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Wave measurements in the dump area of the Constanta breakwater project

Prepared by: Wessel Hollander

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1 Summary

During the construction of the Constanta breakwater it was questioned how the waves are influenced by the half-finished-breakwater. Because a lot of uncertainties exist in theoretical predictions, it was decided to do measurements. A simple pressure meter was available to do these measurements; the wave logger.

Measuring waves based on their pressure has its limitations. Small, short waves may not be measured since they do not induce enough pressure. On top of that the device also produces noise, which makes it necessary to throw a part of the data away. The performance of the wave logger decreases as the depth of deployment increases. Altogether, this results in limited areas to deploy the pressure meter, and limited wave conditions able to measure. Taking into account these limitations, the wave logger was placed on top of the core material of the breakwater, at -7 meter. The device collected data for 13 days. The most appropriate wave conditions were chosen to analyse.

The measurements of the wave logger are compared to measurements of the Waverider. The Waverider measures the wave conditions that are unaffected by the half-finished underwater construction. The comparison of the wave spectra gives most insight in the situation. It was noticed that the waves lost energy when passing the breakwater core, especially for the larger periods. This corresponds with the expectations that the larger periods are subject to stronger reflections. See Figure 1 for a typical example of the wave spectra.

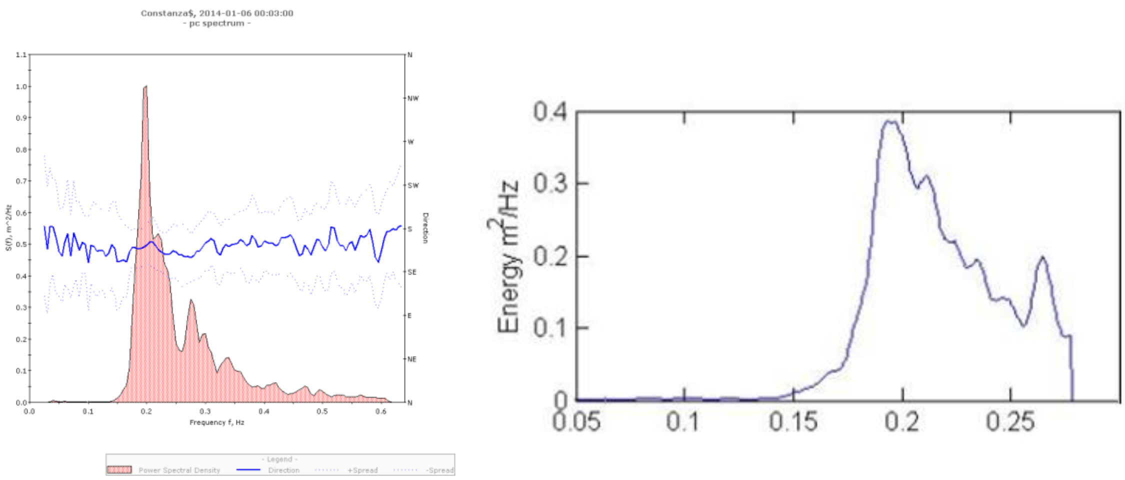

Figure 1 Typical example of the results. Left: wave spectrum Waverider, right: wave spectrum Wave logger

This finding supports the explanation for the disappointing performance of the Razende Bol. This backhoe was operating around the breakwater core. From the workability analysis of the Razende Bol was concluded that the workable wave height was dropping rapidly for waves higher than 5 seconds. It can be presumed that the wave reflection has a large influence on this workability. The incoming waves together with the reflection result in tougher work conditions for the Razende Bol. This insight must be taken into account for future workability estimations.

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2 Contents

3 Introduction

To investigate the effects of the breakwater on the wave conditions, it is necessary to carry out extra research. From experiences of the Razende Bol’s crew was supposed that the wave conditions near the breakwater differ from the Waverider’s measurements. More insight in the waves near the breakwater might be useful for future workability estimations.

A fully theoretical approach is not adequate, because some processes are hard to take into account. The amount of reflection is hard to predict, thereby the situation is not expected to be linear. A purely theoretical approach will bring a lot of uncertainties, for that reason is chosen to do measurements.

It is necessary that the measurements are done within the limitations of the device. A pressure meter is available to measure the wave induced pressure. Pressure measurements and the processing of the data bring some limitations and inaccuracies. The inaccuracies are acceptable as long as the data is interpreted carefully. One of the limitations of the pressure meter is the placement depth. When the depth increases, the quality of the data decreases. This limitation is decisive for the choice of the measurement location.

First some background is given about wave measurements based on pressure. Also, more about the accuracy of the measuring device is explained. This served as a basis to choose a measurement location. This is followed by the theoretical expectation of the results. Finally, the measured results are presented.

4 Use of a pressure sensor

4.1 Theoretical background

Waves induce pressure below the sea surface. From the linear wave theory an expression can be given for this wave induced pressure.

$$p = -\rho g z + \rho g a \frac{\cosh[k(d+z)]}{\cosh(kd)} \sin(\omega t - kx)$$

The left hand side of the expression represents the hydrostatic pressure, the right hand side represents the wave induced pressure. If the pressure is recorded, the related wave height can be found. The hydrostatic pressure is influenced by the tide and atmospheric pressure. These two factors fluctuate on a larger timescale than the waves, which enables it to find the wave induced pressure. The following expression gives the relation between the pressure and the wave height. .

$$\eta = \frac{\Delta p}{\rho g} \frac{\cosh kh}{\cosh k(h+z)}$$

The wave induced pressure decreases as the depth increases. On a very large depth, the wave-induced pressure approaches zero, and only the hydrostatic pressure will be recorded by the wave logger. Therefore it is preferred to place the wave logger close to the water surface. In Figure 2 an example is presented of some waves with their wave induced pressure over depth.

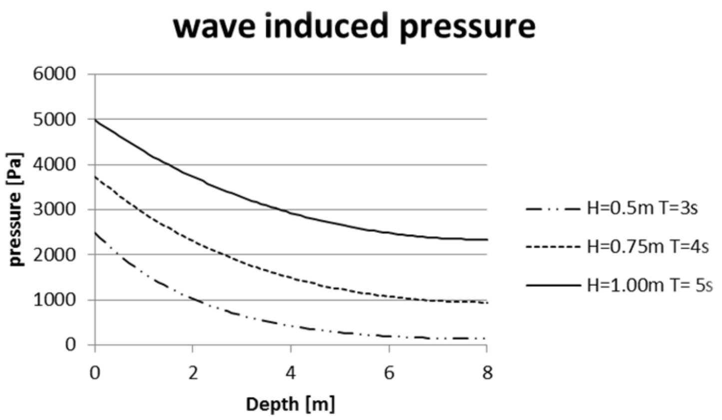


Figure 2 amplitude of the wave induced pressure at the depth of 8 meters

It can be noticed that smaller waves only cause very little pressure variation on larger depths. Only larger waves will be recorded. If the wave logger is placed too deep, a distorted wave pattern might be measured.

4.2 The wave logger

The wave logger is a simple instrument. It consists of a pressure meter with a battery, and stores the information on a SD card. The data has to be collected by hand, the wave logger has to be taken out of the water to collect the data from the SD card. The logfile contains the measured data. The output of the pressure meter is in volts. A linear relation exists between this voltage and the corresponding pressure. To find this relationship, the wave logger is calibrated.

Figure 3 picture of the wave logger

4.3 Data processing

A matlab script is available to process the wave logger's data. Two types of analysis can be carried out on the data.

- Time domain analysis
- Frequency domain analysis

For the time domain analysis the pressure waves are separated from the record using the downward zero-crossing method. Then the period for each wave is known and the corresponding height can be determined. All waves are sorted on height so that characteristic values can be calculated. The time domain analysis calculates the significant wave height, mean wave height and root mean square wave height. Also wave exceedance graphs are processed by the script.

In the frequency domain analysis the pressure spectrum is processed. Then, the variance density spectrum can be calculated from the pressure spectrum. For each frequency bin the formula of the linear wave theory is used to obtain the variance density of the surface elevation. This variance density spectrum also presents the energy per frequency. If the variance is multiplied with gravity and water density, the energy spectrum is obtained.

4.4 Accuracy

4.4.1 Restrictions resulting from frequency domain analysis

From the equation of the wave induced pressure can be seen that waves with shorter periods induce less pressure. However, the wave logger itself produces noise. Because of the absence of wave induced pressure for the higher frequencies, the noise becomes dominant at those frequencies. In the data processing, the wave induced pressure equation interprets the noise at the higher frequencies as a high short waves. This results in a distorted energy spectrum, with an extreme amount of energy in the higher frequencies. Figure 4 shows an example of a pressure spectrum and a corresponding energy spectrum. It is clear that the peak on the right hand side of the energy spectrum is unrealistic.

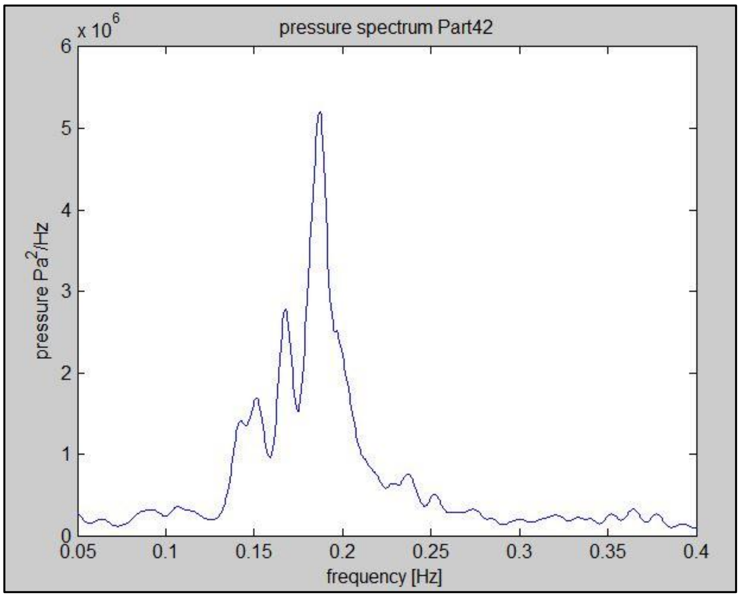


Figure 4 example of a pressure spectrum

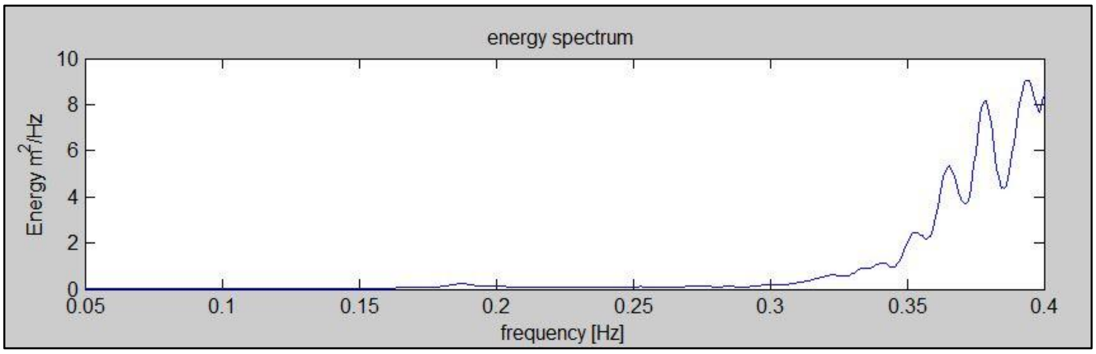


Figure 5 energy spectrum

This unrealistic part of the spectrum should be cut away, the pressure spectrum can be used to determine the frequency. At some point the pressure spectrum has a constant value. It is assumed that for the frequencies where the variance density of the pressure is constant, only noise dominates, and should be cut-off the spectrum. Figure 6 shows the same energy spectrum as Figure 5, but now a cut-off value of 0.25 Hz is used.

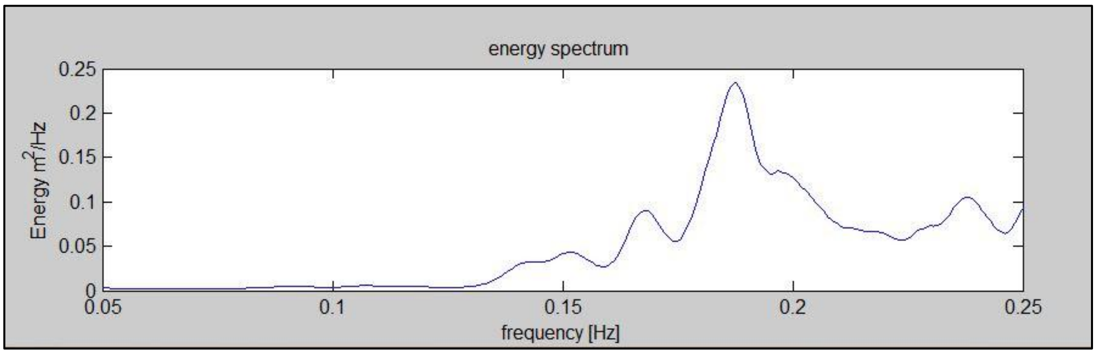


Figure 6 energy spectrum with cut-off value of 0.25 Hz

The downside of cutting of the spectrum is that data is lost. At the noise dominated frequencies no useful data of the waves is available anymore. In reality waves exist with the deleted frequencies. This results in distorted values for the moments of the spectrum. These moments are important to determine the significant wave heights and periods.

From this is concluded that applicability of the wave logger decreases as wave conditions occur with higher frequencies. For conditions with a lot of swell the processed data will be more reliable than conditions with a lot of wind wave. It is estimated that a reliable wave period is 4 seconds.

Another check that should be made when producing wave spectra is the maximum measurable frequency resulting from the measurement interval of the wave logger. Higher harmonics may be measured as longer waves. Therefore, energy from higher frequencies are is added to the lower frequencies in the spectrum. The Nyquist frequency gives the limiting frequency.

$$f_{nyquist} = \frac{1}{2\Delta t}$$

The wave logger logs the pressure 4 times per second. So the resulting Nyquist frequency is 2 Hz. So it can be concluded that this will not introduce errors in the wave spectrum, since it can be safely assumed that waves with a frequency higher than 2 Hz will not exist in the wave field.

4.4.2 Minimum wave height

The value of the minimum wave height depends on the water depth and accuracy of the pressure sensor. It is stated that the accuracy of the wave logger is 250 Pa [1]. De depth of deployment is approximately 7 meter. From the linear wave theory can be calculated that the minimum wave height should be 0.15 meter. However, the results of the calibration imply a larger uncertainty. An accuracy of 450 Pa is more realistic, which correspond in a minimum wave height of roughly 0.25 meter.

4.5 Calibration

The wave loggers measure the pressure in volts. This corresponds to a certain pressure. In this report is explained how the calibration is conducted. The relation between the output in volt and the corresponding water depth is found. This relation is as follows:

$$\begin{gathered} P(V_m) = A \cdot V_m + B \\ where: \\ A = calibration\ parameter \\ B = calibration\ parameter \\ V_m = measured\ Volts \end{gathered}$$

The wave logger is placed at certain known depths. Together with the known density of the water, it is possible to find the calibration values from a regression analysis. See Figure 7. The calibration parameters are presented in Table 1.

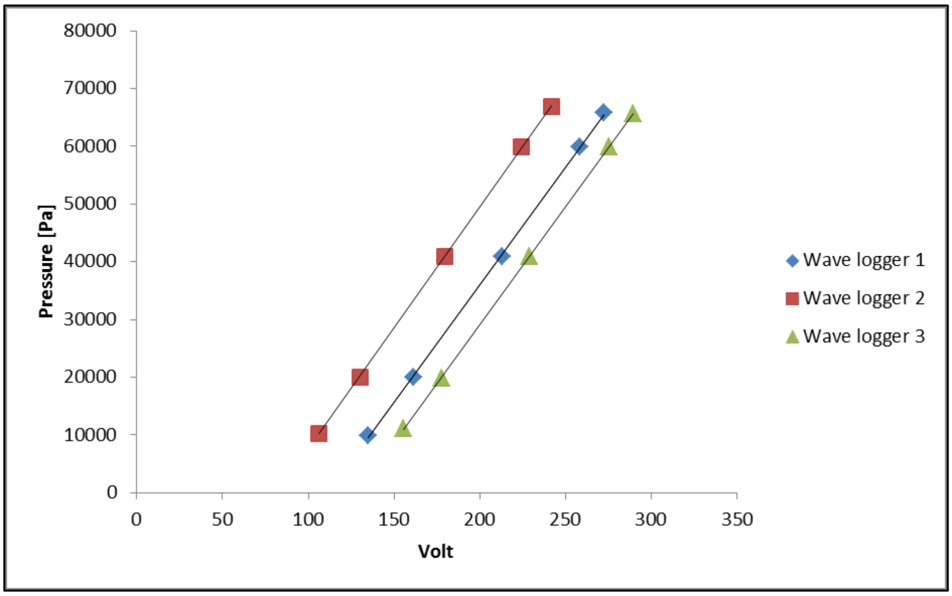


Figure 7 regression lines though output values of the wave logger at a known depth

	Wave logger 1	Wave logger 2	Wave logger 3
A	408.7	419.4	408.3
B	-45693	-34342	-52541

Table 1 calibration values

4.6 Configuration

The duration of the measurements is set to 30 minutes. It is assumed that the wave conditions are stationary during this time. The Waverider also determines the energy spectra with 30 minutes intervals.

5 Location

5.1 Overview

Figure 8 gives an overview of the location of the Waverider and the wave logger. It is assumed that the waves measured by the Waverider are not influenced by the half-finished underwater breakwater. This is a doubtful assumption when waves come from North and north-east direction, this situation is avoided during the interpretation of the results.

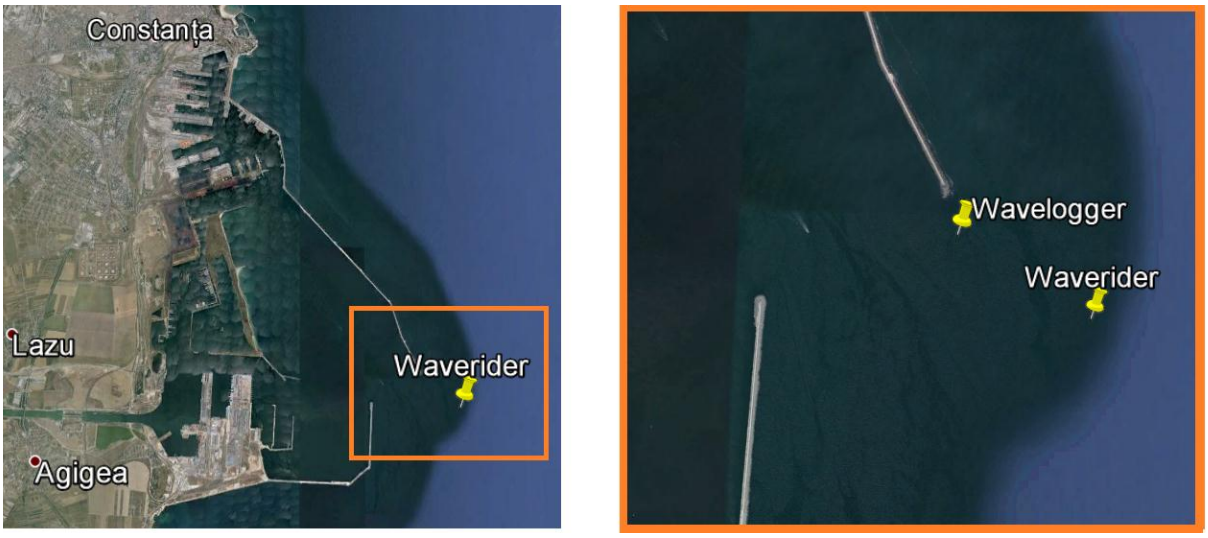


Figure 8 location of the Waverider and wave logger [Google earth]

5.2 Location of the wave logger

The accuracy of the results of the wave logger is to a large extent dependent on the placement depth. If placed too deep, the smaller wav es will disappear from the measurement. Therefore, the options to place the wave logger are limited. Because the goal of the measurements is to gain insight in the wave conditions, the most obvious location is on top of the breakwater dump material. The depth is approximately 7 meter.

Unfortunately it is not possible to obtain insight in purely the reflection. The depth is too large to deploy the instrument in front of the breakwater. However, the location on top of the breakwater dump will give information about the wave conditions in the working area. It will give an idea of the shoaling over the core of the breakwater.

Figure 9 shows a top view of the breakwater. The orange dot indicates the location of the wave logger. The location is chosen in agreement with the dump plans of the side stone dumper. During the measurements, no dumps are made near the wave logger.

Figure 10 shows the cross section of the breakwater. The location of the wave logger is in the centre of the dumped material.

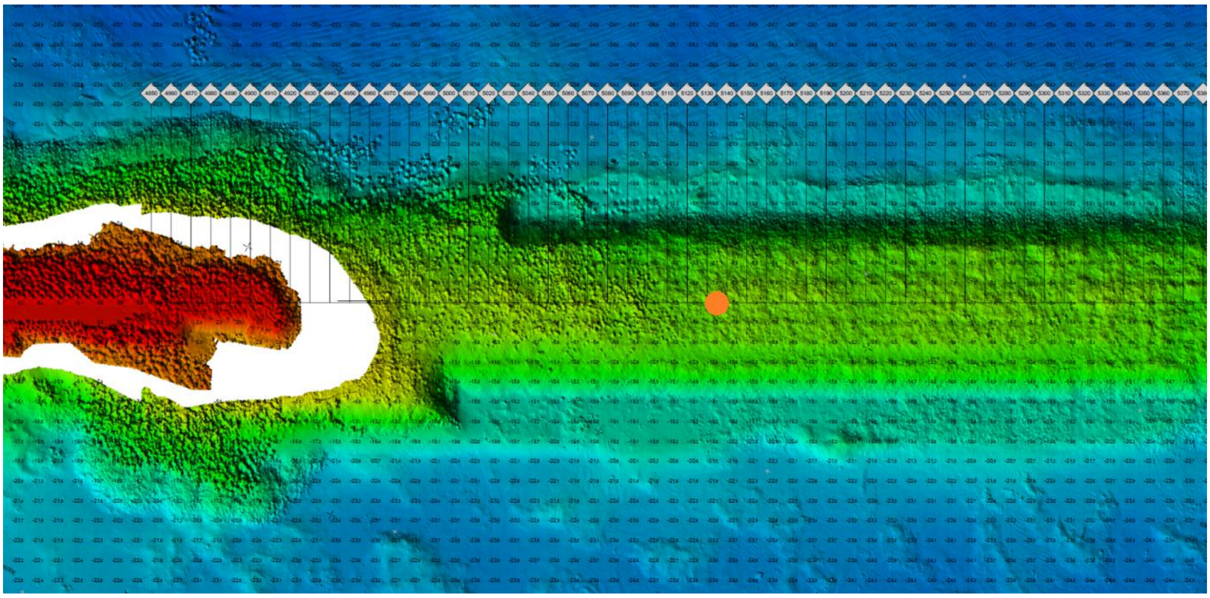


Figure 9 top view breakwater

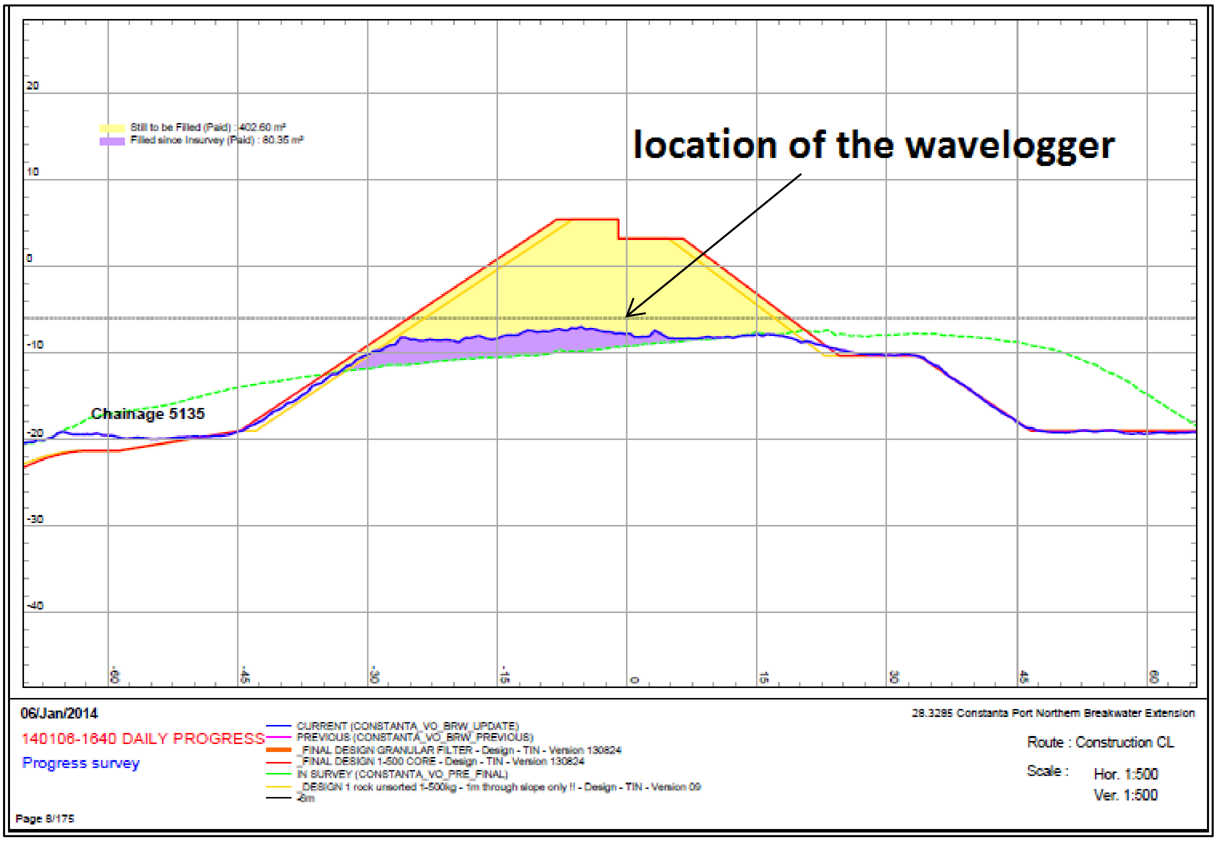


Figure 10 cross section at location of the wave logger

The depth of the wave logger can be determined from the pressure records. The average pressure over time gives the depth. Together with the survey department, this depth is checked. A bottom profile is obtained from the location of the anchor with the attached wave logger. This survey confirmed the depth of approximately 7 meter. Figure 11 and Figure 12 show the results of the survey. The profile of the anchor was easy to find with the survey equipment.

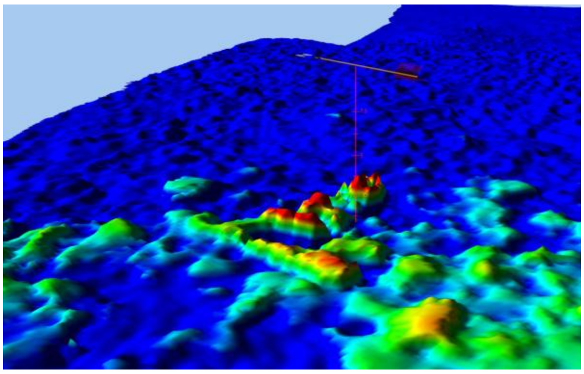


Figure 11 3d depth profile with anchor

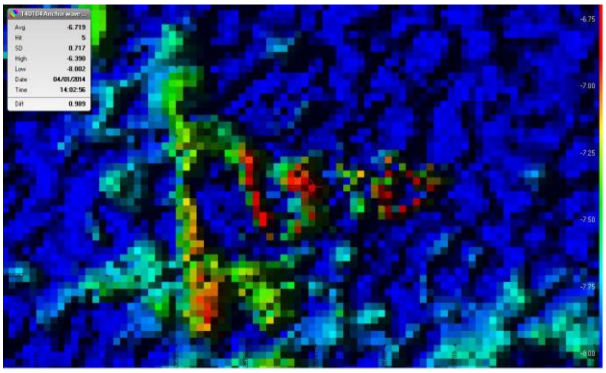


Figure 12 2d depth profile with anchor

Figure 13 picture of the anchor with the wave logger

6 Expectation

Theoretically, it is expected that the waves shoal, refract and reflect when passing the submerged core of the breakwater. It is hard to calculate these effects altogether, especially the reflection is hard to calculate. An energy balance can be used to calculate shoaling and refraction. The effect of refraction will be very limited when waves pass the breakwater, so this is neglected. The following expression can be used to calculate wave height.

$$H_2 = K_s \cdot K_r \cdot H_1$$
$$where:$$
$$K_s = \sqrt{\frac{c_{g,1}}{c_{g,2}}} = shoaling\ coefficient$$
$$K_r = refraction\ coefficient = 1$$

When a wave approaches shallower water the dispersion equation will remain valid. The phase speed will decrease. Initially the group velocity will increase, but eventually it also decreases. The shoaling follows from the group velocity, initially a slight decrease in the wave height is expected, but eventually the wave height increases.

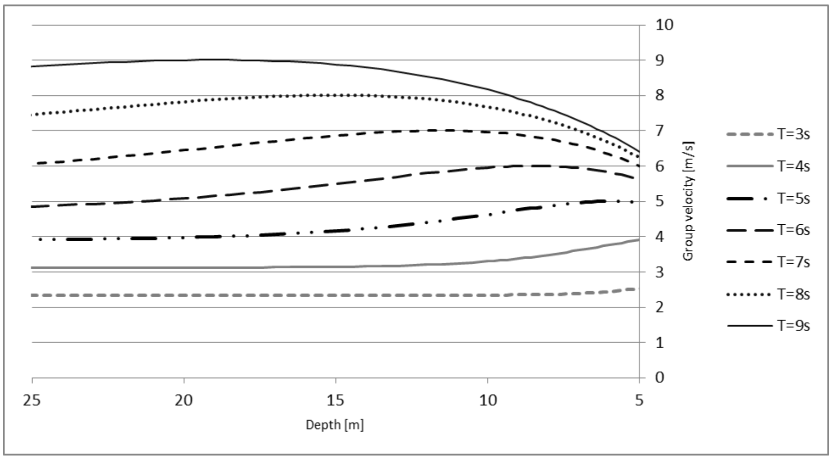


Figure 14 group velocities for different periods

In Figure 14 the group velocities are plotted for some different wave periods. This graph gives insight in the development of the group velocity . It can be seen that the wave periods have a large influence on the group velocity. The depth of deployment of the wave logger is around 7 meter. At this depth, for some periods the group velocity has increased compared to the group velocity in deeper water. For other periods, the group velocity is decreased. This implies that shoaling can cause an increase as well a decrease for different wave periods at our measurement location.

At the project location wave periods from 3 up to 9 seconds are measured. The expected shoaling varies for different periods. This is presented in Figure 15. The shoaling coefficient can be positive or negative for the different wave periods.

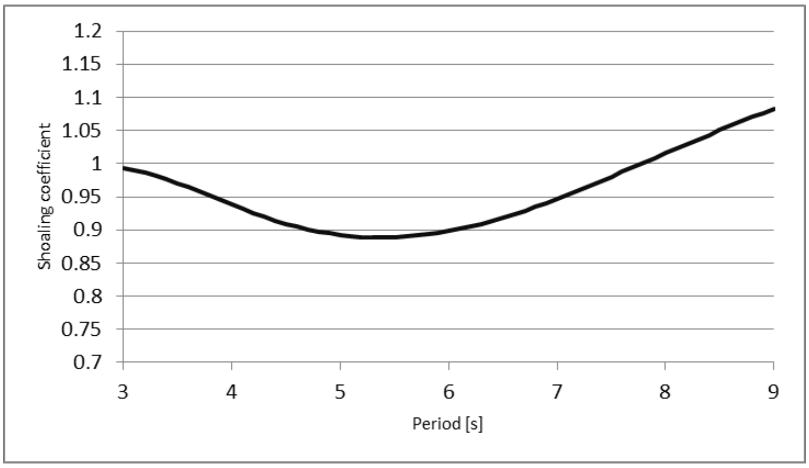


Figure 15 shoaling coefficient for different wave periods for a wave passing from 26 to 7.5 meters depth

There are some doubts in the applicability of approach to calculate the shoaling. The slope of the breakwater is not gentle, but rather steep. The approach is fully linear, while non-linearity is likely when waves pass this slope. On top of that, the approach consist of an energy balance, and it is not possible to take the loss of energy due to reflection into account. The loss of energy will result in lower wave heights on top of the breakwater.

Altogether, the theoretical calculation of the wave conditions on top of the breakwater dump are very uncertain. Therefore, the measurements are crucial to determine the wave conditions on top of the breakwater dump.

7 Results

The results will be compared to the Waverider's measurements. The difference in the results is caused by two factors:

- Influence of the breakwater
- Inaccuracies in the measurements

To draw reliable conclusions form the results it is necessary to filter out the inaccuracies as much as possible. It is assumed that the Waverider's measurements are accurate, and that the wave spectra produced by the Waverider's software are accurate as well. For the wave logger is known that the measurements are reliable till the cut-off frequency, and that the measurable wave height has a lower bound.

The chosen wave conditions to compare are based on the Waverider's measurement and corresponding spectra. From the spectrum is clear how the energy is divided over the frequencies. No rigorous changes in the bandwidth of the wave periods are expected when the waves are influenced by the breakwater. Therefore is chosen to compare the wave conditions where little to no energy exist above 0.3 Hz. Consequently, we can use a cut-off frequency of approximately 0.3 Hz for the interpretation of the wave logger's results. This way, the inaccuracy of the wave logger's maximum cut-off frequency will be filtered out as much as possible.

Secondly, wave conditions are chosen where the significant wave height is higher than 0.5 meter. The minimum measurable wave height was is approximately 0.25 meter (with a 4 second period).

The demands we make on the wave conditions, result in mainly the analysis of swell waves. Wind wave is hard to take into account, because the frequency of wind wave is mostly higher than the cut-off frequency. However, It is the swell that is most interesting, not the wind wave. The half-finished-breakwater will less influence the shorter waves, and have more effect on the longer swell waves. It is precisely this influence where we want to gain insight in. Therefore it is not only justified to only take into account the wave conditions that mainly consist of swell, it is also preferred.

In Appendix C the Waverider's measurements and wave spectra are found. From this data is decided to compare the following wave conditions:

	Peak direction °	Significant wave height m	Mean period s
03-01-2014 12:20	101.3	0.32	4.19
05-01-2014 12:20	160.3	0.76	3.54
06-01-2014 00:20	163.1	1	3.85
06-01-2014 12:20	142	0.81	4.28
07-01-2014 00:20	109.7	0.52	3.74
11-01-2014 00:20	147.7	0.51	3.94

Table 2 Waverider's wave conditions

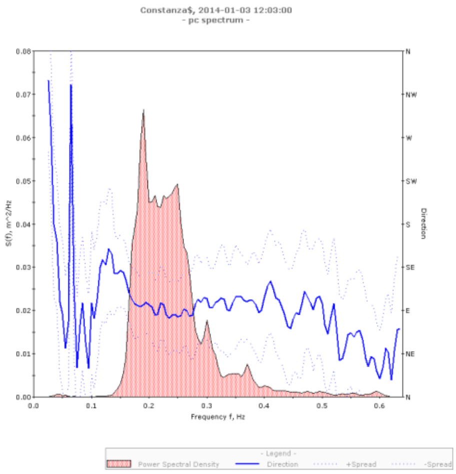
Date	Waverider's measurements			Wave logger's measurements			
				Time domain		Spectral analysis	
	Direction	H_s	T_{mean}	$H_{1/3}$	T_{mean}	H_{m0}	T_{m02}
03-01-2014 12:20	101.3	0.32	4.19	0.53	1.9	0.26	4.5
05-01-2014 12:20	160.3	0.76	3.54	0.71	2.3	0.46	4.3
06-01-2014 00:20	163.1	1	3.85	0.84	2.6	0.6	4.6
06-01-2014 12:20	142	0.81	4.28	0.82	2.7	0.53	4.5
07-01-2014 00:20	109.7	0.52	3.74	0.75	2.6	0.42	5
11-01-2014 00:20	147.7	0.51	3.94	0.71	2.5	0.36	5.3

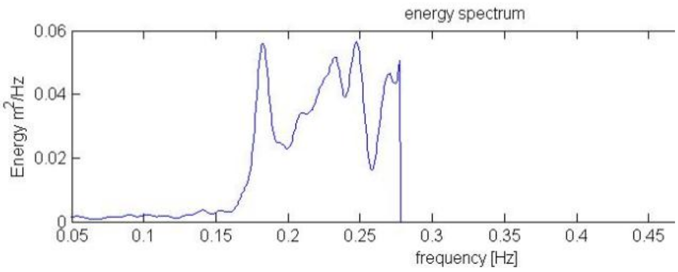
Table 3 measurements of the Waverider compared to the wave logger

Large differences are measured between the values of the Waverider and the wave logger. However, also large differences are measured between the time domain analysis and the spectral domain analysis of the wave logger's data. This is not ideal, but can be explained with reference to the accuracy of the pressure meter. For the frequency analysis, a part is cut from the wave spectrum. Since the calculations in the spectral analysis are based on the moments of the spectrum, results are influenced by this cut-off frequency. For example, the H_{m0} (which represents the significant wave height) is calculated as follows: $H_{m0} = 4\sqrt{m_0}$. Therefore H_{m0} will result in smaller values due to the cut-off frequency, because the higher frequencies cannot be taken into account. For the time domain analysis, the downward zero-crossing method is used to separate the different waves. The waves are ranked in height, the highest one third of the waves represents $H_{1/3}$. Because the lower waves are not measured due to the wave logger accuracy, this $H_{1/3}$ tends to be on the higher side. On the basis of only the numbers it is not possible to draw conclusions, but together with the wave spectra, more insight is gained.

The wave spectra have more-or-less the same shape. However, It is noticed that the energy in the 0.2 Hz frequency has decreased significantly. It seems that this energy in not replaced to other frequencies in the spectrum, so indicates a loss in energy. This loss in energy may be a result of reflection and friction. Because the area of the breakwater's dump is only small, it is presumed that mainly the reflection is the phenomenon that affects the 0.2 Hz energy peak. This indicates that the higher period waves (5 seconds) are reflected stronger than the shorter waves.

03-01-2014 12:20





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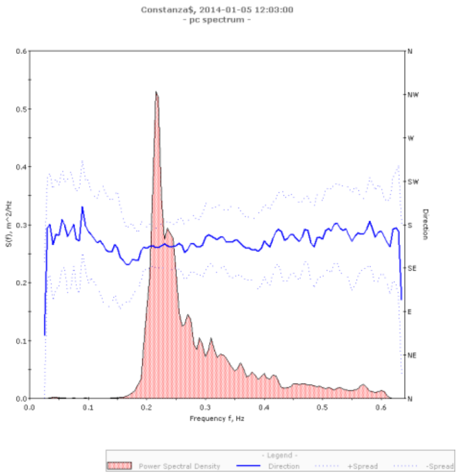

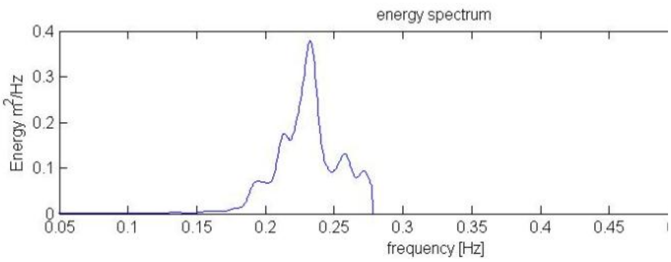

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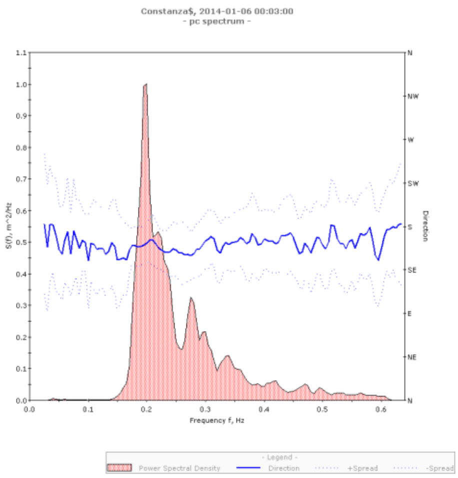

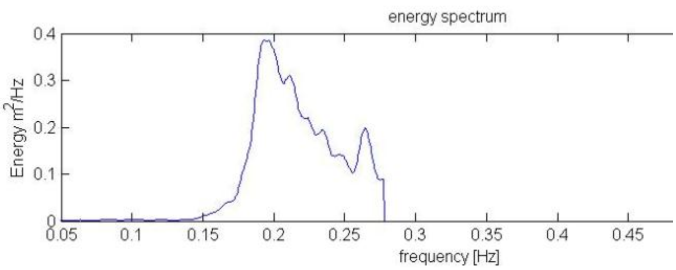

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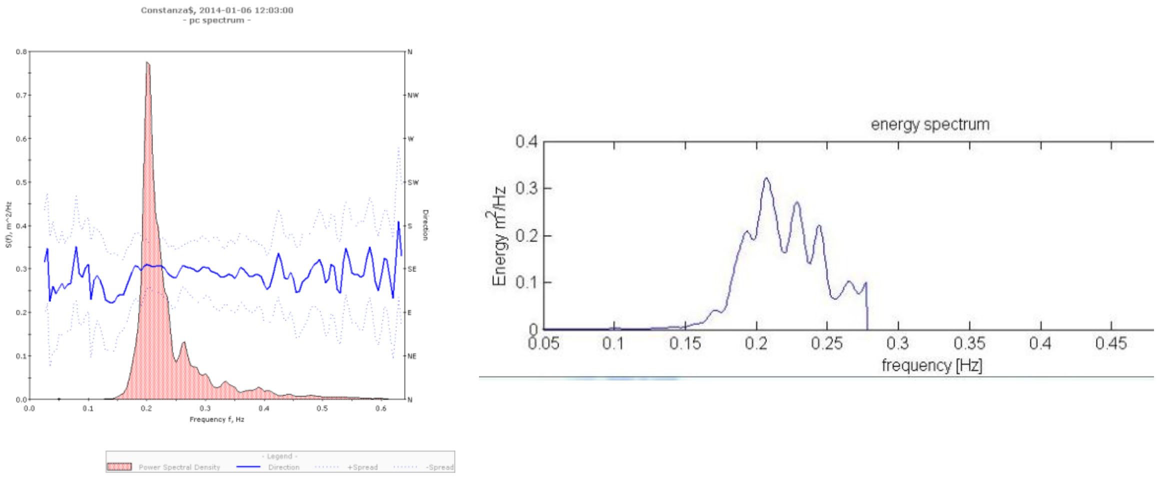

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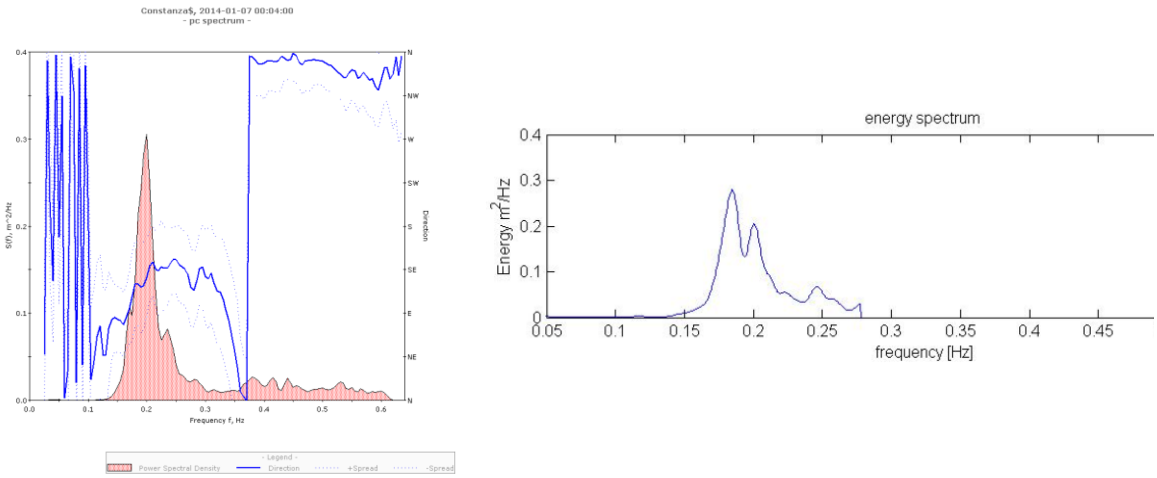


11-01-2014 00:20

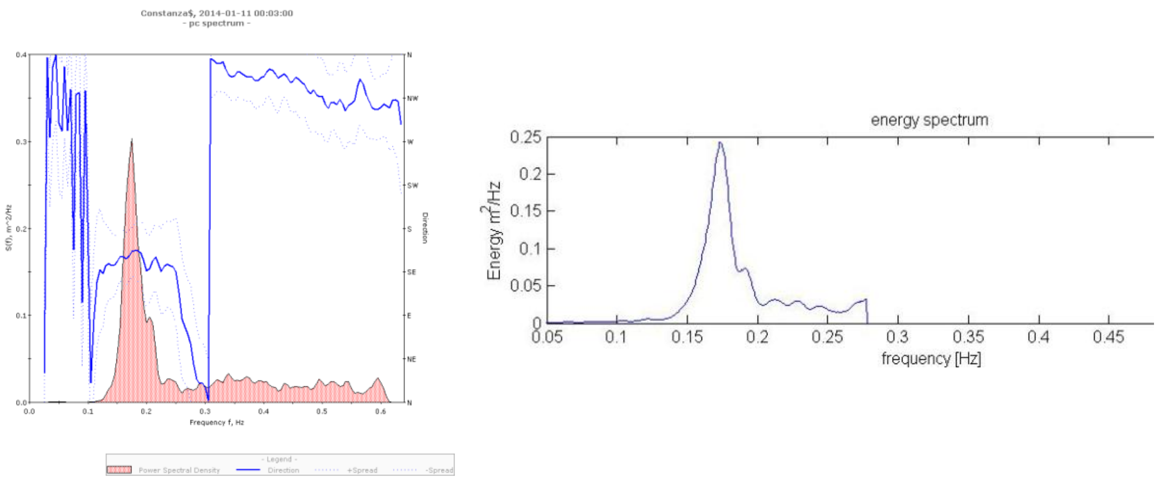


Figure 16 Left: wave spectra of the Waverider Right: Wave spectra of the wave logger

8 Conclusion

From the results of the wave logger can be concluded that the waves are partly reflected when passing the half-finished underwater construction. The energy of the waves with a period of 5 seconds and higher decreases significantly when passing the breakwater dump. This may be an explanation for the drop in workability of the Razende Bol. From the workability analysis of the Razende Bol was concluded that the workability was dropping seriously for waves higher than 5 seconds. It is presumed that the reflections had a large influence on this workability. The incoming waves together with the reflection resulted in tougher work conditions for the Razende Bol. This insight must be taken into account for future workability estimations. Especially when estimating the workability for backhoes on other breakwater project, similar effects regarding the reflections are likely to arise.

For the significant wave height above the breakwater dump is noticed that in most of the time a decrease in wave height is expected. But this cannot be stated with complete certainty, because of the limits and in accuracies of the wave logger.

Furthermore, a lot is found out about the use of the wave logger. The placement depth is one of the large limitations of the device. Thereby, it will always be a challenge to measure wind wave accurately in the black sea, because of the small wave periods. Therefore is suggested to use this device when the focus is mainly on the longer waves, and place the device as close to the sea surface as possible.

9 Discussion

During the analysis, it is assumed that the Waverider measures the unaffected incoming wave conditions. The assumption that the waves are unaffected is very likely if we look to the wave direction during the measurements. However, measuring errors in the Waverider's device are not taken into account. As each measurement device, also the Waverider will have its accuracy. The possible errors in the Waverider are neglected in this report.

During the two weeks in which the wave logger was active, the wave conditions were quite mild. It was hoped for that some more extreme waves would be present, because the accuracy is higher when for larger waves. It would be interesting to evaluate the wave behaviour for larger waves.

10 Next steps

It is learned that the breakwater influences the wave conditions. The next step is to take the reflection into account when estimating the workability of equipment on future works. This leads to more realistic estimates. On the breakwater project the Goliath will be used to place the first 4 layers of accropodes on the seaside of the breakwater. An estimation will be made where the influence of the breakwater is taken into account.

11 References

[1] Verhagen (2013), EMS wave logger data processing

[2] Holthuijsen (2007), Waves in oceanic and coastal waters

12 Appendices

12.1 Calibration of the wave logger

Before the wave loggers are used they need to be calibrated. The output of the pressure meter is a voltage. This voltage can be interpret as a pressure. But first, the relation between this voltage, and pressure head needs to be found.

To calibrate the wave loggers, they are tested in still water. The wave logger is placed at a multiple known depths. Thereafter, the relation between the voltage and pressure head can be found.

12.1.1 Location & setup

A location with still water is found in the harbour, between two berthed barges. Only very little movement in the water is present, which is estimated to be around 1 centimeter. This is acceptable, and can be filtered out when processing the results.

The depth is 7 meter. To calibrate the wave logger, it will be placed on multiple depths; around 1 meter, 2 meter, 4 meter and just above the bottom at 7 meter. The wave logger is attached to a measuring tape, so the depth can be found easily. Note that the measuring tape is attached under the cap of the wave logger (close to the location of the pressure sensor itself), so this will be the reference point when determine the depth of the logger. At the other end of the wave logger a weight is attached to the logger.

The depth is measured from the top of the logger, where the pressure sensor is located.

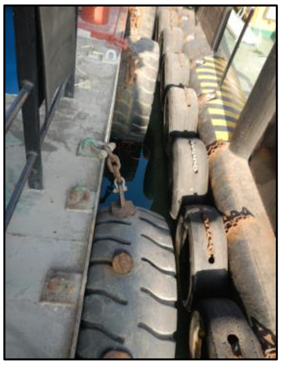


Figure 17 measurement location

Figure 18 setup of the calibration measurements

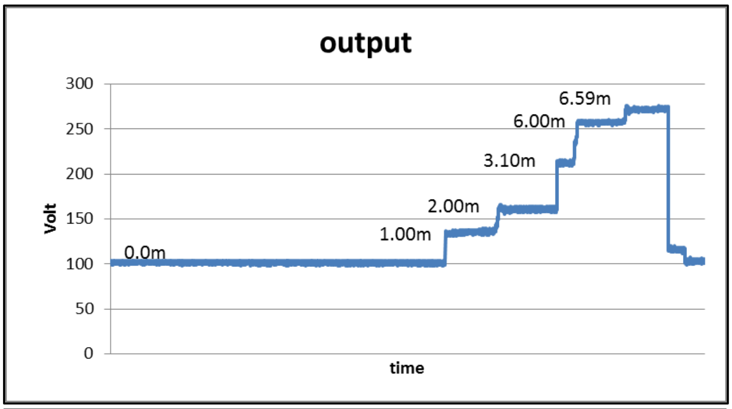
12.1.2 Calibration values

The output of the logger is presented in this section. For each logger, a plot of the output is presented, with the corresponding water depth. The logger is place at a constant depth for around 5 minutes. Another plot is presented with a regression line. The calibration values are obtained from this regression line. The density of the seawater is 1018 kg/m^3. A linear relation can be found between the measured Volts and the corresponding pressure.

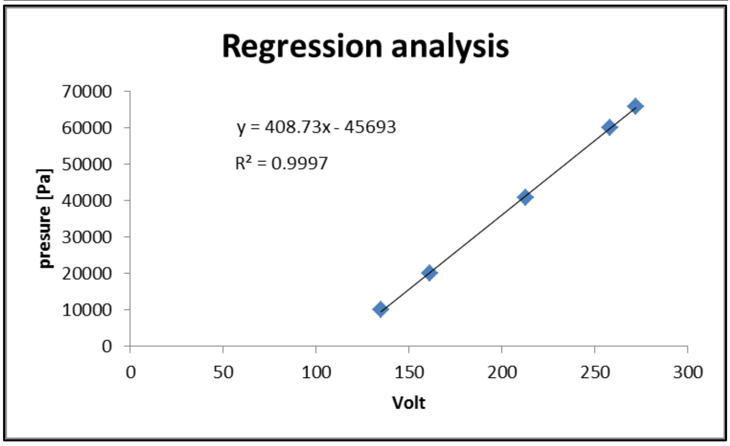
$$
\begin{gathered}
P(V_m) = A \cdot V_m + B \\
where: \\
A = calibration\ parameter \\
B = calibration\ parameter \\
V_m = measured\ Volts
\end{gathered}
$$

For each logger the calibration values are found via the regression line.

12.1.2.1 Wave logger I

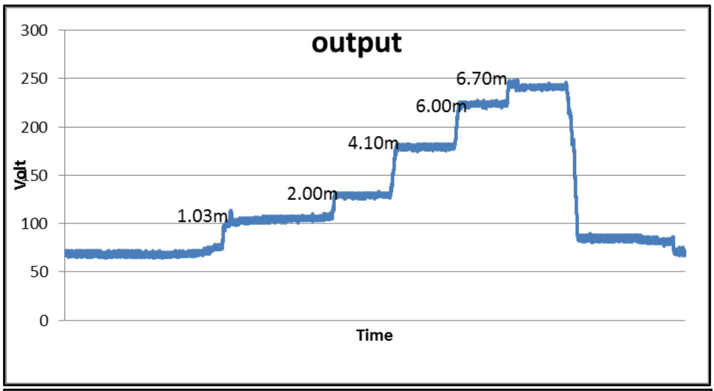


depth [m]	output [Volt]	pressure [Pa]
1	135	9987
2	162	19973
4.1	213	40945
6	258	59919
6.59	272	65812

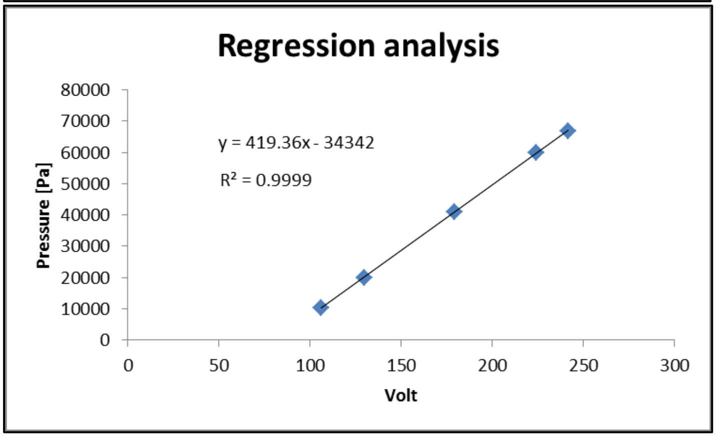


Calibration values wave logger 1	
A	408.7
B	-45693

12.1.2.2 *Wave logger II*

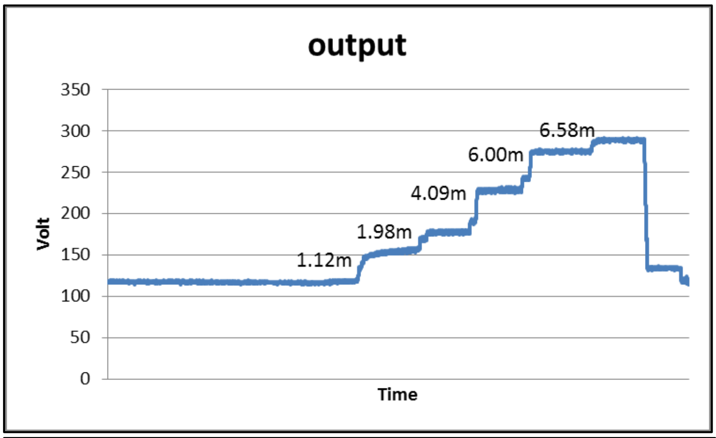


depth [m]	output [Volt]	pressure [Pa]
1.03	106	10286
2	130	19973
4.1	180	40945
6	224	59919
6.7	242	66910

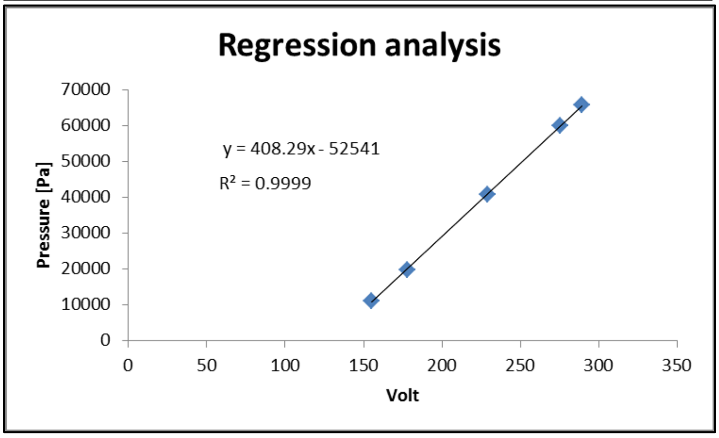


Calibration values wave logger 2	
A	419.36
B	-34342

12.1.2.3 *Wave logger III*

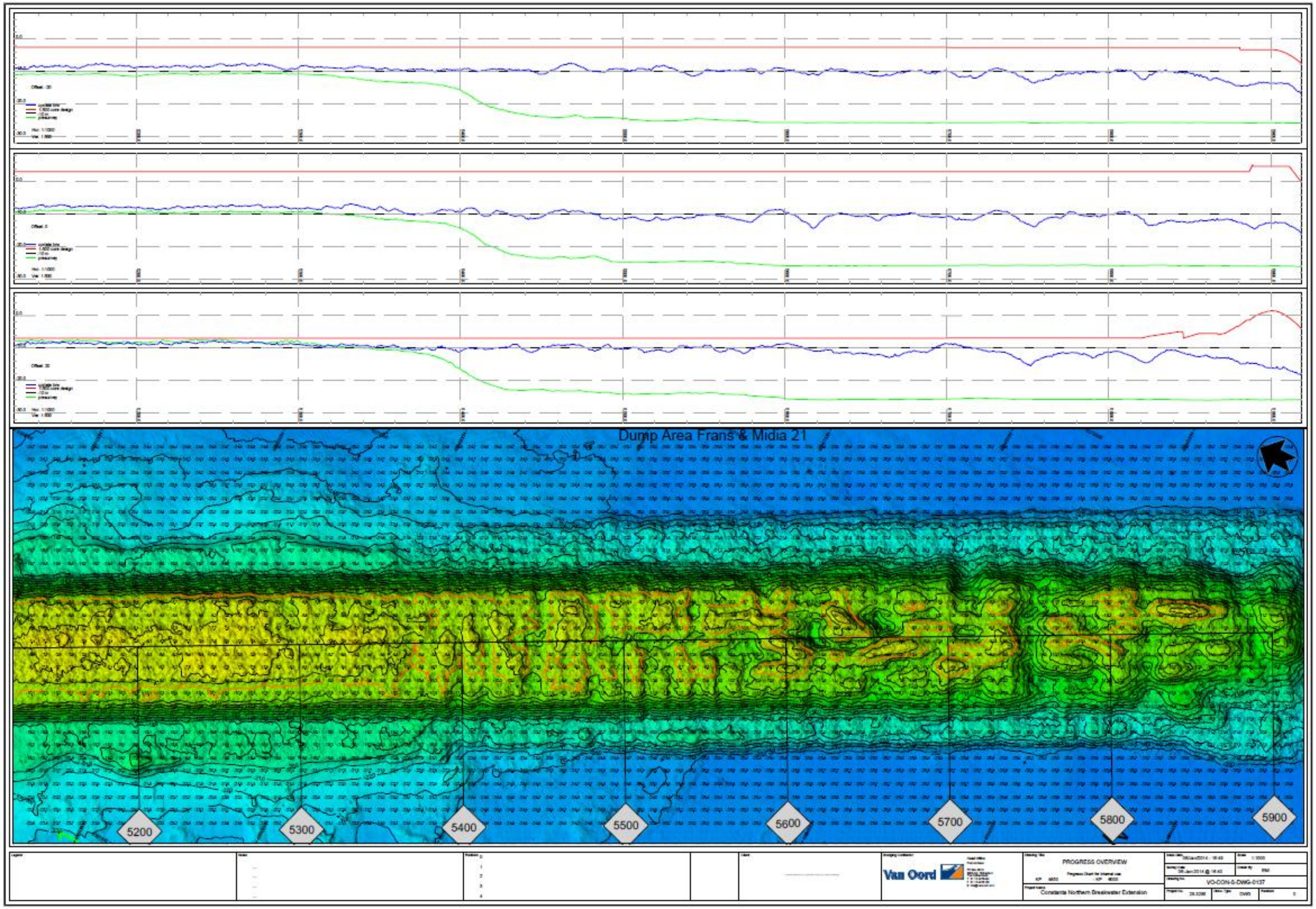


depth [m]	output [Volt]	pressure [Pa]
1.12	155	11185
1.98	178	19773
4.09	229	40845
6	275	59919
6.58	289	65712



Calibration values wave logger 3	
A	408.29
B	-52541

12.2 overview breakwater at time of measurements



12.3 Planning

activity	31-Dec	01-Jan	02-Jan	03-Jan	04-Jan	05-Jan	06-Jan	07-Jan	08-Jan	09-Jan	10-Jan	11-Jan	12-Jan	13-Jan	14-Jan	15
Place anchor with Toomai	■															
measure depth anchor with geosolution		■														
collect data with Toomai				■												
replace wave logger				■												
measure depth anchor with geosolution					■											
collect data with Toomai														■		
measure depth anchor with geosolution														■		
remove anchor														■		

Depending on the weather conditions the dates of data collection may change (at this moment is expected to collect data the 7th, 13th and 17th of January). The 17th of January the anchor will be removed again. So until the removal on the 17th no dumps should be made at the measurement location.

12.4 Waverider's data during measurements

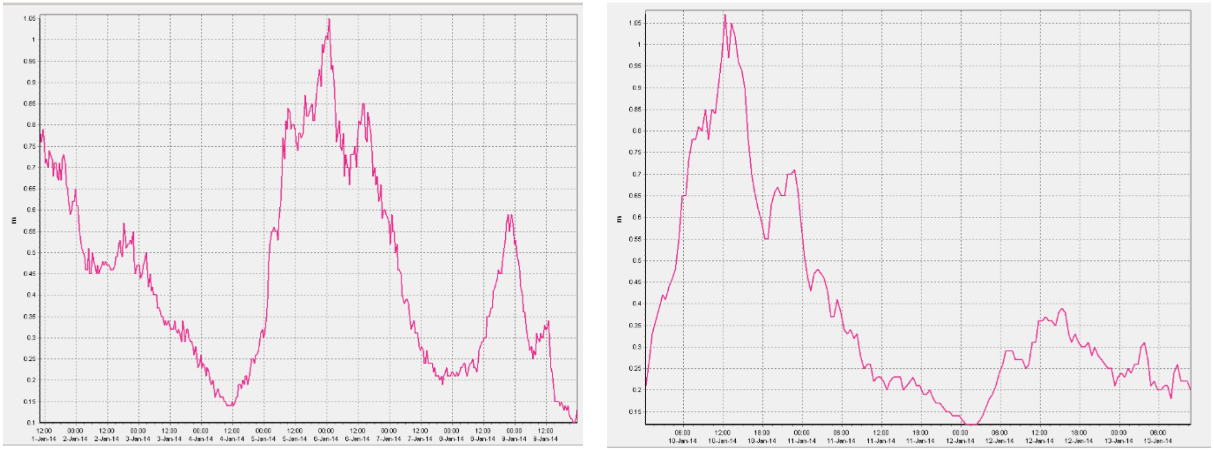
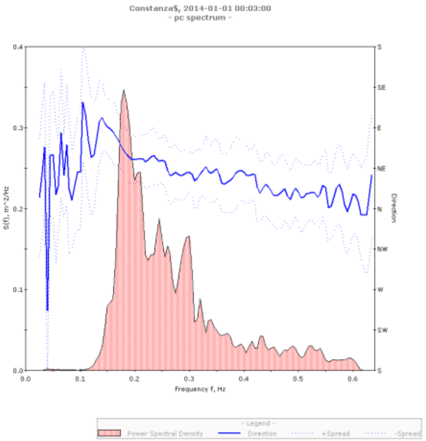


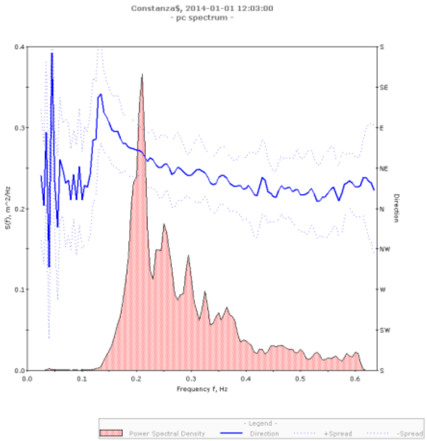
Figure 19 Significant wave height during measurements

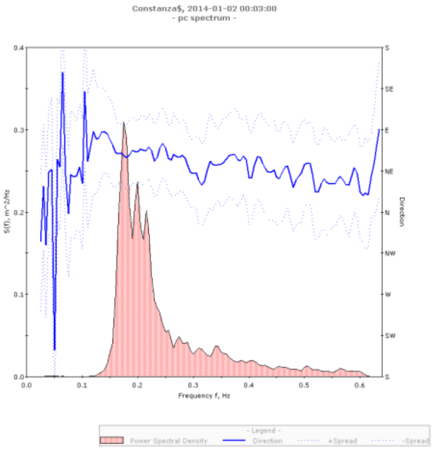
Table 4 wave data measured by Waverider

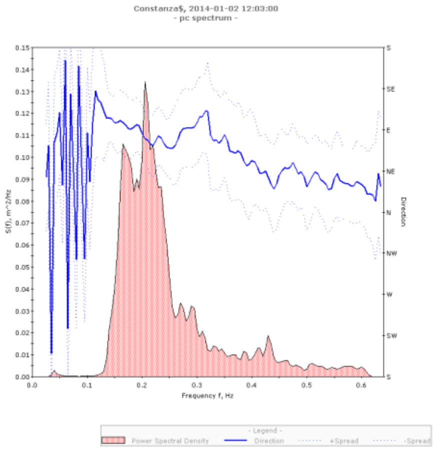
	Peak direction °	Significant wave height m	Mean period s
01-01-2014 12:20	63.3	0.71	3.52
02-01-2014 00:20	67.5	0.61	4.18
02-01-2014 12:20	87.2	0.47	4.15
03-01-2014 00:20	88.6	0.47	4.41
03-01-2014 12:20	101.3	0.32	4.19
04-01-2014 00:20	92.8	0.23	4.1
04-01-2014 12:20	105.5	0.14	4.05
05-01-2014 00:20	161.7	0.31	2.84
05-01-2014 12:20	160.3	0.76	3.54
06-01-2014 00:20	163.1	1	3.85
06-01-2014 12:20	142	0.81	4.28
07-01-2014 00:20	109.7	0.52	3.74
07-01-2014 12:20	90	0.28	4.04
08-01-2014 00:20	88.6	0.22	2.87
08-01-2014 12:20	167.3	0.3	2.81
09-01-2014 00:20	170.2	0.53	3.2
09-01-2014 12:20	350.2	0.32	2.69
10-01-2014 00:20	171.6	0.21	2.2
10-01-2014 12:20	164.5	1.07	3.96
11-01-2014 00:20	147.7	0.51	3.94
11-01-2014 12:20	133.6	0.22	4.61
12-01-2014 00:20	136.4	0.13	3.97
12-01-2014 12:20	153.3	0.36	2.78
13-01-2014 00:20	126.6	0.24	3.21

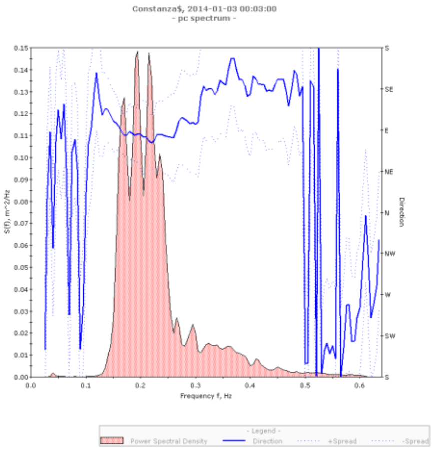
Van Oord
Marine ingenuity

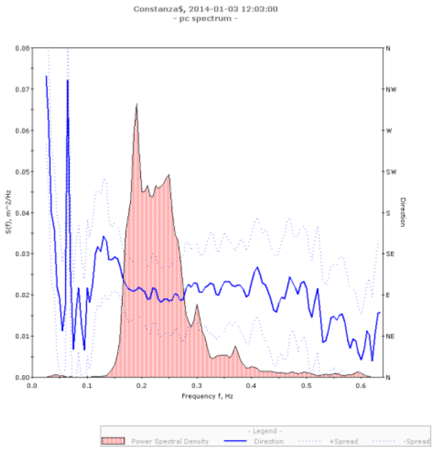




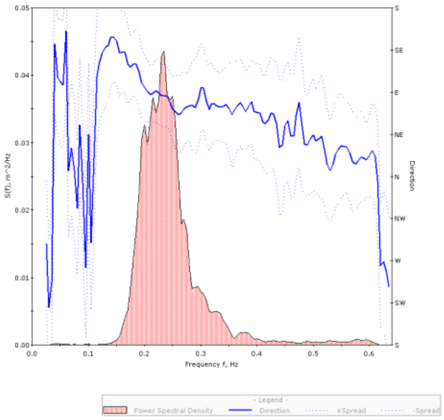




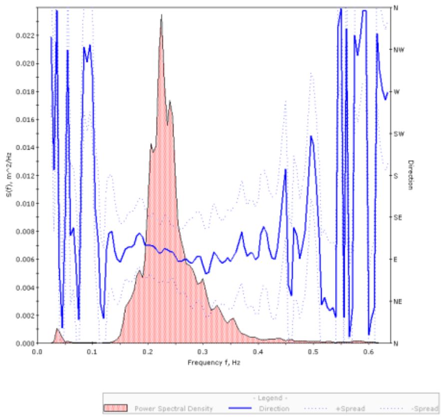




Constanza$, 2014-01-04 00:03:00
- pc spectrum -



Constanza$, 2014-01-04 12:03:00
- pc spectrum -



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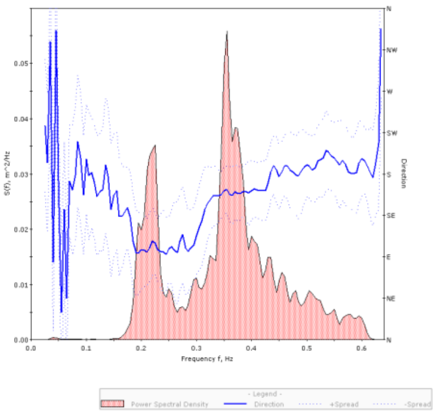
- pc spectrum -



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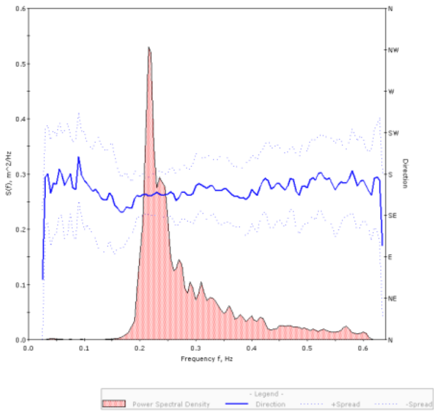
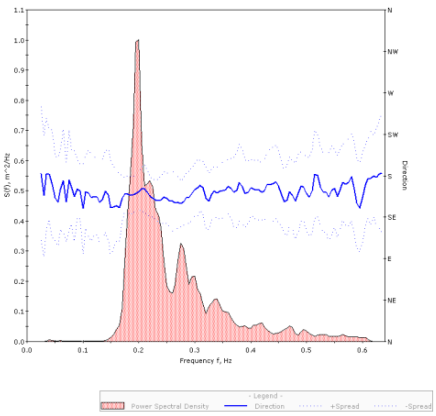
- pc spectrum -



Constanza$, 2014-01-06 00:03:00
- pc spectrum -



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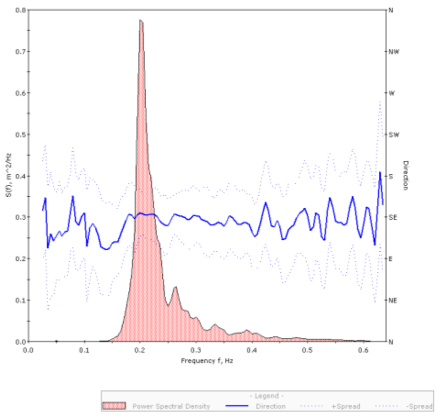
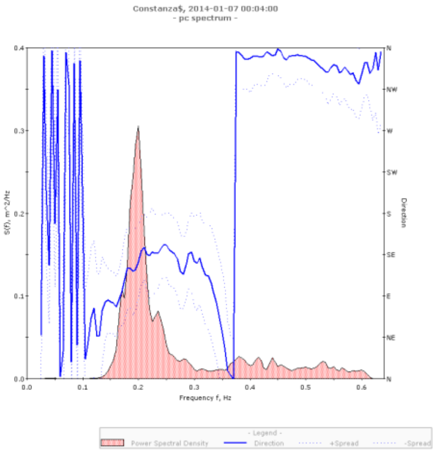
- pc spectrum -

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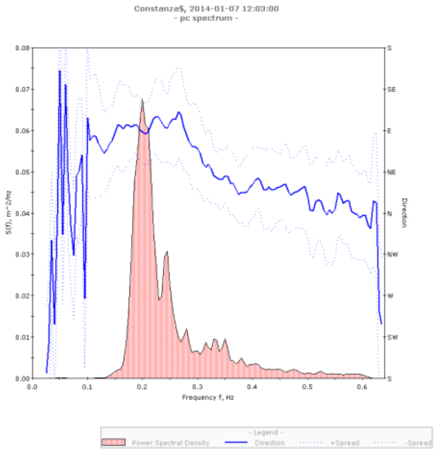
S(f), m^2/Hz
Direction
Frequency f, Hz
- Legend -
Power Spectral Density
Direction
+Spread
-Spread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S(f), m^2/Hz
Direction
Frequency f, Hz
- Legend -
Power Spectral Density
Direction
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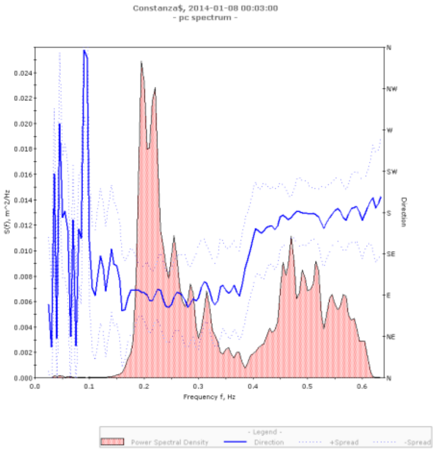
-Spread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S(f), m^2/Hz
Direction
Frequency f, Hz
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Power Spectral Density
Direction
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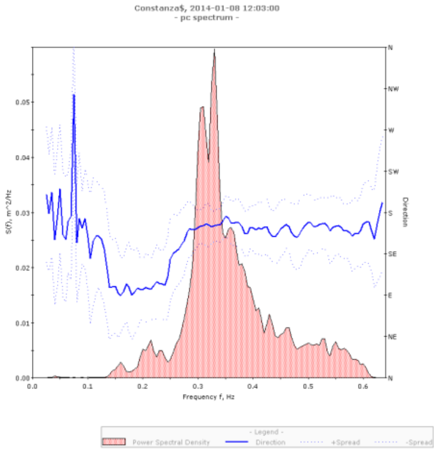
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- Legend -
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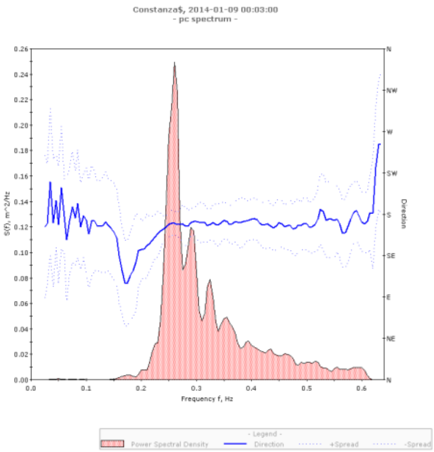
Constanza$, 2014-01-09 00:03:00
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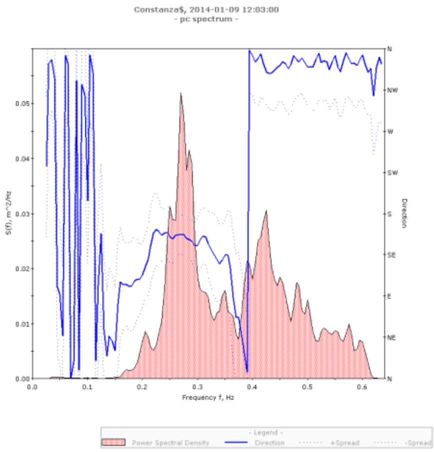
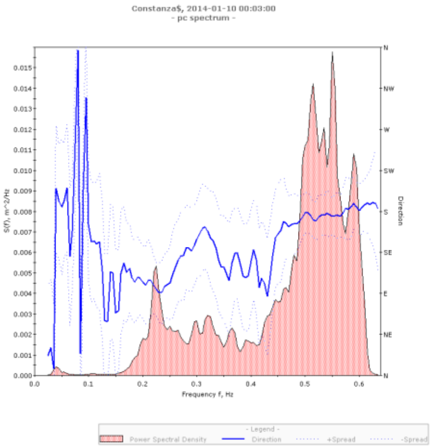
S(f), m^2/Hz
Direction
Frequency f, Hz
- Legend -
Power Spectral Density
Direction
+Spread
-Spread


Constanza$, 2014-01-09 12:03:00
- pc spectrum -
S(f), m^2/Hz
Direction
Frequency f, Hz
- Legend -
Power Spectral Density
Direction
+Spread
-Spread


Constanza$, 2014-01-10 00:03:00
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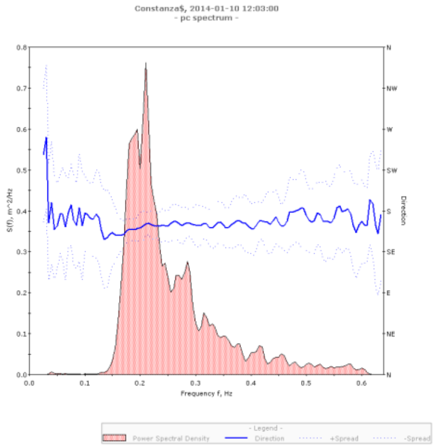
S(f), m^2/Hz
Direction
Frequency f, Hz
- Legend -
Power Spectral Density
Direction
+Spread
-Spread


Constanza$, 2014-01-10 12:03:00
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Direction
Frequency f, Hz
- Legend -
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Direction
+Spread
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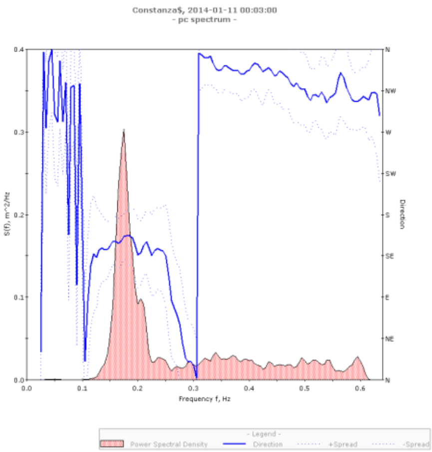
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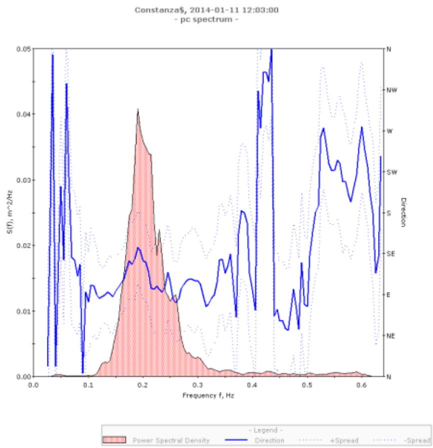
S(f), m^2/Hz
Direction
Frequency f, Hz
- Legend -
Power Spectral Density
Direction
+Spread
-Spread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S(f), m^2/Hz
Direction
Frequency f, Hz
- Legend -
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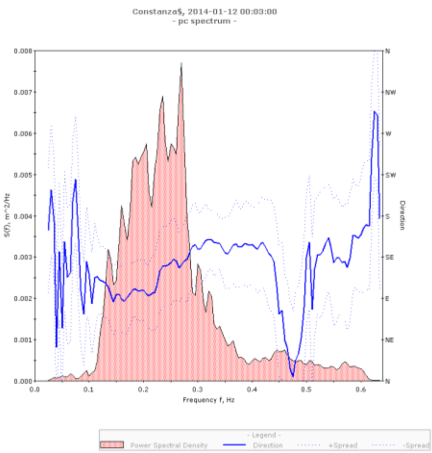
Direction
+Spread
-Spread


Constanza$, 2014-01-12 00:03:00
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Direction
Frequency f, Hz
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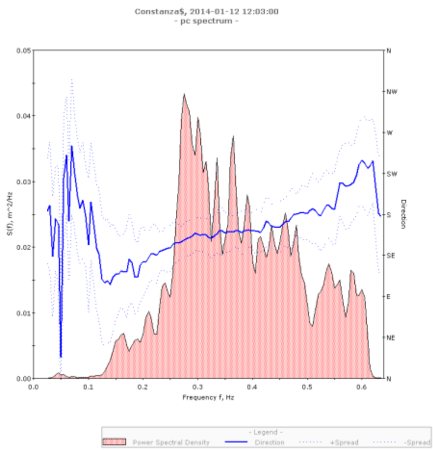
Direction
+Spread
-Spread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Direction
Frequency f, Hz
- Legend -
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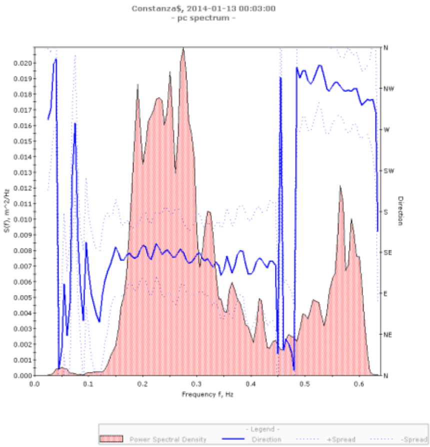
Direction
+Spread
-Spread


Constanza$, 2014-01-13 00:03:00
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S(f), m^2/Hz
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0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010
0.011
0.012
0.013
0.014
0.015
0.016
0.017
0.018
0.019
0.020
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency f, Hz
Direction
N
NE
E
SE
S
SW
W
NW
N
- Legend -
Power Spectral Density
Direction
+Spread
-Spread