ministerie van verkeer en waterstaat rijkswaterstaat

dienst weg- en waterbouwkunde
afdeling advisering waterbouw

coastal measurements in the Netherlands

Jarkus

Introduction

Because a sandy coast is a very dynamic coastline, and because stability of the coastline is vital for the safety of the Netherlands against inundation by storm surges (dunes protect the polder-area, which is situated below sea level), already in former centuries it was necessary to get some knowledge about the movements of the coastline. In the middle of the 19th century systematic coastal measurements started. On fixed intervals (approx. 250 m) the position of the dune-foot, the high water line and the low water line was measured every year. In order to have a fixed reference, monuments were placed on the beach.
Around 1960 it became clear that more detailed information was necessary. Therefore the system of monuments and base lines was somewhat updated, and a detailed program for coastal measurements was set up.
Along the whole North Sea coastline from Cadzand in the south to Rottumeroog a fixed set of measuring lines was defined (see fig. 1). In total approx. 3000 lines are defined this way. The lines have a intermediate distance of 200 m and are perpendicular to the base line. The base line is parallel to the coastline, and is positioned approx. near the high water line. On coastal sections with groins, the measuring lines are placed in the middle between the groins. Profiles are measured every year from 200 m landward of the base line to 800 m seaward of the base line (that means to an average depth of 8 m below mean sea level). Every five years every kilometer a line is measured until 2500 m from the base line. All measurements are made in the period between april and september.
The measurements are performed in two parts (see fig. 2):

* leveling above the low water line
* sounding below approx. mean sea level line

leveling

The levelings are done by the survey department of Rijkswaterstaat, using aerial photography (see fig. 3). In the field only some calibration points are measured using conventional equipment. In flight direction 60 % overlap is used in order to get a good stereoscopic effect. In more than one strip is required, an overlap of 20 - 30 % between the strips is used. With the use of an analytic plotter the height is measured in the measuring lines. In this plotter the overlapping photographs are presented a a three dimensional image. The position of the bends in the profile are read as digital values. The program interpolated the data, and every 5 m a height-point of the profile is stored in memory.

soundings

The soundings are done by survey vessels of various Rijkswaterstaat departments and by survey vessels of the waterboards. Profile data are automatically stored on board as x-y-z- values. Postprocessing equipment calculates the depths in the profile with intermediate distances of 10 m.

storage

Leveling data and sounding data are coupled and stored on a mainframe computer of Rijkswaterstaat. The data are available to coastal managers, researchers and everyone else who is interested. All data are on-line available since 1963. This data-base is called Jarkus (abbreviation from JAaRlijkse KUStmetingen, yearly coastal measurements).

Post processing software is available to read the data, and to perform additional computations. Standard Postprocessing is plotting profiles (fig. 4) and making three dimensional plots (fig.5). Also volumetric calculations can be made. This can be done in horizontal and in vertical slices (fig. 6). The vertical sections are used for gentle coastlines, while the horizontal sections are used for coastlines facing relatively steep tidal channels.

Records of the Jarkus-database have a fixed format (fig. 7). This format has become the standard of all coastal information systems and coastal computer models in the Netherlands.

One measurement consists of a header and depth data. The header format is 7I6 and contains the following information:

1. Coastal section
   1. Rottum
   2. Schiermonnikoog
   3. Ameland
   4. Terschelling
   5. Vlieland
   6. Texel
   7. Noord Holland
   8. Rijnland
   9. Delfland
   10. Maasvlakte
   11. Voorne
   12. Goeree
   13. Schouwen
   14. Noord Beveland
   15. Walcheren
   16. Zeeuwsch-Vlaanderen
2. year, in 4 digit (1982)
3. profile number (which is in fact a distance from a zero-point along the coast). The profile number is given in 10 m (thus: profile 07 - 234 is 2.34 km south of Den-Helder along the coast of Noord Holland).
4. Profile type
   0 - normal (official) profile
   1 - additional profile in the axis of a groin
   2 - additional profile parallel to a groin
5. date of measurement (leveling) ddmm
6. date of sounding ddmm
7. number of points

The depth lines contain the following information 5(2I6,I1,3X)

8. horizontal distance in meters from base line (seaward is positive)
9. vertical distance in centimeters relative to National Datum (NAP), which is approx. at Mean Sea Level (depth are negative, heights are positive).
10. control code (from the code it can be seen if data are leveling or sounding data).

Dune erosion

The Jarkus database is at this moment in use for routine checks of the safety of our dune coast. Every year all profiles have to be judged if the provide enough safety. The technique to do this is described in the "guide to the assessment of the safety of dunes as a sea defense" [english edition, CUR, 1989].

In fact an storm induced erosion analysis has to be made for a series of pro-

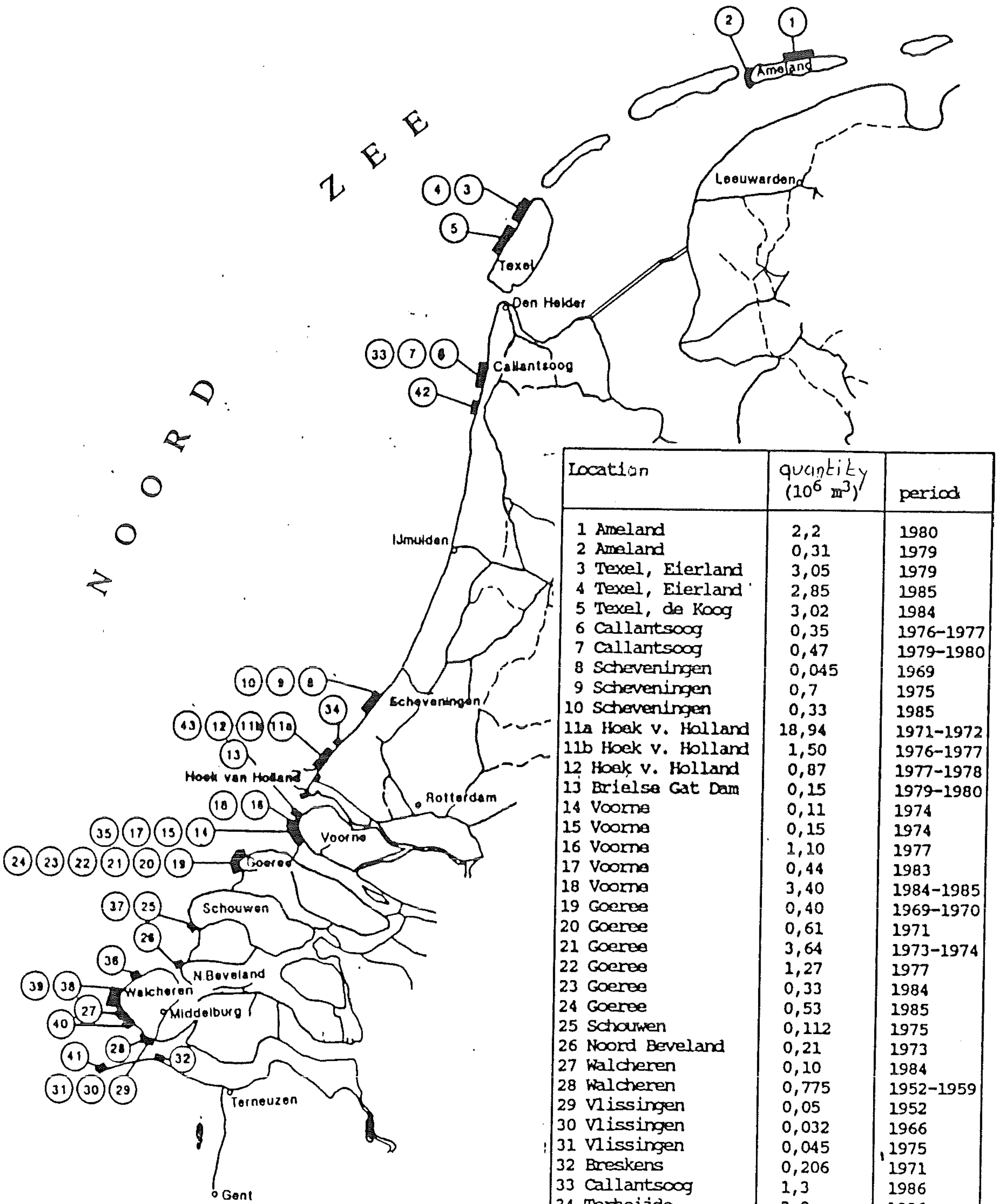

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Table 1

file measurements (approx. 10 years). For each year the calculation resulted in a maximum erosion point during a design storm. Through the calculated erosion points (point P), a regression line has to be drawn (fig. 8). Extrapolation of this line until next year indicates if there is still sufficient safety available.
Computer programs on a PC are available to perform the computations, using the data from the Jarkus database. All coastal managers have to do these computations on a routine basis (fig. 9).

Evaluation of beach nourishment projects

In October 1987 a report has been prepared to evaluate beach nourishment projects in the Netherlands. For the preparation of the Coastal Memorandum of 1989 a number of technical reports has been prepared. The technical report nr. 12 (beach and dune nourishment) is a follow up of the report to the parliament of October 1987.
In this paper a summary of these reports is given, with some more detailed information on a few specific projects.

Beach nourishments can be placed at several sites in the cross-sectional profile, see figure 10. Sand is in the Netherlands almost always placed by hydraulic equipment. Dry hauling is hardly used. Using hydraulic dredges a quantity of 200 000 - 500 000 m^3 per week is feasible. The coast of a nourishment work increase significantly if the sand has to be placed higher on the beach. In figure 11 is indicated the quantity of sand nourished on the Dutch coast in the former years. Table 1 gives an overview of the executed nourishment works.

For the evaluation a selection was made from all the projects. The criteria for this selection were

- the size of the nourishment, in relation to the natural process of erosion
- the type of nourishment; dune improvements were not evaluated.

The evaluation is done by using the data from the Jarkus-database. It is assumed that the boundary of the active zone lies within 800 m from the base lines and that consequently the whole active zone is covered by the Jarkus data. Because of tidal channels for the nourishments in Zeeland data are only used until the middle of the tidal channel.
On the basis of the data in the Jarkus database the volume of the coastal section in front of the nourishment has been calculated. This has been done for a number of years, before and after the nourishment. In this way it is possible to determine how much sand is disappearing due to the natural erosion of the coast and of the effect of the nourishment.
In the first year generally sand moves quite fast from the dry beach to the region around the low water line. The visual effect is a quick decrease of the beach. Volumetric computation show, however, that not really very much sand disappears from the profile. The adaptation to the natural profile is completely filtered out, by making correct volumetric computations.
Nine projects were evaluated more in detail to see if the nourishments did fulfill the expectations. Table 2 summarizes these projects:

project	year	design life	expected lifetime
1. Ameland	1980	10 years	1990 will be reached
2. Texel-north	1979	5 years	fulfilled expectations
3. Texel-north	1985	5 years	had a lifetime of 4 years
5. Texel-middle	1984	10 years	probably 1994 will be reached
9. Scheveningen	1975	-	nourishment only if necessary
16. Voorne	1977	5 years	had a lifetime of more than 5 years
21. Goeree	1973	-	had a lifetime of more than 5 years
22. Goeree	1977	5 years	had a lifetime of more than 5 years
27. Westkapelle	1984	5 years	fulfilled expectations

Table 2: results of beach nourishment evaluation

From the evaluation followed that:

* From the 9 evaluated nourishments, 5 did fulfill the expectations, three will probably fulfill the expectations and one failed (lifetime 4 years instead of 5 years).
* It has been proved that it is possible within the varying situations along a natural coastline, to design a beach nourishment project with a pre-defined lifetime.
* The application of beach nourishment projects as a method of coastal defense is efficient. The occurring erosion is adequately compensated by the nourished sand, at a relatively low cost.

In general all beach nourishments in the Netherlands have been designed on basis of the known coastal recession. Calculated is the volume of sediment which dissappeared during the last years from the coast (i.e. from the top of the dune to a distance of approx. 800 m out of the base line). Then a quantity of sand was placed on the beach, compensating the erosion during a given number of years. Fron economical optimaztion follows that the optimal design life of a beach nourishment in the Netherlands is generally in the order of 5 years. Every year the volume of sand in the coastal section is determined and plotted. If this quantity becomes lower than a minimum quantity, renourishment is necessary. See also fig. 12.
Because the new coastline forms some kind of a promontory into the sea, in the first years some extra erosion might be expected, especially if the length of the nourishment is relatively small. No detailed information is available on the required extra quantity. Mostly an overfill ratio of 20 % is used for this purpose. It is assumed that this overfill ratio also compensates minor differences in grain size.

The costs of beach nourishment

The costs did vary very much with the borrowing site of the sand for the nourishment. Besides the borrowing area, also the way of determining the price is of importance. Three scenarios are used to determine the cost of sand winning.

1 Present borrow areas more near to the coastline
2 Alternative borrowing sites, based on newest morphological knowledge
3 Present borrow areas, using a high calculation value

In table 3 can be seen that the price (including all taxes) varies from US $ 1.50 per m^3, if sand can be borrowed form areas near the coast, up to US $ 5.35, if the borrow area is far away (at a depth of 20 m, 20 km offshore) and a high calculation value is used.

scenario for sand winning price in US $ per m^3	wadden area	coast of Holland	coast of Zeeland
present borrow areas	1.50	4.80	2.40
alternative borrow areas	2.25	2.40	2.40
present borrow areas and a high calculation value	2.90	5.35	3.20

Table 3: price of sand

Dune nourishment is US $ 2.00 per m^3 more expensive. In determining these prices market effects are not taken into account. Because of overproduction the dredging prices on the world market are lower at this moment, but for basis of a long term policy, this should not be taken into account.

beach nourishment on the island of Texel

The northern sectiion of the island of Texel has been norished twice, in 1979 and in 1985. Figure 13 shows the effects of the nourisment on the volume of sand. It can be seen that after the nourishment of 1979 the erosion rate was almost identical to the erosion rate befor 1979.

beach nourishment on the island of Goereee

Figure 14 shows the nourisments on the island of Geree. This is on a first view a strange nourishment, because it is on an accreting coast. The reason of this nourisment was that the dunes did not give enough safety against inundation of the polders behind the dunes, and more sand was required on the dunefront and the (dry) beach. This sand was placed there in 1974, 1978 and 1985. The beach nourisments caused that too much sand came in the active zone, and the surplus of sand eroded away.

beach nourishment near Westkapelle

The former island of Walcheren (nowadays it is connected to the mainland by dams and reclamations) is situated in the south-western part of the Netherlands (see fig. 15). Very near to the south-west coast of the island, a deep and relatively narrow tidal channel, can be found, the Oostgat. Because of the general morphological dynamics in the area (it is the mouth of the river Scheldt) this channel tends to move in a south-eastern direction, and consequently eroding the coast. This is a rather slow process, because boulder-clay layers and other densely packed formulations prevent the erosion. Also, along this coastline a number of groins has been build, each with a groin-head with stone-protection extending to a great depth. These stony "headlands" prevent movement of the channel. Because of these processes and man's reaction on it, the coast is very steep and the beach relatively narrow. The orientation of the coast causes that all waves come from the same direction, consequently there is a clear wave-induced longshore transport from the village of Westkapelle towards the town of Vlissingen in the south of Walcheren. The existing groins (low stone-groins with piles (see fig. 16) do not stop the longshore transport. Almost the entire coast is a sandy coast with a single row of dunes. However near Westkapelle no dunes are present and a heavy sea dike has been constructed. Because of this configuration, there is no natural nourishment for the longshore transport near Westkapelle and consequently the dunes just south of Westkapelle suffer from erosion. In. the past this was the reason to extend the seadike in a more southern direction. Because the polder-area behind the dunes is lower than Mean High Water, the dunes also have a function as seadefense. A breakthrough will cause inundation of the island (In fact in 1944 allied bombers destroyed the dike at Westkapelle in order the inundate the island for

strategic reasons. After several raids the succeeded and during the winter 1944/1945 the island was drowned). Figure 16 shows a profile of the coast just south of Westkapelle and it can be seen easily that the remaining dune does not give much safety.
In such cases, according to Dutch Laws, reinforcement works have to be performed. Because it was the intention not to extend the seadike any more, reinforcement had to be made with sand. In the past (in 1974) a reinforcement was already made on landward side of the dune. Such a reinforcement does provide the required level of safety but does not stop coastal erosion and coastal regression.

Planning the nourishment
Therefore the idea was to make future reinforcements by placing sand on the seaward side of the dunes. Thus artificial beach and dune nourishment. A technical problem which arose was that the beach is very narrow, not allowing placing much sand on the beach. It was decided to place the sand as much as possible against the existing sea front of the dunes. The height of the dune nourishment was equal to the height of the existing dunes. The slope of the beach was determined by the natural slope of free flowing sand from a discharge-pipe in in the surf zone. The amount of sand placed in this way on the coast should guarantee safety for a period of five years. It is in fact a relatively small artificial beach nourishment project but this project has several interesting aspects from coastal engineering viewpoint. Therefore it was decided to follow this nourishment in detail with measurements of the profile. The nourishment was placed in 1984. The expected life-time was five years, in 1988 a renourishment has been made. This paper describes the changes in the period 1984-1988.

Nourishment quantity
The total loss of stand in the period 1971-1981 between km 22.550 and km 23.865 in a strip between dune-foot (MSL - 4.00 m) was 88000 m^3. Based upon this figure the required quantity for a five years nourishment was 44000 m^3. Using this quantity, it was possible to improve the dune at the seaward side in order to reach the required safety-level. The width of the dune was therefore increased with 10 m, requiring 22000m^3. For losses during execution a surcharge of 10-15% is required. It was decided to place a quantity of 75.000 m^3 on the beach. During the execution of the work the coastal manager decided to place an additional 25000 m^3 on the beach, in order to improve two adjacent beach sections and in order to get a better beach level near the stone groins.

Groins
Lee erosion, caused by the stone groins, gives a lower beach and a local backwards movement of the dunes, just south-east of each groin. In order to maintain a higher beach level near to weak dune row at km 23.250, preventing a backwards movement of the dune at that point, the distance between the stone groins was decreased by constructing three extra groins between the existing ones. At the location of the new build stone groins only pile-rows with a stone head were present. These constructions stopped the landward movement of the tidal channel (because of their stone head), but had hardly any influence on erosion caused by surf-included transport. It is expected that the new stone groins have a positive effect on the beach level.

Analysis
In order to evaluate the beach nourishment, the regular yearly coastal measurements were used. Along the Dutch coast every year a full profile is measured,

approx. 200 m apart. Because of the position of the groins, in this area profiles are measured 125 m apart. See fig. 15. This date are worked out in the following way.

For nine profiles, a yearly volume integration has been made for the period 1973 until 1988. This integration is done in horizontal layers of 1 m thickness, starting form the bottom of the channel until the top of the dune.
- three strips have been regarded (see fig. 17).
- channel-slope between bottom and MSL - 4.00 m
- the "beach" between the channel edge (MSL - 4.00 m) and the dune foot (MSL +3.50 m)
- the dune above the dune foot (MSL = 3.50 m).

The results of the volume integration is presented in fig. 18, using 1973 as the base-year.
In figure 19 the changes in the cross-sectional profile are plotted, using the profile of 1984 (before nourishment) as base line. In this figure also the expected 1987 profile is presented, if no beach nourishment was performed. From figure 195 can be seen that in the period 1984-1987 the expected "natural" erosion is in the order of 4.000 m^3/m height of profile in the zone between MSL - 4.00 and MSL + 7.00 m. The beach nourishment was mainly placed between MSL and MSL + 2.00 m (17000 m^3/m). In the strip between MSL + 8.00 m the placed quantity was approx. 5000 m^3/m. In the strip between MSL and MSL - 2.00 m the placed quantity was approx. 6000 m^3/m.

<u>Observations</u>
From the analysis the following observations can be drawn:

dune
1. The regression-speed of the dune was not changed by the nourishment. The regression-speed is now equal to the speed before nourishment. Three years after placing the sand 70% of the nourished sand is till in the dune-strip.

beach
2. Also for the strip "beach", it can be seen that during the first two years no sand was moved out of this strip. In the third year erosion started. In 1987 22% of the placed quantity was transported out of this strip.

3. The beach area between MSL and the dune foot (this is an important value for beach recreation) was increased by d9% due to the nourishment. However, because of the offshore transport the beach area increased until 23% more of the original surface in the 2nd year. In the 3rd year the beach surface was still 19% more than before nourishment.

dune and beach
4. In the total profile there was not any loss in the first and second year after nourishment. In the third year was a loss of 24%.

5. There was some longshore redistribution of the beach sand, but this quantity was negligible wit respect to the offshore transport.

6. Because of the nourishment a none-natural, steep beach slope was formed. This caused a offshore transport, introducing erosion of the dune front. Approx. 9000 m^3 was transported from the dune towards the beach.

As mentioned before, after three years 25% of the material was removed from the section (above MSL - 4.00 m). It may be assumed that this is mainly caused by offshore transport. The accuracy of soundings in the tidal channel is too low for proving this. The quantity of sand nourished above MSL gives a direct contribution to the safety of the dunes. During the first 3 years 53% of the sand nourished above MSL was still above MSL and contributed to the safety.

Discussion

In this case there was not much space for a beach nourishment. This gave the need to place the sand very high on the beach and near the dune front. The resulting beach profile is too steep and not stable. From the data presented follows that the steep profile will adapt to a more stable profile, but that this adaptation is a slow process. In a case like this it is doubtful if even a stable profile will be reached.

However, having an unstable, too steep profile gives some advantages. Because relative much sand was placed above MSL the dune became more safe. Also the beach is wider than it would be at a stable beach. It is not known how long the adaptation period is, but this period is in any case longer than five years, which is the life time of the nourishment. So during the whole life-time the profile is unstable, giving the advantages of extra safety and a wider beach.

Conclusion

Designing a beach nourishment, the main design quantity is the required quantity of sand. A secondary problem is where to place the sand in the profile. It is advantageous to place the sand as high as possible on the beach. Trying to make a stable profile is in many cases not useful.

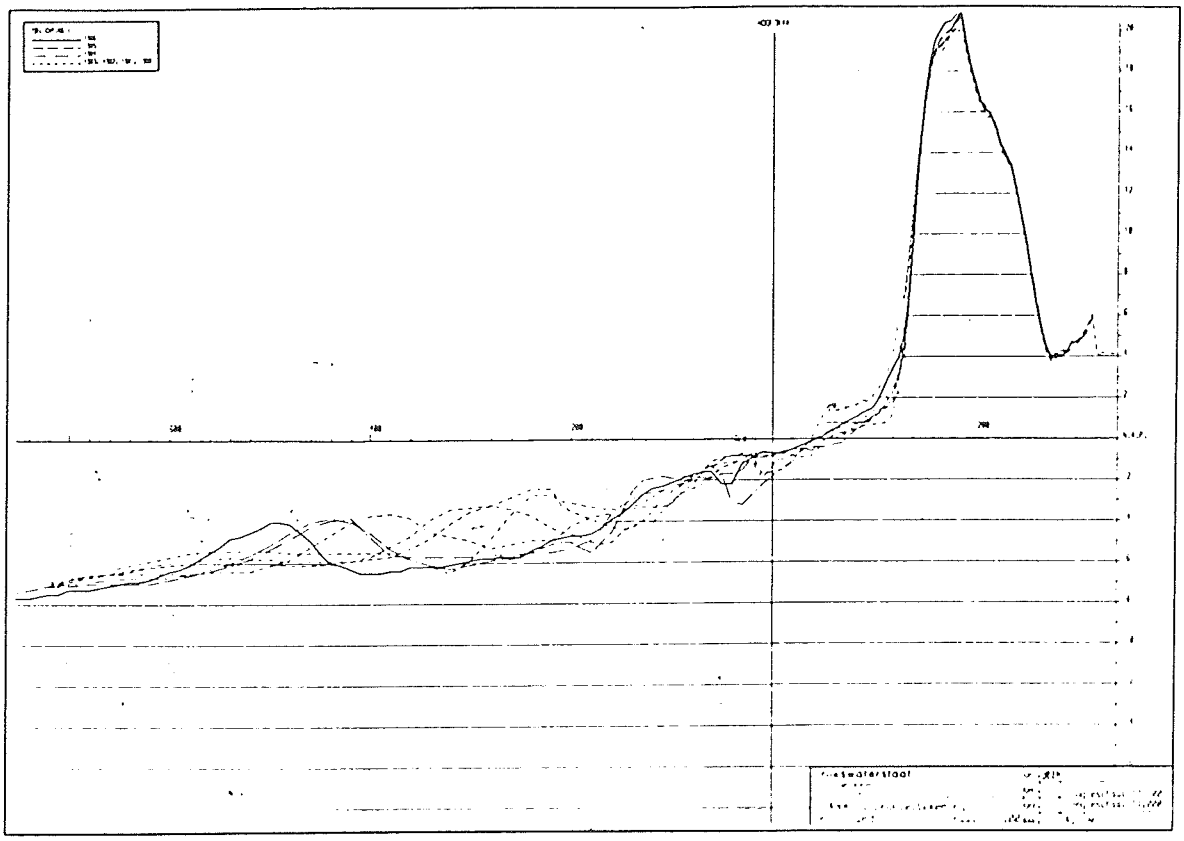


fig 4

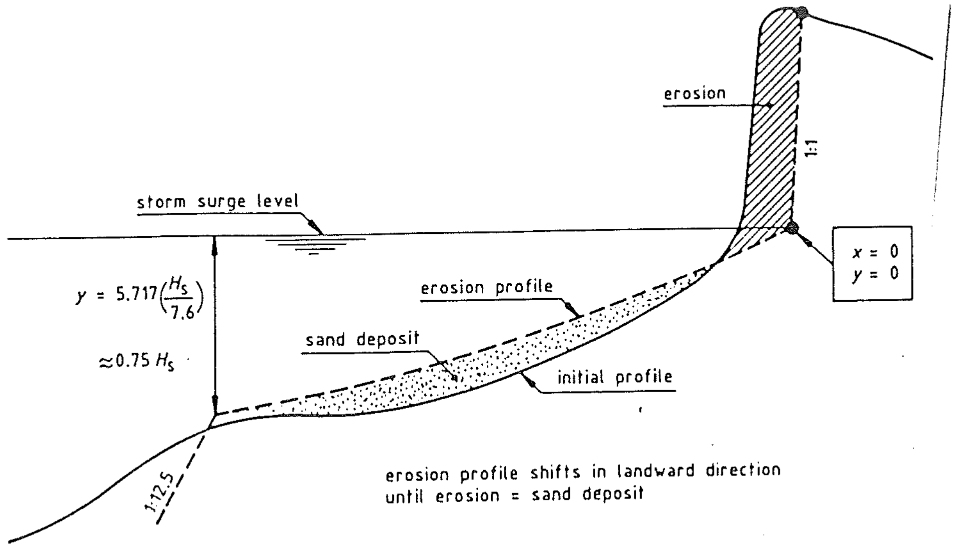
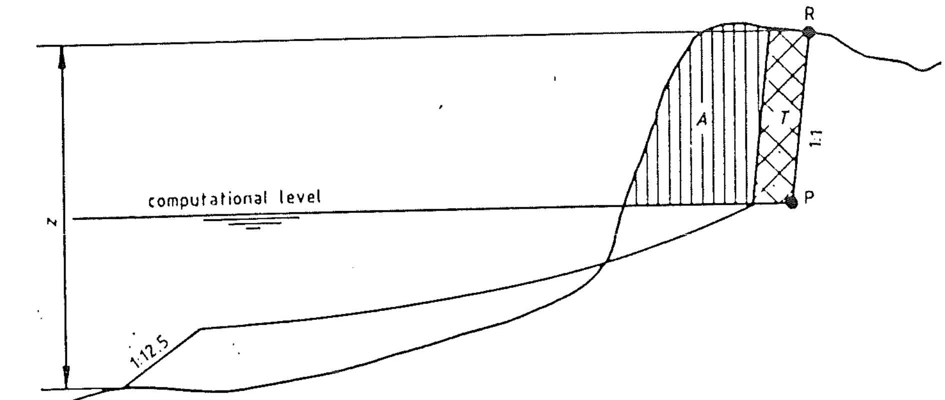


Fig. 1. Principle of the computational model for dune erosion.

$$\frac{7.6}{H_s} y = 0.4714 \left\{ \left(\frac{7.6}{H_s} \right)^{1.28} \left(\frac{w}{0.0268} \right)^{0.56} x + 18 \right\}^{0.5} - 2.00$$



A = calculated amount of dune erosion above computational level
T = surcharge on A for - duration of storm surge
- gust surges and gust oscillations } (3.1.2)
- inaccuracy computational model

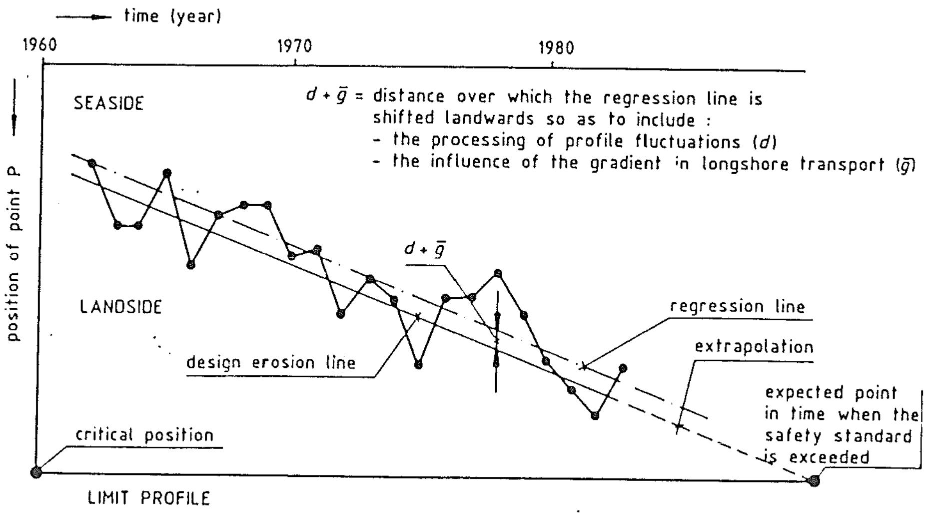
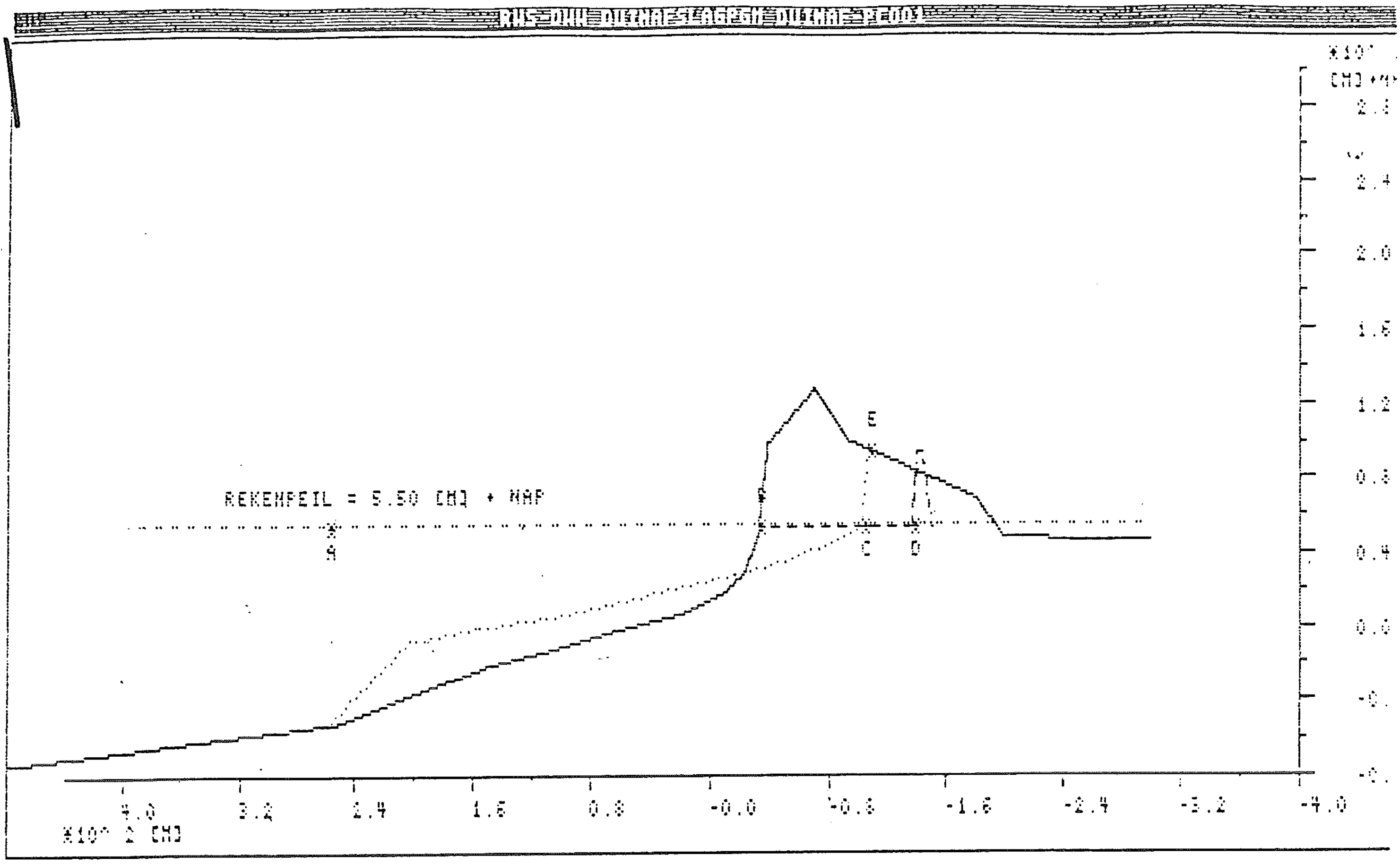


fig 8



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——— DUINPROFIEL
··········· AFSLAGPROFIEL ZONDER TOESLAG
- - - - - - AFSLAGPROFIEL MET TOESLAG
-·-·-·-·- GRENSPROFIEL

AFSLAGHOEVEELHEDEN

Aanzanding (excl. invloed langstransport)	=	482.49	(m3)
Afslag (excl. invloed langstransport)	=	-482.49	(m3)
Afslag boven rekenpeil(excl. invloed langstr.)	=	-389.88	(m3)
Toeslag op afslag boven rekenpeil	=	-117.47	(m3)

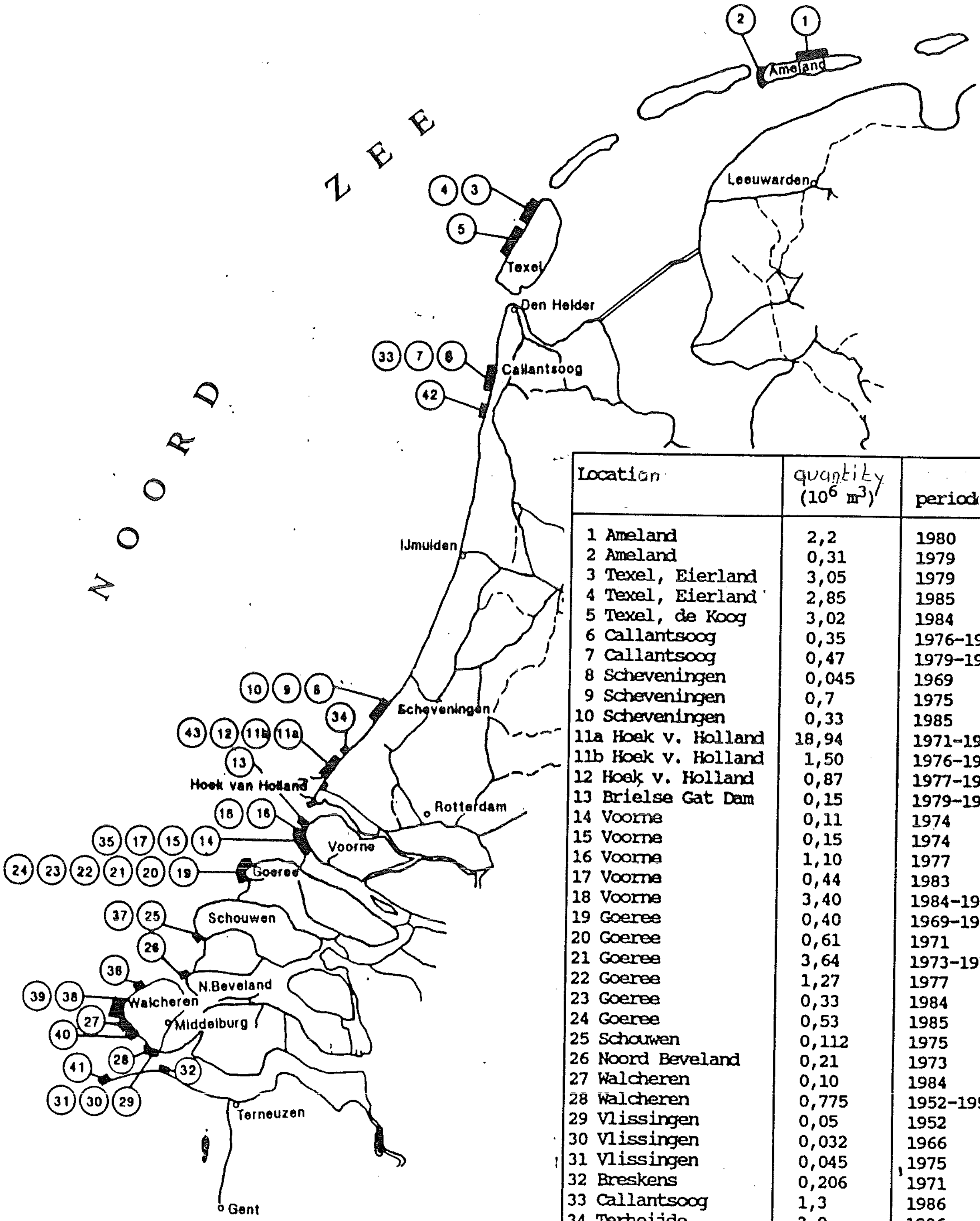
AFSTANDEN

Aanzandafstand	(X[A]-X[B])	=	291.86	(m)
Afslagafstand	(X[B]-X[E])	=	74.33	(m)
Extraverschuifafstand tgv langstransport (in BC)		=	0.00	(m)
Verschuifafstand incl. langstransport	(X[B]-X[C])	=	70.25	(m)
Verschuifafstand voor de toeslag	(X[C]-X[D])	=	33.56	(m)
Verschuifafstand incl. langstransport + toeslag	(X[B]-X[D])	=	103.82	(m)
Xcoord. van afslagprofiel op rekenpeil	(X[C])	=	-103.05	(m)
Xcoord. afslag+toeslagprofiel op rekenpeil	(X[D])	=	-136.62	(m)

Oefening Zeeburgerbad alle raaien stormvloed

RWS-DWW DUINAFSLAGPGM DUINAF-PC001

fig 9



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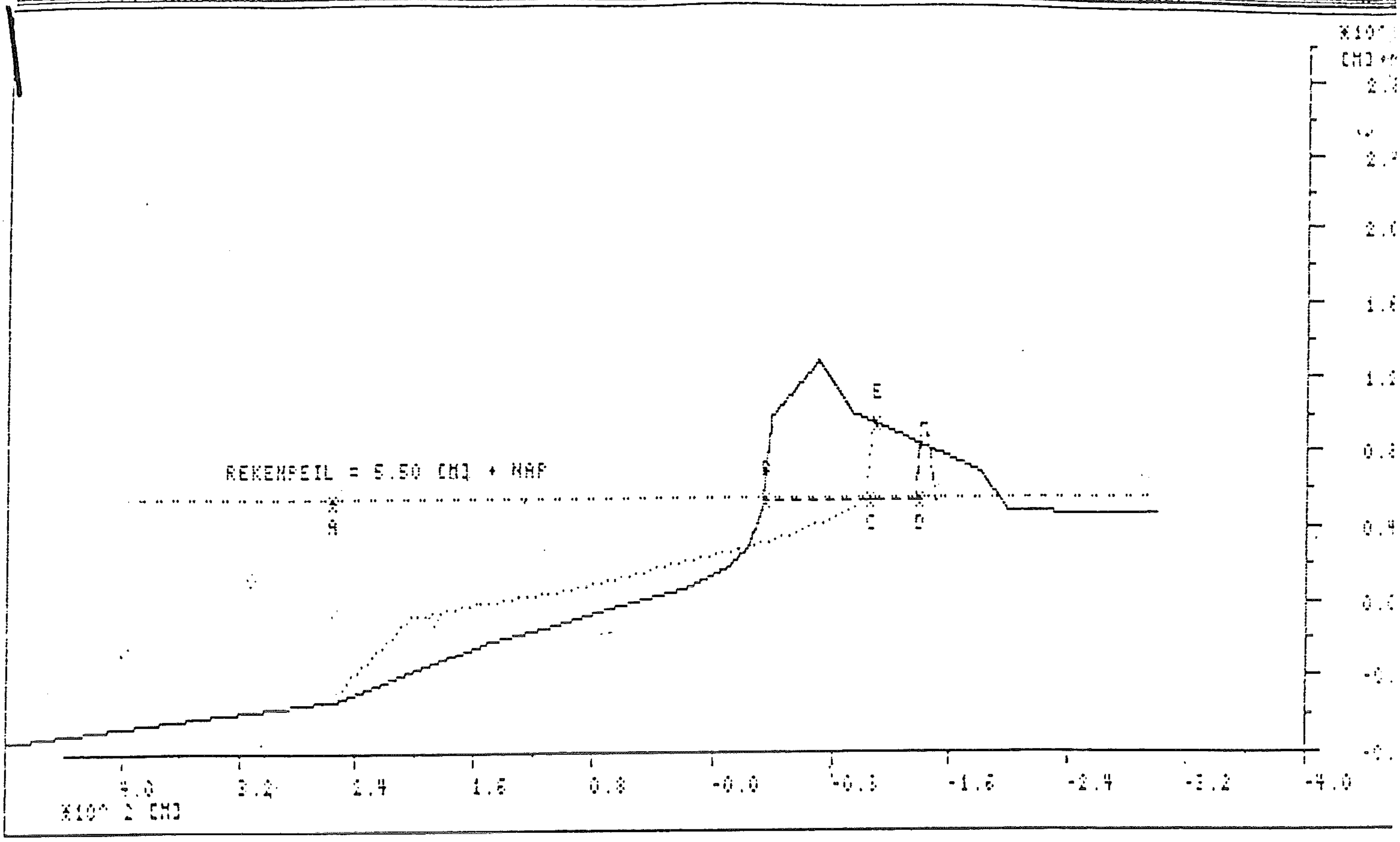


SIGN. GOLFHOOGTE IN	[M] :	[illegible]
GOLFPERIODE IN	[S] :	12.00
KORRELDIAMETER IN	[10^-6 M] :	200.00

KUSTVAKNAAM	JAAR	RAAI	TYPE	DATH	DATL
???????????	1990	1000	0	1605	1508

- ———— DUINPROFIEL
- ·········· AFSLAGPROFIEL ZONDER TOESLAG
- - - - - - AFSLAGPROFIEL MET TOESLAG
- -·-·-·-· GRENSPROFIEL

FSLAGHOEVEELHEDEN

anzanding (excl. invloed langstransport)	=	482.49 (m3)
fslag (excl. invloed langstransport)	=	-482.49 (m3)
fslag boven rekenpeil(excl. invloed langstr.)	=	-389.88 (m3)
oeslag op afslag boven rekenpeil	=	-117.47 (m3)

FSTANDEN

anzandafstand	(X[A]-X[B])	=	291.86 (m)
fslagafstand	(X[B]-X[E])	=	74.33 (m)
xtraverschuifafstand tgv langstransport (in BC)		=	0.00 (m)
erschuifafstand incl. langstransport	(X[B]-X[C])	=	70.25 (m)
erschuifafstand voor de toeslag	(X[C]-X[D])	=	33.56 (m)
erschuifafstand incl. langstransport + toeslag	(X[B]-X[D])	=	103.82 (m)
coord. van afslagprofiel op rekenpeil	(X[C])	=	-103.05 (m)
coord. afslag+toeslagprofiel op rekenpeil	(X[D])	=	-136.62 (m)

efening Zeeburgerbad   alle raaien stormvloed

WS-DWW DUINAFSLAGPGM DUINAF-PC001

fig 9

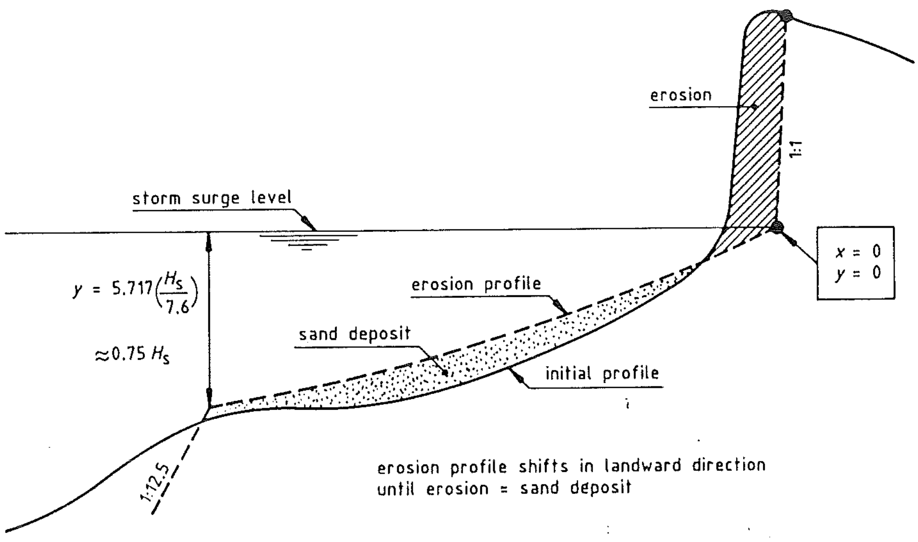
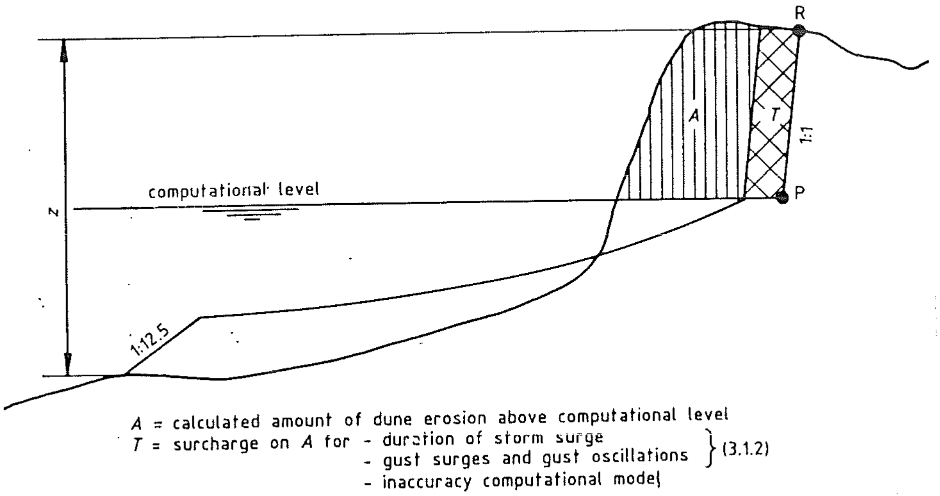


Fig. 1. Principle of the computational model for dune erosion.

$$\frac{7.6}{H_s}y = 0.4714\left\{\left(\frac{7.6}{H_s}\right)^{1.28}\left(\frac{w}{0.0268}\right)^{0.56}x + 18\right\}^{0.5} - 2.00$$



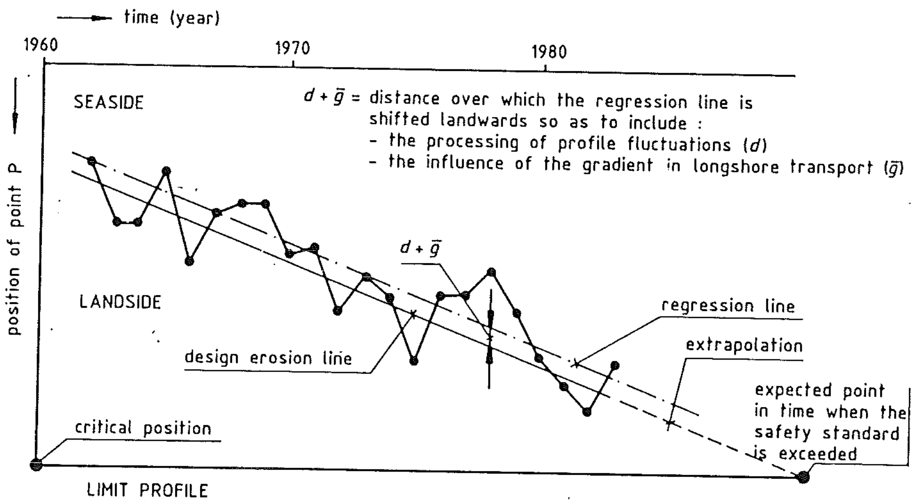


fig 8

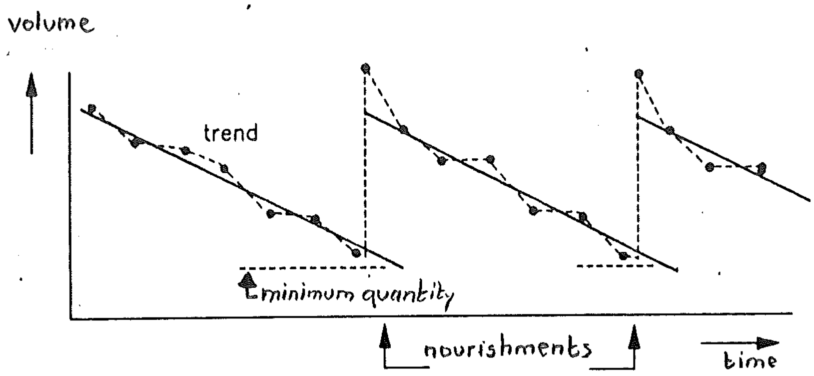


fig 12

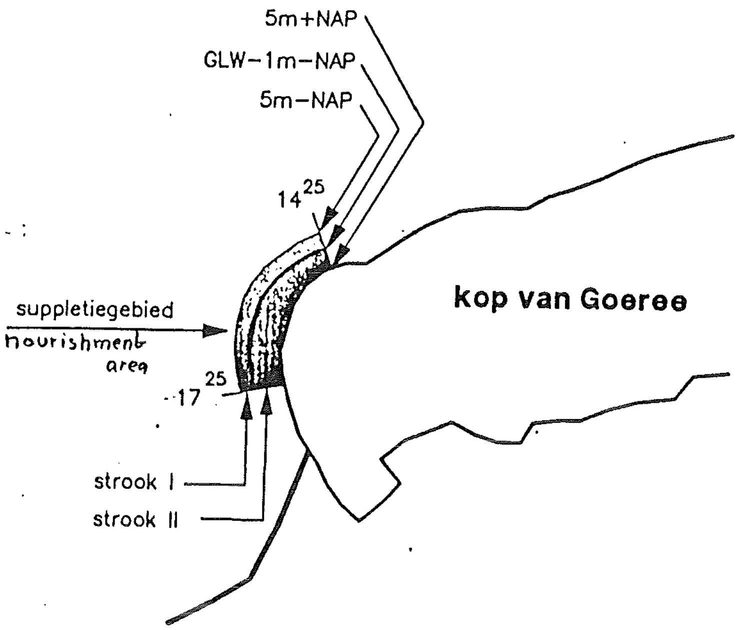
fig 13

(1) 13 (2) 1976 (3) 1668 (4) 0 (5) 0 (6) 2506 (7) 109 ← header

(8) (9) (10)

-115	2310	5	-110	1960	5	-105	1990	5	-100	2230	5	-95	2430	5
-90	2320	5	-85	1910	5	-80	1550	5	-75	1210	5	-70	680	5
-65	550	5	-60	290	5	-55	250	5	-50	220	5	-45	200	5
-40	210	5	-35	210	5	-30	210	5	-25	180	5	-20	140	5
-15	90	5	-10	50	5	-5	50	5	0	50	5	10	30	5
20	10	5	30	20	5	40	20	5	50	0	5	60	-40	5
70	-80	5	80	-140	5	90	-160	5	100	-180	5	105	-200	5
110	-240	5	115	-270	5	120	-300	5	125	-340	5	130	-380	5
135	-420	5	140	-480	5	145	-520	5	150	-580	5	160	-640	5
170	-670	5	190	-720	5	190	-770	5	200	-790	5	210	-740	5
220	-780	5	230	-770	5	240	-750	5	250	-740	5	260	-750	5
270	-790	5	280	-730	5	290	-660	5	300	-650	5	310	-640	5
320	-800	5	330	-600	5	340	-590	5	350	-570	5	360	-530	5
370	-500	5	380	-460	5	390	-440	5	400	-400	5	410	-400	5
420	-390	5	430	-360	5	440	-330	5	450	-410	5	460	-470	5
470	-540	5	480	-590	5	490	-690	5	500	-770	5	510	-530	5
520	-900	5	530	-970	5	540	-1040	5	550	-1110	5	560	-1160	5
570	-1230	5	580	-1260	5	590	-1330	5	600	-1380	5	610	-1420	5
620	-1460	5	630	-1520	5	640	-1590	5	650	-1640	5	660	-1690	5
670	-1740	5	680	-1780	5	690	-1840	5	700	-1890	5	710	-1980	5
720	-2040	5	730	-2090	5	740	-2120	5	750	-2150	5	760	-2190	5
770	-2190	5	780	-2230	5	790	-2260	5	800	-2320	5	9999999999		9

Fig 7


5m+NAP
GLW-1m-NAP
5m-NAP
14 25
suppletiegebied
nourishment area
-17 25
strook I
strook II
kop van Goeree

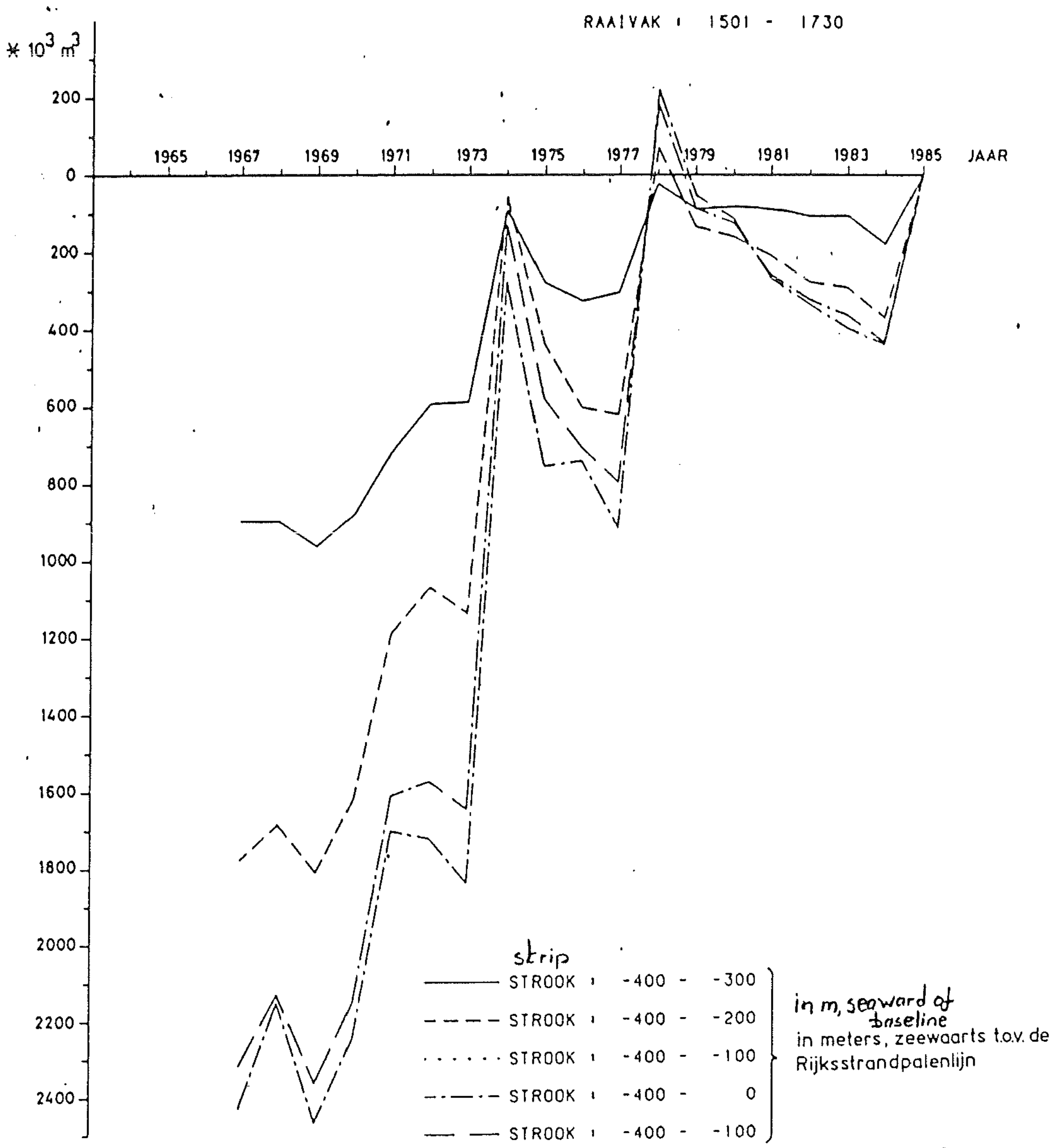

RAAIVAK : 1501 - 1730
* 10³ m³
200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 JAAR
strip
STROOK : -400 - -300
STROOK : -400 - -200
STROOK : -400 - -100
STROOK : -400 - 0
STROOK : -400 - -100
in m, seaward of baseline
in meters, zeewaarts t.o.v. de Rijksstrandpalenlijn

fig 14

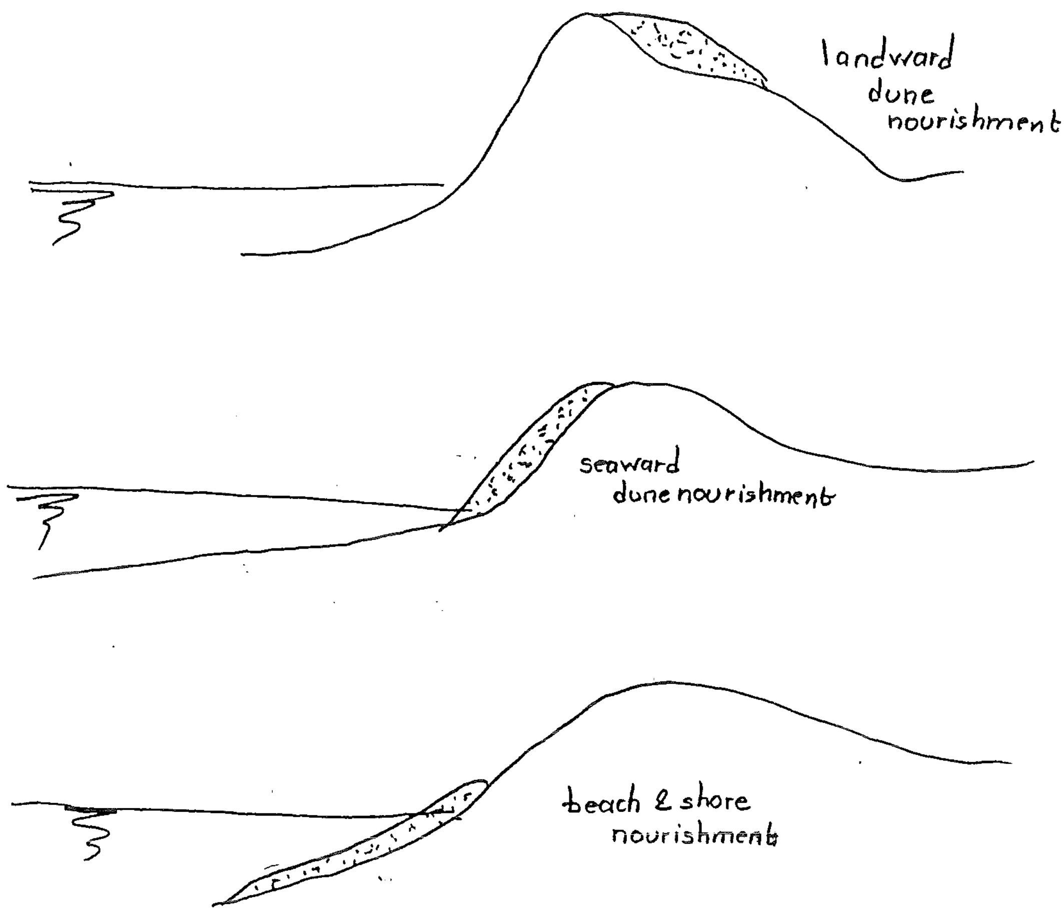

landward dune nourishment
seaward dune nourishment
beach & shore nourishment

fig. 10

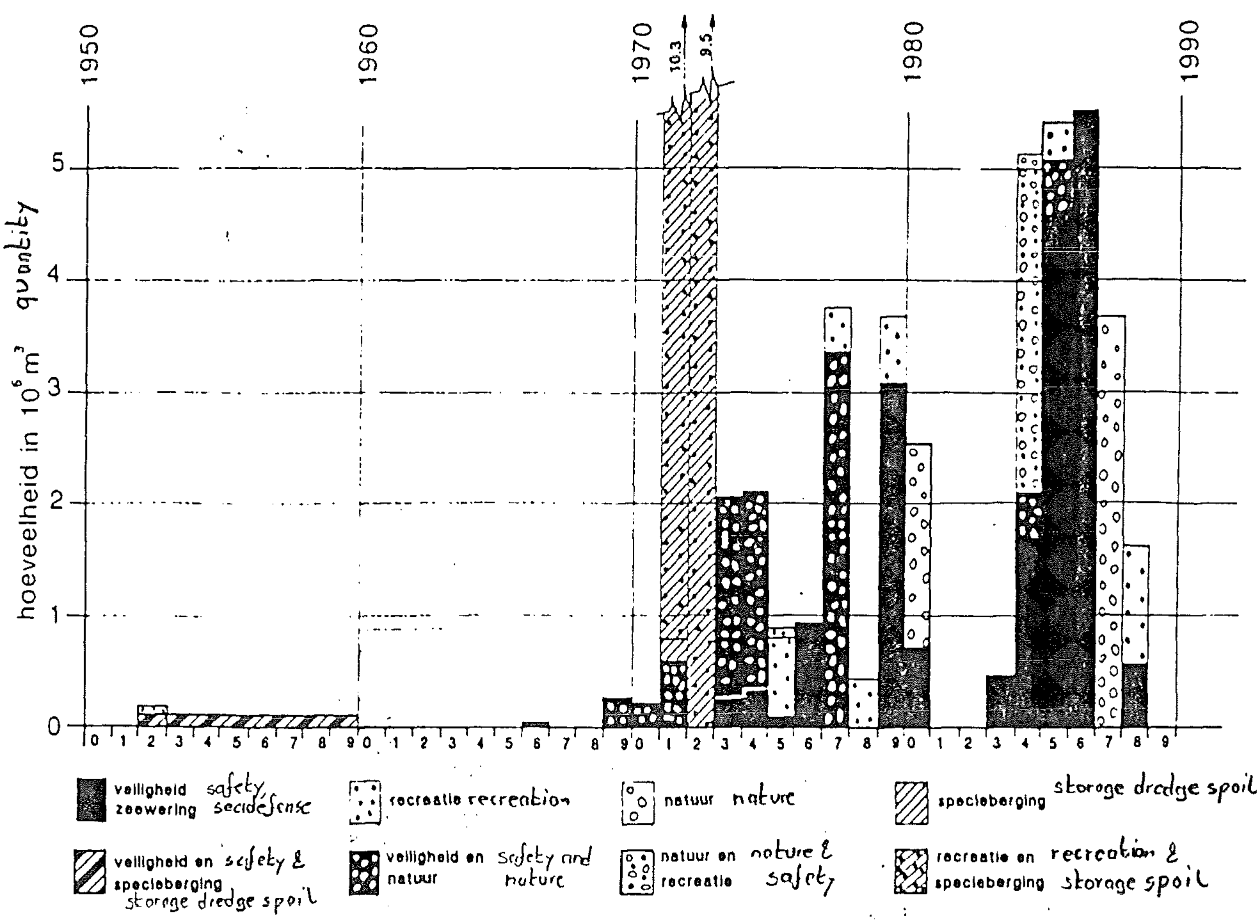
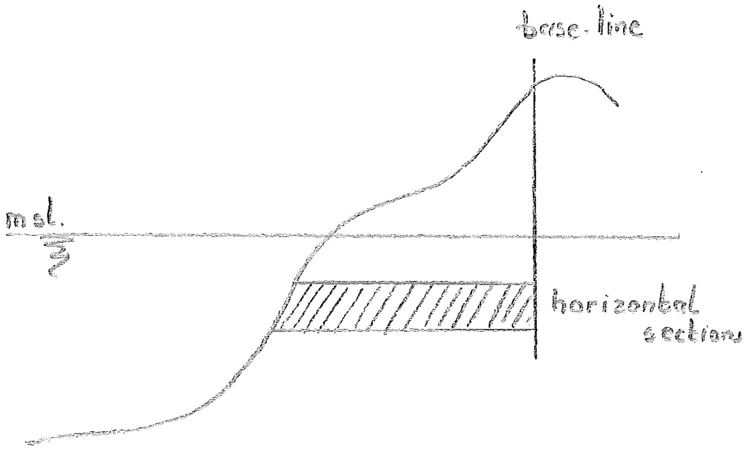
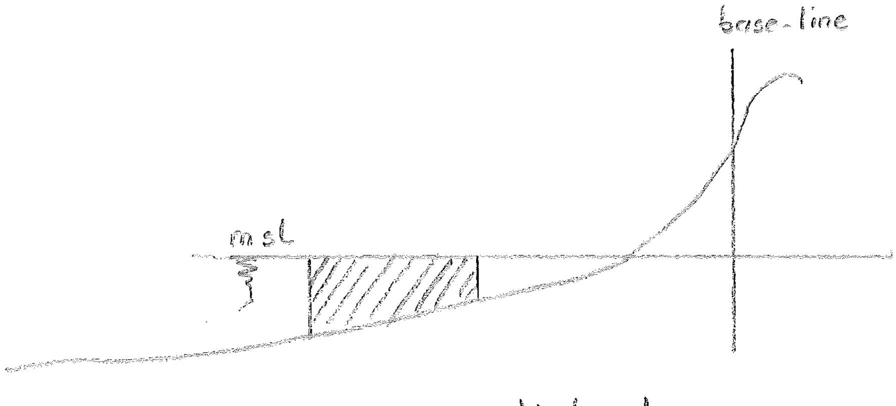

1950
1960
1970
1980
1990
10.3
9.5
hoeveelheid in 10^6 m^3 quantity
0
1
2
3
4
5
veiligheid zeewering safety sea defense
recreatie recreation
natuur nature
speciebergging storage dredge spoil
veiligheid en speciebergging safety & storage dredge spoil
veiligheid en natuur safety and nature
natuur en recreatie nature & safety
recreatie en speciebergging recreation & storage spoil

fig 11





vertical sections

Fig 6.

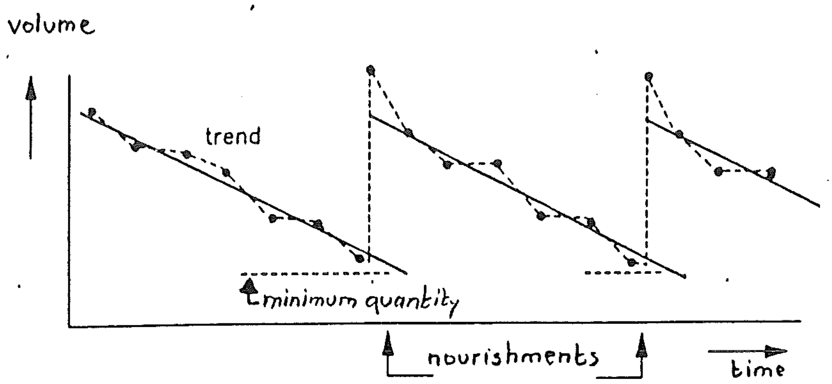

volume
trend
minimum quantity
nourishments
time

fig 12

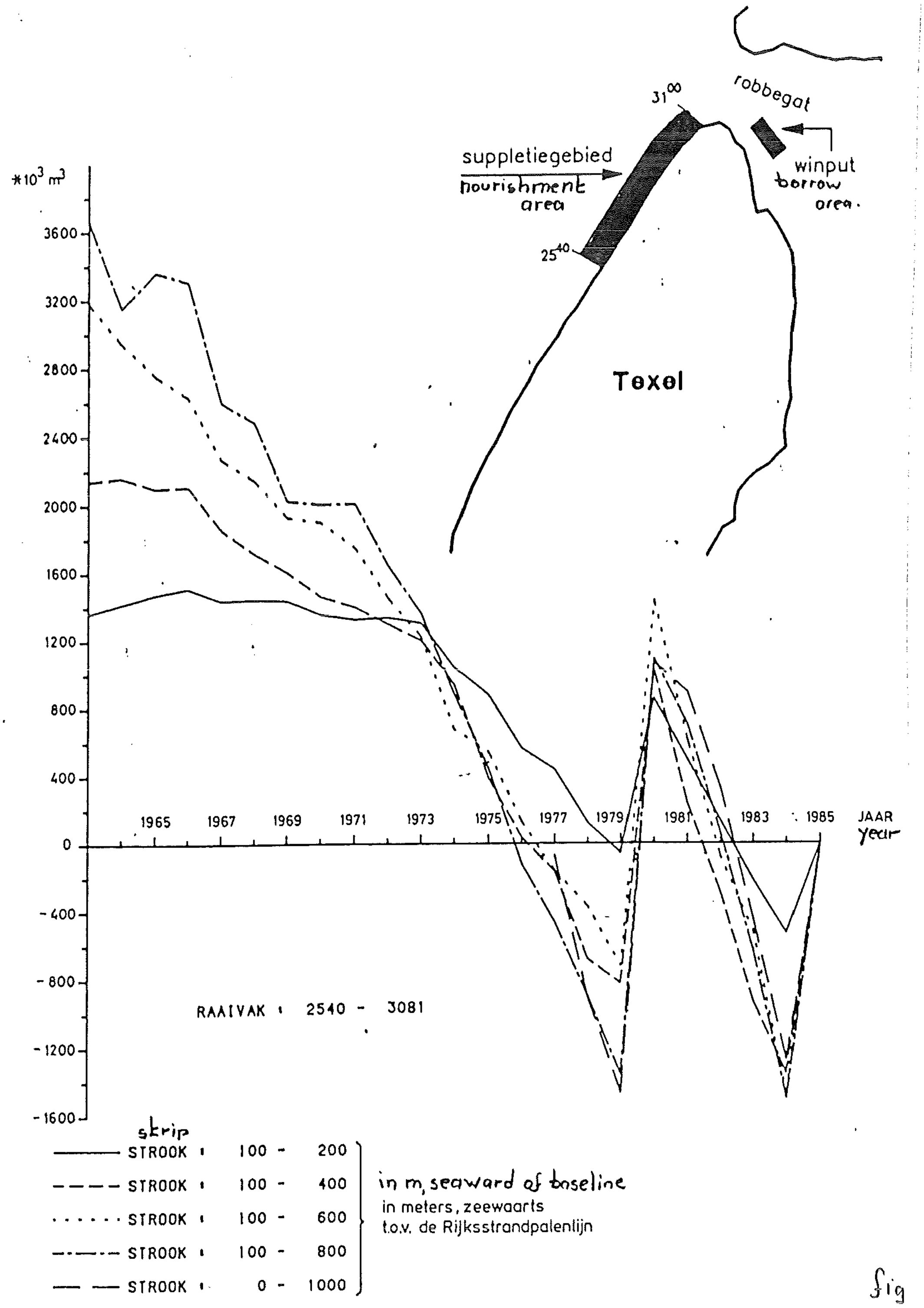

robbegat
31⁰⁰
suppletiegebied
nourishment area
winput
borrow area.
25⁴⁰
Texel
*10³ m³
3600
3200
2800
2400
2000
1600
1200
800
400
0
-400
-800
-1200
-1600
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
JAAR
year
RAAIVAK : 2540 - 3081
strip
STROOK : 100 - 200
STROOK : 100 - 400
STROOK : 100 - 600
STROOK : 100 - 800
STROOK : 0 - 1000
in m, seaward of baseline
in meters, zeewaarts
t.o.v. de Rijksstrandpalenlijn

fig 13

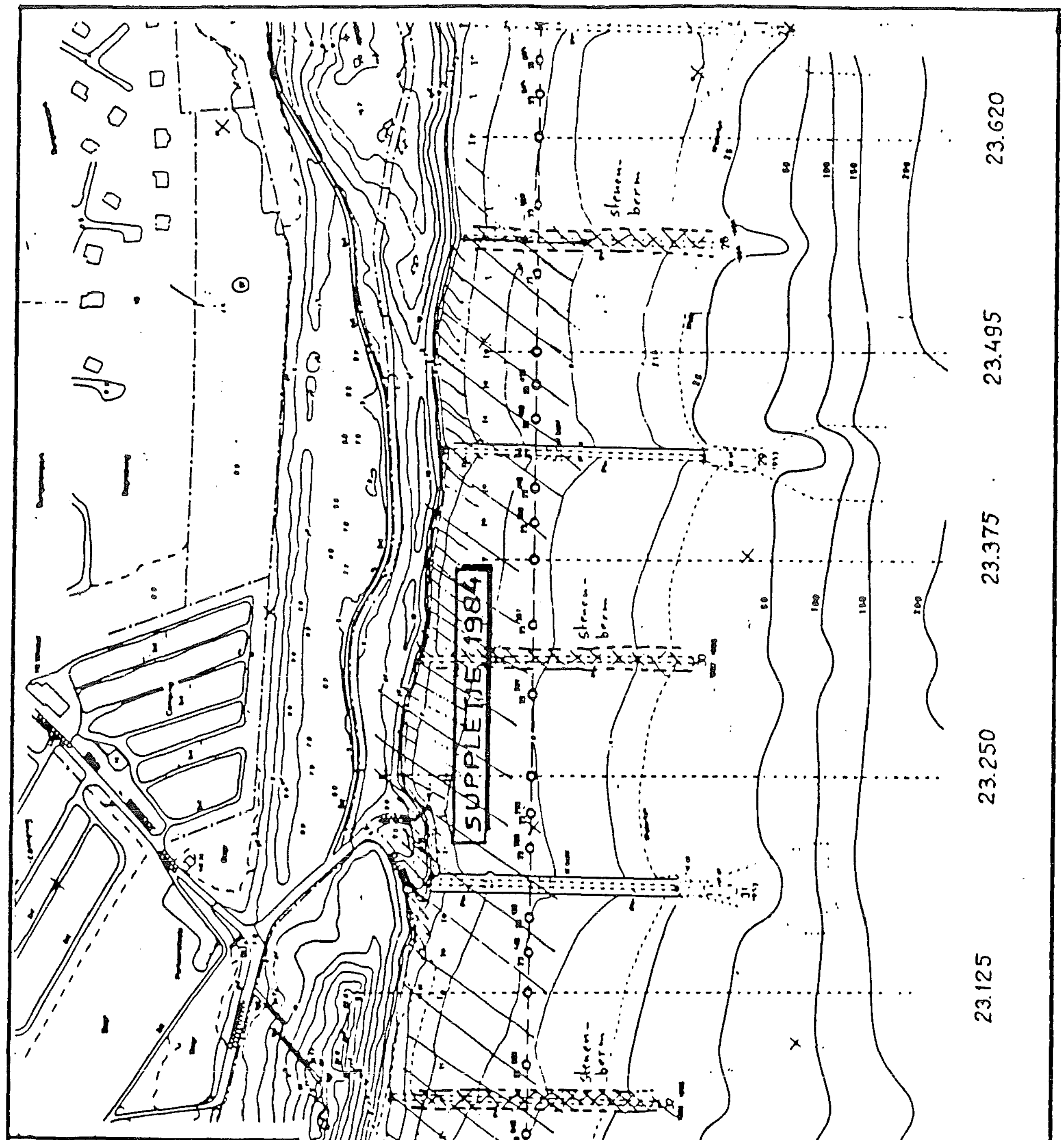
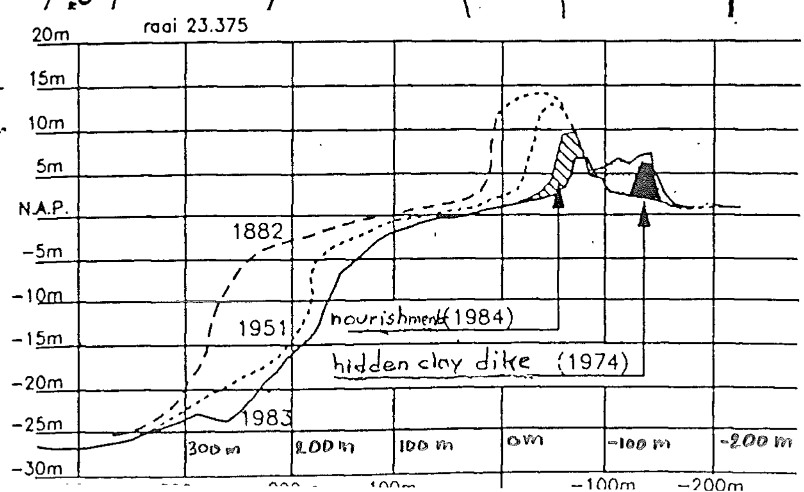


Fig. 15



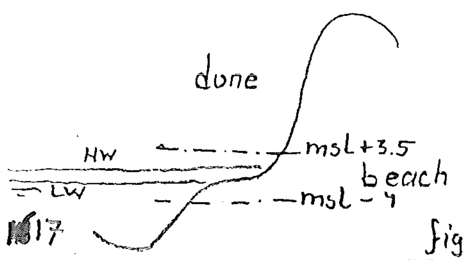


fig 17

fig 16

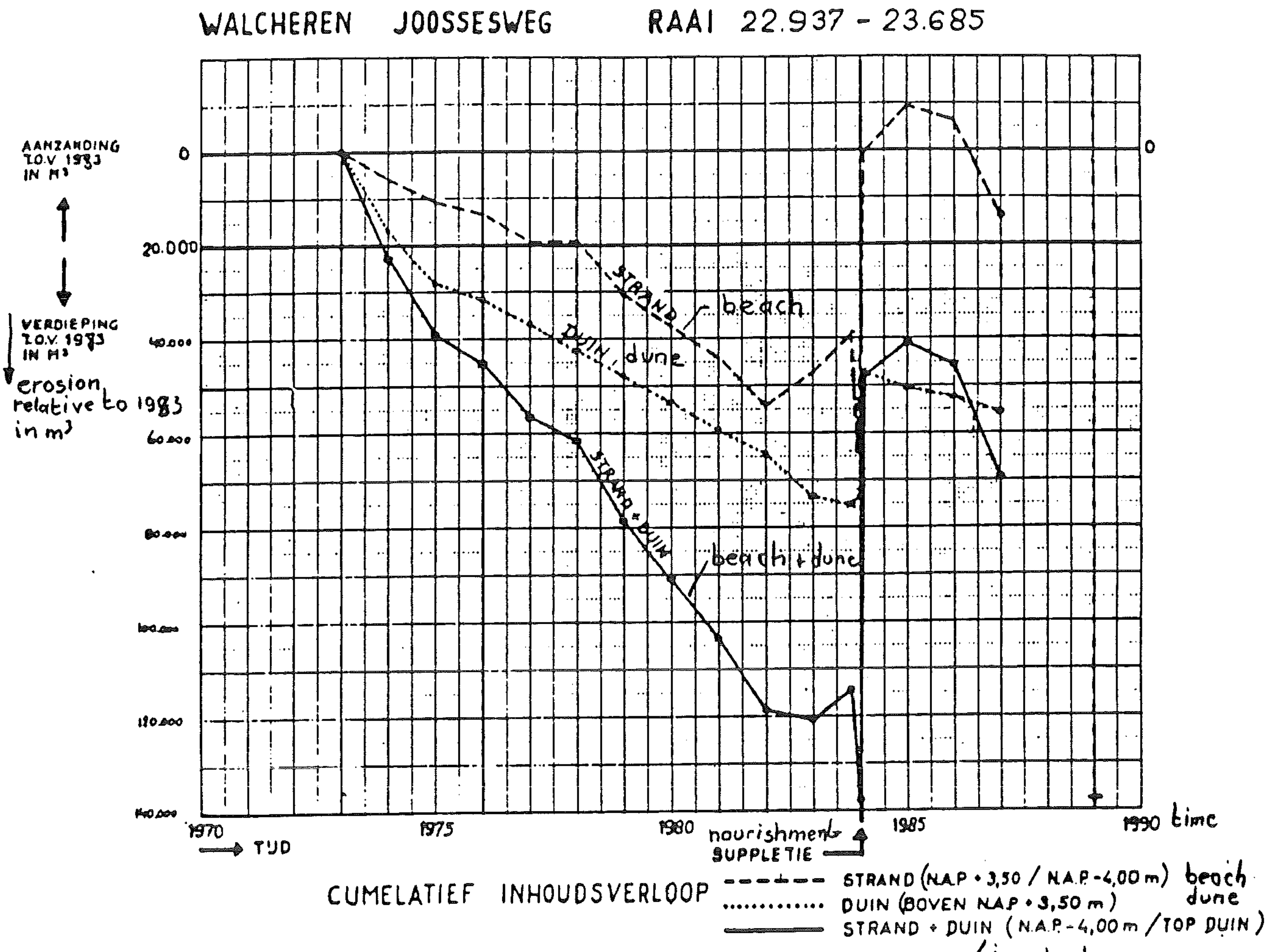


Fig. . Inhoudsveranderingen sedert 1973.

fig 18

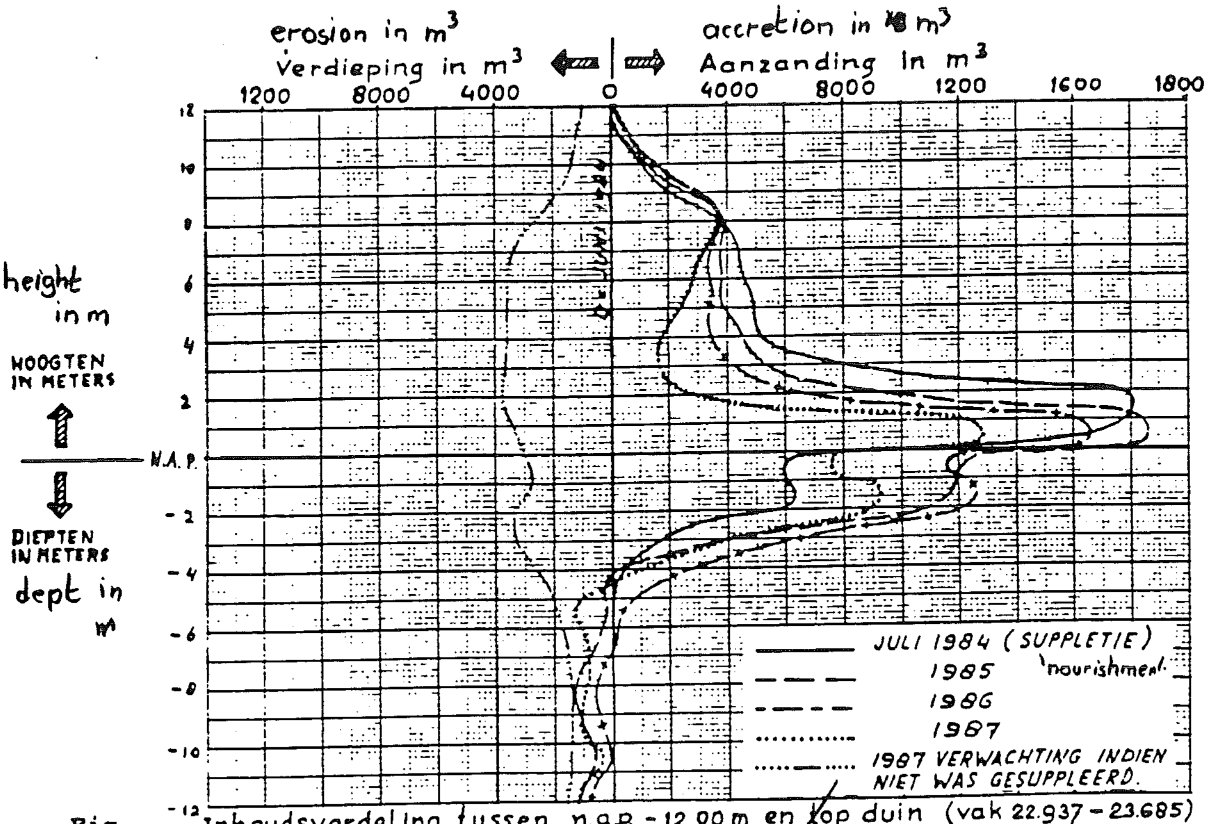


Fig. . Inhoudsverdeling tussen n.a.p -12,00 m en top duin (vak 22.937 - 23.685)
volume changes between msl-12 and top dune
expected position without nourishment

fig 19