Results from the Dutch Ecobeach pilot project

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Introduction

Ecobeach is an innovative vertical passive beach drainage system discovered by accident by the Danish contractor Poul Jakobsen in the early 1990’s. The invention was initially called “Pressure Equalizing Module System” (PEM). The inventor indicated a positive effect on natural accretion and reduction of erosion of the beach. The demonstrated positive results at different pilot projects around the world triggered the Dutch contractor BAM to set up a test of the system at the beach of Egmond aan Zee (Figure 2), along the Dutch North Sea coast, in cooperation with Rijkswaterstaat (Dutch Ministry of Public Works). This pilot, which was called Ecobeach, was carried out between 2007 and 2011. The system was installed in 2 sections of 3 km length at the test area North and test area South, separated by an area of 1 km without Ecobeach. These selected areas were located within a coastal zone which has been monitored intensively.

Dutch pilot

A field experiment was carried out for the pilot, in which a statistical analysis was executed for coastal state indicators (CSI’s). In addition a scientific approach was used to investigate possible working principles of the system. The drainage system consists of vertical drainage tubes with a length of 1.75 m which are installed between the dune foot and average low waterline at 0.25 m below the beach surface (Figure 1). The tubes have filter slots. The tubes are placed with an interspacing of 10 m in cross-shore rows, while the long-shore distance between the rows is 100 m. Over 600 drains were installed in the test areas.


Figure 1: Installation of a drainage tube below the beach surface

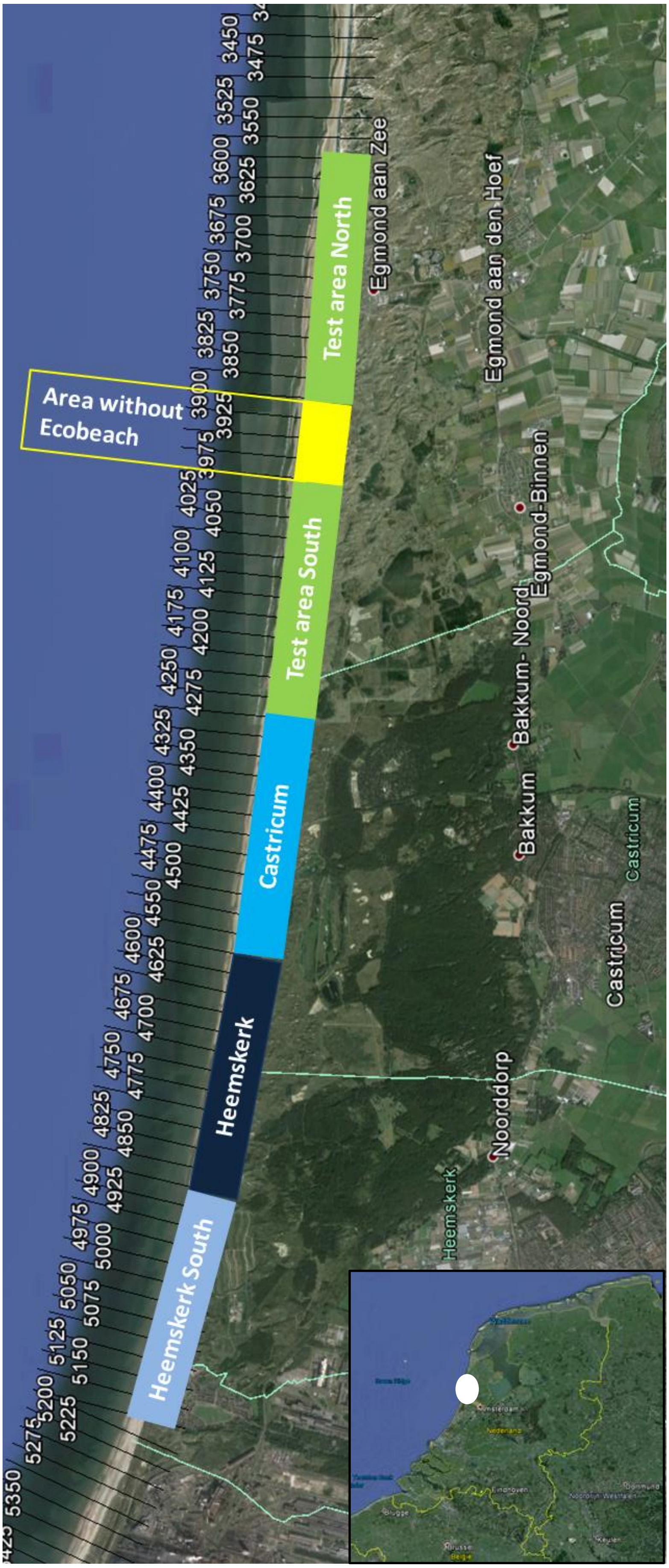


Figure 2: Test area Ecobeach system

Coastal changes

According to (Pieterse, 2009) the direction of the net long-shore sediment transport along the Dutch coast near Egmond is from South to the North. The Egmond area (test area North) is frequently nourished over time (Figure 3). Test area South is less affected by direct nourishments. The statistical analyses of the sand volumes consider test area South in comparison with Castricum as test area South is adjacent to Castricum. Test area North is separated from test area South by a 1 km area without Ecobeach. Castricum is bounded by Heemskerk to the south. Test area North and Heemskerk are compared as in both areas a beach nourishment was applied in 2005, before the Ecobeach installation.

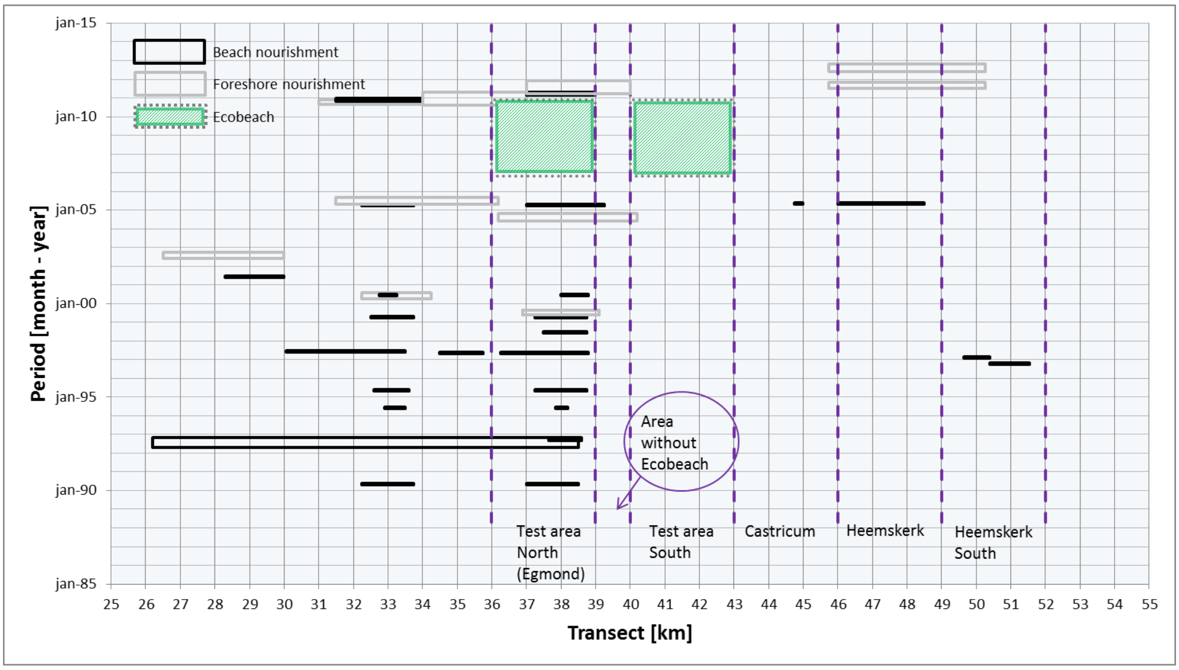
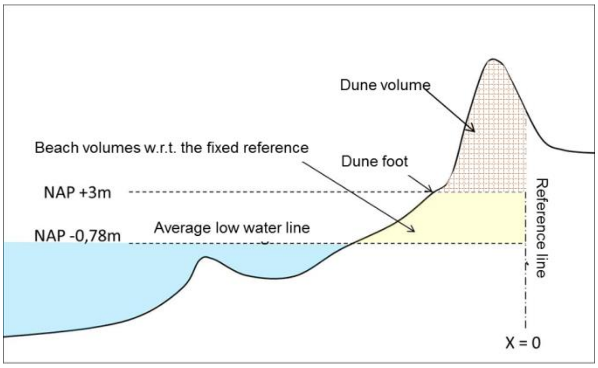


Figure 3: Long-shore locations of the nourishments over time

Approach

The main objective of the experiment was to investigate potential working principles as well as to measure possible sand volume changes caused by the Ecobeach system. The sand volumes were measured at the project location and the adjacent locations in order to compare effects of the Ecobeach system. In geographical terms from North to South, the considered project locations are test area North (JARKUS transects from RSP 36 to 39), area without Ecobeach (RSP 39 to 40), test area South (RSP 40 to 43), Castricum (RSP 43 to 46), Heemskerk (RSP 46 to 49) and Heemskerk South (RSP 49 to 52). The sand volumes are also compared with the historical data (annual coastal measurements carried out since 1965) in order to be able to draw conclusions on the effect of the Ecobeach system along the coast. The morphological behavior of the coast can be distinguished in three parts: natural variability, impact of nourishments and effects of the Ecobeach system.

The definition of the beach volume describes the layer between the dune foot at NAP + 3 m and the average low water level at NAP – 0.78 m. The boundary extends from the beach surface until a defined reference line shoreward (Figure 4). The volume above the dune foot is defined as the dune volume which is also bounded by the reference line shoreward. The total volume covers the sand volume between the level NAP – 8 m and the dune crest, extending to the defined reference line. The statistical analyses of test area South and Castricum comprise both total volumes and beach volumes. Test area North and Heemskerk consider statistical analysis of beach volumes alone and beach + dune volumes combined. The volumes are derived from the JARKUS data which is the annual survey of the dune, beach and foreshore profiles extending to approximately RSP + 2500 m seawards. The survey data consists of data from 1965 to 2014. Along the Dutch coast near Egmond, the JARKUS transects are located every 250 m (perpendicular to the coastline). The aggregated values of 12 or 13 transects along the length of the areas were used to average the variability of the volumes at which 1965 = 0 m^3/m. Both test areas have 13 JARKUS transects. Also in both outer transects of the test areas, drains have been installed. The behavior of the CSI's including trends and confidence limits prior to the installation of the Ecobeach system were determined.



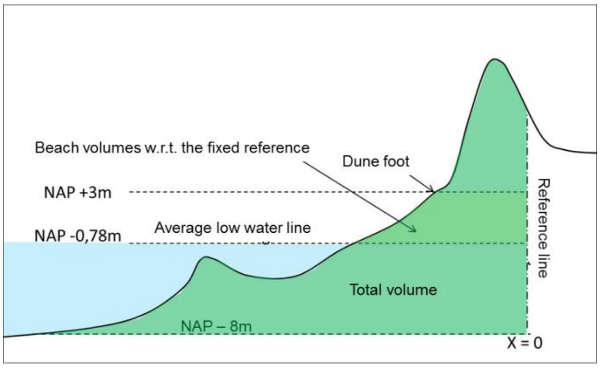


Figure 4: Definition of beach and dune volume (left) and total volume (right)

Statistical analyses beach volume

The statistical data obtained from the experimental results led to an analysis that includes both the total sand volumes and theories of potential working principles.

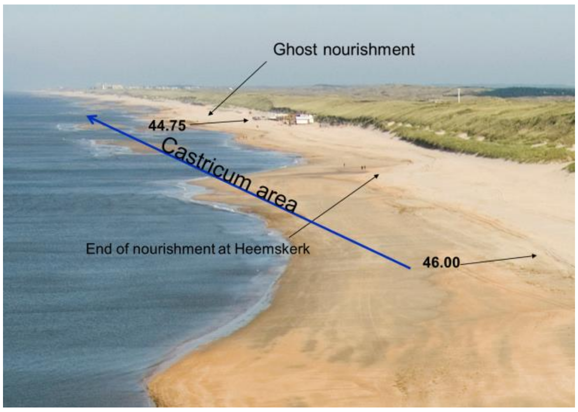


Figure 5: Partly nourished beach of Heemskerk and Castricum (2005)

Test area South and Castricum

The beaches at test area South and Castricum are stable and show limited variation of beach volume based on historical data from 1965 to 2007 (prior to the installation of the Ecobeach system) (Figure 6). No significant influence of the approximately 15 years sand bar cycle can be observed on the beach volume. Directly after installation of the Ecobeach system, the beach volume in the southern test area started to grow. It reached the highest measured value since 1965 in January 2011, gaining almost 50 m^3/m of beach. Wave conditions during the test period were similar to previous periods (Walstra, 2014). Although the severe storm Tilo occurred in November 2007 with the highest waves ever measured at IJmuiden, and the first storm closure of the Rotterdam storm surge barrier, no decrease in beach volume was observed in 2008. After completing the removal of the Ecobeach system in February 2011, the beach volume decreased, and in 2014 the beach volume was almost back to the value of 1965. After the Ecobeach system was installed in the southern test area, the Castricum area showed a similar growth rate of the beach volume. The beach volume for both the test area South and the Castricum area is outside the confidence limits for the years 2009 to 2011 based on the historical data.

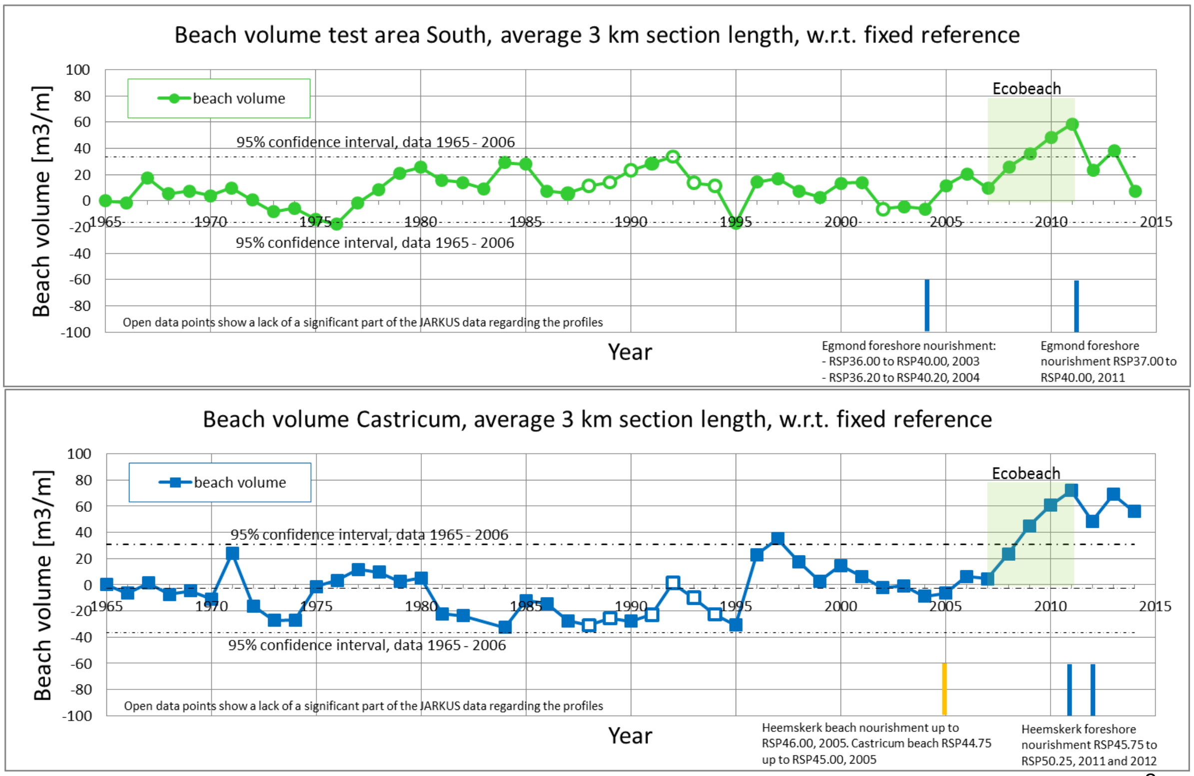


Figure 6: Beach volumes of test area South and Castricum over time, 1965= 0 m^3/m

However, the growth rate of the total volume between NAP -8 m and the dune crest for both areas is different. Due to the foreshore nourishment in 2004 in 200 m of the test area South (up to RSP 40.20), the total volume at this site is significantly increasing until 2006. After 2006, during the Ecobeach period, the northwards directed net sediment transport causes a decrease of the total volume at test area South due to erosion of this foreshore nourishment. While the total volume of test area South decreased during the Ecobeach period, the total volume in the Castricum area increased due to feeding from outside this area. Feeding of the Castricum area has occurred by the 250 m^3/m beach nourishment which was placed in the adjacent Heemskerk area in May/June 2005, see Figure 5.

It is rather remarkable that after installation of the Ecobeach system in test area South, both areas show a similar growth in beach volume, while the total volume of test area South decreased and the total volume of the Castricum area increased. Coarsening of sand particles of the upper 2 m of the beach has been observed in the southern test area (Ekkelenkamp, 2011). This coarsening has led to increased beach stability and reduced longshore transport in the southern test area. The Castricum area is wedged in between the 2005 nourishment at Heemskerk and the southern

Ecobeach test area and will have been affected by both the sand feeding from the 2005 nourishment at Heemskerk and the beach growth and coarsening in the southern test area. It is remarkable that although from 2005 onwards the total volume from NAP -8 m to dune crest of the Castricum area started to grow significantly, only after installation of the Ecobeach system the beach volume started to show a significant growth (Figure 7). It has been observed that after installation of the Ecobeach system an increase of Aeolian transport occurs (Pieterse, 2009). This Aeolian transport is not bounded by artificial human demarcations. Also during severe wave conditions and during storm surges, when dune erosion takes place, sand will move from one area to the other.

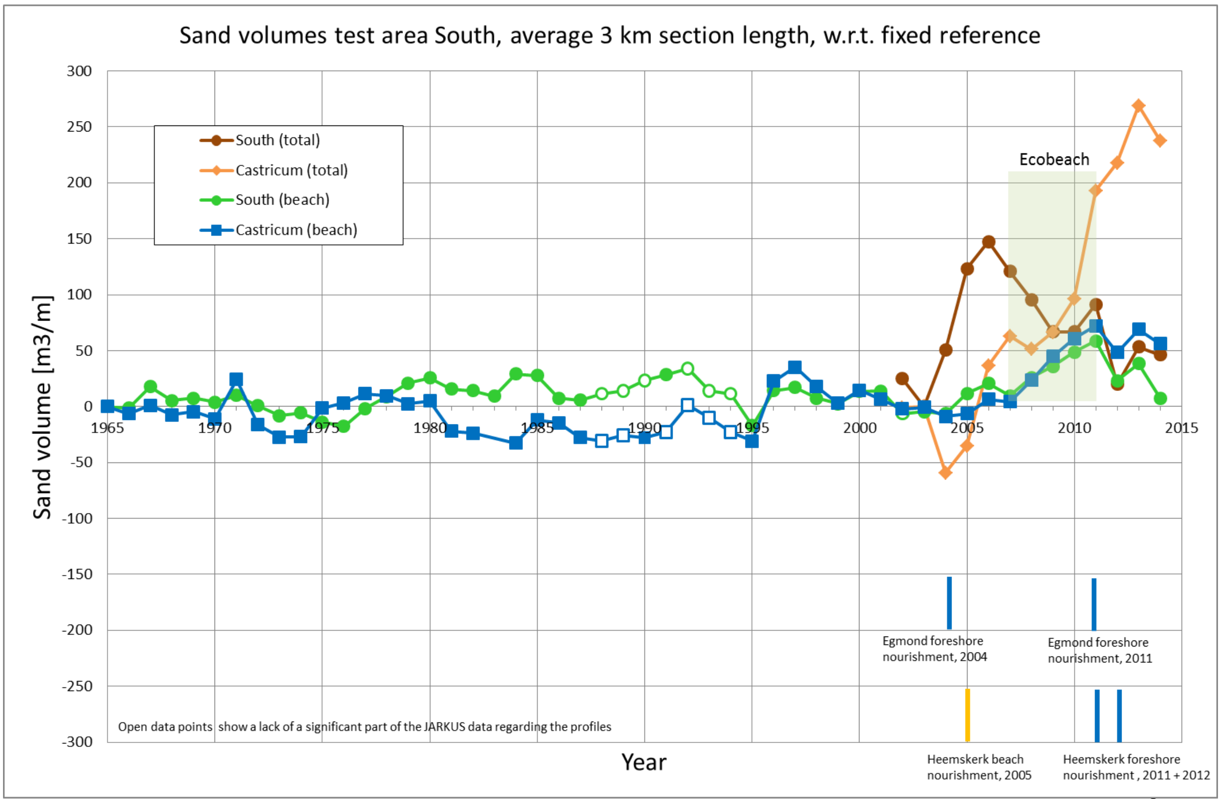


Figure 7: Sand volumes of test area South and Castricum over time, 1965= 0 m^3/m

Test area North and Heemskerk

Test area North (Egmond) is a frequently nourished section along the Dutch coast. The most recent nourishments, just before the Ecobeach installation, were carried out in 2004 – 2005, including both foreshore and beach nourishments. The location at Heemskerk, however, is less frequently nourished compared to Egmond. The 2005 beach nourishment was the first nourishment in the Heemskerk area. Both coast sections show receding beach volumes on average based on historical data from 1965 until present. The Egmond area is receding more than the Heemskerk area. Nourishments in the Egmond area started in 1990. From Figure 8, it can be observed that the nourishments at Egmond were able to counteract the beach erosion. However, nourishments erode in the years after placement. The beach volume in 2004 is again below the beach volume of 1999. In November 2006, 1.5 year after the beach nourishment at Egmond, the drains were installed in the northern test area. The drains have also been installed in the beach nourishment.

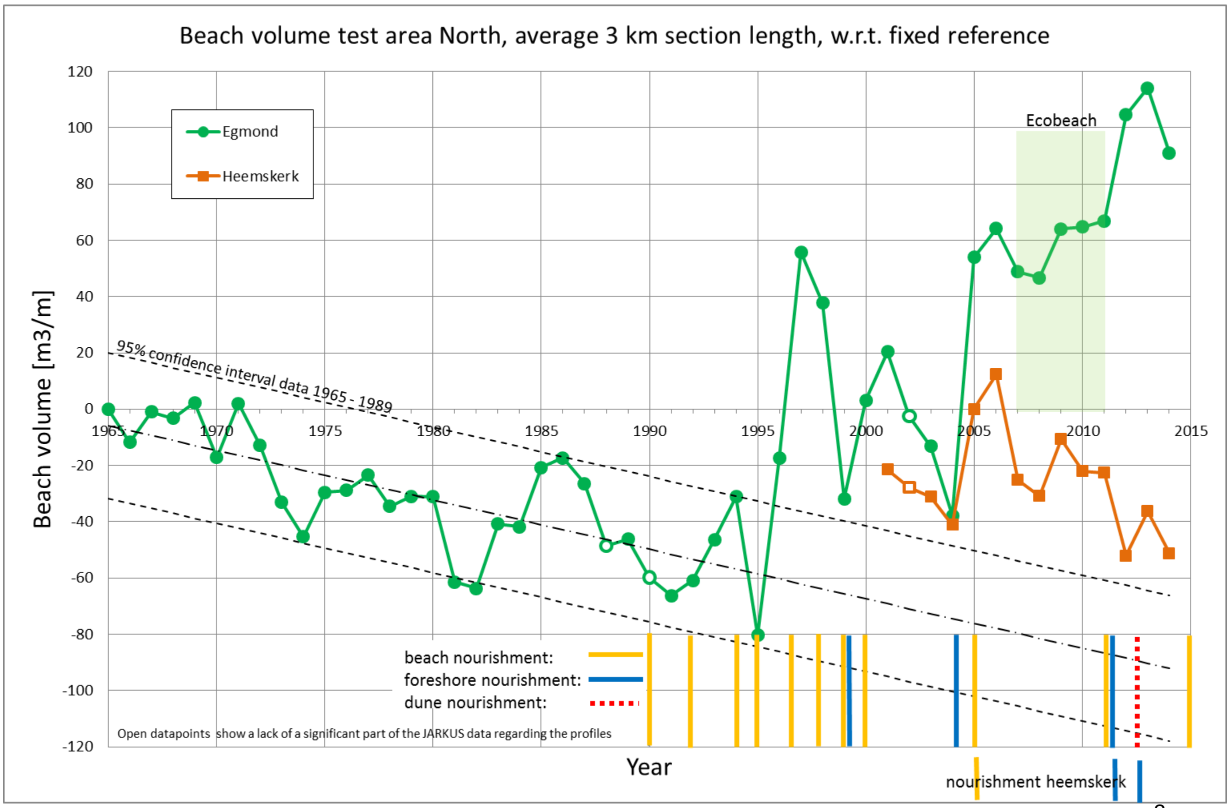


Figure 8: Sand volumes of test area North and Heemskerk over time, 1965= 0 m^3/m

Without Ecobeach, a rapid erosion of the beach nourishment would have been expected. However, after installation of the Ecobeach system in combination with the foreshore and beach nourishment, an increase of the beach volume occurred at the northern test area. Also this area shows the highest beach volume ever measured at the end of the test period in 2011. The measured beach volume is higher at the end of the Ecobeach test period in January 2011 than measured in 2006 after the beach nourishment. The growth is even more when the combination of beach and dune volume is considered as shown in Figure 9.

The beach at Heemskerk (3 km south of test area South) is assumed not to be significantly affected by the Ecobeach system. Beach volume variations after the Heemskerk beach nourishment of 2005 are within the historical natural variability from 2007 onwards. Furthermore, the behavior of combined beach and dune volumes during the Ecobeach test period is similar to the behavior before the nourishment of 2005. A significant difference is observed between the nourished beach at test area North with Ecobeach and the coast at Heemskerk without Ecobeach during the test period

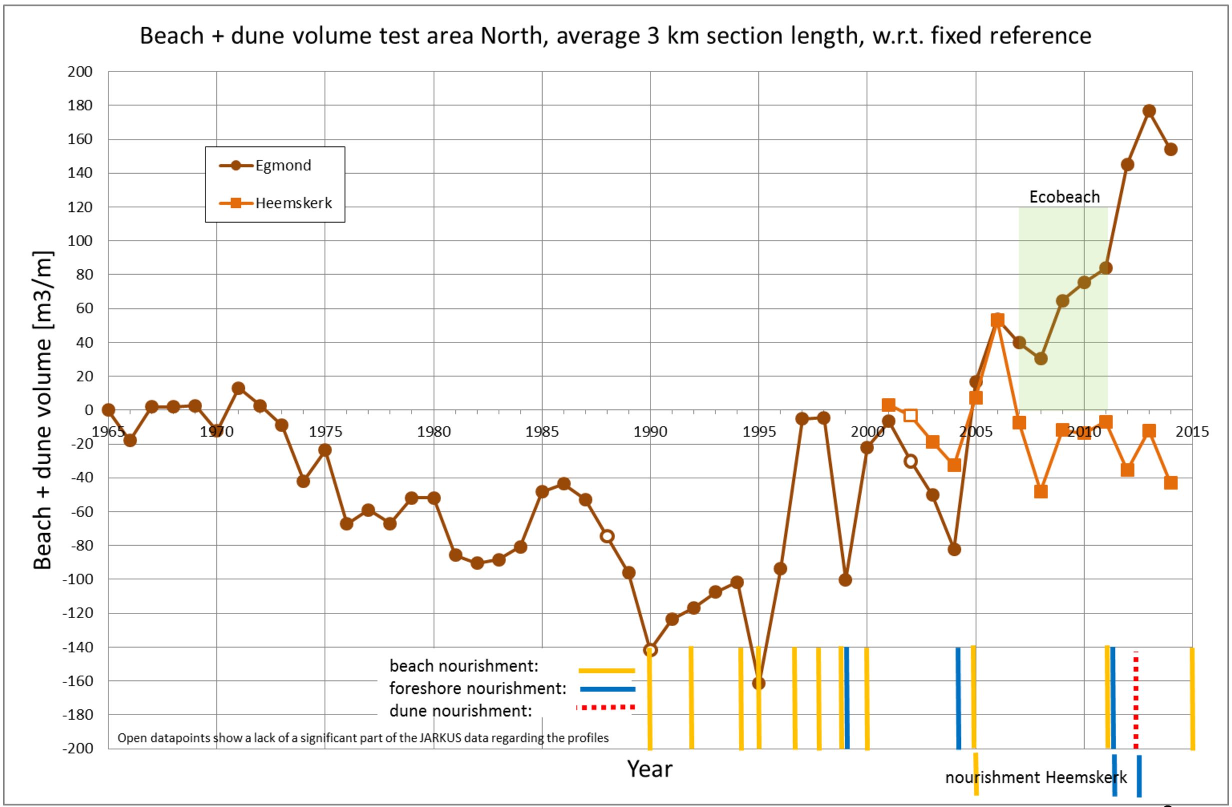


Figure 9: Beach volumes of test area North and Heemskerk over time, 1965= 0 m^3/m

Scientific research

Scientific research for possible working principles of Ecobeach was carried out by BAM together with universities and scientists from different fields of specialism. The research took place from 2008 to 2014. Hypotheses for possible working principles were formulated in relation with the field of (geo) hydrology, geology, sedimentology and biology.

Coarsening of beach sediments was found in the upper 2 m of the intertidal zone of the southern test area (Ekkelenkamp, 2011), while measurements of ground water pressure and salinity showed the outflow of fresh water from a drainage tube near the low water line (Pieterse, 2009). This triggered the research to focus more on beach sediment.

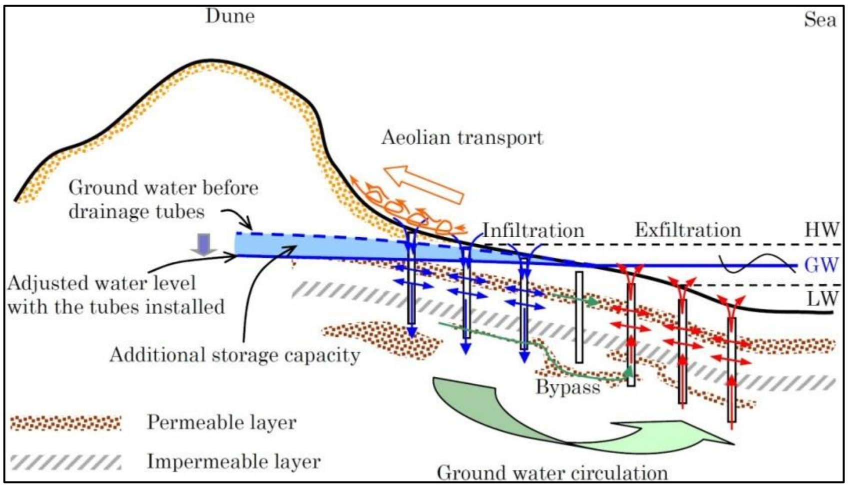


Figure 10: Indication of possible working mechanisms (Ekkelenkamp, 2011)

Sediment coarseness investigation

Many sand samples were analyzed by using a laser diffraction spectrophotometer. Most important property output for the purpose of this investigation is the grading and the grain shape of the sample. Beach sampling was carried out along 20 km coastline including the Ecobeach test areas. The granulometric analysis comprised the comparison of the sediment data from before, during and after the test. To determine the sediment properties, cone penetration tests and boreholes were made. The results showed a significant coarsening of the sediment in the active zone of the beach at the test area South. The upper 2 m of the beach is defined as the active beach zone. Moreover, soil stratification was observed. The beach consists of horizontal layers with each layer containing its own permeability. The drainage tubes connects the highly permeable layers resulting into drying of the beaches after high water conditions. Dry beaches promote Aeolian transport of fine sediments to the dunes. Therefore, sediments at the beach become coarser leading to a higher permeability. The last measurements in 2014, three years after the end of the test period, resulted in a decrease of the presence of relatively coarse material within the southern test area. Test area North did not show significant coarsening of the sediments during the Ecobeach test period. This may be due to the extensive nourishments of this area with offshore sand and thus absence of coarser fractions. Investigations in Denmark also showed the presence of coarser sand in two Ecobeach test areas along the coast of Hvide Sande which is also located on the North Sea coast.

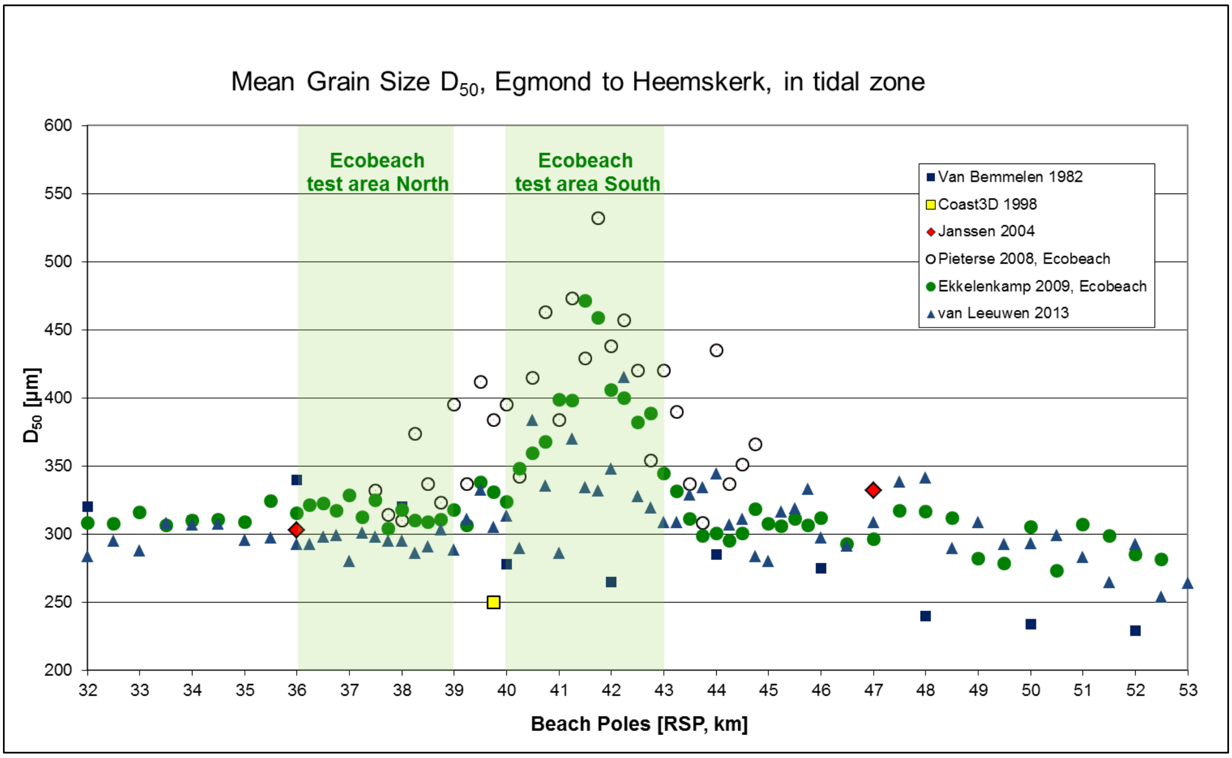


Figure 11: Grain size D_{50} during and after the Dutch Ecobeach pilot

Working principle

Several hypotheses concerning the working principles of the Ecobeach system were investigated. Beach stabilization based on groundwater transport through the drainage tubes is a possible working mechanism. Outflow from fresh water through a drain near the low water line has been observed. The drainage tubes will penetrate through less permeable silt layers and connect more permeable shell layers, leading to a higher vertical permeability of the beach near the drains. As the beach is able to dry quicker, the wind driven sediment transport increases. More fine sand is transported by wind towards the dunes resulting in a coarsening of the active beach zone in the vicinity of the drainage tubes. A coarser beach dries relatively quick, because the infiltration capacity of water is improved and the thickness of the capillary zone is decreased. Therefore a local effect near the drainage tubes can be extended to the rest of the beach. A coarser beach has higher permeability and a higher permeability causes faster infiltration of water. Therefore less backwash of incoming waves is expected leading to less suspension of sediments caused by backwash.

Coarsening of the beach also affects the stability. During stormy conditions, the eroded sand volume at a relatively coarse-grained beach is significantly lower than at a relatively fine-grained beach. Therefore the coarsening of the beach will have a stabilizing effect on the coastline. Moreover, due to the increased wind driven sand transport, the volume of the dunes will increase, creating an additional sand buffer to protect the coastline during a storm.

Conclusion

After installation of the Ecobeach system near Egmond, significant changes in beach volume trends were observed during the test period between 2007 and 2011. A significant increase in beach volumes was observed during the test period compared to the natural variability before the test, reaching highest measured values since 1965 at the end of the test period in January 2011. Coarser sand was observed in the upper 2 m of the beach at test area South and at test areas in Hvide Sande, Denmark. A potential cause for coarsening of sediments is the increase in wind driven transport of fine sand to the dunes because of a dryer beach.

Reference

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