

**2020**

# **WIND AND WAVE CONDITIONS – LIVERPOOL BAY – MARINE FINFISH LEASES 1205, 1432, 1433**

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Dynamic Systems Analysis

Title	<b>Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433</b>
DSA Document	Report-DSA-CMAR-19EXM-Liverpool Bay Wind and Wave Conditions RevB.1.docx
Revision	B
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Prepared for	CMAR
Client reference / project	N/A
DSA project	CMAR-19EXM
Last revised	2020-04-20
Pages (incl. Grove Br)	32

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Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

## Revision history

Revision	Revision description	Date	Summary of changes / additions	Revisions by	Checked by	Approved for release by	Issued to
A	IFR	2020-04-14	Report draft	MK	DS	DS	CMAR
B	IFR	2020-04-20	CMAR comments applied, Approved for public release	MK	DS	DS	CMAR

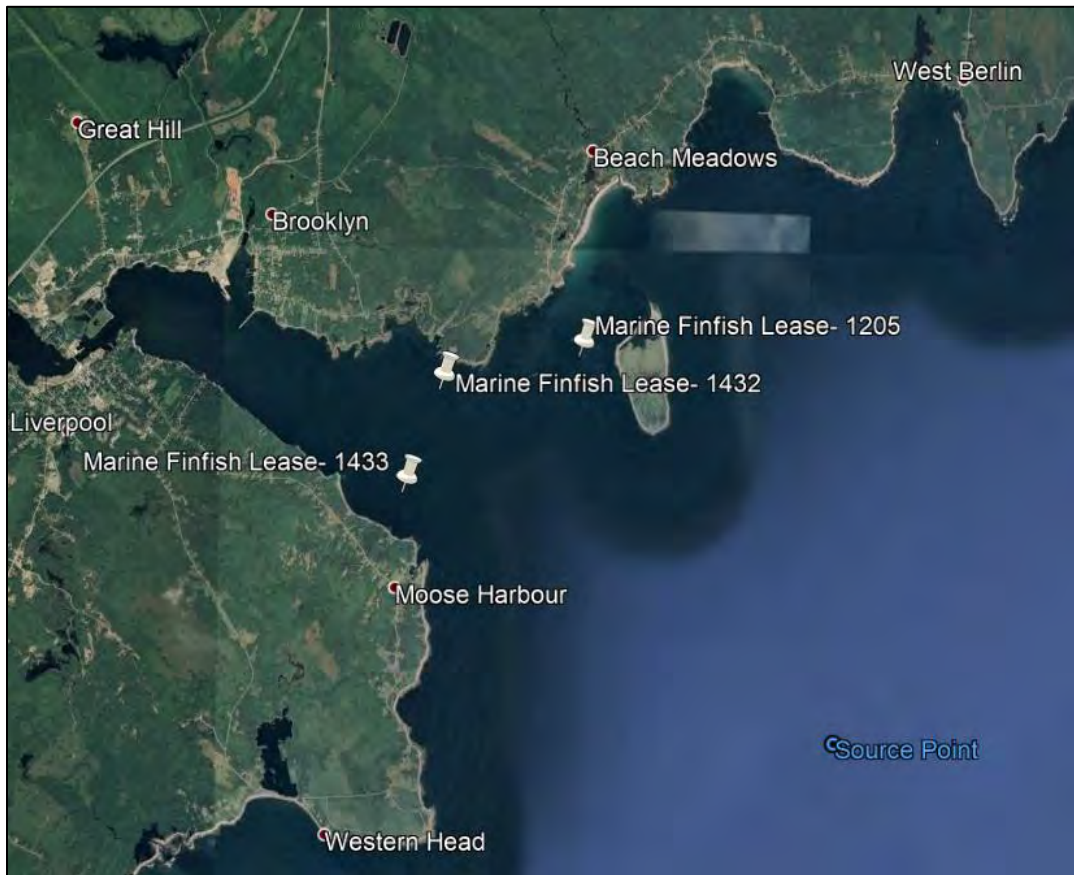
Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

## Executive Summary


In support of Centre for Marine Applied Research (CMAR), the following report presents wind and wave conditions at three locations in Liverpool Bay, Nova Scotia, Canada.

In this report, wave and wind conditions are presented for 3 locations:

- Marine Finfish Lease- 1205: 44° 2.513'N, 64° 38.390'W.
- Marine Finfish Lease- 1432: 44° 2.282'N, 64° 39.664'W.
- Marine Finfish Lease- 1433: 44° 1.601'N, 64° 39.993'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 Liverpool Bay area, STWave was used to model the nearshore wave conditions. The results showed reduced wave heights, in comparison to the source point, 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 locations are determined in part by propagating wave from the offshore hindcast model location into the site of interested.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

## Contents

Revision history .....	2
Executive Summary.....	3
Contents .....	4
Figures .....	4
Tables .....	5
1 Introduction .....	6
1.1 Overview .....	6
1.2 Objective(s) .....	7
2 Abbreviations and acronyms .....	8
3 Reference documents and drawings .....	8
4 Wave conditions .....	8
4.1 Overview .....	8
4.2 Wave Model Description .....	9
4.3 Boundary conditions – offshore wind and wave conditions .....	10
4.4 Wave modeling results .....	21
4.4.1 Wave/wind conditions for Liverpool Bay- Marine Finfish Lease- 1205 .....	24
4.4.2 Wave/wind conditions for Liverpool Bay- Marine Finfish Lease- 1432 .....	27
4.4.3 Wave/wind conditions for Liverpool Bay- Marine Finfish Lease- 1433 .....	30

## Figures

Figure 1 Three (3) site locations at Liverpool Bay [4] .....	6
Figure 2 Liverpool Bay, Nova Scotia, Canada.....	7
Figure 3 Bathymetry at site on hydrographic charts- Depth reported in meters.....	9
Figure 4 Bathymetry at site on STWave. Note the MSC50 HindCast model source point indicated at 43° 60.000'N, 64° 36.001'W .....	10
Figure 5 Wave height versus wave direction plot for the source point.....	11
Figure 6 Wind speed versus wind direction plot for the source point .....	12
Figure 7: Extreme value analysis on wind data – for Source Point offshore location [1] .....	15
Figure 8: Extreme value analysis on wave data – for Source Point offshore location [1] .....	17
Figure 9 Maximum wind speed at 10 year return period and direction [from]- for Source Point offshore location [1] .....	19



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

Figure 10 Maximum wind speed at 50 year return period and direction [from]- for Source Point offshore location [1] .....	19
Figure 11 Maximum wave height at 10 year return period and direction [from]- for Source Point offshore location [1] .....	20
Figure 12 Maximum wave height at 50 year return period and direction [from]- for Source Point offshore location [1] .....	20
Figure 13 Wave modeling results for direction [From] 90 deg- E .....	22
Figure 14 Wave modeling results for direction [From] 135 deg- SE .....	23
Figure 15 Wave modeling results for direction [From] 180 deg- S .....	24
Figure 16 Maximum wave height at 10 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1205 .....	26
Figure 17 Maximum wave height at 50 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1205 .....	27
Figure 18 Maximum wave height at 10 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1432 .....	29
Figure 19 Maximum wave height at 50 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1432 .....	30
Figure 20 Maximum wave height at 10 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1433 .....	32
Figure 21 Maximum wave height at 50 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1433 .....	32

## Tables

Table 1 Results extreme value analysis for wind and waves at the offshore source point location in Figure 4 .....	18
Table 2 $T_p$ values used in analysis. ....	21
Table 3 Estimated wave and wind design conditions for Liverpool Bay- Marine Finfish Lease- 1205 .....	25
Table 4 Estimated wave and wind design conditions for Liverpool Bay- Marine Finfish Lease- 1432 .....	28
Table 5 Estimated wave and wind design conditions for Liverpool Bay- Marine Finfish Lease- 1433 .....	30



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

## 1 Introduction

### 1.1 Overview

For the locations in Liverpool Bay 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 these locations.

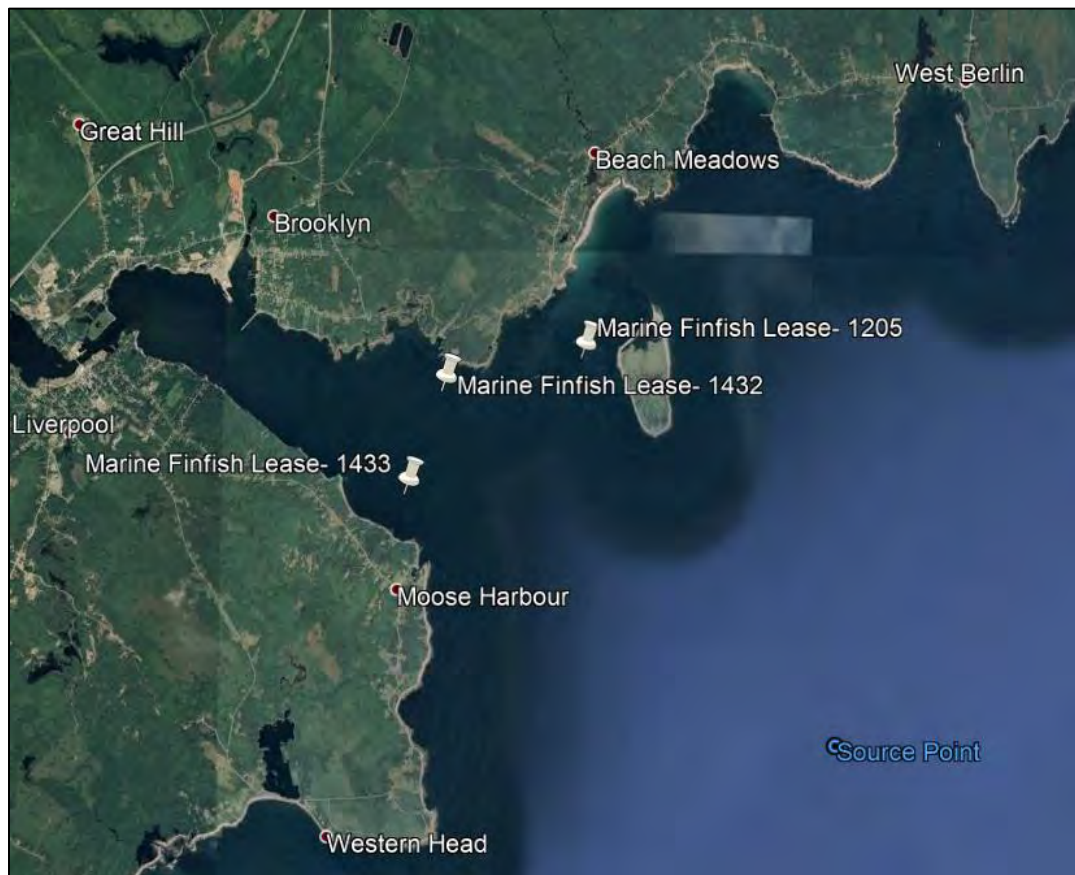



Figure 1 Three (3) site locations at Liverpool Bay [4]

Liverpool Bay is overall protected from offshore waves by surrounding lands, but is vulnerable to waves from the east and southeast which will travel directly into the bay, as can be 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.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

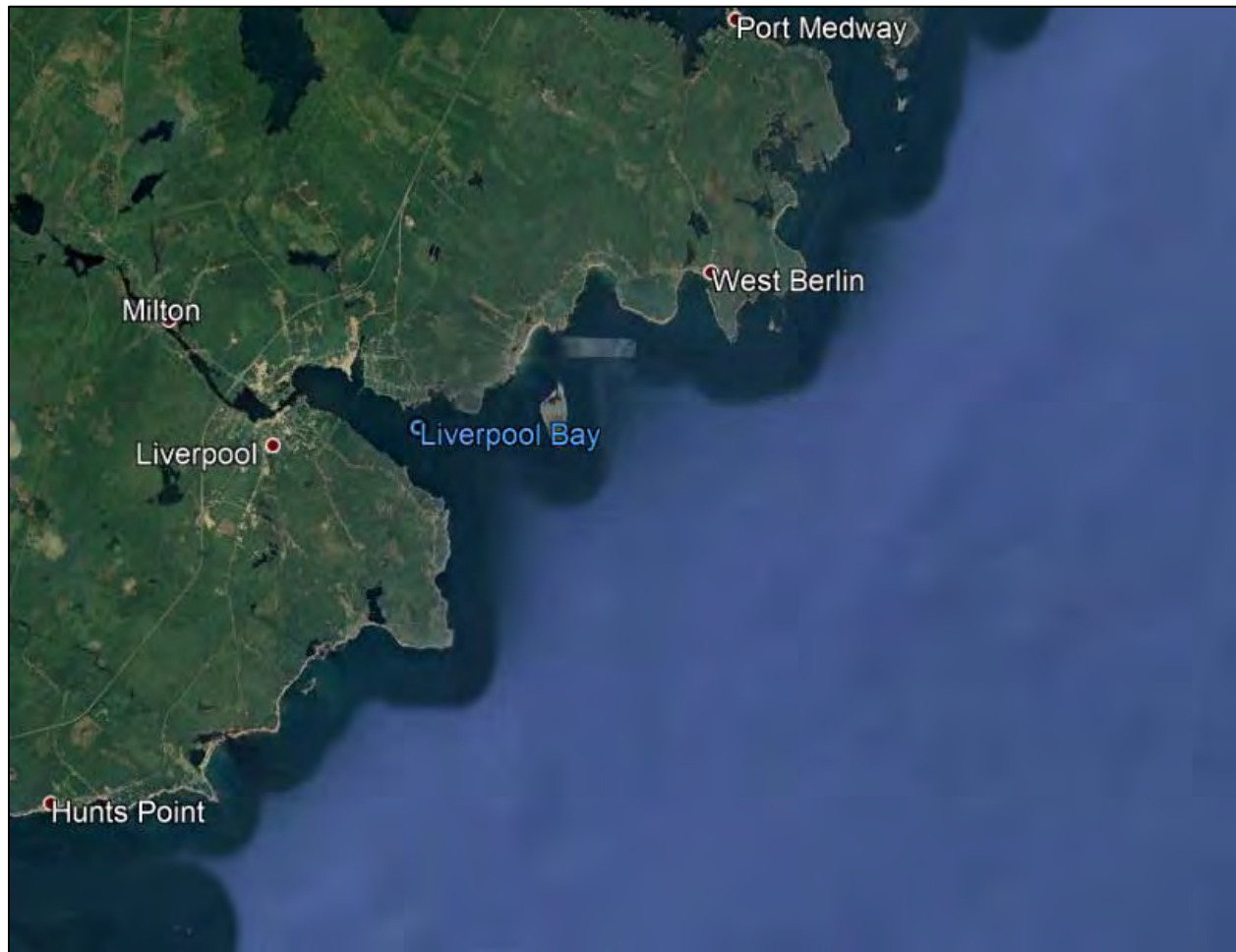



Figure 2 Liverpool Bay, Nova Scotia, Canada

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 locations assessed as part of this modeling exercise are actual aquaculture site locations, the data produced for these locations 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 three locations in Liverpool Bay and find the conditions with 10 and 50 year return periods.



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

## 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]	V. Swail, V. Cardone, M. Ferguson, D. Gummer, E. Harris, E. Orelup, and A. Cox, “The msc50 wind and wave reanalysis,” in <i>9th International Workshop On Wave Hindcasting and Forecasting</i> , 2006.
[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. <i>Standard Norge, Lysaker</i> .
[4]	CMAR approved 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.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

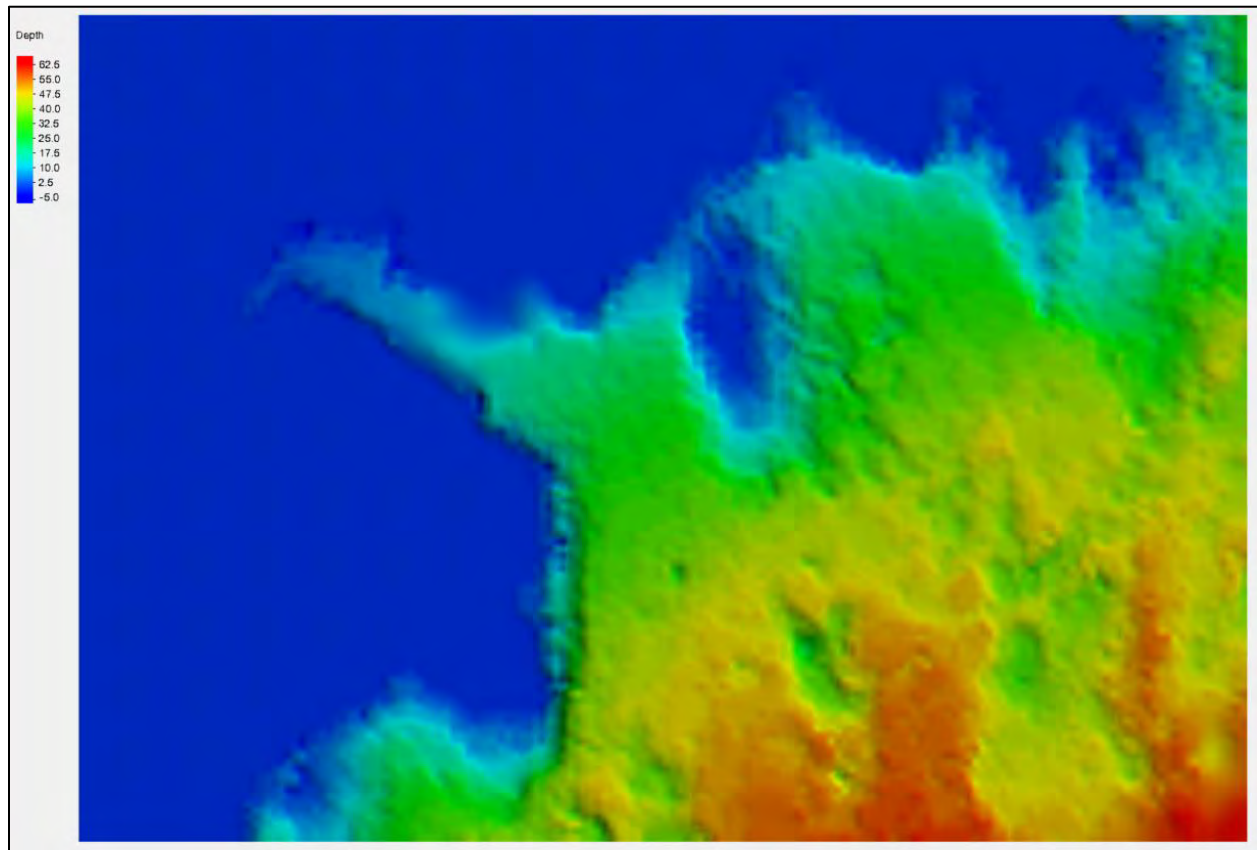



Figure 3 Bathymetry at site on hydrographic charts- Depth reported in meters

## 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 8.9km x 11.9km. The mesh size was 10m x 10m, resulting in 890 x 1193 = 1,061,770 grid cells.

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

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

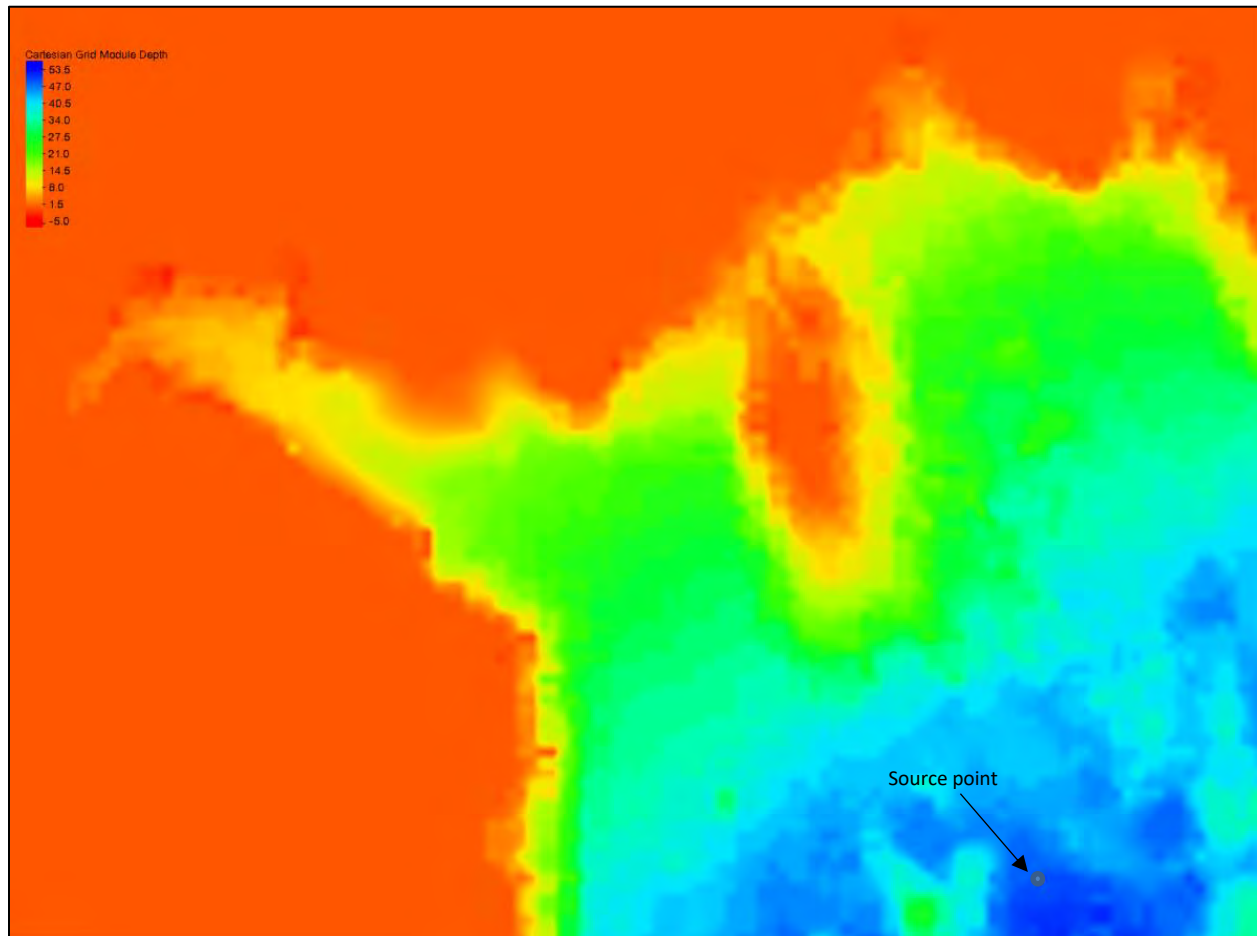



Figure 4 Bathymetry at site on STWave. Note the MSC50 HindCast model source point indicated at 43° 60.000'N, 64° 36.001'W

### 4.3 Boundary conditions – offshore wind and wave conditions

The MSC50 HindCast model [1] data from location 43° 60.000'N, 64° 36.001'W was used to determine the 10 and 50 year return periods for wind and wave of the Liverpool Bay reference sites; 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 east, southeast and south.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

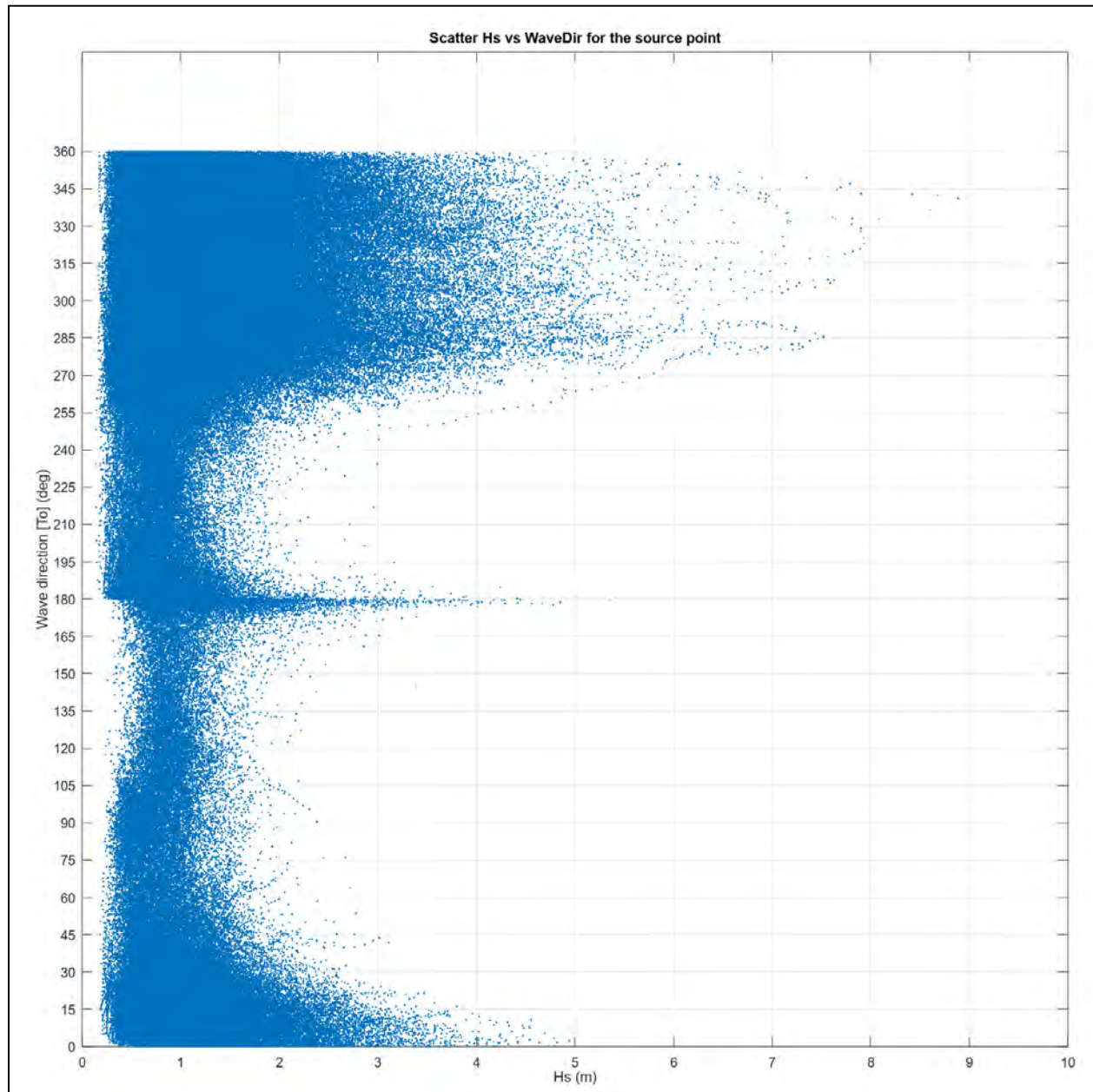



Figure 5 Wave height versus wave direction plot for the source point



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

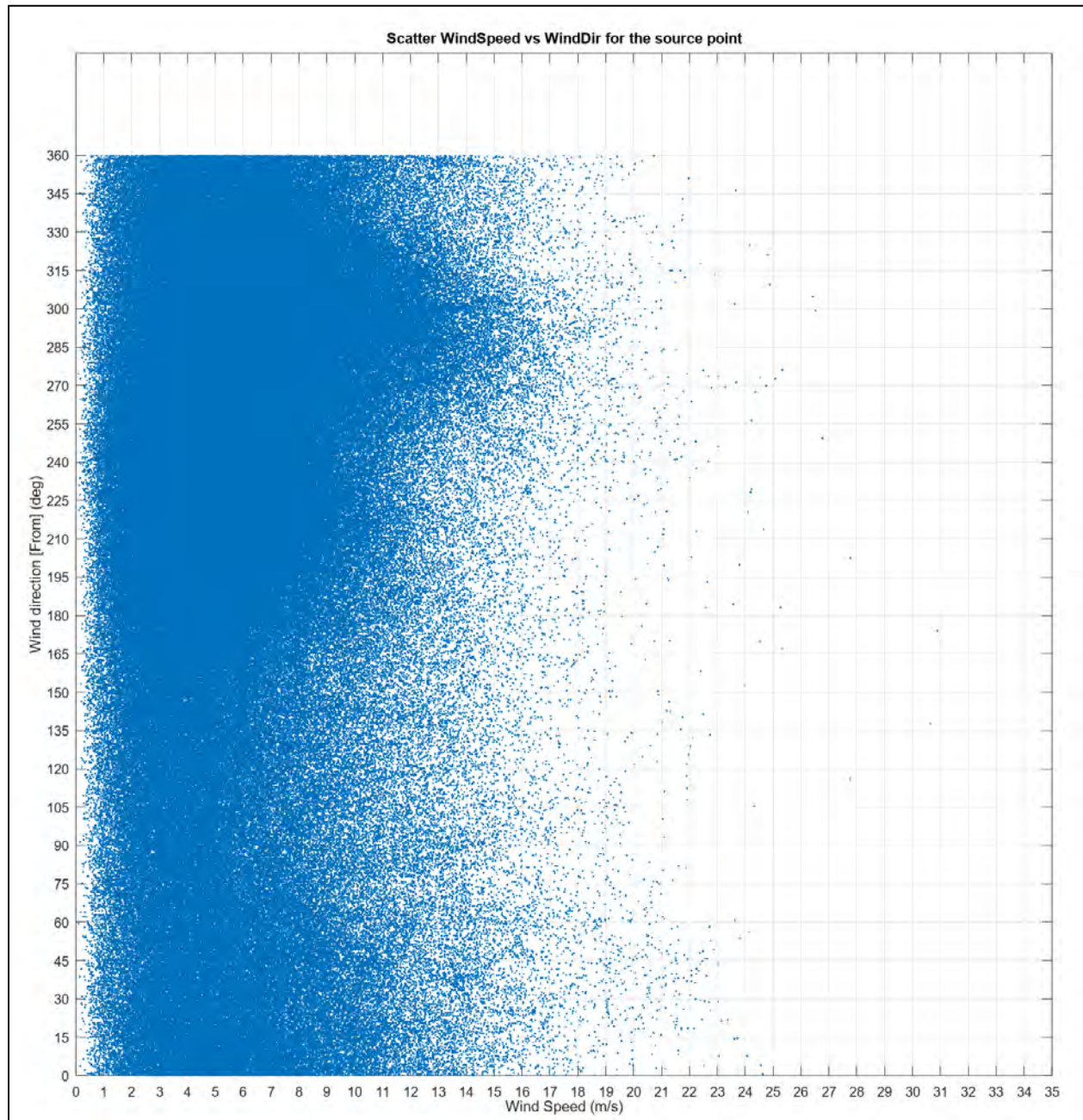



Figure 6 Wind speed versus wind direction plot for the source point

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

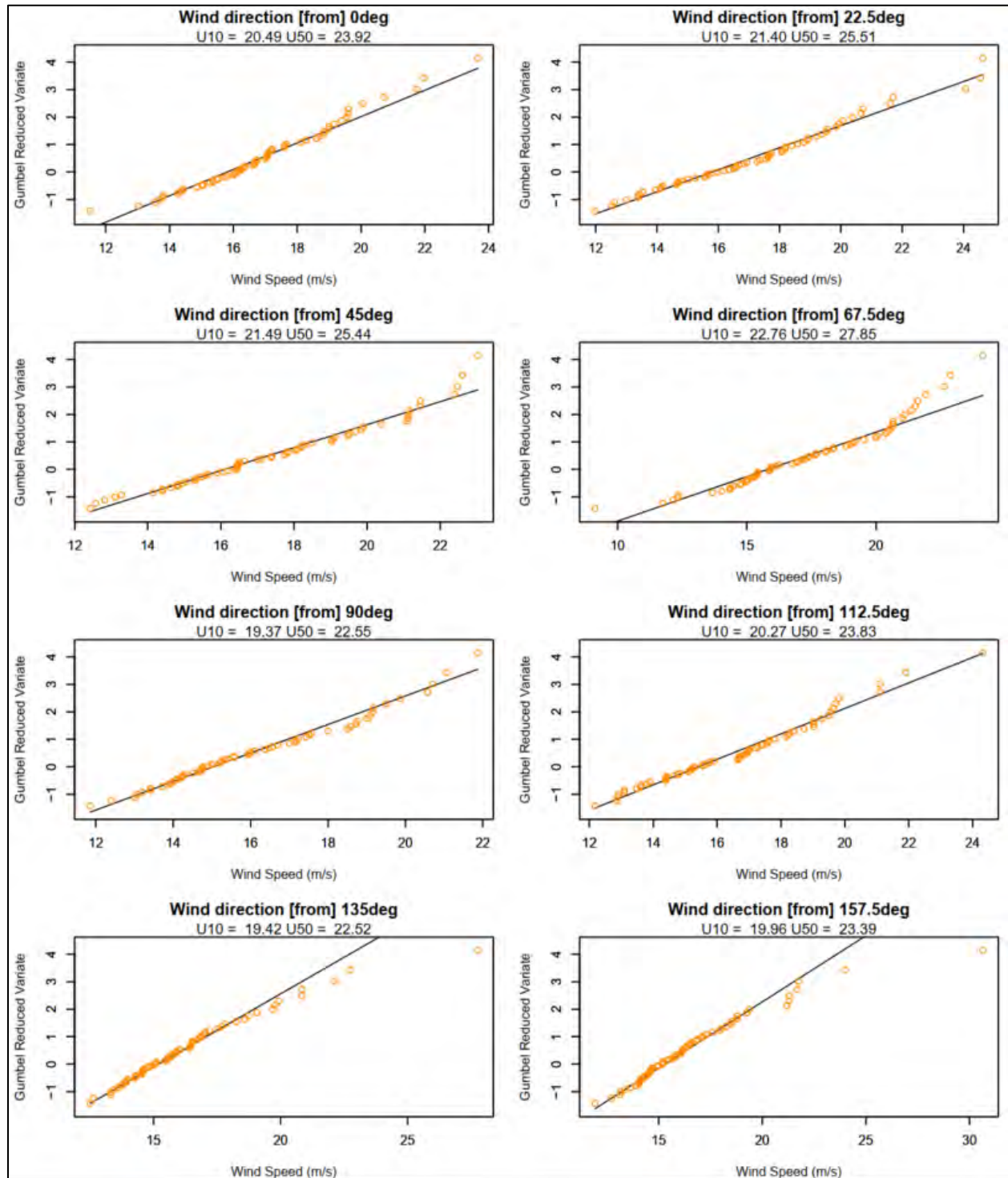
Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	


- 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.



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

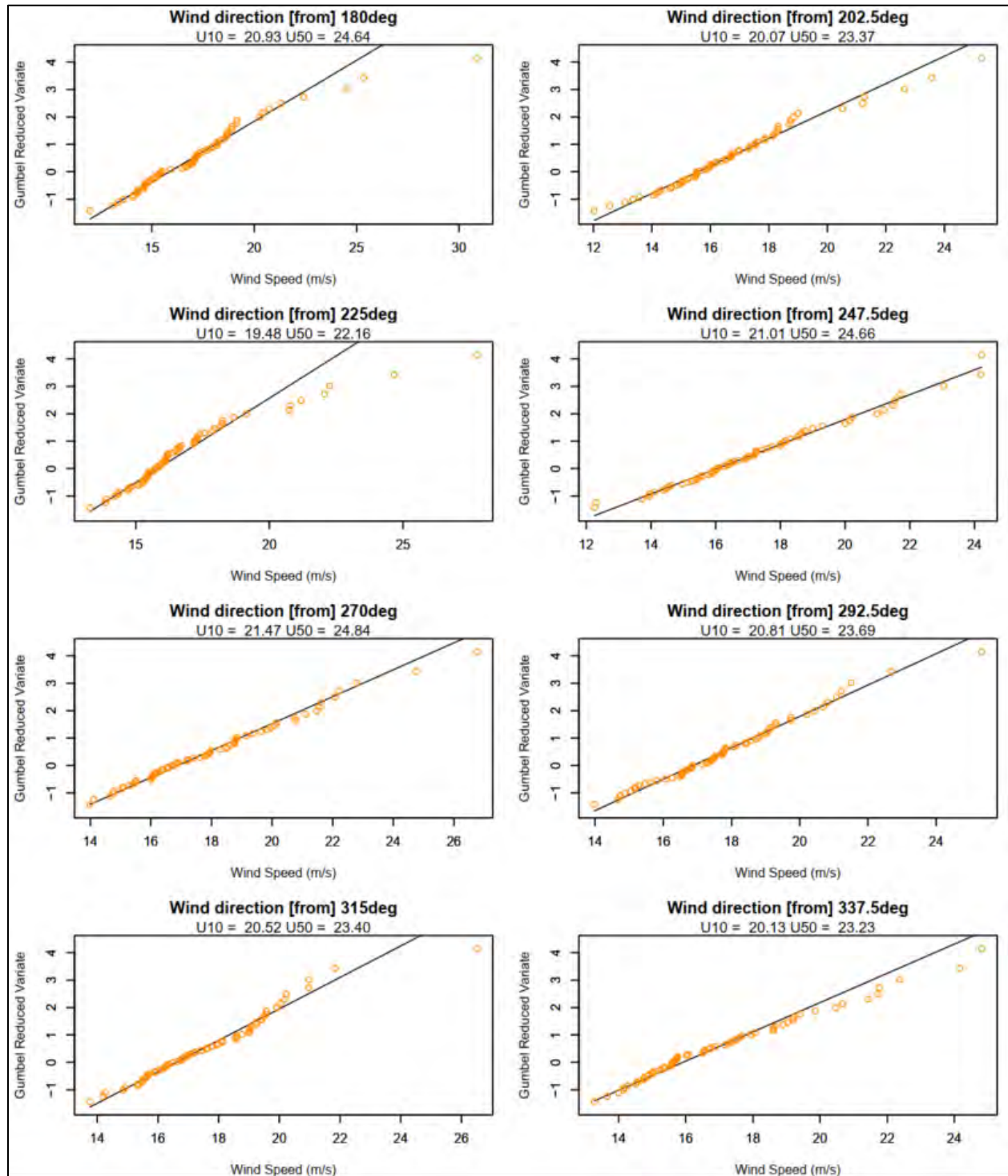

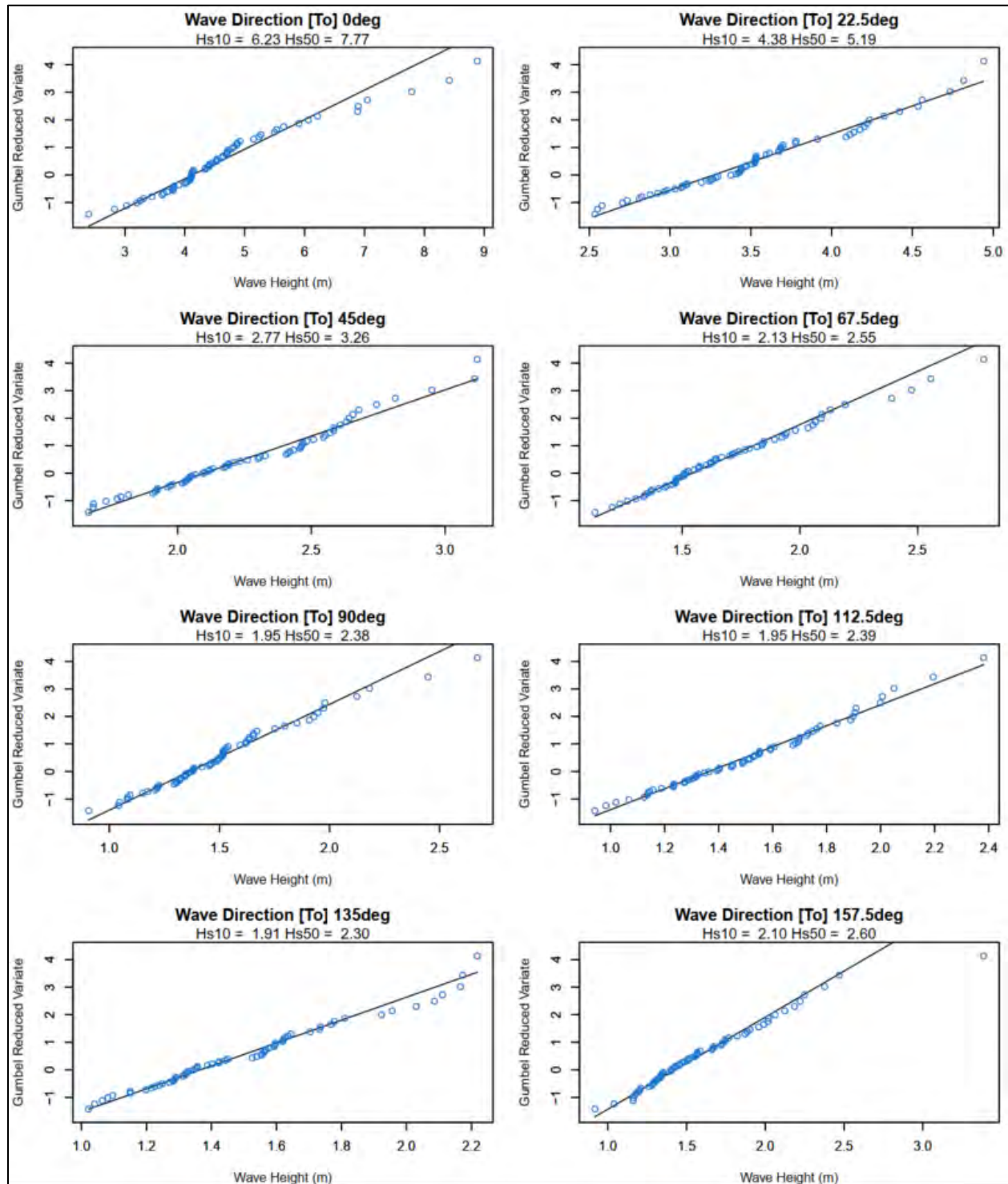



Figure 7: Extreme value analysis on wind data – for Source Point offshore location [1]

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.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

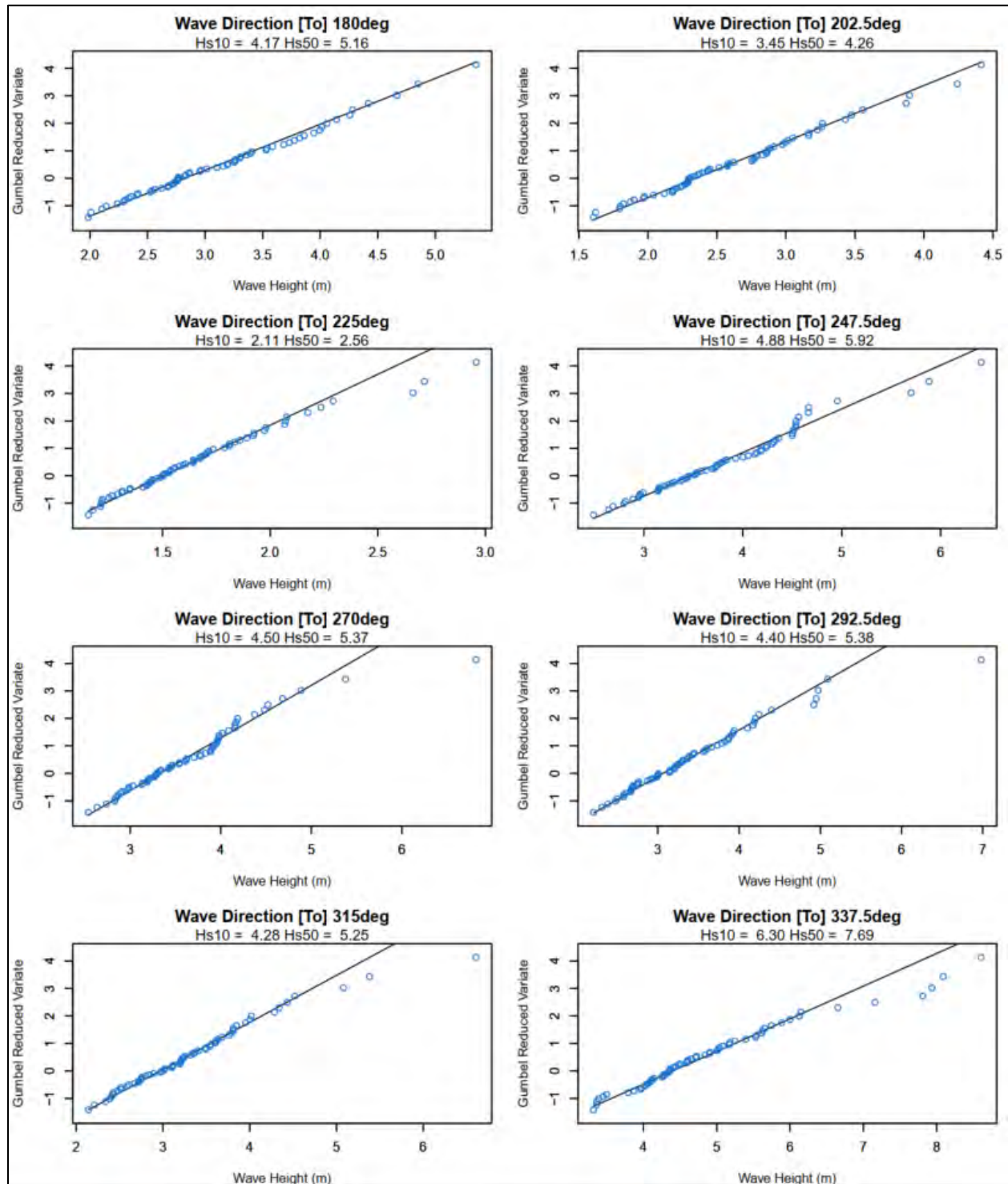



Figure 8: Extreme value analysis on wave data – for Source Point offshore location [1]




Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

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 location 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	20.49	23.92	4.17	5.16
23	NNE	21.4	25.51	3.45	4.26
45	NE	21.49	25.44	2.11	2.56
68	ENE	22.76	27.85	4.88	5.92
90	E	19.37	22.55	4.5	5.37
113	ESE	20.27	23.83	4.4	5.38
135	SE	19.42	22.52	4.28	5.25
158	SSE	19.96	23.39	6.3	7.69
180	S	20.93	24.64	6.23	7.77
203	SSW	20.07	23.37	4.38	5.19
225	SW	19.48	22.16	2.77	3.26
248	WSW	21.01	24.66	2.13	2.55
270	W	21.47	24.84	1.95	2.38
293	WNW	20.81	23.69	1.95	2.39
315	NW	20.52	23.4	1.91	2.3
338	NNW	20.13	23.23	2.1	2.6

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.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

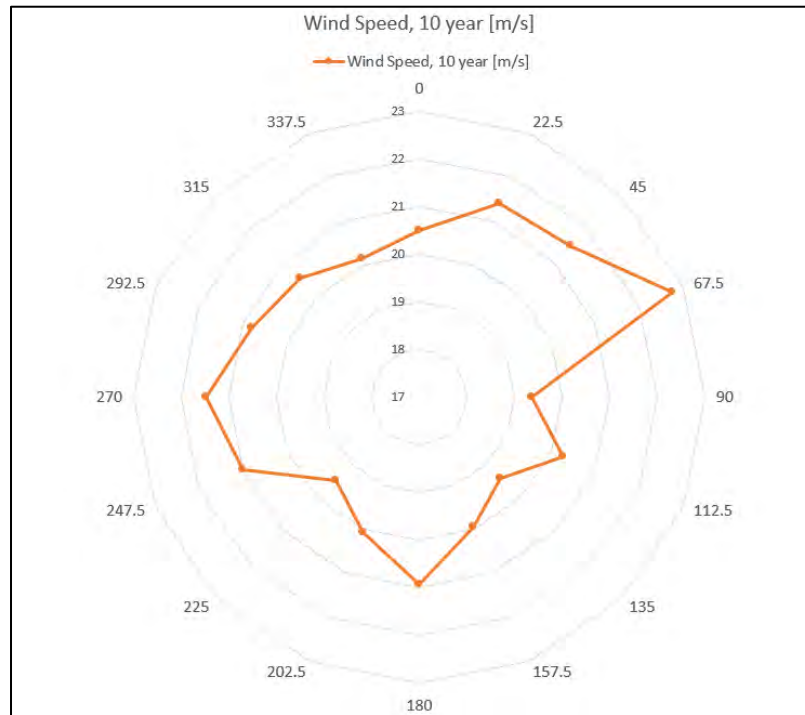


Figure 9 Maximum wind speed at 10 year return period and direction [from]- for Source Point offshore location [1]

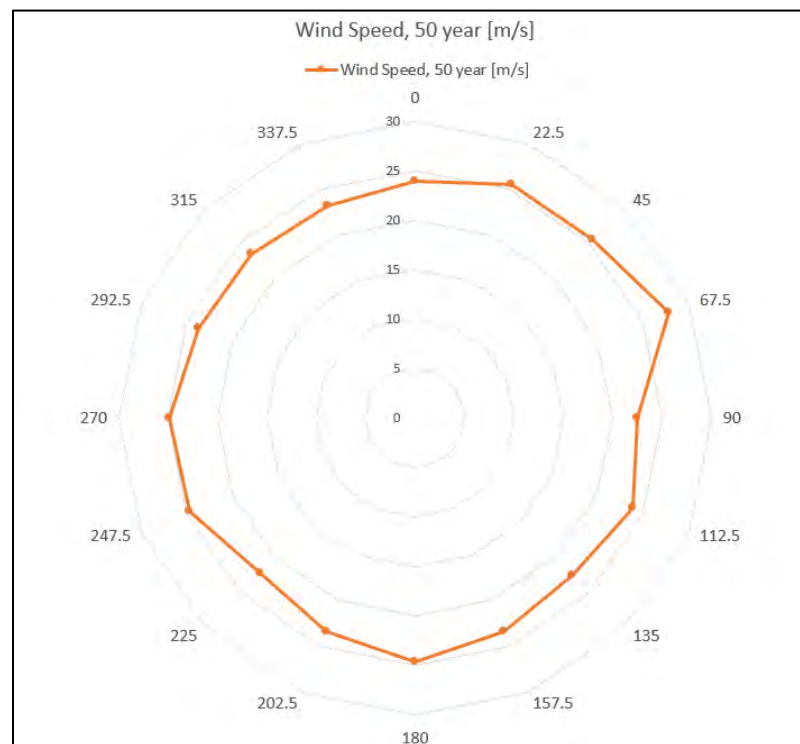



Figure 10 Maximum wind speed at 50 year return period and direction [from]- for Source Point offshore location [1]



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

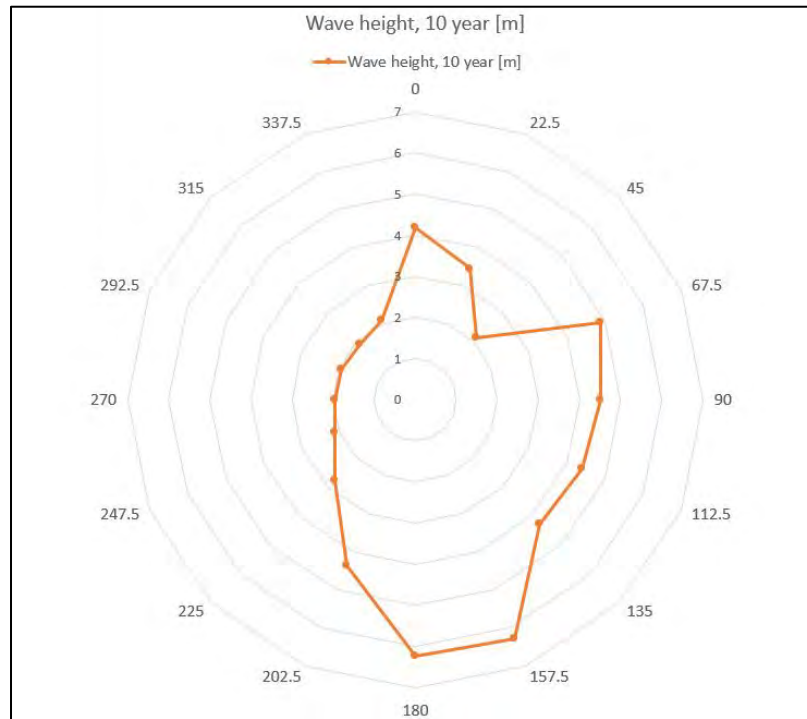


Figure 11 Maximum wave height at 10 year return period and direction [from]- for Source Point offshore location [1]

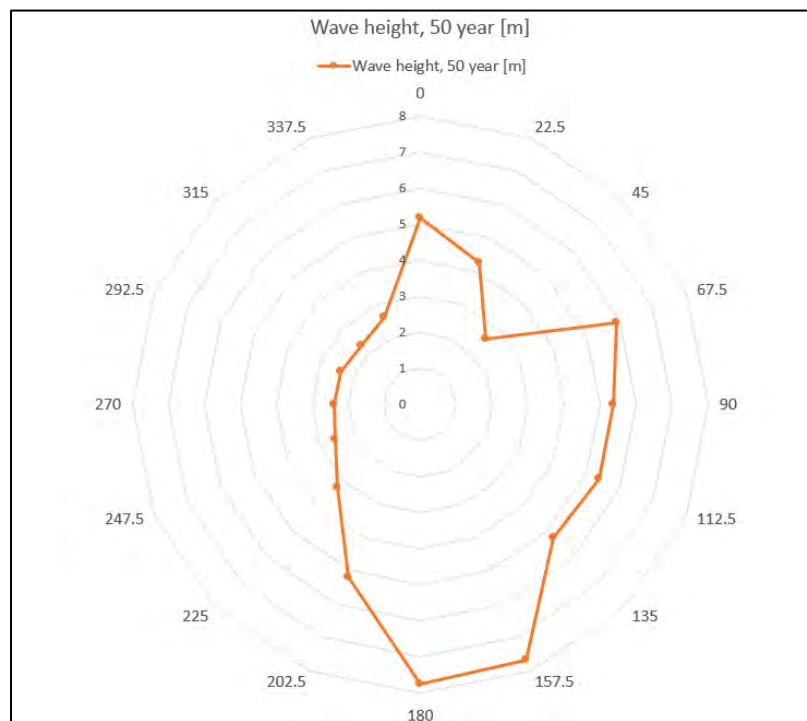



Figure 12 Maximum wave height at 50 year return period and direction [from]- for Source Point offshore location [1]

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

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.

Eight 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	8.13_14.9
23	NNE	6.45_12.9
45	NE	3.8_12.8
68	ENE	8.3_14
90	E	8.5_14
113	ESE	9.2_15
135	SE	9_15.6
158	SSE	8.2_16.7
180	S	8_15.6
203	SSW	8.1_14.1
225	SW	6.8_14.1
248	WSW	4.5_14.3
270	W	3.7_14.3
293	WNW	3.3_14.5
315	NW	3.8_14.6
338	NNW	4_14.7

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 to Figure 15 for directions from east, southeast, and south, respectively for three 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.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

The location of sites at the Liverpool Bay are presented in Figure 1. The estimated wave and wind conditions for each site based on the STWave modeling are presented in the following sections.

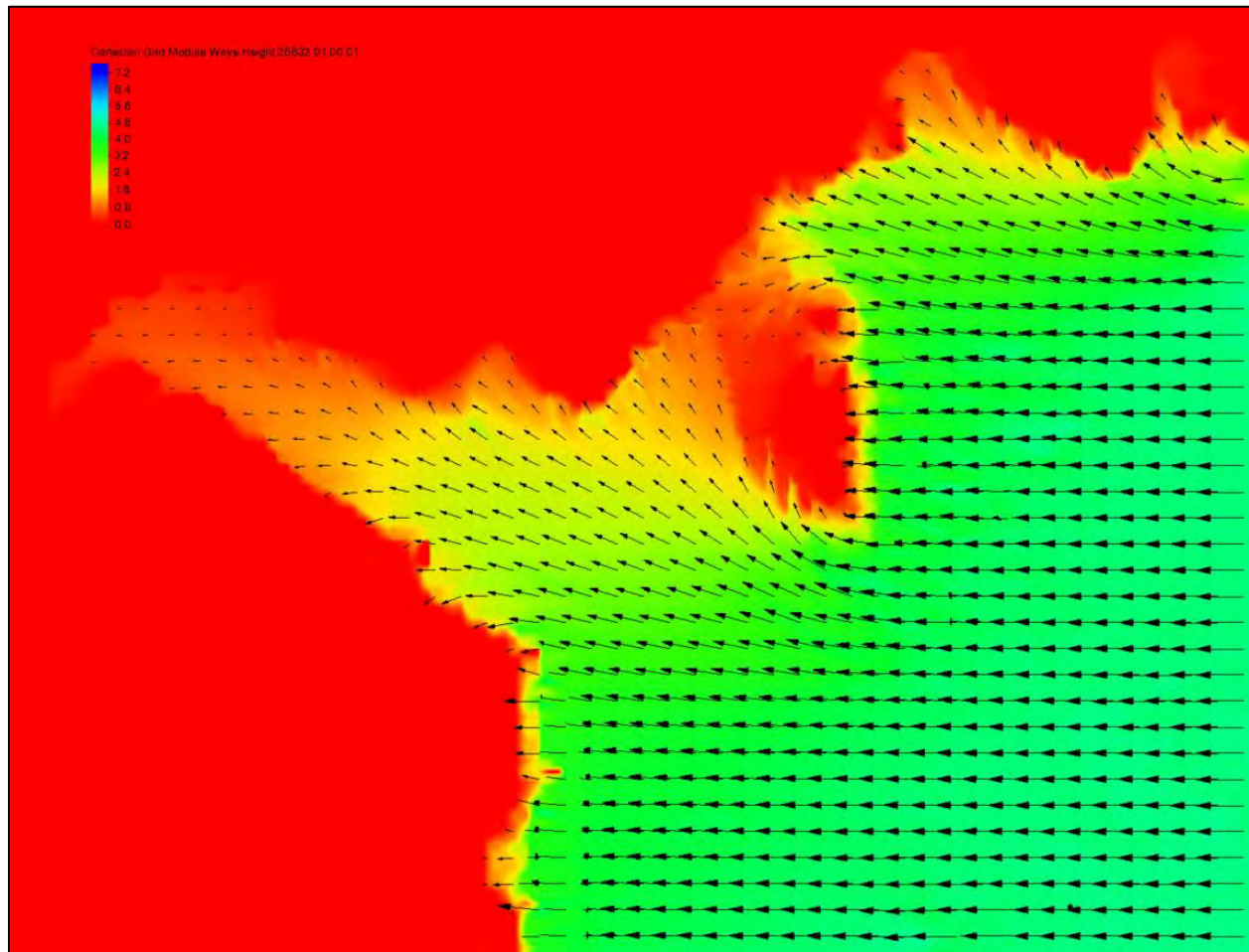



Figure 13 Wave modeling results for direction [From] 90 deg- E

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

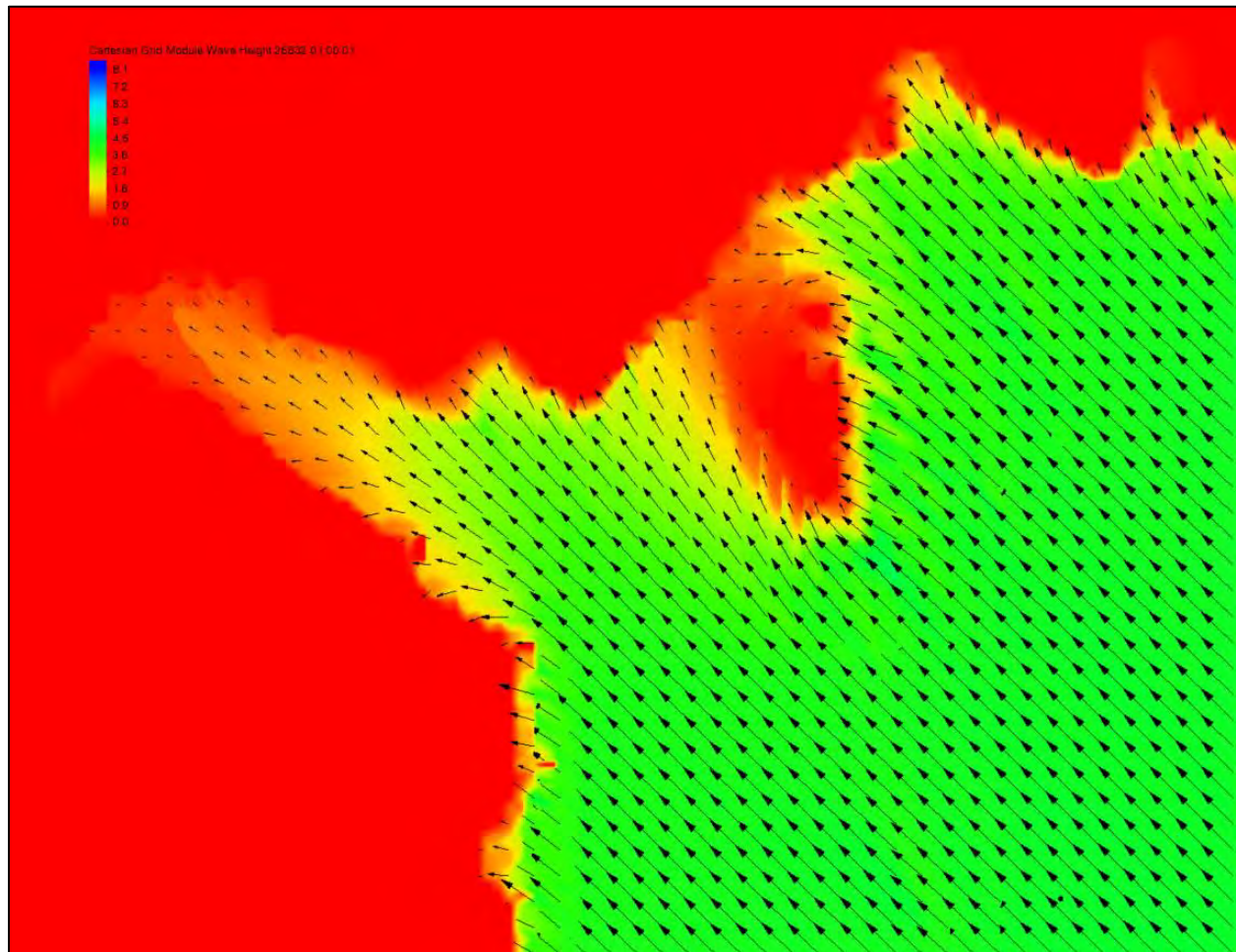



Figure 14 Wave modeling results for direction [From] 135 deg- SE



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

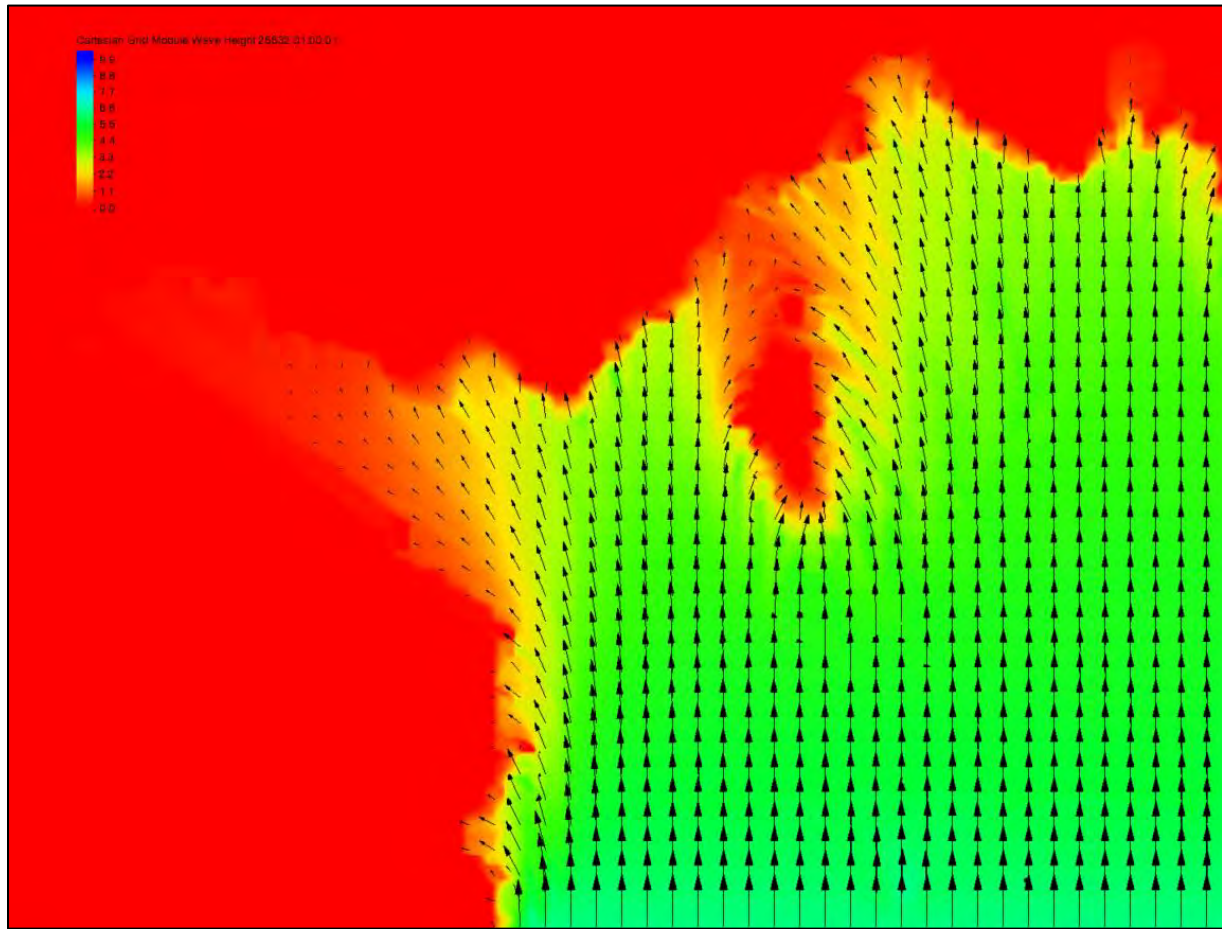



Figure 15 Wave modeling results for direction [From] 180 deg- S

#### 4.4.1 Wave/wind conditions for Liverpool Bay- Marine Finfish Lease- 1205


The wave and wind results from the STWave model, for the Liverpool Bay- Marine Finfish Lease- 1205, are summarized in Table 3. Note that the results in Table 3 indicate significant wave height ( $H_s$ ) and peak period ( $T_p$ ) for the selected site. These represent the extreme wave conditions at this coordinate: 44° 2.513'N, 64° 38.390'W.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

**Table 3 Estimated wave and wind design conditions for Liverpool Bay- Marine Finfish Lease- 1205**

Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	Hs (m)	Tp (s)
10yr wave/wind	0	N	20.49	0.45	1.95
	23	NNE	21.4	0.4	2.3
	45	NE	21.49	0.4	2.46
	68	ENE	22.76	0.41	1.9
	90	E	19.37	0.3	1.67
	113	ESE	20.27	0.17	1.6
	135	SE	19.42	0.42	2.72
	158	SSE	19.96	1.3	4.33
	180	S	20.93	3.24	13.88
	203	SSW	20.07	0.7	2.6
	225	SW	19.48	0.64	2.6
	248	WSW	21.01	0.7	2.5
	270	W	21.47	0.62	2.26
	293	WNW	20.81	0.29	1.73
	315	NW	20.52	0.32	2.1
	338	NNW	20.13	0.35	2
50yr wave/wind	0	N	23.92	0.53	2.1
	23	NNE	25.51	0.5	2.5
	45	NE	25.44	0.45	2.03
	68	ENE	27.85	0.51	1.96
	90	E	22.55	0.33	1.75
	113	ESE	23.83	0.22	1.7
	135	SE	22.52	0.49	2.88
	158	SSE	23.39	1.39	4.27
	180	S	24.64	4.05	13.86
	203	SSW	23.37	0.83	2.77
	225	SW	22.16	0.75	2.73
	248	WSW	24.66	0.85	2.67
	270	W	24.84	0.73	2.4
	293	WNW	23.69	0.35	1.82
	315	NW	23.4	0.38	2.22
	338	NNW	23.23	0.42	2.1



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

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 16 and Figure 17.

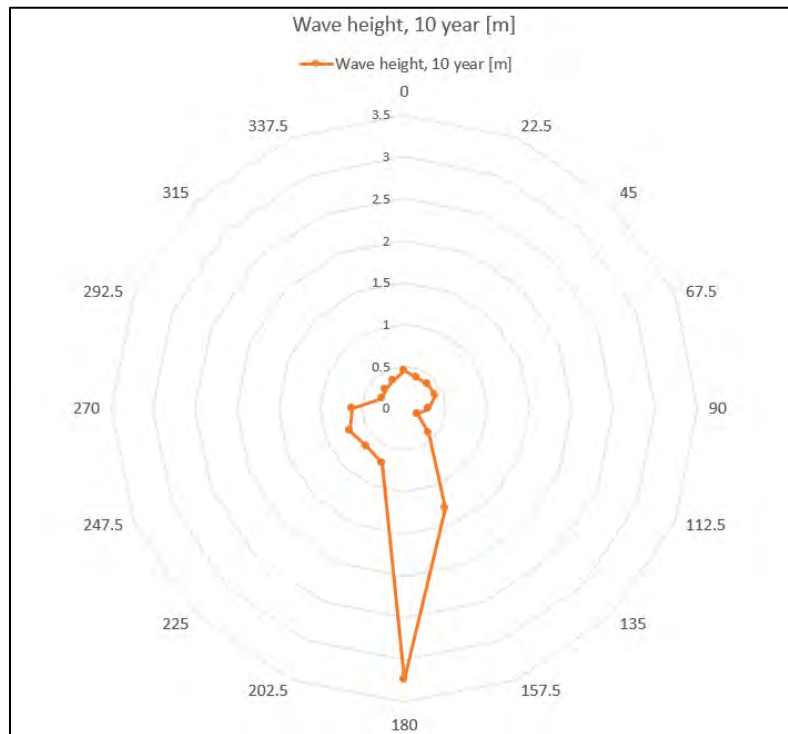



Figure 16 Maximum wave height at 10 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1205

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

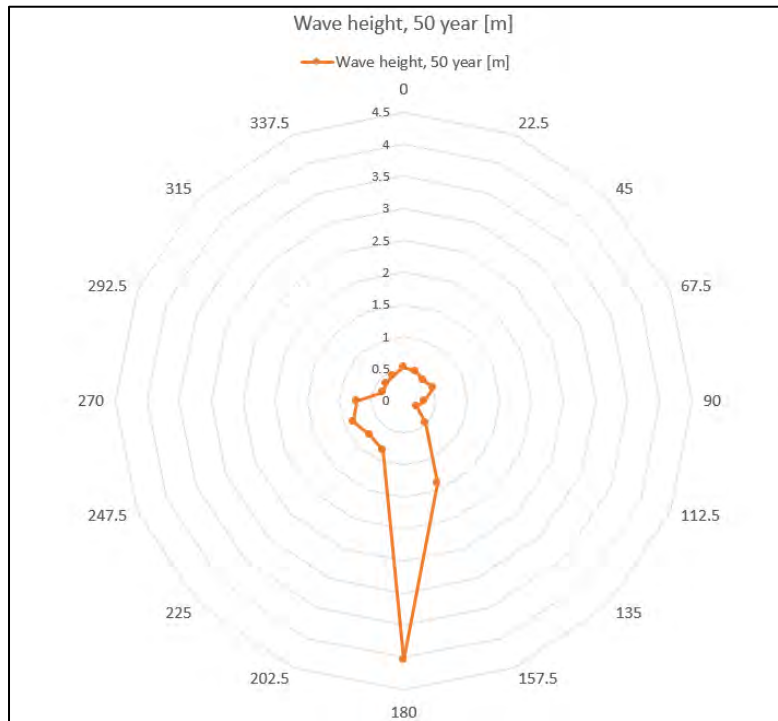



Figure 17 Maximum wave height at 50 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1205


#### 4.4.2 Wave/wind conditions for Liverpool Bay- Marine Finfish Lease- 1432

The wave and wind results from the STWave model, for the Liverpool Bay- Marine Finfish Lease- 1432, are summarized in Table 4. Note that the results in Table 4 indicate significant wave height ( $H_s$ ) and peak period ( $T_p$ ) for the selected site. These represent the extreme wave conditions at this coordinate: 44° 2.282'N, 64° 39.664'W.

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

**Table 4 Estimated wave and wind design conditions for Liverpool Bay- Marine Finfish Lease- 1432**

Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	Hs (m)	Tp (s)
10yr wave/wind	0	N	20.49	0.3	1.64
	23	NNE	21.4	0.16	1.35
	45	NE	21.49	0.55	8.23
	68	ENE	22.76	0.55	2.4
	90	E	19.37	0.57	2.26
	113	ESE	20.27	2.27	7.03
	135	SE	19.42	2.92	6.82
	158	SSE	19.96	3.42	6.5
	180	S	20.93	0.61	2.3
	203	SSW	20.07	0.39	2
	225	SW	19.48	0.43	2.56
	248	WSW	21.01	0.54	2.44
	270	W	21.47	0.6	2.43
	293	WNW	20.81	0.35	1.85
	315	NW	20.52	0.36	1.81
	338	NNW	20.13	0.35	1.67
50yr wave/wind	0	N	23.92	0.35	1.73
	23	NNE	25.51	0.22	1.53
	45	NE	25.44	0.64	9.33
	68	ENE	27.85	0.68	2.6
	90	E	22.55	0.68	2.4
	113	ESE	23.83	2.7	12.15
	135	SE	22.52	3.24	6.82
	158	SSE	23.39	3.89	14.61
	180	S	24.64	0.74	2.45
	203	SSW	23.37	0.48	2.14
	225	SW	22.16	0.5	2.71
	248	WSW	24.66	0.65	2.62
	270	W	24.84	0.71	2.6
	293	WNW	23.69	0.4	1.91
	315	NW	23.4	0.42	1.87
	338	NNW	23.23	0.42	1.76

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

It should be noted that the return periods indicated for each wave parameter in Table 4 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 18 and Figure 19.

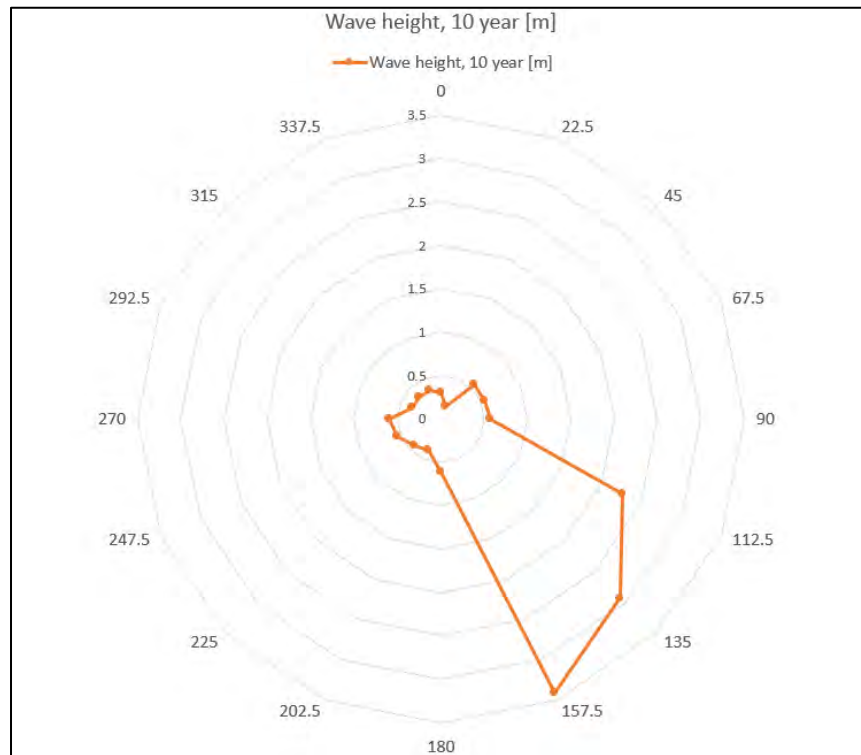



Figure 18 Maximum wave height at 10 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1432

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

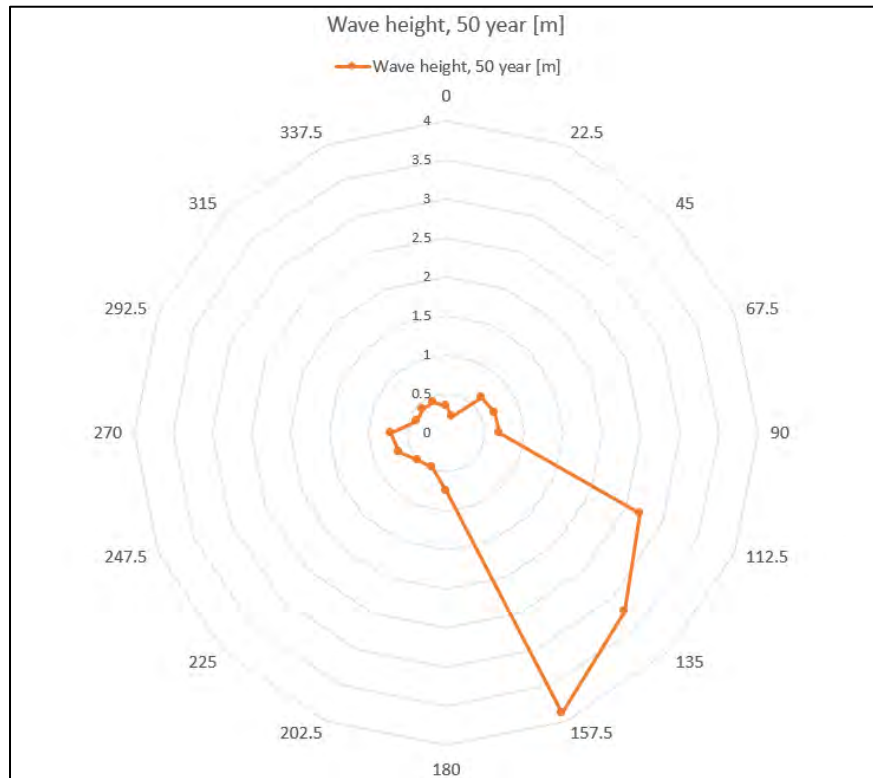



Figure 19 Maximum wave height at 50 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1432

#### 4.4.3 Wave/wind conditions for Liverpool Bay- Marine Finfish Lease- 1433

The wave and wind results from the STWave model, for the Liverpool Bay- Marine Finfish Lease- 1433, are summarized in Table 5. Note that the results in Table 5 indicate significant wave height ( $H_s$ ) and peak period ( $T_p$ ) for the selected site. These represent the extreme wave conditions at this coordinate: 44° 1.601'N, 64° 39.993'W.

Table 5 Estimated wave and wind design conditions for Liverpool Bay- Marine Finfish Lease- 1433


Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	$H_s$ (m)	$T_p$ (s)
10yr wave/wind	0	N	20.49	0.57	2.2
	23	NNE	21.4	0.4	2.1
	45	NE	21.49	0.83	8.23
	68	ENE	22.76	0.9	3.15
	90	E	19.37	2.4	7
	113	ESE	20.27	2.95	6.9
	135	SE	19.42	2.8	6.9

Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

	158	SSE	19.96	0.5	2.11
	180	S	20.93	0.31	1.7
	203	SSW	20.07	0.17	1.4
	225	SW	19.48	0.23	1.86
	248	WSW	21.01	0.32	1.78
	270	W	21.47	0.35	1.75
	293	WNW	20.81	0.35	2
	315	NW	20.52	0.6	2.3
	338	NNW	20.13	0.54	2.2
50yr wave/wind	0	N	23.92	0.68	2.35
	23	NNE	25.51	0.47	2.23
	45	NE	25.44	0.95	9
	68	ENE	27.85	1.1	3.44
	90	E	22.55	2.6	7
	113	ESE	23.83	3.3	6.9
	135	SE	22.52	3	11.9
	158	SSE	23.39	0.6	2.24
	180	S	24.64	0.38	1.77
	203	SSW	23.37	0.22	1.56
	225	SW	22.16	0.28	1.95
	248	WSW	24.66	0.39	1.86
	270	W	24.84	0.41	1.83
	293	WNW	23.69	0.42	2.13
	315	NW	23.4	0.7	2.44
	338	NNW	23.23	0.64	2.33

It should be noted that the return periods indicated for each wave parameter in Table 5 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 20 and Figure 21.



Title	Wind and Wave Conditions – Liverpool Bay – Marine Finfish Leases 1205, 1432, 1433			
Revision	B	Date Last Revised	2020-04-20	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

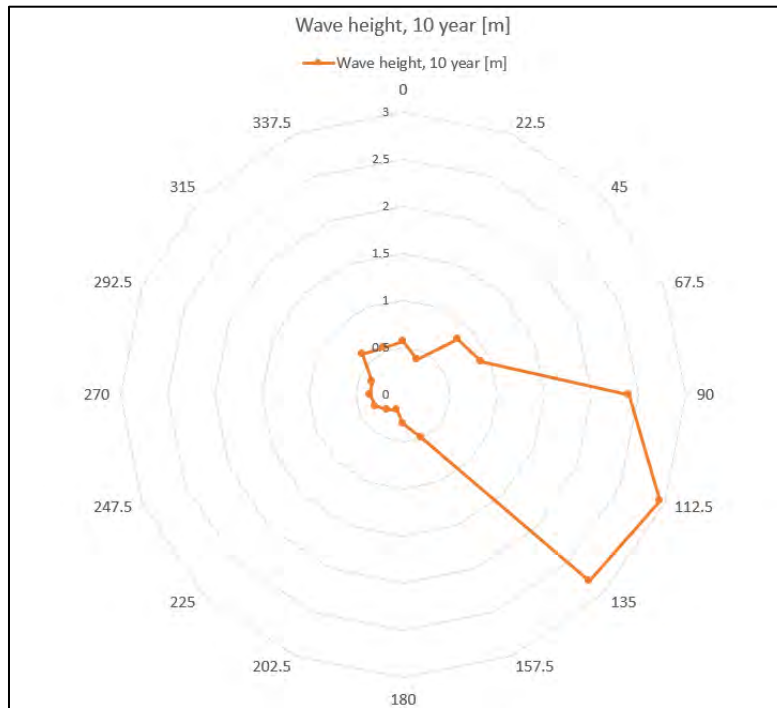


Figure 20 Maximum wave height at 10 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1433

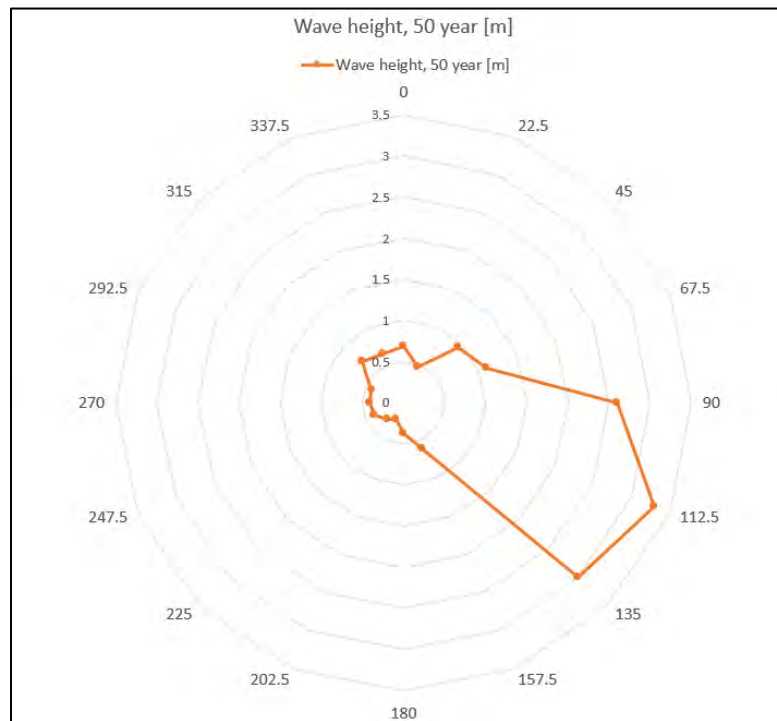


Figure 21 Maximum wave height at 50 year return period and direction [from]- Liverpool Bay- Marine Finfish Lease- 1433