Field tests with vertical perforated drain pipes used for beach protection at Southern Holmsland Barrier on the Danish North Sea Coast

Report of 12 October 2005
by
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1. Introduction

In accordance with the agreement of 18 August 2004 between Skagen Innovation Center (SIC) and the Danish Governmental Coastal Authority (KDI) a field test with the purpose of demonstrating the efficiency of the SIC vertical drain method as a mean for coastal protecting was initiated in a meeting 24 August 2004.
The test period is three years after which a final report has to be presented. The report shall contain an evaluation of the drain system with respect to qualitative and quantitative efficiency and environmental impact, as well as a related comparison with conventional coastal protection methods.
Besides the final report yearly reports have to be presented as well as a report half a year after the start of the field test.
For the evaluation the following two experts were retained

Prof.dr.techn., dr.h.c. Hans Falk Burcharth (HFB)
Prof.dr.techn. Jørgen Fredsøe (JF)

The two experts were obliged to take part in the planning of the field tests including selection of the test location.
Besides the two experts the project group consists of

Director Poul Jakobsen, SIC
Air captain Claus Brögger, SIC
Project manager, Christian Laustrup, KDI
M. Sc. John Jensen, KDI

The present report is the first half year report.

2. Planning of the tests

Project group meetings were held in the autumn of 2004 with the objective of selecting a test size and decide the positioning of the pipes and the methods of monitoring the response of the coast.

2.1 Selection of test size

According to agreement between SIC and the Ministry of Transport a stretch of approximately 10 km on the Danish North Sea Coast should be selected for the tests.
Conditions with respect to hydrographic and geomorphological conditions should be as homogenous as possible along the stretch. Moreover, influence of man-made interventions should be as small as possible.
Two potential sites were discussed: A 15 km long stretch at Skodbjerge just south of the part of Hvide Sande, and a 7 km long stretch at Skallingen north of the town of Esbjerg.
The net-sediment transport is southwards at both site, but much larger at the Skodbjerge site. The Hvide Sande jetties north of the Skodbjerge site create leeside erosion for which reason some beach parallel detached rock structures are placed just south of the jetties. This coastal protection has been

supplemented with beach nourishment and nourishment at the offshore bar approximately 600 m from the shore, cf. Fig. 1. Erosion decrease to the south so that just south of the 15 km stretch the beach is stable. Further south accretion takes place. Beach nourishment will not take place in the three years test period, but nourishment at the offshore bar will continue.

A long groin at the northern boundary of the Skallingen site creates lee side erosion. Erosion takes place over the full length of the actual stretch of coast.

KDI and JF were in favour of inspecting and most probably selecting the Skallingen site as it seems more homogeneous, and no nourishment takes place.
SIC argued that the length was too short as a 10 km stretch was needed. Moreover, SIC regarded the influence of the long groin to be to disturbing for the tests. As SIC refused to use Skallingen it was decided to use the Skodbjerge site, despite the not ideal conditions as explained.

2.2 Planning of the test

The main basis for the evaluation of the tests will be a comparison of the morphological changes in stretches with and without drain pipes.
The total length of the Skodbjerge test site was limited to approximately 11 km in order not to come too close to the beach breakwaters to the North and the accreting coast to the South.
KDI and JF preferred a spilt of the site in a number of relatively short stretches (say 2 km) with alternating drains and no drains. SIC could not accept this as – based on experience – they wanted longer stretches, basically a 6 km stretch with drains and a 4 km stretch without drains. However, due to the gradient in erosion along the test site this was not acceptable and HFB proposed as a minimum stretches with no pipes on both sites of the drained stretch.
A compromise as shown in Fig. 2 was found in which two stretches of 4.7 km (Rør I, chainage 4019200 - 4014500) and 0.9 km (Rør II, chainage 4014500 - 4012700) respectively were drained, and three stretches of 1.8 km (Reference I, chainage 4021000 – 4019200), 1.8 km (Reference II, chainage 4014500 – 4012700) and 1.8 km (Reference III, chainage 4011800 – 401000) respectively were left undrained.

The drains were installed in January 2005. The positions of the drains are shown in Fig. 3.

2.3 Monitoring of the test site

2.3.1 Surveying

Profiling per 100 m of the beach including the dune front four times per year was decided as well as soundings per 200 m of the seabed within 600 m from the shoreline. The first profiling took place in January 2005 just after placement of the drains. The second and third in April and June 2005. Carl Bro A/S performs the landward surveying and KDI the depth sounding.

2.3.2 Monitoring of ground water levels

According to SIC the function of the drain relates to changes in the ground water flow caused by pressure equalisation in the surroundings of the drains. For this reason a comparison between pressure fields near the drains and far from the drains is of importance. The method of instrumentation is under discussion.
As it is generally accepted that ground water outflow in the beachface affects the sedimentation, it was decided to monitor in one line the ground water table across the narrow land spit between Ringköbing Fjord and the test beach. Application for permission the establish wells is forwarded to the authorities.

2.3.3 Grain size analyses

In order to check the hypothesis of SIC that the drains increase the groundwater outflow through the beachface and thereby wash out the fine beach material, it was decided to investigate if changes in the composition of the beach material take place as a result of the installation of the drains. Five borings were taken app. three month after the installation of the drains. (SIC has raised the question if this was too late compared to the rapid development in accreation observed after placement of the drains).
Grain size analyses of the samples have been made for comparison with samples to be taken later in the course of the project. Focus will be on changes in the amount of very fine material in near-drain regions compared to regions without drains.
The samples provide general information on the character of the beach with respect to stratification and permeability conditions.

2.3.4 Satellite images, aerial photographs, and airborne laser photogrametry

Method(s) and frequency are still under consideration.

3. Characteristics of the test site

3.1 Geomorphologic conditions

The test site is on the southern part of a barrier spit separating the Ringkøbing Fjord lagoon from the sea. The spit is formed by sand deposition resulting from a decrease in the rate of southwards longshore sediment transport. The natural southwards shift of the opening between the lagoon and the sea has been stopped by the construction of a permanent sluice and a lock at Hvide Sande where also a fishing port is located. The entrance is protected by jetties of which the longest to the north built in 1962 at present extends approximately 450 m from the foot of the dunes.
As to the coastal profile along the test site, the distance from the coastline at level 0.0 m (equal to mean water level) to the 6 m depth contour is approximately 650 m over the full length of the test site, i.e. an average slope of app. 1:100. This slope has remained almost constant during the last 20 years according to the profiling by KDI. The coastline has in the same period shown large fluctuations with changes in position ranging from 50 m to 100 m.
Grain size analyses of the sand in the foreshore and in the beach top layers shows medium to very coarse sand with grain diameter in the range 0.3-2.5 mm. Deeper borings show fine sand down to approximately 10-12 m below the surface. Underneath is very fine sand or silt, and in some places clay.
Several shore parallel bars, typically three, are formed along the coast. The net sediment transport in front of the test site is southwards amounting to approximately 2.1 million m^3 per year in average (ref. KDI). Most of the longshore transport takes place in the bar zones.

3.2 Hydrographic conditions

Water levels

At the coast the difference between mean high water and mean low water is 0.7-0.8 m. Storm surge caused by strong westerly gales and low pressures can give water levels of up to approximately 3.1 m above mean water level. Low water levels down to -2.0 m can occur during easterly winds.
In the Ringköbing Fjord lagoon the water level varies between -0.5 m and +0.5 m, dependent on the operation of the sluices and on the wind set-up.

Waves

The prevailing westerly winds cause quite frequently storm waves with significant wave heights in the range H_s = 3-4 m offshore in 20 m water depth, and related peak periods of approximately T_p = 10 s. During more extreme events, say return periods of 5 years or more, H_s will exceed 6 m and T_p exceed 12 s. It is not often that H_s is less than 1 m and T_p less than 5 s during westerly winds. The waves are strongly seasonal as storms occur mainly in the autumn and during the winter.

3.3 Former coastal changes and man-made interventions

The natural erosion (retreat of the coastline) is estimated by KDI to vary gradually from approximately 3.5 m/year just south of the Hvide Sande jetties to approximately 1.5 m/year at the southern end of the test site, calculated as averages over the years 1977-96.
The actual erosion is different due to man-made interventions. Actually the coastline has, apart from fluctuation, in average been stable over the last 5-10 years as documented by the KDI profiling of lines 5700-5810 (chainage 4010000-4021000). Table 1 lists the man-made interventions for the stretches Årgab (5 km stretch north of the test site), Havrvig (northern half part of the test site) and Skodbjerge (southern half part of the test site).

4. Method of presentation of surveys

With the objective of gaining information on the development of the coast with respect to the following beach properties

- beach width
- width of beachface
- volume of accreted/eroded material
- average height of beach
- average slope of beach
- average slope of the beachface

the coastal profile was divided into four zones defined as shown in Fig. 4.

The quantities a_1, a_2, a_3, A_1, A_2, A_3, A_4 will be calculated from the coastal profiles and compared from survey to survey.
Based on the experience from the April and the June surveys the definition of these quantities will be adjusted in order to obtain the most relevant interpretation of the data with respect to the above mentioned beach properties.

5. Results of surveys January, April and July, 2005

Tables, diagrams and related comments based on definitions given in Fig. 4. Next report will present the results in accordance with updated definitions.

5.1 Beach width

The evolution in beach width calculated as the changes in $a_2 + a_3$ observed in the period from 18.-28.1.2005 to 4.-7.7.2005 is shown in Fig. 5. It is seen that already ultimo January there was a significant undulation in Rør I. It can be seen that the main contour of the coastline is maintained in the period from January to July. A longshore shift in the ondulations cannot be observed in this period.
Fig. 6 shows $\Delta a_2 + \Delta a_3$, i.e. the net changes in beach width, between the first and the second and the third surveys. There seems to be no clear tendency as all defined stretches exhibit both increase and decrease in beach width, except for Rør II where only increase took place.

5.2 Beach volume

The net change in beach volume calculated as $\Delta A_1 + \Delta A_2 + \Delta A_3$ is shown in Fig. 7. It is seen that significant net deposition has taken place in Rør I, Rør II and Ref. III whereas both erosion and deposition - almost equalizing each other - have taken place in Ref. I and Ref. II.

The net changes in the volume, calculated as the sum of the average net volume changes in each of the defined stretches: $\overline{\Delta A_2} + \overline{\Delta A_3}$ between the first and the third surveys, are given in Table 2.

Table 2. Net changes in beach volume from 18.-28.1.2005 to 4.-7.7.2005

Stretch	Average net changes in m^3/m	Net changes in m^3
Ref. III	18.9	34,020
Rør II	51.2	46,080
Ref. II	-13.6	-24,480
Rør I	33.0	155,100
Ref. I	1.0	1800
Total		228,720

It is seen that a significant deposition on the beach has taken place in Rør I and Rør II. However, also in Ref. III a large deposition has occurred.

5.3 Beach and nearshore volumes

The water depths in the foreshore region influence the wave impact on the beach and thereby also the resistance of the beach. The changes in the total volumes of the beach and the foreshore are therefore of interest.
The net changes in the volume, calculated as the sum of the average net volume changes in each of the defined stretches: $\overline{\Delta A_1} + \overline{\Delta A_2} + \overline{\Delta A_3} + \overline{\Delta A_4}$ between the first and the third surveys, are given in Table 3.

Table 3. Net changes in beach and nearshore volumes from 18.-28.1.2005 to 4.-7.7.2005

Stretch	Average net changes in m^3/m	Net changes in m^3
Ref. III	59.4	106,920
Rør II	22.2	19,980
Ref. II	-11.0	-19,800
Rør I	30.0	141,000
Ref. I	-13.9	-25,020
Total		221,300

It is seen that a very significant deposition has taken place in Ref. III seen in relation to the limited length of this stretch. Also in Rør I and Rør II significant depositions have taken place.

6. Preliminary observations

In the period ultimo January – primo July no significant changes have taken place in the beach planform as the coastline ondulations have more or less maintained their positions. Despite this it can be observed that significant accumulation of sand has taken place within the two areas with drains, Rør I and Rør II, i.e. the beach level has been raised. The same development is however observed in Ref. III with no drains, whereas Ref. I and Ref. II -also with no drains- exhibit both erosion and accretion.

This observed development has taken place in a period with no severe storms and extreme high water levels since the very severe storm around 8 January 2005 occurred. At that occasion large quantities of sand was probably eroded from the beach. Usually part of this sand will be transported back to the beach in periods with milder wave climate, normally occurring in the spring and the summer. The changing wave climate causes large natural fluctuations in the beach planform and volume. Moreover, coastline ondulations moving along the coast in the direction of net sand transport might contribute to these fluctuations. The effect of the drains has to be detected from such "background noise" which is not easy during a short period, even if the drains might have a significant effect. For this reason the following conclusions are of preliminary character.

7. Preliminary conclusions

During the first six month of tests the beach has increased its volume significantly in the stretches where the SIC-drain system has been installed. In the three stretches without drains accretion has taken place in one stretch and erosion in two stretches. Thus there seems to be a certain correlation between areas with deposition and areas where the drains are located.

The beach planform and thereby the beach width has not changed significantly. No migration of the coastline ondulations along the coast has been detected.

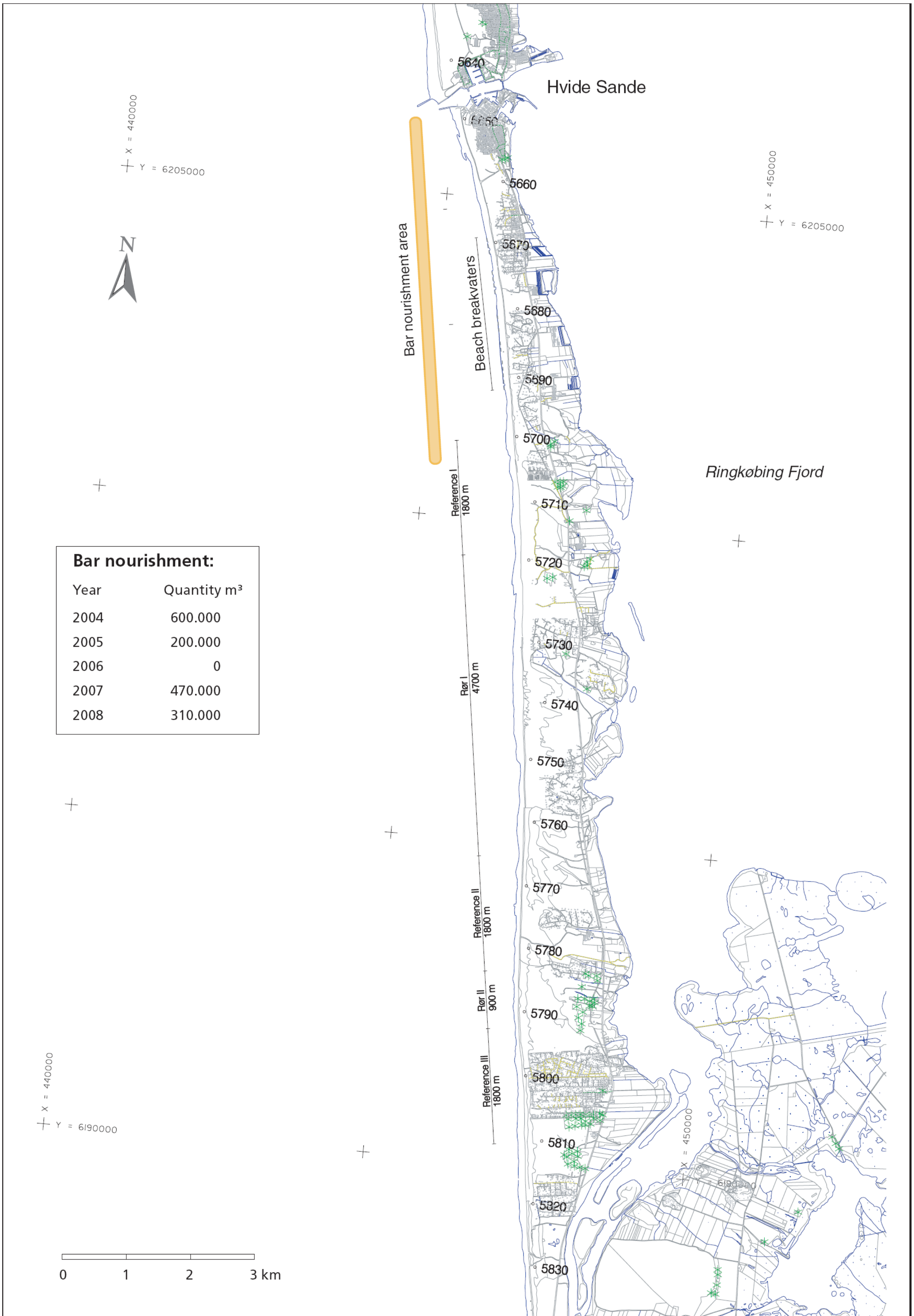
13 October 2005

Hans F. Burcharth Jørgen Fredsøe

Table 1. Man-made interventions, 1977-2004

Volumes m^3

	Årgab					Havrvig			Skodbjerge	
	dumping at dune foot	beach nourishment	beach scraping	foreshore nourishment	bar nourishment	beach nourishment	beach scraping	foreshore nourishment	beach nourishment	beach scraping
1977	158.007									
1978	48.817			34.959						
1979	57.813			29.014						
1980	54.383			17.005						
1981	87.100									
1982	95.342									
1983	84.656									
1984	89.002		21.726							
1985	119.288		17.704	18.491						
1986	85.816		21.604	29.927						
1987	97.542		9.384	25.900						
1988	173.960		750	44.864						26.997
1989	165.361			41.336			4.410			21.182
1990	187.306			7.100			4.418			21.222
1991	177.766			1.318			4.084			24.422
1992	197.907			3.855		21.099			115.669	
1993	82.333	208.099		2.955		152.115	108.904			81.128
1994	60.602	148.455	13.395	1.591		214.945	51.288		82.345	25.123
1995	35.528	184.655	23.848	33.136			58.969			
1996	18.288	395.811		1.973		185.946	11.131			79.873
1997	12.534	187.718	19.001	2.618			36.565			42.875
1998	36.095	504.742		382		326.358	43.637			57.680
1999	17.480	388.036				228.020	8.010	200.255	154.110	41.624
2000	60.256	519.733		10.800		218.080	13.075			56.060
2001	14.342	429.572					4.634			60.900
2002		628.317					12.540			17.188
2003	28.706	527.925			2.632		20.239			42.907
2004		73.900	11.443		600.041		3.951			15.061
Total	2.246.230	4.196.963	138.855	307.224	602.673	1.346.563	385.855	200.255	352.124	614.242



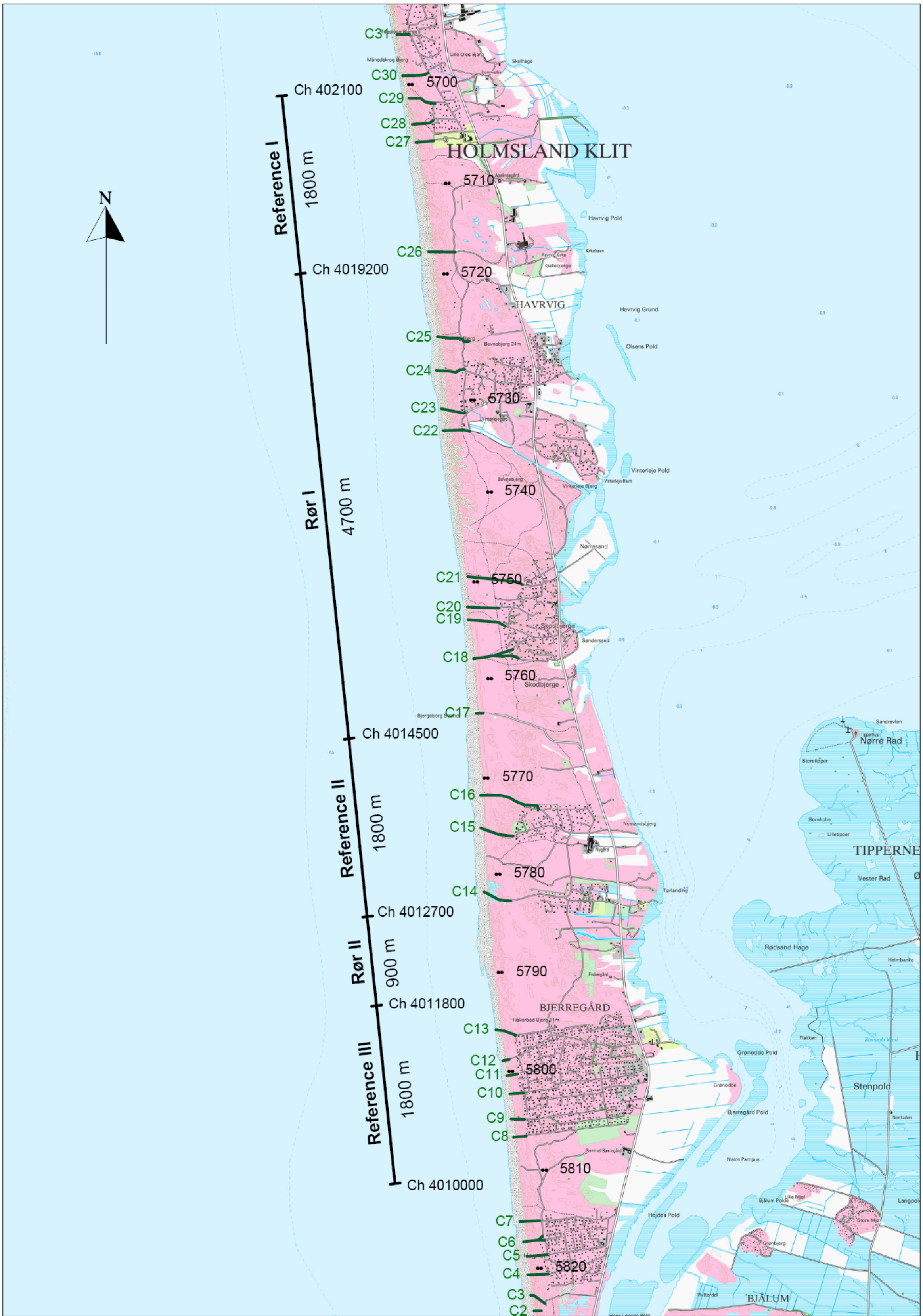
Bar nourishment:

Year	Quantity m³
2004	600.000
2005	200.000
2006	0
2007	470.000
2008	310.000

KYSTDIREKTORATET

Figure 1
Planned bar nourishment

Mål:	Tegn. nr.
Projekt: JJ/TL	Nr.
Rev.:	Gr. 103-659-2
Godkendt: 05.10.2005	



KYSTDIREKTORATET	Figure 2 Location of test stretches	Mål: 1:50000 Projekt: JJ/TL Rev.: 05.10.2005	Tegn. nr. Nr. 100 Gr. 103-659-2
		Godkendt: 11.05.2005	

	PEM modules Skodbjerge start 2005				
stn	Total	additional	additional	additional	Total
	28-jan	28-mar	06-maj	05-aug	05-aug
4011900	6	3	1	0	10
4012000	6	2	2	0	10
4012100	7	0	3	0	10
4012200	6	1	3	0	10
4012300	7	2	0	0	9
4012400	7	4	0	0	11
4012500	6	4	0	0	10
4012600	6	4	0	0	10
4012700	7	3	0	0	10
4012800	7	2	0	0	10
4014500	6		0	0	4
4014600	6		0	0	5
4014700	6		0	0	6
4014800	7		0	0	6
4014900	7		1	0	8
4015000	7		0	0	7
4015100	7		1	0	8
4015200	7		0	0	7
4015300	7		0	0	7
4015400	7		0	0	7
4015500	7		0	0	7
4015600	7		0	0	7
4015700	7		1	0	8
4015800	7		0	0	7
4015900	7		2	0	9
4016000	7		2	0	9
4016100	7		2	0	9
4016200	7		3	0	10
4016300	7		5	0	12
4016400	7		4	0	11
4016500	7		4	0	11
4016600	7		4	0	11
4016700	7		5	0	12
4016800	7		4	0	11
4016900	7		4	0	11
4017000	7		4	0	11
4017100	7		2	2	11
4017200	7		1	3	11
4017300	7		2	2	11
4017400	7		0	4	11
4017500	7		0	4	11
4017600	7		3	1	11
4017700	7		3	1	11
4017800	7		3	1	11
4017900	7		2	1	10
4018000	7		0	2	9
4018100	7		0	2	9
4018200	7		0	1	8
4018300	7		0	2	9
4018400	7		1	1	9
4018500	7		2	0	9
4018600	7		2	1	10
4018700	7		1	0	8
4018800	7		0	0	7
4018900	7		0	0	7
4019000	7		0	1	8
4019100	7		0	1	8
4019200	7		0	2	9
	398	25	77	32	529

Fig. 3. Positions and number of drains per October 2005

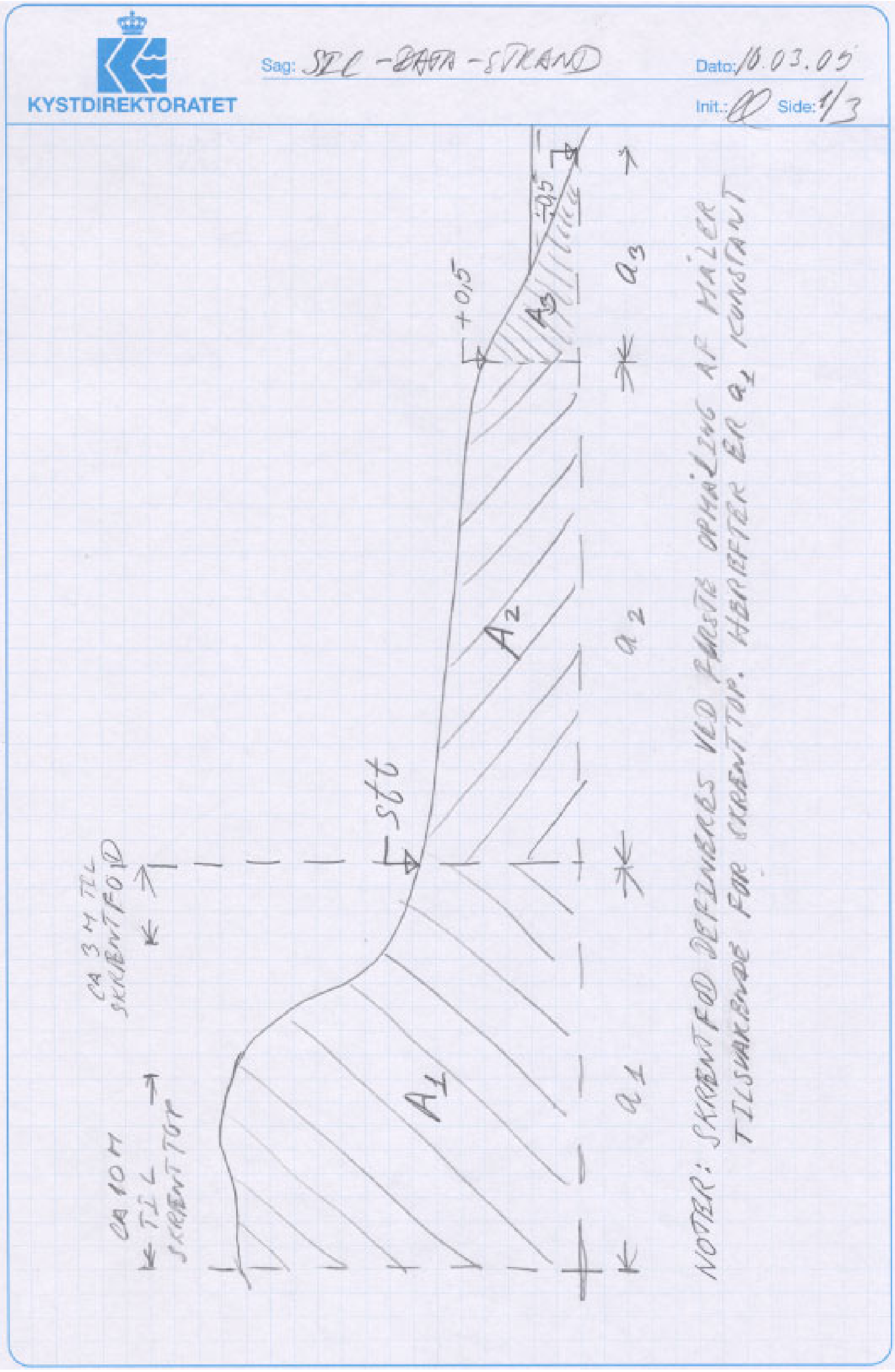


Fig. 4. Illustration of geometrical properties extracted from the surveyed beach surface profiles. (To be modified later).

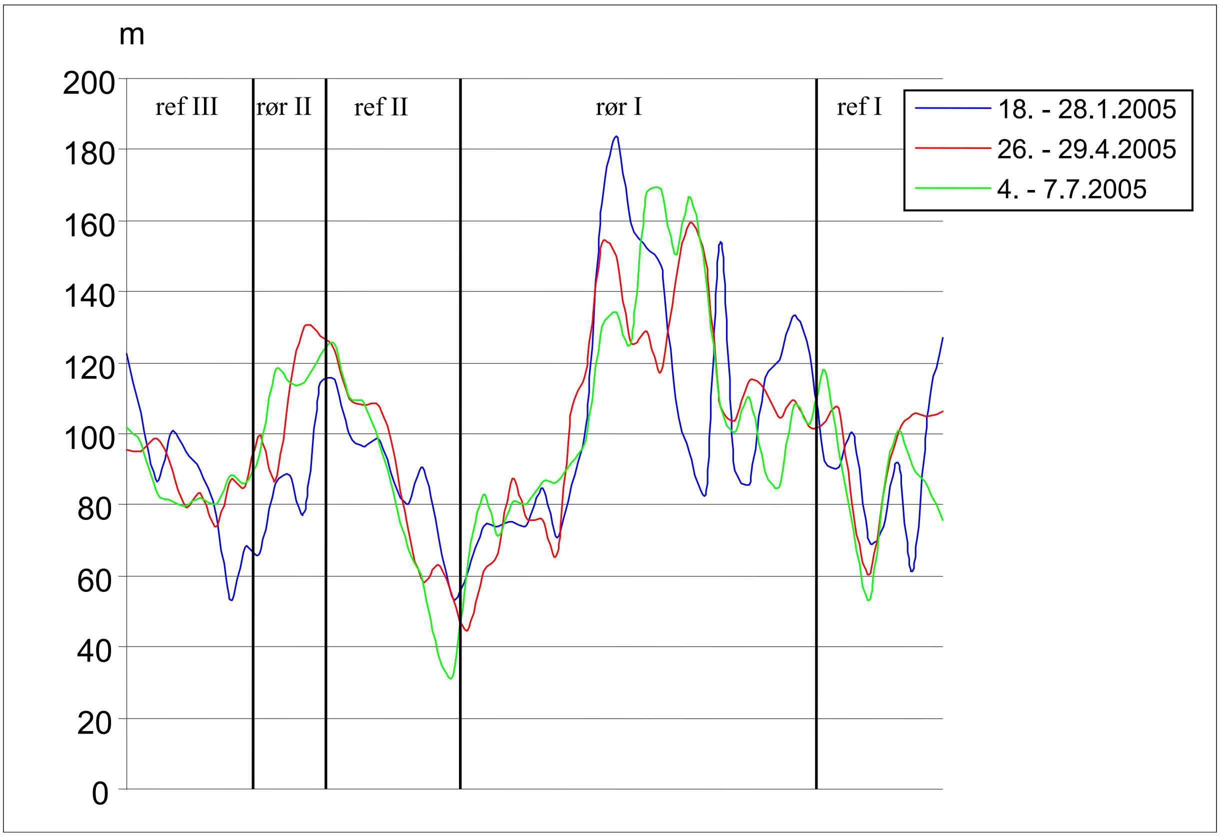


Fig. 5. Beach width evolution, $a_2 + a_3$

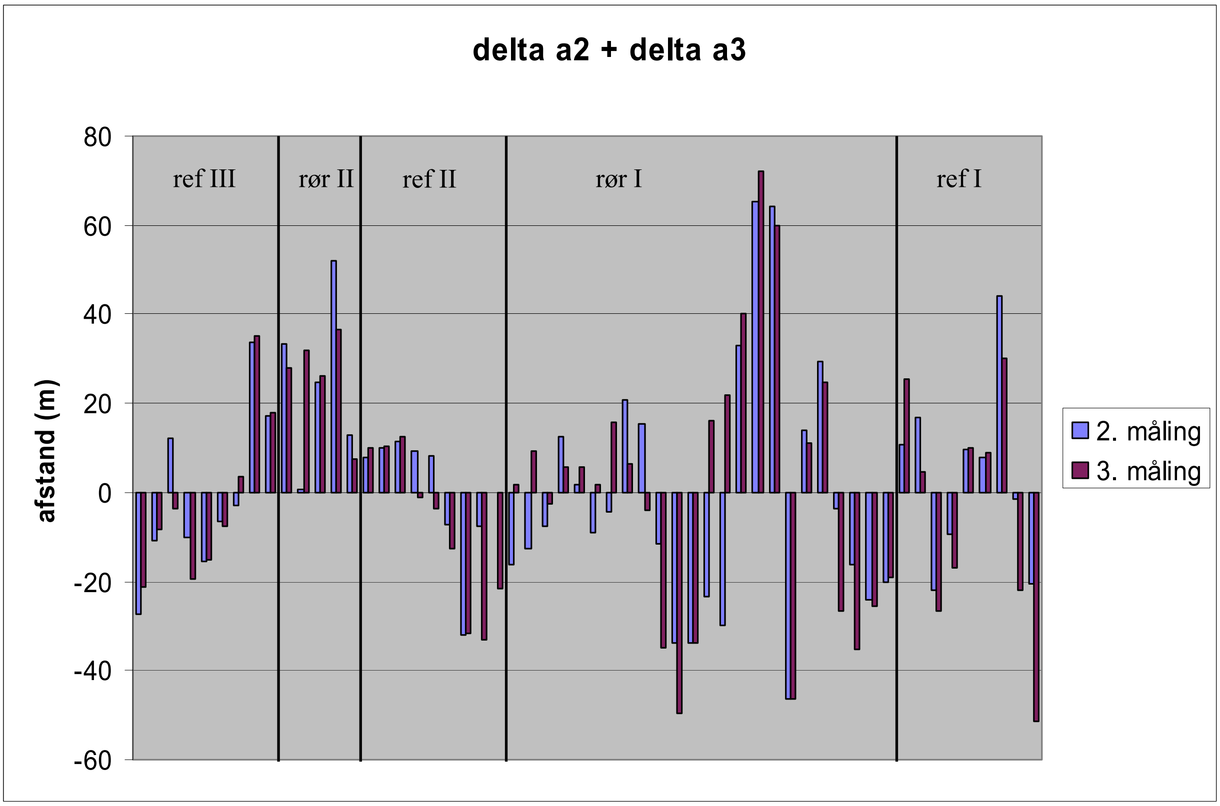


Fig. 6. Changes in beach width $\Delta a_2 + \Delta a_3$

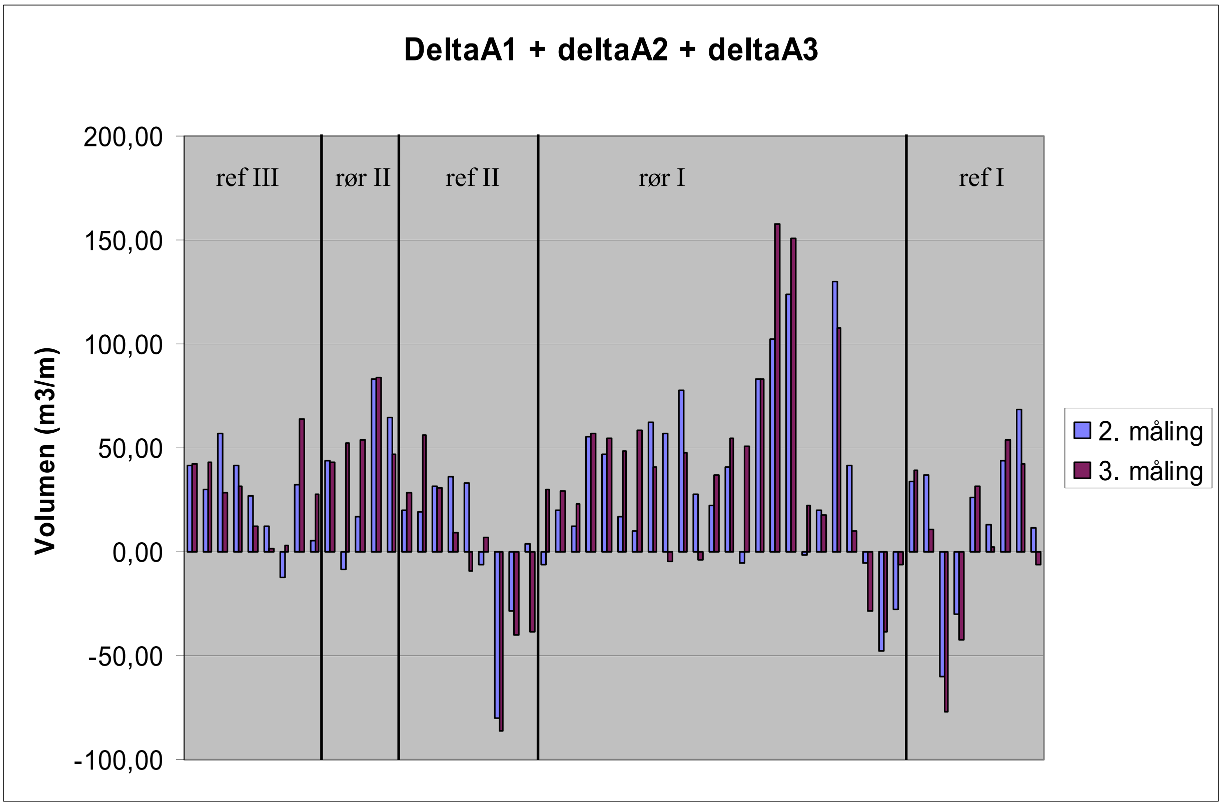


Fig. 7. Changes in beach volume $\Delta A_1 + \Delta A_2 + \Delta A_3$