CIE 5318 Fieldwork Hydraulic Engineering

- Final Report -

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PREFACE

This report is written for the course CIE5318 "Fieldwork Hydraulic Engineering". This is an elective course in the curriculum of the master Hydraulic Engineering at the Faculty of Civil Engineering and Geosciences. The content of this report is the elaboration of the October 2011 fieldwork in Bulgaria.

A group of 12 Dutch students from the Delft University of Technology and 5 students from the Sofia University stayed in St Konstantin near Varna at the coast of Bulgaria. The purpose of the stay is a field research in the discipline of coastal engineering. During the trip a lot of data is collected which is elaborated mainly when the students were back in Holland. Several measurements are executed at the beach and the coastal structures. Cross shore profiles are measured, samples of sand are taken, depth contour of an area in front of the beach is mapped, waterlines are determined, coastal structures are investigated and a visit to a quarry is made. This visit has the purpose to see the on-going processes and to determine the sizes and weight of stones in the quarry for the design of a breakwater. The last day of the trip to Bulgaria was an excursion to the surroundings of Varna to see some landslide areas and an oilfield.

Many thanks go to the coordinators and organization of the trip. From the Netherlands ir. Henk Jan Verhagen, and ing. Mark Voorendt, from Bulgaria, ir. Boyan Savov, prof. Kristjo Daskalov and PhD-student Vladimir Kukurin, thank you for the assistance during, and the organization of the fieldtrip.

Delft, November 2011

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SUMMARY

In the beginning of October 2011, a group of 12 Dutch students and 5 Bulgarian students went on a fieldwork to the surroundings of Varna in east Bulgaria. The trip is divided in different field studies.

On the first day research is done at a beach north of Varna, which is called Sirius Beach. This research is presented in chapter 2. In the research the waterline and cross sections are compared with the previous years. The following is concluded: there is a strong seasonal variation which influenced the measured data, there is a decreasing trend of erosion at the north side and increasing at the south side of Sirius beach and finally the beach is heading towards an equilibrium.

In chapter 3 a research to the breakwater next to Sirius Beach is done. Conclusion of the research is that the breakwater shows a lot of damage. This damage is caused by wave attacks during storms. The stones were to small and could be lifted by waves. Also research is done to the breakwater in front of the Grand Hotel Varna. Conclusions are that there is no good cost-benefit analysis done before constructing the breakwater, the breakwater is never finished which brings with it that the parts of the breakwater are still in stock and the freeboard is too low. So overtopping happens a lot. And finally the entrance is at the wrong position, so in the summer (the period the breakwater is used) the waves enter the harbor.

The second day of the fieldtrip the group went to Asparuhovo Beach. This beach at the south side of Varna is described in chapter 4. Two cross sections are made and depth measurements are done by an echo-sounder. The most important conclusion is that a sand bank in front of the coast is observed in this year, which wasn't at this location in 2010. This might be a result of the weather, because in 2011 the weather was much better than the year before. Future measurements should confirm of reject this hypothesis. An analysis of the breakwater at Asparuhovo Beach gave us the result that in the construction of the breakwater some mistakes are made. A pipe in the breakwater is a weak point, the combination of the tetrapots with the stones is a bad filter and the concrete slab at the top of the breakwater isn't flexible.

Chapter 5 will give an overview of the Sieve Analysis done by the samples taken from Asparuhovo Beach. The most important conclusions are that the calcium percentage in the sand is lower than 10%. So it does not affect the sieve curves. The beach is rather uniform in long shore direction, the finer sand

is found off shore and the coarser sand can be found at the waterline and off shore the sand is more well-graded than at the beach.

At day four of the trip, two quarries in the neighbourhood of Varna are visited, the Marciana quarry and the Sini Vir quarry. In the Marciana quarry the weight, elongation and blockiness of several stones are determined. Along with these parameters, the determined d_{n50} and density are presented in chapter 6. Furthermore, based on the estimated significant wave height at Sirius beach (see chapter 3), the required dimensions of the armourstones from both quarries are determined, based on the formula of Van der Meer. The final conclusions are that the available rock in the Marciana quarry isn't suitable for the repair works of the St. Konstantin groin. The rock in Sini Vir has a higher density which makes it more suitable.

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1 INTRODUCTION

In the east coast of Bulgaria some problems occur in the coastal regions. A research is done in the surroundings of the city Varna. Two beaches are investigated for erosion. And some structures are investigated. This because the idea lived that the structures weren't sufficient for the local circumstances.

1.1 PROJECT AREA

The east coast of Bulgaria, adjacent to the Black Sea, is the playground of the fieldwork.

FIGURE 1-1 - MAP OF BULGARIA

In Figure 1-1, the location of the fieldtrip is given. All the measurements are done in the surroundings of the city of Varna. This is a city with 350 000 civilians ant it is the third important harbor city in Bulgaria.

The city Varna is located adjacent to the Black Sea. The surroundings of Varna are famous for their sandy beaches and resorts which is every summer a great attraction for tourists. To manage the growing amount of tourism in the summer months it is important that beaches are maintained and new hotels are constructed in the last years.

Unfortunately not everything is build very well and the coast is eroding at some places. Students from the Delft University of Technology and the Sofia University were asked to do an investigation to the state of some groins and breakwaters. Also a research is done in a quarry to verify if the stones in the quarry are useful for structures at the coast of the Black Sea. And finally a research is done to investigate if erosion appears at two beaches.

1.2 Research

The first investigation was at Sirius Beach. This beach is located in St. Konstantin, a small place north of Varna.
The question is if erosion occurs at the beach. The owner of the hotel adjacent to the beach has the idea the beach is decreasing every year. So by compare the situation this year with other years an answer is derived to the question of the hotel owner.

The second location for the research is at Asparuchovo Beach, which is located South of the Port of Varna.
Here a lot of research is done. Sand samples are taken to find out the composition of the sand in the breaking zone. With an echosounder the depth contour is generated for the area in front of the beach. And here also some data is gathered to investigate the development of the beach. So if erosion, accretion or no movement at all occurs, is the question. Finally the breakwater between the entrance channel of the harbour and the beach, is investigated for damage that occurred in the years.

The third location is south of the Sirius beach. Here a groin is located and a small port is build in front of the Grand Hotel Varna.
Here two questions has to be answered. For the groin, how much stone is lost during the years before and how concerning is the damage. At the breakwater it looks like it is a total chaos. The question here is, how does this situation become so bad and is it constructed in the right way?

The fourth investigation is at two quarries. Here a lot of big stones are in stock. The information provided from here is if the rocks are meets the requirements to repair or rebuild the groin in St. Konstantin.

1.3 Structure of the report

The structure in this report is as followed. In chapter 2 the research at Sirius Beach is stated. In chapter 3 the investigation in the groin at St. Konstantin and the harbor in front of the Grand Hotel Varna are described. In the fourth chapter all the different researches at Asparuchovo Beach are reported. In chapter five, the sieve results of the sand samples are elaborated. This is followed in chapter 6 with the results of the quarry visits and finally conclusions and recommendations are given in chapter 7.

2 Sirius Beach

2.1 Introduction

Figure 2-1 shows the situation of Sirius Beach again.

Figure 2-1- Sirius Beach.

Sirius Beach is located north of Varna, Bulgaria. Local tourism entrepreneurs are worried by the supposed beach erosion. Therefore the beach position has been monitored in the past couple of years, including 2011. The monitoring was done in two ways; 1) a waterline position measurement using GPS, and 2) Survey of the cross-shore profiles using a measuring rope, a theodolite and a levelling rod. In the following sections the results of this year will be investigated and a comparison will be drawn with previous measurements.

2.2 Sirius Beach Background

The Sirius beach has a strong seasonal variance; since there is hardly any tide in the Black Sea the beach profile is fully determined by wave action. In general the winter season is the season of the severe storms while the summer is relatively calm. So in summer a wide beach is created with a relatively steep foreshore while in winter months the waves create a more flatten foreshore with a narrower beach. All the yearly measurements since 2003 are done around the first week of October which is more or less the period where the beach is starting to transform from a summer profile into a winter profile. Whether or not there have been already some storms prior to our date of measurement influences the measured data. In Table 2-1 and Table 2-2 the storms since the 1th of August for 2010 and 2011 are noted. It can be concluded that in the 2011 season there were more storms than in 2010. However, the previous report described 2010 as a mild storm season so this year can be described as a normal season.

Date	Wind Speed [knots]	Main Direction
22/08	13	NE
1/09	16	NW
2/09	15	W
10/09	18	NE
11/09	14	NE
30/09	13	W

Table 2-1 - 2010 (source windguru, location sunny beach, dates of wind speeds with more than 3 readings of 13 knots or more).

Date	Wind Speed [knots]	Main Direction
11/08	20	N
12/08	20	N
26/08	13	NE
27/08	13	NE
21/09	18	NE
22/09	16	NE
30/09	16	N
8/10 (night)	12	S

Table 2-2 - 2011 (source windguru, dates of wind speeds with more than 3 readings of 13 knots or more).

2.3 Waterline-measurements (GPS)

One type of beach measurements is measuring the waterline with a handheld GPS receiver. The waterline is defined as the still water line excluding individual waves. GPS devices have a log option which automatically saves the location every couple of meters. Depending on the amount of available satellites the accuracy is in the order of 5 meters. Also it should be noted that every individual through the years will choose a different path as the Waterline; even in data from the same years a difference between different tracks can be seen. The data is good for a global image whether or not beach waterlines are retreating or not but should not be used for very detailed purposes. GPS data of the waterline position has been collected since 2003 and is compared in Figure 2-4.

The waterlines don't show a clear trend. In 2003 beach nourishment was done which was quickly eroded in the years after; after this the waterlines are more or less stabilized. This is illustrated nicely by the fact that the measurement of 2011 is quite similar to the measurement of 2004.
In the Northern part of the beach it seemed like an eroding trend was active, which is also described in previous reports but the 2011 data is contradicting this. It's more likely that since the 2003 beach nourishment there has been some erosion until a stable position was reached around the level of the 2007 measurement.

In the southern part there has been some accretion since 2003 but there is no clear trend visible since there is a large variance in-between individual years (see for example 2010 and 2011). The 2010 data seems inconsistent; the 2010 storm season was mild compared to 2011 which should indicate a wide beach while in the measurements the narrowest beach in 10 years is shown.
Overall the whole data-set shows a large variability due to the seasonal influence which is much stronger than the long term pattern. That's why it can be concluded that the beach is more or less stable according to the current data. A larger dataset is necessary to filter out the seasonal differences in order to discover a small trend.

The effect of individual storms was already noticeable during the week of measurements. During the night of 7 to 8 October wind speeds of 12 knot were recorded [windguru.com], and there was some wave action. On Figure 2-2 the result the following day is shown. An escarpment line is clearly visible, the beach is transitioning into a winter profile. On Figure 2-3 the GPS tracks of 3 and 8 October are compared which also shows that in some locations there was a retreat of the waterline of 5-10 meters. This also gives a good indication on the reliability of the measured data; even small wave action has significant influence on the result. The data is really depending on the whether or not there have been some storms yet.

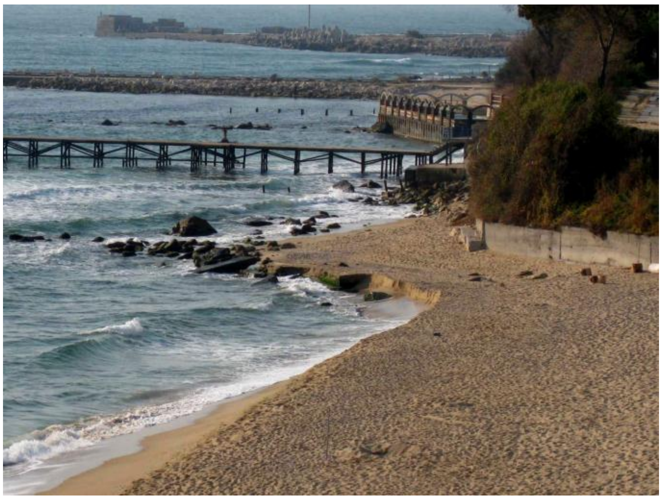


FIGURE 2-2 - CLEARLY VISIBLE ESCARPMENT LINE DUE TO WAVE ACTION IN THE NIGHT OF 7 TO 8 OCT.

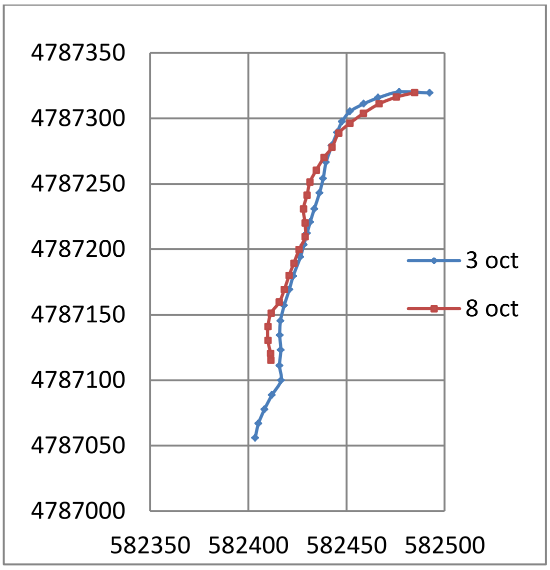


FIGURE 2-3 - GPS TRACKS OF 3 AND 8 OCTOBER 2011.

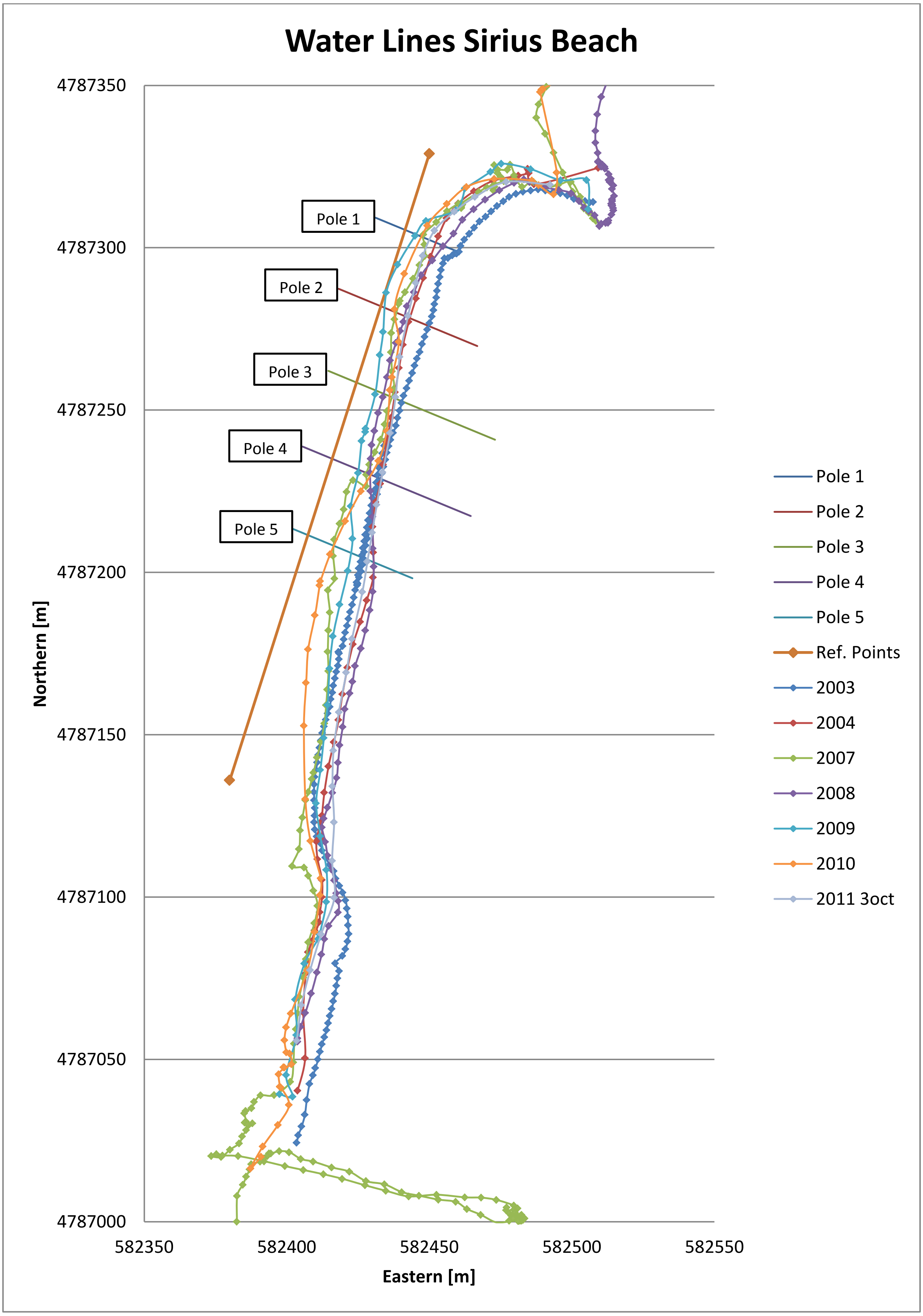
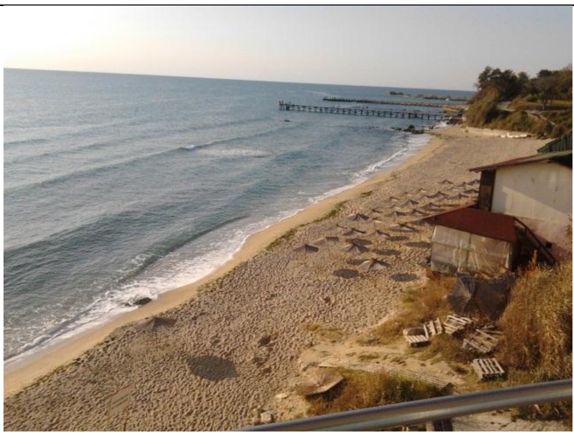


Figure 2-4 - Water lines Sirius Beach (2003 - 2011).

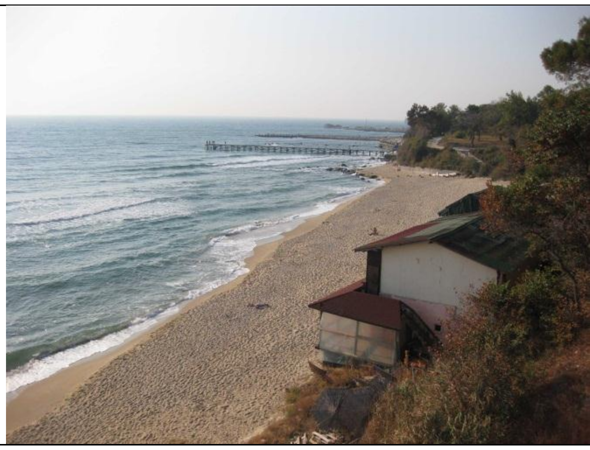
Previous year photographs were taken on arrival and departure from the balcony of the Sirius Hotel. This year almost identical photos were taken. The pictures of last year also show that a lot can happen in a short time span.

3-10-2010

9-10-2010



3-10-2011



8-10-2011

FIGURE 2-5 - PICTURES OF SIRIUS BEACH AT ARRIVAL AND DEPARTURE (2010 & 2011).

2.4 Cross-section measurements

In order to give a more detailed picture of the development of the beach, the cross-section of the beach was measured. In this manner, the volume of sand which is present on the beach and in the surf zone can be made visible. These volumes of sand are key factors when investigating supposed beach erosion.

First the procedure of measuring the cross-section will be covered, then the results will be shown and eventually the conclusions are drawn.

2.4.1 Baseline

A baseline is required to be able to compare this year's results with previous data. To determine a baseline at least two reference points are required.

Reference point 1 is situated at the stairs of hotel Sirius, and was also used to provide a reference height. In UTM coordinates the position of Ref 1 is 35T, 582450 m east, 4787329 m north. The top of the concrete slab serves as the reference height, being 2.705 m + MSL.

Reference point 2 was positioned at the Southern end of the beach, also at a staircase. The UTM coordinates for this point are 35T, 582380 m East, 4787136 m North.

These points are the exact same points that were used in previous years, to simplify conversion.

Figure 2-6 - Reference point 1 (LHS) and Reference point 2 (RHS).

2.4.2 Cross-shore profile positions

In previous years first a baseline was set up between two reference points. Then a zero-point was arbitrarily placed between these reference points. Since every group made their own zero-point, this led to some confusion. Therefore this year it was decided to use the first reference point at the staircase of the hotel as a zero point. From there on, 5 poles were placed with a mutual distance of 25 m. Given that Sirius Beach does not display very much alongshore variation, it was decided that a representative image of the beach could be produced with 5 cross-shore profiles. Figure 2-7 shows the location of the alongshore positions at which a cross-shore profile was to be measured.

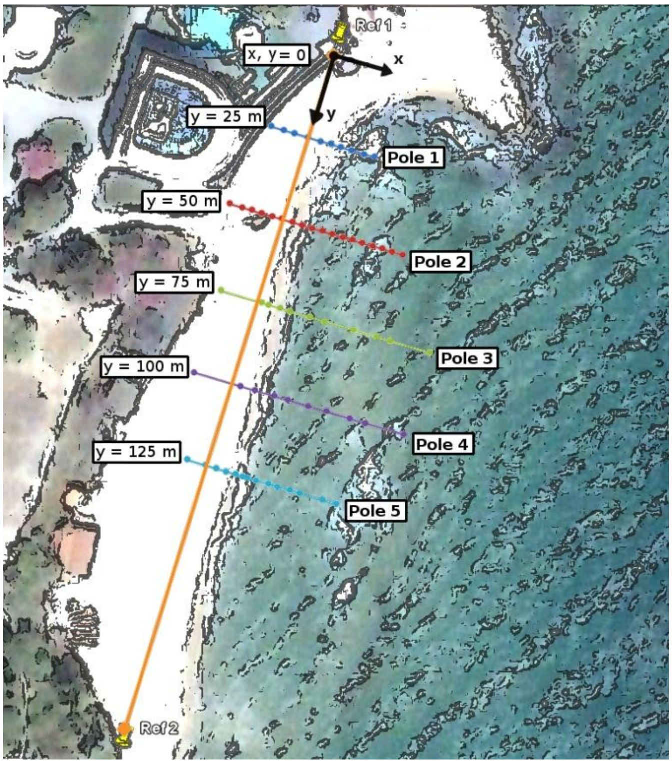


Figure 2-7 - Theodolite positions.

In the ideal case, only one theodolite is used to measure all 5 cross-shore profiles. Every theodolite requires of course its own coupling to the reference point; the height of the line of sight of that theodolite should be determined based on a levelling rod at the reference point. Unfortunately, at further distances the measuring pole cannot be seen clearly anymore. In this case, it was decided to use 3 theodolites, so every levelling rod could be read accurately. Figure 2-8 shows the procedure of measuring a vertical position with a theodolite.

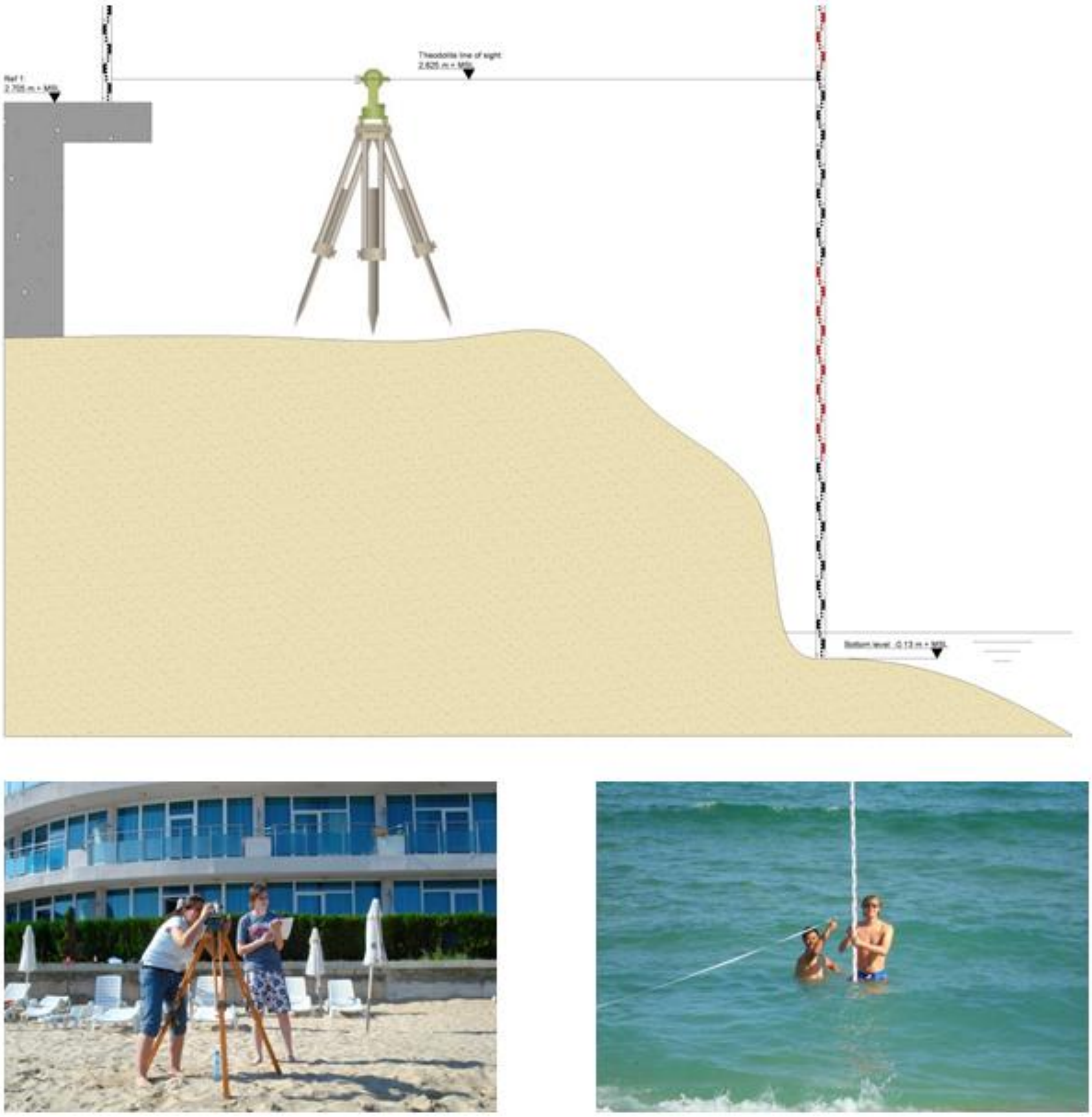


FIGURE 2-8 - PROCEDURE OF MEASURING A VERTICAL POSITION WITH A THEODOLITE

2.4.3 Cross-shore profiles

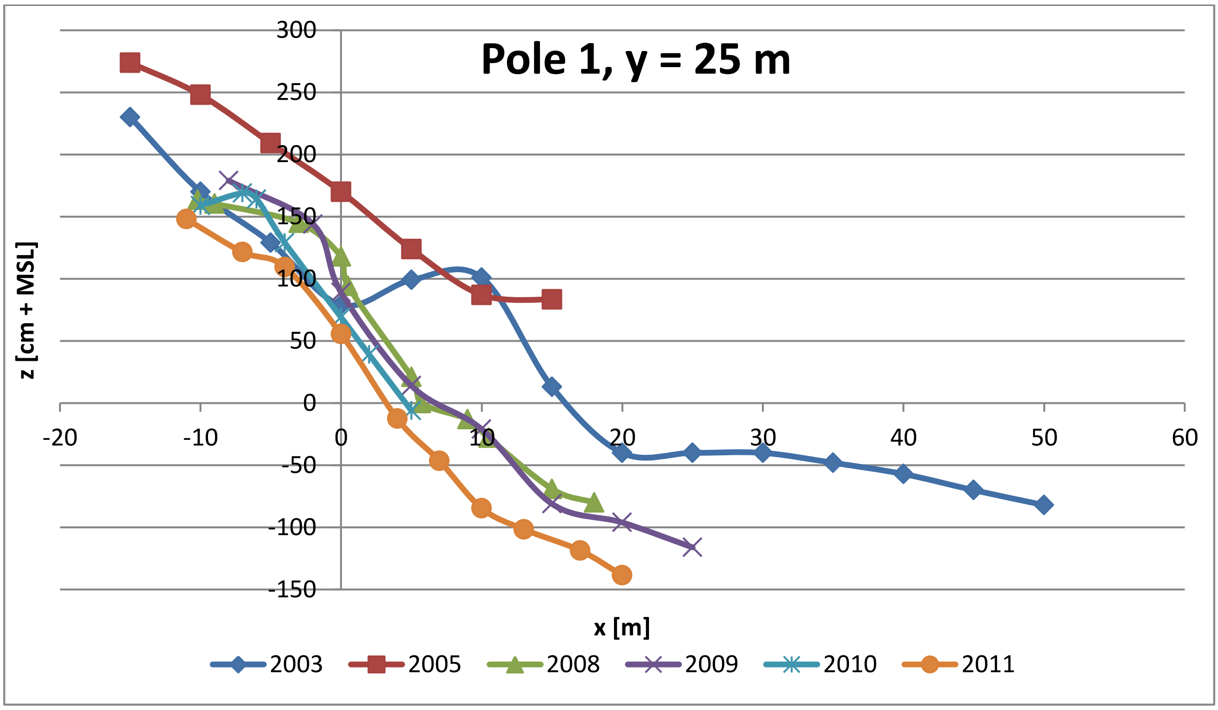


Figure 2-9 - Cross shore profile Pole 1 (at 25 m).

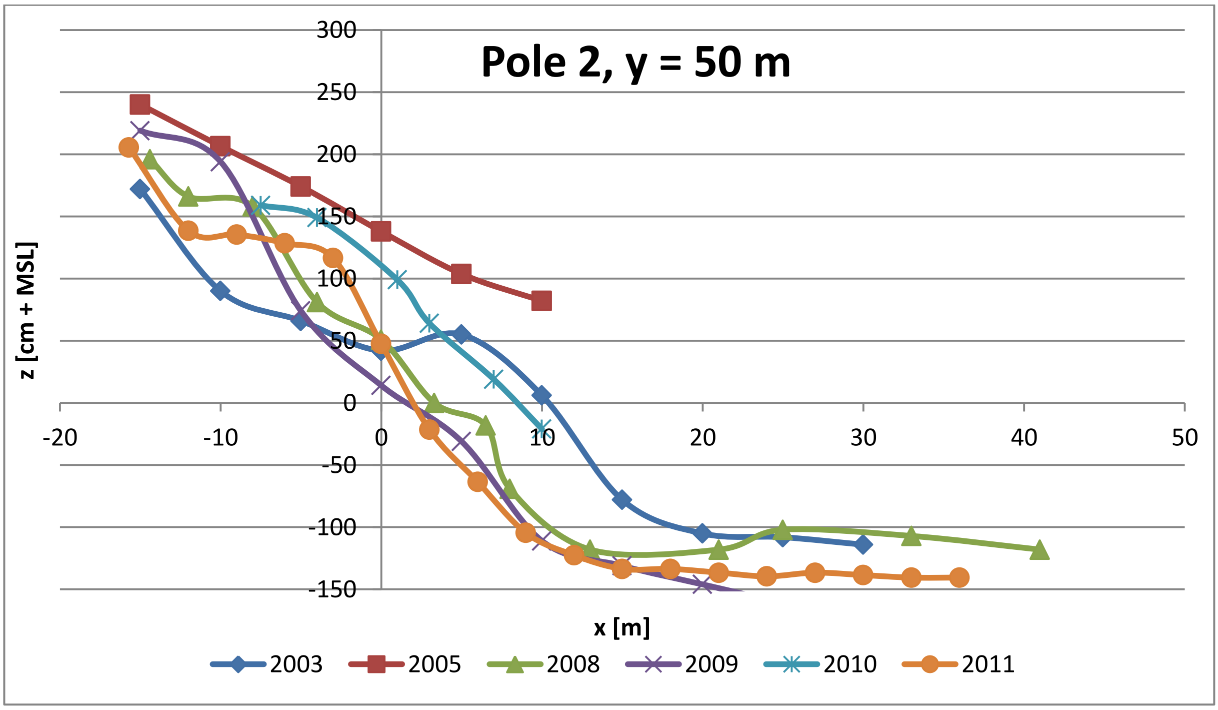


Figure 2-10 - Cross shore profile Pole 2 (at 50 m).

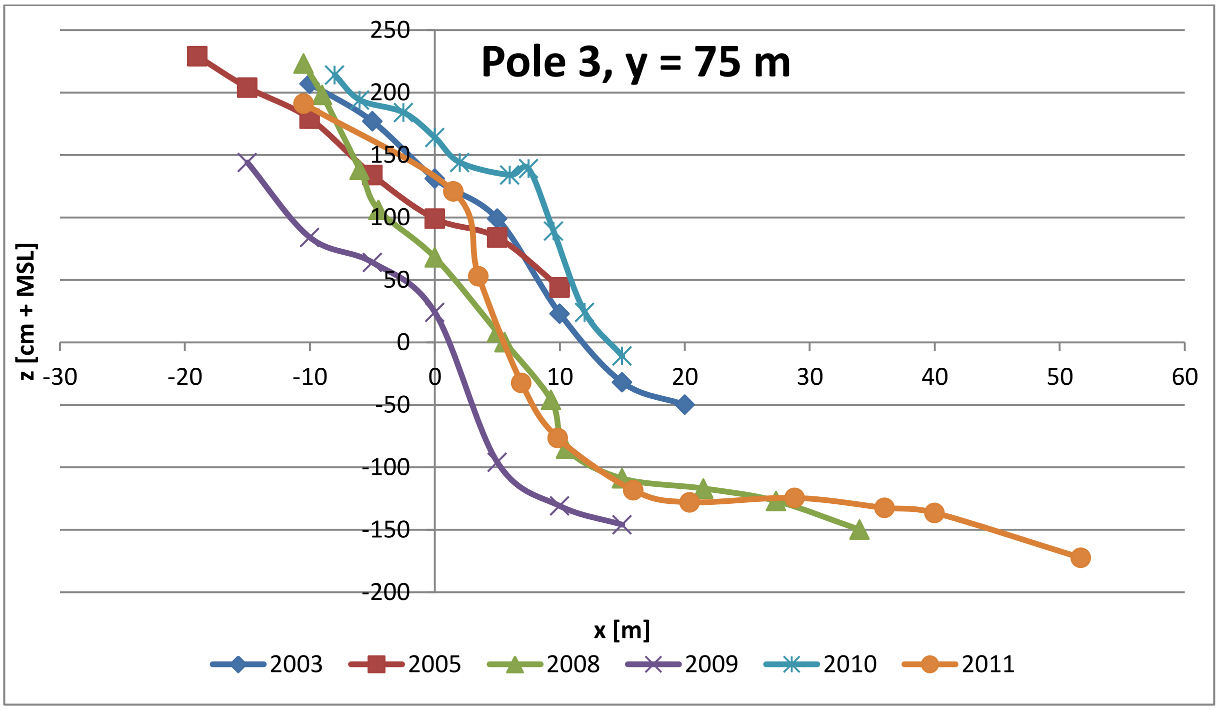


FIGURE 2-11 - CROSS SHORE PROFILE POLE 3 (AT 75 M).

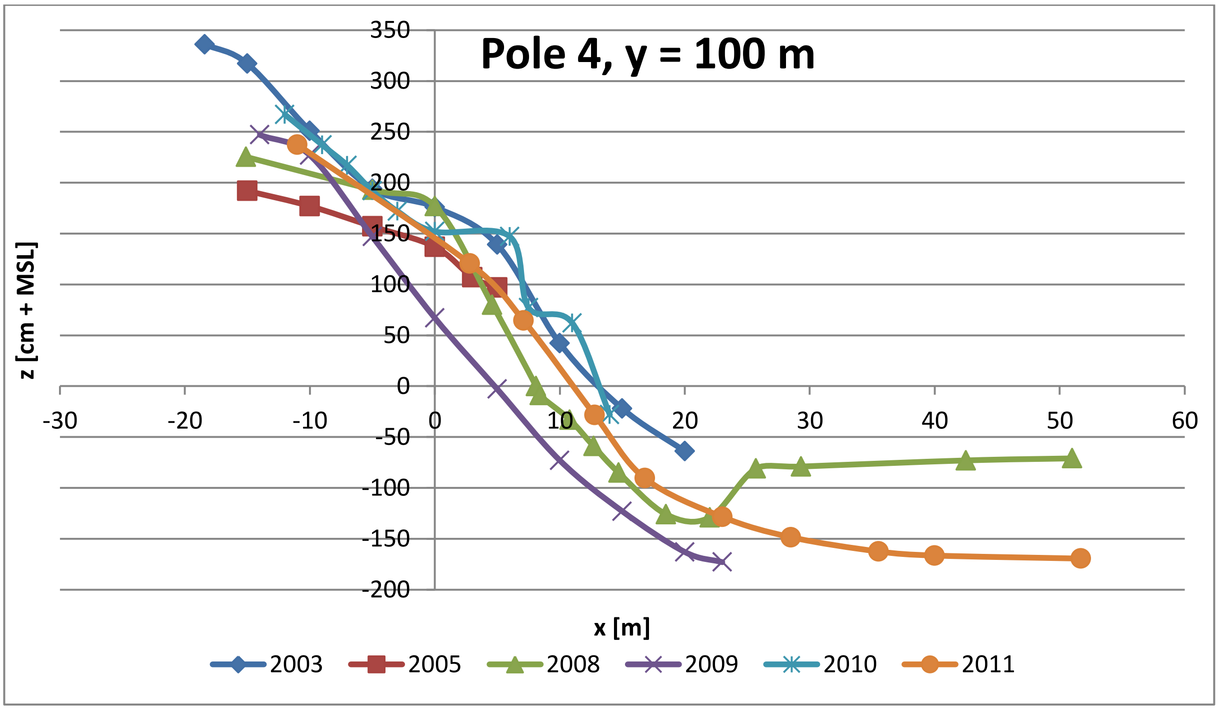


FIGURE 2-12 - CROSS SHORE PROFILE POLE 4 (AT 100 M).

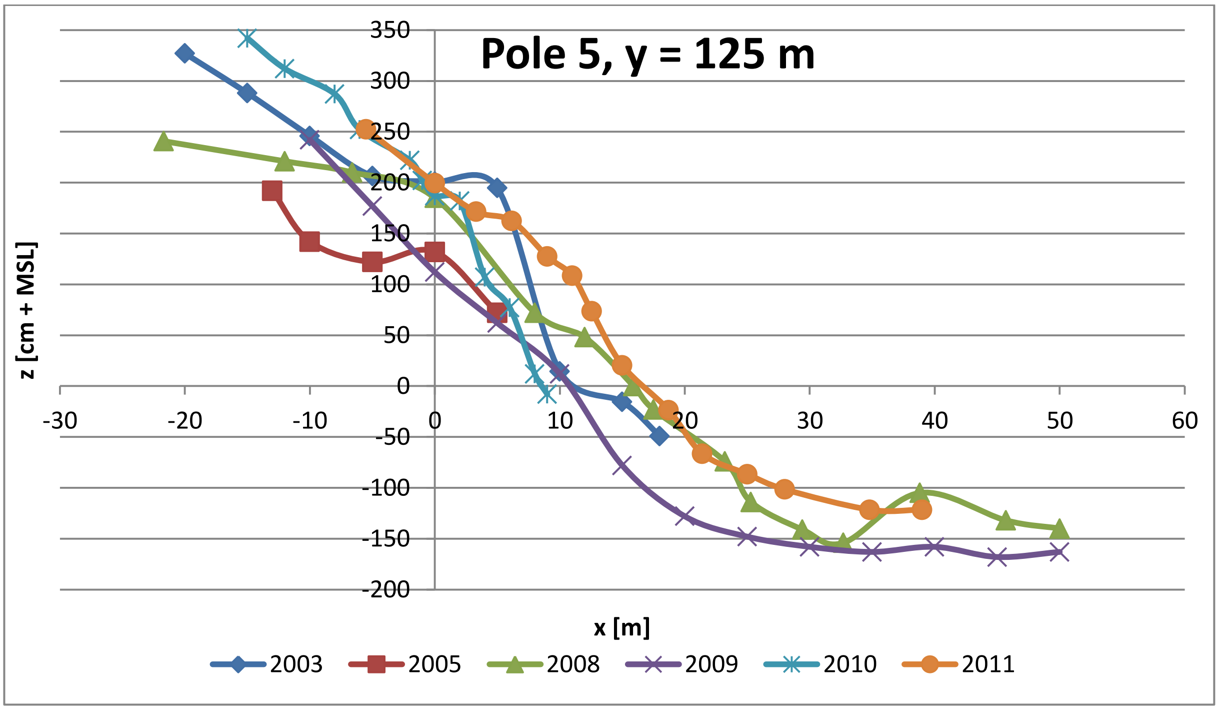


FIGURE 2-13 - CROSS SHORE PROFILE POLE 5 (AT 125 M).

Figure 2-9 to Figure 2-13 show the various cross-shore profiles, per alongshore position. It should be kept in mind that the alongshore position of the cross-shore profile can vary slightly because of inconsistency in the used reference point. I.e. the alongshore position at which a cross-shore profile is determined this year is presumably a couple of meters different from the alongshore position at which last year's group measured their cross-shore profile. However, of all dimensions the accuracy in alongshore position is least important, so this difference is not invincible.

The cross-shore profiles do not provide an unambiguous picture of a long term trend. The first positions - closest to the Hotel Sirius – show a retreat of the coast in the past few years. Then at pole 4 it appears that the coastline is more or less stable in time. Pole 5 shows an accretion of the coast over time. When considering all cross-shore profiles, it can be noted that the rate of accretion/erosion is much smaller than the initial rate (at 2003).

Concluding: it seems that the coastline is heading towards equilibrium; the rates of changes are getting smaller when comparing with the years just after the beach nourishment. The beach at Pole 1-3 is slowly retreating while the beach at Pole 4 is constant. Pole 5, including the Southern end of the coastal cell, seems to be moving seaward. However, these trends seem to be reducing in time. Overall, the volume of sand in the coastal cell appears to be more or less constant (which is the definition of a coastal cell), The sand is being transported from the Northern end of the coastal cell to the Southern end of the coastal cell.

Note: The variability of the data used in this investigation is rather large. Apart from the accuracies in measuring equipment, the position of the waterline/cross-shore profile is very much influenced by wave conditions. The fieldwork is carried out during the transition between the summer- and winter-profile. Measurements of one year can be preceded by storm conditions while the measurements of the following can represent a perfect summer profile.

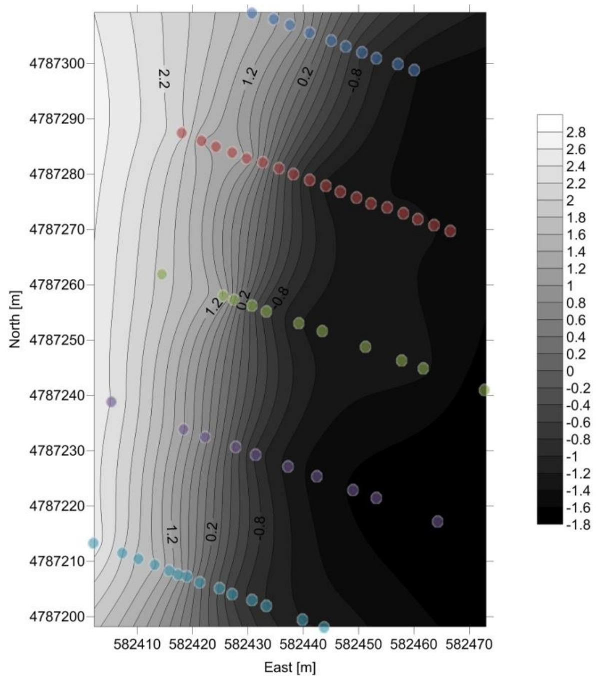


FIGURE 2-14 - DEPTH CONTOUR MAP OF SIRIUS BEACH.

Figure 2-14 displays a depth contour map of Sirius Beach, which was produced with the data of the cross-sectional measurements. The coloured dots are the measurement locations. From this image it may be noted that the foreshore at pole 2 and 3 is somewhat flatter than at pole 4 and 5. Figure 2-15 provides a bird's eye perspective of the beach.

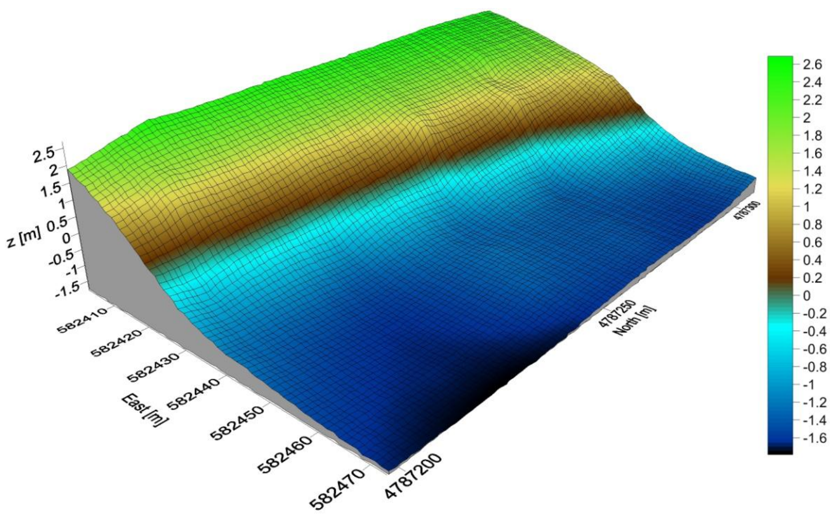


FIGURE 2-15 - BIRD'S EYE PERSPECTIVE OF SIRIUS BEACH.

2.5 Conclusion / Evaluation / Forecasting

The 2 types of measurements for the Sirius Beach give a slightly contradicting picture. Based on the GPS data one can conclude that there is a large seasonal variance and no real clear trend in the water lines. Based on the measured cross sections with the theodolite one could conclude that Sirius beach is a coastal cell with erosion in the northern end and accretion in the southern end. Both data sets show a beach which is heading towards equilibrium. The reliability of the cross-section data is higher than the GPS-tracks, the baseline is very accurately defined and the error with the tape measurements and the readings from the measuring pole are in the order of 0,1 m while the error made with a GPS is much larger (order of 5m).

This is why the following conclusions can be made:

- Sirius beach has a strong seasonal variation which influences measured data.
- There is a small trend of erosion in the northern part and accretion in the southern end of Sirius beach. This trend is decreasing in time.
- Sirius beach is heading towards an equilibrium.

In the future no large changes are expected, although it’s wise to continue the measurements since the database is still relatively small and heavily influenced by seasonal variances. Any measures are not necessary and not advisable in the current situation. It’s advisable to further standardize the measurement methods to avoid confusion; future groups should actively read previous reports before starting any measurements. Also it is advised to use the same alongshore locations for the cross-sectional measurements.

3 GROIN AND HARBOR ST. KONSTANTINE

3.1 INTRODUCTION

Within this chapter two elements will be evaluated, the groin and the harbor located near the St. Konstantine beach.

As mentioned in the introduction of the report, we stayed at the Sirius Beach Hotel during the Fieldwork. The Sirius Beach Hotel is situated at the beach of St. Konstantine. Approximately 400m to the South of the resort a 25 years old groin is situated. And the investigated harbor is located 300m south of the groin (see Figure 3-1).

The harbor in front of Grand Hotel Varna is still “under construction”. Because of a shortage of money, the breakwater in front of the harbor is unfinished. The remaining of the building phase and an unfinished breakwater can still be seen at the location site and has been visited.

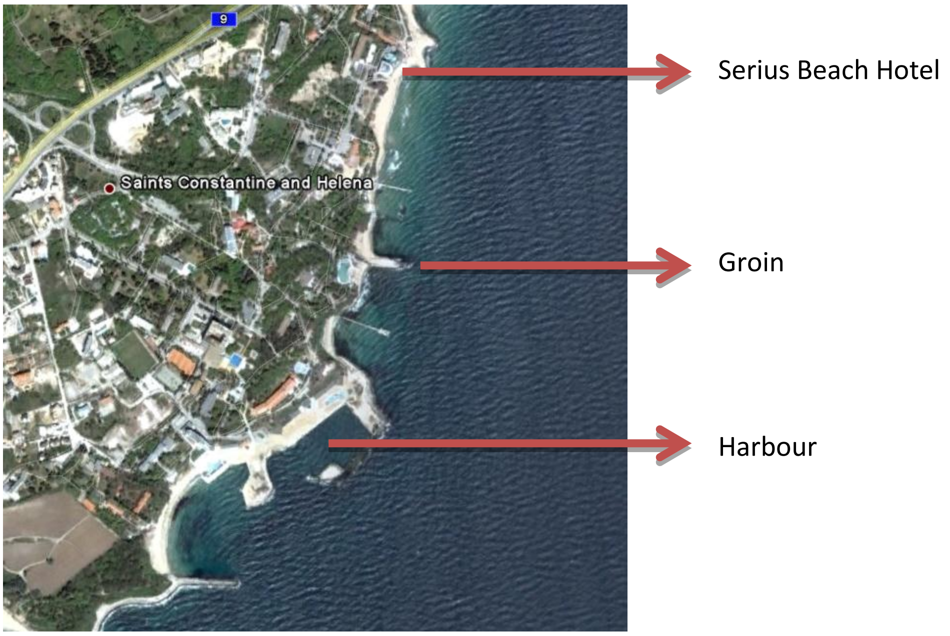


FIGURE 3-1 - OVERVIEW OF THE AREA

In paragraph 3.2 the groin is evaluated and in paragraph 3.3 the harbor.

3.2 GROIN

The evaluation of the groin is split up in several parts, first the nominal stone diameter of the stones on the groin are estimated. They are followed by the measurement of the cross-sections and the volume of the groin.

3.2.1 ESTIMATION OF NOMINAL STONE DIAMETER

The core of the breakwater exists out of caissons. Around the caissons natural stone is placed to break waves. The dimensions of those stones are measured. Within this paragraph the measurements are discussed, followed by the visual inspection and the calculation of the design wave.

3.2.1.1 MEASUREMENTS

An estimation of the stone sizes is made with the following method. The length, width and height are determined as the smallest dimensions for a box where the stone fit in exactly (See Figure 3-2). The blockiness is determined in two ways;

- The first method is used for the first 12 stones. They are determined with a mean blockiness of 62%. This results from four students that have guessed the blockiness of five stones. After each stone the blockiness for that particular stone was discussed. This gives the following blockiness for the five stones; 75%, 70%, 50%, 60% and 55%. The mean of the percentages is 62%;
- The second method is used on the last 15 stones. The blockiness is predicted for each measured stone individually. This gives for every stone an individual blockiness. The average blockiness of these 16 stones is 61%.

Both methods result in approximately the same blockiness. From this point of view the methods are reliable.

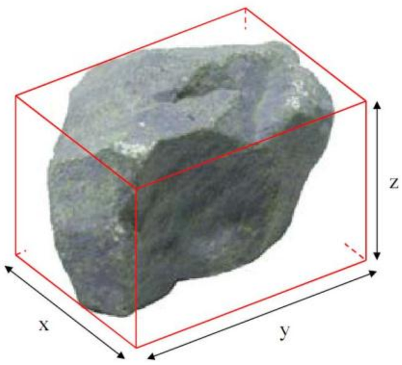


FIGURE 3-2 - DIMENSIONS OF THE BOX FOR THE STONE

The volume of the stone is determined by calculating the volume of the box (see Figure 3-2) and multiplying this volume with the blockiness factor. The d_{n50} is defined as; $D_{n50} = V^{1/3}$. When the volume is multiplied by the density of the block (ρ_s =2400 kg/m^3) the weight of each stone can be calculated.

The measurements results are given in Table 3-1. This data results in;

- D_{50} = 0.54 m
- W_{50} = 378 kg

The D_{n50} can been determined by;

$$D_{n50} = \left(\frac{W_{50}}{\rho_a}\right)^{1/3} = \left(\frac{378}{2400}\right)^{1/3} = 0.54 \qquad (3.1)$$

The nominal grain diameter (D_{n50}) of the stones is 0.54 m.

The diameter and the weight of each individual stone in order from smallest to largest													
D (m)	0.10	018	0.22	0.26	0.30	0.30	0.32	0.34	0.36	0.40	0.41	0.46	0.52
D (m)	0.56	0.56	0.61	0.67	0.71	0.74	0.78	0.90	0.93	0.94	1.22	1.31	1.35
W (kg)	2	14	25	44	62	65	76	91	114	155	167	226	335
W (kg)	421	428	538	711	847	964	1151	1726	1923	1971	4406	5417	5958

TABLE 3-1 RESULTS FROM THE STONE MEASUREMENTS

3.2.1.2 VISUAL INSPECTION

The quality of the stones is not that good as can be seen in Figure 3-3. The stones break easily, and have a lot of cracks.

Several stones where lying on top of the groin. Those stones are placed there during storms. When comparing photos of previous years with each other, it is clear that the stones are moving. For example the stones that where laying on the south side of the top of the groin (2011) where not there in 2009. From the photos can be concluded that the stones are moving and that the stones are to light.

FIGURE 3-3 - PHOTOS OF STONES ON TOP OF THE GROIN

3.2.1.3 Calculation of the design wave height of the groin

When the groin was designed the Hudson formula was used. This was a fault during design, because Hudson is not valid for impermeable breakwaters such as breakwaters with a core of caissons. Instead of the Hudson formula the Van der Meer formula had to be used.

With the in paragraph 3.2.1.1 determined M_{50} and the Hudson formula the design wave can be calculated;

$$M_{50} = \frac{\rho_s H_s^3}{K_D \Delta^3 \cot\alpha} \rightarrow H_s = \sqrt[3]{\frac{M_{50} K_D \Delta^3 \cot\alpha}{\rho_s}} = \sqrt[3]{\frac{378 \cdot 3.5 \cdot 1.33^3 \cdot 5}{2400}} = 1.86\ m \qquad (3.2)$$

M_{50}	= weight of the median element: M_{50} = 378 kg
ρ_s	= density of stone: ρ_s = 2400 kg
H_s	= significant wave height
K_D	= damage coefficient: K_D = 3.5 (K_D factor for a double layer armor stones attacked by breaking waves)
Δ	= relative density $\Delta = \frac{\rho_s - \rho_w}{\rho_w} = \frac{2400-1030}{1030} = 1.33$
$\cot\alpha$	= slope of the breakwater: $\cot\alpha$ = 5

In the calculation a design slope of 1:5 is assumed. In the current situation the slope at the south side of the breakwater is 1:8 ($\cot\alpha$ = 8) and on the north side 1:6 ($\cot\alpha$ = 6). Because of the visual damage it is a realistic assumption that the design slope was steeper than the current slope.

With the formula of Hudson it is determined that the design is based on a significant wave height of 1.86 meter.

However, between the construction of the groin and our fieldwork in 2011 approximately half of all the stones where broken. This means that during the construction phase, the stones where bigger than they are now. So a rough assumption gives us that the stones where 30% heavier than at that moment of our fieldwork. Recalculating the H_s with the assumed bigger stone diameter gives a H_s of 2.04 meter.

3.2.1.4 Conclusion

When visually inspecting the breakwater it is easy to see there is a lot of damage. This damage is caused by wave attacks during storms. The stones where to small and could be lifted by waves.

The stones used are of a low quality and highly breakable, a reason for this could be found due to the high concentration of calcium within the used stones. The stones also have a low density. When using stones with a low density, the nominal diameter should be larger.

3.2.2 Measurement setup

In 2002 the groin near St. Konstantine is measured for the first time. In this year they marked a base point at the groin, just before the bent in the groin (see Figure 3-4 and Figure 3-5). This base point is considered stable and not to vary over the years. From the base point in the direction of the beach, a straight line over the crest of the groin, the base line is created with reference points every 5 meters (in Figure 3-4 only the base point, and from the 5m point on a point every 10 meters are shown). Cross-sections will be measured perpendicular to the base line.

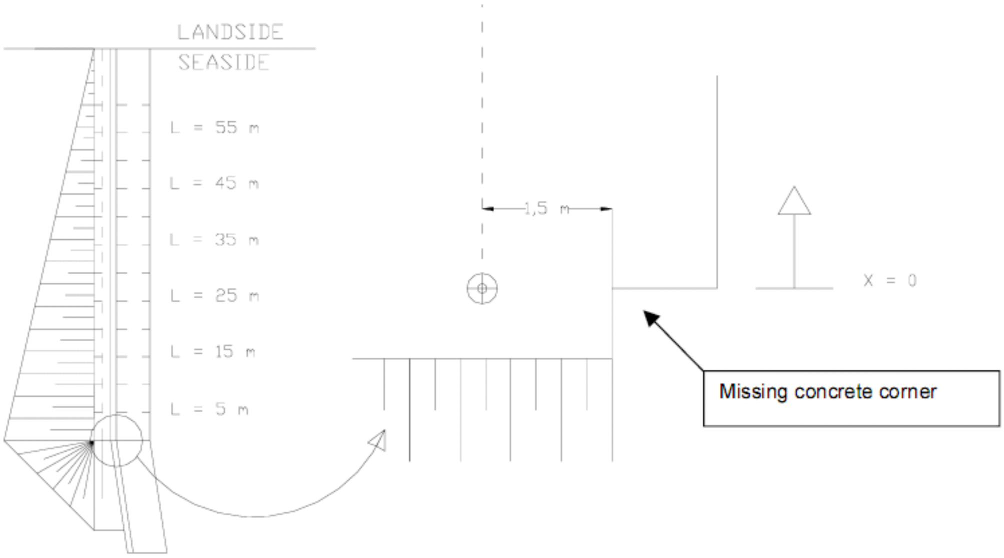


FIGURE 3-4 - OVERVIEW OF THE BREAKWATER, INCLUDING LOCATIONS OF THE CROSS-SECTIONS OF PREVIOUS YEARS

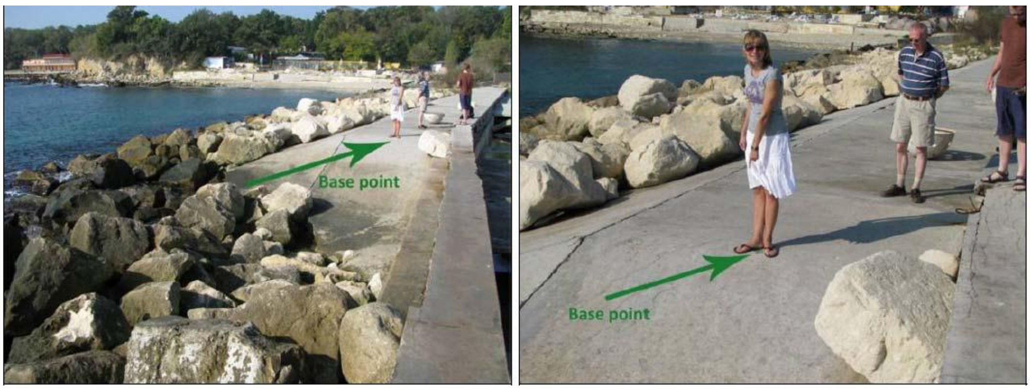


FIGURE 3-5 - LOCATION OF THE BASE POINT

The following cross-sections where measured in the previous years;

- 2002, cross-sections: L = 5m, L = 15m, L = 25m, L = 35m, L=45m, L=55m
- 2003, cross-sections: L = 5m, L = 15m, L = 25m, L = 35m, L=45m, L=55m
- 2004, cross-sections: L = 5m, L = 15m, L = 25m, L = 35m, L=45m, L=55m
- 2008, cross-sections: L = 5m, L = 15m, L = 25m, L = 35m, L=45m, L=55m
- 2009, cross-sections: L = 5m, L = 10m, L = 15m, L = 20m, L = 25m, L=30m, L = 35m, L=40m, L=45m, L=50m, L=55m

The groin measurements, done in other years than mentioned above, were of a different groin and not useful for this report. From the cross-sections mentioned above only data from the years 2002, 2003 and 2004 is available. From the years 2008 and 2009 only some figures are available.

This year (2011) different cross-sections where measured by accident. This year the measured cross-sections are at: L = 0m (base point), L = 10m, L = 20m, L=30m, L=40m, L=50m, L=60m. Because different cross-sections where measured this year it is not possible to make a comparison with the cross-sections of previous years. With the measured cross-sections the volume can been calculated, in this way the volume can been compared with previous years.

The measurements are performed using a theodolite, a measuring rod fixed to a hemisphere and a measuring tape. Measurements are done relative to the base point and the mean sea level. The hemisphere at the end of the measuring rod is used to smooth the measured profile since it prevents that the rod is being positioned in a gap between two stones.

The crest height is measured at every profile at the edge of the concrete slab. There was about 25 cm difference in height between the seaward side and the landward side of the groin. The height increased towards the landside. This height difference is negligible, since it will have no impact on the functioning of the groin. The height difference was also noticed in previous years.

3.2.3 Cross-sections

As mentioned in the previous paragraph this year different cross-sections where measured in comparison with previous years. Because of this, the new measured cross-sections cannot be compared with the previous years.

To get a complete overview the comparison of the cross-sections of the years 2002-2003-2008 are added to this paragraph, see Figure 3-6 till Figure 3-9 (the figure are from the report of 2008). In those figures the baseline is located at x=0. The negative values along the x-axis represent the southern side of the groin and the positive values represent the northern side. The concrete slab is assumed to be at a fixed level and is not included in the figures. The y-direction gives the height, where y = 0m is the height of the reference point. Negative values represents points higher than the reference point (on the concrete slab) and positive values are points lower than the reference point.

The north side of cross-section L = 5m is measured for the first time in 2008. For the cross-sections L = 15m, L = 25m and L = 35m, both, the north and south side of the groin is measured in all the years. From the cross-sections L = 45m and L = 55m no reliable data is available. Because of a lack of reliable data those last to cross-sections are not added to this report.

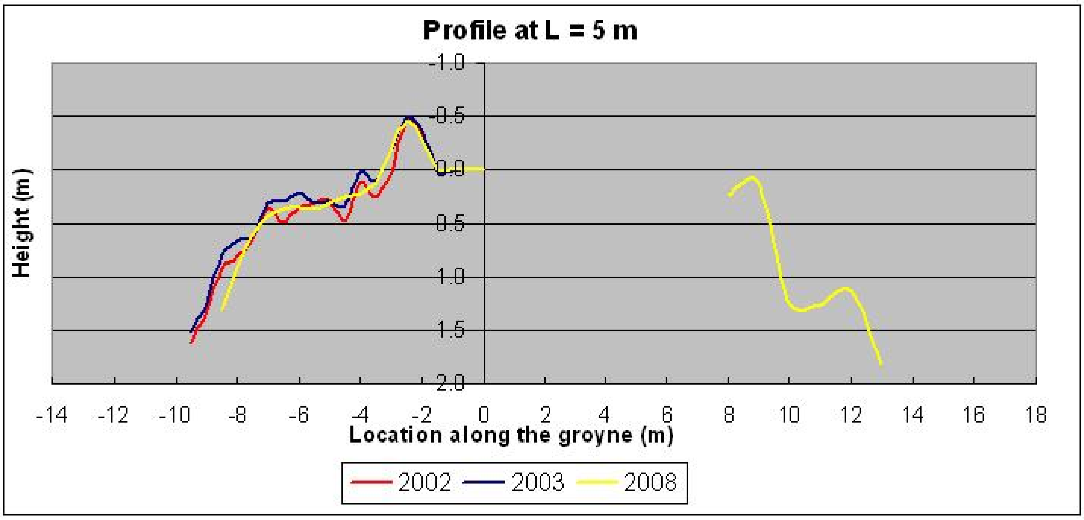


FIGURE 3-6 - CROSS-SECTION AT L = 5M (REPORT 2008)

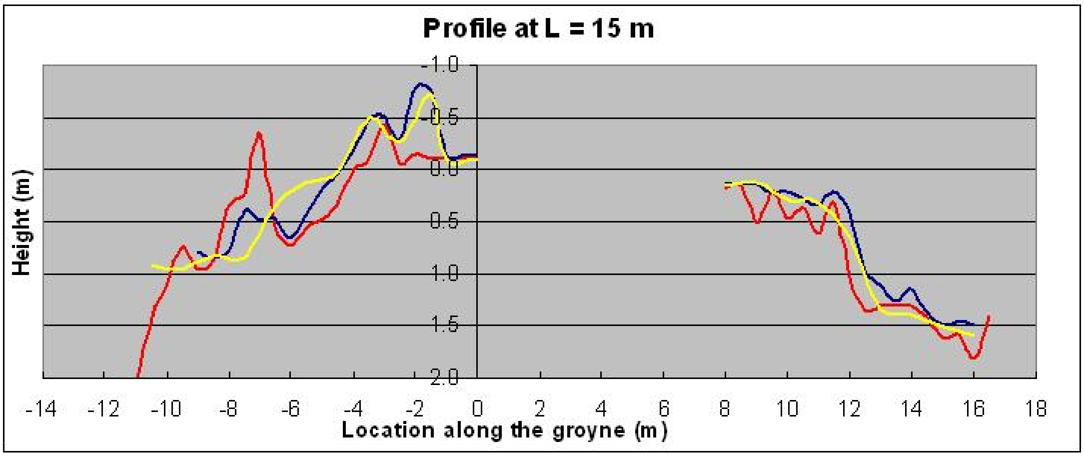


FIGURE 3-7 - CROSS-SECTION AT L = 15M (REPORT 2008)

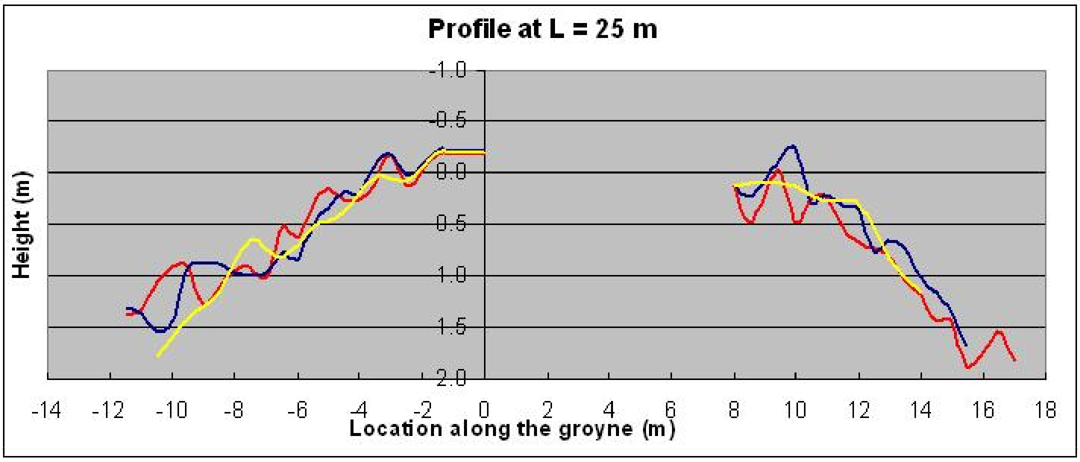


FIGURE 3-8 - CROSS-SECTION AT L = 25M (REPORT 2008)

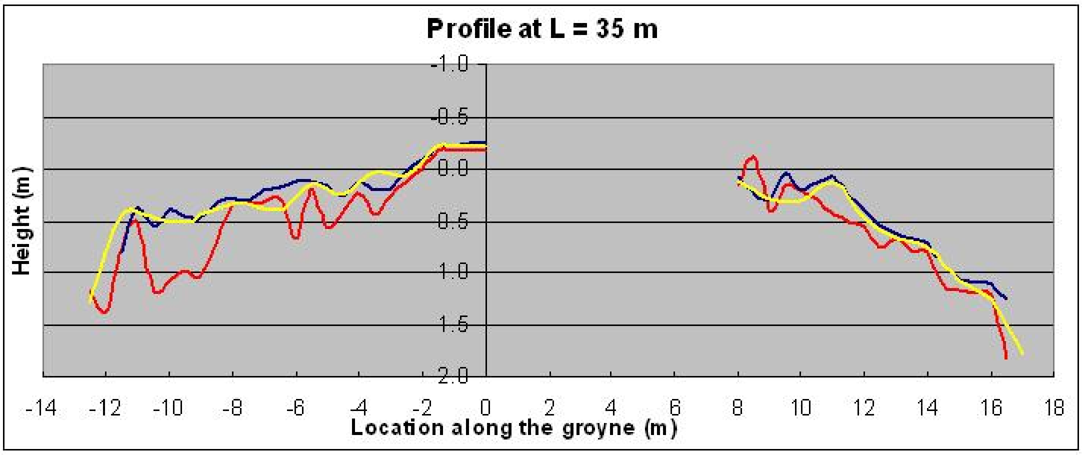


FIGURE 3-9 - CROSS-SECTION AT L = 35M (REPORT 2008)

3.2.4 CHANGE OF VOLUME

Within this paragraph the change of volume over the years will be elaborated. The north and south side of the groin will be looked at separately. This is done because of the difference in load. Besides a difference between the north and south side, the groin is split up in sections of 10 meter (see Figure 3-10).

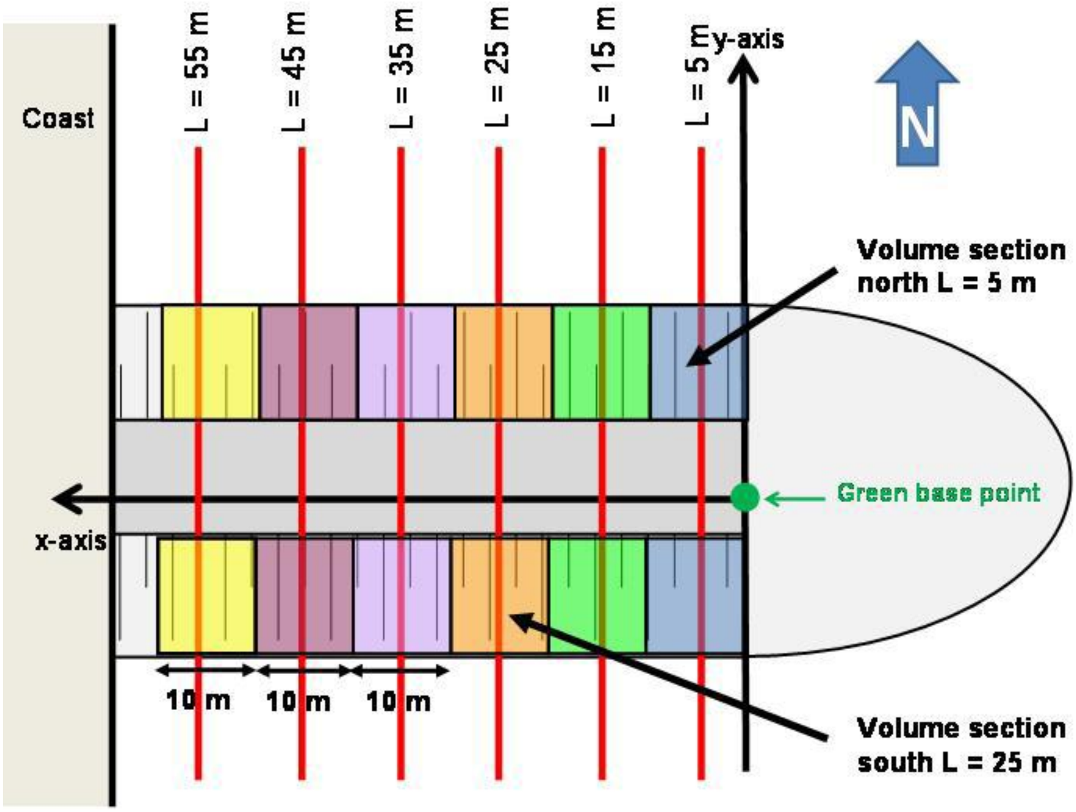


FIGURE 3-10 - SECTIONS OF VOLUME CALCULATION (REPORT 2008)

The volume is calculated as follows;

- The volume above the water level is taken into account as the volume of the groin section. The water level of 2011 is used for all the years (such that comparison is possible). Because the water level of 2011 is used, the volumes calculated in previous years are recalculated. This is done with the data from the report of 2004;
- For the volume calculation of the years 2002, 2003 and 2004, the cross-section of L=5m is taken as normative for the volume of the first section (L = 0-10m), the cross-section of L=15m is taken as normative for the volume of the second section (L = 0-20m), and so on;
- For the volume calculation of this year, the average of the cross-sections L=0m and L=10m is taken as normative for the volume of the first section (L=0-10m), the average of the cross-sections L=10m and L=20m is taken as normative for the volume of the first section (L=10-20m), and so on.

Because of the lack of data from the last cross-sections only the sections L=0-10m till L=30-40m are taken into account in the comparison of the volume.

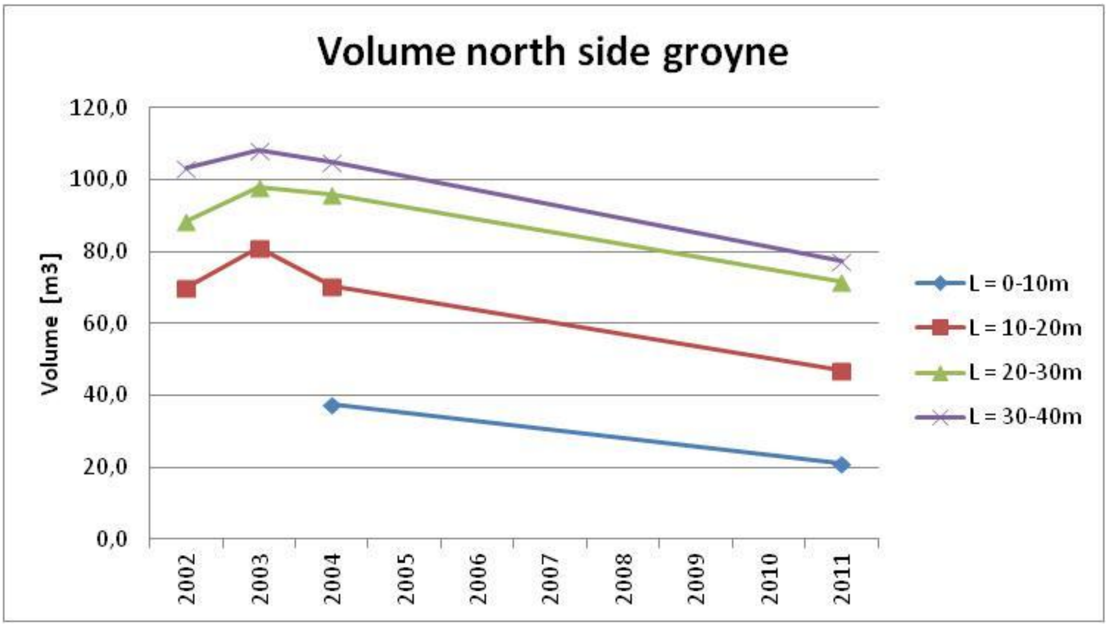


Figure 3-11 - Volume north side groin per section

The volume change of the sections on the north side of the groin is given in Figure 3-11. At the north side of the groin no measurements were done at the first section in the first two years. The overall change that can been seen over the years for all the sections is as follows;

- An increase of volume in the first year;
- A steady decrease after 2003.

Figure 3-12 gives the change in volume for the south side of the groin. On average a decrease of volume can been measured over the years.

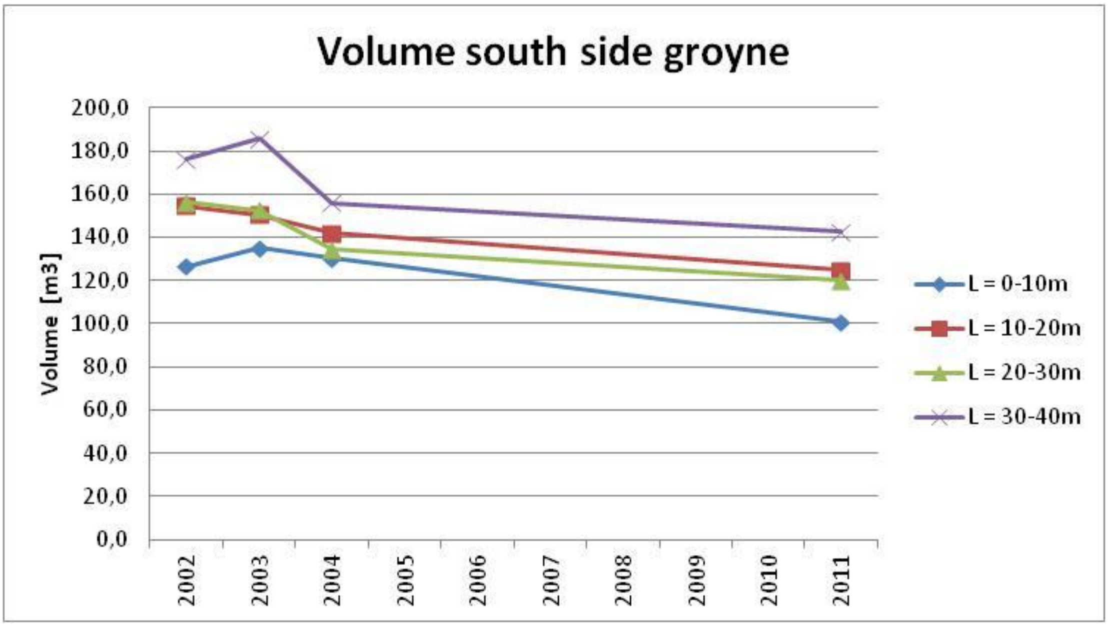


Figure 3-12 - Volume south side groin per section

Multiple reasons can be given as explanation of the change of volume, the most important ones are mentioned beneath;

- Inaccurate measuring. Because of inaccurate measuring an increase (or decrease) of volume can be measured. Because of the rough surface differences because of different measuring points are easy acquired. It also depends on the person who is measuring, does the person place the measuring stick more on high point or low points?;
- An increase of volume can be explained by movement of stones of the tip of the groin (where no cross-sections are measured) in the direction of the shore. The tip of the breakwater was heavenly damaged, which makes it assumable that stones have been moved in the direction of the shore. After the first year the small stones where moved from the tip in the direction of the shore. The next year the heavy storms moved those stones further in the direction of the shore or moves them into to the sea, what results in an decrease of the volume;
- The stones applied on the groin are too small, this results in moving of the stones during the storms. This is clearly visible in Figure 3-3 where stones are moved from the slope to the top of the groin. Besides movement of stones, the stones are also rocking during storms, which finally results in breaking of stones. So the stones become smaller, which will results in even more damage during storms.

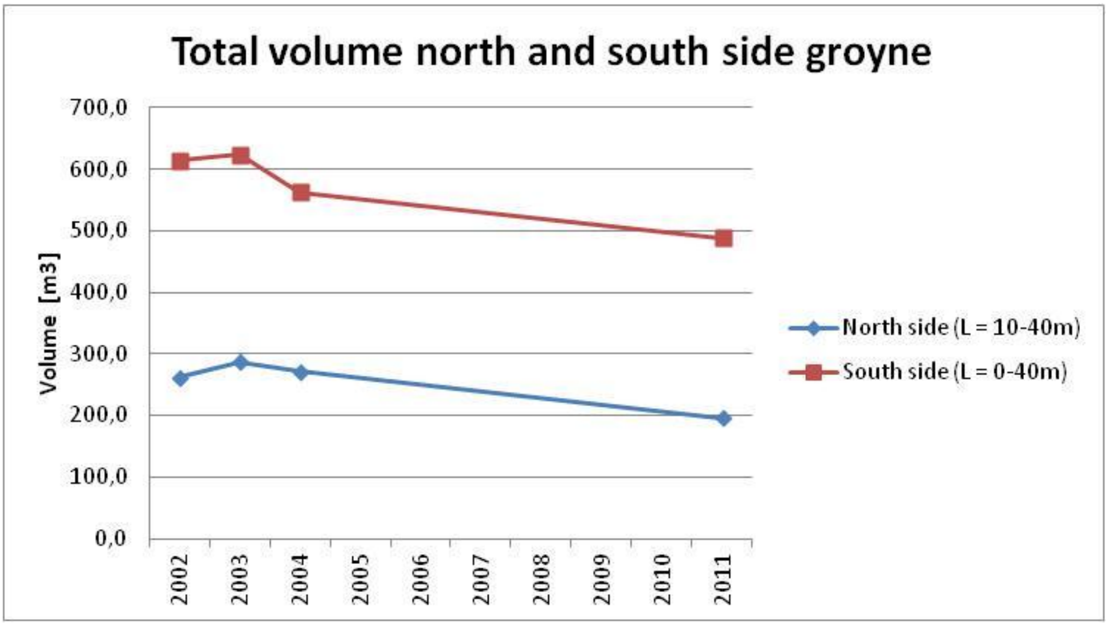


FIGURE 3-13 - TOTAL VOLUME NORTH AND SOUTH SIDE OF THE GROIN

Figure 3-13 gives the total volume of the north and south side of the groin. Also in the total volume the same tendency is visible;

- A small increase in volume in the first year;
- And after the first year a steady decrease.

An overview of the volumes is given in Table 3-2. The relative chance of volume is given in Table 3-3. As can be seen in Table 3-3 the total volume increased 4% in 2003 (in comparison with 2002), the total volume decreased 8% between 2003 and 2004 (and 5% between 2002 and 2004). In comparison with the first measurement in 2002 a total decrease of volume of 22% has occurred till now.

Year	Volume of north side L = 10-40m [m3]	Volume of south side L = 0-40m [m3]	Total volume [m3]
2002	262	614	876
2003	287	624	911
2004	271	563	834
2011	196	489	685

TABLE 3-2 - CALCULATED VOLUMES OF THE CROSS-SECTIONS

	2002	2003	2004	2011
2002	x	x	x	x
2003	+4%	x	x	x
2004	-5%	-8%	x	x
2011	-22%	-25%	-18%	x

TABLE 3-3 - RELATIVE CHANGE IN VOLUME (DATA USED: NORTH SIDE L = 10-40M & SOUTH SIDE L = 0-40)

3.3 HARBOR IN FRONT OF GRAND HOTEL VARNA

A couple of years ago the construction of a new harbor in front of the coast line was started. The harbor would be used in summer for pleasure boats, for tourism purposes. As mentioned in the introduction of this chapter, the construction has stopped and the harbor and the breakwater are still unfinished.

A part of the materials needed to finish the breakwater are already in stock in the harbor, such as natural rock, tetrapods and massive rectangular concrete blocks.

At the shore behind the harbor a new hotel is build. This hotel is probably not only a hotel but also a sea defense protected structure. Nowadays it is not allowed to build a hotel this close to the shoreline, exceptions are made for structures that also have a function as land protection structure.

Currently the breakwater is used by fishermen, just like all the groins and breakwaters are used as ideal spot for fishermen. Those spots are rich in fish.

The protected space between the structure and the beach attract large groups of fish. Fishes are using those protected spots as a natural birthing place.

FIGURE 3-14 - OVERVIEW OF THE BREAKWATER AND HARBOR

In normal circumstances the wind on the black sea blows from the East South East (ESE[1]). The harbor entrance is in the same direction as the main wind direction and hereby also the main wave direction. This is possible but it is more preferable that there is a small angle between the waves and the entrance of the harbor channel. The waves move into the harbor and are reflected on the concrete wall and moves further into the harbor. The reflecting waves in the harbor can form a problem for the moored vessels.

Looking at the breakwater situated to the far south (see Figure 3-14 and Figure 3-15) it is clearly visible that the wave energy behind this breakwater is much less. But during storm conditions the waves are coming from a different direction. So the southern breakwater is only effective during summer.

Within the harbor design some mistakes are made;

- The position of the breakwater is wrong. In the current situation the waves enter the harbor and reflecting against the walls in the harbor;
- The walls inside the breakwater reflecting the waves. This results in amplification of the wave. Placing rough material (rocks) in front of the wall which is reflecting the waves into the harbor can result in wave energy dissipation, and in this way reducing the reflection;
- There is an overestimate of the amount of boats in the area;
- The cost/benefits where estimated wrong. The harbor is not feasible (this is one of the most important reasons the construction is stopped).

[1] www.windfinder.com

The current breakwater is not yet finished and blocks are stored in the harbor. The quality of the concrete elements is bad as well. A part of the elements are not reinforced and by those who are reinforced, the reinforcement is eroded. It is remarkable that there are so much different building materials used in the design. In the design they want to place tetrapods in front of the caisson elements to dissipate wave energy. By using tetrapods and caisson elements, the design becomes expensive.

Because the harbor is used only in summer an alternative could be a floating breakwater. The floating breakwater can be used to protect the boats during summer. And when the harbor isn't used anymore (during winter), the breakwater can be towed to another place. Because the breakwater is only used in summertime, the design can also be less massive.

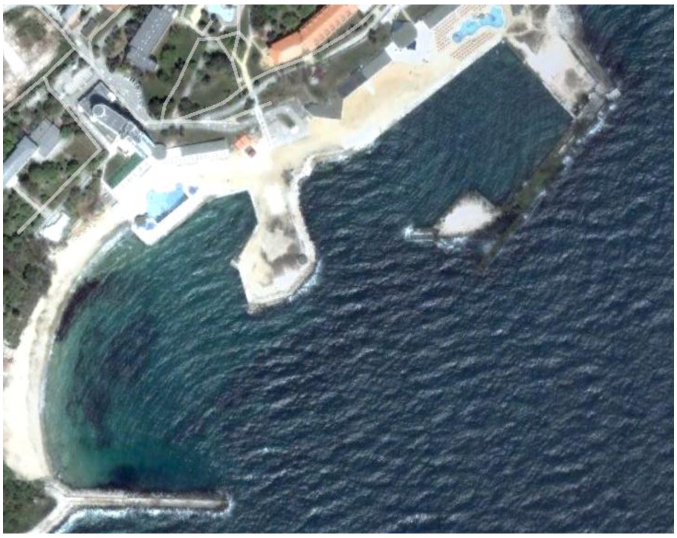


Figure 3-15 - The wave patterns in the harbor and at the small beach

Figure 3-16 - The northern part of the breakwater

At the right site of Figure 3-16, the concrete breakwater elements can be seen. These elements have a length of 8.2m and are 2.68m wide. The height of the elements is 0.52m. In the current situation, the breakwater has a freeboard of 0.45m.

In the Black Sea there is hardly any tide, the difference is at most 9 centimetres. Because of a lack of wave data, the maximum wave is taken as half of the depth. The depth is approximately 5m (taken from Figure 3-17). This results in waves of approximately 2.5 meter high in storm conditions (higher waves will break before they reach they breakwater).

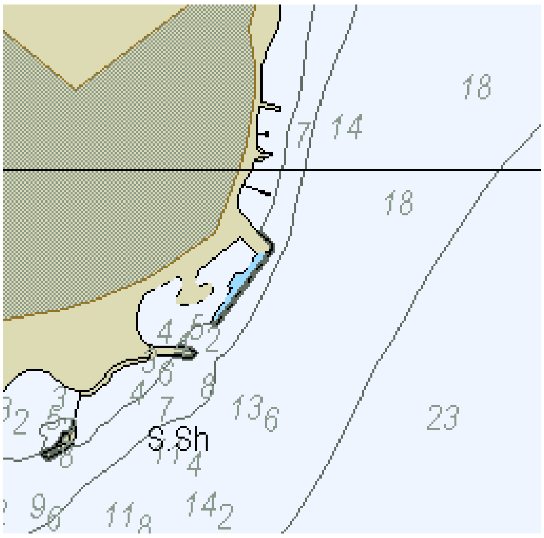


FIGURE 3-17 - DEPTHS IN FRONT OF THE BREAKWATER OF THE HARBOR

Overtopping over vertical walls (like the caisson breakwater) can be calculated by the following formula (d'Angremond, 2009):

$$\frac{q}{\sqrt{gH_{m0}^3}} = ae^{\left(-b\frac{R_C}{H_{m0}}\right)} \rightarrow q = a\sqrt{gH_{m0}^3}e^{\left(-b\frac{R_C}{H_{m0}}\right)} \qquad (3.3)$$

q = discharge

a = experimental coefficients with a value of 0.04

b = experimental coefficients with a value of 1.8

H_{m0} = wave height calculated from the zero-th moment of the spectrum

R_c = crest level (above Still Water Level)

g = acceleration of gravity

This formula is valid for wave impact under non-impulsive conditions.

When a wave hits a vertical breakwater, it can result in large amounts of spray. This spray can be blown over the breakwater by wind. This effect of water spray over the breakwater is not included in the above formula.

$$q = a\sqrt{gH_{m0}^3}e^{\left(-b\frac{R_C}{H_{m0}}\right)} = 0.04\sqrt{9.81 * 2.5^3}e^{\left(-1.8\,\frac{0.45}{2.5}\right)} = 358\ l/s/m \qquad (3.4)$$

When applying the above formula a very large amount of overtopping is found. This is directly related to the extreme low free-board (in comparison with the wave height).

For a breakwater in front of a harbor the quantity of overtopping is far too large. When visiting the breakwater it is directly clear that the breakwater is not finished yet. But from the information gained at the visit it looks like construction of the breakwater will not be continued. In this case the current situation is the “final” structure.

The Eurotop manual [PULLEN ET AL, 2007] gives the following recommendations for overtopping over a rubble mound breakwater separating a harbor and the sea;

- A mean discharge of 50 l/s/m will result in significant damage or even sinking of large yachts;
- A mean discharge of 10 l/s/m can result in sinking of small boats (5 to 10m behind the wall) and/or damage to larger yachts.

The current calculated 358 l/s/m is far too large for a harbor. When creating a crest height of 5.4m above sea level, the overtopping will be brought back to 10 l/s/m.

3.3.1 Conclusion

Resulting from the above analyze the following conclusions can be drawn;

- There was no cost benefit analyze made for the project (a heavy protected, expensive harbor for a small capacity of ships);
- The breakwater/entrance is not in the right position. During the summer season (the season for which the harbor is build) the waves enter the harbor by the entrance. Inside the harbor the waves are reflected, this results in fluctuations inside the harbor;
- Building materials were made. But the breakwater is never finished, so the materials are still in stock;
- Because the breakwater is never finished, the free-board is to small and overtopping occurs even when there are only small waves.

Especially a good cost benefit analyze could prevent a project failure like this one.

4 Asparuhovo Beach

4.1 Introduction

Asparuhovo Beach is located south of Varna, adjacent to the Black Sea. Nowadays the beach is used by the local people. The beach is not maintained very well, the restaurants and other facilities are in a bad condition. The main cause of this deterioration is the absence of economic activity on that beach. Therefore this area needs a new impulse.

Figure 4-1 - Overview of Asparuhovo Beach

In the project area there is need for a new marina. Some other marinas are located in the neighbourhood, but the capacity is not enough. By creating a marina at Asparuhovo Beach the area gets a new impulse and the need for a marina is also fulfilled.

The entrance of the marina cannot be connected with the channel which connects the lake 'Varnensko Ezero' with the Black Sea, because large vessels cross this channel and produce large waves, which will consequently enter the marina. Also from the point of safety it is not feasible. The second option is to create an entrance in the existing Asparuhovo beach. To investigate this option it is necessary to know the profile of the beach and the bathymetry in front of the beach. In the previous year this investigation has been done by another group of Bulgarian and Dutch students. By comparing these results with the present results a conclusion can be made about the stability of the beach. Also there is a need to know the soil parameters, to determine the best location of the entrance.

The existing breakwater at the northern tip of the beach is slightly damaged. The causes of this damage need to be investigated. Also a prediction has to be made of the safety of the breakwater if a marina entrance channel will be constructed in the future.
This chapter will look for an answer on the following questions:

- Is it possible to place the entrance of the marina at Asparuhovo beach?
    - Is the beach stable?
    - What kind of sediment has to be dredged?
    - What are the implications for the existing breakwater

In order to be able to answer these questions the following measurements have been done:

- Water line measurements with GPS
- Cross-section measurement with a theodolite
- Bathymetry measurement in front of the beach
- Sand samples of the beach and in front of the beach
- Investigation of the breakwater

4.2 WATER LINE MEASUREMENTS

The water line has been measured this year for the second time. The results can be compared with the results from the last year. In Figure 4-2 - Waterline measurements is the graph of the waterline had been depicted. The GPS coordinates are plotted into this graph. The underlying graph is showing a different waterline, which means that the waterline has shifted easterly, which would indicate accretion of the beach. But not hard conclusions could be made because of the two lines from two different years are very close to each other. The measurements could show the development of the waterline.

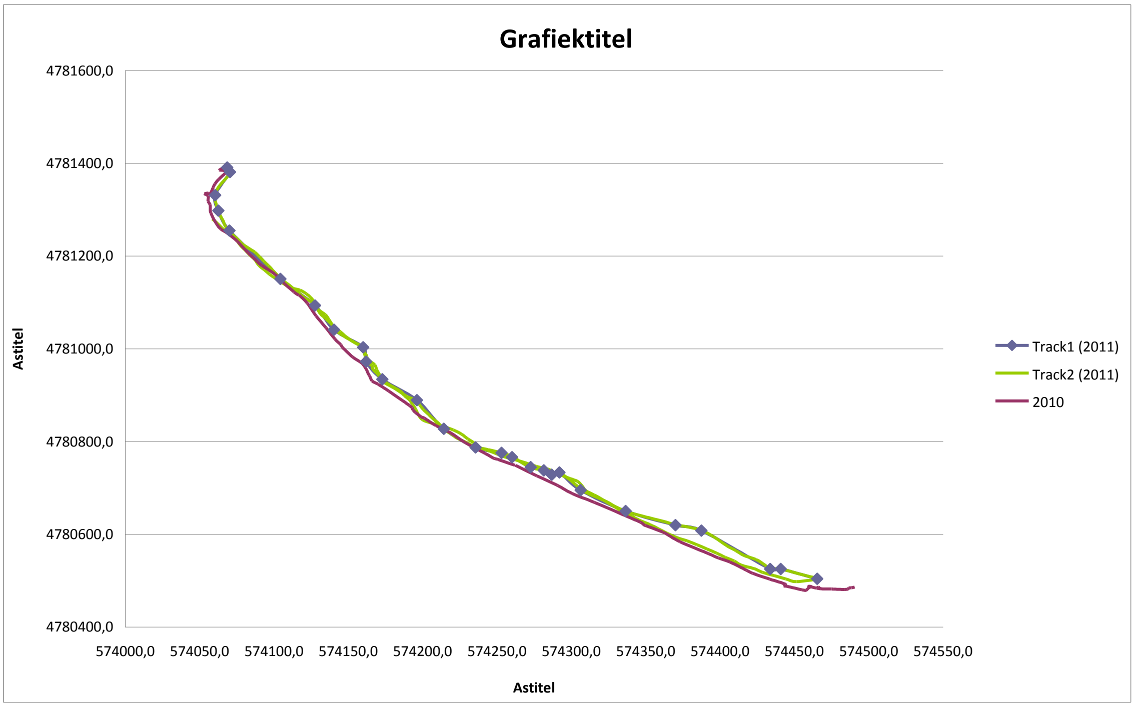


FIGURE 4-2 - WATERLINE MEASUREMENTS

4.3 Cross-section measurements

In this section the measurements of the cross-sections are presented. This measurement have also been done last year. To get reliable measurements the following sequence of activities has been followed:

1. Determining the reference height point
2. Determining the base line
3. Setting the base line
4. Measuring the cross-section

An overview of the base line, reference points and measured cross-section are viewed in Figure 4-3.

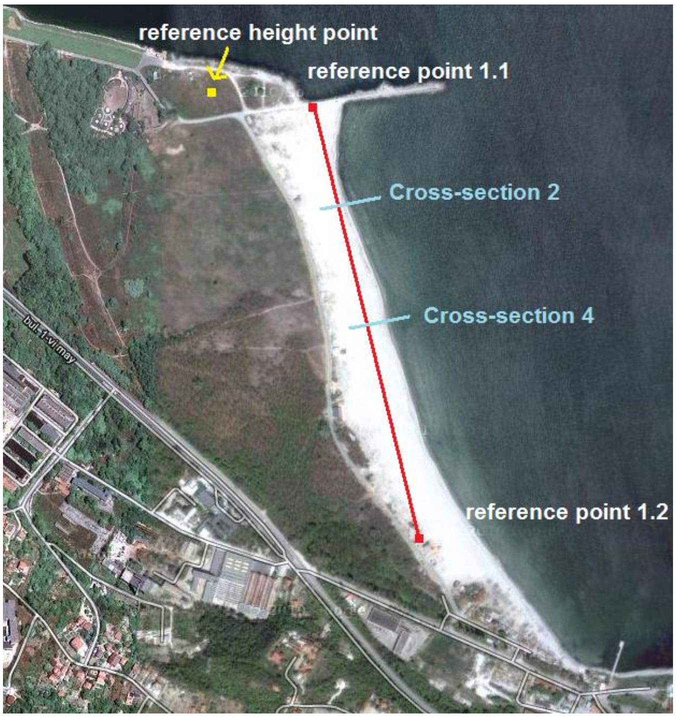


Figure 4-3 - Overview of cross-section measurement points

4.3.1 Determining the reference height point of the previous measurements

To be able to compare the results of this measurement and the one of previous year, the same reference height and reference points had to be used. To avoid confusion the reference points in this report have the same name as in the report of 2010. During the measurements of 2010 the reference points have been marked. The reference height was located on a small building, see Figure 4-4. It is assumed that the building hasn't displaced. All the beach profiles are measured relative to the red line on the building, which is taken as the zero level.

FIGURE 4-4 - OVERALL REFERENCE HEIGHT POINT ASPARUHOVO

4.3.2 DETERMINING THE BASE LINE OF THE PREVIOUS MEASUREMENTS

The previous measurement has shown that the beach is quite uniform. Because of the uniformity of the beach not all the cross-sections of previous measurements has been taken into account. Only two cross-sections, which lie on a large distance from each other, have been taken into account. The measured cross-sections are corresponding to cross-section 2 and 4 of the measurements of 2010. By comparing the results from these measurements an idea can be obtained of the stability of the beach. During the previous measurement two base lines have been used, because of the curvature of the beach. This year only one base line has been used, because not all point have been taken into account.

The base line is created by two fixed objects:

- Reference point 1.1: Near breakwater, marked with 'BL Delft'. Coordinates: T 574027 E /4781393 N, see Figure 4-5

- Reference point 1.2: Yellow dressing box on the beach, marked with '2010 CT5318'. Coordinates: T 574167 E / 4780749N, see Figure 4-6

Figure 4-5 - Reference point 1.1

Figure 4-6 - Reference point 1.2 (yellow box)

4.3.3 Setting the base line

It was decided that the profiles to be measured are located at 200 m and 400 m from reference point 1.1, corresponding with cross-section 2 and 4 from the research of the previous year.

To set the baseline the following instruments were used:

- Poles
- Measuring tape(50m)
- Prism (to determine a point in line with two other points)
- Handheld transceivers

Every time 50 meter was measured with the tape. Then a pole was placed as a temporary fixed point. Subsequently the second point was set out on a distance of 50 m in line with the previous poles. This sequence was repeated until the desired points were reached (200m and 400 m).

Some errors may be introduced because of the fact that we couldn't measure 200 m in one time. It was done in steps of 50 m. Each measurement has a certain accuracy in X and Y direction. X is defined as the transverse axis and Y is defined as the longitudinal axis. Errors in y direction are not very important because of the uniformity of the beach. Errors in X direction have a greater impact on the measurement results. For example if the base line poles are placed too much seawards, an artificial erosion rate will be measured. The possible errors which can influence the results of this investigation could be in order of meters in Y-direction and in the order of 1m in X-direction.

4.3.4 Measuring the cross-section

To measure the cross-section it was decided to measure the height of the locations near the discontinuities in the beach profile. The measurement was done with the following instruments:

- Theodolite
- Levelling rod
- Measuring tape

The two profiles are measured with two different theodolites, from different places, with different heights. The height of the theodolite, which was used for cross-section 2, was measured by holding a levelling rod near the reference height point. It was hard to determine the exact height, because of the large distance between the theodolite and the reference height point. The introduced error in height can be in the order of a few centimetres. This error is not thought to be significant, because of the scope of the profile measurements. The theodolite, which was used for cross-section 4, couldn't see the reference height point. Therefore the height of this theodolite was determined by placing a levelling rod near the other theodolite. So also the height of this theodolite may have some error, which is in the order of a few centimetres.

During measuring the cross-section in the sea, some extra errors might have been introduced, because of the instability of the levelling rod. The error is assumed to be several centimetres. So the measured heights are quite accurate in the order of decimetres, which is accurate enough for this research.

The measured beach profiles of 2011 are plotted together with the profiles at 2010 in Figure 4-7 and Figure 4-8.

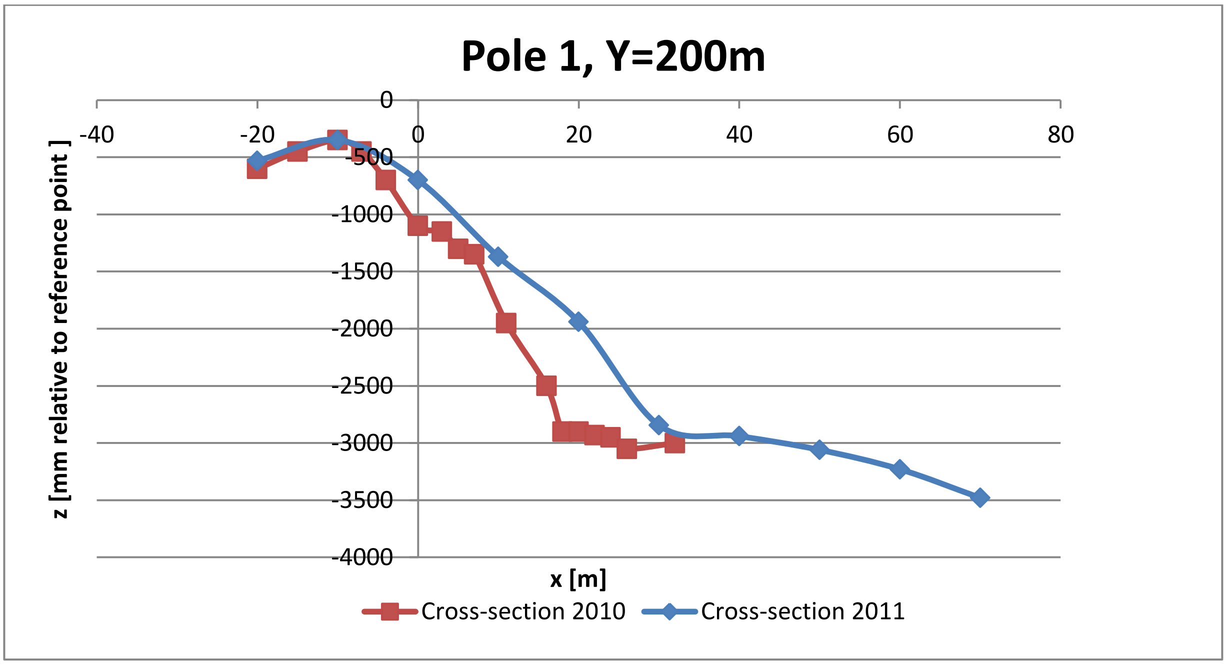


Figure 4-7 - Cross-section at Y=200m in 2010 and 2011

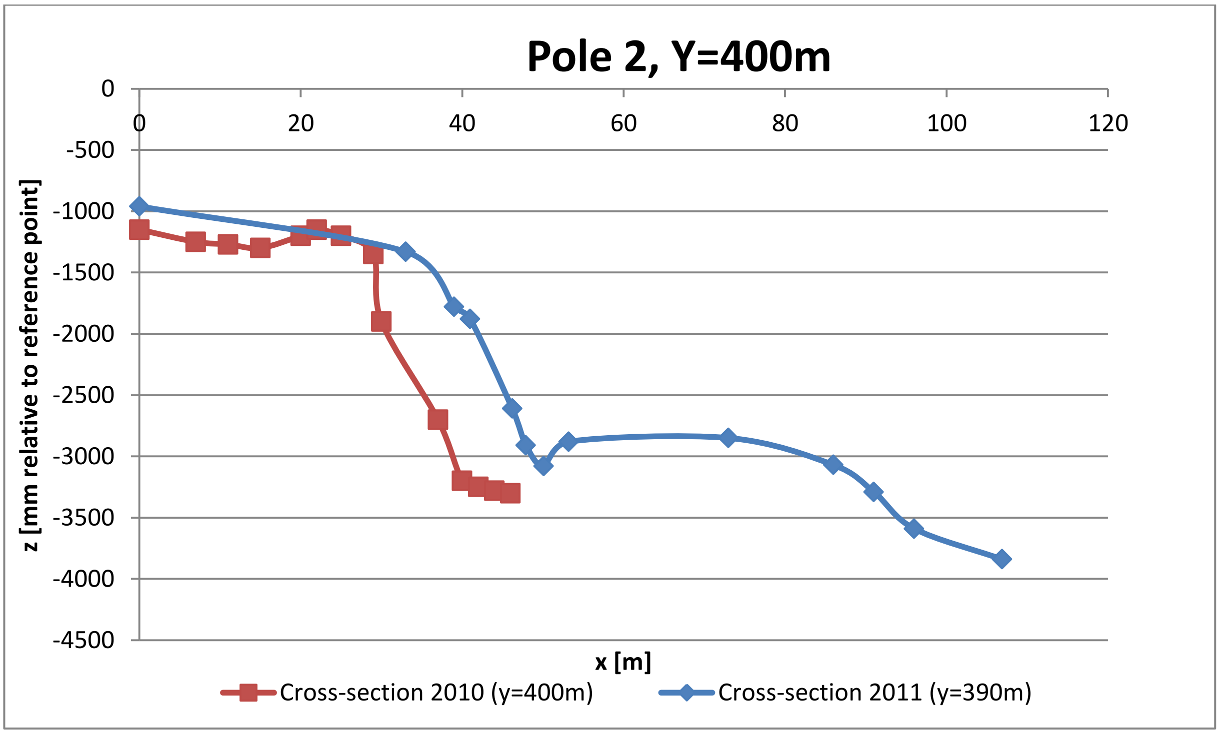


Figure 4-8 - Cross-section at Y=400m in 2010 and 2011

4.3.5 Conclusion of cross-section measurement

The introduced errors in the measurement, which causes are explained above, are summarized in Table Table 4-1.

Direction	Accuracy
X (transverse on the beach)	O(m)
Y (longitudinal on the beach)	O(10m)
Z	O(dm)

Table 4-1 - Accuracy of the profile measurements

The cross-section at y=200m is quite similar for 2010 and 2011 between x=-20m and x=-5m. This supports the idea that the baseline is set at the same location as previous year. Seawards from x=-5m a significant accretion can be observed. At some points the beach profile has moved about 10m seawards. According to Table Table 4-1 this observed accreting cannot (only) be the cause of measurement errors.

The cross-section at y=400m also shows a significant accretion, which is, like the cross-section at y=200m, in the order of 10m. The sand bank in front of the beach, which is observed during the measurements of 2011, was not observed during the measurements of 2010.

Although a certain accretion seems plausible after observing the results, an accretion rate of 10m/year doesn't seem very realistic. The difference between the beach profiles of 2010 and 2011 are probably not caused by seasonal variation. Both measurements took place in October, and as shown in Table 2-1 and Table 2-2, more storm events occurred prior to the measurements in 2011. More surveys are needed to analyse the exact accretion rate of Asparuhovo Beach.

4.4 Bathymetry measurement

To provide data for the bathymetry of the Asparuhovo Beach measurements are made by use of an Echosounder. Thanks to the good weather it was possible to sail for the whole day and the boat has made several trips to provide the data needed for the figures of the bathymetry. The results of the bathymetry measurements are presented in Figure 4-9 - Upper figure is the depth contours and below a 3-dimensional plot of the bathymetry. The white area represents the waterline.

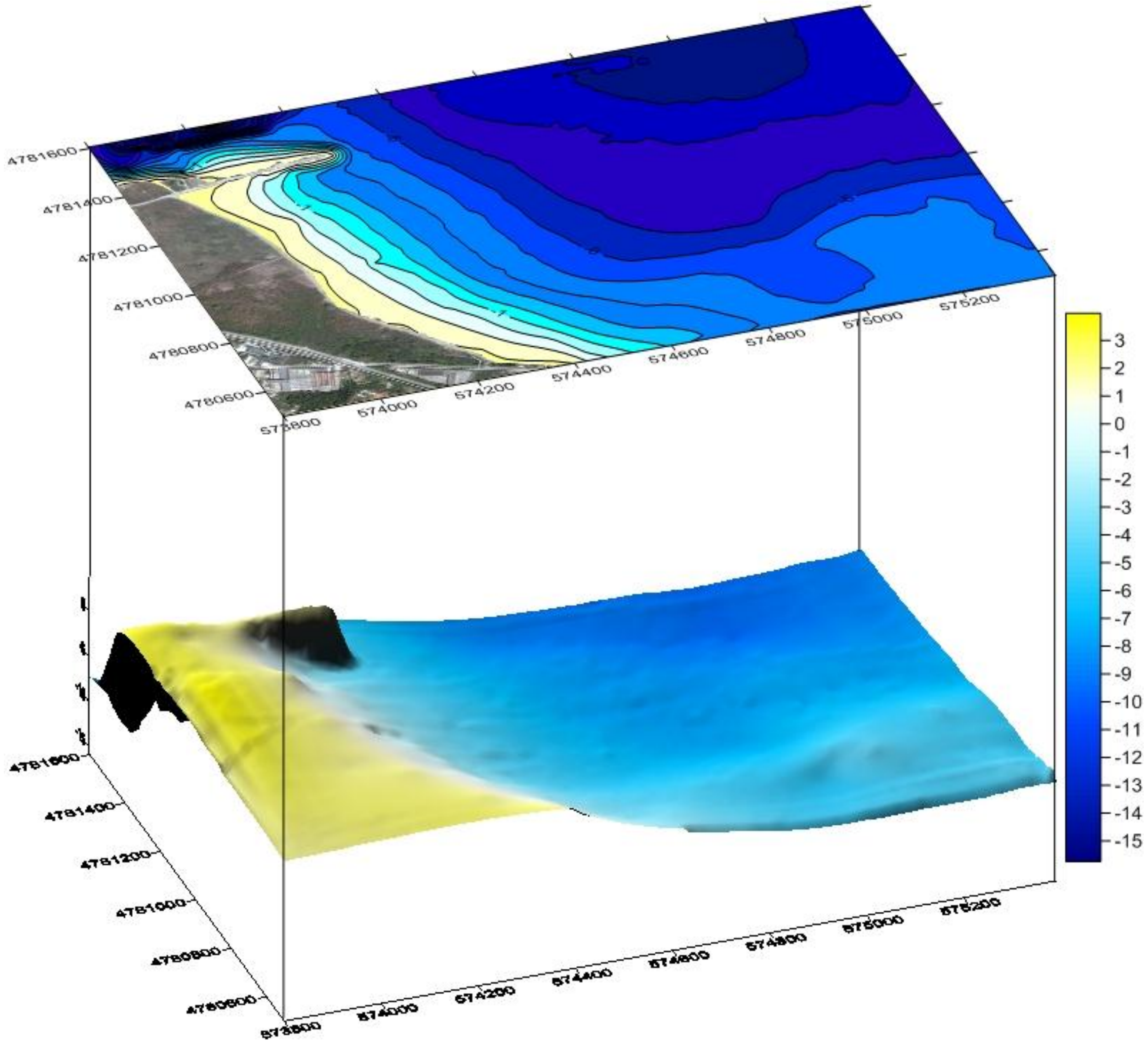


Figure 4-9 - Upper figure is the depth contours and below a 3-dimensional plot of the bathymetry. The white area represents the waterline

4.4.1 Input of data

Besides the data provided from the echo sounder some other data is used. The waterline is measured (see paragraph 4.2) and as input we gave it a depth of 0 m. The hard structures behind the beach are added to the data with an height of 2 m up to the ground. The same is done for the breakwater. The combination of the data gives a clear view on the bathymetry and the positioning comparing to the beach.

4.4.2 Difference measurements between 2010 and 2011

2010

In 2010 the weather wasn't that good to provide good depth measurements with the echo sounder. The waves were too high to provide very good and reliable measurements. So the sailing route was only one trip to cover the outer boundaries of the area for the bathymetry measurements. For good results near shore in 2010 eight cross sections are made over the whole beach.

2011

This year the weather was a lot better. So the boat with the echo sounder has made several trips to provide more data. The difference in measure points with 2010 can be seen in Figure 4-10. A note has to be made. In 2011 the reference height (zero-level) is the water level. In 2010 this is the reference point which is around 2.3 meters higher than the water level. The last difference is that in 2011 only two cross sections are measured.

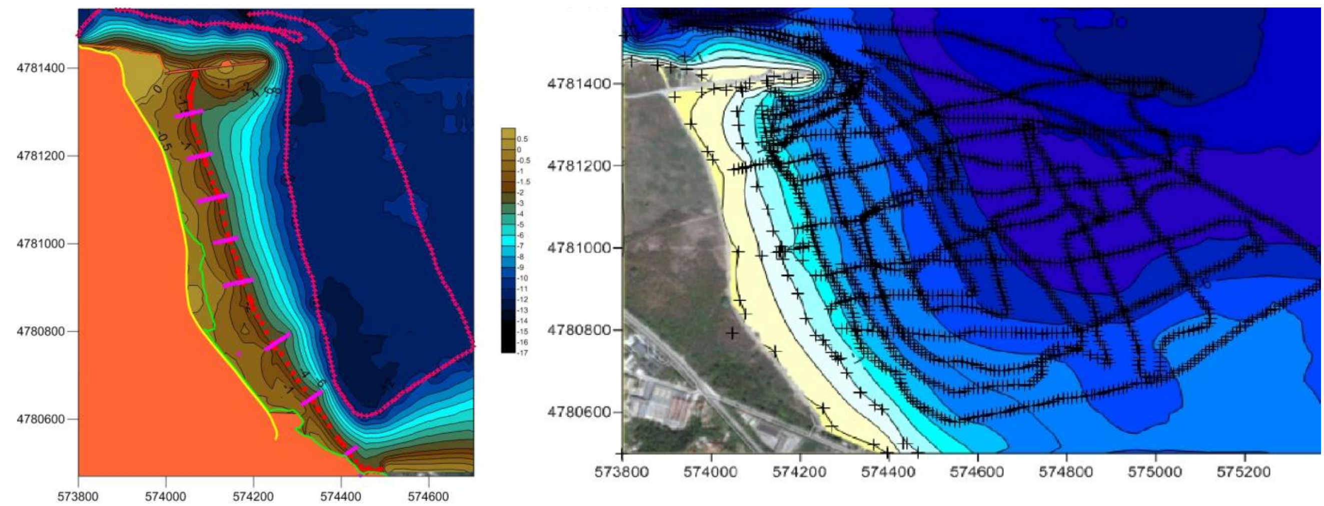


Figure 4-10 - Left: the contourplot of 2010. The red dotted line represents the waterline and the red crosses are the measured points with the echosounder. Right: The waterline is the white area and the black crosses are the measured points

4.4.3 Conclusions

The most notable difference is the slope of the beach. From the figures it can be seen that the slope has decreased over the last year. This can be explained by the weather conditions. Because in 2010 there were much more waves and the weather was less than it was in October of 2011. This year there were no waves worth mentioning. The result of this difference in weather conditions can lead to a different beach profile. In 2010 the beach profile probably looked like a winter of a storm profile and in 2011 the summer beach profile was clearly visible. Further off shore it is hard to draw some conclusions because in 2010 the boat didn't sail a lot and all the data is provided by interpolation between the measured points. These interpolated values are less reliable.

Doing measurements in the future will provide data to compare with the situation in 2011 for the bathymetry a bit more offshore from Asparuhovo beach.

4.5 Breakwater Asparuhovo Beach

4.5.1 Introduction

Figure 4-11 - Breakwater Asparuhovo

In this part of the report the breakwater of the Asparuhovo Beach is described. The breakwater is located at the northern part of the beach. The design function of the break water is to maintain the entrance of the Chanel, which connects the harbor of Varna to the black sea. The secondary function of the breakwater is to protect the Asparuhovo Beach against erosion during. In this part the breakwater will be analyzed and a conclusion will be taken about the technical and functional state of the breakwater. In Figure 4-11 the location of the breakwater is depicted.

In general the following aspects are observed: length, cross-section used material and the state of the break water.

To measure the dimensions of the break water measuring tape is used. Some parts of the breakwater were in-accessible to measure. To solve this, estimations are made. The technical state of the break water is analyzed by observations. Later on some pictures will be used to describe the technical state of the break water.

4.5.2 Dimensions

The breakwater can be divided in four different cross sections. In Figure 4-12 the breakwater with the cross sections are shown.

Figure 4-12 - Sections

Section 1

The first one is around 60m long, with the beach on the southern side and small natural stones with d_{50} between 20 and 40 cm on the northern side. Part of the stones (sandstone) was obtained by dredging the canal and was used to build the breakwater.

Section 2

The second section is 25m long and has the same kind of stones as the first cross-section on both sides and the gaps between the stones are filled with sand, coming from normal wave action. During heavy wave action this sand may be washed away and can cause sliding of the stones, resulting in a gap under the concrete slab. On the northern side there are concrete cubes with an edge length of 0,8m and 1,0m because of the heavier wave action.

Section 3

The third section is the longest one (ca. 100m) and is reinforced with concrete cubes with edge length of 1.0 m at the beginning to 1.3 m at the end of the section. Those cubes are randomly placed. In the middle of the section there is a part twice as wide as the other part, probably for the passing of trucks during construction time. On its outer part there were some concrete elements with rusty reinforcement, probably left over from some other construction site.

Section 4

The last section at the tip of the breakwater is a combination of tetrapods, blocks and stones. The tetrapods are all of the same size (H=2.3m). There is just one layer of tetrapods in most places. Sometimes there are two. Especially at the head of the breakwater the amount of tetrapods was not as much as you would expect. So probably some tetrapods were moved during storm. Some blocks were placed in between the tetrapods and the sub-layer consisted usually of stones with a D_{50} of about 40cm. Rocking seems to have caused damage to a lot of tetrapods and sometimes even a whole leg was broken off. It's hard to tell whether this happened during storms or if it's a matter of poor construction. The concrete slab at the end of the breakwater was constructed in situ. From this you can see that the tetrapods have moved, because there was a gap between the slab and the adjacent tetrapods.

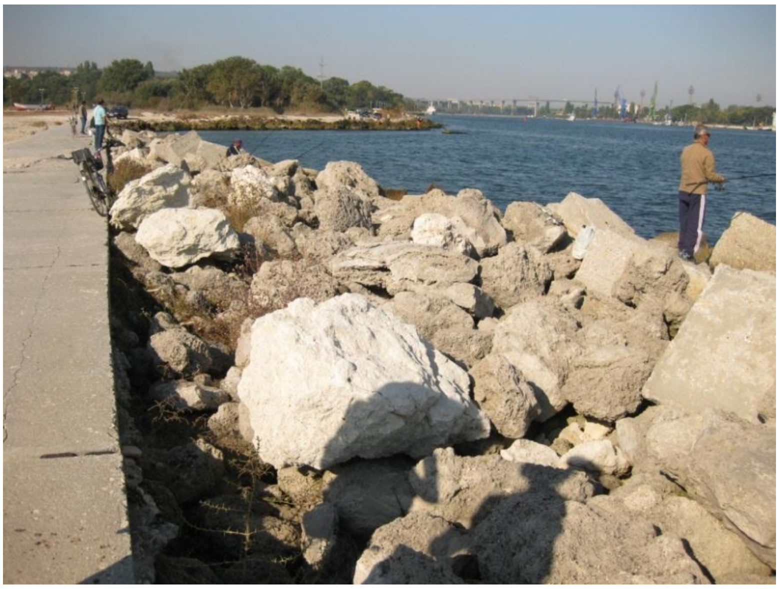
4.5.3 TECHNICAL STATE OF THE BREAKWATER

To determine and analyze the technical state of the breakwater an observation took place.

First of all some pictures will present the technical state. After this a conclusion will be given.

The concrete slab was broken in many places which led to the conclusion that the sub-layer wasn't really even or settlements of the sub-layer took place. The concrete slab has been casted on the stones. In the base of the breakwater the concrete slab was severely damaged and a completely corroded steel pipe was visible on one side. This pipe served for electricity cables for lamps that are missing (the rectangular openings in the slab).
This picture shows a crack that has propagated along the entire length of the breakwater. On the broken part you can see a corroded iron pipe for electricity

cables. This iron pipe is a weak spot in the concrete and that explains why the crack is in the same place on every section of the slab.



This is an overview of the main problem of the breakwater. Next to the slab there are small stones that may be washed away by the next big storm. This will cause the visible crack along the slab to open further and eventually it will break off.

We cannot be sure what is under the concrete slab but it is not stable.

This picture was taken at the very tip of the breakwater. You can see two tetrapods with missing legs. Because of heavy wave attacks the tetrapods are rocking and sometimes even moving (local people say that). Because of

rocking, tetrapods hit each other and this can result in broken legs. Another explanation is poor construction which is obvious in some of the tetrapods (a crack in the middle). On the tip are not enough tetrapods.

The number of broken tetrapods is in the order of 10 to 15. They usually break in the middle of the leg, which is the place of stress concentration.

4.5.4 Conclusion

From the observation it is clear that the breakwater is not in a good condition. From the technical state it can be concluded that the maintenance is not proper. Also some construction mistakes were visible. First of all from the state of the concrete elements it is clear that that the quality of concrete is very poor. Secondly from the base of the breakwater till the head of the breakwater there runs a crack. Further investigation in this crack led to the outcome that exactly at the position of the crack, there is an iron pipe placed in the concrete surface plate. This iron pipe is a weak spot in the concrete and that explains why the crack is in the same place on every section of the slab.

The tetrapods, together with blocks and stones aren't a good filter, because the concrete slab was undermined at the front (and not only there).
By the observation it became also clear that some of the tetrapods were not constructed / casted at the same time. Probably the casting was stopped halfway and continued the next day or even after the weekend which led to a bad cohesion between the different castings. These are the weak links in the design of the terapods. This also means that the wave breaking capacity of the tetrapods will reduce if some elements are broken. Which means more loads attacks the break water.

The concrete slab on the top of the break water is not flexible. The plates are all connected with each other. This will lead to a larger stress in the ''floor'' of the breakwater by an upcoming wave. Also settlement of the subsoil will introduce large stresses in the concrete plates. At some parts of the breakwater the tetrapods were rigid connected to the concrete slab. It means, less flexibility of the tetrapods and also less wave breaking capacity of the tetrapods, because they to be able to move a little bit if they are hit by a wave.

4.5.5 DESIGN WAVE HEIGHT

To be able saying something about the stability of the breakwater we must also know for what kind of waves this structure has been designed. It will also provide a proper conclusion about the stability of the breakwater if the wave condition will be changed. The amour layer exists of tetrapods. The size and weight of these elements could give an idea of the design wave height.

To determine the design wave height several methods could be used. The following methods
are available to determine the design wave height:

- Hudson
- Van der Meer
- Hanzawa

In our case we are dealing with large tetrapods with a height of 2.3m (H = 2.3 m). In the van der Meer formula a lot of parameters need to be specified, like the permeability, damage level, etc. Because of the lack of data the Hudson formula is used instead of the Van der Meer formula.

<u>Mass of Tetrapods</u>

The formula's from the book of the course 'Introduction to bed, bank, and shore protection' (Schiereck, 2001), has been used to determine the volume and the mass of tetrapods.

$$C = 0.477\ H \tag{4.1}$$

C= is the leg length of tetrapod

H= is the total height of the tetrapod

V= the total volume of the tetrapod

$$V = 0.280\ H^2 \tag{4.2}$$

Assumption:

We assume that the mass of the concrete is $2400\ kg/m^3$

V= $0.280 * 2.3^3 = 3.41\ m^3$

M= $3.41 * 2400 = 8184\ kg$

Hudson formula:

$$W = \frac{p_s g H^3_{\left(\frac{1}{10}\right)}}{K_d \, \Delta^3 \cot \alpha} \qquad (4.3)$$

- W = Weight of the element [ton]
- H = Design wave height (0 damage) [m]
- Kd = Hudson coefficient [-]
- Δ = Relative density [-]
- ρ = Density of concrete [$\left[\frac{kg}{m^3}\right]$
- cot Alpha = Slope of breakwater [-]

It was not possible to determine the slope of the breakwater on a proper way. That's why some assumptions has been made for the slope. To be able to calculate a reliable wave height tree slopes has been assumed for the break water, which are generally used in breakwater design. For the values of Kd it has been assumed that Kd has a value of 7 at the trunk of the breakwater and 4 on the head of the breakwater. The different values are presented in Table 4-2 and Table 4-3

For Kd = 4

Slope	$H_{1/10}$	H_s
1:2	1,98	2.43
1:4	2,46	3.13
1:3	2.23	2.84

TABLE 4-2 - DESIGN WAVE HEIGHT FOR KD=4

For Kd = 7

Slope	$H_{1/10}$	H_s
1:2	2.30	2.93
1:4	2.97	3.76
1:3	2.69	3.42

TABLE 4-3 - DESIGN WAVE HEIGHT FOR KD=7

From the calculations of the design wave height it appears that the waves could be severe in the storm conditions. The significant wave height during storms is in the order of 3 – 4 m.

4.6 Common conclusion

In this conclusion the research questions will be answered:

- Is it possible to place the entrance of the marina at Asparuhovo Beach?
    - Is the beach stable?

According to the water line measurements and the beach profiles measurements the beach can be assumed to be stable. In comparison with the data of 2010 even an accretion of the beach is observed. The profiles have moved about 10m seawards in one year. This accretion rate doesn't seem very realistic. More surveys in the coming years are needed to be able to determine the exact accretion rate of Asparuchova Beach.

- What kind of sediment has to be dredged?

The sand sample measurement has shown that the beach is quite uniform in long shore direction. Therefore the location of the entrance channel of the marina makes no difference regarding dredging. In cross shore direction some differences have been observed regarding the grain size. At the water level the largest grains can be found (up to 0.5 mm). The sediment 30-50 m from the shoreline of the water has a grain size in the order of 0.0625 mm till 0.18 mm. While the grain size at the beach has a grain size in the order of 0.125 mm till 0.250 mm. On average the grading D_{90}/D_{10} is between 2 and 3.

- What are the implications for the existing breakwater if a marina entrance is placed at Asparuhovo Beach?

If a new marina will be located at Asparuhovo Beach more ships will pass at the southern side of the breakwater. It is assumed that the marina will be constructed for pleasure cruising. Therefore the vessels are thought to be quite small, so are their generated waves have been assumed. The implications for the breakwater are therefore negligible. Nevertheless, the breakwater is already in a bad condition, so it necessary to repair the breakwater before it collapses.

5 SIEVE ANALYSIS

The people of Bulgaria want to investigate the possibility to construct a new marina at the Asparuhovo beach. For this investigation it is important to know the properties of the sand especially the grading, the D_{50} and the amount of calcium between the sand. At first glance the beach has a high concentration of sea shells.

To determine a series of sand samples at different cross-sections are collected. The samples had to be taken to the laboratory in Delft and therefore not too many samples could be made. However, to get an accurate view of the situation this number of samples should be sufficient. An optimum needs to be found.

5.1 SAMPLING LOCATIONS

From the first observation can be concluded that the beach is quite uniform in long-shore direction. Therefore three cross-sections have been chosen, to investigate the sub-soil. The first location is the furthest away from the northern breakwater. It is chosen, because this location is just outside the area where the future marina can be constructed. The second location is in the middle between the breakwater and the first location. The third location was planned to be close to the breakwater, but due to logistics and communication problems it moved southward and it was placed 100 m from the second location. The advantage is that two samples relatively close to each other can be compared. The three locations are shown on the map in Figure 5-1with the GPS coordinates and longitude/latitude in Table 5-1.

FIGURE 5-1 - SAMPLING LOCATIONS

	UTM E (m)	UTM N (m)	Long(°)	Lat (°)
Point 1	0574291	4780709	27.913.589	43.175.494
Point 2	0574153	4781010	27.912.398	43.178.218
Point 3	0574129	4781106	27.912.126	43.179.087

TABLE 5-1 - COORDINATES OF THE SAMPLING LOCATIONS

For every cross-section five samples have been made. The first two points have two dry and three wet samples. The third point has only wet samples (due to the same communicative reasons as above) and to make a comparison with the other measurements only two of them are selected in the analysis. The x-coordinate of the cross-section is positive landward from the waterline (WL) and negative seaward. An overview of the measured locations can be found in

Point 1	Point 2	Point 3	
WL + 15	WL + 15		onshore
WL + 5	WL + 5		
WL	WL	WL	
WL - 30	WL - 30	WL - 30	offshore
WL - 50	WL - 50		

TABLE 5-2 - MEASURING LOCATIONS AT CROSS-SECTIONS

5.2 USED METHOD

5.2.1 DURING SAND SAMPLING

On the dry beach a small shovel is used to dig the sand until the waterline. Due to this primitive tool only sand from the top 50 cm of the bottom could be included in the sample. In the water a piston is used to make the sand samples. At the moment of sampling the sea was calm and there were only small waves. The samples in the water where taken approximately 1.5 meter deep. There was a clear visual observation of the colour difference in the sand from bottom to 1.5 meter lower. It can be seen that it is lighter at the sea bed than deeper into the bottom. An example of this can be found in **Error! Reference source not found.**. To get a clear sample of the entire column at three sections of the column some sand has been taken to the laboratory. Some sand from the top, middle and lower layer.

FIGURE 5-2: SAMPLE AT POINT 1 WL-50M

5.2.2 DURING CALCIUM REMOVING

As said before, the sand samples contain a lot of seashells. These seashells are in fact built up of calcium. The need to determine the amount of calcium is due to the difference in density of sand and seashells. Therefore the pickup rate by waves differs and moreover there is a difference in fall velocity/settling velocity. If one should sieve the sand samples including the seashells, the sieve curve could give a curve which is not representative for the actual sand content of that particular beach and therefore creating an inaccurate dataset. To determine the amount of calcium within the sand sample a weighing of the dried samples with and without calcium should be made. In order to show the effect on the sieving process as well, point two is sieved once with calcium and once without.

To remove the calcium from the sand samples hydrochlorideacid (HCL, *Dutch: zoutzuur*) is used. By adding HCL to calcium a chemical reaction will form CO_2. Based on the NEN 2651, concentration of 6 to 12 moles/l of HCL can be used to remove the calcium content. In our case a lot of seashells can be observed within the samples. Therefore a HCL of 12mol/l has been used to remove the calcium. In order to reduce the needed volume of HCL, the larger shells were removed manually. *Note: 12 moles/l ≈ 30% diluted hydrochloride acid.*

First the dried sand sample is weighed, than it is mixed with a small amount of demineralised water (*demi-water*). When it becomes a muddy substance, 10 ml of HCL is added which will react with the calcium and form CO_2, this step is repeated for several times until no noticeable CO_2 is formed anymore.

The muddy substance needs to be cleaned; this can be done by flushing demi-water through the sand sample above a filter. This filter can be a sieve or filter paper. For this case study a sieve size with a mesh size of 0.053 mm is used to clean the treated sand sample. After this the sand sample needs to be dried within an oven again. *Note: Oven setting 105^{0}C for 24 hours.*

5.2.3 During Sieving

After the Calcium is removed from the samples and the samples are dry again, the samples are sieved using a sieving machine (Figure 5-3). With this analysis it is possible to define the grading of the sand at different spots. A comparison between the sand-grading over a cross-shore profile as well between the sand-grading at different spots alongshore can give information about the uniformity of the beach. It also gives information as input for erosion and accretion models.

From every sample a random sub-sample of around 50-60 gram was made to investigate. The sieve machine was suited with several sieves with mesh-size: 1.7 mm, 1.0 mm, 0.5 mm, 0.25 mm, 0.18 mm, 0.125 mm and 0.063 mm. These sieves were weighed before sieving a sand sample and afterwards. The difference between these values gives the weight of the sand in a certain sieve. The sieve-time was set on 15 minutes per sample, based on experience from the laboratory.
After sieving and weighing the cumulative mass percentage is plotted against the sieve-diameter on log-scale. This is the sieve-curve; different curves can be plotted in one graph in order to make comparisons.

Figure 5-3 - Sieving Machine

5.3 Accuracy

5.3.1 During Sampling

In the long-shore direction the coordinates of the locations are measured with the GPS. The shore is relatively uniform at certain distance in long-shore direction, so the accuracy of the GPS is sufficient. The coordinates of the measured locations in the cross-shore direction are defined perpendicular to the coast-line. The points on the dry coast are measured with a measuring tape. Therefore these places can be determined quite accurate. When there is some deviation from the real distance this does not lead to much difference in the results, because the beach is very gently sloped in cross-shore direction. For the measurements in the water it was harder to measure with the measurement tape, due to the fact that the water surface is not exactly flat and it is a challenge to be exactly perpendicular to the coast. The location in cross-shore direction can therefore be approximately 1 meter closer to the shore than given. This does not make the accuracy of the measurements too low, because also in the water the slope is gentle and quite uniform.

The dry samples are taken mostly from the upper 50 cm of the surface of the beach. This is due to the lack of good equipment. A good shovel or a better dry sub-soil tool would make it possible to get samples from deeper layers of the dry beach. This would make it possible to get a clearer picture of the sand grading on the beach.

Due to the lack of experience with the piston the first samples that were taken, are of lower quality than the latter ones. The measurements have been started at point 1. The first samples contained more water and did not result in a 1.5 m column of sand, where the latter ones result in columns as shown in **Error! Reference source not found.**.

5.3.2 During removing of Calcium

The method use to dissolve the calcium can be a point of discussion. Because the adding of additional HCL is stopped once no noticeable changes are visible with the naked eye. Therefore it could be possible that there are still small particles of calcium left behind in the sand sample.

To wash out the excessive HCL a sieve with a mesh size of 0.053 mm is used. One could argue if this is an appropriate method. Because after the flushing of the excessive HCL the colour of the flushed water was dark greenish meaning that some very fine sediment is still flushed through the filter and got lost. See Figure 5-4. However one could also argue if this is a real problem because the main focus of this case study is to provide a good sand gradation and not looking to the very small particles like clay and silt.

Figure 5-4 - Filtering treated sand sample

Another problem is the fact that some sand is left behind in the filter. It appeared to be impossible to bring all the sand back to the sample-plate. Therefore probably 1 or 2 gram of the sand can be loosed and counted as calcium. However, if it is assumed that still some Calcium remains in the sample as well, this problem is partly solved. It can be stated that the obtained percentages of Calcium are quite accurate.

5.3.3 During Sieving

The sieving process can be executed relatively accurate. It is important not to lose any sand during weighing and replacing of the sand into the sieve machine. By careful handling it is reasonable to assume that the lost weight of sand is negligible during this process. The weighing devices in the laboratory are accurate till 0.05 gram. This is sufficient in order to get a reliable view on the mass of sand in one sieve. To assure that the sieving machine was working properly the samples that were sieved where between 50 and 60 gram. The exact value is not important, because the results are presented as cumulative mass percentages.

The samples that are sieved should be randomly chosen from the larger soil sample. So a random sand sample with material from the entire column should be included. In order to do so a special separation device was used. Three samples have been sieved twice, in order to see the influence of the calcium. However, these curves can also be used in order to check the randomness of the sample and the accuracy of the sieve machine. This can be done because the calcium does not influence the sieve curve too much (especially at WL+15 m). The result of this test is basically shown in Figure 5-6 and it can be concluded that the samples are random defined accurate enough as the curves coincide very well.

5.4 Sand Sampling Results

5.4.1 The Calcium Content

The results of dissolving the calcium are presented in Table 5-3.

Point 1	Location	Weight with Calcium		Weight without Calcium			weight lost due to HCL		Percentage of Calcium
	WL +15	203,0	g	189,0	g		14,0	g	6,9%
	WL +5	249,4	g	234,8	g		14,6	g	5,9%
	WL	357,2	g	324,1	g		33,1	g	9,3%
	WL -30	412,4	g	371,6	g		40,8	g	9,9%
	Wl -50	533,2	g	496,1	g		37,1	g	7,0%
Point 2	**Location**	**Weight with Calcium**		**Weight without Calcium**			**weight lost due to HCL**		**Percentage of Calcium**
	WL +15	**312,7**	**g**	**241,8**	**g**		**14,3**	**g**	**5,6%**
	WL +5	*382,6*	*g*	*358,2*	*g*		*24,4*	*g*	*6,4%*
	WL	**318,4**	**g**	**228,0**	**g**		**27,8**	**g**	**10,9%**
	WL -30	*420,4*	*g*	*392,3*	*g*		*28,1*	*g*	*6,7%*
	Wl -50	**409,4**	**g**	**314,0**	**g**		**33,3**	**g**	**9,6%**
Point 3	**Location**	**Weight with Calcium**		**Weight without Calcium**			**weight lost due to HCL**		**Percentage of Calcium**
	WL	399,1	g	NaN	g		NaN	g	NaN
	WL -30	393,6	g	369,3	g		24,3	g	6,2%

Table 5-3 - Calcium sand samples

The general trend is that the beach has a calcium content of the beach around 6 to 7%. However, there are some exceptions that are explained below. Concluding from point 1 the highest calcium concentration is within the region of the waterline and around -30m offshore from the waterline. Point 2 shows a high concentration around the waterline and at -50m offshore from the waterline. That the highest concentration of seashells is around waterline is

quite logical. Due to the light density of the seashells waves are able to easily pick them up and transport them towards and throwing them on the coast.
As said before, point 3 is sampled differently than point 1 and 2. Therefore some samples were quite useless. One can notice that point 3 at location WL has not been treated with HCL to remove the calcium. This is due to the fact that this sand sample was contaminated with so many seashells, that it would not be representative against the other two points. Basically, the sampling of this sample went wrong. Therefore it is decided not to take this point into account.

The exact reason of the high concentration calcium at WL -30m from point 1 and WL -50m from point 2 is unknown. One possible theory is that seashells got stuck within an alternating bar which moves from the near shore in offshore direction. Sand covers the seashells within the sub-layers. During the penetration sampling offshore, sand was taken from three sections of the sampling pole. So from the top, the middle and lower part of the sand sample. One could see seashells covered by sand deeper within the penetration column.

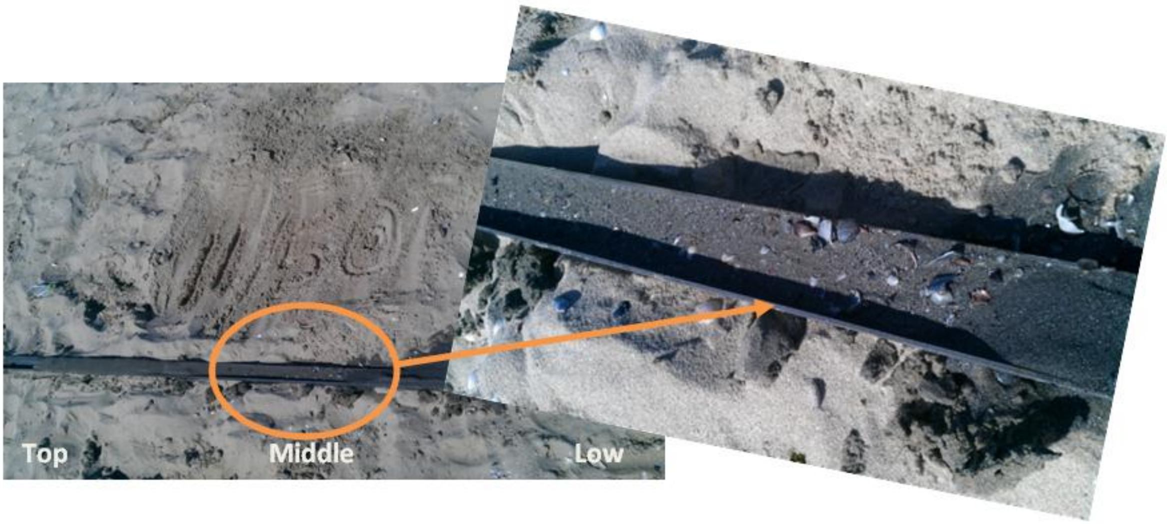


FIGURE 5-5 – SHELLS IN THE SAND COLUMN

In Table 5-3 locations WL +15m, WL and WL -50m are being printed bold. The reason is that these three points where chosen to show the necessity of removing the amount of calcium with respect to the sieve curves. One could already tell from Table 5-3 that above 10% calcium contamination of the sand sample cannot be neglected. This is also shown within the following sand curves.

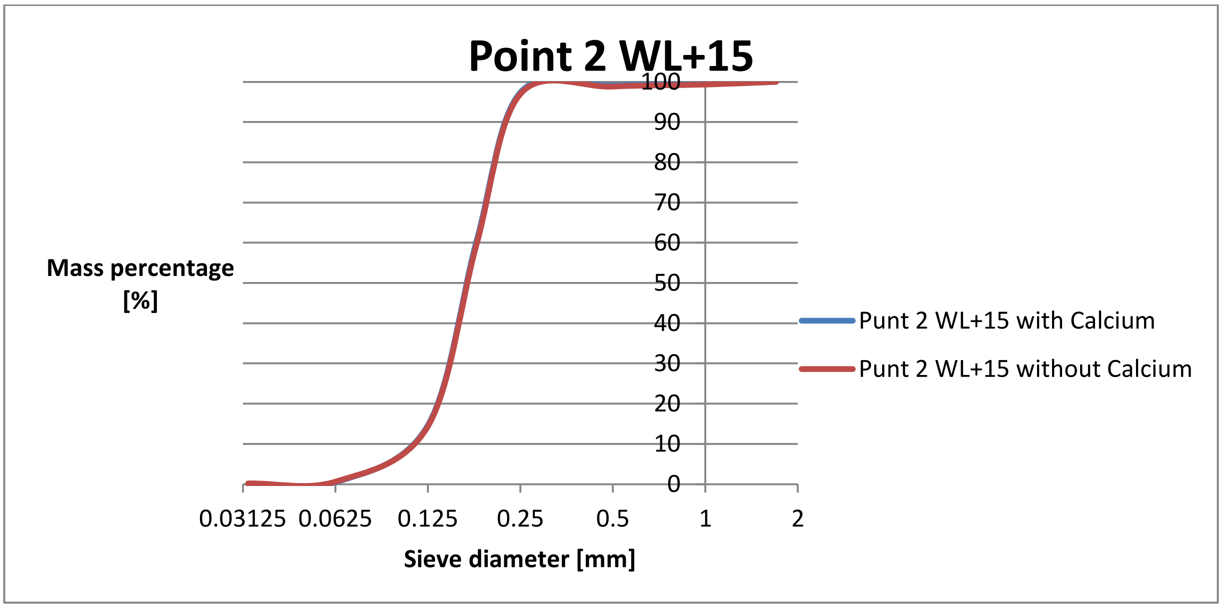


Figure 5-6 - Sieve curves Point 2 WL+15 with and without Calcium

The first sieve curves (Figure 5-6) show that with a 6% calcium contamination the necessity of removing the calcium is quite small. The two curves do show good agreement.

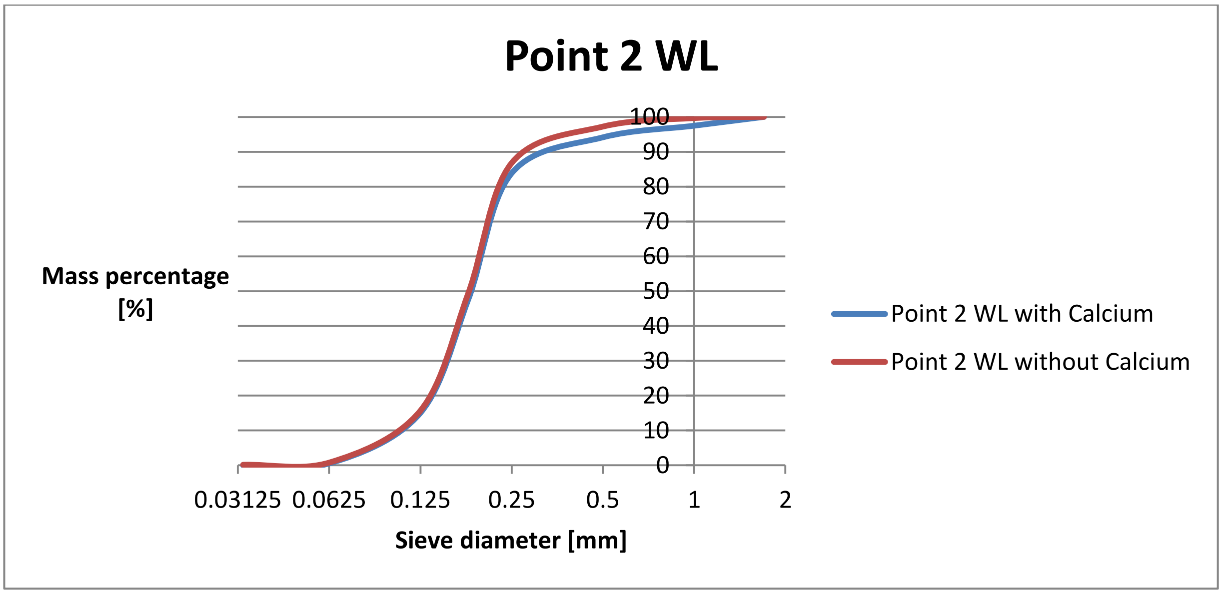


Figure 5-7 - Sieve curve Point 2 WL with and without Calcium

Within the sieve-curve of Figure 5-7 the percentage of calcium is rather high, around 11%. One can notice that the curve with calcium is more gentle sloped than the curve in which the calcium is removed. This implies that sand with this amount calcium gives the impression that the variety of sand gradations is higher than in reality.

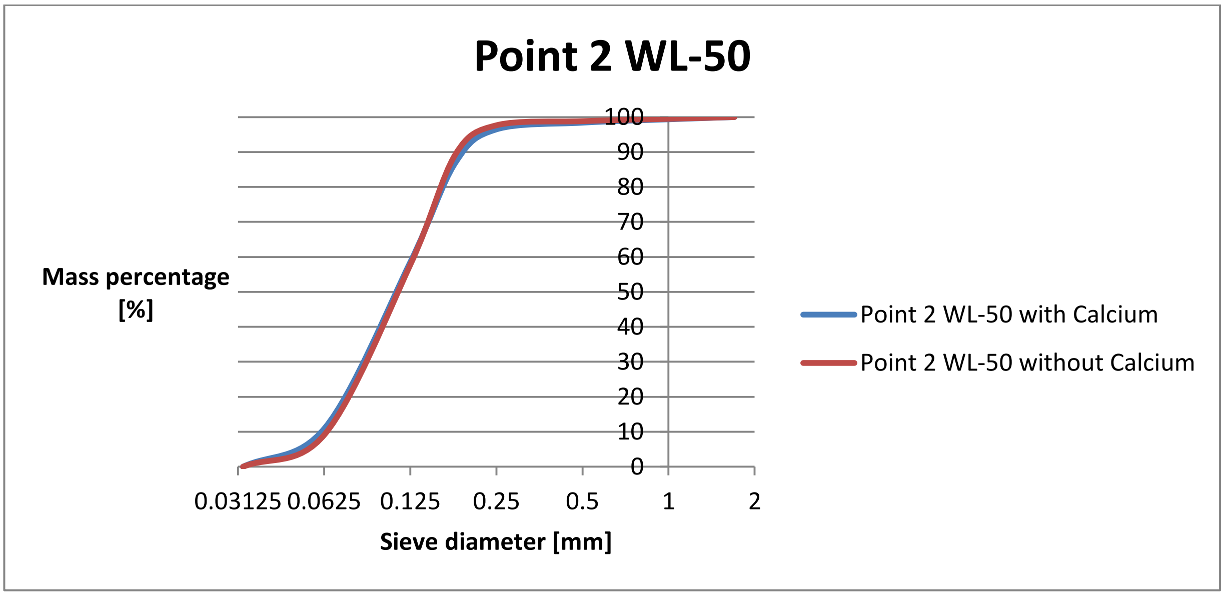


FIGURE 5-8 - SIEVE CURVE POINT 2 WL-50 WITH AND WITHOUT CALCIUM

In point 2 at WL-50m the calcium contaminations is somewhat lower than 10%. The two curves show some disturbance but one could conclude that it is still quite good and that this contamination is still one which can be neglected.

5.4.2 The Sieve Analysis

For every point alongshore the different sieve curves are plotted in one graph. The results can be found in Figure 5-9, Figure 5-10 and Figure 5-12. The sieve curves at point 1 are rather similar at the different locations in cross-shore directions. The blue line (WL-50) is more to the left of the graph and therefore the smallest grains can be found at this spot. On the other hand the green curve (water line) can be found more situated to the right, which indicates larger grains. Also the beach measurements (WL+5 and WL+15) contain coarser grains than the samples from offshore. This corresponds to the idea that coarsest material is at the water line where the water is the most energetic and that the grains are in general finer off shore than on the beach. The D10, D50 and D90 are shown in Table 5-4, as well as the D90/D10, which is a measure for the grading.
The fact that the lines are close to each other at the different spots in Figure 5-9 can probably be explained by the fact that the researchers were not experienced when doing their first measurements at this point 1. Working with the piston requires some practice and therefore it appeared that at point 2 better and clearer distinctions between the curves can be made.

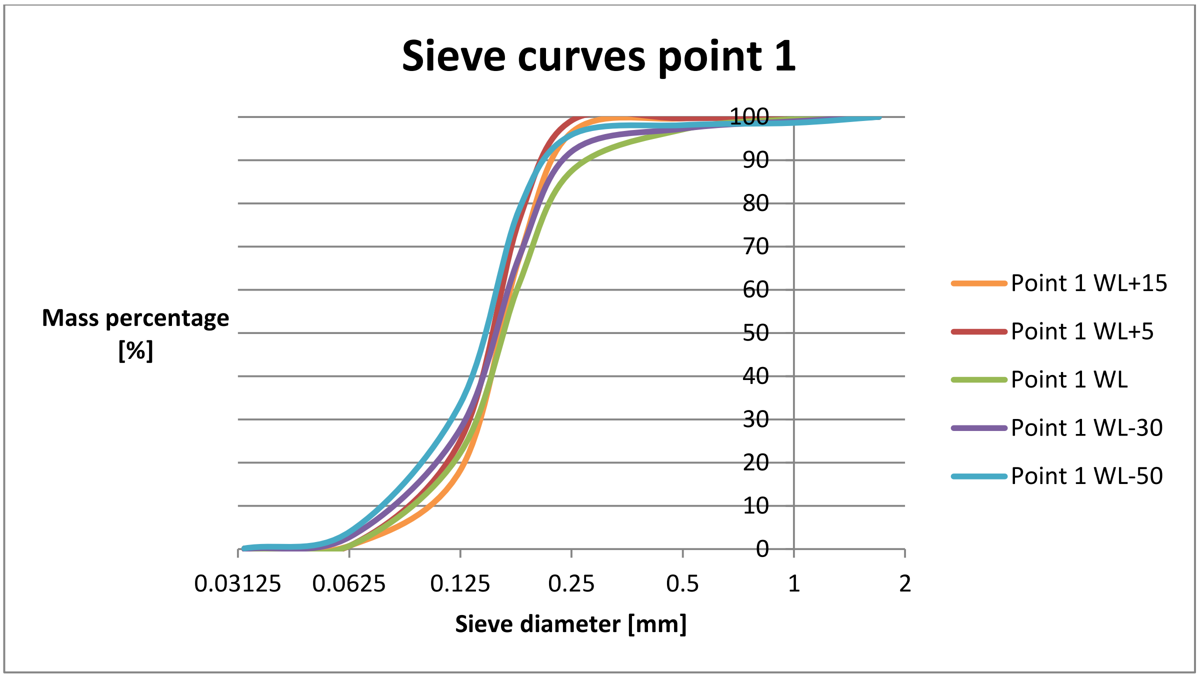


Figure 5-9 - Sieve curves point 1

	D10 [mm]	D50 [mm]	D90 [mm]	D90/D10
WL+15	0,106	0,160	0,220	2,075
WL+5	0,094	0,152	0,208	2,213
WL	0,096	0,164	0,280	2,917
WL-30	0,084	0,156	0,236	2,810
WL-50	0,078	0,144	0,212	2,718

Table 5-4 - Grain size and grading point 1

The sieve curves at point 2 (Figure 5-10) show the same trend as at point 1, but now the distinction between the curves is clearer. Finer material (0.0625-0.18 mm) can be found offshore and moving onshore the material gets coarser (0.125-0.150 mm). At the water line the situation is different, because the waves tens to pick up finer material therefore leaving relative coarse material at this spot. Consequently the coarsest material (up to 0.5 mm) can be found there. From the graph it is also visible that the curves 30 m and 50 m offshore have a gentler slope than the other curves. This can be explained by the fact that with the piston a soil cylinder can be obtained of about 1.5 m depth. On the contrary for the beach and waterline sampling a simple shovel was used, which delivers only samples until 0.5 m depth. Besides that within the piston more different soil layers samples were included, whereas the shovel samples contains more material of the same layer. When a sample contains relatively much sand of one layer the slope is steep, because many grains have the same size.

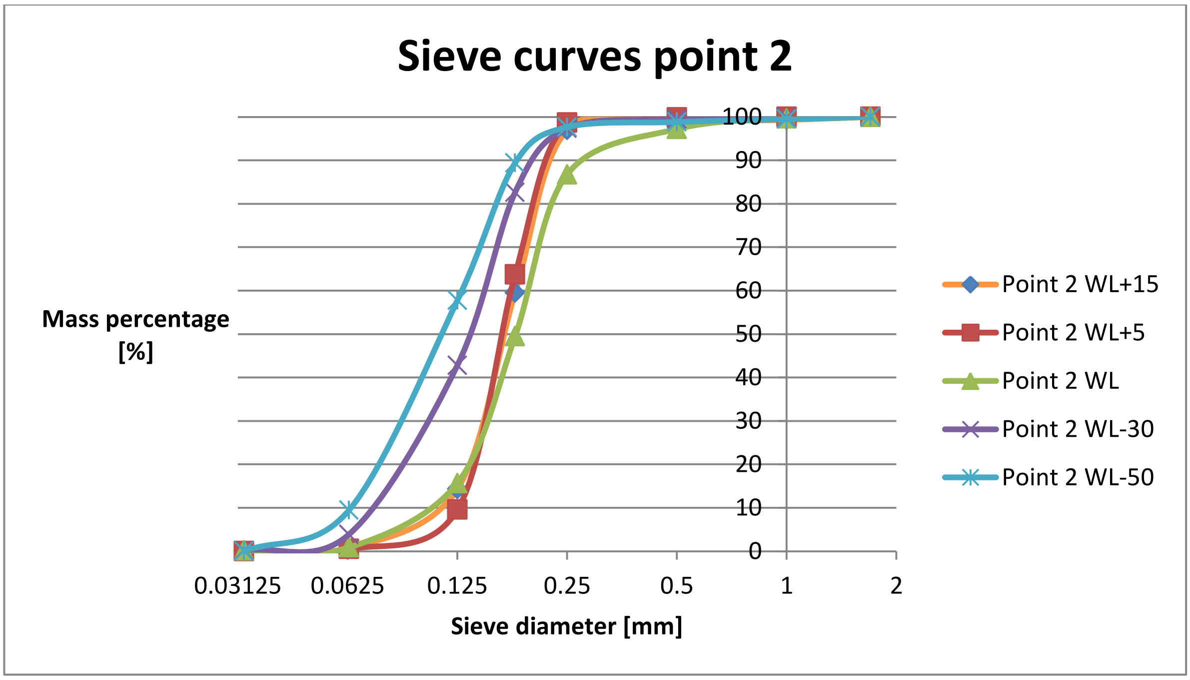


FIGURE 5-10 - SIEVE CURVES POINT 2

The trends from the sieve curves can also be shown in numbers. The grain sizes and the grading are shown in Table 5-5.

	D10 [mm]	D50 [mm]	D90 [mm]	D90/D10
WL+15	0,116	0,168	0,224	1,931
WL+5	0,126	0,164	0,218	1,730
WL	0,108	0,18	0,276	2,556
WL-30	0,075	0,136	0,202	2,693
WL-50	0,064	0,116	0,182	2,844

TABLE 5-5 - GRAIN SIZE AND GRADING POINT 2

Point 3 has only two curves. The same trend can be seen here, finer material is detected further off shore and coarser material at the water line. However, the curve at the water line differs considerably, because the sample contained too many shells (Figure 5-11). Therefore this sample is not treated with Hydrochloric Acid, because it seemed too complicated to remove all the shells. Table 5-6 shows that the influence of the Calcium on the D90/D10 is large.

FIGURE 5-11 - SAMPLE CONTAINING TOO MUCH SHELLS

It is clear that relatively many large particles can be found at the water line, in contrast to the other curves.

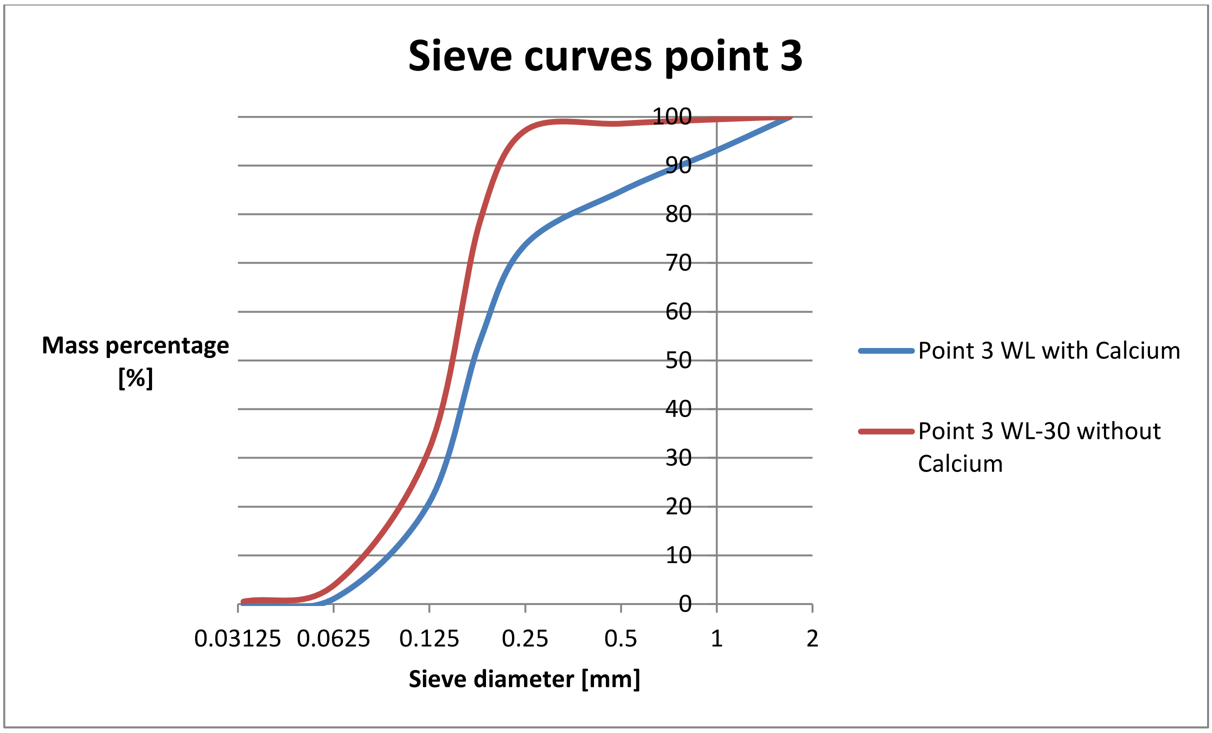


FIGURE 5-12 - SIEVE CURVES POINT 3

	D10 [mm]	D50 [mm]	D90 [mm]	D90/D10
WL	0,096	0,156	0,800	8,333
WL-30	0,080	0,146	0,208	2,600

TABLE 5-6 - GRAIN SIZE AND GRADING POINT 3

5.4.1 Uniformity of the beach

It is also interesting to plot the curves of the spots at the same x-coordinate, but at the different locations at alongshore in one graph. These graphs (Figure 5-13 until Figure 5-17) can visualize whether the coast is uniform or not. At the beach (15 m and 5 m inland from the water line) the sieve curves are quite comparable for point 1 and point 2. At the water line the curves of point 1 and 2 are still in quite agreement. However, point 3 at this location clearly deviates from these curves, due to the high calcium concentration in this sample as explained above. The sieve curves of the bottom material in the sea are less similar at the different points. The reason for this can be the sampling method. During the first sampling at point 1 the piston was used for the first time by the researchers. Therefore, these samples are less reliable. However the difference between the curves can also indicate difference in grain size at the different locations alongshore and therefore a not entirely uniform bottom in the sea.

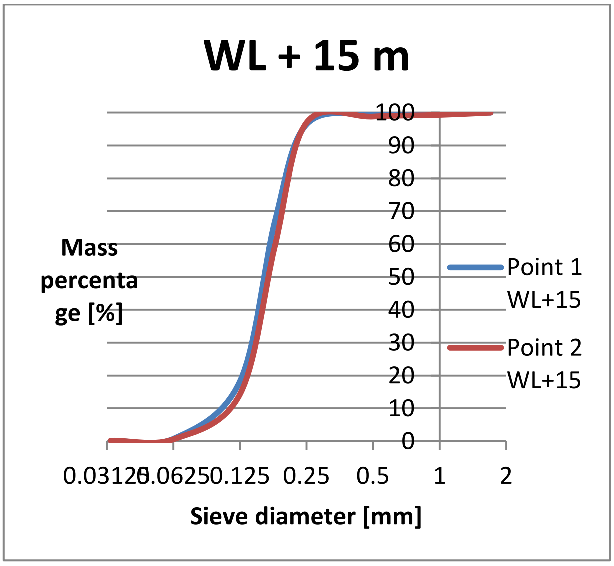


Figure 5-13 - Sieve curves WL+15 m

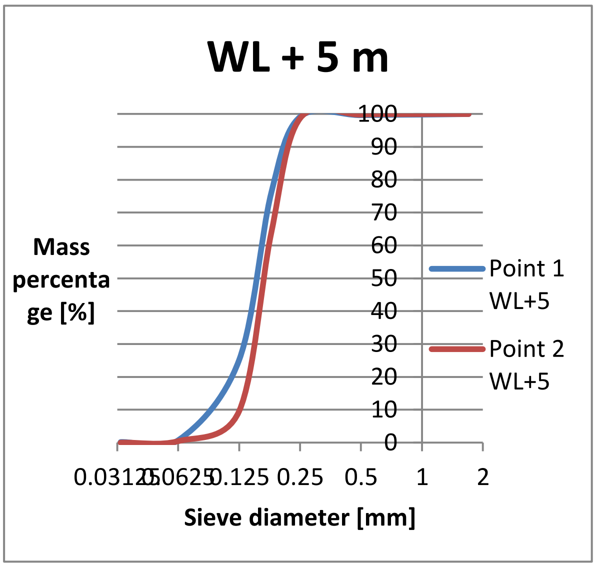


Figure 5-14 - Sieve curves WL+5 m

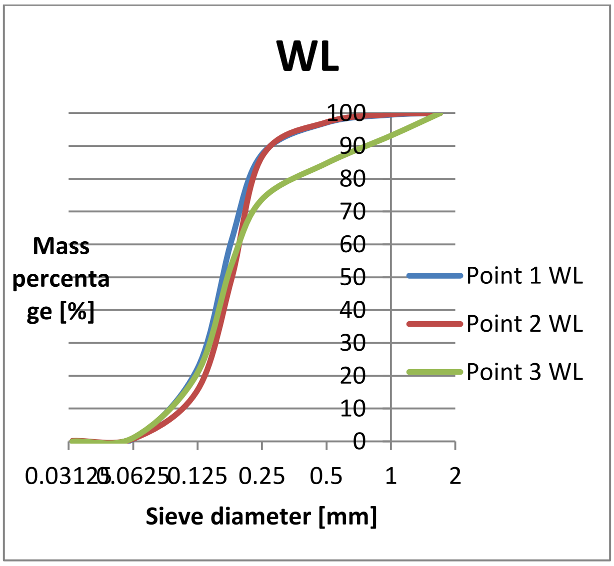


Figure 5-15 - Sieve curves WL

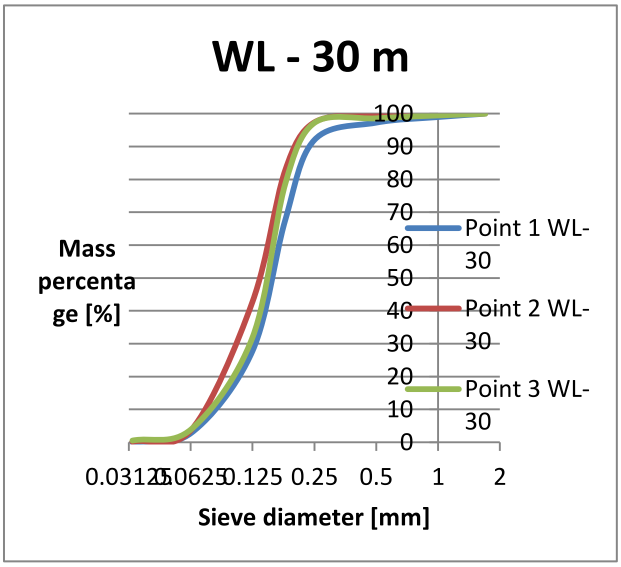


Figure 5-16 - Sieve curves WL-30 m

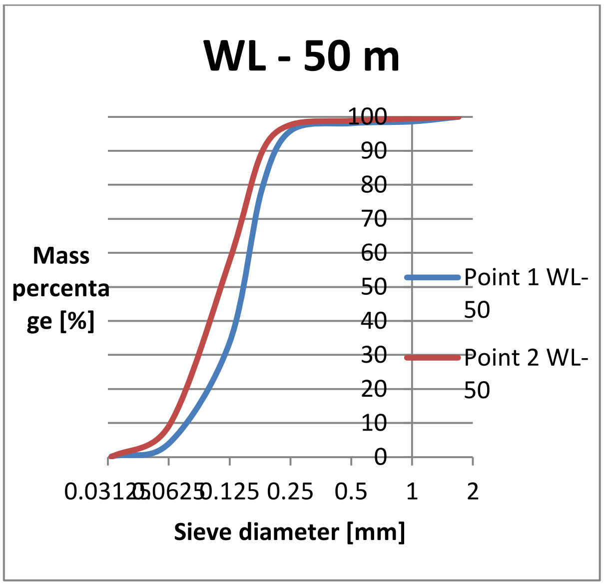


FIGURE 5-17 - SIEVE CURVES WL-50 M

5.5 CONCLUSION

The following statements about the sand of the Asparuhovo beach can be concluded from the results of this research:

- The average Calcium concentration is 6 – 7 %.
- Calcium concentrations lower than roughly 10% hardly influence the sieve curves.
- At the entire beach the finest material can be found further off shore. When approaching the shore and moving onto the beach the material gets coarser. The coarsest material can be found at the waterline
- The beach is rather uniform in long shore direction, but due to the inaccuracy of the measurements small deviations can be present. The tendency of the measurements shows that the southern part of the beach has slightly larger grain size than the northern part, especially off shore.
- The grain size of the sand at locations 30-50 m off shore is mostly in the order of 0.0625 mm till 0.18 mm.
- The grain size of the sand at the beach 5-15 m from the waterline is mostly in the order of 0.125 mm till 0.250 mm.
- The grain size of the sand at the water line is up to 0.5 mm.
- On average the grading D90/D10 is between 2 and 3.
- The grain size off shore is ‘more well-graded’ than on shore.

6 Quarry

6.1 Introduction

To determine whether the locally produced rock is suitable for future coastal protection works or for repair purposes, two quarries in the neighbourhood of Varna are visited. The most easily available stones in both quarries are a stone class with a d_{n50} of 0.2 m (stone class 1) and a stone class with a d_{n50} of 1 m (stone class 2).

This chapter will provide an overview of the characteristics of the rock that is produced in both quarries. Furthermore, the currently used rock in protections work is compared with the available rock at the quarries. This chapter will end with conclusions about the use of the quarry rock in coastal protection works.

6.2 Stone characteristics

In order to get insight into the properties of the stones in quarry Marciana and quarry Sini Vir, several properties are determined for a number of stones taken from the quarry. The dimensions and the weight of these samples are measured and the density is determined.

6.2.1 Stone distribution

In the Marciana quarry the dimensions of stones from both class 1 and class 2 are measured, in order to develop a sieve curve for both stone classes. In Appendix 1, all the data obtained from these measurements are presented. Figure 6-1 and Figure 6-2 show that the stones of both class 1 and class 2 are Gaussian distributed, all data points are quite close to the Gaussian distribution. Figure 6-3 and Figure 6-4 show these Gaussian distributions of the stone classes, both the probability density function as well as the cumulative probability density function. The D_{n50} of stone class 1 is 0.2 m and the D_{n50} of stone class 2 is 1 m.

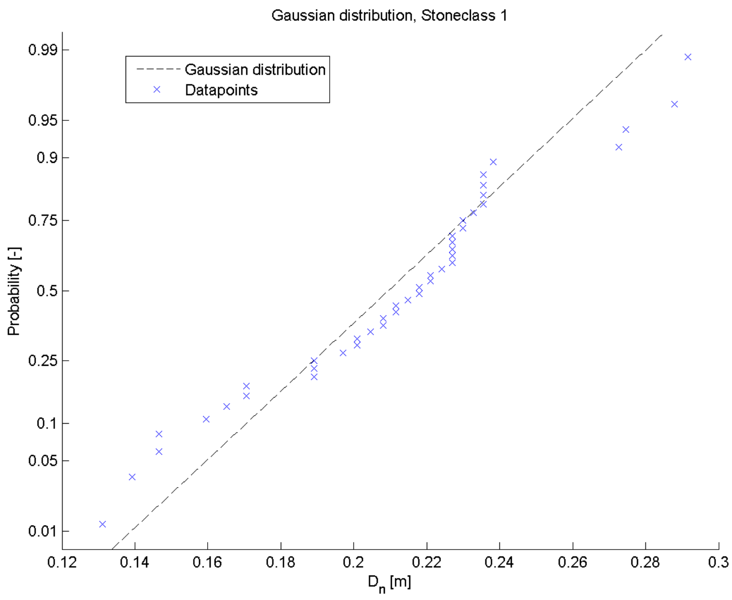


FIGURE 6-1 - THE DATA POINT OF STONE CLASS 1 ARE GAUSSIAN DISTRIBUTED

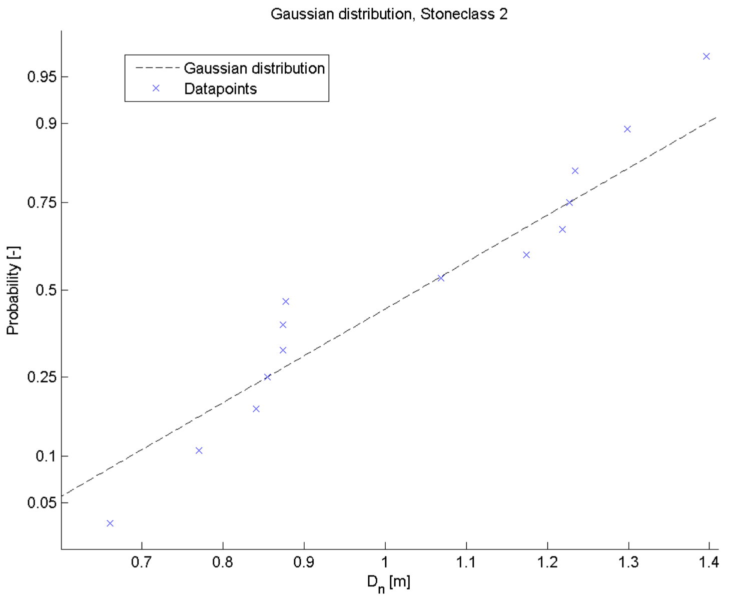


FIGURE 6-2 - THE DATA POINT OF STONE CLASS 2 ARE GAUSSIAN DISTRIBUTED

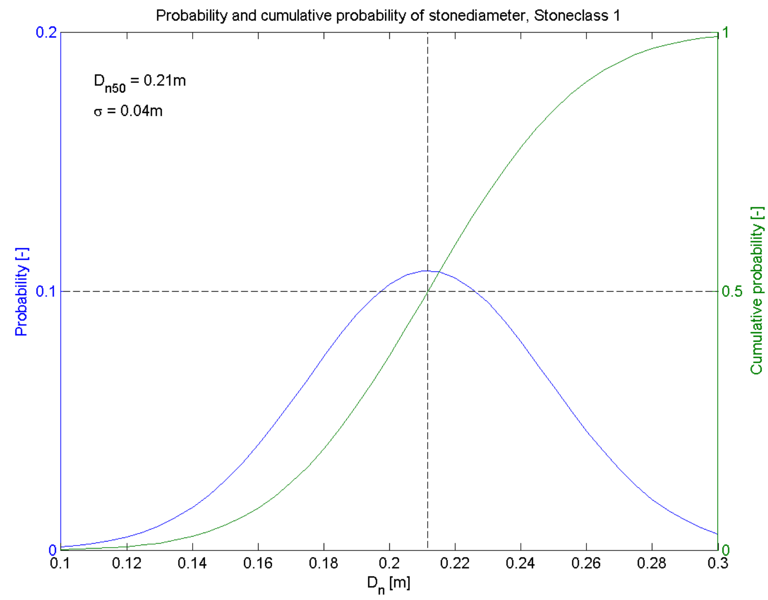


FIGURE 6-3 - THE PROBABILITY DENSITY FUNCTION AND CUMULATIVE PROBABILITY DENSITY FUNCTION OF STONE CLASS 1.

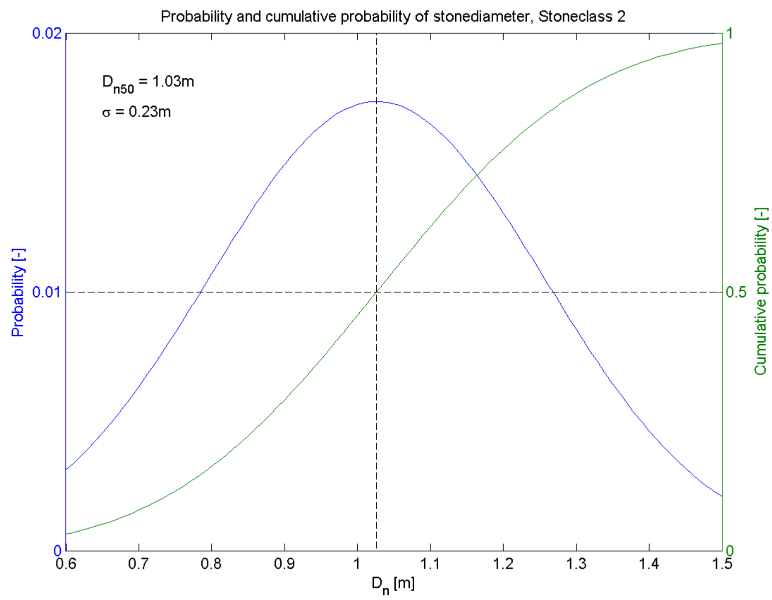


FIGURE 6-4 - THE PROBABILITY DENSITY FUNCTION AND CUMULATIVE PROBABILITY DENSITY FUNCTION OF STONE CLASS 2.

Both stone classes meet the requirements for ‘Wide gradations’, according to the standards mentioned in [Schiereck,2001], see equation 6.1.

$$1.\quad 2.7 < \left(\frac{D_{85}}{D_{15}}\right)^3 < 16$$

$$2.\quad 1.5 < \left(\frac{D_{85}}{D_{15}}\right) < 2.5 \qquad (6.1)$$

6.2.2 DENSITY

The density of the stone in quarry Marciana and quarry Sini Vir have been determined by means of the principle of Archimedes. Archimedes stated that for an object in a fluid, the displaced fluid volume equals the volume of the object. In this way, the volumes of the samples have been determined. After that, the mass of the sample has been measured and by dividing these two values, the density has been obtained. The density of the stones of quarry Marciana is 2220 kg/m^3, the density of the stones of the quarry Sini Vir is 2350 kg/m^3.

6.2.3 ELONGATION

The elongation, defined as the ratio of the longest and the shortest axial length, is an important parameter in determining whether stones are suitable for construction of coastal structures. Two requirements are described in the Rock manual, namely:

1. 'The quarry stone sample shall not contain more than 5% of stones with a length to thickness ratio (l/d) greater than 3;'
2. 'The quarry stone sample shall not contain more than 50% of stones with a length to thickness ratio (l/d) greater than 2 and no stone with l/d greater than 3;'

The minimum elongation in the samples taken from the quarry is 1.5, while the maximum elongation equals 5.65. Almost 12% of the samples has an elongation of more than 3 and 62% of the samples has an elongation of more than 2. The samples collected from the quarry are thus not suitable for the construction or repair of a groin. Due to practical restrictions, only the elongation of the relatively small stones in stone class 1 is measured.

6.2.4 BLOCKINESS

Another property of the stones is the blockiness. The blockiness is defined as the ratio of the volume of the stone and the smallest box in which the stone fits. The mathematical expression is shown below and figure 6-5 depicts the blockiness.

$$BLx = \frac{Volume\ of\ the\ rock\ block}{X \cdot Y \cdot Z}$$

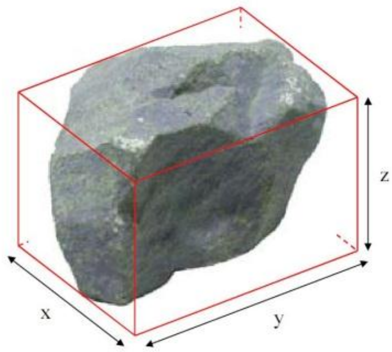


FIGURE 6-5 - BLOCKINESS

Stones with a large blockiness are easier to handle and to place on a structure. In addition, stones with a large blockiness are in general stronger. Furthermore, with stones having a large blockiness, a larger range of layer thickness is achievable.

For practical considerations the blockiness of the samples in stone class 1 is calculated. For these relatively small stones it was possible to measure the dimensions of the smallest possible box and the weight of the samples accurately. With these values and the density, the volume of the samples and the blockiness could be determined. For stone class 1, the blockiness is calculated to be on average almost 50%.

The blockiness of the samples in stone class 2, however, is estimated after visual inspection by a number of persons. The average blockiness of the samples of stone class 2 is estimated to be slightly more than 70%.

6.3 REDESIGNING THE GROIN IN ST. KONSTANTIN

The formula of Hudson, which is used for the current design of the St. Konstantin breakwater, results in a significant wave height of 2.04 m, see chapter 3). When estimating the wave height with the shallow water equation ($H_s/h=0,5$), this value of H_s seems to be a minor underestimation. Because the water depth in front of the groin is roughly 5 m, see Figure 6-6, the significant wave height which is taken into account in the new design of the St. Konstantin breakwater is 2.5 m.

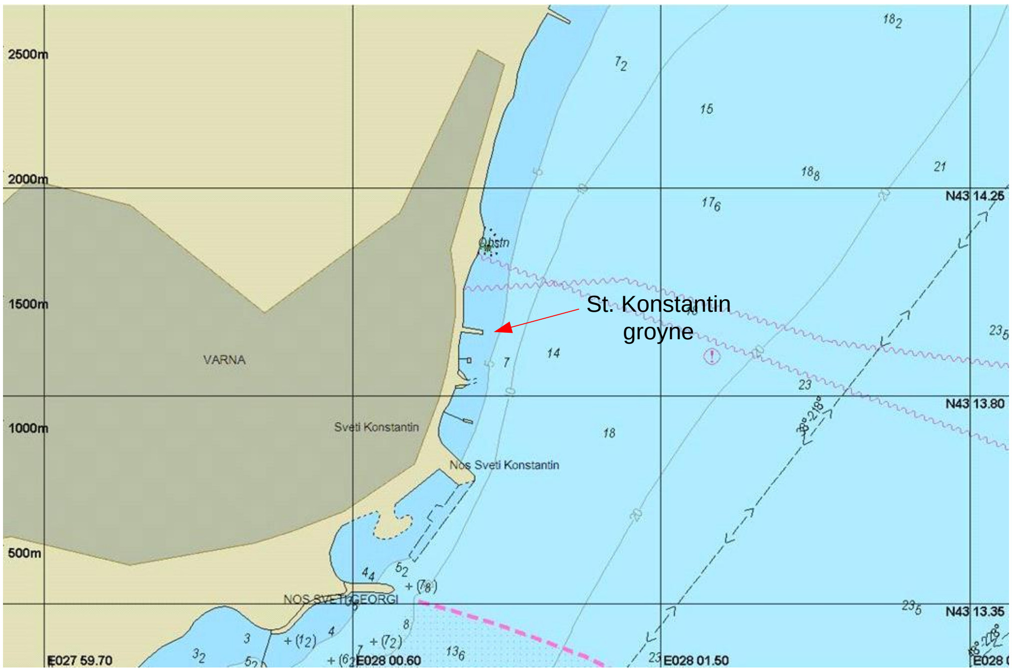


FIGURE 6-6 - COASTLINE OF ST. KONSTANTIN

The armour stones in the redesign of the breakwater will be designed with the Van der Meer-formula instead of the Hudson formula that is used in the current design. The big difference between these formulas is that Van der Meer included more parameters in his formula than Hudson. In the Van der Meer-formula the dimensions of the armour stones depend also on the wave period, the number of waves, the damage level that is allowed and, most importantly, the permeability of the groin, see equation 6.2.

$$\frac{H_{sc}}{\Delta d_{n50}} = 6.2P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2}\xi^{-0.5} \text{ (plunging breakers)}$$

$$\frac{H_{sc}}{\Delta d_{n50}} = 1.0P^{-0.13}\left(\frac{S}{\sqrt{N}}\right)^{0.2}\xi^{P}\sqrt{\cot\alpha} \text{ (surging breakers)} \qquad (6.2)$$

In which: P = permeability parameter, [-]
S = damage level, [-]
N = number of waves, [-]
ξ = Iribarren number, [-]

The waves around the St. Konstantin groin will have a plunging character, because $\xi < \xi_{transition}$, see equation**Error! Reference source not found.**.

$$\frac{\tan\alpha}{\sqrt{H_s / L_0}} < \left(6.2P^{0.31}\sqrt{\tan\alpha}\right)^{\frac{1}{P+0.5}} \qquad (6.3)$$

In which: L_0 = the deep water wave length, [m]

H_s/L_0 is taken 0.04 for a first approximation. As a result of this approximation, the wave period is 5.3 s, which agrees well with previous observations. In the case of the St. Konstantin groin, the permeability parameter is 0.1, because the groin consists of a caisson and is therefore impermeable. Furthermore, the porosity of the filter construction is of minor importance.

Hudson is essentially only applicable for permeable groins, which is the main reason why the Van der Meer-formula is used in the redesign. In this approximation N is set to 7500, which is representative for an average storm climate. A durable design of a groin will incorporate a damage factor of less than 2, which is equal to the threshold of damage. The damage level of the current St. Konstantin groin a probably much higher, because on some places the armour stones are broken or even removed, see Figure 6-7. Furthermore, the coefficient in the Van der Meer-formula for plunging groin, 6.2, is replaced by 7.71 according to Stewart, see

Appendix . The Van der Meer-formula for plunging breakers results in the required dimensions of the armour stones of Marciana quarry of 1.15 m and of Sini Vir 2 of 1.04 m.

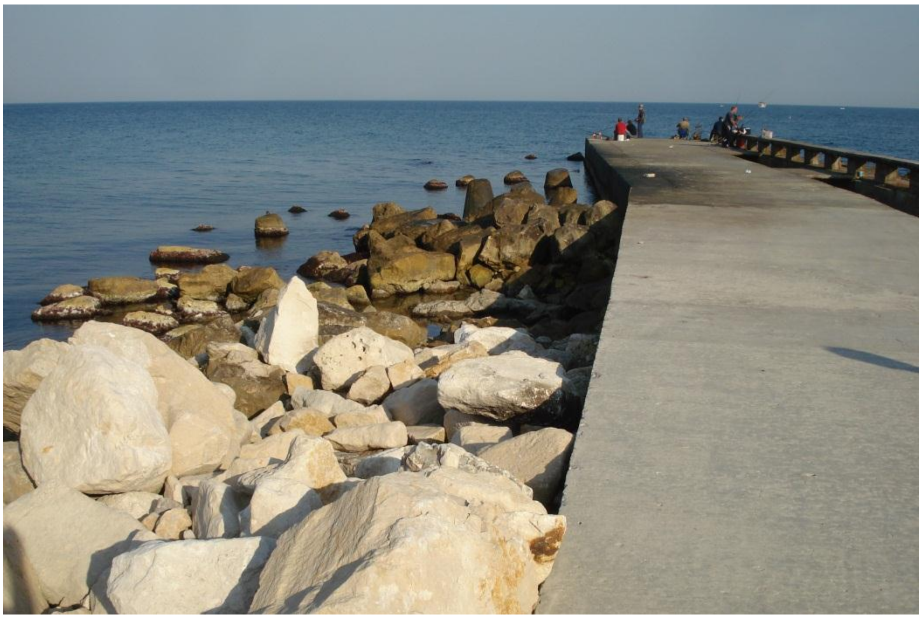


FIGURE 6-7 - CURRENT ST. KONSTANTIN GROIN

The amount of stones of stone class 2 easily available at the Marciana quarry is sufficiently large to repair or even rebuild the St. Konstantin breakwater. A first estimation of the amount of stones available is 4500 m^3, while only a volume of armour stones of 750 m3 is necessary when constructing a new one-layer thick armour layer.

$$V_{armour} = t * h\sqrt{1+\cot^2\alpha} * L \qquad (6.4)$$

In which: t = armour layer thickness = 0.55*d_{n50} for a one-layer thick armour layer

h = average height of the groin = 4 m

α = slope of the groin = 1:3

L = length of the groin = 65 m

6.4 CONCLUDING REMARKS

The currently available stones from both quarries don't meet the requirements for elongation and blockiness. Furthermore, when the armor stones should be large enough to withstand a wave height of 2.5 m without being severely damaged, the required stone size of the Marciana rock is 1.15 m and of the Sini Vir rock is 1.04 m. However the stone class that is easily available has a d_{n50} that is slightly smaller than the required dimensions. Both observations have led to the following conclusions:

1. The easily available rock in the Marciana quarry isn't suitable for the repair works of the St. Konstantin groin. Even though the amount of stones available is sufficient, the size, blockiness and elongation don't meet the requirements. However if only a selection of the available stones is applied, these requirements can be met. Especially when looking at the large amount of stones available, making a selection of suitable stones seems quite possible.

2. The only characteristic which makes a comparison between both quarries possible is the density, which is slightly larger for the Sini Vir quarry (2350 kg/m3) than for the Marciana quarry (2220 kg/m3). Due to this difference in density, one might prefer using the Sini Vir rock, but other properties can be decisive as well.

7 Conclusions and recommendations

7.1 Conclusions

The conclusions are listed below, sorted by the order of the whole report. So it starts with Sirius Beach and ends with the quarry operations.

7.1.1 Sirius Beach

The measurements at Sirius Beach gave a slightly contradicting picture. Based on the GPS data one can conclude that there is a large seasonal variance and no clear trend in the water lines.
This is why the following remarks are made:

- Sirius beach has a strong seasonal variation which influences measured data.
- There is a small trend of erosion in the northern part and accretion in the southern end of Sirius beach. This trend is decreasing in time.
- Sirius beach is heading towards an equilibrium.

7.1.2 St Konstantin

Groin

The damage on the groin is caused by wave attacks during storms. The stones where too small and could be lifted by waves.

The stones used, are of low quality and highly breakable. These properties arise because the stones have a high concentration of calcium and a low density.

Marina

Resulting from the analysis the following conclusions can be drawn;

- There was no cost benefit analysis made for the project (a heavy protected, expensive harbor for a small capacity of ships);
- The breakwater/entrance is not in the right position. During the summer season (the season for which the harbor is build) the waves enter the harbor by the entrance. Inside the harbor the waves are reflected, this results in fluctuations inside the harbor;
- Building materials were made. But the breakwater is never finished, so the materials are still in stock;
- Because the breakwater is never finished, the free-board is to small and overtopping occurs even when there are only small waves.

7.1.3 ASPARUHOVO BEACH

Waterline

According to the water line measurements and the beach profiles measurements the beach can be assumed to be stable. In comparison with the data of 2010 even an accretion of the beach is observed. The profiles have moved about 10m seawards in one year. This accretion rate doesn't seem very realistic. The explanation for this can be the weather. Because in 2010 the weather was a lot worse than in 2011. So the difference between the summer and a winter profile (after a storm) can be this 10 meter.

Sand samples

The sand sample measurement has shown that the beach is quite uniform in long shore direction. Therefore the location of the entrance channel of the marina makes no difference regarding dredging. In cross shore direction some differences have been observed regarding the grain size. At the water level the largest grains can be found (up to 0.5 mm). The sediment 30-50 m from the shoreline of the water has a grain size in the order of 0.0625 mm till 0.18 mm. While the grain size at the beach has a grain size in the order of 0.125 mm till 0.250 mm. On average the grading D_{90}/D_{10} is between 2 and 3.

Breakwater

The breakwater is damaged a lot. This is because of the bad quality of the concrete in the elements and some mistakes in the construction. For example the concrete slab at the top of the breakwater is too stiff, a pipeline in the breakwater creates weak spots over the whole breakwater. And finally the combination of the tetrapods, blocks and the stones form a bad filter.

7.1.4 SIEVE ANALYSIS

The following statements about the sand of the Asparuhovo beach can be concluded from the results of this research:

- The average Calcium concentration is 6 – 7 %.
- Calcium concentrations lower than roughly 10% hardly influence the sieve curves.
- At the entire beach the finest material can be found further off shore. When approaching the shore and moving onto the beach the material gets coarser. The coarsest material can be found at the waterline
- The beach is rather uniform in long shore direction, but due to the inaccuracy of the measurements small deviations can be present. The tendency of the measurements shows that the southern part of the beach has slightly larger grain size than the northern part, especially off shore.
- The grain size of the sand at locations 30-50 m off shore is mostly in the order of 0.0625 mm till 0.18 mm.

- The grain size of the sand at the beach 5-15 m from the waterline is mostly in the order of 0.125 mm till 0.250 mm.
- The grain size of the sand at the water line is up to 0.5 mm.
- On average the grading D90/D10 is between 2 and 3.
- The grain size off shore is ‘more well-graded’ than on shore.

7.1.5 Quarry operations

The currently available stones from both quarries don’t meet the requirements for elongation and blockiness. Furthermore, when the armor stones should be large enough to withstand a wave height of 2.5 m without being severely damaged, the required stone size of the Marciana rock is 1.15 m and of the Sini Vir rock is 1.04 m. However the stone class that is easily available has a d_{n50} that is slightly smaller than the required dimensions. Both observations have led to the following conclusions:

1. The easily available rock in the Marciana quarry isn’t suitable for the repair works of the St. Konstantin groin. Even though the amount of stones available is sufficient, the size, blockiness and elongation don’t meet the requirements. However if only a selection of the available stones is applied, these requirements can be met. Especially when looking at the large amount of stones available, making a selection of suitable stones seems quite possible.

2. The only characteristic which makes a comparison between both quarries possible is the density, which is slightly larger for the Sini Vir quarry (2350 kg/m3) than for the Marciana quarry (2220 kg/m3). Due to this difference in density, one might prefer using the Sini Vir rock, but other properties can be decisive as well.

7.2 Recommendations

A general recommendation for future research in general and the groups of the fieldwork in the following years, is that the literature research is very important. So one should always know what research is done before starting a research. This because it is important to draw conclusions, which is only possible if the results are comparable with the researches done in the past.

7.2.1 Sirius Beach

It is wise to continue the measurements since the database is still relatively small and heavily influenced by seasonal variances. Any measures are not necessary and not advisable in the current situation.

It's advisable to further standardize the measurement methods to avoid confusion; future research should actively read previous reports before starting any measurements. Also it is advised to use the same alongshore locations for the cross-sectional measurements.

7.2.2 St. Konstantin

Groin

For the near future if you want the groin to remain stable it is important to reinforce the groin and construct a new armor layer. For future designs of groins and breakwaters it is important to have sufficient wave data.

Marina

For future projects like the construction of a marina it is advisable to make a cost benefit analysis to avoid that the construction is cancelled halfway. The second recommendation is to have good look for the use of the marina and the circumstances, like the wave data, over the year. This because the design was wrong for the purpose of the marina.

7.2.3 Asparuhovo Beach

Waterline

More surveys in the coming years are needed to be able to determine if it indeed is a summer of winter profile or that the beach enlarges over time.

Breakwater

If a new marina will be located at Asparuhovo Beach more ships will pass at the southern side of the breakwater. It is assumed that the marina will be constructed for pleasure cruising. Therefore the vessels are thought to be quite small, so are their generated waves have been assumed. The implications for the breakwater are therefore negligible. Nevertheless, the breakwater is already in a bad condition, so it necessary to repair the breakwater before it collapses.

8 REFERENCE

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9 APPENDICES

APPENDIX 1 - MEASUREMENTS QUARRY MARCIANA

In this appendix, the results of the measurements of the samples in quarry Marciana are tabulated.

Stone nr	Weight (kg)	Longest (cm)	Shortest (cm)	X (cm)	Y (cm)	Z (cm)	Elongation	Volume (m^3)	Blockiness	D50
1	22	30	17	32	20	30	1,76	0,0099	0,52	0,215
2	28	40	18	32	20	45	2,22	0,0126	0,44	0,233
3	20	30	20	30	25	25	1,50	0,0090	0,48	0,208
4	7	23	10	20	25	15	2,30	0,0032	0,42	0,147
5	29	36	18	15	30	40	2,00	0,0131	0,73	0,236
6	11	23	12	25	25	15	1,92	0,0050	0,53	0,170
7	7	23	11	20	15	25	2,09	0,0032	0,42	0,147
8	46	42	25	40	45	30	1,68	0,0207	0,38	0,275
9	15	29	13	20	25	35	2,23	0,0068	0,39	0,189
10	30	43	23	25	45	30	1,87	0,0135	0,40	0,238
11	23	30	20	30	30	35	1,50	0,0104	0,33	0,218
12	26	40	22	35	30	25	1,82	0,0117	0,45	0,227
13	29	37	20	35	30	25	1,85	0,0131	0,50	0,236
14	11	44	12	50	20	25	3,67	0,0050	0,20	0,170
15	29	46	18	45	20	20	2,56	0,0131	0,73	0,236
16	55	53	20	60	35	30	2,65	0,0248	0,39	0,292
17	21	37	17	25	35	25	2,18	0,0095	0,43	0,211
18	26	43	20	35	35	30	2,15	0,0117	0,32	0,227
19	20	33	16	35	25	30	2,06	0,0090	0,34	0,208
20	19	39	12	25	40	15	3,25	0,0086	0,57	0,205
21	27	38	17	25	35	25	2,24	0,0122	0,56	0,230
22	24	30	20	33	31	23	1,50	0,0108	0,46	0,221
23	26	45	8	39	38	19	5,63	0,0117	0,42	0,227
24	17	34	20	28	25	20	1,70	0,0077	0,55	0,197
25	6	23	7,5	25	22	15	3,07	0,0027	0,33	0,139
26	26	38	20	23	38	31	1,90	0,0117	0,43	0,227
27	9	26	10	17	27	15	2,60	0,0041	0,59	0,159
28	5	27	13	17	15	27	2,08	0,0023	0,33	0,131
29	45	45	17	49	35	27	2,65	0,0203	0,44	0,273
30	15	30	18	30	25	18	1,67	0,0068	0,50	0,189
31	29	48	20	29	40	25	2,40	0,0131	0,45	0,236
32	24	36	23	29	35	24	1,57	0,0108	0,44	0,221
33	23	39	23	32	30	24	1,70	0,0104	0,45	0,218
34	15	30	16	19	33	19	1,88	0,0068	0,57	0,189
35	10	50	10	15	50	15	5,00	0,0045	0,40	0,165
36	27	47	18	18	43	25	2,61	0,0122	0,63	0,230
37	53	54	26	26	15	29	2,08	0,0239	2,11	0,288
38	21	39	14	19	38	20	2,79	0,0095	0,66	0,211
39	25	45	16	43	20	21	2,81	0,0113	0,62	0,224
40	18	35	12	24	35	19	2,92	0,0081	0,51	0,201
41	18	40	13	23	33	13	3,08	0,0081	0,82	0,201
42	26	40	12	31	28	22	3,33	0,0117	0,61	0,227

FIGURE 9-1. STONE CLASS 1, MARCIANA QUARRY

Stone nr	X	Y	Z	Blockiness (%)	Volume (m^3)	Weigth	Dn
1	1,65	1,25	1,35	65	1,81	4017,85	1,22
2	1,9	1,1	1,5	60	1,88	4175,82	1,23
3	1,1	0,85	0,95	75	0,67	1478,94	0,87
4	1,7	1,7	0,8	70	1,62	3592,85	1,17
5	2,45	1	1,85	60	2,72	6037,29	1,40
6	0,8	0,75	0,6	80	0,29	639,36	0,66
7	1,6	0,8	1,9	90	2,19	4859,14	1,30
8	1,45	1,1	0,9	85	1,22	2708,79	1,07
9	1,5	0,6	1	75	0,68	1498,50	0,88
10	1,5	0,9	0,6	73	0,59	1318,68	0,84
11	1,4	0,5	1,3	73	0,67	1481,48	0,87
12	1,25	0,85	0,8	73	0,62	1383,80	0,85
13	1,3	0,8	0,6	73	0,46	1015,87	0,77
14	1,4	1,5	1,2	73	1,85	4102,56	1,23

FIGURE 9-2. STONE CLASS 2, MARCIANA QUARRY

Appendix 2 – Determination of the coefficients in the Van der Meer-formula

Blockiness-range	Elongation-range	Armour Porosity (%)	Placement method	"6.2"	"1.0"
40%-50%	1.3 - 3.0	38.7	standard	7.09	-
40%-50%	1.3 - 3.0	36.1	dense	6.68	1.67
50%-60%	1.3 - 3.0	37.1	standard	6.44	1.51
50%-60%	1.3 - 3.0	35.2	dense	7.12	2.08
60%-70%	**1.3 - 3.0**	**35.5**	**standard**	**7.71**	**2.63**
60%-70%	1.3 - 3.0	34.4	dense	10.85	-
50%-60%	1.0 - 2.0	36.1	standard	8.50	1.45
50%-60%	1.0 - 2.0	34.6	dense	8.80	-

Figure 9-3 - Coefficients in the Van der Meer-formula