CENTRE FOR MARINE APPLIED RESEARCH

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WIND AND WAVE CONDITIONS – GUYSBOROUGH – REFERENCE SITE 2

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IFI – Issued for information
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Executive Summary

In support of Centre for Marine Applied Research (CMAR), the following report presents wind and wave conditions at one reference location at Dover Bay in Guysborough County, Nova Scotia, Canada.

In this report, wave and wind conditions are presented for the location:

- Guysborough - Reference Site 2: 45° 14.653'N, 61° 1.057'W.

To determine the wave field evolution closer to shore at a specific site, and to determine more accurate 10- and 50- year return period wave data, near shore wave modelling can be used. For the Guysborough Reference Site 2, STWave was used to model the wave conditions inside the area. The results showed reduced wave heights, in comparison to the hindcast source point which is located at the southeast entrance to the Dover Bay, due to depth induced energy dissipation (bottom friction, breaking). The STWave model results are determined using wind and wave boundary condition data from the MSC50 HindCast model of a nearby offshore location. The extreme wave conditions at the reference location is determined in part by propagating wave from the offshore hindcast model location into the site of interest.

Contents

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1 Introduction

1.1 Overview

For the reference location at Dover Bay in Guysborough County shown in Figure 1, wind and wave conditions have been estimated. The following presents data on the predicted 10- and 50- year wind and wave conditions at the reference location.

Figure 1 One (1) Reference Site location at Dover Bay in Guysborough county [4]

The location in Dover Bay is protected overall from offshore waves by surrounding lands to the north, but is vulnerable to waves from south and southeast which will travel directly into the area, as seen in Figure 2. These waves are expected to lose energy by travelling into shallower waters. Detailed wave modelling is required to determine the amount of energy lost and wave height reduction.

Figure 2 Dover Bay in Guysborough County, Nova Scotia, Canada

The context of this project is that extreme wind and wave conditions are needed to select engineering load cases for those wishing to install finfish or shellfish farms in the area. For example, extreme environmental conditions with minimum 10-year and 50-year return periods are required for the design of a marine fish farm site, as per guidance in the Scottish technical standard [2] and NS9415 [3]. While the location assessed as part of this modeling exercise is not an actual aquaculture site location, the data produced for this location is useful for understanding the approximate wave climate in the region and can be used to evaluate any proposals for sites in the area. Understanding the wind and wave climates at aquaculture sites is important for mitigating risks.

1.2 Objective(s)

- Determine wave/wind conditions at one reference location at Dover Bay in Guysborough County and find the conditions with 10- and 50- year return periods.

2 Abbreviations and acronyms

DSA	Dynamic Systems Analysis Ltd.
SMS	Surface-water Modeling System
CMAR	Centre for Marine Applied Research
CHS	Canadian Hydrographic Services

3 Reference documents and drawings

[1]	Report-DSA-CMAR-19EXM-Guysborough Wind and Wave Conditions RevB.0.pdf
[2]	Marine Scotland. (2015). A Technical Standard for Scottish Finfish Aquaculture. Ministerial Group for Sustainable Aquaculture's Scottish Technical Standard Steering Group
[3]	Norge, S. (2009). Norwegian Standard NS 9415. E: 2009. Marine Fish Farms—Requirements for Site Survey, Risk Analyses, Design, Dimensioning, Production, Installation and Operation. *Standard Norge, Lysaker*.
[4]	CMAR proposed sites -RevB.kmz

4 Wave conditions

4.1 Overview

SMS version 12.2.13 was used to setup the bathymetric and computational grid. This section provides a description of the grid size, mesh size and offshore environmental conditions. Site bathymetry is provided in Figure 3. Note that a CHS hydrographic chart is used to generate the bathymetric data for wave modeling.

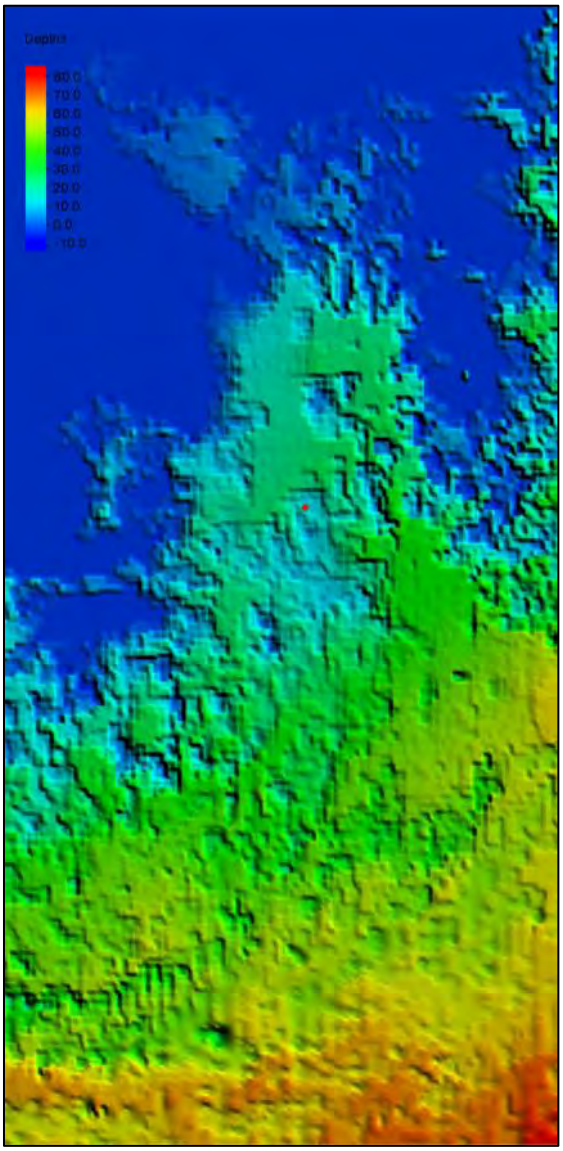


Figure 3 Bathymetry at site on hydrographic charts - Depth reported in meters

4.2 Wave Model Description

SMS, created by Aquaveo, is a modelling suite in which various water surface modelling tools, like wave and flow models, can be used. For this analysis SMS in combination with STWave is used. STWave is a nearshore spectral Hydraulics model, developed by U.S. Army Engineer Research and Development Center (ERDC) and Coastal and Hydraulics Laboratory (CHL). It is capable of modelling accurately wave transformation and propagation.

Two grids were setup, computational grid and spectral grid. The computational grid and its mesh sizes are mainly defined by the bathymetry. The bathymetry in SMS is presented in Figure 4. For this analysis the computational grid size was 24.6 km x 24.1 km. The mesh size was 15 m x 15 m, resulting in 1642 x 1610= 2,643,620 grid cells.

The spectral domain was divided into 72 directions and 50 frequencies, with a minimum frequency of 0.03 Hz and a maximum frequency of 1.01 Hz.

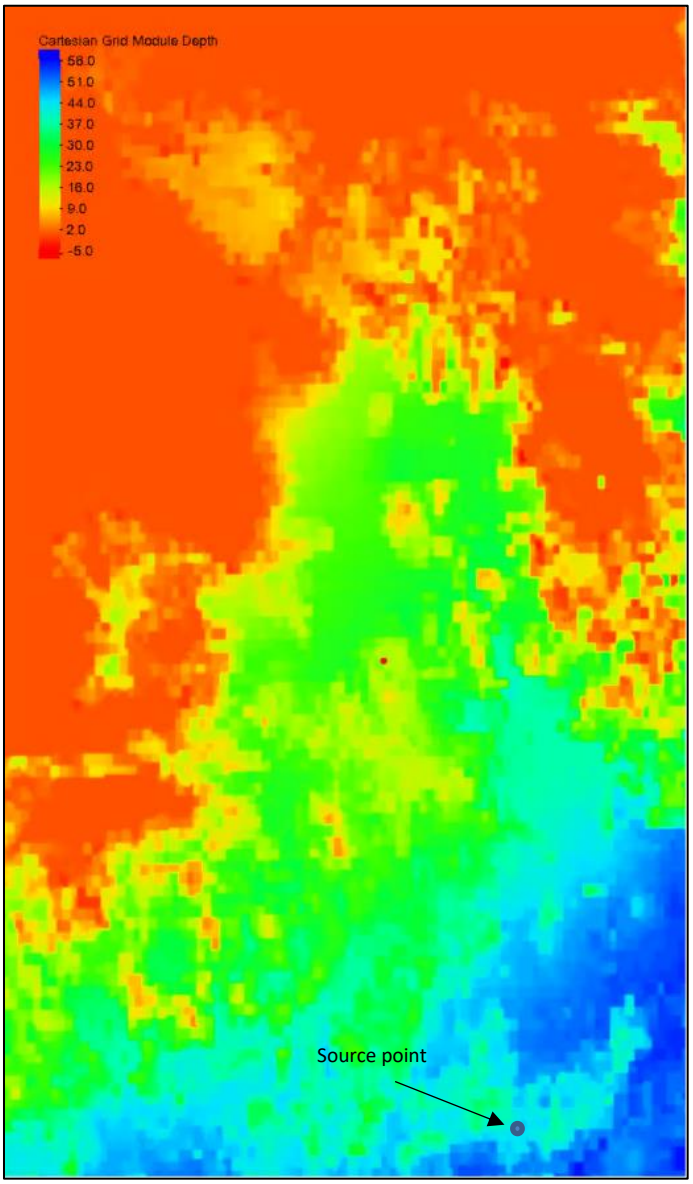


Figure 4 Bathymetry at site on STWave. Note the MSC50 HindCast model source point indicated at 45° 12.000'N, 61° 0.000'W

4.3 Boundary conditions – offshore wind and wave conditions

The MSC50 HindCast model [1] data from location 45° 12.000'N, 61° 0.000'W was used to determine the 10- and 50- year return periods for wind and wave of the Dover Bay Reference Site 2; the location is labelled as the "Source point" in Figure 4. The scatterplot of wave heights versus wave directions for the source point is shown in Figure 5. The scatter plot of wind speeds versus wind directions for the source

point is also shown in Figure 6. Extreme waves and wind at the source point appear to originate more frequently from the southeast and south.

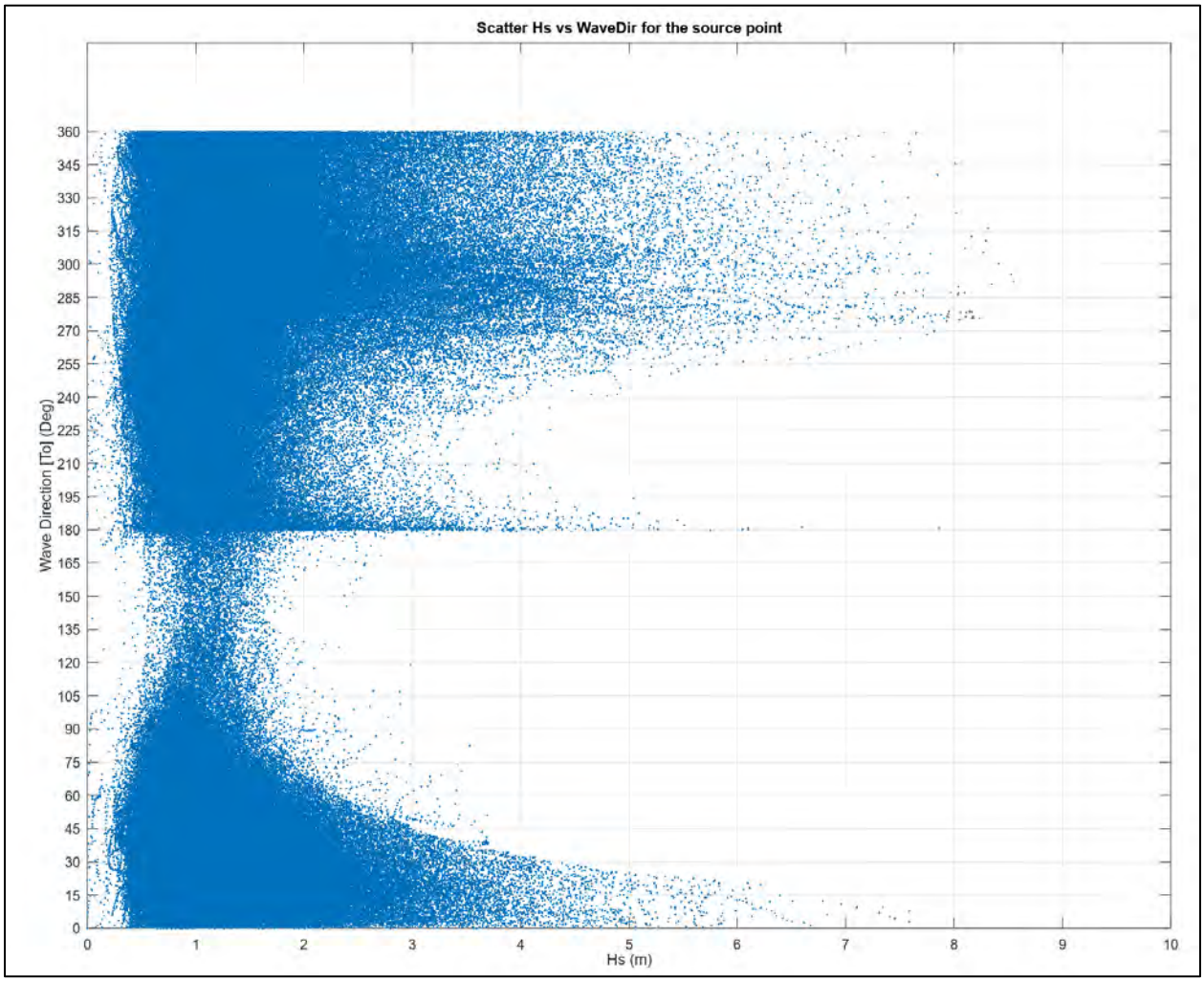


Figure 5 Wave height versus wave direction plot

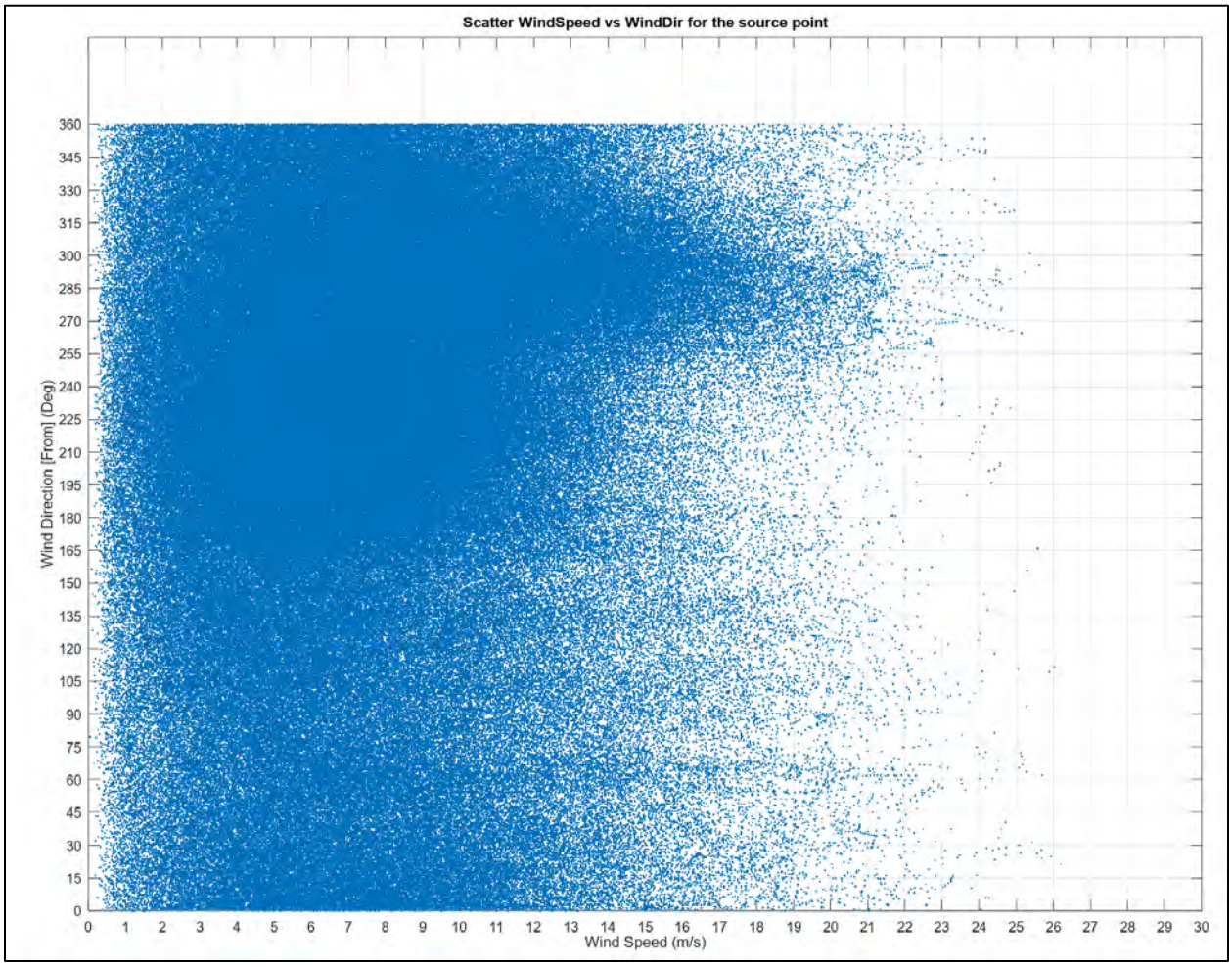
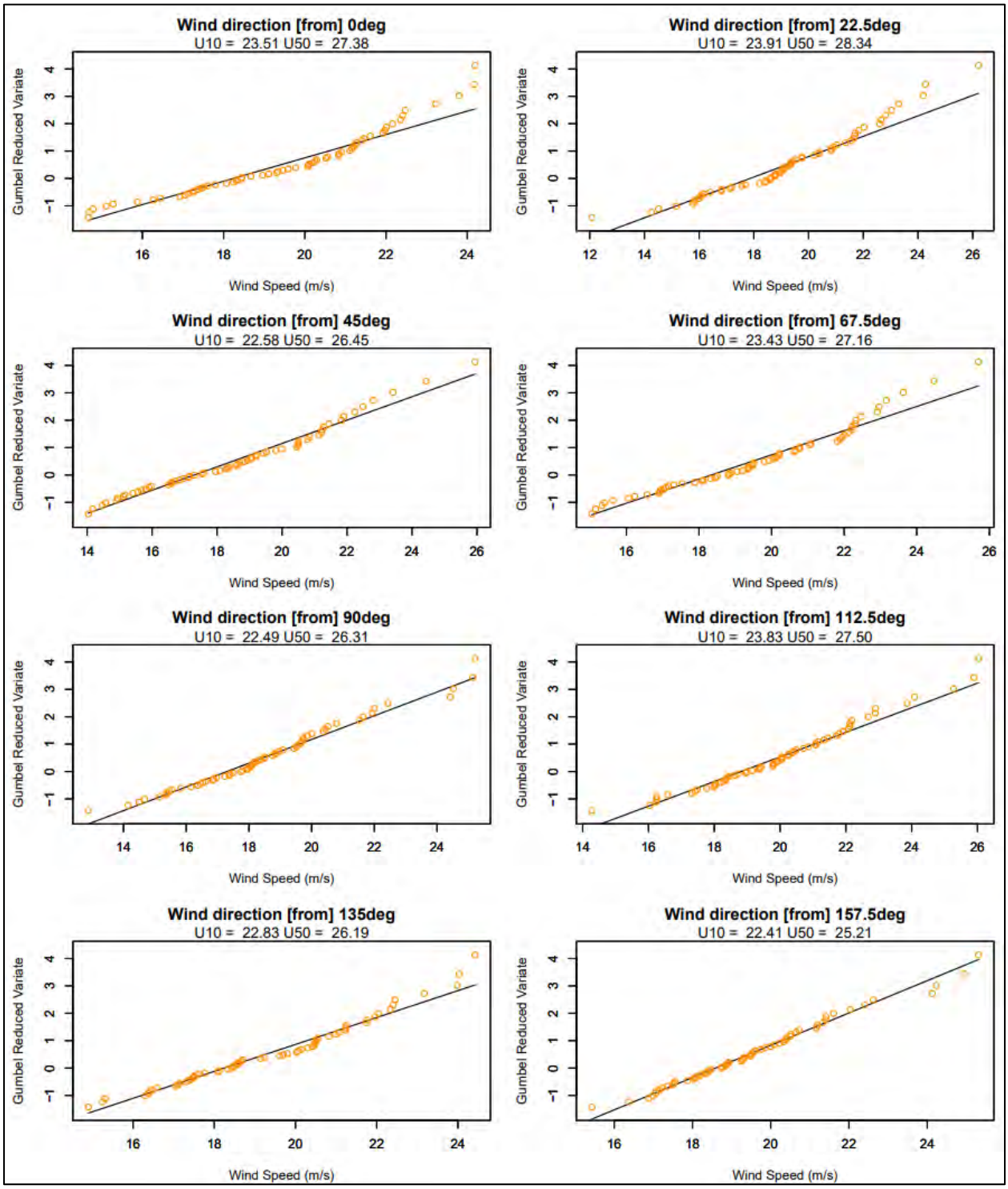


Figure 6 Wind speed versus wind direction plot for the source point

10- and 50- year return period conditions are in general achieved by:

- Obtaining measured or hindcast data for parameter in question
- For each parameter, bin data by direction
- Perform extreme value analysis.
    - Extract annual maxima
    - Fit Gumbel or Weibull distribution to this data
    - Use fitted distribution to calculate values corresponding to 10- and 50- year return period

The extreme value analysis of the wind velocities is presented in Figure 7. U10 and U50 represent the 10- and 50- year return period wind velocities, respectively.


Wind direction [from] 0deg
U10 = 23.51 U50 = 27.38
Wind direction [from] 22.5deg
U10 = 23.91 U50 = 28.34
Wind direction [from] 45deg
U10 = 22.58 U50 = 26.45
Wind direction [from] 67.5deg
U10 = 23.43 U50 = 27.16
Wind direction [from] 90deg
U10 = 22.49 U50 = 26.31
Wind direction [from] 112.5deg
U10 = 23.83 U50 = 27.50
Wind direction [from] 135deg
U10 = 22.83 U50 = 26.19
Wind direction [from] 157.5deg
U10 = 22.41 U50 = 25.21
Gumbel Reduced Variate
Wind Speed (m/s)

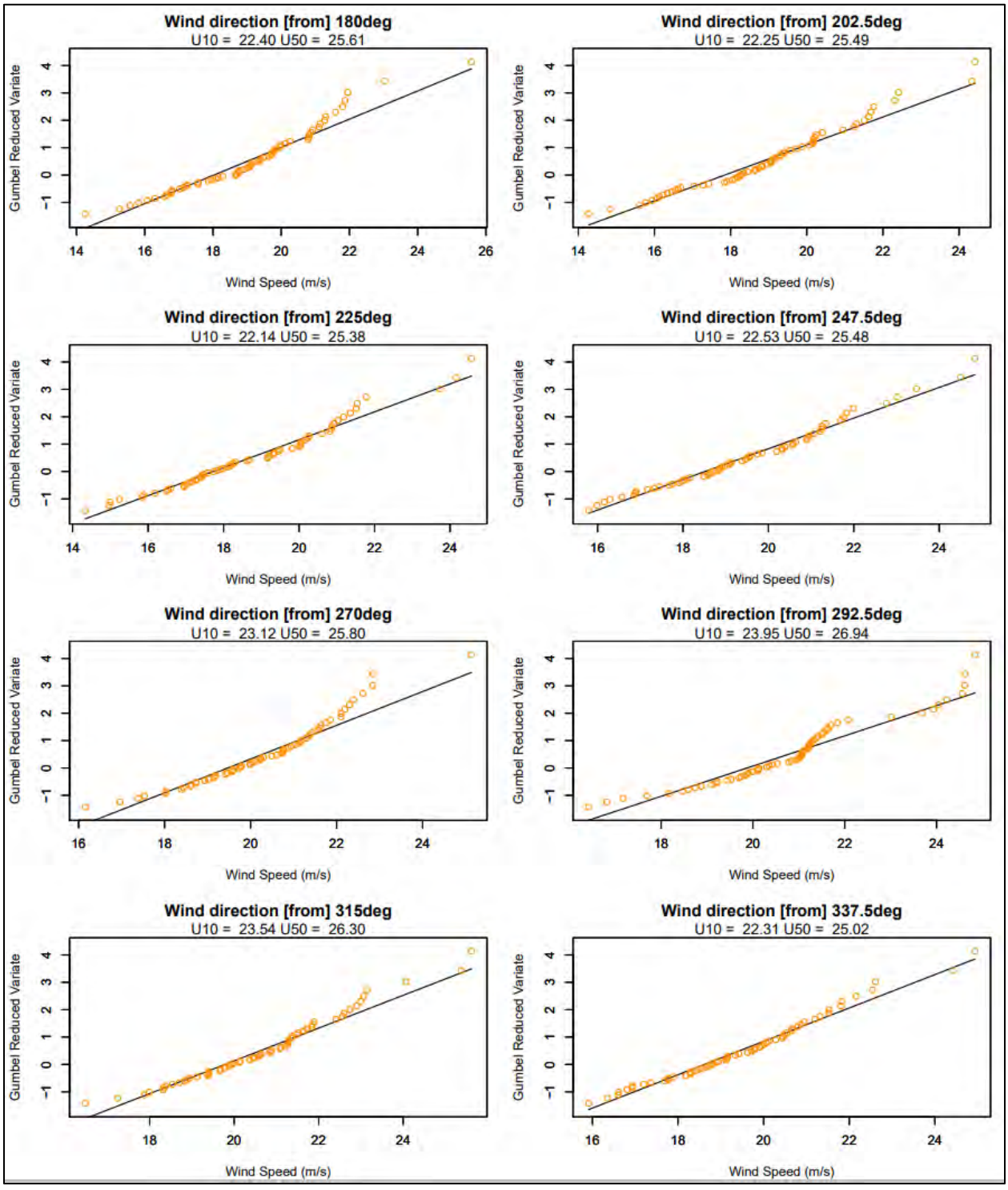
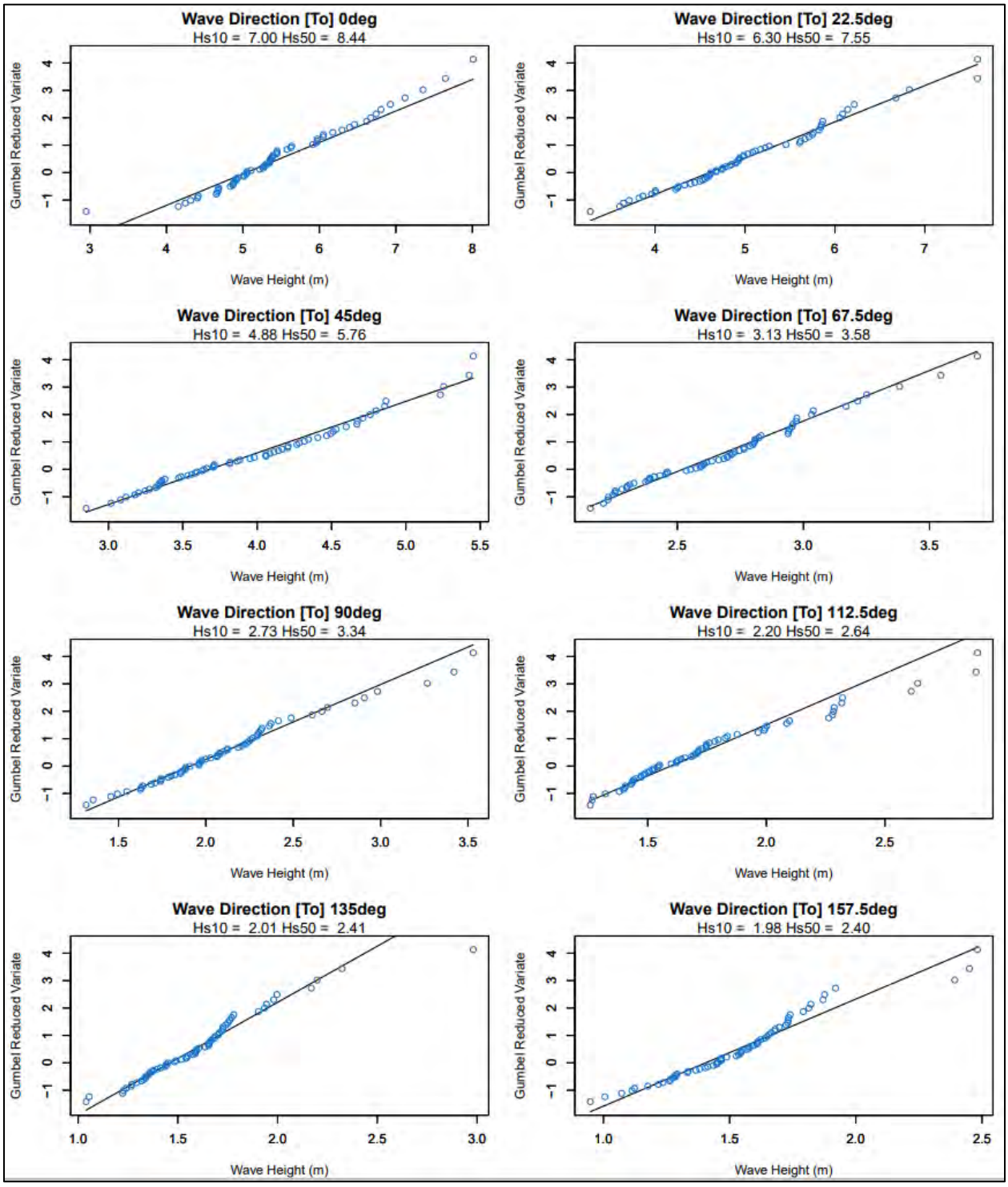


Figure 7: Extreme value analysis on wind data – for Source Point offshore location [1]

The extreme value analysis of the wave heights is presented in Figure 8. Similar to the presentation of the wind data, Hs10 and Hs50 represent the 10- and 50- year return period wave heights, respectively.


Wave Direction [To] 0deg
Hs10 = 7.00 Hs50 = 8.44
Wave Direction [To] 22.5deg
Hs10 = 6.30 Hs50 = 7.55
Wave Direction [To] 45deg
Hs10 = 4.88 Hs50 = 5.76
Wave Direction [To] 67.5deg
Hs10 = 3.13 Hs50 = 3.58
Wave Direction [To] 90deg
Hs10 = 2.73 Hs50 = 3.34
Wave Direction [To] 112.5deg
Hs10 = 2.20 Hs50 = 2.64
Wave Direction [To] 135deg
Hs10 = 2.01 Hs50 = 2.41
Wave Direction [To] 157.5deg
Hs10 = 1.98 Hs50 = 2.40
Gumbel Reduced Variate
Wave Height (m)

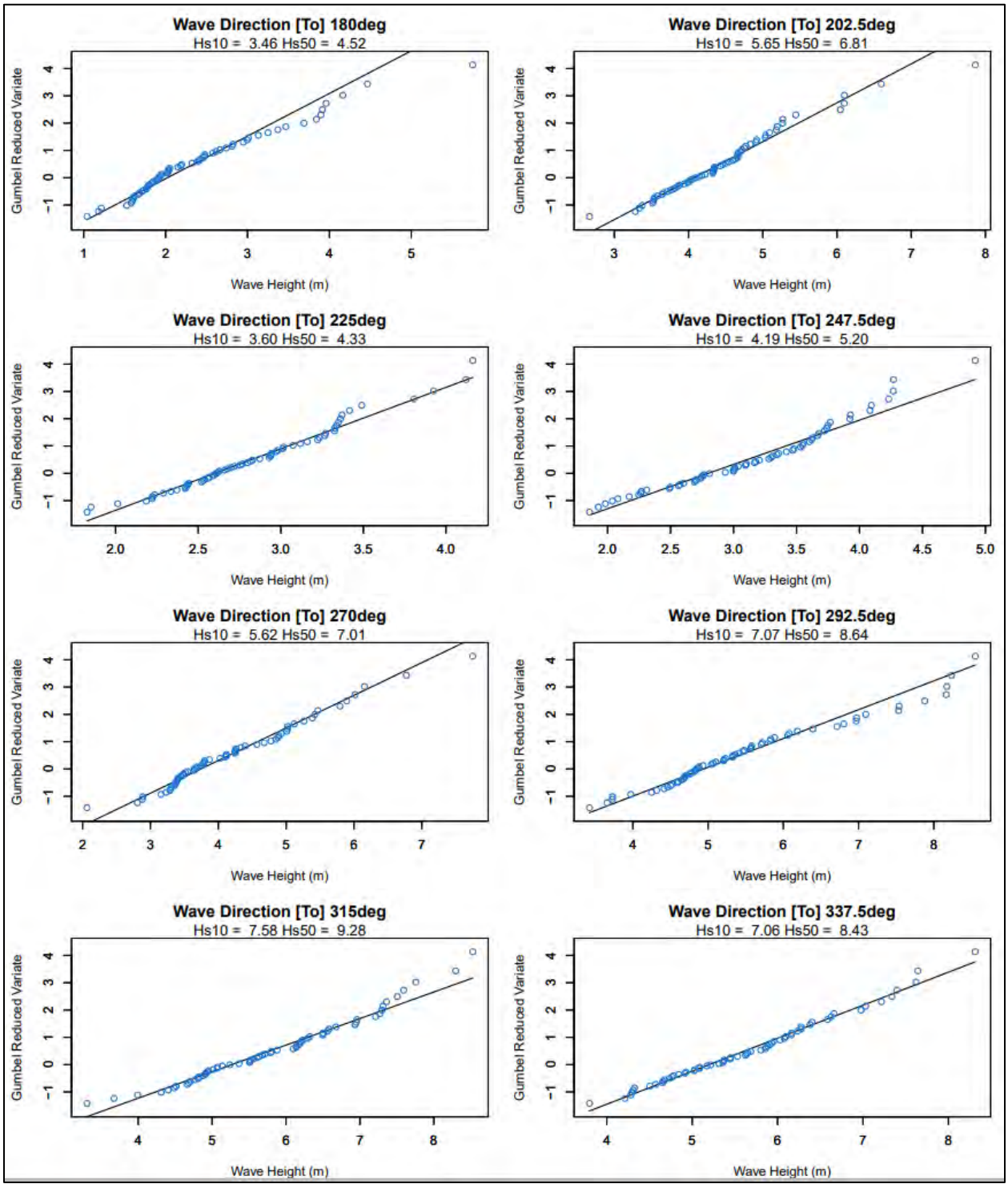


Figure 8: Extreme value analysis on wave data – for Source Point offshore location [1]

In summary, the following data was obtained from the extreme value analysis:

Table 1 Results extreme value analysis for wind and waves at the offshore source point locations in Figure 4

Direction [from] [°]		$U_{wind,10year}$ [m/s]	$U_{wind,50year}$ [m/s]	$H_{s,10year}$ [m]	$H_{s,50year}$ [m]
0	N	23.51	27.38	3.46	4.52
23	NNE	23.91	28.34	5.65	6.81
45	NE	22.58	26.45	3.6	4.33
68	ENE	23.43	27.16	4.19	5.2
90	E	22.49	26.31	5.62	7.01
113	ESE	23.83	27.5	7.07	8.64
135	SE	22.83	26.19	7.58	9.28
158	SSE	22.41	25.21	7.06	8.43
180	S	22.4	25.61	7	8.44
203	SSW	22.25	25.49	6.3	7.55
225	SW	22.14	25.38	4.88	5.76
248	WSW	22.53	25.48	3.13	3.58
270	W	23.12	25.8	2.73	3.34
293	WNW	23.95	26.94	2.2	2.64
315	NW	23.54	26.3	2.01	2.41
338	NNW	22.31	25.02	1.98	2.4

Polar plots for maximum wind speeds and wave heights at 10 year and 50 year return periods are shown in Figure 9 to Figure 12, respectively.

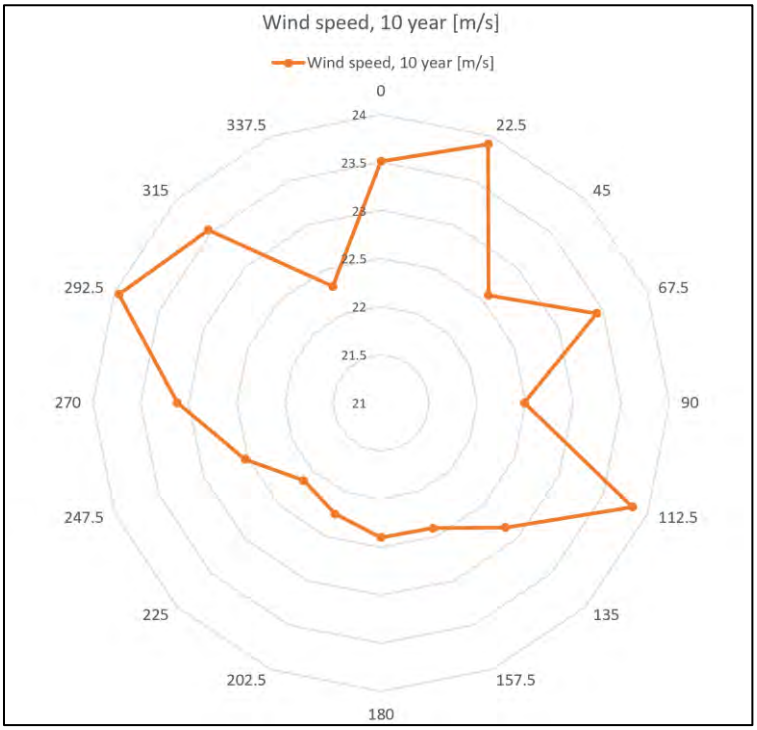


Figure 9 Maximum wind speed at 10- year return period and direction [from]- for Source Point offshore location [1]

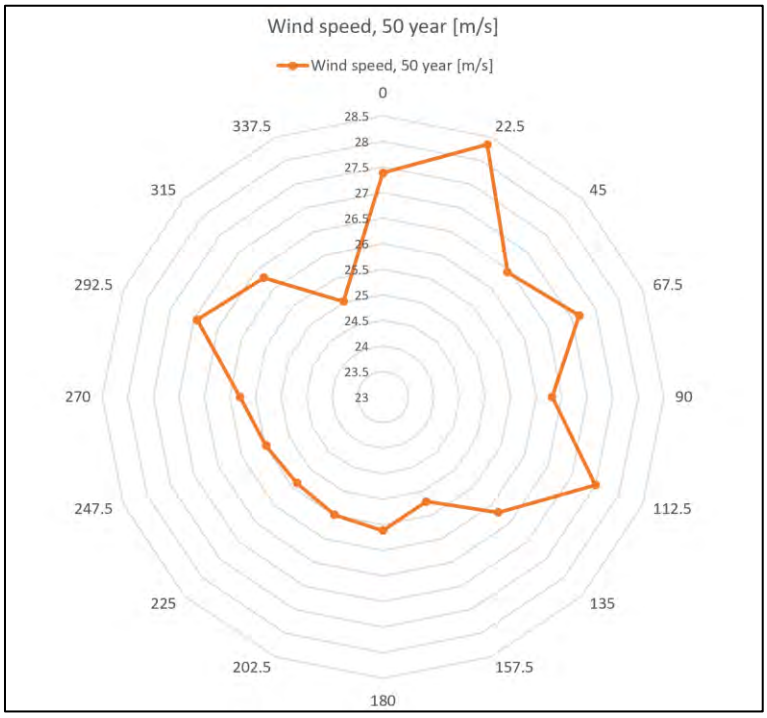


Figure 10 Maximum wind speed at 50- year return period and direction [from]- for Source Point offshore location [1]

Figure 11 Maximum wave height at 10- year return period and direction [from]- for Source Point offshore location [1]

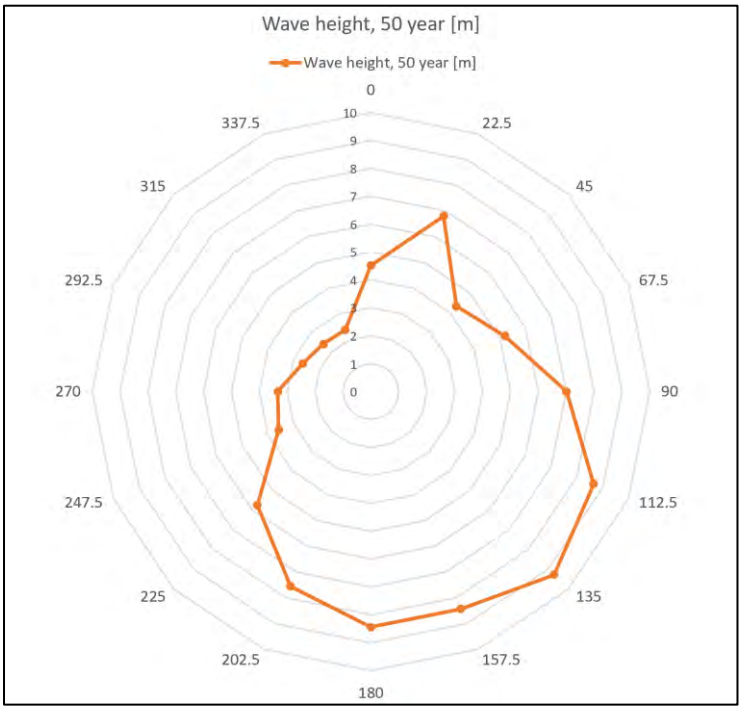


Figure 12 Maximum wave height at 50- year return period and direction [from]- for Source Point offshore location [1]

The wave data, presented in Table 1, was set as boundary condition and specified as a JONSWAP spectrum. The peak-enhancement factor was set to 3.3 and directional spreading was included as a $\cos^m(\theta)$ distribution.

Only wind-wave interaction was considered. Current-wave interaction was not included because local flow velocities are very small.

16 headings were used, the wind direction was kept constant within its directional bin. T_p was varied in the presented range as shown in Table 2.

Table 2 T_p values used in analysis.

Direction [from] [°]		*T_p [s]*
0	N	4.14_15.45
23	NNE	9_14.5
45	NE	6.6_14.6
68	ENE	6.6_13
90	E	6.5_14
113	ESE	8.2_14
135	SE	8.4_13
158	SSE	8.8_13.8
180	S	9_14.8
203	SSW	8.9_14.4

225	SW	8.9_14.1
248	WSW	7.5_15.3
270	W	4.1_15.4
293	WNW	4.1_14.3
315	NW	3.5_14.5
338	NNW	3.7_14.4

In this method, wave design conditions for the project location are based on 10- and 50- year return period sea-state and winds for an offshore location, which have subsequently been transferred to the project location. This will provide reasonable design conditions; however, they cannot be linked directly to a return period at the site.

4.4 Wave modeling results

The results of the wave modeling are presented in Figure 13 and Figure 14 for directions from southeast, and south, respectively for two key wave headings with the highest wave heights. As stated in the previous section, the wind conditions are assumed to stay constant for the region. The results from STWave represent the maximum significant wave height value at the region including its spectral peak period and wave direction.

The location of the Reference Site 2 in Dover Bay is presented in Figure 1. The estimated wave and wind conditions for each site based on the STWave modeling are presented in the following sections.

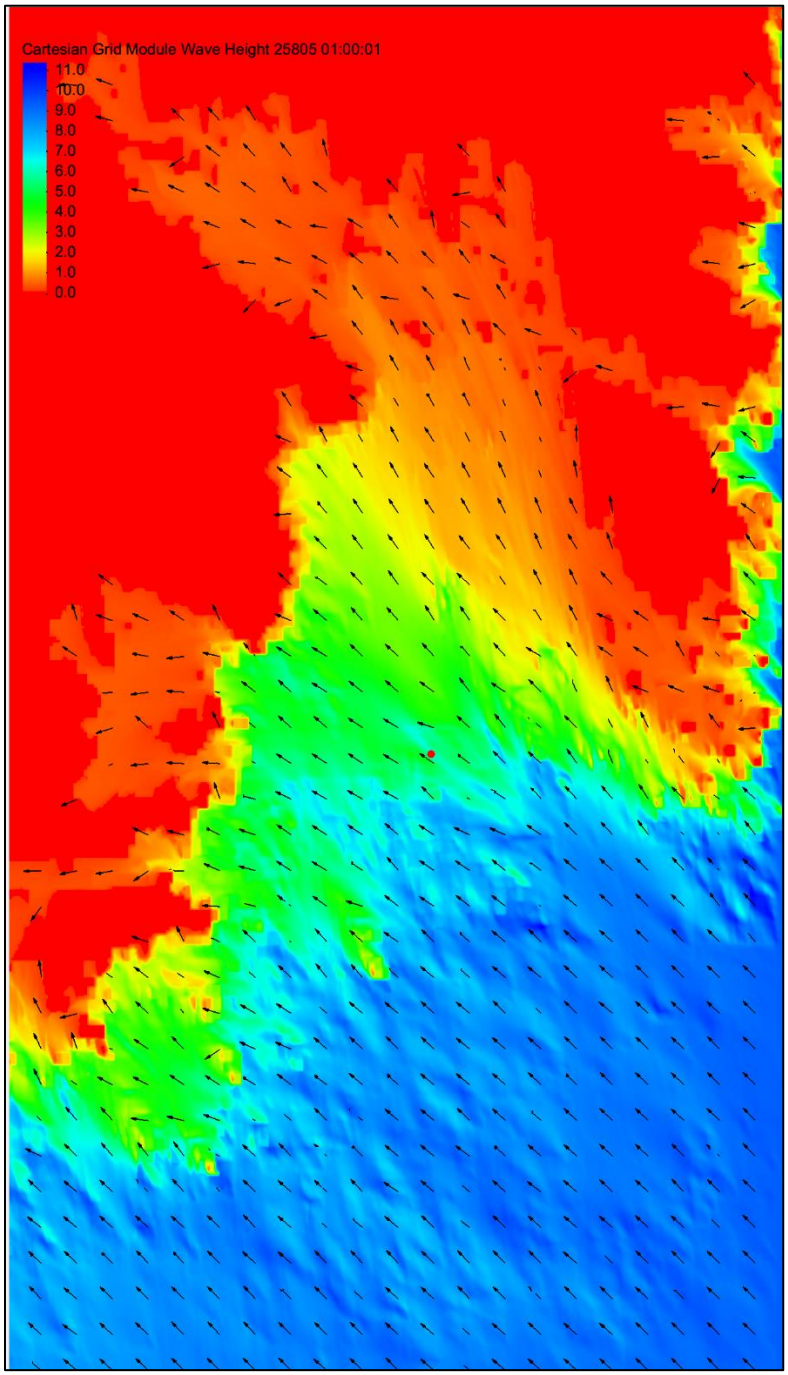


Figure 13 Wave modeling results for direction [From] 135 deg- SE

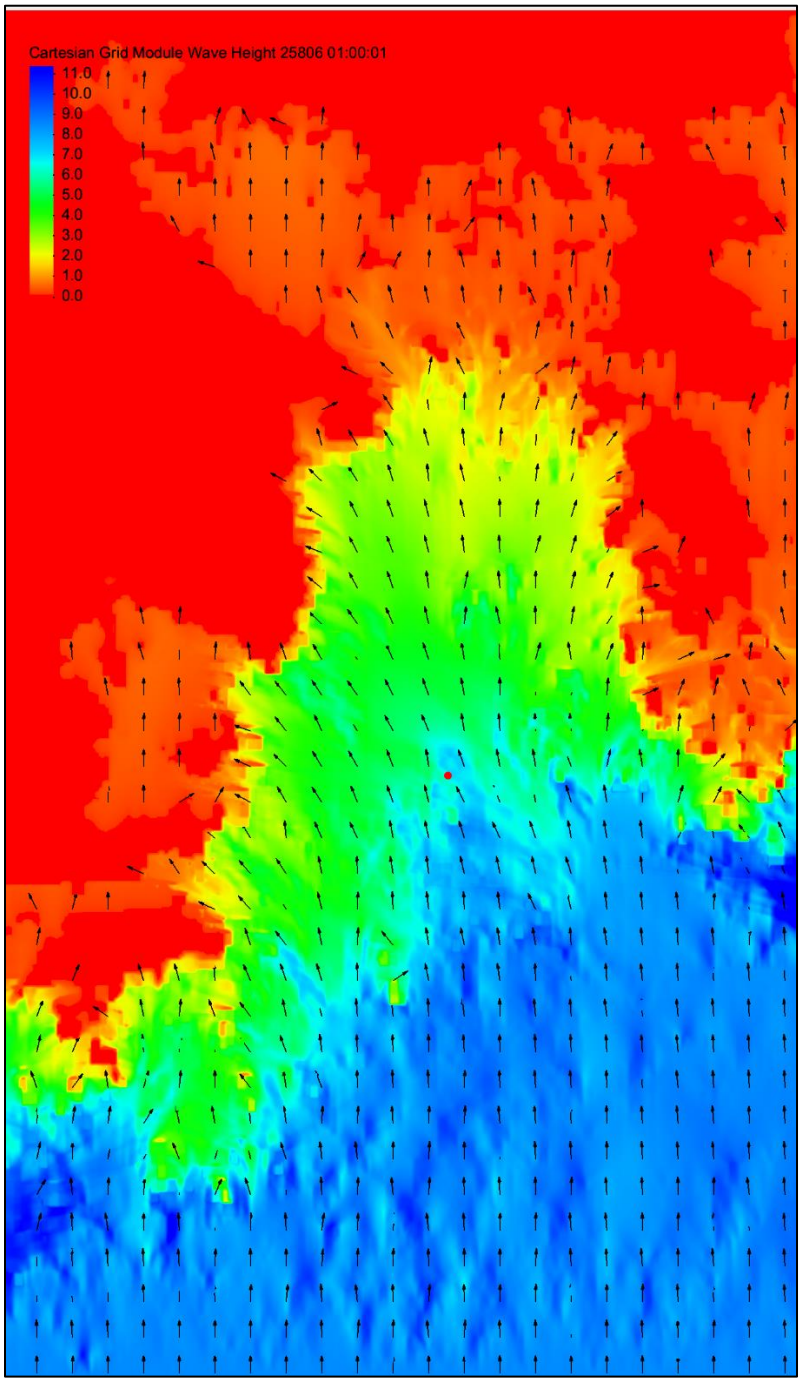


Figure 14 Wave modeling results for direction [From] 180 deg- S

4.4.1 Wave/wind conditions for Guysborough – Reference Site 2

The wave and wind results from the STWave model, for the Guysborough – Reference Site 2, are summarized in Table 3. Note that the results in Table 3 indicate significant wave height (Hs) and peak period (T_P) for the selected site. These represent the extreme wave conditions at this coordinate: 45° 14.653'N, 61° 1.057'W.

Table 3 Estimated wave and wind design conditions for Guysborough – Reference Site 2

Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	Hs (m)	Tp (s)
10yr wave/wind	*0*	N	23.51	0.92	2.83
	23	NNE	23.91	0.64	2.55
	45	NE	22.58	0.61	2.67
	68	ENE	23.43	0.68	2.55
	90	E	22.49	2.6	11.5
	113	ESE	23.83	4.65	11.33
	135	SE	22.83	6	11.18
	158	SSE	22.41	4.63	11.28
	180	S	22.4	6.72	13.72
	203	SSW	22.25	1.02	5.85
	225	SW	22.14	0.9	2.67
	248	WSW	22.53	0.7	2.44
	270	W	23.12	0.67	2.39
	293	WNW	23.95	0.55	2.54
	315	NW	23.54	0.55	2.24
	338	NNW	22.31	0.74	2.79
50yr wave/wind	*0*	N	27.38	1.1	3.03
	23	NNE	28.34	0.78	2.76
	45	NE	26.45	0.73	2.85
	68	ENE	27.16	0.81	2.72
	90	E	26.31	2.65	11.25
	113	ESE	27.5	4.68	11.21
	135	SE	26.19	6.05	11.12
	158	SSE	25.21	4.65	11.18
	180	S	25.61	6.74	13.71
	203	SSW	25.49	1.03	5.83
	225	SW	25.38	1.04	2.83
	248	WSW	25.48	0.81	2.58
	270	W	25.8	0.76	2.51
	293	WNW	26.94	0.64	2.68
	315	NW	26.3	0.63	2.35
	338	NNW	25.02	0.84	2.93

It should be noted that the return periods indicated for each wave parameter in Table 3 are representative of the boundary condition used to derive that value, not the value itself. Polar plots for maximum wave heights are presented in Figure 15 and Figure 16.

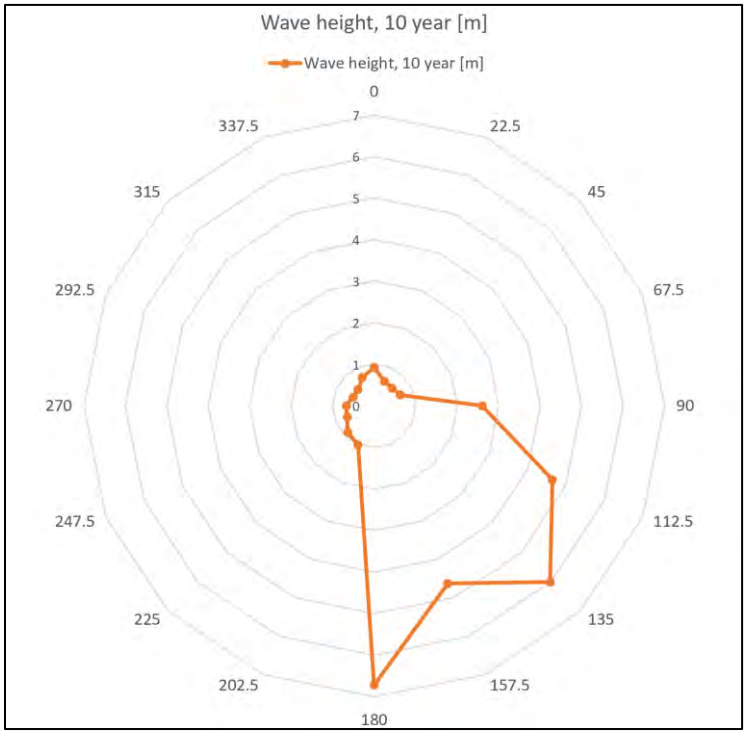


Figure 15 Maximum wave height at 10- year return period and direction [from]- Guysborough – Reference Site 2

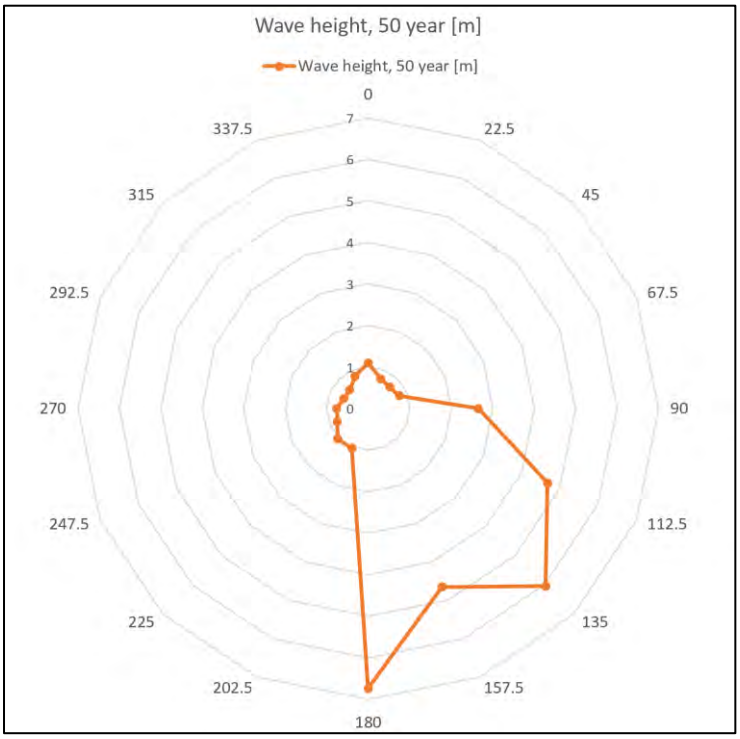


Figure 16 Maximum wave height at 50- year return period and direction [from]- Guysborough – Reference Site 2