



Whitby Wave Buoy

**Cell 1 Regional Coastal Monitoring Programme  
Wave Data Analysis Report 1: 2010 - 2011**



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**Scarborough Borough Council  
Final Report  
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Much of the wave data presented and analysed in this report has been obtained from the Cefas WaveNet site (<http://www.cefas.defra.gov.uk/our-science/observing-and-modelling/monitoring-programmes/wavenet.aspx>) and are subject to the Cefas data usage license as described on the next page.

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## Abbreviations and Acronyms

Acronym / Abbreviation	Definition
AONB	Area of Outstanding Natural Beauty
DGM	Digital Ground Model
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
m	metres
ODN	Ordnance Datum Newlyn

## Glossary of Terms

Term	Definition
Beach nourishment	Artificial process of replenishing a beach with material from another source.
Berm crest	Ridge of sand or gravel deposited by wave action on the shore just above the normal high water mark.
Breaker zone	Area in the sea where the waves break.
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by the fixing of the high water mark, e.g. a sea wall.
Downdrift	Direction of alongshore movement of beach materials.
Ebb-tide	The falling tide, part of the tidal cycle between high water and the next low water.
Fetch	Length of water over which a given wind has blown that determines the size of the waves produced.
Flood-tide	Rising tide, part of the tidal cycle between low water and the next high water.
Foreshore	Zone between the high water and low water marks, also known as the intertidal zone.
Geomorphology	The branch of physical geography/geology which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.
Groyne	Shore protection structure built perpendicular to the shore; designed to trap sediment.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean Sea Level (MSL)	Average height of the sea surface over a 19-year period.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm.
Swell	Waves that have travelled out of the area in which they were generated.
Tidal prism	The volume of water within the estuary between the level of high and low tide, typically taken for mean spring tides.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Updrift	Direction opposite to the predominant movement of longshore transport.
Wave direction	Direction from which a wave approaches.
Wave refraction	Process by which the direction of approach of a wave changes as it moves into shallow water.



## Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the north east coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. This coastline is often referred to as 'Coastal Sediment Cell 1' in England and Wales (Figure 1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing salt marshes, hard rock cliffs that are mantled with glacial sediment to varying thicknesses, softer rock cliffs and extensive landslide complexes.

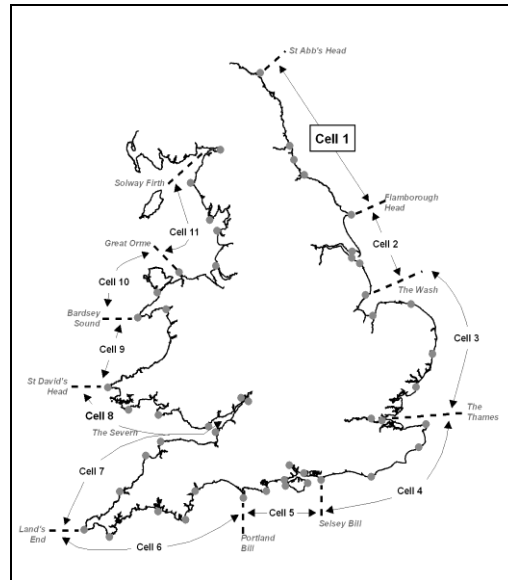


Figure 0.1 Sediment Cells in England and Wales

The work commenced with a three-year monitoring programme in September 2008 that was managed by Scarborough Borough Council on behalf of the North East Coastal Group. This initial phase has been followed by a five-year programme of work, which started in October 2011. The work is funded by the Environment Agency, working in partnership with the following organisations:



The original three year programme of work was undertaken as a partnership between Royal Haskoning, Halcrow and Academy Geomatics. For the current five year programme of work the data collection associated with beach profiles, topographic surveys and cliff top surveys is being undertaken by Academy Geomatics. The analysis and reporting for the programme is being undertaken by Halcrow. Wave and tide data collection, starting in January 2013 and not included in this baseline report, is being undertaken by Fugro EMU, and the new wave and tide data that will be collected will be available in near real-time on both the Channel Coast Observatory website and the [www.northeastcoastalobservatory.org.uk](http://www.northeastcoastalobservatory.org.uk) website developed for this programme.



The main elements of the Cell 1 Regional Coastal Monitoring Programme involve:

- beach profile surveys
- topographic surveys
- cliff top recession surveys
- real-time wave data collection
- bathymetric and sea bed characterisation surveys
- aerial photography
- walk-over surveys

The beach profile surveys, topographic surveys and cliff top recession surveys are undertaken as a 'Full Measures' survey in autumn/early winter every year. Some of these surveys are then repeated the following spring as part of a 'Partial Measures' survey.

Each year, an Analytical Report is produced for each individual authority, providing a detailed analysis and interpretation of the 'Full Measures' surveys. This is followed by a brief Update Report for each individual authority, providing ongoing findings from the 'Partial Measures' surveys.

The present report is **Wave Data Analysis Report 1** and provides an analysis of the wave data collected from 2010 to 2011 as part of the programme alongside other relevant regional data.

In addition, separate reports are produced for other elements of the programme as and when specific components are undertaken, such as wave data collection, bathymetric and sea bed sediment data collection, aerial photography, and walk-over visual inspections.

## 1. Introduction

### 1.1. Study Background and Scope

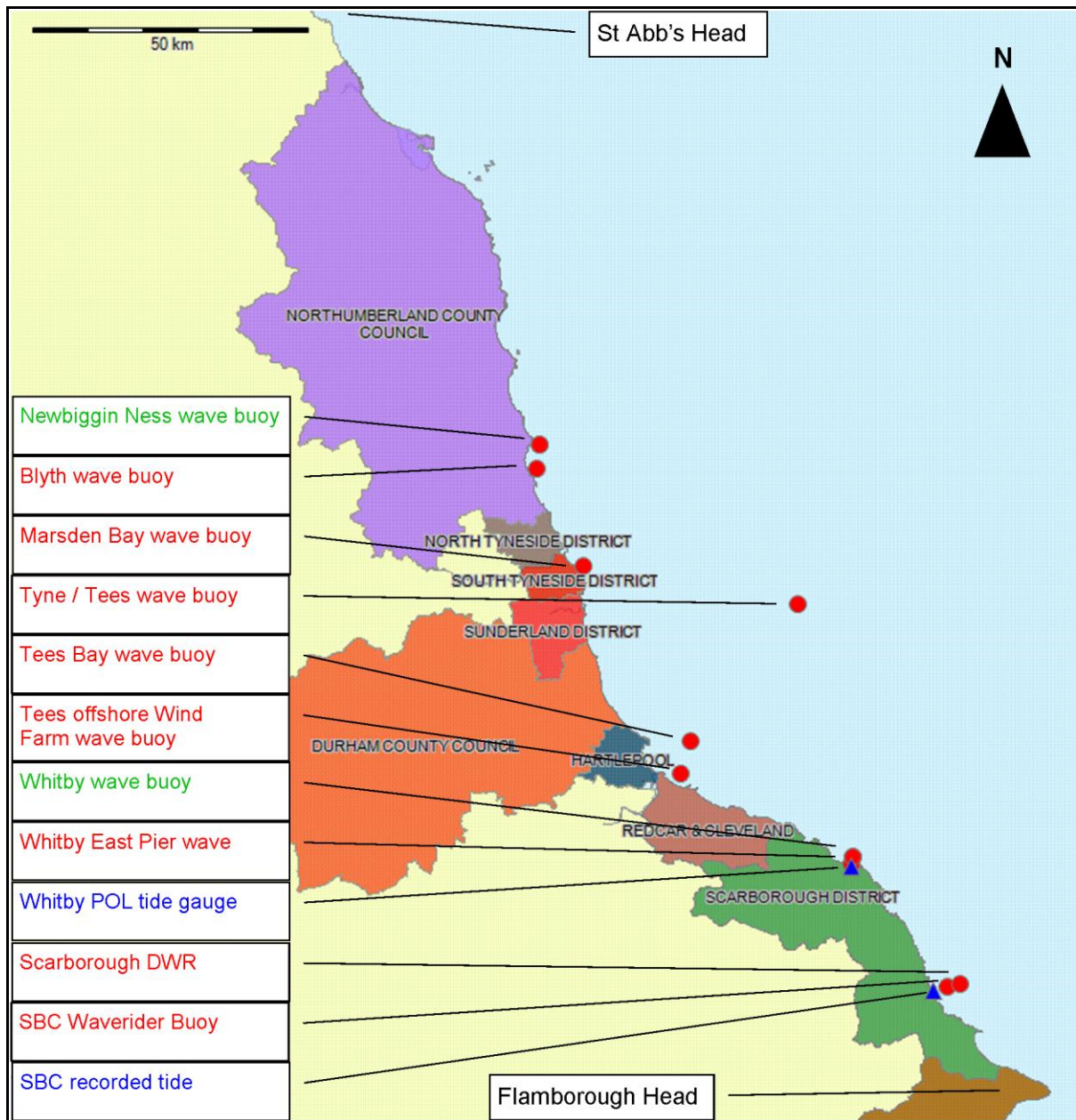
Wave data collection is an integral part of the Cell 1 Regional Coastal Monitoring programme. Under the present programme data collection commenced in June 2010 when two Waverider buoys were deployed at Newbiggin and Whitby in June 2010 by Cefas. During the period of deployment the data was made available on the internet in near real time via the WaveNet site (Access via the Cefas website <http://www.cefas.defra.gov.uk/our-science/observing-and-modelling/monitoring-programmes/wavenet.aspx>) and was also available on the Cell 1 Regional Coastal Monitoring programme website at [www.northeastcoastalobservatory.org.uk](http://www.northeastcoastalobservatory.org.uk). The two wave buoys were recovered at the end of the contract, with the Newbiggin buoy recording until June 2011 and the Whitby buoy recording until November 2011.

The present report is **Wave Data Analysis Report 1** and provides an analysis of the wave data collected from 2010 to 2011 as part of the programme. The report also takes into consideration other freely available data that has previously been collected in the region in order to both cross-check the consistency of available data and to form a baseline against which future data can be compared and to inform the programme analytical reports and annual overview reports on wave conditions.

Under the current phase of the Cell 1 Regional Coastal Monitoring programme a deployment of three new Waverider buoys was initially planned to take place in late 2012. The data from these new buoys will be available on the project website and will be reported on in subsequent annual wave data analysis reports. At the time of writing, April 2013, two of the three planned buoys have been deployed so far (at Scarborough and Whitby) and the third buoy, at Newbiggin Ness is expected to be deployed soon. Additionally the existing tide gauge at Scarborough has been serviced and linked up to record concurrent water level data and a new tide gauge is expected to be deployed at Whitby soon.

### 1.2. Study Area and Available Wave Data

The Cell 1 study area extends along the northeast coast of England, from the Scottish border through to Flamborough Head. This report considers the data at each location shown in Figure 2 below, progressing from North to South along the coastline. More detailed location maps of the wave buoys that have been considered are shown in Appendix A.



Note: green text denotes the wave buoys that were installed by Cefas within the Cell 1 programme.

Figure 1.1 Study Area and data sets reviewed

### 1.3. Methodology

The data received from the deployments at Newbiggin Ness and at Whitby were imported into the SANDS (Shoreline And Nearshore Data System) database set up for the Cell 1 Regional Monitoring project for analysis and for comparison with other datasets from the adjacent coastline.

The relevant metadata together with graphs of the significant wave height, peak period, zero crossing period, peak direction, wave spread and water temperature for the Newbiggin Ness and Whitby locations can be found in Appendix B and C respectively. This information was provided by Cefas at the end of the deployments.

The Cefas WaveNet website <http://cefasmapping.defra.gov.uk/Map> was reviewed to identify additional datasets which were available in the region and relevant data were downloaded. Data were also obtained directly from Fugro Emu Ltd from their previous Waverider deployment off Scarborough for monitoring associated with Scarborough strategy and the

Castle Headland scheme. Nearshore data collected by Fugro at Whitby for the East Pier urgent works scheme were also obtained.

The following wave analyses were carried out:

- Wave roses were produced from the wave height and direction data at each location;
- Scatter tables of peak period and wave height were generated at each location; and
- Where there was sufficient data, storm and extremes analyses were also undertaken.

Due to seasonal variations in the wave climate comparison of wave roses is best undertaken using consistent datasets. There is considerable variation in record length across the wave buoy locations, with some having records for only a few months and others multiple years. Where sites had more than a full year of data the wave record used for the wave roses and scatter plots was rounded down to the nearest full year in each case.

#### 1.4. Summary of Data available

The data types and sources considered in this report are listed in Table 1-1 below.

*Table 1.1 List of datasets with depths, record lengths and deploying organisation*

Name of Location	Type of Data	Water depth (m)	Deploying Organisation	Start Time	End Time
<b>Newbiggin Ness Waverider Buoy</b>	<b>Wave Data</b>	<b>23m</b>	<b>Cefas</b>	<b>20/05/2010</b>	<b>07/06/2011</b>
Blyth WaveNet Site	Wave Data	8m	Garrad Hassan and Partners	19/11/2001	22/12/2001
Tyne/Tees WaveNet Site (WMO ID 62293)	Wave Data	65m and 66m	Wavenet	07/12/2006	02/09/2012
Tees-Bay WaveNet Site	Wave Data	38m	Cefas	03/01/1996	18/01/1997
Tees Offshore Wind Farm WaveNet Site	Wave Data	TBC	ParTrac for EDF Energy	03/07/2008	26/11/2008
Marsden-Bay WaveNet Site	Wave Data	26m	Cefas	15/11/1990	04/01/1991
<b>Whitby Waverider Buoy</b>	<b>Wave Data</b>	<b>16m</b>	<b>Cefas</b>	<b>20/05/2010</b>	<b>04/11/2011</b>
Whitby POL Tide Record	Tidal Levels	N/A	Proudman / NTSLF	01/01/1991	30/04/2011
WV#1 Whitby East Pier	Wave Data	8m	Fugro	10/03/2010	16/05/2010
WV#2 Whitby East Pier	Wave Data	8m	Fugro	30/03/2010	27/04/2010
Scarborough DWR	Wave Data	30m	Emu	30/04/2004	31/03/2006
SBC Recorded Tide	Tidal Levels	N/A	Emu	13/05/2003	06/06/2006
<b>SBC Waverider Buoy</b>	<b>Wave Data</b>	<b>22m</b>	<b>Cefas</b>	<b>30/04/2003</b>	<b>20/07/2004</b>

The sites highlighted in bold are the locations planned to be re-established under the current phase of the Cell 1 regional Monitoring programme

## 2. Analysis of Wave Data

This section looks at the data collected under the Cell 1 monitoring programme, the two wave buoys deployed by Cefas at Newbiggin Ness and Whitby respectively.

### 2.1. Newbiggin Ness

The wave data for Newbiggin Ness was collected by the Cefas wave buoy and published on the Cefas website. The data collected runs from 20/05/2010 to 07/06/2011. One full year's data, from June 2010 to June 2011, has been analysed in SANDS. Supporting graphs and the relevant metadata information can be found in Appendix B. Scatter tables of wave height vs wave period and wave height vs direction derived using the time series data analysis facilities in SANDS have also been included in Appendix B.

#### 2.1.1. Wave Height vs Peak Period

The wave height and peak period for the wave data record has been plotted as a scatter plot (see Figure 2.1 below). The largest waves appear to have a peak period of 11.5 seconds.

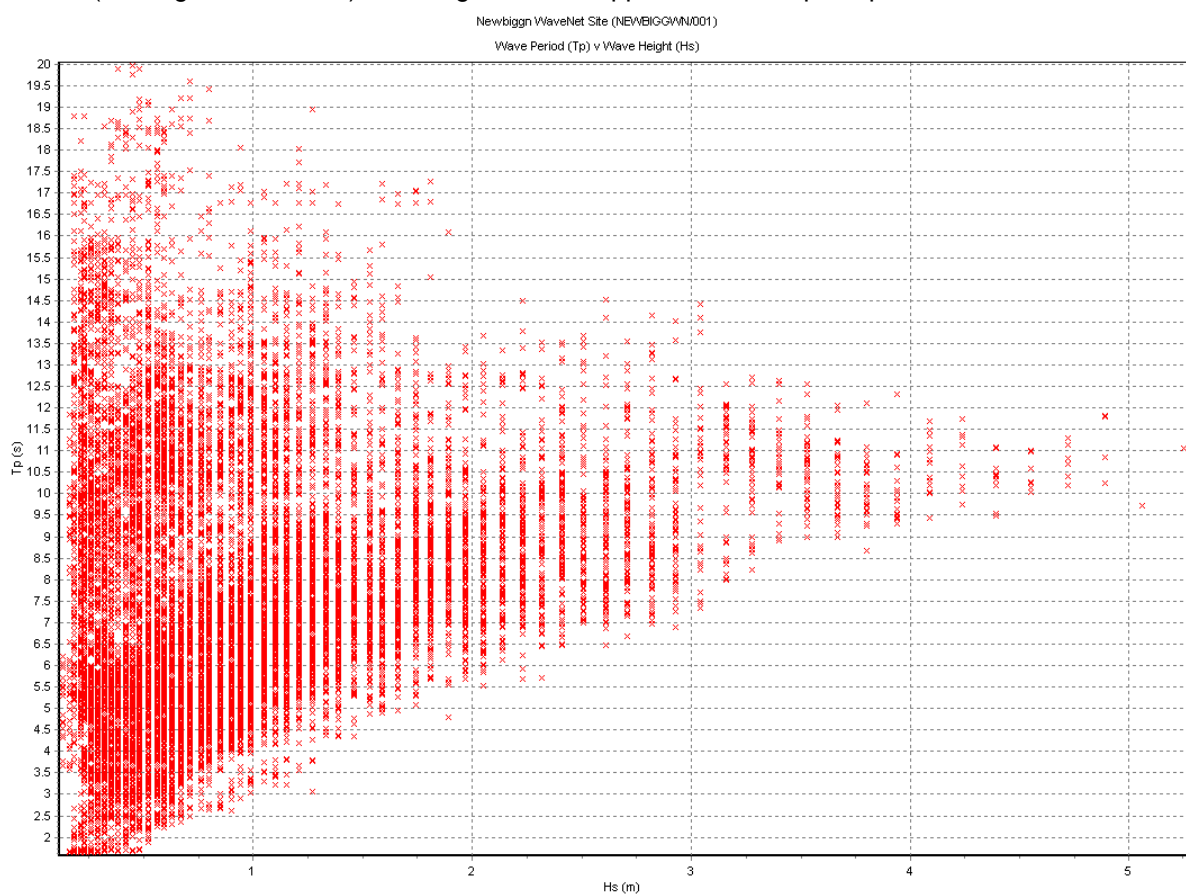


Figure 2.1 Scatter plot of Wave Height Vs Peak Period at Newbiggin wave buoy

#### 2.1.2. Wave Rose

The directional data of the wave record has also been analysed and the wave rose in Figure 2.2 below shows that the waves predominantly approach the Newbiggin Ness wave buoy from the Northeast (30 to 60 degrees).

Comparing the wave rose in Figure 2.2 to the other locations analysed, see later in report, indicates that the Newbiggin Ness site is relatively sheltered from wave from the north.

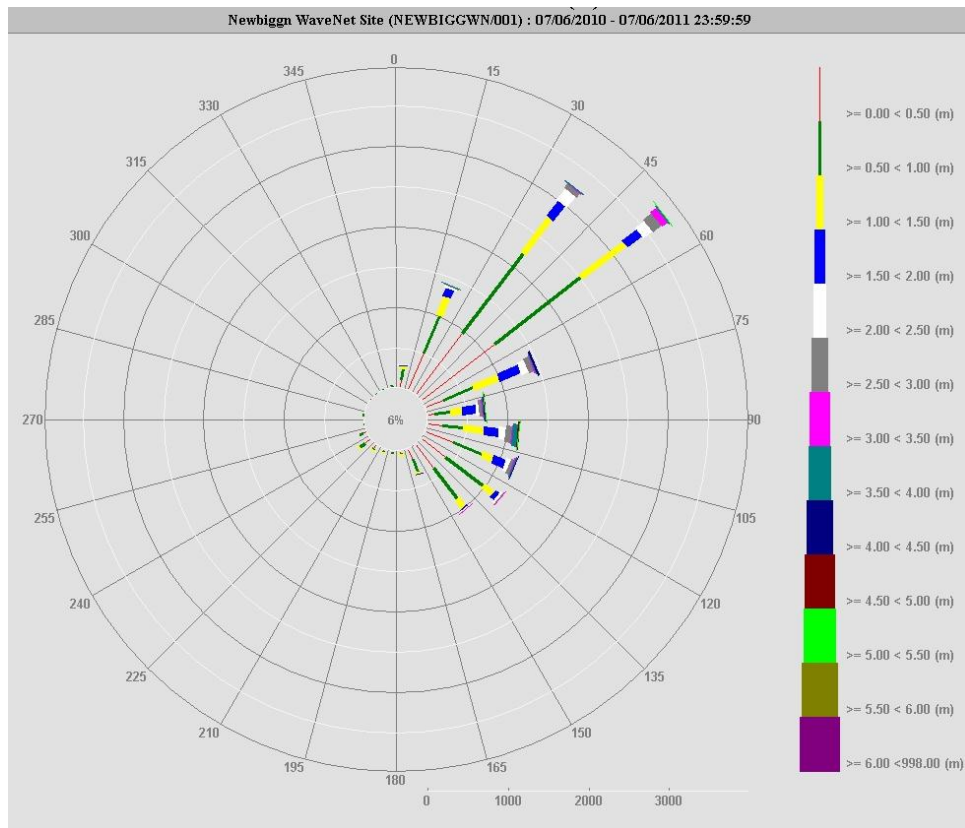


Figure 2.2 Wave Rose for Newbiggin wave buoy site

### 2.1.3. Storm Analysis

A storm analysis of the Newbiggin Ness wave dataset was undertaken using a wave height threshold of 3m and a storm separation threshold of 120 hours. This analysis used the full data range available, from 20/05/2010 to 07/06/2011. The storms recorded at this wave buoy arrive from the Northeast to East directions (47 to 105 degrees.) The results are presented in Table 2.1 below. The storm with the largest wave height at peak, highlighted in bold occurred on 9th November 2011.

Table 2.1 Storm analysis for Newbiggin Ness

General Storm Information							At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Dir(°)	No of Events (30 min dataset)	Mean Dir Vector (°)	Hs (m)	Tp (s)	Dir (°)	Energy @ Peak (KJ/m/s)
19/06/2010 12:30	20/06/2010 09:00	21	19/06/2010 23:00	48	39	42.99	3.94	10.33	51	3265.41
06/09/2010 18:30	07/09/2010 20:30	26	07/09/2010 15:30	99	51	351.95	3.80	9.30	90	2465.24
17/09/2010 10:00	17/09/2010 15:30	5.5	17/09/2010 14:30	53	4	42.03	3.04	12.10	51	2667.52
24/09/2010 03:00	25/09/2010 23:30	45	25/09/2010 10:00	47	79	43.22	3.53	10.54	56	2728.71
<b>08/11/2010 06:30</b>	<b>10/11/2010 00:30</b>	<b>42</b>	<b>09/11/2010 04:00</b>	<b>89</b>	<b>70</b>	<b>1.90</b>	<b>5.25</b>	<b>9.29</b>	<b>84</b>	<b>4688.60</b>
28/11/2010 23:30	02/12/2010 13:30	86	29/11/2010 20:00	81	78	10.65	4.24	9.86	62	3445.38
12/02/2011 01:30	12/02/2011 12:00	11	12/02/2011 12:00	100	4	0.03	3.16	8.12	73	1298.84
19/02/2011 06:00	19/02/2011 09:30	3.5	19/02/2011 08:30	105	3	357.42	3.28	6.91	84	1013.98

## 2.2. Whitby

The wave data for Whitby was collected by the Cefas wave buoy and published on the Cefas website. One full year's data, from October 2010 to October 2011, has been analysed in SANDS. Supporting data tables and the relevant metadata information can be found in Appendix C. Scatter tables of wave height vs wave period and wave height vs direction derived using the time series data analysis facilities in SANDS have also been included in Appendix C.

### 2.2.1. Wave Height vs Peak Period

The distribution of the wave height and peak period for the wave data record has been plotted as a scatter plot (see Figure 2.3 below). The larger storm waves at Whitby appear to have a typical peak period of around 11.5 seconds.

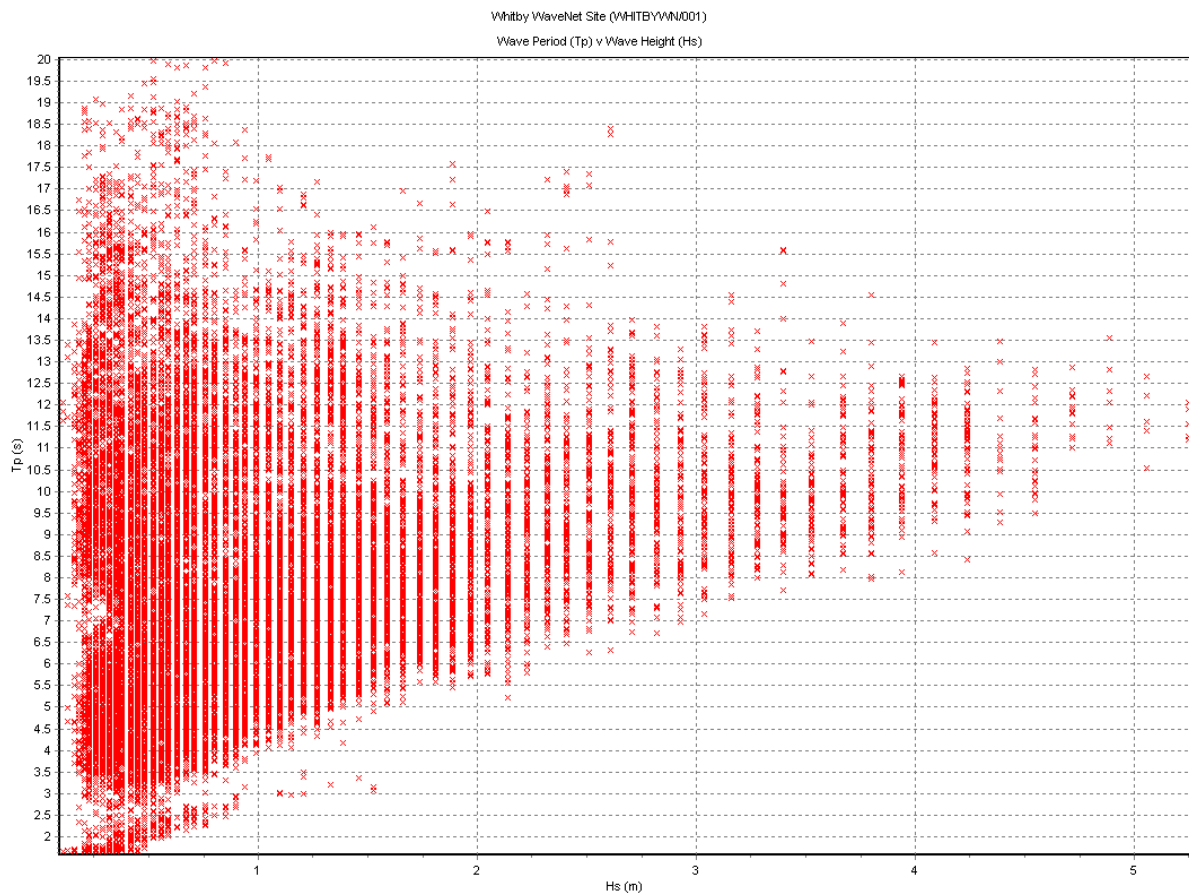


Figure 2.3 Scatter plot of Wave Height Vs Peak Period at Whitby wave buoy site

### 2.2.2. Wave Rose

The directional data of the wave record has also been used to plot a wave rose and Figure 2.4 below shows that the waves predominantly approach the coastline at Whitby from the Northeast by North direction (0 to 30 degrees).



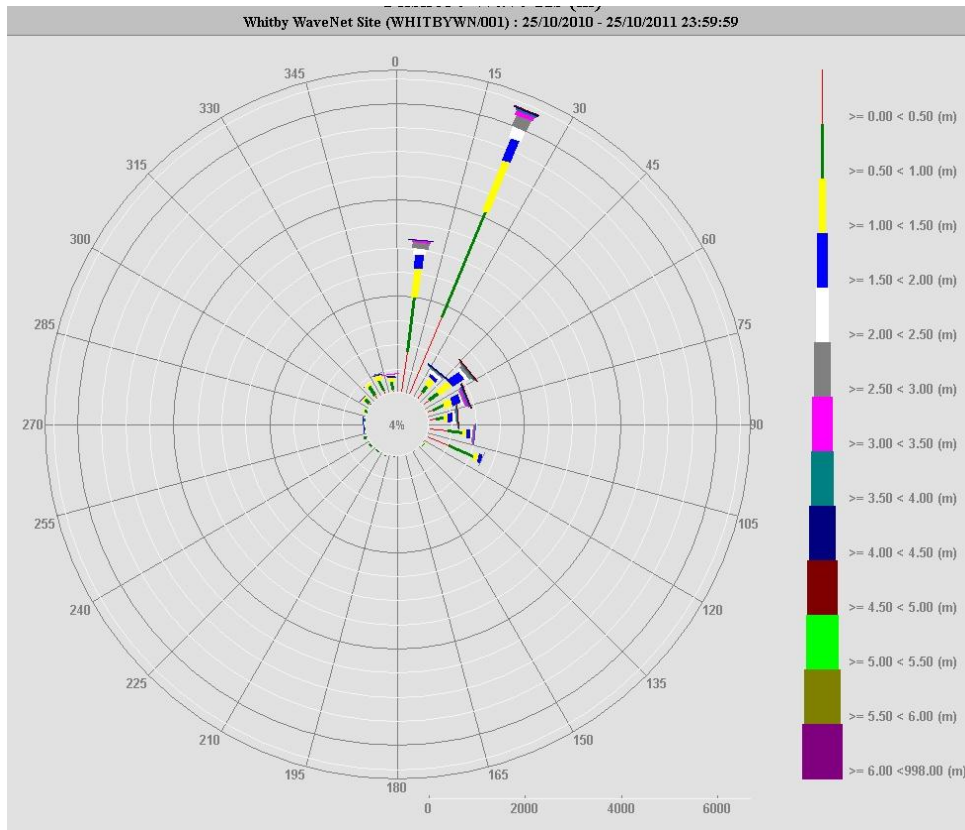


Figure 2.4 Wave Rose at Whitby wave buoy site

### 2.2.3. Storm Analysis

A storm analysis of the Whitby data set was undertaken using a wave height threshold of 4m and a storm separation threshold of 120 hours. The period of data examined ran from 20/05/2010 to 25/10/2011 and the results are presented in Table 2.2 below. The storms mostly arrive from the North to East-Northeast (5 to 66 degrees). The storm with the largest wave height (5.1m Hmo) at peak was on 25<sup>th</sup> September 2010, whilst the storm with greatest wave energy at peak was on 20<sup>th</sup> June 2010.

Table 2.2 Storm Analysis results for Whitby

General Storm Information							At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Dir (°)	No of Events (30 min dataset)	Mean Dir Vector (°)	Hs (m)	Tp (s)	Dir (°)	Energy @ Peak (KJ/m/s)
19/06/2010 08:30	20/06/2010 07:30	23	20/06/2010	26	38	64.52	4.89	11.36	28	<b>6085.33</b>
29/08/2010 16:30	30/08/2010 02:30	10	29/08/2010 17:30	5	7	85.09	4.39	8.00	6	2429.65
17/09/2010 09:00	17/09/2010 11:00	2	17/09/2010 11:00	28	2	67.50	4.39	11.30	22	4853.93
<b>24/09/2010 05:30</b>	<b>26/09/2010 03:30</b>	<b>46</b>	<b>25/09/2010 17:00</b>	<b>23</b>	<b>67</b>	<b>66.86</b>	<b>5.06</b>	<b>10.24</b>	<b>28</b>	<b>5298.61</b>
09/11/2010 03:30	09/11/2010 19:00	16	09/11/2010 05:30	66	19	24.89	4.72	9.25	68	3755.58
29/11/2010 20:00	02/12/2010 01:00	53	29/11/2010 22:00	60	19	31.32	4.72	9.93	56	4327.96
23/07/2011 15:30	24/07/2011 11:00	20	24/07/2011 03:00	29	29	61.86	4.24	10.77	22	4114.25

Comparing the storm dates at Whitby in Table 2-2 with those in Table 2-1 for Newbiggin it can be seen that several of the storms were recorded at both locations, but the durations, peak wave heights and directions for the storms were quite different.

## 2.2.4. Whitby Water Levels

There is a tide gauge at Whitby that is operated continuously by the National Tide and Sea Level Facility (NTSLF) on behalf of the Environment Agency as part of the main UK tide gauge network. Information on this tide gauge installation is available on the NTSLF website: <http://www.ntsfl.org/tgi/portinfo?port=Whitby> , including the site history reproduced below. The Chart datum at Whitby is 3m below Ordnance Datum (<http://www.ntsfl.org/tides/datum>).

### Whitby Tide Gauge Site history

- 1980 - Installed Aanderaa recorder attached to a pneumatic bubbler
- 1989 - DATARING system installed with full-tide pressure points; the Aanderaa recorder was removed
- 1995 - New steel work with two full-tide and mid-tide measuring systems installed
- 2002 - POL data logger installed

*Table 2.3 Predicted tide levels at Whitby*

Tidal State	Level (m Chart Datum)	Level (m Ordnance Datum)
HAT	6.21	3.21
LAT	0.22	-2.78
MHWS	5.59	2.59
MHWN	4.50	1.50
MLWN	2.25	-0.75
MLWS	0.99	-2.01
Highest predicted 2013	6.03	3.03
Lowest predicted 2013	0.41	-2.59
Highest predicted 2014	6.17	3.17
Lowest predicted 2014	0.32	-2.68

Note: Based on data from <http://www.ntsfl.org/tgi/portinfo?port=Whitby>

Data is available on the internet in real time (<http://www.ntsfl.org/data/realtime?port=Whitby> ) and quality controlled data can be downloaded from the British Oceanographic Data Centre (BODC) website.

An example plot of water level data from the POL tidal gauge record at Whitby is shown in Figure 2.5 below (Source: BODC, [https://www.bodc.ac.uk/data/online\\_delivery/](https://www.bodc.ac.uk/data/online_delivery/)). The data available for analysis runs from 01/01/1991 to 30/04/2011.

There are occasional gaps in the Whitby data as illustrated in the example plot below in Figure 2.5. Reviewing the overall record it is notable that the incidence of gaps in the data appears to increase significantly since 2004, prior to which the record was nearly continuous. A comparison of the recorded water level data at Scarborough and Whitby was made with SANDS and an example plot is shown below in Figure 2.6. This shows that the tidal signature is very similar, even during periods of significant weather induced surge variations, as shown on 21<sup>st</sup> to 22<sup>nd</sup> December 2003 in the plot.

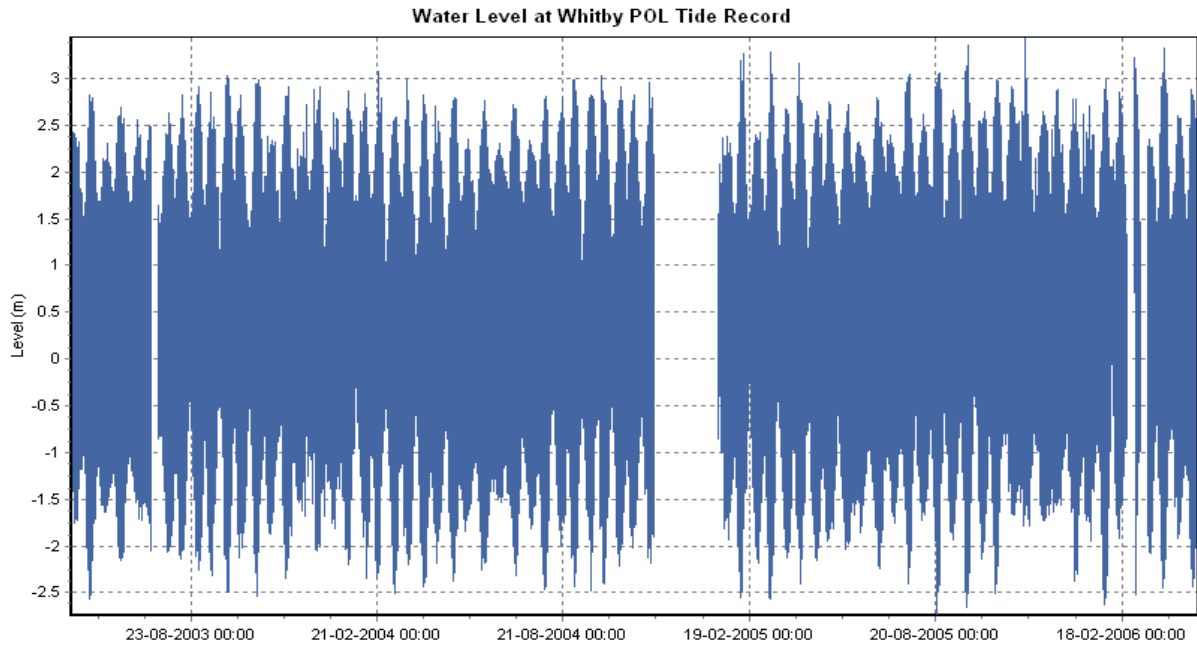


Figure 2.5 Water Level at Whitby POL tidal gauge site

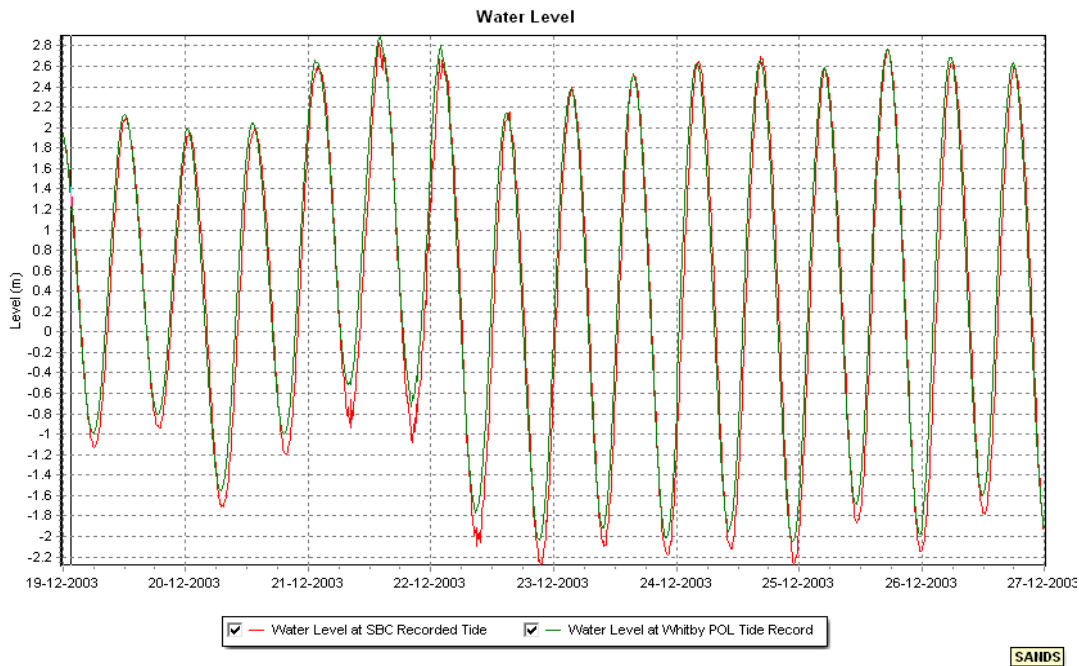


Figure 2.6 Comparison of recorded water levels at Whitby and Scarborough

The Whitby tide gauge data has also been used to consider the joint occurrence of high waves and high water levels as these are the most damaging events for coastal defences and most likely to precipitate coastal erosion events. The analysis results are shown in Table 2.4 below. Cells have been highlighted in orange to show for each 0.5m wave height increment, the water level at which the highest numbers of wave events were recorded. This appears to indicate a slight tendency for larger waves to occur at higher water levels. This may in part be due to depth limited wave breaking at the wave buoy which was located in about 16m water depth. However, it is difficult to draw conclusions as the combined record analysed is just less than one year. It is recommended that the analysis is repeated in future when a longer concurrent data set is available.

Table 2.4 Scatter table of water level and offshore wave height at Whitby

		Water level (mOD) from NTSLF tide gauge														
		m / m	-3 to -2.5	-2.5 to -2	-2 to -1.5	-1.5 to -1	-1 to -0.5	-0.5 to 0	0 to 0.5	0.5 to 1	1 to 1.5	1.5 to 2	2 to 2.5	2.5 to 3	3 to 3.5	Total
Wave Height (Hs, m) from Cell 1 Waverider	0-0.5	6	75	187	368	465	474	377	357	385	463	346	115	14	3632	
	0.5-1	3	49	181	467	601	589	537	542	663	707	446	114	4	4903	
	1-1.5	5	49	125	232	363	342	272	289	349	349	262	105	8	2750	
	1.5-2	5	19	74	186	209	183	169	194	234	231	154	86	12	1756	
	2-2.5	0	3	21	70	87	79	63	65	83	117	74	22	0	684	
	2.5-3	0	1	9	53	61	59	55	56	62	49	42	16	0	463	
	3-3.5	0	0	1	18	34	34	37	33	40	58	27	10	0	292	
	3.5-4	0	0	2	17	25	16	25	23	27	34	27	13	0	209	
	4-4.5	0	0	0	9	6	7	8	8	10	9	14	11	0	82	
	4.5-5	0	0	0	2	0	3	1	2	3	8	8	6	0	33	
	5-5.5	0	0	0	0	0	0	1	0	1	1	0	1	0	4	
	Total	19	196	600	1422	1851	1786	1545	1569	1857	2026	1400	499	38	0	

Water Level (x) vs Offshore Wave Height Hm0 (y) (numbers of 30 minute observations)  
 For date range :20/05/2010 to 30/04/2011 (Less than 1 full year of data)

### 3. Other Freely Available Data

The sources for the data reviewed in this section are tabulated in Table 1.1 (Section 1.4). The analyses carried out on this data varied, depending on the length of the available datasets.

#### 3.1. Blyth

The wave data available from Blyth is just over a month in length and runs from 19/11/2001 to 22/12/2001. The available data is wave height and direction only (no period data). The data was downloaded and reviewed but it was found that the direction data appears to be in error (probably 180 degrees out) as the dominant wave direction is from the south west and no waves were incident from the north east. Due to these issues this location has not been considered further.

#### 3.2. Tyne / Tees

The Tyne/Tees WaveNet buoy is in Tees Bay, approximately 35 km offshore, at a depth of 65m. This buoy was deployed by Cefas in 2006 and continues to operate as part of the National Network managed by Cefas for the Environment Agency alongside the UK strategic tide gauge network. This wave buoy is located some 70km offshore in around 65m water depth and therefore potentially provides a suitable baseline of offshore data as the record is continuous since before the Cell 1 strategic programme commenced in 2008.

A sample comparison of the recorded waves at Newbiggin and Whitby under the Cell 1 programme to the WaveNet buoy Tyne/Tees buoy is shown in Figure 3.1 below. This shows similarities but also highlights some significant differences. During the early part of the record around the 9<sup>th</sup> October, see blue circle, the wave heights at the three sites were very similar.

However, there are some storms, for example the one the 13<sup>th</sup> November 2010, circled in red in Figure 3.1, when storms were only picked up at the further offshore, Tyne/ Tees buoy. Reviewing the wave direction data over this period shows that for Tyne/Tees the waves were directed offshore (270 degrees) for this storm. Due to the fetch of around 70km for the dominant south west to westerly winds it is not surprising that there are storms in the record from the buoy for periods when the wind is directed offshore at the coast. During periods of offshore winds the record at the Tyne/Tees buoy will be dominated by wind waves, whereas the conditions at the closer inshore Newbiggin and Whitby wave riders would be dominated by swell waves from the decaying previous storm and indicate relatively small waves. This serves to illustrate the need for the programme to continue with several strategic buoys fairly near to the coast rather than just relying on the Tyne/Tees buoy.

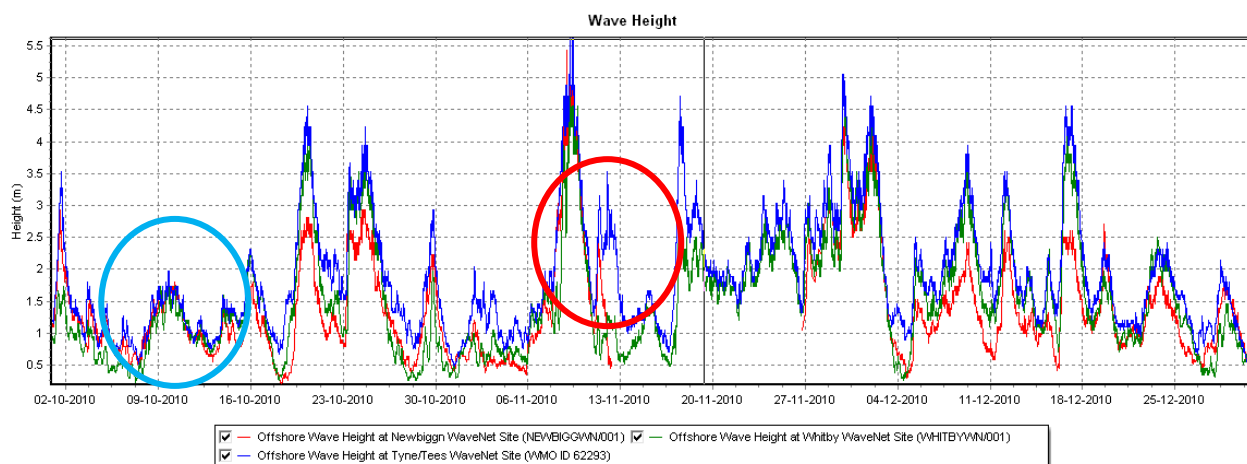


Figure 3.1 Comparison of recorded wave heights during winter 2010

The data record which was reviewed at the Tyne / Tees wave buoy for this baseline report runs from December 2006 to September 2012. A scatter table and wave rose was produced

for the buoy using five full years of wave data. Storm and extremes analyses were also carried out and are shown in the sub-sections below.

### 3.2.1. Wave height vs Wave Period

The distribution of the wave height, peak and zero crossing period for the wave data record has been plotted as a scatter plot (see Figure 3.1 below). The largest storms recorded have a peak period of 12.4 and 13.4 seconds, see Table 3.4 below.

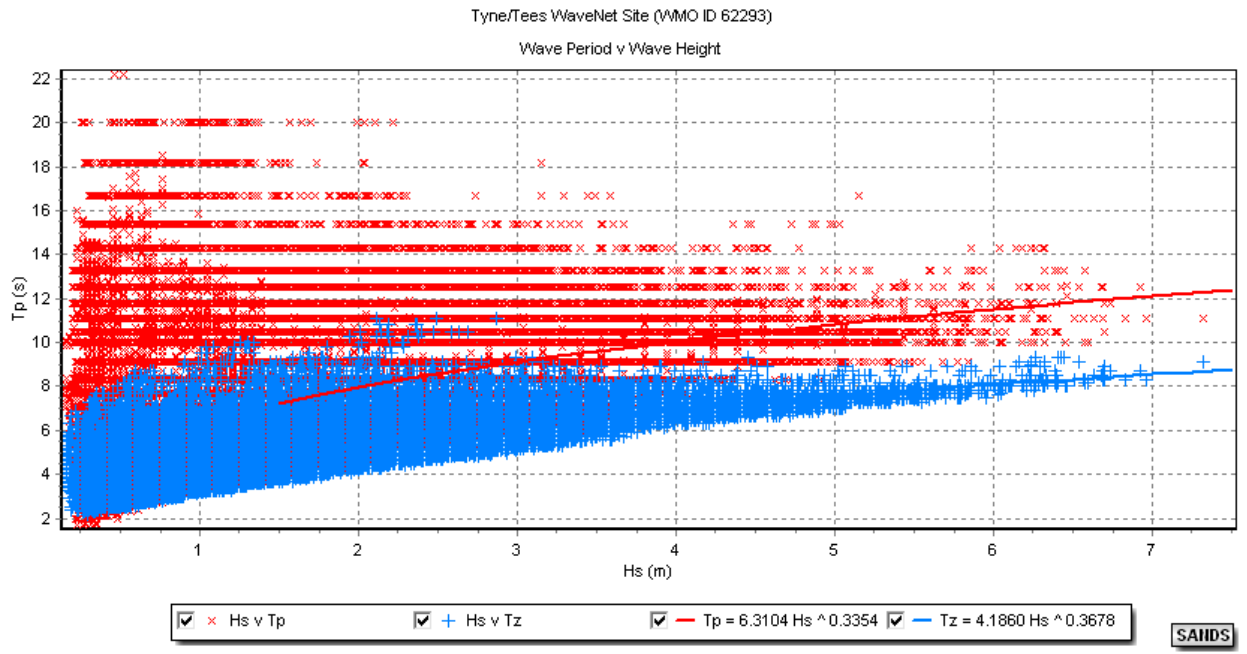


Figure 3.2 Scatter plot of Wave Height Vs Peak Period at Tyne/Tees wave buoy site

### 3.2.2. Wave Rose and Wave Direction Scatter Tables

The wave rose analysis of 5 full years of wave data in Figure 3.3 shows that the majority of the waves come from the north to north-northeast (0-30 degrees). There is a small secondary peak from the south east (135-150 degrees). Due to the offshore location of this buoy there are also small peaks from the south west and north west, although of course these would represent calm periods as the coast.

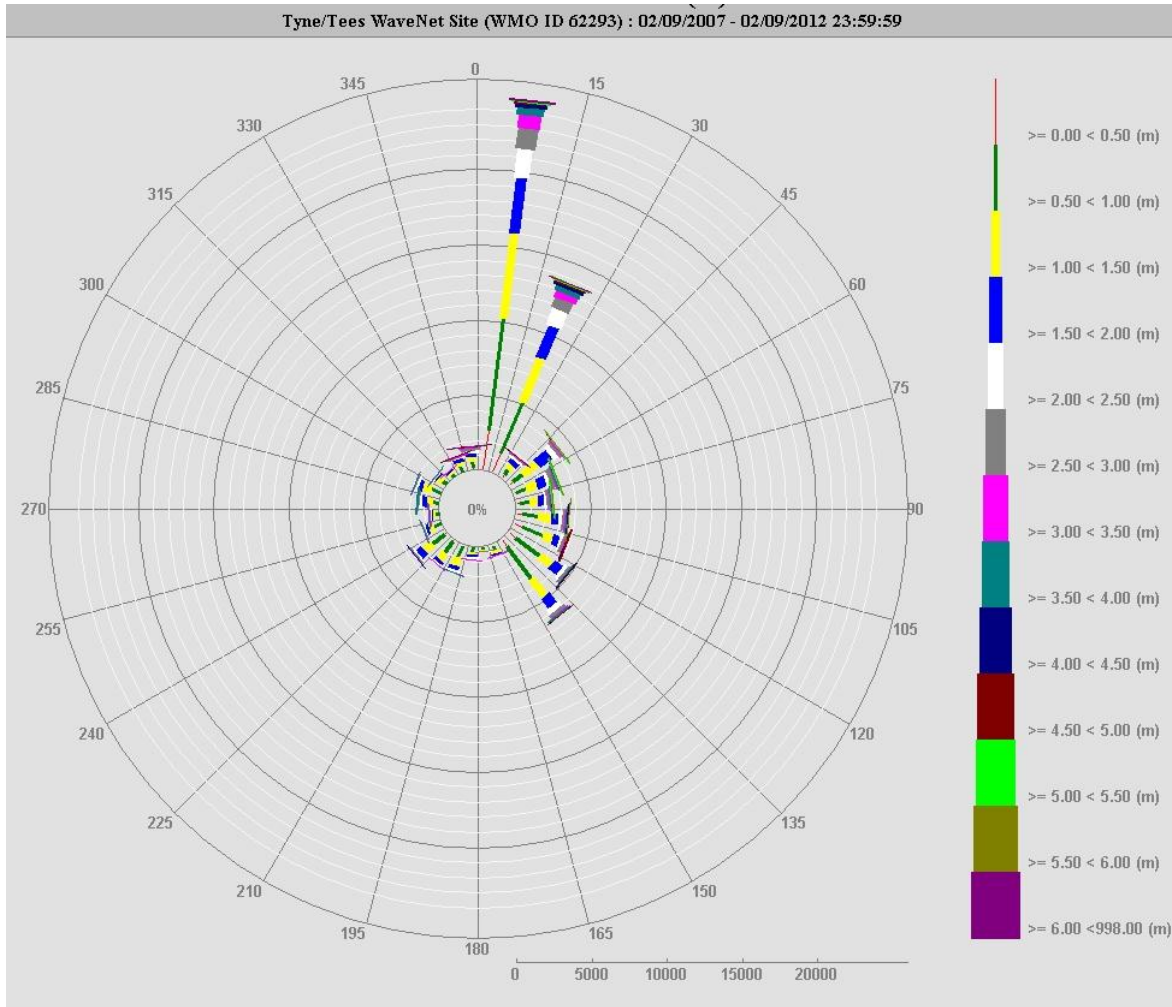


Figure 3.3 Wave Rose at Tyne/Tees wave buoy site (WMO ID 62293)

The associated wave height and wave period vs wave direction data are provided below in Tables 3-1 and 3-2 respectively.

Table 3.1 Wave Height and Direction Scatter Table for Tyne/Tees WaveNet Site

Hmo (m) / Dir	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	Total
0-0.5	4088	536	403	933	1087	130	141	318	89	89	90	220	8124
0.5-1	11138	1232	1308	2500	4711	431	1039	1981	770	1173	542	816	27641
1-1.5	8903	1646	1317	1660	2467	292	821	1316	548	987	508	559	21024
1.5-2	5956	1329	1044	882	1493	137	484	682	337	655	262	494	13755
2-2.5	3135	526	455	440	664	42	212	176	86	274	92	278	6380
2.5-3	2034	267	365	314	362	18	72	118	85	158	50	196	4039
3-3.5	1387	162	188	163	138	2	13	24	28	43	12	69	2229
3.5-4	799	59	105	114	84	0	2	3	6	9	1	29	1211
4-4.5	391	18	80	92	42	0	0	1	0	0	0	17	641
4.5-5	219	17	48	30	16	0	0	0	0	0	0	18	348
5-5.5	99	3	38	3	0	0	0	0	0	0	0	8	151
5.5-6	37	1	8	2	0	0	0	0	0	0	0	5	53
6-6.5	47	0	0	0	0	0	0	0	0	0	0	4	51
6.5-7	10	0	0	0	0	0	0	0	0	0	0	1	11
7-7.5	2	0	0	0	0	0	0	0	0	0	0	0	2
7.5-8	9	0	0	0	0	0	0	0	0	0	0	0	9
<b>Total</b>	<b>38254</b>	<b>5796</b>	<b>5359</b>	<b>7133</b>	<b>11064</b>	<b>1052</b>	<b>2784</b>	<b>4619</b>	<b>1949</b>	<b>3388</b>	<b>1557</b>	<b>2714</b>	<b>0</b>

Location: Tyne/Tees WaveNet Site (WMO ID62293); Date range :02/09/2007 to 02/09/2012 (5 full years of data)  
 Offshore Wave Direction Peak (x) vs Offshore Wave Height Hm0 (y), showing numbers of 30 min observations.

Table 3.2 Wave Period and Direction Scatter Table for Tyne/Tees WaveNet Site

Tp(s) / Dir	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	Total
0-1	0	0	0	0	0	0	0	0	0	0	0	0	0
1-2	1	0	0	0	0	1	2	2	0	1	0	0	7
2-3	16	5	6	30	80	79	90	243	90	56	22	15	732
3-4	120	33	72	226	828	299	765	1604	700	974	387	187	6195
4-5	387	168	334	1177	2999	360	1146	1629	647	1308	636	566	11357
5-6	1049	623	955	1828	3158	179	541	699	296	671	338	568	10905
6-7	2039	1211	1218	1846	1796	38	98	157	105	188	89	489	9274
7-8	3563	1367	1159	1156	1233	8	2	13	11	23	3	308	8846
8-9	5204	1246	793	459	549	1	0	0	0	0	0	101	8353
9-10	6248	647	479	210	129	0	0	1	0	0	0	82	7796
10-11	5686	290	227	72	17	0	0	0	0	0	0	71	6363
11-12	4869	65	46	3	0	0	0	0	0	0	0	81	5064
12-13	3172	15	1	0	0	0	0	0	0	0	0	50	3238
13-14	1835	1	0	0	0	0	0	0	0	0	0	16	1852
14-15	1009	2	0	0	0	0	0	0	0	0	0	12	1023
15-16	470	4	0	0	0	0	0	0	0	0	0	9	483
16-17	189	3	0	0	0	0	0	0	0	0	0	4	196
17-18	126	2	0	0	0	0	0	0	0	0	0	4	132
18-19	101	3	0	0	0	0	0	0	0	0	0	5	109
19-20	23	0	0	0	0	0	0	0	0	0	0	1	24
20-21	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	<b>36107</b>	<b>5685</b>	<b>5290</b>	<b>7007</b>	<b>10789</b>	<b>965</b>	<b>2644</b>	<b>4348</b>	<b>1849</b>	<b>3221</b>	<b>1475</b>	<b>2569</b>	<b>0</b>

Location: Tyne/Tees WaveNet Site (WMO ID62293); date range :02/09/2007 to 02/09/2012 (5 full years of data)  
 Offshore Wave Direction Peak (x) vs Offshore Peak Wave Period Tp (y), showing numbers of 30 minute observations.

### 3.2.3. Extremes Analysis

An extremes analysis was undertaken for the Tyne/Tees buoy location. A peak wave height threshold of 4.6m was used, providing 30 peaks in 5.75 years. The Gumbel distribution used for extrapolation gives a good correlation coefficient of 0.99352 and the visual fit appeared satisfactory. Given the length of the record, the data should only be considered reliable up to a 1:20 year return period. The results of the extremes analysis are shown in Table 3-3 below.

Table 3.3 Extremes Analysis for Tyne / Tees buoy

Return Period (1 in X years)	Gumbel Fit Extreme Wave Height (Hs, m)
0.2	4.4
0.3	5.1
0.5	5.5
1	5.9
2	6.4
3	6.6
5	6.9
10	7.3
20	7.7

### 3.2.4. Storm Analysis

A SANDS storm analysis of the Tyne/Tees data set was undertaken using a wave height threshold of 4m and a storm separation threshold of 120 hours. This allows extraction of typically between 3 and 10 storms of the biggest storms each year. The period of data examined ran from 07/12/2006 to 02/09/2012. Note that a full year was not examined for 2012 and this should be done in the next annual wave report, which will be produced in 2014.



The storm analysis results are presented in Table 3-4 below. To aid interpretation of the results in Table 3.4 alternate years have been shaded and the storm with the largest peak wave height each year has been highlighted in bold. The storm with the highest wave energy at peak has also been highlighted in bold red text as this depends on wave period as well as wave height and so is not always the same as the largest wave height, e.g. in 2009 and 2010.

Plots of storm direction and storm duration are shown in Figures 3.4 and 3.5 below Table 3-4. The storms mostly arrive from the north to northeast direction, 0 to 40 degrees, which has the longest fetch, but there are also a significant number of storms from other directions, particularly 80 to 140 degrees. The largest peak wave height ( $H_s = 7.9\text{m}$ ) was associated with the longest duration storm (180 hrs) in March 2008.

Comparing the annual storm records it can be seen that 2010 had the most storms (13). 2010 was also unusual in that the largest storm had an incident direction of 73 degrees at peak, whereas in all of the other years direction at peak of the largest storm was from the north to north-east sector. From these results we might expect that the alongshore drift on the Cell 1 beaches in 2010 may have been atypical with unusual changes from the storm conditions. This was indeed noted in several of the 2010 Full Measures reports, for example the Hartlepool report noted unusual beach lowering along North Sands, and there was significant beach lowering at a number of locations at Sunderland.

The year with the fewest storms was 2011. This was reflected by accretion recorded in a number of the annual Full Measures reports, for example recovery of the beaches at North Sands and Middleton beaches in Hartlepool, and recovery of beaches was noted at Sunderland.

*Table 3.4 Storm Analysis at Tyne Tees WaveNet Buoy*

General Storm Information							At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Direction (Degrees)	No of Events (30 min dataset)	Mean Direction Vector (Degrees)	Hs (m)	Tp (s)	Direction (Degrees)	Energy @ Peak (KJ/m/s)
19/03/2007 10:30	21/03/2007 05:30	43	20/03/2007 14:30	21	73	79.0	6.2	12.4	22	11759.3
25/06/2007 20:00	26/06/2007 13:30	17.5	26/06/2007 10:00	33	28	81.6	4.4	8.6	22	2832.6
26/09/2007 03:00	27/09/2007 05:00	26	26/09/2007 19:00	10	36	80.4	4.6	11.6	6	5488.7
<b>08/11/2007 20:00</b>	<b>12/11/2007 15:00</b>	<b>91</b>	<b>09/11/2007 08:30</b>	<b>14</b>	<b>64</b>	<b>78.7</b>	<b>6.2</b>	<b>13.4</b>	<b>6</b>	<b>13698.9</b>
19/11/2007 03:30	25/11/2007 21:30	162	23/11/2007 05:00	74	59	78.8	4.9	10.7	17	5353.7
08/12/2007 03:00	10/12/2007 14:30	59.5	08/12/2007 03:30	65	11	85.1	4.1	10.8	17	3816.4
03/01/2008 10:30	04/01/2008 01:30	15	03/01/2008 23:30	77	24	14.8	4.2	9.1	62	2964.9
01/02/2008 15:00	02/02/2008 09:30	18.5	02/02/2008	37	34	80.9	6.0	13.8	17	13641.7
10/03/2008 08:30	10/03/2008 12:30	4	10/03/2008 11:00	146	9	307.6	4.6	8.0	141	2631.9
<b>17/03/2008 15:00</b>	<b>25/03/2008 03:00</b>	<b>180</b>	<b>22/03/2008 05:00</b>	<b>59</b>	<b>78</b>	<b>83.8</b>	<b>7.9</b>	<b>12.4</b>	<b>6</b>	<b>19123.9</b>
05/04/2008 22:00	07/04/2008 05:00	31	06/04/2008 19:00	44	22	83.8	4.6	11.6	6	5520.5
20/07/2008 16:00	21/07/2008 09:30	17.5	20/07/2008 23:30	15	8	75.9	4.2	9.9	11	3492.5
03/10/2008 03:00	03/10/2008 20:30	17.5	03/10/2008 16:30	30	32	82.4	4.7	11.4	22	5728.4
21/11/2008 04:00	25/11/2008 12:30	104.5	22/11/2008 11:30	15	112	75.8	6.0	13.1	11	12267.5
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	109	37	331.9	4.9	8.3	129	3286.2

General Storm Information							At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Direction (Degrees)	No of Events (30 min dataset)	Mean Direction Vector (Degrees)	Hs (m)	Tp (s)	Direction (Degrees)	Energy @ Peak (KJ/m/s)
31/01/2009 16:30	03/02/2009 09:00	64.5	02/02/2009 22:00	84	57	7.1	5.8	9.5	84	6078.5
23/03/2009 20:30	28/03/2009 20:30	120	28/03/2009 18:30	92	26	89.7	4.9	9.3	0	4053.0
10/07/2009 01:30	10/07/2009 02:30	1	10/07/2009 01:30	13	2	78.8	4.2	9.9	11	3504.3
<b>29/11/2009 20:00</b>	<b>30/11/2009 15:00</b>	<b>19</b>	<b>30/11/2009 00:30</b>	<b>17</b>	<b>38</b>	<b>73.4</b>	<b>6.0</b>	<b>9.4</b>	<b>11</b>	<b>6331.4</b>
17/12/2009 10:30	18/12/2009 05:00	18.5	17/12/2009 19:30	64	36	26.4	5.4	10.6	68	<b>6549.5</b>
30/12/2009 09:00	30/12/2009 23:00	14	30/12/2009 12:30	84	24	7.7	5.1	7.5	90	2866.0
06/01/2010 05:30	06/01/2010 11:00	5.5	06/01/2010 06:30	30	10	63.7	4.2	10.7	11	4044.1
29/01/2010 10:30	30/01/2010 00:30	14	29/01/2010 22:30	6	29	83.9	5.4	8.6	6	4258.2
26/02/2010 22:30	27/02/2010 02:30	4	27/02/2010 01:00	18	7	72.6	4.6	8.5	17	2925.7
19/06/2010 07:00	20/06/2010 08:30	25.5	19/06/2010 20:00	21	49	69.4	5.4	10.7	22	<b>6611.8</b>
29/08/2010 14:00	30/08/2010 06:30	16.5	29/08/2010 22:30	131	26	91.8	4.9	8.9	0	3715.5
06/09/2010 22:30	07/09/2010 16:00	17.5	07/09/2010 15:30	101	22	353.3	4.6	8.8	90	3192.5
17/09/2010 07:00	17/09/2010 18:30	11.5	17/09/2010 08:30	10	17	80.8	4.7	11.0	11	5323.3
24/09/2010 03:00	26/09/2010 10:00	45	24/09/2010 10:00	19	86	73.1	5.3	10.1	11	5564.7
20/10/2010 02:00	24/10/2010 16:30	110.5	20/10/2010 10:00	13	16	78.3	4.2	11.3	17	4514.5
<b>08/11/2010 14:00</b>	<b>09/11/2010 20:30</b>	<b>30.5</b>	<b>09/11/2010 10:00</b>	<b>87</b>	<b>58</b>	<b>3.1</b>	<b>5.6</b>	<b>8.8</b>	<b>73</b>	<b>4870.6</b>
17/11/2010 11:00	17/11/2010 18:30	7.5	17/11/2010 12:00	136	9	322.2	4.7	7.8	129	2646.0
29/11/2010 19:30	02/12/2010 08:30	61	29/11/2010 21:00	80	45	11.8	5.1	9.4	56	4474.2
16/12/2010 15:00	17/12/2010 06:30	15.5	17/12/2010 03:30	10	25	80.2	4.6	10.5	17	4504.6
<b>23/07/2011 14:00</b>	<b>24/07/2011 11:00</b>	<b>21</b>	<b>24/07/2011 03:00</b>	<b>23</b>	<b>39</b>	<b>67.5</b>	<b>4.7</b>	<b>10.8</b>	<b>17</b>	<b>5082.6</b>
24/10/2011 18:30	25/10/2011 09:30	15	25/10/2011 09:30	103	26	348.5	4.1	9.5	79	2986.1
09/12/2011 08:30	09/12/2011 10:00	1.5	09/12/2011 08:30	6	3	84.4	4.1	11.9	6	4669.0
05/01/2012 15:30	06/01/2012 05:00	13.5	06/01/2012 03:00	11	21	79.6	4.6	10.5	17	4475.9
<b>03/04/2012 13:30</b>	<b>04/04/2012 10:30</b>	<b>21</b>	<b>03/04/2012 17:30</b>	<b>66</b>	<b>38</b>	<b>25.1</b>	<b>5.6</b>	<b>8.1</b>	<b>56</b>	<b>4125.2</b>

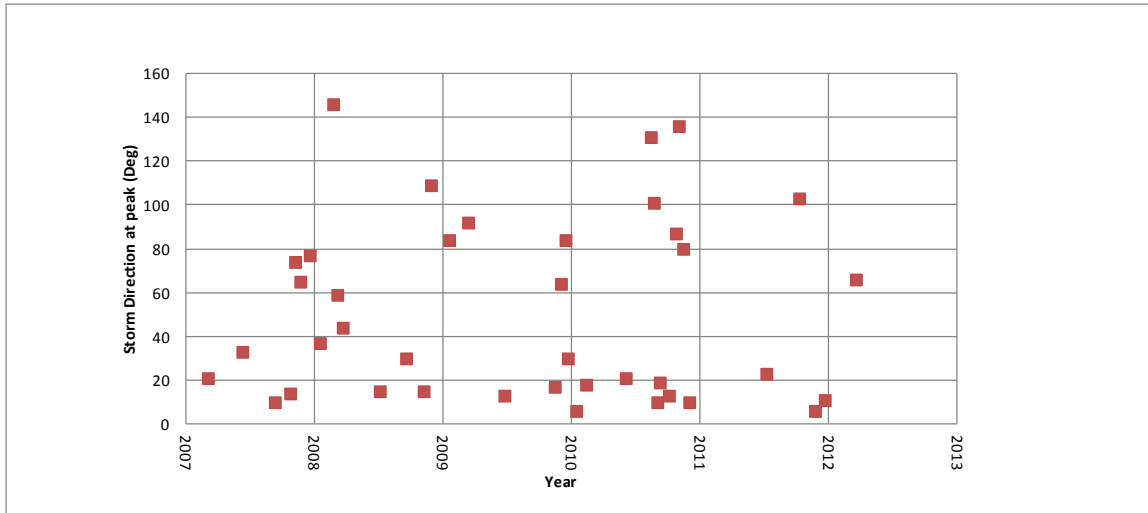


Figure 3.4 Storm direction data at Tyne / Tees Wave Buoy

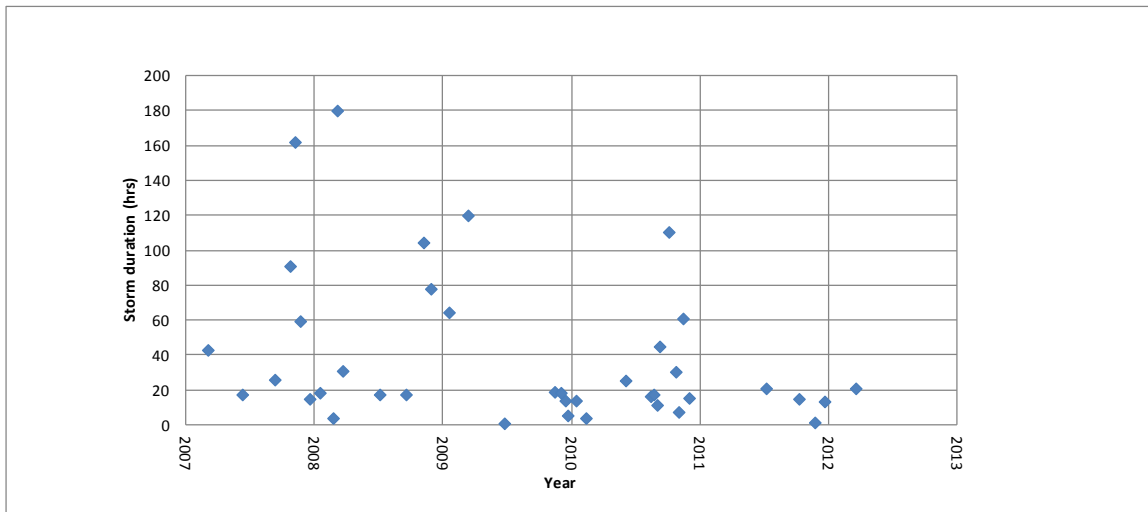


Figure 3.5 Storm duration data at Tyne / Tees Wave Buoy

### 3.3. Tees-Bay

There is a years' data available from Cefas' WaveNet site for Tees-bay from 3/01/1996 to 18/01/1997. However, this data set is wave height only and there are no associated direction data. It was therefore considered that this data is of limited use to the Cell 1 monitoring programme and no analysis was undertaken.

### 3.4. Tees Offshore Windfarm Site

Wave data from for this location is held of the Cefas WaveNet historical sites records for 03/07/2008 to 26/11/2008. As with the Tees bay data, this record contains wave height data only and no direction data. The data set is too short to undertake extremes analysis and while it may be useful for local studies it is of limited use for the Cell 1 regional monitoring programme and so has not been analysed further.

### 3.5. Marsden Bay

The Marsden Bay wave data set is limited to about a month and a half, from 15/11/1990 to 04/01/1991. As with the Tees Bay and Tees Windfarm data sets this is non-directional data.

This data is not concurrent with any of the other datasets considered and therefore is of limited use to the regional monitoring programme and so has not been analysed further.

### 3.6. Whitby East Pier

The Whitby East Pier nearshore wave data was collected during the site investigations for the urgent repair works to the Whitby east pier extension. The wave recorders were located in relatively sheltered locations close to the shore, at a depth of 8m. The data record reviewed at this location runs from March 2010 to May 2010 and is less than a full year and thus cannot be reliably compared with other datasets. It is unfortunate that this period of data collection did not coincide with the deployment of the Cell 1 Whitby buoy further offshore, which was deployed shortly after the inshore instruments were recovered. This limits the usefulness of the data for future model calibration.

The data at WV#1 was collected at a sheltered location inside the outer breakwater extensions, close to the end of the main east pier. The data at WV#2 was collected with an ADCP deployed further north, outside the east of the east pier extension.

It should also be noted that the Fugro data collection report indicates that the pressure sensor on the WV#2 instrument was damaged when the bed frame turned over, possibly due to 3<sup>rd</sup> party interference, and therefore some data is missing and some of the data may be inaccurate.

A scatter table and wave rose analysis were carried out and are shown in the sub-sections below. Further more detailed plots presenting the full data set are available in the Fugro report, June 2010.

#### 3.6.1. Wave height vs Wave Period

The distribution of the wave height and peak period for the wave data record has been plotted as scatter plots (Figures 3.6 and 3.7). The records run for two months and thus the plots are more sparsely populated than at other locations. During this limited time period, the largest waves had a peak period of approximately 9 seconds.

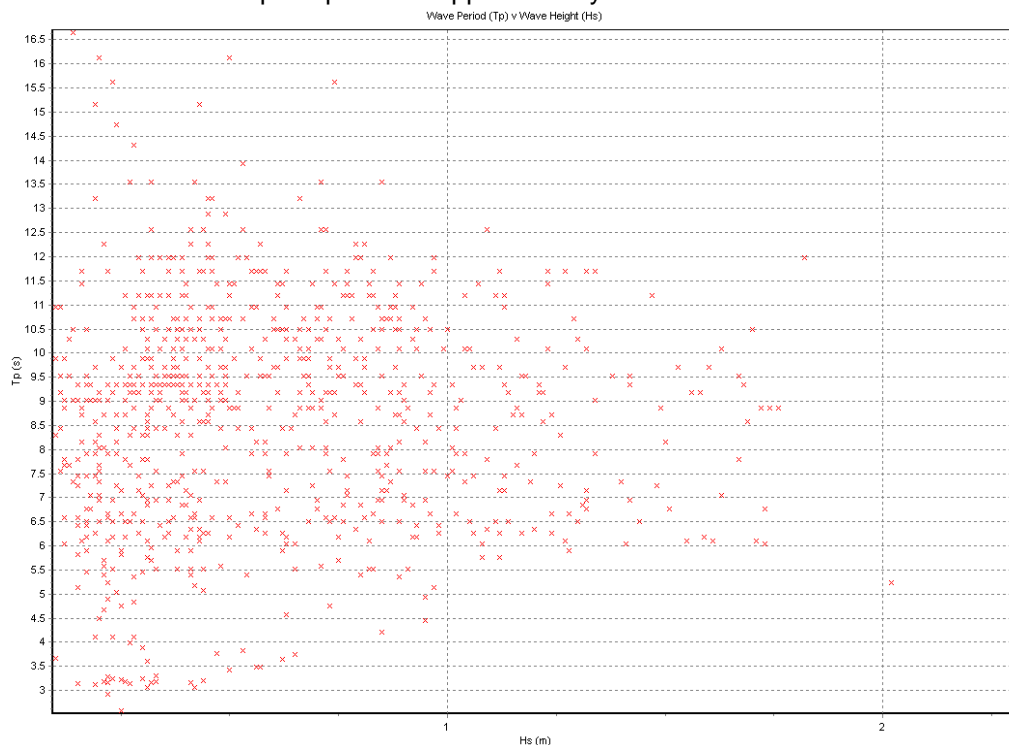


Figure 3.6 Scatter plot of Wave Height Vs Peak Period at Whitby East Pier site (WV#1)



Figure 3.7 Scatter plot of Wave Height Vs Peak Period at Whitby East Pier site (WV#2)

### 3.6.2. Wave Rose

The wave rose analysis for Whitby East Pier (Figures 3.8 and 3.9) shows that the majority of the waves come from the Northwest to North (315 - 0 degrees). The wider spread of data at WV#2 reflects the more sheltered position of WV#1 inside the outer breakwaters.

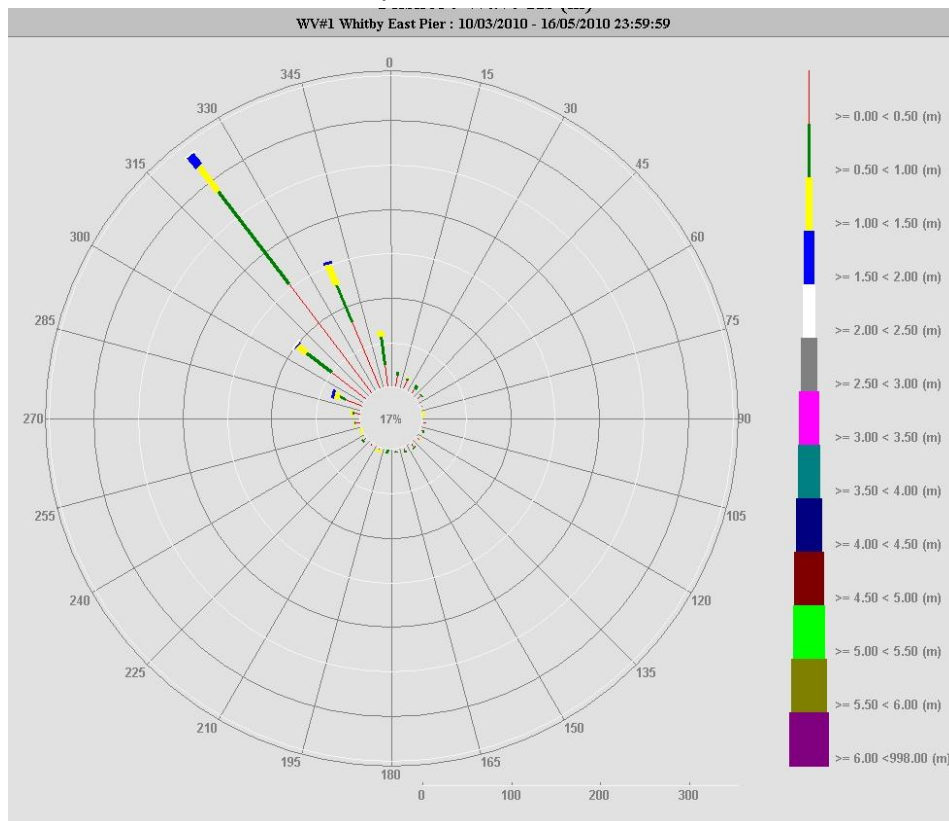


Figure 3.8 Wave Rose for Offshore Wave Height at Whitby East Pier (WV#1)

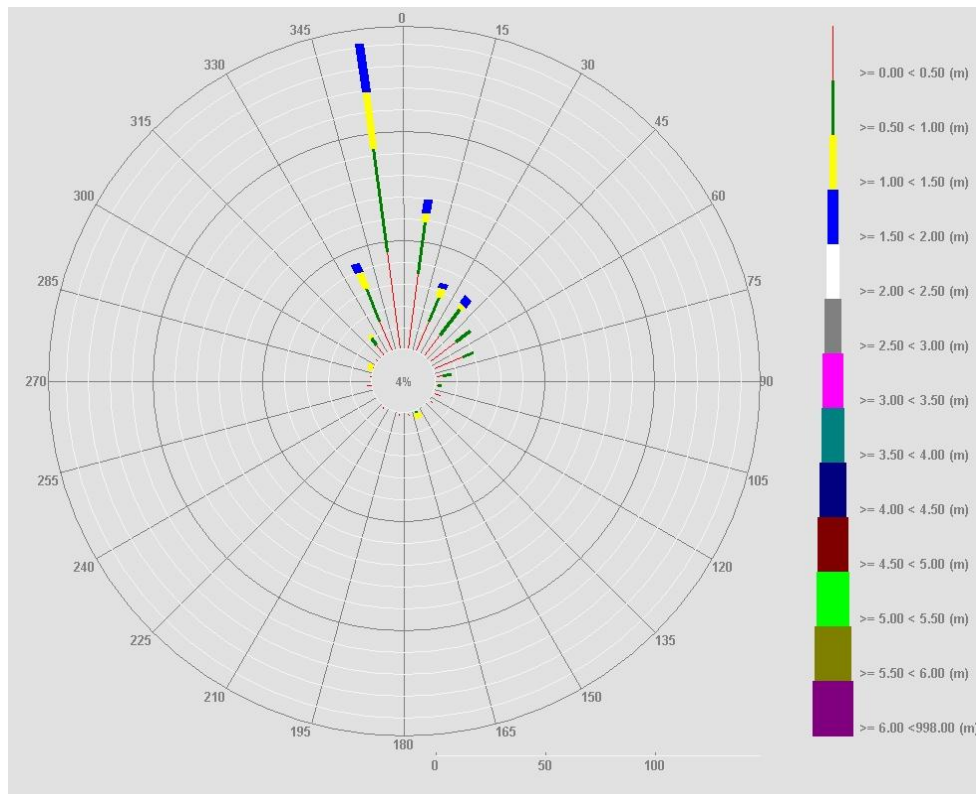


Figure 3.9 Wave Rose for Offshore Wave Height at Whitby East Pier (WV#2)

### 3.7. Scarborough

At Scarborough, data from the Waverider buoys deployed by Cefas and Emu (labelled as SBC and DWR wave buoys) have been considered. These are located 4.5 and 2 km offshore respectively. The data record which was reviewed at the Emu DWR wave buoy runs from April 2004 to March 2006 and the record for the Cefas SBC buoy runs from April 2003 to July 2004. Scatter tables and wave roses were produced for both datasets using full years of data and these are for two and one year respectively. Storm and extremes analyses were carried out for the full record of the DWR wave data; the resulting figures and tables are shown in the sub-sections below.

#### 3.7.1. Wave height vs Wave Period

The distribution of the wave height and peak period for the wave data record at Scarborough DWR and Scarborough SBC wave buoys has been plotted as a scatter plot (see Figures 3.10 and 3.11 below, respectively). The largest waves at the Scarborough SBC buoy appear to have a peak period of 9.5 seconds.

Within Figure 3.10 there appears to be two peaks for the higher wave heights, likewise it was also observed that there appeared to be two datasets plotted. On closer examination the earlier readings were processed in a different way to the later datasets which accounts for the two peaks.

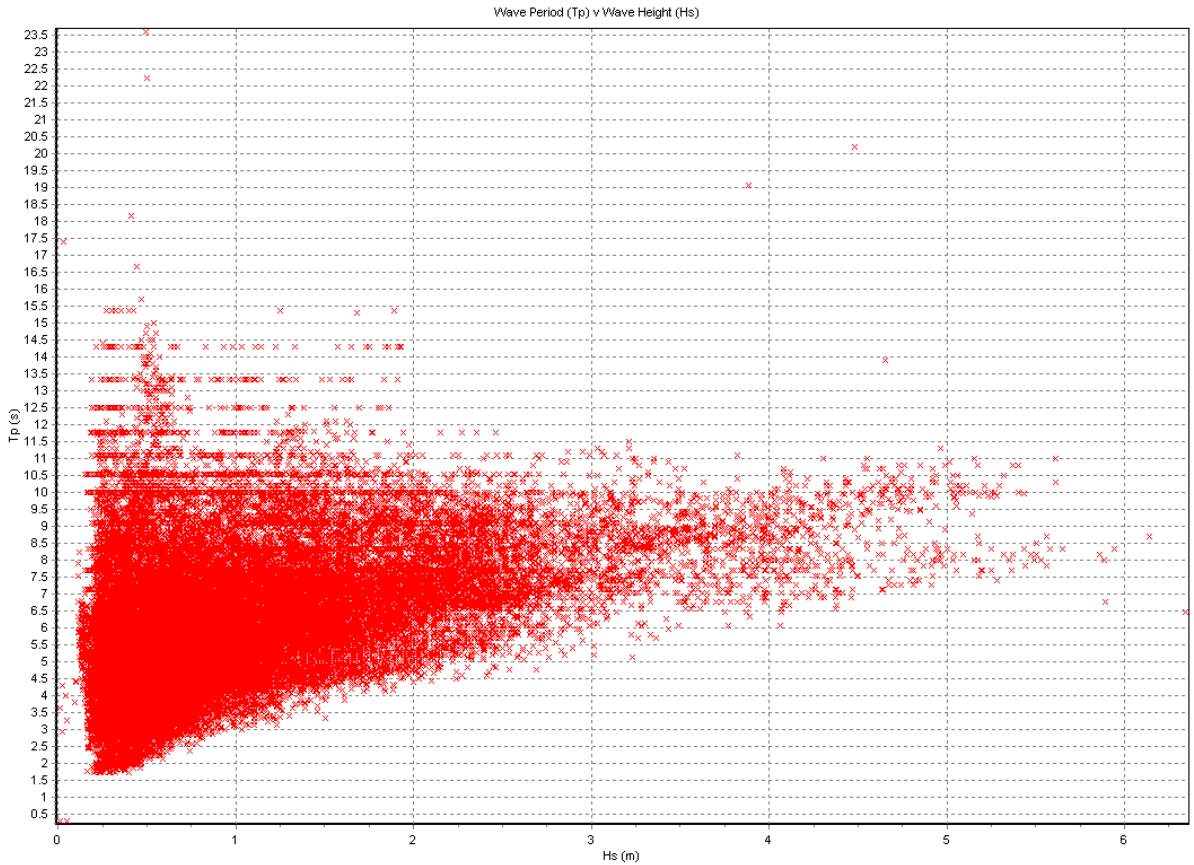


Figure 3.10 Scatter plot of Wave Height Vs Peak Period at Scarborough DWR site

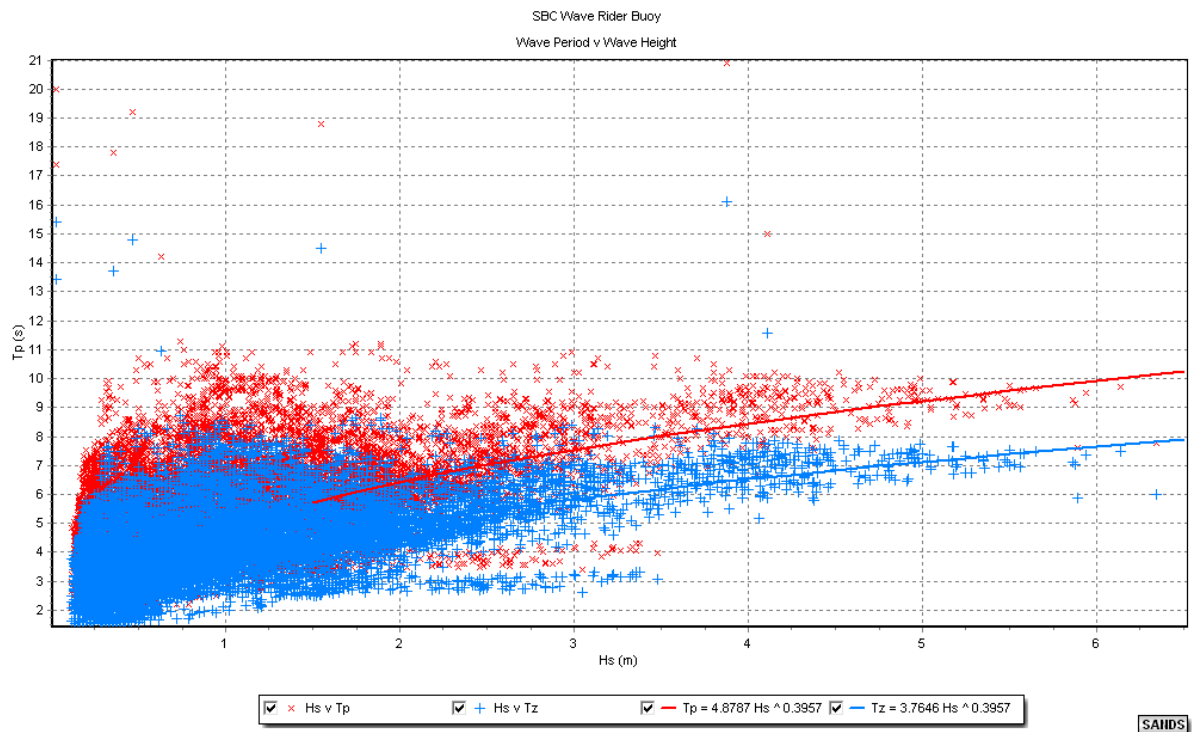


Figure 3.11 Scatter plot of Wave Height Vs Period at Scarborough SBC site

### 3.7.2. Wave Rose

The wave rose analysis of the Scarborough DWR and SBC Waverider datasets (Figures 3.12 and 3.13 respectively) show that the majority of the waves come from the North to Northeast (0-30 degrees). The SBC dataset also shows a secondary wave direction from 105 to 120 degrees. This is interesting as the DWR buoy is further offshore and so might have been expected to have a wider spread of directions. It may be that the wider direction spread is made more apparent at the closer inshore location as it is slightly more sheltered from waves from the north, but alternatively the difference it is more likely to reflect the different conditions between the two time periods analysed.

In order to further compare the two Scarborough wave data sets Figure 3.14 shows a time series plot over the winter period from December 2003 through to March 2004 when there is data from both locations. This indicates almost identical results, although slightly higher wave heights were recorded at the further offshore DWR site than the closer inshore SBC site.

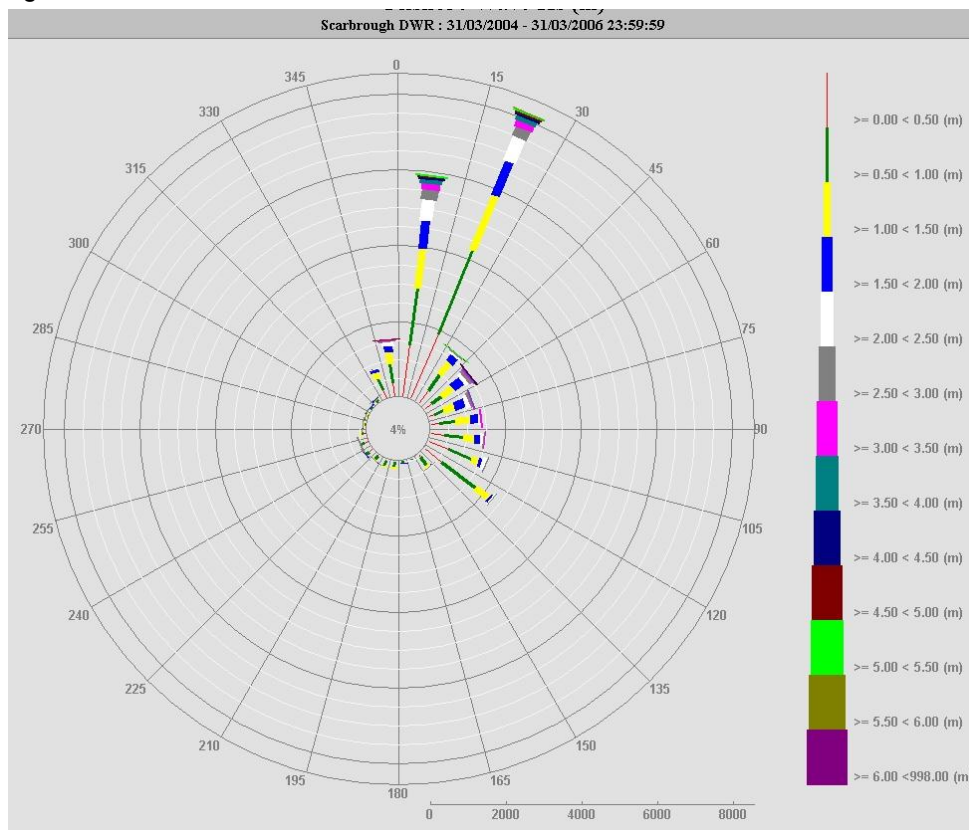


Figure 3.12 Wave Rose at Scarborough DWR site



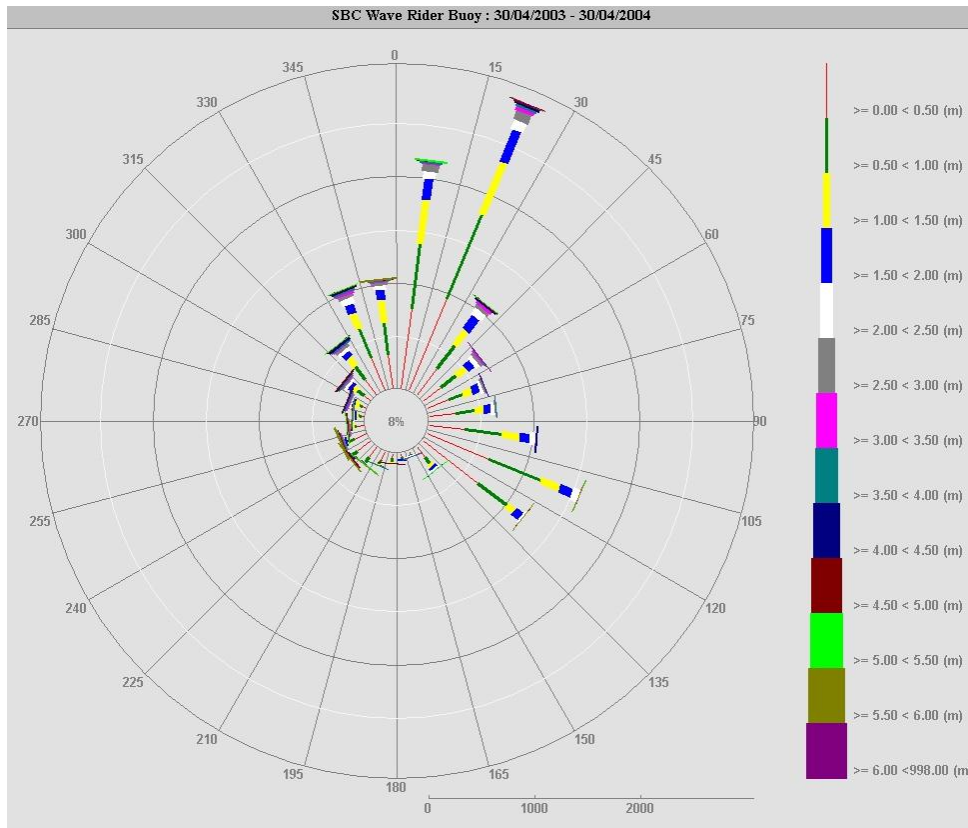


Figure 3.13 Wave Rose at Scarborough SBC site

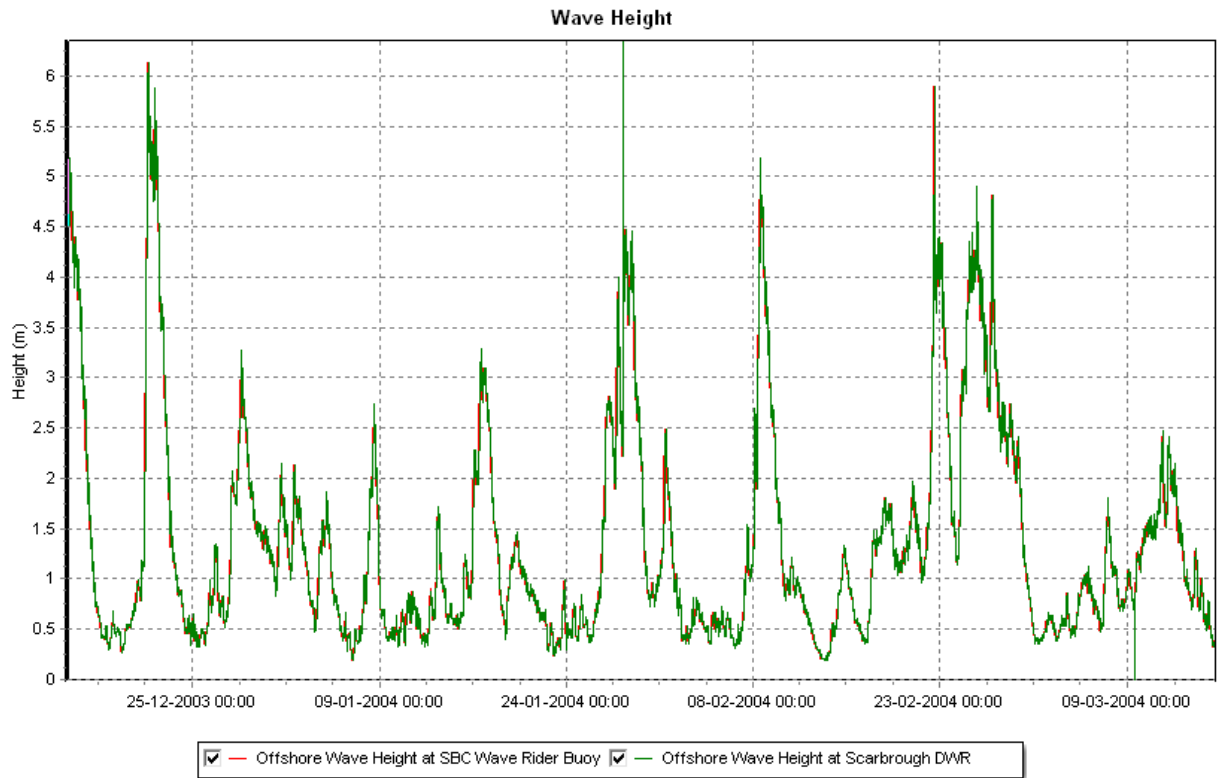


Figure 3.14 Example wave data from SBC and DWR wave data sets at Scarborough

### 3.7.3. Extremes Analysis

For the Scarborough DWR buoy, a peak wave height threshold of 4m was used, providing 18 peaks in 2.92 years. The Gumbel distribution gives a reasonable correlation coefficient of 0.9859 and the visual fit is satisfactory. Given the length of the record, the data should only be read up to a 1:10 year return period. The SBC dataset is not long enough to complete such an analysis. The results of the extremes analysis are shown in Table 3-5 below.

Table 3.5 Extremes Analysis for Scarborough DWR

Return Period (1 in x years)	Gumbel Fit Extreme Wave Height (Hs, m)
<b>0.2</b>	4.5
<b>0.3</b>	4.9
<b>0.5</b>	5.4
<b>1</b>	5.8
<b>2</b>	6.3
<b>3</b>	6.5
<b>5</b>	6.8
<b>10</b>	7.3

### 3.7.4. Storm Analysis

A storm analysis was carried out on the Scarborough DWR wave data (between 30/04/2003 and 31/03/2006), using a storm separation threshold of 120 hours and a wave height threshold of 4m. The results are shown in Table 3.5 below.

As with the Tyne/Tees analysis alternate years have been shaded, the largest storm each year is highlighted in bold and the largest wave energy at storm peak highlighted in bold red. Note that only 2004 and 2005 are complete years so the conclusions that can be drawn from this analysis are limited. The largest recorded wave height at the storm peak was 6.3m on 28 January 2004. The largest wave energy at peak occurred on 25<sup>th</sup> November 2005.

A new Waverider buoy was deployed offshore from Scarborough as part of the current programme in January 2013. Data from this will allow future annual reports to make comparison of new data to these two previous deployments and start to build up a longer record that will begin to allow more informed interpretation of the changes that are seen on the beach and cliff monitoring data.

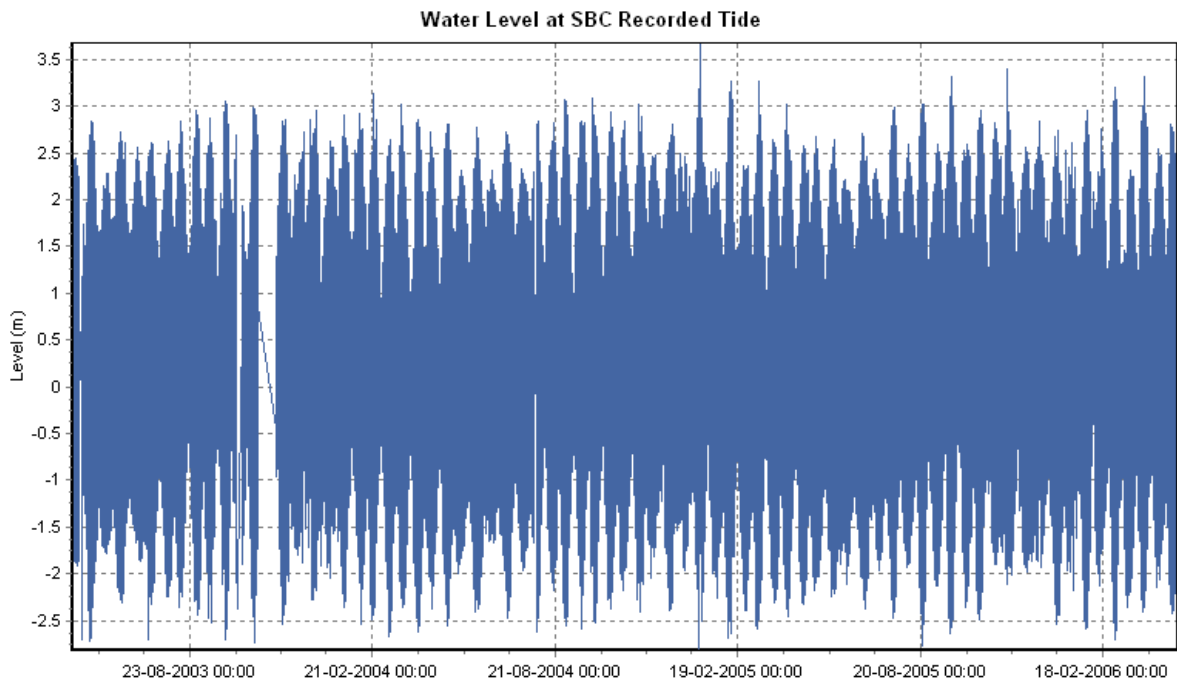
Table 3.6 Storm analysis for Scarborough DWR wave buoy

General Storm Information							At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Dir (°)	No of Events (30 min dataset)	Mean Dir Vector (°)	Hs (m)	Tp (s)	Dir (°)	Energy @ Peak (KJ/m/s)
<b>14/12/2003 20:05</b>	<b>15/12/2003 20:35</b>	<b>25</b>	<b>15/12/2003 01:05</b>	<b>197</b>	<b>44</b>	<b>100.20</b>	<b>5.17</b>	<b>7.30</b>	<b>13</b>	<b>2808.33</b>
21/12/2003 06:05	22/12/2003 08:05	26	21/12/2003 10:05	205	52	198.01	6.14	7.30	18	3961.00
<b>28/01/2004 14:05</b>	<b>29/01/2004 08:05</b>	<b>18</b>	<b>28/01/2004 14:05</b>	<b>281</b>	<b>19</b>	<b>121.24</b>	<b>6.34</b>	<b>5.41</b>	<b>56</b>	<b>2321.28</b>
08/02/2004 11:35	08/02/2004 23:35	12	08/02/2004 14:35	227	22	190.14	5.18	6.33	242	2123.16

22/02/2004 13:05	27/02/2004 06:35	114	22/02/2004 14:05	177	64	98.96	4.11	8.19	25	2233.64
12/11/2004 21:05	13/11/2004 01:35	4.5	12/11/2004 23:35	7	8	82.91	4.36	8.11	4	2467.49
23/01/2005 19:05	24/01/2005 09:35	15	24/01/2005 00:05	23	30	67.39	5.40	8.39	20	4047.78
19/02/2005 08:35	24/02/2005 14:05	126	24/02/2005 02:35	36	33	54.70	4.61	7.51	46	2363.07
<b>08/04/2005 05:05</b>	<b>09/04/2005 01:05</b>	<b>20</b>	<b>08/04/2005 11:05</b>	<b>15</b>	<b>40</b>	<b>74.92</b>	<b>5.61</b>	<b>9.23</b>	<b>16</b>	<b>5286.16</b>
24/11/2005 18:35	26/11/2005 10:05	40	25/11/2005 03:05	22	40	76.21	4.48	16.95	22	<b>11368.10</b>
16/12/2005 10:36	17/12/2005 18:35	32	16/12/2005 11:36	18	56	72.47	4.65	11.66	11	5799.16
<b>08/02/2006 21:35</b>	<b>10/02/2006 00:35</b>	<b>27</b>	<b>09/02/2006 16:35</b>	<b>21</b>	<b>54</b>	<b>68.90</b>	<b>5.21</b>	<b>8.56</b>	<b>16</b>	<b>3920.17</b>
28/02/2006 11:35	01/03/2006 00:05	13	28/02/2006 22:05	11	11	79.41	4.01	8.30	8	2183.29

### 3.7.5. Water Level Data

The water level data from the Scarborough SBC tidal gauge record is shown in Figure 3-15 below. The data runs from 28/04/2003 to 06/06/2006.



*Figure 3.15 Water Levels at Scarborough SBC Recorded Tide Site*

The Scarborough tide gauge data has been analysed by Fugro-EMU and Channel Coast Observatory, and standard tidal heights are presented in Table 3.7 below. However, it should be noted that when the site was checked and re-surveyed by Fugro-EMU in June 2013 a discrepancy was found with the original datum established in 2003, with the tide gauge zero

now 0.195m higher than previously assumed. It is not known when the offset applies from, but Fugro-EMU (2013)<sup>1</sup> note that “*This offset brings the data back in line with predictions created through the harmonic analysis of the data from 2003 and also predictions created from the Admiralty harmonic constants for Scarborough.*”

**Table 3.7 Predicted tide levels at Scarborough**

Tidal State	Level (m Ordnance Datum)
HAT	3.10
MHWS	2.46
MHWN	1.31
MSL	0.175
MLWN	-0.96
MLWS	-2.11
LAT	-3.04

Note: Based on analysis of 2007 data collected at Scarborough by Fugro EMU; See note above re-potential issue with datum.

**Table 3.8 Annual maxima data from Scarborough Tide gauge analysis (source CCO, 2013)<sup>2</sup>**

Year	Annual extreme maxima		Annual surge maxima		Z <sub>0</sub> (OD)	Annual recovery rate
	Elevation (OD) (Surge)	Date/Time	Value (m)	Date/Time		
2006	3.20 (0.33)	06-Nov-2006 03:40	1.29	31-Oct-2006 15:40	-	22%
2007	3.40 (0.71)	25-Nov-2007 04:00	1.60	08-Nov-2007 21:30	0.221	97%
2008	3.05 (0.16)	09-Mar-2008 17:20	0.90	22-Feb-2008 02:10	-	65%
2009	3.19 (0.44)	12-Jan-2009 16:50	1.15	18-Jan-2009 16:30	-	84%
2010	3.21 (0.05)	11-Sep-2010 05:30	0.81	12-Nov-2010 04:20	-	82%
2011	3.03 (-0.14)	21-Mar-2011 17:10	1.33	04-Feb-2011 11:00	-	80%
2012	2.94 (0.06)	17-Oct-2012 04:40	0.92	05-Jan-2012 16:40	-	70%

Note: See note above re-potential issue with tide gauge datum zero, levels may be 0.195m higher.

The water level data has also been used to analyse joint occurrence of high waves and water levels data, by tabulating the frequencies of coincident wave and water level measurements, see Table 3.9 below.

This analysis was hampered by the unusually random sampling periods used in the water level measurements and had to be post-processed using interpolation to derive water level at the same times as the wave height data. It is recommended that in future the tide gauge should be set to record data on the hour and at constant time intervals of 5, 10, 15 or 20 minutes thereafter each hour.

In Table 3.9 the water level with the highest number of wave observations has been highlighted for each 0.5m increment in water level. The table does not appear to indicate any particular trend but shows that the water level at which most wave observations occur is 1 to 1.5m OD.

<sup>1</sup> Fugro EMU, August 2013, Northeast regional coastal monitoring framework; hydrodynamic services; December 2012 to June 2013 Reports.

<sup>2</sup> CCO April 2013, Scarborough tide gauge annual report (Draft).

Table 3.9 Scatter table of water level and wave height at Scarborough

		Water level data mODN														
		-3 to -2.5	-2.5 to -2	-2 to -1.5	-1.5 to -1	-1 to -0.5	-0.5 to 0	0 to 0.5	0.5 to 1	1 to 1.5	1.5 to 2	2 to 2.5	2.5 to 3	3 to 3.5	3.5 to 4	Total
Offshore Wave Height (m)	0-0.5	13	159	476	757	775	702	660	714	876	817	506	127	3	0	6585
	0.5-1	9	169	465	735	863	936	786	887	968	829	535	141	7	2	7332
	1-1.5	12	92	269	385	488	464	443	485	536	459	291	79	3	0	4006
	1.5-2	4	93	181	245	246	245	232	271	303	224	162	56	3	0	2265
	2-2.5	2	17	71	110	149	139	159	166	178	173	106	27	1	0	1298
	2.5-3	0	13	28	44	66	57	63	69	80	54	28	10	1	0	513
	3-3.5	0	3	9	24	32	31	18	32	43	37	23	13	0	0	265
	3.5-4	0	2	10	16	19	23	26	25	32	24	13	7	1	0	198
	4-4.5	0	5	3	11	22	19	8	13	11	14	15	5	0	0	126
	4.5-5	0	0	1	1	9	13	8	8	10	16	4	5	0	0	75
	5-5.5	0	0	0	3	7	2	2	4	2	3	3	4	0	0	30
	5.5-6	0	0	0	1	2	0	1	0	0	0	1	0	0	0	5
	6-6.5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	6.5-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	40	553	1513	2332	2678	2632	2406	2674	3039	2650	1687	474	19	2	0

Water Level (x) vs Offshore Wave Height Hm0 (y) (numbers of 30 minute observations)  
 For date range :31/03/2004 to 31/03/2006 (2 years full data)

## 4. Problems Encountered and Uncertainty in Analysis

### Wave Data

The wave direction data at the Blyth historical site off WaveNet appeared to be in error and was excluded from further analysis.

There is great variability in the length of the datasets presented and as such the wave records do present some uncertainty with regards to how reliably the sites can be compared. Where possible full years of data were used for the wave scatter and wave rose analyses. Records shorter than one full year are not fully representative of the wave conditions at the wave buoy location.

The Whitby East Pier records are extremely short (approximately two months) and only include data from March to May. This results in an incomplete analysis where only data from the spring is included and thus will miss many of the storm events which will occur during the rest of the year.

### Water level data

Across the range of datasets used in this analysis the record intervals vary, making direct comparisons between the datasets difficult. It is recommended that in future the contractor should be asked to set the instruments to record data on the hour and at regular 10, 15, 20 or 30 minute intervals afterwards. This will greatly facilitate inter-site comparison of the wave data throughout the study area and analysis of joint wave and water level or wave and surge data.

As noted in the text there is uncertainty over datum changes for the Scarborough tide gauge between the original deployment in 2003 and the site checks in 2013, with a discrepancy of 0.195m

## 5. Summary of Baseline and Recommendations for Future Annual Reports

This report has set out information on existing wave and water level data relevant to National Sediment Cell 1 as a baseline for subsequent annual reports. Future reports in this series should compare the data recorded in subsequent years with the results presented here. The key points are summarised below:

- Wave direction along the Cell 1 coast is predominantly between 0 and 30 degrees (north to northeast);
- A secondary wave approach direction from the East to Southeast was also observed (cf Figure 3.13 - Scarborough SBC wave rose);
- The waves at the Newbiggin Ness site are partially sheltered from waves from the north.
- The longest consistent wave record in the region is for the Wavenet Tyne/Tees buoy, which has been operating since 2006.
- Analysis of the 2006 to 2012 data from Tyne/Tees indicates that the stormiest year was 2010 whilst the year with the least number of storms was 2011. Due to only one year of data being available from Newbiggin and Whitby it is not yet possible to make reliable comparisons to Tyne/ Tees.

The wave roses for Newbiggin Ness, Tyne/Tees, Whitby, Scarborough DWR and Scarborough SBC are collated in Figure 5.1 to supplement the points made above.

In the future annual reports it is recommended that scatter tables (Hs vs Tp) could be produced with a different colour for each year overlaying each other if at the same location. This would allow a simple comparison to see how the conditions vary from year to year.

Storm analysis should be done for each year and at each site (Newbiggin Ness, Tyne/Tees, Whitby and Scarborough), using the same parameters as in this report, adding the results to the tables that have already been produced. Where tide gauges are to be deployed (Whitby and Scarborough) if possible the surge component should be extracted by subtracting the predicted tides during the identified storms to show how the storms have influenced the tidal signal.

Wave roses should also be produced side by side for each year. Plotting for each year for different locations may identify changes in the climate which occur at more than one location.

Scatter tables of wave period vs direction should also be produced annually this shows predominant direction of swell and the storm waves and if this changes year on year.

It is recommended that hindcast WaveWatch III Met Office wave model data is obtained at a point close to or coincident to the four main measurement locations (i.e Newbiggin Ness, Tyne/Tees, Whitby and Scarborough). Comparison against measurements will allow correlation between observed and model to be known, may be useful to fill in gaps in data or for follow on years after wave buoys decommissioned. The measured data should also be offered to the Met Office to allow them to calibrate and improve their model in the cell 1 region.

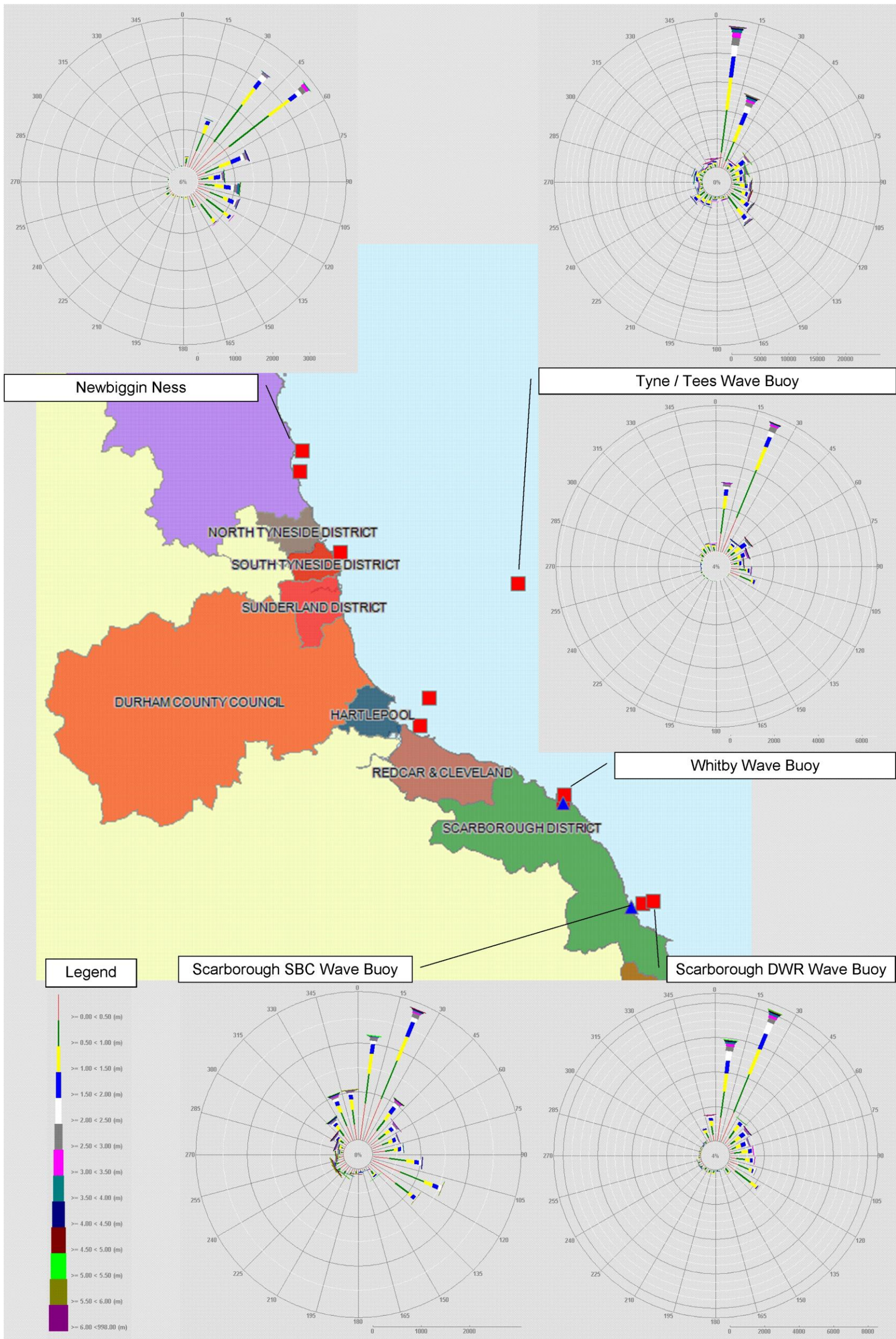


Figure 5.1 Wave Rose Locations from Newbiggin Ness to Scarborough



## **6. Conclusions**

This report has documented the review of available wave data across Cell 1 and analysed the data sets with strategic value, concentrating on the two wave buoys that were deployed under the strategic monitoring programme at Newbiggin Ness and Whitby, alongside the Cefas buoy located at Tyne / Tees and the historical deployments at Scarborough.

Recommendations for the future annual reports are contained in Section 5. These will essentially replicate and add to the analysis presented in this report for the new data at Newbiggin, Tyne/Tees, Whitby and Scarborough.

It has also been recommended that WaveWatch III Met Office wave model data is obtained at a point close to or coincident to measurements for comparison. In return the measured wave data can be made available to the Met office to allow them to improve their model if necessary.

## **Appendices**

## **Appendix A**

### **Detailed Location of Wave Buoys**

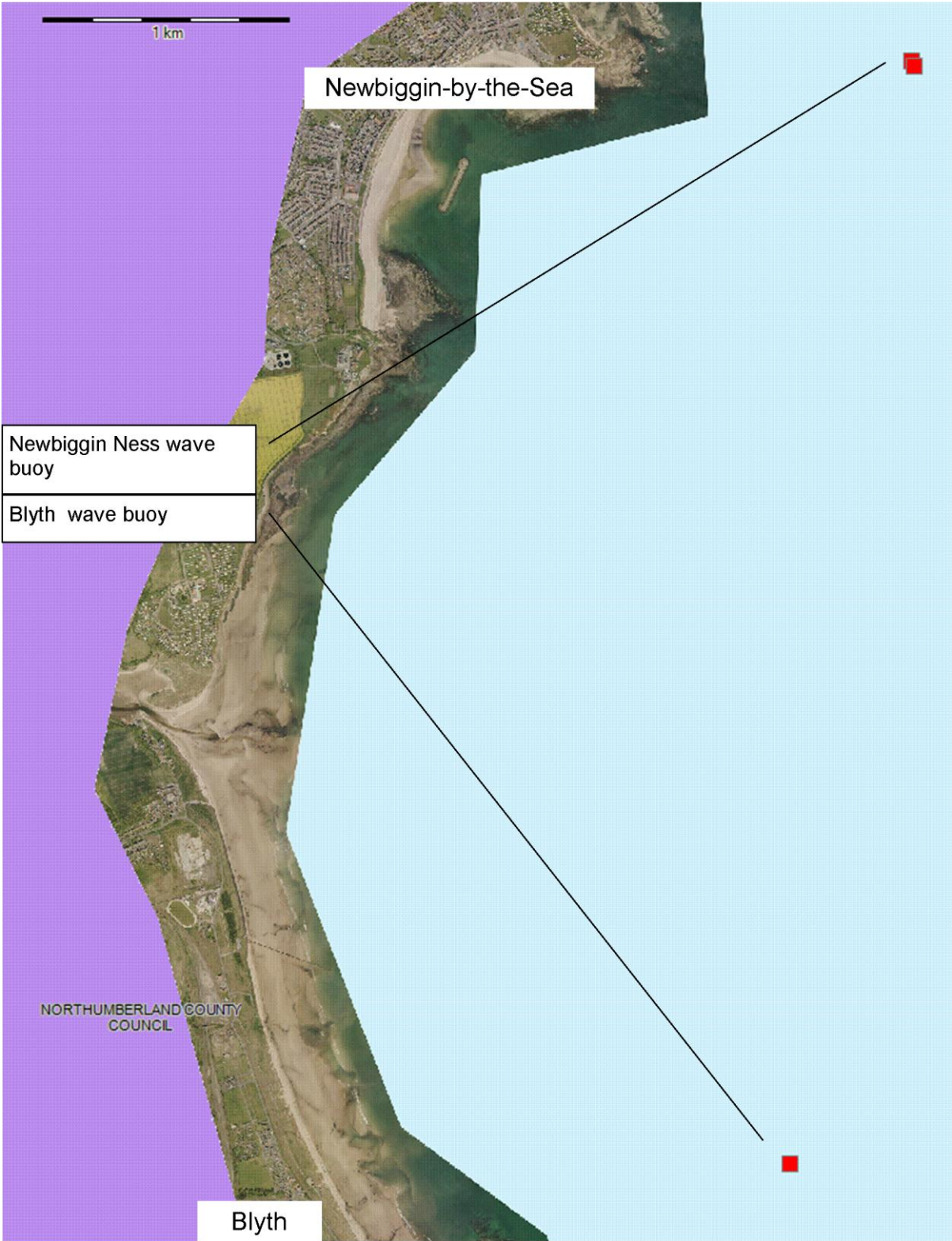


Figure A1 Location of Newbiggin Ness and Blyth wave buoys.

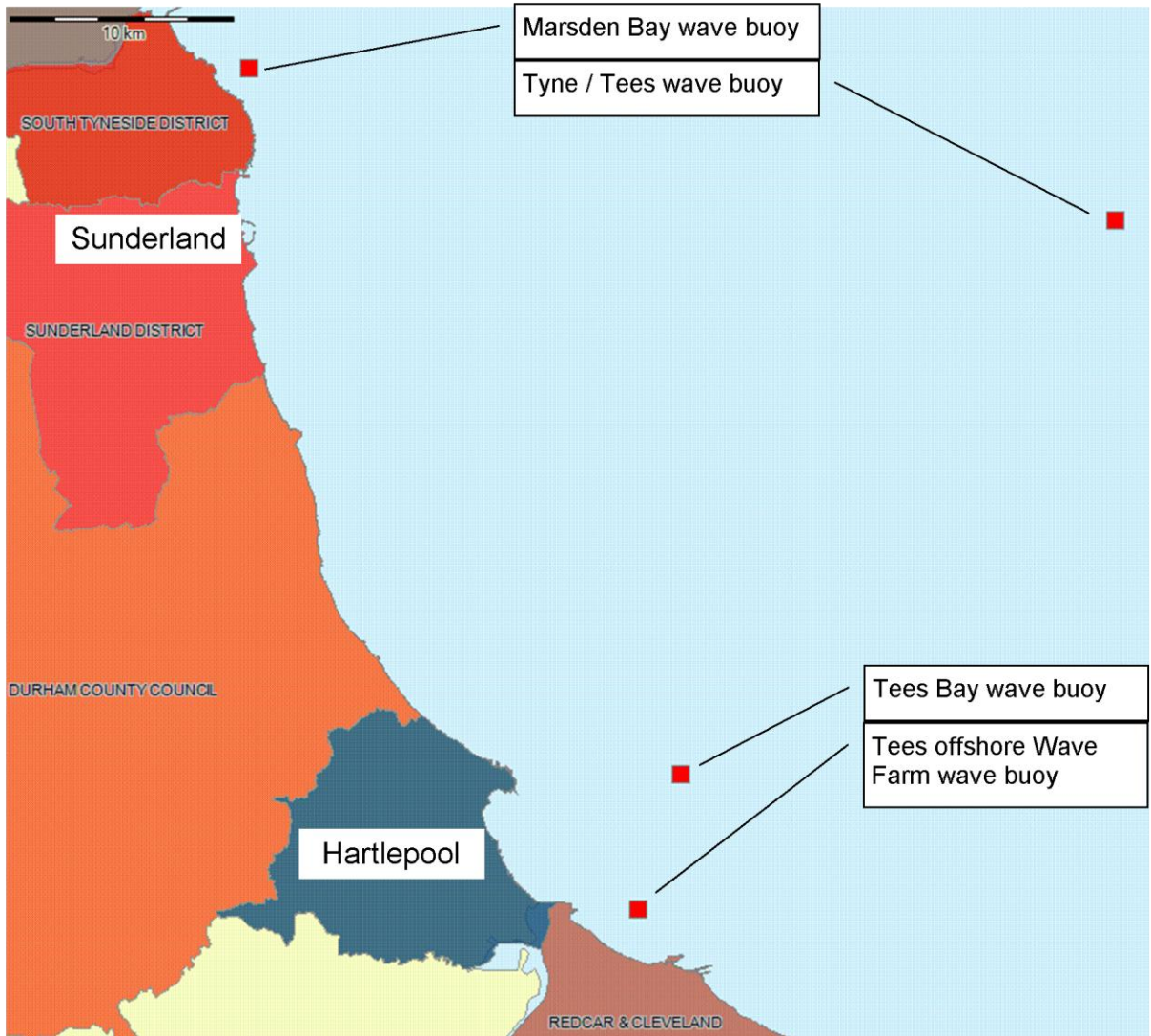


Figure A2 Location of Tyne/Tees wave buoys

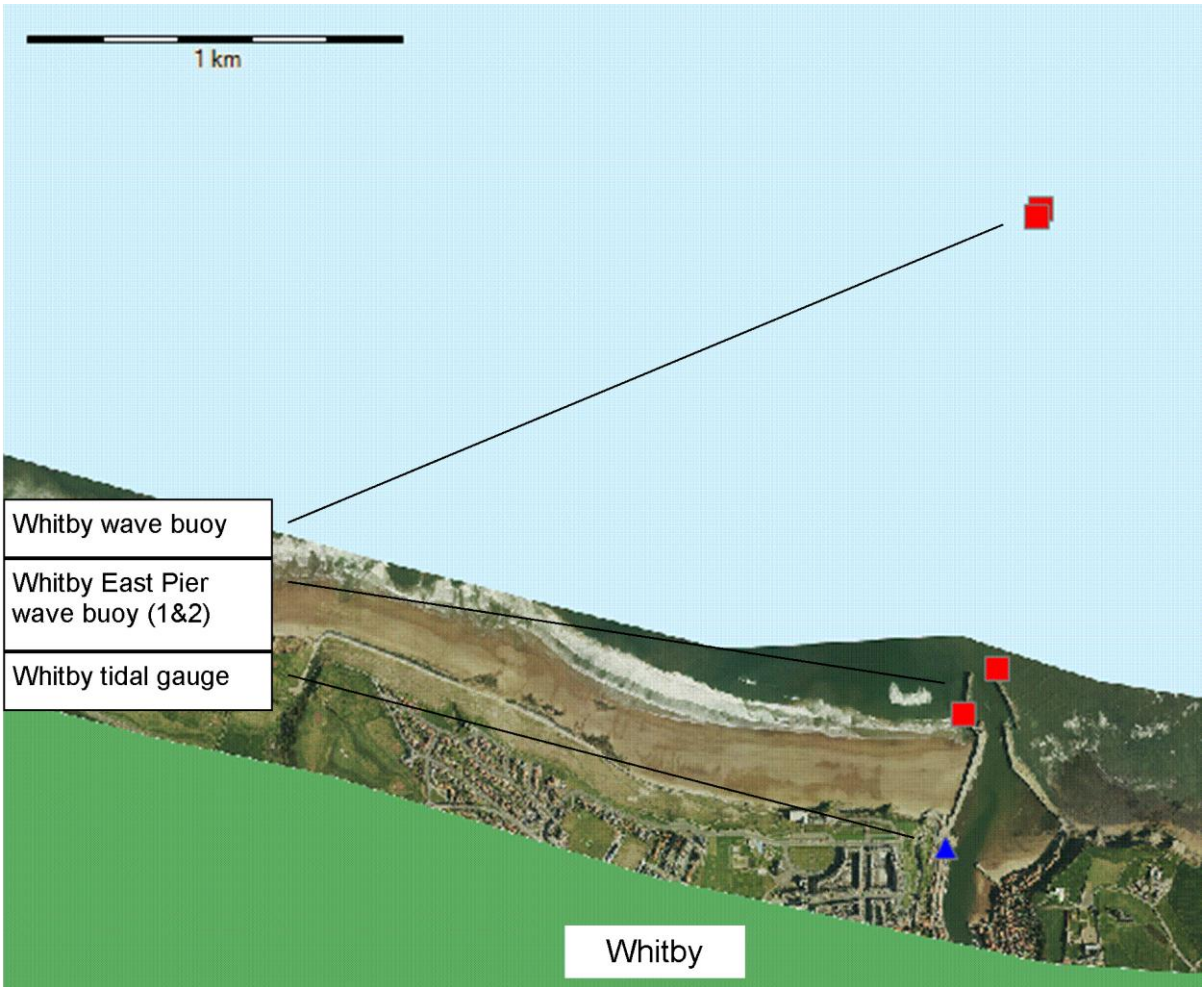


Figure A3 Location of Whitby and Whitby East Pier wave buoys

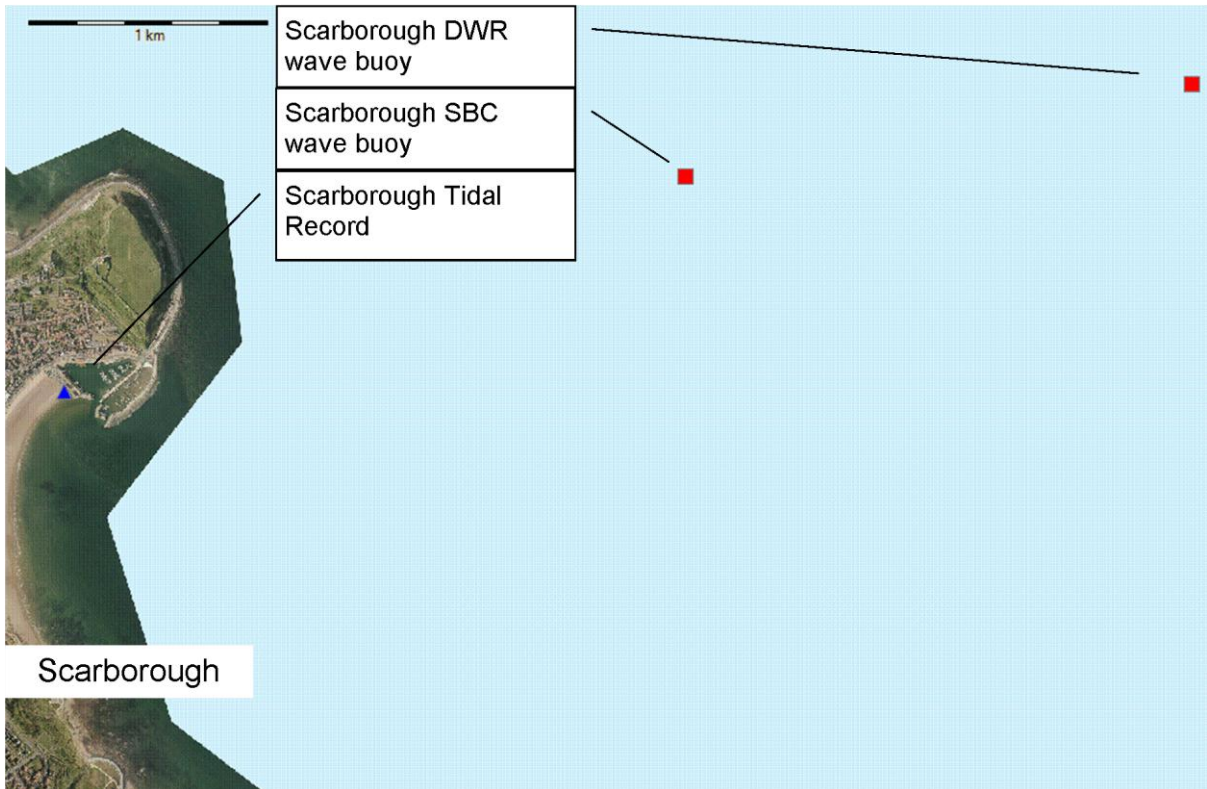


Figure A4 Location of Scarborough wave buoys

## **Appendix B**

### **Metadata and Supporting Graphs: Newbiggin Ness**

## **Newbiggin Ness Metadata**

Cefas Project Reference: C3732

Scarborough Borough Council Wave Monitoring - Newbiggin Ness Waverider buoy

Datawell DWR III directional waverider with logger and Orbcomm.

Processed logger data using Waves21 v 2.1.17 software.

Approximate position 55° 11'.1N 001° 28'.7W; Approximate depth 23m

Magnetic variation (May 2010): 2° 45' W changing by 0° 9' E/year

20/05/2010: Waverider buoy deployed

12/11/2010: Waverider adrift

26/11/2010: Waverider buoy re-deployed

07/06/2011: Waverider adrift

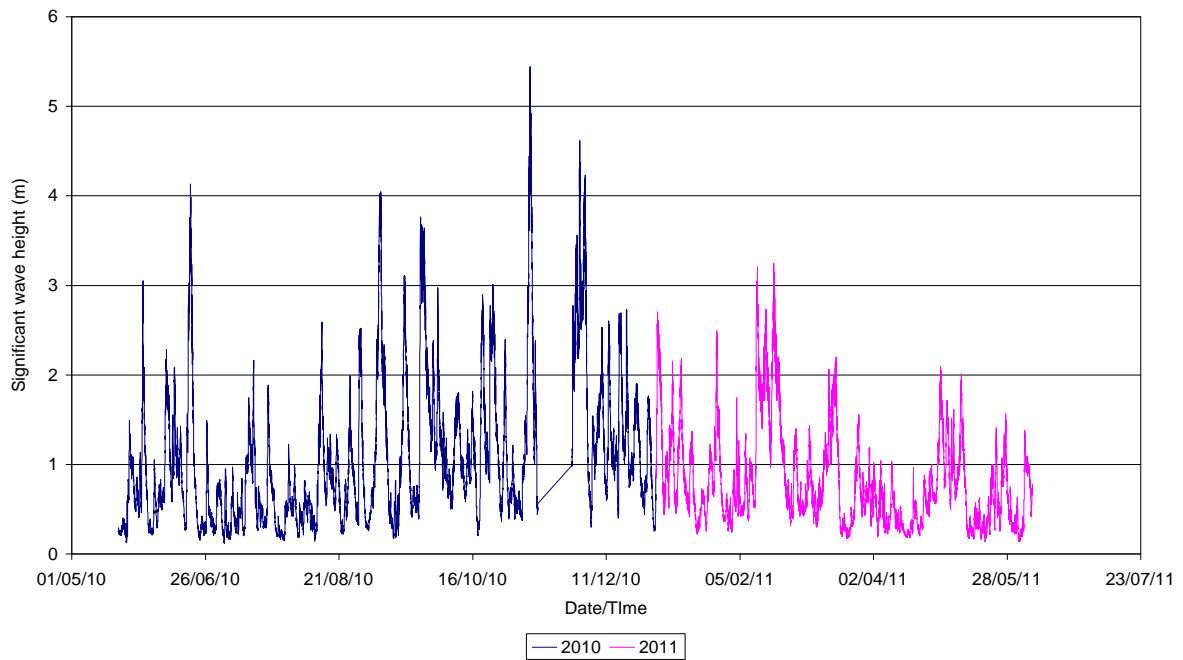
09/06/2011: Waverider buoy recovered

Data periods:

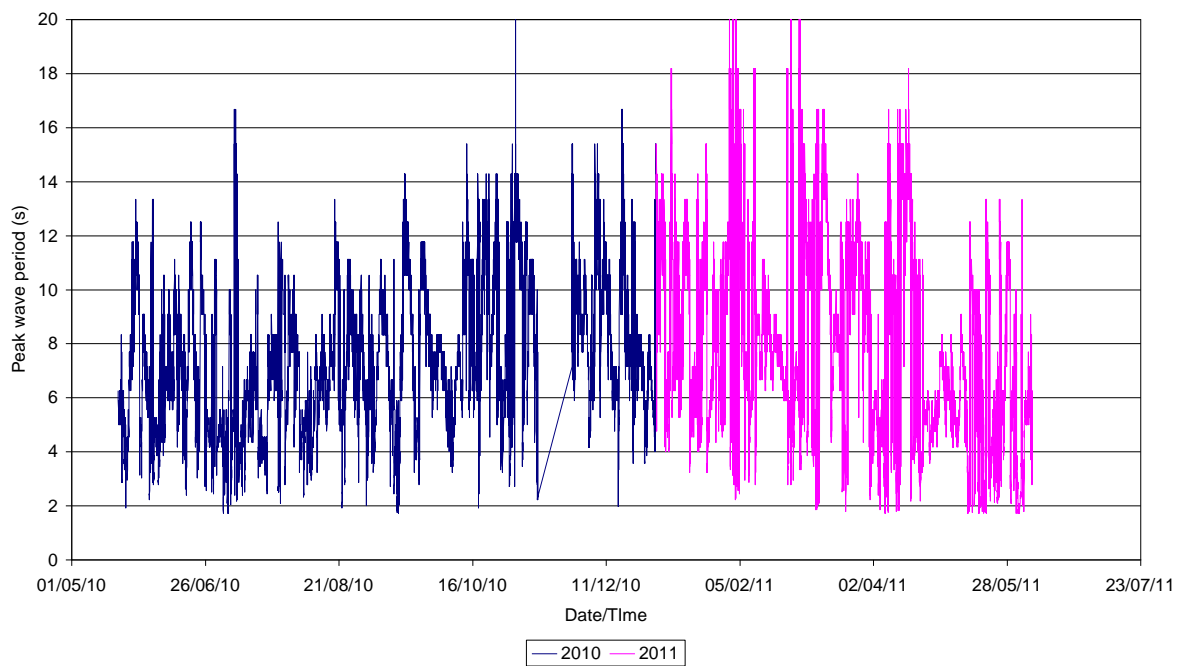
Serial Number	Start time	End time	Latitude	Longitude
30676-6	20/05/2010 13:30	12/11/2010 09:30	55°11'.106N	001°28'.732W
30676-6	26/11/2010 17:00	07/06/2011 15:30	55°11'.110N	001°28'.710W



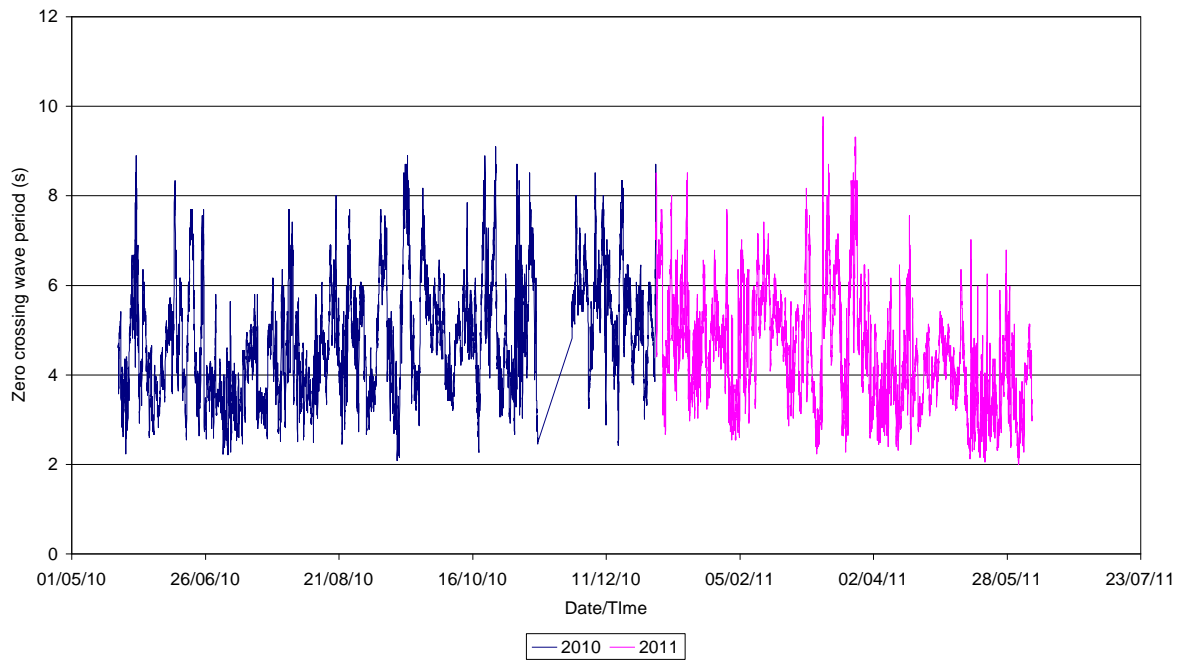
### Newbiggin Ness – Significant Wave Height ( $H_{m0}$ )



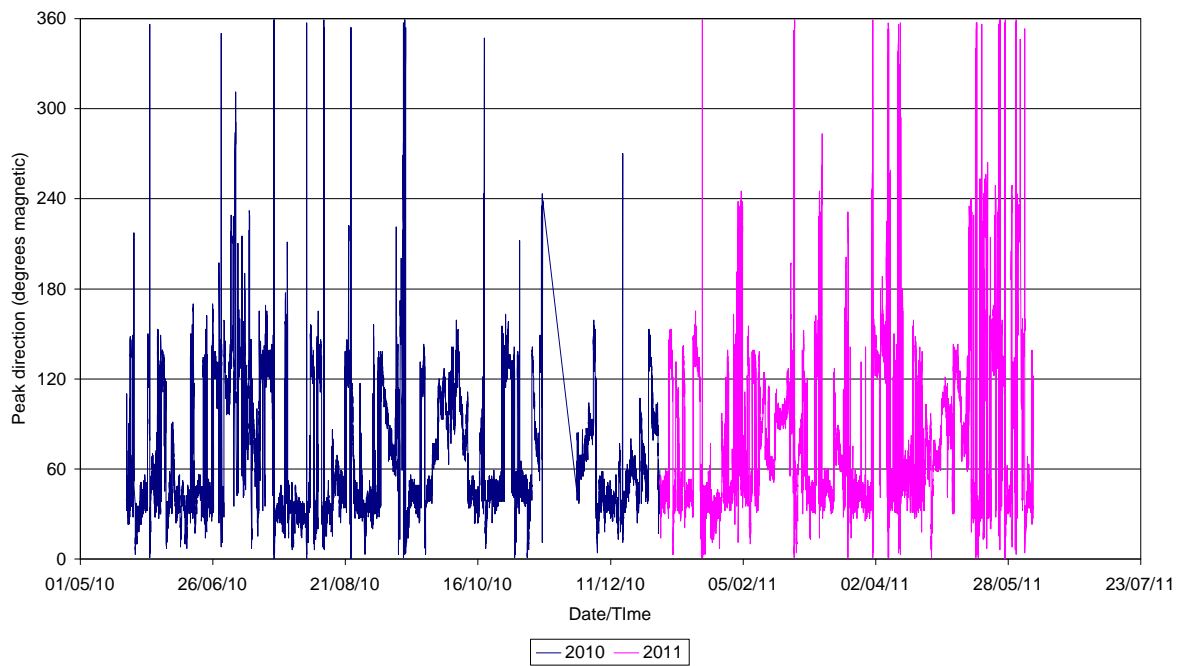
### Newbiggin Ness – Peak Wave Period ( $T_p$ )



## Newbiggin Ness – Zero Crossing Wave Period ( $T_z$ )

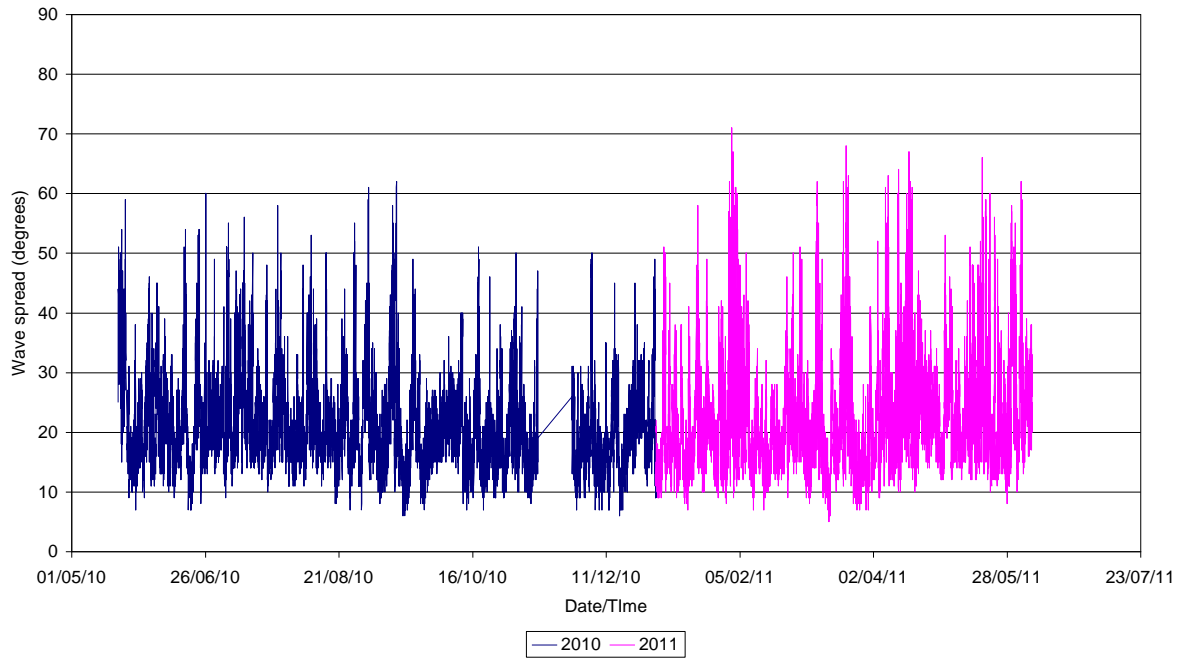


## Newbiggin Ness – Peak Direction ( $^{\circ}$ )

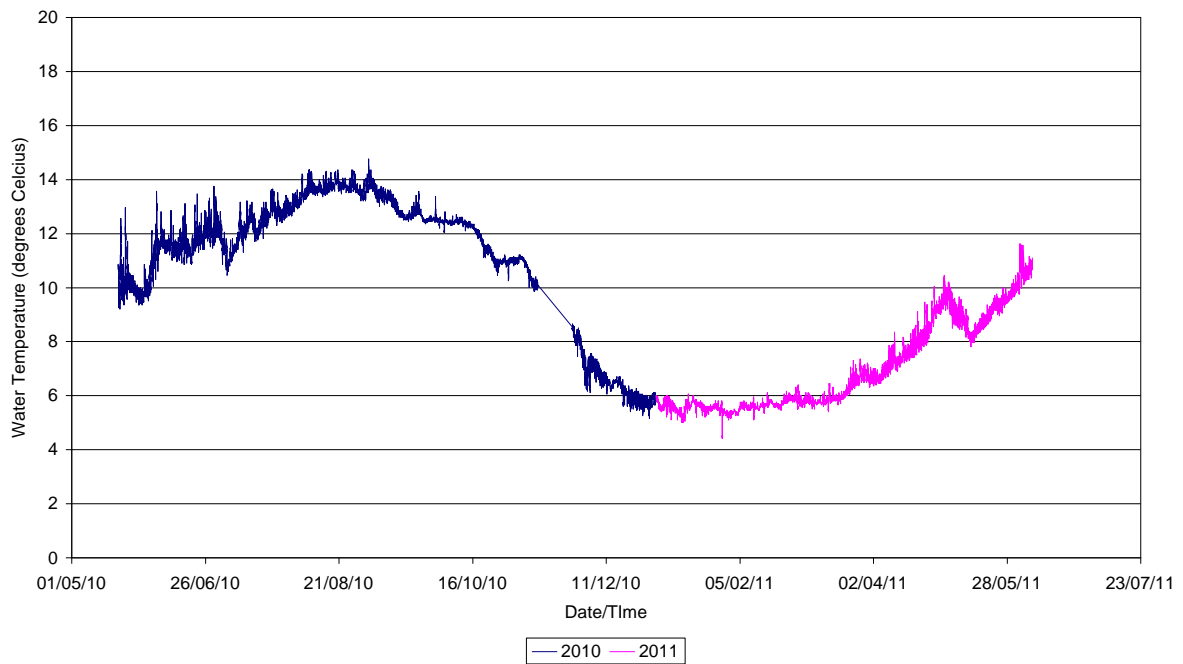


## Newbiggin Ness – Wave Spread

(°)



## Newbiggin Ness – Water Temperature (°C)



### **Newbiggin Ness – Scatter table of wave direction vs wave period**

s / Dir	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	Total
0-1	0	0	0	0	0	0	0	0	0	0	0	0	0
1-2	0	0	1	4	0	5	9	49	38	14	3	1	124
2-3	23	3	2	7	56	41	31	123	48	6	1	14	355
3-4	98	28	31	81	275	167	14	55	2	0	0	9	760
4-5	181	104	87	296	618	106	0	0	0	0	0	5	1397
5-6	282	308	290	491	683	25	0	0	0	0	0	2	2081
6-7	331	489	294	489	328	0	0	0	0	0	0	0	1931
7-8	337	553	421	491	126	0	0	0	0	0	0	0	1928
8-9	184	675	422	236	32	0	0	0	0	0	0	0	1549
9-10	84	917	269	89	1	0	0	0	0	0	0	0	1360
10-11	20	1047	91	58	0	0	0	0	0	0	0	0	1216
11-12	10	931	40	5	0	0	0	0	0	0	0	0	986
12-13	2	639	9	0	0	0	0	0	0	0	0	0	650
13-14	0	334	25	0	0	0	0	0	0	0	0	0	359
14-15	2	237	33	0	0	0	0	0	0	0	0	1	273
15-16	1	139	30	0	0	0	0	0	0	0	0	0	170
16-17	1	60	17	0	0	0	0	0	0	0	0	0	78
17-18	1	46	7	0	0	0	0	0	0	0	0	0	54
18-19	0	34	19	1	0	0	0	0	0	0	0	0	54
19-20	0	6	6	0	0	0	0	0	0	0	0	0	12
20-21	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	1557	6550	2094	2248	2119	344	54	227	88	20	4	32	0

Location: Newbiggin WaveNet Site (NEWBIGGWN/001)

Offshore Wave Direction Peak (x) vs Offshore Peak Wave Period Tp (y) (number of 30 minute observations)

For date range :07/06/2010 to 07/06/2011 (1 full year of data)

### **Newbiggin Ness – Scatter table of wave direction vs wave height**

m / Dir	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	Total
0-0.5	595	2090	324	547	737	164	41	152	64	18	9	23	4764
0.5-1	621	2589	589	642	1068	194	21	90	40	4	1	13	5872
1-1.5	291	1229	492	409	281	25	1	23	0	0	0	0	2751
1.5-2	109	466	453	345	86	4	0	0	0	0	0	0	1463
2-2.5	40	301	129	139	47	0	0	0	0	0	0	0	656
2.5-3	9	201	92	108	17	0	0	0	0	0	0	0	427
3-3.5	0	96	25	28	2	0	0	0	0	0	0	0	151
3.5-4	1	29	29	68	0	0	0	0	0	0	0	0	127
4-4.5	0	0	23	10	0	0	0	0	0	0	0	0	33
4.5-5	0	0	10	7	0	0	0	0	0	0	0	0	17
5-5.5	0	1	1	1	0	0	0	0	0	0	0	0	3
5.5-6	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	1666	7002	2167	2304	2238	387	63	265	104	22	10	36	0

Location: Newbiggin WaveNet Site (NEWBIGGWN/001)

Offshore Wave Direction Peak (x) vs Offshore Wave Height Hm0 (y) (number of 30 minute observations)

For date range :07/06/2010 to 07/06/2011 (1 full year of data)

## **Appendix C**

### **Metadata and Supporting Graphs: Whitby**

## Whitby Metadata

Cefas Project Reference: C3732

Scarborough Borough Council Wave Monitoring - Whitby Waverider buoy

Datawell DWR III directional waverider with logger and Orbcomm.

Processed logger data using Waves21 v 2.1.17 software.

Approximate position 54° 30'.3 N 000° 36'.5W; Approximate depth 16m

Magnetic variation (May 2010): 2° 17' W changing by 0° 9' E/year

20/05/2010: Waverider buoy deployed

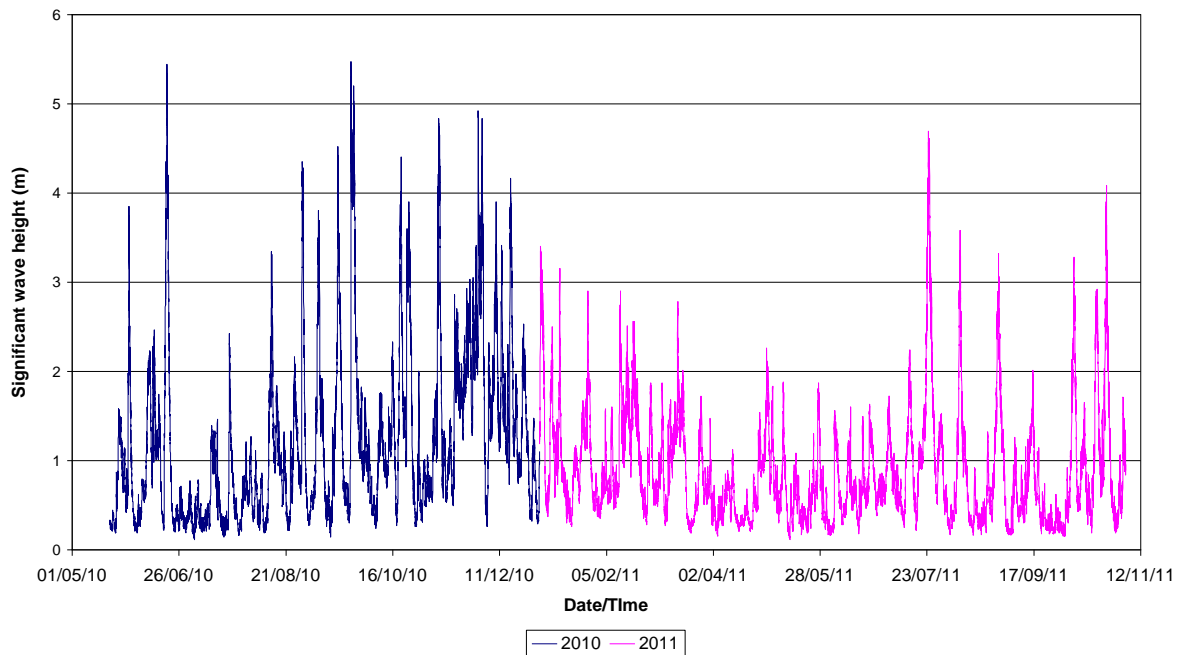
25/10/2011: Waverider stopped telemetering

04/11/2011: Waverider buoy recovered

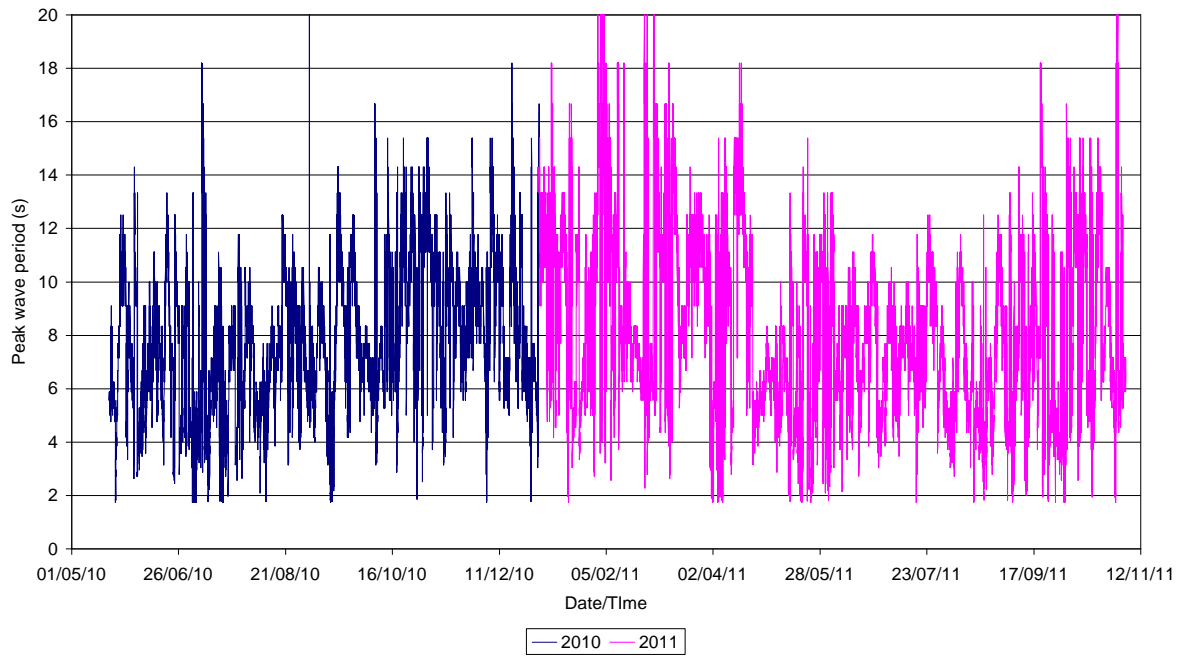
Data period:

Serial Number	Start time	End time	Latitude	Longitude
30665-6	20/05/2010 18:00	04/11/2011 06:00	54°30'.309N	000°36'.488W

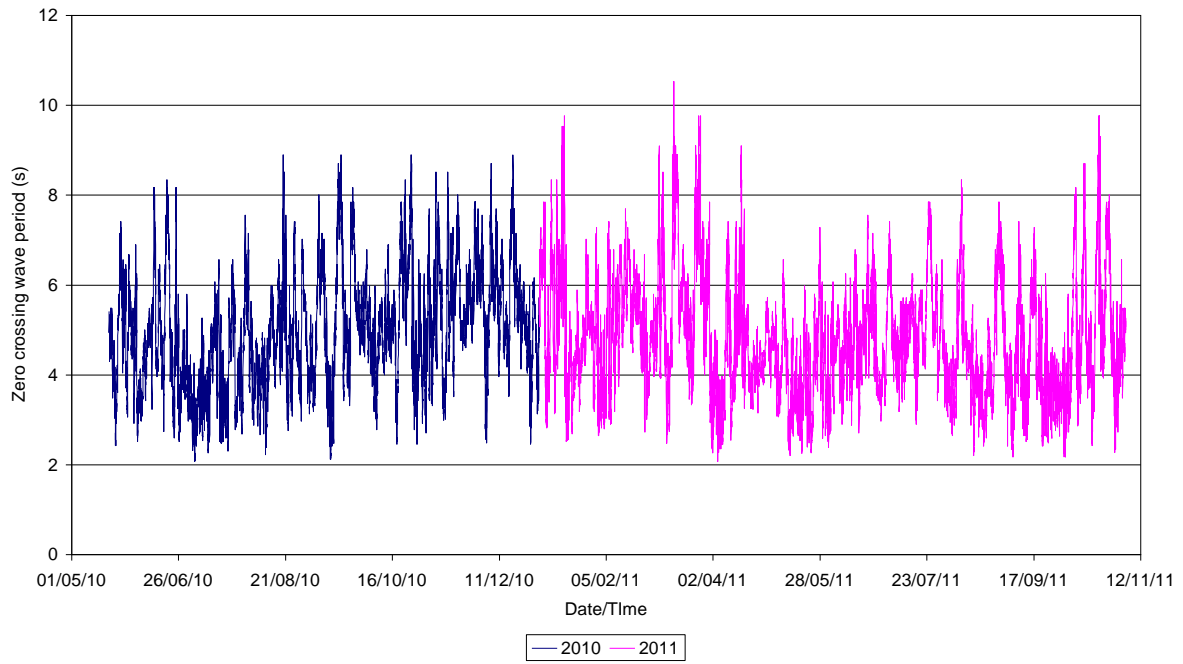
## Whitby - Significant Wave Height ( $H_{m0}$ )



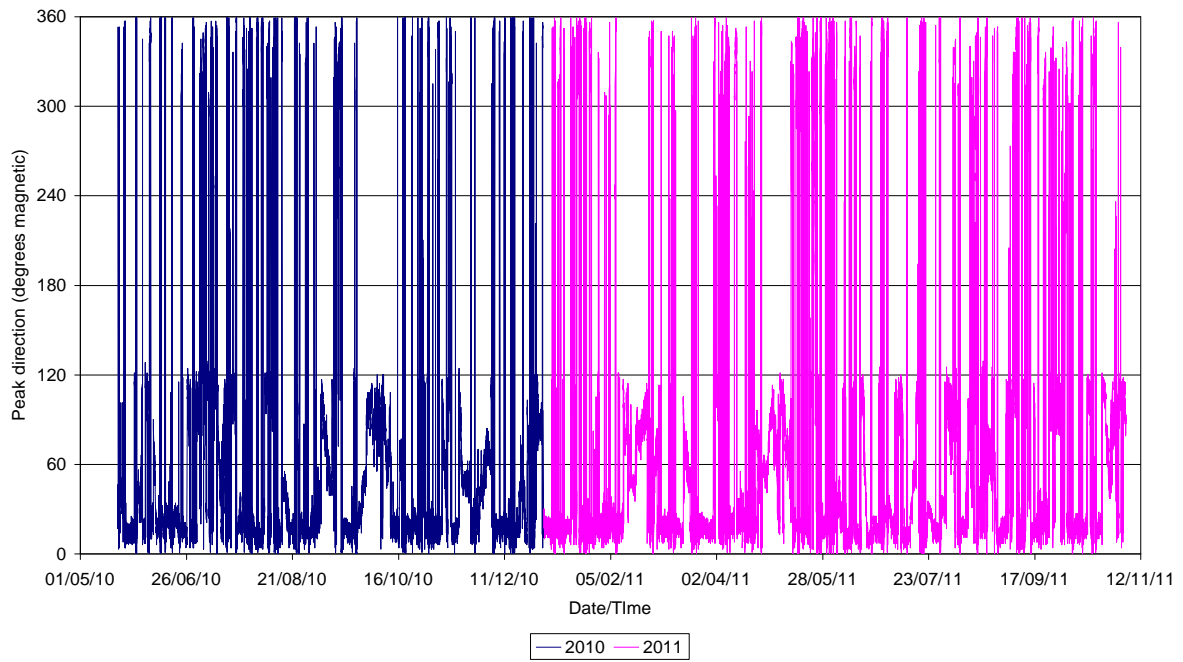
### Whitby – Peak Wave Period ( $T_p$ )



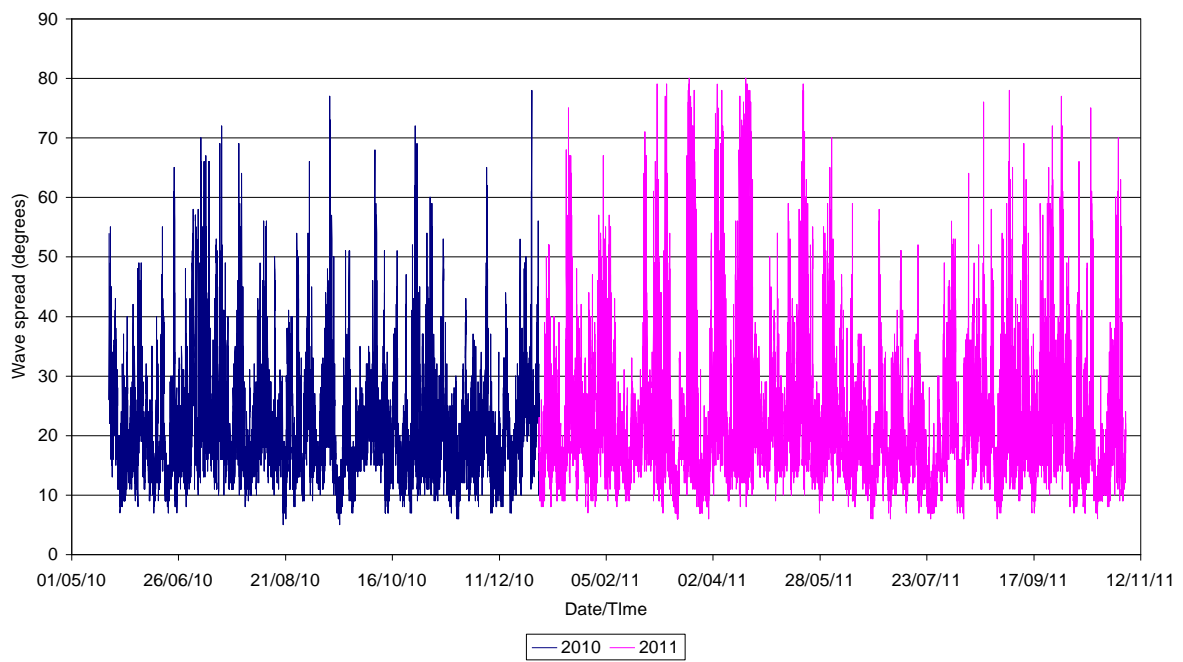
### Whitby – Zero Crossing Wave Period ( $T_z$ )



### Whitby – Peak Direction (°)

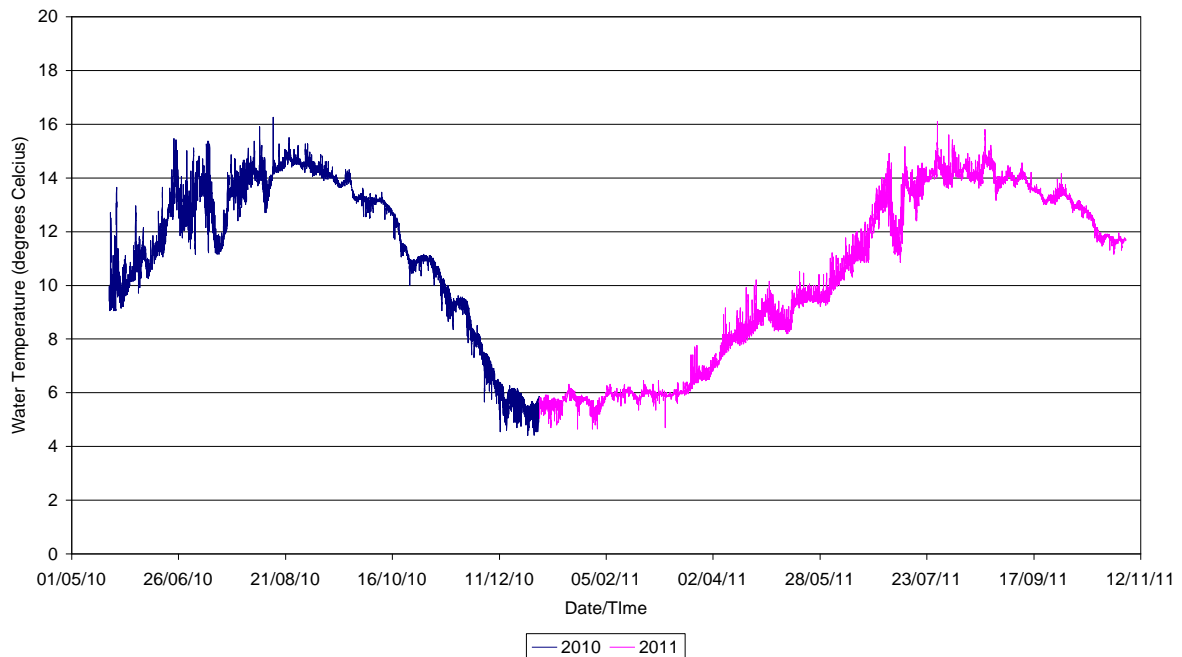


### Whitby – Wave Spread (°)





## Whitby – Water Temperature (°C)



## Whitby – Wave Direction vs wave period scatter table

s / Dir	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	Total
0-1	0	0	0	0	0	0	0	0	0	0	0	0	0
1-2	0	0	0	0	0	0	29	29	19	11	2	0	90
2-3	0	0	6	0	0	0	10	28	60	52	21	10	187
3-4	30	4	41	130	0	0	0	0	4	29	204	106	548
4-5	143	46	112	508	13	0	0	0	0	24	208	251	1305
5-6	343	218	279	552	12	0	0	0	0	4	102	259	1769
6-7	483	388	307	438	2	0	0	0	0	0	5	97	1720
7-8	691	421	325	242	2	0	0	0	0	0	0	42	1723
8-9	1070	324	262	94	0	0	0	0	0	0	0	4	1754
9-10	1262	235	90	30	0	0	1	0	2	1	0	1	1622
10-11	1246	111	30	1	0	0	0	1	0	1	0	5	1395
11-12	1271	34	3	0	0	0	0	2	0	1	0	5	1316
12-13	922	18	2	0	0	0	0	1	0	0	1	5	949
13-14	549	7	0	0	0	0	1	1	2	1	2	5	568
14-15	400	12	0	0	0	0	0	0	0	0	0	0	412
15-16	234	5	0	0	0	0	0	0	0	0	0	2	241
16-17	120	4	0	0	0	0	0	0	0	0	0	0	124
17-18	75	4	0	0	0	0	0	0	0	0	0	0	79
18-19	72	4	0	0	0	0	0	0	0	0	0	2	78
19-20	16	0	0	0	0	0	0	0	0	0	0	0	16
20-21	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	8927	1835	1457	1995	29	0	41	62	87	124	545	794	0

Location: Whitby WaveNet Site (WHITBYWN/001)

Offshore Wave Direction Peak (x) vs Offshore Peak Wave Period Tp (y) (number of 30 minute observations)

For date range :20/10/2010 to 25/10/2011 (1 year of data)

### **Whitby – Wave Direction vs wave height scatter table**

<b>m / Dir</b>	<b>0-30</b>	<b>30-60</b>	<b>60-90</b>	<b>90-120</b>	<b>120-150</b>	<b>150-180</b>	<b>180-210</b>	<b>210-240</b>	<b>240-270</b>	<b>270-300</b>	<b>300-330</b>	<b>330-360</b>	<b>Total</b>
<b>0-0.5</b>	2587	324	260	866	16	1	50	58	48	49	172	161	4592
<b>0.5-1</b>	3506	418	415	884	15	0	3	25	59	89	341	398	6153
<b>1-1.5</b>	1729	496	277	183	1	0	0	0	2	16	92	198	2994
<b>1.5-2</b>	768	363	278	143	0	0	0	0	1	1	10	61	1625
<b>2-2.5</b>	359	140	105	42	0	0	0	0	0	0	1	14	661
<b>2.5-3</b>	359	83	39	36	0	0	0	0	0	0	0	9	526
<b>3-3.5</b>	114	23	52	6	0	0	0	0	0	0	0	1	196
<b>3.5-4</b>	51	24	37	5	0	0	0	0	0	0	0	0	117
<b>4-4.5</b>	25	14	14	0	0	0	0	0	0	0	0	0	53
<b>4.5-5</b>	2	6	7	0	0	0	0	0	0	0	0	0	15
<b>5-5.5</b>	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	9500	1891	1484	2165	32	1	53	83	110	155	616	842	0

Location: Whitby WaveNet Site (WHITBYWN/001)

Offshore Wave Direction Peak (x) vs Offshore Wave Height Hmo (y) (number of 30 minute observations)

For date range :20/10/2010 to 25/10/2011 (1 year of data)

