16 Coastal Processes

16.1 Introduction

This chapter assesses the potential impact of the proposed project on coastal processes and has been prepared by ESBI in conjunction with the Hydraulic Maritime Research Centre (HMRC) based in Cork.

HMRC has carried out an analysis of the baseline conditions at Belmullet with the view of assessing the potential coastal impacts of limited Wave Energy Converter (WEC) deployments in the AMETS Test Areas A and B – see **Appendix 12:** AMETS Coastal Process Report (HMRC 2011).

Coastal processes include the wave resource and its effects on sediment transport and coastal landform. Wave action is responsible for coastal land formation, including beaches. A change in wave action, resulting from the effects of wave energy converters, taking energy from the resource, could result in changes to landform and sediment movements in the marine environment .

An assessment of the impact on the wave resource, (wave height, period and direction) was also carried out.

16.2 Approach and methodology

An analysis of all available existing and newly collected data was made to provide (where relevant) both a quantitative and qualitative assessment of the coastal processes in the test areas. The proposed works to be carried out at the test areas have been outlined in Chapter 4 and the assessment is based on a consideration of the possible impacts that these may have.

Wave modelling has been undertaken but scoping indicated that quantitative modelling of sediment transport was not required. However, a qualitative assessment of sediment transport has been made based on the environmental forcings and the sediment characteristics with the aid of numerical calculation. It was concluded that baseline conditions at the site are so extreme that the seabed is naturally mobile.

Both long-term and short-term records were reviewed to provide an understanding of the wave conditions at the site. Data provided by the Marine Institute with respect to wave and current monitoring were input into the numerical wave model. The study specifically considered the conditions in Annagh Bay with particular emphasis on beaches in the area and particularly that at Belderra Strand, the location of the proposed landfall for the cables.

The following analyses were carried out as part of the coastal process assessment:

- Wave climate analysis: analysis of a relevant long-term wave record in order to determine the offshore wave conditions
- Analysis of collected wave data for the AMETS test areas and its use in the calibration of the numerical models
- Numerical modelling: refined modelling using MIKE21 software to determine nearshore wave conditions at the site – this was used to determine the nature of sediment transport at the site
- Review and assessment of available current data: the nature of tidal currents in the coastal area were examined using field and numerical model data – the significance of these is discussed.

- Review and assessment of historical coastal position: various Ordnance Survey maps and aerial photographs have been used to show how the beach has changed historically
- Assessment of beach profile data: based on the available profile data, the type of beach system is defined and its typical behaviour patterns explained
- Sediment transport analysis: examination of existing sediment transport regime and potential changes that are likely to occur as a consequence of the various works

The wave climate in Annagh Bay was established using long-term data on the nature of the offshore wave climate which was then transformed using numerical models to the nearshore area.

Fifteen years of offshore data was obtained from the Numerics Warehouse (available on request on www.seai.ie/oceanenergy) as was output from a wave climate analysis of the test sites.

Numerical modelling of the wave conditions in the Belmullet area was undertaken using MIKE21 software as developed by the Danish Hydraulic Institute (DHI). This software is one of the world's leading commercial software packages used for wave data analysis and has a good reputation in terms of flexibility, ease of use and reliability of its output. The MIKE21 software wave module was used for all modelling in this project.

Two acoustic doppler current profilers (ADCP), were deployed by SEAI to measure wave and current data for a one month period (June/July 2011). The data collected was used to determine wave propagation characteristics from offshore to nearshore and to provide calibration data for the numerical model. The ADCPs were located in the Test Area B (50m contour) area and at the 28m contour offshore of Annagh Bay (area of water bounded on the northern side by Annagh Peninsula and on the southern side by Inishglora Island) see Figure 16-12 .

The calibrated wave model was used to run simulations to determine the coincident wave climate at a nearshore point. This analysis is important for determining the nature of the waves approaching the shoreline both in terms of heights and incident direction. For instance; oblique waves on the shoreline would induce a longshore sediment drift while a direct wave approach typically leads to cross-shore sediment transport.

Current data (measured by the ADCPs) was used to derive tidal constituents at each of the ADCP locations and a prediction of the flow velocities was carried out to provide input to the calculation of the thresholds for sediment movement along the cable route.

16.3 Receiving environment

16.3.1 Wave data

The wave data was characterised by generating a wave rose plot and scatter diagrams relating significant wave height (the mean of the highest one third waves, Hs) to peak wave periods and peak wave directions respectively. It is this discretisation of the wave conditions that was used as input to a numerical model required for the transformation/propagation of the offshore wave conditions to locations closer to the area of interest in Annagh Bay. The general offshore wave rose and scatter plots are shown in Figure 16-2, 16-3 and 16-4. From these plots the following general features on the wave conditions can be observed:

- The predominant wave directions range from WNW to WS

- The significant wave height value (Hs) is generally less than 5m but extreme values up to 15m have been modelled
- Peak wave periods in excess of 20s can occur but the most commonly occurring values range between 8 and 12 seconds. It is interesting that a few wave periods do not feature but this is likely to be an artefact of the numerical modelling.

With the aid of the numerical model, the offshore wave conditions were propagated to the location of the test areas, with little difference between the wave heights at Test Area A and those at Test Area B. Differences in wave height begin to become obvious in the shallow water location (28m) where the second temporary ADCP was located. Larger differences in wave height between the two ADCP recorders occur when the waves propagate from an oblique direction to Annagh Bay. Analysis of wave periods indicates similar trends. There is also less directionality in the waves as they come closer to shore and this is important to the understanding of the behaviour of the beach system. The sediment transport process exists in a state of quasi-equilibrium, which indicates that while the sediment may move it is not transported out of the coastal system.

Extreme wave analysis

The input data for the extreme wave analysis consisted of the 16 years of simulated output from the model that was run for the Numerics Warehouse study of the Belmullet area.

Both the offshore and the resultant nearshore extreme wave conditions are shown in Table 16-1. Figures 16-5 to 16-9 show how waves approach Annagh Bay from various offshore directions of approach.

Table 16-1: Extreme offshore and inshore (Belderra Strand) wave conditions

Return Period (yrs)	Offshore			Belderra Strand		
	Hs (m)	Tp (sec)	Dir (deg.)	Hs (m)	Tp (sec)	Dir (deg.)
1 in 1	6.0	12.4	180.0	0.7	10.8	281.3
1 in 10	9.0	15.2	180.0	1.6	13.4	287.6
1 in 50	10.9	16.7	180.0	2.2	14.8	289.3
1 in 100	11.7	17.3	180.0	2.5	15.3	289.7
1 in 1	7.0	13.4	202.5	1.5	12.0	286.9
1 in 10	10.6	16.5	202.5	2.9	14.8	290.1
1 in 50	13.0	18.2	202.5	3.7	16.2	290.7
1 in 100	14.0	18.9	202.5	3.9	16.7	290.8
1 in 1	8.4	14.7	225.0	2.9	13.4	290.0
1 in 10	13.1	18.3	225.0	4.3	16.3	290.8
1 in 50	15.7	20.1	225.0	4.7	17.6	290.5
1 in 100	16.8	20.8	225.0	4.8	18.1	290.4
1 in 1	11.6	17.2	247.5	4.5	15.5	290.8
1 in 10	14.9	19.6	247.5	4.8	17.3	290.8
1 in 50	16.6	20.6	247.5	4.9	18.0	290.8
1 in 100	17.2	21.0	247.5	5.0	18.3	290.8

1 in 1	12.1	17.6	270.0	4.7	15.8	291.3
1 in 10	16.1	20.3	270.0	5.0	17.9	291.0
1 in 50	18.7	21.9	270.0	5.1	19.0	291.1
1 in 100	19.9	22.6	270.0	5.1	19.5	291.1
1 in 1	11.2	16.9	292.5	4.7	15.3	292.0
1 in 10	14.5	19.3	292.5	4.9	17.1	291.7
1 in 50	16.6	20.6	292.5	5.0	18.1	291.7
1 in 100	17.5	21.2	292.5	5.1	18.5	291.7
1 in 1	9.7	15.8	315.0	4.4	14.4	292.9
1 in 10	12.9	18.2	315.0	4.8	16.3	292.5
1 in 50	15.0	19.6	315.0	4.9	17.4	292.4
1 in 100	15.9	20.2	315.0	5.0	17.8	292.3
1 in 1	7.6	13.9	337.5	3.4	12.9	294.5
1 in 10	9.7	15.7	337.5	4.1	14.4	294.0
1 in 50	11.0	16.8	337.5	4.4	15.3	293.8
1 in 100	11.6	17.2	337.5	4.5	15.6	293.7
1 in 1	4.8	11.1	360.0	1.4	10.5	297.8
1 in 10	6.3	12.7	360.0	2.0	11.9	296.9
1 in 50	7.2	13.6	360.0	2.4	12.7	296.5
1 in 100	7.6	14.0	360.0	2.5	13.0	296.3

Modelling of extreme wave conditions indicated that:

- There is a lot of dissipation of the incident wave energy as it approaches the beach area with offshore heights of up to 20m being reduced to about 5m. Five metres is the maximum significant wave height that can be achieved at shallow water depths. The water depth places a limit on wave size.
- The inshore area is most significantly affected by waves approaching from directions ranging from southwest (SW) to northnorthwest (NNW)
- Waves approaching the beach are essentially uniform in direction, West northwest (WNW), regardless of the offshore incident direction. Given the orientation of Beldarra beach this means that waves have little to no obliqueness, which indicates that the beach is swash aligned (cross-shore transport) rather than drift aligned (longshore transport)
- The peak wave periods are generally reduced from their offshore equivalents and this can be attributed to the change in the energy profile of the waves as shallow water wave processes such as breaking, refraction, wave-to-wave interactions occur

Current data

The current speed and direction data as collected by the ADCPs is shown in Figures 16-10 and 16-11. Figure 16-10 shows that the offshore currents are faster than those closer to shore. This is because the strong tidal streams off the Belmullet coastline reduce in speed as they enter the indented coastline past Annagh Head and move further from the main tidal stream. Tidal currents are not significant in the vicinity of the beaches near Annagh Head. At test Area B the currents flow in NE and SW directions. At the location of the nearshore ADCP, it is difficult to determine coherent flow directions – mainly because of low flow velocities.

16.4 Impact of the development

16.4.1 Impact of WECs on nearshore wave conditions

Wave energy converters (WECs) normally operate for a range of wave heights and periods, ideally centred around the mean wave conditions at the site and they do not normally operate when waves are significantly higher or lower than the mean. They are also less efficient at frequencies outside the range of their own natural resonant frequencies. So, because the WECs proposed for the Belmullet sites will not be extracting energy for a portion of the time (when wave heights are significantly outside the mean range), they will have a negligible impact on nearshore wave conditions and coastal processes at such times. As the operational characteristics are different for each device, no precise figures can be given on the range of conditions for which they will be operational.

As the MIKE21 software model (and software in general) has not been designed to represent how WECs extract energy, an alternative approach was adopted to examine their effects on wave propagation. This involved modelling each WEC as 25% larger than its actual size, and assuming that they could potentially extract 100% of the wave-incident energy. As WECs normally extract significantly less than 50% of the wave-incident energy it can be seen that this approach represents an extreme, if not impossible, worst case scenario.

A number of scenarios of device placement were examined and these are now summarised in terms of the type and number of WECs in Test A and Test B. It should be noted that the setups represented in Table 16-3 reflect projected maximum usage of the test areas. It is not likely that these usage levels will be achieved on the site.

Table 16-3: Scenarios used for model run

Setup Number	Test A	Test B
1	Array of 5 Wavebobs	No WEC
2	Array of 5 Pelamis	No WEC
3	Array of 5 Wavebobs and 5 Pelamis	No WEC
4	No WEC	3 OE Buoys
5	No WEC	2 OE Buoys
6	No WEC	1 OE Buoys
7	Array of 5 Wavebobs and 5 Pelamis	2 OE Buoys

Model simulations were run for a range of wave heights, periods and directions, first for the baseline case with no WECs and then for each particular setup. These simulations allowed an assessment to be made of the potential impacts in each case,.

From the simulation output the change in wave height from the baseline (no WECs) condition was determined for each direction of wave approach and the results are displayed in Figures 16-13 to 16-16.

These plots show the highest percentage change in wave height for all the wave heights and periods that were simulated from each particular direction.

The following points can be made about the output

- No results are presented from the first two setup situations (Test A) as they showed no discernible change to the wave conditions at the output points. Therefore separate arrays of Wavebob and Pelamis devices at this location will not impact on inshore coastal processes.
- Small changes in incident wave heights may occur as a consequence of the deployment of other arrangements of WECs at Belmullet. These changes are not deemed significant in terms of altering the nature of the inshore wave conditions as the possible maximum order of change is only 2.7%, considerably below the 10% that would be regarded as significant
- Test area A due to its offshore location has a lesser impact and it requires a significant deployment of WECs to give a wave height change of 0.8%. The magnitude of the wave height change is dependent on wave direction with W to NW waves being most important, and southerly waves having no impact on the coastline.
- In the simulations for Test area B site, deployments of 3, 2 and 1 WECs were run, however it is not planned to have more than 2 devices in place at any one time. Modelled data output for the 28m water depth location (Figure 3.25 (b)) indicated a maximum wave height change of 1.5% occurs. This is a relatively insignificant change and is likely to reduce further as the waves propagate onwards towards the shore and continue to lose energy.
- For all simulation setups the wave periods and wave directions did not change from the baseline conditions.

So, given the conservative nature of the modelling process, it can be stated that nearshore waves will essentially be unaffected by the presence of WECs.

16.4.2 Sediment transport and coastal changes

Sediment transport

During the cable laying operations it is likely that some sediment will be mobilised so it is important to assess the nature of sediment transport along the cable route based on a knowledge of sediment gradation and environmental forcing from waves and currents. Data obtained from various core samples and from measurements of waves and currents was used to determine the thresholds of motion for the sediment at various points along the cable route to shore. Based on calculations carried out by HMRC (see **Appendix 12**) it was concluded that:

- The bed material is naturally mobile based on the forcings that result in an excedance of the threshold of motion
- Any sediment that is mobilised by the cable laying operations will quickly settle back on the seabed

In its natural state it is likely that there is a lot of movement of the sand sediment, and this will be greater during storms.

Coastal changes

An analysis of various Ordnance Survey maps and aerial photographs (see **Appendix 12**) was undertaken to provide an indication of the changes that have occurred to coastline position and provides information on the processes that are occurring. The analysis indicated very little variability in the coastline position. It indicates that this shoreline is very stable and that no significant persistent erosion is occurring. It is possible that certain storms may result in erosion but given that the beaches are swash aligned and the sediment moves in a cross-shore direction they can self-repair over time.

Changes to the beach are dictated by storm events and the overall effect of WEC deployments on beach processes will be negligible.

An analysis of topographic survey data of Belderra beach carried out in September 2009 and in August 2010 re-affirmed the conclusion that the coastline is stable. It also highlighted the natural variability of the beach levels.

The beach profile will continue to respond directly to incoming waves as it has always done. As the level of energy loss caused by the WECs will be negligible so the nearshore wave climate will remain unchanged from the baseline condition. Therefore there will continue to be periods of drawdown and regeneration of the three beach systems. What is important is that even with this variability in the profile levels, the beach is inherently stable with no loss of sediment from the active system and no erosion tendency.

It is unlikely that the cable laying operations will have any influence on the overall behaviour given that the work will be undertaken during calm conditions, and provided no sand is removed from the beach in the process.

16.5 Mitigation measures

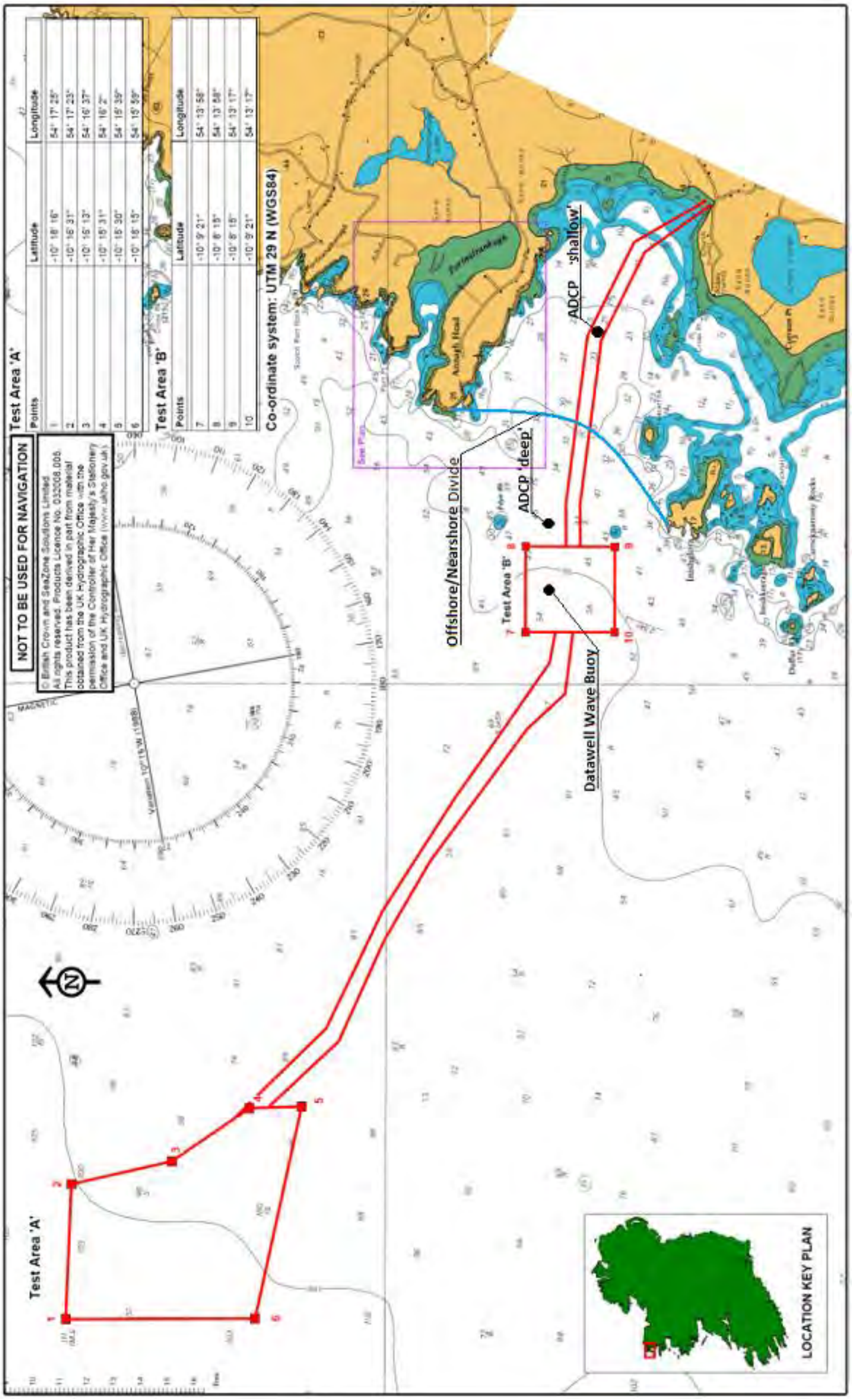
No mitigation is required with respect to wave climate as the predicted impact is very low.

During the construction phase the cable should be buried deep enough to ensure that it would not be exposed during extreme storm events.

During the operational phase surveys should be carried out to ensure that the cables do not become exposed or moorings undermined by scouring around anchor blocks.

16.6 Conclusion

This HMRC study considered wave currents and sediment transport processes in the region of the AMETS and concluded that neither the construction works nor the operation of the WECs will have any significant impact on coastal processes at the locations of interest. In addition the report recommends that the cable burial be sufficient to avoid cable exposure. It also recommends that prior to construction additional surveys of Belderra Strand be carried out to determine the optimal cable burial depth.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Test Area 'A'
Points | Latitude | Longitude
1 | -10° 18' 16" | 54° 17' 25"
2 | -10° 16' 31" | 54° 17' 23"
3 | -10° 15' 13" | 54° 16' 37"
4 | -10° 15' 31" | 54° 16' 2"
5 | -10° 15' 30" | 54° 15' 39"
6 | -10° 18' 15" | 54° 15' 59"
Test Area 'B'
Points | Latitude | Longitude
7 | -10° 9' 21" | 54° 13' 58"
8 | -10° 8' 15" | 54° 13' 58"
9 | -10° 8' 15" | 54° 13' 17"
10 | -10° 9' 21" | 54° 13' 17"
Co-ordinate system: UTM 29 N (WGS84)
Offshore/Nearshore Divide
ADCP 'deep'
ADCP 'shallow'
Test Area 'B'
Datawell Wave Buoy
Test Area 'A'
LOCATION KEY PLAN

Figure 16-1: Wave and Current Measurement locations

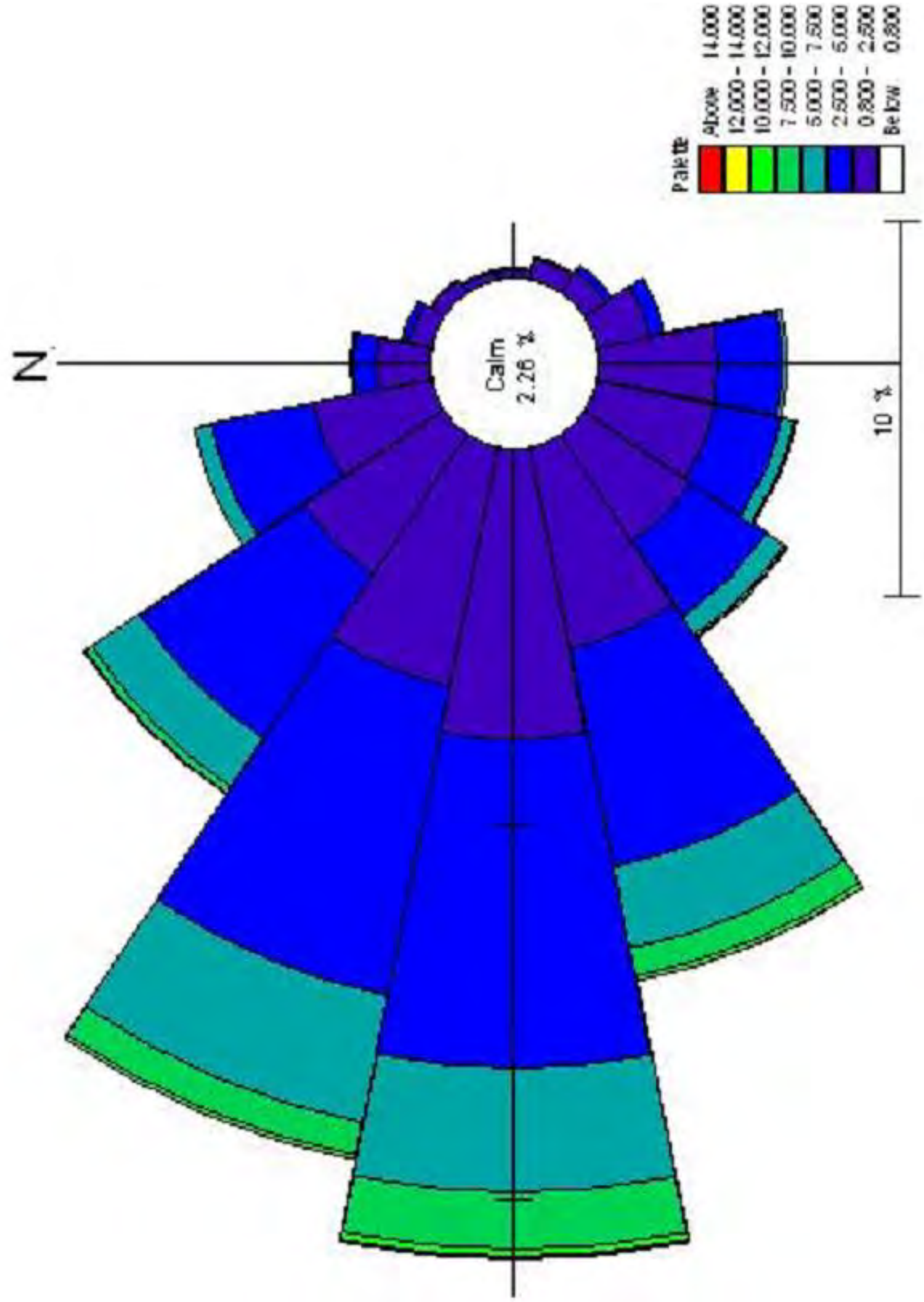

Figure 16-2: Offshore Wave Rose

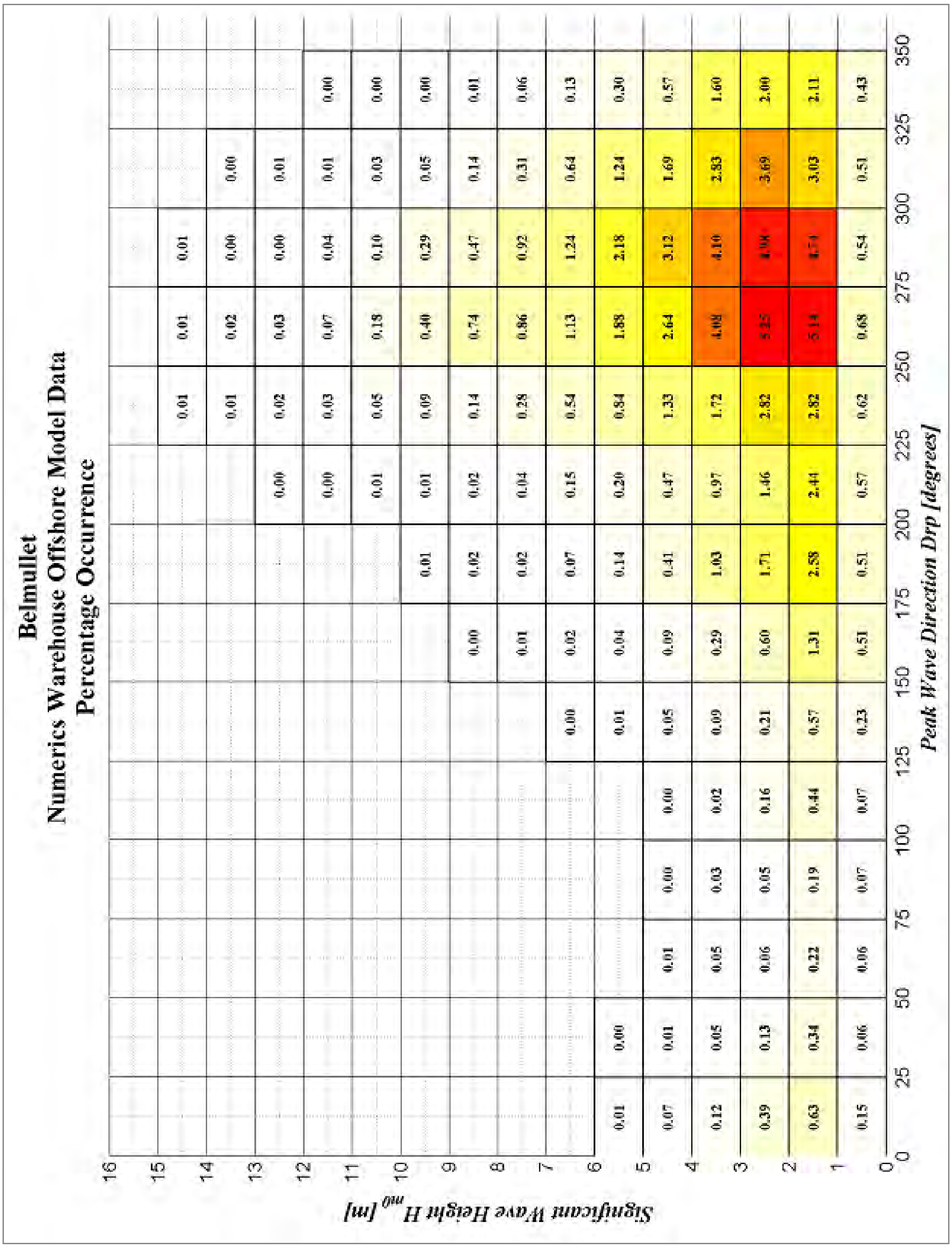

Figure 16-3: Offshore Hs/Wave Direction Scatter Diagram

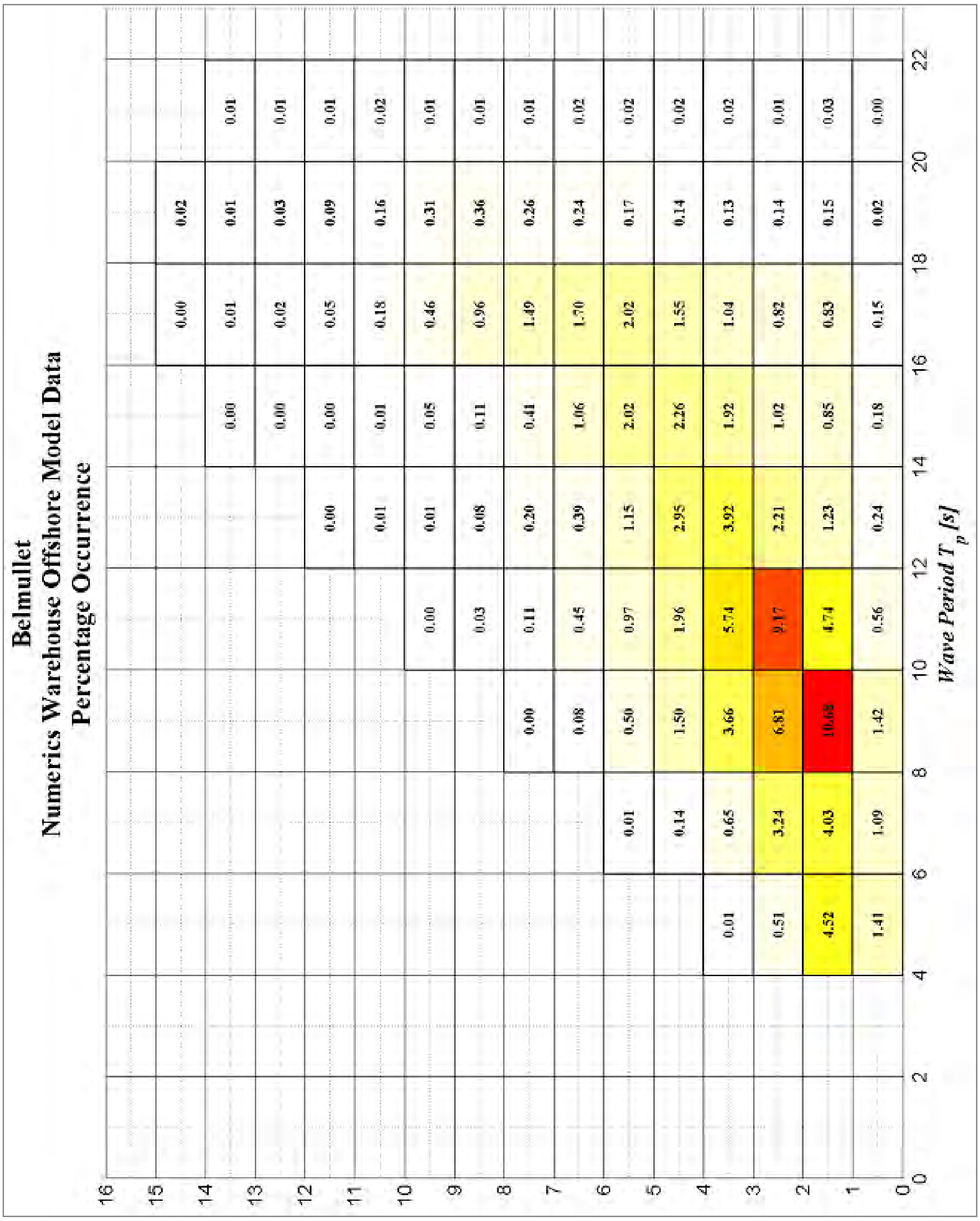

Figure 16-4: Offshore Hs/Wave period scatter diagram

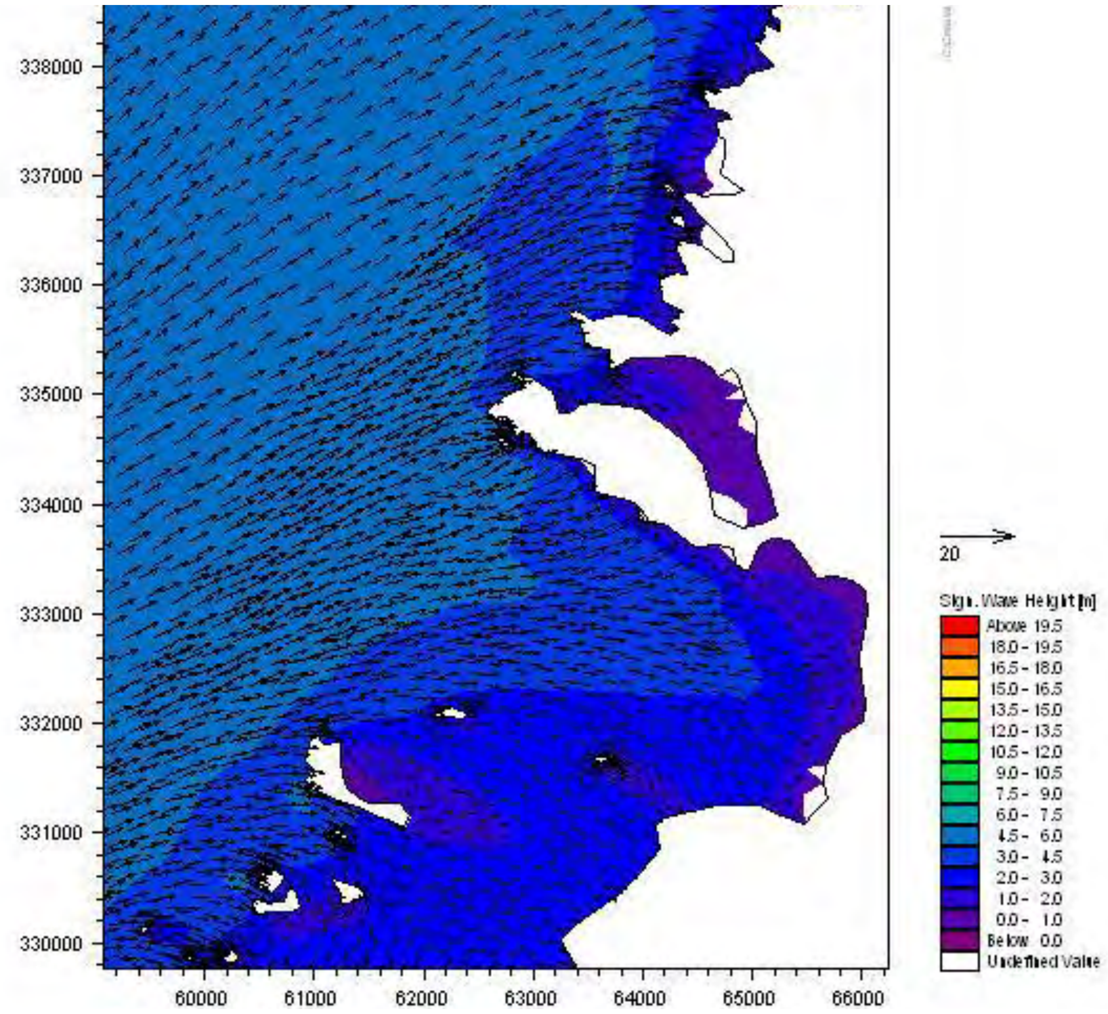

Figure 16-5: Southerly wave approach

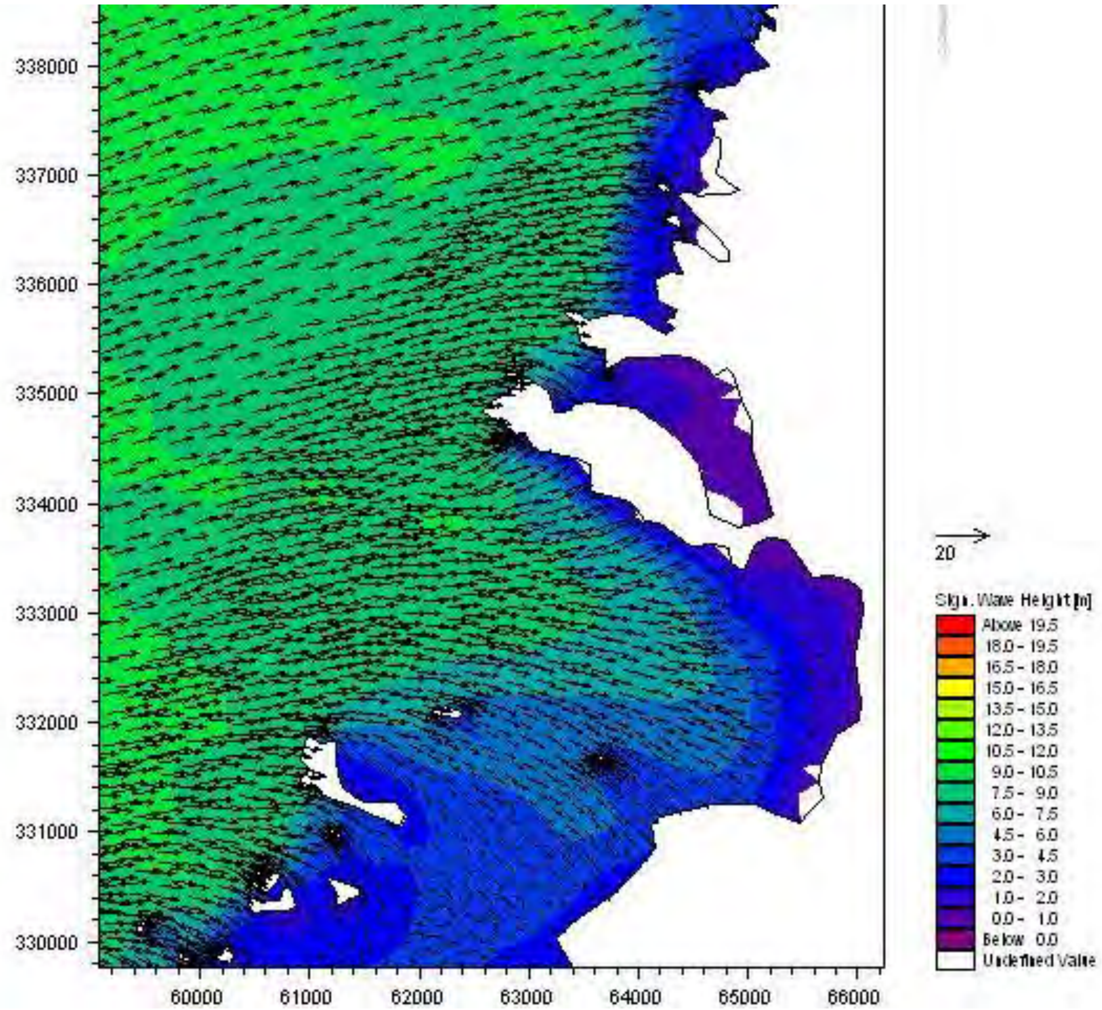

Figure 16-6: SW wave approach

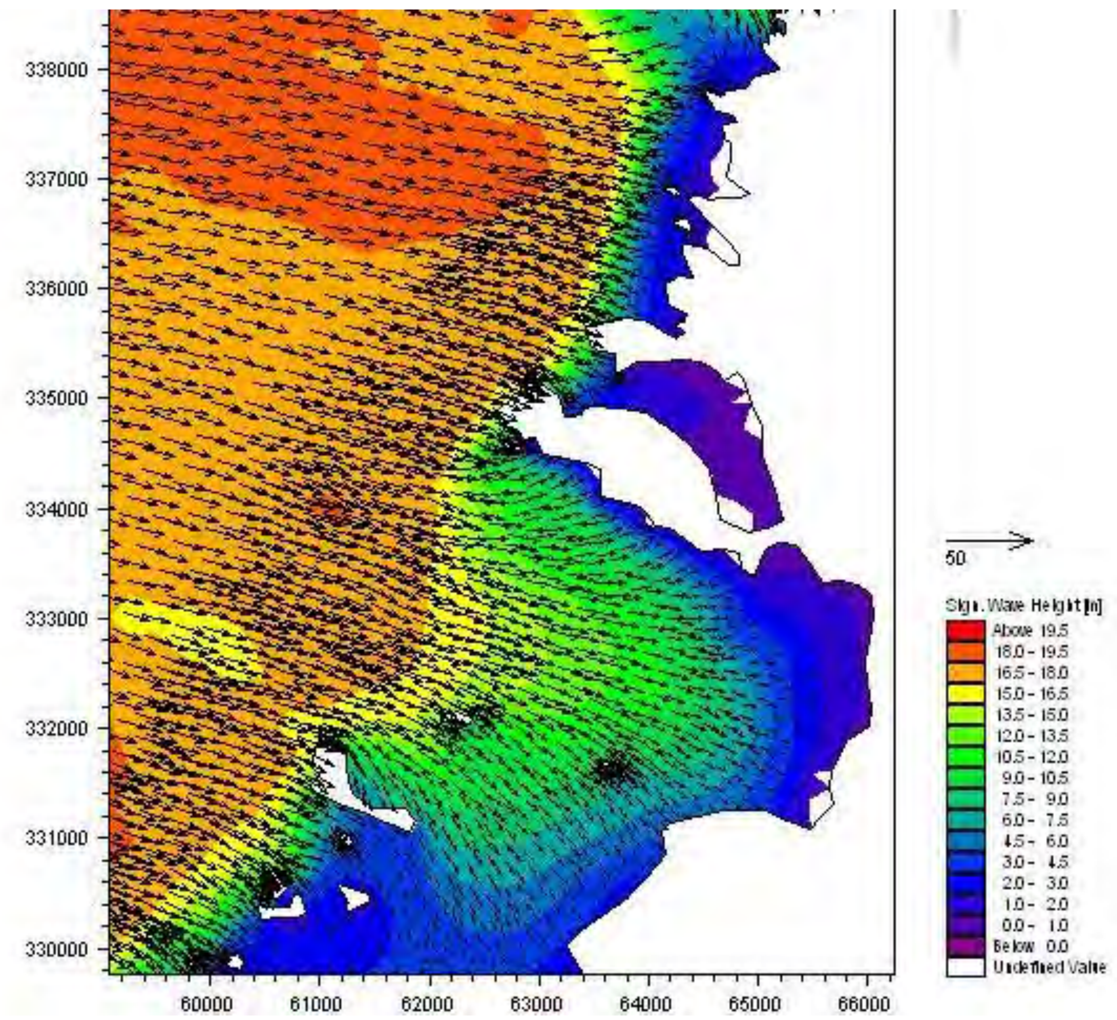

Figure 16-7: WNW Wave Approach

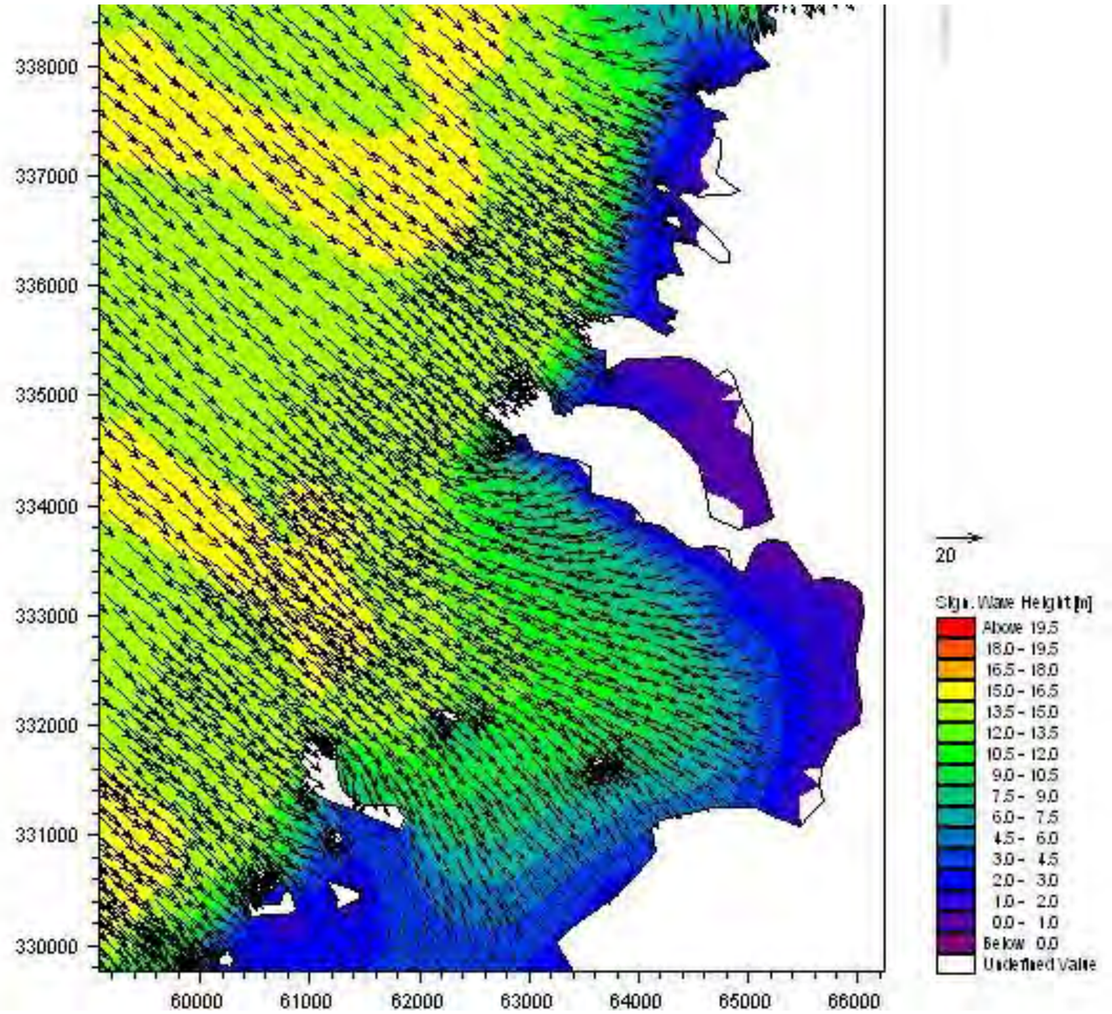

Figure 16-8: NW Wave Approach

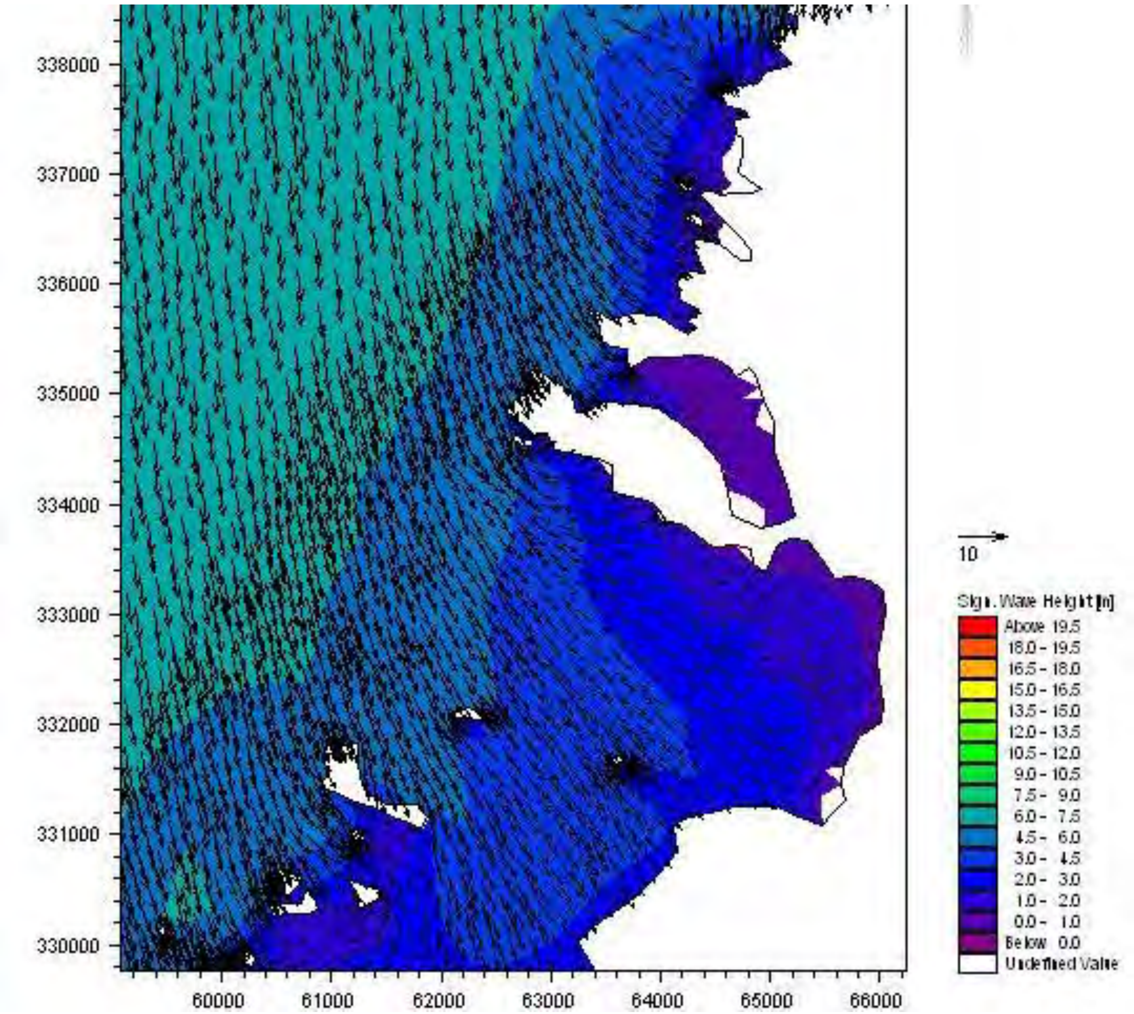

Figure 16-9: N wave approach

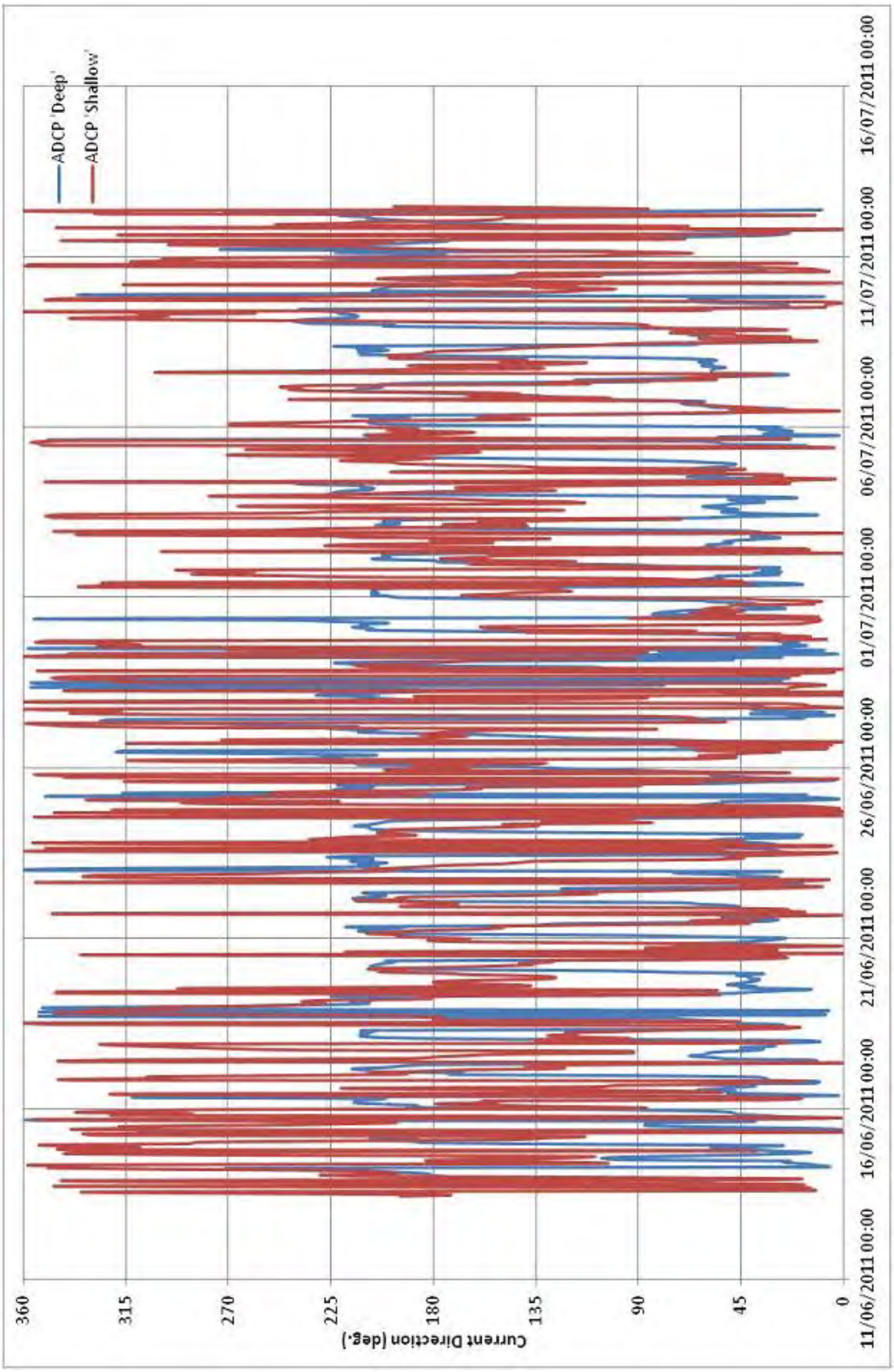

Figure 16-10: ADCP Current Speeds

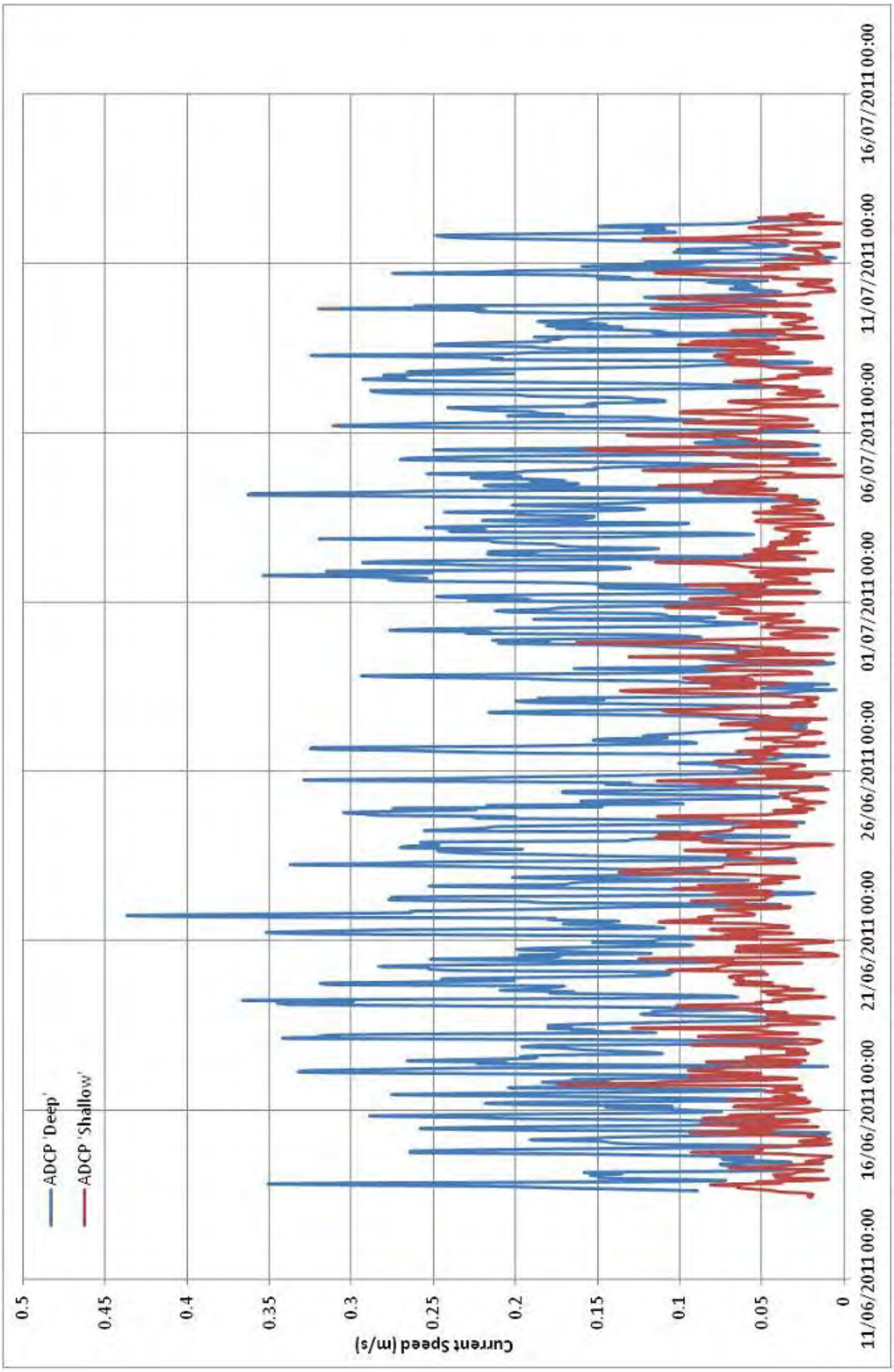

Figure 16-11: ADCP current directions

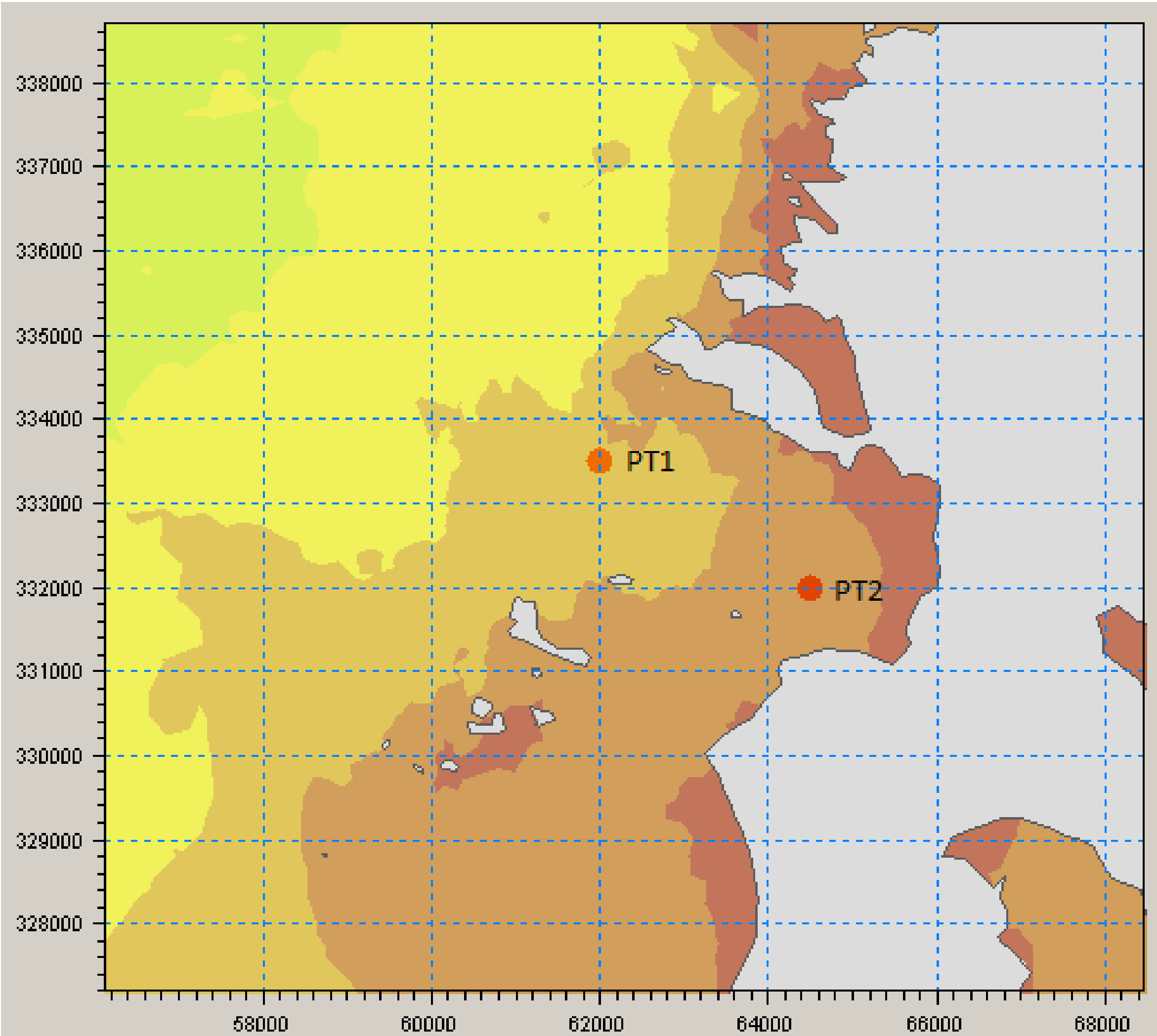

Figure 16.12 Data Extraction Points

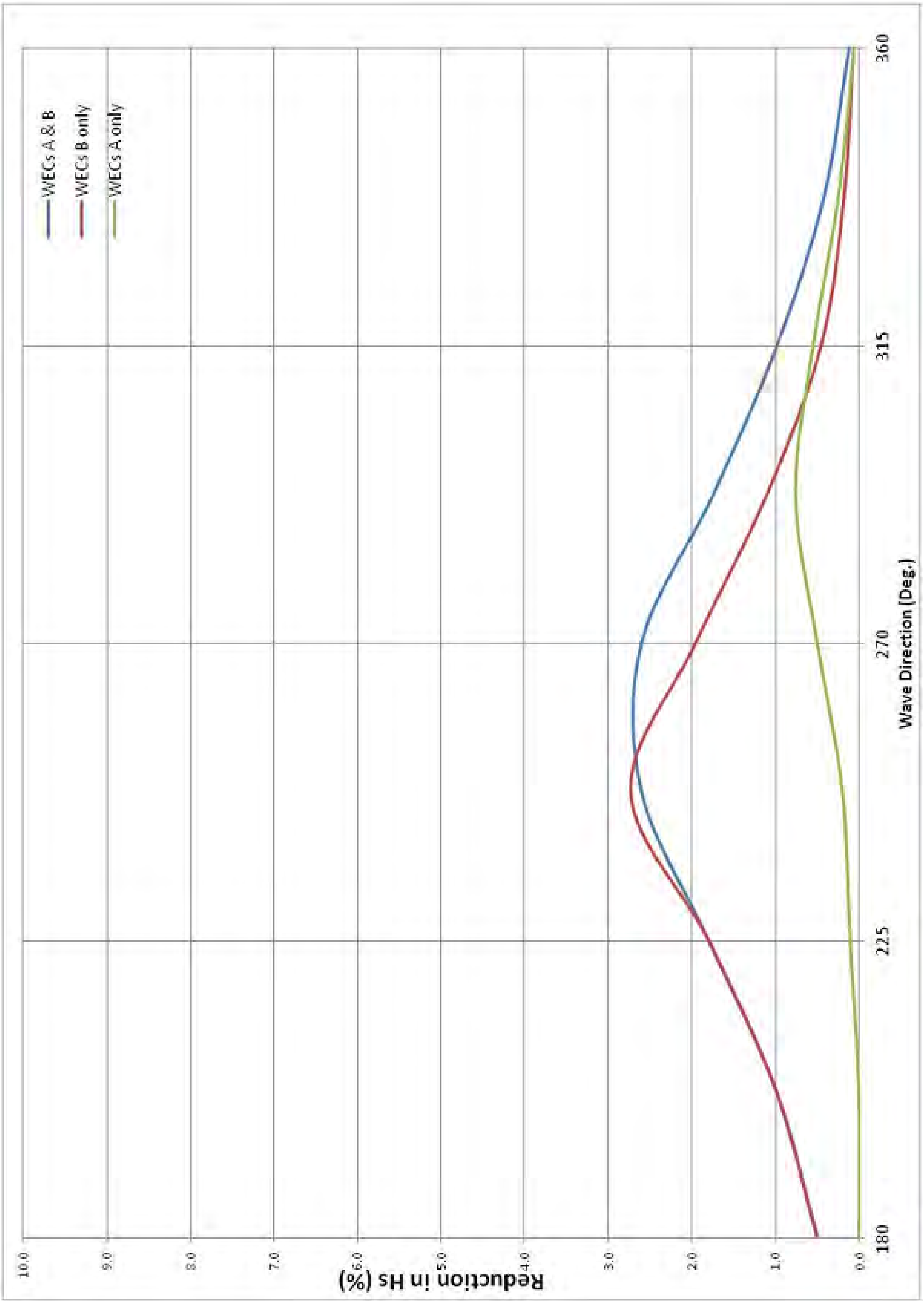

Figure 16-13: Modelled wave height change at position PT1 (Scenario Setup No 3, 4 &7)

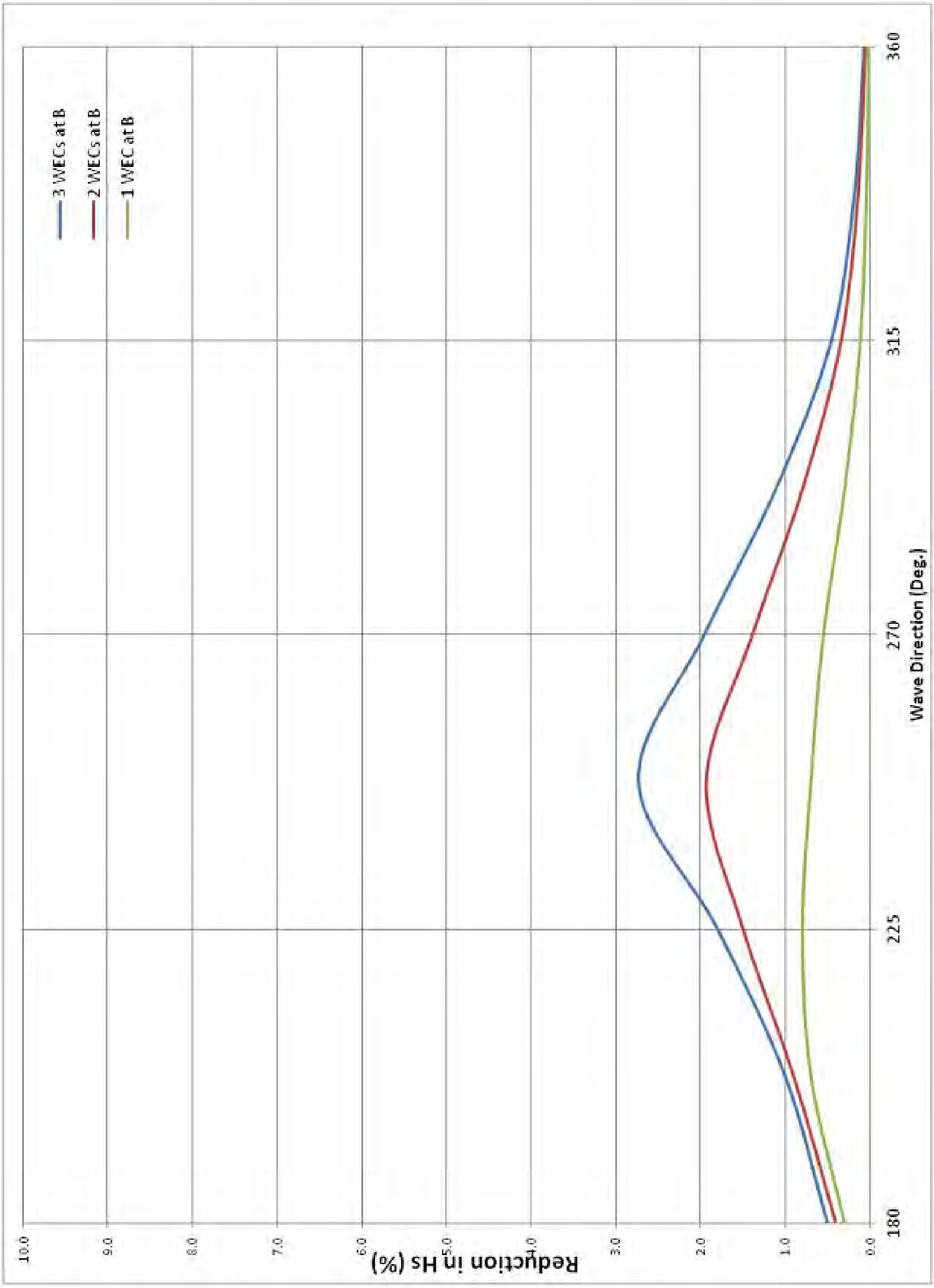

Figure 16-14: Modelled wave height change at position PT1 (Scenario Setup No 4, 5 & 6)

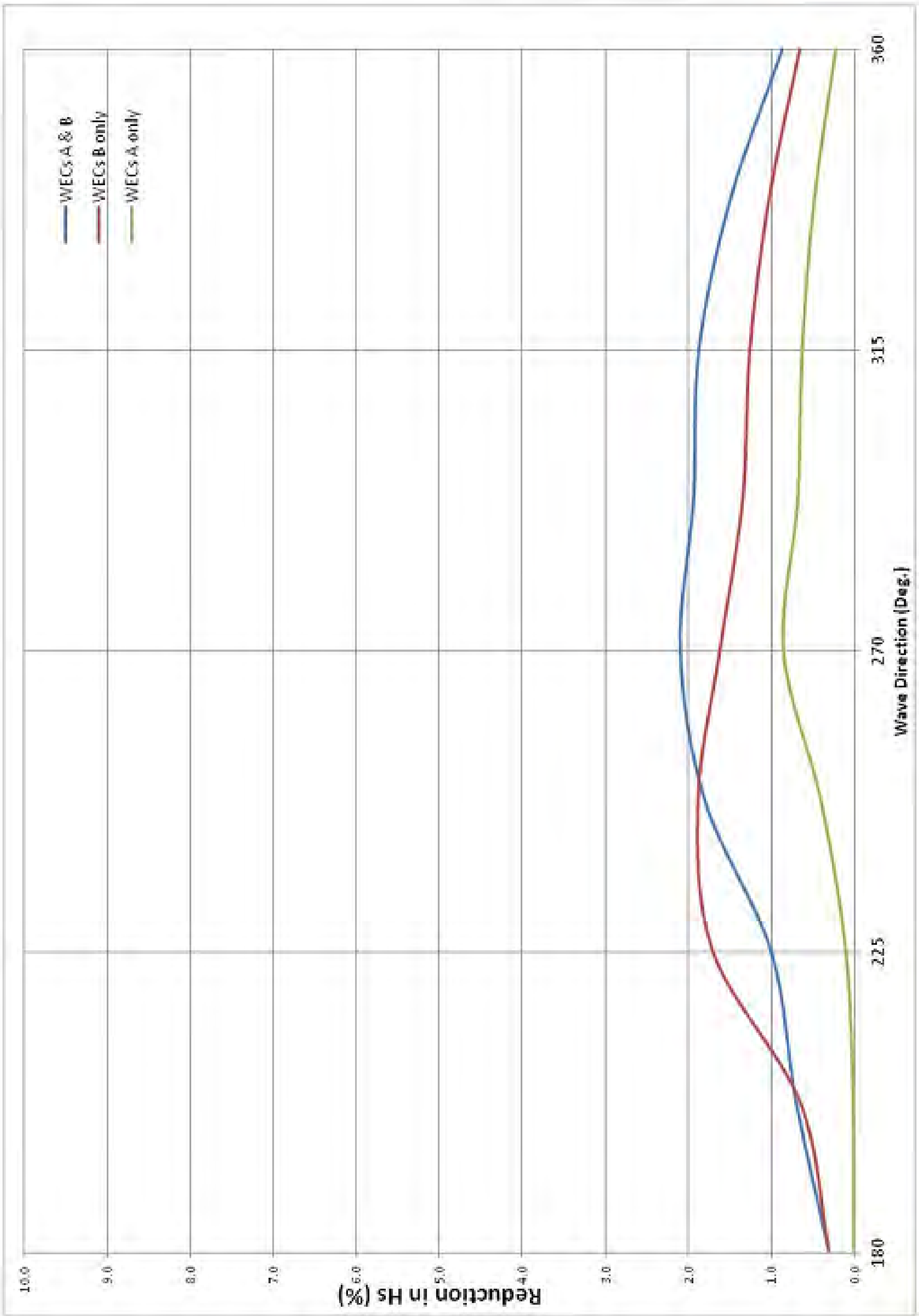

Figure 16-15: Modelled wave height change at position PT2 (Scenario Setup No 3, 4 and 7)c

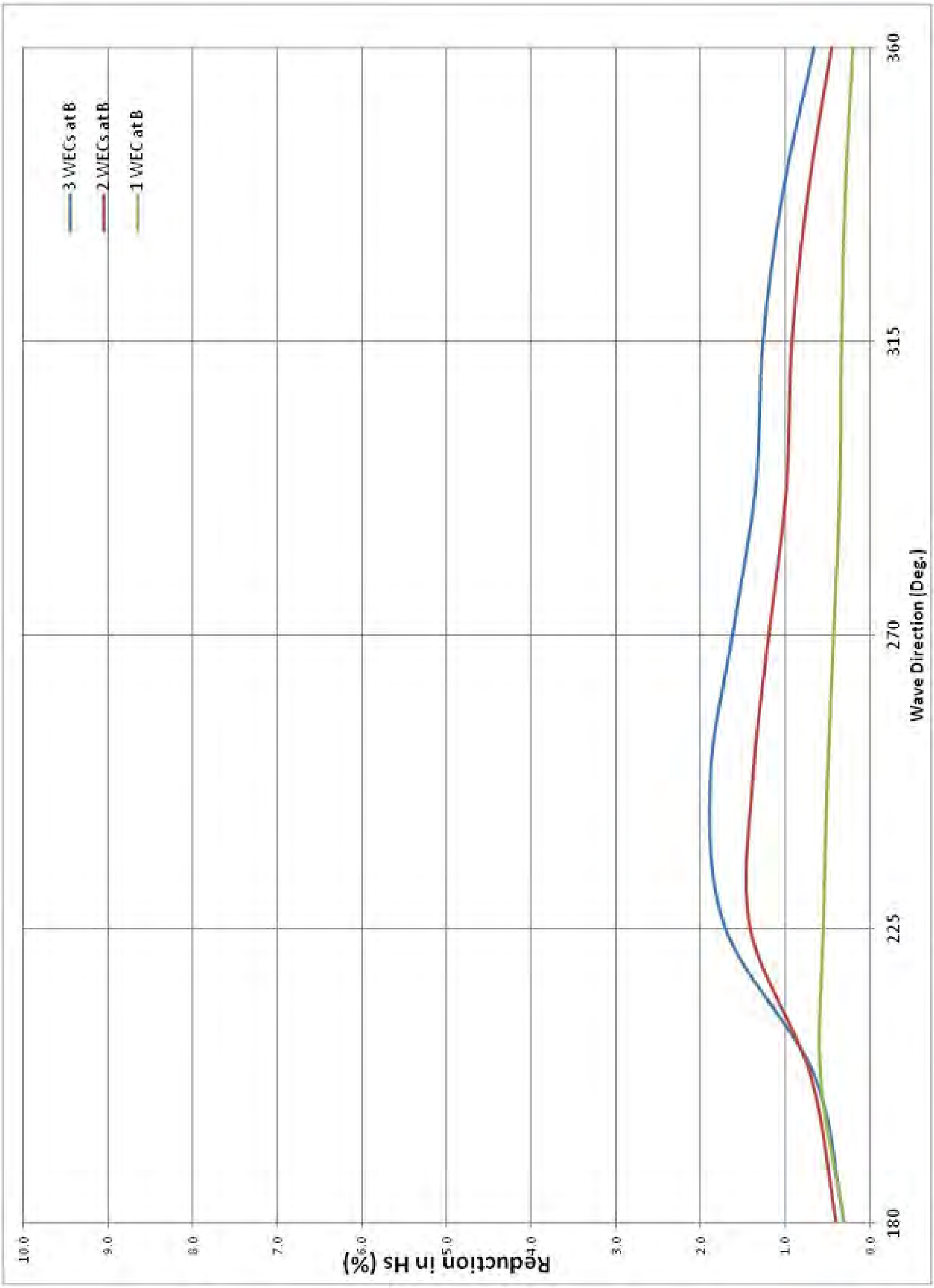

Figure 16-16: Modelled wave height change at position PT2 (Scenario Setup No 4, 5 & 6)