similar variations near the structure have been observed.

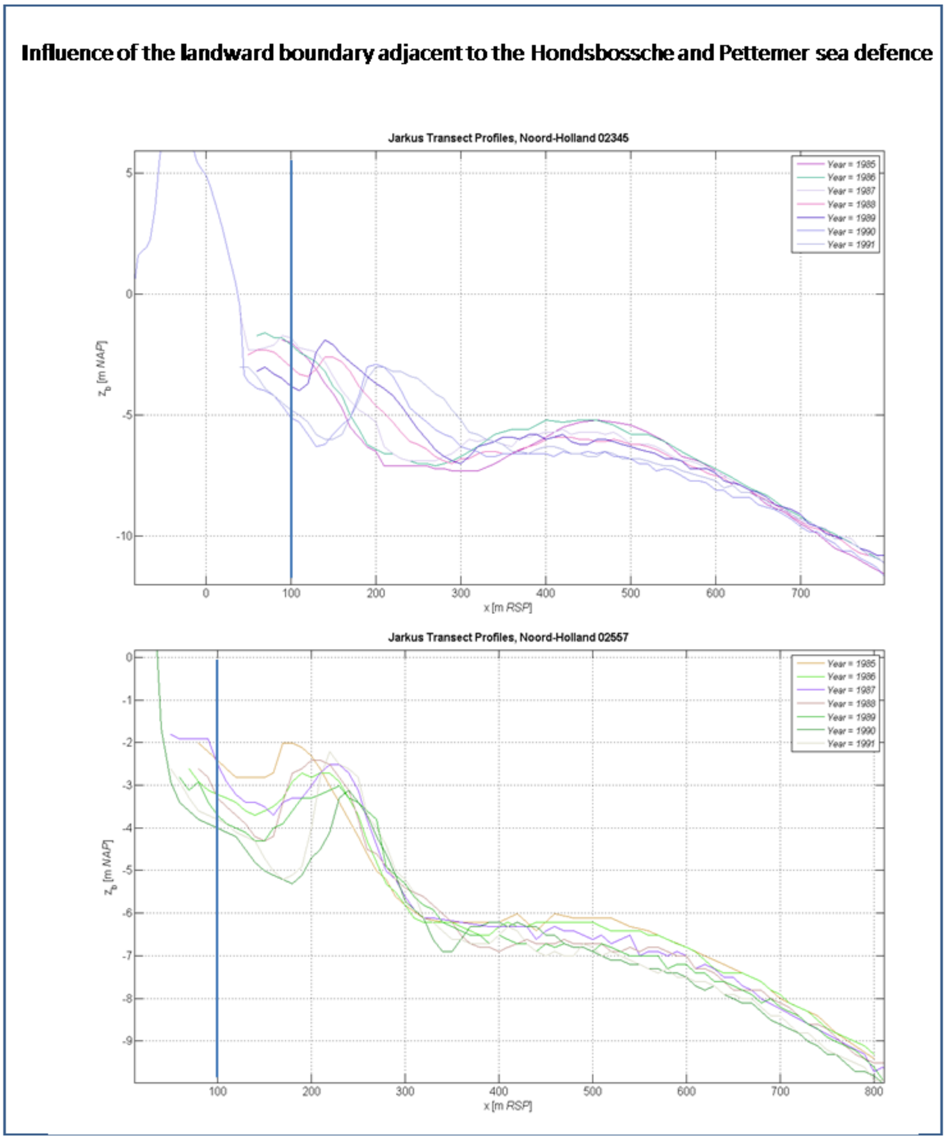


Fig A.8.2 Bar behaviour cell 3

Cell 4

Sedimentation and erosion patterns near artificial dune breach “de Kerf”.

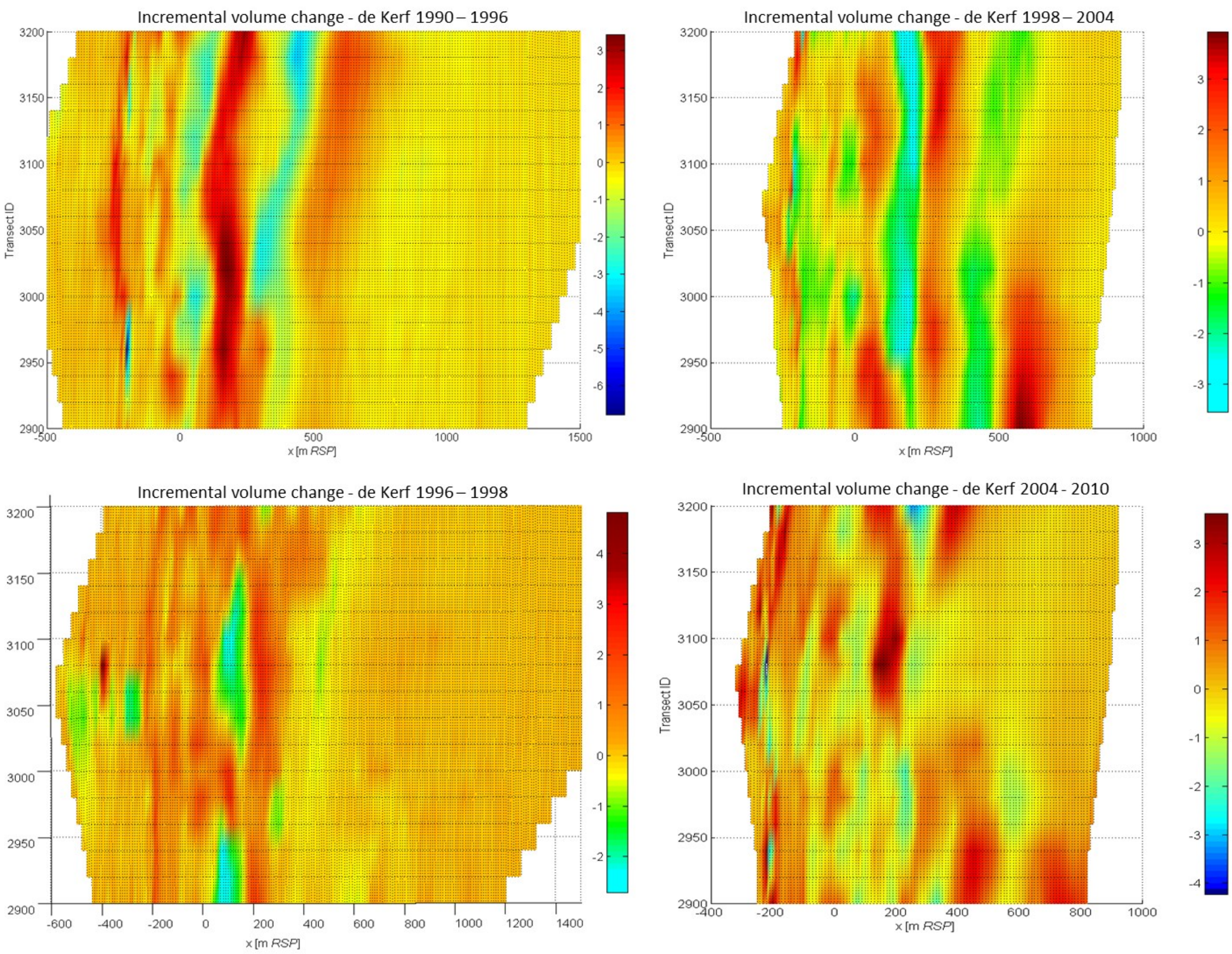


Fig A.8.3 Sedimentation and erosion patterns near “de Kerf”

Cell 5

By examining various profiles along the coastal stretch, land and seaward movement of a bar near the seaward boundary can be observed. The observed temporal volume fluctuations can be at least partly supported by the qualitative examples presented.

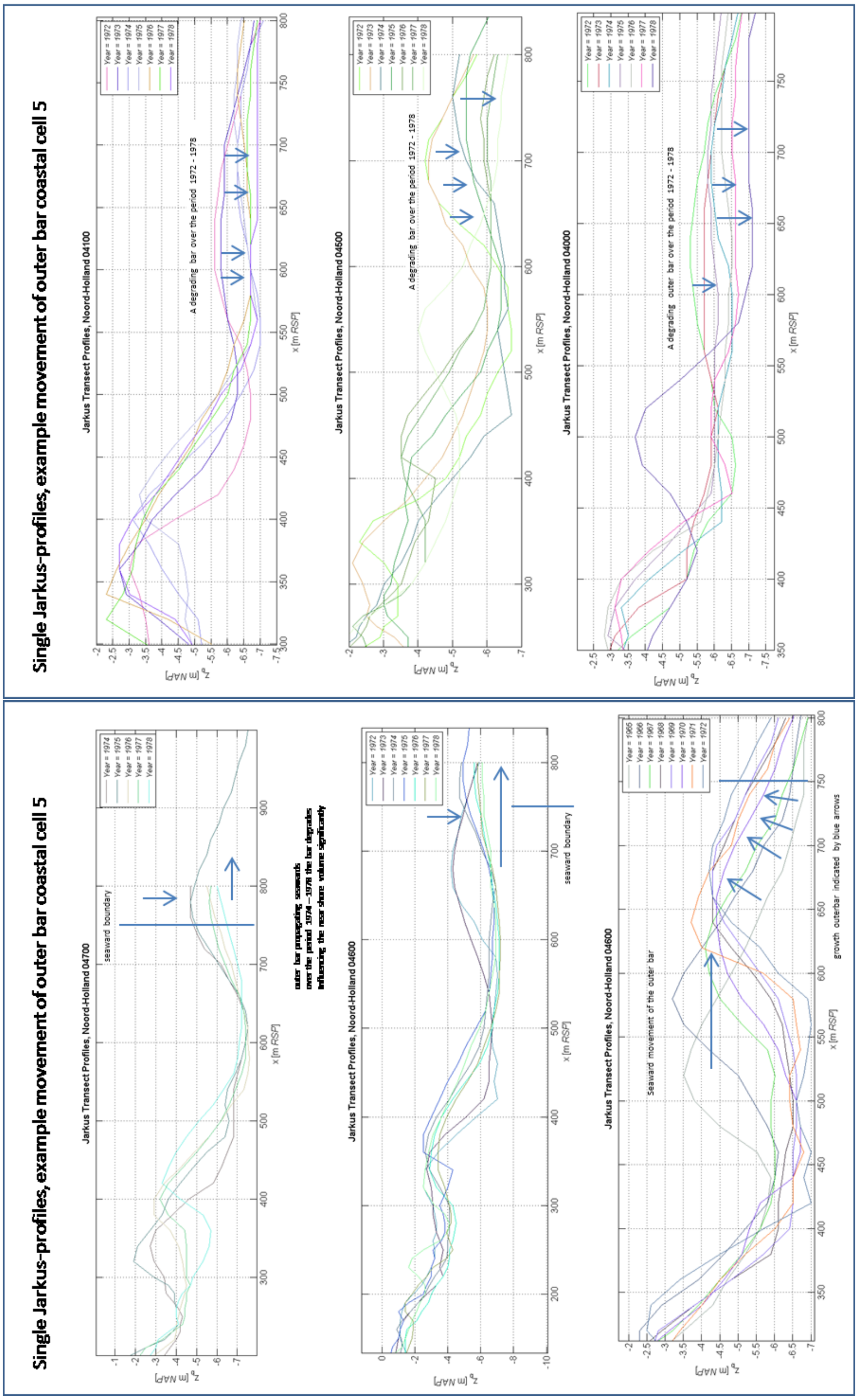


Fig A.8.4 Bar behaviour cell 5

Cell 6

Example seaward movement outer bar years 1970, 1974 and 1978

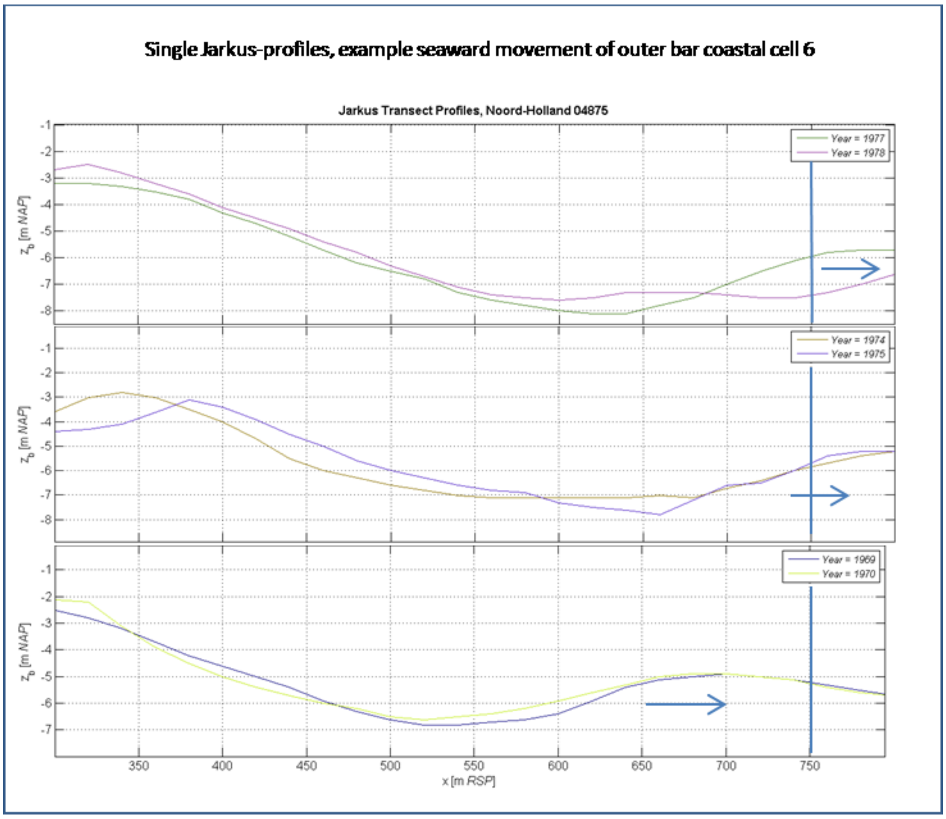


Fig A.8.5 Jarkus-profile 4875

10.9 Anex IX Matlab scripts

All Matlab scripts can be found in the Open Earth repository, Rijkswaterstaat, Jarkus.
For information: http://public.deltares.nl/display/OET/OpenEarth

Jarkus profile volumes

This script is used to generate profile volumes. With these volumes the near shore volume evolution plots are made. The script plots volumes per transect over a certain period.

```
%% JARKUS-Volume
%%
%   This script is enables users to calculate and save the volume in m2 under a
%   JARKUS-profile, for multiple profiles, for each year directly from the Jarkus-file.
%
%%  Boundaries
%   The script calculates the volume according
%   to the following boundaries:
%   Upper boundary:     f(z) (value of z as determined in the Jarkus-data)
%                       if  z > 50 ; + 50 m  NAP is used
%   Lower boundary:     - 50 m NAP
%   Seaward boundary:   as input parameter in m with respect to RSP
%   Landward boundary:  as input parameter in m with respect to RSP
%   Transect A:         as input parameter a transect number is required
%   Transect B:         as input parameter a second transect number is required
%%  Timeframe
%   Consequently the script will ask for the first and last year as bounds
%   in time.
%   Input start year: '1990'
%   Input end year: '2010'
%%  Area
%   As input both the coastal area and area name are required
%
%   Coastal areas are listed as follows:
%   1     Rottum
%   2     Schiermonnikoog
%   3     Ameland
%   4     Terschelling
%   5     Vlieland
%   6     Texel
%   7     Noord-Holland
%   8     Rijnland
%   9     Delftland
%  10     Maasvlakte
%  11     Voorne
%  12     Goeree
%  13     Schouwen
%  14     Oosterschelde
%  15     Noord Beveland
%  16     Walgeren
%  17     Zeeuws Vlaanderen
%
%%
Start_y=1970;
End_y=2010;

prompt = {'Knum', 'Knam ', 'Start_y ', 'End_y '};
dlg_title = 'Plotting parameters';
num_lines = 1;

% Es. def = {'16','Walgeren','1990','2010'};
def = {'7','Noord-Holland','1990','2010'};
answer = inputdlg(prompt,dlg_title,num_lines,def);
Years=End_y-Start_y+1;
Knum=answer{1};

prompt = {'Input Landward x ', 'Input Seaward x '};
dlg_title = 'Transect x interval';
num_lines = 1;
def = {'-65','780'};
answers = inputdlg(prompt,dlg_title,num_lines,def);
```

```
maxL=def(2)
minS=def(1)

prompt = {'Input transect begin ', 'Input transect end '};
dlg_title = 'Transect x interval';
num_lines = 1;
transects = {'20','810'};
answers = inputdlg(prompt,dlg_title,num_lines,transects);

TransectA=transects(1)
TransectB=transects(2)

if str2double(TransectA)>=10000
   trans_b=strcat(Knum,'0',num2str(TransectA));
elseif str2double(TransectA)>=1000 && str2double(TransectA)<10000
   trans_b=strcat(Knum,'00',num2str(TransectA)) ;
elseif str2double(TransectA)<1000 && str2double(TransectA)>=100
   trans_b=strcat(Knum,'000',num2str(TransectA));
end
if str2double(TransectB)>=10000
   trans_e=strcat(Knum,'0',num2str(TransectB));
elseif str2double(TransectB)>=1000 && str2double(TransectB)<10000
   trans_e=strcat(Knum,'00',num2str(TransectB)) ;
elseif str2double(TransectB)<1000 && str2double(TransectB)>=100
   trans_e=strcat(Knum,'000',num2str(TransectB));
end

% Calculates the number of transects
id = nc_varget('C:\Users\Hollandia\Documents\Msc Thesis\Open Earth\Volume
Trend\jarkusdune.nc','id');
trans_nr = find(id(:)>=str2double(trans_b) & id(:)<=str2double(trans_e));
Trans=trans_nr(length(trans_nr))-trans_nr(1)+1;

%Reading profiles and intergrating surface
for m=1:Trans
i=0;
for j = 1:Years
    i = i + 1;
    clear t
    t = jarkus_readTransectDataNetcdf('C:\Users\Hollandia\Documents\Msc Thesis\Open
Earth\Volume Trend\Jarkusclean.nc',id(trans_nr(m)), j+Start_y-1);
    Y(j)=t.year;
       x(i) = {t.xi(~isnan(t.zi))};
    if isempty(t.zi(~isnan(t.zi)))==0 %&& max(x{j})>=minS && min(x{j})<=maxL
       z(i) = {t.zi(~isnan(t.zi))};
       [Volume result Boundaries] = getVolume(x{i}, z{i}, 50, -50, maxL, minS);
       V(m,j)=Volume;
       B=Boundaries;
       L(j)=B.Landward;
       S(j)=B.Seaward;
    else V(j)=NaN;
         L(j)=NaN;
         S(j)=NaN;
    end
end
save(['Volume\','Volumecell.mat'],'-struct','V')
% To load, add path and write Volumecell
end
```

This script is used to generate the trends per profile. It enables for volume trends per transect and allows to correct for nourishment volumes. Furthermore, figure 1 (as reffered to in the script) generates the alongshore distribution of the profile volume trends.

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
          Trend analysis nourishment volumes
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all
close all

%Select transects (kustvaknr + transect)
%NH 7000000 + transect 1000 = 7001000

trans_b = '7002900';
trans_e = '7005500';

% Finds out how many transects are between the starting and ending transects
id = nc_varget('C:\Users\Hollandia\Documents\Msc Thesis\Open Earth\Volume Trend\jarkusclean.nc','id');
trans_nr = find(id(:)>=str2double(trans_b) & id(:)<=str2double(trans_e));
Trans=trans_nr(length(trans_nr))-trans_nr(1)+1;

%Select kustvak / nummer / start-end years to load

Knum='7';
 Knam='Noord-Holland';
 Start_y=1970;
 End_y=2010;
prompt = {'Knum', 'Knam ', 'Start_y ', 'End_y '};
 dlg_title = 'Plotting parameters';
 num_lines = 1;
% Es. def = {'8','Rijnland','1990','2010'};
 def = {'7','Noord-Holland','1970','2010'};
 answer = inputdlg(prompt,dlg_title,num_lines,def);

prompt = {'Input Landward x ', 'Input Seaward x '};
dlg_title = 'Transect x interval';
num_lines = 1;
def = {'-100','750'};
answers = inputdlg(prompt,dlg_title,num_lines,def);

% Routine per transect (jarkus raai)
for m=1:Trans

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%    ROUTINE FOR EACH TRANSECT    %%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
close all
 clearvars -except m MultiTrans* id trans* Trans answer Knum Knam Start_y End_y answers def
% Reads the Jarkus data from the repository and returns volumes and
% boundaries
i = 0;
Years=End_y-Start_y+1;
for j = 1:Years
    i = i + 1;
    clear t
    t = jarkus_readTransectDataNetcdf('C:\Users\Hollandia\Documents\Msc Thesis\Open Earth\Volume
Trend\jarkusclean.nc',id(trans_nr(m)), j+Start_y-1);
    Y(j)=t.year;
    if isempty(t.zi(~isnan(t.zi)))==0
       x(i) = {t.xi(~isnan(t.zi))};
       z(i) = {t.zi(~isnan(t.zi))};
       [Volume result Boundaries] = getVolume(x{i}, z{i}, 50, -50, -2500, 6000);
       B=Boundaries
       V(j)=Volume;
       Lr(j)=B.Landward;
       Sr(j)=B.Seaward;
    else V(j)=NaN;
         Lr(j)=NaN;
         Sr(j)=NaN;
    end
end

% Max Landward boundary and min Seaward boundary in the years
maxL=max(Lr(1:Years));
minS=min(Sr(1:Years));
```

```
% Reads again the Jarkus data from the repository and returns volumes and
% boundaries, from maxL to minS
i=0;
for j = 1:Years
    i = i + 1;
    clear t
    t = jarkus_readTransectDataNetcdf('C:\Users\Hollandia\Documents\Msc Thesis\Open Earth\Volume
Trend\jarkusclean.nc',id(trans_nr(m)), j+Start_y-1);
    Y(j)=t.year;
    if isempty(t.zi(~isnan(t.zi)))==0
       x(i) = {t.xi(~isnan(t.zi))};
       z(i) = {t.zi(~isnan(t.zi))};
       [Volume result Boundaries] = getVolume(x{i}, z{i}, 50, -50, maxL, minS);
       V(j)=Volume;
       B=Boundaries;
       L(j)=B.Landward;
       S(j)=B.Seaward;
    else V(j)=NaN;
       L(j)=NaN;
       S(j)=NaN;
    end
end

% Shows the Landward and Seaward boundaries changed
Bound = [Y', L', S'];
SL=(S'-L')';
% Calls modified_rws_suppletiedatabase_mod.m, that creates the structure data
% from ModifiedSuppletiedatabaseVoorprojectGiorgio.xls
suppl=modified_rws_suppletiedatabase_mod;
% Defining:
volk_kustvak=Knam;
% Reads nourishment data
suppl_bdatum=floor((suppl.p_beginuitvoering+suppl.begin_uitvoering_mnd/12)*365.24);
suppl_edatum=floor((suppl.p_einduitvoering+suppl.Eind_uitvoering_mnd/12)*365.24);
suppl_vol=suppl.b_gemeten;
suppl_vol(isnan(suppl_vol))=0;
suppl_braai=suppl.l_beginraai*100; % [decam]
suppl_eraai=suppl.l_eindraai*100; % [decam]
suppl_vol2=suppl_vol./(suppl_eraai-suppl_braai)/10; % [m3/m]
suppl_vol2(isnan(suppl_vol2))=0;
suppl_kustvak=(suppl.Kustvak)';
suppl_type=(suppl.b_typewerk)';
%%%%%%%%%%%%%
% Max date between topo&bathy measurements in the chosen transect
topo = 1970+nc_varget('C:\Users\Hollandia\Documents\Msc Thesis\Open Earth\Volume
Trend\jarkusclean.nc','time_topo')/365.24;
bathy = 1970+nc_varget('C:\Users\Hollandia\Documents\Msc Thesis\Open Earth\Volume
Trend\jarkusclean.nc','time_bathy')/365.24;
Tmeas=max(topo,bathy);
Tmeas=(Tmeas((Start_y+1-1965):(End_y+1-1965),find(nc_varget('C:\Users\Hollandia\Documents\Msc Thesis\Open
Earth\Volume Trend\jarkusclean.nc','id')==id(trans_nr(m)))))';
% Creates a new folder in the directory for the figures
mkdir('Jarkus_cell 2a\');
% Evaluation of measured and corrected
% volumes. Black points and blue points
% Introducing the alpha-Factor (as red points) here together with the
% blue points
suppl_edatummax=max(floor((suppl_edatum(:,1))/365.24));
dum(j)=0;
dum_alpha(j)=0;
for j=1:Years
    nourvol(j)=0;
    nourvol_alpha(j)=0;
    corvol(j)=V(j);
    corvol_alpha(j)=V(j);
    k=1;
    dum2(j)=1;
for i=1:length(suppl_kustvak)
    if strcmp(char(volk_kustvak),suppl_kustvak(k,1)) == 1 ...
       && suppl_braai(k,1)<=str2double(t.transectID) && suppl_eraai(k,1)>=str2double(t.transectID) ...
       && floor(suppl_bdatum(k,1)/365.24) ==Y(j);
       dum2(j)=k;
       % The "if" below can be useful when a nourishment has built in more
       % than one year
        if  suppl_edatum(k,1)/365.24 < (Y(j)+1.);
            if nourvol(j)~=0
            nourvol(j)=nourvol(j)+suppl_vol2(k,1);
            else
            nourvol(j)=suppl_vol2(k,1);
            end
        else suppl_edatum(k,1)/365.24 >= (Y(j)+1.);
            if corvol(j)~=0
            nourvol(j)=nourvol(j)+suppl_vol2(k,1);
            else
            nourvol(j)=V(j)-suppl_vol2(k,1);
            end
```

```
         end
        % Here are the volumes corrected by the alpha-Factor
        if  strcmp(char('onderwatersuppletie'),suppl_type(k,1)) == 1
        alpha=0; % Assigning alpha-Factor=1 to shoreface nourishments and 1 to others
        else
        alpha=0;
        end
         if  suppl_edatum(k,1)/365.24 < (Y(j)+1.);
             if nourvol_alpha(j)~=0
             nourvol_alpha(j)=nourvol_alpha(j)+suppl_vol2(k,1)*alpha;
             else
             nourvol_alpha(j)=suppl_vol2(k,1)*alpha;
             end
         else suppl_edatum(k,1)/365.24 >= (Y(j)+1.);
             if corvol_alpha(j)~=0
             nourvol_alpha(j)=nourvol_alpha(j)+suppl_vol2(k,1)*alpha;
             else
             nourvol_alpha(j)=V(j)-suppl_vol2(k,1)*alpha;
             end
         end
         fill_edatum(k)=suppl_edatum(k,1)/365.24;
         fill_bdatum(k)=suppl_bdatum(k,1)/365.24;
    end
    k=k+1;
end
    dum(j+1)=dum(j)+nourvol(j);
    corvol(j)=V(j)-dum(j+1);
    if strcmp(char(volk_kustvak),suppl_kustvak(dum2(j),1)) == 1 ...
        && suppl_braai(dum2(j),1)<=str2double(t.transectID) &&
suppl_eraai(dum2(j),1)>=str2double(t.transectID) ...
        && floor(suppl_bdatum(dum2(j),1)/365.24) ==Y(j)...
        && Tmeas(j)<=suppl_edatum(dum2(j),1)/365.24;
        % Could be also Tmeas(j)<suppl_bdatum(dum2(j),1)/365.24,
        % but I choose to subtract only when the nourishment period is ended
        corvol(j)=V(j)-dum(j);
    end
    % Here are the operations on the alpha volumes (Volumes corrected with alpha)
    dum_alpha(j+1)=dum_alpha(j)+nourvol_alpha(j);
    corvol_alpha(j)=V(j)-dum_alpha(j+1);
    if strcmp(char(volk_kustvak),suppl_kustvak(dum2(j),1)) == 1 ...
        && suppl_braai(dum2(j),1)<=str2double(t.transectID) &&
suppl_eraai(dum2(j),1)>=str2double(t.transectID) ...
        && floor(suppl_bdatum(dum2(j),1)/365.24) ==Y(j)...
        && Tmeas(j)<=suppl_edatum(dum2(j),1)/365.24;
        corvol_alpha(j)=V(j)-dum_alpha(j);
    end
end
clear dum
clear dum_alpha
clear dum2
% Now figures 3 and 4
figure(3) % Measurements extension
% Barplot on Seaward
bar_Sr=bar(Y(find(~isnan(Sr(:)>=0))),Sr(find(~isnan(Sr(:)>=0))));
set(bar_Sr,'FaceColor',[0.04 0.52 0.78])
hold on
% Barplot on Landward
bar_Lr=bar(Y(find(~isnan(Lr(:)<=0))),Lr(find(~isnan(Lr(:)<=0))));
set(bar_Lr,'FaceColor',[1 0.69 0.39])
% White barplot for the lack of Seaward data
Sr_white=Sr;
Sr_white(:,find(~(Sr(:)>0==0)))=0;
if isequal(Sr_white(~isnan(Sr_white)),...
    zeros(1,length(Sr_white(~isnan(Sr_white)))))~=1
    legwardwS = (' Lack of Seaward meas.');
    wS=bar(Y(1:Years),Sr_white(1:Years));
    set(wS,'FaceColor','w')
end
% White barplot for the lack of Landward data
Lr_white=Lr;
Lr_white(:,find(~(Lr(:)<0==0)))=0;
if isequal(Lr_white(~isnan(Lr_white)),...
    zeros(1,length(Lr_white(~isnan(Lr_white)))))~=1
    wL=bar(Y(1:Years),Lr_white(1:Years));
    legwardwL = (' Lack of Landward meas.');
    set(wL,'FaceColor','w')
end
% Plot features
xlim([1969 2011])
ylim([-300 3200])
%ylim([min(Lr)-100 max(Sr)+200])
title(['Cross-shore Measurements Extension, ', volk_kustvak,' ', t.transectID],...
    'FontSize',12,'FontWeight','bold')
xlabel('Year','FontSize',12)
ylabel('x [m {\itRSP}]','FontSize',12')
set(gcf,'Position',[5 35 1040 760])
```

```
set(gca,'FontSize',12)
% Defining legend (1)
legward = {' Seaward boundary';' Landward boundary'};
if isequal(Sr_white(~isnan(Sr_white)),...
    zeros(1,length(Sr_white(~isnan(Sr_white)))))~=1 &&...
    isequal(Lr_white(~isnan(Lr_white)),...
    zeros(1,length(Lr_white(~isnan(Lr_white)))))~=1
    legendward=[legward;legwardwS;legwardwL];
elseif  isequal(Lr_white(~isnan(Lr_white)),...
    zeros(1,length(Lr_white(~isnan(Lr_white)))))~=1
    legendward=[legward;legwardwL];
elseif isequal(Sr_white(~isnan(Sr_white)), ...
    zeros(1,length(Sr_white(~isnan(Sr_white)))))~=1
    legendward=[legward;legwardwS];
else
  legendward=legward;
end
hold on
grid on
xbathy{:}(:)=NaN;
loi = [-8,-7,-5,0,10]; % Bedlevels of interest
for i=1:length(loi)
     for j=1:length(x);
        clear dum
        if isempty(x{j})==1 || isempty(z{j})==1
            xbathy{i}(j)=NaN;
        else
            % These dum. are necessary to evaluate the Matlab function
            % findXValueSeaward...
            dum.xe = x{j};
            dum.ze = z{j};
            xbathy{i}(j) = findXValueSeaward(dum,loi(i));
        end
    end
     plot(Y(1:length(x)),xbathy{i},'Color',[rand rand rand],'Marker','x',...
         'MarkerSize',8,'LineWidth',1.5)
    hold on
    % Defining legend (2)
    legbat{i} = ['z_b = ' num2str(loi(i)) ' \itm'];
end
% Legend
legend3=legend([legendward;legbat'],2);
set(legend3,'Location','NorthWest','FontSize',10);
print(gcf,'-dpng','-r300',['Jarkus_cell 2a\',char(Knam),t.transectID,'_','fig3']);
clear dum

i=1;
try % Try/catch cycle for the transects without nourishments
figure(4) % Nourishment type
for i=1:length(fill_edatum)
    if strcmp(char('strandsuppletie'),suppl_type(i))==1;

hvol_st=fill([fill_bdatum(i),fill_bdatum(i),fill_edatum(i),fill_edatum(i)],[0,suppl_vol2(i),suppl_vol2(i),0
],[1 0.69 0.39]);
    set(hvol_st,'EdgeColor',[1 0.69 0.39]);
    hold on
    elseif strcmp(char('onderwatersuppletie'),suppl_type(i))==1;

hvol_on=fill([fill_bdatum(i),fill_bdatum(i),fill_edatum(i),fill_edatum(i)],[0,suppl_vol2(i),suppl_vol2(i),0
],[0.04 0.52 0.78]);
    set(hvol_on,'EdgeColor',[0.04 0.52 0.78]);
    hold on
     else

hvol_ot=fill([fill_bdatum(i),fill_bdatum(i),fill_edatum(i),fill_edatum(i)],[0,suppl_vol2(i),suppl_vol2(i),0
],[0.5 0.5 0.5]);
    set(hvol_ot,'EdgeColor',[0.5 0.5 0.5]);
    end
end
% Plot features
xlim([1969 2011]);
title(['Nourishments type, ', volk_kustvak,' ', t.transectID],'FontSize',12,'FontWeight','bold')
xlabel('Year','FontSize',12)
ylabel('Nourishment Volumes [m^3/m]','FontSize',12)
set(gcf,'Position',[5 35 1040 760])
set(gca,'FontSize',12)
% Again, to be added if we insert other options in the legend
% Mhvol={' Strandsuppletie';' Onderwatersuppletie';' Duinverzwaring';...
%' Landwaartse duinverzwaring';' Zeewaartse duinverzwaring';' Other'};
Mhvol={' Strandsuppletie';' Onderwatersuppletie';' Other'};
hvol=([hvol_st; hvol_on; hvol_ot]); % hvol_dv; hvol_dv; hvol_dv; hvol_ot]);
legend4=legend(hvol,Mhvol,'Location','NorthWest');
set(legend4,'Location','NorthWest','FontSize',10);
grid on
print(gcf,'-dpng','-r300',['Jarkus_cell 2a\',char(Knam),t.transectID,'_','fig4']);
catch
```

```
end
 disp('Evaluating this transect...')
maxL=str2double(answers{1});
minS=str2double(answers{2});

% Re-definition of volumes and boundaries
i=0;
for j = 1:Years
    i = i + 1;
    clear t
    t = jarkus_readTransectDataNetcdf('C:\Users\Hollandia\Documents\Msc Thesis\Open Earth\Volume
Trend\jarkusclean.nc',id(trans_nr(m)), j+Start_y-1);
    Y(j)=t.year;
    if isempty(t.zi(~isnan(t.zi)))==0  && max(x{j})>=minS  && min(x{j})<=maxL
       x(i) = {t.xi(~isnan(t.zi))};
       z(i) = {t.zi(~isnan(t.zi))};
       [Volume result Boundaries] = getVolume(x{i}, z{i}, 50, -50, maxL, minS);
       V(j)=Volume;
       B=Boundaries;
       L(j)=B.Landward;
       S(j)=B.Seaward;
    else V(j)=NaN;
          L(j)=NaN;
          S(j)=NaN;
    end
end

% Re-evaluation of measured and corrected
% volumes. Black points and blue points
% Re-introducing the alpha-Factor (as red points) here together with the
% blue points
suppl_edatummax=max(floor((suppl_edatum(:,1))/365.24));
dum(j)=0;
dum_alpha(j)=0;
for j=1:Years
    nourvol(j)=0;
    nourvol_alpha(j)=0;
    corvol(j)=V(j);
    corvol_alpha(j)=V(j);
    k=1;
    dum2(j)=1;
for i=1:length(suppl_kustvak)
    if strcmp(char(volk_kustvak),suppl_kustvak(k,1)) == 1 ...
       && suppl_braai(k,1)<=str2double(t.transectID) && suppl_eraai(k,1)>=str2double(t.transectID) ...
       && floor(suppl_bdatum(k,1)/365.24) ==Y(j);
       dum2(j)=k;
       % The "if" below can be useful when a nourishment has built in more
       % than one year
        if  suppl_edatum(k,1)/365.24 < (Y(j)+1.);
            if nourvol(j)~=0
            nourvol(j)=nourvol(j)+suppl_vol2(k,1);
            else
            nourvol(j)=suppl_vol2(k,1);
            end
        else suppl_edatum(k,1)/365.24 >= (Y(j)+1.);
            if corvol(j)~=0
            nourvol(j)=nourvol(j)+suppl_vol2(k,1);
            else
            nourvol(j)=V(j)-suppl_vol2(k,1);
            end
        end
       % Here are the volumes corrected by the alpha-Factor
       if  strcmp(char('onderwatersuppletie'),suppl_type(k,1)) == 1
        % Assigning alpha-Factor=1 to shoreface nourishments and 1 to
        % others
       alpha=0;
       else
       alpha=0;
       end
       if  suppl_edatum(k,1)/365.24 < (Y(j)+1.);
            if nourvol_alpha(j)~=0
            nourvol_alpha(j)=nourvol_alpha(j)+suppl_vol2(k,1)*alpha;
            else
            nourvol_alpha(j)=suppl_vol2(k,1)*alpha;
            end
        else suppl_edatum(k,1)/365.24 >= (Y(j)+1.);
            if corvol_alpha(j)~=0
            nourvol_alpha(j)=nourvol_alpha(j)+suppl_vol2(k,1)*alpha;
            else
            nourvol_alpha(j)=V(j)-suppl_vol2(k,1)*alpha;
            end
        end
        fill_edatum(k)=suppl_edatum(k,1)/365.24;
        fill_bdatum(k)=suppl_bdatum(k,1)/365.24;
    end
```

```
    k=k+1;
end
    dum(j+1)=dum(j)+nourvol(j);
    corvol(j)=V(j)-dum(j+1);
    if strcmp(char(volk_kustvak),suppl_kustvak(dum2(j),1)) == 1 ...
        && suppl_braai(dum2(j),1)<=str2double(t.transectID) &&
suppl_eraai(dum2(j),1)>=str2double(t.transectID) ...
        && floor(suppl_bdatum(dum2(j),1)/365.24) ==Y(j)...
        && Tmeas(j)<=suppl_edatum(dum2(j),1)/365.24;
        % Could be also Tmeas(j)<suppl_bdatum(dum2(j),1)/365.24,
        % but I choose to subtract only when the nourishment period is ended
        corvol(j)=V(j)-dum(j);
    end
    % Here are the operations on the alpha volumes (Volumes corrected with alpha)
    dum_alpha(j+1)=dum_alpha(j)+nourvol_alpha(j);
    corvol_alpha(j)=V(j)-dum_alpha(j+1);
    if strcmp(char(volk_kustvak),suppl_kustvak(dum2(j),1)) == 1 ...
        && suppl_braai(dum2(j),1)<=str2double(t.transectID) &&
suppl_eraai(dum2(j),1)>=str2double(t.transectID) ...
        && floor(suppl_bdatum(dum2(j),1)/365.24) ==Y(j)...
        && Tmeas(j)<=suppl_edatum(dum2(j),1)/365.24;
        corvol_alpha(j)=V(j)-dum_alpha(j);
    end
end
clear dum
clear dum_alpha
clear dum2

% And then finally figure 1
figure(1) % Transect volumes and erosion trends
set(gcf,'PaperUnits','centimeters','PaperOrientation','portrait','papersize',[20 15],'paperposition',[0 0
20 15])
axes('position',[.1 .1 .86 .83]);
plot(Tmeas(:),V(:),'ko','MarkerFaceColor','k','MarkerSize',5)
hold on
plot(Tmeas(:),corvol(:),'bo','MarkerFaceColor','b','MarkerSize',5)
%%%plot(Tmeas(:),corvol_alpha(:),'ro','MarkerFaceColor','r','MarkerSize',5) % Comment if alpha=1
% fit1: until 1990 and deletes isnan cells
% Alpha volumes are added
if Start_y<=1990;
    if End_y>=1990;
    Yfit1=Tmeas(1:(1990-Start_y+1));
    Yfit1(:,isnan(corvol(1:(1990-Start_y+1))))=[];
    Yfit1_alpha=Tmeas(1:(1990-Start_y+1));
    Yfit1_alpha(:,isnan(corvol_alpha(1:(1990-Start_y+1))))=[];
    corvolfit1=corvol(1:(1990-Start_y+1));
    corvolfit1(:,isnan(corvol(1:(1990-Start_y+1))))=[];
    corvolfit1_alpha=corvol_alpha(1:(1990-Start_y+1));
    corvolfit1_alpha(:,isnan(corvol_alpha(1:(1990-Start_y+1))))=[];
    elseif End_y<1990;
    Yfit1=Tmeas(1:Years);
    Yfit1(:,isnan(corvol))=[];
    Yfit1_alpha=Tmeas(1:Years);
    Yfit1_alpha(:,isnan(corvol_alpha))=[];
    corvolfit1=corvol(1:Years);
    corvolfit1(:,isnan(corvol))=[];
    corvolfit1_alpha=corvol_alpha(1:Years);
    corvolfit1_alpha(:,isnan(corvol_alpha))=[];
    end
p1=polyfit(Yfit1(:),corvolfit1(:),1);
trend_per1=polyval(p1,Yfit1(:));
std1=sqrt(1/(length(Yfit1)-1)*sum((corvolfit1-polyval(p1,Yfit1)).^2));
up1=polyfit([Yfit1(1) Yfit1(length(Yfit1))],[trend_per1(1)-...
    std1 trend_per1(length(Yfit1))+std1],1);
down1=polyfit([Yfit1(1) Yfit1(length(Yfit1))],[trend_per1(1)+...
    std1 trend_per1(length(Yfit1))-std1],1);
%plot(Yfit1(:),polyval(up1,Yfit1(:)),'b','LineWidth',1.5) % greatest trend1
%plot(Yfit1(:),polyval(down1,Yfit1(:)),'b','LineWidth',1.5) % smallest trend1
plot(Yfit1(:),trend_per1,'b--','LineWidth',1.5)
p1_alpha=polyfit(Yfit1_alpha(:),corvolfit1_alpha(:),1);
trend_per1_alpha=polyval(p1_alpha,Yfit1_alpha(:));
plot(Yfit1_alpha(:),trend_per1_alpha,'k','LineWidth',1.5) % Comment if alpha=1
end
% fit2: since 1990 and deletes isnan cells
% Alpha volumes are added
if End_y>=1990;
   if Start_y<=1990;
    Yfit2=Tmeas(1990-Start_y+1:Years);
    Yfit2(:,isnan(corvol(1990-Start_y+1:Years)))=[];
    Yfit2_alpha=Tmeas(1990-Start_y+1:Years);
    Yfit2_alpha(:,isnan(corvol_alpha(1990-Start_y+1:Years)))=[];
    corvolfit2=corvol(1990-Start_y+1:Years);
    corvolfit2(:,isnan(corvol(1990-Start_y+1:Years)))=[];
    corvolfit2_alpha=corvol_alpha(1990-Start_y+1:Years);
    corvolfit2_alpha(:,isnan(corvol_alpha(1990-Start_y+1:Years)))=[];
   elseif Start_y>1990;
```

```
    Yfit2=Tmeas(1:Years);
    Yfit2(:,isnan(corvol))=[];
    Yfit2_alpha=Tmeas(1:Years);
    Yfit2_alpha(:,isnan(corvol_alpha))=[];
    corvolfit2=corvol(1:Years);
    corvolfit2(:,isnan(corvol))=[];
    corvolfit2_alpha=corvol_alpha(1:Years);
    corvolfit2_alpha(:,isnan(corvol_alpha))=[];
    end
p2=polyfit(Yfit2(:),corvolfit2(:),1);
trend_per2=polyval(p2,Yfit2(:));
std2=sqrt(1/(length(Yfit2)-1)*sum((corvolfit2-polyval(p2,Yfit2)).^2));
up2=polyfit([Yfit2(1) Yfit2(length(Yfit2))],[trend_per2(1)-...
    std2 trend_per2(length(Yfit2))+std2],1);
down2=polyfit([Yfit2(1) Yfit2(length(Yfit2))],[trend_per2(1)+...
    std2 trend_per2(length(Yfit2))-std2],1);
% plot(Yfit2(:),polyval(up2,Yfit2(:)),'b--','LineWidth',1.5) % greatest trend2
% plot(Yfit2(:),polyval(down2,Yfit2(:)),'b--','LineWidth',1.5) % smallest trend2
plot(Yfit2(:),trend_per2,'b--','LineWidth',1.5)
p2_alpha=polyfit(Yfit2_alpha(:),corvolfit2_alpha(:),1);
trend_per2_alpha=polyval(p2_alpha,Yfit2_alpha(:));
plot(Yfit2_alpha(:),trend_per2_alpha,'k','LineWidth',1.5) % Comment if alpha=1
end
% Plots grey lines on the backward representing nourishments
try % Try/catch cicle for the absence of nourishments for the transect
fill_lim = get(gca,'ylim');
    for i=1:length(fill_edatum)

h=fill([fill_bdatum(i),fill_bdatum(i),fill_edatum(i),fill_edatum(i)],[fill_lim(1),fill_lim(2),fill_lim(2),f
ill_lim(1)],[0.5 0.5 0.5]);
    set(h,'EdgeColor',[0.5 0.5 0.5]);
    end
catch
end
% Plotted again to shift grey lines backwards
plot(Tmeas(:),corvol(:),'bo','MarkerFaceColor','b','MarkerSize',5)
%plot(Tmeas(:),corvol_alpha(:),'ro','MarkerFaceColor','r','MarkerSize',5) % Comment if alpha=1
plot(Tmeas(:),V(:),'ko','MarkerFaceColor','k','MarkerSize',5)
% Plots trend lines again to put them forwards
if Start_y<=1990;
% plot(Yfit1(:),polyval(up1,Yfit1(:)),'b--','LineWidth',1.5) % greatest trend1
% plot(Yfit1(:),polyval(down1,Yfit1(:)),'b--','LineWidth',1.5)  % smallest trend1
plot(Yfit1(:),trend_per1,'b--','LineWidth',1.5)
plot(Yfit1_alpha(:),trend_per1_alpha,'k','LineWidth',1.5) % Comment if alpha=1
end
if End_y>=1990;
plot(Yfit2(:),trend_per2,'b--','LineWidth',1.5)
plot(Yfit2_alpha(:),trend_per2_alpha,'k','LineWidth',1.5) % Comment if alpha=1
end

xlim([1969 2011])
ylim([min(min(V),min(corvol)) max(max(V),max(corvol))])
xlabel('Year','FontSize',12)
ylabel('Volume coastal foundation [m^3/m]','FontSize',12)
title(['Jarkus Transect Volumes, ',t.transectID,...
    ' from ',num2str(maxL),' m {\itRSP} to ',num2str(minS),' m {\itRSP}'],... %' [decam]'],...
    'FontSize',12,'FontWeight','bold')
set(gcf,'Position',[5 35 1040 760])
set(gca,'FontSize',12)
% Cycle for the legend. % Comment if alpha=1
if Start_y<=1990 && End_y>=1990 && isempty(V(~isnan(V(1:(1990-Start_y+1)))))~=1 &&...
        isempty(V(~isnan(V(1990-Start_y+1:Years))))~=1;
    legend1=legend(' Not corrected',' Corrected',...
    ['  Corrected Trend ',answer{3},'-1990: ',num2str(p1(1),'%+5.0f'),' m^2/yr'],...
    ['  Maintained coastline ', answer{3},'-1990: ',num2str(p1_alpha(1),'%+5.0f'),'m^2/yr'],...
    ['  Corrected Trend 1990-',answer{4},': ',num2str(p2(1),'%+5.0f'),' m^2/yr'],...
    ['  Maintained coastline 1990-',answer{4},': ',num2str(p2_alpha(1),'%+5.0f'),' m^2/yr'],...
    'Location','Best');
elseif End_y<=1990 || (Start_y<=1990 && isempty(V(~isnan(V(1990-Start_y+1:Years))))==1);
    legend1=legend(' Not corrected',' Corrected',...
    ['  Corrected Trend ',answer{3},'-',answer{4},': ',num2str(p1(1),'%+5.0f'),' m^2/yr'],...
    'Location','Best');
elseif Start_y>=1990 || (End_y>=1990 && isempty(V(~isnan(V(1:(1990-Start_y+1)))))==1);
    legend1=legend(' Not corrected',' Corrected',' Corrected with \alpha-factor',...
    ['  Corrected Trend ',answer{3},'-',answer{4},': ',num2str(p2(1),'%+5.0f'),' m^2/yr'],...
    'Location','Best');
end
set(legend1,'Location','SouthWest','FontSize',10);
grid on
print(gcf,'-dpng','-r300',['Jarkus_cell 2a\',char(Knam),t.transectID,'_','fig1_test']);
```

```
%%%%%%%%%% Here ends the subroutine for each transect

% Defining MultiTrans*

%Define maintained behavior?

MultiTrans1(m)= p1(1); % p1(1) is trend with alpha=1 from starting year to 1990
MultiTrans2(m)= p2(1); % p2(1) is trend with alpha=1 from 1990 to ending year
MultiTrans1_alpha(m)= p1_alpha(1); % p1_alpha(1) is trend with alpha=~1 from starting year to 1990
MultiTrans2_alpha(m)= p2_alpha(1); % p2_alpha(1) is trend with alpha=~1 from 1990 to ending year
MultiTrans1_std(m)=std1; % std1 is sigma from starting year to 1990. alpha=1
%MultiTrans1_std_alpha(m)=std1_a; % std1 is trend with sigma from starting year to 1990. alpha=~1
MultiTrans2_std(m)=std2; % std2 is trend with sigma from 1990 to ending year. alpha=1
%MultiTrans2_std_alpha(m)=std2_a; % std2 is trend with sigma from 1990 to ending year. alpha=~1
MultiTrans1_up(m)=up1(1); % Greatest trend with alpha=1 from starting year to 1990
%MultiTrans1_up_alpha(m)=up1_a(1); % Greatest trend with alpha=~1 from starting year to 1990
MultiTrans1_down(m)=down1(1); % Smallest trend with alpha=1 from starting year to 1990
%MultiTrans1_down_alpha(m)=down1_a(1); % Smallest trend with alpha=~1 from starting year to 1990
MultiTrans2_up(m)=up2(1); % Greatest trend with alpha=1 from 1990 to ending year
%MultiTrans2_up_alpha(m)=up2_a(1); % Greatest trend with alpha=~1 from 1990 to ending year
MultiTrans2_down(m)=down2(1); % Smallest trend with alpha=1 from 1990 to ending year
%MultiTrans2_down_alpha(m)=down2_a(1); % Smallest trend with alpha=~1 from 1990 to ending year
MultiTrans_maxL(m)=maxL; % Max landward boundary
MultiTrans_minS(m)=minS; % min seaward boundary

%disp('Press any key to continue.')
%pause

% End of the cycle that skips bad transects and fig.1
end
% End of the cycle for the m-transect
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

figure(6) % Coastal erosion trend position. Erosion trends along the coast
set(gcf,'PaperUnits','centimeters','PaperOrientation','portrait','papersize',...
    [20 15],'paperposition',[0 0 20 15])
axes('position',[.1 .1 .86 .83]);
clear x1 y1 x1_a y1_a x2 y2 x2_a y2_a n up* down*
x2=id(trans_nr(find(~isnan(MultiTrans2))))-str2double(Knum)*10^6;
y2=MultiTrans2(~isnan(MultiTrans2));
x2_a=id(trans_nr(find(~isnan(MultiTrans2_alpha))))-str2double(Knum)*10^6;
y2_a=MultiTrans2_alpha(~isnan(MultiTrans2_alpha));
%y_0=zeros(1,length(MultiTrans2_alpha(~isnan(MultiTrans2_alpha))));
x1=id(trans_nr(find(~isnan(MultiTrans1))))-str2double(Knum)*10^6;
y1=MultiTrans1(~isnan(MultiTrans1));
x1_a=id(trans_nr(find(~isnan(MultiTrans1_alpha))))-str2double(Knum)*10^6;
y1_a=MultiTrans1_alpha(~isnan(MultiTrans1_alpha));
up2=MultiTrans2_up(~isnan(MultiTrans2_up));
%up2_a=MultiTrans2_up_alpha(~isnan(MultiTrans2_up_alpha));
down2=MultiTrans2_down(~isnan(MultiTrans2_down));
%down2_a=MultiTrans2_down_alpha(~isnan(MultiTrans2_down_alpha));
up1=MultiTrans1_up(~isnan(MultiTrans1_up));
%up1_a=MultiTrans1_up_alpha(~isnan(MultiTrans1_up_alpha));
down1=MultiTrans1_down(~isnan(MultiTrans1_down));
%down1_a=MultiTrans1_down_alpha(~isnan(MultiTrans1_down_alpha));
maxL=MultiTrans_maxL(~isnan(MultiTrans_maxL));
minS=MultiTrans_minS(~isnan(MultiTrans_minS));

%% TYPE 1 PLOT Comparison in time
% plot(x1_a,y1_a,'b--','LineWidth',1) %1970-1990 maintained
% hold on
% plot(x2_a,y2_a,'b','LineWidth',2) %1990-2010 maintained
% ylim([-100 100])
% legend6=legend(' Trend 1970-1990 maintained coast', ' Trend 1990-2010 maintained coast',2);
% xlabel('Transect ID number','FontSize',12)
% ylabel('Volume trend [m^2/yr]','FontSize',12)
% title('Coastline erosion trend position','FontSize',12,'FontWeight','bold')
% set(gcf,'Position',[5 35 1040 760])
% grid on
% n=get(gca,'Xtick');
% set(gca,'FontSize',12,'XDir','reverse','XTickLabel',sprintf('%d|', n))
% print(gcf,'-dpng','-r300',['Jarkus_cell 2a\','Maintained_per12']);
% close
%% Type 2 PLOT MAINTAINED vs NATURAL 1970-1990
%plot(x1_a,y1_a,'b--','LineWidth',1) %maintained
%hold on
%plot(x1,y1,'k','Linewidth',2) %natural

%ylim([-100 100])
%legend6=legend(' Trend 1970-1990 maintained coast', ' Trend 1970-1990 natural behavior' ,2);
%xlabel('Transect ID number','FontSize',12)
%ylabel('Volume trend [m^2/yr]','FontSize',12)
%title('Coastline erosion trend position','FontSize',12,'FontWeight','bold')
```

```
%set(gcf,'Position',[5 35 1040 760])
%grid on
%n=get(gca,'Xtick');
%set(gca,'FontSize',12,'XDir','reverse','XTickLabel',sprintf('%d|', n))
%print(gcf,'-dpng','-r300',['Jarkus_cell 2a\','Main_vs_Nat_per1']);
%close

%% Type 3 PLOT Maintained vs Natural 1990-2010
plot(x1_a,y1_a,'r','Linewidth',2) %maintained
hold on
plot(x1,y1,'r--','Linewidth',2) %natural
hold on
plot(x2_a,y2_a,'b','LineWidth',2) %maintained
hold on
plot(x2,y2,'b--','Linewidth',2) %natural
xlim([5000 5500])
ylim([-100 100])
legend6=legend( ' Trend 1970-1990 maintained coast', ' Trend 1970-1990 natural behavior',' Trend 1990-2010 
maintained coast', ' Trend 1990-2010 natural behavior', 3);
xlabel('Transect ID number','FontSize',12)
ylabel('Volume trend [m^2/yr]','FontSize',12)
title('near shore volume trend,  coastal cell 5, transect 5000-5500','FontSize',12,'FontWeight','bold')
set(gcf,'Position',[5 5 1040 760])
%set(gcf,'Position',[5 35 1040 760])
grid on
n=get(gca,'Xtick');
set(gca,'FontSize',12,'XDir','reverse','XTickLabel',sprintf('%d|', n))
print(gcf,'-dpng','-r300',['Jarkus_cell 2a\','Main_vs_Nat_per2']);
close
%%


% Here the variables are stored in a .mat file, called MultiTrans_*_*.mat
M.x1=x1; M.y1=y1; M.x1_a=x1_a; M.y1_a=y1_a; % x and y of trends 1970-1990
M.x2=x2; M.y2=y2; M.x2_a=x2_a; M.y2_a=y2_a; % x and y of trends 1990-2010
M.std1=std1; %M.std1_a=std1_a; % standard deviation 1970-1990
M.std2=std2;  % standard deviation 1990-2009
%M.up1=up1; M.up1_a=up1_a; % upper trend 1970-1990
%M.up2=up2; M.up2_a=up2_a; % upper trend 1990-2010
%M.down1=down1; M.down1_a=down1_a; % lower trend 1970-1990
%M.down2=down2; M.down2_a=down2_a; % lower trend 1990-2010
M.maxL=maxL; M.minS=minS; % boundaries
save(['Jarkus_cell 2a\','MultiTrans_9_smallbw.mat'],'-struct','M')
% To call it back, just write:
% load('MultiTrans_test.mat','x1','y1','x1_a','y1_a','x2','y2','x2_a','y2_a',...)

% Here ends the routine for Crossshore.m
```

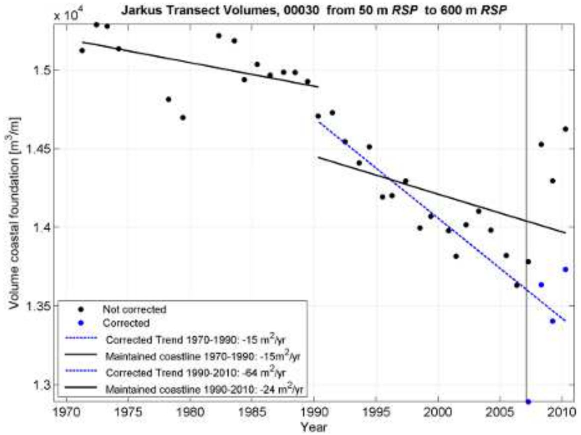
10.10 Annex X Plots volume-trends per transect

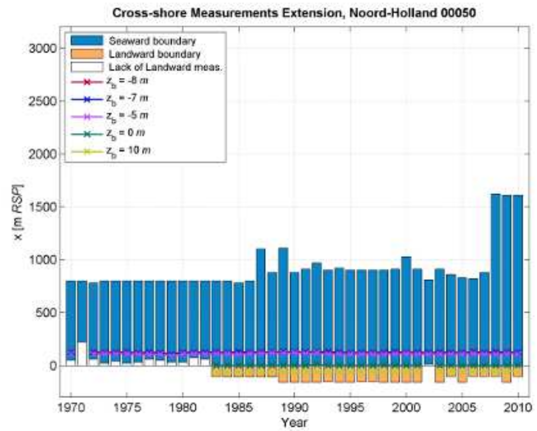
To generate the alongshore near shore volume trends (for an example figure 4.3 paragraph 4.2.3) the volume evolution per transect is used. By linear interpolation these trends are made. For the period 1970 – 1990 volumes could not always be calculated, due to a lack of data. In these cases the Jarkus - profiles did not extend far enough seaward, to reach the used boundary. As a consequence, the trends showed steep, unnatural slopes. Mostly due to the fact that they were only based on a few years of data. Therefore they were not representative for the occurring trend. For these transects, the boundaries were adjusted. The seaward boundary was moved landward. At the least a seaward boundary of 600 m, instead of 750 m, with respect to the RSP has been used.

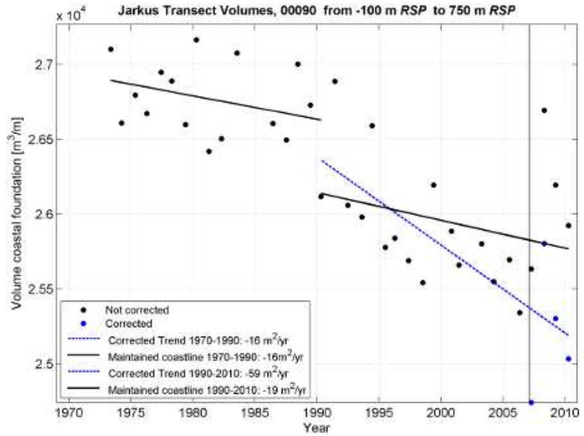
The consequences of these adjustments are not considered to be substantial. Less seaward extention does imply an approximation of the whole near shore volume. However, the presented alongshore distribution is composed of volume trends. When the largest part of the coastal profile shows erosion over a period of 20 years, one can assume that a similar profile, with boundaries that extend 100 m less seaward, shows a similar rate of change.

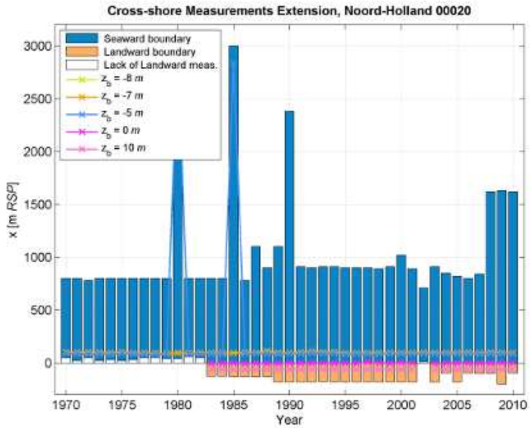
In the following pages, the used profiles and their volume trends are presented. For each plot the boundaries are shown.

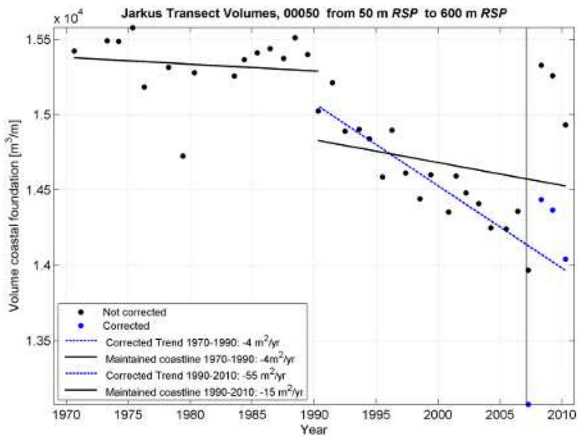
Note:
The plots are (also) provided on the enclosed CD.

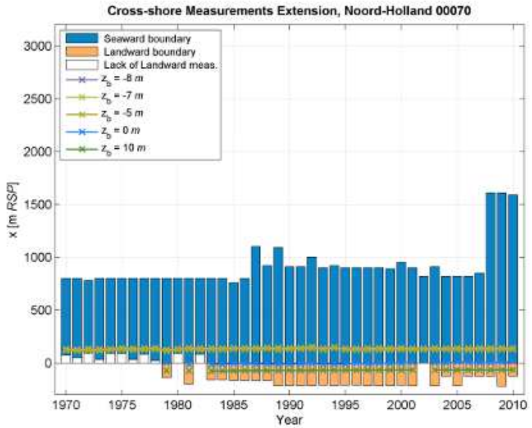

Jarkus Transect Volumes, 00030 from 50 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -15 m^2/yr
Maintained coastline 1970-1990: -15m^2/yr
Corrected Trend 1990-2010: -64 m^2/yr
Maintained coastline 1990-2010: -24 m^2/yr

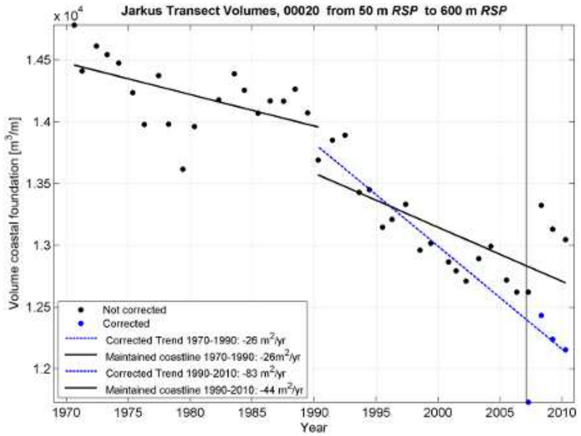

Cross-shore Measurements Extension, Noord-Holland 00050
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

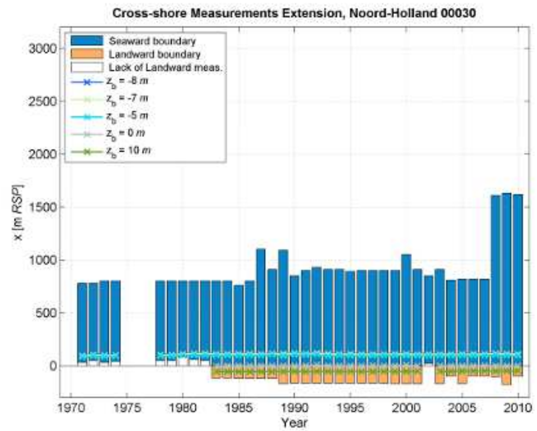

Jarkus Transect Volumes, 00090 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -16 m^2/yr
Maintained coastline 1970-1990: -16m^2/yr
Corrected Trend 1990-2010: -59 m^2/yr
Maintained coastline 1990-2010: -19 m^2/yr

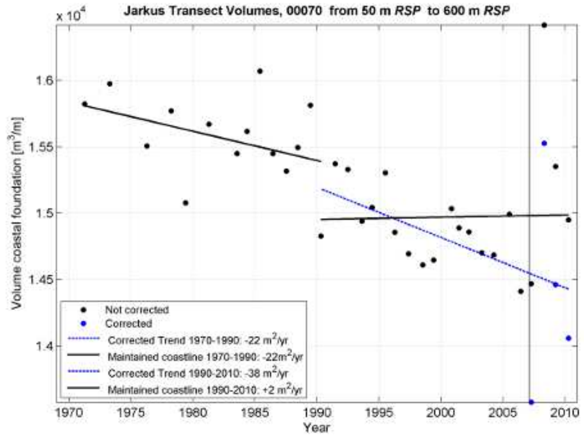

Cross-shore Measurements Extension, Noord-Holland 00020
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

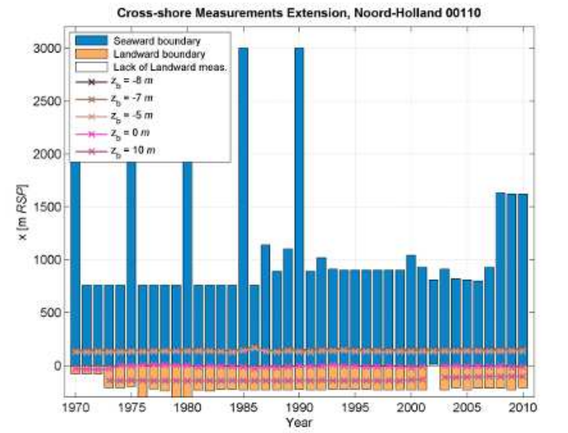

Jarkus Transect Volumes, 00050 from 50 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: -4m^2/yr
Corrected Trend 1990-2010: -55 m^2/yr
Maintained coastline 1990-2010: -15 m^2/yr

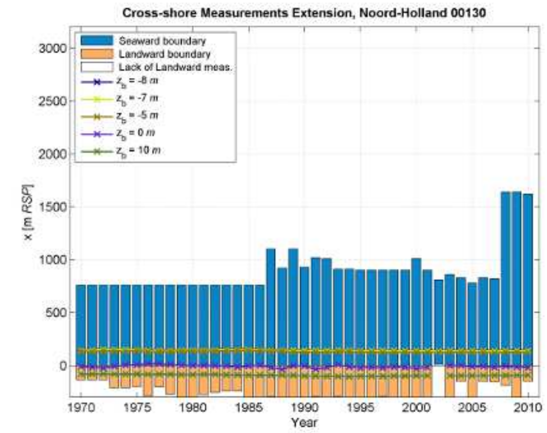

Cross-shore Measurements Extension, Noord-Holland 00070
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

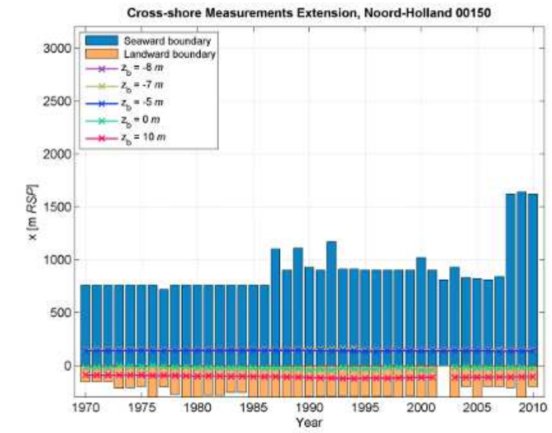

Jarkus Transect Volumes, 00020 from 50 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -26 m^2/yr
Maintained coastline 1970-1990: -26m^2/yr
Corrected Trend 1990-2010: -83 m^2/yr
Maintained coastline 1990-2010: -44 m^2/yr

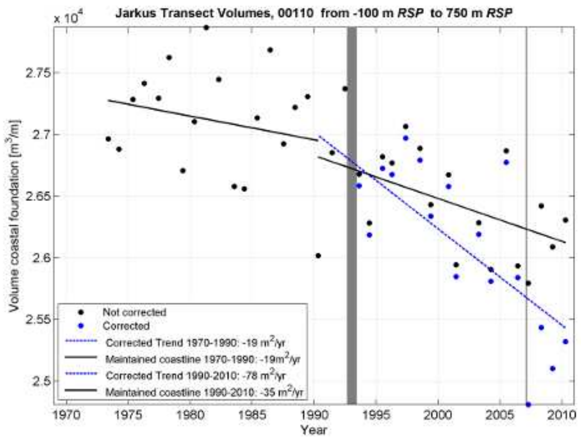

Cross-shore Measurements Extension, Noord-Holland 00030
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

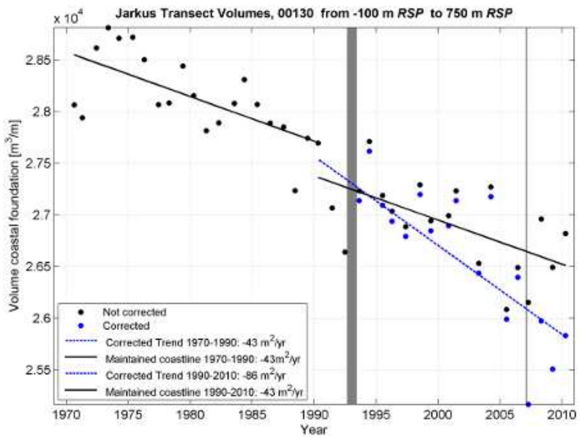

Jarkus Transect Volumes, 00070 from 50 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -22 m^2/yr
Maintained coastline 1970-1990: -22m^2/yr
Corrected Trend 1990-2010: -38 m^2/yr
Maintained coastline 1990-2010: +2 m^2/yr

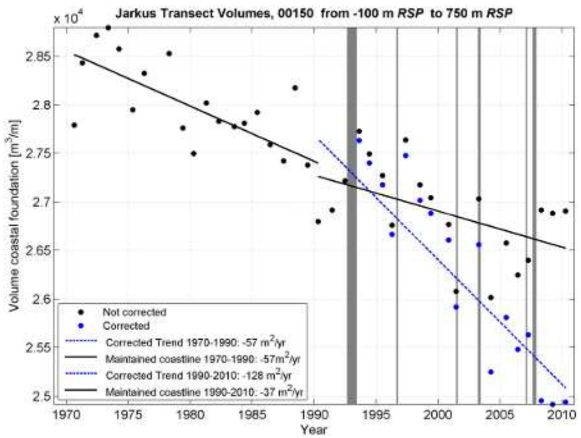

Cross-shore Measurements Extension, Noord-Holland 00110
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

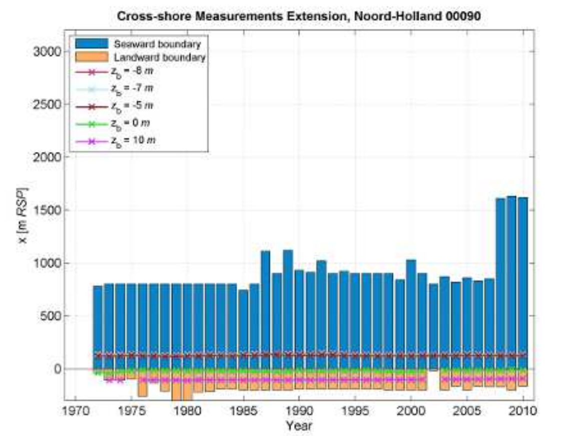

Cross-shore Measurements Extension, Noord-Holland 00130
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

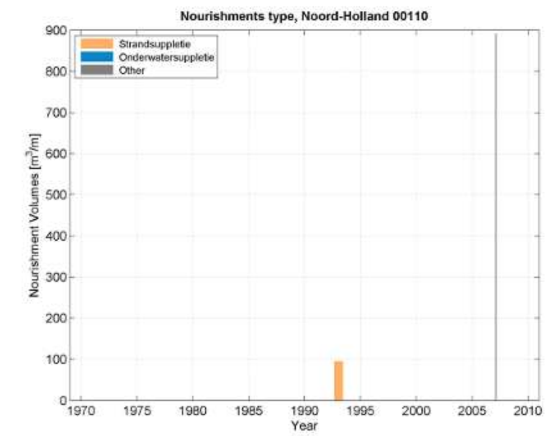

Cross-shore Measurements Extension, Noord-Holland 00150
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

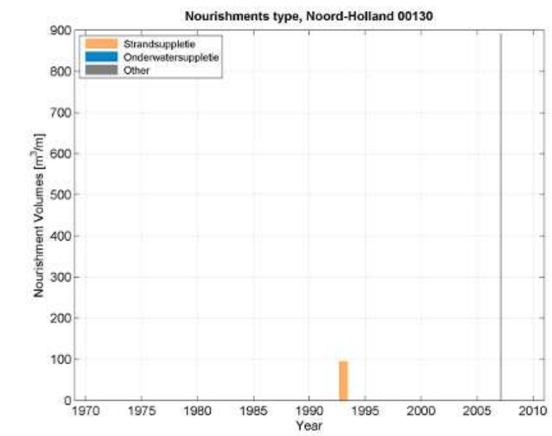

Jarkus Transect Volumes, 00110 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -19 m^2/yr
Maintained coastline 1970-1990: -19m^2/yr
Corrected Trend 1990-2010: -78 m^2/yr
Maintained coastline 1990-2010: -35 m^2/yr
Volume coastal foundation [m^3/m]
Year

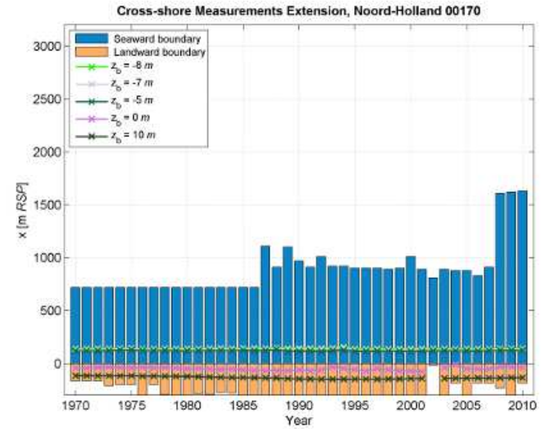

Jarkus Transect Volumes, 00130 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -43 m^2/yr
Maintained coastline 1970-1990: -43m^2/yr
Corrected Trend 1990-2010: -86 m^2/yr
Maintained coastline 1990-2010: -43 m^2/yr
Volume coastal foundation [m^3/m]
Year

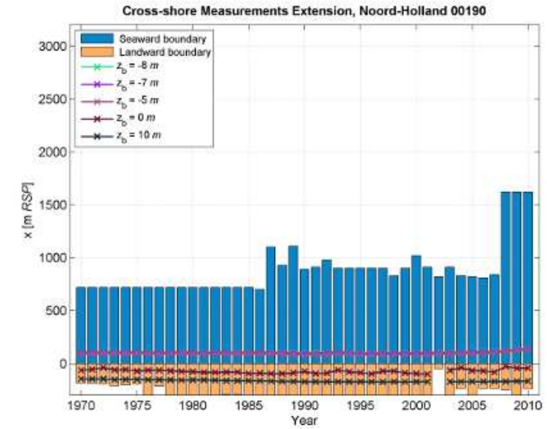

Jarkus Transect Volumes, 00150 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -57 m^2/yr
Maintained coastline 1970-1990: -57m^2/yr
Corrected Trend 1990-2010: -128 m^2/yr
Maintained coastline 1990-2010: -37 m^2/yr
Volume coastal foundation [m^3/m]
Year

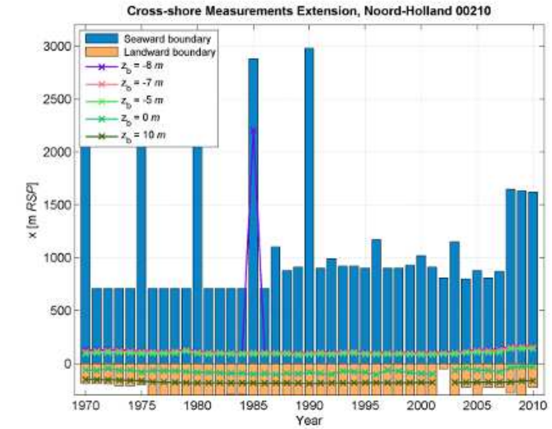

Cross-shore Measurements Extension, Noord-Holland 00090
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

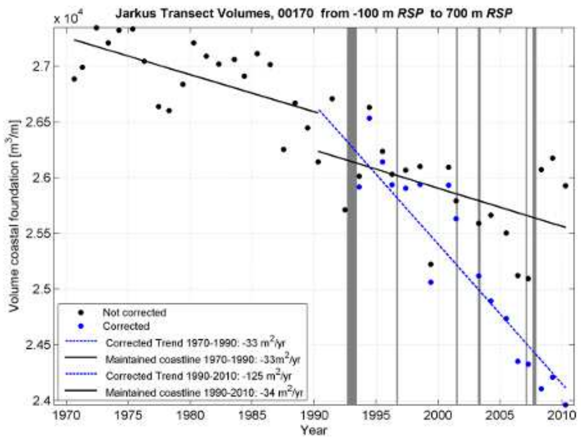

Nourishments type, Noord-Holland 00110
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

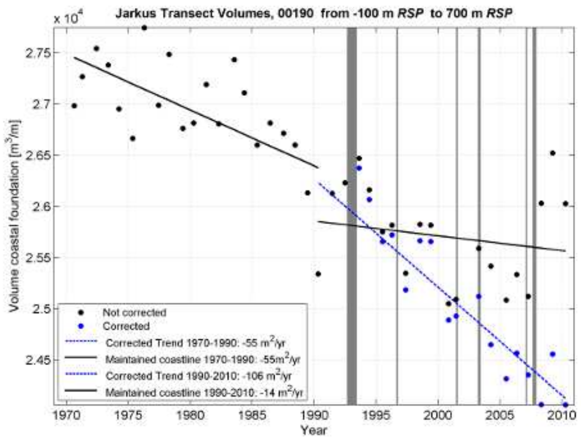

Nourishments type, Noord-Holland 00130
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

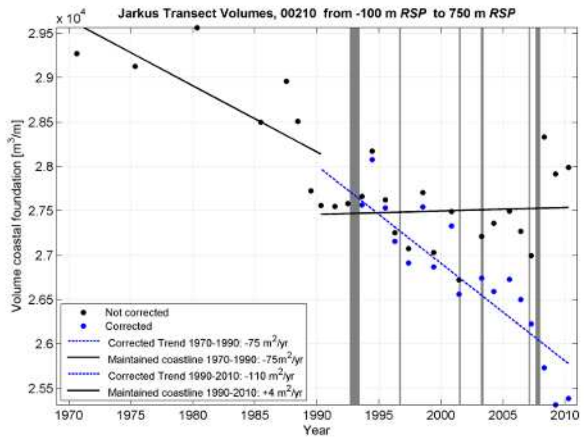

Cross-shore Measurements Extension, Noord-Holland 00170
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

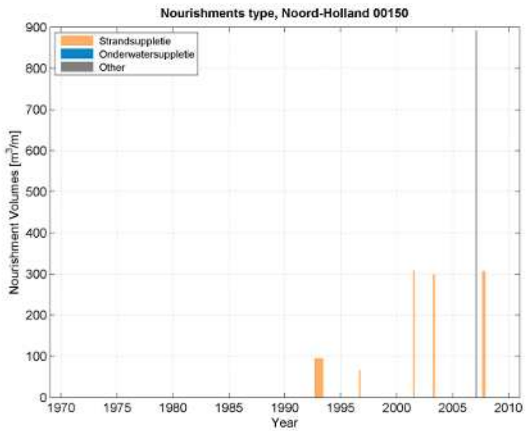

Cross-shore Measurements Extension, Noord-Holland 00190
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

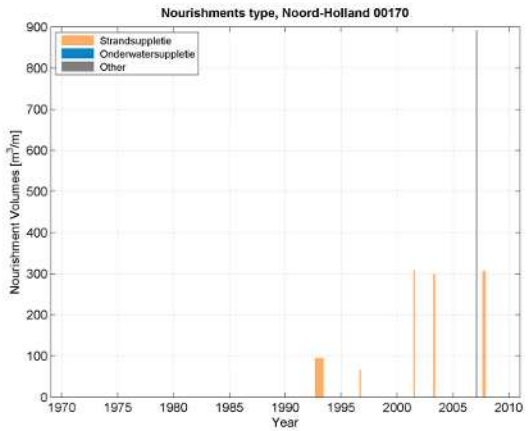

Cross-shore Measurements Extension, Noord-Holland 00210
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

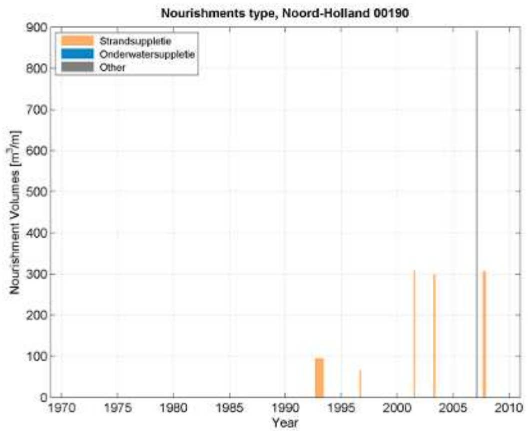

Jarkus Transect Volumes, 00170 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -33 m^2/yr
Maintained coastline 1970-1990: -33m^2/yr
Corrected Trend 1990-2010: -125 m^2/yr
Maintained coastline 1990-2010: -34 m^2/yr
Year

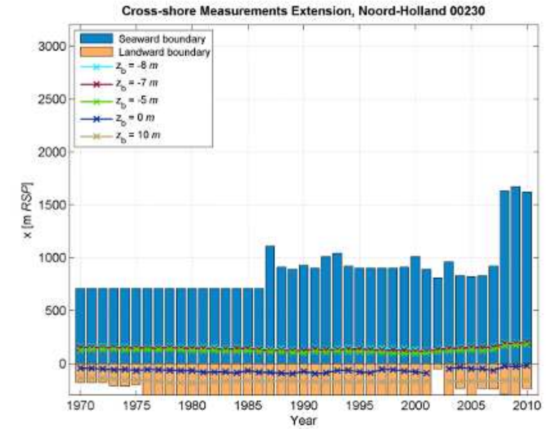

Jarkus Transect Volumes, 00190 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -55 m^2/yr
Maintained coastline 1970-1990: -55m^2/yr
Corrected Trend 1990-2010: -106 m^2/yr
Maintained coastline 1990-2010: -14 m^2/yr
Year

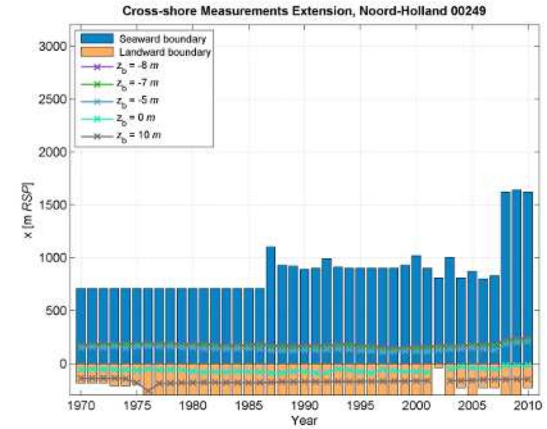

Jarkus Transect Volumes, 00210 from -100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -75 m^2/yr
Maintained coastline 1970-1990: -75m^2/yr
Corrected Trend 1990-2010: -110 m^2/yr
Maintained coastline 1990-2010: +4 m^2/yr
Year

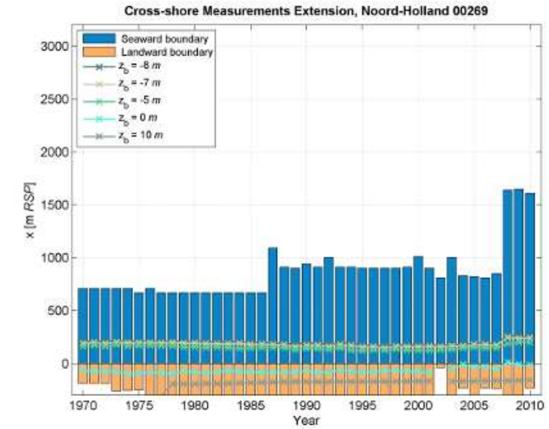

Nourishments type, Noord-Holland 00150
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

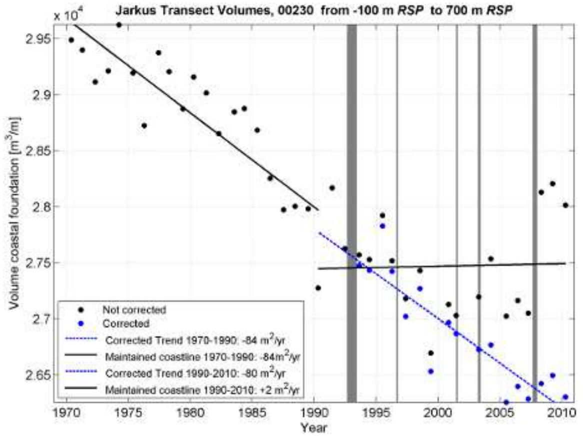

Nourishments type, Noord-Holland 00170
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

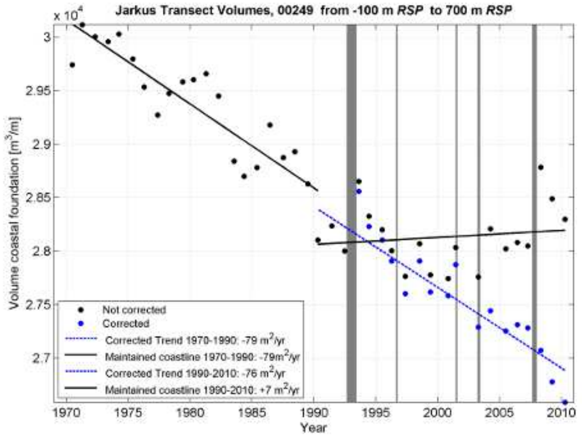

Nourishments type, Noord-Holland 00190
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

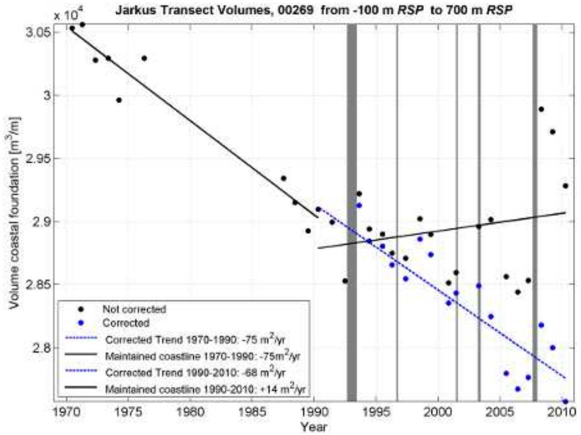

Cross-shore Measurements Extension, Noord-Holland 00230
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

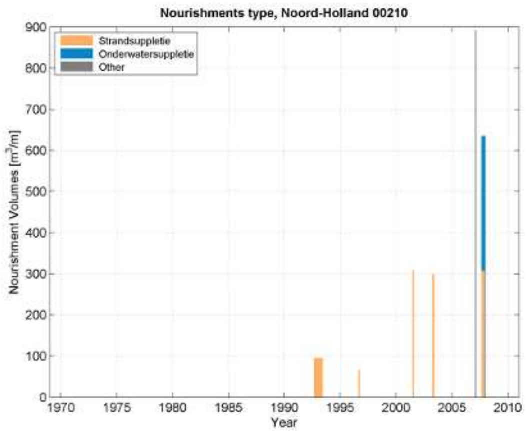

Cross-shore Measurements Extension, Noord-Holland 00249
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

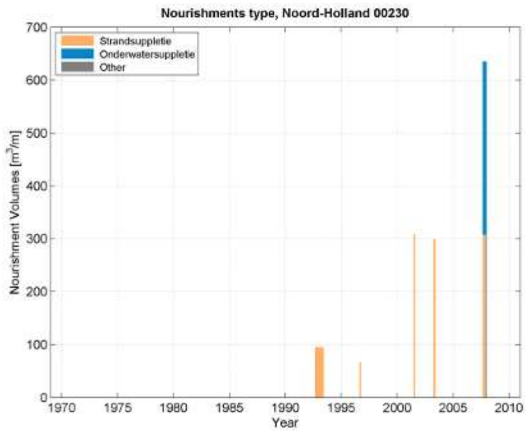

Cross-shore Measurements Extension, Noord-Holland 00269
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

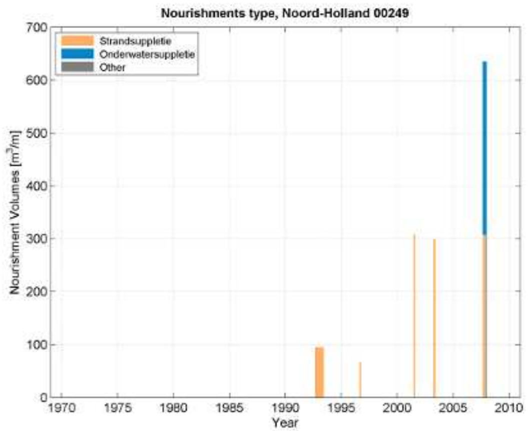

Jarkus Transect Volumes, 00230 from -100 m RSP to 700 m RSP
Volume coastal foundation [m³/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -84 m²/yr
Maintained coastline 1970-1990: -84m²/yr
Corrected Trend 1990-2010: -80 m²/yr
Maintained coastline 1990-2010: +2 m²/yr

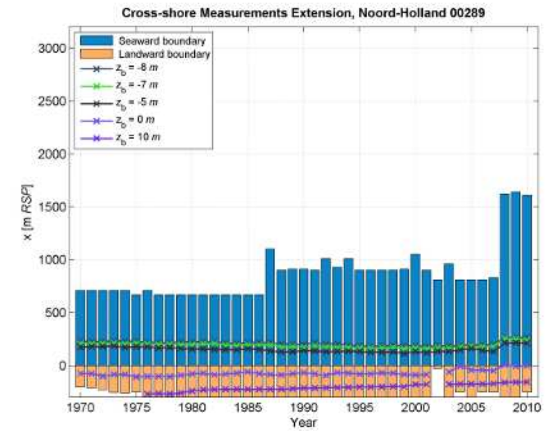

Jarkus Transect Volumes, 00249 from -100 m RSP to 700 m RSP
Volume coastal foundation [m³/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -79 m²/yr
Maintained coastline 1970-1990: -79m²/yr
Corrected Trend 1990-2010: -76 m²/yr
Maintained coastline 1990-2010: +7 m²/yr

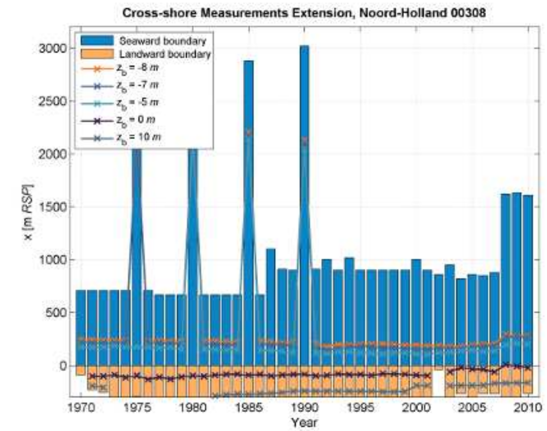

Jarkus Transect Volumes, 00269 from -100 m RSP to 700 m RSP
Volume coastal foundation [m³/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -75 m²/yr
Maintained coastline 1970-1990: -75m²/yr
Corrected Trend 1990-2010: -68 m²/yr
Maintained coastline 1990-2010: +14 m²/yr

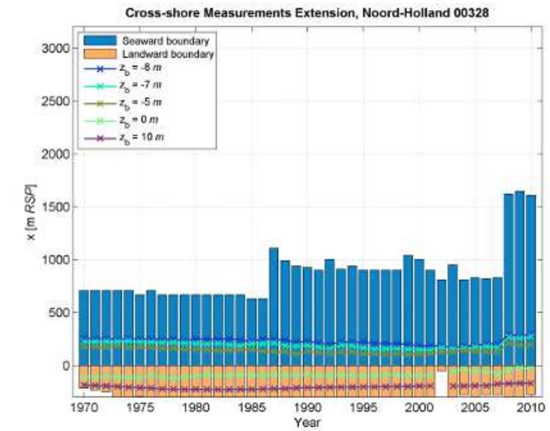

Nourishments type, Noord-Holland 00210
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

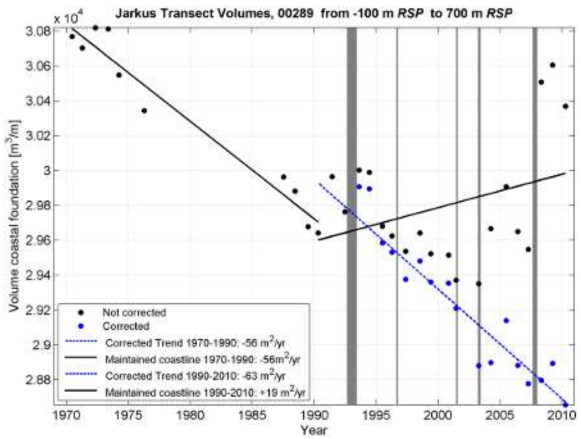

Nourishments type, Noord-Holland 00230
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

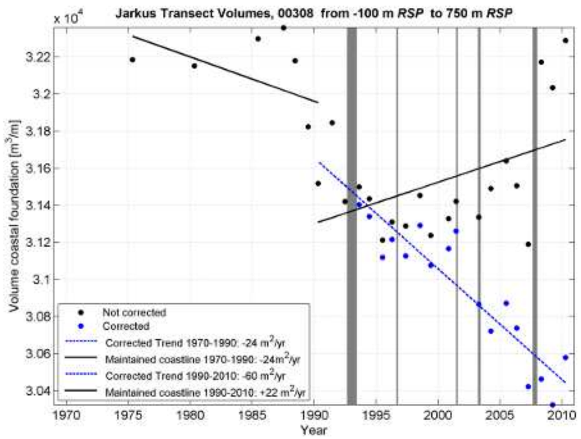

Nourishments type, Noord-Holland 00249
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

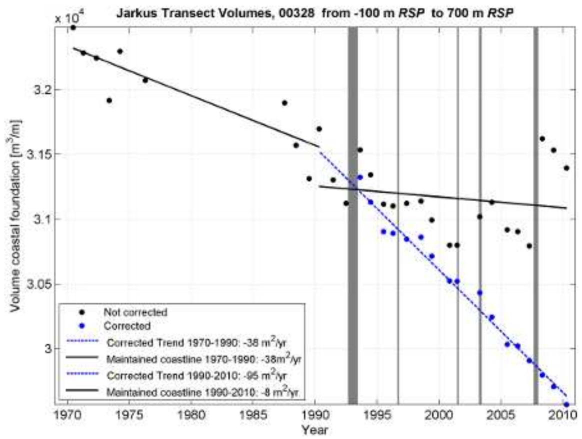

Cross-shore Measurements Extension, Noord-Holland 00289
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

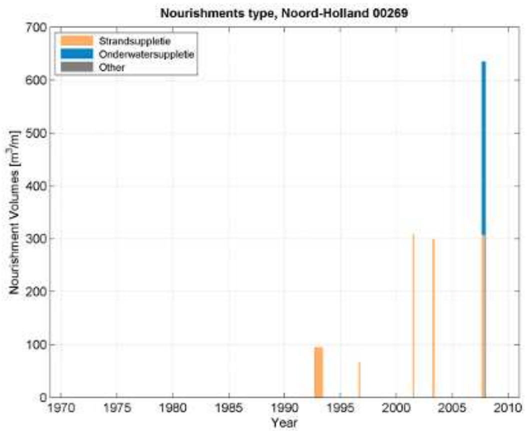

Cross-shore Measurements Extension, Noord-Holland 00308
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

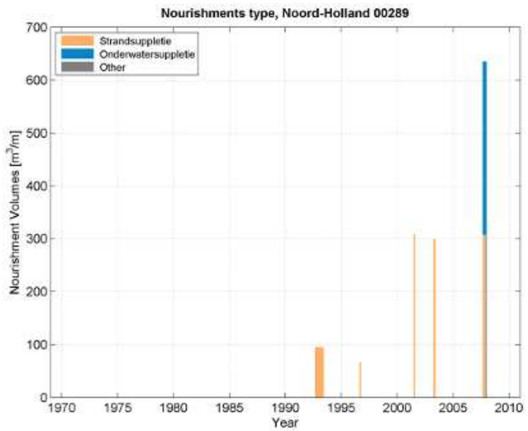

Cross-shore Measurements Extension, Noord-Holland 00328
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

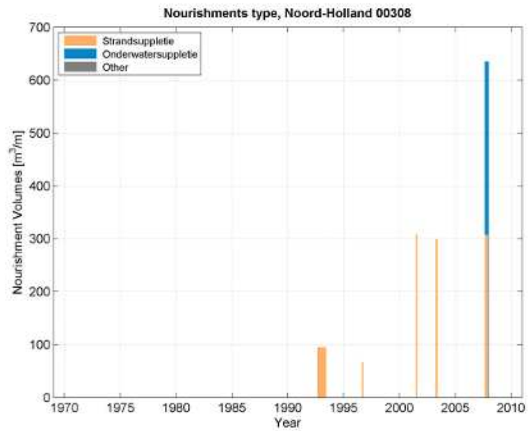

Jarkus Transect Volumes, 00289 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -56 m^2/yr
Maintained coastline 1970-1990: -56m^2/yr
Corrected Trend 1990-2010: -63 m^2/yr
Maintained coastline 1990-2010: +19 m^2/yr
Year

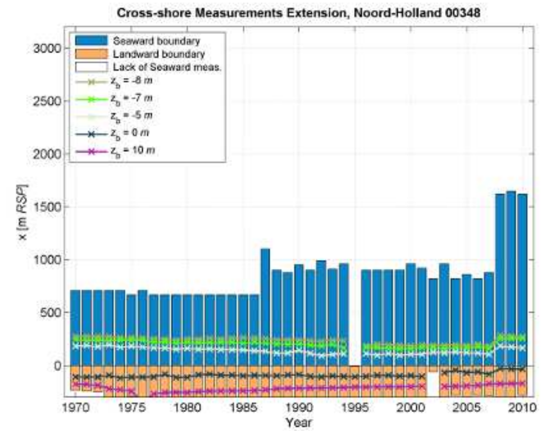

Jarkus Transect Volumes, 00308 from -100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -24 m^2/yr
Maintained coastline 1970-1990: -24m^2/yr
Corrected Trend 1990-2010: -60 m^2/yr
Maintained coastline 1990-2010: +22 m^2/yr
Year

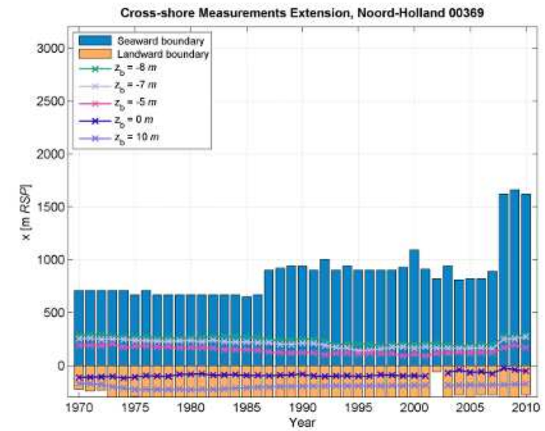

Jarkus Transect Volumes, 00328 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -38 m^2/yr
Maintained coastline 1970-1990: -38m^2/yr
Corrected Trend 1990-2010: -95 m^2/yr
Maintained coastline 1990-2010: -8 m^2/yr
Year

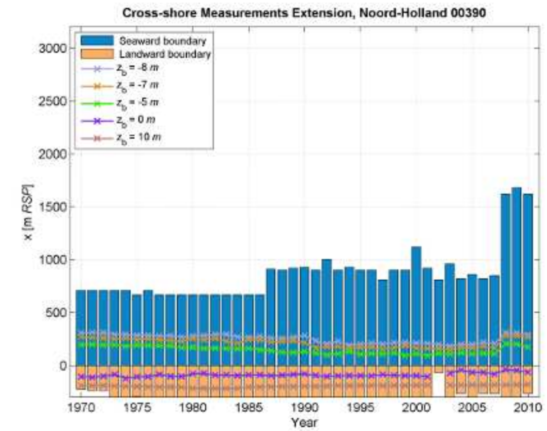

Nourishments type, Noord-Holland 00269
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

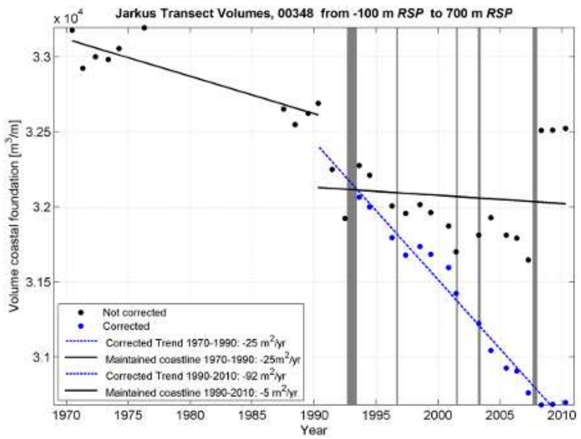

Nourishments type, Noord-Holland 00289
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

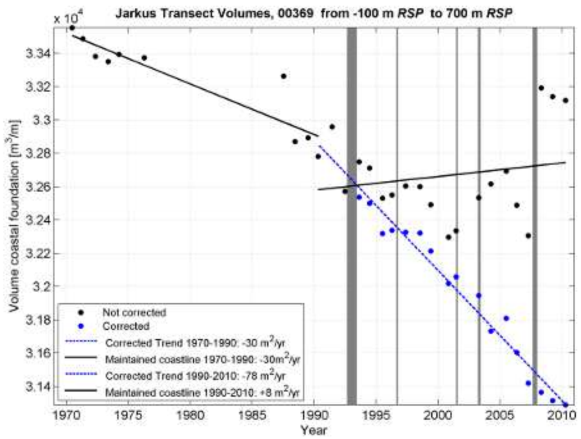

Nourishments type, Noord-Holland 00308
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

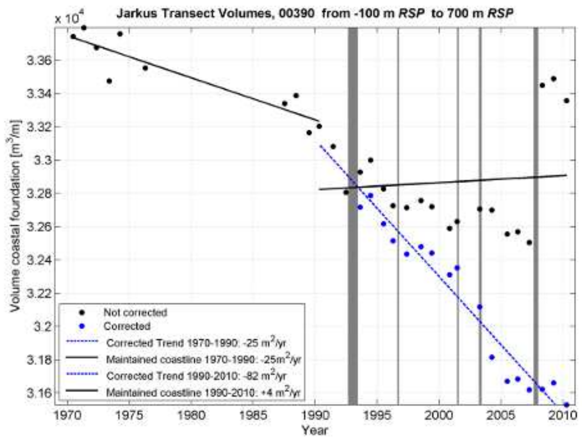

Cross-shore Measurements Extension, Noord-Holland 00348
Seaward boundary
Landward boundary
Lack of Seaward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

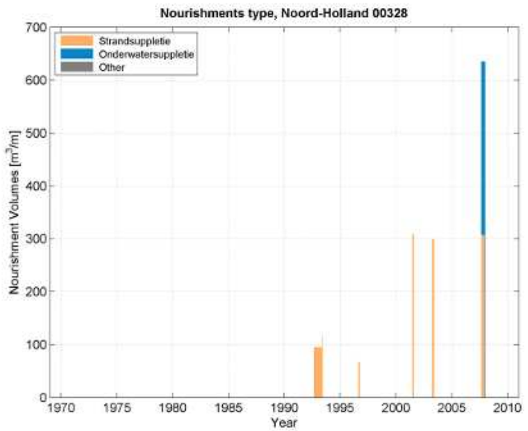

Cross-shore Measurements Extension, Noord-Holland 00369
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

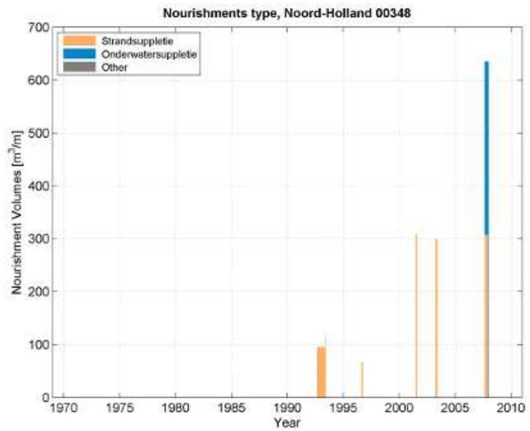

Cross-shore Measurements Extension, Noord-Holland 00390
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

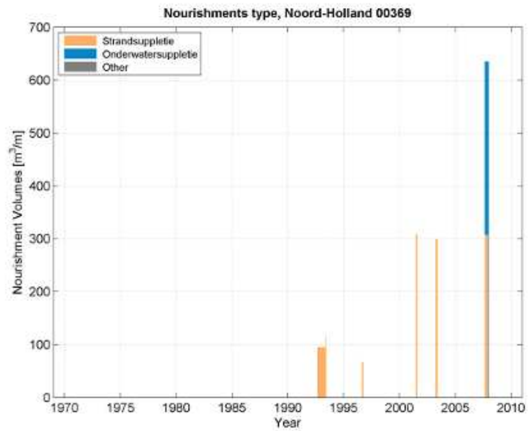

Jarkus Transect Volumes, 00348 from -100 m RSP to 700 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -25 m^2/yr
Maintained coastline 1970-1990: -25m^2/yr
Corrected Trend 1990-2010: -92 m^2/yr
Maintained coastline 1990-2010: -5 m^2/yr
Volume coastal foundation [m^3/m]
Year

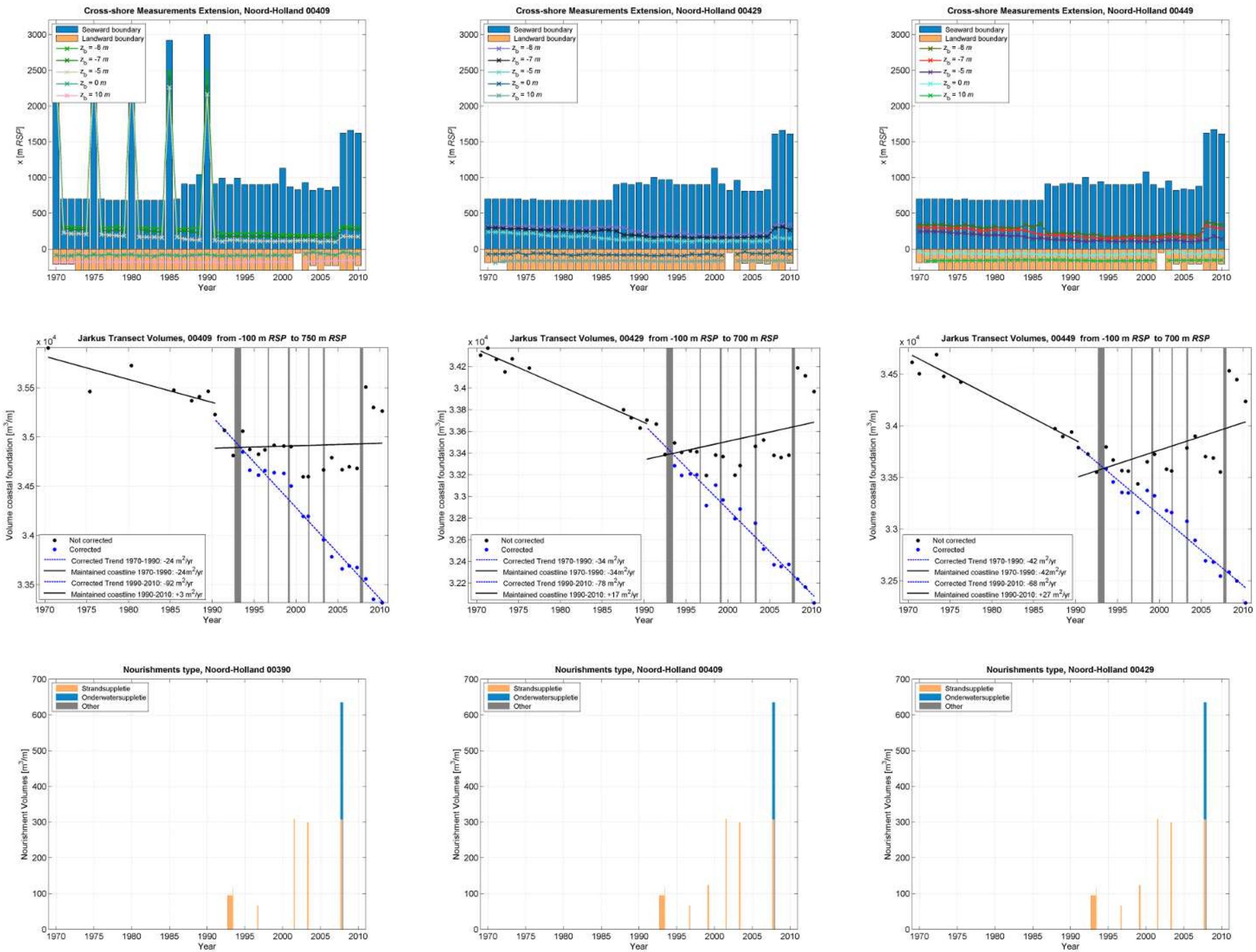

Jarkus Transect Volumes, 00369 from -100 m RSP to 700 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -30 m^2/yr
Maintained coastline 1970-1990: -30m^2/yr
Corrected Trend 1990-2010: -78 m^2/yr
Maintained coastline 1990-2010: +8 m^2/yr
Volume coastal foundation [m^3/m]
Year


Jarkus Transect Volumes, 00390 from -100 m RSP to 700 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -25 m^2/yr
Maintained coastline 1970-1990: -25m^2/yr
Corrected Trend 1990-2010: -82 m^2/yr
Maintained coastline 1990-2010: +4 m^2/yr
Volume coastal foundation [m^3/m]
Year

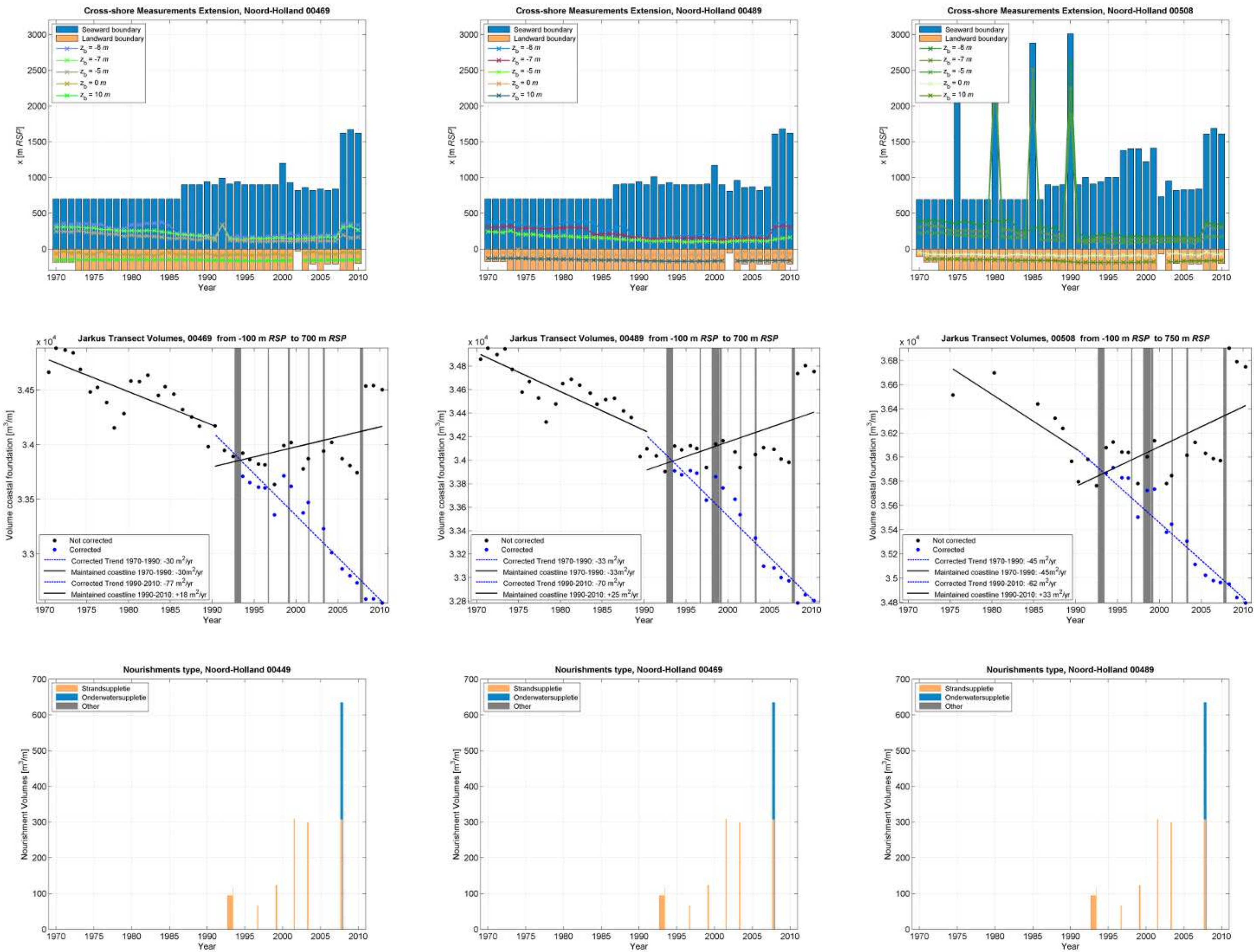

Nourishments type, Noord-Holland 00328
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

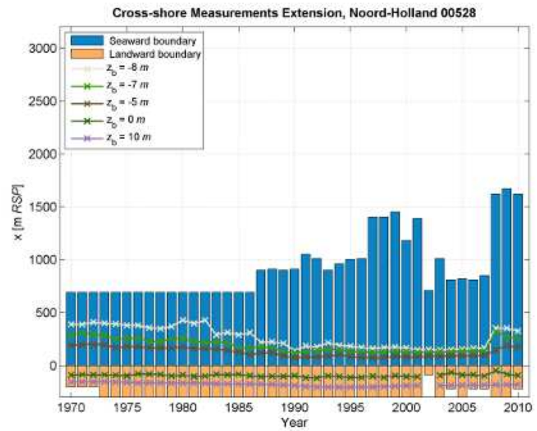

Nourishments type, Noord-Holland 00348
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

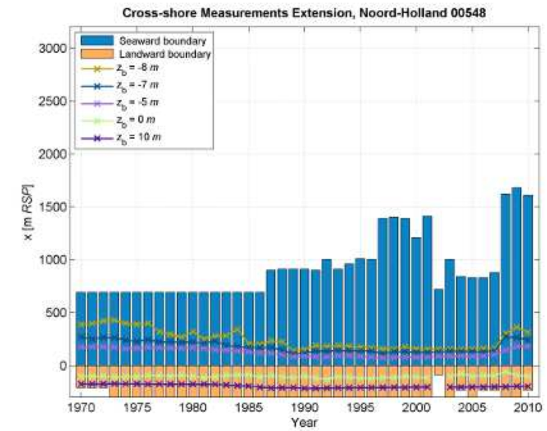

Nourishments type, Noord-Holland 00369
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

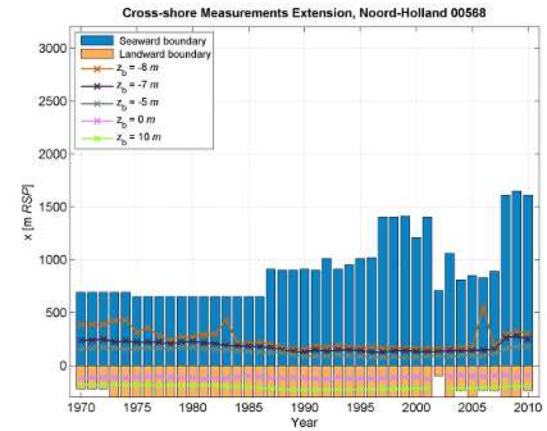


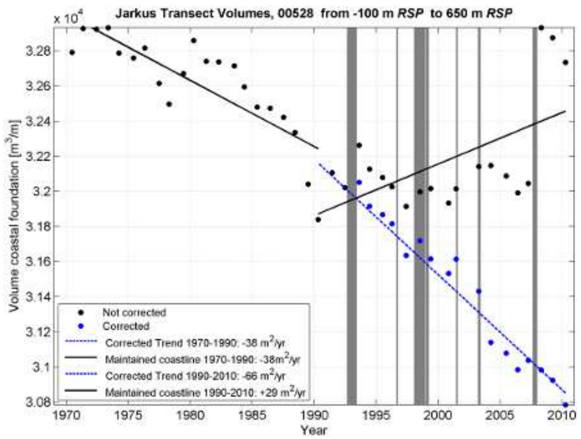
Cross-shore Measurements Extension, Noord-Holland 00409
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year
Cross-shore Measurements Extension, Noord-Holland 00429
Cross-shore Measurements Extension, Noord-Holland 00449
Jarkus Transect Volumes, 00409 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -24 m^2/yr
Maintained coastline 1970-1990: -24m^2/yr
Corrected Trend 1990-2010: -92 m^2/yr
Maintained coastline 1990-2010: +3 m^2/yr
Volume coastal foundation [m^3/m]
Jarkus Transect Volumes, 00429 from -100 m RSP to 700 m RSP
Corrected Trend 1970-1990: -34 m^2/yr
Maintained coastline 1970-1990: -34m^2/yr
Corrected Trend 1990-2010: -78 m^2/yr
Maintained coastline 1990-2010: +17 m^2/yr
Jarkus Transect Volumes, 00449 from -100 m RSP to 700 m RSP
Corrected Trend 1970-1990: -42 m^2/yr
Maintained coastline 1970-1990: -42m^2/yr
Corrected Trend 1990-2010: -68 m^2/yr
Maintained coastline 1990-2010: +27 m^2/yr
Nourishments type, Noord-Holland 00390
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Nourishments type, Noord-Holland 00409
Nourishments type, Noord-Holland 00429

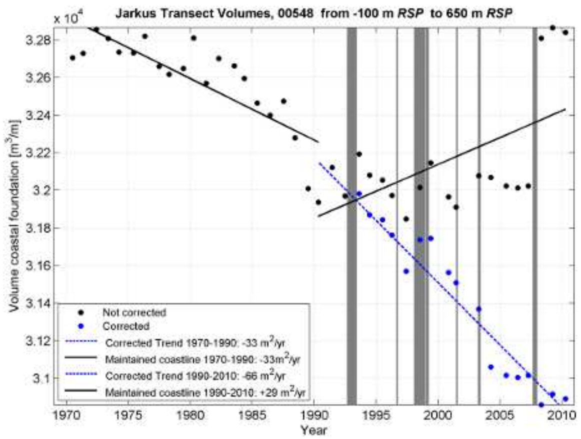

Cross-shore Measurements Extension, Noord-Holland 00469
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year
Cross-shore Measurements Extension, Noord-Holland 00489
Cross-shore Measurements Extension, Noord-Holland 00508
Jarkus Transect Volumes, 00469 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -30 m^2/yr
Maintained coastline 1970-1990: -30m^2/yr
Corrected Trend 1990-2010: -77 m^2/yr
Maintained coastline 1990-2010: +18 m^2/yr
Jarkus Transect Volumes, 00489 from -100 m RSP to 700 m RSP
Corrected Trend 1970-1990: -33 m^2/yr
Maintained coastline 1970-1990: -33m^2/yr
Corrected Trend 1990-2010: -70 m^2/yr
Maintained coastline 1990-2010: +25 m^2/yr
Jarkus Transect Volumes, 00508 from -100 m RSP to 750 m RSP
Corrected Trend 1970-1990: -45 m^2/yr
Maintained coastline 1970-1990: -45m^2/yr
Corrected Trend 1990-2010: -62 m^2/yr
Maintained coastline 1990-2010: +33 m^2/yr
Nourishments type, Noord-Holland 00449
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Nourishments type, Noord-Holland 00469
Nourishments type, Noord-Holland 00489

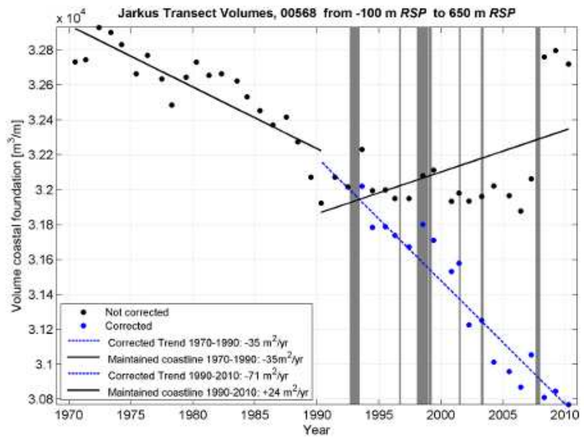

Cross-shore Measurements Extension, Noord-Holland 00528
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

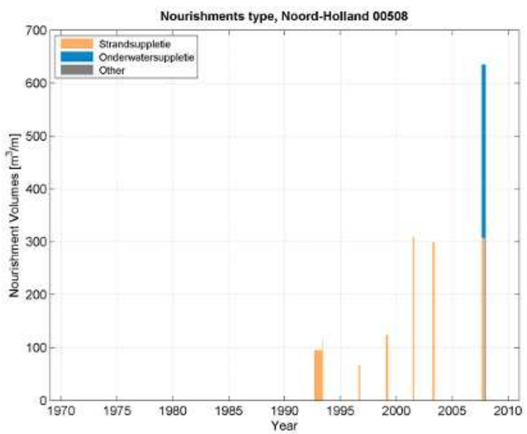

Cross-shore Measurements Extension, Noord-Holland 00548
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

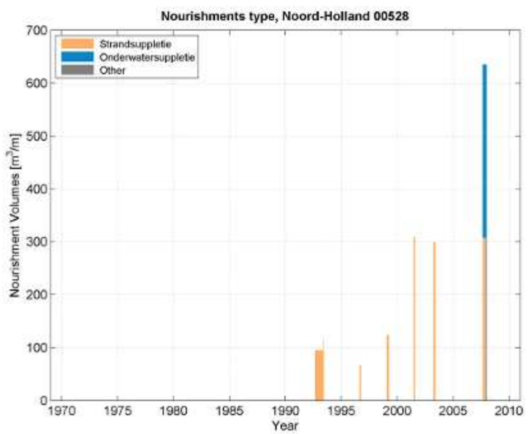

Cross-shore Measurements Extension, Noord-Holland 00568
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

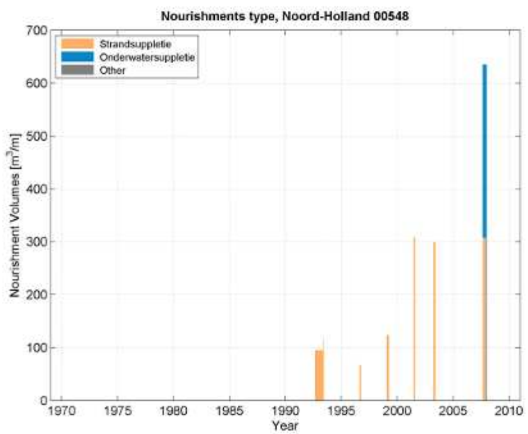

Jarkus Transect Volumes, 00528 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -38 m^2/yr
Maintained coastline 1970-1990: -38m^2/yr
Corrected Trend 1990-2010: -66 m^2/yr
Maintained coastline 1990-2010: +29 m^2/yr
Year

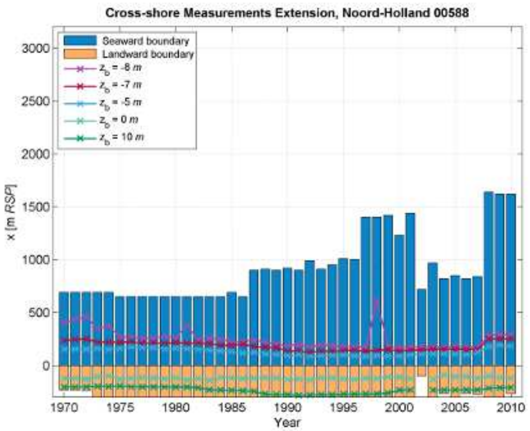

Jarkus Transect Volumes, 00548 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -33 m^2/yr
Maintained coastline 1970-1990: -33m^2/yr
Corrected Trend 1990-2010: -66 m^2/yr
Maintained coastline 1990-2010: +29 m^2/yr
Year

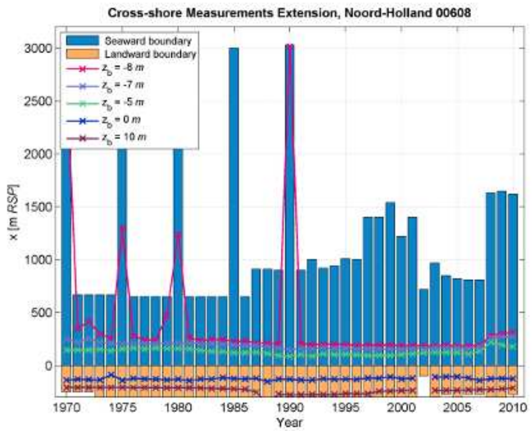

Jarkus Transect Volumes, 00568 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -35 m^2/yr
Maintained coastline 1970-1990: -35m^2/yr
Corrected Trend 1990-2010: -71 m^2/yr
Maintained coastline 1990-2010: +24 m^2/yr
Year

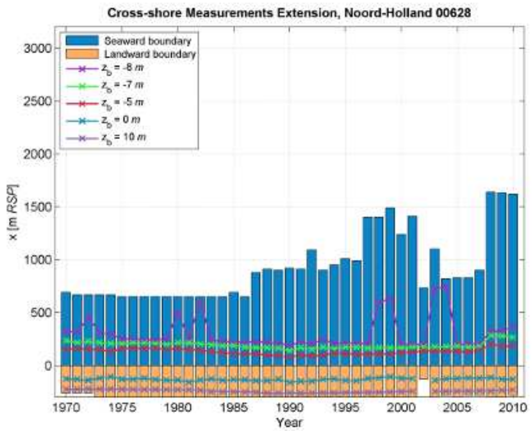

Nourishments type, Noord-Holland 00508
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

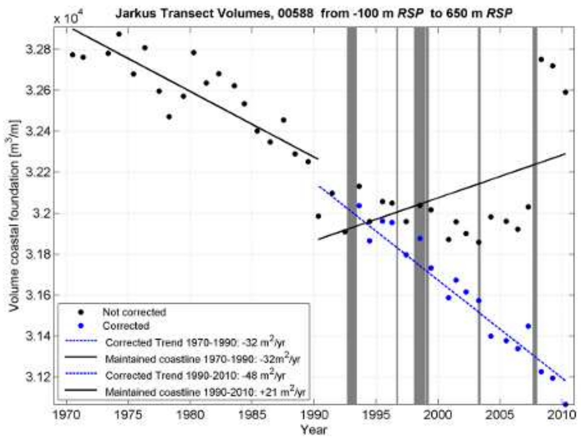

Nourishments type, Noord-Holland 00528
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

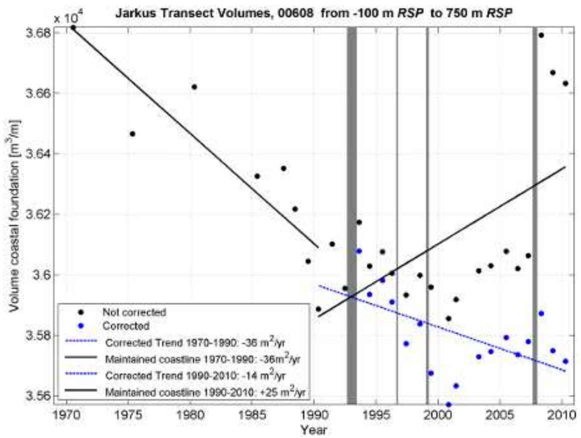

Nourishments type, Noord-Holland 00548
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

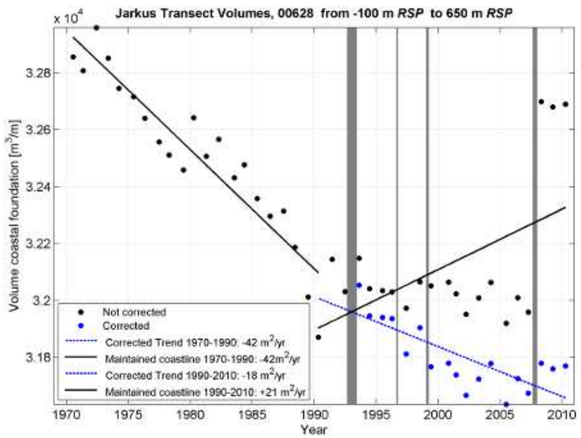

Cross-shore Measurements Extension, Noord-Holland 00588
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

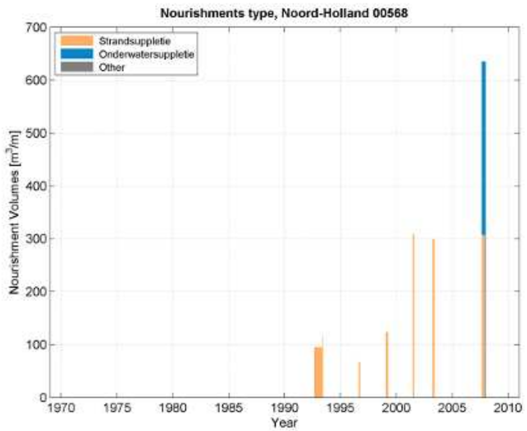

Cross-shore Measurements Extension, Noord-Holland 00608
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

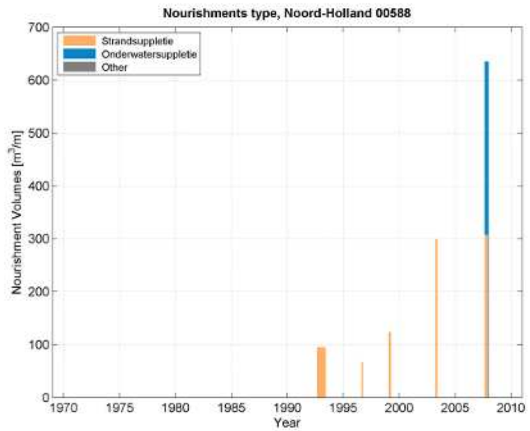

Cross-shore Measurements Extension, Noord-Holland 00628
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

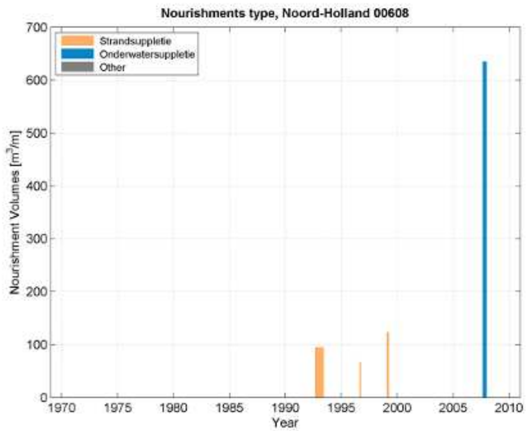

Jarkus Transect Volumes, 00588 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -32 m^2/yr
Maintained coastline 1970-1990: -32m^2/yr
Corrected Trend 1990-2010: -48 m^2/yr
Maintained coastline 1990-2010: +21 m^2/yr
Year

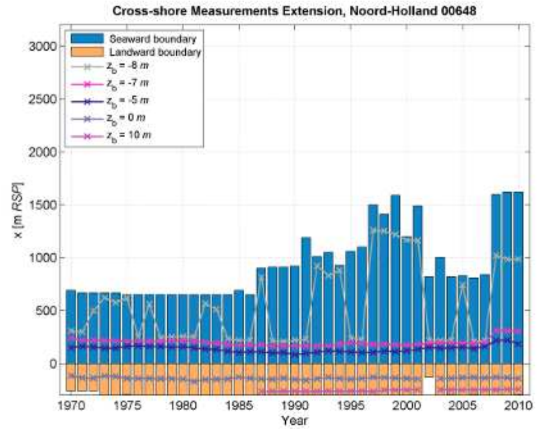

Jarkus Transect Volumes, 00608 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -36 m^2/yr
Maintained coastline 1970-1990: -36m^2/yr
Corrected Trend 1990-2010: -14 m^2/yr
Maintained coastline 1990-2010: +25 m^2/yr
Year

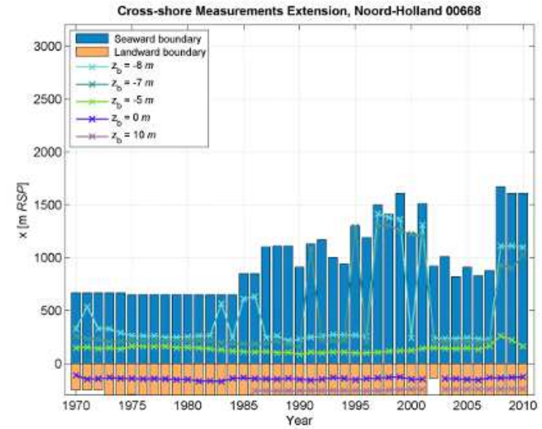

Jarkus Transect Volumes, 00628 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -42 m^2/yr
Maintained coastline 1970-1990: -42m^2/yr
Corrected Trend 1990-2010: -18 m^2/yr
Maintained coastline 1990-2010: +21 m^2/yr
Year

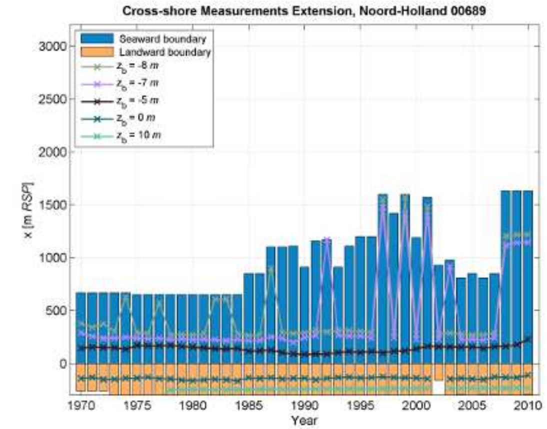

Nourishments type, Noord-Holland 00568
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

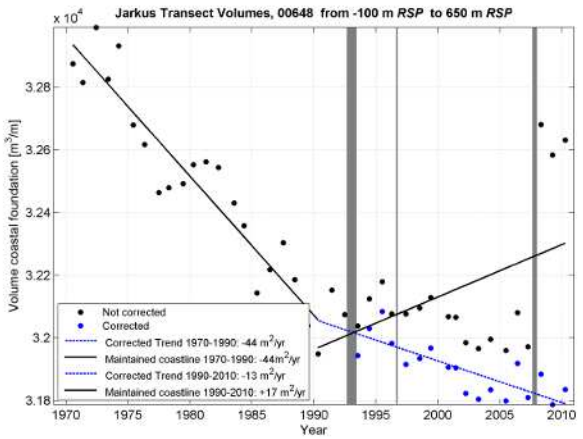

Nourishments type, Noord-Holland 00588
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

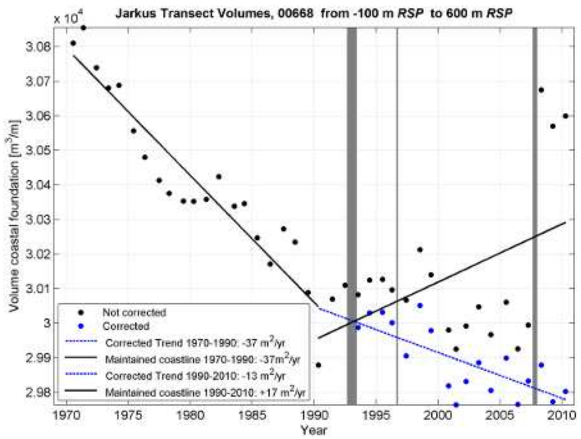

Nourishments type, Noord-Holland 00608
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

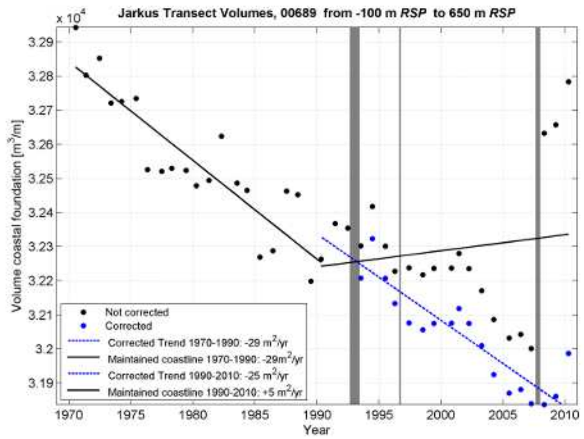

Cross-shore Measurements Extension, Noord-Holland 00648
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

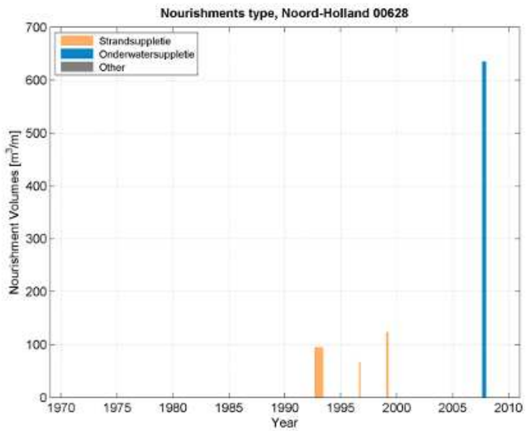

Cross-shore Measurements Extension, Noord-Holland 00668
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

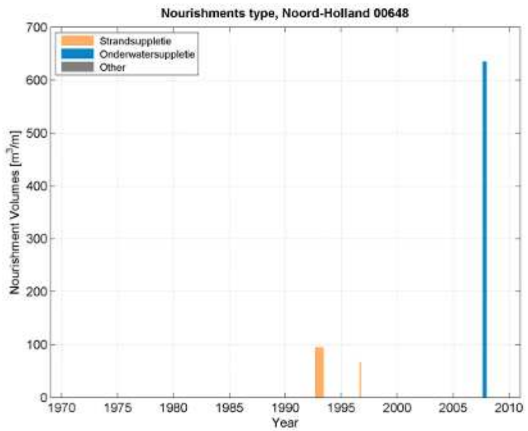

Cross-shore Measurements Extension, Noord-Holland 00689
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

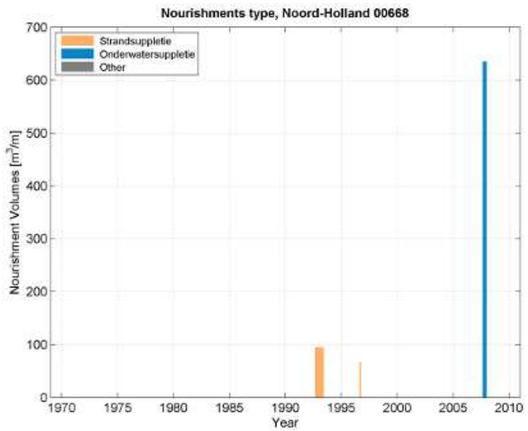

Jarkus Transect Volumes, 00648 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -44 m^2/yr
Maintained coastline 1970-1990: -44m^2/yr
Corrected Trend 1990-2010: -13 m^2/yr
Maintained coastline 1990-2010: +17 m^2/yr

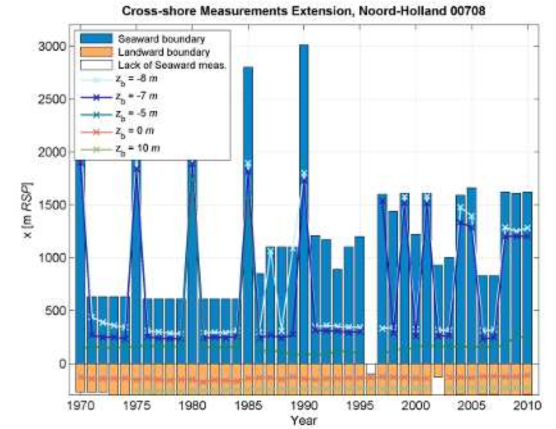

Jarkus Transect Volumes, 00668 from -100 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -37 m^2/yr
Maintained coastline 1970-1990: -37m^2/yr
Corrected Trend 1990-2010: -13 m^2/yr
Maintained coastline 1990-2010: +17 m^2/yr

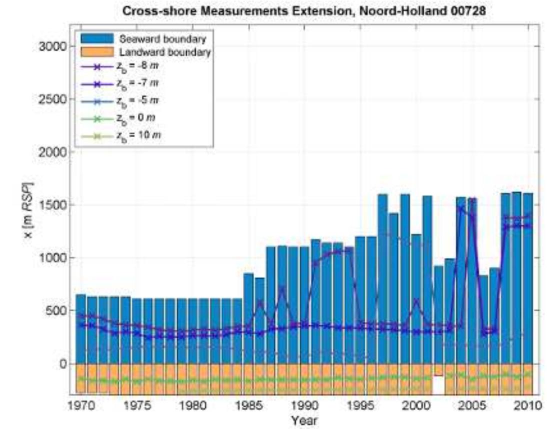

Jarkus Transect Volumes, 00689 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -29 m^2/yr
Maintained coastline 1970-1990: -29m^2/yr
Corrected Trend 1990-2010: -25 m^2/yr
Maintained coastline 1990-2010: +5 m^2/yr

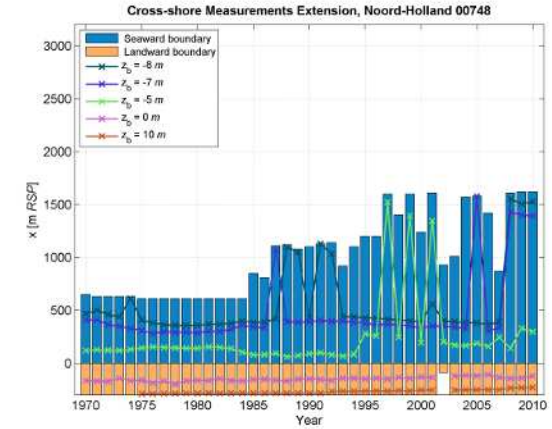

Nourishments type, Noord-Holland 00628
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

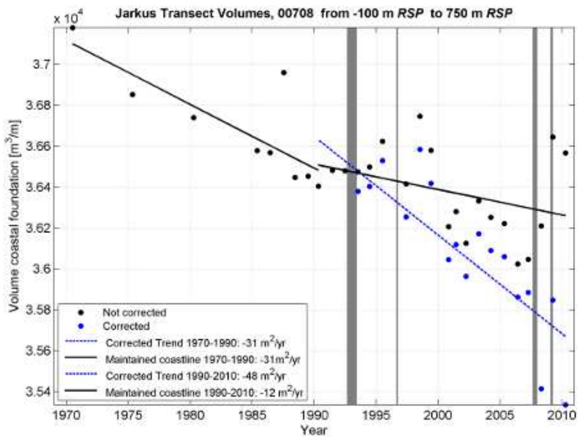

Nourishments type, Noord-Holland 00648
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

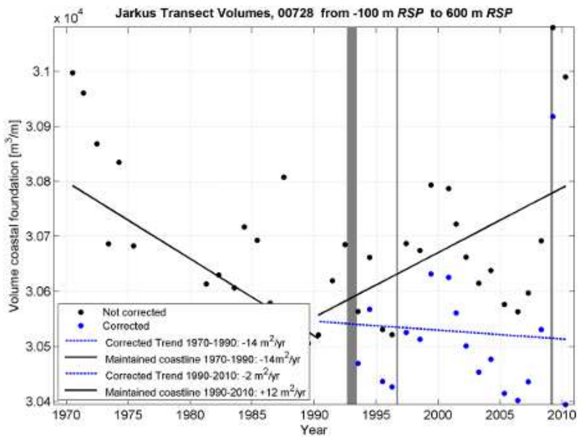

Nourishments type, Noord-Holland 00668
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

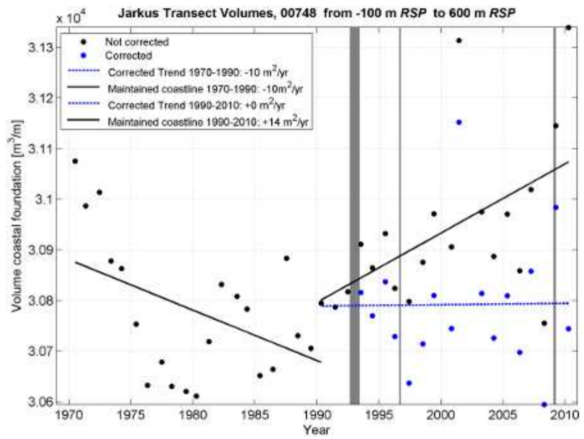

Cross-shore Measurements Extension, Noord-Holland 00708
Seaward boundary
Landward boundary
Lack of Seaward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

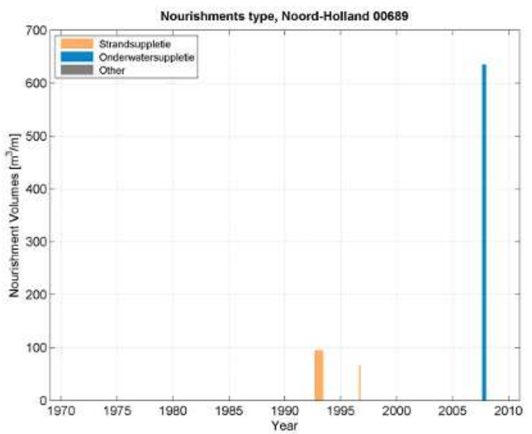

Cross-shore Measurements Extension, Noord-Holland 00728
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

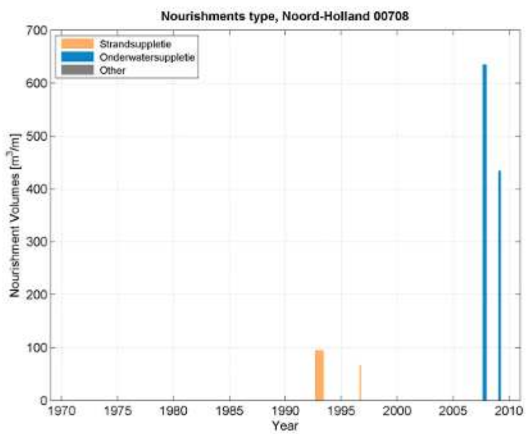

Cross-shore Measurements Extension, Noord-Holland 00748
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

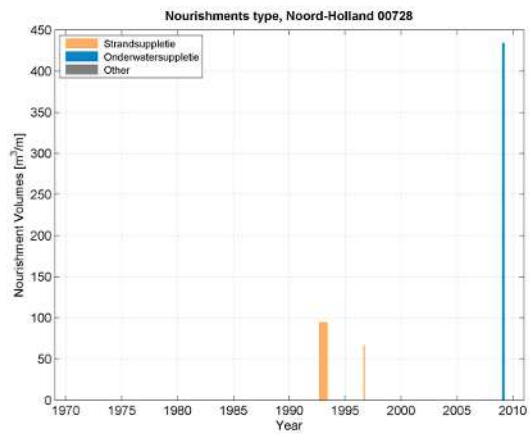

Jarkus Transect Volumes, 00708 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -31 m2/yr
Maintained coastline 1970-1990: -31m2/yr
Corrected Trend 1990-2010: -48 m2/yr
Maintained coastline 1990-2010: -12 m2/yr
Volume coastal foundation [m3/m]
Year

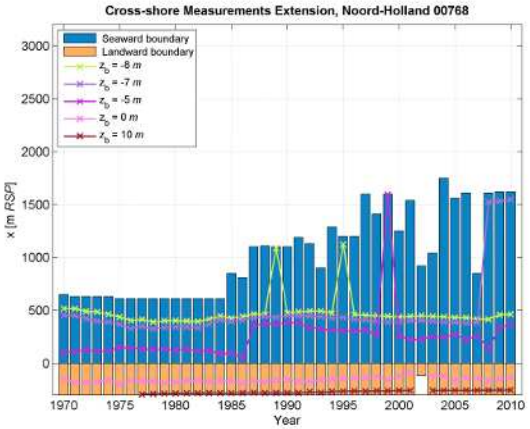

Jarkus Transect Volumes, 00728 from -100 m RSP to 600 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -14 m2/yr
Maintained coastline 1970-1990: -14m2/yr
Corrected Trend 1990-2010: -2 m2/yr
Maintained coastline 1990-2010: +12 m2/yr
Volume coastal foundation [m3/m]
Year

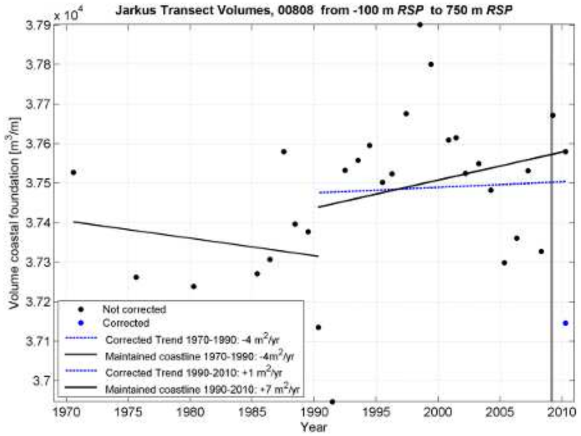

Jarkus Transect Volumes, 00748 from -100 m RSP to 600 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -10 m2/yr
Maintained coastline 1970-1990: -10m2/yr
Corrected Trend 1990-2010: +0 m2/yr
Maintained coastline 1990-2010: +14 m2/yr
Volume coastal foundation [m3/m]
Year

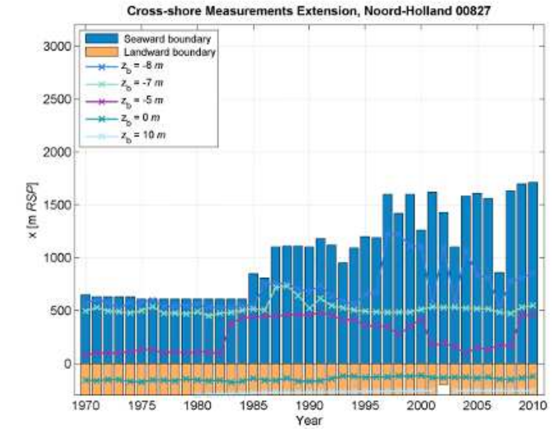

Nourishments type, Noord-Holland 00689
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

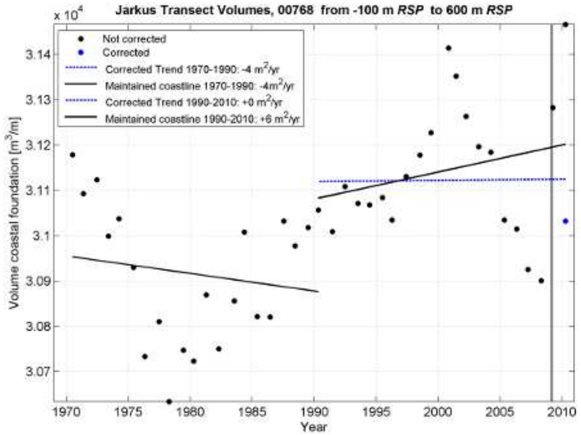

Nourishments type, Noord-Holland 00708
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

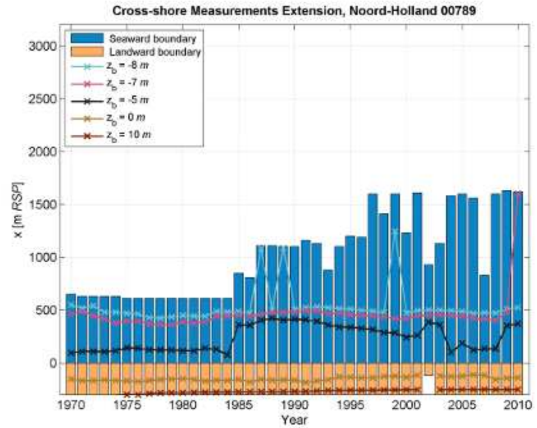

Nourishments type, Noord-Holland 00728
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

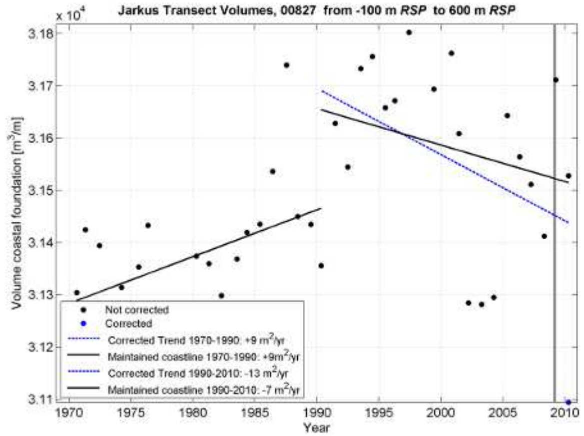

Cross-shore Measurements Extension, Noord-Holland 00768
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

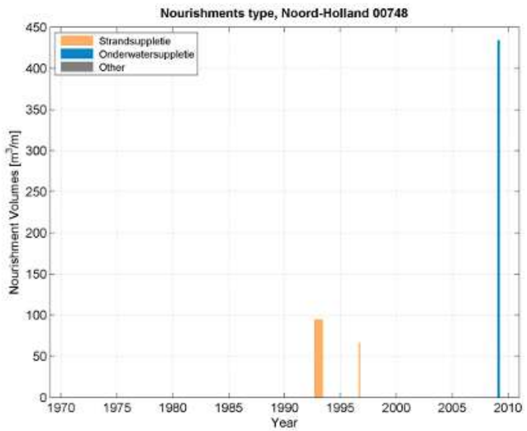

Jarkus Transect Volumes, 00808 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: -4m^2/yr
Corrected Trend 1990-2010: +1 m^2/yr
Maintained coastline 1990-2010: +7 m^2/yr
Volume coastal foundation [m^3/m]
Year

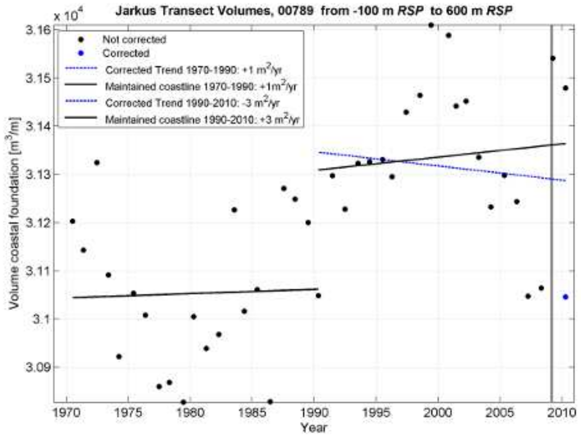

Cross-shore Measurements Extension, Noord-Holland 00827
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

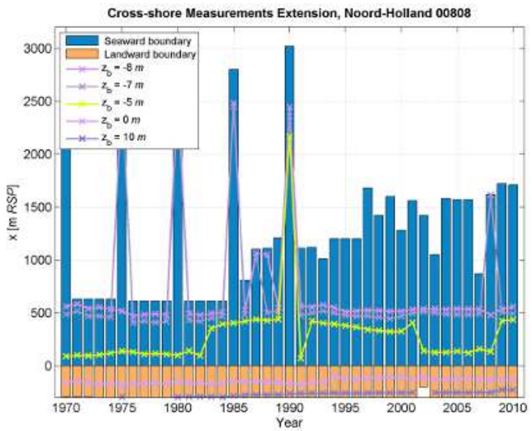

Jarkus Transect Volumes, 00768 from -100 m RSP to 600 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: -4m^2/yr
Corrected Trend 1990-2010: +0 m^2/yr
Maintained coastline 1990-2010: +6 m^2/yr
Volume coastal foundation [m^3/m]
Year

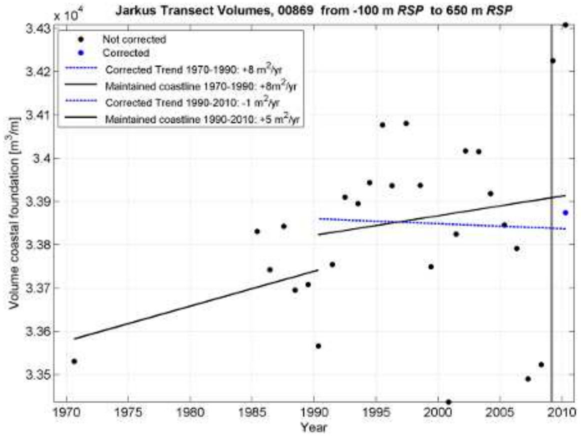

Cross-shore Measurements Extension, Noord-Holland 00789
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

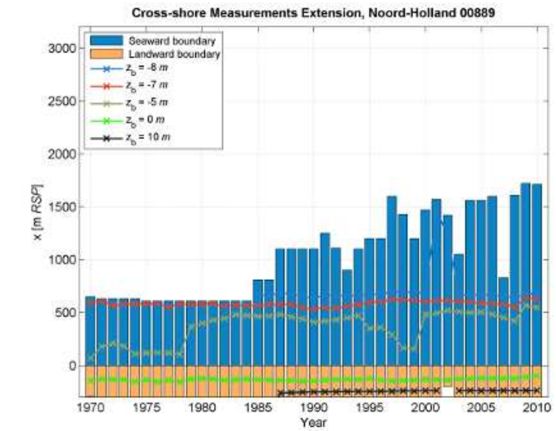

Jarkus Transect Volumes, 00827 from -100 m RSP to 600 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +9 m^2/yr
Maintained coastline 1970-1990: +9m^2/yr
Corrected Trend 1990-2010: -13 m^2/yr
Maintained coastline 1990-2010: -7 m^2/yr
Volume coastal foundation [m^3/m]
Year

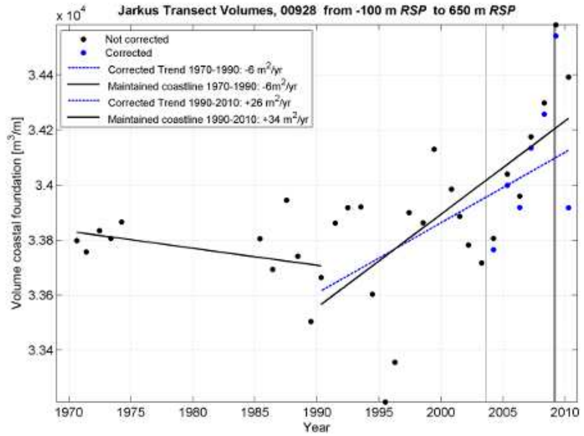

Nourishments type, Noord-Holland 00748
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

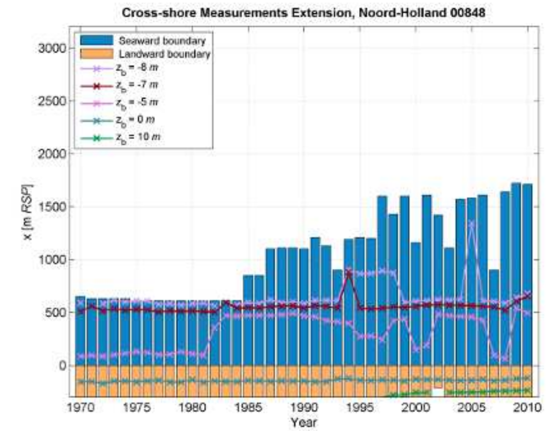

Jarkus Transect Volumes, 00789 from -100 m RSP to 600 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +1 m^2/yr
Maintained coastline 1970-1990: +1m^2/yr
Corrected Trend 1990-2010: -3 m^2/yr
Maintained coastline 1990-2010: +3 m^2/yr
Volume coastal foundation [m^3/m]
Year

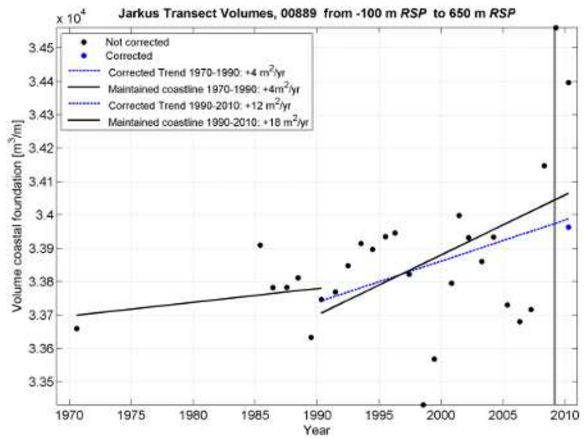

Cross-shore Measurements Extension, Noord-Holland 00808
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

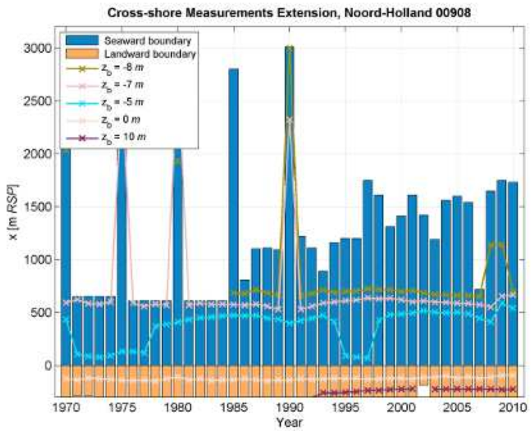

Jarkus Transect Volumes, 00869 from -100 m RSP to 650 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +8 m²/yr
Maintained coastline 1970-1990: +8m²/yr
Corrected Trend 1990-2010: -1 m²/yr
Maintained coastline 1990-2010: +5 m²/yr
Volume coastal foundation [m³/m]
Year

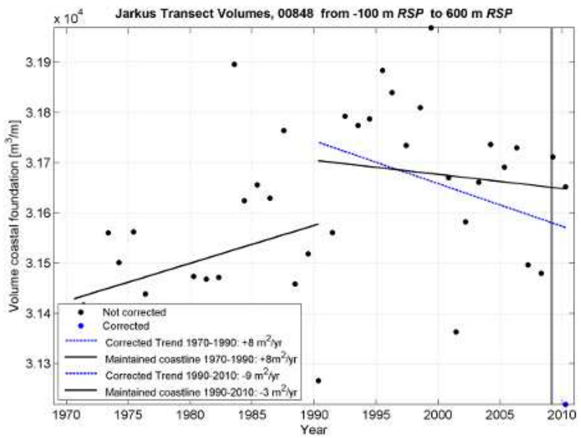

Cross-shore Measurements Extension, Noord-Holland 00889
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

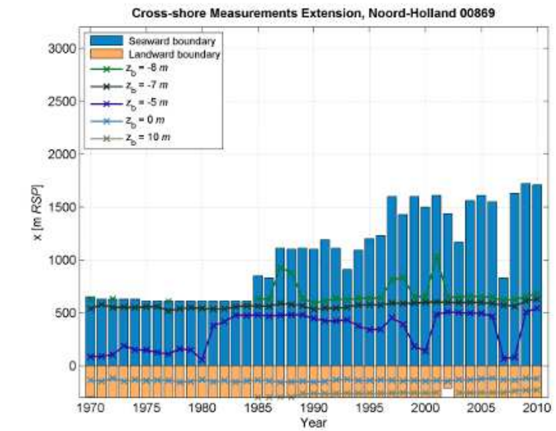

Jarkus Transect Volumes, 00928 from -100 m RSP to 650 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m²/yr
Maintained coastline 1970-1990: -6m²/yr
Corrected Trend 1990-2010: +26 m²/yr
Maintained coastline 1990-2010: +34 m²/yr
Volume coastal foundation [m³/m]
Year

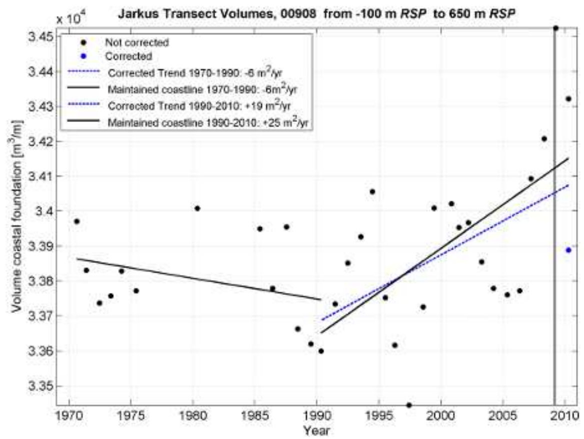

Cross-shore Measurements Extension, Noord-Holland 00848
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

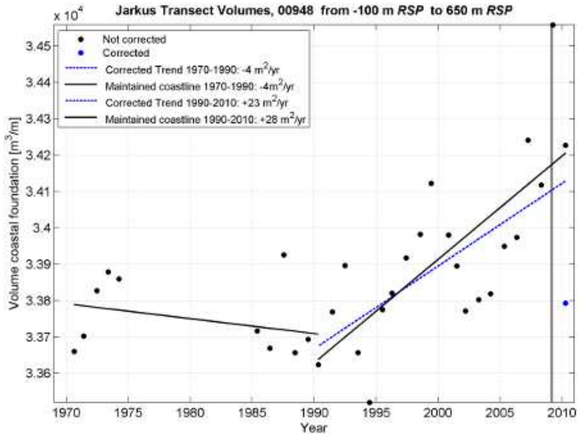

Jarkus Transect Volumes, 00889 from -100 m RSP to 650 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +4 m²/yr
Maintained coastline 1970-1990: +4m²/yr
Corrected Trend 1990-2010: +12 m²/yr
Maintained coastline 1990-2010: +18 m²/yr
Volume coastal foundation [m³/m]
Year

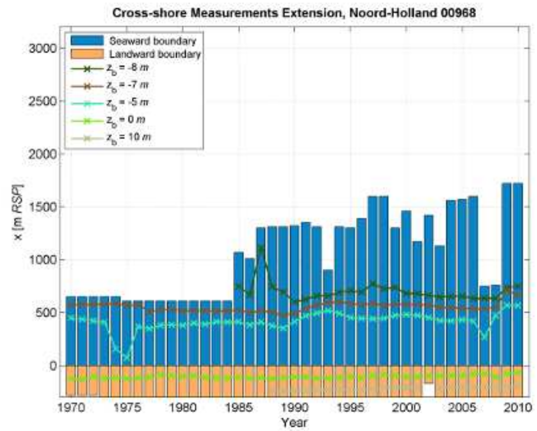

Cross-shore Measurements Extension, Noord-Holland 00908
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

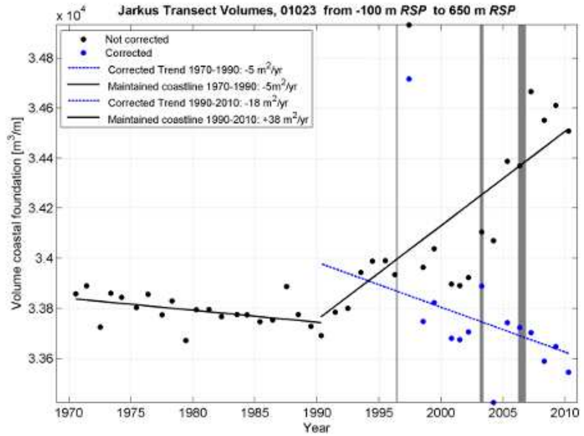

Jarkus Transect Volumes, 00848 from -100 m RSP to 600 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +8 m²/yr
Maintained coastline 1970-1990: +8m²/yr
Corrected Trend 1990-2010: -9 m²/yr
Maintained coastline 1990-2010: -3 m²/yr
Volume coastal foundation [m³/m]
Year

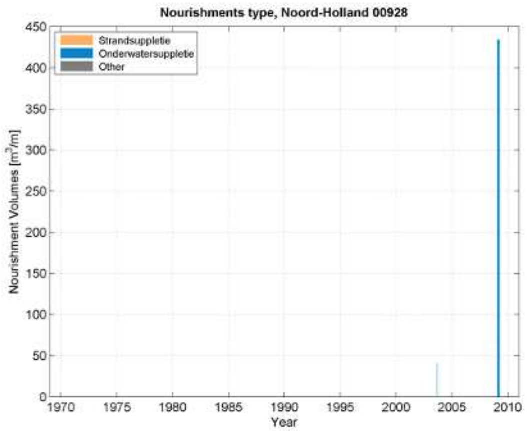

Cross-shore Measurements Extension, Noord-Holland 00869
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

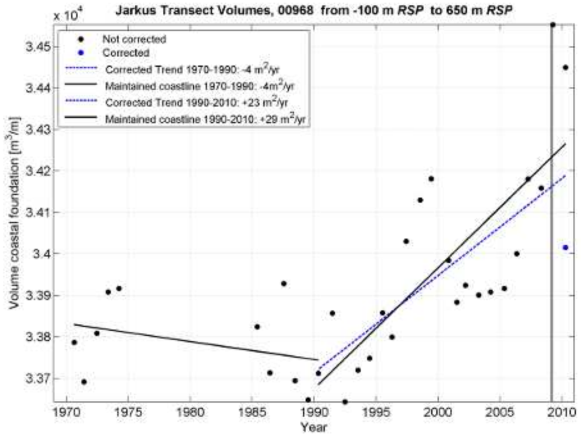

Jarkus Transect Volumes, 00908 from -100 m RSP to 650 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m²/yr
Maintained coastline 1970-1990: -6m²/yr
Corrected Trend 1990-2010: +19 m²/yr
Maintained coastline 1990-2010: +25 m²/yr
Volume coastal foundation [m³/m]
Year

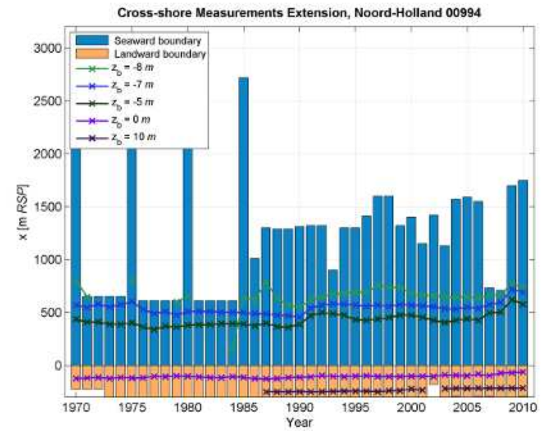

Jarkus Transect Volumes, 00948 from -100 m RSP to 650 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: -4m^2/yr
Corrected Trend 1990-2010: +23 m^2/yr
Maintained coastline 1990-2010: +28 m^2/yr
Volume coastal foundation [m^3/m]
Year

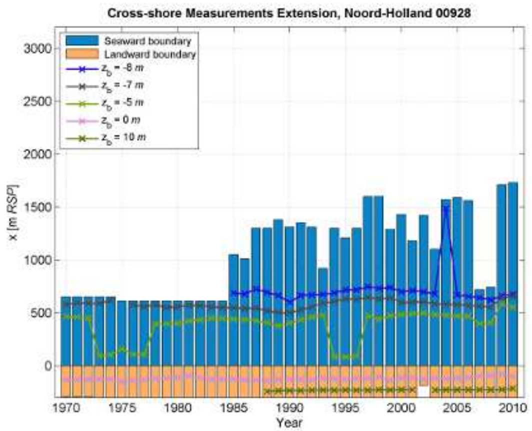

Cross-shore Measurements Extension, Noord-Holland 00968
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

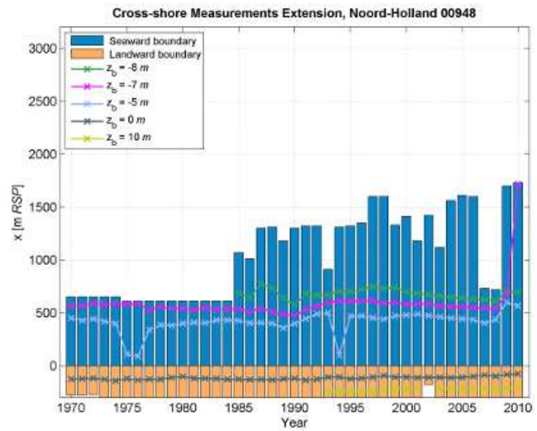

Jarkus Transect Volumes, 01023 from -100 m RSP to 650 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -5 m^2/yr
Maintained coastline 1970-1990: -5m^2/yr
Corrected Trend 1990-2010: -18 m^2/yr
Maintained coastline 1990-2010: +38 m^2/yr
Volume coastal foundation [m^3/m]
Year

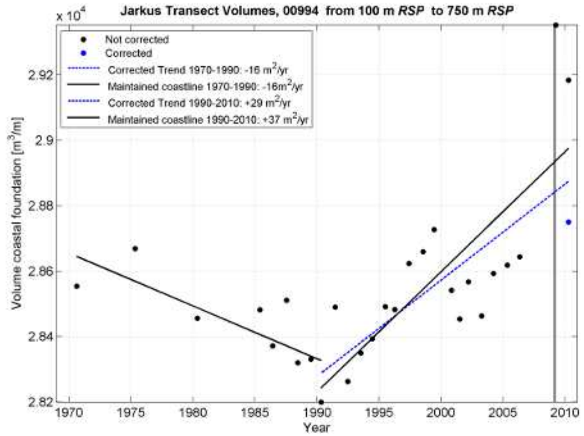

Nourishments type, Noord-Holland 00928
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

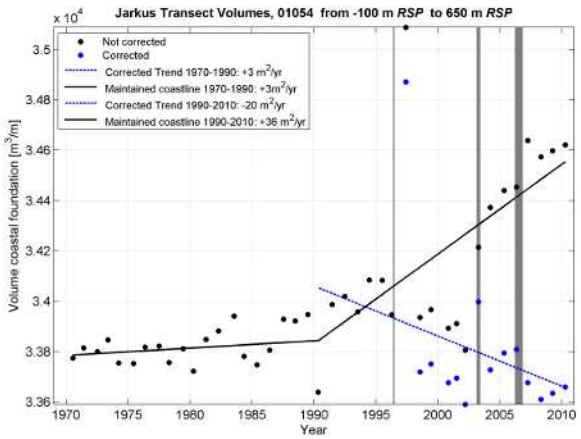

Jarkus Transect Volumes, 00968 from -100 m RSP to 650 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: -4m^2/yr
Corrected Trend 1990-2010: +23 m^2/yr
Maintained coastline 1990-2010: +29 m^2/yr
Volume coastal foundation [m^3/m]
Year

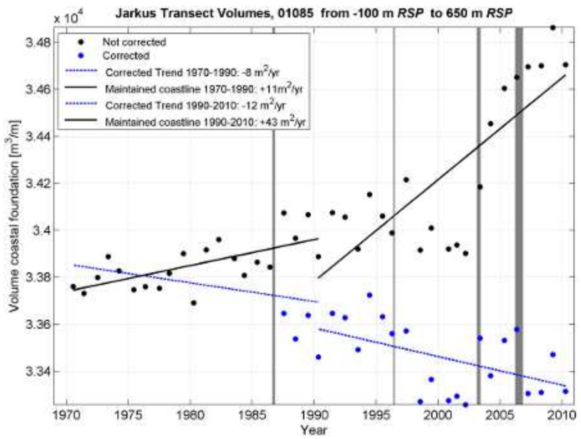

Cross-shore Measurements Extension, Noord-Holland 00994
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

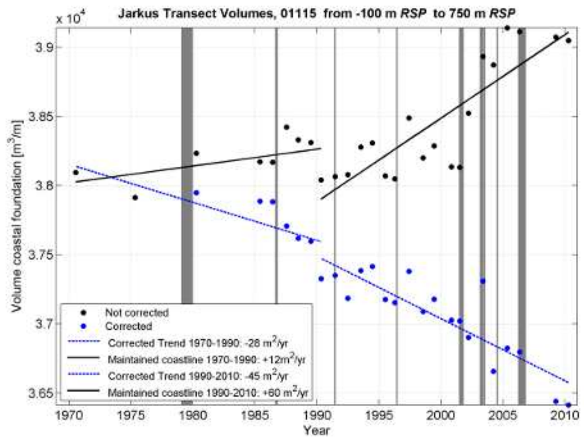

Cross-shore Measurements Extension, Noord-Holland 00928
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

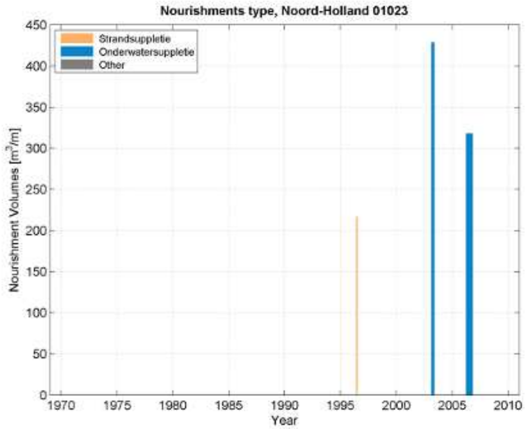

Cross-shore Measurements Extension, Noord-Holland 00948
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

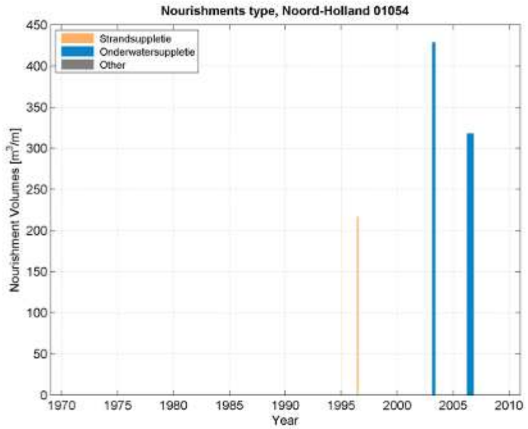

Jarkus Transect Volumes, 00994 from 100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -16 m^2/yr
Maintained coastline 1970-1990: -16m^2/yr
Corrected Trend 1990-2010: +29 m^2/yr
Maintained coastline 1990-2010: +37 m^2/yr
Volume coastal foundation [m^3/m]
Year

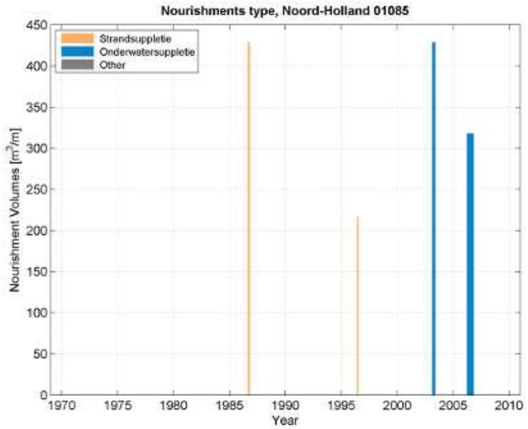

Jarkus Transect Volumes, 01054 from -100 m RSP to 650 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +3 m^2/yr
Maintained coastline 1970-1990: +3m^2/yr
Corrected Trend 1990-2010: -20 m^2/yr
Maintained coastline 1990-2010: +36 m^2/yr
Volume coastal foundation [m^3/m]
Year

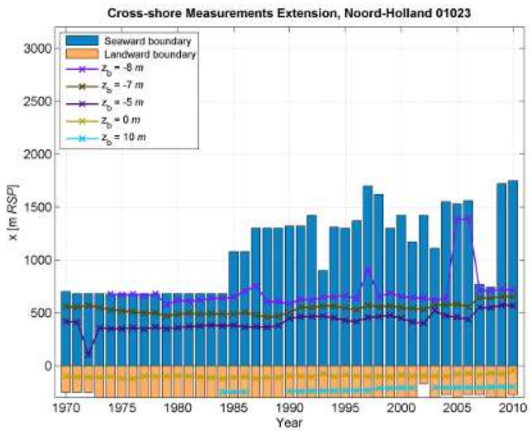

Jarkus Transect Volumes, 01085 from -100 m RSP to 650 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -8 m^2/yr
Maintained coastline 1970-1990: +11m^2/yr
Corrected Trend 1990-2010: -12 m^2/yr
Maintained coastline 1990-2010: +43 m^2/yr
Volume coastal foundation [m^3/m]
Year

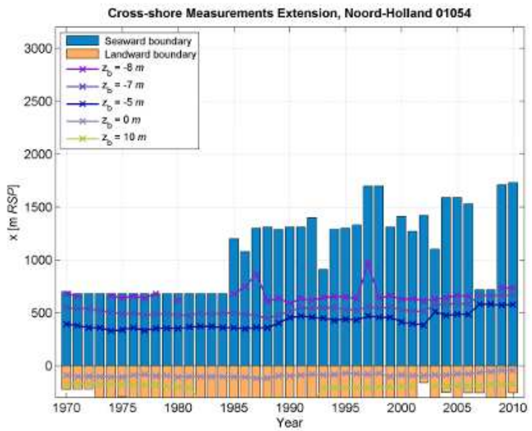

Jarkus Transect Volumes, 01115 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -28 m^2/yr
Maintained coastline 1970-1990: +12m^2/yr
Corrected Trend 1990-2010: -45 m^2/yr
Maintained coastline 1990-2010: +60 m^2/yr
Volume coastal foundation [m^3/m]
Year

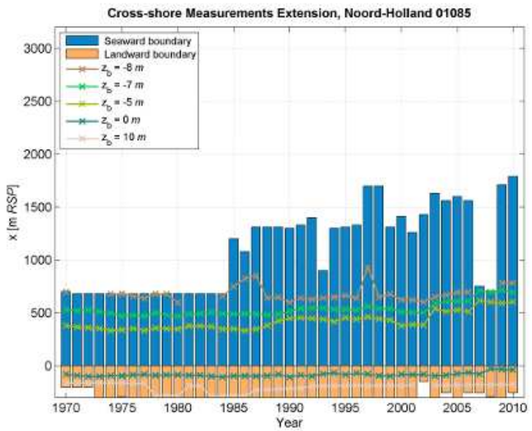

Nourishments type, Noord-Holland 01023
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

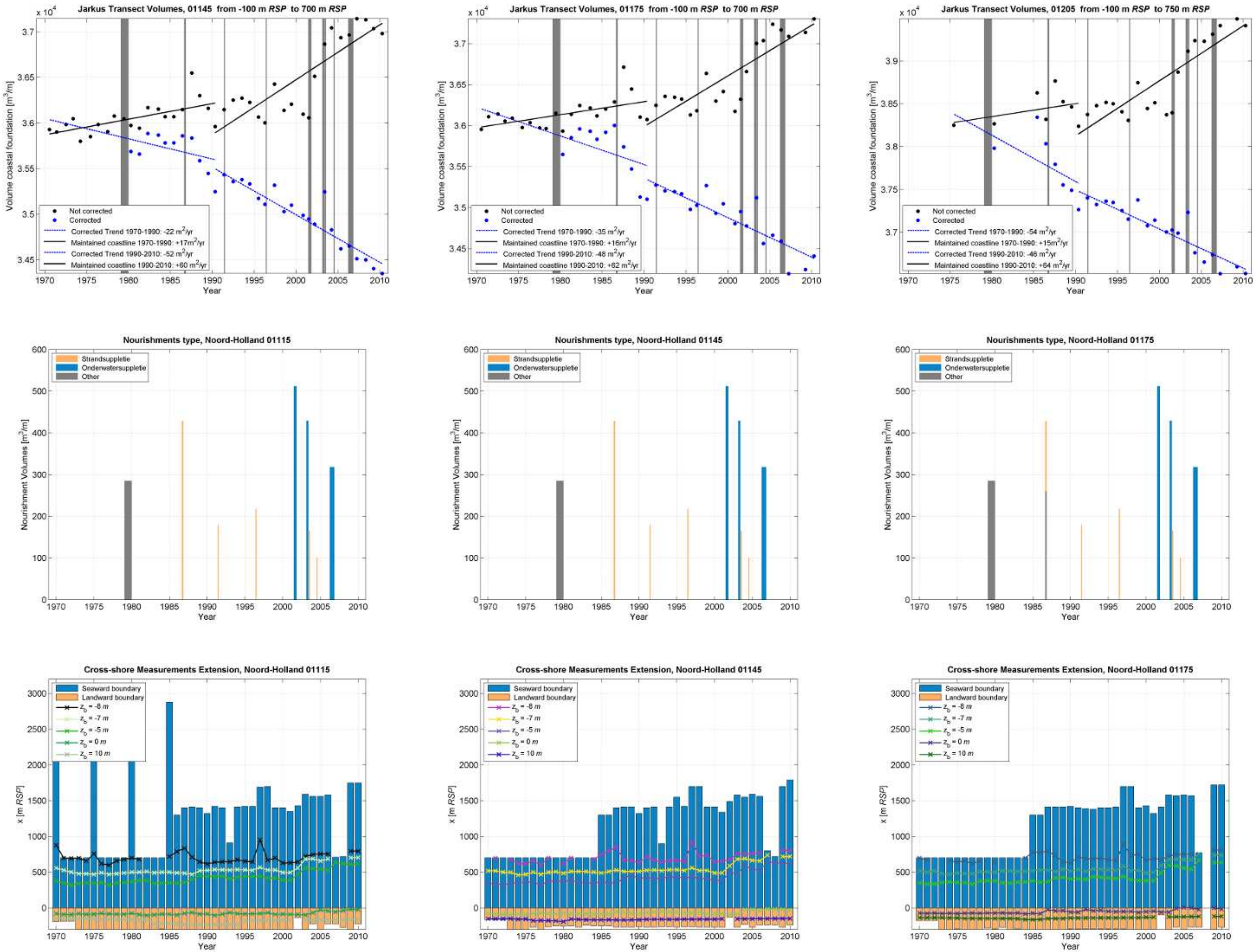

Nourishments type, Noord-Holland 01054
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

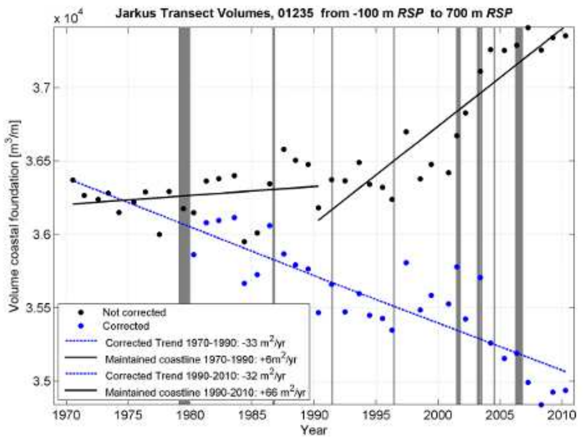

Nourishments type, Noord-Holland 01085
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

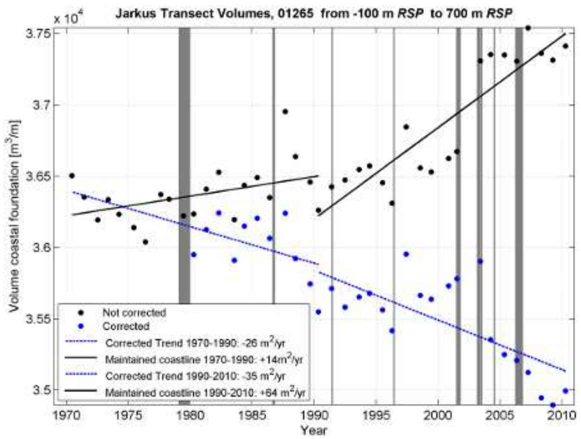

Cross-shore Measurements Extension, Noord-Holland 01023
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

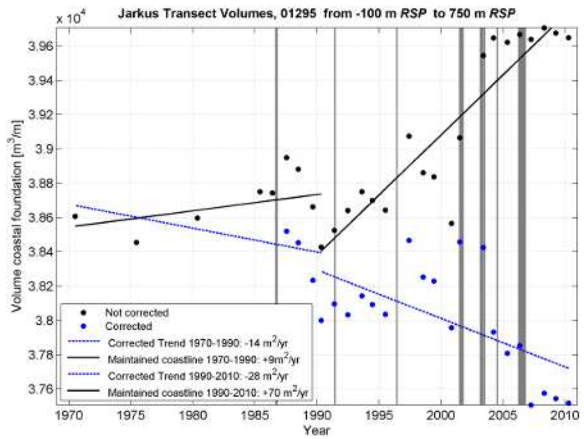

Cross-shore Measurements Extension, Noord-Holland 01054
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

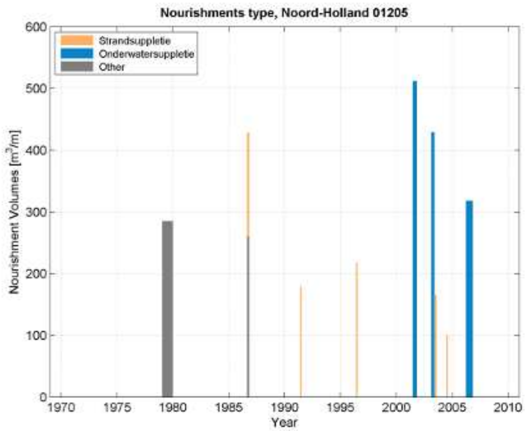

Cross-shore Measurements Extension, Noord-Holland 01085
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

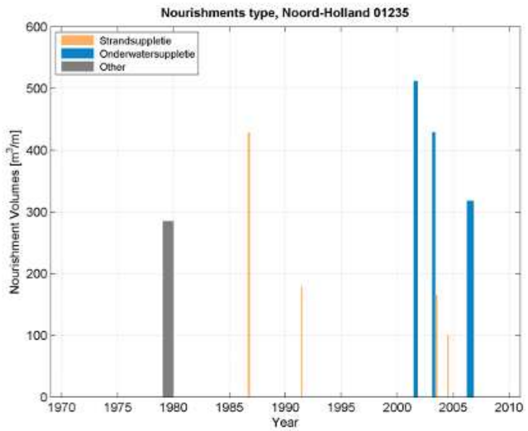

Jarkus Transect Volumes, 01145 from -100 m RSP to 700 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -22 m²/yr
Maintained coastline 1970-1990: +17m²/yr
Corrected Trend 1990-2010: -52 m²/yr
Maintained coastline 1990-2010: +60 m²/yr
Jarkus Transect Volumes, 01175 from -100 m RSP to 700 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -35 m²/yr
Maintained coastline 1970-1990: +16m²/yr
Corrected Trend 1990-2010: -48 m²/yr
Maintained coastline 1990-2010: +62 m²/yr
Jarkus Transect Volumes, 01205 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -54 m²/yr
Maintained coastline 1970-1990: +15m²/yr
Corrected Trend 1990-2010: -46 m²/yr
Maintained coastline 1990-2010: +64 m²/yr
Volume coastal foundation [m³/m]
Year
Nourishments type, Noord-Holland 01115
Nourishments type, Noord-Holland 01145
Nourishments type, Noord-Holland 01175
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year
Cross-shore Measurements Extension, Noord-Holland 01115
Cross-shore Measurements Extension, Noord-Holland 01145
Cross-shore Measurements Extension, Noord-Holland 01175
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

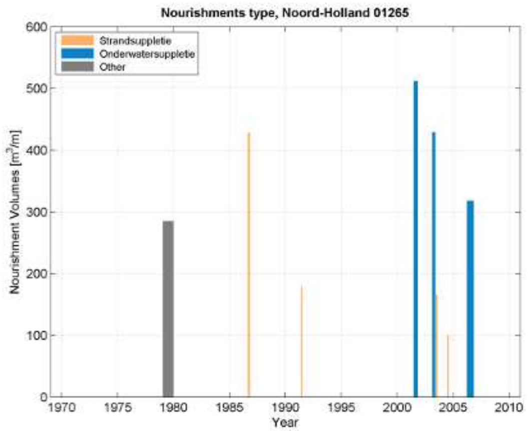

Jarkus Transect Volumes, 01235 from -100 m RSP to 700 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -33 m^2/yr
Maintained coastline 1970-1990: +6m^2/yr
Corrected Trend 1990-2010: -32 m^2/yr
Maintained coastline 1990-2010: +66 m^2/yr

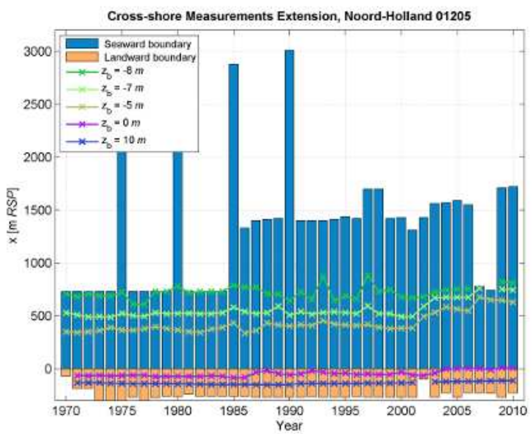

Jarkus Transect Volumes, 01265 from -100 m RSP to 700 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -26 m^2/yr
Maintained coastline 1970-1990: +14m^2/yr
Corrected Trend 1990-2010: -35 m^2/yr
Maintained coastline 1990-2010: +64 m^2/yr

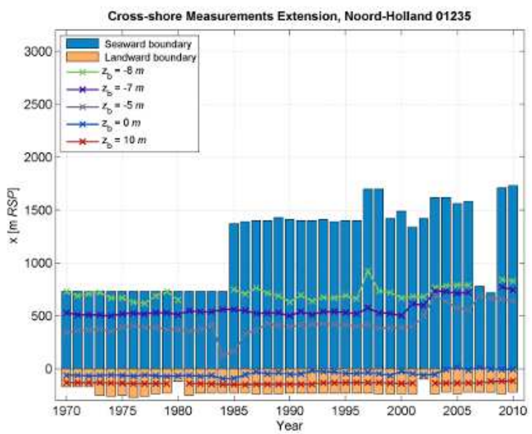

Jarkus Transect Volumes, 01295 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -14 m^2/yr
Maintained coastline 1970-1990: +9m^2/yr
Corrected Trend 1990-2010: -28 m^2/yr
Maintained coastline 1990-2010: +70 m^2/yr

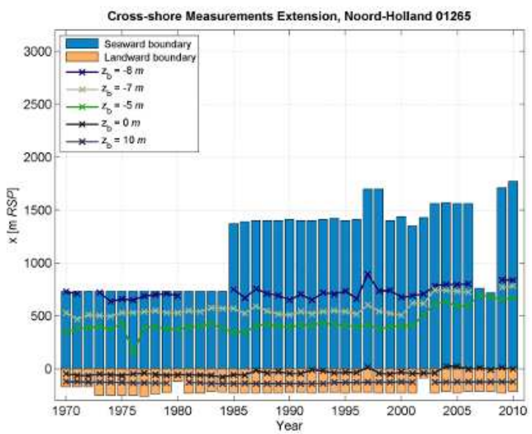

Nourishments type, Noord-Holland 01205
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

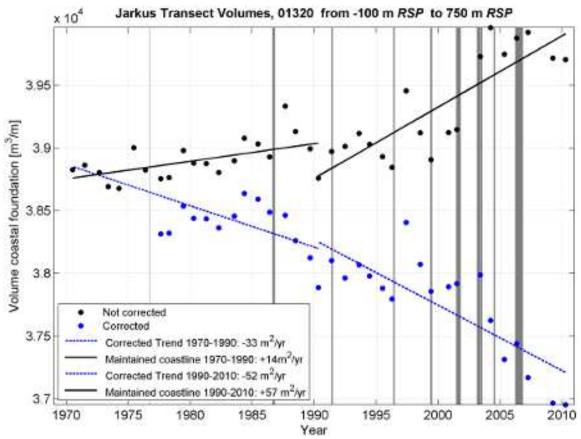

Nourishments type, Noord-Holland 01235
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

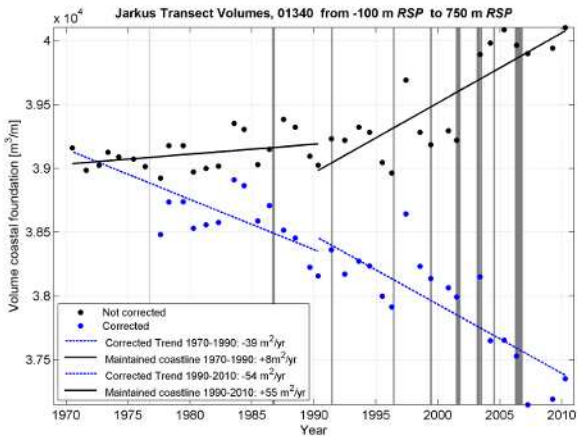

Nourishments type, Noord-Holland 01265
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

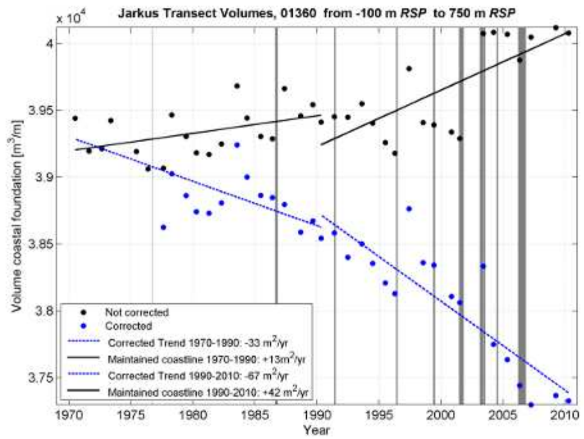

Cross-shore Measurements Extension, Noord-Holland 01205
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

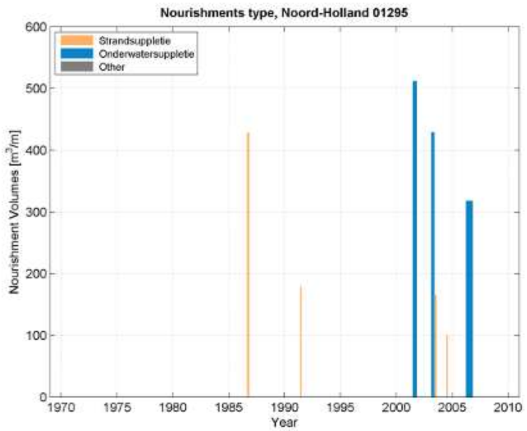

Cross-shore Measurements Extension, Noord-Holland 01235
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

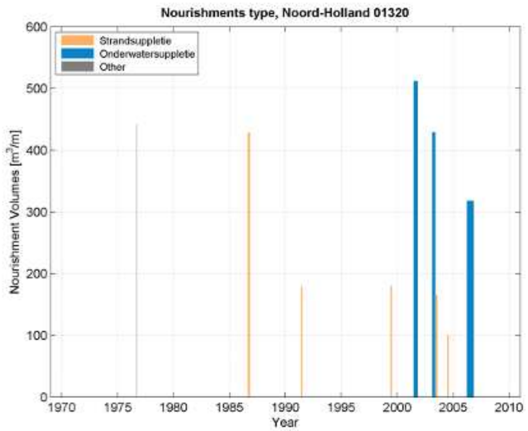

Cross-shore Measurements Extension, Noord-Holland 01265
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

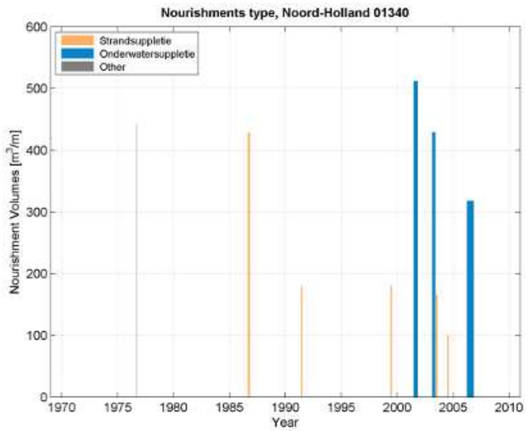

Jarkus Transect Volumes, 01320 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -33 m^2/yr
Maintained coastline 1970-1990: +14m^2/yr
Corrected Trend 1990-2010: -52 m^2/yr
Maintained coastline 1990-2010: +57 m^2/yr

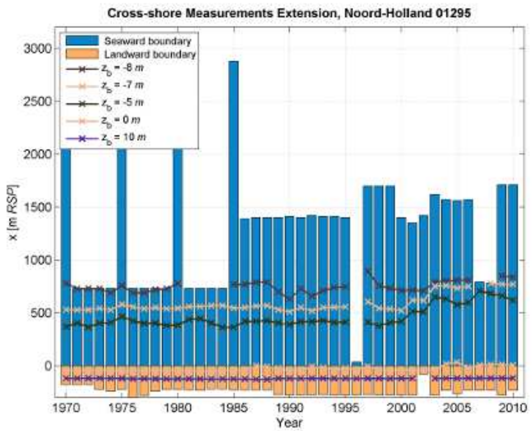

Jarkus Transect Volumes, 01340 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -39 m^2/yr
Maintained coastline 1970-1990: +8m^2/yr
Corrected Trend 1990-2010: -54 m^2/yr
Maintained coastline 1990-2010: +55 m^2/yr

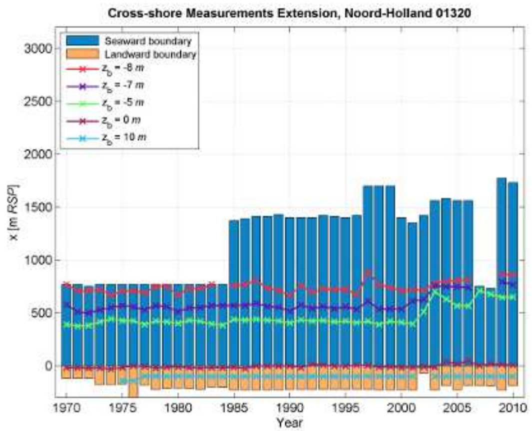

Jarkus Transect Volumes, 01360 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -33 m^2/yr
Maintained coastline 1970-1990: +13m^2/yr
Corrected Trend 1990-2010: -67 m^2/yr
Maintained coastline 1990-2010: +42 m^2/yr

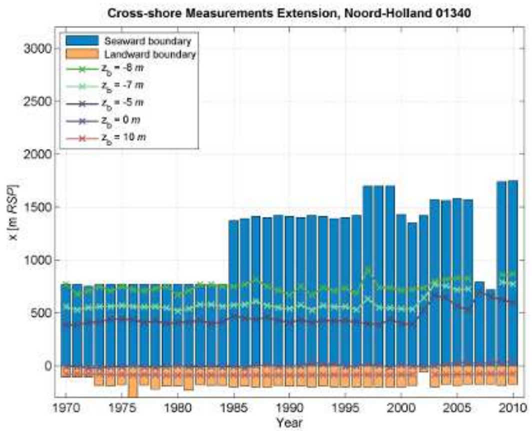

Nourishments type, Noord-Holland 01295
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

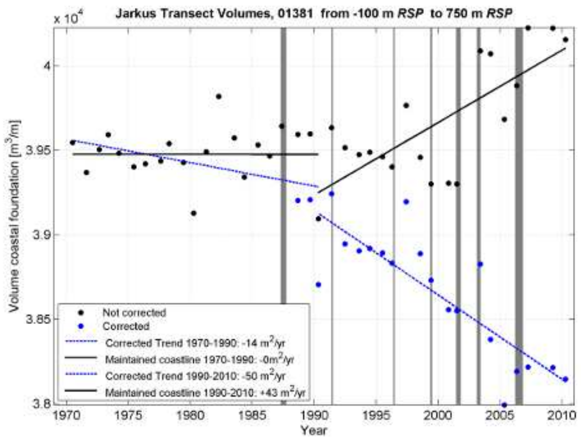

Nourishments type, Noord-Holland 01320
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

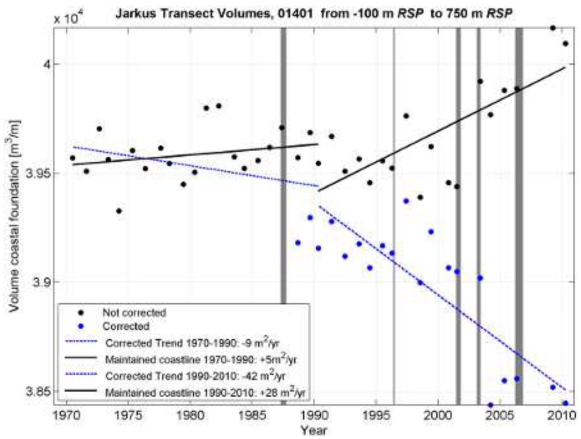

Nourishments type, Noord-Holland 01340
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

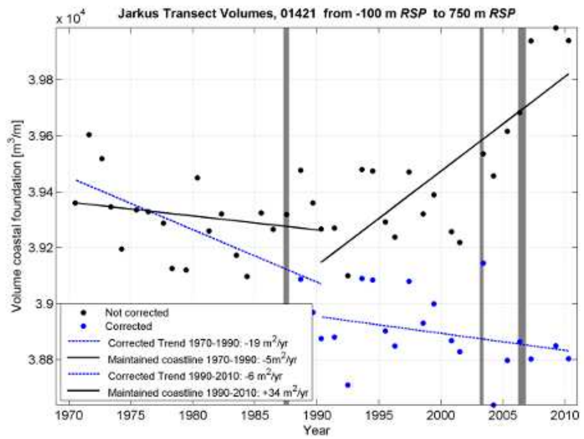

Cross-shore Measurements Extension, Noord-Holland 01295
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

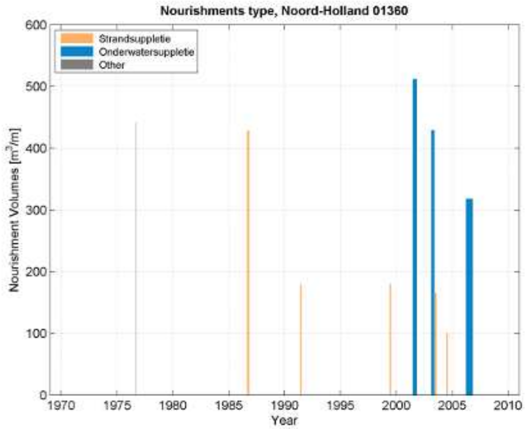

Cross-shore Measurements Extension, Noord-Holland 01320
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

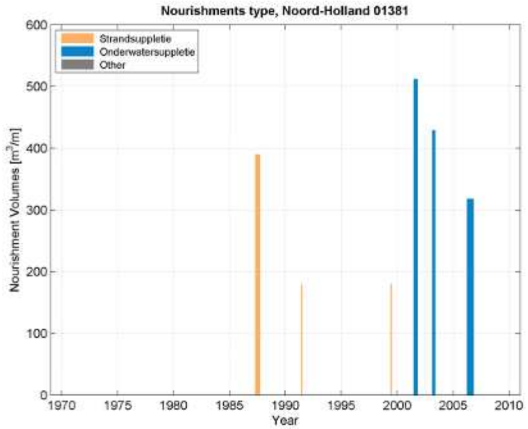

Cross-shore Measurements Extension, Noord-Holland 01340
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

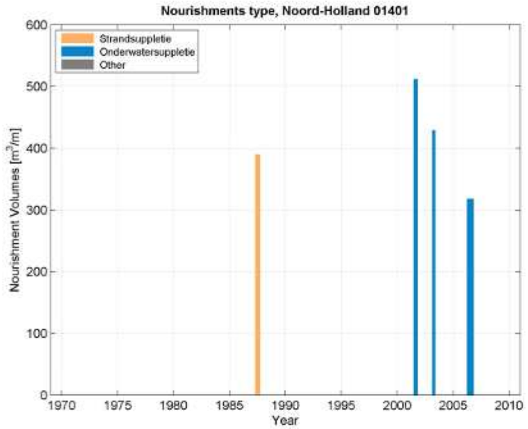

Jarkus Transect Volumes, 01381 from -100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -14 m2/yr
Maintained coastline 1970-1990: -0m2/yr
Corrected Trend 1990-2010: -50 m2/yr
Maintained coastline 1990-2010: +43 m2/yr

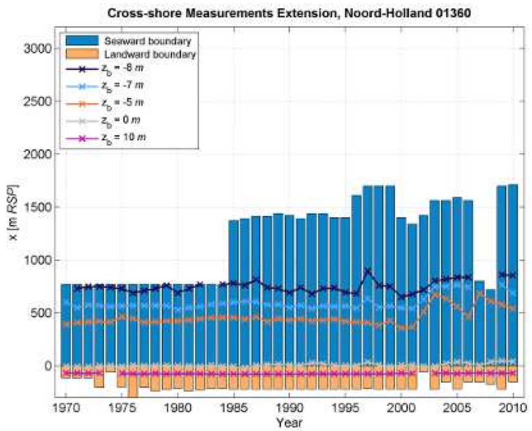

Jarkus Transect Volumes, 01401 from -100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -9 m2/yr
Maintained coastline 1970-1990: +5m2/yr
Corrected Trend 1990-2010: -42 m2/yr
Maintained coastline 1990-2010: +28 m2/yr

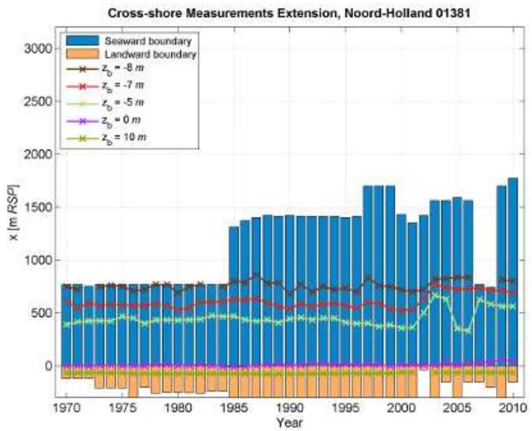

Jarkus Transect Volumes, 01421 from -100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -19 m2/yr
Maintained coastline 1970-1990: -5m2/yr
Corrected Trend 1990-2010: -6 m2/yr
Maintained coastline 1990-2010: +34 m2/yr

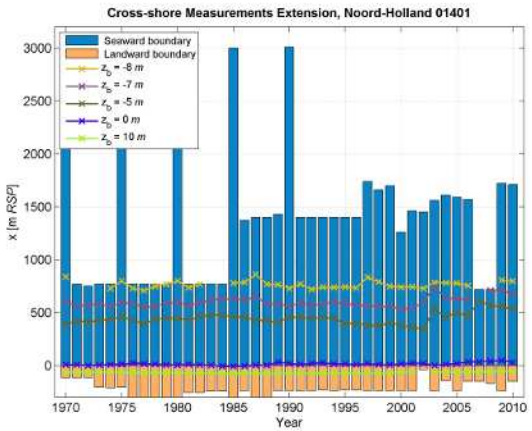

Nourishments type, Noord-Holland 01360
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

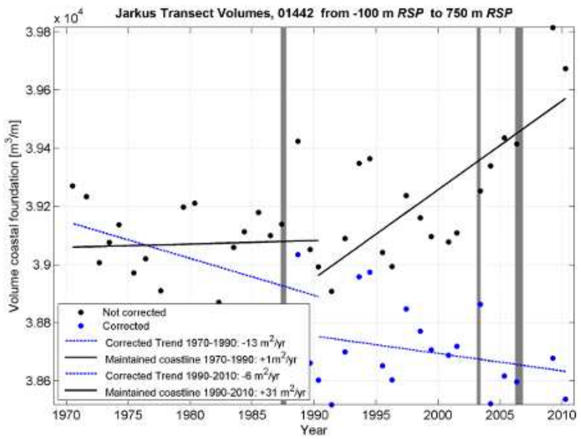
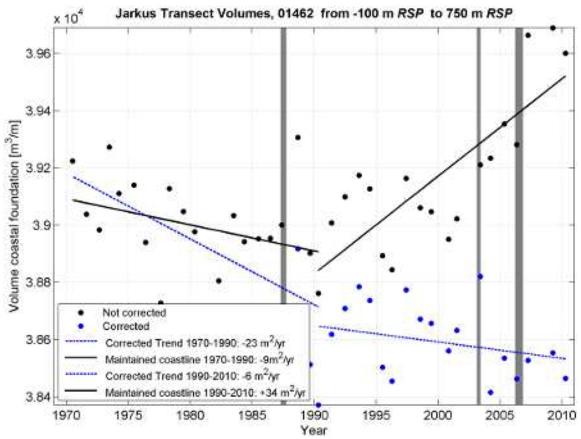
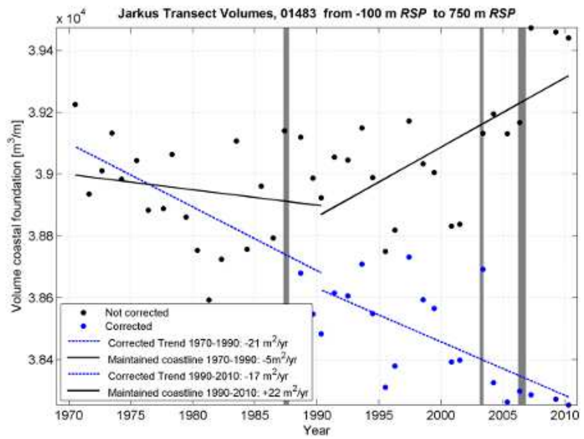
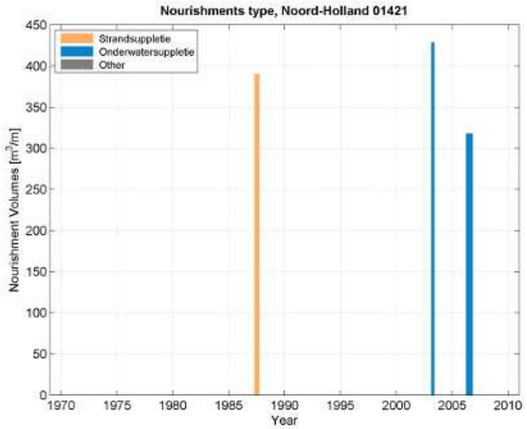
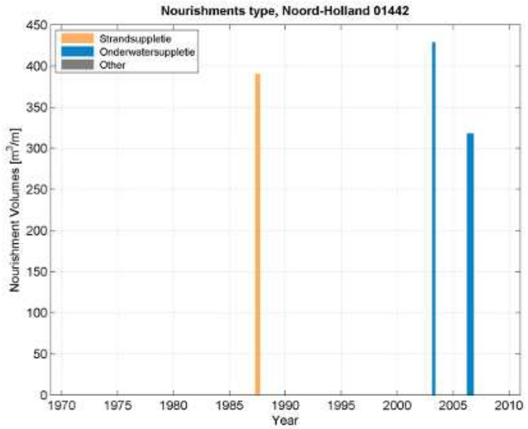
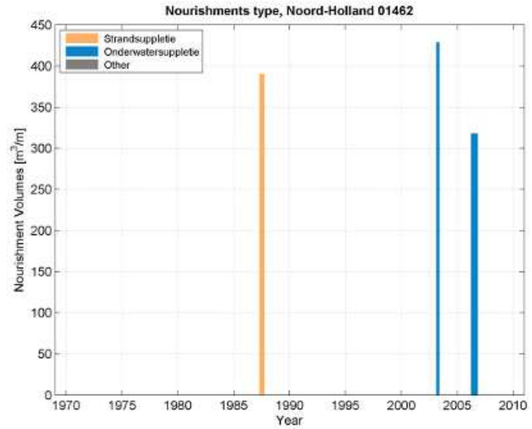
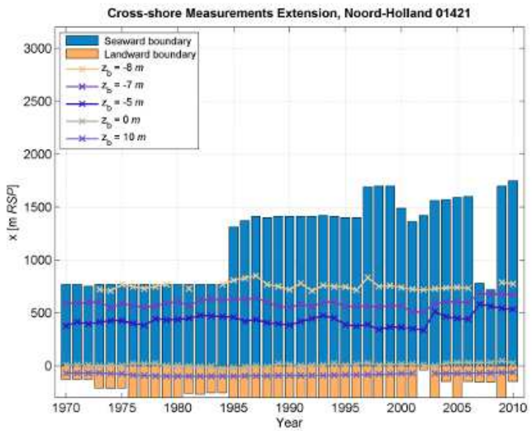
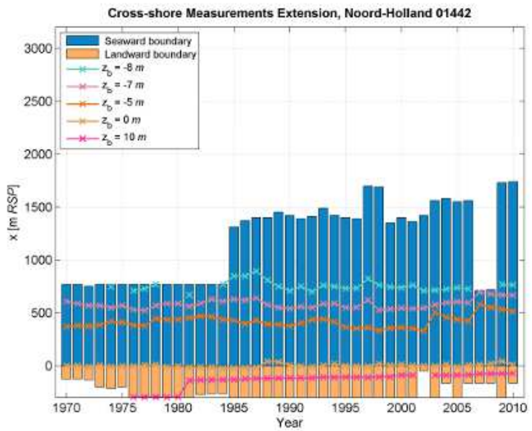
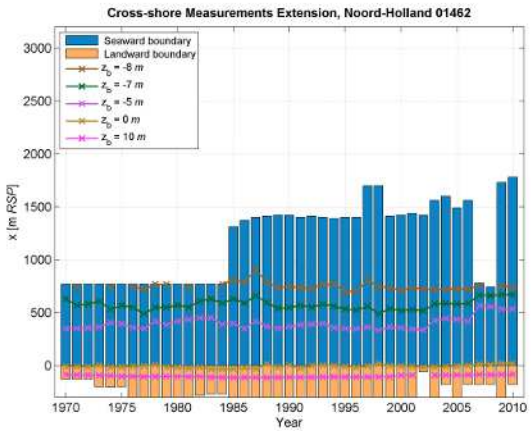

Nourishments type, Noord-Holland 01381
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

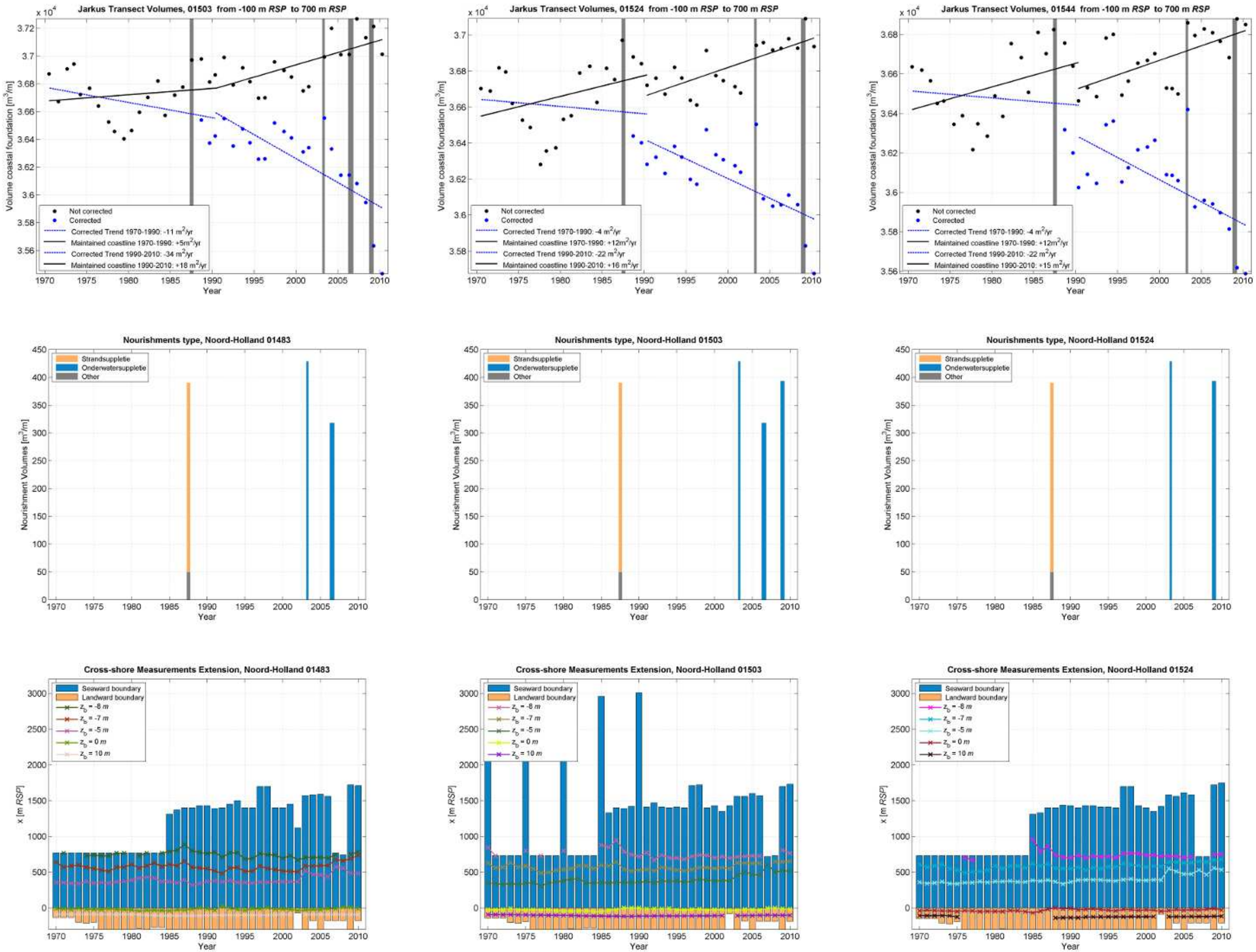

Nourishments type, Noord-Holland 01401
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

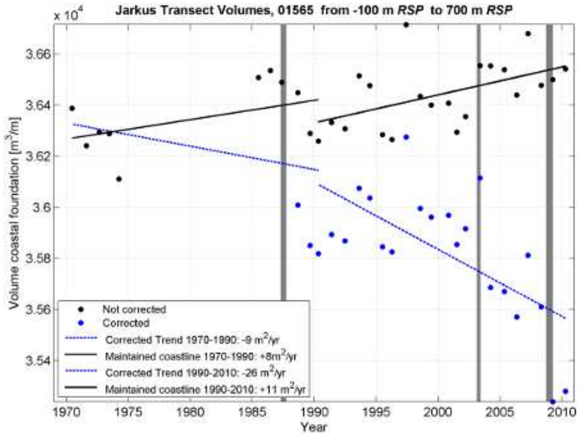

Cross-shore Measurements Extension, Noord-Holland 01360
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

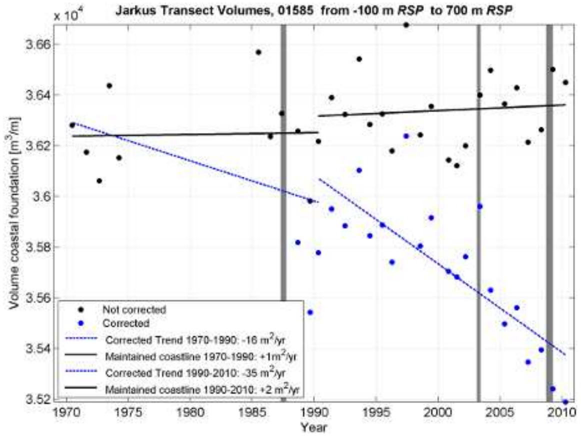

Cross-shore Measurements Extension, Noord-Holland 01381
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

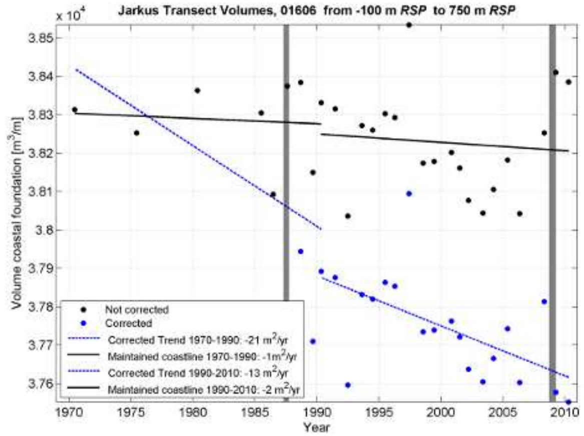

Cross-shore Measurements Extension, Noord-Holland 01401
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

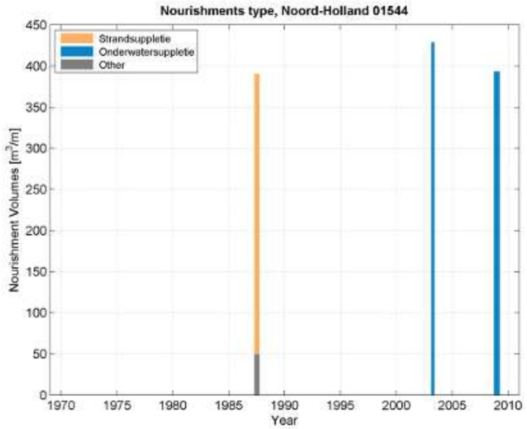

Jarkus Transect Volumes, 01442 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -13 m^2/yr
Maintained coastline 1970-1990: +1m^2/yr
Corrected Trend 1990-2010: -6 m^2/yr
Maintained coastline 1990-2010: +31 m^2/yr

Jarkus Transect Volumes, 01462 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -23 m^2/yr
Maintained coastline 1970-1990: -9m^2/yr
Corrected Trend 1990-2010: -6 m^2/yr
Maintained coastline 1990-2010: +34 m^2/yr

Jarkus Transect Volumes, 01483 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -21 m^2/yr
Maintained coastline 1970-1990: -5m^2/yr
Corrected Trend 1990-2010: -17 m^2/yr
Maintained coastline 1990-2010: +22 m^2/yr

Nourishments type, Noord-Holland 01421
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

Nourishments type, Noord-Holland 01442
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

Nourishments type, Noord-Holland 01462
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

Cross-shore Measurements Extension, Noord-Holland 01421
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

Cross-shore Measurements Extension, Noord-Holland 01442
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

Cross-shore Measurements Extension, Noord-Holland 01462
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

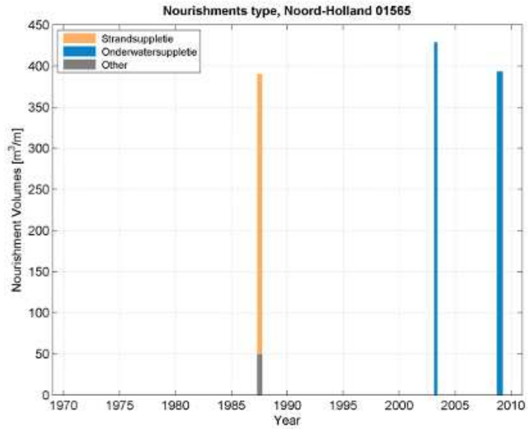

Jarkus Transect Volumes, 01503 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -11 m^2/yr
Maintained coastline 1970-1990: +5m^2/yr
Corrected Trend 1990-2010: -34 m^2/yr
Maintained coastline 1990-2010: +18 m^2/yr
Year
Jarkus Transect Volumes, 01524 from -100 m RSP to 700 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: +12m^2/yr
Corrected Trend 1990-2010: -22 m^2/yr
Maintained coastline 1990-2010: +16 m^2/yr
Jarkus Transect Volumes, 01544 from -100 m RSP to 700 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: +12m^2/yr
Corrected Trend 1990-2010: -22 m^2/yr
Maintained coastline 1990-2010: +15 m^2/yr
Nourishments type, Noord-Holland 01483
Nourishments type, Noord-Holland 01503
Nourishments type, Noord-Holland 01524
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Cross-shore Measurements Extension, Noord-Holland 01483
Cross-shore Measurements Extension, Noord-Holland 01503
Cross-shore Measurements Extension, Noord-Holland 01524
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]

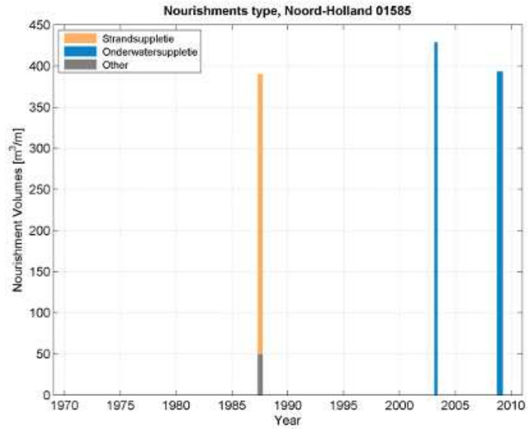

Jarkus Transect Volumes, 01565 from -100 m RSP to 700 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -9 m2/yr
Maintained coastline 1970-1990: +8m2/yr
Corrected Trend 1990-2010: -26 m2/yr
Maintained coastline 1990-2010: +11 m2/yr

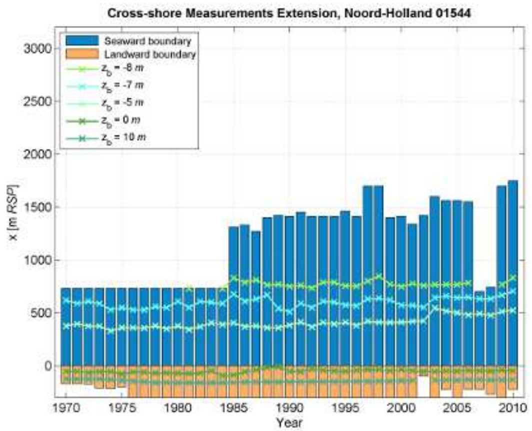

Jarkus Transect Volumes, 01585 from -100 m RSP to 700 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -16 m2/yr
Maintained coastline 1970-1990: +1m2/yr
Corrected Trend 1990-2010: -35 m2/yr
Maintained coastline 1990-2010: +2 m2/yr

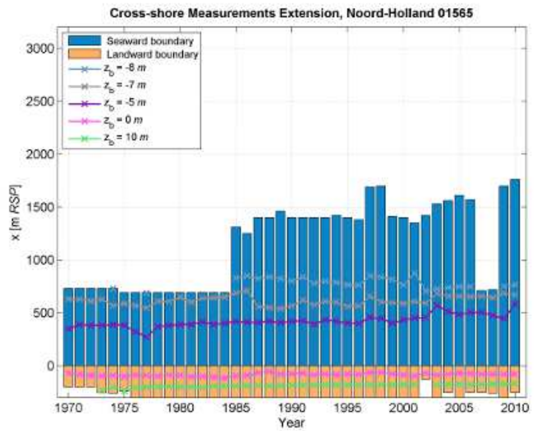

Jarkus Transect Volumes, 01606 from -100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -21 m2/yr
Maintained coastline 1970-1990: -1m2/yr
Corrected Trend 1990-2010: -13 m2/yr
Maintained coastline 1990-2010: -2 m2/yr

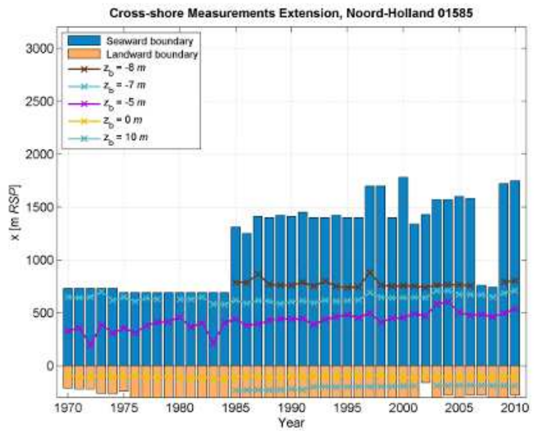

Nourishments type, Noord-Holland 01544
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

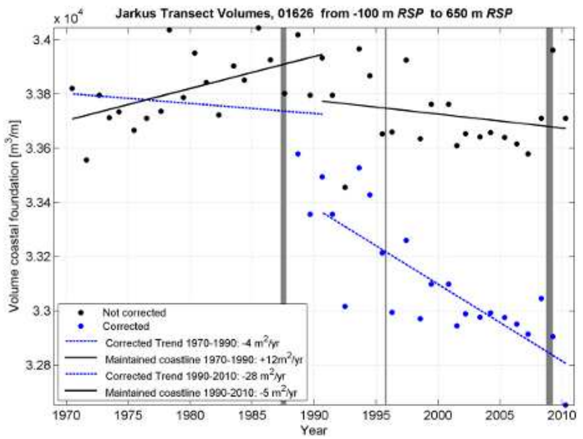

Nourishments type, Noord-Holland 01565
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

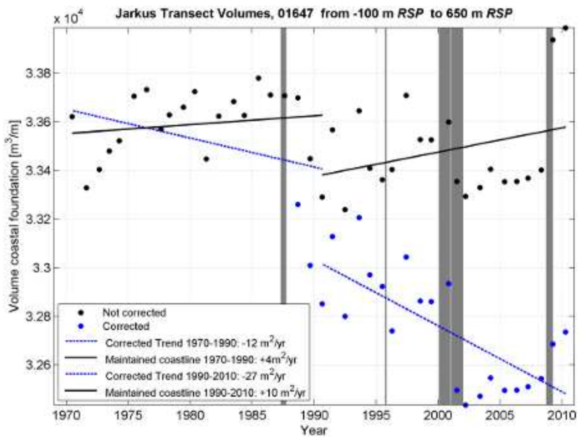

Nourishments type, Noord-Holland 01585
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

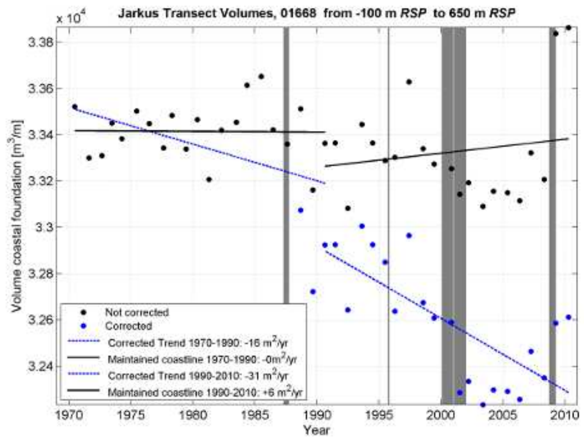

Cross-shore Measurements Extension, Noord-Holland 01544
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

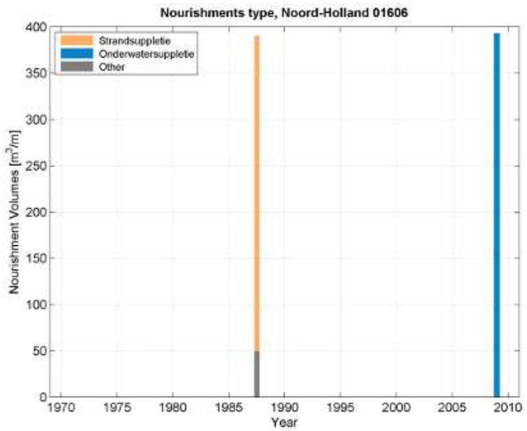

Cross-shore Measurements Extension, Noord-Holland 01565
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

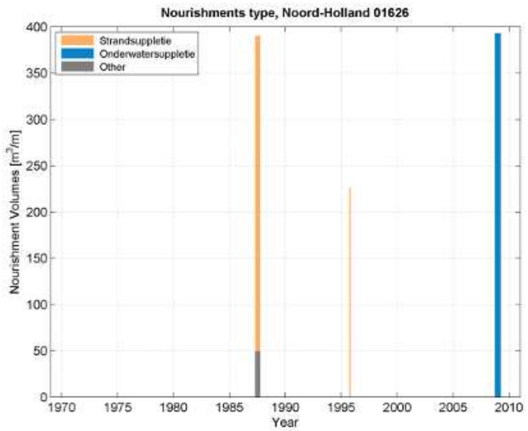

Cross-shore Measurements Extension, Noord-Holland 01585
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

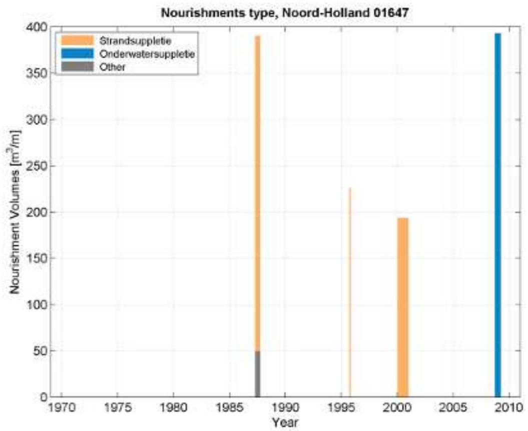

Jarkus Transect Volumes, 01626 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m2/yr
Maintained coastline 1970-1990: +12m2/yr
Corrected Trend 1990-2010: -28 m2/yr
Maintained coastline 1990-2010: -5 m2/yr

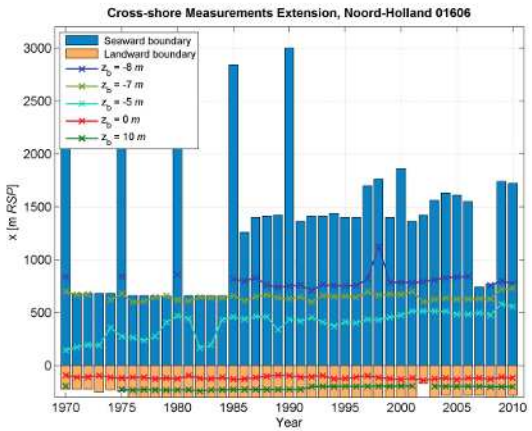

Jarkus Transect Volumes, 01647 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -12 m2/yr
Maintained coastline 1970-1990: +4m2/yr
Corrected Trend 1990-2010: -27 m2/yr
Maintained coastline 1990-2010: +10 m2/yr

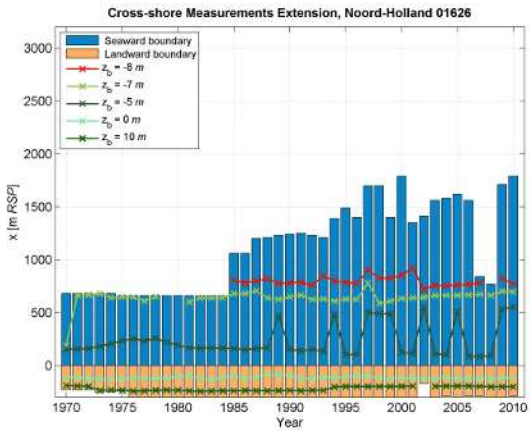

Jarkus Transect Volumes, 01668 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -16 m2/yr
Maintained coastline 1970-1990: -0m2/yr
Corrected Trend 1990-2010: -31 m2/yr
Maintained coastline 1990-2010: +6 m2/yr

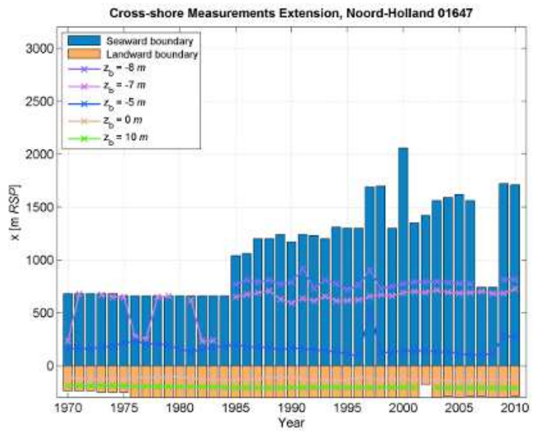

Nourishments type, Noord-Holland 01606
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

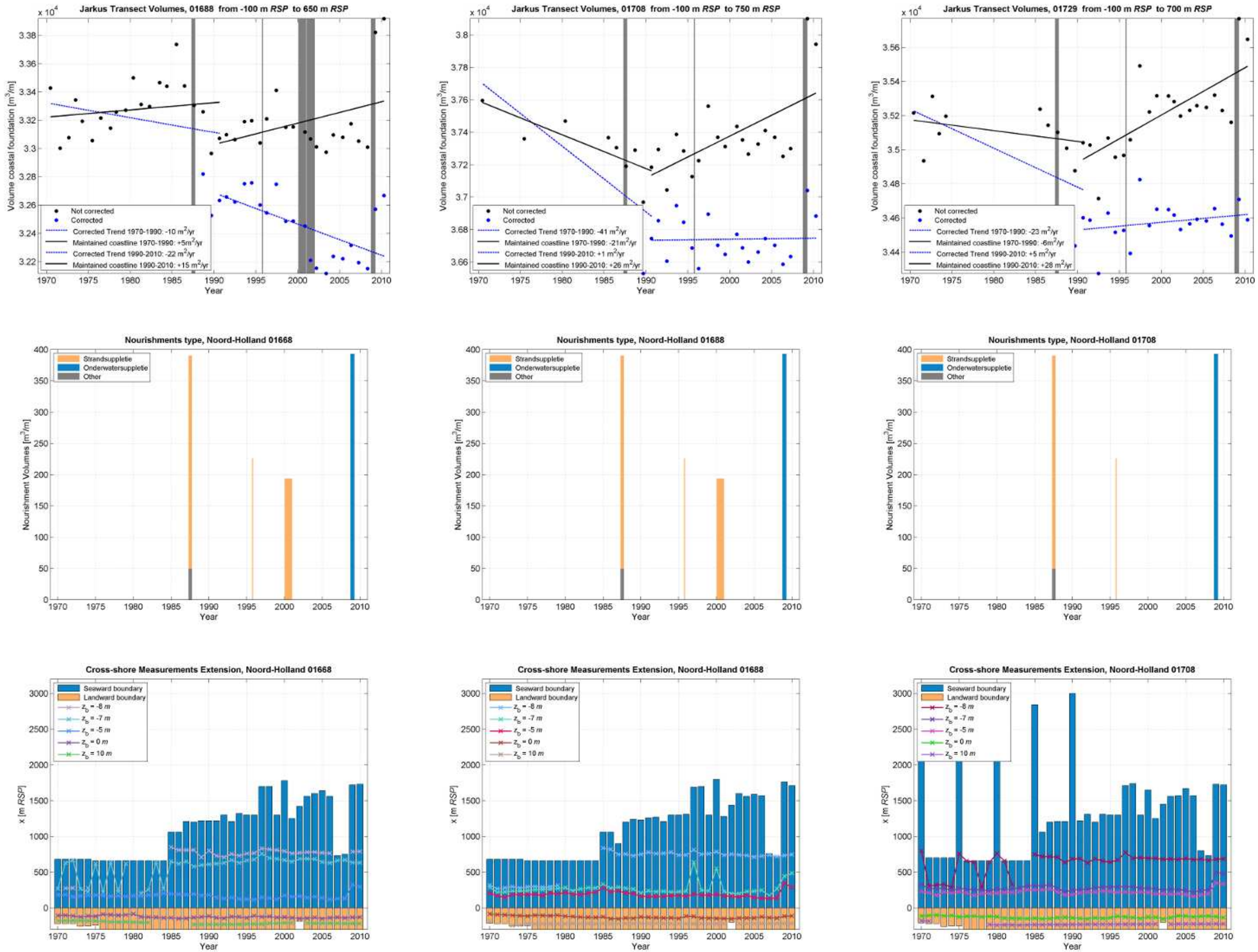

Nourishments type, Noord-Holland 01626
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other


Nourishments type, Noord-Holland 01647
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

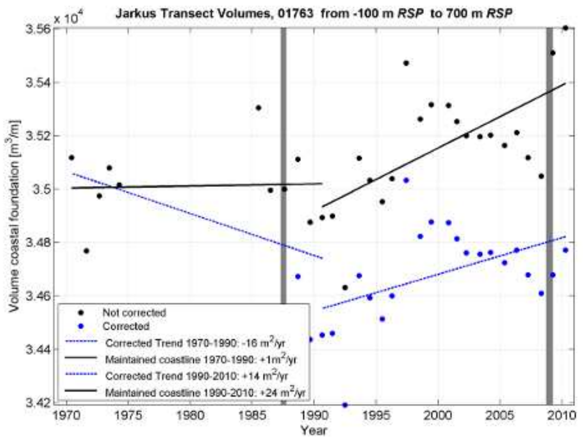

Cross-shore Measurements Extension, Noord-Holland 01606
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

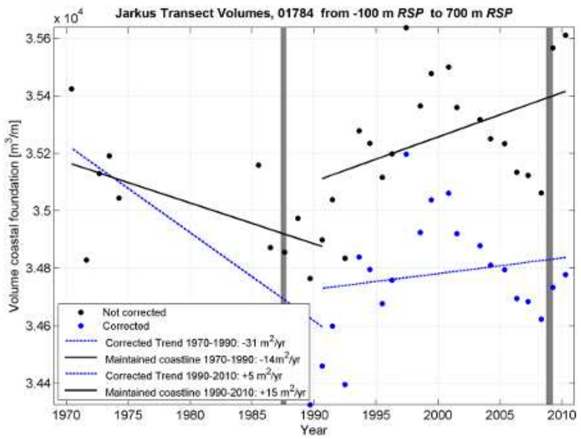

Cross-shore Measurements Extension, Noord-Holland 01626
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

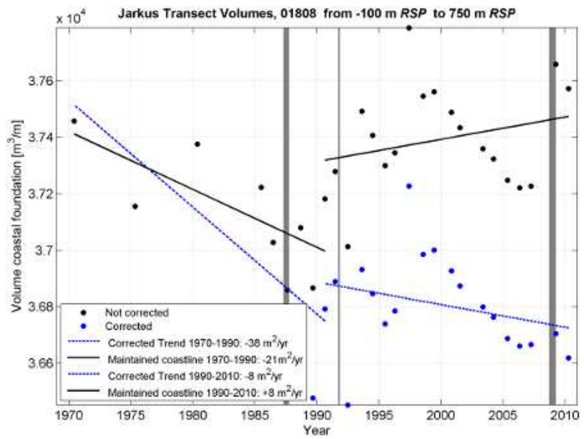

Cross-shore Measurements Extension, Noord-Holland 01647
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

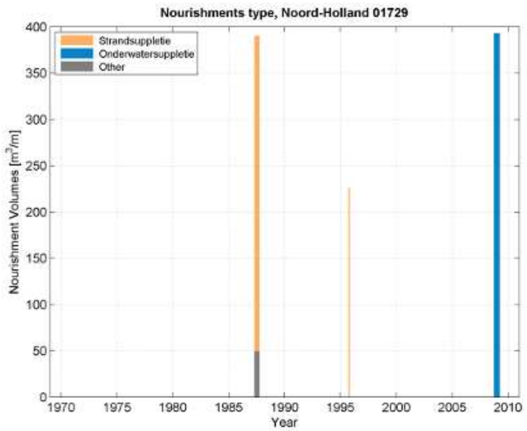


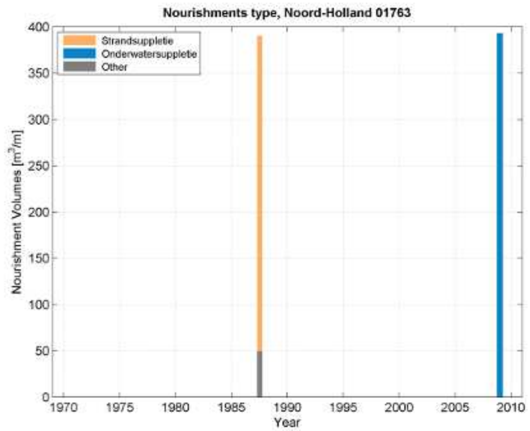
Jarkus Transect Volumes, 01688 from -100 m RSP to 650 m RSP
Jarkus Transect Volumes, 01708 from -100 m RSP to 750 m RSP
Jarkus Transect Volumes, 01729 from -100 m RSP to 700 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -10 m2/yr
Maintained coastline 1970-1990: +5m2/yr
Corrected Trend 1990-2010: -22 m2/yr
Maintained coastline 1990-2010: +15 m2/yr
Corrected Trend 1970-1990: -41 m2/yr
Maintained coastline 1970-1990: -21m2/yr
Corrected Trend 1990-2010: +1 m2/yr
Maintained coastline 1990-2010: +26 m2/yr
Corrected Trend 1970-1990: -23 m2/yr
Maintained coastline 1970-1990: -6m2/yr
Corrected Trend 1990-2010: +5 m2/yr
Maintained coastline 1990-2010: +28 m2/yr
Nourishments type, Noord-Holland 01668
Nourishments type, Noord-Holland 01688
Nourishments type, Noord-Holland 01708
Nourishment Volumes [m3/m]
Strandsuppletie
Onderwatersuppletie
Other
Cross-shore Measurements Extension, Noord-Holland 01668
Cross-shore Measurements Extension, Noord-Holland 01688
Cross-shore Measurements Extension, Noord-Holland 01708
x [m RSP]
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

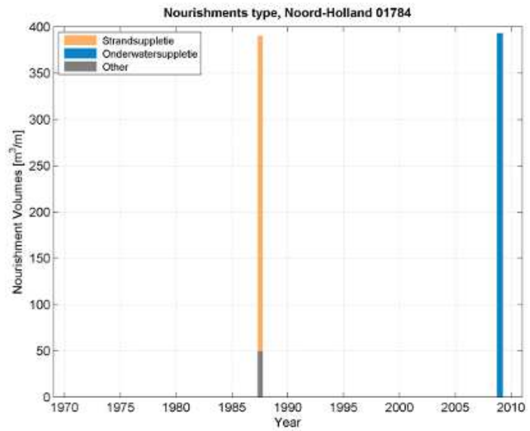

Jarkus Transect Volumes, 01763 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -16 m^2/yr
Maintained coastline 1970-1990: +1m^2/yr
Corrected Trend 1990-2010: +14 m^2/yr
Maintained coastline 1990-2010: +24 m^2/yr

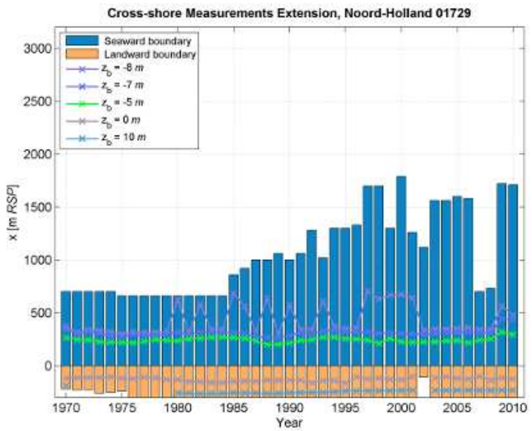

Jarkus Transect Volumes, 01784 from -100 m RSP to 700 m RSP
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -31 m^2/yr
Maintained coastline 1970-1990: -14m^2/yr
Corrected Trend 1990-2010: +5 m^2/yr
Maintained coastline 1990-2010: +15 m^2/yr

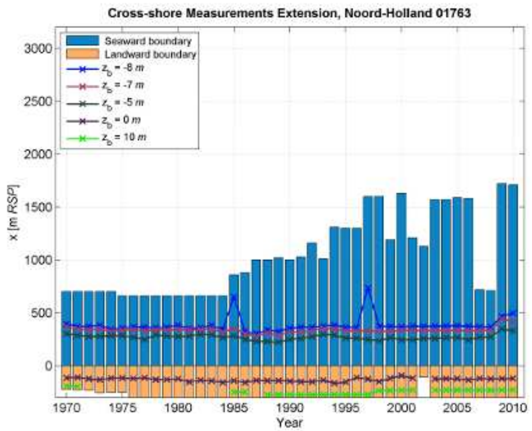

Jarkus Transect Volumes, 01808 from -100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -38 m^2/yr
Maintained coastline 1970-1990: -21m^2/yr
Corrected Trend 1990-2010: -8 m^2/yr
Maintained coastline 1990-2010: +8 m^2/yr

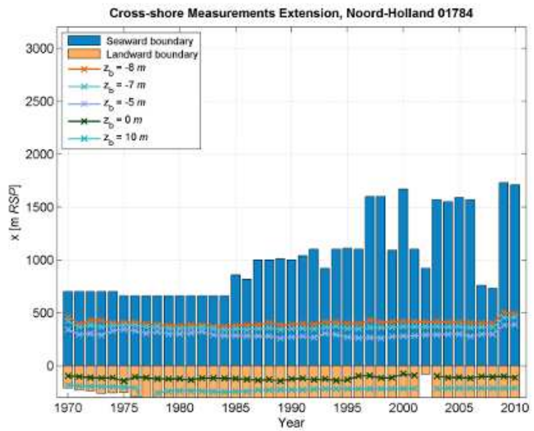

Nourishments type, Noord-Holland 01729
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

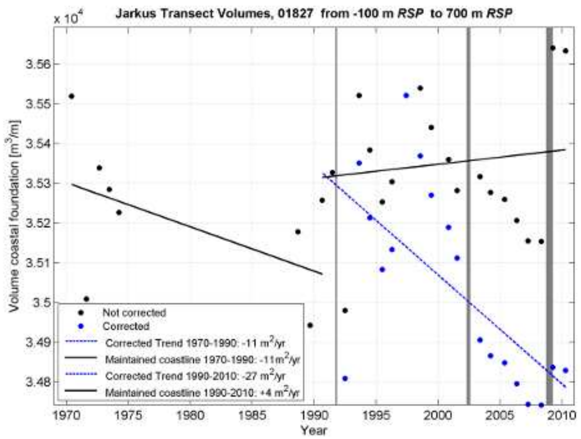

Nourishments type, Noord-Holland 01763
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

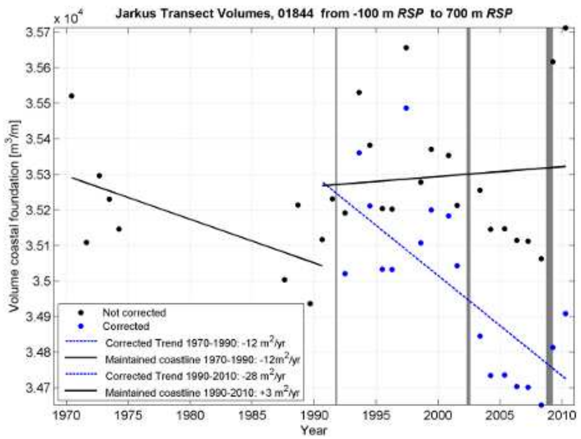

Nourishments type, Noord-Holland 01784
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

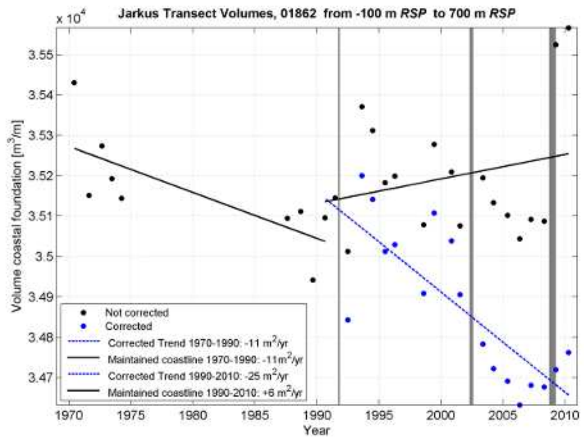

Cross-shore Measurements Extension, Noord-Holland 01729
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

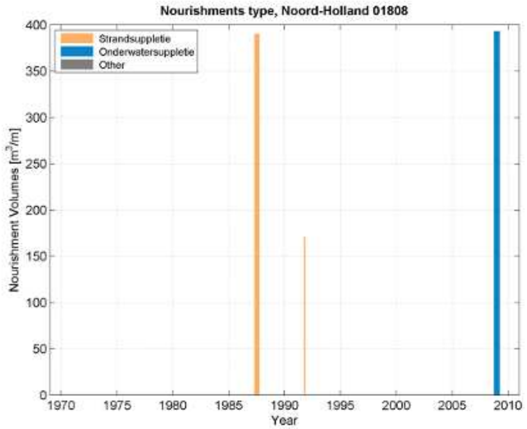

Cross-shore Measurements Extension, Noord-Holland 01763
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

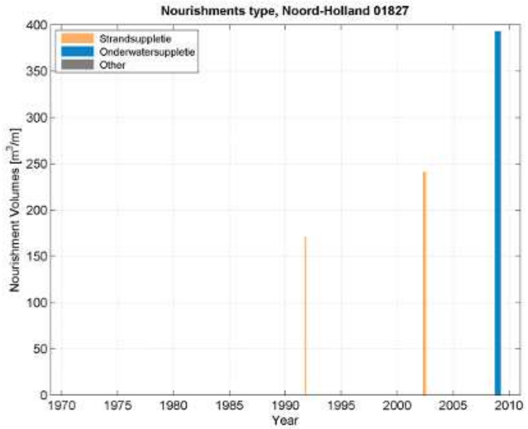

Cross-shore Measurements Extension, Noord-Holland 01784
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

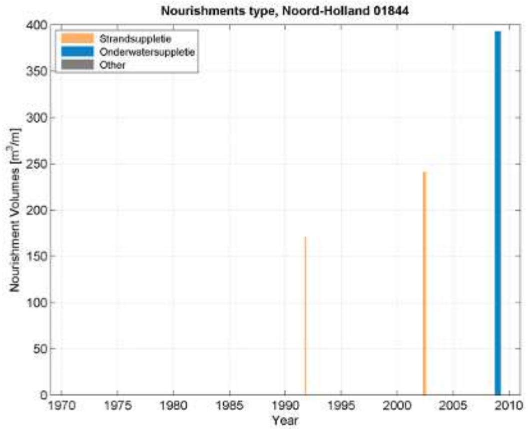

Jarkus Transect Volumes, 01827 from -100 m RSP to 700 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -11 m^2/yr
Maintained coastline 1970-1990: -11m^2/yr
Corrected Trend 1990-2010: -27 m^2/yr
Maintained coastline 1990-2010: +4 m^2/yr

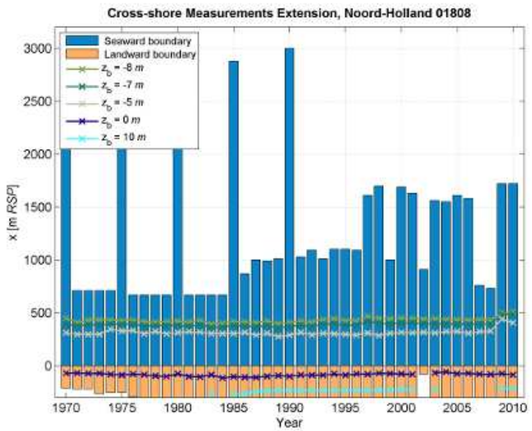

Jarkus Transect Volumes, 01844 from -100 m RSP to 700 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -12 m^2/yr
Maintained coastline 1970-1990: -12m^2/yr
Corrected Trend 1990-2010: -28 m^2/yr
Maintained coastline 1990-2010: +3 m^2/yr

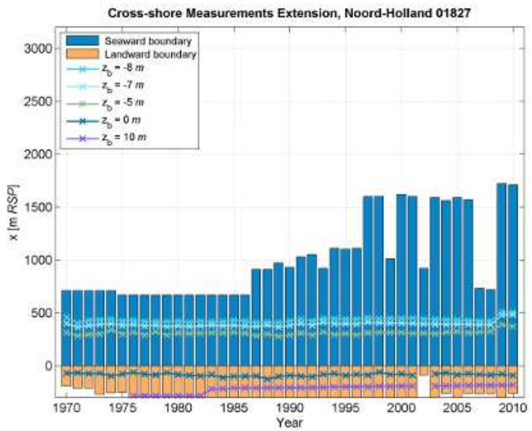

Jarkus Transect Volumes, 01862 from -100 m RSP to 700 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -11 m^2/yr
Maintained coastline 1970-1990: -11m^2/yr
Corrected Trend 1990-2010: -25 m^2/yr
Maintained coastline 1990-2010: +6 m^2/yr

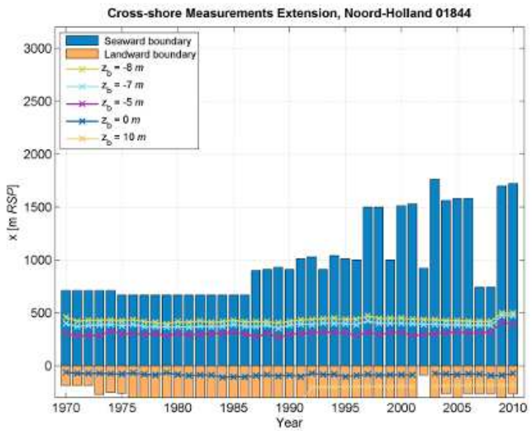

Nourishments type, Noord-Holland 01808
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

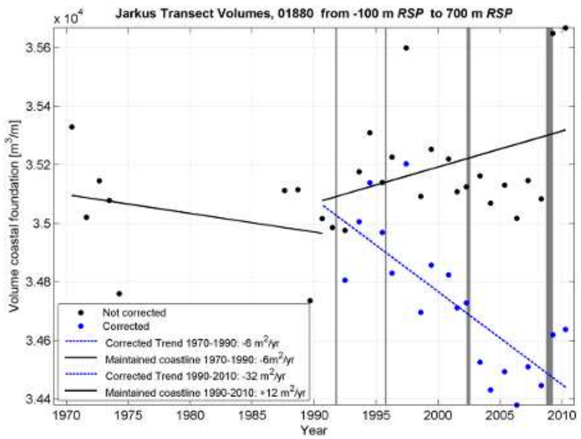

Nourishments type, Noord-Holland 01827
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

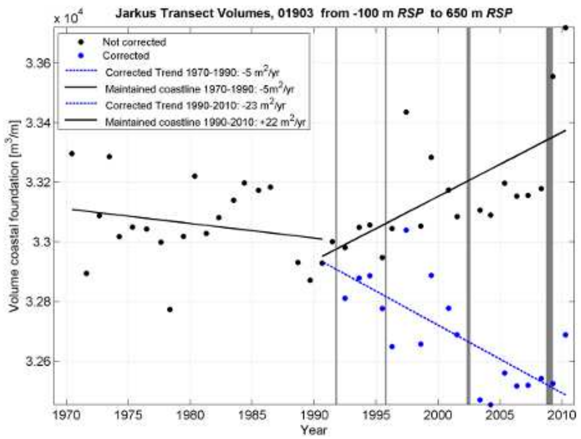

Nourishments type, Noord-Holland 01844
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

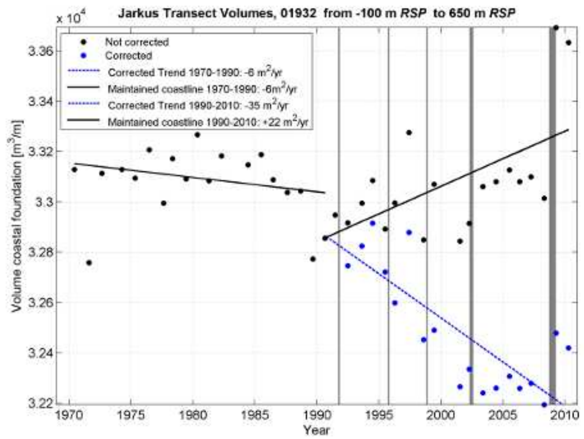

Cross-shore Measurements Extension, Noord-Holland 01808
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

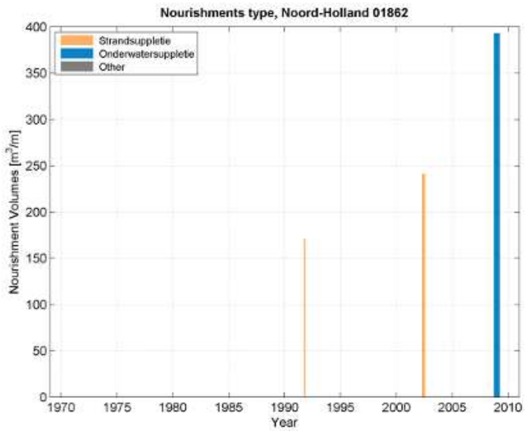

Cross-shore Measurements Extension, Noord-Holland 01827
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

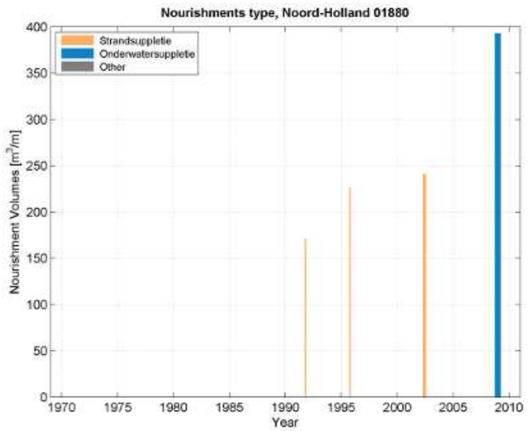

Cross-shore Measurements Extension, Noord-Holland 01844
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

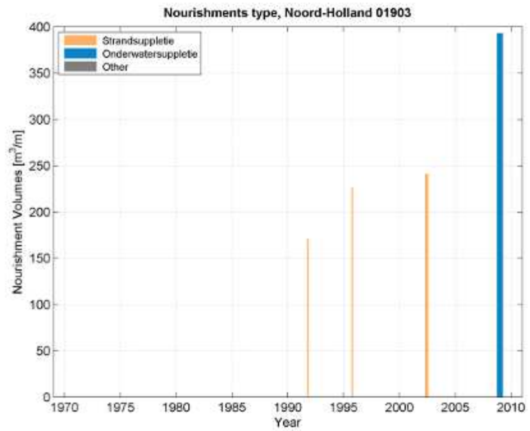

Jarkus Transect Volumes, 01880 from -100 m RSP to 700 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m2/yr
Maintained coastline 1970-1990: -6m2/yr
Corrected Trend 1990-2010: -32 m2/yr
Maintained coastline 1990-2010: +12 m2/yr

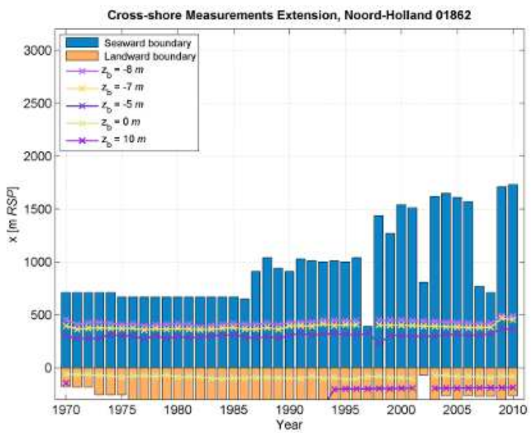

Jarkus Transect Volumes, 01903 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -5 m2/yr
Maintained coastline 1970-1990: -5m2/yr
Corrected Trend 1990-2010: -23 m2/yr
Maintained coastline 1990-2010: +22 m2/yr

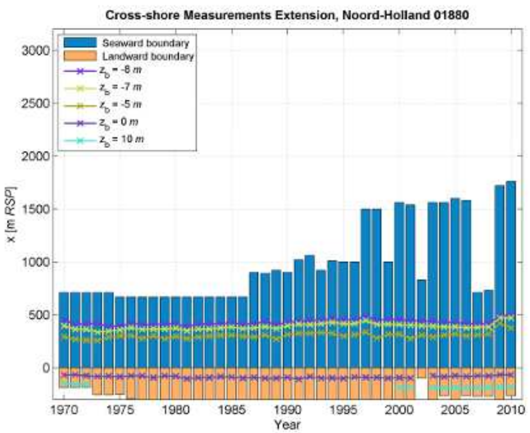

Jarkus Transect Volumes, 01932 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m2/yr
Maintained coastline 1970-1990: -6m2/yr
Corrected Trend 1990-2010: -35 m2/yr
Maintained coastline 1990-2010: +22 m2/yr

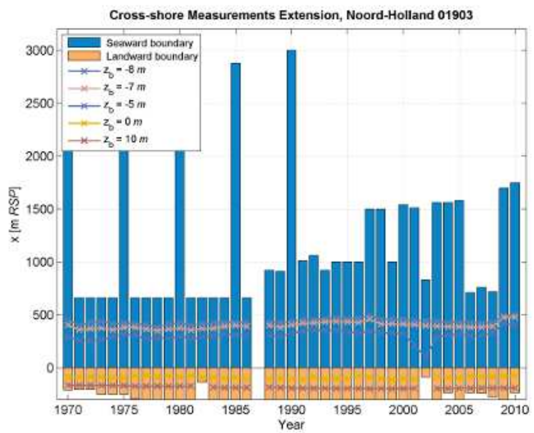

Nourishments type, Noord-Holland 01862
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

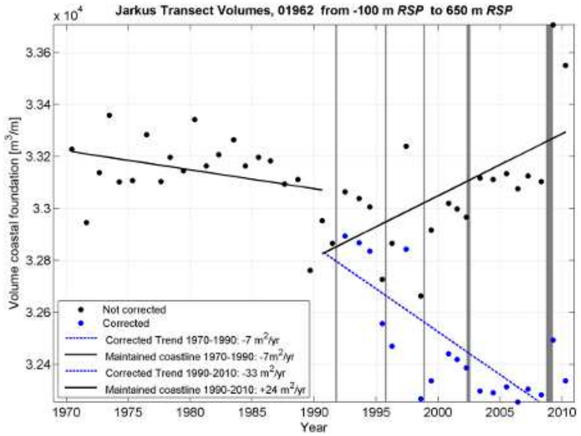

Nourishments type, Noord-Holland 01880
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other


Nourishments type, Noord-Holland 01903
Nourishment Volumes [m3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

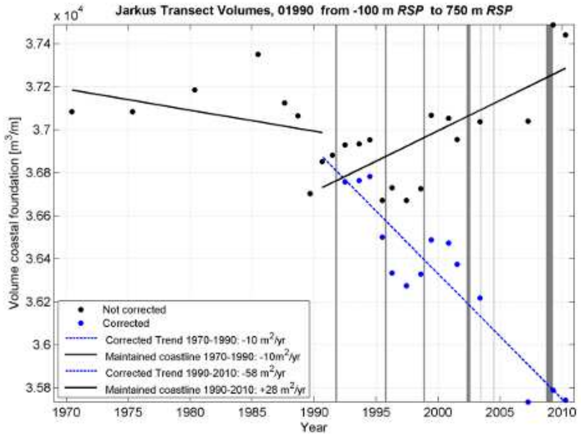

Cross-shore Measurements Extension, Noord-Holland 01862
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m


Cross-shore Measurements Extension, Noord-Holland 01880
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m

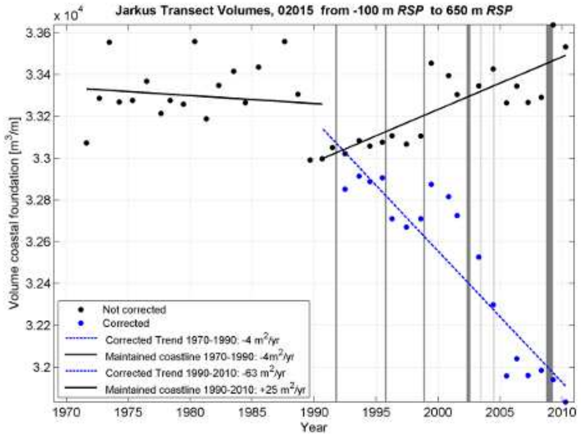

Cross-shore Measurements Extension, Noord-Holland 01903
x [m RSP]
Year
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m



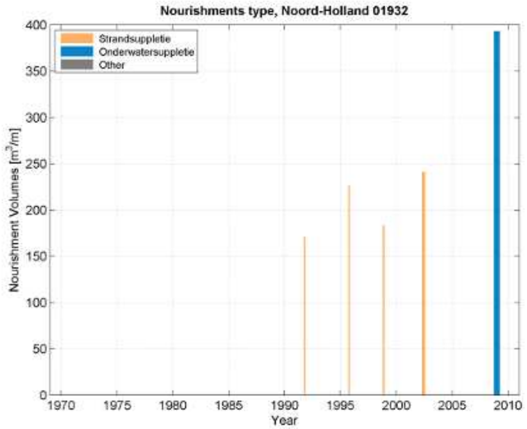
Jarkus Transect Volumes, 01962 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -7 m^2/yr
Maintained coastline 1970-1990: -7m^2/yr
Corrected Trend 1990-2010: -33 m^2/yr
Maintained coastline 1990-2010: +24 m^2/yr



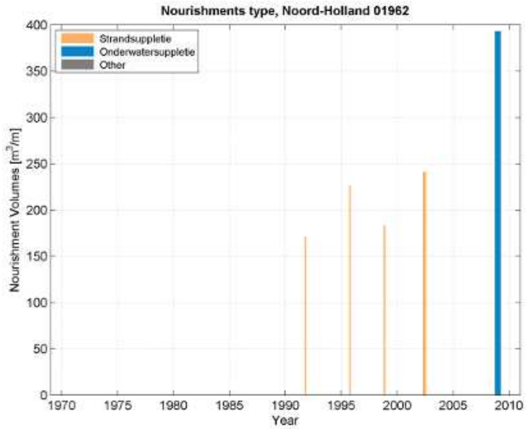
Jarkus Transect Volumes, 01990 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -10 m^2/yr
Maintained coastline 1970-1990: -10m^2/yr
Corrected Trend 1990-2010: -58 m^2/yr
Maintained coastline 1990-2010: +28 m^2/yr



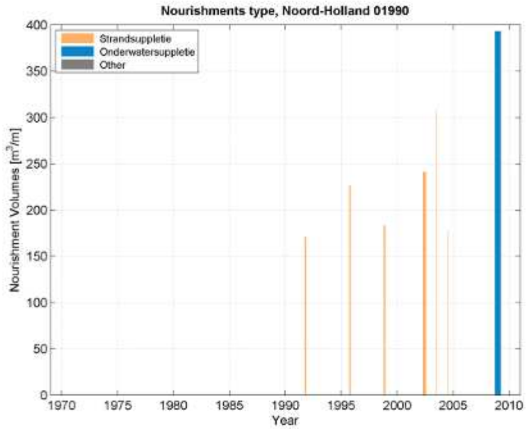
Jarkus Transect Volumes, 02015 from -100 m RSP to 650 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: -4m^2/yr
Corrected Trend 1990-2010: -63 m^2/yr
Maintained coastline 1990-2010: +25 m^2/yr



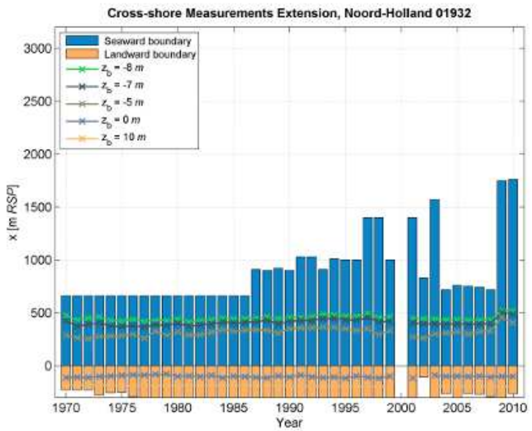
Nourishments type, Noord-Holland 01932
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other



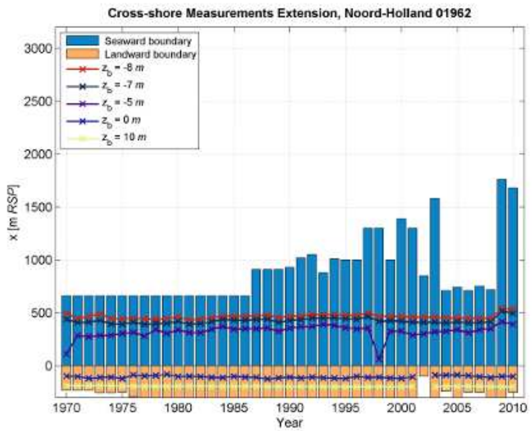
Nourishments type, Noord-Holland 01962
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other



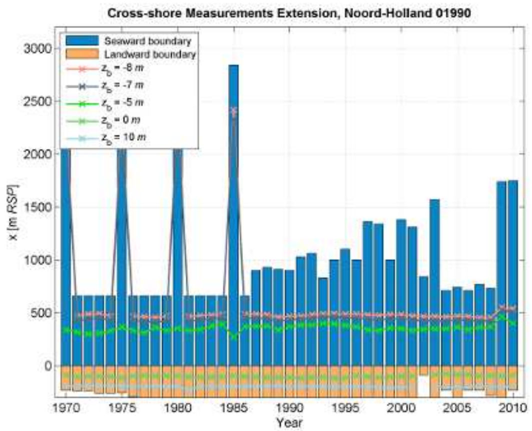
Nourishments type, Noord-Holland 01990
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other



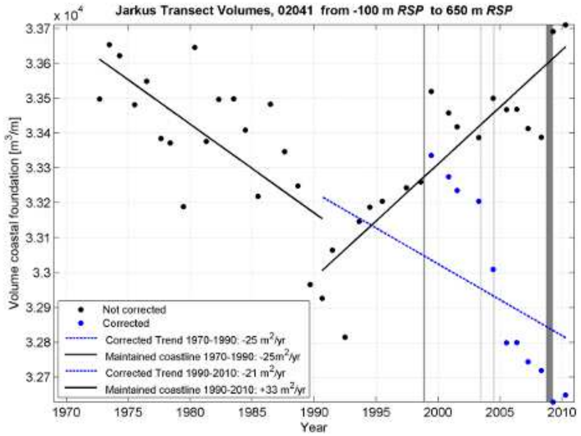
Cross-shore Measurements Extension, Noord-Holland 01932
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

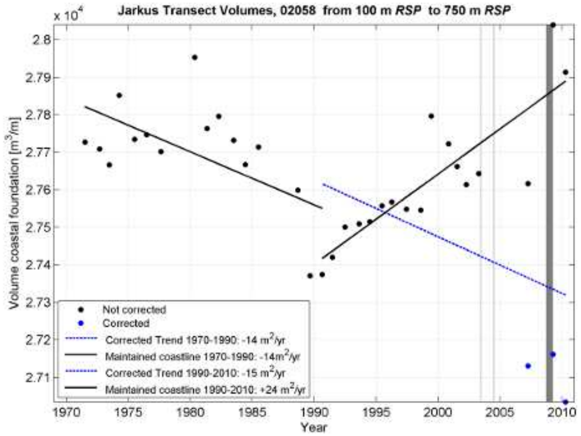


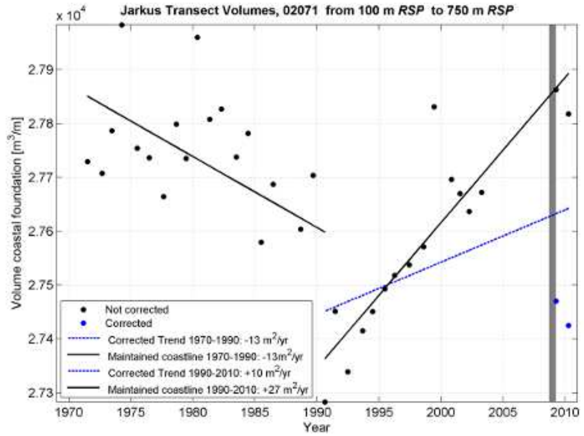
Cross-shore Measurements Extension, Noord-Holland 01962
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

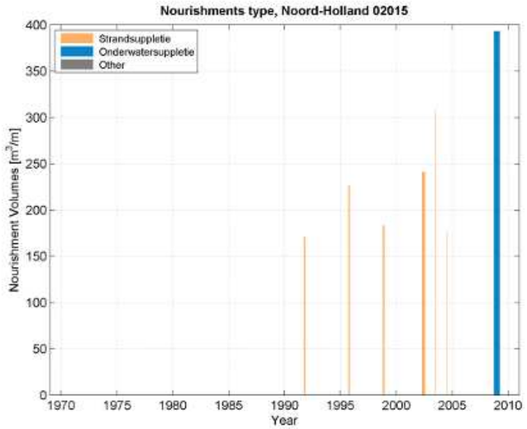


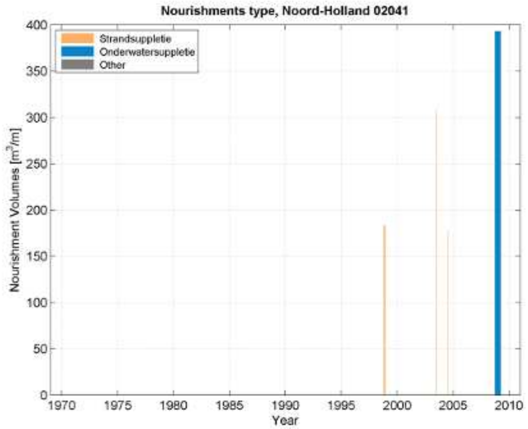
Cross-shore Measurements Extension, Noord-Holland 01990
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

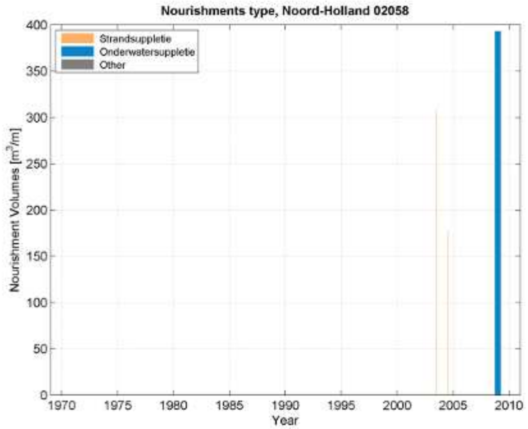

Jarkus Transect Volumes, 02041 from -100 m RSP to 650 m RSP
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -25 m^2/yr
Maintained coastline 1970-1990: -25m^2/yr
Corrected Trend 1990-2010: -21 m^2/yr
Maintained coastline 1990-2010: +33 m^2/yr

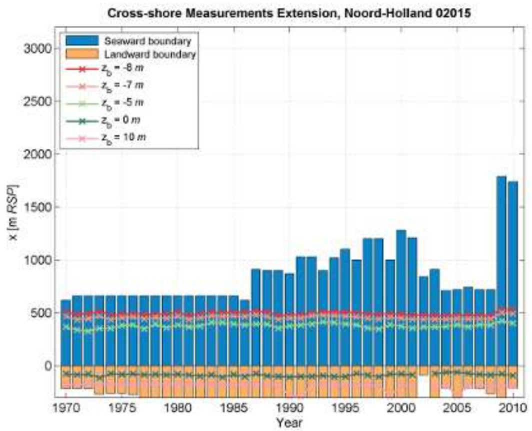

Jarkus Transect Volumes, 02058 from 100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -14 m^2/yr
Maintained coastline 1970-1990: -14m^2/yr
Corrected Trend 1990-2010: -15 m^2/yr
Maintained coastline 1990-2010: +24 m^2/yr

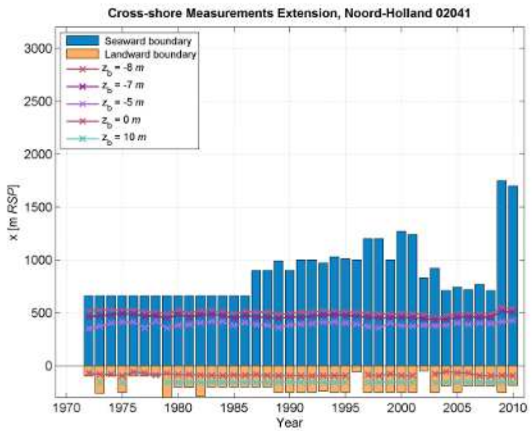

Jarkus Transect Volumes, 02071 from 100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -13 m^2/yr
Maintained coastline 1970-1990: -13m^2/yr
Corrected Trend 1990-2010: +10 m^2/yr
Maintained coastline 1990-2010: +27 m^2/yr

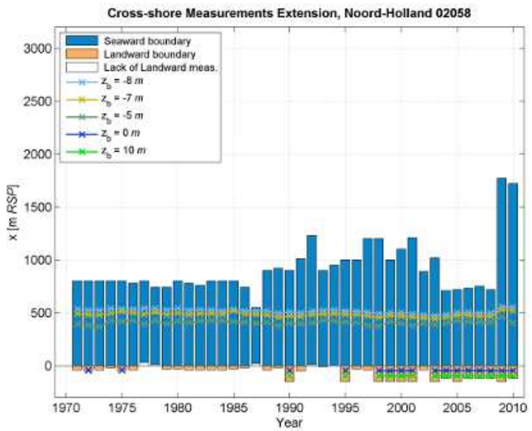

Nourishments type, Noord-Holland 02015
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

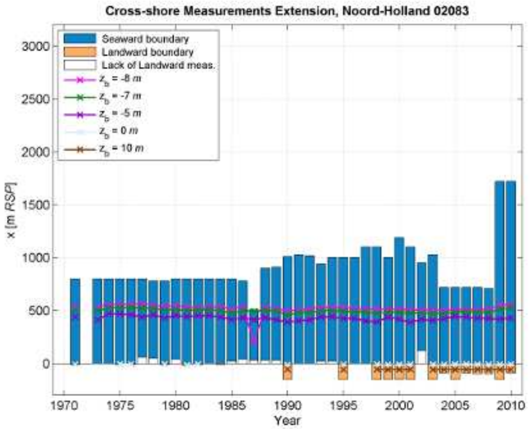
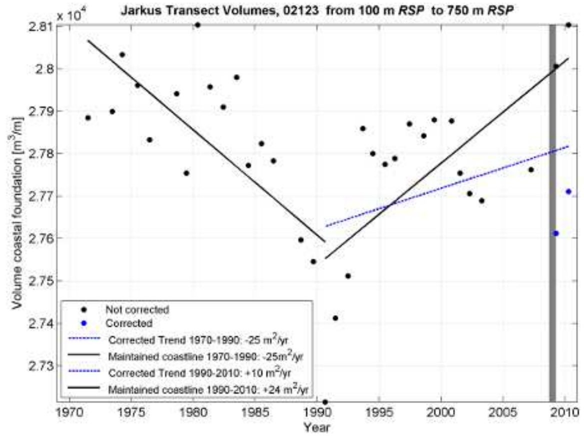
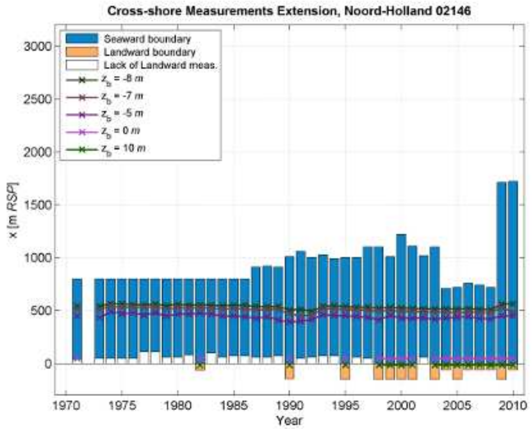
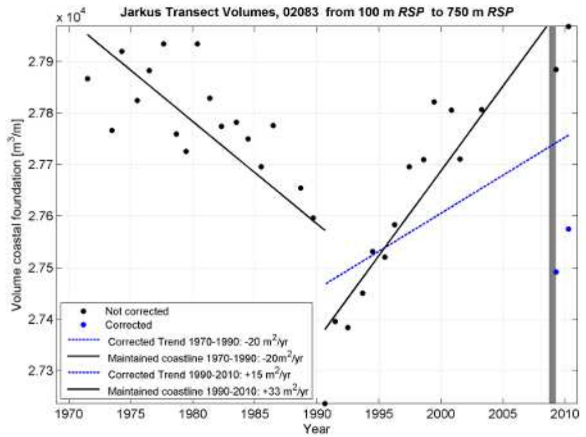
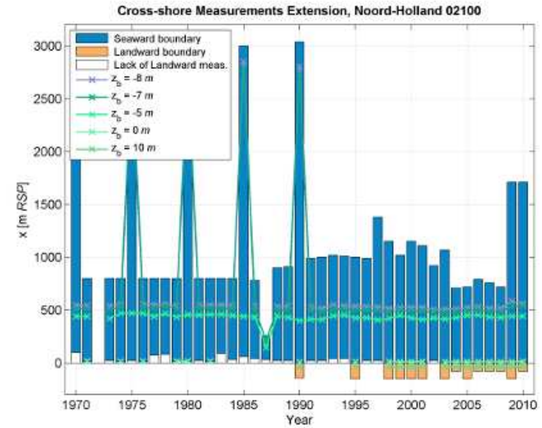
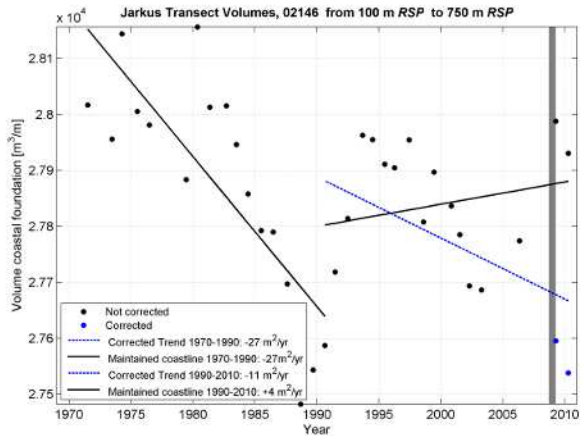
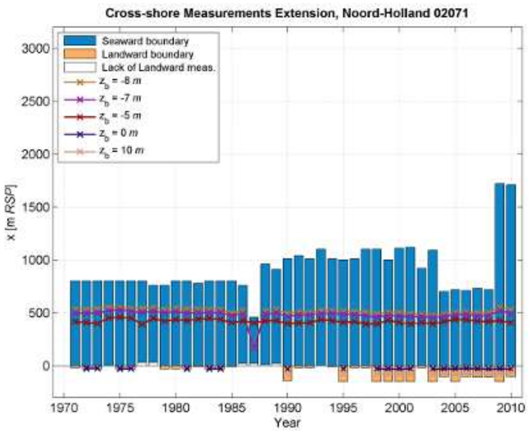
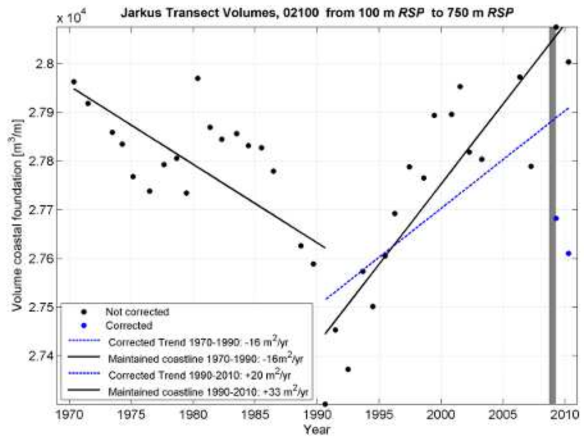
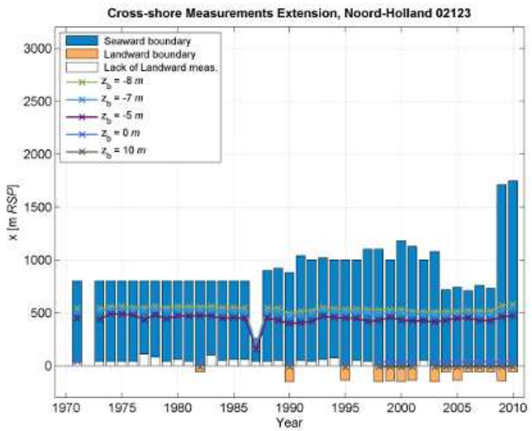

Nourishments type, Noord-Holland 02041
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

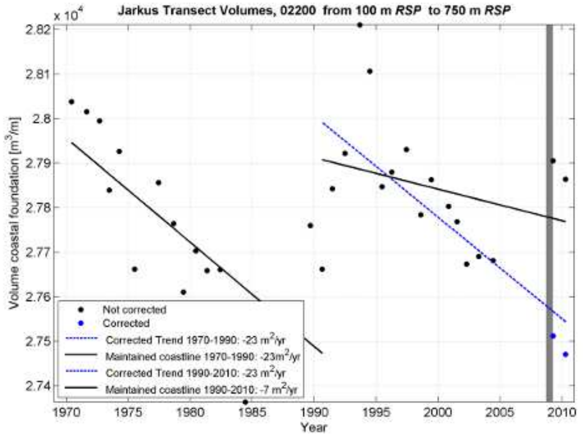

Nourishments type, Noord-Holland 02058
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

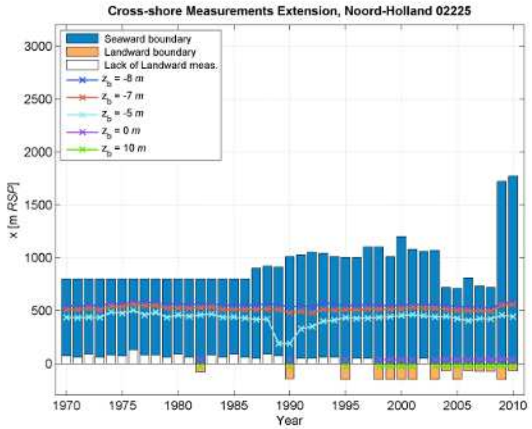

Cross-shore Measurements Extension, Noord-Holland 02015
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

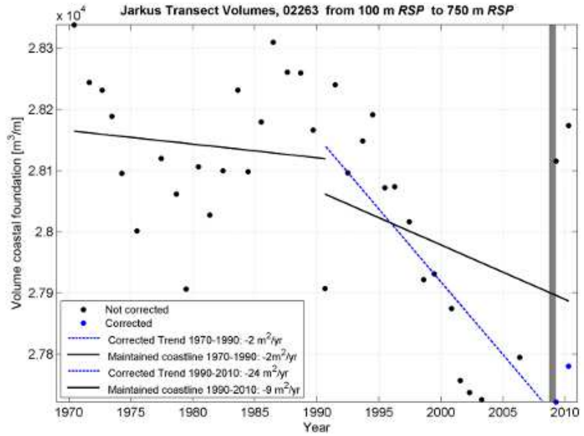

Cross-shore Measurements Extension, Noord-Holland 02041
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

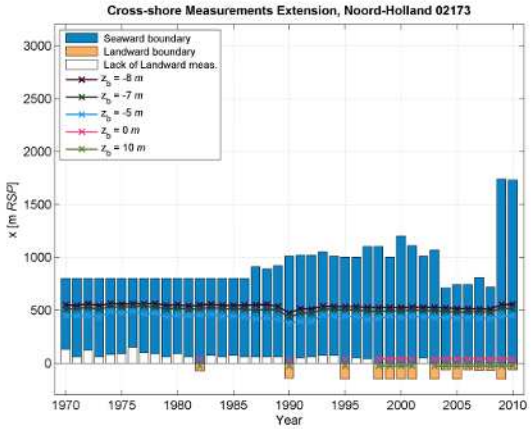

Cross-shore Measurements Extension, Noord-Holland 02058
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

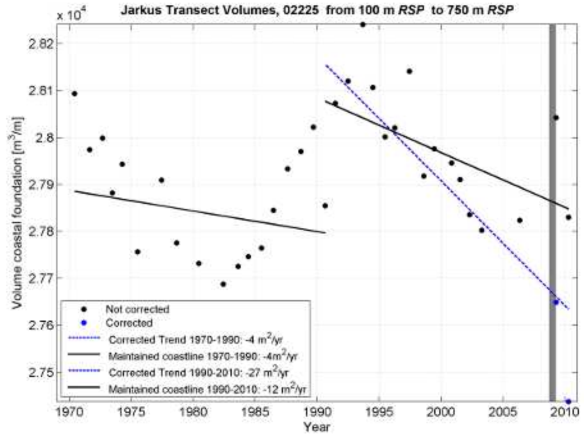

Cross-shore Measurements Extension, Noord-Holland 02083
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

Jarkus Transect Volumes, 02123 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -25 m2/yr
Maintained coastline 1970-1990: -25m2/yr
Corrected Trend 1990-2010: +10 m2/yr
Maintained coastline 1990-2010: +24 m2/yr
Year

Cross-shore Measurements Extension, Noord-Holland 02146
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

Jarkus Transect Volumes, 02083 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -20 m2/yr
Maintained coastline 1970-1990: -20m2/yr
Corrected Trend 1990-2010: +15 m2/yr
Maintained coastline 1990-2010: +33 m2/yr
Year

Cross-shore Measurements Extension, Noord-Holland 02100
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

Jarkus Transect Volumes, 02146 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -27 m2/yr
Maintained coastline 1970-1990: -27m2/yr
Corrected Trend 1990-2010: -11 m2/yr
Maintained coastline 1990-2010: +4 m2/yr
Year

Cross-shore Measurements Extension, Noord-Holland 02071
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

Jarkus Transect Volumes, 02100 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -16 m2/yr
Maintained coastline 1970-1990: -16m2/yr
Corrected Trend 1990-2010: +20 m2/yr
Maintained coastline 1990-2010: +33 m2/yr
Year

Cross-shore Measurements Extension, Noord-Holland 02123
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

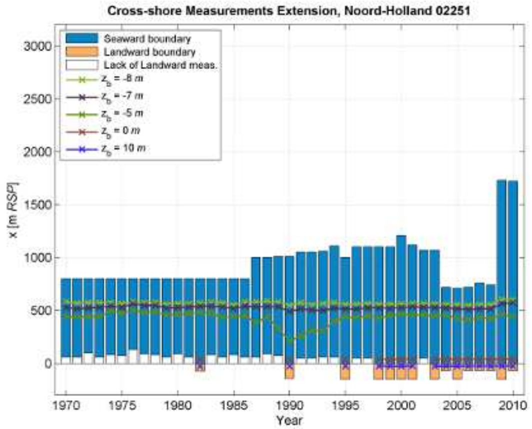

Jarkus Transect Volumes, 02200 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -23 m^2/yr
Maintained coastline 1970-1990: -23m^2/yr
Corrected Trend 1990-2010: -23 m^2/yr
Maintained coastline 1990-2010: -7 m^2/yr

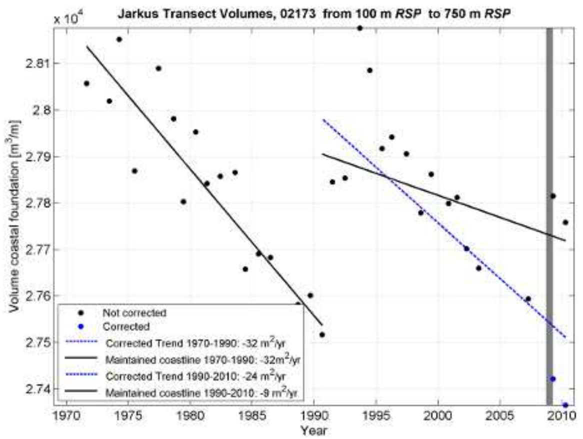

Cross-shore Measurements Extension, Noord-Holland 02225
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

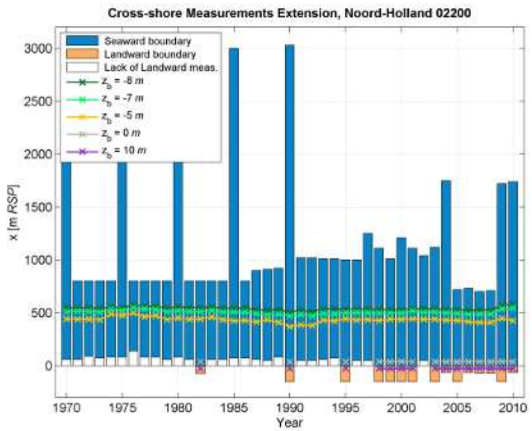

Jarkus Transect Volumes, 02263 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -2 m^2/yr
Maintained coastline 1970-1990: -2m^2/yr
Corrected Trend 1990-2010: -24 m^2/yr
Maintained coastline 1990-2010: -9 m^2/yr

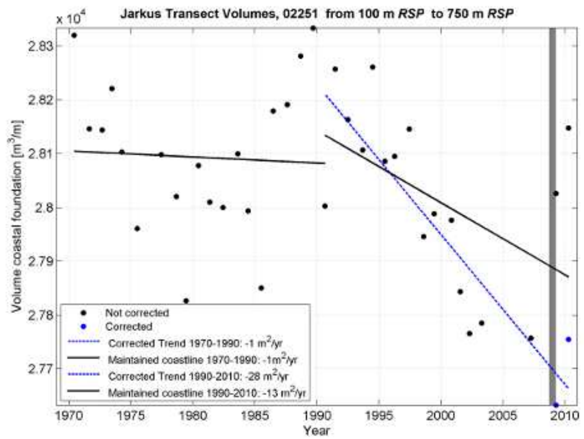

Cross-shore Measurements Extension, Noord-Holland 02173
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

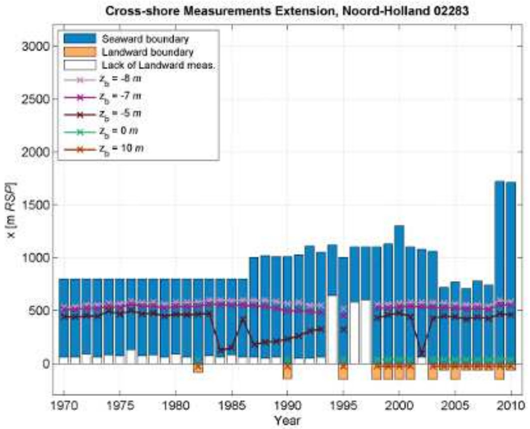

Jarkus Transect Volumes, 02225 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m^2/yr
Maintained coastline 1970-1990: -4m^2/yr
Corrected Trend 1990-2010: -27 m^2/yr
Maintained coastline 1990-2010: -12 m^2/yr

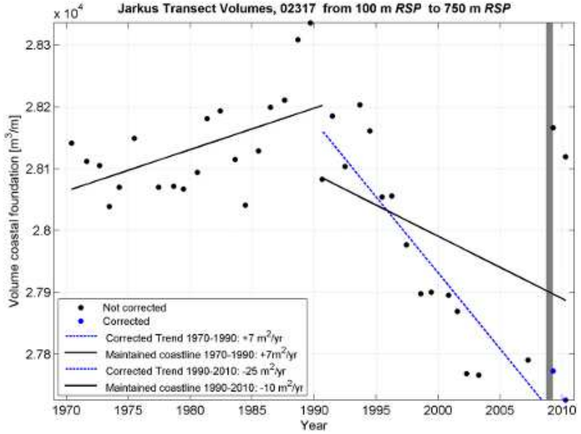

Cross-shore Measurements Extension, Noord-Holland 02251
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

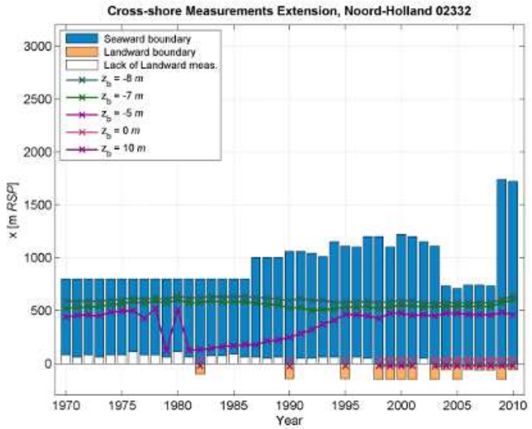

Jarkus Transect Volumes, 02173 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -32 m^2/yr
Maintained coastline 1970-1990: -32m^2/yr
Corrected Trend 1990-2010: -24 m^2/yr
Maintained coastline 1990-2010: -9 m^2/yr

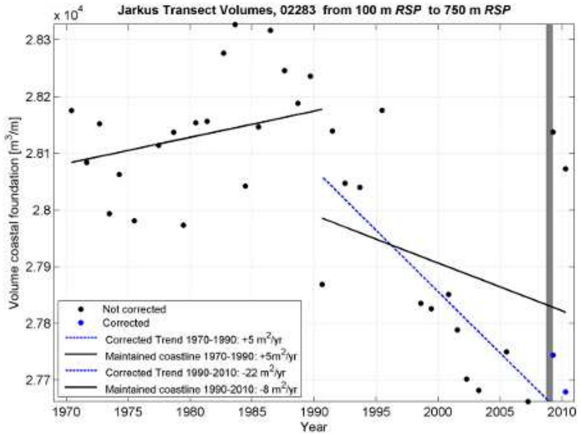

Cross-shore Measurements Extension, Noord-Holland 02200
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

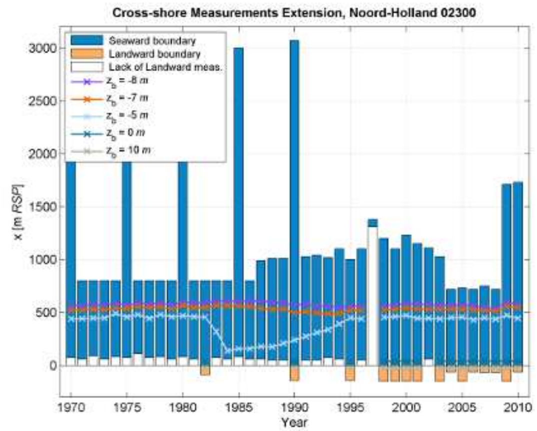

Jarkus Transect Volumes, 02251 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -1 m^2/yr
Maintained coastline 1970-1990: -1m^2/yr
Corrected Trend 1990-2010: -28 m^2/yr
Maintained coastline 1990-2010: -13 m^2/yr

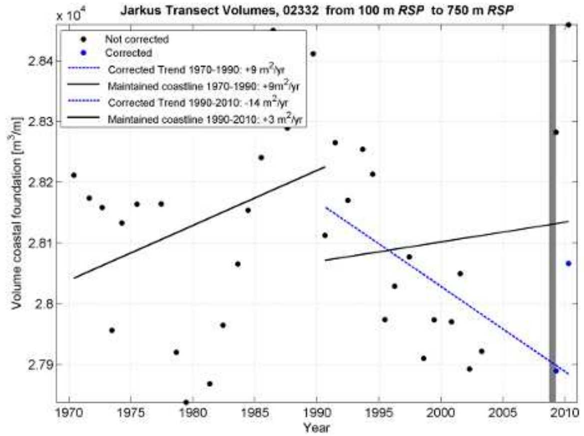

Cross-shore Measurements Extension, Noord-Holland 02283
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

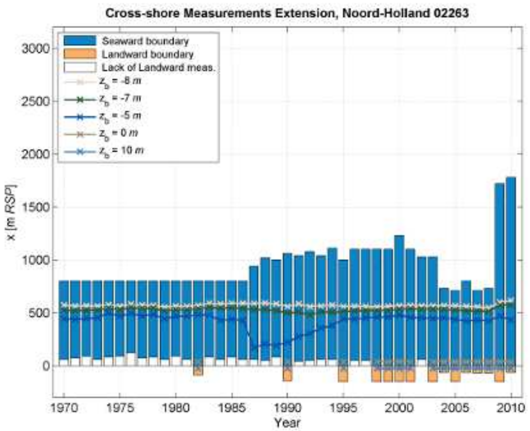

Jarkus Transect Volumes, 02317 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +7 m^2/yr
Maintained coastline 1970-1990: +7m^2/yr
Corrected Trend 1990-2010: -25 m^2/yr
Maintained coastline 1990-2010: -10 m^2/yr
Year

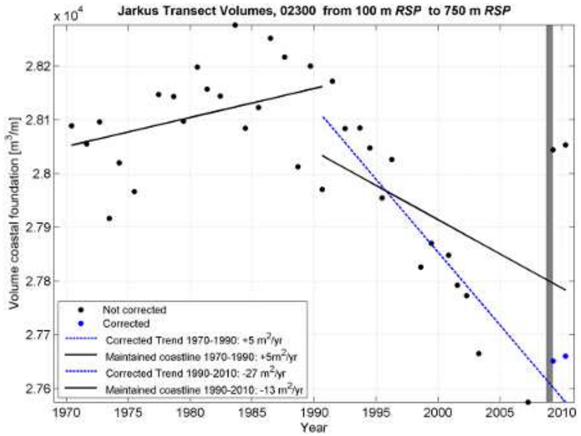

Cross-shore Measurements Extension, Noord-Holland 02332
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

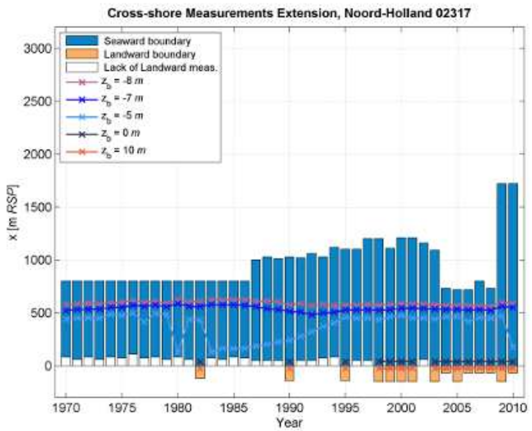

Jarkus Transect Volumes, 02283 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +5 m^2/yr
Maintained coastline 1970-1990: +5m^2/yr
Corrected Trend 1990-2010: -22 m^2/yr
Maintained coastline 1990-2010: -8 m^2/yr
Year

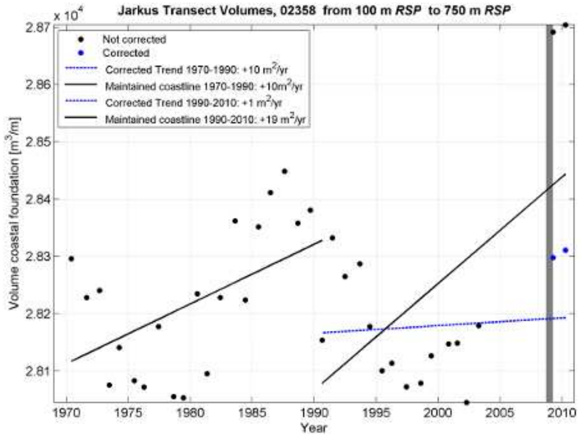

Cross-shore Measurements Extension, Noord-Holland 02300
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

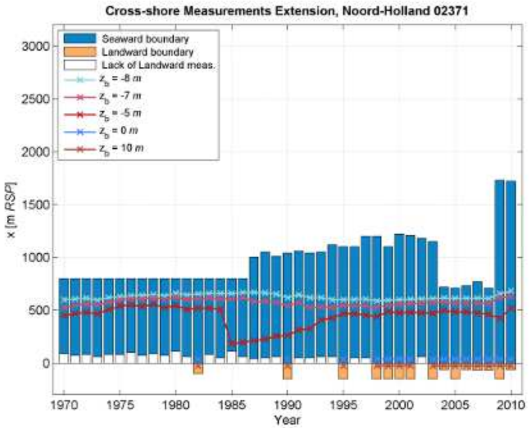

Jarkus Transect Volumes, 02332 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +9 m^2/yr
Maintained coastline 1970-1990: +9m^2/yr
Corrected Trend 1990-2010: -14 m^2/yr
Maintained coastline 1990-2010: +3 m^2/yr
Year

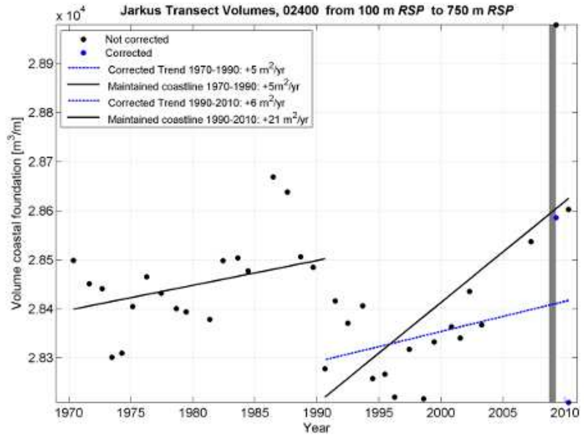

Cross-shore Measurements Extension, Noord-Holland 02263
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

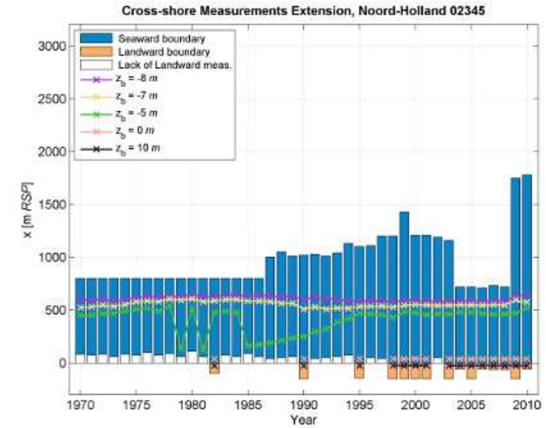

Jarkus Transect Volumes, 02300 from 100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +5 m^2/yr
Maintained coastline 1970-1990: +5m^2/yr
Corrected Trend 1990-2010: -27 m^2/yr
Maintained coastline 1990-2010: -13 m^2/yr
Year

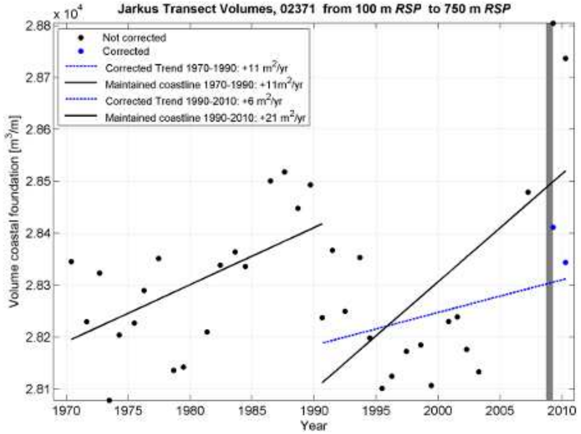

Cross-shore Measurements Extension, Noord-Holland 02317
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

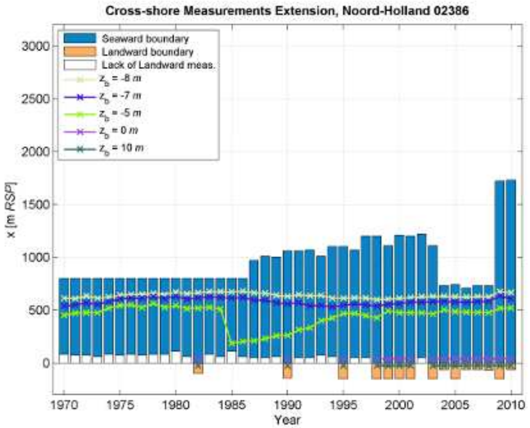

Jarkus Transect Volumes, 02358 from 100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +10 m²/yr
Maintained coastline 1970-1990: +10m²/yr
Corrected Trend 1990-2010: +1 m²/yr
Maintained coastline 1990-2010: +19 m²/yr
Volume coastal foundation [m³/m]
Year

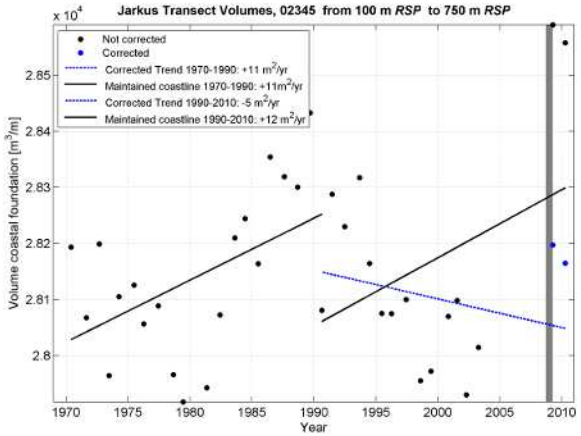

Cross-shore Measurements Extension, Noord-Holland 02371
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

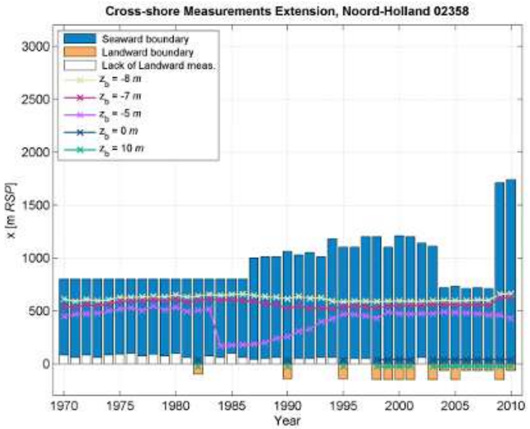

Jarkus Transect Volumes, 02400 from 100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +5 m²/yr
Maintained coastline 1970-1990: +5m²/yr
Corrected Trend 1990-2010: +6 m²/yr
Maintained coastline 1990-2010: +21 m²/yr
Volume coastal foundation [m³/m]
Year

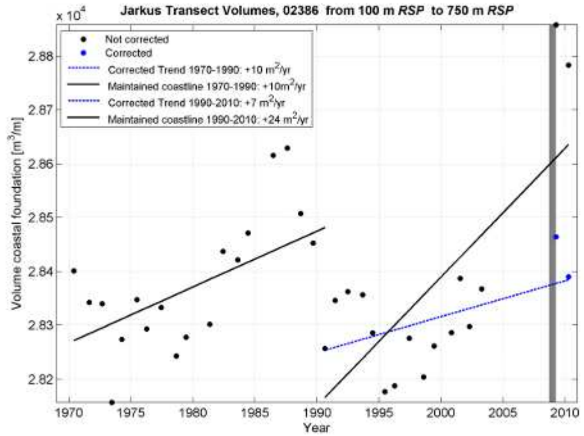

Cross-shore Measurements Extension, Noord-Holland 02345
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

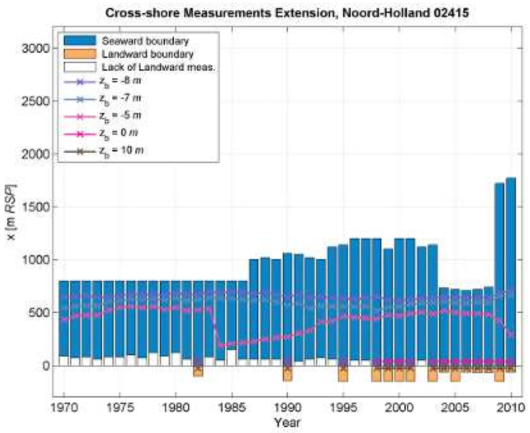

Jarkus Transect Volumes, 02371 from 100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +11 m²/yr
Maintained coastline 1970-1990: +11m²/yr
Corrected Trend 1990-2010: +6 m²/yr
Maintained coastline 1990-2010: +21 m²/yr
Volume coastal foundation [m³/m]
Year

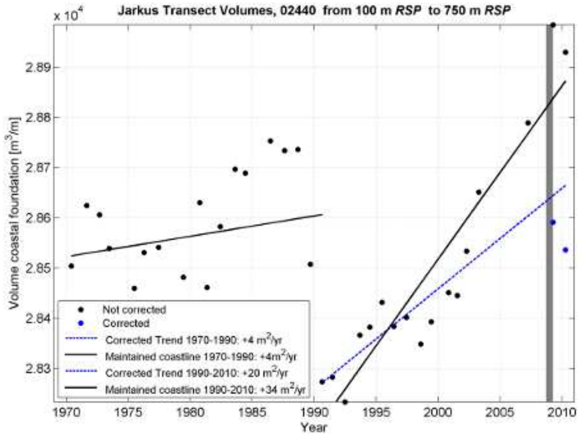

Cross-shore Measurements Extension, Noord-Holland 02386
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

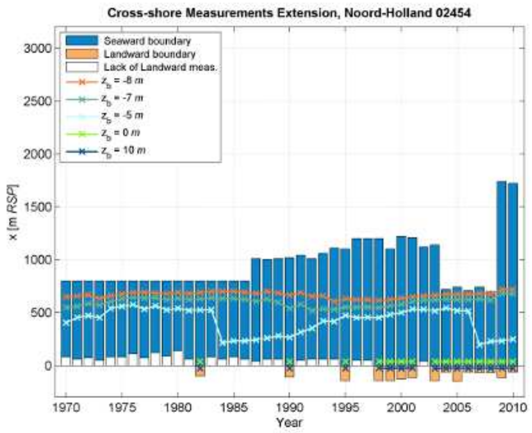

Jarkus Transect Volumes, 02345 from 100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +11 m²/yr
Maintained coastline 1970-1990: +11m²/yr
Corrected Trend 1990-2010: -5 m²/yr
Maintained coastline 1990-2010: +12 m²/yr
Volume coastal foundation [m³/m]
Year

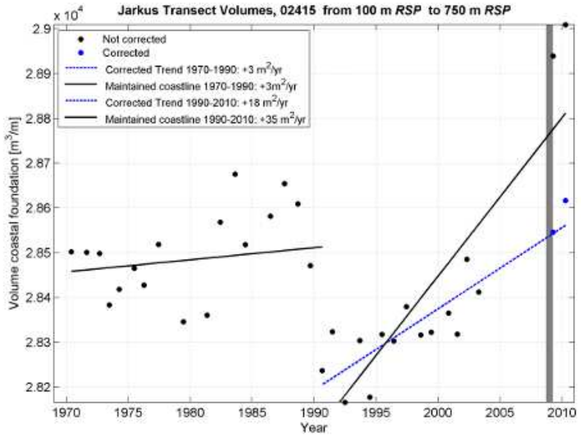

Cross-shore Measurements Extension, Noord-Holland 02358
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

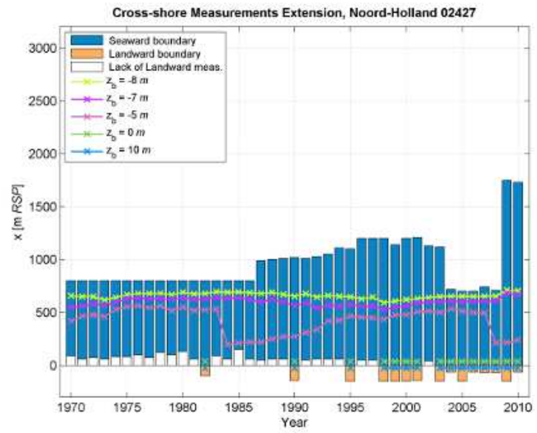

Jarkus Transect Volumes, 02386 from 100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +10 m²/yr
Maintained coastline 1970-1990: +10m²/yr
Corrected Trend 1990-2010: +7 m²/yr
Maintained coastline 1990-2010: +24 m²/yr
Volume coastal foundation [m³/m]
Year

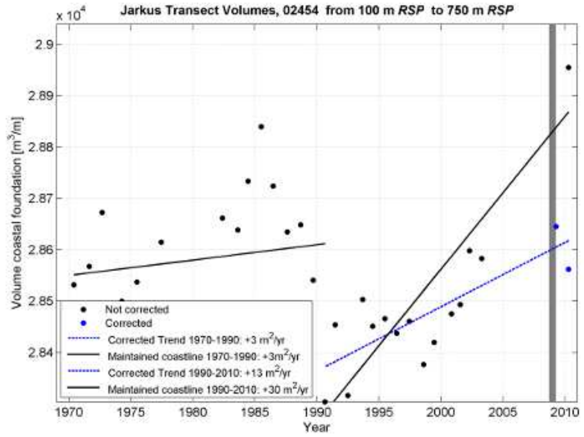

Cross-shore Measurements Extension, Noord-Holland 02415
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

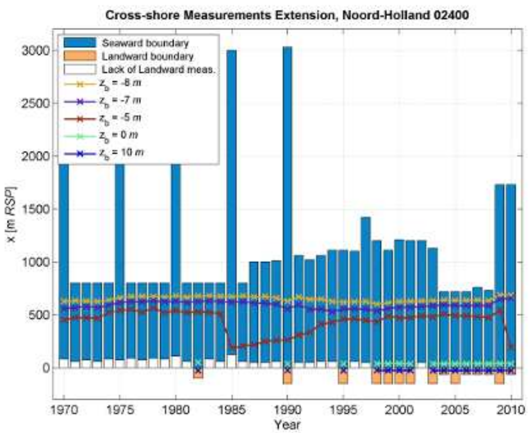

Jarkus Transect Volumes, 02440 from 100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +4 m^2/yr
Maintained coastline 1970-1990: +4m^2/yr
Corrected Trend 1990-2010: +20 m^2/yr
Maintained coastline 1990-2010: +34 m^2/yr
Volume coastal foundation [m^3/m]
Year

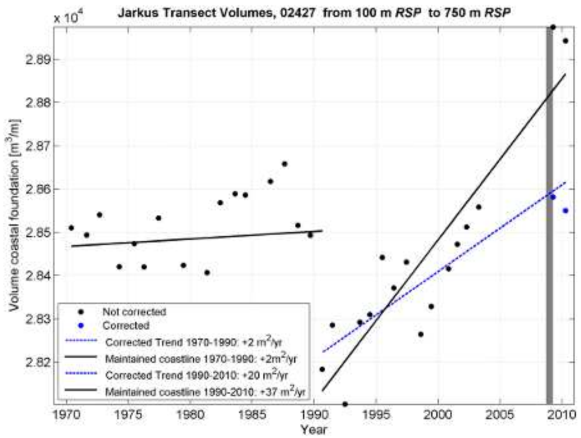

Cross-shore Measurements Extension, Noord-Holland 02454
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

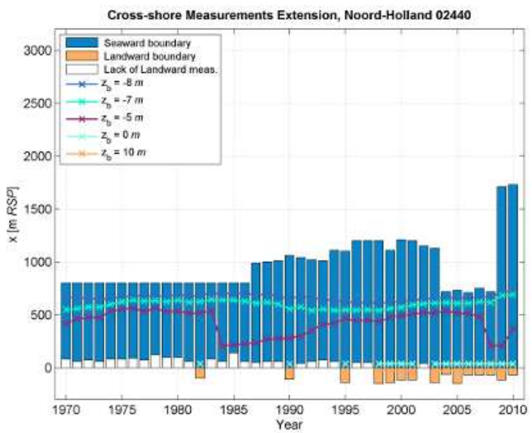

Jarkus Transect Volumes, 02415 from 100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +3 m^2/yr
Maintained coastline 1970-1990: +3m^2/yr
Corrected Trend 1990-2010: +18 m^2/yr
Maintained coastline 1990-2010: +35 m^2/yr
Volume coastal foundation [m^3/m]
Year

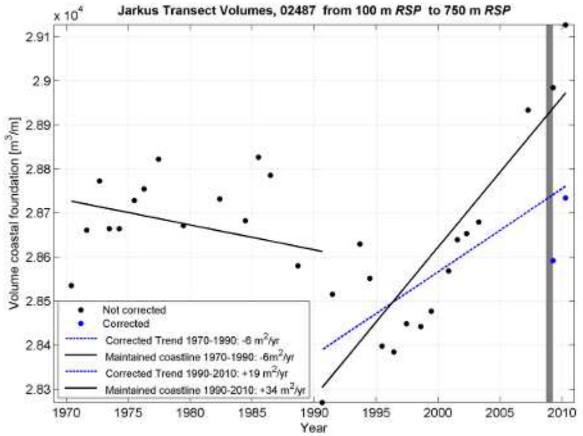

Cross-shore Measurements Extension, Noord-Holland 02427
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

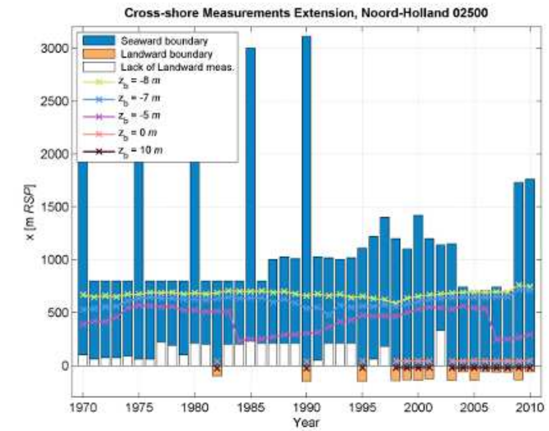

Jarkus Transect Volumes, 02454 from 100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +3 m^2/yr
Maintained coastline 1970-1990: +3m^2/yr
Corrected Trend 1990-2010: +13 m^2/yr
Maintained coastline 1990-2010: +30 m^2/yr
Volume coastal foundation [m^3/m]
Year

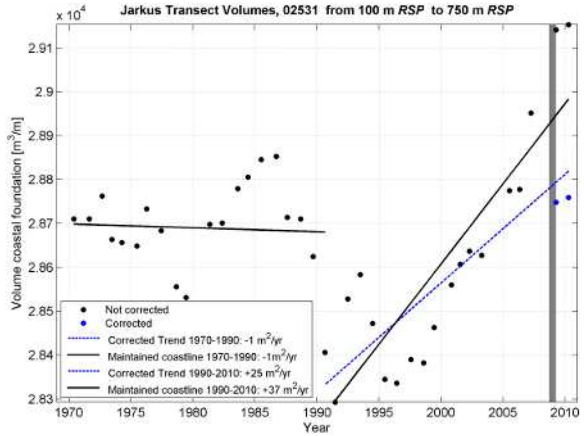

Cross-shore Measurements Extension, Noord-Holland 02400
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

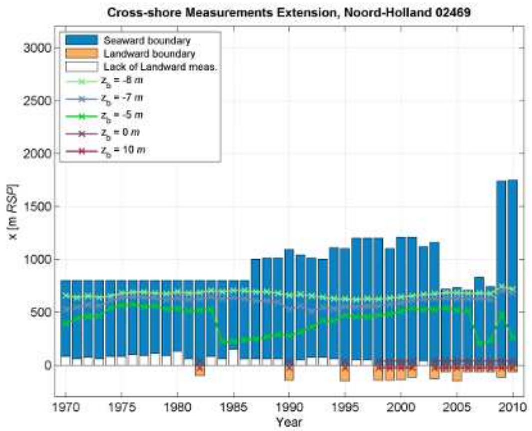

Jarkus Transect Volumes, 02427 from 100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +2 m^2/yr
Maintained coastline 1970-1990: +2m^2/yr
Corrected Trend 1990-2010: +20 m^2/yr
Maintained coastline 1990-2010: +37 m^2/yr
Volume coastal foundation [m^3/m]
Year

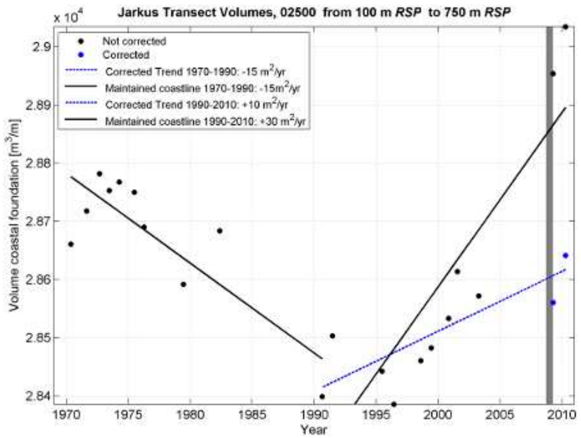

Cross-shore Measurements Extension, Noord-Holland 02440
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

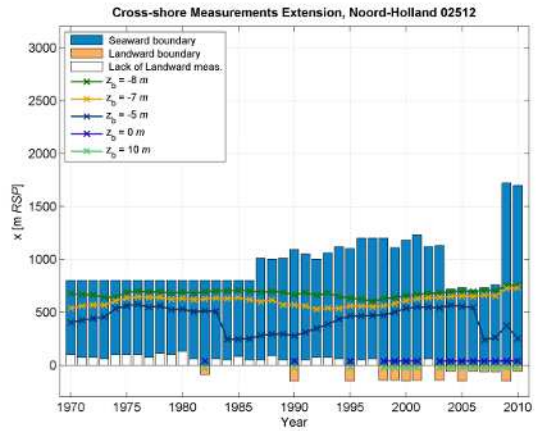

Jarkus Transect Volumes, 02487 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m2/yr
Maintained coastline 1970-1990: -6m2/yr
Corrected Trend 1990-2010: +19 m2/yr
Maintained coastline 1990-2010: +34 m2/yr

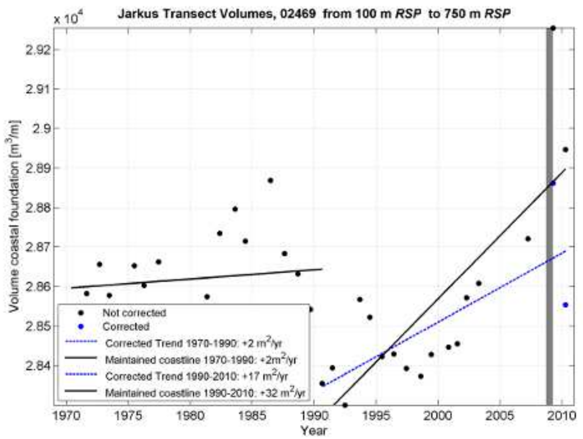

Cross-shore Measurements Extension, Noord-Holland 02500
Seaward boundary
Landward boundary
Lack of Landward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

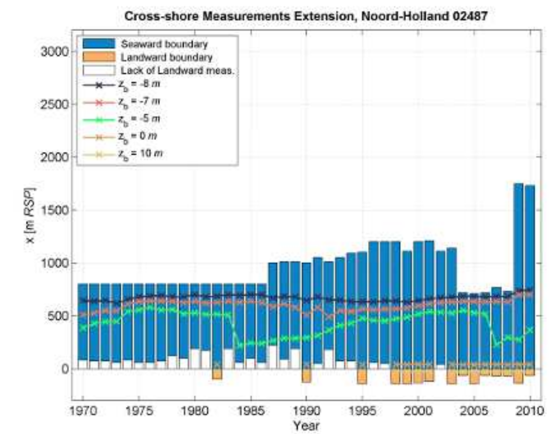

Jarkus Transect Volumes, 02531 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -1 m2/yr
Maintained coastline 1970-1990: -1m2/yr
Corrected Trend 1990-2010: +25 m2/yr
Maintained coastline 1990-2010: +37 m2/yr

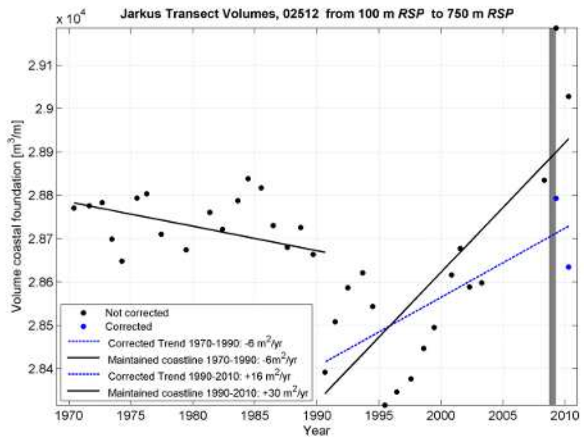

Cross-shore Measurements Extension, Noord-Holland 02469
Seaward boundary
Landward boundary
Lack of Landward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

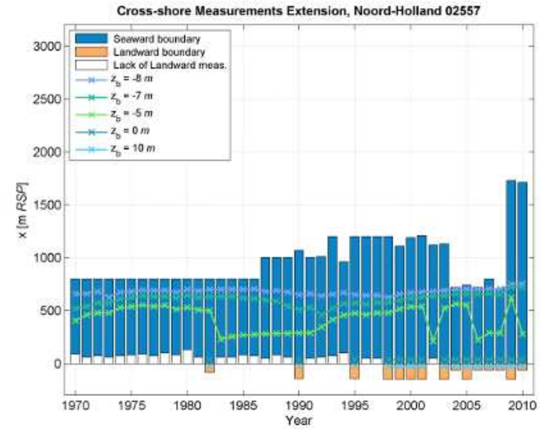

Jarkus Transect Volumes, 02500 from 100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -15 m2/yr
Maintained coastline 1970-1990: -15m2/yr
Corrected Trend 1990-2010: +10 m2/yr
Maintained coastline 1990-2010: +30 m2/yr
Volume coastal foundation [m3/m]
Year

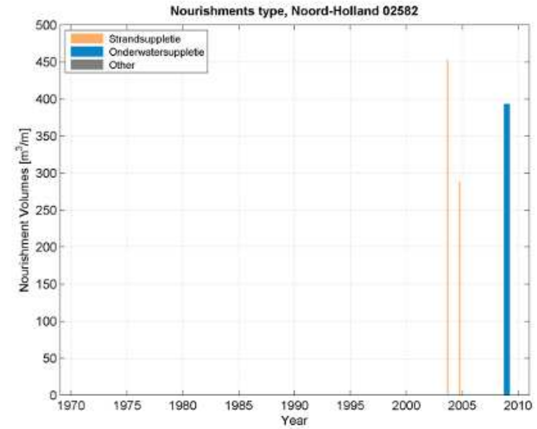

Cross-shore Measurements Extension, Noord-Holland 02512
Seaward boundary
Landward boundary
Lack of Landward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

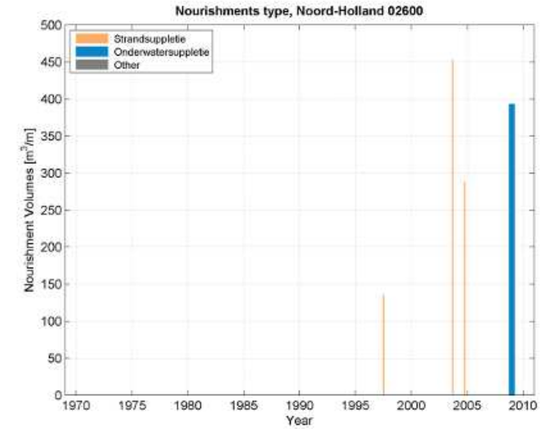

Jarkus Transect Volumes, 02469 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +2 m2/yr
Maintained coastline 1970-1990: +2m2/yr
Corrected Trend 1990-2010: +17 m2/yr
Maintained coastline 1990-2010: +32 m2/yr

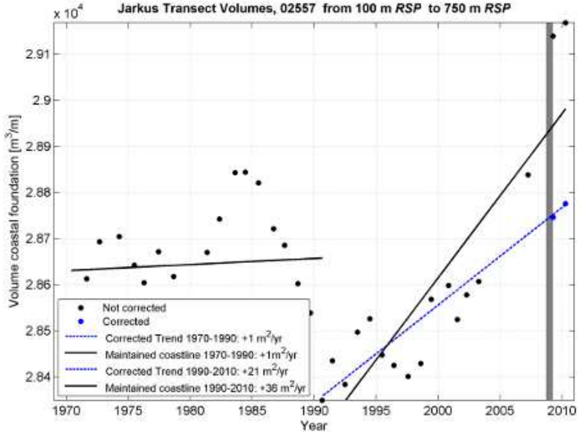

Cross-shore Measurements Extension, Noord-Holland 02487
Seaward boundary
Landward boundary
Lack of Landward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

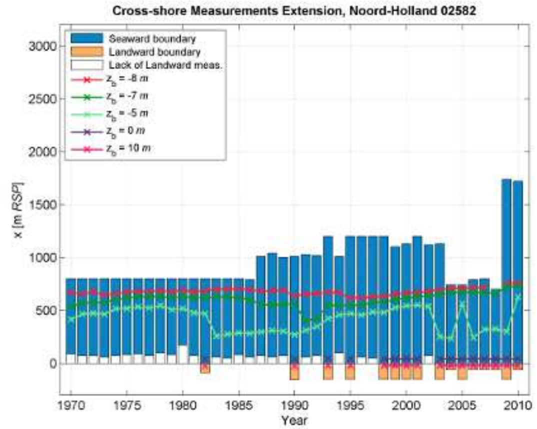

Jarkus Transect Volumes, 02512 from 100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m2/yr
Maintained coastline 1970-1990: -6m2/yr
Corrected Trend 1990-2010: +16 m2/yr
Maintained coastline 1990-2010: +30 m2/yr

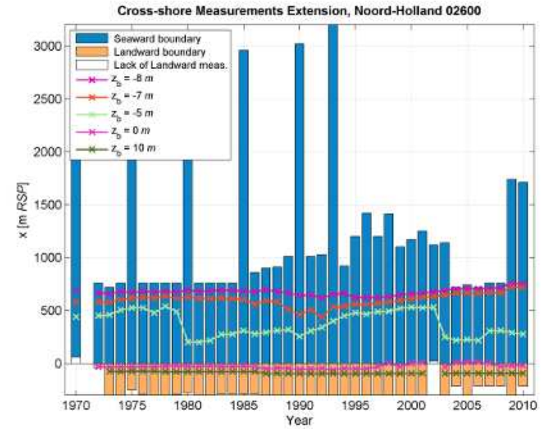

Cross-shore Measurements Extension, Noord-Holland 02557
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

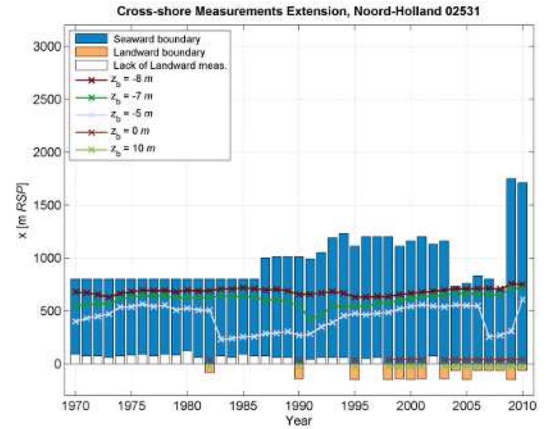

Nourishments type, Noord-Holland 02582
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

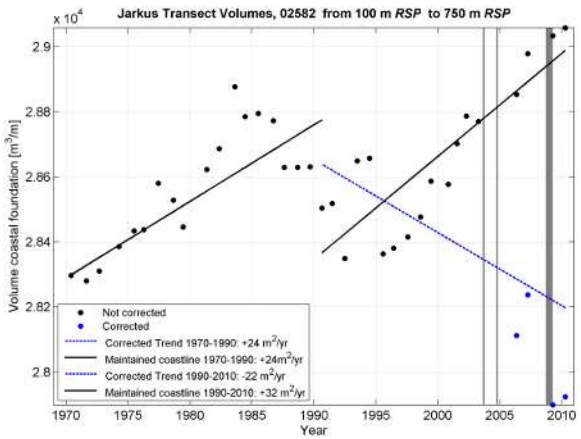

Nourishments type, Noord-Holland 02600
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

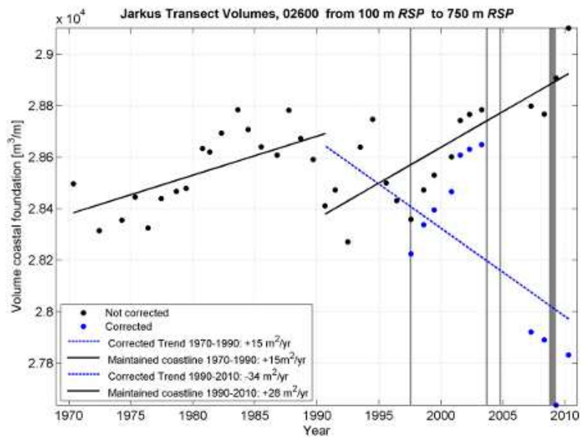

Jarkus Transect Volumes, 02557 from 100 m RSP to 750 m RSP
x 10⁴
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +1 m²/yr
Maintained coastline 1970-1990: +1m²/yr
Corrected Trend 1990-2010: +21 m²/yr
Maintained coastline 1990-2010: +36 m²/yr
Year

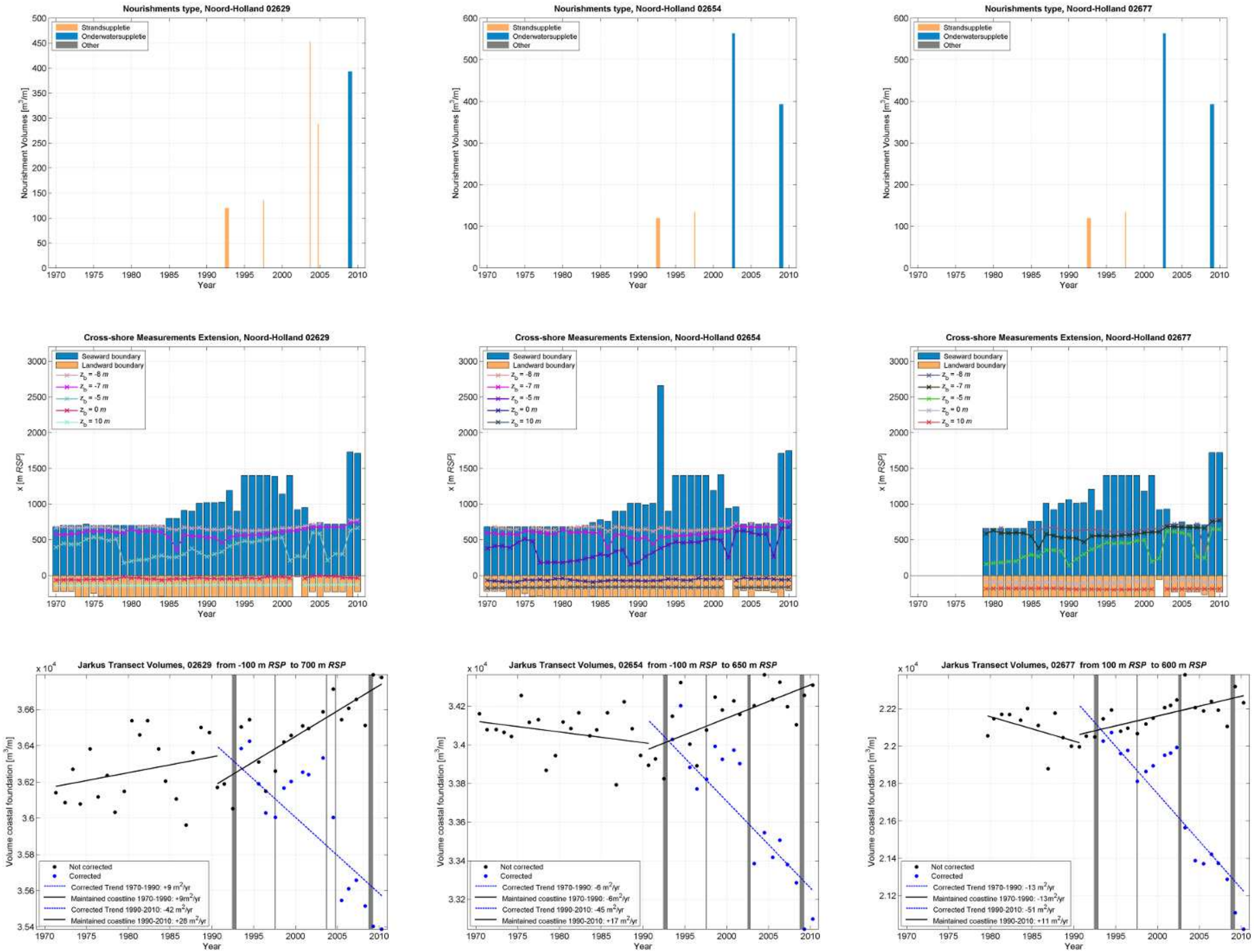

Cross-shore Measurements Extension, Noord-Holland 02582
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year


Cross-shore Measurements Extension, Noord-Holland 02600
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

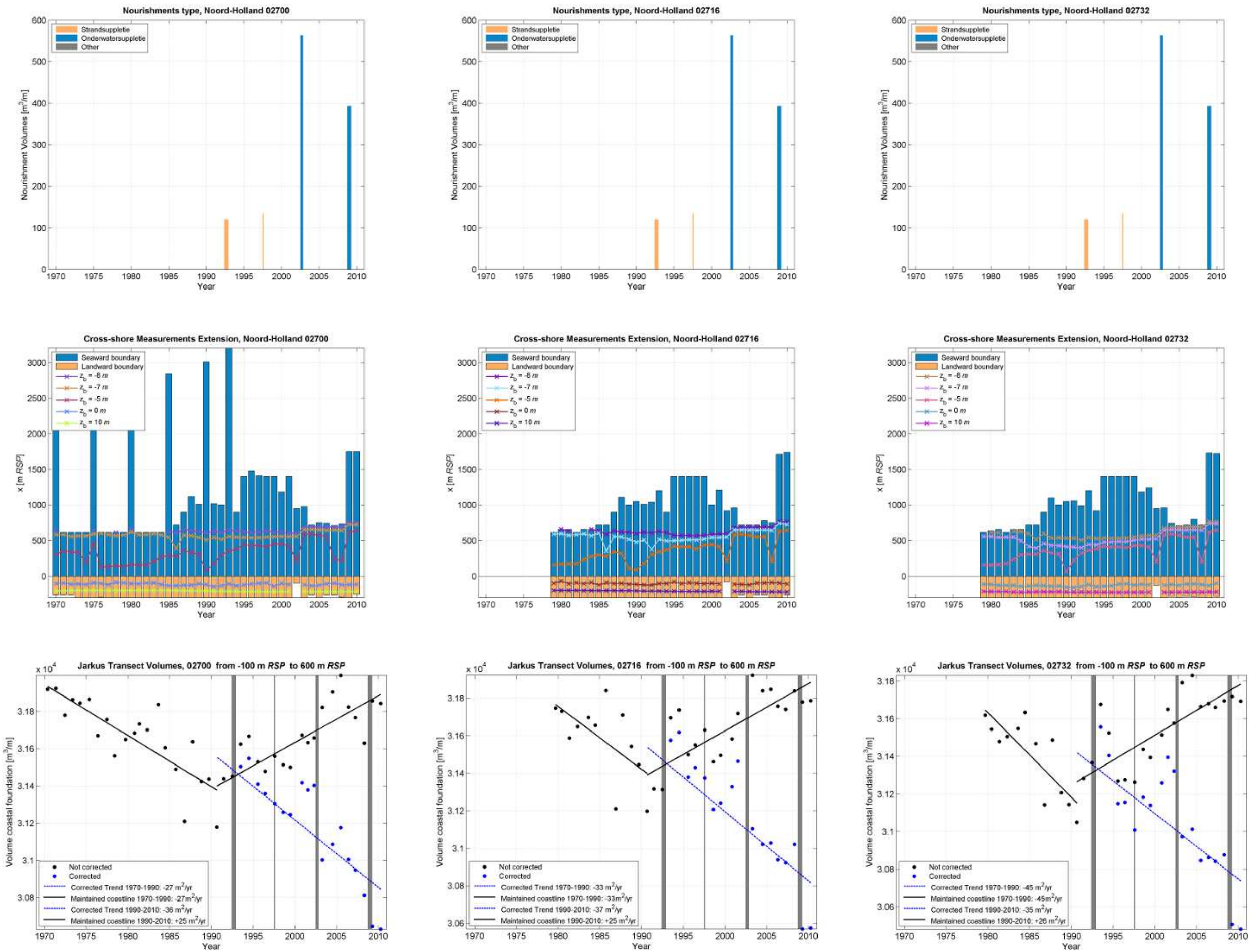

Cross-shore Measurements Extension, Noord-Holland 02531
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

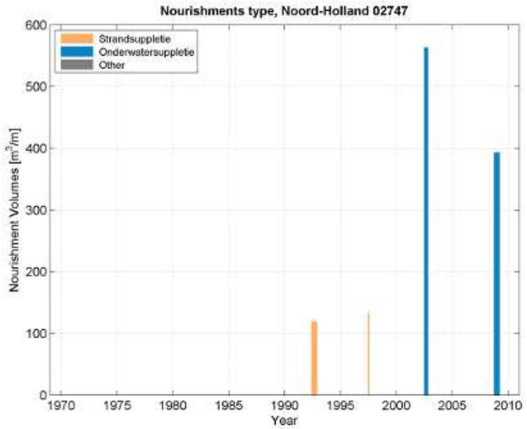

Jarkus Transect Volumes, 02582 from 100 m RSP to 750 m RSP
x 10⁴
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +24 m²/yr
Maintained coastline 1970-1990: +24m²/yr
Corrected Trend 1990-2010: -22 m²/yr
Maintained coastline 1990-2010: +32 m²/yr
Year

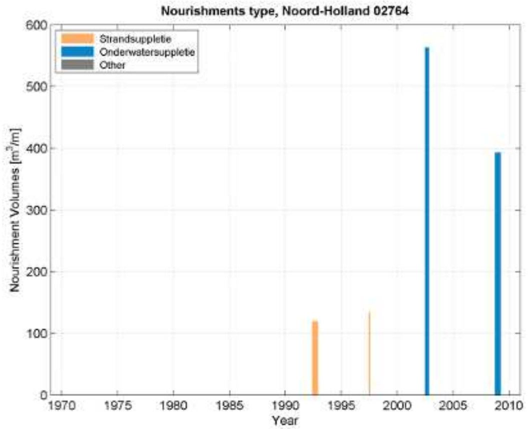

Jarkus Transect Volumes, 02600 from 100 m RSP to 750 m RSP
x 10⁴
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +15 m²/yr
Maintained coastline 1970-1990: +15m²/yr
Corrected Trend 1990-2010: -34 m²/yr
Maintained coastline 1990-2010: +28 m²/yr
Year

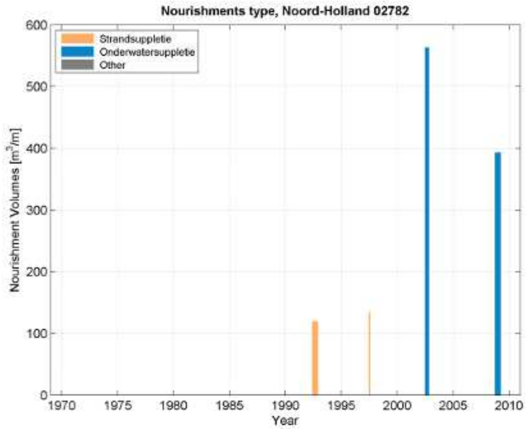


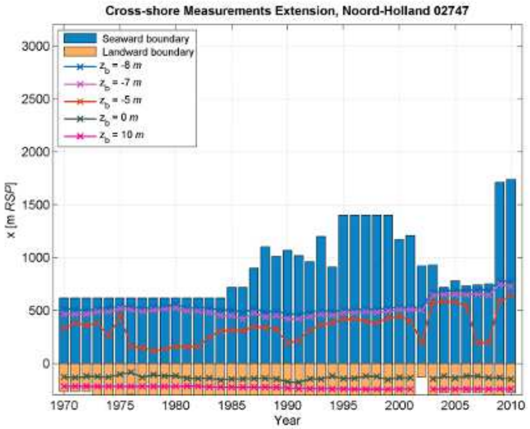
Nourishments type, Noord-Holland 02629
Nourishments type, Noord-Holland 02654
Nourishments type, Noord-Holland 02677
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 02629
Cross-shore Measurements Extension, Noord-Holland 02654
Cross-shore Measurements Extension, Noord-Holland 02677
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Jarkus Transect Volumes, 02629 from -100 m RSP to 700 m RSP
Jarkus Transect Volumes, 02654 from -100 m RSP to 650 m RSP
Jarkus Transect Volumes, 02677 from 100 m RSP to 600 m RSP
Volume coastal foundation [m^3/m]
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +9 m^2/yr
Maintained coastline 1970-1990: +9m^2/yr
Corrected Trend 1990-2010: -42 m^2/yr
Maintained coastline 1990-2010: +28 m^2/yr
Corrected Trend 1970-1990: -6 m^2/yr
Maintained coastline 1970-1990: -6m^2/yr
Corrected Trend 1990-2010: -45 m^2/yr
Maintained coastline 1990-2010: +17 m^2/yr
Corrected Trend 1970-1990: -13 m^2/yr
Maintained coastline 1970-1990: -13m^2/yr
Corrected Trend 1990-2010: -51 m^2/yr
Maintained coastline 1990-2010: +11 m^2/yr

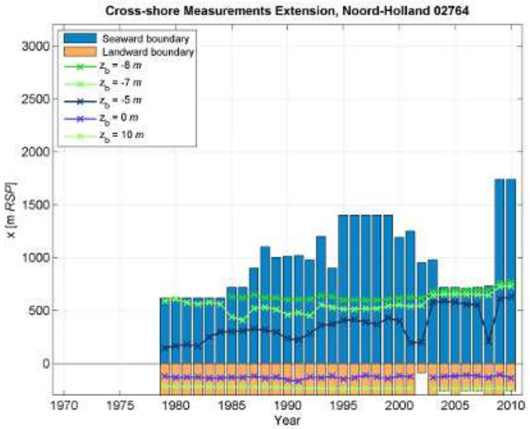

Nourishments type, Noord-Holland 02700
Nourishments type, Noord-Holland 02716
Nourishments type, Noord-Holland 02732
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 02700
Cross-shore Measurements Extension, Noord-Holland 02716
Cross-shore Measurements Extension, Noord-Holland 02732
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Jarkus Transect Volumes, 02700 from -100 m RSP to 600 m RSP
Jarkus Transect Volumes, 02716 from -100 m RSP to 600 m RSP
Jarkus Transect Volumes, 02732 from -100 m RSP to 600 m RSP
Volume coastal foundation [m^3/m]
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: -27 m^2/yr
Maintained coastline 1970-1990: -27m^2/yr
Corrected Trend 1990-2010: -36 m^2/yr
Maintained coastline 1990-2010: +25 m^2/yr
Corrected Trend 1970-1990: -33 m^2/yr
Maintained coastline 1970-1990: -33m^2/yr
Corrected Trend 1990-2010: -37 m^2/yr
Maintained coastline 1990-2010: +25 m^2/yr
Corrected Trend 1970-1990: -45 m^2/yr
Maintained coastline 1970-1990: -45m^2/yr
Corrected Trend 1990-2010: -35 m^2/yr
Maintained coastline 1990-2010: +26 m^2/yr

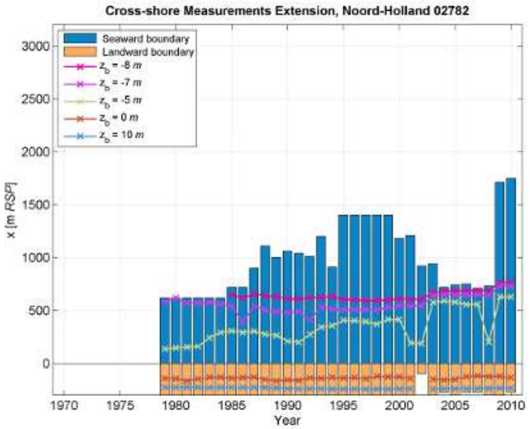

Nourishments type, Noord-Holland 02747
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

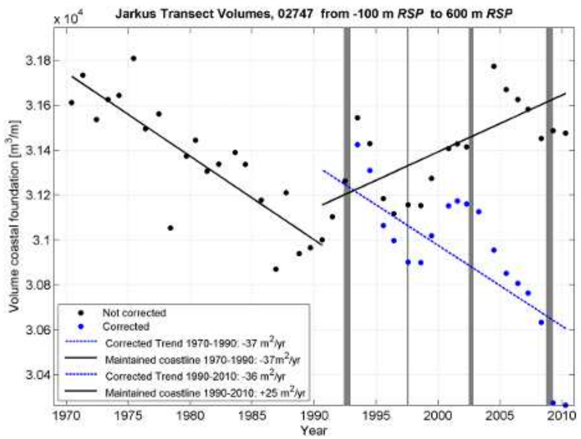

Nourishments type, Noord-Holland 02764
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

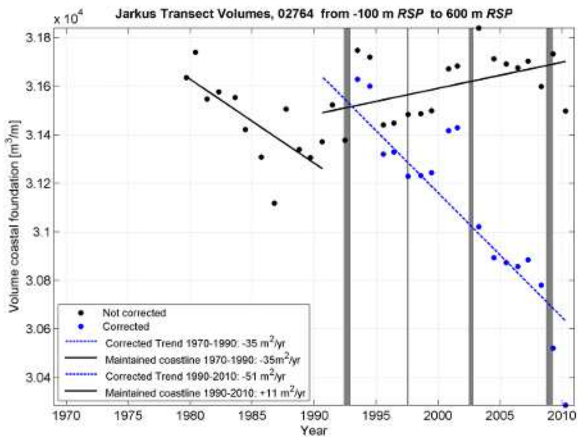

Nourishments type, Noord-Holland 02782
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

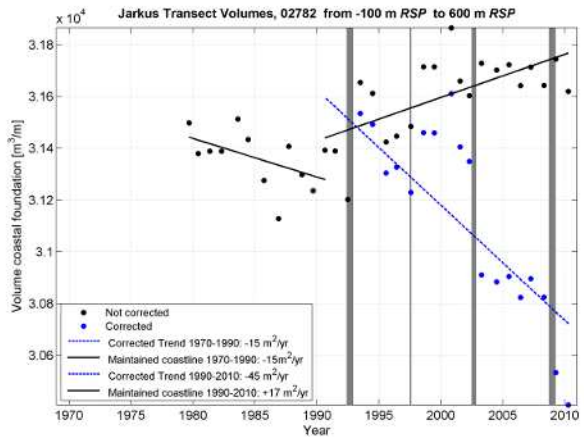

Cross-shore Measurements Extension, Noord-Holland 02747
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

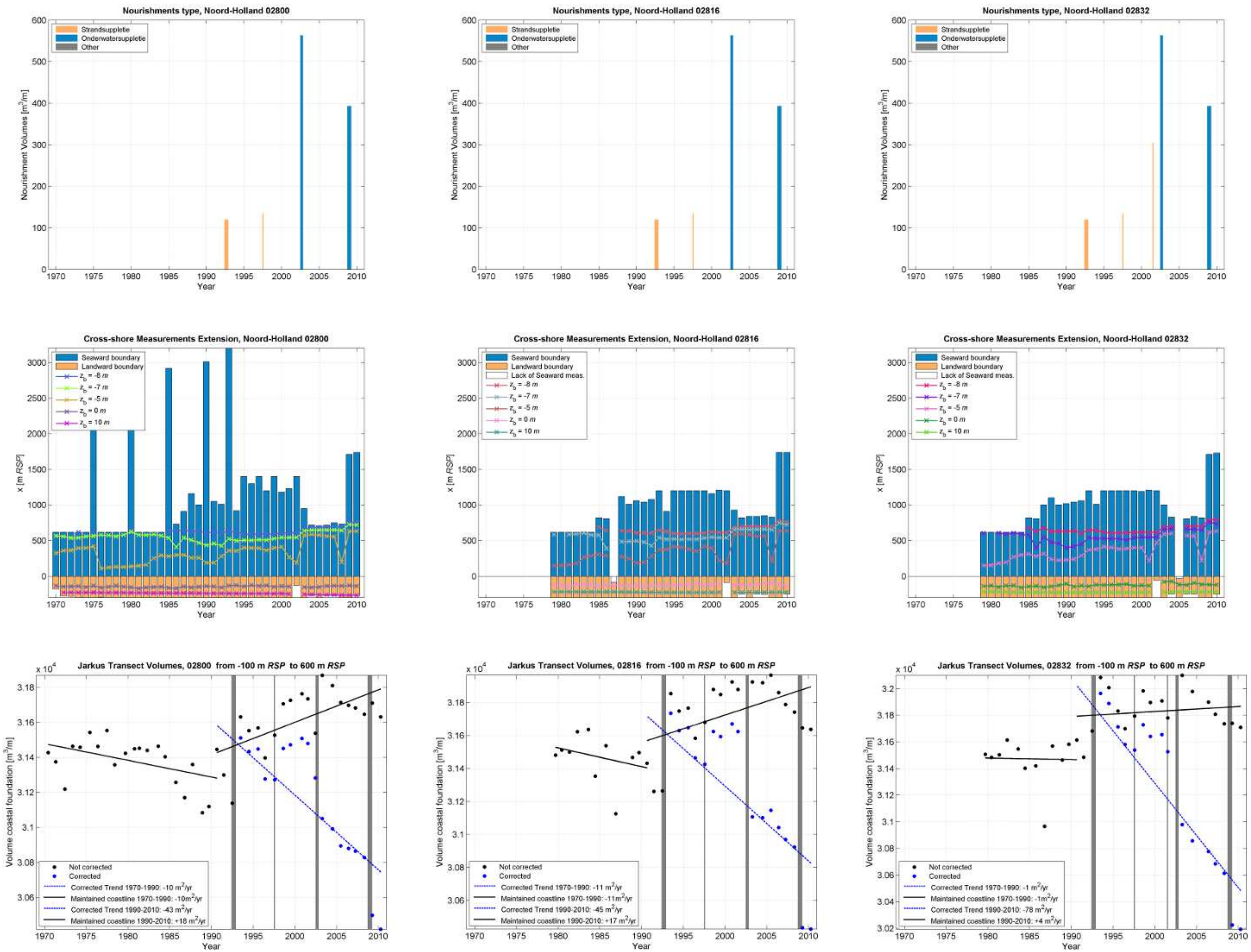

Cross-shore Measurements Extension, Noord-Holland 02764
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

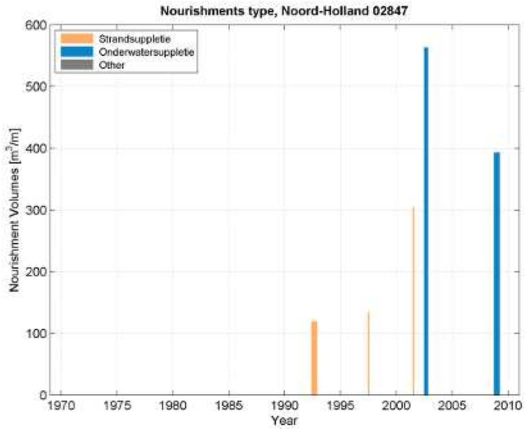

Cross-shore Measurements Extension, Noord-Holland 02782
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

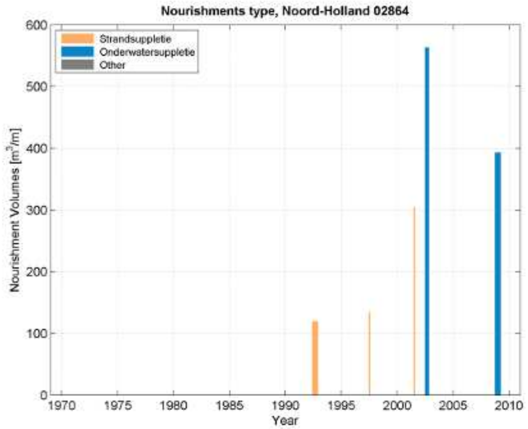

Jarkus Transect Volumes, 02747 from -100 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -37 m²/yr
Maintained coastline 1970-1990: -37m²/yr
Corrected Trend 1990-2010: -36 m²/yr
Maintained coastline 1990-2010: +25 m²/yr
Year

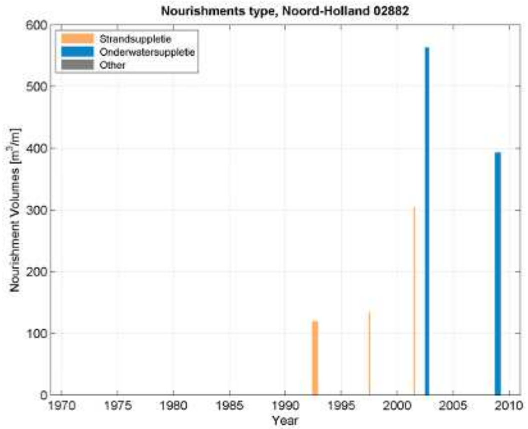

Jarkus Transect Volumes, 02764 from -100 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -35 m²/yr
Maintained coastline 1970-1990: -35m²/yr
Corrected Trend 1990-2010: -51 m²/yr
Maintained coastline 1990-2010: +11 m²/yr
Year

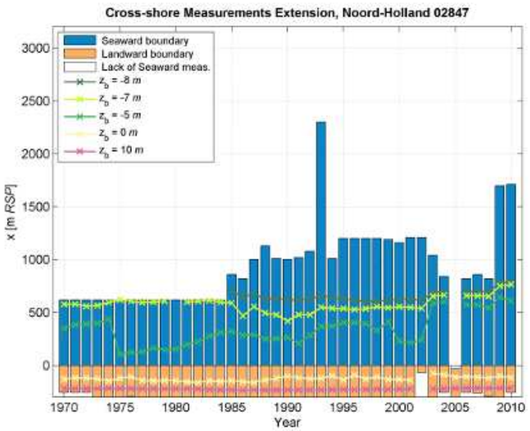

Jarkus Transect Volumes, 02782 from -100 m RSP to 600 m RSP
x 10^4
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -15 m²/yr
Maintained coastline 1970-1990: -15m²/yr
Corrected Trend 1990-2010: -45 m²/yr
Maintained coastline 1990-2010: +17 m²/yr
Year

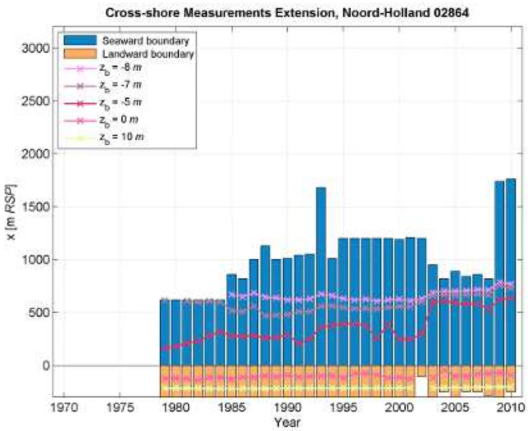

Nourishments type, Noord-Holland 02800
Nourishments type, Noord-Holland 02816
Nourishments type, Noord-Holland 02832
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 02800
Cross-shore Measurements Extension, Noord-Holland 02816
Cross-shore Measurements Extension, Noord-Holland 02832
Seaward boundary
Landward boundary
Lack of Seaward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Jarkus Transect Volumes, 02800 from -100 m RSP to 600 m RSP
Jarkus Transect Volumes, 02816 from -100 m RSP to 600 m RSP
Jarkus Transect Volumes, 02832 from -100 m RSP to 600 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -10 m2/yr
Maintained coastline 1970-1990: -10m2/yr
Corrected Trend 1990-2010: -43 m2/yr
Maintained coastline 1990-2010: +18 m2/yr
Corrected Trend 1970-1990: -11 m2/yr
Maintained coastline 1970-1990: -11m2/yr
Corrected Trend 1990-2010: -45 m2/yr
Maintained coastline 1990-2010: +17 m2/yr
Corrected Trend 1970-1990: -1 m2/yr
Maintained coastline 1970-1990: -1m2/yr
Corrected Trend 1990-2010: -78 m2/yr
Maintained coastline 1990-2010: +4 m2/yr

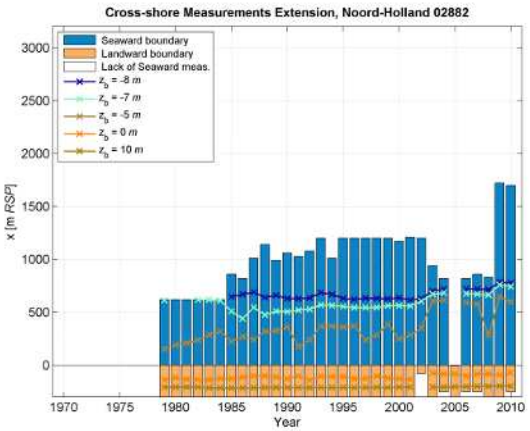

Nourishments type, Noord-Holland 02847
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

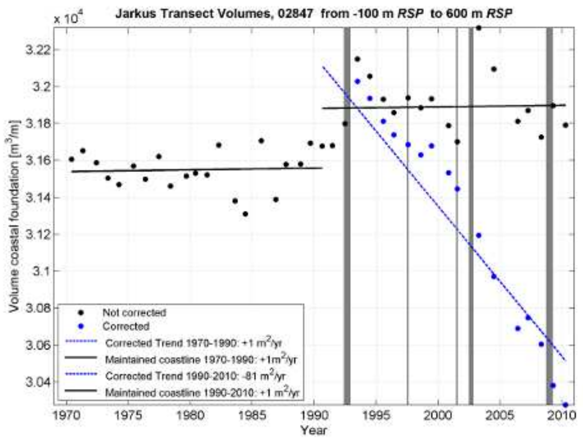

Nourishments type, Noord-Holland 02864
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

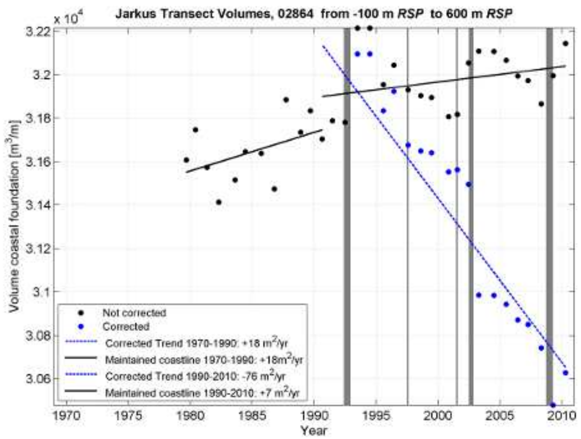

Nourishments type, Noord-Holland 02882
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

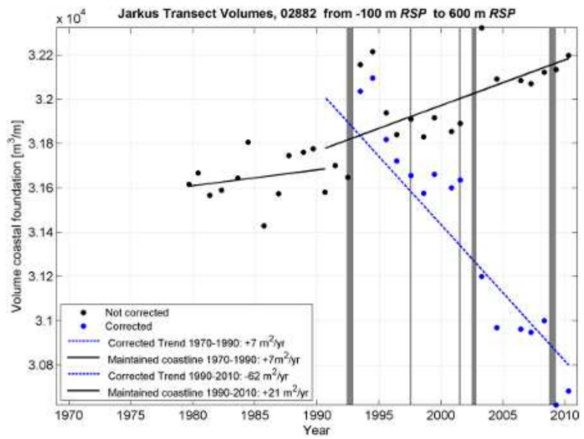

Cross-shore Measurements Extension, Noord-Holland 02847
Seaward boundary
Landward boundary
Lack of Seaward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

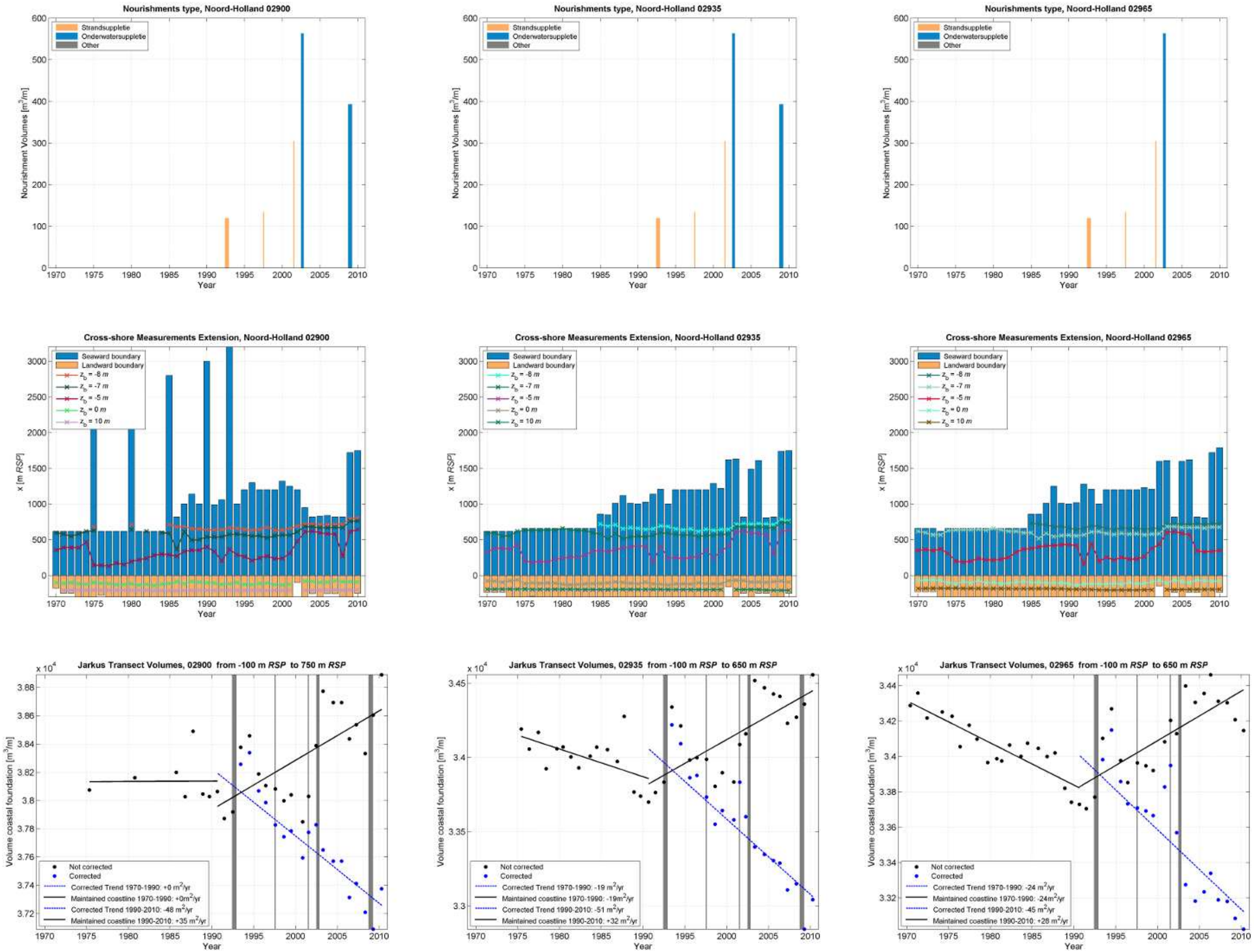

Cross-shore Measurements Extension, Noord-Holland 02864
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

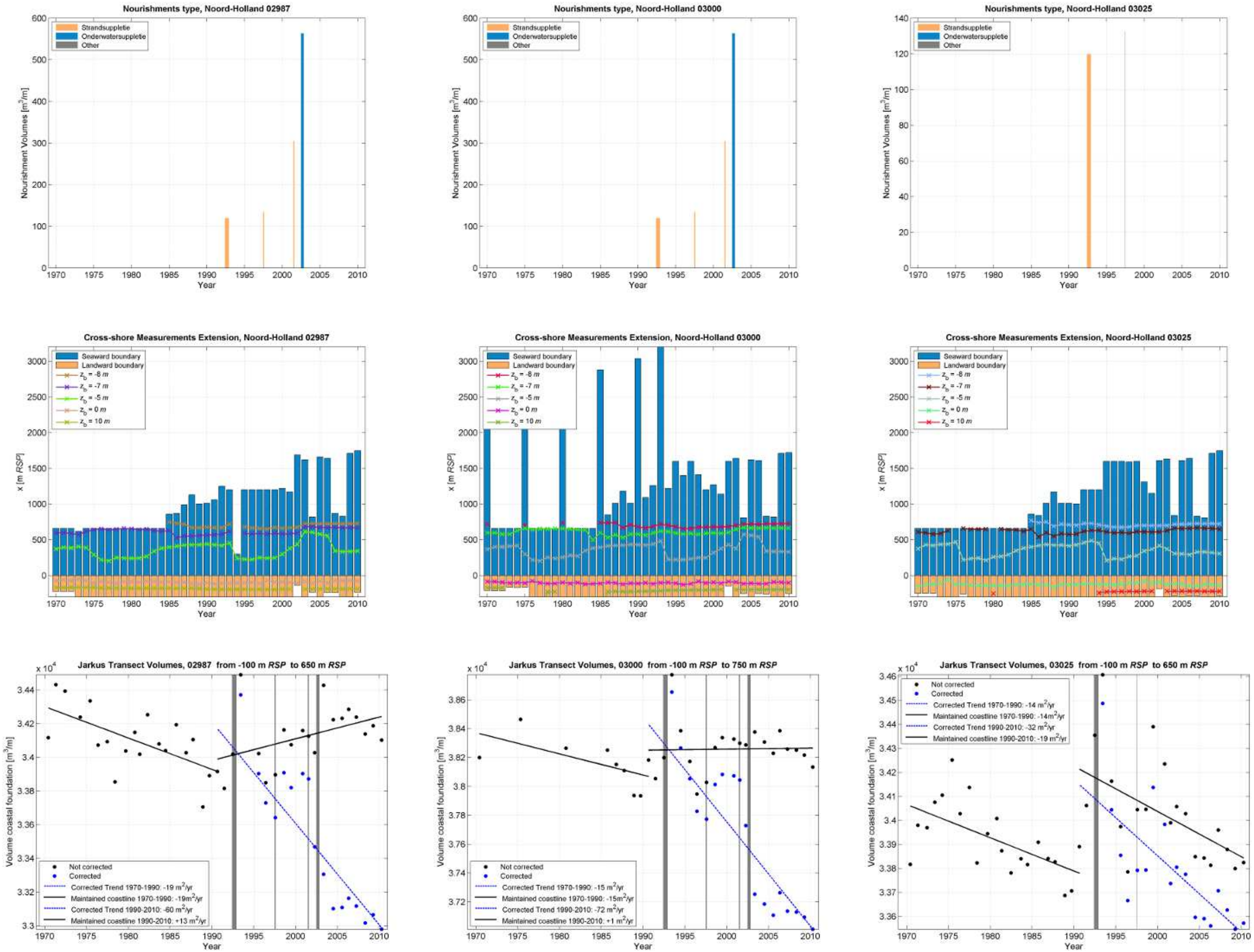

Cross-shore Measurements Extension, Noord-Holland 02882
Seaward boundary
Landward boundary
Lack of Seaward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year


Jarkus Transect Volumes, 02847 from -100 m RSP to 600 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +1 m2/yr
Maintained coastline 1970-1990: +1m2/yr
Corrected Trend 1990-2010: -81 m2/yr
Maintained coastline 1990-2010: +1 m2/yr

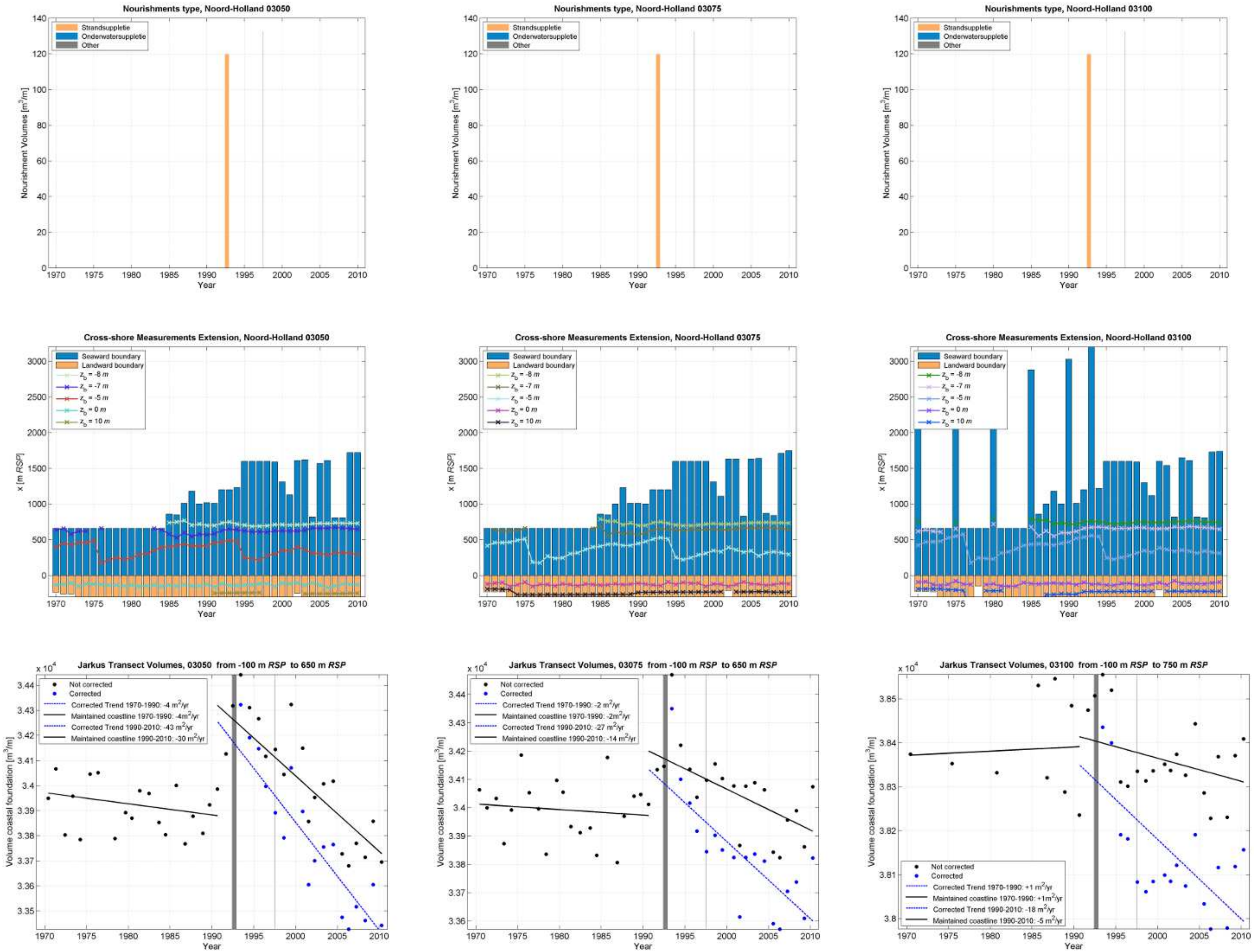

Jarkus Transect Volumes, 02864 from -100 m RSP to 600 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +18 m2/yr
Maintained coastline 1970-1990: +18m2/yr
Corrected Trend 1990-2010: -76 m2/yr
Maintained coastline 1990-2010: +7 m2/yr

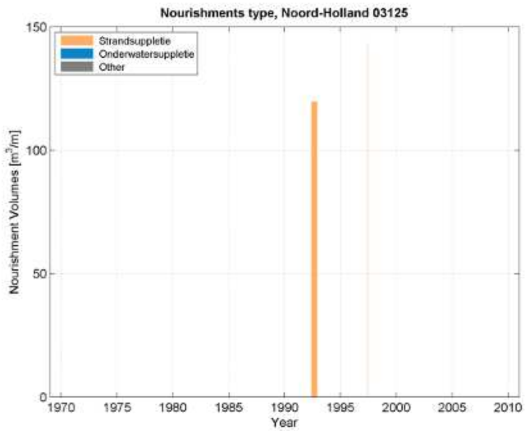

Jarkus Transect Volumes, 02882 from -100 m RSP to 600 m RSP
Volume coastal foundation [m3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +7 m2/yr
Maintained coastline 1970-1990: +7m2/yr
Corrected Trend 1990-2010: -62 m2/yr
Maintained coastline 1990-2010: +21 m2/yr

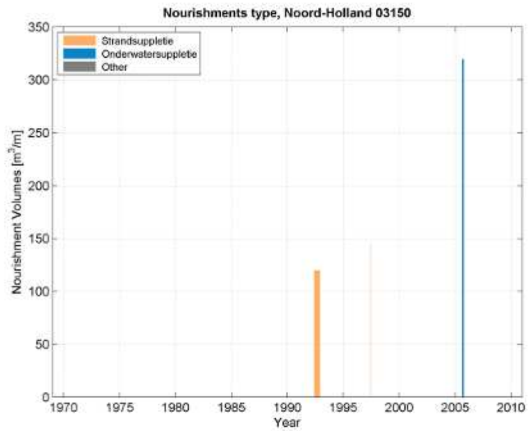

Nourishments type, Noord-Holland 02900
Nourishments type, Noord-Holland 02935
Nourishments type, Noord-Holland 02965
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 02900
Cross-shore Measurements Extension, Noord-Holland 02935
Cross-shore Measurements Extension, Noord-Holland 02965
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Jarkus Transect Volumes, 02900 from -100 m RSP to 750 m RSP
Jarkus Transect Volumes, 02935 from -100 m RSP to 650 m RSP
Jarkus Transect Volumes, 02965 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +0 m2/yr
Maintained coastline 1970-1990: +0m2/yr
Corrected Trend 1990-2010: -48 m2/yr
Maintained coastline 1990-2010: +35 m2/yr
Corrected Trend 1970-1990: -19 m2/yr
Maintained coastline 1970-1990: -19m2/yr
Corrected Trend 1990-2010: -51 m2/yr
Maintained coastline 1990-2010: +32 m2/yr
Corrected Trend 1970-1990: -24 m2/yr
Maintained coastline 1970-1990: -24m2/yr
Corrected Trend 1990-2010: -45 m2/yr
Maintained coastline 1990-2010: +28 m2/yr

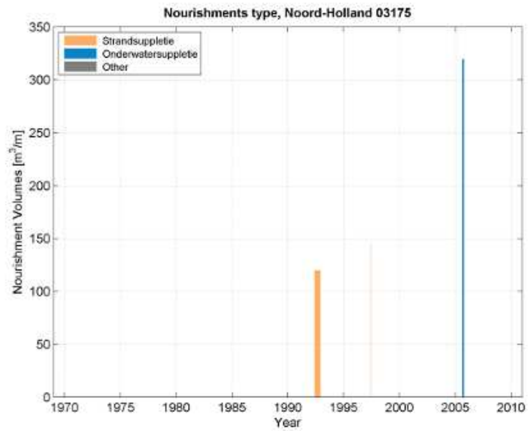


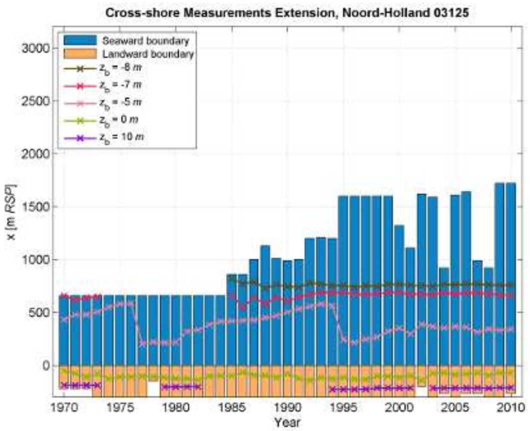
Nourishments type, Noord-Holland 02987
Nourishments type, Noord-Holland 03000
Nourishments type, Noord-Holland 03025
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year
Cross-shore Measurements Extension, Noord-Holland 02987
Cross-shore Measurements Extension, Noord-Holland 03000
Cross-shore Measurements Extension, Noord-Holland 03025
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year
Jarkus Transect Volumes, 02987 from -100 m RSP to 650 m RSP
Jarkus Transect Volumes, 03000 from -100 m RSP to 750 m RSP
Jarkus Transect Volumes, 03025 from -100 m RSP to 650 m RSP
Volume coastal foundation [m³/m]
x 10⁴
Not corrected
Corrected
Corrected Trend 1970-1990: -19 m²/yr
Maintained coastline 1970-1990: -19m²/yr
Corrected Trend 1990-2010: -60 m²/yr
Maintained coastline 1990-2010: +13 m²/yr
Corrected Trend 1970-1990: -15 m²/yr
Maintained coastline 1970-1990: -15m²/yr
Corrected Trend 1990-2010: -72 m²/yr
Maintained coastline 1990-2010: +1 m²/yr
Corrected Trend 1970-1990: -14 m²/yr
Maintained coastline 1970-1990: -14m²/yr
Corrected Trend 1990-2010: -32 m²/yr
Maintained coastline 1990-2010: -19 m²/yr
Year

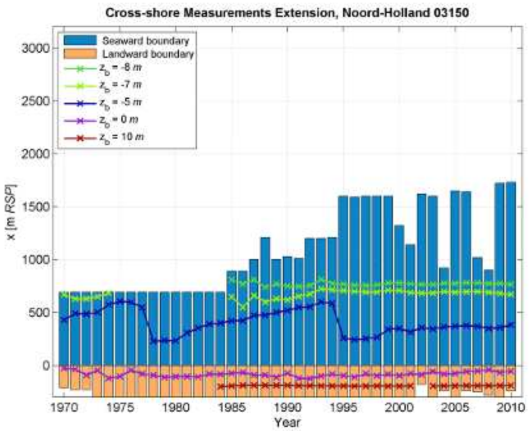

Nourishments type, Noord-Holland 03050
Nourishments type, Noord-Holland 03075
Nourishments type, Noord-Holland 03100
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 03050
Cross-shore Measurements Extension, Noord-Holland 03075
Cross-shore Measurements Extension, Noord-Holland 03100
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Jarkus Transect Volumes, 03050 from -100 m RSP to 650 m RSP
Jarkus Transect Volumes, 03075 from -100 m RSP to 650 m RSP
Jarkus Transect Volumes, 03100 from -100 m RSP to 750 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m2/yr
Maintained coastline 1970-1990: -4m2/yr
Corrected Trend 1990-2010: -43 m2/yr
Maintained coastline 1990-2010: -30 m2/yr
Corrected Trend 1970-1990: -2 m2/yr
Maintained coastline 1970-1990: -2m2/yr
Corrected Trend 1990-2010: -27 m2/yr
Maintained coastline 1990-2010: -14 m2/yr
Corrected Trend 1970-1990: +1 m2/yr
Maintained coastline 1970-1990: +1m2/yr
Corrected Trend 1990-2010: -18 m2/yr
Maintained coastline 1990-2010: -5 m2/yr

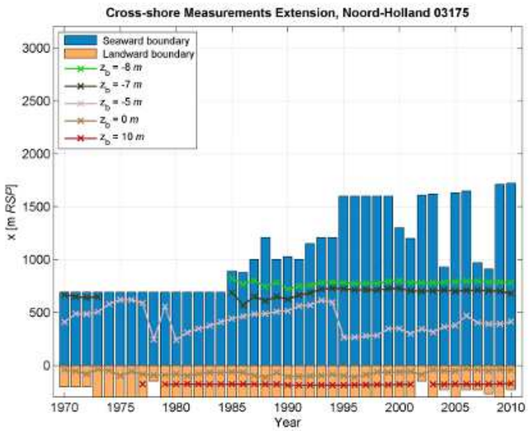

Nourishments type, Noord-Holland 03125
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

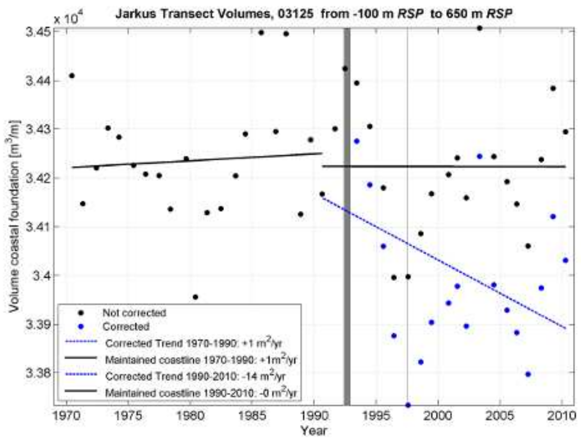

Nourishments type, Noord-Holland 03150
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

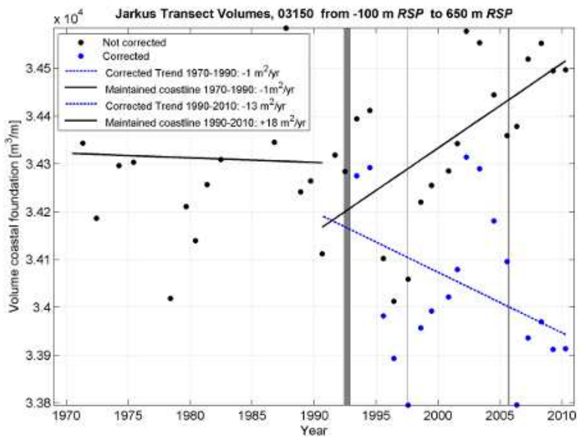

Nourishments type, Noord-Holland 03175
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

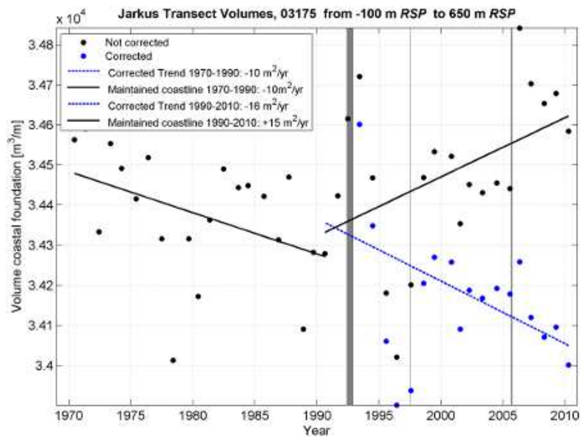

Cross-shore Measurements Extension, Noord-Holland 03125
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year


Cross-shore Measurements Extension, Noord-Holland 03150
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

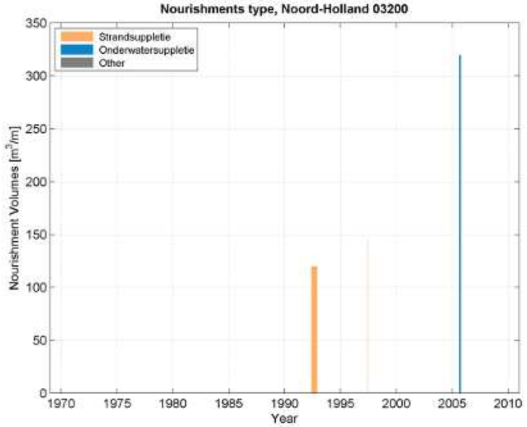

Cross-shore Measurements Extension, Noord-Holland 03175
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year


Jarkus Transect Volumes, 03125 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +1 m2/yr
Maintained coastline 1970-1990: +1m2/yr
Corrected Trend 1990-2010: -14 m2/yr
Maintained coastline 1990-2010: -0 m2/yr
Year

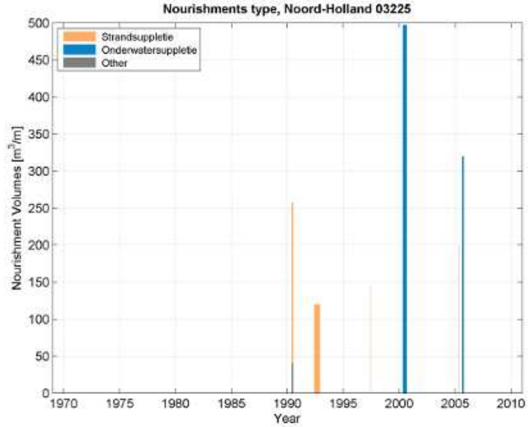

Jarkus Transect Volumes, 03150 from -100 m RSP to 650 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -1 m2/yr
Maintained coastline 1970-1990: -1m2/yr
Corrected Trend 1990-2010: -13 m2/yr
Maintained coastline 1990-2010: +18 m2/yr
Volume coastal foundation [m3/m]
Year


Jarkus Transect Volumes, 03175 from -100 m RSP to 650 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -10 m2/yr
Maintained coastline 1970-1990: -10m2/yr
Corrected Trend 1990-2010: -16 m2/yr
Maintained coastline 1990-2010: +15 m2/yr
Volume coastal foundation [m3/m]
Year

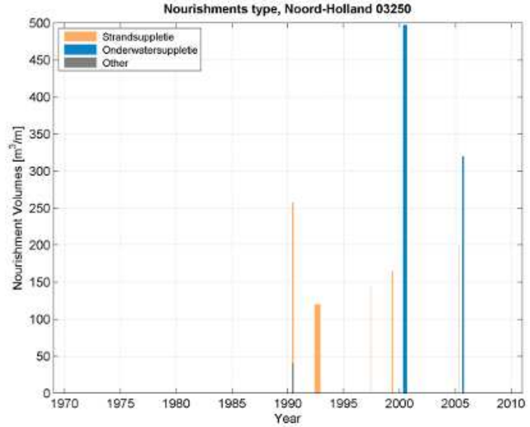
Nourishments type, Noord-Holland 03200



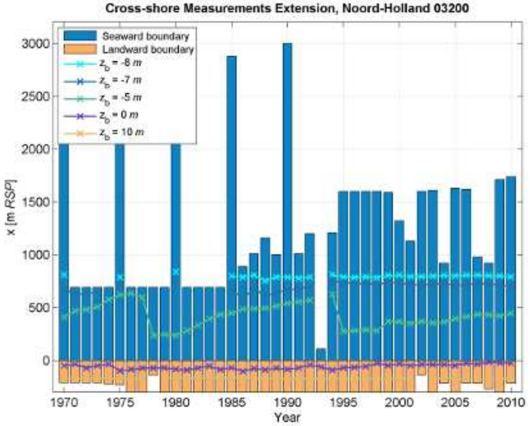
Nourishments type, Noord-Holland 03225



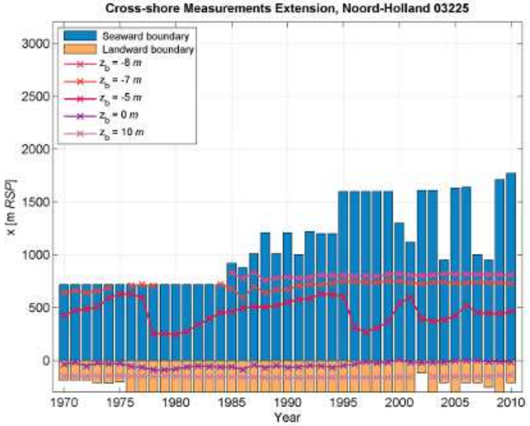
Nourishments type, Noord-Holland 03250



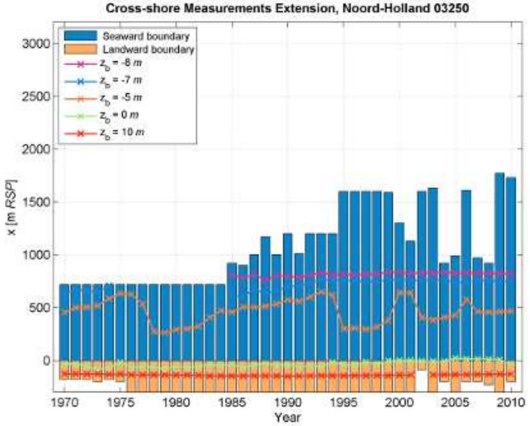
Cross-shore Measurements Extension, Noord-Holland 03200



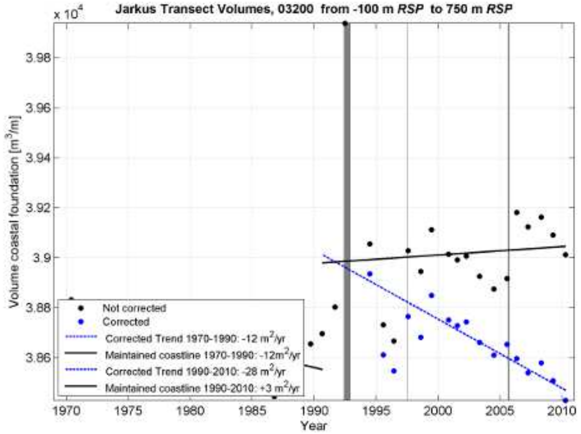
Cross-shore Measurements Extension, Noord-Holland 03225



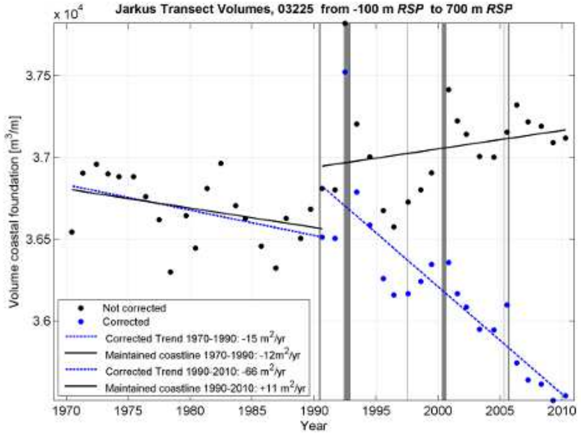
Cross-shore Measurements Extension, Noord-Holland 03250



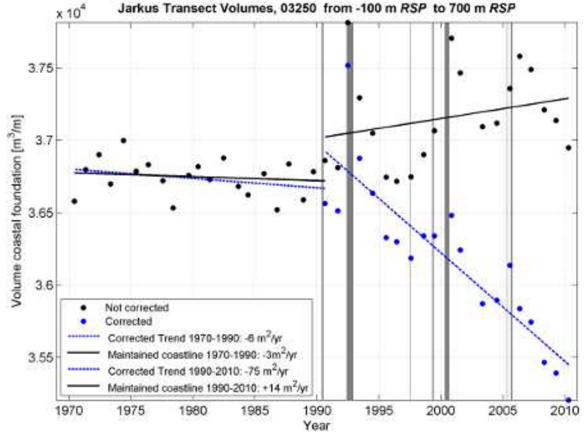
Jarkus Transect Volumes, 03200 from -100 m *RSP* to 750 m *RSP*

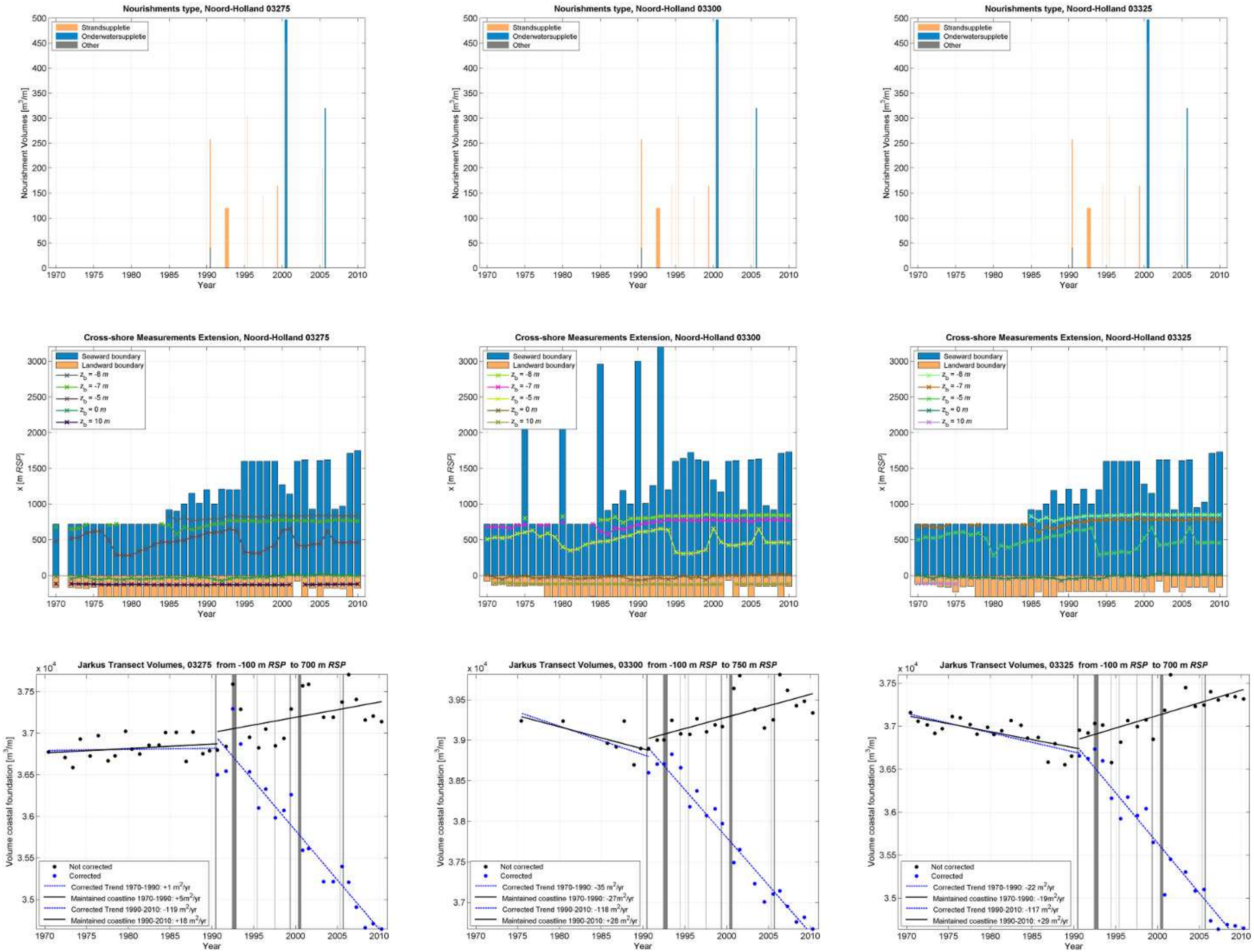


Jarkus Transect Volumes, 03225 from -100 m *RSP* to 700 m *RSP*

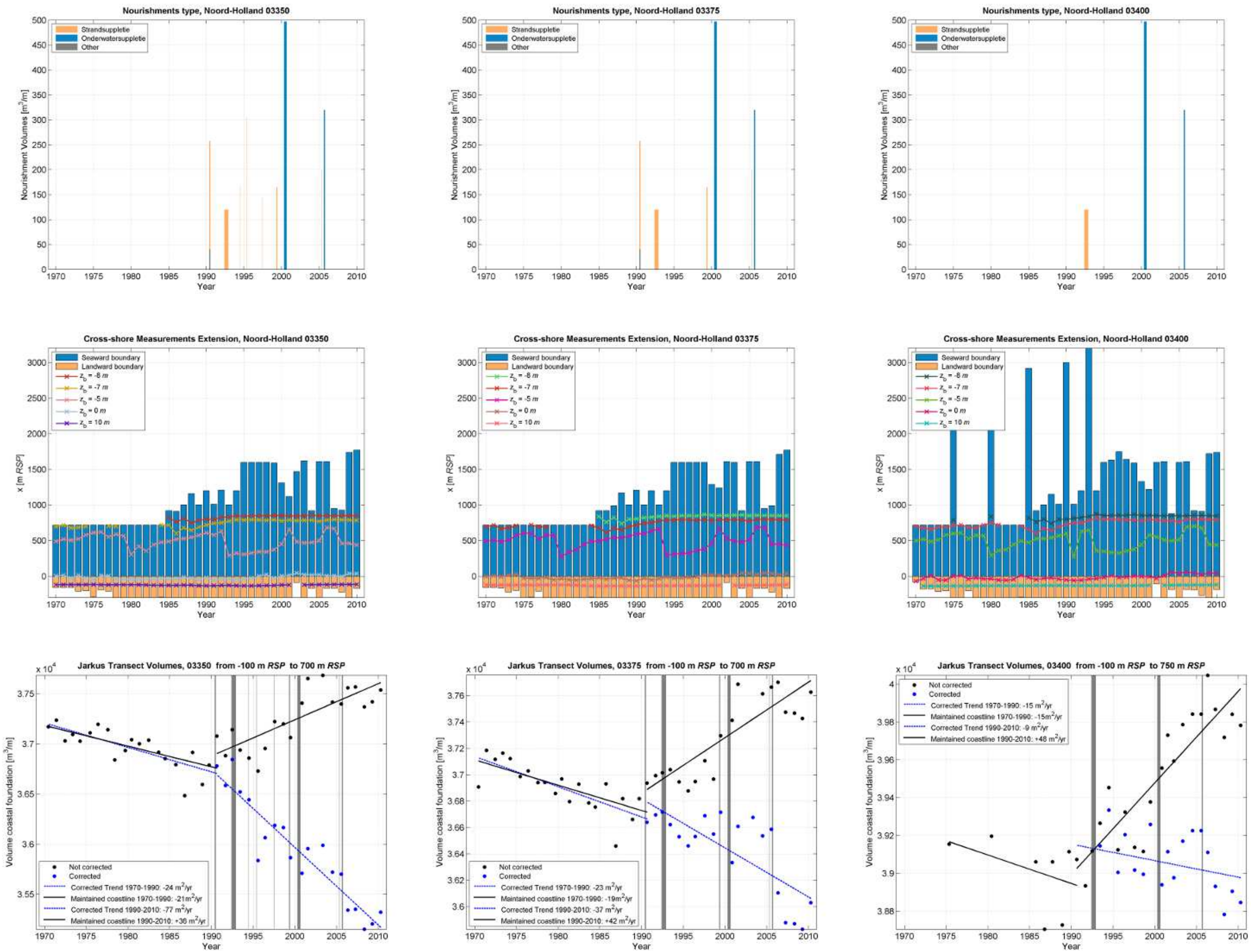


Jarkus Transect Volumes, 03250 from -100 m *RSP* to 700 m *RSP*

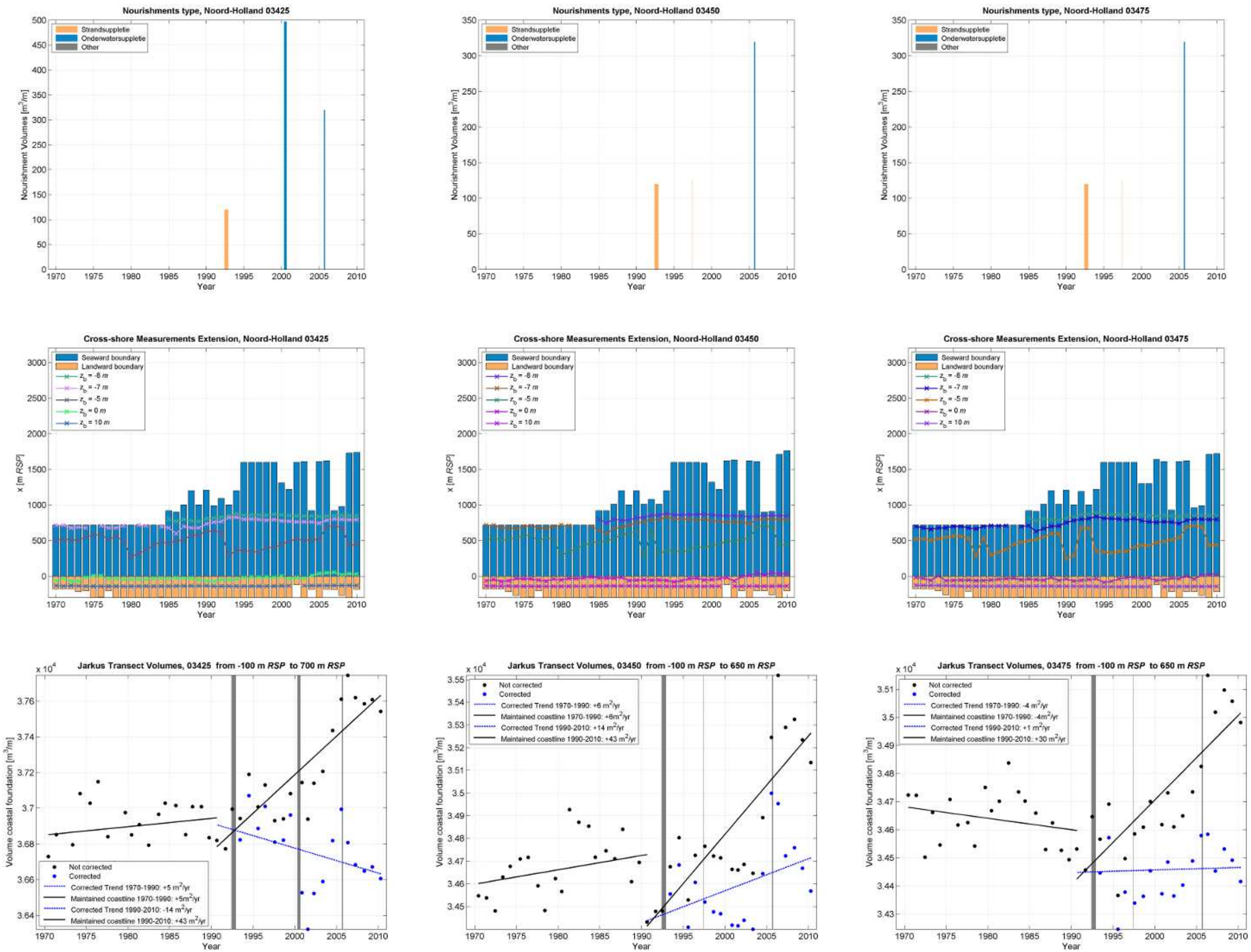




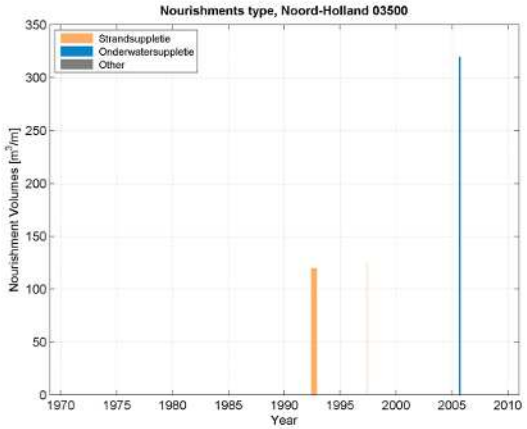
Nourishments type, Noord-Holland 03275
Nourishments type, Noord-Holland 03300
Nourishments type, Noord-Holland 03325
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 03275
Cross-shore Measurements Extension, Noord-Holland 03300
Cross-shore Measurements Extension, Noord-Holland 03325
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Jarkus Transect Volumes, 03275 from -100 m RSP to 700 m RSP
Jarkus Transect Volumes, 03300 from -100 m RSP to 750 m RSP
Jarkus Transect Volumes, 03325 from -100 m RSP to 700 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +1 m2/yr
Maintained coastline 1970-1990: +5m2/yr
Corrected Trend 1990-2010: -119 m2/yr
Maintained coastline 1990-2010: +18 m2/yr
Corrected Trend 1970-1990: -35 m2/yr
Maintained coastline 1970-1990: -27m2/yr
Corrected Trend 1990-2010: -118 m2/yr
Maintained coastline 1990-2010: +28 m2/yr
Corrected Trend 1970-1990: -22 m2/yr
Maintained coastline 1970-1990: -19m2/yr
Corrected Trend 1990-2010: -117 m2/yr
Maintained coastline 1990-2010: +29 m2/yr

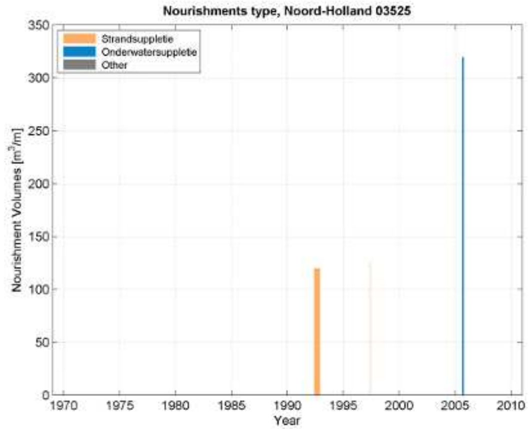


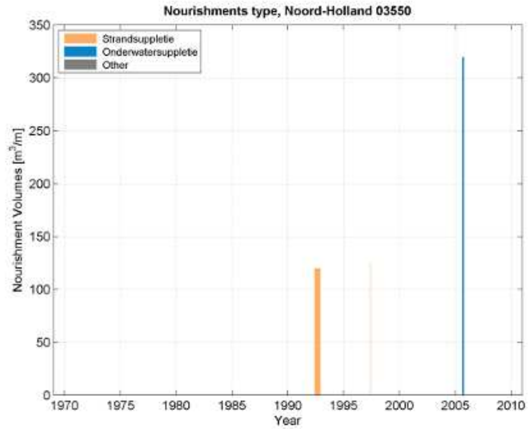
Nourishments type, Noord-Holland 03350
Nourishments type, Noord-Holland 03375
Nourishments type, Noord-Holland 03400
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 03350
Cross-shore Measurements Extension, Noord-Holland 03375
Cross-shore Measurements Extension, Noord-Holland 03400
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Jarkus Transect Volumes, 03350 from -100 m RSP to 700 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -24 m^2/yr
Maintained coastline 1970-1990: -21m^2/yr
Corrected Trend 1990-2010: -77 m^2/yr
Maintained coastline 1990-2010: +36 m^2/yr
Jarkus Transect Volumes, 03375 from -100 m RSP to 700 m RSP
Corrected Trend 1970-1990: -23 m^2/yr
Maintained coastline 1970-1990: -19m^2/yr
Corrected Trend 1990-2010: -37 m^2/yr
Maintained coastline 1990-2010: +42 m^2/yr
Jarkus Transect Volumes, 03400 from -100 m RSP to 750 m RSP
Corrected Trend 1970-1990: -15 m^2/yr
Maintained coastline 1970-1990: -15m^2/yr
Corrected Trend 1990-2010: -9 m^2/yr
Maintained coastline 1990-2010: +48 m^2/yr
Volume coastal foundation [m^3/m]
x 10^4

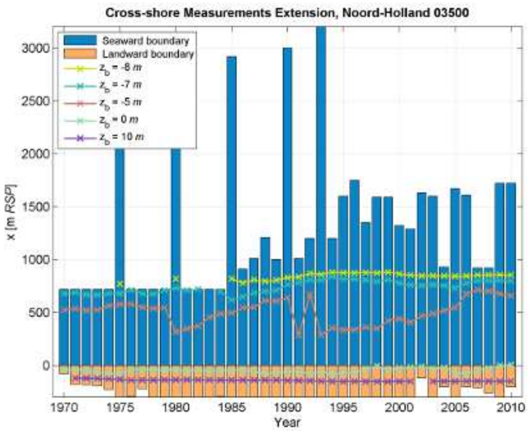


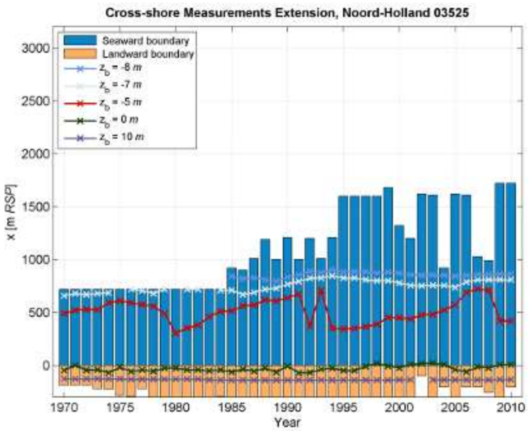
Nourishments type, Noord-Holland 03425
Nourishments type, Noord-Holland 03450
Nourishments type, Noord-Holland 03475
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year
Cross-shore Measurements Extension, Noord-Holland 03425
Cross-shore Measurements Extension, Noord-Holland 03450
Cross-shore Measurements Extension, Noord-Holland 03475
Seaward boundary
Landward boundary
x [m RSP]
Jarkus Transect Volumes, 03425 from -100 m RSP to 700 m RSP
Jarkus Transect Volumes, 03450 from -100 m RSP to 650 m RSP
Jarkus Transect Volumes, 03475 from -100 m RSP to 650 m RSP
Volume coastal foundation [m3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +5 m2/yr
Maintained coastline 1970-1990: +5m2/yr
Corrected Trend 1990-2010: -14 m2/yr
Maintained coastline 1990-2010: +43 m2/yr
Corrected Trend 1970-1990: +6 m2/yr
Maintained coastline 1970-1990: +6m2/yr
Corrected Trend 1990-2010: +14 m2/yr
Maintained coastline 1990-2010: +43 m2/yr
Corrected Trend 1970-1990: -4 m2/yr
Maintained coastline 1970-1990: -4m2/yr
Corrected Trend 1990-2010: +1 m2/yr
Maintained coastline 1990-2010: +30 m2/yr

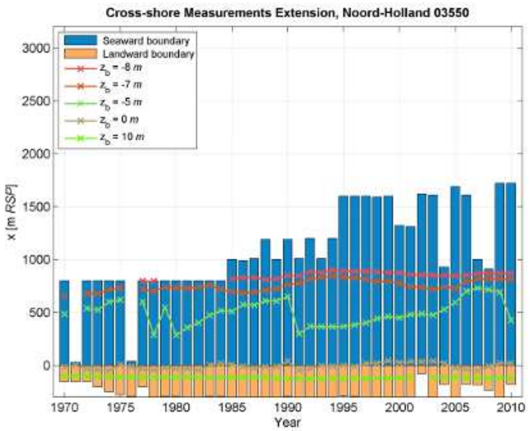

Nourishments type, Noord-Holland 03500
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

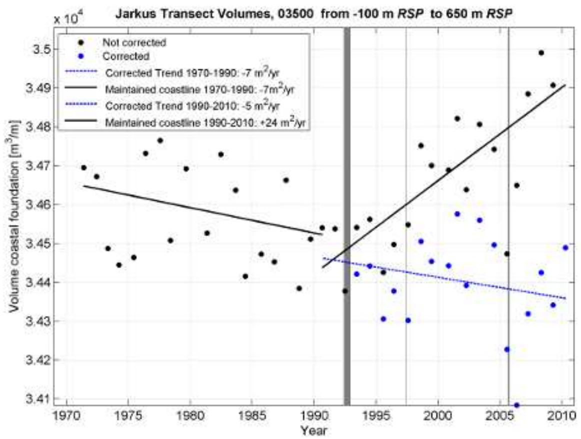

Nourishments type, Noord-Holland 03525
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

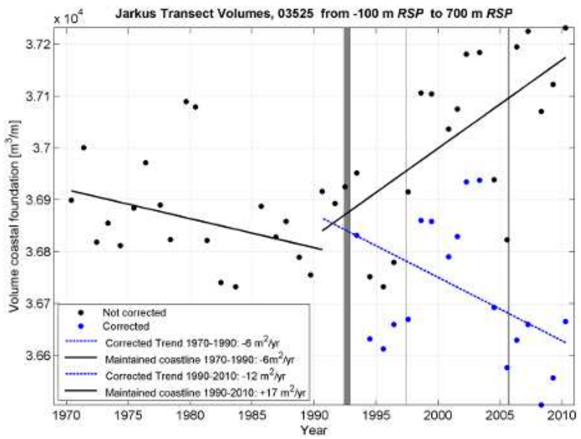

Nourishments type, Noord-Holland 03550
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

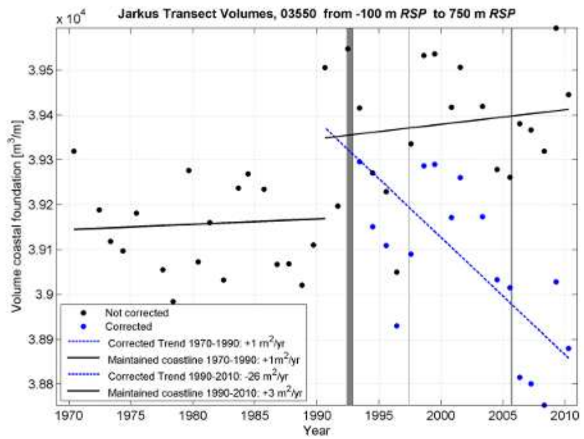

Cross-shore Measurements Extension, Noord-Holland 03500
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

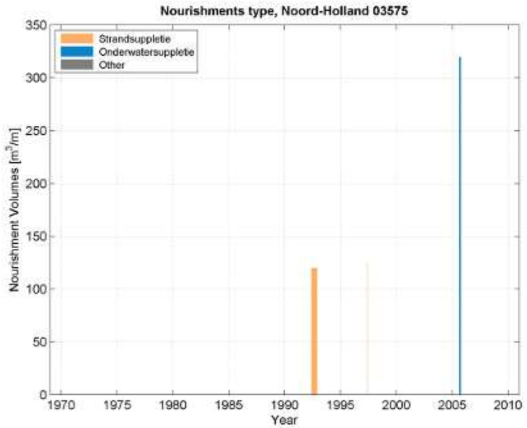

Cross-shore Measurements Extension, Noord-Holland 03525
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

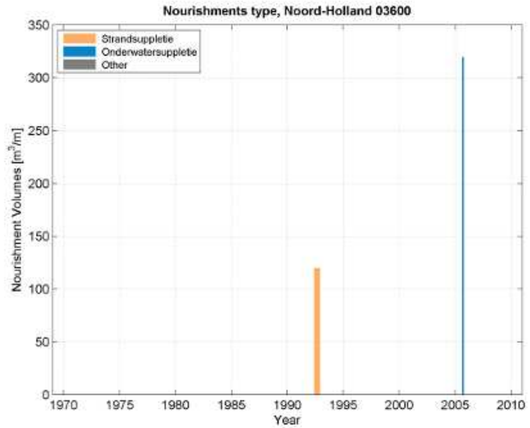

Cross-shore Measurements Extension, Noord-Holland 03550
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

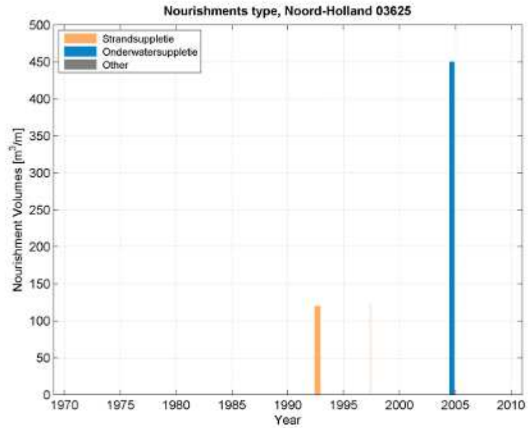

Jarkus Transect Volumes, 03500 from -100 m RSP to 650 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -7 m2/yr
Maintained coastline 1970-1990: -7m2/yr
Corrected Trend 1990-2010: -5 m2/yr
Maintained coastline 1990-2010: +24 m2/yr
Volume coastal foundation [m3/m]
Year

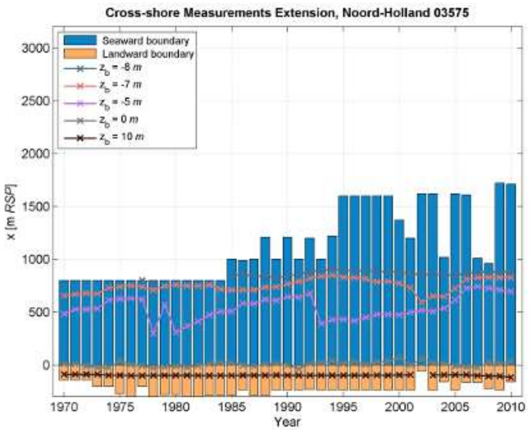

Jarkus Transect Volumes, 03525 from -100 m RSP to 700 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m2/yr
Maintained coastline 1970-1990: -6m2/yr
Corrected Trend 1990-2010: -12 m2/yr
Maintained coastline 1990-2010: +17 m2/yr
Volume coastal foundation [m3/m]
Year

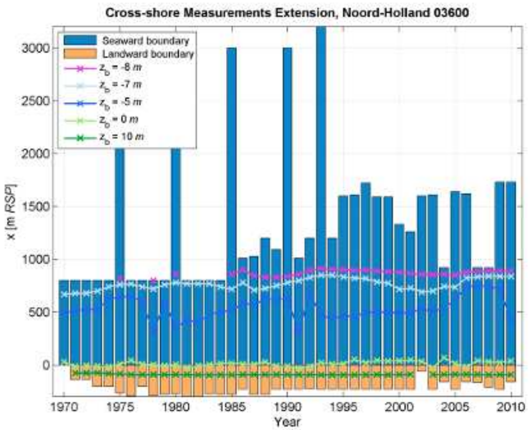

Jarkus Transect Volumes, 03550 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +1 m2/yr
Maintained coastline 1970-1990: +1m2/yr
Corrected Trend 1990-2010: -26 m2/yr
Maintained coastline 1990-2010: +3 m2/yr
Volume coastal foundation [m3/m]
Year

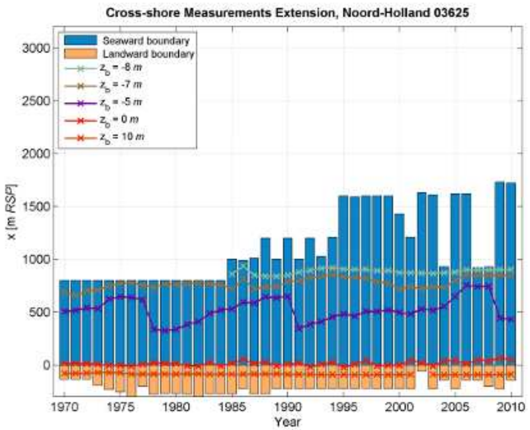

Nourishments type, Noord-Holland 03575
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

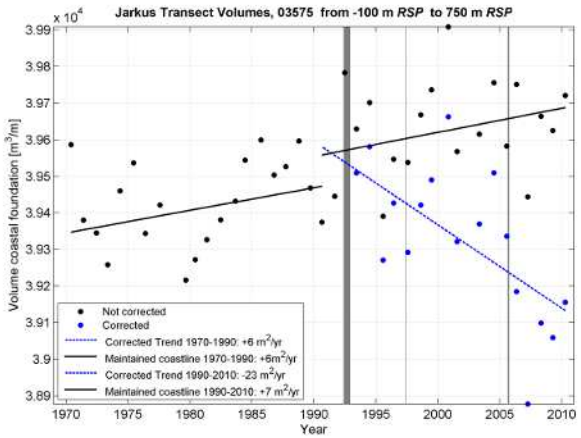

Nourishments type, Noord-Holland 03600
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

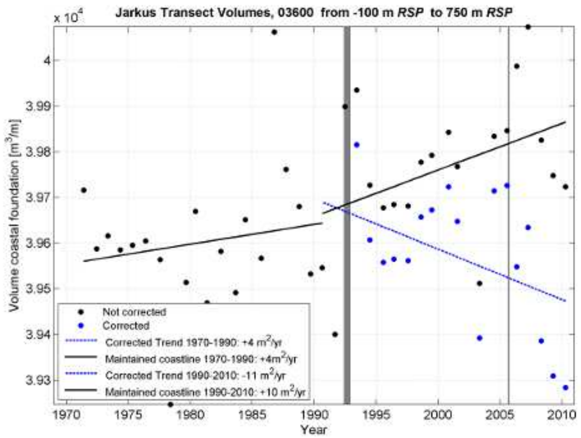

Nourishments type, Noord-Holland 03625
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

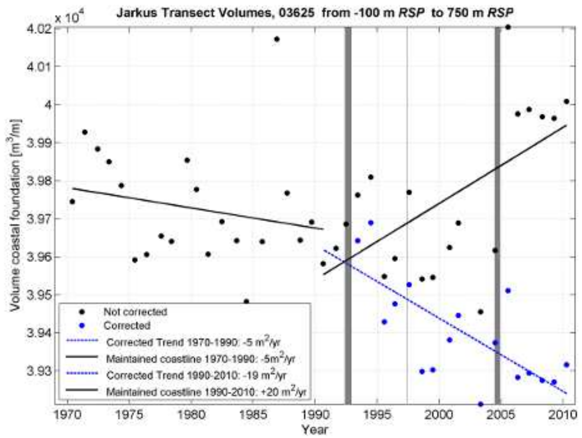

Cross-shore Measurements Extension, Noord-Holland 03575
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

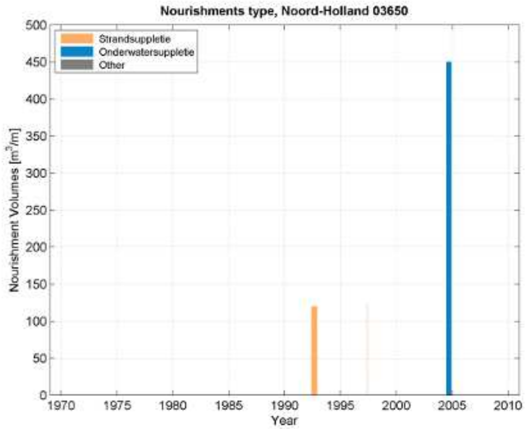

Cross-shore Measurements Extension, Noord-Holland 03600
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

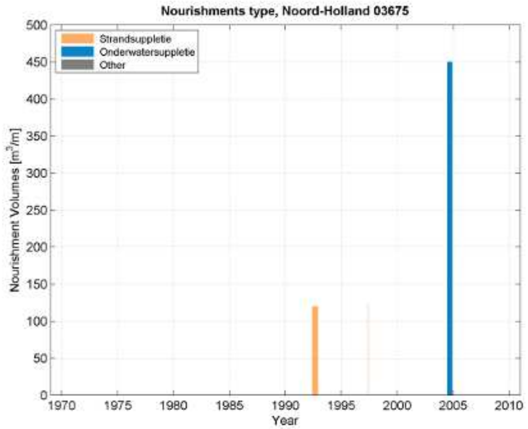

Cross-shore Measurements Extension, Noord-Holland 03625
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

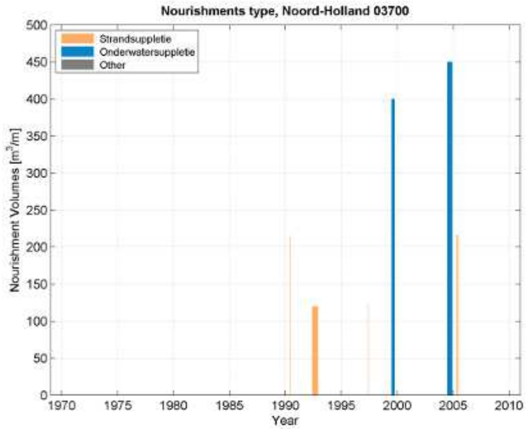

Jarkus Transect Volumes, 03575 from -100 m RSP to 750 m RSP
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +6 m²/yr
Maintained coastline 1970-1990: +6m²/yr
Corrected Trend 1990-2010: -23 m²/yr
Maintained coastline 1990-2010: +7 m²/yr
Year

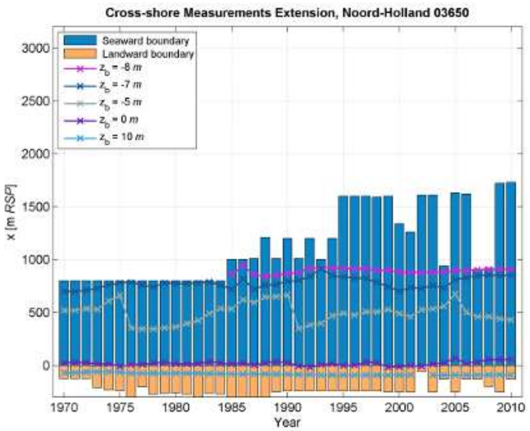

Jarkus Transect Volumes, 03600 from -100 m RSP to 750 m RSP
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +4 m²/yr
Maintained coastline 1970-1990: +4m²/yr
Corrected Trend 1990-2010: -11 m²/yr
Maintained coastline 1990-2010: +10 m²/yr
Year

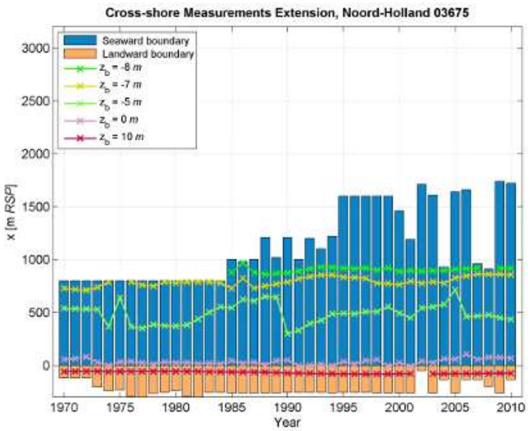

Jarkus Transect Volumes, 03625 from -100 m RSP to 750 m RSP
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -5 m²/yr
Maintained coastline 1970-1990: -5m²/yr
Corrected Trend 1990-2010: -19 m²/yr
Maintained coastline 1990-2010: +20 m²/yr
Year

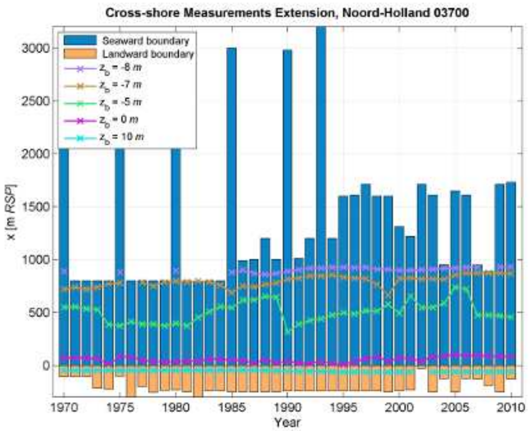

Nourishments type, Noord-Holland 03650
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

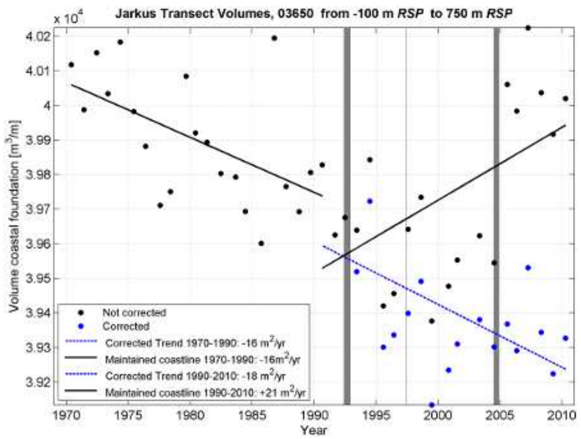

Nourishments type, Noord-Holland 03675
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

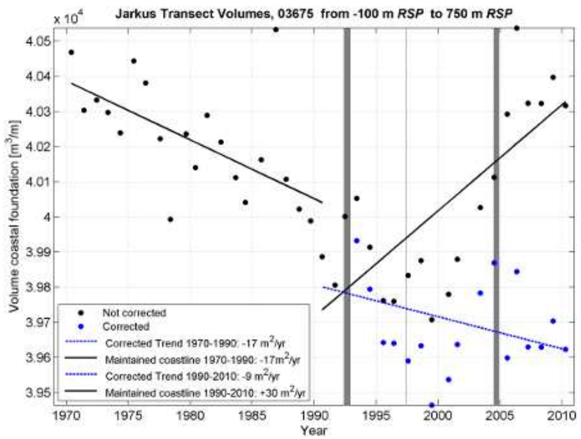

Nourishments type, Noord-Holland 03700
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

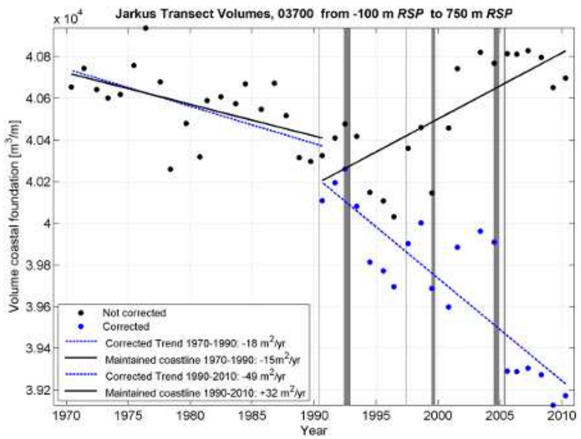

Cross-shore Measurements Extension, Noord-Holland 03650
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

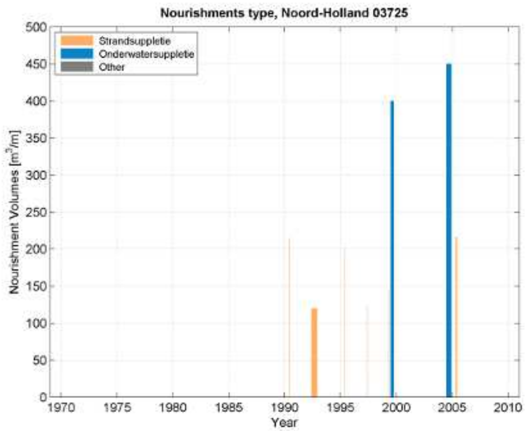

Cross-shore Measurements Extension, Noord-Holland 03675
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

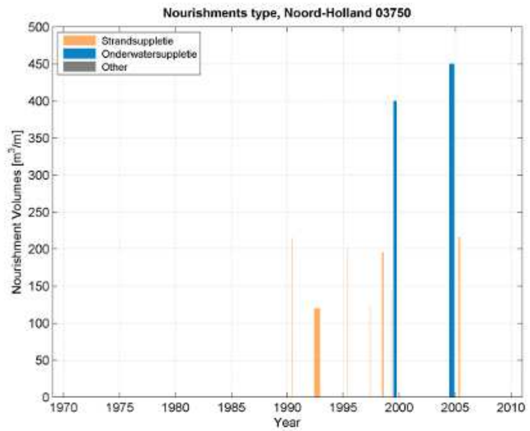

Cross-shore Measurements Extension, Noord-Holland 03700
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

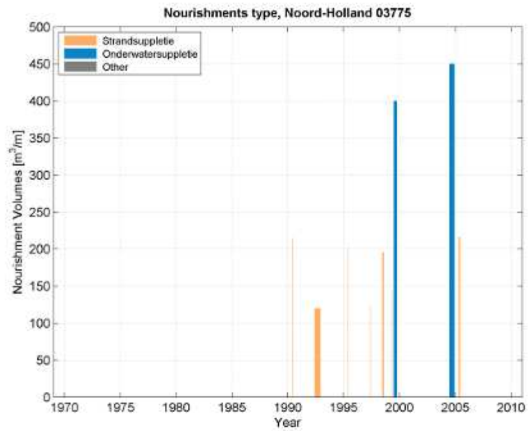

Jarkus Transect Volumes, 03650 from -100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -16 m^2/yr
Maintained coastline 1970-1990: -16m^2/yr
Corrected Trend 1990-2010: -18 m^2/yr
Maintained coastline 1990-2010: +21 m^2/yr
Year

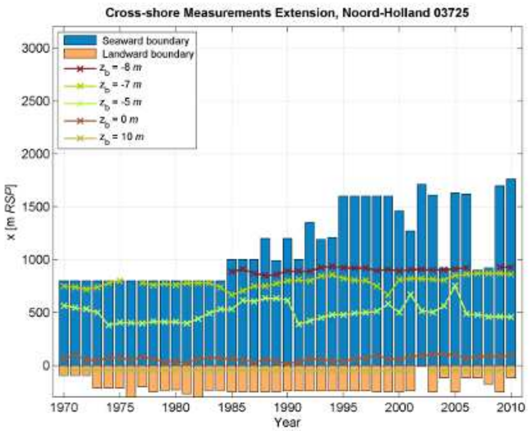

Jarkus Transect Volumes, 03675 from -100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -17 m^2/yr
Maintained coastline 1970-1990: -17m^2/yr
Corrected Trend 1990-2010: -9 m^2/yr
Maintained coastline 1990-2010: +30 m^2/yr
Year

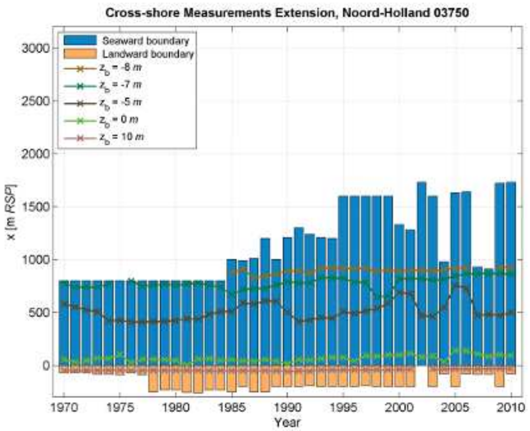

Jarkus Transect Volumes, 03700 from -100 m RSP to 750 m RSP
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -18 m^2/yr
Maintained coastline 1970-1990: -15m^2/yr
Corrected Trend 1990-2010: -49 m^2/yr
Maintained coastline 1990-2010: +32 m^2/yr
Year

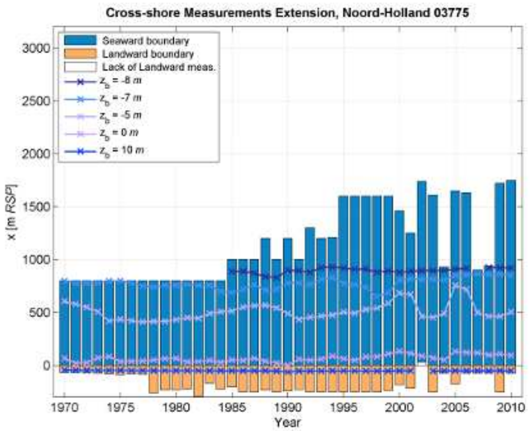

Nourishments type, Noord-Holland 03725
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

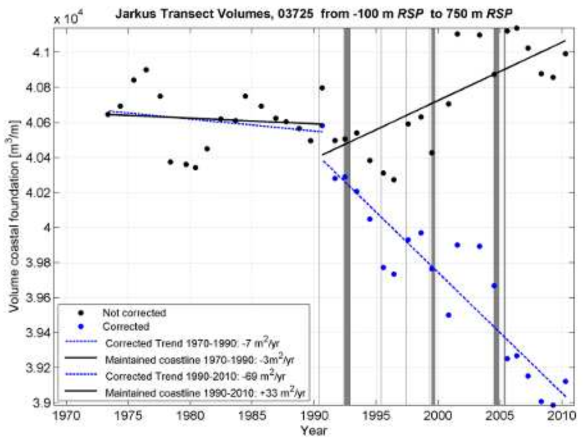

Nourishments type, Noord-Holland 03750
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

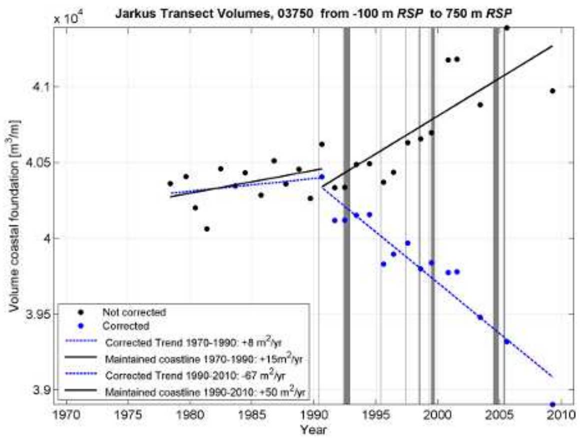

Nourishments type, Noord-Holland 03775
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

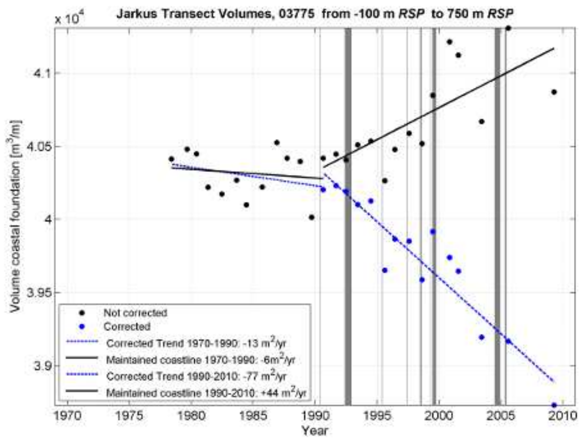

Cross-shore Measurements Extension, Noord-Holland 03725
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

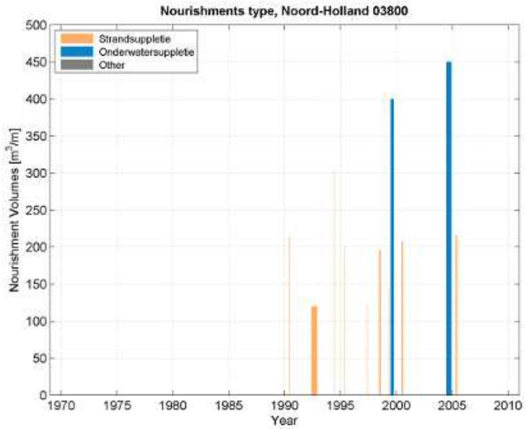
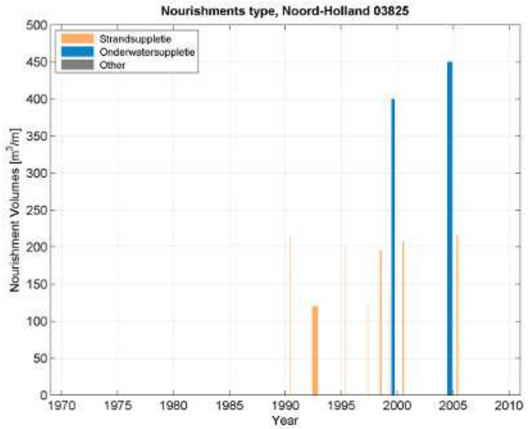
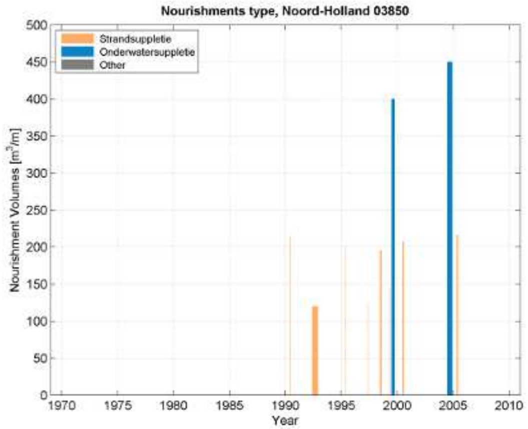
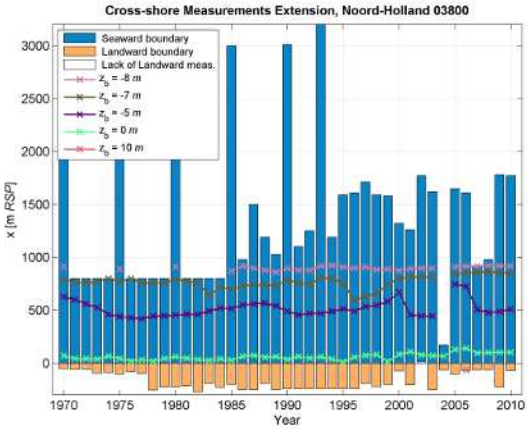
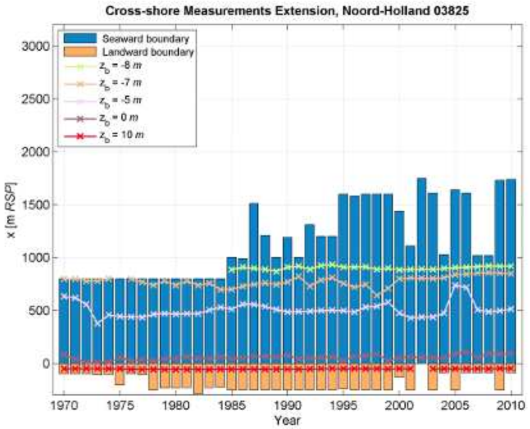
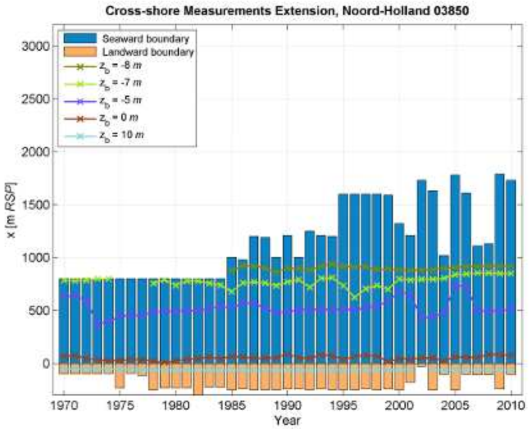
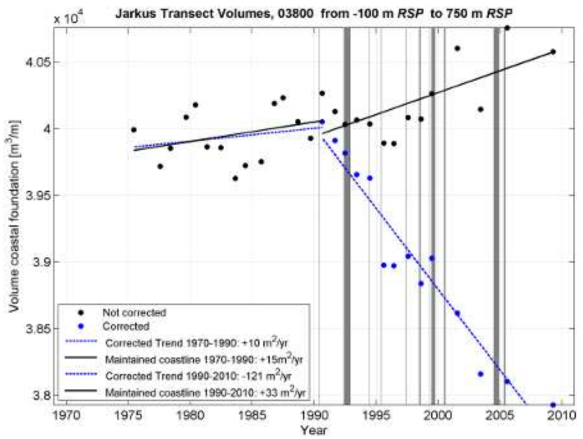
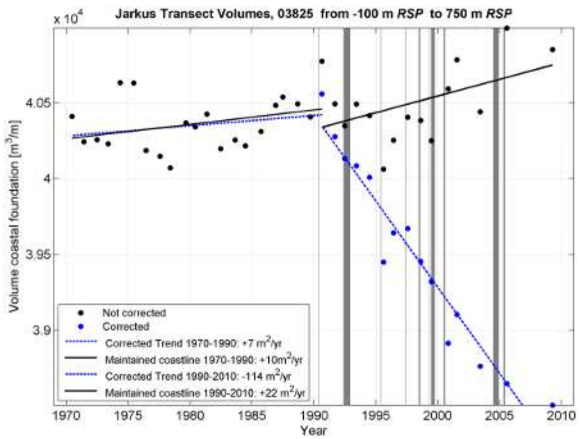
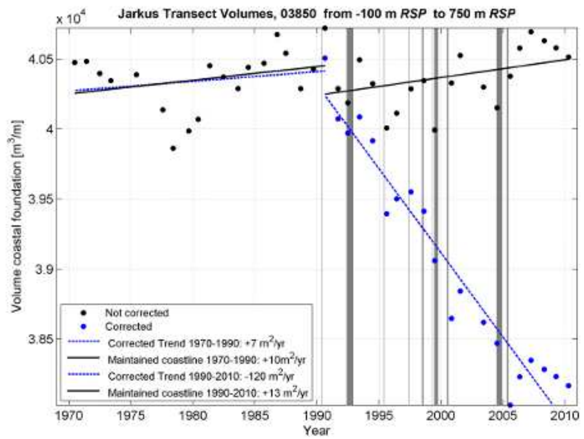

Cross-shore Measurements Extension, Noord-Holland 03750
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

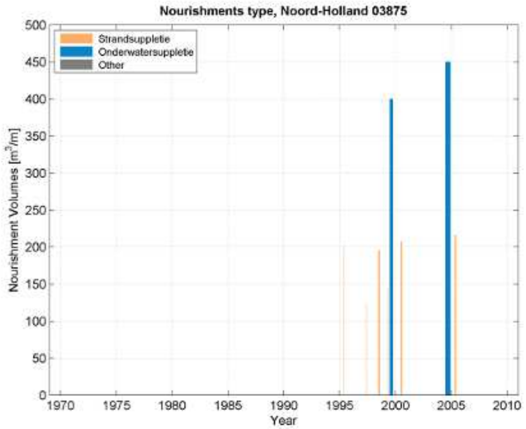

Cross-shore Measurements Extension, Noord-Holland 03775
Seaward boundary
Landward boundary
Lack of Landward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

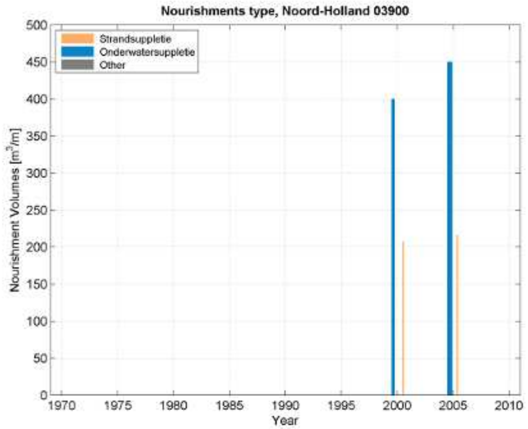

Jarkus Transect Volumes, 03725 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -7 m2/yr
Maintained coastline 1970-1990: -3m2/yr
Corrected Trend 1990-2010: -69 m2/yr
Maintained coastline 1990-2010: +33 m2/yr
Volume coastal foundation [m3/m]
Year

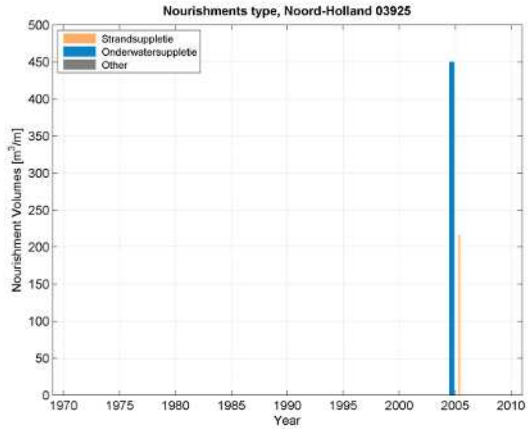

Jarkus Transect Volumes, 03750 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +8 m2/yr
Maintained coastline 1970-1990: +15m2/yr
Corrected Trend 1990-2010: -67 m2/yr
Maintained coastline 1990-2010: +50 m2/yr
Volume coastal foundation [m3/m]
Year

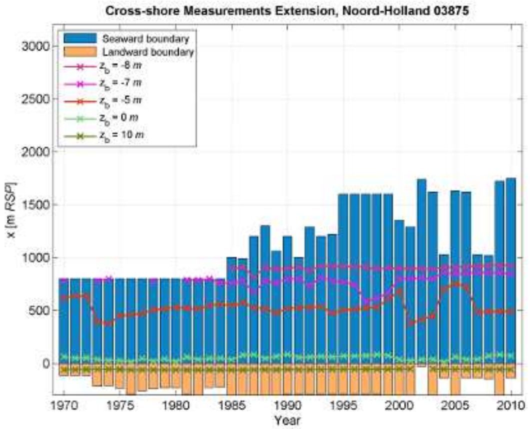

Jarkus Transect Volumes, 03775 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -13 m2/yr
Maintained coastline 1970-1990: -6m2/yr
Corrected Trend 1990-2010: -77 m2/yr
Maintained coastline 1990-2010: +44 m2/yr
Volume coastal foundation [m3/m]
Year

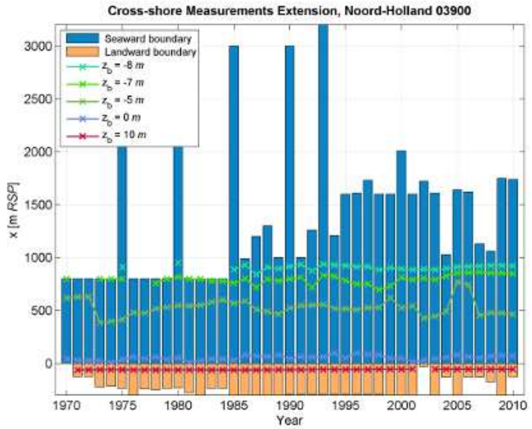

Nourishments type, Noord-Holland 03800
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

Nourishments type, Noord-Holland 03825
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

Nourishments type, Noord-Holland 03850
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

Cross-shore Measurements Extension, Noord-Holland 03800
Seaward boundary
Landward boundary
Lack of Landward meas.
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

Cross-shore Measurements Extension, Noord-Holland 03825
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

Cross-shore Measurements Extension, Noord-Holland 03850
Seaward boundary
Landward boundary
zb = -8 m
zb = -7 m
zb = -5 m
zb = 0 m
zb = 10 m
x [m RSP]
Year

Jarkus Transect Volumes, 03800 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +10 m2/yr
Maintained coastline 1970-1990: +15m2/yr
Corrected Trend 1990-2010: -121 m2/yr
Maintained coastline 1990-2010: +33 m2/yr
Volume coastal foundation [m3/m]
Year

Jarkus Transect Volumes, 03825 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +7 m2/yr
Maintained coastline 1970-1990: +10m2/yr
Corrected Trend 1990-2010: -114 m2/yr
Maintained coastline 1990-2010: +22 m2/yr
Volume coastal foundation [m3/m]
Year

Jarkus Transect Volumes, 03850 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +7 m2/yr
Maintained coastline 1970-1990: +10m2/yr
Corrected Trend 1990-2010: -120 m2/yr
Maintained coastline 1990-2010: +13 m2/yr
Volume coastal foundation [m3/m]
Year

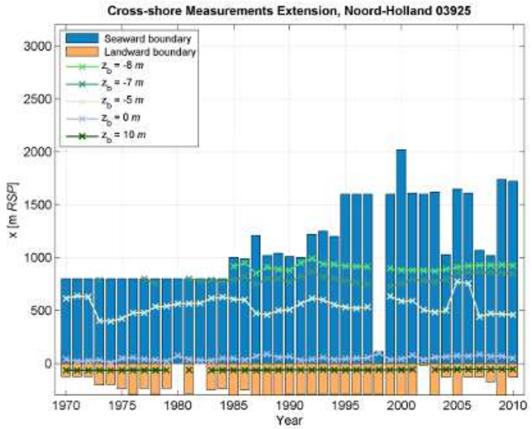

Nourishments type, Noord-Holland 03875
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

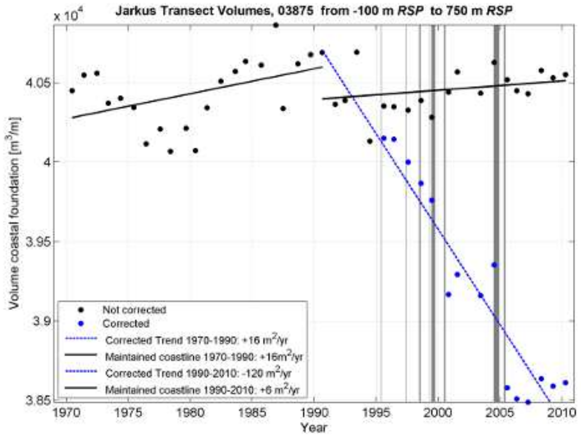

Nourishments type, Noord-Holland 03900
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

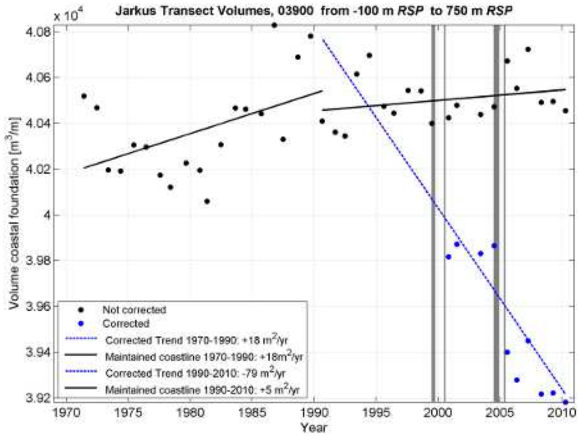

Nourishments type, Noord-Holland 03925
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

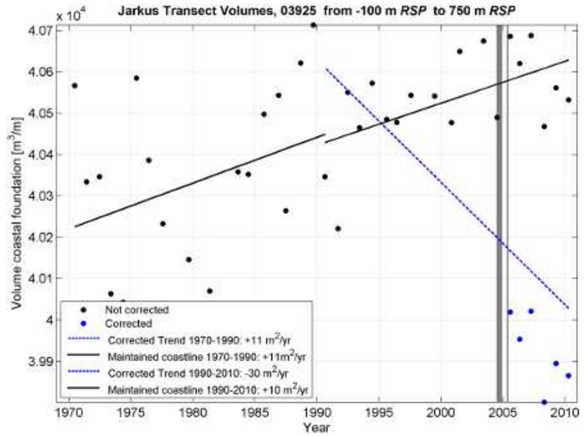

Cross-shore Measurements Extension, Noord-Holland 03875
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

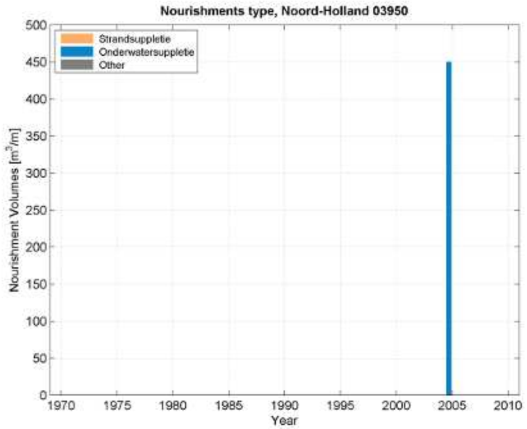

Cross-shore Measurements Extension, Noord-Holland 03900
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

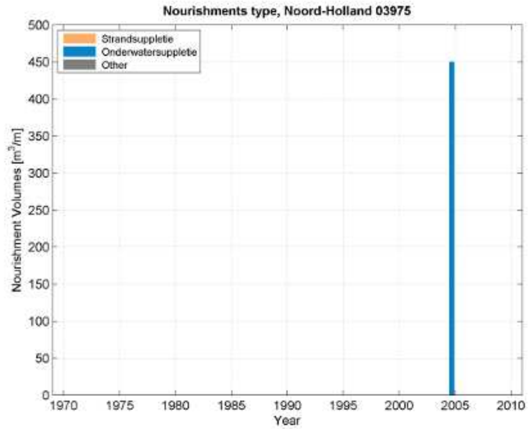

Cross-shore Measurements Extension, Noord-Holland 03925
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

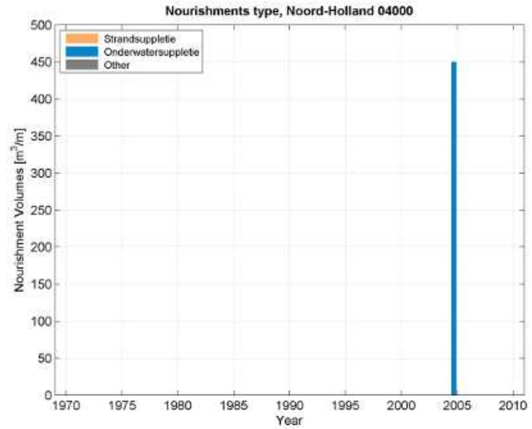

Jarkus Transect Volumes, 03875 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +16 m^2/yr
Maintained coastline 1970-1990: +16m^2/yr
Corrected Trend 1990-2010: -120 m^2/yr
Maintained coastline 1990-2010: +6 m^2/yr
Year

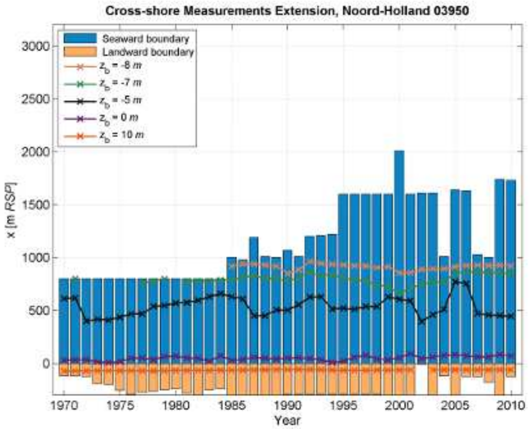

Jarkus Transect Volumes, 03900 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +18 m^2/yr
Maintained coastline 1970-1990: +18m^2/yr
Corrected Trend 1990-2010: -79 m^2/yr
Maintained coastline 1990-2010: +5 m^2/yr
Year

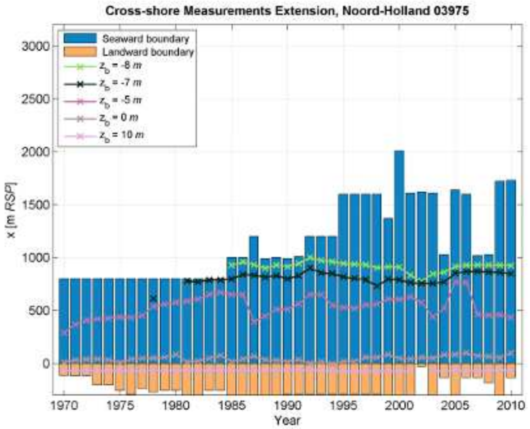

Jarkus Transect Volumes, 03925 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +11 m^2/yr
Maintained coastline 1970-1990: +11m^2/yr
Corrected Trend 1990-2010: -30 m^2/yr
Maintained coastline 1990-2010: +10 m^2/yr
Year

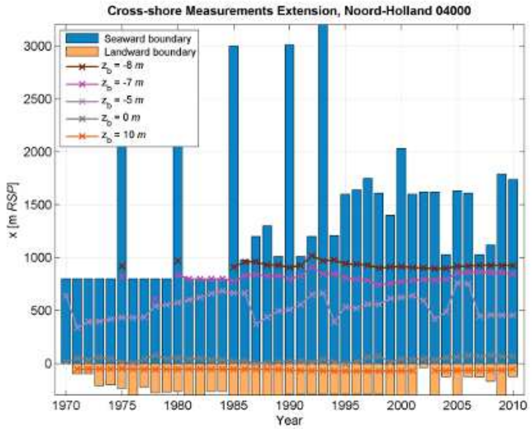

Nourishments type, Noord-Holland 03950
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

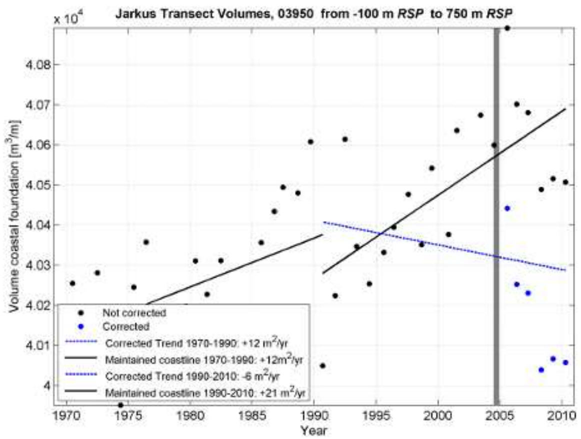

Nourishments type, Noord-Holland 03975
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

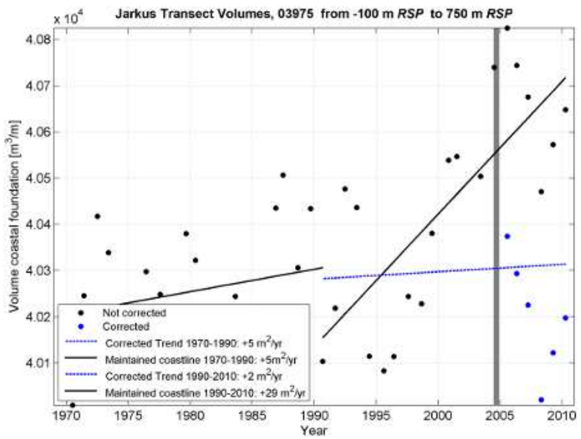

Nourishments type, Noord-Holland 04000
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

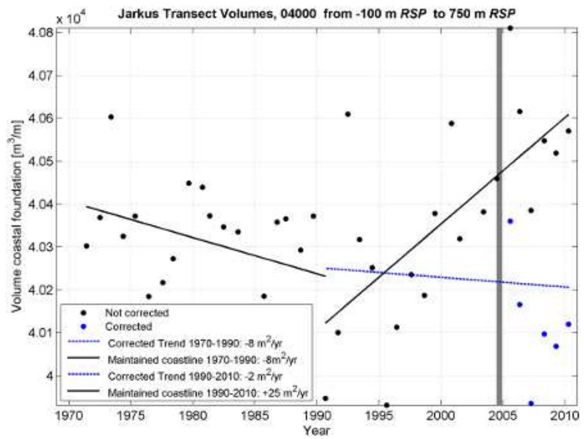

Cross-shore Measurements Extension, Noord-Holland 03950
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

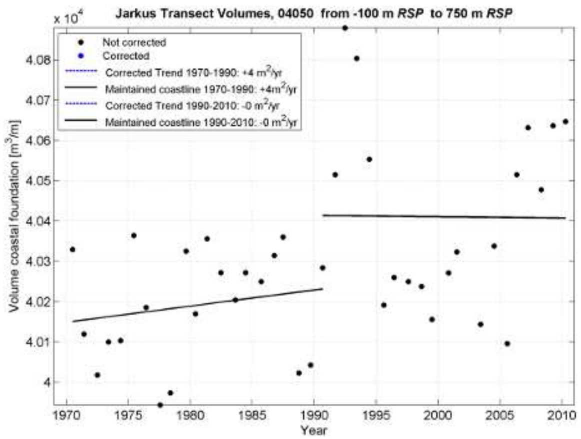

Cross-shore Measurements Extension, Noord-Holland 03975
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

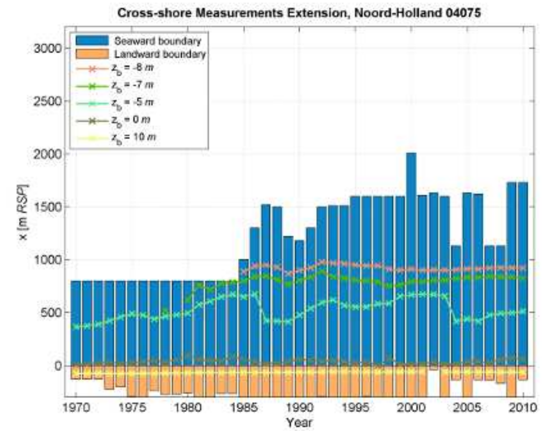

Cross-shore Measurements Extension, Noord-Holland 04000
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

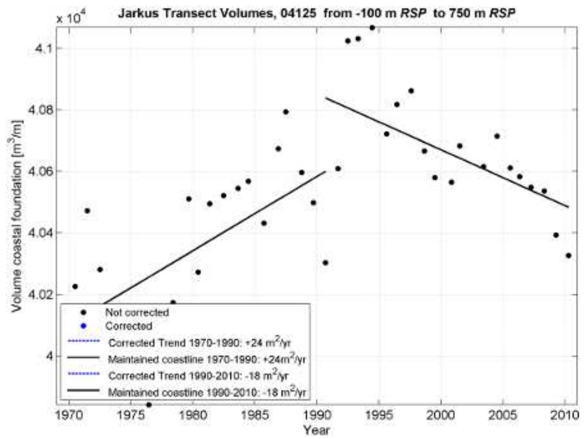

Jarkus Transect Volumes, 03950 from -100 m RSP to 750 m RSP
x 10⁴
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +12 m²/yr
Maintained coastline 1970-1990: +12m²/yr
Corrected Trend 1990-2010: -6 m²/yr
Maintained coastline 1990-2010: +21 m²/yr
Year

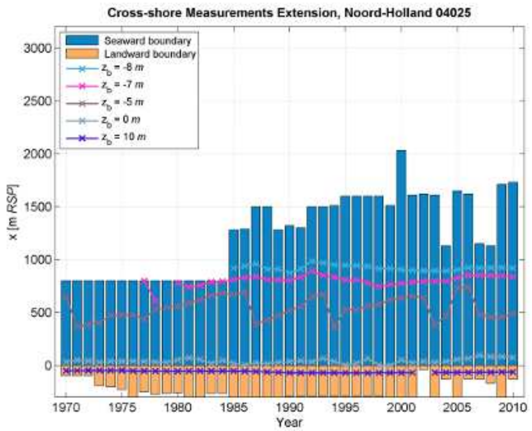

Jarkus Transect Volumes, 03975 from -100 m RSP to 750 m RSP
x 10⁴
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +5 m²/yr
Maintained coastline 1970-1990: +5m²/yr
Corrected Trend 1990-2010: +2 m²/yr
Maintained coastline 1990-2010: +29 m²/yr
Year

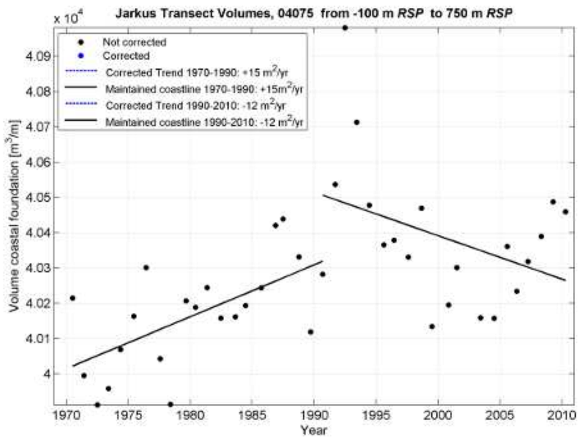

Jarkus Transect Volumes, 04000 from -100 m RSP to 750 m RSP
x 10⁴
Volume coastal foundation [m³/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -8 m²/yr
Maintained coastline 1970-1990: -8m²/yr
Corrected Trend 1990-2010: -2 m²/yr
Maintained coastline 1990-2010: +25 m²/yr
Year

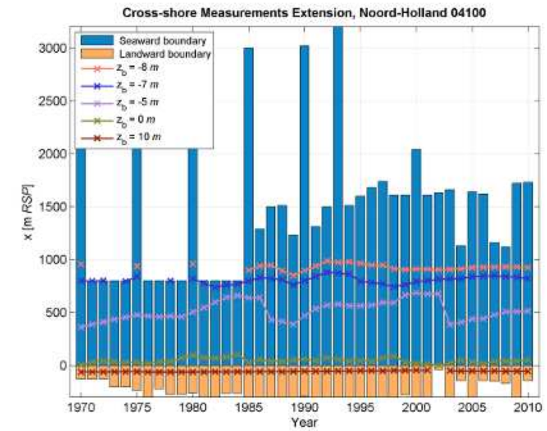

Jarkus Transect Volumes, 04050 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +4 m²/yr
Maintained coastline 1970-1990: +4m²/yr
Corrected Trend 1990-2010: -0 m²/yr
Maintained coastline 1990-2010: -0 m²/yr
Volume coastal foundation [m³/m]
Year

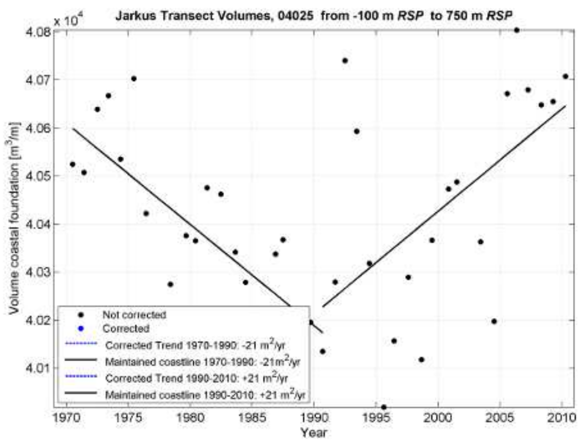

Cross-shore Measurements Extension, Noord-Holland 04075
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

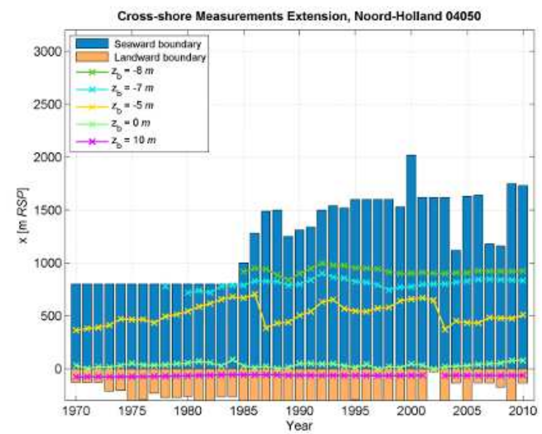

Jarkus Transect Volumes, 04125 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +24 m²/yr
Maintained coastline 1970-1990: +24m²/yr
Corrected Trend 1990-2010: -18 m²/yr
Maintained coastline 1990-2010: -18 m²/yr
Volume coastal foundation [m³/m]
Year

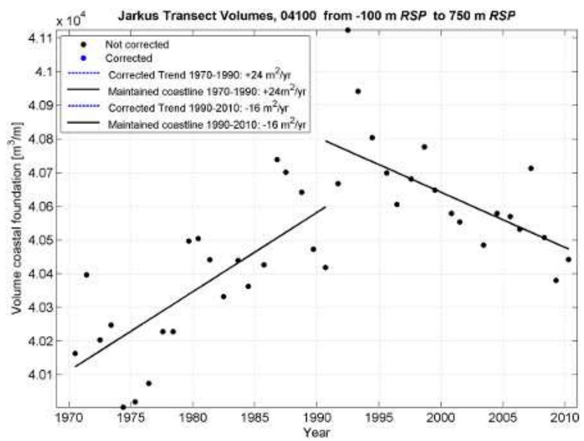

Cross-shore Measurements Extension, Noord-Holland 04025
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

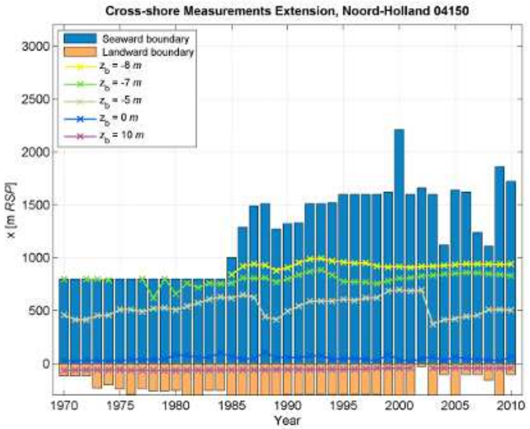

Jarkus Transect Volumes, 04075 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +15 m²/yr
Maintained coastline 1970-1990: +15m²/yr
Corrected Trend 1990-2010: -12 m²/yr
Maintained coastline 1990-2010: -12 m²/yr
Volume coastal foundation [m³/m]
Year

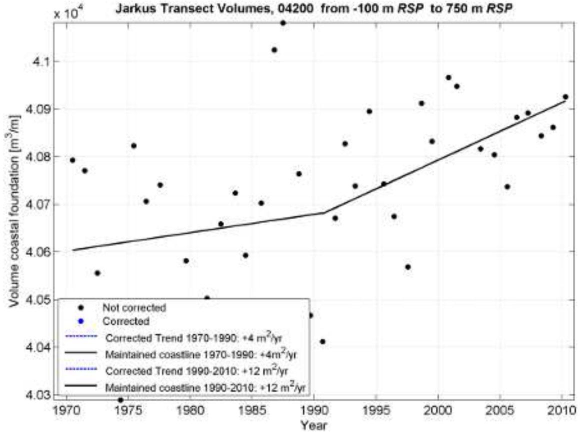

Cross-shore Measurements Extension, Noord-Holland 04100
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

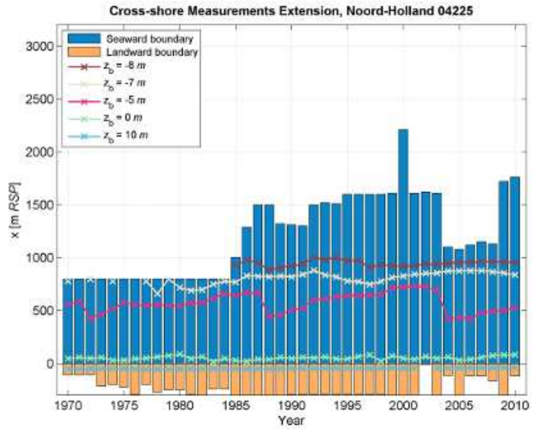

Jarkus Transect Volumes, 04025 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -21 m²/yr
Maintained coastline 1970-1990: -21m²/yr
Corrected Trend 1990-2010: +21 m²/yr
Maintained coastline 1990-2010: +21 m²/yr
Volume coastal foundation [m³/m]
Year

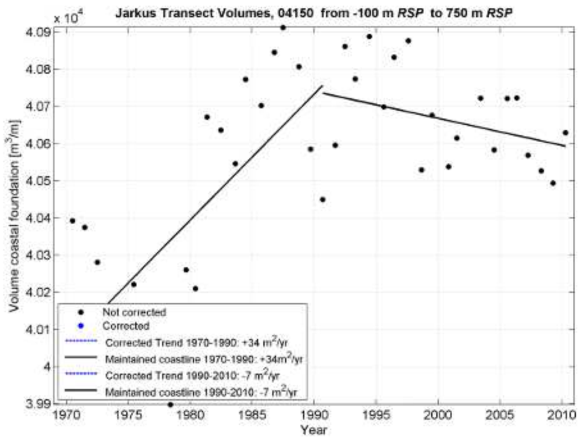

Cross-shore Measurements Extension, Noord-Holland 04050
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

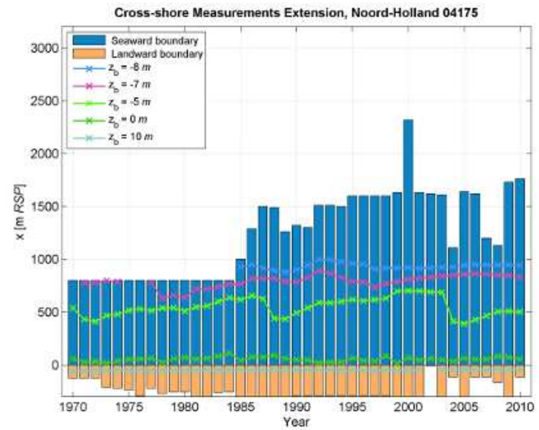

Jarkus Transect Volumes, 04100 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +24 m²/yr
Maintained coastline 1970-1990: +24m²/yr
Corrected Trend 1990-2010: -16 m²/yr
Maintained coastline 1990-2010: -16 m²/yr
Volume coastal foundation [m³/m]
Year

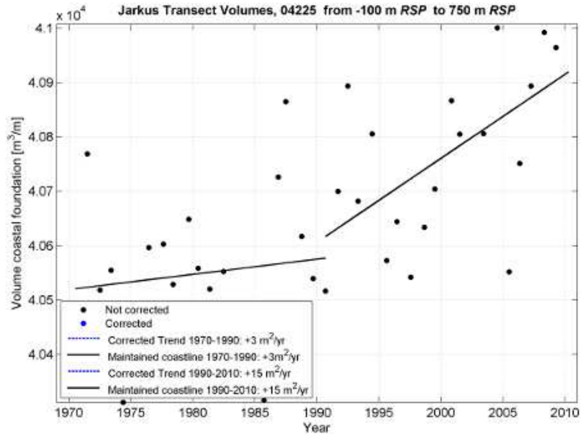

Cross-shore Measurements Extension, Noord-Holland 04150
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

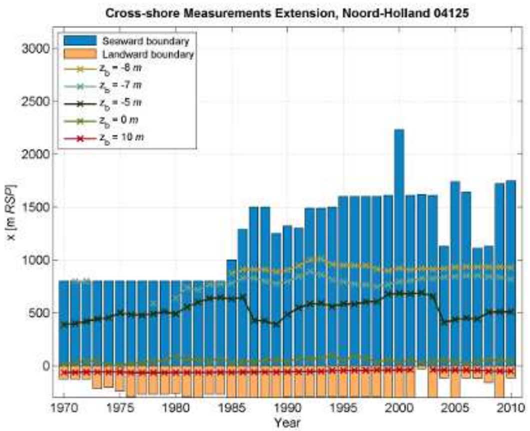

Jarkus Transect Volumes, 04200 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +4 m^2/yr
Maintained coastline 1970-1990: +4m^2/yr
Corrected Trend 1990-2010: +12 m^2/yr
Maintained coastline 1990-2010: +12 m^2/yr
Volume coastal foundation [m^3/m]
Year

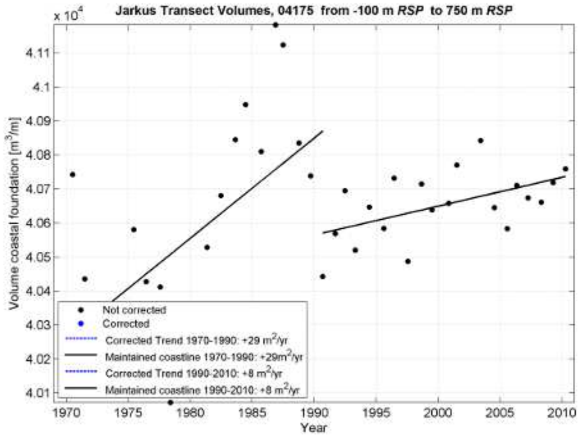

Cross-shore Measurements Extension, Noord-Holland 04225
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

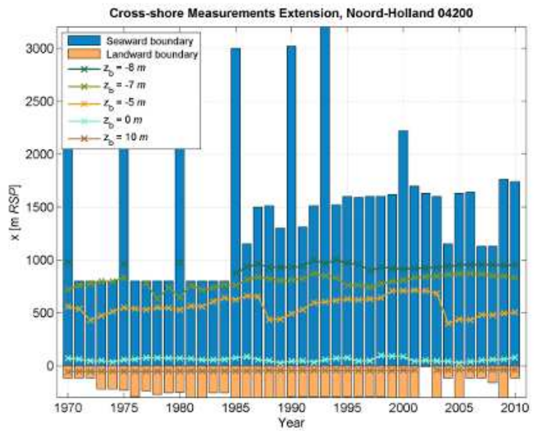

Jarkus Transect Volumes, 04150 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +34 m^2/yr
Maintained coastline 1970-1990: +34m^2/yr
Corrected Trend 1990-2010: -7 m^2/yr
Maintained coastline 1990-2010: -7 m^2/yr
Volume coastal foundation [m^3/m]
Year

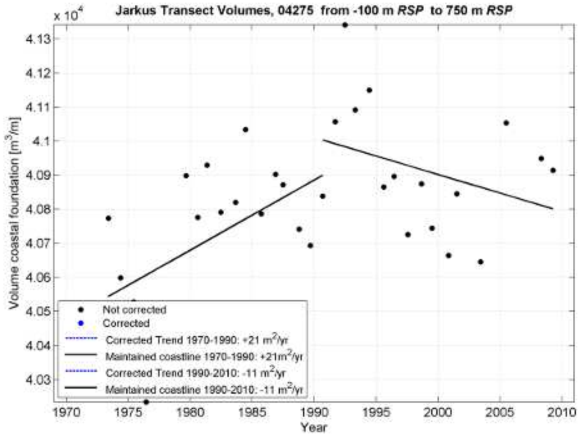

Cross-shore Measurements Extension, Noord-Holland 04175
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

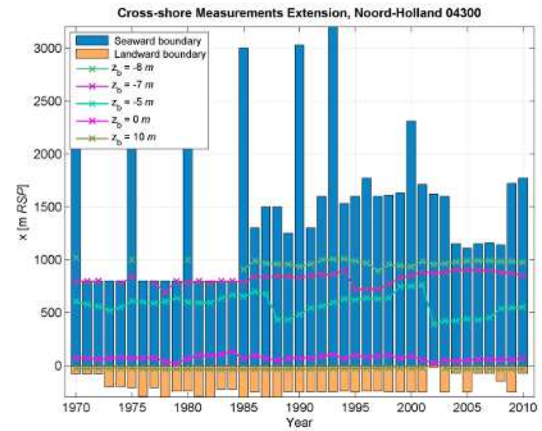

Jarkus Transect Volumes, 04225 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +3 m^2/yr
Maintained coastline 1970-1990: +3m^2/yr
Corrected Trend 1990-2010: +15 m^2/yr
Maintained coastline 1990-2010: +15 m^2/yr
Volume coastal foundation [m^3/m]
Year

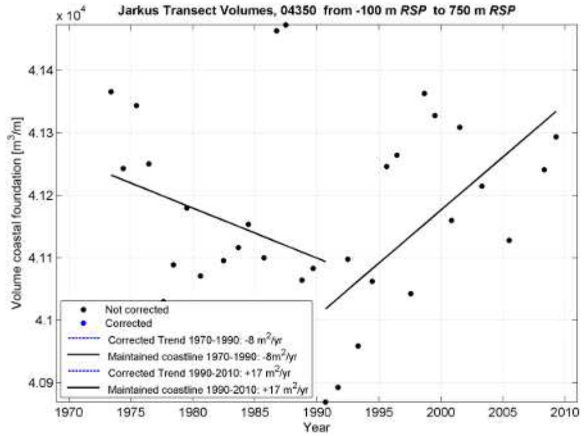

Cross-shore Measurements Extension, Noord-Holland 04125
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

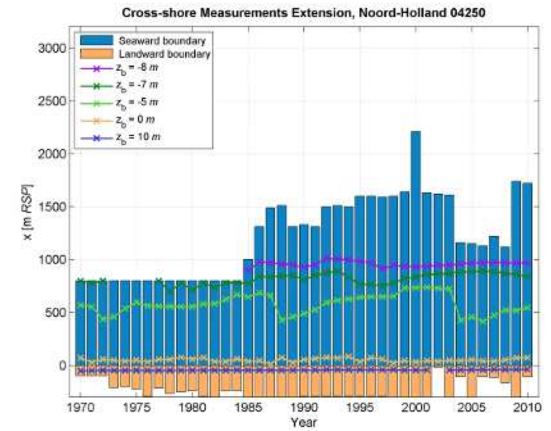

Jarkus Transect Volumes, 04175 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +29 m^2/yr
Maintained coastline 1970-1990: +29m^2/yr
Corrected Trend 1990-2010: +8 m^2/yr
Maintained coastline 1990-2010: +8 m^2/yr
Volume coastal foundation [m^3/m]
Year

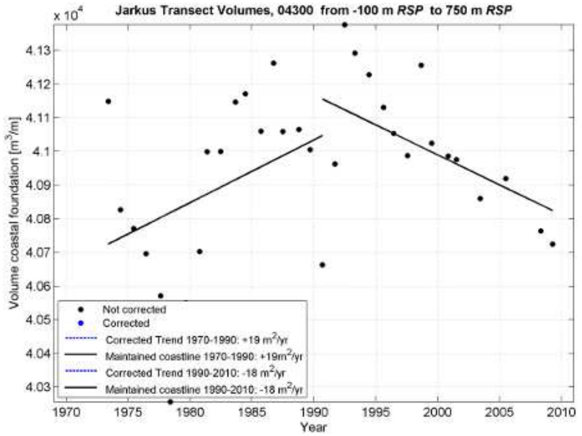

Cross-shore Measurements Extension, Noord-Holland 04200
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

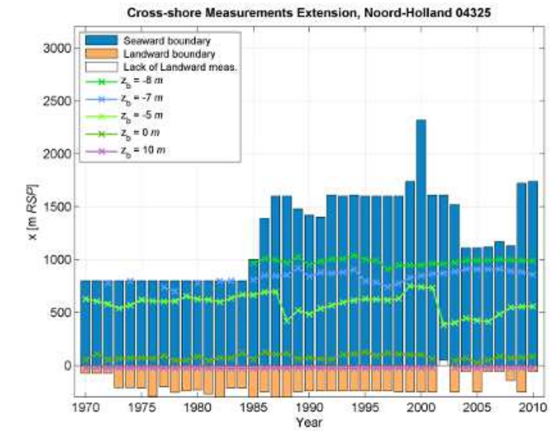

Jarkus Transect Volumes, 04275 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +21 m^2/yr
Maintained coastline 1970-1990: +21m^2/yr
Corrected Trend 1990-2010: -11 m^2/yr
Maintained coastline 1990-2010: -11 m^2/yr

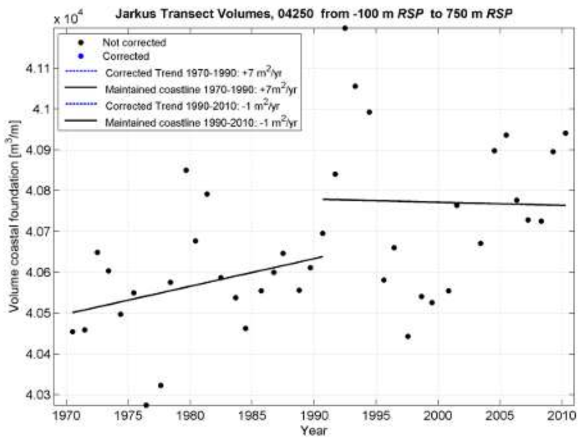

Cross-shore Measurements Extension, Noord-Holland 04300
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

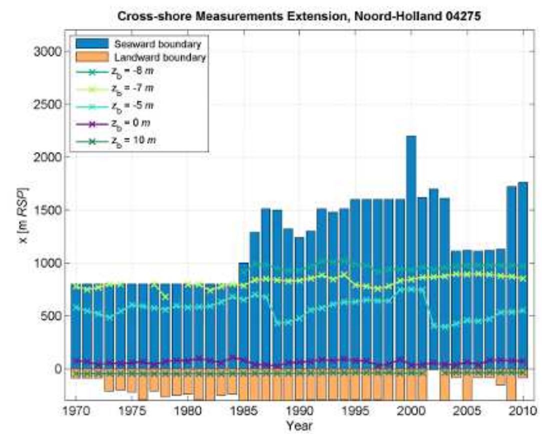

Jarkus Transect Volumes, 04350 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -8 m^2/yr
Maintained coastline 1970-1990: -8m^2/yr
Corrected Trend 1990-2010: +17 m^2/yr
Maintained coastline 1990-2010: +17 m^2/yr

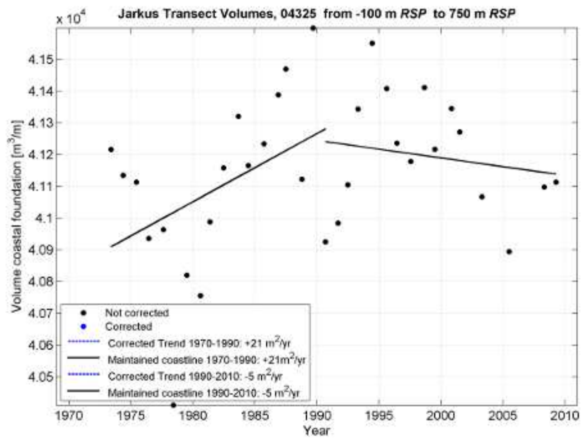

Cross-shore Measurements Extension, Noord-Holland 04250
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

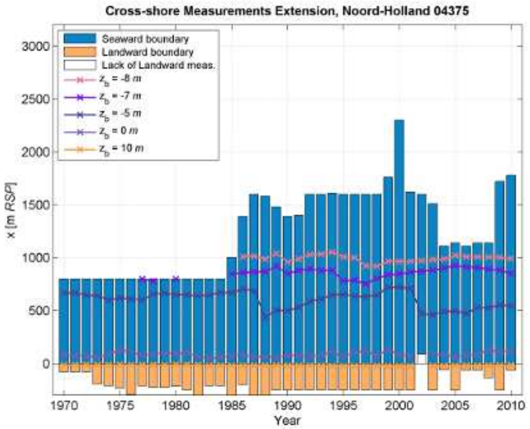

Jarkus Transect Volumes, 04300 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +19 m^2/yr
Maintained coastline 1970-1990: +19m^2/yr
Corrected Trend 1990-2010: -18 m^2/yr
Maintained coastline 1990-2010: -18 m^2/yr

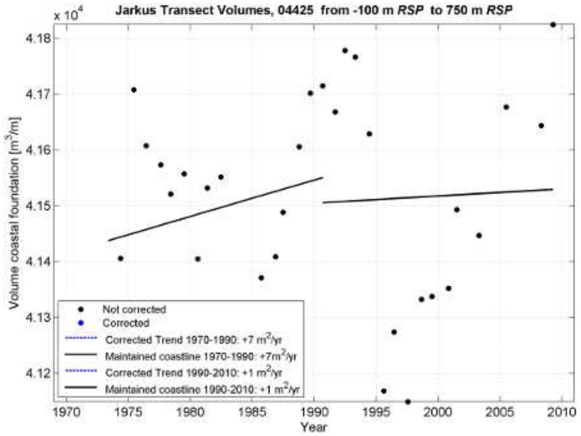

Cross-shore Measurements Extension, Noord-Holland 04325
x [m RSP]
Year
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

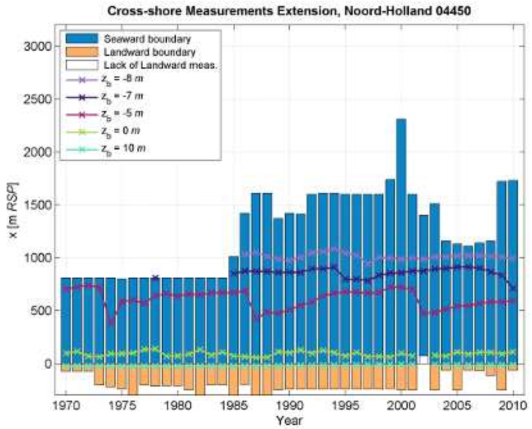

Jarkus Transect Volumes, 04250 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +7 m^2/yr
Maintained coastline 1970-1990: +7m^2/yr
Corrected Trend 1990-2010: -1 m^2/yr
Maintained coastline 1990-2010: -1 m^2/yr

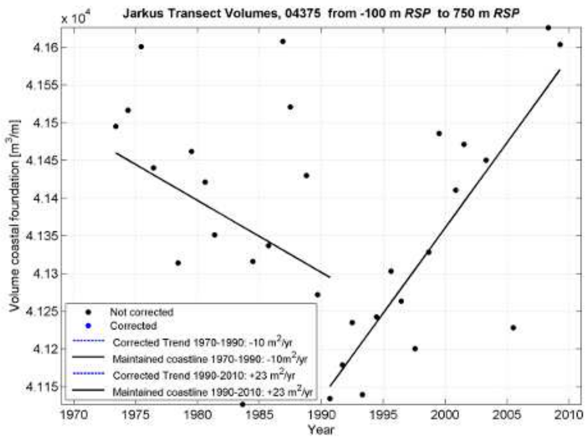

Cross-shore Measurements Extension, Noord-Holland 04275
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

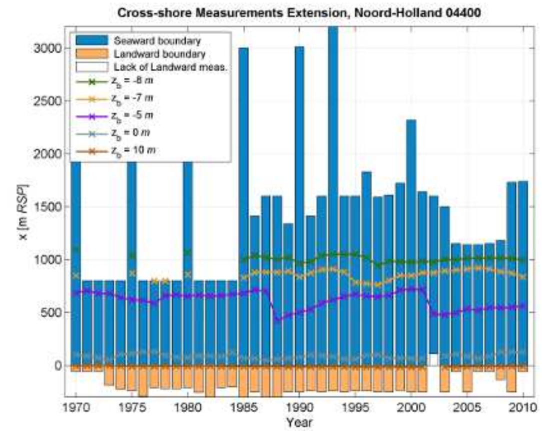

Jarkus Transect Volumes, 04325 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +21 m^2/yr
Maintained coastline 1970-1990: +21m^2/yr
Corrected Trend 1990-2010: -5 m^2/yr
Maintained coastline 1990-2010: -5 m^2/yr

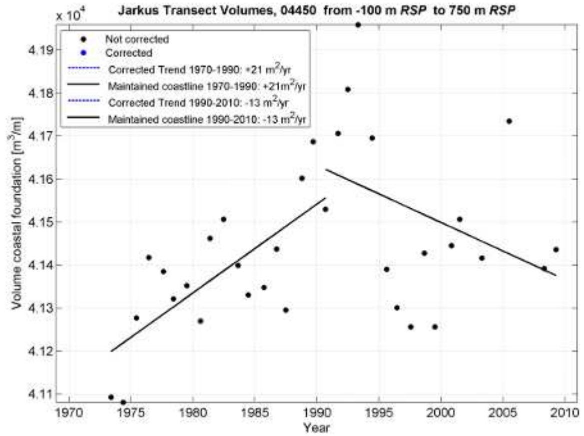

Cross-shore Measurements Extension, Noord-Holland 04375
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

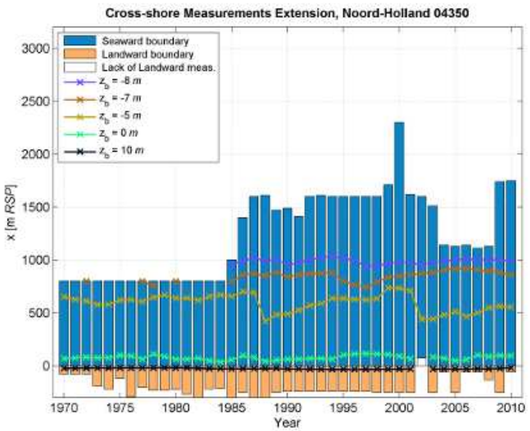

Jarkus Transect Volumes, 04425 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +7 m^2/yr
Maintained coastline 1970-1990: +7m^2/yr
Corrected Trend 1990-2010: +1 m^2/yr
Maintained coastline 1990-2010: +1 m^2/yr
Volume coastal foundation [m^3/m]
Year

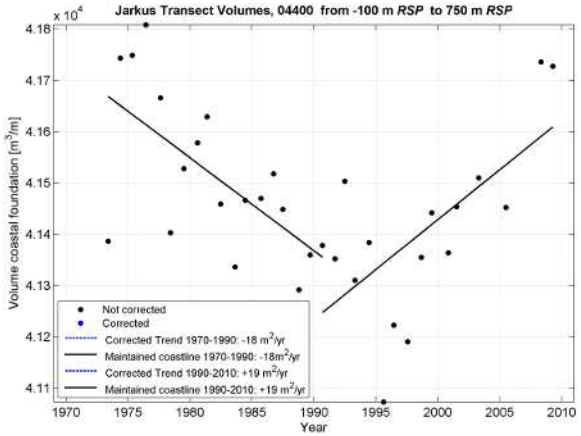

Cross-shore Measurements Extension, Noord-Holland 04450
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

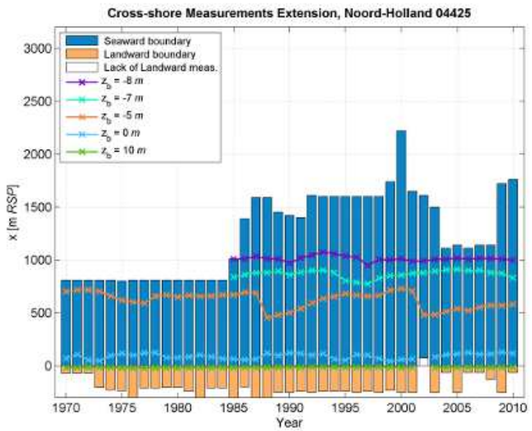

Jarkus Transect Volumes, 04375 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -10 m^2/yr
Maintained coastline 1970-1990: -10m^2/yr
Corrected Trend 1990-2010: +23 m^2/yr
Maintained coastline 1990-2010: +23 m^2/yr
Volume coastal foundation [m^3/m]
Year

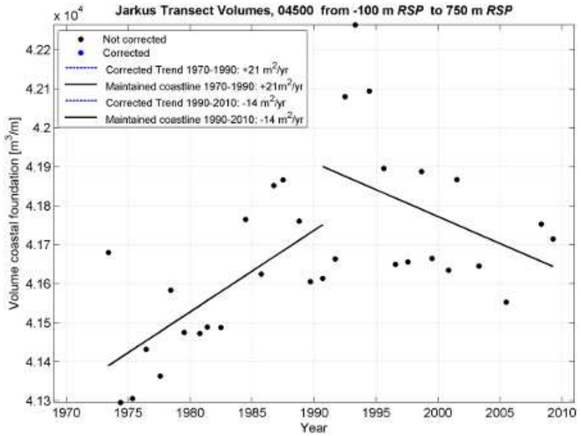

Cross-shore Measurements Extension, Noord-Holland 04400
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

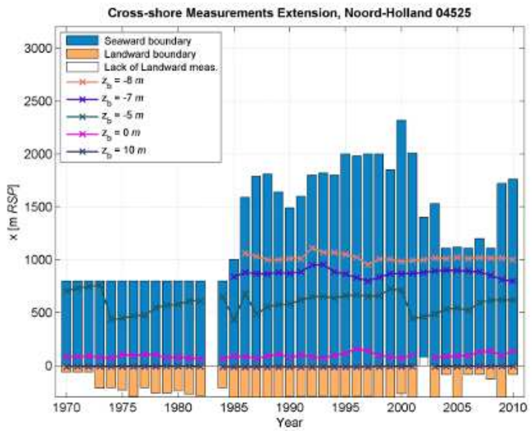

Jarkus Transect Volumes, 04450 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +21 m^2/yr
Maintained coastline 1970-1990: +21m^2/yr
Corrected Trend 1990-2010: -13 m^2/yr
Maintained coastline 1990-2010: -13 m^2/yr
Volume coastal foundation [m^3/m]
Year

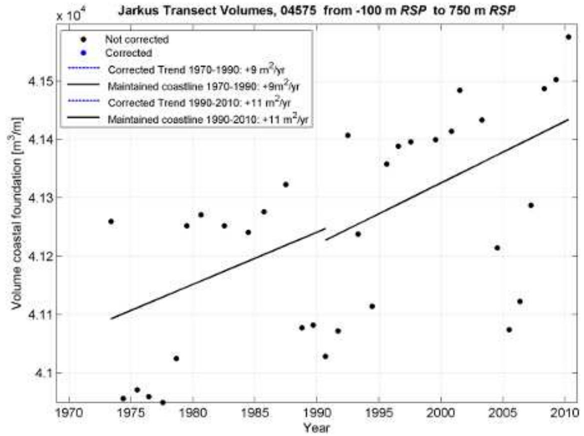

Cross-shore Measurements Extension, Noord-Holland 04350
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

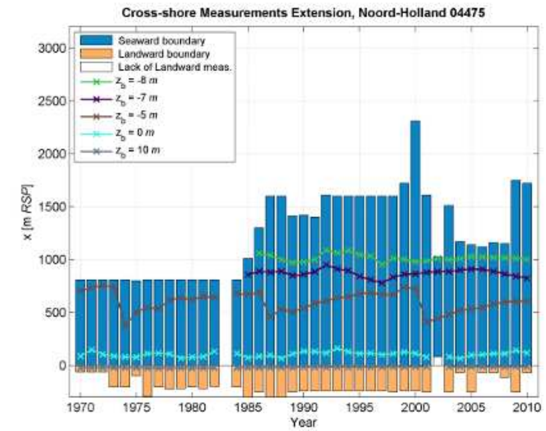

Jarkus Transect Volumes, 04400 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: -18 m^2/yr
Maintained coastline 1970-1990: -18m^2/yr
Corrected Trend 1990-2010: +19 m^2/yr
Maintained coastline 1990-2010: +19 m^2/yr
Volume coastal foundation [m^3/m]
Year

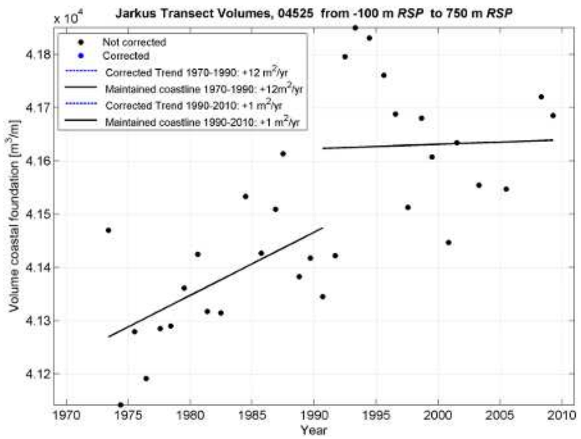

Cross-shore Measurements Extension, Noord-Holland 04425
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

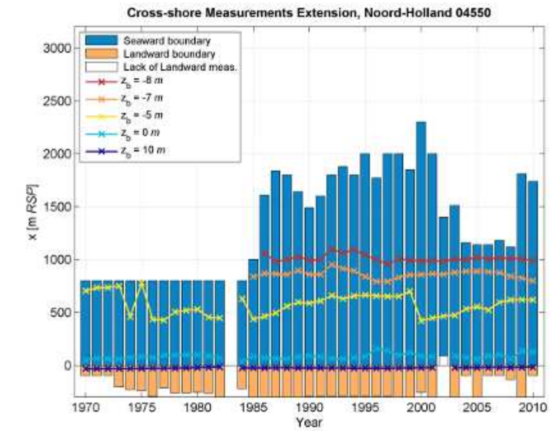

Jarkus Transect Volumes, 04500 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +21 m²/yr
Maintained coastline 1970-1990: +21m²/yr
Corrected Trend 1990-2010: -14 m²/yr
Maintained coastline 1990-2010: -14 m²/yr
Volume coastal foundation [m³/m]
Year

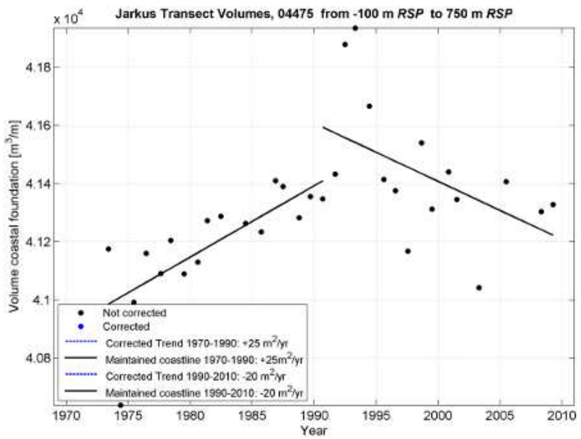

Cross-shore Measurements Extension, Noord-Holland 04525
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

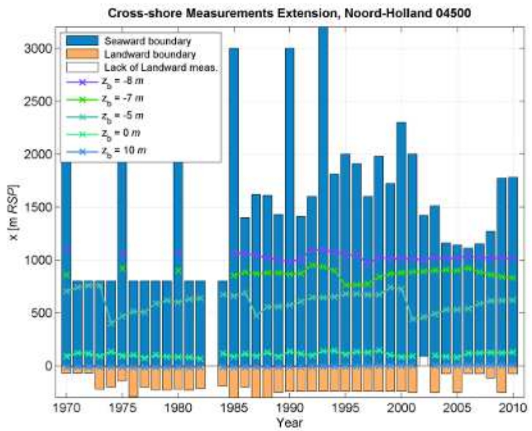

Jarkus Transect Volumes, 04575 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +9 m²/yr
Maintained coastline 1970-1990: +9m²/yr
Corrected Trend 1990-2010: +11 m²/yr
Maintained coastline 1990-2010: +11 m²/yr
Volume coastal foundation [m³/m]
Year

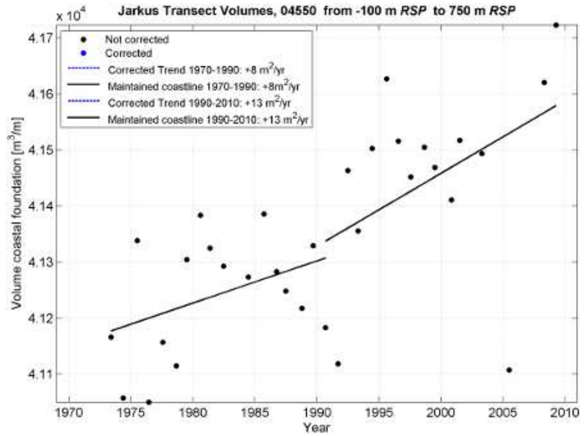

Cross-shore Measurements Extension, Noord-Holland 04475
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

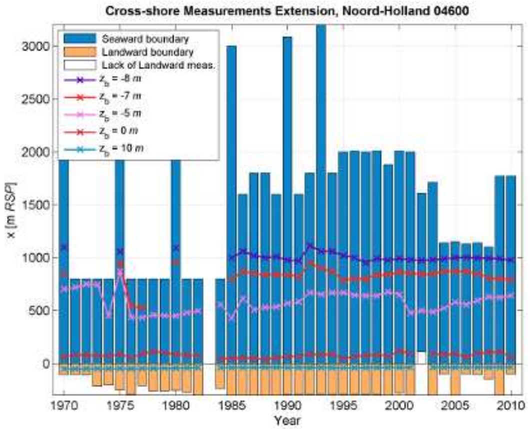

Jarkus Transect Volumes, 04525 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +12 m²/yr
Maintained coastline 1970-1990: +12m²/yr
Corrected Trend 1990-2010: +1 m²/yr
Maintained coastline 1990-2010: +1 m²/yr
Volume coastal foundation [m³/m]
Year

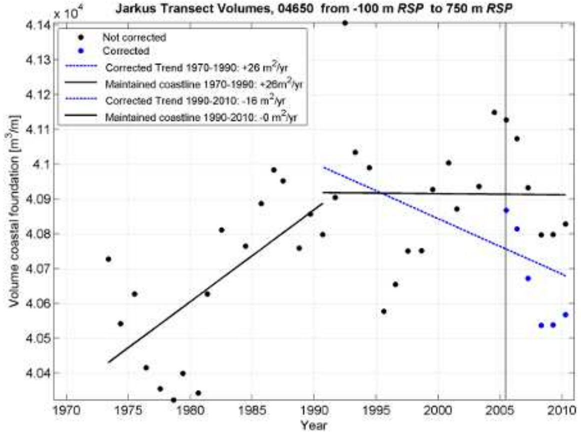

Cross-shore Measurements Extension, Noord-Holland 04550
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

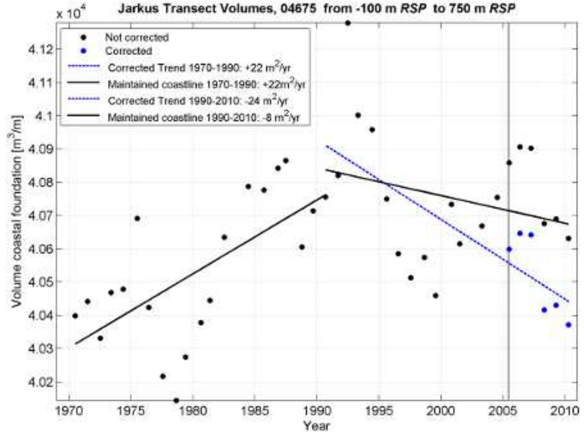

Jarkus Transect Volumes, 04475 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +25 m²/yr
Maintained coastline 1970-1990: +25m²/yr
Corrected Trend 1990-2010: -20 m²/yr
Maintained coastline 1990-2010: -20 m²/yr
Volume coastal foundation [m³/m]
Year

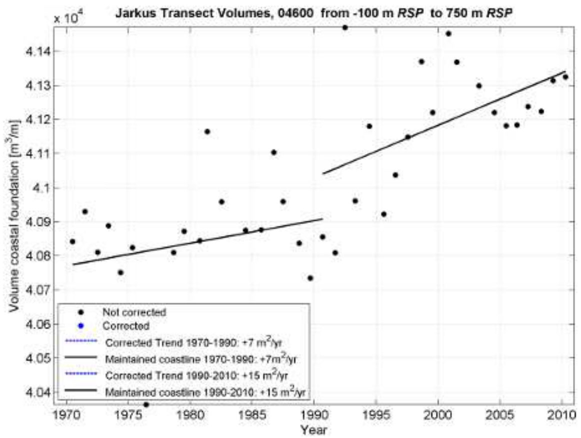

Cross-shore Measurements Extension, Noord-Holland 04500
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

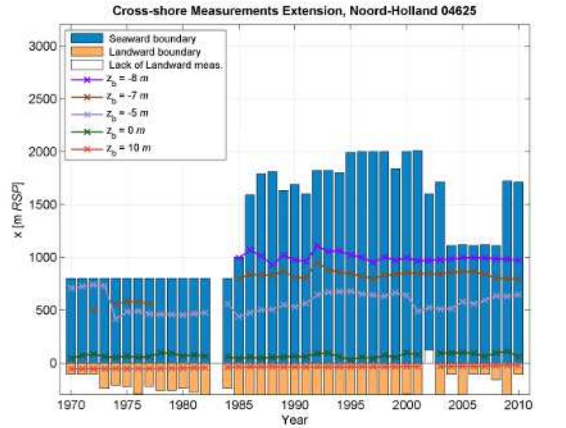

Jarkus Transect Volumes, 04550 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +8 m²/yr
Maintained coastline 1970-1990: +8m²/yr
Corrected Trend 1990-2010: +13 m²/yr
Maintained coastline 1990-2010: +13 m²/yr
Volume coastal foundation [m³/m]
Year

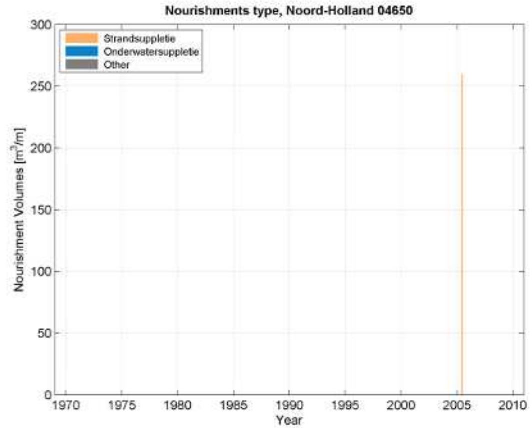

Cross-shore Measurements Extension, Noord-Holland 04600
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

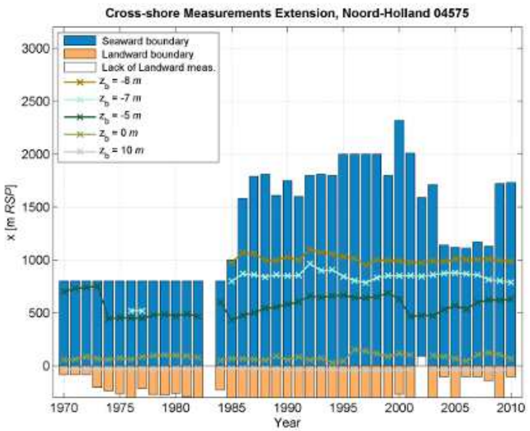

Jarkus Transect Volumes, 04650 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +26 m²/yr
Maintained coastline 1970-1990: +26m²/yr
Corrected Trend 1990-2010: -16 m²/yr
Maintained coastline 1990-2010: -0 m²/yr
Volume coastal foundation [m³/m]
Year

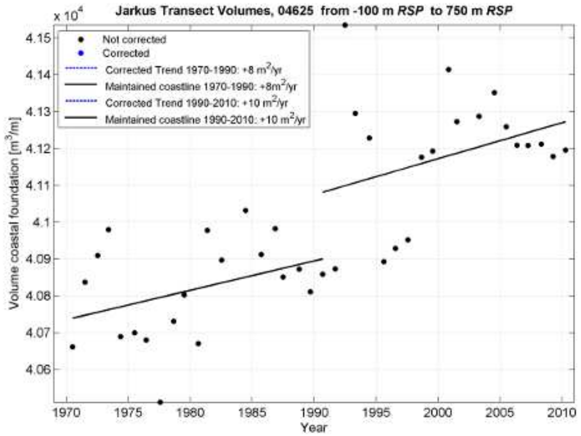

Jarkus Transect Volumes, 04675 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +22 m²/yr
Maintained coastline 1970-1990: +22m²/yr
Corrected Trend 1990-2010: -24 m²/yr
Maintained coastline 1990-2010: -8 m²/yr
Volume coastal foundation [m³/m]
Year

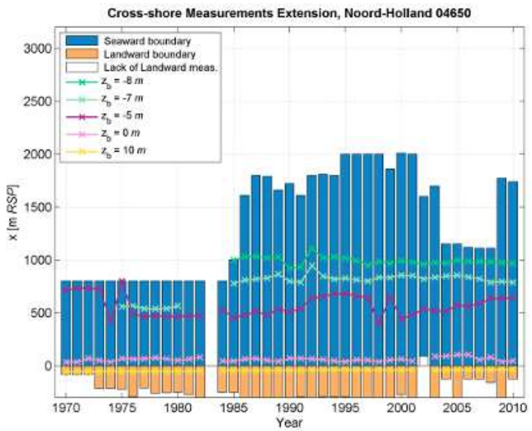

Jarkus Transect Volumes, 04600 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +7 m²/yr
Maintained coastline 1970-1990: +7m²/yr
Corrected Trend 1990-2010: +15 m²/yr
Maintained coastline 1990-2010: +15 m²/yr
Volume coastal foundation [m³/m]
Year

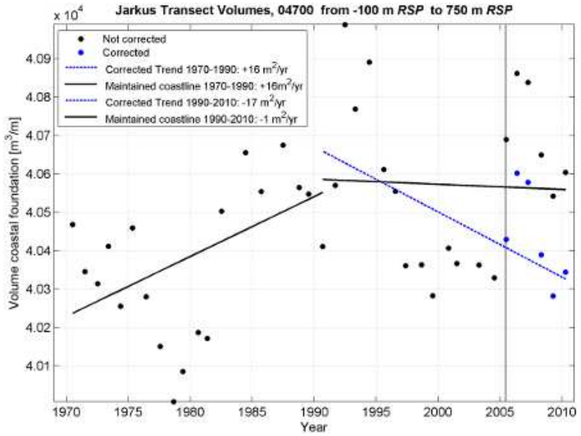

Cross-shore Measurements Extension, Noord-Holland 04625
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year


Nourishments type, Noord-Holland 04650
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year

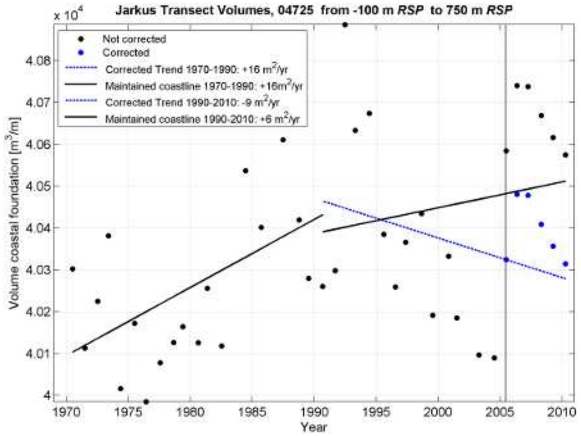

Cross-shore Measurements Extension, Noord-Holland 04575
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year


Jarkus Transect Volumes, 04625 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +8 m²/yr
Maintained coastline 1970-1990: +8m²/yr
Corrected Trend 1990-2010: +10 m²/yr
Maintained coastline 1990-2010: +10 m²/yr
Volume coastal foundation [m³/m]
Year

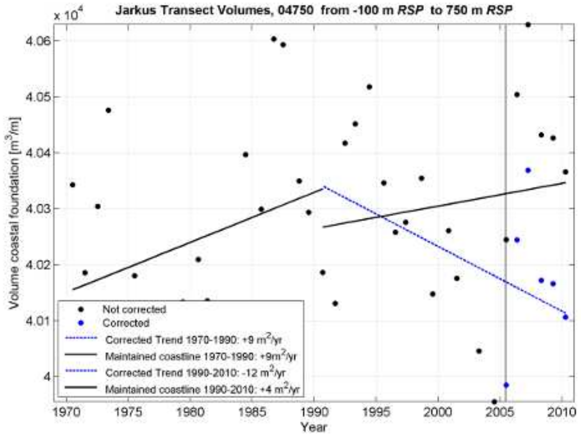

Cross-shore Measurements Extension, Noord-Holland 04650
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year



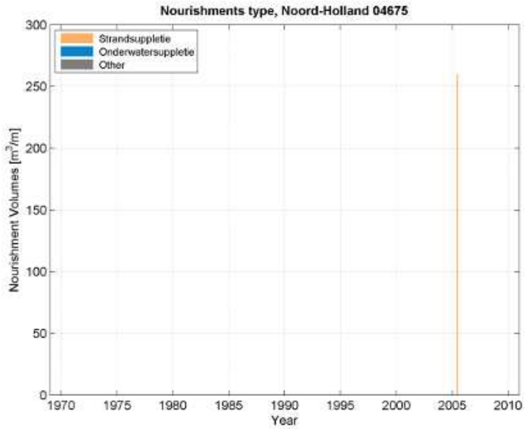
Jarkus Transect Volumes, 04700 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +16 m²/yr
Maintained coastline 1970-1990: +16m²/yr
Corrected Trend 1990-2010: -17 m²/yr
Maintained coastline 1990-2010: -1 m²/yr
Volume coastal foundation [m³/m]
Year



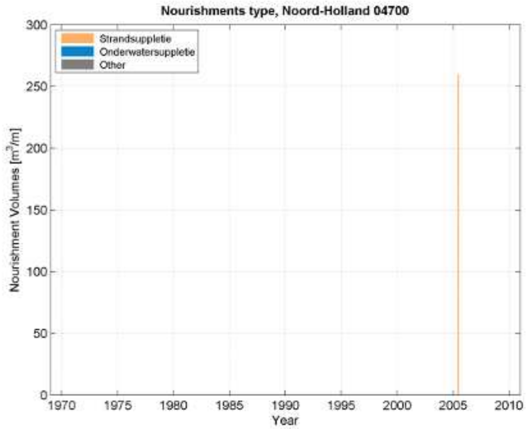
Jarkus Transect Volumes, 04725 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +16 m²/yr
Maintained coastline 1970-1990: +16m²/yr
Corrected Trend 1990-2010: -9 m²/yr
Maintained coastline 1990-2010: +6 m²/yr
Volume coastal foundation [m³/m]
Year



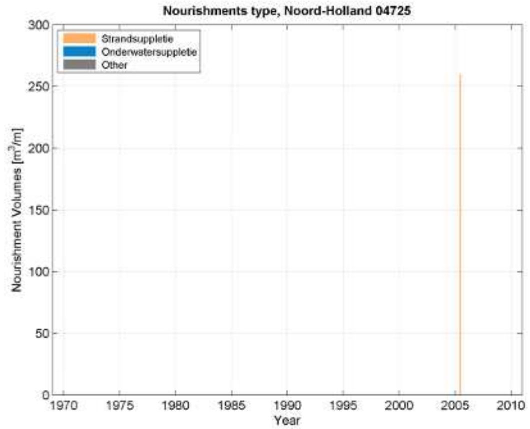
Jarkus Transect Volumes, 04750 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +9 m²/yr
Maintained coastline 1970-1990: +9m²/yr
Corrected Trend 1990-2010: -12 m²/yr
Maintained coastline 1990-2010: +4 m²/yr
Volume coastal foundation [m³/m]
Year



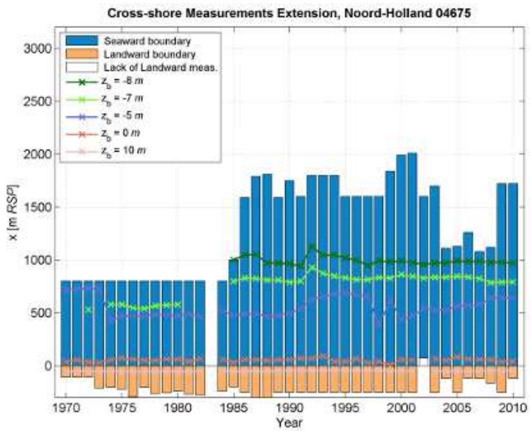
Nourishments type, Noord-Holland 04675
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year



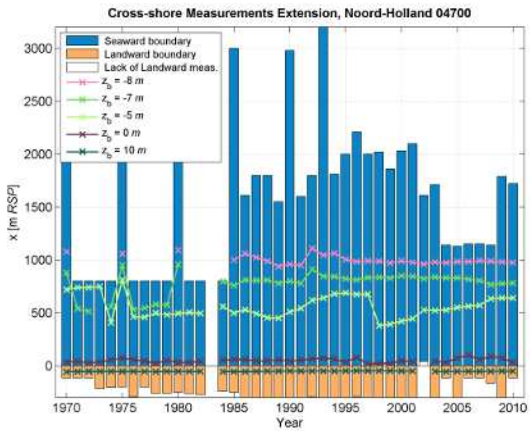
Nourishments type, Noord-Holland 04700
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year



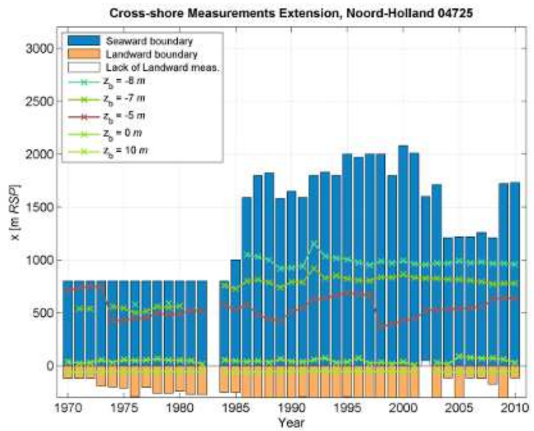
Nourishments type, Noord-Holland 04725
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m³/m]
Year



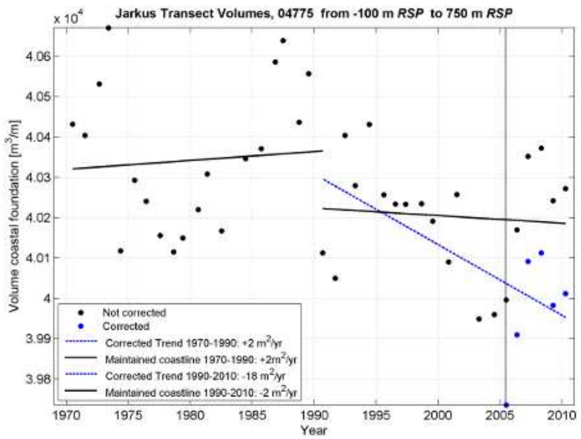
Cross-shore Measurements Extension, Noord-Holland 04675
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

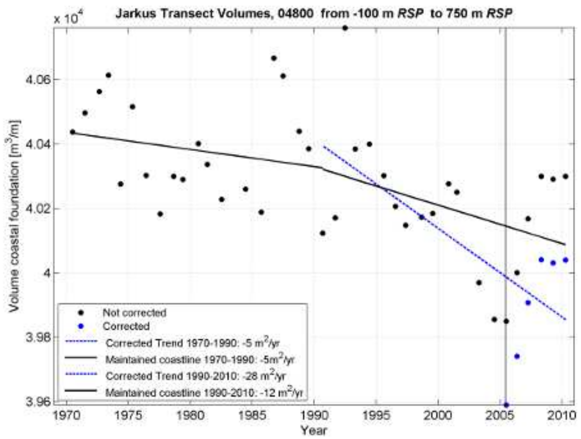


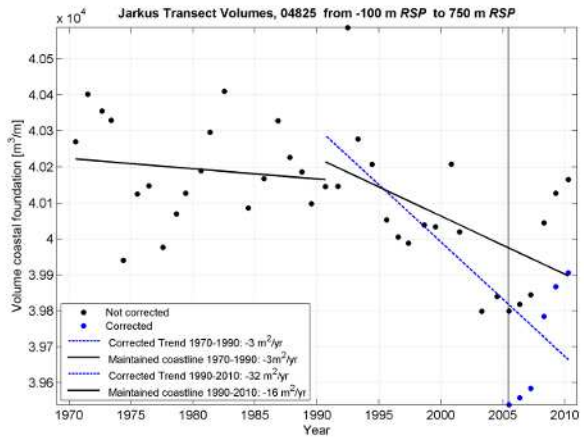
Cross-shore Measurements Extension, Noord-Holland 04700
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

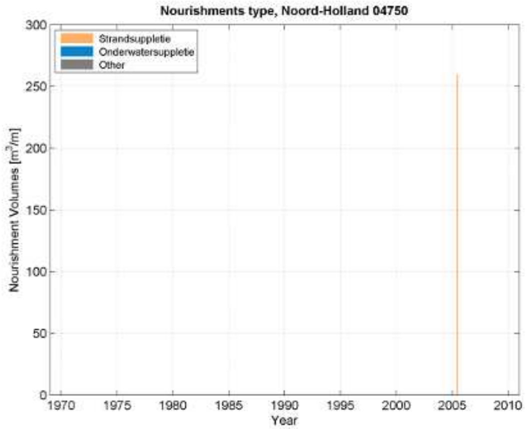


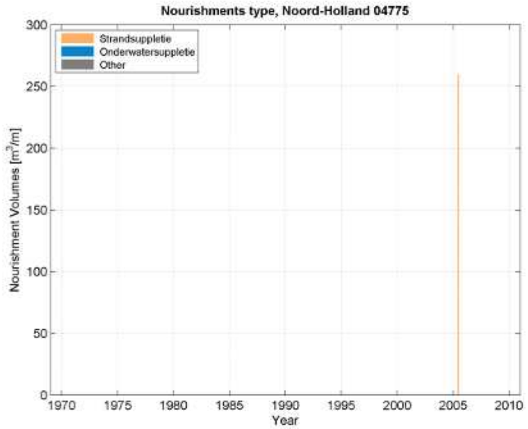
Cross-shore Measurements Extension, Noord-Holland 04725
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

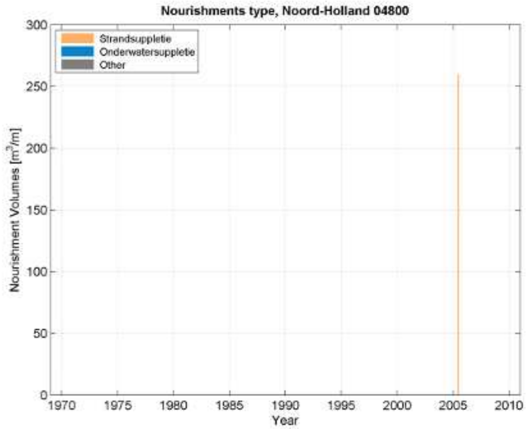

Jarkus Transect Volumes, 04775 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +2 m^2/yr
Maintained coastline 1970-1990: +2m^2/yr
Corrected Trend 1990-2010: -18 m^2/yr
Maintained coastline 1990-2010: -2 m^2/yr

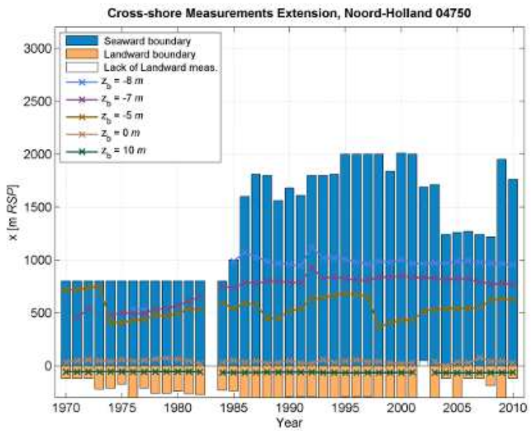

Jarkus Transect Volumes, 04800 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -5 m^2/yr
Maintained coastline 1970-1990: -5m^2/yr
Corrected Trend 1990-2010: -28 m^2/yr
Maintained coastline 1990-2010: -12 m^2/yr

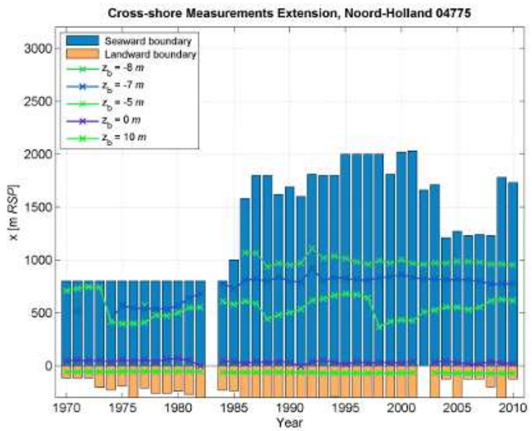

Jarkus Transect Volumes, 04825 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -3 m^2/yr
Maintained coastline 1970-1990: -3m^2/yr
Corrected Trend 1990-2010: -32 m^2/yr
Maintained coastline 1990-2010: -16 m^2/yr

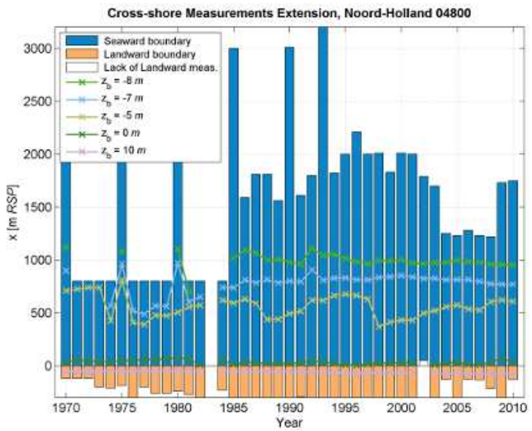

Nourishments type, Noord-Holland 04750
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

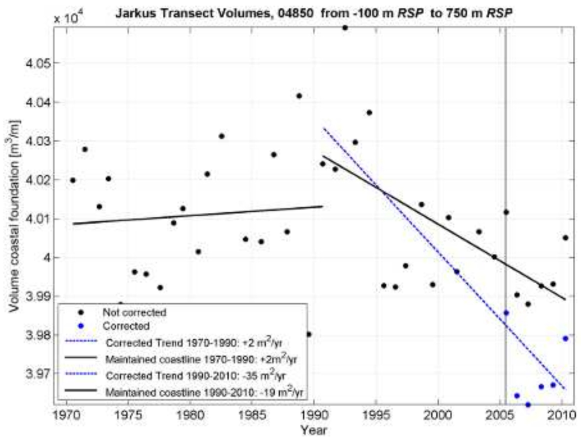

Nourishments type, Noord-Holland 04775
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

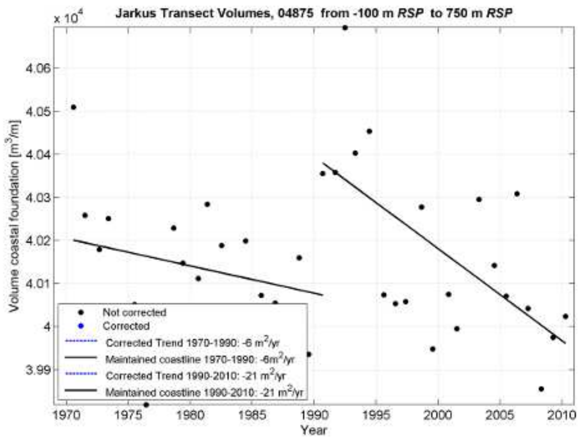

Nourishments type, Noord-Holland 04800
Nourishment Volumes [m^3/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

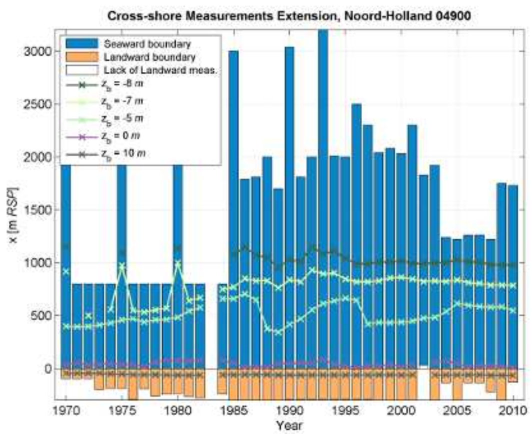

Cross-shore Measurements Extension, Noord-Holland 04750
x [m RSP]
Year
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

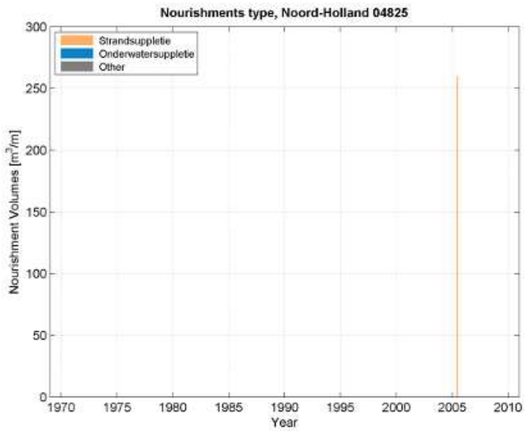

Cross-shore Measurements Extension, Noord-Holland 04775
x [m RSP]
Year
Seaward boundary
Landward boundary
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

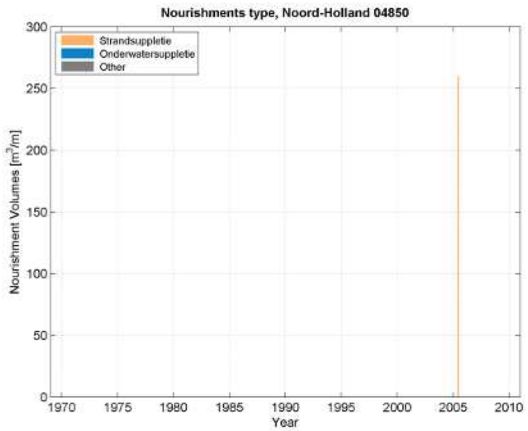

Cross-shore Measurements Extension, Noord-Holland 04800
x [m RSP]
Year
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

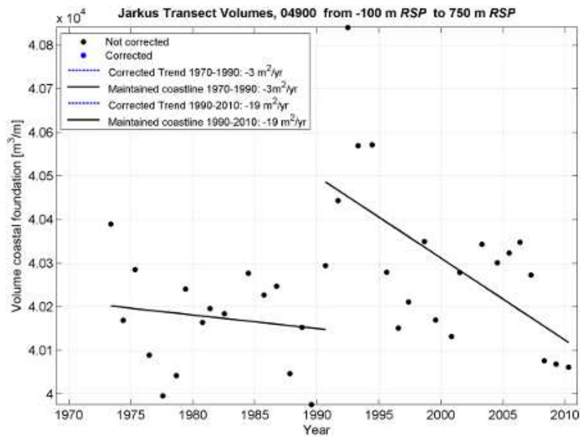

Jarkus Transect Volumes, 04850 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: +2 m^2/yr
Maintained coastline 1970-1990: +2m^2/yr
Corrected Trend 1990-2010: -35 m^2/yr
Maintained coastline 1990-2010: -19 m^2/yr
4.05
4.04
4.03
4.02
4.01
4
3.99
3.98
3.97
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

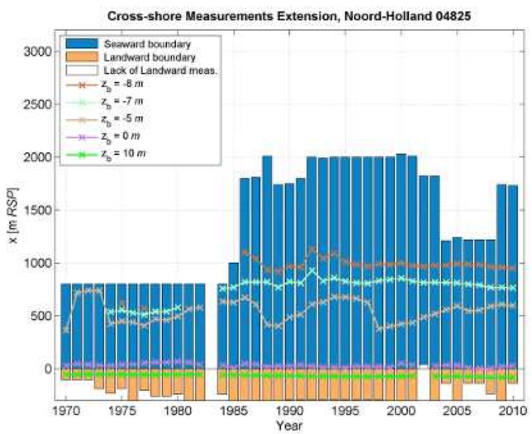

Jarkus Transect Volumes, 04875 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -6 m^2/yr
Maintained coastline 1970-1990: -6m^2/yr
Corrected Trend 1990-2010: -21 m^2/yr
Maintained coastline 1990-2010: -21 m^2/yr
4.06
4.05
4.04
4.03
4.02
4.01
4
3.99
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

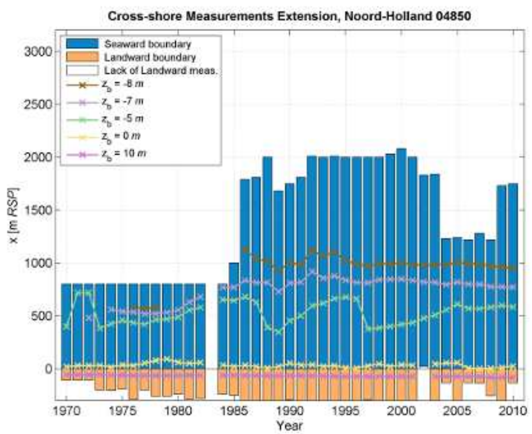

Cross-shore Measurements Extension, Noord-Holland 04900
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
3000
2500
2000
1500
1000
500
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

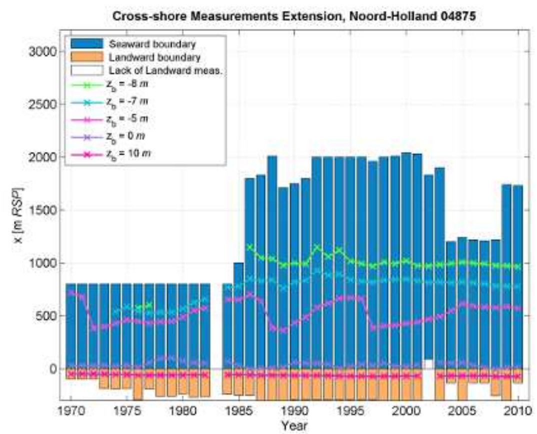

Nourishments type, Noord-Holland 04825
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

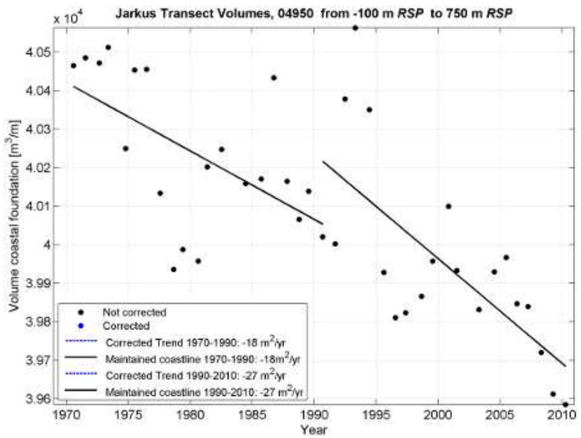

Nourishments type, Noord-Holland 04850
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

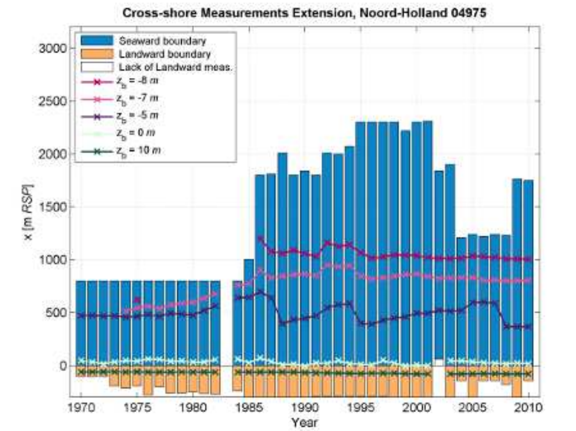

Jarkus Transect Volumes, 04900 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Not corrected
Corrected
Corrected Trend 1970-1990: -3 m^2/yr
Maintained coastline 1970-1990: -3m^2/yr
Corrected Trend 1990-2010: -19 m^2/yr
Maintained coastline 1990-2010: -19 m^2/yr
4.08
4.07
4.06
4.05
4.04
4.03
4.02
4.01
4
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

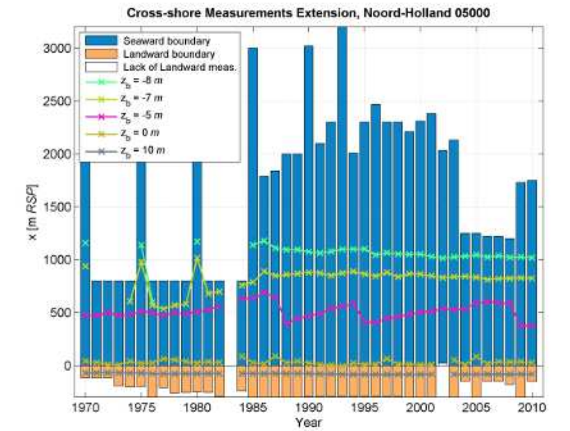

Cross-shore Measurements Extension, Noord-Holland 04825
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
3000
2500
2000
1500
1000
500
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

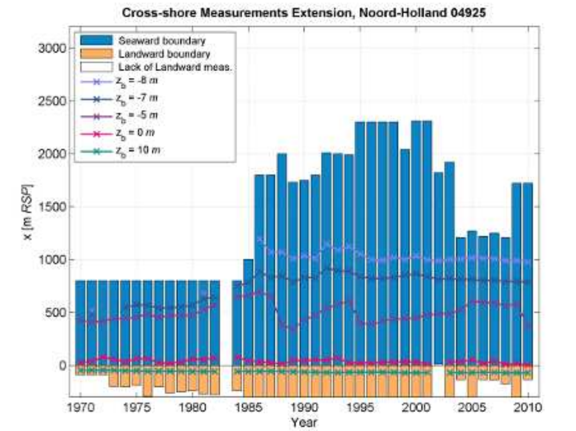

Cross-shore Measurements Extension, Noord-Holland 04850
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
3000
2500
2000
1500
1000
500
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

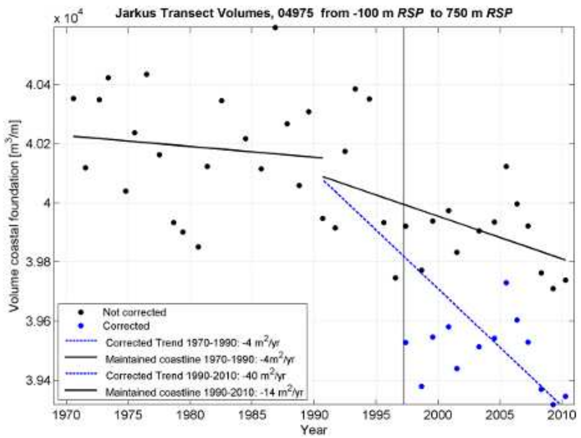

Cross-shore Measurements Extension, Noord-Holland 04875
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
3000
2500
2000
1500
1000
500
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

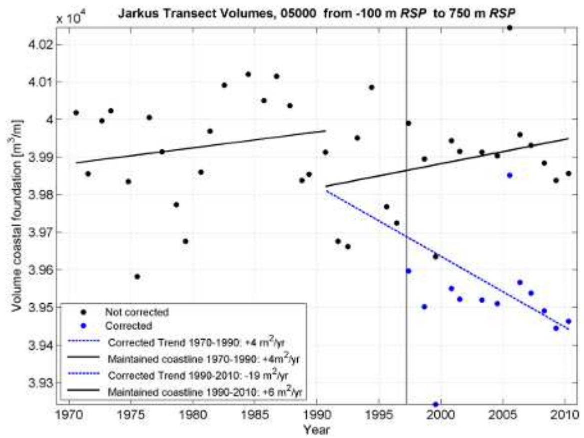

Jarkus Transect Volumes, 04950 from -100 m RSP to 750 m RSP
Volume coastal foundation [m³/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -18 m²/yr
Maintained coastline 1970-1990: -18m²/yr
Corrected Trend 1990-2010: -27 m²/yr
Maintained coastline 1990-2010: -27 m²/yr

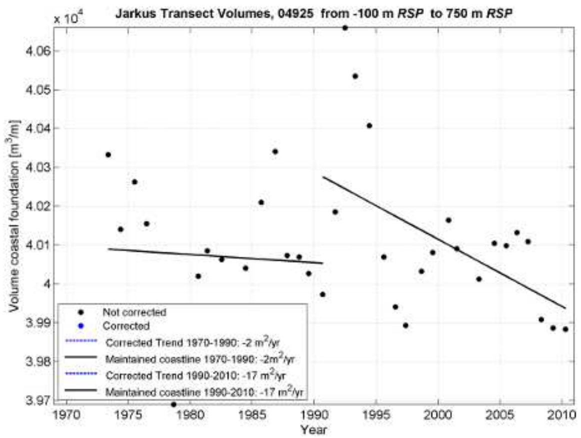

Cross-shore Measurements Extension, Noord-Holland 04975
x [m RSP]
Year
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

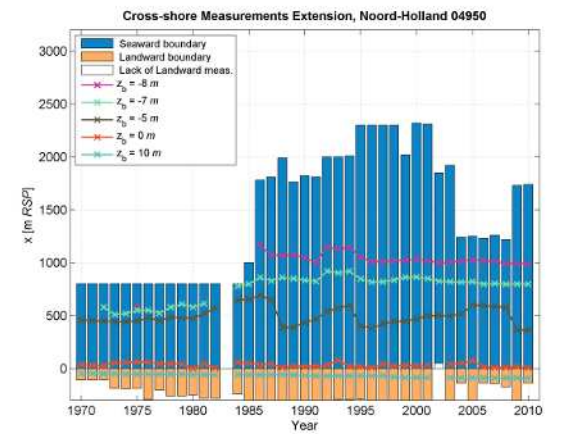

Cross-shore Measurements Extension, Noord-Holland 05000
x [m RSP]
Year
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

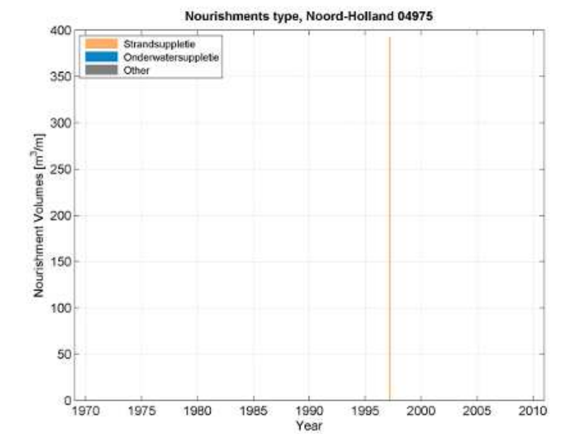

Cross-shore Measurements Extension, Noord-Holland 04925
x [m RSP]
Year
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

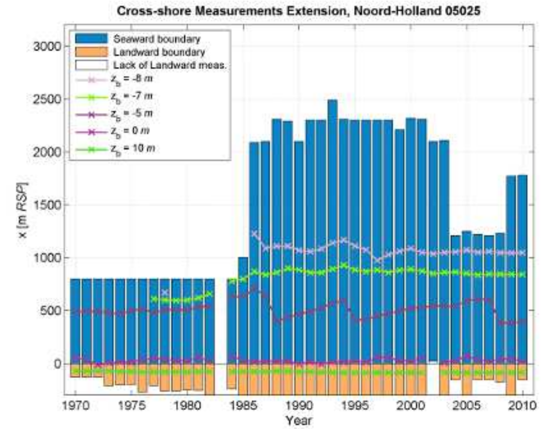

Jarkus Transect Volumes, 04975 from -100 m RSP to 750 m RSP
Volume coastal foundation [m³/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -4 m²/yr
Maintained coastline 1970-1990: -4m²/yr
Corrected Trend 1990-2010: -40 m²/yr
Maintained coastline 1990-2010: -14 m²/yr

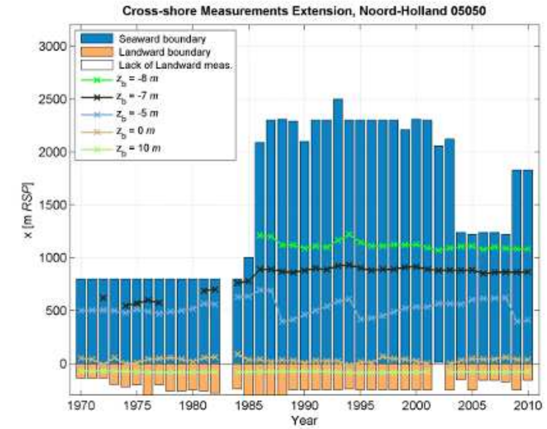

Jarkus Transect Volumes, 05000 from -100 m RSP to 750 m RSP
Volume coastal foundation [m³/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +4 m²/yr
Maintained coastline 1970-1990: +4m²/yr
Corrected Trend 1990-2010: -19 m²/yr
Maintained coastline 1990-2010: +6 m²/yr

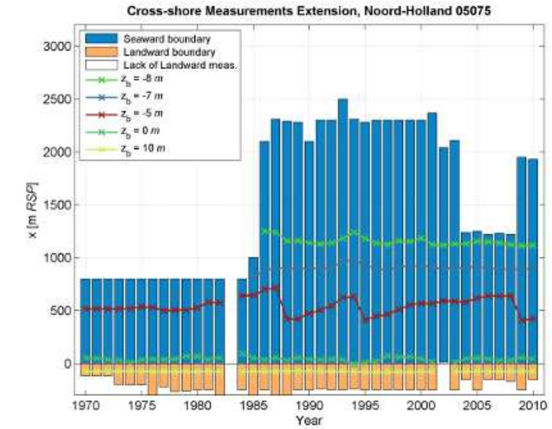

Jarkus Transect Volumes, 04925 from -100 m RSP to 750 m RSP
Volume coastal foundation [m³/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: -2 m²/yr
Maintained coastline 1970-1990: -2m²/yr
Corrected Trend 1990-2010: -17 m²/yr
Maintained coastline 1990-2010: -17 m²/yr

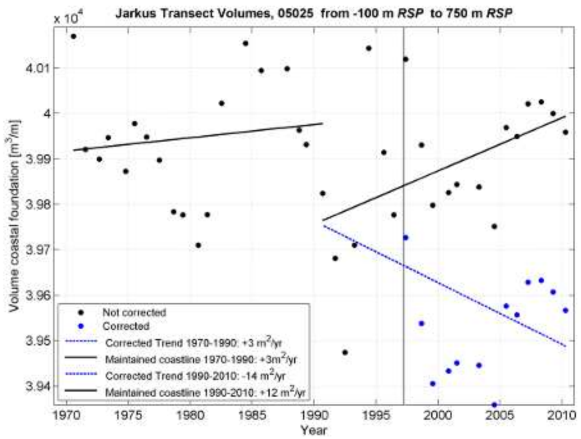

Cross-shore Measurements Extension, Noord-Holland 04950
x [m RSP]
Year
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m

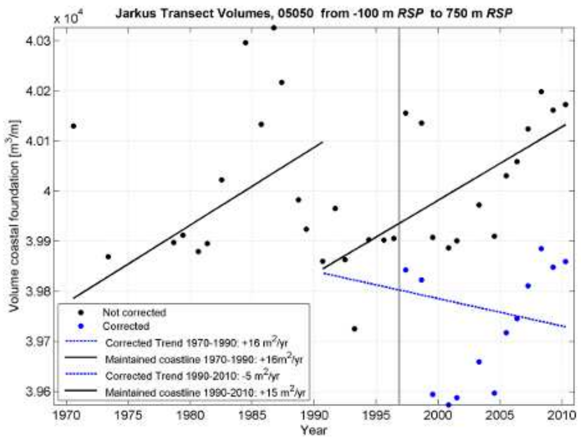

Nourishments type, Noord-Holland 04975
Nourishment Volumes [m³/m]
Year
Strandsuppletie
Onderwatersuppletie
Other

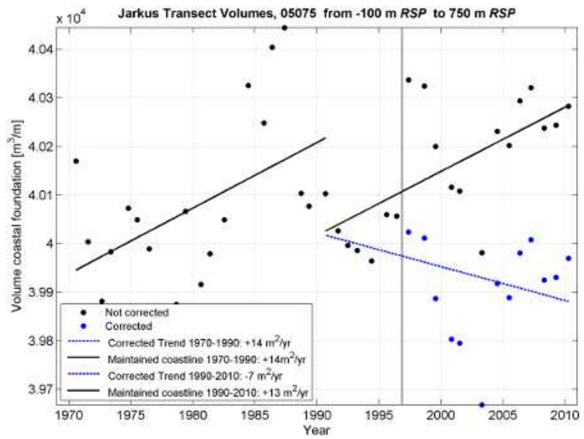

Cross-shore Measurements Extension, Noord-Holland 05025
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

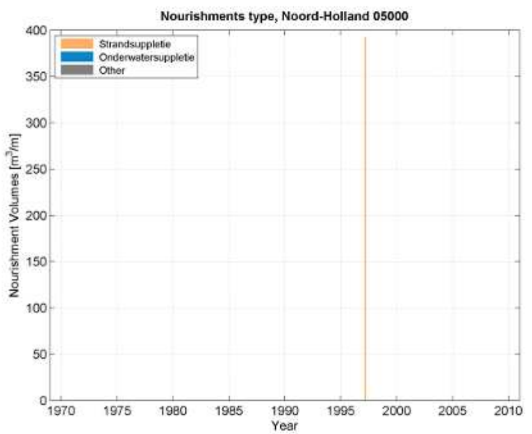

Cross-shore Measurements Extension, Noord-Holland 05050
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

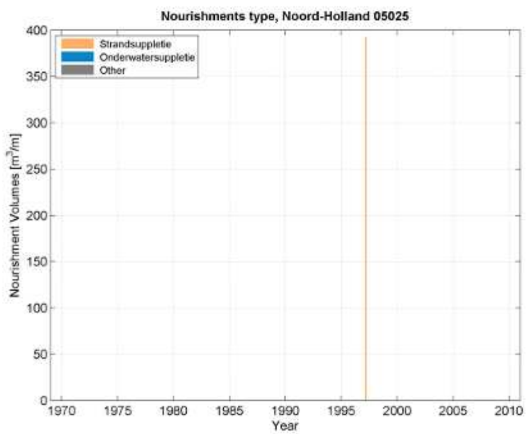

Cross-shore Measurements Extension, Noord-Holland 05075
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

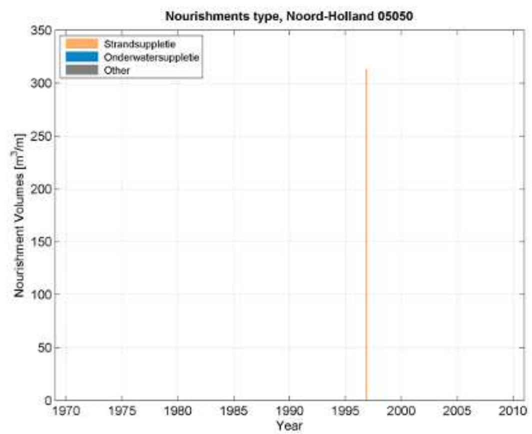

Jarkus Transect Volumes, 05025 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +3 m^2/yr
Maintained coastline 1970-1990: +3m^2/yr
Corrected Trend 1990-2010: -14 m^2/yr
Maintained coastline 1990-2010: +12 m^2/yr

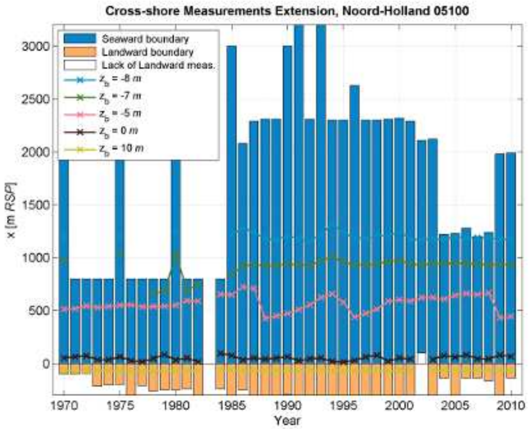

Jarkus Transect Volumes, 05050 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +16 m^2/yr
Maintained coastline 1970-1990: +16m^2/yr
Corrected Trend 1990-2010: -5 m^2/yr
Maintained coastline 1990-2010: +15 m^2/yr

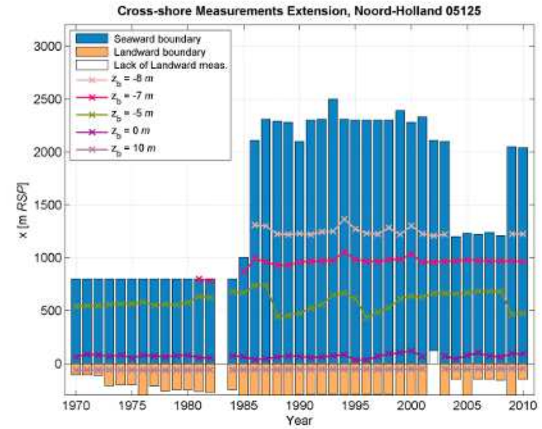

Jarkus Transect Volumes, 05075 from -100 m RSP to 750 m RSP
x 10^4
Volume coastal foundation [m^3/m]
Year
Not corrected
Corrected
Corrected Trend 1970-1990: +14 m^2/yr
Maintained coastline 1970-1990: +14m^2/yr
Corrected Trend 1990-2010: -7 m^2/yr
Maintained coastline 1990-2010: +13 m^2/yr

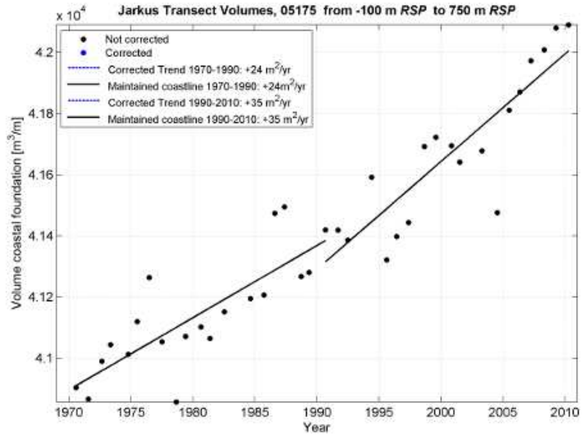

Nourishments type, Noord-Holland 05000
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

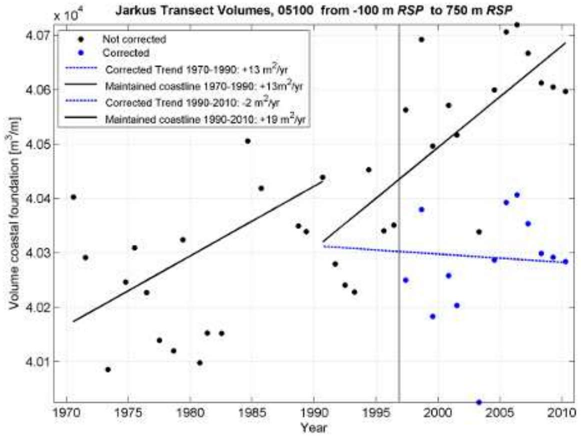

Nourishments type, Noord-Holland 05025
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

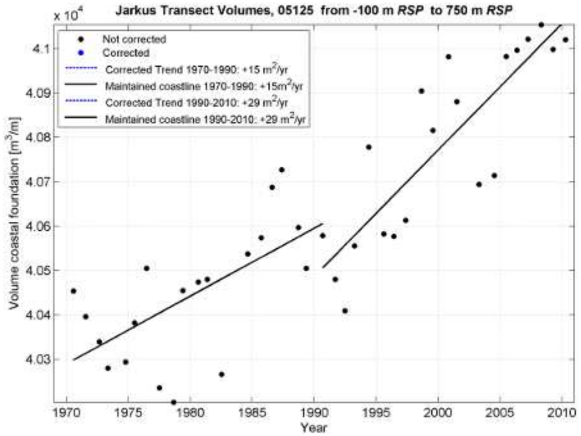

Nourishments type, Noord-Holland 05050
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m^3/m]
Year

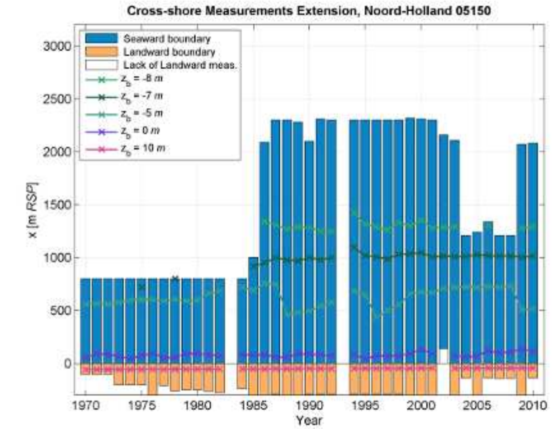

Cross-shore Measurements Extension, Noord-Holland 05100
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

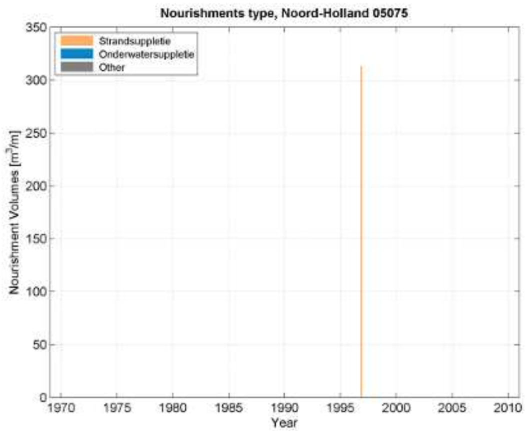

Cross-shore Measurements Extension, Noord-Holland 05125
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

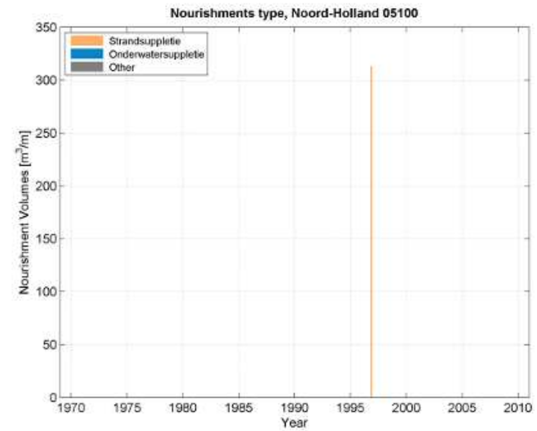

Jarkus Transect Volumes, 05175 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +24 m2/yr
Maintained coastline 1970-1990: +24m2/yr
Corrected Trend 1990-2010: +35 m2/yr
Maintained coastline 1990-2010: +35 m2/yr
Volume coastal foundation [m3/m]
Year

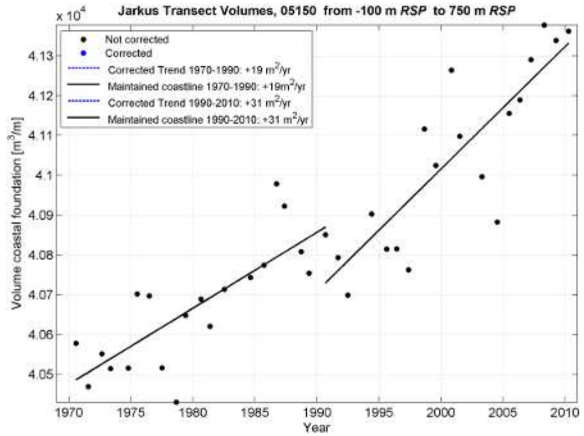

Jarkus Transect Volumes, 05100 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +13 m2/yr
Maintained coastline 1970-1990: +13m2/yr
Corrected Trend 1990-2010: -2 m2/yr
Maintained coastline 1990-2010: +19 m2/yr
Volume coastal foundation [m3/m]
Year

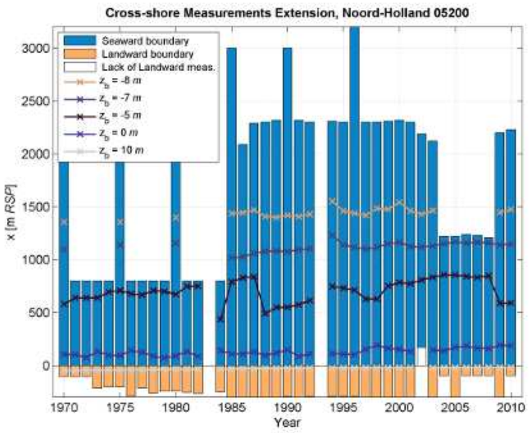

Jarkus Transect Volumes, 05125 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +15 m2/yr
Maintained coastline 1970-1990: +15m2/yr
Corrected Trend 1990-2010: +29 m2/yr
Maintained coastline 1990-2010: +29 m2/yr
Volume coastal foundation [m3/m]
Year

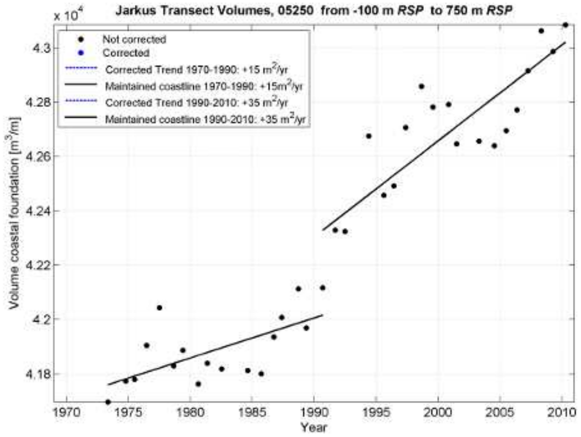

Cross-shore Measurements Extension, Noord-Holland 05150
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

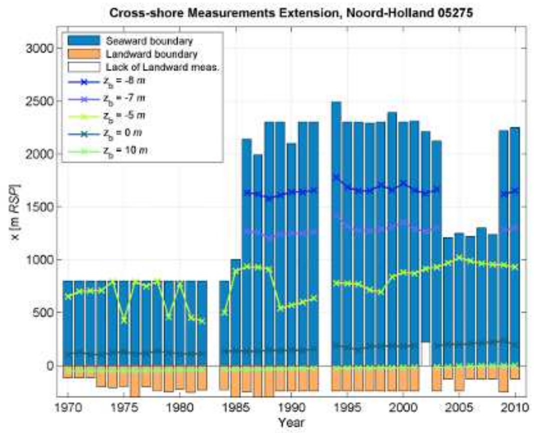

Nourishments type, Noord-Holland 05075
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

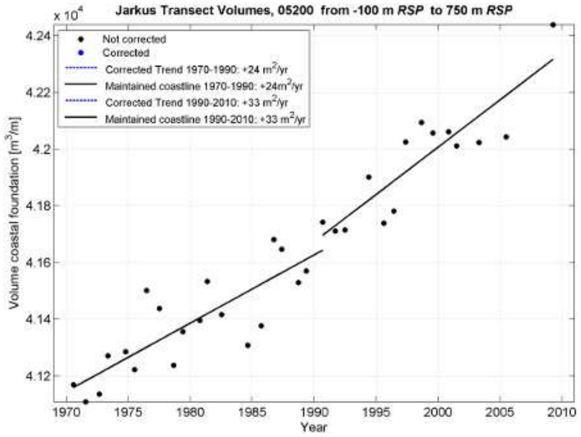

Nourishments type, Noord-Holland 05100
Strandsuppletie
Onderwatersuppletie
Other
Nourishment Volumes [m3/m]
Year

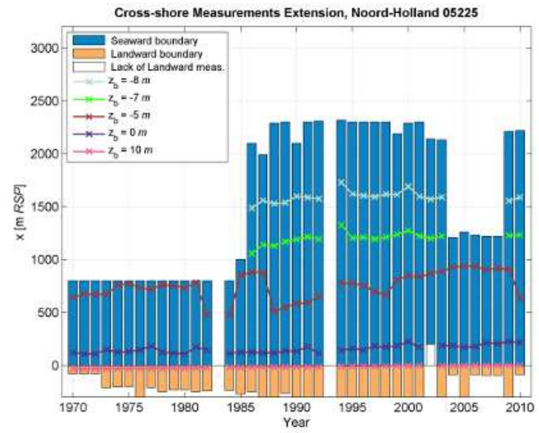

Jarkus Transect Volumes, 05150 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +19 m2/yr
Maintained coastline 1970-1990: +19m2/yr
Corrected Trend 1990-2010: +31 m2/yr
Maintained coastline 1990-2010: +31 m2/yr
Volume coastal foundation [m3/m]
Year

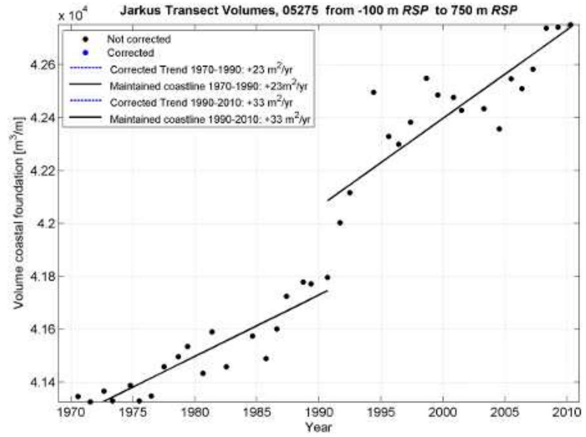

Cross-shore Measurements Extension, Noord-Holland 05200
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

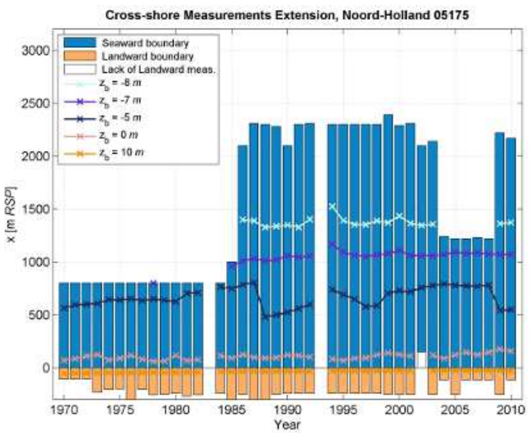

Jarkus Transect Volumes, 05250 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +15 m^2/yr
Maintained coastline 1970-1990: +15m^2/yr
Corrected Trend 1990-2010: +35 m^2/yr
Maintained coastline 1990-2010: +35 m^2/yr
Volume coastal foundation [m^3/m]
Year

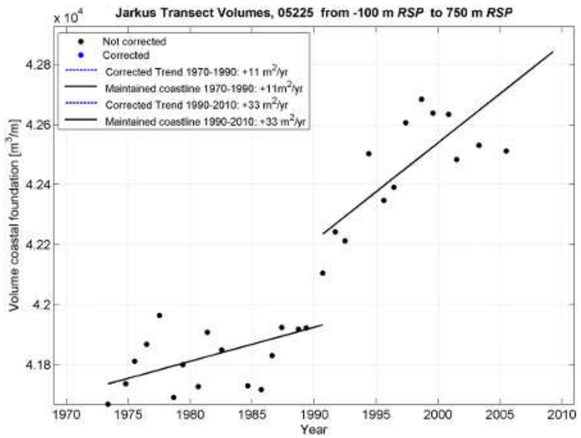

Cross-shore Measurements Extension, Noord-Holland 05275
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

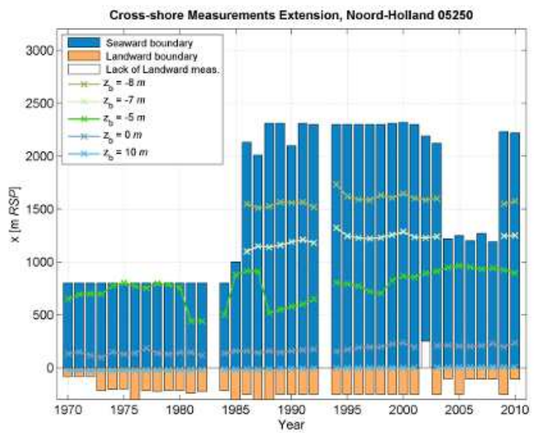

Jarkus Transect Volumes, 05200 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +24 m^2/yr
Maintained coastline 1970-1990: +24m^2/yr
Corrected Trend 1990-2010: +33 m^2/yr
Maintained coastline 1990-2010: +33 m^2/yr
Volume coastal foundation [m^3/m]
Year

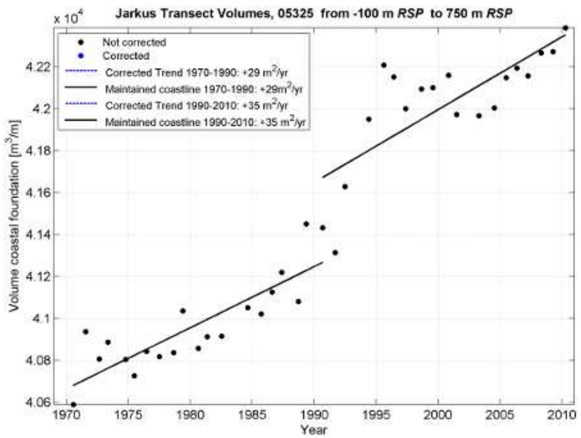

Cross-shore Measurements Extension, Noord-Holland 05225
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

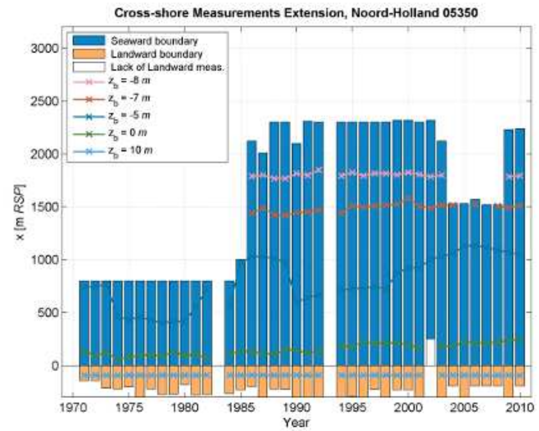

Jarkus Transect Volumes, 05275 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +23 m^2/yr
Maintained coastline 1970-1990: +23m^2/yr
Corrected Trend 1990-2010: +33 m^2/yr
Maintained coastline 1990-2010: +33 m^2/yr
Volume coastal foundation [m^3/m]
Year

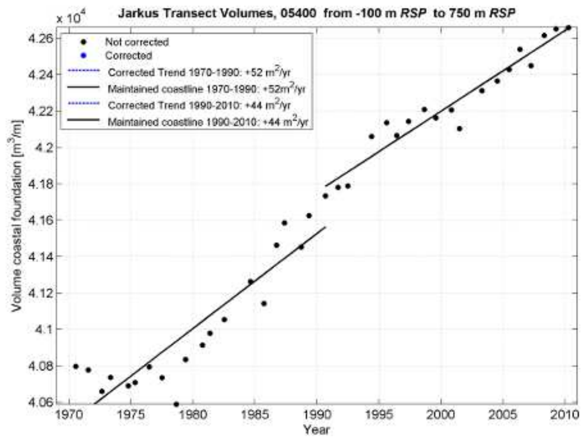

Cross-shore Measurements Extension, Noord-Holland 05175
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

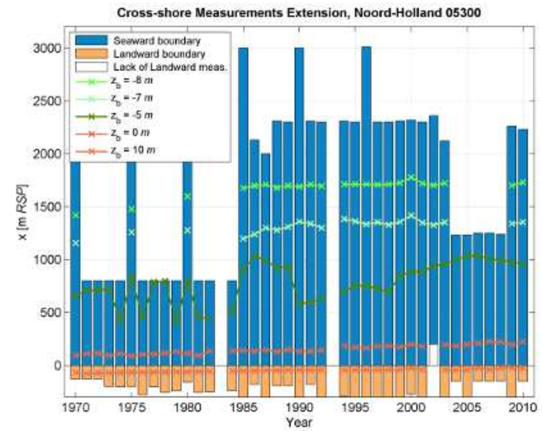

Jarkus Transect Volumes, 05225 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +11 m^2/yr
Maintained coastline 1970-1990: +11m^2/yr
Corrected Trend 1990-2010: +33 m^2/yr
Maintained coastline 1990-2010: +33 m^2/yr
Volume coastal foundation [m^3/m]
Year

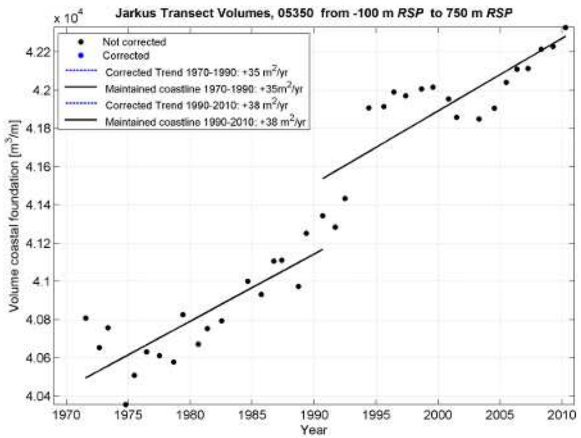

Cross-shore Measurements Extension, Noord-Holland 05250
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

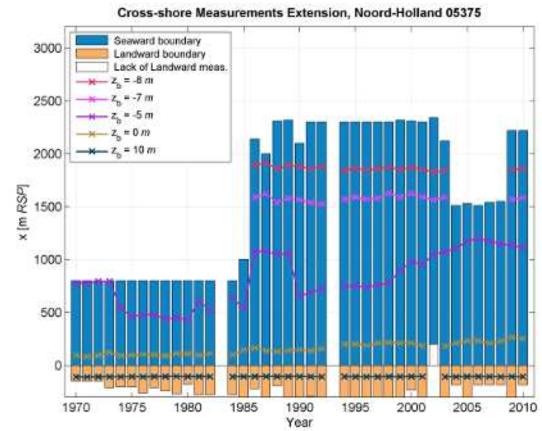

Jarkus Transect Volumes, 05325 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +29 m²/yr
Maintained coastline 1970-1990: +29m²/yr
Corrected Trend 1990-2010: +35 m²/yr
Maintained coastline 1990-2010: +35 m²/yr
Volume coastal foundation [m³/m]
Year

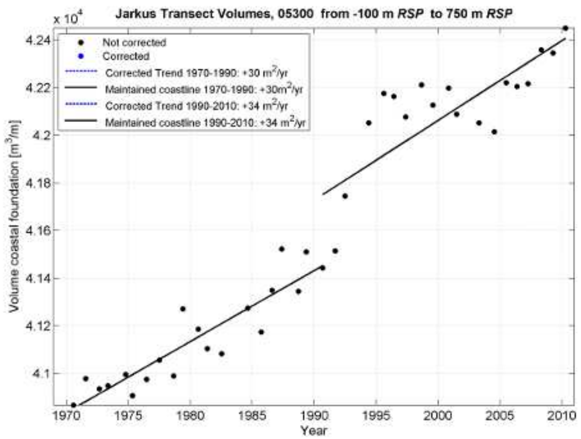

Cross-shore Measurements Extension, Noord-Holland 05350
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

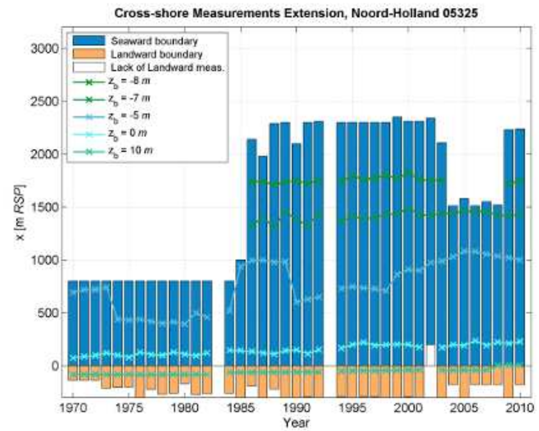

Jarkus Transect Volumes, 05400 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +52 m²/yr
Maintained coastline 1970-1990: +52m²/yr
Corrected Trend 1990-2010: +44 m²/yr
Maintained coastline 1990-2010: +44 m²/yr
Volume coastal foundation [m³/m]
Year

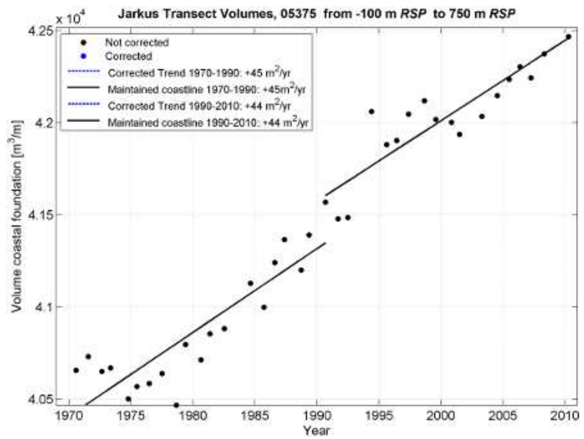

Cross-shore Measurements Extension, Noord-Holland 05300
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

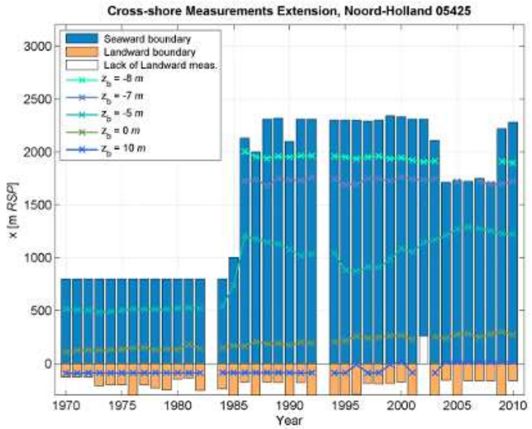

Jarkus Transect Volumes, 05350 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +35 m²/yr
Maintained coastline 1970-1990: +35m²/yr
Corrected Trend 1990-2010: +38 m²/yr
Maintained coastline 1990-2010: +38 m²/yr
Volume coastal foundation [m³/m]
Year

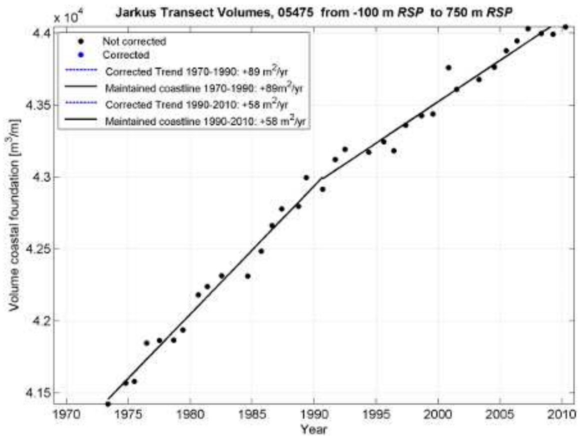

Cross-shore Measurements Extension, Noord-Holland 05375
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

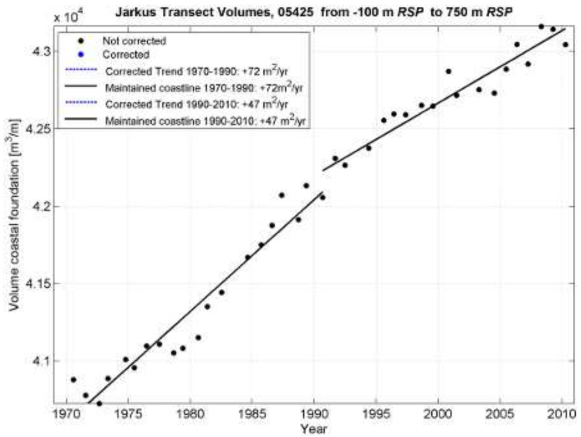

Jarkus Transect Volumes, 05300 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +30 m²/yr
Maintained coastline 1970-1990: +30m²/yr
Corrected Trend 1990-2010: +34 m²/yr
Maintained coastline 1990-2010: +34 m²/yr
Volume coastal foundation [m³/m]
Year

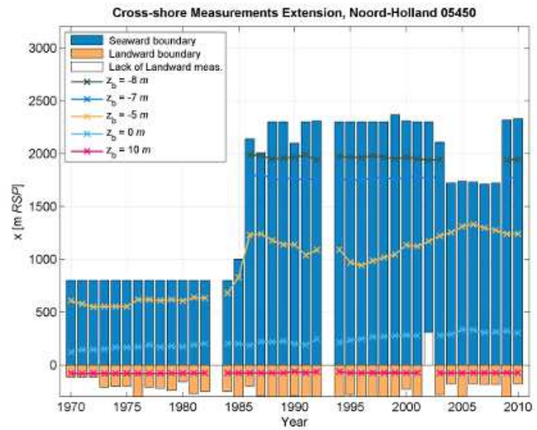

Cross-shore Measurements Extension, Noord-Holland 05325
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

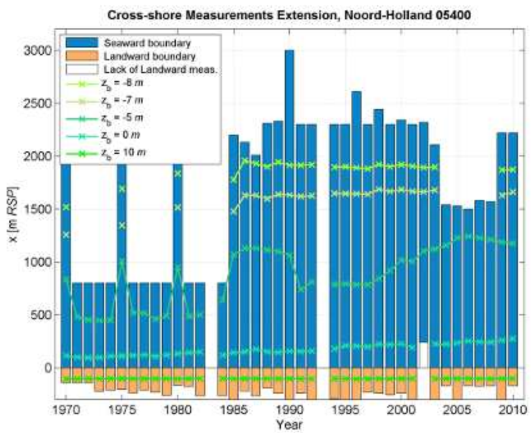

Jarkus Transect Volumes, 05375 from -100 m RSP to 750 m RSP
Not corrected
Corrected
Corrected Trend 1970-1990: +45 m²/yr
Maintained coastline 1970-1990: +45m²/yr
Corrected Trend 1990-2010: +44 m²/yr
Maintained coastline 1990-2010: +44 m²/yr
Volume coastal foundation [m³/m]
Year

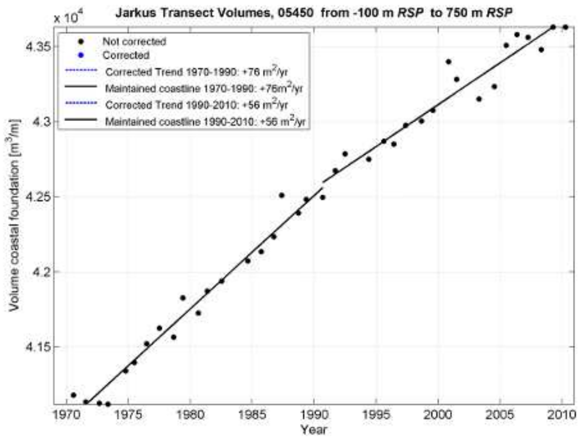

Cross-shore Measurements Extension, Noord-Holland 05425
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year

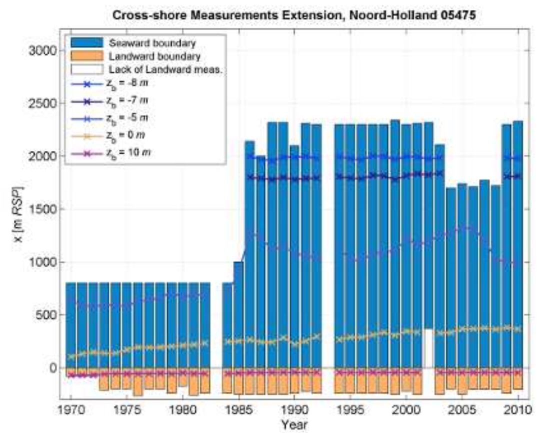

Jarkus Transect Volumes, 05475 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +89 m²/yr
Maintained coastline 1970-1990: +89m²/yr
Corrected Trend 1990-2010: +58 m²/yr
Maintained coastline 1990-2010: +58 m²/yr
Volume coastal foundation [m³/m]
Year


Jarkus Transect Volumes, 05425 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +72 m²/yr
Maintained coastline 1970-1990: +72m²/yr
Corrected Trend 1990-2010: +47 m²/yr
Maintained coastline 1990-2010: +47 m²/yr
Volume coastal foundation [m³/m]
Year


Cross-shore Measurements Extension, Noord-Holland 05450
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year


Cross-shore Measurements Extension, Noord-Holland 05400
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year


Jarkus Transect Volumes, 05450 from -100 m RSP to 750 m RSP
x 10^4
Not corrected
Corrected
Corrected Trend 1970-1990: +76 m²/yr
Maintained coastline 1970-1990: +76m²/yr
Corrected Trend 1990-2010: +56 m²/yr
Maintained coastline 1990-2010: +56 m²/yr
Volume coastal foundation [m³/m]
Year


Cross-shore Measurements Extension, Noord-Holland 05475
Seaward boundary
Landward boundary
Lack of Landward meas.
z_b = -8 m
z_b = -7 m
z_b = -5 m
z_b = 0 m
z_b = 10 m
x [m RSP]
Year