Trafikudvalget (2. samling)
TRU alm. del - Bilag 399
Offentligt

Chapter 10 Morphodynamic fingerprints.

In this chapter it is briefly discussed which kind of changes in the bathymetry that might be expected due to the presence of the tubes and which can be related to nature. These changes are called the morphological fingerprint. Also washed sand is discussed, since this according to SIC has a morphological impact. The description below is applied in the next two chapters: in the discussion, chapter 11, and in the conclusion, chapter 12. In chapter 11, some repetitions of this chapters discussions are repeated to get the understanding easier. However, this chapter put all the things together.

1. The morphological fingerprint of the PEM-system.

Perpendicular to the waterline, the mutual distance between the tubes is - as mentioned earlier - 10 meter, while the distances alongshore between the individual rows is 100 m. The reason for these selections is not clear, and must be based on instinct by SIC rather than any kind of flow mechanics reasoning.
By instinct you would say that the alongshore distance of 100 m is quite long, and that you can not feel any impact from a tube more than, say, a few meters (or, - as the numerical modelling suggests, a few centimetres). SIC is aware of this, and explains that the functioning is based on a mechanism called “washed sand”.

Washed Sand:
Due to the (postulated) increased flow velocities near the tubes (because of the draining effect of the tubes), all the finer fractions of the beach sand are being removed, washed away, as the sand in the beach passes the individual rows in the system. The remaining part of the sand is coarse, and therefore easy to drain, and therefore stable.
It is correct that a beach consisting of coarse sand is more stable than fine. But the tube-induced flow is very slow as discussed in chapter 4 and much weaker than for example the wave induced flow, especially in the swash, where the sand must be expected to be “washed”. So if the argument that high flow velocities will remove the fine sand fractions, then the wave-induced flow in the swash zone will wash much more efficiently. Here you have wave-induced velocities in the sand more than 1000 times as high as those induced by the tubes. The sand should, if the mechanism of washing really exists, anyway be washed, with or without the presence of tubes!

SIC also explains a ‘trigger-mechanism’: they are aware that the impact radius from the individual tubes is small. The trigger is that when the fine fractions are removed from the near-tube location, then more water will flow in and out of the tube because of the reduced flow resistance, and hereby more and more sand can be washed further away from the tubes. Based on continuity in the water flow, a simple calculation gives that the flow only 10 cm away from the tube to be 0.01 m /hour (!) if the flow inside the tube is as high as 3 mm/sec, see chapter 4. So there exists no additional washing effect from the tubes!

This is also supported by the fact, that (a few) samples taken during the field test showed no systematic changes in the grain sizes close to and further away from the tubes.

Finally it can be mentioned that the total volume of sand in the beach (typical 50-100 cbm/m) is so large, so that each tube shall wash 500 cbm sand, - which is replaced by new “unwashed” sand all the time, since you have a very large south going sand transport.

If the mechanism ‘washing of sand’ really exists , one may ask what the extension of tube impact shall be. Reference 2 is 1800 m long, so will the sand be washed in this section? SIC says no, stating that so much sand has to be washed in rør 1 (4700 m), that this effect has not come into function yet in Ref 2.
On the other hand side, SIC claims that the mechanism works in reference 3, which is even further down drift. This simply cannot be correct. If the tubes – in one way or another – wash the sand, then the fine fractions must be washed out into the sea since the wash occurs in the swash. Because the tube density remain unchanged whether the stretch is long or short, the sand down drift a PEM-system must be washed whatever you have 50 rows or only 10. So you can not explain both the erosion in ref 2 and the deposition in ref 3 by the effect of washing.
If you should keep the reasoning by SIC anyway, then it would be more logical to say that the sand not is washed in ref3 because this is more down-drift than ref 2, so even more sand has to been washed up-drift of ref3. And therefore, you would expect more erosion in ref 3 than in ref 2. The opposite has been observed, because this is more in line with the natural behaviour of the coast.

Local Fingerprint: Development of salient and ridges
Since washing of sand not is a possible mechanism, the tubes must (at least initially before each tube has washed all the 500 cbm of sand) have a *local* impact close to the tubes.
Sediment to the beach is supplied (or eroded) by waves from the sea or by wind. Deposition/erosion in the beach by waves occurs in the swash zone and if you can increase the deposition (or decrease the erosion) you will get more volume in the beach, and hereby obtain to get a larger reservoir of sand to resist storms.
You will think that the effect of the tubes will be to catch sand in the swash, so the immediate effect will be to see a collection of sand around the tubes, especially in the swash. The water level will change with tide or storm surge, so you may expect accumulation around more than one tube in the row, so the accumulated sand will form a kind of a ridge around each row.
It cannot be observed that each tube collects sand in the neighbourhood of the tube. Maybe because the tubes are buried so deep in the beach that it can’t be felt at the beach surface: you actually only have an one meter long active part with slots buried more than one meter below beach surface, so the radius in the local sink in the water table will be increased by some meters. However, *the drain must form a local sink of the water table to work,* if you do not have a local lowering around the tubes, then the water will not flow to the sink, because the water flow in the downwards direction.

Figure 10.1 A.

Fig 10.1B.

Figure 10.1A and B: No local accumulation is found around each array of tubes .You can see two tubes in the lower picture. (Pictures taken by Prof. Burcharth).

Since no local accumulation occurs around the individual tubes, at least collection of sand must take place around the individual *arrays* if the tubes shall have any function As sketched in figure 10.2 below. For instance during the first 3 month period, where the beach in rør 1 in average gained volume of 25-30 cbm/m: with so much accretion, you must expect a local increase around each row, if this increase is caused by the tubes rather than by natural causes (a natural cause could be the regeneration of the profile after a severe storm: in this case the sand will be transported to the beach more uniformly along the coast – as actually observed). If this increase in beach volume is due to the tubes, each tube row collect 25 cbm per meter multiplied by 100 m (the distance between the rows) or 2500 cbm. How can you collect so much sand without visually to be able observing local accretion around each row??

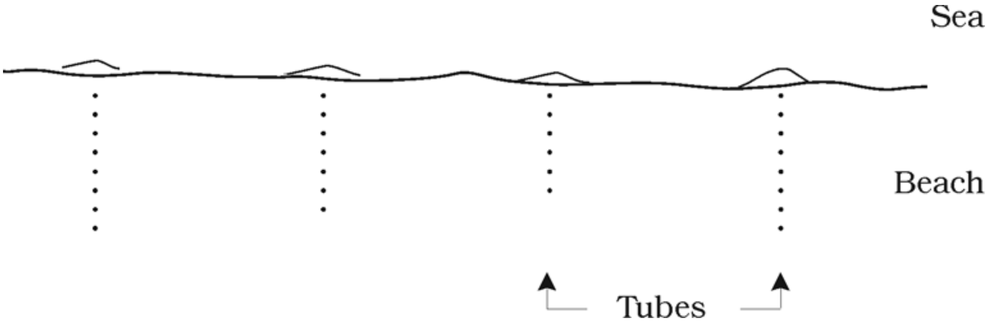

Figure 10.2: No individual salient are observed in front of the tubes just after installation, like no ridges are observed on the beach, see fig 10.1 and 6.1.

Another mechanism suggested by SIC is, that the individual accumulations act as a *local groin*, which trap the sand downstream this groin, and therefore you do not need a larger density of the rows than 100 m. But how can each accumulation act as a groin, when you even cannot observe any accumulation? The coast line passes the individual rows without any local changes in width or height, and it has been like that from the very beginning of the tests.

If the tubes act as a drain, you will create a local sink in the water table. Referring to an internal note by Peter Nielsen, there should be “a bend between in the borderline between the saturated (glassy looking) and drained (mat looking) sand surface”. No such local drying around the individual tubes in the surface sand occurs earlier during backwash in the swash zone.

Figure 10.3: Seaward peaks in the borderline between drained and saturated sand surface caused by active line drains perpendicular to the coastline. (From Peter Nielsen's note on the PEM-system). No such bends or peaks are observed in relation to the SIC system, indicating that a passive drain has no drainage effect.

Fig. *10.4A: The term "leeside deposition" does not exist in nature: an irregular swash can easily exist. Here from the SIC test at Egmond, Holland April 9th 2008.*

*Figure 10.B4***:** *Small ridges formed by nature in the swash at the test site.*
You don't observe similar ridges around the row of tubes.

SIC claims that there is an interaction between the initial salient, which merge to one bigger coherent structure, but the merging of the salient cannot occur before the individual salient has reached a certain size and such one is not observed. In nature ridges and salient can easily exist as demonstrated in the pictures, figure 10.4.

The interesting thing is, that SIC themselves demonstrate the above functioning of the tubes in their PR-material, see the figure 10.5 below, where they explain that a sand groin will be formed in front of a tube row. It has been claimed by SIC, that due to drainage, accumulation will start to take place. However the picture shown in figure 10.5 is taken just down drift of other hard coastal structures (real groins), so the morphological behaviour here is a little bit complex to interpret.

The PEM modules create a groin that catches long shore sand transport.

Figure 10.5: Observed accumulation of sand in front of a row of tubes at Skagen (from a SIC report).

Fingerprint from the tubes on the dunes.

The fingerprint from the tubes on the dune can only be indirectly. *The only direct implication* would be a lowering of the water table in the dunes, because the water table here must be slightly higher than in the beach, due to fresh water flow from land. So if the tubes drain, then they make the dunes dryer and therefore more vulnerable to wind erosion. So the only direct effect of the tubes will be loss of sand from the dunes to the hinterland!

The indirect effect is more speculative and can maybe be explained in the following way. If the tubes collect sand and make the beach higher, then the vegetation at the dune foot will be more protected, and vegetation on the dune is extremely important for its ability not to be eroded by wind.

As discussed into detail in chapter 11, you do not get a nice correlation in between Mean Beach Level and sand volume in the dunes. In the long term, tens or hundreds of years, you might observe such a correlation (though weak), but in the short term, you first need the beach to be reshaped, then next get the impact on the vegetation and finally catch the sand.

You get a higher correlation between the instantaneous *width of beach and trapped sand in the dunes.* This is understandable because on a wider beach in front of the dunes, the wind have a larger area from where it can sweep sand to the dunes.

But you need to keep in mind that most windblown transport occurs during strong landwards directed wind, and a lot of sediment is transported over long distances along the dune foot. Therefore deposition of sand in the dune does not exactly depend on the beach level and beach width just in front of the dune. The deposition of sand is just as much a function of the height of the dunes, local shape, local wetness and local vegetation.

So there is a big difference in the wave related sand transport and the windblown transport: the wave related response locally on changes like a lowering in the ground water table in the beach or changes in the wave climate. The windblown transport on the other hand is more determined by the characteristics of the dunes, but do not depends very much on the position of groundwater table. Only the *wetness* of the beach surface plays a role: the more wet, the less is the transport. The dryness of the beach is not affected by the tubes, when the groundwater level lies well below the beach surface. If the water table is located close to the beach surface, a lowering of the water table will make the beach surface dryer, and this will enhance the windblown sediment transport capacity in these regions. The beach can be drier either if it becomes higher, or by drainage!

If the tubes really drain the beach, then the beach will be dryer and easier to erode by wind, thus causing a thinner beach. The result will be a redistribution of sand from that part of the beach, which is near the sea to the dunes. This should actually cause a loss in sediment in the beach-box and a gain in the dune-box. So drying the beach surface itself will lead to a total loss, because some of the windblown sand will pass the dune ridges and be transported further into the hinterland.

You can always speculate what is most resistant to coastal erosion: a strong dune system and a weak beach, or the opposite.

If the tubes by lowering the beach water table further collect more sand in the swash, you get a stronger and possibly higher beach, and more windblown transport because the beach become dryer. This windblown transport may increase the volume of the dunes. So the ideal case will be to get a higher beach in combination with stronger dunes. However, as will be seen in chapter 11, we can not identify such a correlation on the tube-covered stretches.

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Offshore fingerprint

The tubes are placed in the beach, and some of them are totally submerged during high tide. Nevertheless it is difficult to assign any direct impact from the tubes to the offshore bathymetry. Indirectly an increase in the beach volume will of course have an impact on the near shore bathymetry, like pushing the location of the inner bar a little bit offshore etc. Also redistribution of sand between beach and near shore might cause a negative correlation in between volume changes in the beach and offshore. However this can not be identified from the measurements of profiles. For these reasons it is questionable whether changes in the offshore volume shall be considered when evaluating the success of the tubes. The data are included in chapter 9 and in the discussion given in chapter 11, but the offshore data are mainly used to get the offshore bathymetry, which is necessary for evaluating the natural behaviour of the beach.

Transition zones and direction of sediment transport.

In case of a positive impact from the tubes on a larger scale, this impact might be felt also outside the tube covered regions. SIC denote it “transition area”. Here it is important to note from the wave roses presented in chapter 3, that during all three years the large waves approaching the coast are mainly in the window from West to North, so the sediment transport is *South going* most of the time (in total around 2 million cubic meter a year). Changes in bathymetry can therefore be felt by changes occurring North of the location, but not from the Southern direction. Therefore the transition areas must behave asymmetric: in a transition zone, you can feel the impact from the up drift stretch southwards of this, but hardly north of.

2.Natural fingerprints on the beach

The spatial and temporal variations in beach width and beach volume occur in a natural environment due to partly the stochastic variation in nature, but also because the beach is a part of a larger system including the dunes onshore the beach and the coastal part offshore the beach.

The dune system: breaches.

The dune is an integrated part of the beach system. Usually, sand is transported to the beach by the waves, and transported further inland over the dunes by the wind.
If you have high dunes, it is difficult for the wind to transport all the sand over the dunes. Instead most of the sand is transported along the dunes at their foot, and transported inland through openings (breaches, Danish: vindbrud or vindskår) in the dune system as sketched in figure 10.7. A breach occurs where there is a local depression in the dunes in combination with a weak beach in front of this location, the low beach allows wave attack on the dune foot during storms, destroying the vegetation. A depression in the dune ridge will create a concentration of wind during storms, and this wind will transport a lot of windblown sand landwards creating an opening in the dune system. The sand will settle behind the breach thus creating a new dune here. This is quite a normal behaviour of a natural dune system as for instance described in “Danmarks Natur, volumen 4, p 174-176, 6th edition). On the test stretch you have large breaches at two locations: in the middle of rør 1 and in the transition in between rør 1 and ref 2. The last mentioned is under its development, while the other has been there for a number of years. The breach at the transition is shown in figure 10.6. This breach has been dramatized by SIC to be “disastrous”, but is a quite common event along the coast, and has by no way decreased the overall stability of the coastline. For instance the offshore 5 m contour line can not feel this local breach at all.
A breach in the dune system has a strong impact on the beach. Since a lot of sand will departure through the breach, it is missing downwind the breach, so the beach volume here will be smaller, see figure 10.7. Since the wind direction shifts this will cause erosion in the dunes and in the beach on both sides of the breach, and the extend can be several 100 meters at both ends of the breach, which itself only is 40-50 meters wide.

Fig. 10.6. Breach in dune in the transition between rør 1 and ref2.

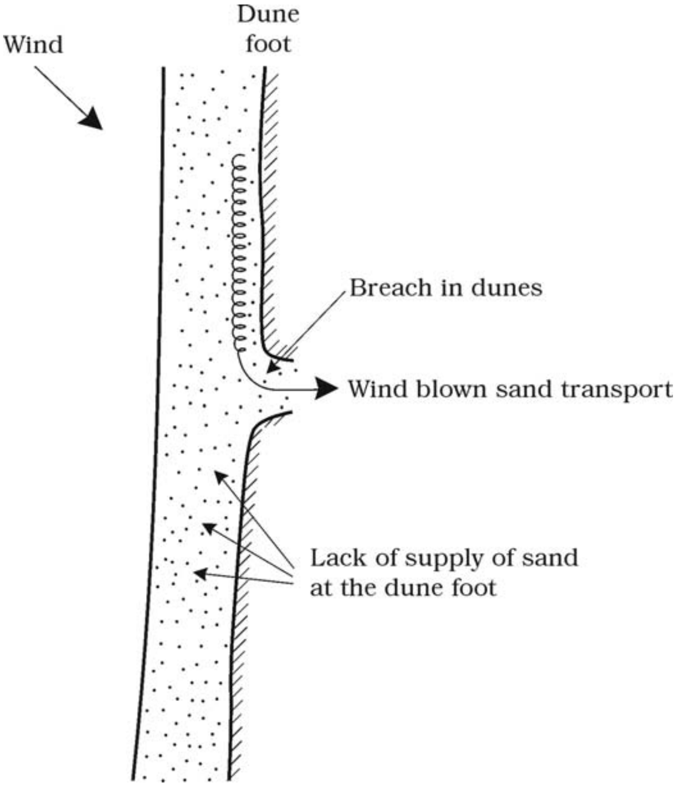


Figure 10.7: A breach will accelerate the wind born sediment transport through the dune system and will result in a decrease in the beach volume

Bar-beach interaction.

The bars are of significant importance for the beach: the bars are formed by breaking waves, and after the breaking the waves loose height and thereby reduce their impact further onshore. When the waves break, they generate a long shore current, which together with the waves is responsible for the long shore sediment transport. So on a barred coast the main long shore sediment transport occurs on the bars, while the transport in the swash zone at the beach is minor, typically less than 10 % of the total transport. However, if you have no bars, the distribution of the long shore sediment transport will be different: the waves will break further onshore, and the near shore sediment transport will be relatively larger. So if you in one way or another have an interruption in the bar system, you get an increase in the near shore long shore sediment transport. This increase in transport will cause local erosion in the beach.

- A hole in the outer bar or termination of the bar can imply, that waves can penetrate more onshore without breaking (on the bar), and hence be the cause to the narrower beach, see the sketch figure 10.8.
- Figures 10.9, 10.10 and 10.11 illustrate other possible mechanisms which might be responsible for getting narrow beaches on some locations: concentration of the long shore current behind the bars and presence of rip holes in the bars. The fingerprint of these mechanisms will be large scale undulations along the beach: the length scale will typical be related to the distance from the beach to the bar, or 1- 2 kilometres.
- Finally can be mentioned migrating long shore undulations due to obliquely incoming waves as discussed in appendix 4. As illustrated by the wave roses in chapter 5, the waves actually approach the coast with a large angle, where an instability mechanism may form undulations with a wavelength of 2-3 km.

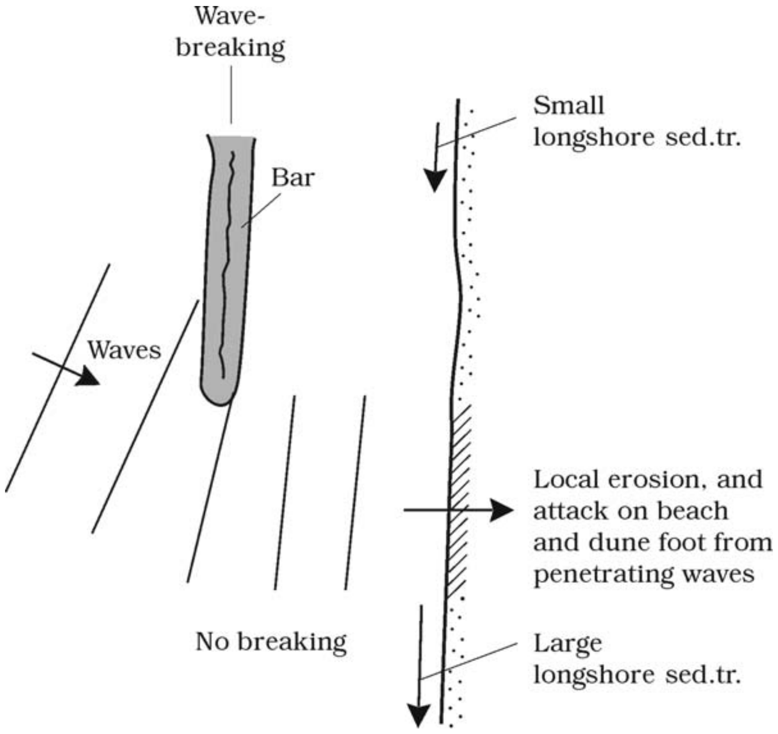


Figure 10.8: If the bar terminates, the beach will be exposed to a larger wave attack.

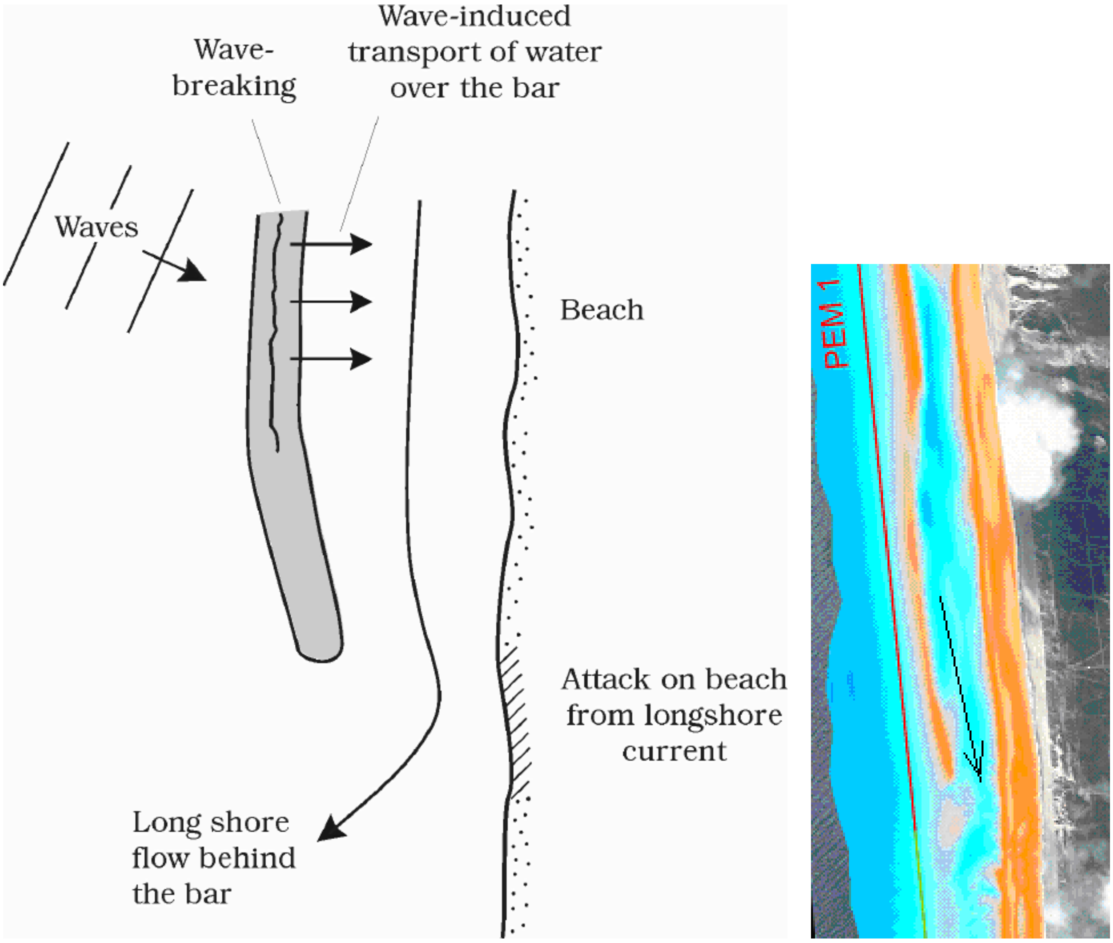


Figure 10.9: Another possible mechanism for a local narrowing beach is a concentration of the long shore current behind a crescendic long shore bar (originally suggested by Søren Knudsen, KDI).

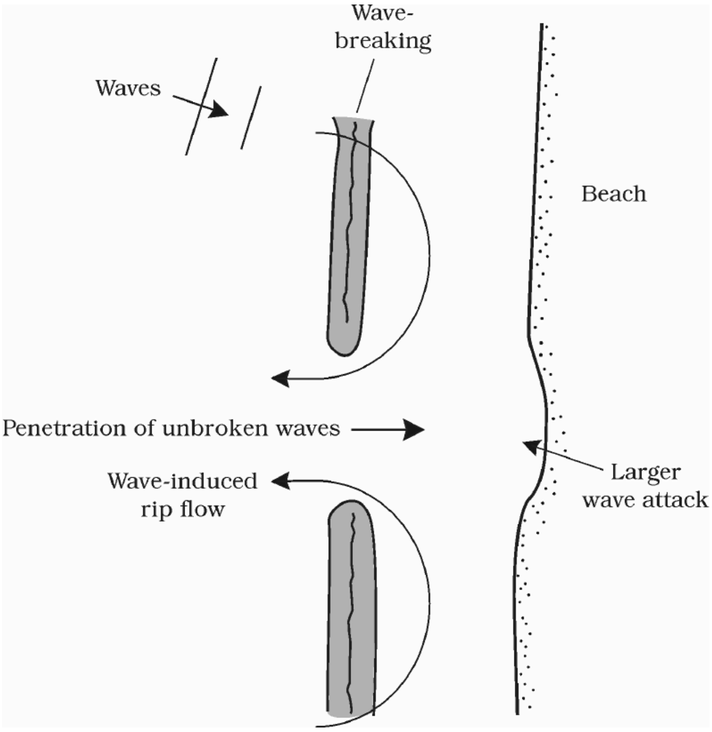


Figure10.10: Also rip holes allow waves to attack the beach locally.

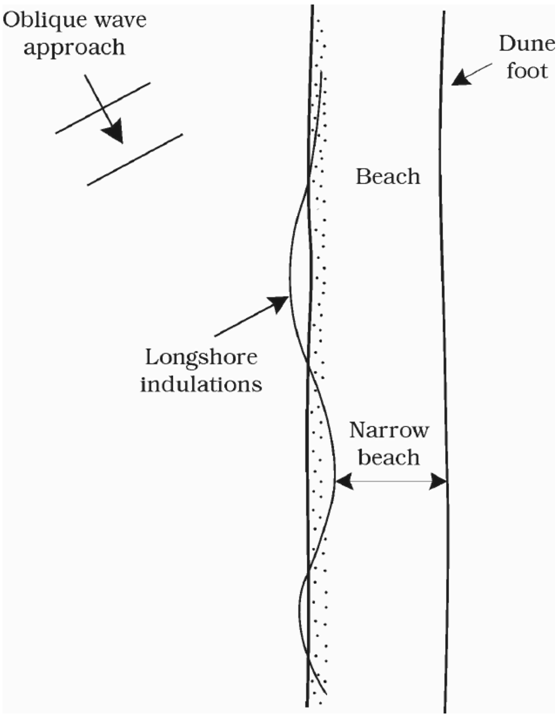


Figure 10.11: Obliquely approaching waves will form long shore undulations as described in the appendix 4.

Summary: Difference between tube-induced morphological changes and natural changes.

Since natural changes occurs at all times along the coast you need to distinguish in between those changes caused by nature and those created by the tubes.

From the tubes you should expect:

- Local accumulation around the individual tubes, and if these accumulation-berms merges, a larger accumulation ridge around each array of tubes, i.e. a scale of say 5-10 meters.

- A significant change in the beach width and volume in the zones with tubes as compared with those without.

- Only weak changes offshore and in the dunes.

From nature:

- More evenly distributed long shore changes with spatial scales of variability equal 100 of meters to several kilometres. Spatial changes are caused by rips, bar migration and large scale migrating undulations.

- Large temporal variability throughout the year (summer and winter profiles).

- Local changes with scales down to 20-40 meters near wind breaches.

Chapter 11 Discussion of the observed results.

In this chapter all the results presented in chapter 7, 8 and 9 are evaluated and discussed based on the morphodynamic considerations outlined in chapter 10.

11.1 Integrated tables

First a number of integrated values of changes in D1 and D2 are given in the tables below to be applied in the further discussion.

A. All integrated data on ΔD1

Stretch	04.05	07.05	10.05	01.06	04.06	07.06	10.06	01.07	03.07	08.07	09.07	01.08
	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m
Ref. I	5,8	2,8	1,1	15,3	17,5	17,1	19,5	11,6	14,9	5,6	7,9	11,5
Rør I	7,7	8,3	5,5	19,1	22,5	21,9	16,8	9,5	15,0	4,8	8,2	11,1
Ref. II	9,2	21,1	0,9	16,9	14,7	18,8	3,5	-8,4	-18,9	-19,0	-18,9	-39,8
Rør II	-9,9	3,5	-6,8	19,7	9,7	11,7	6,9	10,9	17,2	6,2	13,5	13,8
Ref. III	4,7	11,5	4,5	16,1	8,0	7,7	9,7	5,6	0,5	0,5	-0,7	1,4
Average	5,5	9,4	2,8	17,7	17,0	17,4	13,2	6,6	7,6	0,7	3,0	2,0

Table 11.1 Cumulative Changes in D1 (ΔD1) from 01.05 (January 2005). The last line is the average over all 10900 meters.

Stretch	04.05	07.05	10.05	01.06	04.06	07.06	10.06	01.07	03.07	08.07	09.07	01.08
Ref. I	5,8	-3,0	-1,7	14,2	2,2	-0,4	2,4	-7,9	3,3	-9,3	2,2	3,6
Rør I	7,7	0,6	-2,8	13,7	3,4	-0,6	-5,1	-7,3	5,5	-10,2	3,4	3,0
Ref. II	9,2	11,9	-20,1	16,0	-2,2	4,1	-15,3	-11,9	-10,5	-0,1	0,1	-20,8
Rør II	-9,9	13,4	-10,3	26,5	-10,0	2,0	-4,8	4,0	6,3	-10,9	7,3	0,3
Ref. III	4,7	6,8	-7,0	11,7	-8,2	-0,3	2,0	-4,1	-5,1	0,0	-1,2	2,1
Average	5,5	3,9	-6,6	15,0	-0,7	0,4	-4,2	-6,6	1,0	-6,9	2,3	-1,0

Table 11.2 Like table 11.1, but now consecutive changes in D1.

B. All integrated data on ΔD2

Stretch	*04.05*	*07.05*	*10.05*	*01.06*	*04.06*	*07.06*	*10.06*	*01.07*	*03.07*	*08.07*	*09.07*	*01.08*
	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m
Ref. I	13,4	2,6	-12,2	-11,5	-6,9	-18,2		-32,5	24,4	-12,8	38,3	-36,3
Rør I	22,3	28,8	17,5	16,7	39,9	18,5	43,2	11,5	21,1	21,3	34,5	0,3
Ref. II	-9,5	-32,2	-42,3	-54,6	-41,3	-64,7		-104,8		-150,3		-163,8
Rør II	45,0	58,3	68,1	93,3	91,7	87,3	99,9	37,5	184,6	27,2	206,7	-25,7
Ref. III	25,2	29,3	38,2	54,4	93,2	81,5	118,2	104,3	188,0	113,0	139,2	114,8
Average	18,5	17,9	11,4	14,2	60,4	16,2	74,1	4,0	68,2	4,9	66,8	-14,5

Table 11.3 Cumulative changes in D2 (ΔD2) from 01.05 (January 2005). The last line is the average over all 10900 meters.

Stretch	*04.05*	*07.05*	*10.05*	*01.06*	*04.06*	*07.06*	*10.06*	*01.07*	*03.07*	*08.07*	*09.07*	*01.08*
	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m	m^3/m
Ref. I	13,4	-10,8	-14,8	0,7	4,6	-11,3			57,0	-37,3	51,2	-74,6
Rør I	22,3	6,5	-11,3	-0,8	23,3	-21,4	24,6	-31,6	9,5	0,3	13,1	-34,2
Ref. II	-9,5	-22,8	-10,1	-12,3	13,3	-23,4						
Rør II	45,0	13,3	9,8	25,3	-1,6	-4,4	12,6	-62,4	147,1	-157,4	179,5	-232,4
Ref. III	25,2	4,1	8,9	16,2	38,8	-11,8	36,8	-13,9	83,7	-75,0	26,2	-24,4
Average	18,5	-0,6	-6,5	2,8	46,2	-44,2	57,9	-70,2	64,2	-63,3	61,9	-81,3

Table 11.4 Consecutive Changes in D2 (ΔD2) Note the large fluctuations in the lowest line (the average over all 10900 meters).

C. Annual Δ-Changes in the individual sections for D1, D2, E1 and E2.

(The last digit in these calculations may deviate by +/- 1 as compared to the original data due to abbreviations.)

Ref1	***Year***	***Δ D1***	***Δ D2***	***Δ(D1+D2)***	***ΔE1***	***ΔE2***	***Δ(E1+E2)***
	1	15	-11	4	12	-10	2
	2	-4	-21	-25	3	-30	-27
	3	0	-4	-4	1	5	6
Total change after 3 years		+11	-36	-25	+16	-35	-19

Table 11.5: Changes in cbm/m in ref1 in year 1 (Jan 05-Jan 06), year 2 (Jan 06-Jan 07) and year 3 (Jan07-Jan 08)

RØR1	***Year***	***Δ D1***	***Δ D2***	***Δ(D1+D2)***	***ΔE1***	***ΔE2***	***Δ(E1+E2)***
	1	19	17	36	21	23	44
	2	-10	-5	-15	-10	-24	-34
	3	2	-11	-9	3	0	3
Total change after 3 years		+11	+1	+12	+14	-1	13

Table 11.6: Changes in cbm/m in rør1 in year 1 (Jan 05-Jan 06), year 2 (Jan 06-Jan 07) and year 3 (Jan07-Jan 08)

Ref 2	***Year***	***Δ D1***	***Δ D2***	***Δ(D1+D2)***	***ΔE1***	***ΔE2***	***Δ(E1+E2)***
	1	17	-55	-38	17	-37	-20
	2	-25	-50	-75	-18	-63	-81
	3	-31	-59	-90	-18	-61	-79
Total change after 3 years		-39	-164	-203	-19	-161	-180

Table 11.7: Changes in cbm/m in ref2 in year 1 (Jan 05-Jan 06), year 2 (Jan 06-Jan 07) and year 3 (Jan07-Jan 08)

RØR2	***Year***	***Δ D1***	***Δ D2***	***Δ(D1+D2)***	***ΔE1***	***ΔE2***	***Δ(E1+E2)***
	1	20	93	113	23	103	126
	2	-9	-56	-65	-10	-72	-82
	3	3	-63	-60	4	-64	-60
Total change after 3 years		+14	-26	-12	+17	-33	-16

Table 11.8: Changes in cbm/m in rør2 in year 1 (Jan 05-Jan 06), year 2 (Jan 06-Jan 07) and year 3 (Jan07-Jan 08)

Ref3	***Year***	***Δ D1***	***Δ D2***	***Δ(D1+D2)***	***ΔE1***	***ΔE2***	***Δ(E1+E2)***
	1	16	54	70	20	59	79
	2	-10	50	40	-13	49	36
	3	-4	10	6	-3	74	71
Total change after 3 years		+2	+114	+116	+4	+182	+186

Table 11.9: Changes in cbm/m in ref2 in year 1 (Jan 05-Jan 06), year 2 (Jan 06-Jan 07) and year 3 (Jan07-Jan 08).

D- or E profiles: is there any difference?

In tables 11.1- 11.4 only D-values are given. In tables 11.5-11.9 the D- as well as the E-values is given. The behavior of D and E follows exactly the same trend, - as already described in chapter 7. In the following discussion e1 is used for the dune foot movement (there is no similar d-values for this), E1 for dune volume, since this is the only one which provides information on the spatial (along shore) variation. Finally D2 (or Mean Beach Level MBL=D2/100meters) is used as a measure for the beach volume.

Yearly temporal variations.

Some of the data regarding the variation in beach volume D2 from tables 11.3 and 11.4 are plotted in figure 11.1. This figure speaks for itself: the volume in rør 1 (the full drawn line) shows a strong fluctuating signal over the year, so the final answer regarding the test simply depends on the cut: you get two different conclusions whether you stop the test three month earlier or later. This is typical for a process with big fluctuations: you need a lot of time to find a weak trend (like the global temperature increase in the atmosphere: you cannot detect it in months or a few years, you need decades of years). The situation is schematized in figure 11.2.

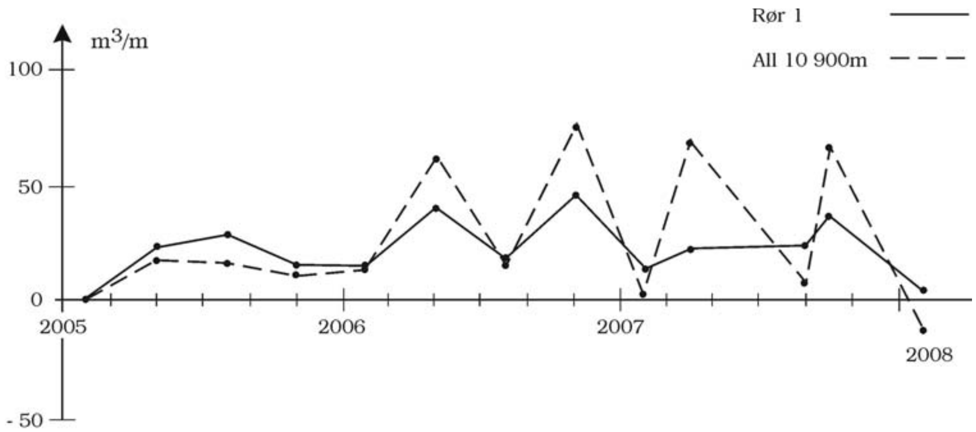


Figure 11.1: Temporal Variation in beach volume: The beach volume changes so much that the conclusion depends on the cut of the test. Sep 2007: +35 cbm/m in front of rør1, Jan 08: 0 cbm/m. On the total test stretch (dashed line in the figure) you have in average Sep 07: +67 cbm/m and Jan 08: -15 cbm/m.
The values are positive because the test began just after the big storm January 8th and 9th 2005.

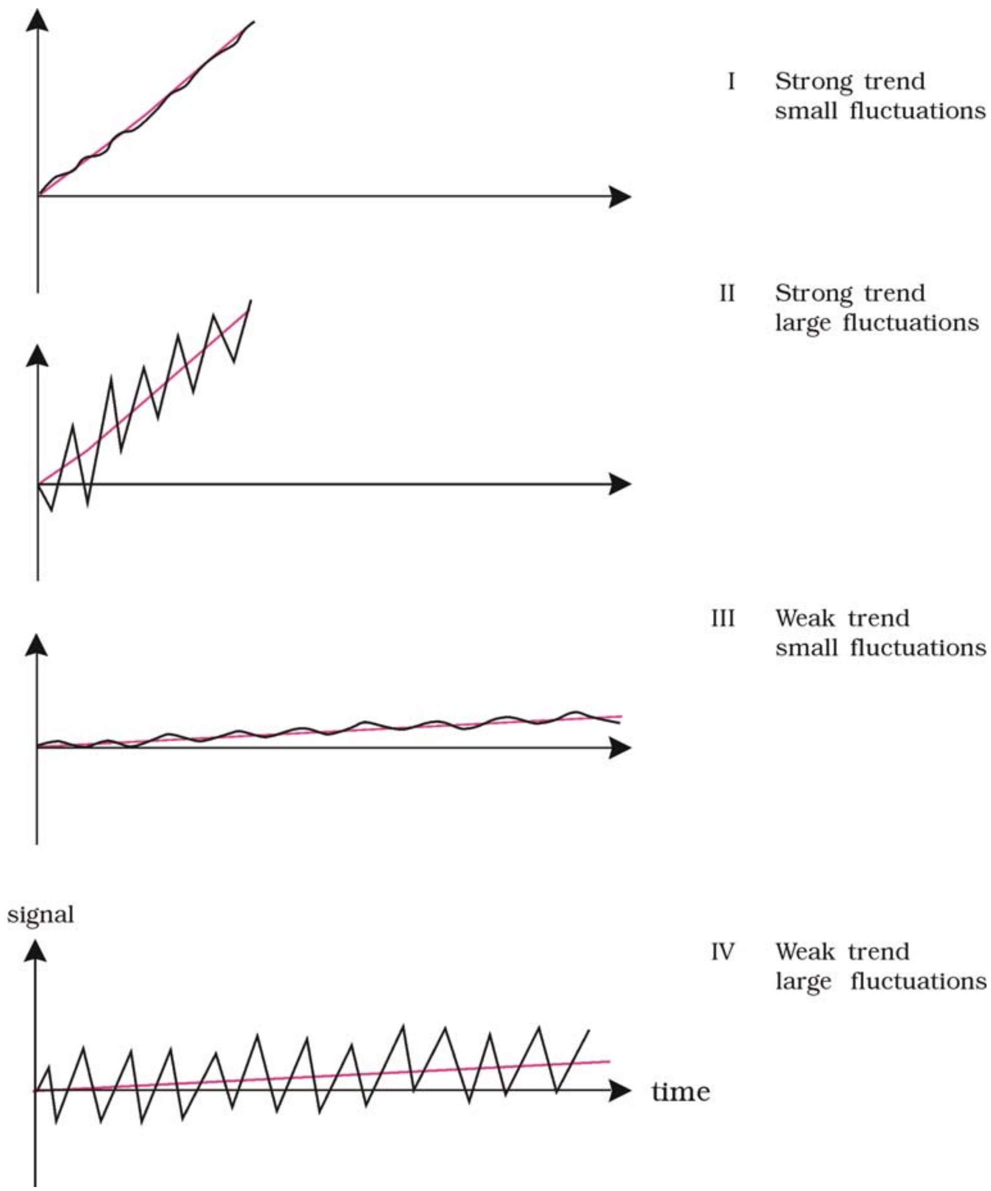


Figure 11.2: examples on different combinations of trends and fluctuations. For the present case, the lower situation applies.

11.2 The dunes and the beach.

Sediment to the beach is supplied (or eroded) by waves from the sea or by wind. Deposition/erosion in the beach by waves occurs in the swash zone. Erosion/deposition by wind occurs over the whole surface area of the beach. If you have a breach in the dunes, the wind will flow through this breach and transport a lot of sand through this breach. All this is discussed in chapter 10.

In the first section below the spatial variations in dunes and beach are compared to get an idea whether these changes are related.

Correlations: Dune volume versus Mean Beach Level

As explained in the introduction chapter 2, the dunes have been an important issue in the group discussions. Figure 11.3A and 11.3B compare changes in dune volume E1 with changes in beach volume. These figures together gives the clear picture, that a positive change in mean beach level do not automatically gives a larger volume in the dune. As an example, all the gain in E1 close to the transition from ref1 to rør 1 actually is correlated with a *decrease* in beach volume, so the wind has blown sand from the beach to the dunes. In ref 2 a loss can be observed in the beach as well as in the dunes, because the wind is blowing the sand more inland through the breach.
However you can conclude that there are no clear correlation in between changes in the dune volume and the changes in mean beach level.

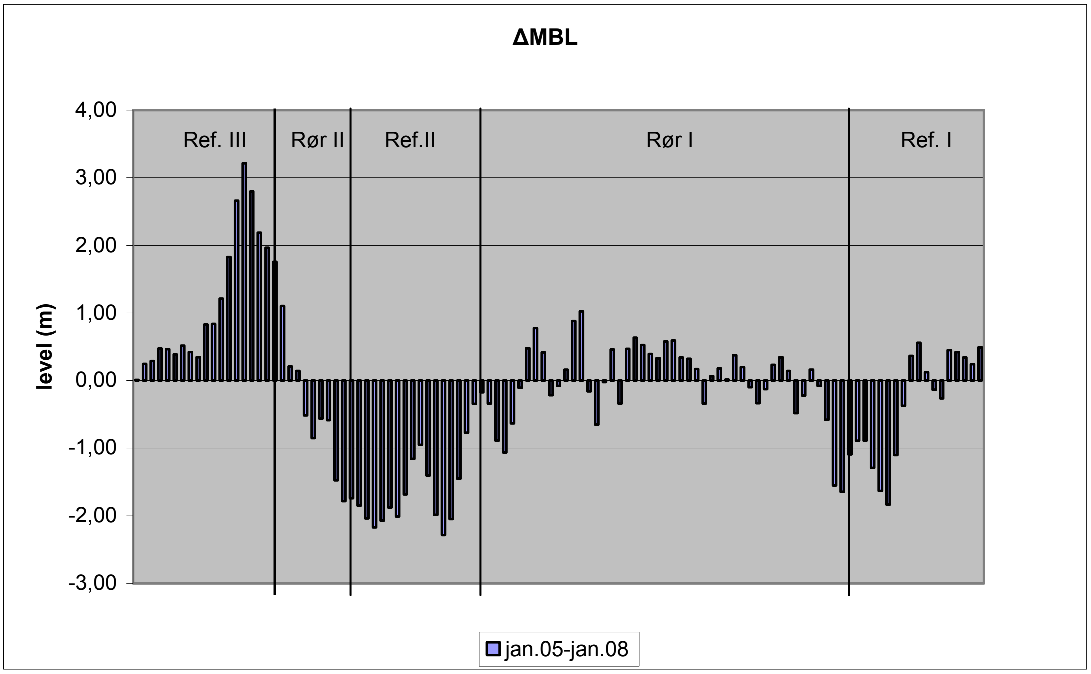


Fig 11.3A (= fig 8.2 i) Changes in mean beach level (=ΔD2/100).

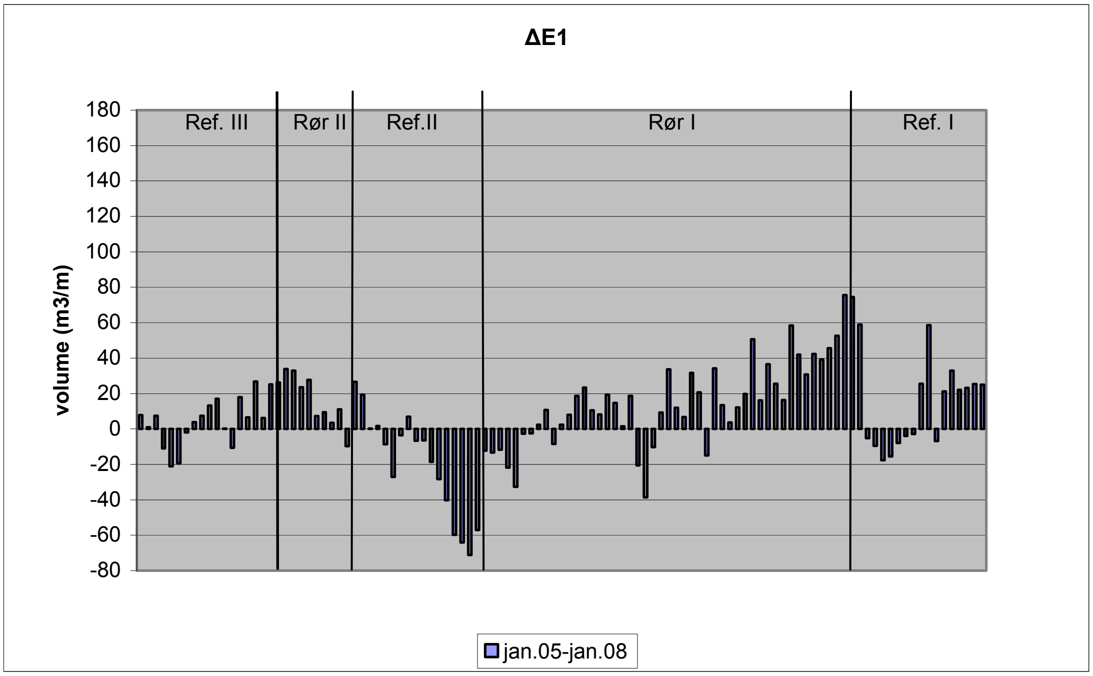


Fig 11.3B (= fig. 7.2 l) Changes in mean dune volume.

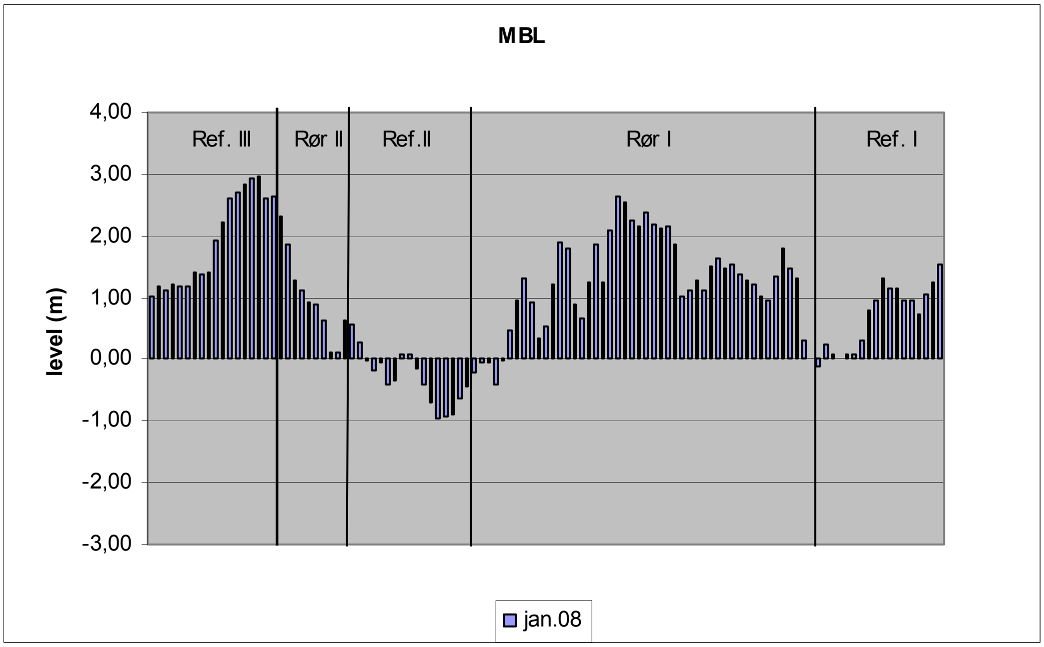


Fig 11.3C Final beach level.

Figure 11.3C shows the beach level at the end of the test. The beach is strongest in the middle of rør1, and around here the change in dune volume fluctuates around zero. These values would probably be higher, was it not for the breach in the middle. Also the beach is strong in ref 3, and also here the change in dune volume fluctuates around zero.

Conclusion: there are no clear relation in between gain in the dune volume and the Mean Beach Level, among other things because the breaches in the dunes play an important and dominating role.

Correlations: Dune volume versus width of beach.

As described in chapter 10, the width of the beach might be important for accumulation of sand in the beach, since the wind have a larger area available to pick up sand when the beach is wide. Figures 11.3D and E show the spatial variation in width e2 before and after the test. There are some changes (see Δe2 in chapter 8) but for the present purpose it is more important to look at the absolute variations in e2. Here it is realized that the gross behavior of the beach is the same during the whole test. If we next compare the width of the beach (Figure 11.3D and E) with the accumulated sand in the dune during the three year of testing we can identify similar patterns: large accumulation where the beach is wide and vice versa. As explained detailed in chapter 10 far from complete correlation is to be expected due to the mechanics of windblown transport.

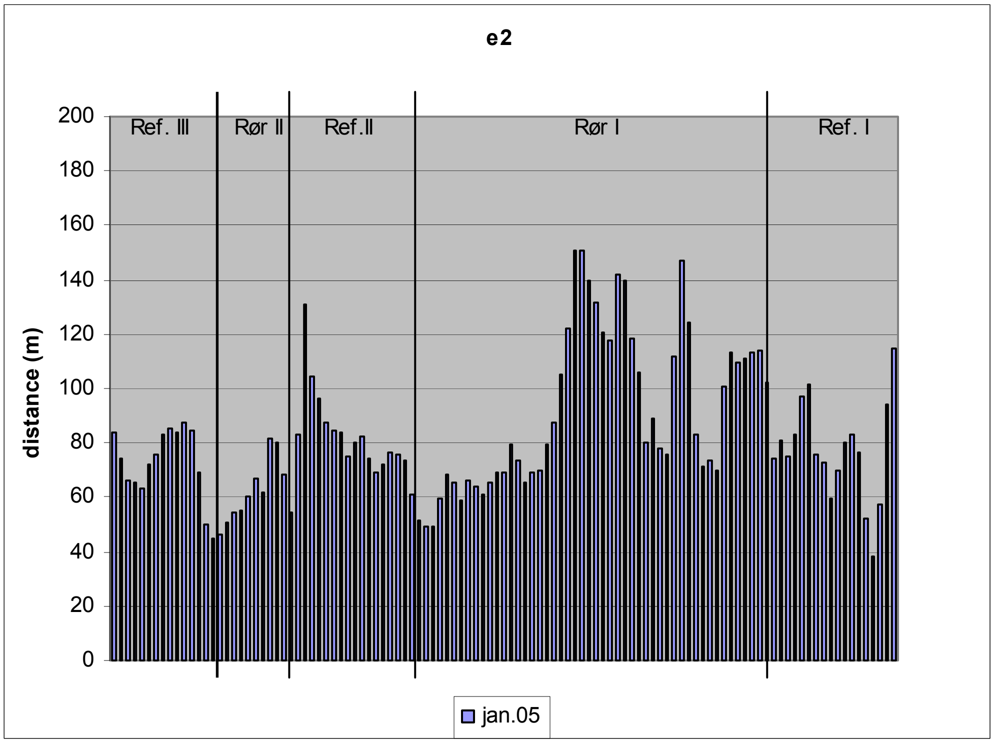


Figure 11.3D: Original width of beach

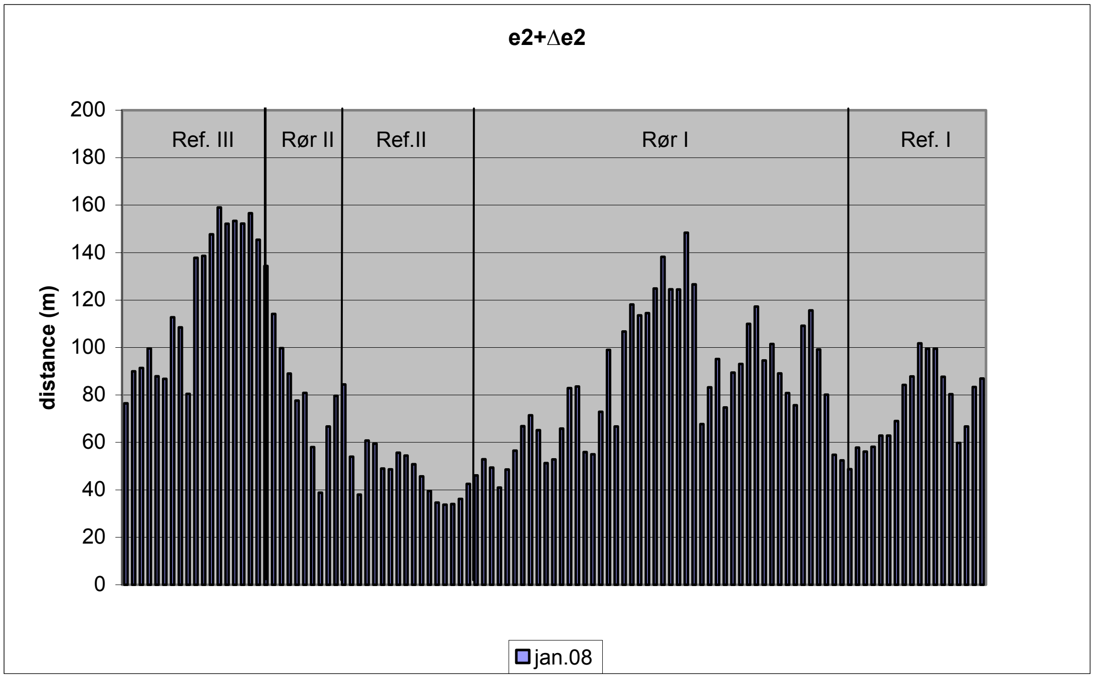


Figure 11.3E: Final width of beach.

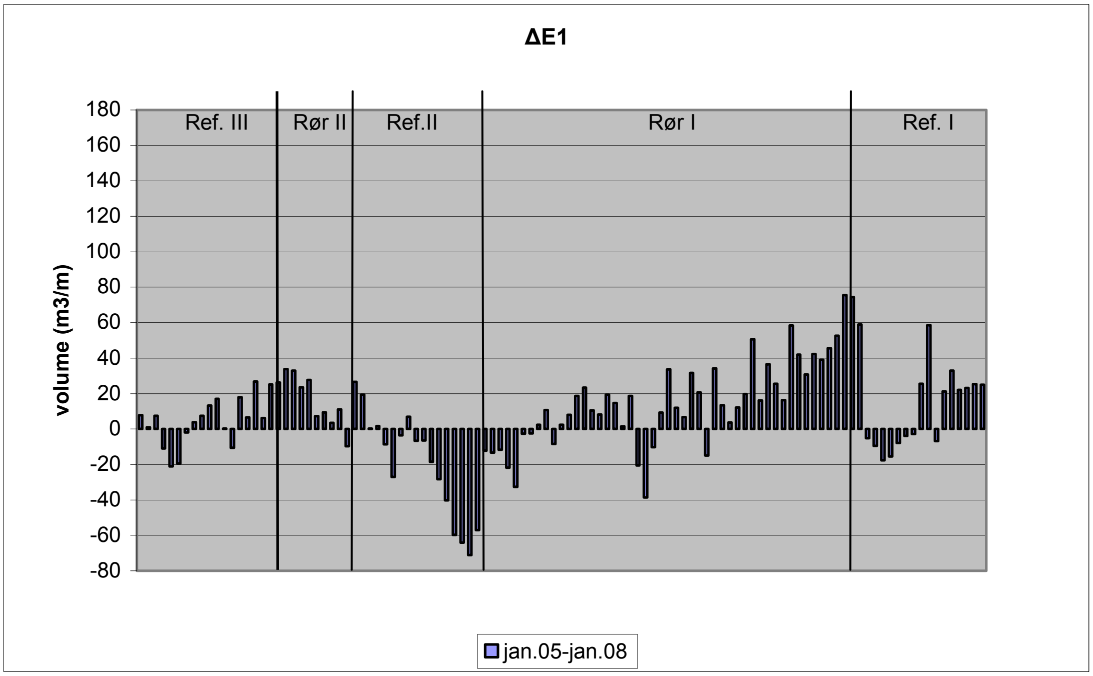


Figure 11.3B (repeated for comparison). Changes in dune volume.

Conclusion: Although weak, there is a correlation in between the gain in the dune volume and the Beach width. The correlation is related to the fact, that the main sand supply to the dunes is windblown and there is a larger reservoir of sand in front of the dunes when the beach is wide. Again the presence of breaches disturbs the overall picture.

Correlations: Dune foot position versus Mean beach level

By comparing fig 11.3A with fig 11.3F it is observed that the dune foot moves with very much the same trend all over the test site as the changes in Mean Beach Level: if the beach level increases, the dune foot expands offshore and vice versa. This has of course to do with the definition of the location of the dune foot at level +4.0 m. if you increase the beach level in front of the dune, the dune foot will automatically progress forward.

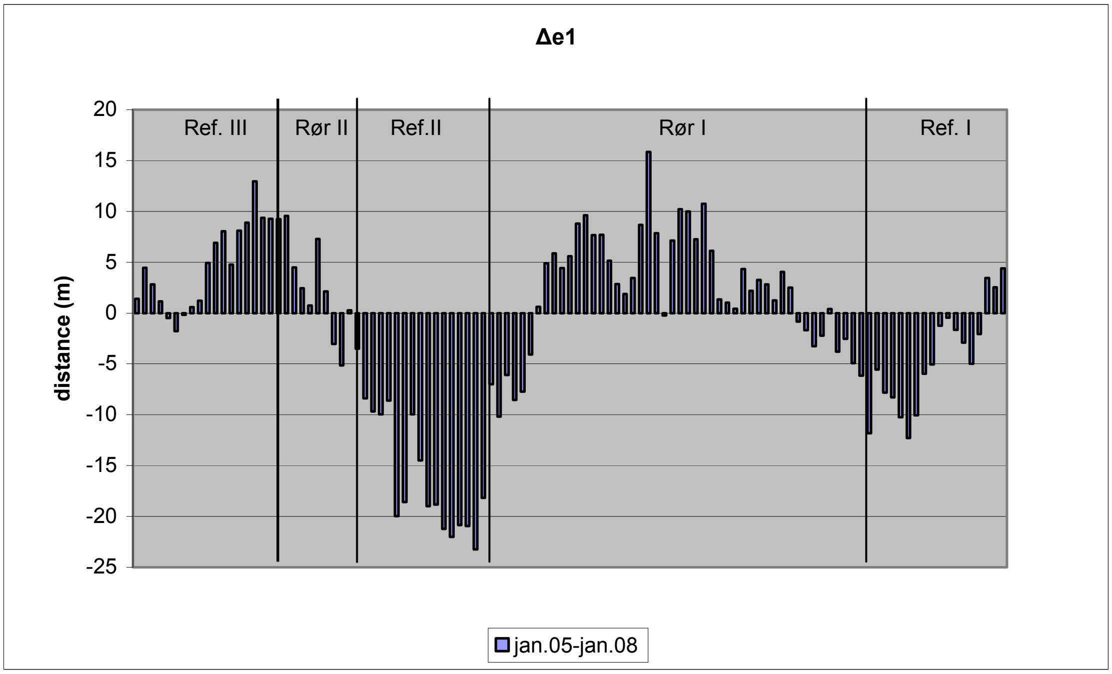


Figure 11.3F. (= fig 7.2 l) Changes in dune foot position

***Conclusions regarding dunes and beach:** there are no obvious relation in between changes in the dunes and the beach volume, respectively the changes in the beach volume. With regard to correlation in between beach width and trapped sand in the dunes, this is slightly stronger. For this reason it is not possible significantly to relate the functioning of the tubes to changes in dune volume.*

You can observe a positive correlation in between changes in foot position and MBL. This is related to our definition of the foot position: at level +4.0 meter.

11.3 Listing of observed large scale trends in the individual sections.

This section is a short description of the erosion and deposition pattern along the whole test stretch.

Reference 1.

Averaged over the whole stretch.
In average over the three years, we have accretion in the *dunes* in ref1: at the end of the test, the dunes have increased their volume by 11.5 cbm/m, see table 11.1. If we look at the temporal variations, the fluctuations within a few month (like Oct 2005 to Jan 06: 14.2 cbm/m) can be even larger than this three years gain.

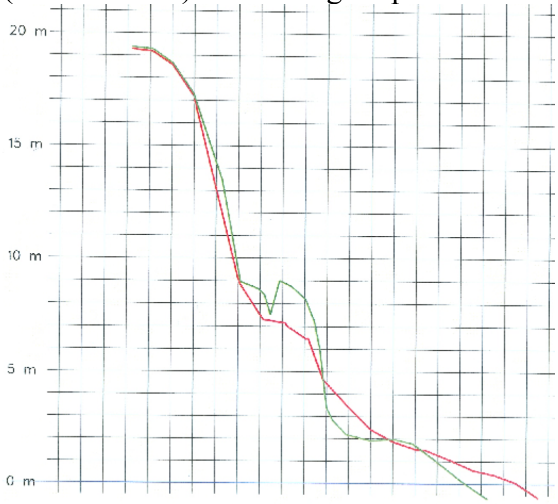
On the other hand side, the *beach* has lost 36.3 cbm/m, so in total the loss in dune plus beach is 25 cbm/m.

Regarding the temporal variations in the beach, they are like the dunes observed in a few months to be larger than this three years loss. (like Sep 2007 to Jan 08: -74.6 cbm/m or Jan 07 to March 07: + 57 cbm/m).

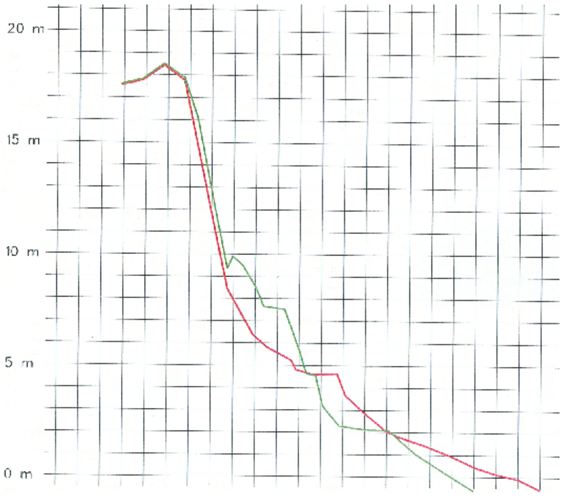
Spatial variation.
The loss in the *beach* is very unevenly distributed alongshore, which can be seen from figs 11.3A and B: in the northern (up drift) part, the beach has gained height, but the last kilometer (and 300-400 meters down in rør1), the beach has lost height. Not exactly the same picture relates to the *dune*: you also gain volume at the northern part, and loose further south, but some hundred meters before the transition you get a significant increase in the dune volume. This increase becomes slowly less as you move further down in the rør1 region, and after 1200-1500 meters it disappears.

Migration of dune foot.
Figure 11.3F shows the migration of the 4 m level: + is offshore, - onshore. In ref1, there can be observed landwards motion (erosion) of the dune foot, up to 12 meters. The landward motion continues into the rør1-area, about 700-800 meters. The whole pattern of changes in e1 looks like a large coherent structure

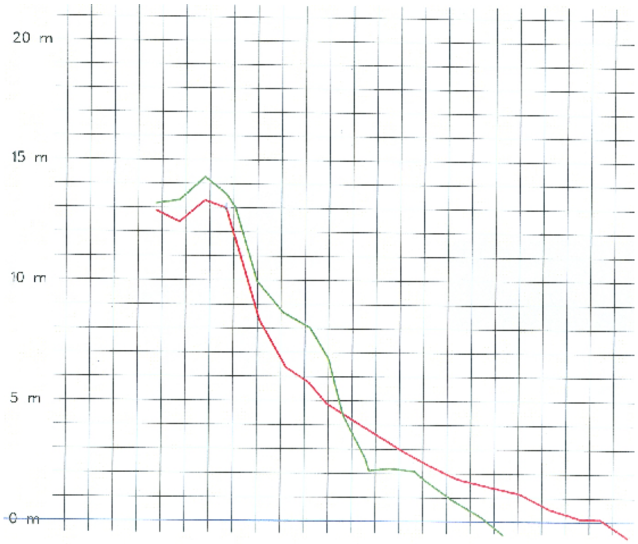
Wider dunes however do not automatically means more volume in the dunes: Still looking into figure 11.3B, it is observed that the long shore variation in E1 do not follow exactly the same trend as the variation in e1, figure 11.3D: for instance in the transition between ref1 and rør 1, the dune volume *increases* while the dune narrows, which only can be explained by an increase in the volume of the dunes at that location above level +4.00. Figure 11.4 shows a number of dune profiles around this location. It is seen that the dunes are not becoming higher, but there has been redistribution in between the foot (below + 4.00) and the higher part of the dune.



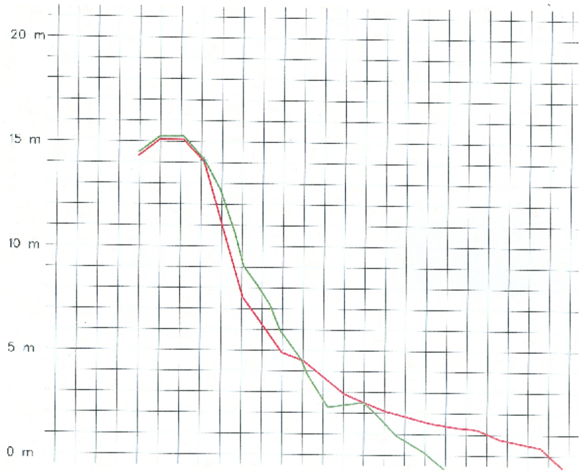
4019400 (300 N of tube 1)



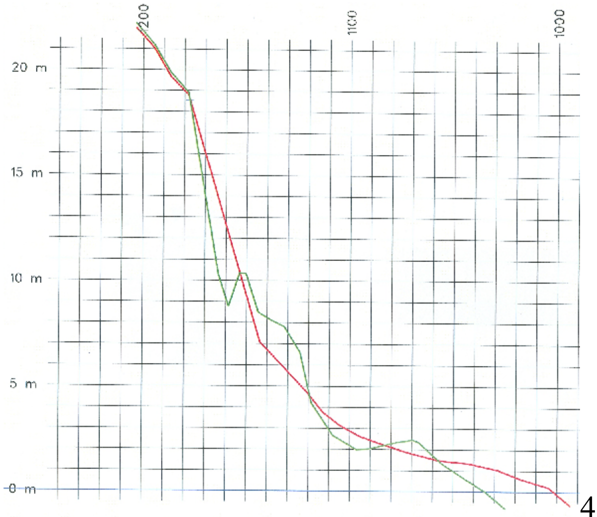
409300 (200 meter N of rør 1)



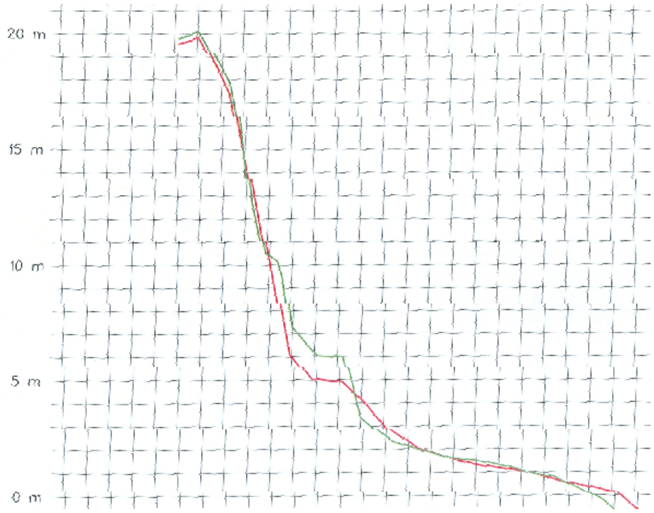
409200 (100 meter N of rør1)



409100 (first row from N in rør 1)



409000 (second row in rør1)



408900 (third row in rør1)

Figure 11.4 B. Dune profiles at the start (red) and at the end (green) of the test.

Rør1.

Beach and dune volume.

Averaged over the whole stretch.
In average, we have accretion in the *dunes* at ref1: at the end of the test, the dunes have increased their volume by 11.1 cbm/m, see table 11.1. The fluctuations in the average gain in ref 1 can a few month (like Oct 2005 to Jan 06: 13.7 cbm/m) be even larger than this three years gain.

Also the *beach* has a gain, but only negligible 0.3 cbm/m, so in total the gain in dune plus beach is 11.4 cbm/m.
The fluctuations can in a few months be even larger than this three years loss. (like Sep 2007 to Jan 08: -74.6 cbm/m or Jan 07 to March 07: + 57 cbm/m).

Spatial variations.
The loss in the beach is unevenly distributed alongshore, which can be seen from figs 11.3A and 11.B: close to the transition in North and South you have a loss in the beach, and in the middle a slight gain. Regarding the dune: as mentioned above you gain volume at the northern part, and loose at the southern transition

Migration of dune foot.

By considering figure 11.3, it is observed that the dune foot has moved up to around 10 meters offshore in rør 2. At the transition, the dune foot moves inland by 5-10 meters.

Reference 2.

Ref 2 behaves very differently from all the other stretches. You have enormous losses of sand in the dunes and the beach.

Beach and dune volume.

Averaged over the whole stretch.
In average, we have erosion in the dunes at the end of the test equal 40 cbm/m, see table 11.1. If we look at the variation in time, you have an increase in volume in the first half year, and after that large mostly negative fluctuation.
The beach has lost more than 164 cbm/m, so in total the loss in dune plus beach is 204 cbm/m. Here the timevariation is steadier with erosion occurring nearly at all times, figure 11.2-II.

Spatial variations.
The loss in the beach is increasing in the southern direction alongshore, see fig. 11.3A: The dunes on the other hand side decreases its loss as we move south, fig. 11.3B.

Migration of dune foot.
The dune foot moves inland, more than 20 meters, and most in the beginning of ref2 – to the north.

Rør2.

Beach and dune volume.

Averaged over the whole stretch.

Accretion occurs in the dunes at rør2: at the end of the test, the dunes have increased their volume by 13.8cbm/m, see table 11.1. If we look at the temporal variation, you have fluctuations, which in a few month (like Oct 2005 to Jan 06: 26.5 cbm/m) can be even larger than the three years gain.

The beach has a loss equal 25.7 cbm/m, so in total the gain in dune plus beach is 11.4 cbm/m.
Also here very large fluctuations in the average gain/loss in the beach are observed. In a few month they can be nearly 10 times larger than this three years loss. (like Sep 2007 to Jan 08: -232.4 cbm/m or Aug 07 to Sep 07: + 179.5 cbm/m).

Spatial variations.
The loss in the beach is unevenly distributed alongshore: The loss in the beach is decreasing in the southern direction alongshore, see fig. 11.3A. Also the dunes increase its gain slightly moving south.

Migration of dune foot.
By considering figure 11.3D, it is observed that the dune foot has moved up to around 10 meters offshore in rør2. At the transition to ref2 , the dune foot moves inland by 5-10 meters.

Reference 3.

Beach and dune volume.

Averaged over the whole stretch
Accretion occurs in the dunes at ref3: at the end of the test, the dunes have increased their volume by 1.4 cbm/m, see table 11.1. The temporal variation within a few month can be more than 8 times larger this three years gain (like Oct 2005 to Jan 06: 11.7 cbm/m).

In the beach you have a significant gain of 114.8 cbm/m, so in total the gain in dune plus beach is 116.2 cbm/m.
Temporal fluctuations are in a few month nearly as large as this three years gain. (like Jan 2007 to March 07: +83.7 cbm/m or March 07 to August 07: -75 cbm/m).

Spatial variations.
The loss in the beach is unevenly distributed alongshore with most gain in the Northern part. Regarding the dunes, the picture is diffuse and fluctuating around zero.

Migration of dune foot.
By considering figure 11.3, it is observed that the dune foot has moved up to around 10 meters offshore in the northern part of ref3.

11.4 Correlation between tubes covered stretches and deposition.

Along the test stretch you have a sometimes erosion, and sometimes deposition. You can then ask whether there is a correlation between deposition and the tube covered regions and visa versa. If there is a correlation, this could be an indication of a positive impact of the tubes.

	Reference 1	*Rør 1*	*Reference 2*	*Rør 2*	*Reference 3*
Dune box: (D1)	12	11	-40	14	1
Beach box: (D2)	-36	0	-164	-26	114
Beach+dune	-24	11	-204	-12	115

Table 11.10 Changes in volume cbm/m after three years.

Table 11.10 lists the average values after 3 years on each individual stretch.
You have strong erosion (-) in ref2 which is in favor of the tubes and strong deposition(+) in ref3 which is in disfavor of the tubes.
You have a gain in the beach in ref1 and a loss in the dunes in ref1, which is in favor and the opposite for the tubes regarding ref1, and you have exactly the same thing in rør 2, so here the beach is in disfavor and the dunes in favor of the tubes.
Finally, the important very long rør1 simply ends up with a zero regarding the beach, and a small plus regarding the dunes.

You can make another table based on table 11.10, where you take a plus (in favor of the tubes) if you have positive values in the Rør-stretches, or negative values in the reference stretches, - and vice versa. This is shown in table 11.11A and B.

	Reference 1	*Rør 1*	*Reference 2*	*Rør 2*	*Reference 3*
Dune box: (D1)	-	+	+	+	*0*

Table 11.11A. + means accretion in rør, or erosion in ref, and vice versa.

	Reference 1	*Rør 1*	*Reference 2*	*Rør 2*	*Reference 3*
Beach box: (D2)	+	0	+	-	-

Table 11.11B. + means accretion in rør, or erosion in ref, and vice versa.

The dune alone, Table 11.11A, gives three + and one -, and one 0. The beach alone, table 11.11B, gives two plus, two minus and one 0 (or ?). So if you consider only the dunes, there is an indication that the tubes have an impact. If you consider the beach (where the tubes are!) it is pure random (if you can conclude anything with so few data).

11.5 The Offshore Data.

Table 11.12 includes the offshore measurements. Here you can make the same exercise as done in table 11.11. the results are shown in table 11.13.

		Accretion (Jan. 05-jan.06)				-	-			
Stretch	Length	ΔMBL	ΔD1	ΔD2	ΔD3	ΔD4	ΔD1+ΔD2	ΔD1+ΔD2	ΔD3+ΔD4	ΔD3+ΔD4
	m	M	m3/m	m3/m	m3/m	m3/m	m3/m	m3	m3/m	m3
Ref. I	1800	-0,11	15,31	-11,47	-27,88	70,55	4	6.916	42,67	76.800
Rør I	4700	0,17	19,14	16,66	25,26	-26,80	36	168.248	-1,55	-7.268
Ref. II	1800	-0,55	16,87	-54,57	2,93	-33,61	-38	-67.849	-30,69	-55.240
Rør II	900	0,93	19,74	93,32	30,90	-7,39	113	101.751	23,52	21.164
Ref. III	1800	0,55	16,13	54,42	13,37	8,48	71	126.995	21,85	39.333

		Accretion (Jan. 05-jan.07)				-	-			
Stretch	Length	ΔMBL	ΔD1	ΔD2	ΔD3	ΔD4	ΔD1+ΔD2	ΔD1+ΔD2	ΔD3+ΔD4	ΔD3+ΔD4
	m	m	m3/m	m3/m	m3/m	m3/m	m3/m	m3	m3/m	m3
Ref. I	1800	-0,32	11,59	-32,55	39,27	83,79	-21	-37.719	123,06	221.510
Rør I	4700	0,11	9,50	11,54	4,41	13,78	21	98.883	18,19	85.509
Ref. II	1800	-1,05	-8,39	-104,75	61,29	-88,77	-113	-203.646	-27,48	-49.456
Rør II	900	0,38	10,90	37,50	38,72	-130,26	48	43.555	-91,54	-82.388
Ref. III	1800	1,04	5,60	104,29	37,37	44,71	110	197.799	82,08	147.737

		Accretion (Jan. 05-jan.08)				-	-			
Stretch	Length	ΔMBL	ΔD1	ΔD2	ΔD3	ΔD4	ΔD1+ΔD2	ΔD1+ΔD2	ΔD3+ΔD4	ΔD3+ΔD4
	m	m	m3/m	m3/m	m3/m	m3/m	m3/m	m3	m3/m	m3
Ref. I	1800	-0,36	11,49	-36,26	-70,35	109,34	-25	-44.582	38,99	70.183
Rør I	4700	0,00	11,11	0,32	-60,08	-39,07	11	53.713	-99,15	-466.026
Ref. II	1800	-1,64	-39,77	-163,81	30,79	-104,37	-204	-366.451	-73,57	-132.434
Rør II	900	-0,26	13,79	-25,68	46,28	-230,71	-12	-10.697	-184,43	-165.990
Ref. III	1800	1,15	1,37	114,85	37,36	97,15	116	209.202	134,51	242.121

Table 11.12: Integrated tables including the offshore measurements. The table further provides information on total accretion in each individual stretch as well as accretion pr. Meter beach.

	Reference 1	*Rør 1*	*Reference 2*	*Rør 2*	*Reference 3*
Inner Offshore box: (D3)	+	-	-	+	-

	Reference 1	*Rør 1*	*Reference 2*	*Rør 2*	*Reference 3*
Outer Offshore box: (D4)	-	-	+	-	-

Table 11.13: like table 11.11, but now for the offshore regions.

The inner offshore box D3, extending from 100 m from dune foot to 400 meter offshore, gives two + and three -. The outer offshore box D4, extending from 400 m from dune foot to 700 meter offshore, gives one + and four -. So if you consider the offshore part, there is an indication that the tubes have a negative impact.

Beach-offshore.

The last statement above is certainly without meaning, because the tubes can have no effect offshore, at least not due to drainage. What could happen would be that in case of accretion/erosion, the offshore movement of the beach would change the offshore bathymetry close to the beach. The further offshore you move from the beach, the smaller this effect will be. Further, a gain in the beach could stem from a loss offshore, so in this content, a loss offshore could be in favor of the tubes, - but this will require a similar gain in he beach at the same location.

11.6 Conclusions regarding large scale boxes.

The only thing you can **conclude** from table 11.11 and 11.13 is
There is no systematic pattern at all in the spatially averaged values.

From table 11.1 and 11.3 you can **conclude** that
The temporal variations overshadow any possible time-averaged tendencies.

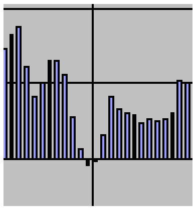
11.7 Detailed spatial observations.

As described above, the first attempt was to evaluate whether correlation between tubes and accretion occurs on spatial scales of the size like the individual reaches. The correlation was found not to be significant. The next step will be to go into further details (not as detailed as to the near-tube morphology as described in chapter 10), namely to look at how the transition between the different stretches behave.

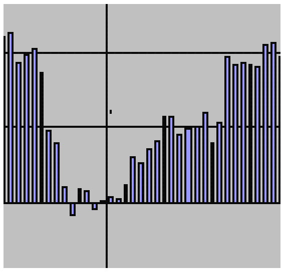
The breach in the transition between rør 1 and ref 2.

The most striking feature at all along the site is the breach in the dunes in the neighborhood of the transition between rør 1 and ref 2. Here, the beach becomes weaker over a wider and wider distance during the test. It could be a proof of a positive impact from the tubes, since the erosion develops at the transition location from a tube covered area to a no-tube area.

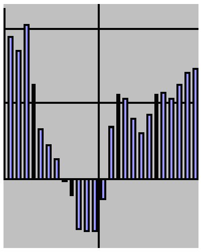
Figures 11.5 and 6 are snapshots of the Mean Beach Level and dune volume obtained from chapter 7 and 8. Fig 11.5 focus on the weak beach between rør 1 and ref 2 during the test, and it is seen that in January 05, (just after the major storm Jan 8th and 9th), the MBL was nil or negative over about 350 m (each coulomb in the graphs represent 100 meter). The beach is weak in as well RØR 1 as In REF 2, say 200 m in both stretches. As time goes by, this weak part expands, and mainly in the Southern direction: in Oct 05 it has grown from 200 to 700 meter, and in Jan 07 it is more than 1200 meter wide.



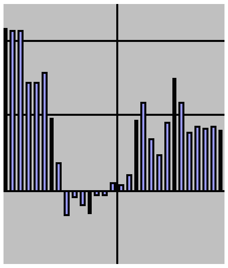
January 05



April 05



July 05



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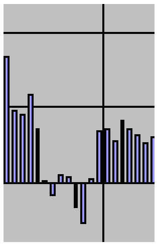
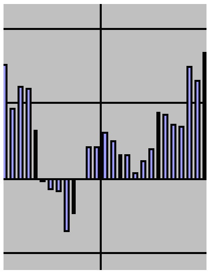


January 06



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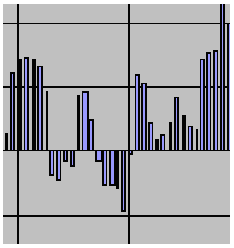

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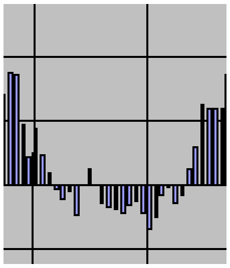

August 07

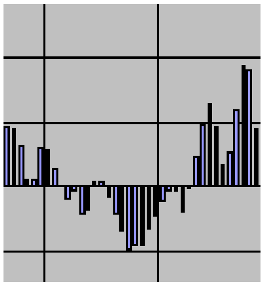

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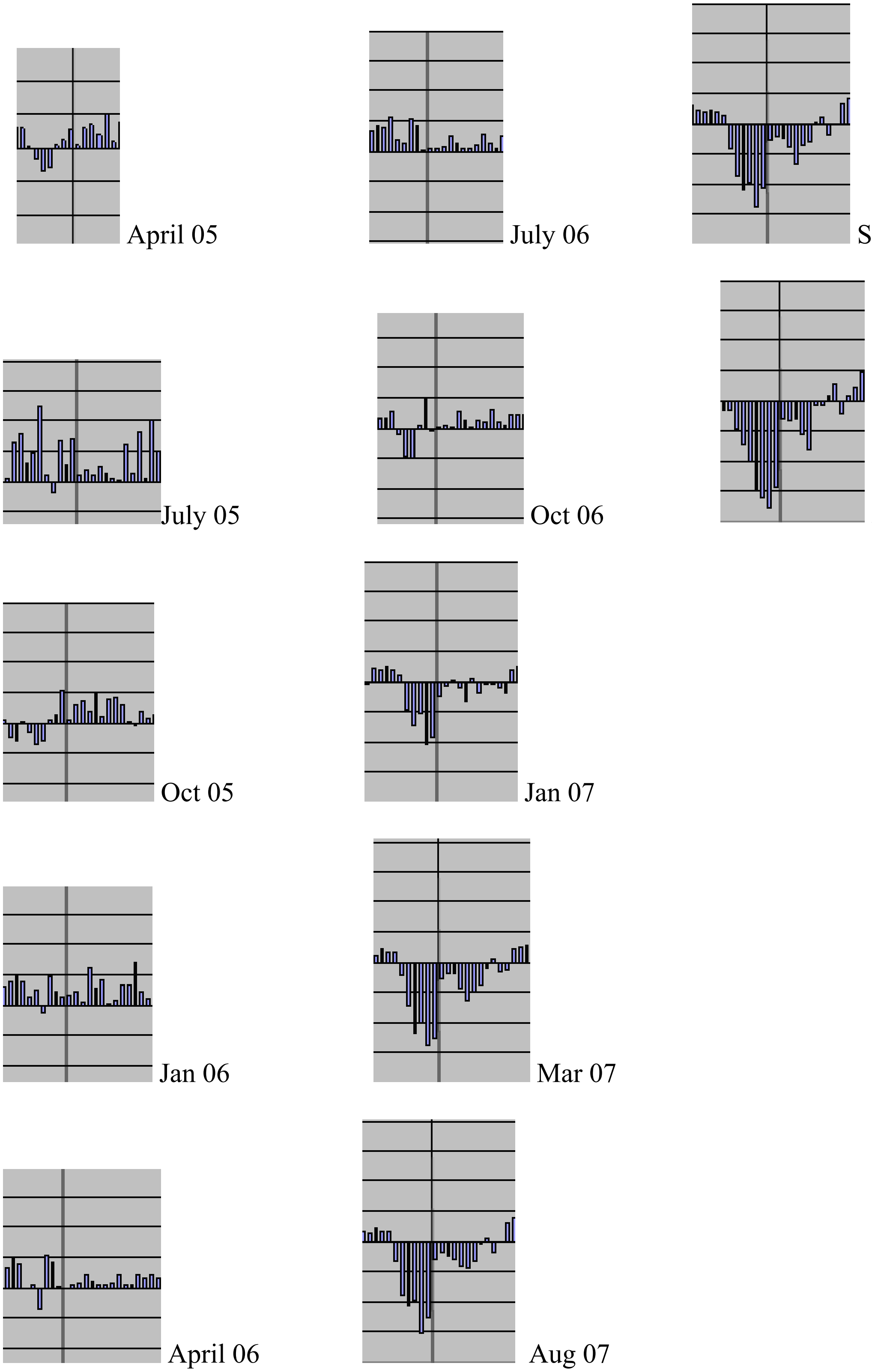
Figure 11.5: Development with time in MBL (D2/100) of the weak part in the transition between rør1 and ref 2.



April 05

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Oct 05

Jan 07

Jan 06

Mar 07

April 06

Aug 07

Figure 11.6: Development of erosion (plot of ΔE1) in the dune at the transition between rør1 and ref2.

The dune also loss significant volume as illustrated in fig. 11.6: erosion is not observed before October 06, i.e. with a significant delay as compared to the erosion in the beach. From January 07 the erosion caused a real breach 40 meter wide. The process is most likely that the narrow beach allows attack on the vegetation of the dune foot during the storms late 2006, and with a destroyed vegetation, the wind can easier attack remove the dune sand. The erosion will most likely stop when the beach again becomes wider.

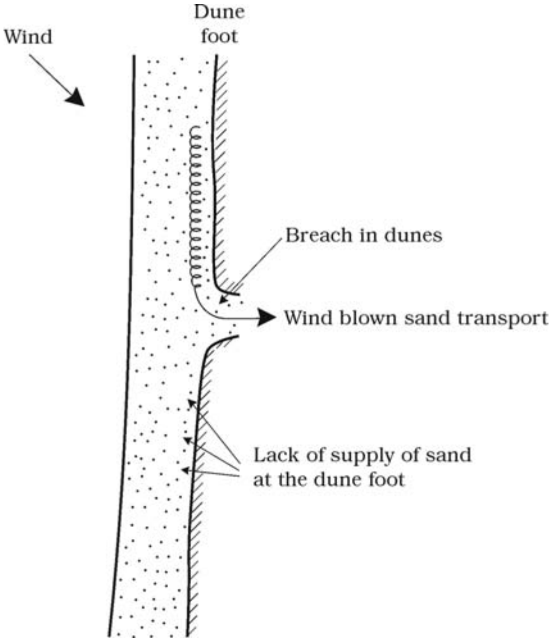


Figure 11.7 (like figure 10.7): A breach will accelerate the wind born sediment transport through the dune system and will result in a lack of sediment downwind the breach. When the breach matures, the foot downwind will be re-established.

The presence of the breach will be loss of sediment in the beach and in the dunes, especially to the south of the breach, since the dominating drift of sand is South, see the sketch figure 11.7.

The question is whether this breach could be anticipated anyway by natural causes, or it is due to the termination of the tube covered stretch, rør1. This is discussed below.

Impact on beach morphology from the outer bars.

Figure 11.8 shows the spatial variation in the dune volume at the beginning of the test illustrates that the transition between tubes and no tubes is placed exactly where the beach had minimum volume. (The beach is also thin down in ref 3, but in a smaller

spatial scale). The further expansion of this narrow beach as observed in figure 11.5 can be explained in terms of the termination of the outer bar:
The bottom bathymetry in front of the coast is known to have a major impact on the beach as discussed in chapter 10 (Morphodynamic fingerprint): Bars in front of the beach protect the beach, because the larger waves break on the bar, and thus result in less wave action further onshore. A hole or a break in the bar on the other hand side allows the waves to propagate through this hole without breaking, resulting in larger wave action closer to the shore as explained in chapter 10.

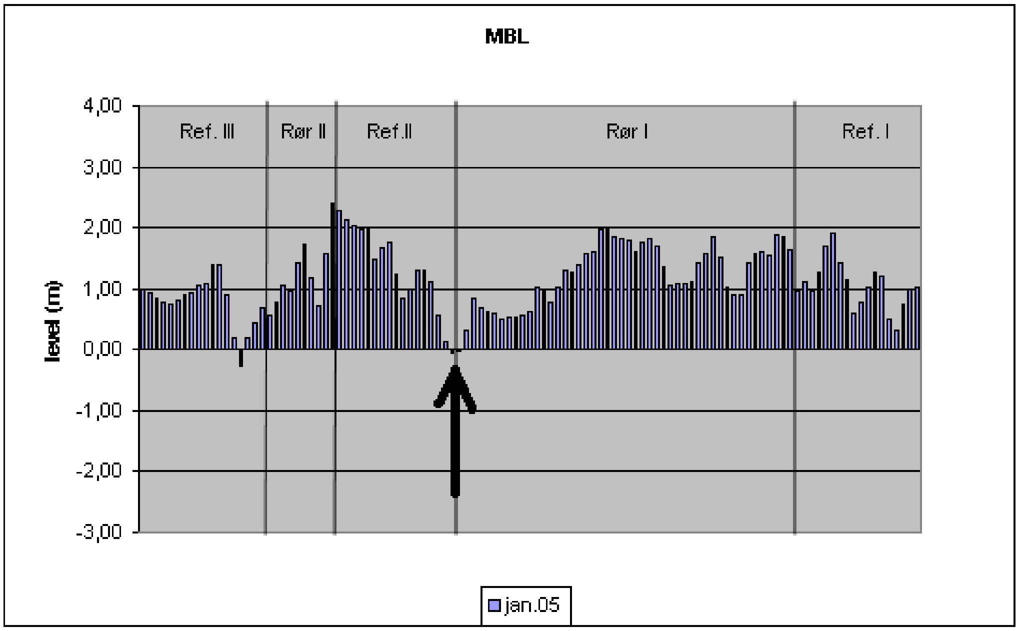


Figure 11.8: The beach was weak at the transition from the very beginning.

The bar-behavior in the entire region is quite complicated, and probably also affected by the large nourishment on the bar just north of ref 1. With respect to the site under investigation – the transition between rør 1 and ref 2 – it is clearly seen from figure 11.9 that the outer bar located around 3-400 meter offshore terminates just updrift the location, where the beach becomes narrow.

This termination of the bar implies, that waves can penetrate further onshore without breaking (on the bar), thus causes the locally weaker beach, see the sketch figure 11.11.The photo in figure 11.10 shows the impact on the waves from the termination of the outer bar at the location under consideration, so the termination can actually be observed visually without viewing the seabed.

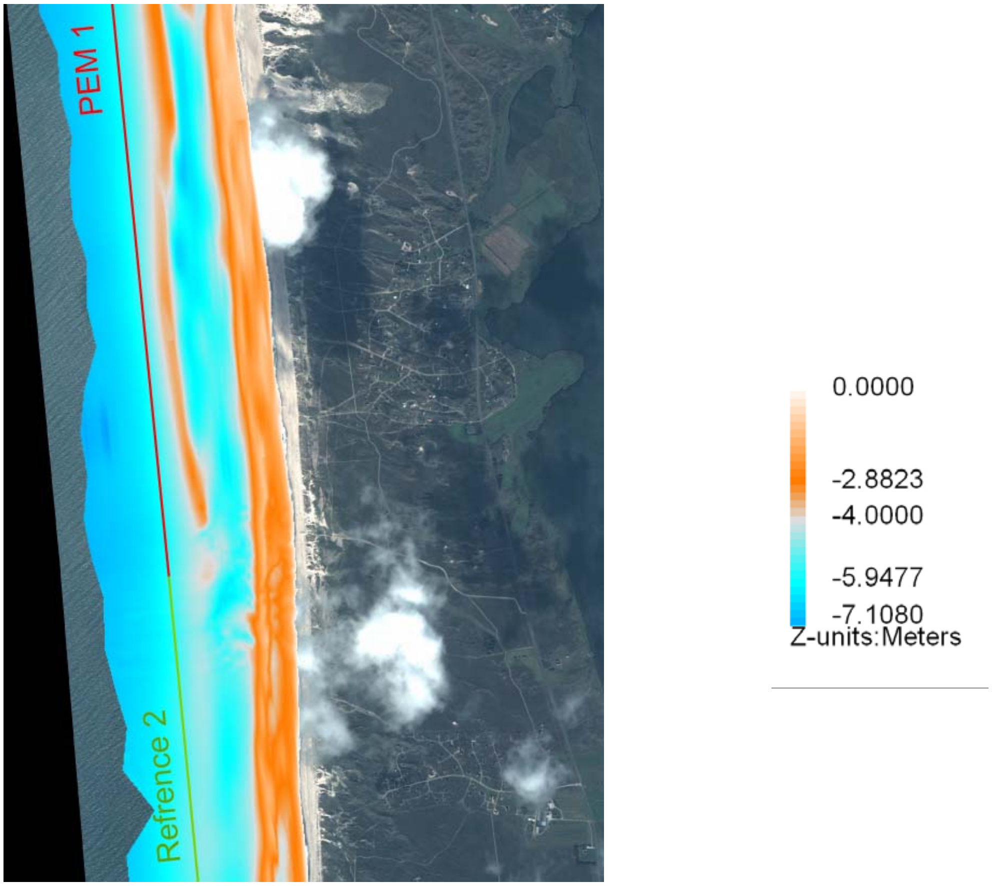


Figure 11.9: Detailed survey of the bathymetry in the transition region between Rør 1 and Ref 2, summer 2007. The measurements here are with a mutual distance equal 25 m between the measured lines.

Figure 11.10: the termination of the outer bar is visualized by the disappearance of the wave braking offshore at the left of the photo, taken from road C16 towards north in 2006.

When the outer bar disappear, a redistribution of the long shore sediment transport will occur: as long as the outer bar is present, the high waves will break here, generating a long shore current and associated long shore sediment transport on this bar. When the bar is no longer present, the high waves will break closer to the shore, and thereby increase the sediment transport closer to the beach. This local increase in near long shore sediment transport capacity results in a local erosion of the beach (figure 11.11).

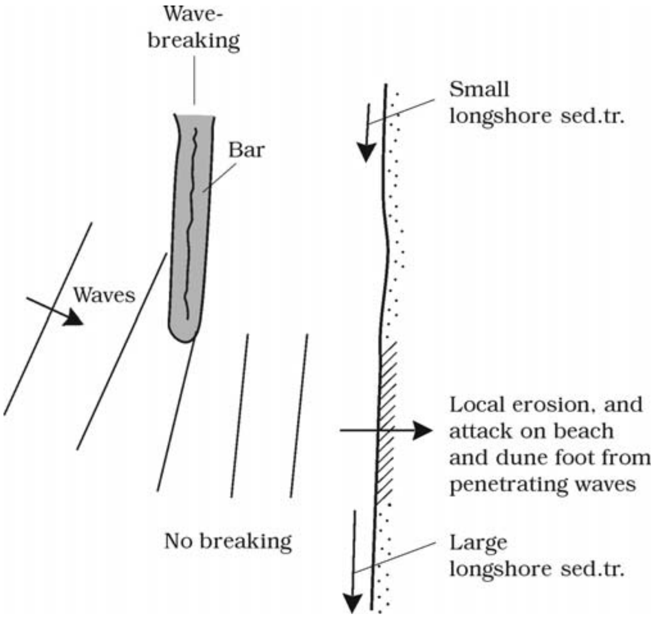
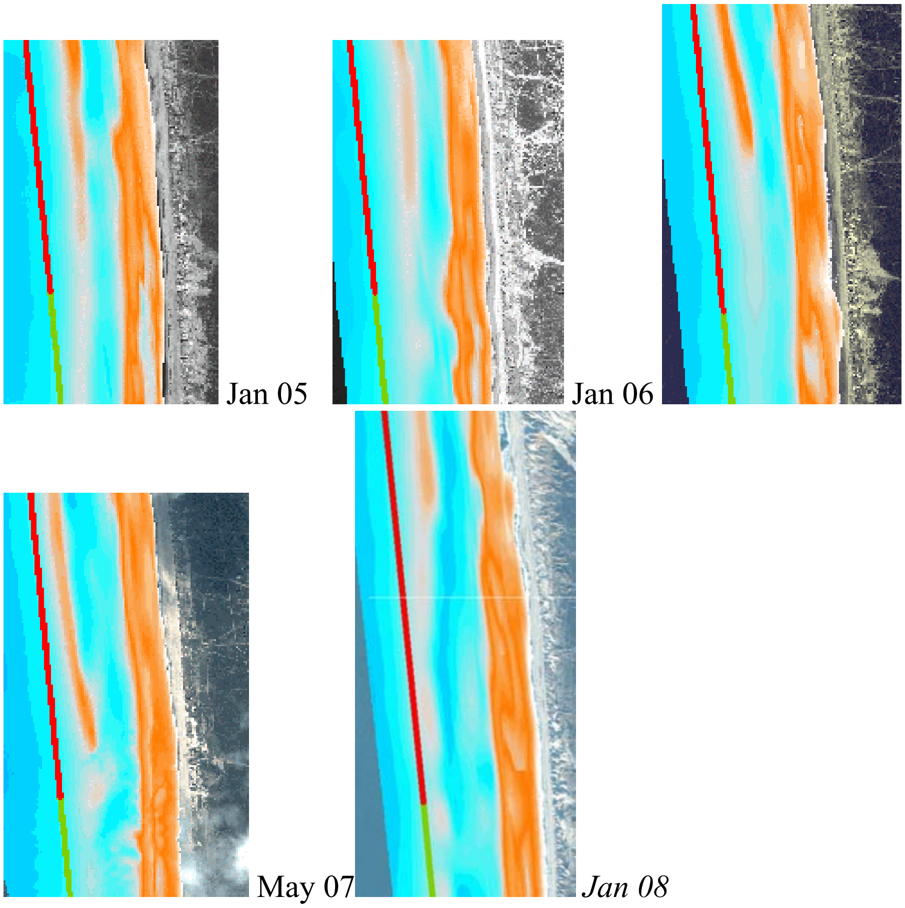


Figure 11.11 (like figure 10.8): formation of a narrow beach after the termination of the outer bar.

It is further observed from figure 11.12 that the bar generally expands in the Southern (down drift) direction, but fluctuates a lot. This can be one reason for the expansion of the narrow beach to a wider area during the test.



Jan 05 Jan 06 Jan 07

May 07 *Jan 08*

Figure 11.12: Snapshots of the bar behavior in the transition in between rør 1 and ref 2, based on figure 9.6.

Is the breach caused by the stop in the tubes?
It is certainly important to realize whether the breach is due to the termination of the tubes at the transition from rør1 to ref2.
Here the waves could attack the foot of the dunes, remove the vegetation and hereby allow the wind to create a breach in the dunes. As mentioned earlier and seen from fig 11.8 the beach was also weak at one location in ref 3, but here the dunes were a couple of meters higher, see figure 11.20, and the beach much wider. Looking at the *beach width*, this is small in the transition: it was here only 60 meter at the start of the test as compared to an average width equal 110 meters, see figure 11.3D. The narrow width less than 80 meter continues more than 1500 meters up into rør1 at the start of the test. Therefore the supply of sand to the dunes from the beach is here smaller than where the beach is wider. If you look at the weak part in ref 3, the width here is more than 100 meter.

It is certainly not easy to predict where the next breach will take place, but breaches most likely occurs at a location where the beach is low and narrow in combination with a depression in the dune ridge, so the dunes are less resistant. A lowering in the dune ridge will create a concentration of wind during storms, and this wind will transport a lot of windblown sand landwards and hence accelerate the erosion of the dune causing a breach.
Figure 11.13 shows some photos of the breach, and figure 11.14 shows similar pictures from an earlier, now nearly mature breach in the middle of rør1. So the breach in the transition is not an unique feature, and develops from time to time along the coast.

This expert assigns the development of the breach to natural causes.
The termination of the outer bar fits perfectly with the location of a weak beach, and you know that a weak beach allows erosion of the vegetation in the dune foot, and hereby allows erosion by wind.
Next the development of the beach weakening up into rør1 (it expands 600 meter up into this stretch) do not fit with tube impact: SIC denote it “transition area”, but as discussed in chapter 10, the sand is transported *South* most of the time. Therefore *no negative impact from the reference2 stretch can be felt significantly up into rør 1, and by no way 600 meter*. So this weakening can only be explained by the termination of the outer bar, in combination with the northwards development in wind erosion of the dunes. The erosion in the dunes in ref2 decays in towards the South, and is easily related to the *sink* of sediment through the breach and the associated downwind lack of supply to the dunes.

Conclusion: the beach behavior in the transition can not be explained by the configuration of tubes, no-tubes. On the other hand it can easily be explained by natural causes.
The dune behavior in ref2 can be explained by the presence of the developing breach.

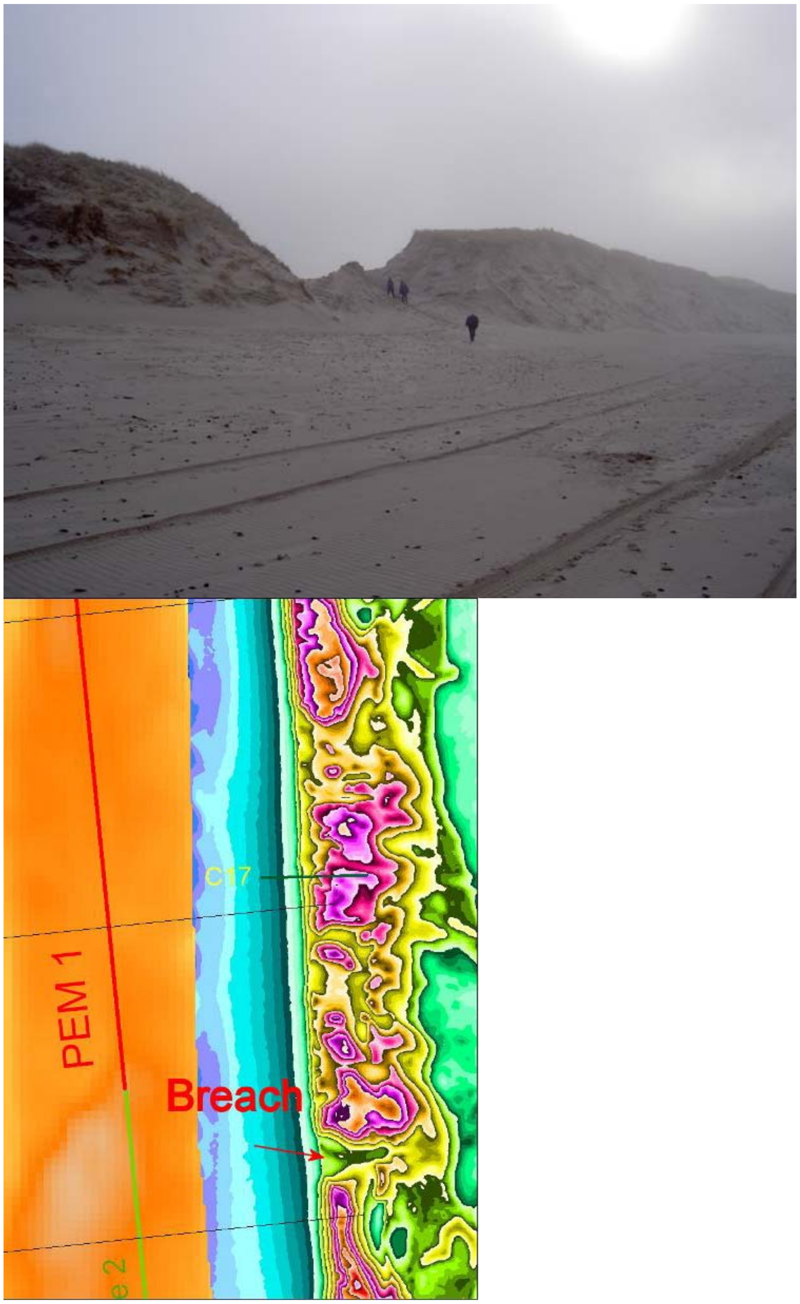


Figure 11.13A: Observed breach in the dune close to the position between Rør 1 and Ref 2. If you compare with figure 11.14 you can see that the hinterland is not build up yet.

Figure 11.13 B and C: further photos of the wind breach at the northern end of ref 2 from January 2007.

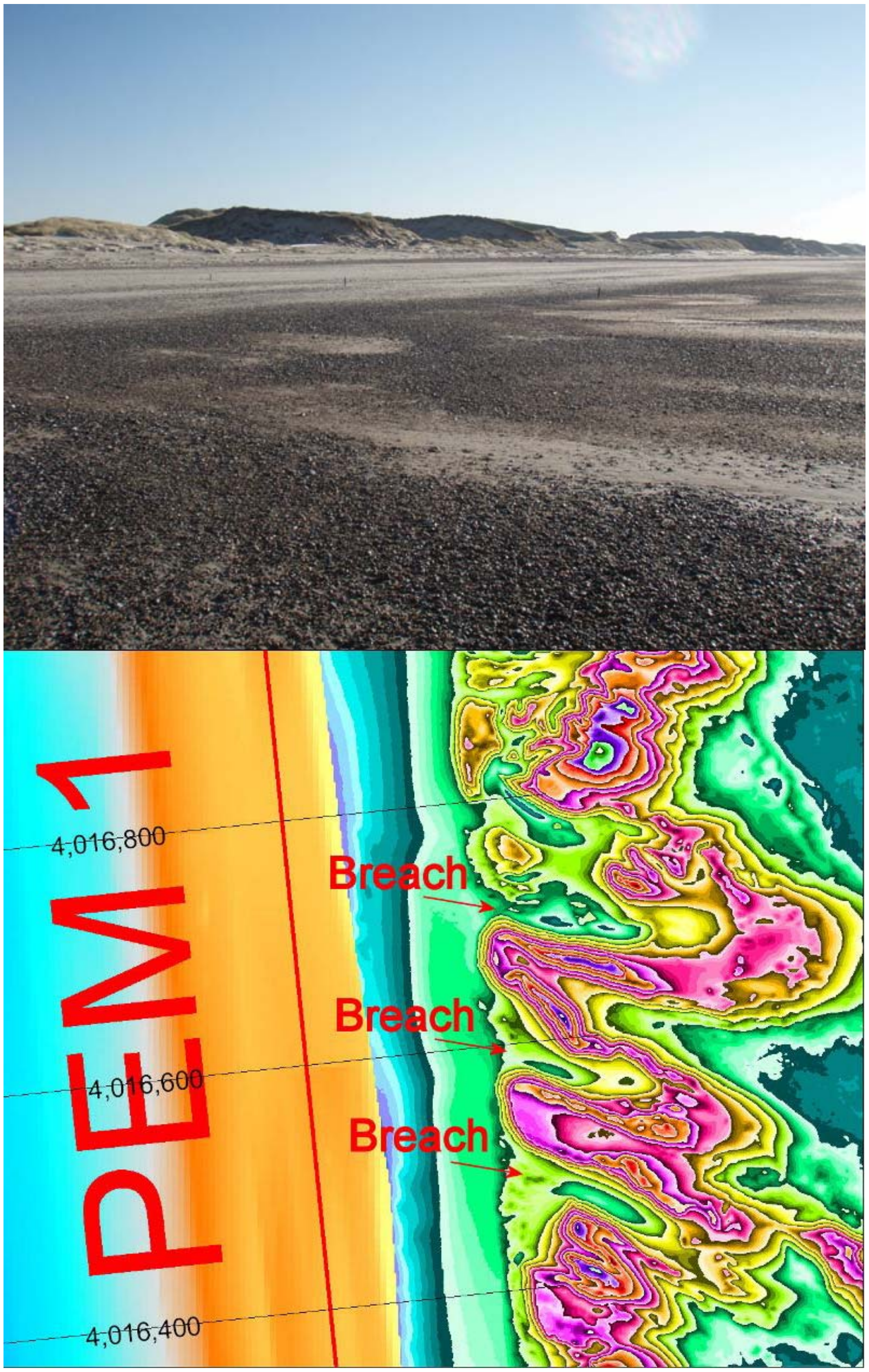
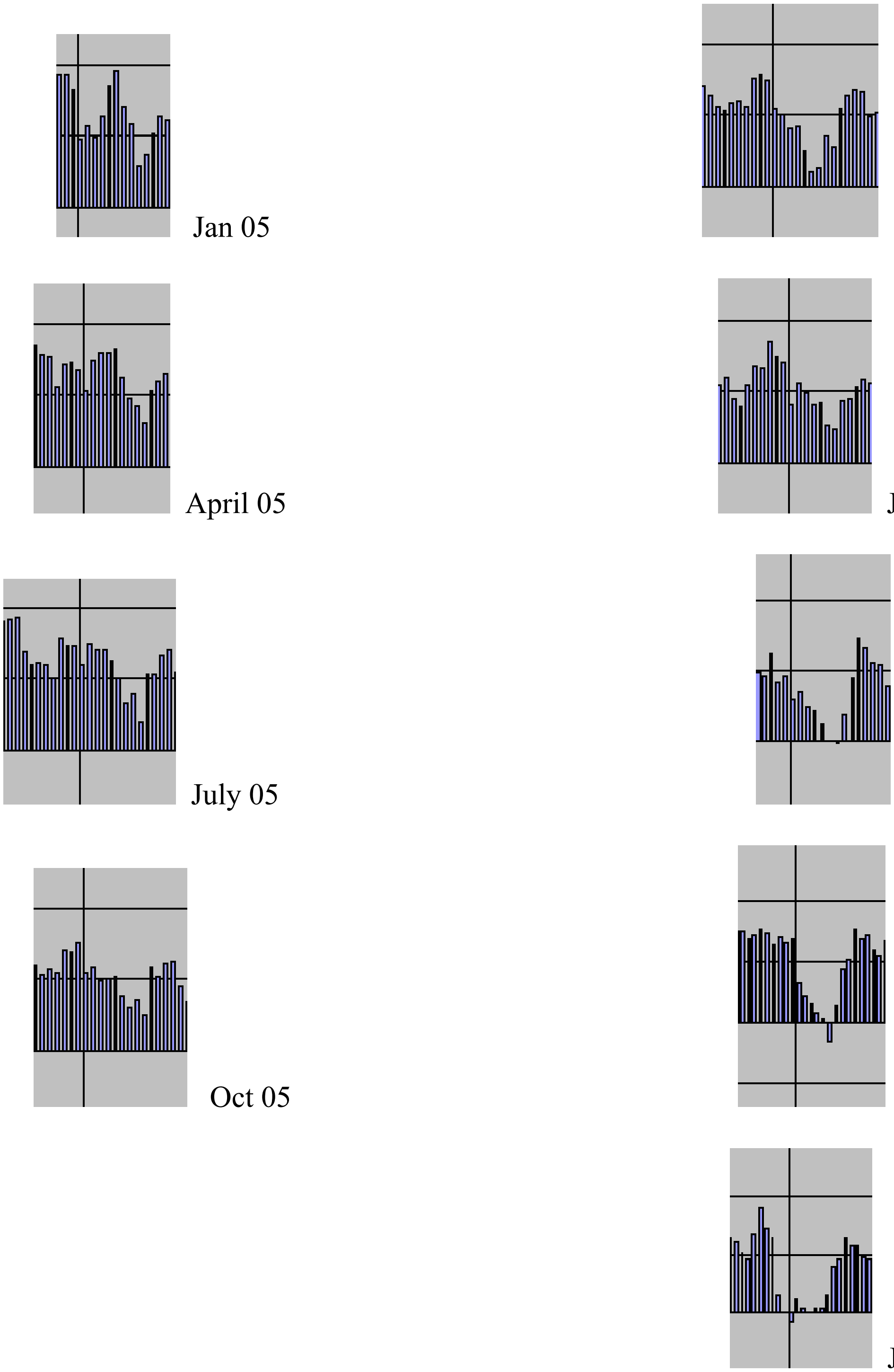


Figure 11.14: Mature breaches in the dune in the middle of Rør 1. (Note the tubes in the photo).

The weak part in ref1 close to rør 1.

Also in ref1 just north of the transition to rør1 the development of a weak beach can be detected, see figure 11.15.



Jan 05

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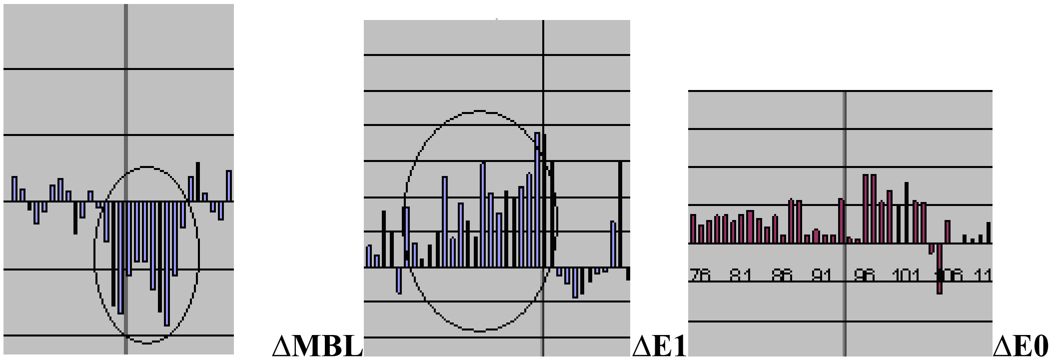
Figure 11.15 Development in MBL in ref1 around the location where the outer bar stops (The upper arrow in figure 11.11, right)

Can the narrowing of the beach here be caused by the absence of the PEM-system in ref1?

Initially the weakening occurs in ref1 1 kilometre north of the tubes, see figure11.15. The initial weakening is local and not influenced by the transition, recalling that the sediment drift is south going in the main part of the time. So you can feel *no negative impact from the tubes north of rør 1 in ref 1.* If there should exist a mechanism from the tubes such as a general lowering of the beach water table which could keep more sand in place, then this should extend up into ref1. and also partly keep the sand here in place, just as a real groin which accumulate sand *up drift* of the groin. Initially the weakening occurs in ref1 1 kilometer north of the tubes. The initial weakening is local and can not be influenced by the transition, recalling that the sediment drift is South going.

But we actual observe erosion just north of the transition both in the beach volume, see the series of snapshots figure 11.15, and also in the dune volume, figure 11.16. The only positive quantity at this location is in ΔE0, so the wind must have blown sand from the beach up into the dune and further up to the dune top.



ΔMBL **ΔE1** **ΔE0**

Figure 11.16. Changes close to ref1-rør1 in volume during the three years testing in beach, dune slope and dune top. The local Gain in dunes in rør1: approx 5000 cbm in three years. The local loss in beach: approx 15000 cbm in three years.

With reference to figure 11.16, the increase in E0 occurs in an 800 meter long stretch terminating 200 meter north of rør1. The similar loss in E1 is smaller and occurs in nearly the same section, namely in a 700 meter long stretch also terminating 200 meters north of rør1. The erosion in beach volume MBL begins nearly at the same location 800-900 north of rør1, but extend 3-400 meter down into rør1.

Can the narrow beach north of the transition be explained by natural causes?

As shown in figure 11.17 the outer bar next to ref2 also terminates in ref 1, see also figure 11.18. Its behaviour is quite similar to the one discussed regarding the transition rør1-ref2, and from figure 11.15 you also observe a similar temporal development of a weak beach at this location. This confirm that the weakening rather is caused by the bar behaviour than by anything else. Later it expands down into rør 1, and this expert assigns this expansion of the weakening most likely to be associated to the motion of the outer bar. At least it can for sure not be related to the downdraft tubes as just explained above.

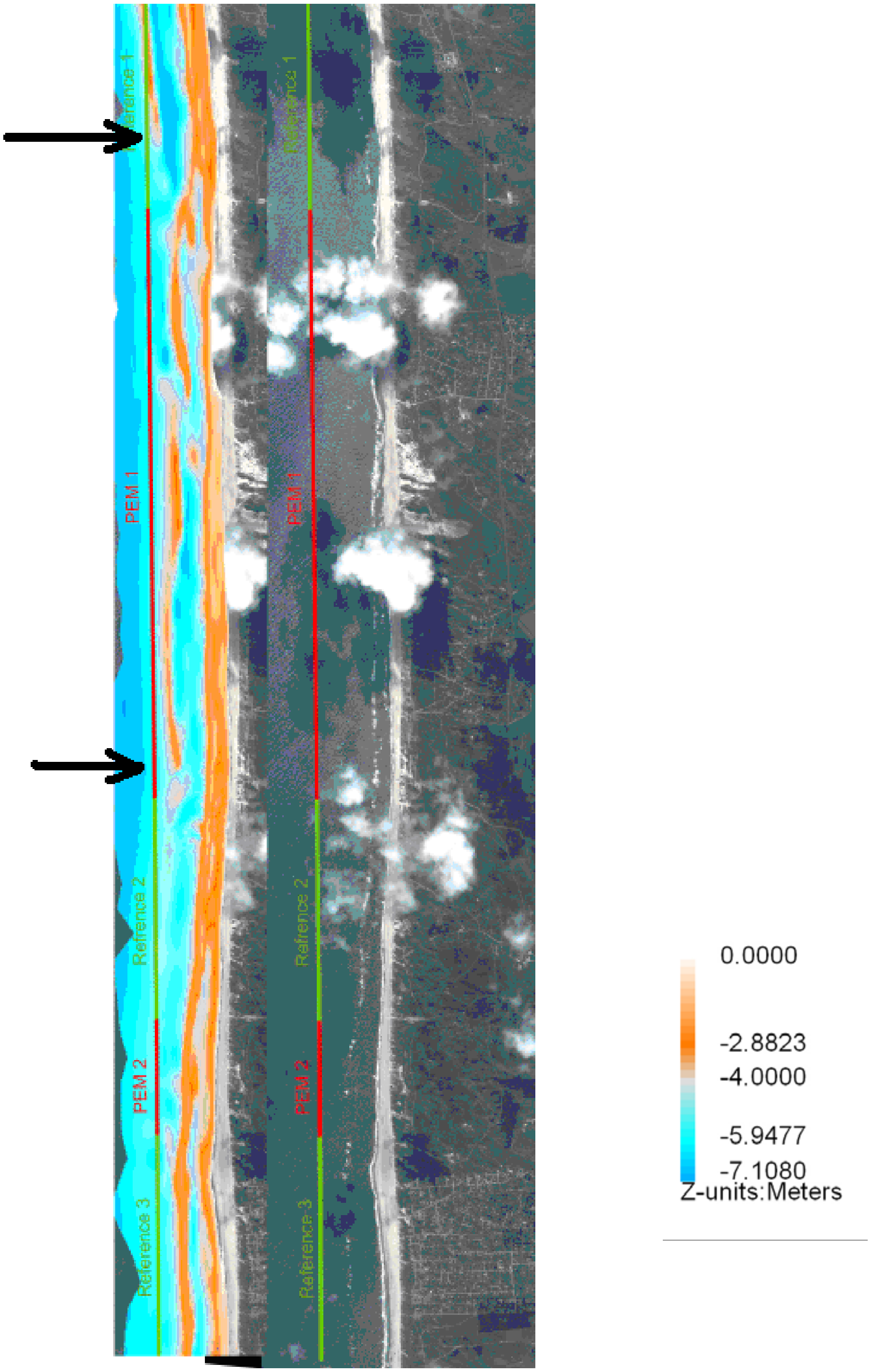
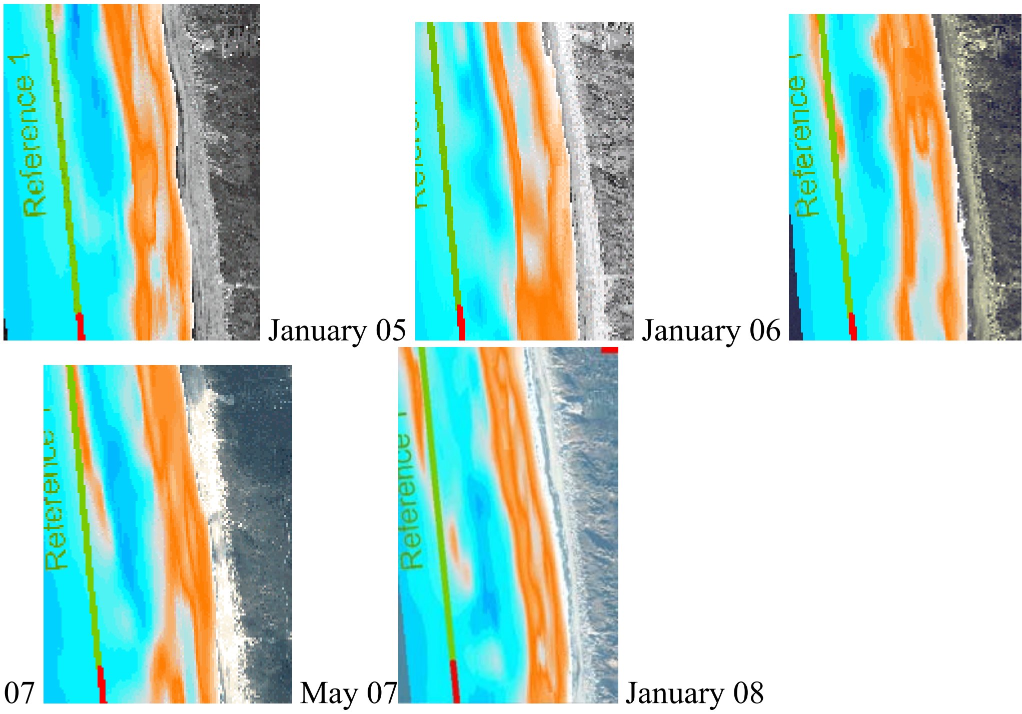


Figure 11.17: Measured bar pattern summer 2007. Orange Color represents depth smaller than 2.9 m, while light grey is depth larger than 4.0 meters. The measurements are based on lines perpendicular to the coast with a distance of 200 m. The arrows indicate the location where the outer bar stops.



January 05 January 06 January 07 May 07 January 08

Figure 11.18: Bar behaviour in ref 1.

Next, the changes and redistribution of sand in the dune from lower to higher level can only be related to action of wind.

So the changes here are natural, and can have nothing with the tubes to do, an impact from the tubes would on the contrary have caused an increase in MBL at this location as described detailed in chapter 10.

The increase in dune volume in the upper part of rør1.

Moving further south into rør1 you observe an increase in dune volume, in total about 5000 cbm as encircled in figure 11.16. At the first 400 meters you get a similar loss in the beach, so here you might have a transport of sand from beach to dunes. The total loss in the beach shown in the circle figure 11.16 is about 15000 cubic meters, of which about 4000 cbm is in rør1. Should it be related to the tubes you should have no loss here in the beach. Further south in rør 1 you still have a certain accumulation in the dunes and no loss in the beach (say: 400 to 1400 meter down into rør1), so here you have in total accumulation. This is most likely due to the characteristics of windblown sand, which can deposit further downwind of where it is eroded, as discussed several times in this report.

However, it is striking that you get a sudden increase in the accumulation of sand in the dune. As already pointed out earlier, you have another feature: the sudden increase in beach width by about 40% *at exact the same location and present also before the test began!* As shown in the beginning of this chapter, we have correlation between beach width and dune accumulation, so accumulation is to be expected in the dunes.

A.

B.


C.

Figure 11.19 Photo of the hole just in the transition between ref1 and rør 2, May 2008. Figure B and C show that there is a room for sedimentation upstairs the dunefoot.

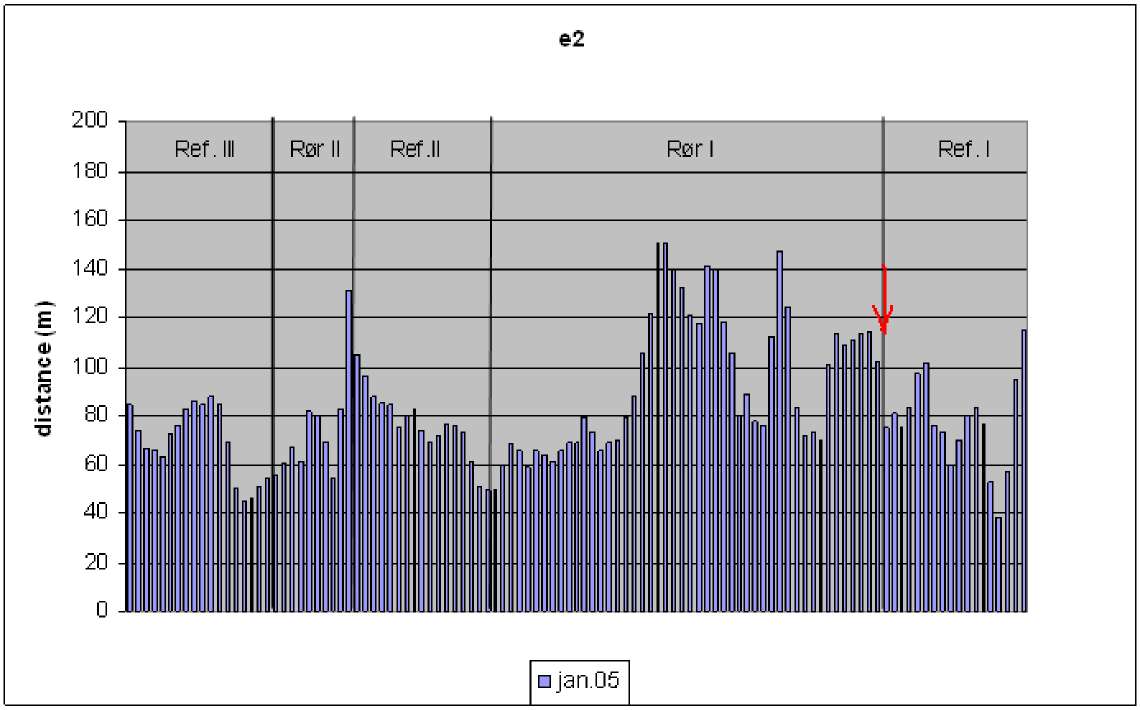


Figure 11.20: The beach became470 % wider just before the transition between ref1 and rør2 already in 2005. This however is not the most likely cause to the large accumulation of sand in the dunes. The local dune geometry with a shelf between the dune top and dune foot towards south is probably more important for trapping windblown sand.

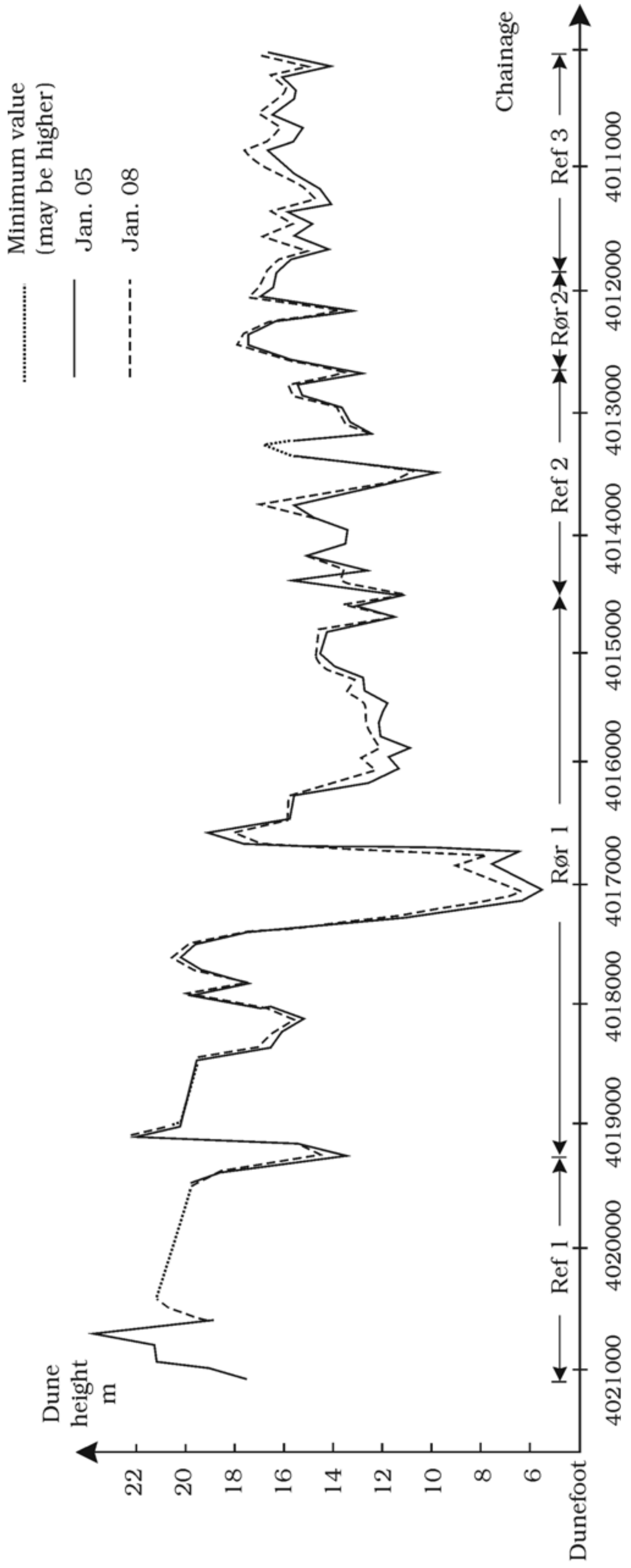


Figure 11.21: Spatial variation in the dune height.

Why does the dune accumulation start so abruptly?
The beach widens abruptly, so the dune accumulation could respond on this. However windblown transport should maybe react slightly less abrupt.
If the gain is related to the tubes, the gain should be more or less evenly distributed along the rør1 section, maybe with an exception just south of the breach in the middle of rør1, because a breach drains sand. However the signature of the volume gain in the dune ΔE1 is much more likely due to a local *source* of sediment supply just north of the transition: it has a sharp maximum just at the beginning (200 meters north of the transition) and decays smoothly in the downdrift direction (this is actually just opposite to the picture downwind the breach in ref2, where we got a *sink).*

Figure 11.22: In the northern direction, the shelf is not so pronounced.

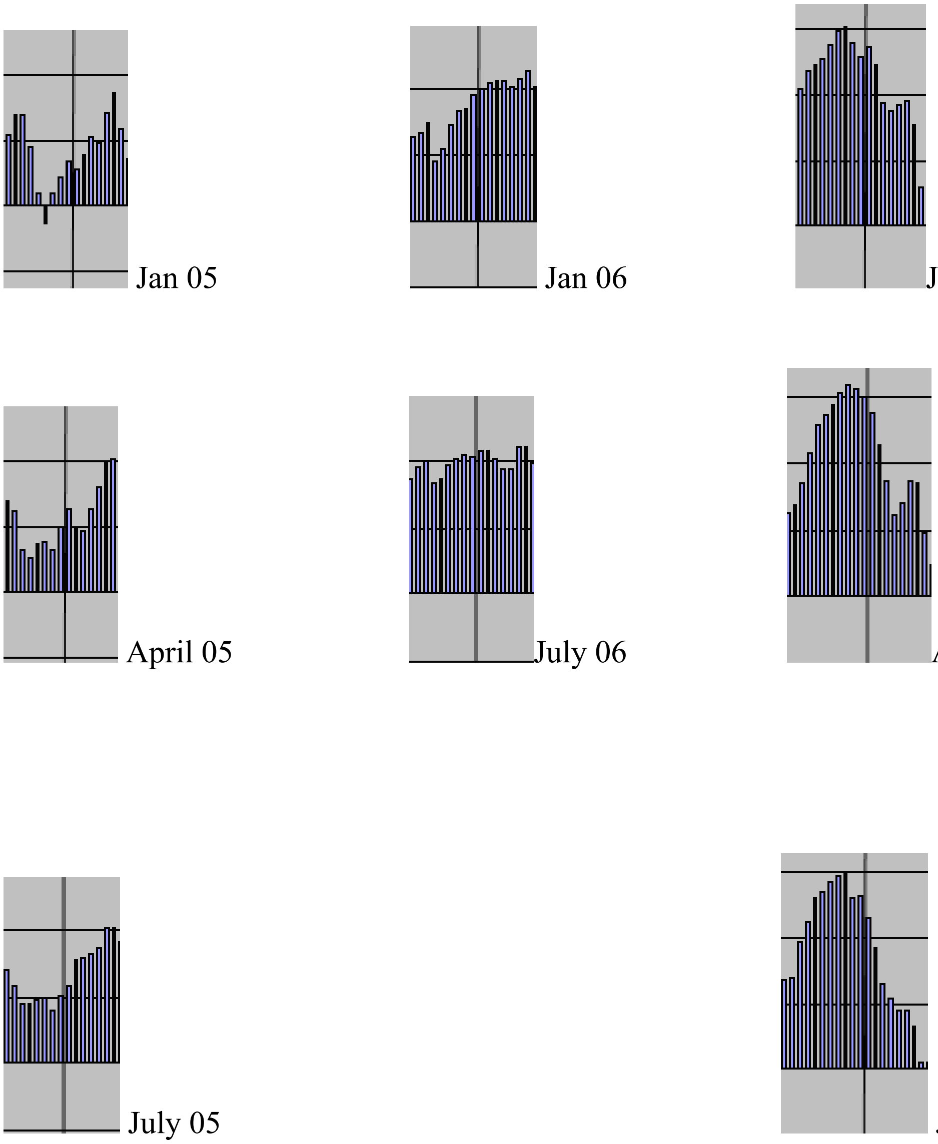
Whether this supply originates from the beach erosion (equal 15000 cbm), or from the dunes or- more likely – from further North is open.. Regarding the beach, the loss here is 3 times as large as the gain in the dunes, but as discussed in chapter 10, you have to go through the process of moving sand from the swash to the beach and next to the dune to get this transport.
Regarding supply from the upwind dunes, you can observe a large hole free of vegetation close to the transition from ref1 to rør 1 as shown in the figure 11.19A. The hole is not a real breach, since it does not cut through the dunes further inland.
The hole can also be observed from fig 11.21 showing the variation in the dune height along the whole test site: at the transition in between ref1 and rør1 you can observe a local lowering of 8 meters, which partly can explain some of the losses of sand as described above. The volume of the hole is about 5-10000 cubic meters. This un-vegetated section can most likely contribute to the supply of the downwind dunes with sand.
However the most likely cause to the change in the deposition pattern is the geometry of the dune: South of the hole in the transition, we observe a wide shelf-like dune slope in

between the top of the dunes and the dune foot. As seen in figure 11.19C this is covered by vegetation, which is an ideal trap for catching sand.

Conclusion: the beach behavior in the transition can not be explained by the configuration of tubes, no-tubes. On the other hand it can be explained by natural causes, namely due to the termination of the outer bar.
The dune behavior in ref1-rør1 can be explained by the spatial variation in beach width, in combination with weak un-vegetated dunes close to the transition and the geometry of the dunes south of the transition.

The transition between rør 2 and ref3.

This transition behaves very smoothly like you have no changes in the tube environment at all as can be observed in figure 11.23. The whole system is like a down drift moving sand wave or undulation, as can see on the erosion-deposition fingerprint shown in figure 11.24 and appendix 4.



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Jan 06

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July 06

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July 05

January 08

Fig 11.23: The beach MBL development in the transition between rør 2 and ref 3. Here you actually get an increase in the beach downstream the tube covered region.

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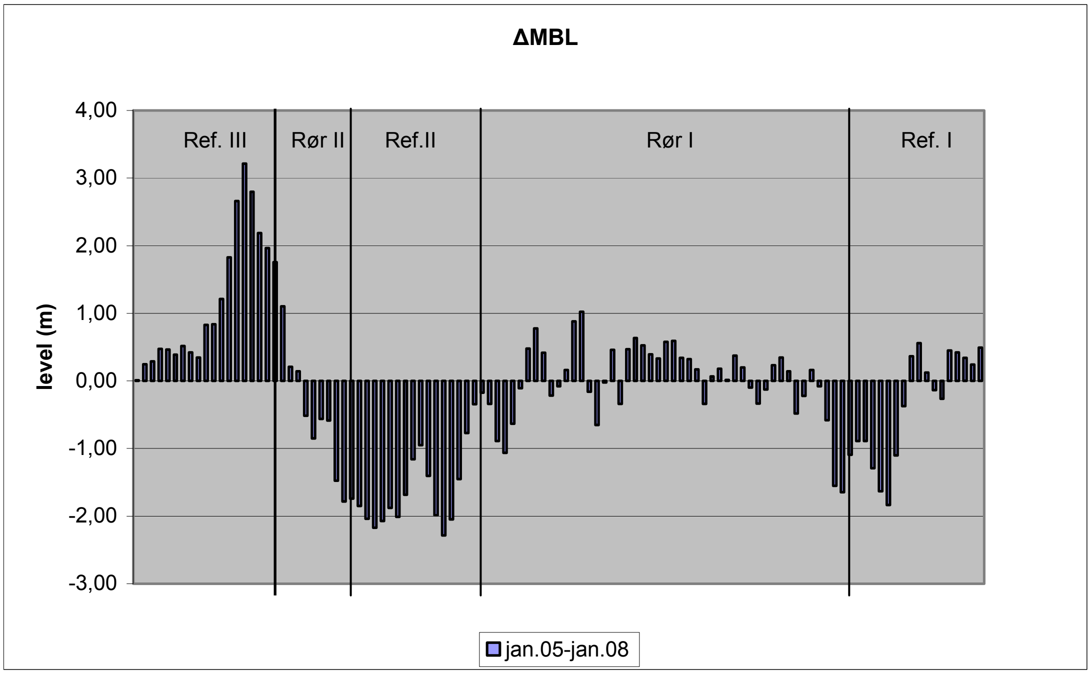

Fig 11.24: The changes in the beach mean level is especially in ref3-rør2 very similar to those caused by down drift migrating undulations, see appendix 4. But also in rør 1 the structure resembles moving undulations.

Summary:

Weak points in the beach are observed at two locations, at the southern transition between rør1 and ref 2, and further in ref 1 just north of rør 1. At both locations this coincides with the termination of the outer bar, so the waves will attack the beach heavier down drift this point, thus causing erosion.
A breach in the dunes at the southern location accelerates the weakening of the beach due to increased windblown sand transport to the hinterland. This breach develops during the test and removes a lot of sand from beach and dunes. A similar hole in rør1 is more mature, and the dune system has stabilized, so you can not very clearly identify this place in the measurements, but there is still some windblown transport through the breach.
The northern transition between ref1 and rør1 has an unstable dune with a large hole without vegetation. The increase of dune volume in rør 1 can be due to supply of sand from here, and from sand eroded in the beach. The beach actually widens at exactly the same spot as where the dune accumulation increase. This widening was distinct already in January 2005.
The transition in between rør 2 and ref 3 runs smoothly.

Chapter 12 English Summary and Conclusions.

A large field test has been performed at an exposed location at the Danish West coast,

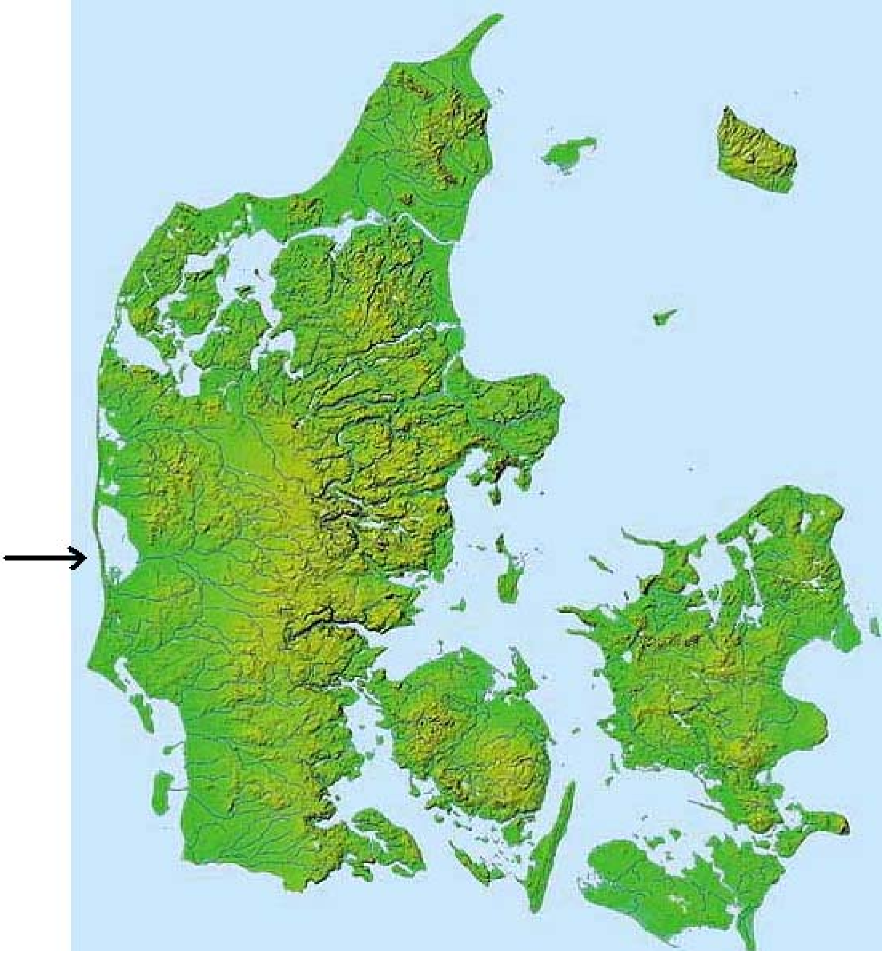

Figure 12.1: Location of the site in Denmark.

which is located in front of the North Sea.

The purpose was to investigate whether the PEM system (Pressure Equalization System) developed by the company SIC (Skagen Innovation Center) would protect the coast.

The system consists of vertical tubes (around two meter in height, inner diameter 5-6 centimeters) with small slots (0.2 mm) put in a row perpendicular to the coast with a mutual distance of ten meters. There is one hundred meters between each row along the beach. The top of the tubes is initially about 30 centimeter below the local beach surface.

The details of the PEM system are given in chapter 4.

An 11 kilometer long stretch was allocated to the test, the details shown below: you have sections with tubes, which in Danish are “rør”, so rør1 means the northern 4500 meter long section covered by tubes, and rør 2 is another much shorter (900 meter) section also covered by tubes. Three Reference section, each 1800 meters long, are sections without tubes, for comparison. Unfortunately, because SIC would like a long uninterrupted section with tubes, the different sections do not have the same length.

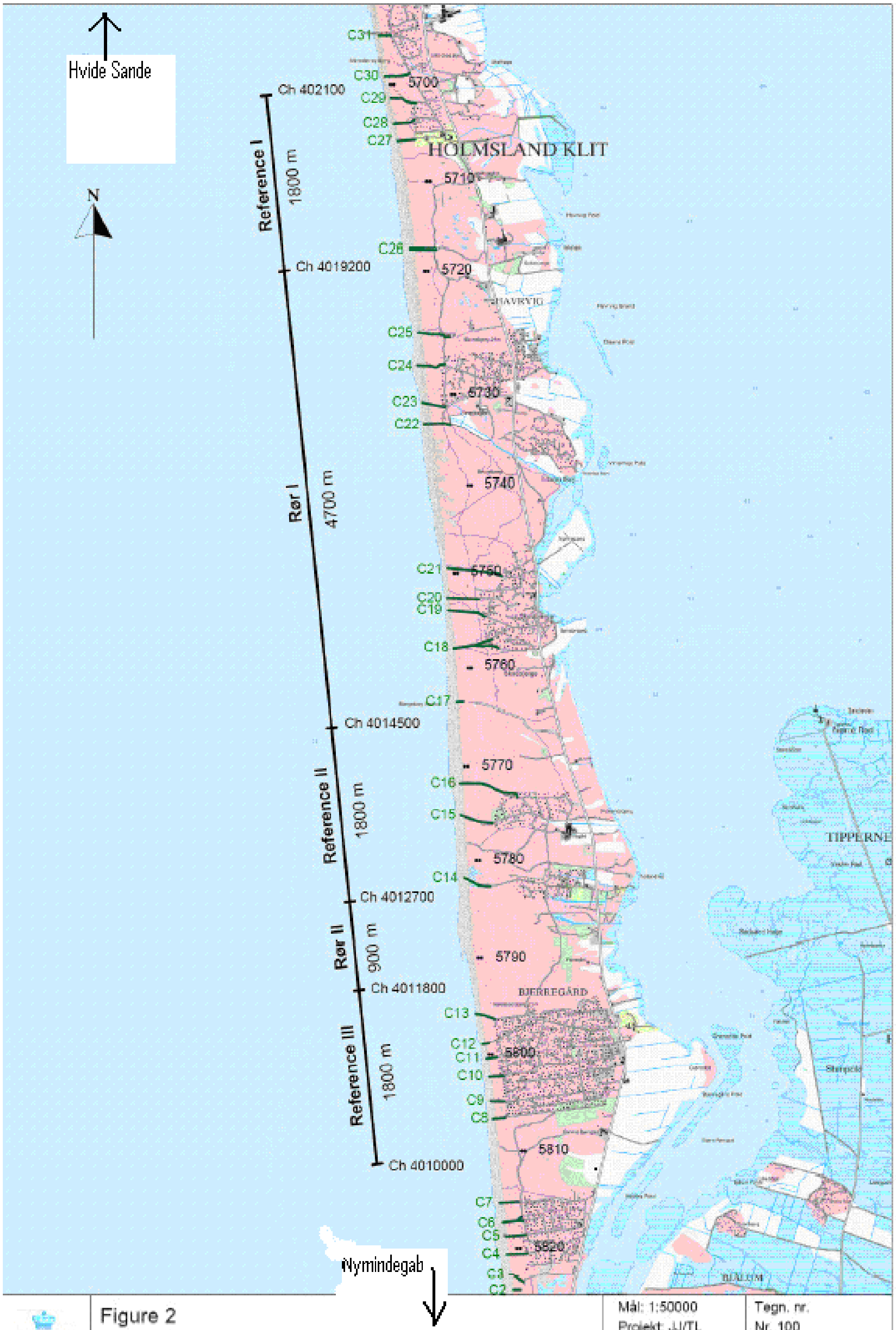

Figure 2
Location of test stretches

Mål: 1:50000
Projekt: JJ/TL
Rev.: 05.10.2005

Tegn. nr.
Nr. 100
Gr. 103-659-2

Godkendt: 11.05.2005

1. **Detailed flow field and sand accumulation.**

The functioning of the system is not clear. SIC has a lot of explanations, which not all are discussed in this report, but is listed in the ending chapter, ch. 13 (in Danish).
This expert can not find other explanations than a smaller (actually zero) flow resistance inside the tubes as compared to that in the sand outside the tube will lead to a local redistribution of the flow patterns. A small amount of water in a distance 2-3 times the tube diameter prefer to flow through the tubes rather than outside in the sand. This requires a vertical pressure gradient, which you for instance have in the case of a tidal flow, where you have a damped standing wave in the beach. In other words: the impact diameter of the tubes is less than 20 centimeters, leading to an improved drainage of the whole beach less than a tenth of one per thousand (less than 0.0001) of the tidal flow in and out of the beach. The flow velocity inside the tubes will in the most extreme cases not exceed 5-6 mm /second for common beach sand.
We have never measured the flow velocity inside the tubes, but we all agreed in, that it would be too low to measure with an ordinary propeller. But this expert measured it in the lab, where it was confirmed that it was just as low as explained above.
So you can conclude that *the drainage effect leading to a local depression in the water table in the beach is negligible.*

Another possible effect is to *reduce the upwards directed pressure gradient* in the sand. The upward directed gradients stem partly from a falling tide, and partly from freshwater supply from the hinterland. The upward directed gradient is estimated to be maximum 0.05 for the specific site, which is far away from mobilizing the sand (fluidization). The changes due to the PEM-system are again estimated to be negligible.

Numerical modeling of the flow with and without tubes in a real environment confirms our estimates, that the impact of the tubes seems very small. The numerical runs include tide, freshwater supply from land and inclusion of permeable/impermeable layers. Still the impact radius is always negligible (sometimes the impact of the tubes is, that you get more water flowing into the beach than out, causing a rise in the water table. This corresponds to the well-known rise in the MWL in a beach as compared to the Sea in a tidal environment). The numerical modeling is described in chapter 5 and appendix 4.

Visual observations in the beach face confirm the negligible drainage effect: the transition between the wet surface and the drained surface moves smoothly along the shore, and don’t realize that you pass an array of tubes, If you have drainage, a local bend should be observed.

Water level measurements in the field.
We studied the water level variation inside the tubes and compared with the water level outside the tubes. (Actually, you usually measure the water level variation in soil using a system of perforated slots in a tube very similar to the PEM-system; however the slots are

in this case restricted to the very lower end of the tubes). We observed a water level difference up to about 15 centimetres, which agrees perfect with the numerical modeling, and do not demonstrate any significant drainage effect.

The description of the functioning of the tubes is given in chapter 5, and the field test is described in appendix 1 and 2.

Accumulation of sand.
Local accumulation of sand is not observed, neither around the individual tubes nor around each array of tubes. You would expect a ridge of accumulated sand at least around each array, and a spit in front of the row. This is certainly a very strong indication that the impact of the tubes on the beach morphology at the most is very weak.

Conclusions regarding near tube observations.

- *The flow through the tubes is weak, we are talking about a few millimeters per second*
- *The drainage effect is usually less than half of one per thousand.*
- *No local sink can be observed in the beach face*
- *No local accumulation of sand is observed around individual tubes or array of tubes.*

2. Large scale control boxes.

Actually the intention of this test has from the very beginning been to look at larger control boxes containing the whole beach, the dune system and the offshore part. This expert also included the considerations above, because it is such a strong indication on, whether the tubes have any impact at all.

The large scale test is certainly difficult because of the large scale spatial and temporal variations in the coastal profile and the beach. We divided the profile up into four parts: the dunes was that part of the profile above 4 meter above MSL, the beach was the next 100 meter in the offshore direction, offshore 1 the next 300 meter and offshore 2 the next 300 meter again.
The most relevant part is the beach box, where the tubes are implemented. However wind interaction between beach and dunes is also of importance to explain whether the interaction between tubes and beach occurs.
Figure 3 shows the variation in accumulated sand in the “beach box” (rather than “beach” because the width always is 100 meters independent of the actual beach).

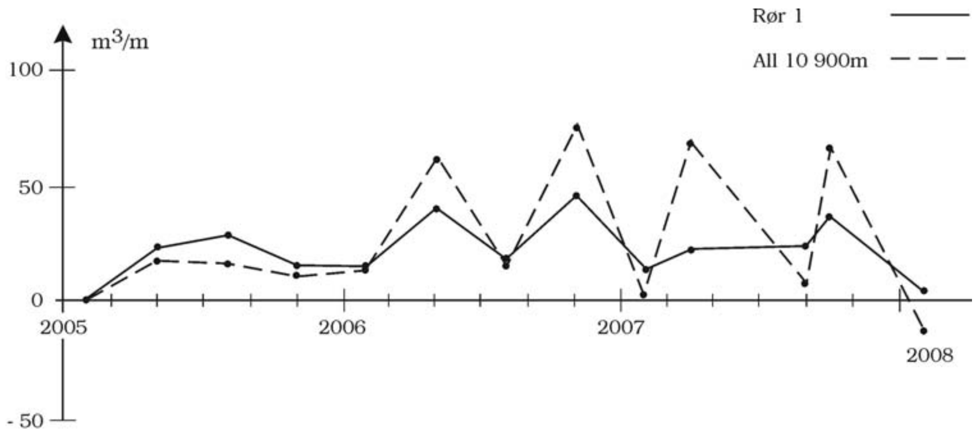

Figure 12.3: Temporal Variation in beach volume: The beach volume changes so much that the conclusion depends on the cut of the test.

The full drawn line shows the accumulated amount of sand per meter alongshore in the large tube covered section rør1, while the dashed shows the similar one averaged over all 11 kilometers. Before the test the coastline is an average stable due to heavy sand nourishment (in average 600.000 cbm a year since 1993).
The figure demonstrates that the *natural fluctuations* in the coast are so large, that you can not identify the weak signal which might exist from the tubes. The values plotted are positive because the tubes were put into the beach just after a major storm occurring January 8th and 9th 2005, so we had a lot of backfilling to the beach from offshore after that occasion. Else the variation is as usual large temporal fluctuations, and because we stopped the experiment in January 2008, we got nearly zero total accumulation in the large tube-covered area during the whole test. If we instead had stopped just 4 month earlier, we would instead predict accumulation of 34 cubic meters per meter. Figure 3 demonstrates that in order to detect the possible signal from the tubes, you should run this test for 25 or maybe 100 years.

In reference 2 you have a large loss of sand from the dunes and the beach due to a developing wind breach. (SIC would like to attach the breach to the lack of tubes, but the position of the breach was the most likely place for it to occur: low and narrow beach and relative low dunes were present there *before* the test).

In reference 3 with no tubes installed you had the largest gain of sand at all.

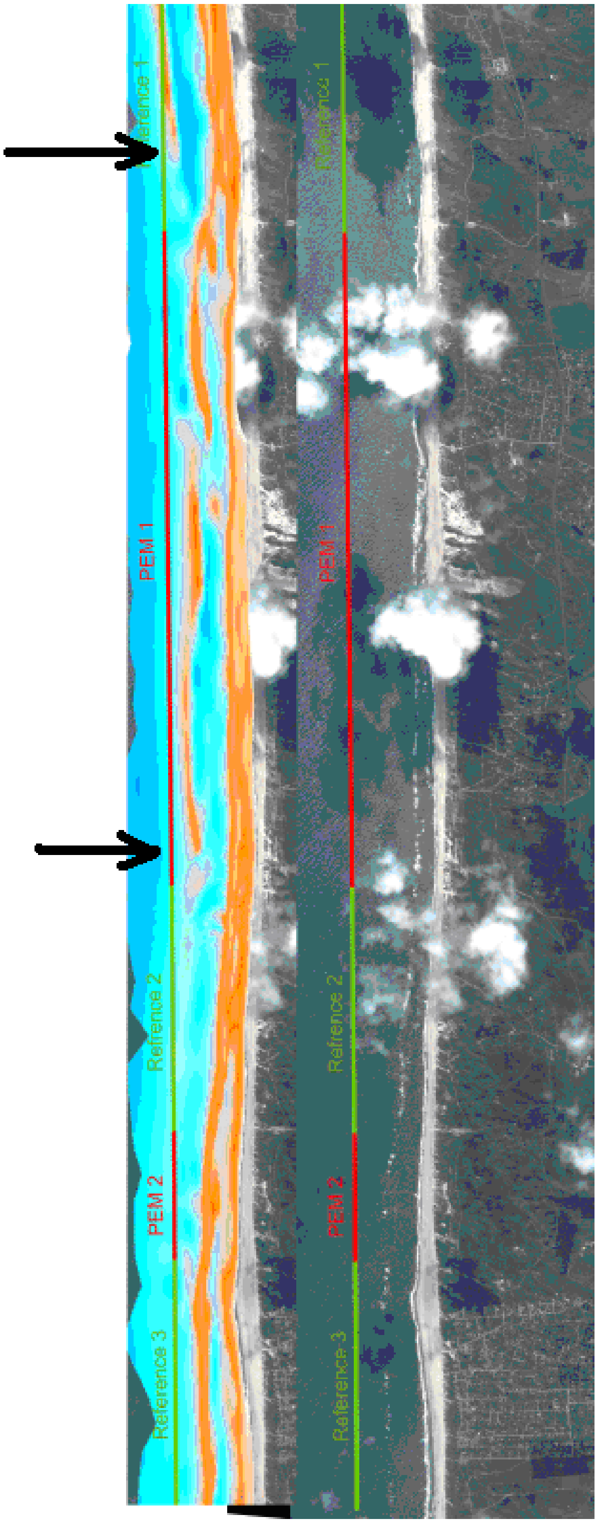

Figure 12.4. The outer bars terminate just up drift of the location of the transitions.

Close to the transition from ref1 to rør 1 and also from rør1 to ref2 the beach is weak. From the offshore measurements we have identified, that the outer bars terminate just up drift the narrow beaches, so this has a natural explanation. But you can also conclude that these locations of transition sections are chosen very unfortunate.

Table 1 shows the condensed outcome of three years investigation: plus is in favor of tubes, minus is in disfavor and zero is nothing. The tables tell that everything is random, like nature!

The details of the table are given in chapter 11.

	Reference 1	***Rør 1***	***Reference 2***	***Rør 2***	***Reference 3***
Dune box: (D1)	-	+	+	+	0

	Reference 1	***Rør 1***	***Reference 2***	***Rør 2***	***Reference 3***
Beach box: (D2)	+	0	+	-	-

	Reference 1	***Rør 1***	***Reference 2***	***Rør 2***	***Reference 3***
Inner Offshore box: (D3)	+	-	-	+	-

	Reference 1	***Rør 1***	***Reference 2***	***Rør 2***	***Reference 3***
Outer Offshore box: (D4)	-	-	+	-	-

Table 12.1. Integrated evaluation of the test. + means accretion in rør, or erosion in ref, and vice versa.

The most relevant table above is the one regarding the beach (put in green), because this is the location, where the tubes are! Whether the dune boxes shall be included as a box indicating the usefulness of the tubes is a bit open for discussion. There can be a link because a wider beach may cause more windblown sand to the dunes. All this is discussed in chapters 10 and 11.
The offshore boxes deserve even less attention regarding the accounting of the sediment budget in relation to the tubes, but are included for reasons of completeness.

Conclusions regarding large scale boxes.

The variation in the beach volume through the year is large; the average beach level fluctuates up to 30-50 cm a year. Because the signal from the tubes is weak, a possible

signal is totally overshadowed by natural variations, so you can conclude nothing after only three years.
This is confirmed by the table 12.1, from where you can see no sign of systematic changes in favor of the tubes.
All observed changes observed in the beach can be related to natural processes like migrating bars and breaching in the dunes.

The *overall conclusion* is that you after three years of testing can see no distinct fingerprint of the PEM-system on the coast. All processes can be identified by natural causes.

For this reason it can not be recommended as a coastal protection measure.

Chapter 13: SICs forklaringer (in Danish).

Gennem hele forløbet har SIC lavet sine egne rapporter – og kasseret eksperternes. I SICs rapporter har de givet deres opfattelse af hvad forsøget dokumenterer. Hertil har de kommet med en række forklaringer på kystens adfærd og rørets virkemåde, som eksperten ikke føler, kan stå ubesvaret. Herudover har møder i gruppen været en del af projektet, hvorfor følgende kommentarer er inkluderet i rapporten:

1. SIC hævder at røret allerede efter 6 måneder inde i forsøget har demonstreret sin succes. Som forklaret ovenfor er der efter 6 måneder blot sket det, at det sand, der blev eroderet væk i vinteren 04-05 har ligget som et reservoir udenfor stranden og er skyllet tilbage på stranden i løbet af foråret. Dette er tydeligt dokumenteret af figur 11.1, der netop viser at strandens styrke svinger frem og tilbage.
2. Som vist ovenfor, f.eks. i tabellen 12.1, er rørene nogle gange en succes (et +), andre gange det modsatte (et -). Plusserne blev straks taget til efterretning af SIC. Minusserne er gang på gang blevet bortforklaret. Eksempler: hvorfor er der stadig aflejring nedenfor et rørområde 2, her skulle aflejringen da stoppe? Svar: rørene ”vasker” sandet, så det fine forsvinder og stranden bliver mere stabil. Ja men hvorfor er der så ikke aflejring bag det store rørområde: jo, her er der mere sand, der skal vaskes.
3. På den måde forsvinder hele ideen med reference områder pist væk: man kan jo ikke mere bruge dem til sammenligning med rørområderne, da rørområderne åbenbart også skulle stabilisere referenceområderne ifølge SIC. Dog ikke i reference 2, for her var der jo erosion, altså +, så dette blev godkendt af SIC.
4. Reference område 1 opfører sig heller ikke helt gunstigt for rørene: her er der ikke rør, men der er stadig aflejring mest mod nord, og erosion mod syd. Derfor opdeler SIC dette område i to: det øverste hedder 1a, og skal ikke tælles med. Det ligger for tæt ved sandfodringen. I så fald skulle det ikke have været medtaget fra starten for derefter ”at tage det ud af forsøget” hvis det ikke passer med forventningerne. Sandfodringen er desuden flyttet totalt væk fra stranden ud på revlen, så SIC accepterede sandfodringen her ved forsøgets begyndelse. Det er i øvrigt helt uvist hvorledes den sandfodrede mængde skyller ind mod kysten.
5. Forklaringen om ”vasket sand” hænger overhovedet ikke sammen. For det første er det så lidt vand, der strømmer gennem røret, at det ikke kan gennem skylle en strand igennem og fjerne de fine fraktioner, stranden skylles meget mere igennem af de bølger, der hamrer ind mod stranden i blæsevejr. Dernæst er det så enorme mængder sand der skal ”vaskes” at det vil tage år. Og i mellemtiden er stranden så blevet fyldt op med nyt ”uvasket” sand. For det tredje er det da lige så let at vaske i det store rørområde som i det lille, godt nok er der mere, der skal ”vaskes”, men der er jo også tilsvarende flere rør.
6. Vi har prøvet om vi kunne identificere en ”vaskning” af sandet ved at lave kornkurver af sandet til forskellige tider. Dette viste en total usystematisk variation, men datamaterialet var godt nok lille.

7. I øvrigt må man ikke håbe, at der er alt for meget fint materiale, der skal vaskes. Så vil meget af det blive transporteret ind gennem sprækkerne i røret (0,2 mm) og fylde røret op med fint materiale. Vi har aldrig gennemgået rørene for at se om noget sådant er sket. (I nogle af rørene der stikker op på stranden har vi observeret sand i rørene, men det kan jo også være børn, der har hældt sand i).
8. At hastighederne i rørene er små er accepteret af SIC: eksperten foreslog flere gange under forsøget om vi da ikke skulle måle hastigheden i røret. SIC sagde hver gang at hastighederne var alt for små til at de kunne måles. Dette overraskede naturligvis eksperten, for hvis hastighederne var små, ja så er der jo ingen dræningseffekt og så virker det ikke! Eksperten kom flere gange uden held tilbage til dette med at måle hastigheden med en lille propel.
9. En anden forklaring på at der ikke systematisk er erosion uden rør og aflejring med rør, er den såkaldte "læsideaflejring": på grund af udbulinger samles der sand neden for disse udbulinger, altså en slags høfdevirkning. Denne "læside aflejring" er brugt til forklaring i 2 øjemed:
10. A: til at forklare at der ikke er lokal ophobning omkring de enkelte rørrækker. Og B: til at forklare aflejringen i reference 3, der jo er særdeles uheldig for rørenes virkemåde.
11. Først punkt A: SIC er åbenbart klar over, at de har et forklaringsproblem, idet der ikke er lokal ophobning af sand omkring rørene. SIC mener, at der kan opstå en høfdevirkning uden en høfde: vi har jo aldrig set ophobninger, se f.eks. foto figur 10.1. I øvrigt, som vist i foto figur 10.4, findes ophobninger overalt naturligt på stranden uden at have nogen som helst læside aflejrings effekt. SIC bruger selv et foto af ophobet sand som dokumentation for at systemet virker, figur 10.5. Men det findes ikke ved Skodbjerge.
12. Så til punkt B: SIC har sagt, at det er klart, at de store udbulinger i rør 1 vil medføre at der komme læsideaflejring nedenfor. Men lige nedenfor er der altså erosion, - ifølge denne ekspert på grund af vindskåret. Og vindskåret hævder SIC skyldes manglende rør. Så her kommer altså først erosion i "læside aflejrings området"! Først et godt stykke længere nede kommer effekten åbenbart, da der her aflejres selv om der ikke er rør! Som det ses er forklaringen totalt usammenhængende. I øvrigt forekommer naturlige bugtninger mange steder langs kyster, for eksempel udtalt øst for Hirtshals, og her forårsager de ikke læside aflejring. Læside aflejring forekommer ikke bag ved bløde naturlige bugtninger.
13. SIC er godt klar over at der er problemer med den meget store *aflejring* i reference 3, hvor der ikke er rør. En anden forklaring her er, at når vi går mod syd langs kysten vender erosion til aflejring. Men ser vi på kystens adfærd fra 1987-2004 som vist i figur 3.15 har der her de tidligere 17 år været erosion.
14. Rørets virkemåde: der har været en del forskellige forklaringer på rørets virkemåde, eksperten vil holde sig til de 3 dominerende*: ferskvandstryk, permeable lag og impermeable lag.* SIC hævder at det øgede *vandtryk* fra baglandet eroderer de danske strande. Så er man jo forbavset over, at de vælger at lave forsøg på en smal tange, hvor vandtrykket (der stammer fra nedbøren) er forsvindende. Vandtrykket har kun en ringe effekt på strandens volumen, det er jo ikke sådan langs de danske kyster, at en strand er smal dér hvor baglandet er stort og bred, hvor baglandet er smalt.

15. *Impermeable* lag: det er klart at hvis der er et skålformet impermeabelt lag i stranden, som man kan prikke hul på ved hjælp af rørene, så hjælper det lokalt på afvandingen af stranden, nemlig lige over skålen. Ellers betyder uigennemtrængelige lag ikke meget for rørets funktion, og det er absolut ikke almindeligt, at man har sådanne store sammenhængende ugennemtrængelige lag, generelt er en strand rodet op af bølgerne.
16. *Permeable* lag findes der hyppigere i stranden, da man kan få aflejringer af grovere materialer i lag i opskylszonen. Disse lag er gode for stranden, da de dræner den, og her har man jo ikke brug for rør.
17. *Publicering*: SIC har publiceret 2 artikler (måske en tredje er på vej?) om forsøget i Geologisk Nyt. Bladet, der udgives af en gruppe knyttet til Århus Universitet, er et diskussions tidsskrift uden videnskabelig vurdering før publikation. SIC kan med andre ord ikke hævde at projektet videnskabeligt har fået et blåt stempel. Eksperten har, trods opfordring fra bladet, valgt ikke at svare gennem bladet mens vurderingen foregår.
18. *PEM-systemets succes andre steder*: Det må afsluttende være på sin plads at nævne, at PEM systemet efterhånden har været anvendt en række steder. Ser man bort fra SICs egne vurderinger - SIC er jo ikke uvildige –, er det ikke lykkedes denne ekspert nogen steder at kunne identificere, at systemet har været en succes. Nogen steder har man en kort tid efter opsætningen observeret positive effekter (der er jo fifty-fifty chance for det ene og det andet), men på længere sigt har effekterne ikke været synlige.