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## **WIND AND WAVE CONDITIONS – ST. MARGARET’S BAY**

Prepared by:  
Meysam Karimi, PhD, Dean Steinke, P.Eng.  
Dynamic Systems Analysis

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Co-authors	Dean Steinke, P.Eng
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**DSA Pacific Office**


201-754 Broughton St  
Victoria, BC V8W 1E1  
+1.250.483.7207

**DSA Atlantic office**

210 – 3600 Kempt Road  
Halifax, NS B3K 4X8  
+1.902.407.3722


info@dsaocean.com  
www.dsaocean.com



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## Revision history

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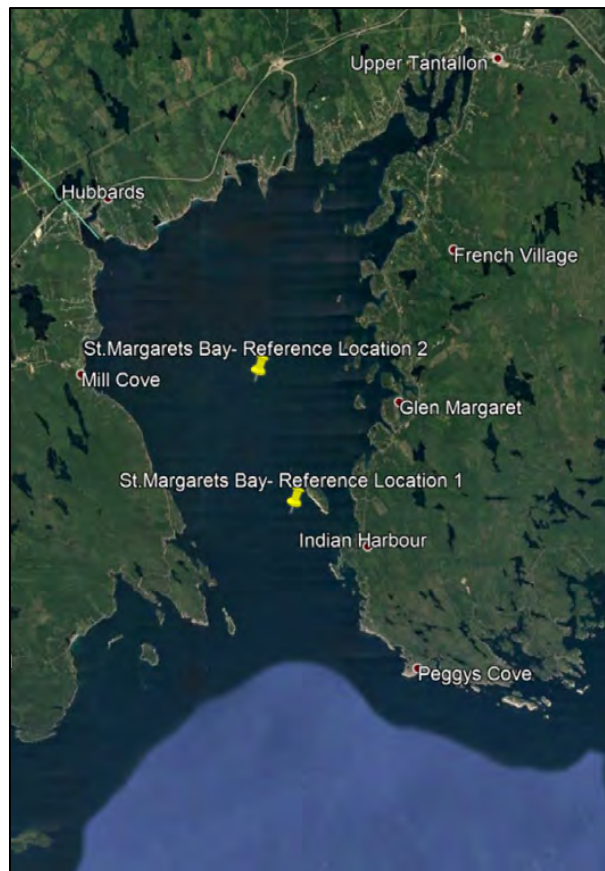
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## Executive Summary


In support of Centre for Marine Applied Research (CMAR), the following report presents wind and wave conditions at two reference locations in St. Margaret’s Bay, Nova Scotia, Canada.

In this report, wave and wind conditions are presented for 2 reference locations:

- St. Margaret’s Bay- Reference Location 1: 44° 32.554'N, 63° 58.175'W.
- St. Margaret’s Bay- Reference Location 2: 44° 35.071'N, 63° 59.153'W.



To determine the wave field evolution closer to shore at a specific location, and to determine more accurate 10 and 50 year return period wave data, near shore wave modelling is used. For the St. Margaret’s Bay area, STWave was used to model the nearshore wave conditions. The results showed reduced wave heights, in comparison to the hindcast model 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 reference locations are determined in part by propagating waves from the offshore hindcast model location into the site of interest.

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# 1 Introduction

## 1.1 Overview

For the reference locations in St. Margaret’s Bay, Nova Scotia, Canada, shown in Figure 1, extreme 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.

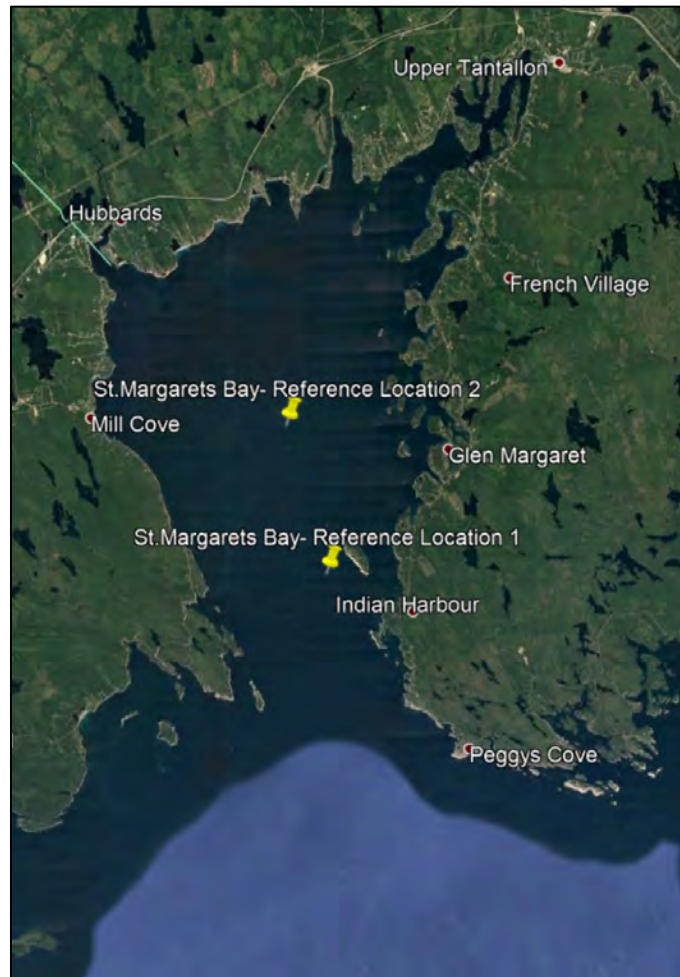

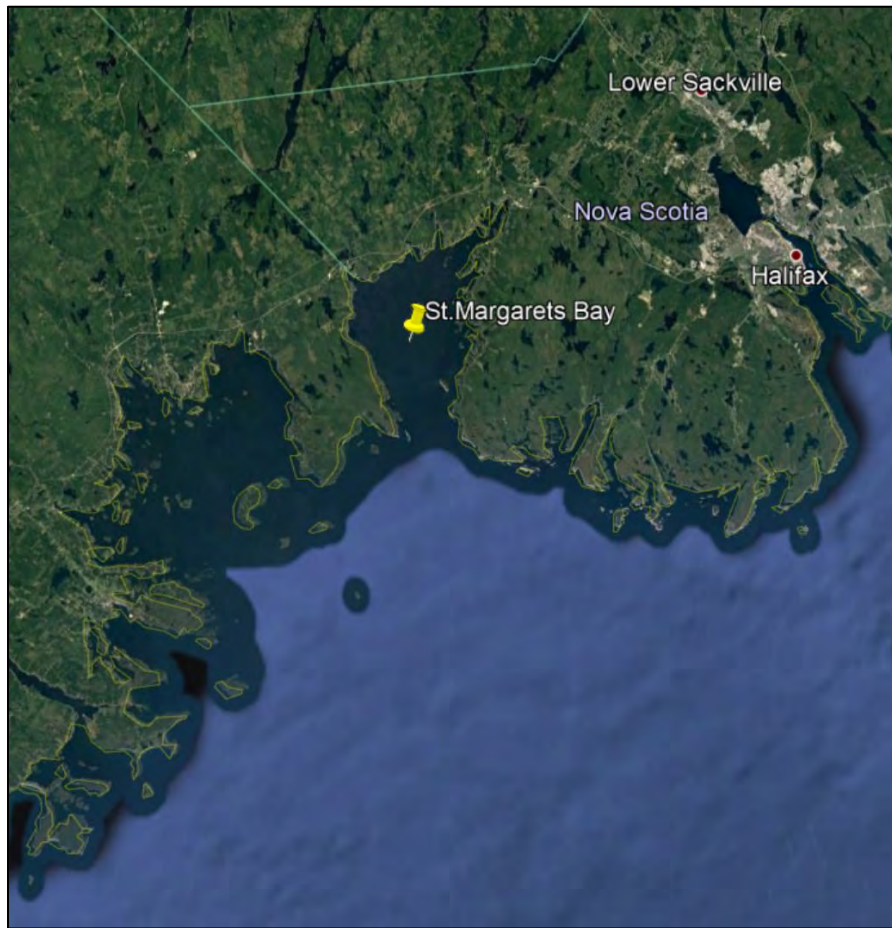


Figure 1 Two (2) reference locations at St. Margaret’s Bay [4]

The St. Margaret’s Bay is overall protected from offshore waves by surrounding lands, but is vulnerable to waves from the south 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. How much energy is lost and how much the wave height is reduced requires detailed wave modelling.



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**Figure 2 St. Margaret’s 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 not actual proposed 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 extreme wave/wind conditions at two reference locations in St. Margaret’s Bay with 10 and 50 year return periods.



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## 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]	Norwegian Standard NS9415.E:2009: Marine fish farms: Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation. Standards Norway
[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.

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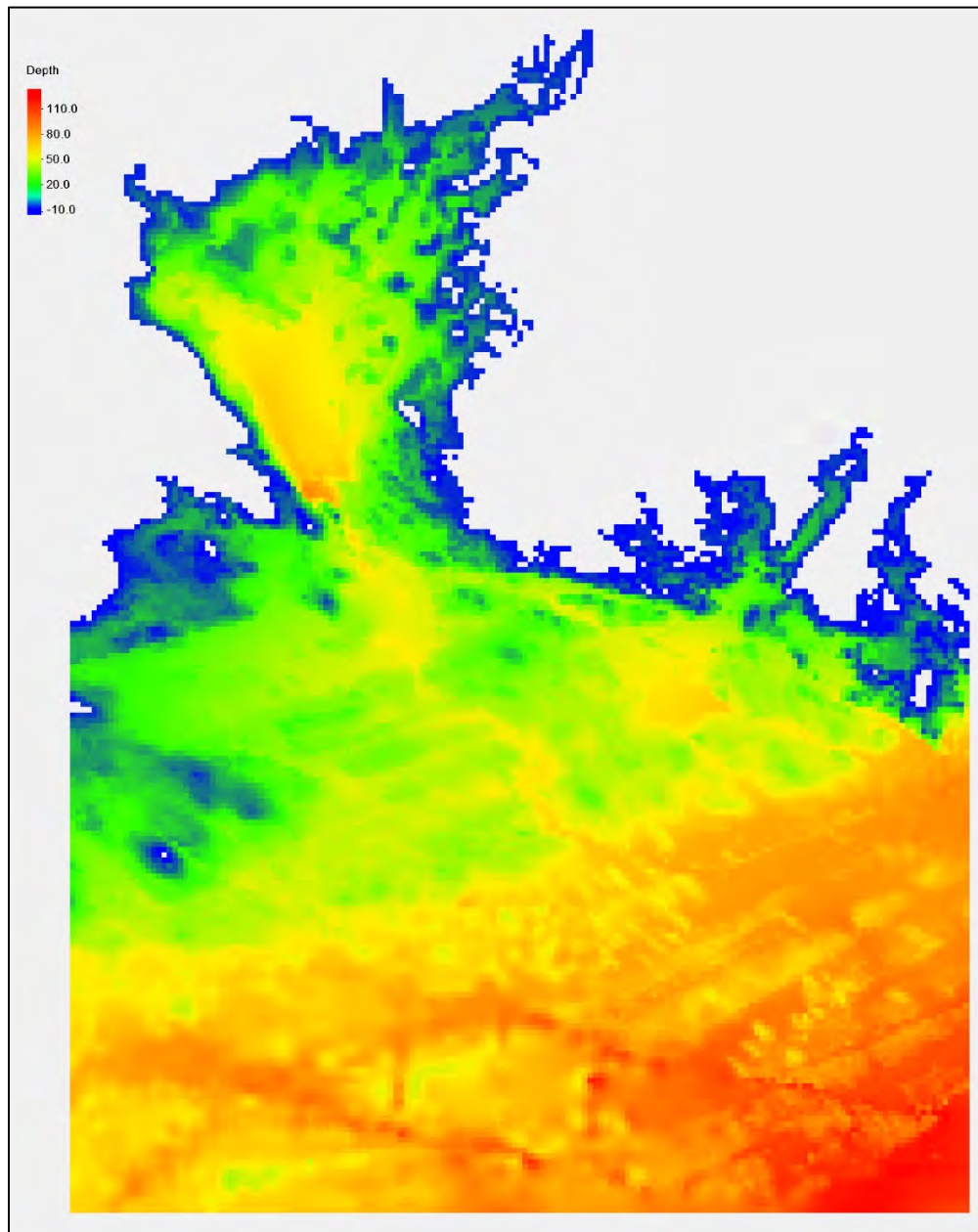



Figure 3 Bathymetry at site on hydrographic charts- Depth reported in meters

## 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.

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Two grids have to be 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 45 x 17.8 km. The mesh size was 25m x 25m, resulting in  $1803 \times 715 = 1,289,145$  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.

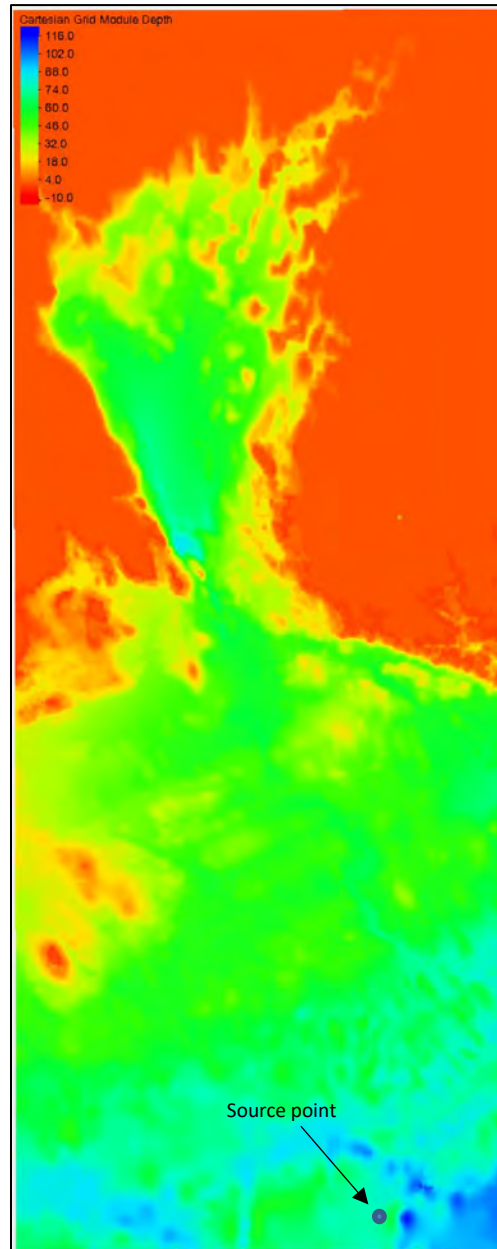



Figure 4: Bathymetry at site on STWave

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

The MSC50 HindCast model [1] data from location 44° 18.000'N, 63° 54.000'W was used to determine the 10 and 50 year return periods for wind and wave of the St. Margaret’s Bay reference locations; the location is labelled as the “Source point” in Figure 4. The scatter plot 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 winds at the source point appear to originate more frequently from the south.

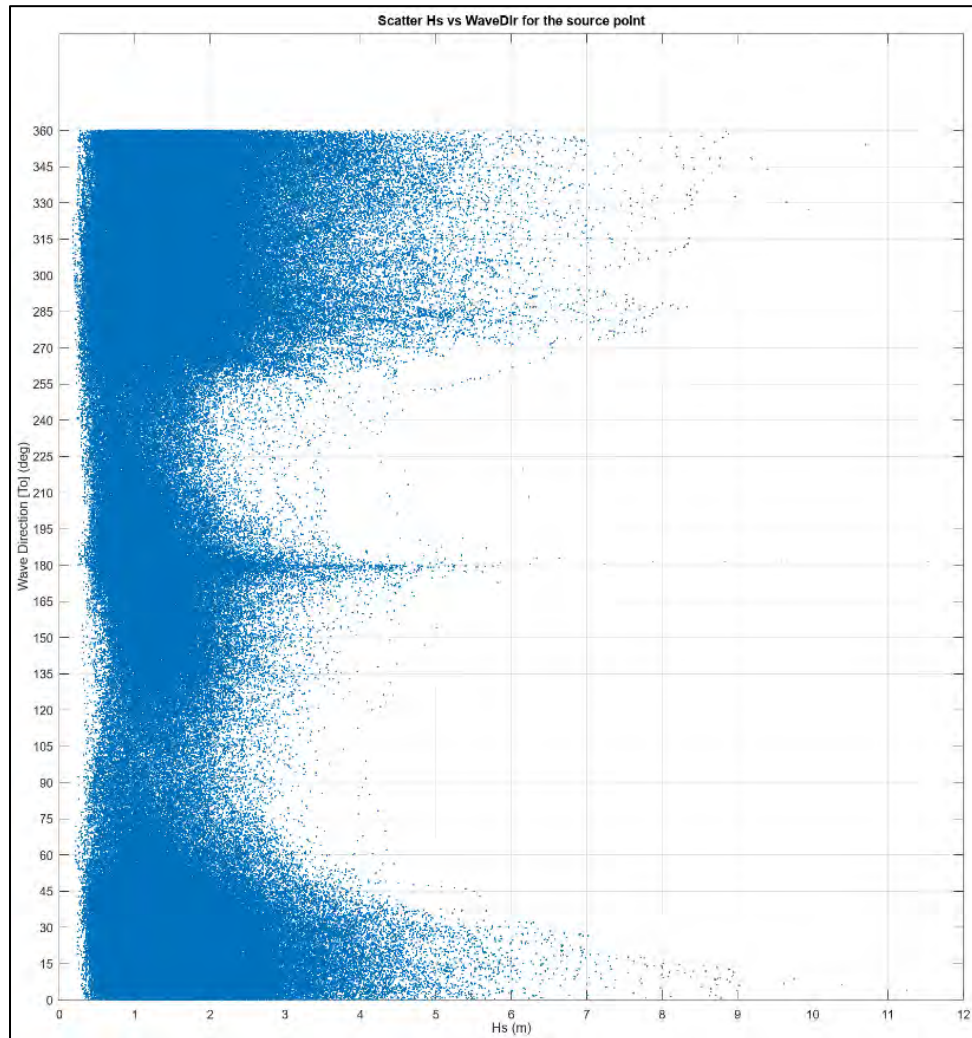



Figure 5 Wave height versus wave direction plot for the source point



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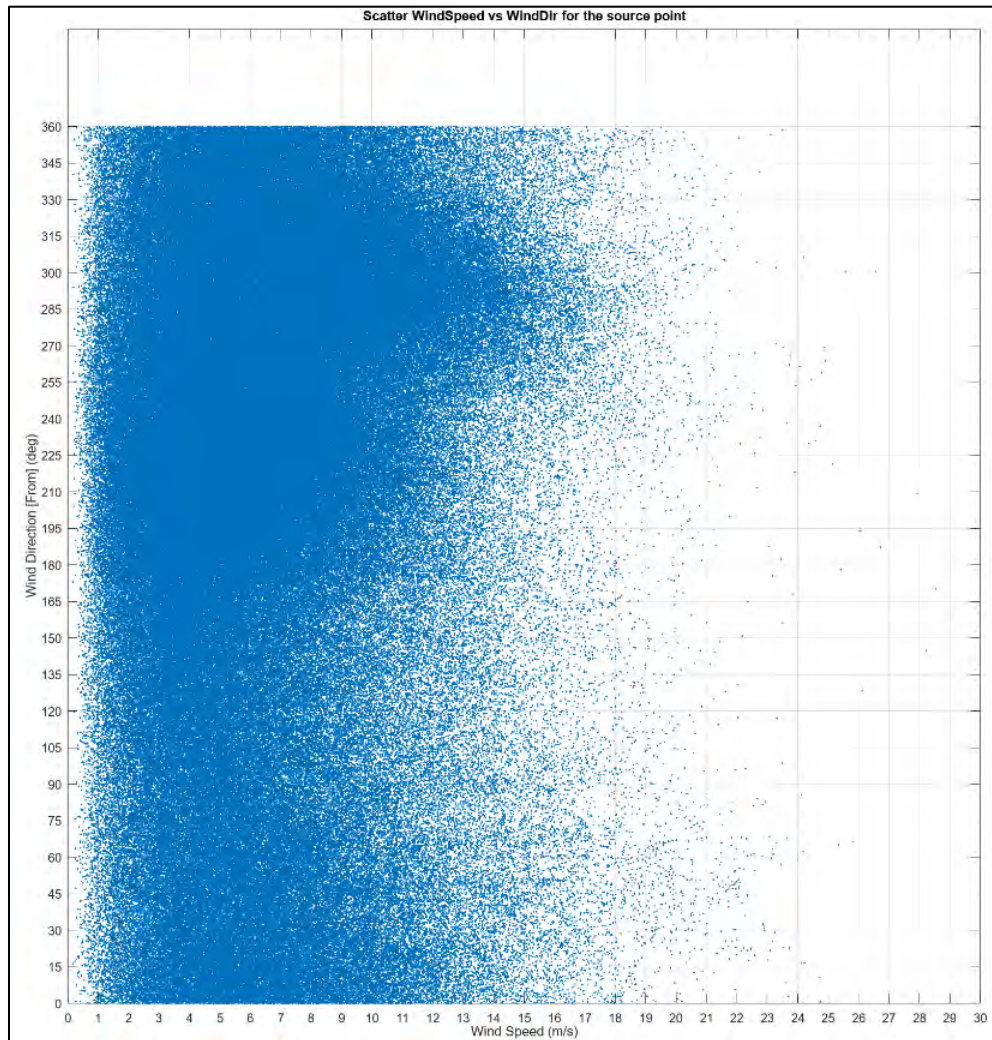



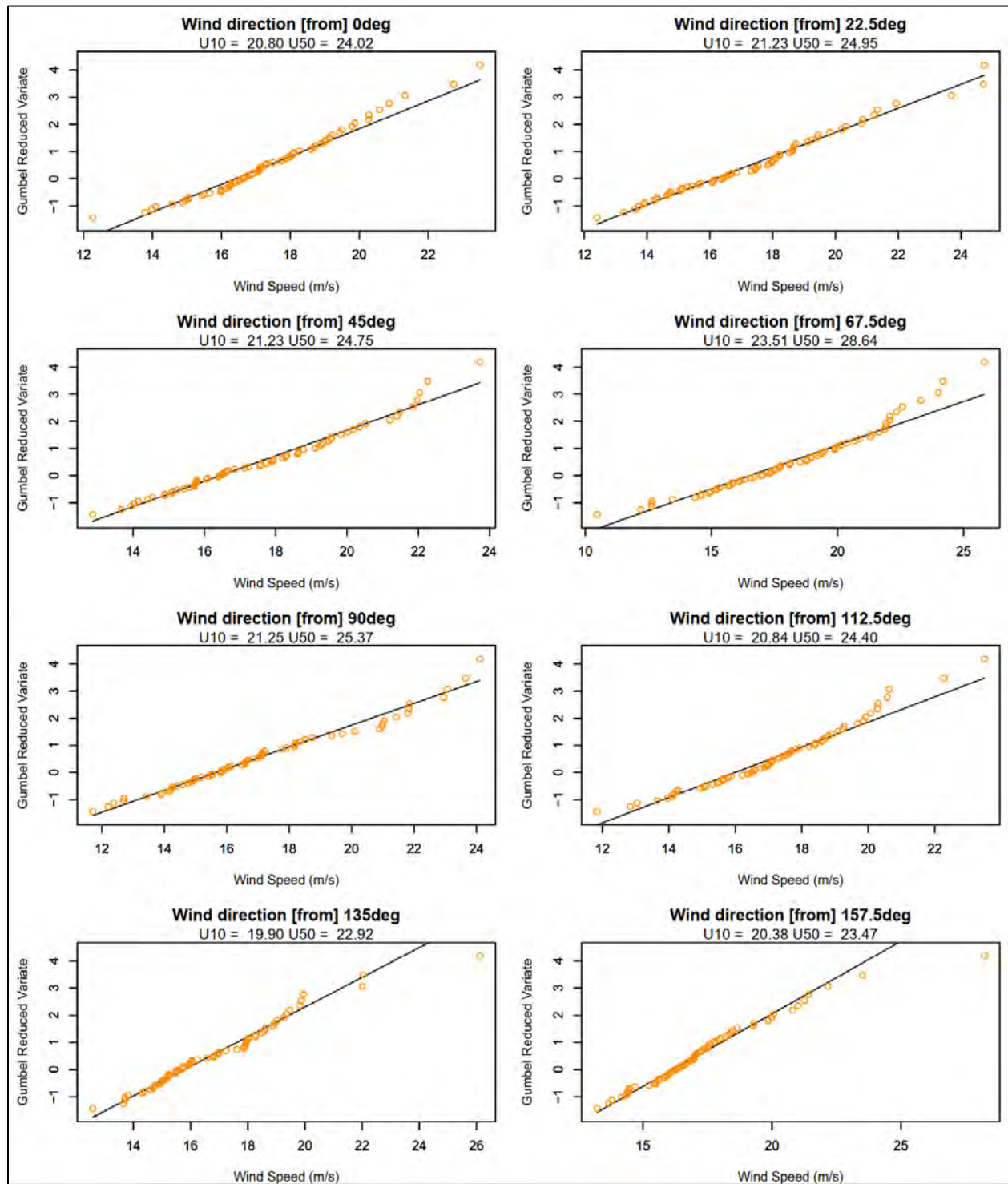
Figure 6 Wind speed versus wind direction plot for the source point

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.

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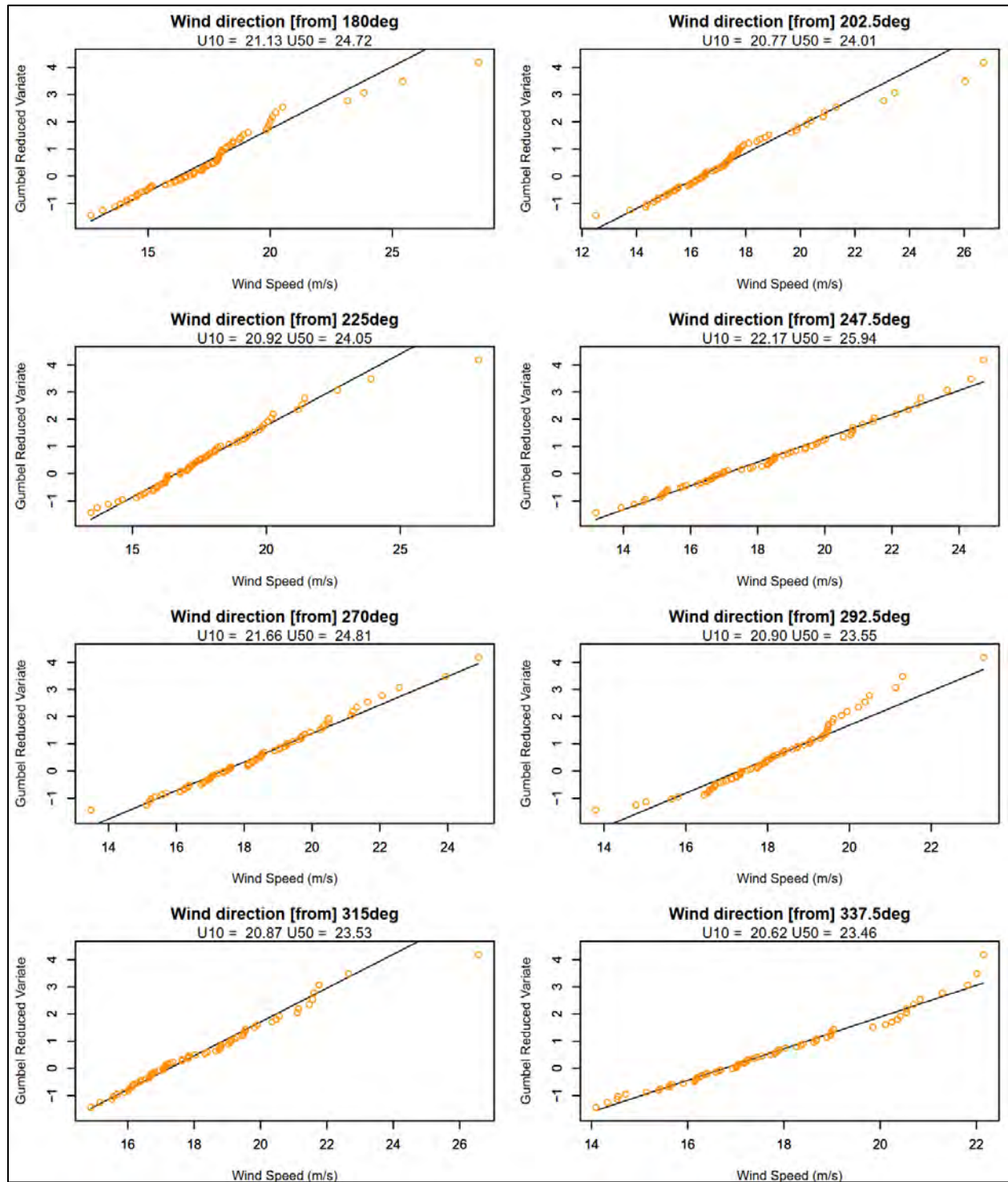

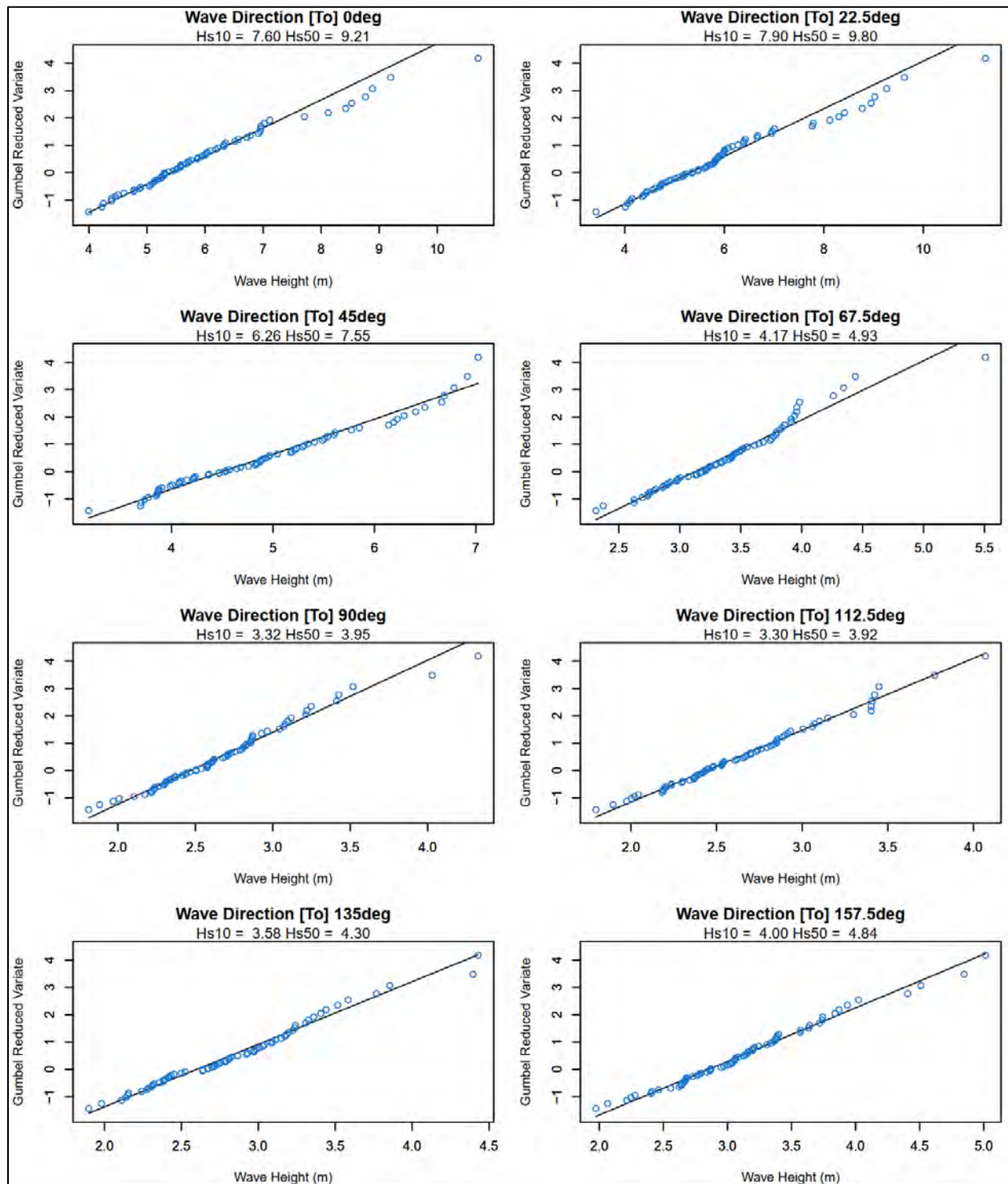



Figure 7: Extreme value analysis on wind data – for Source Point offshore location [1].

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.

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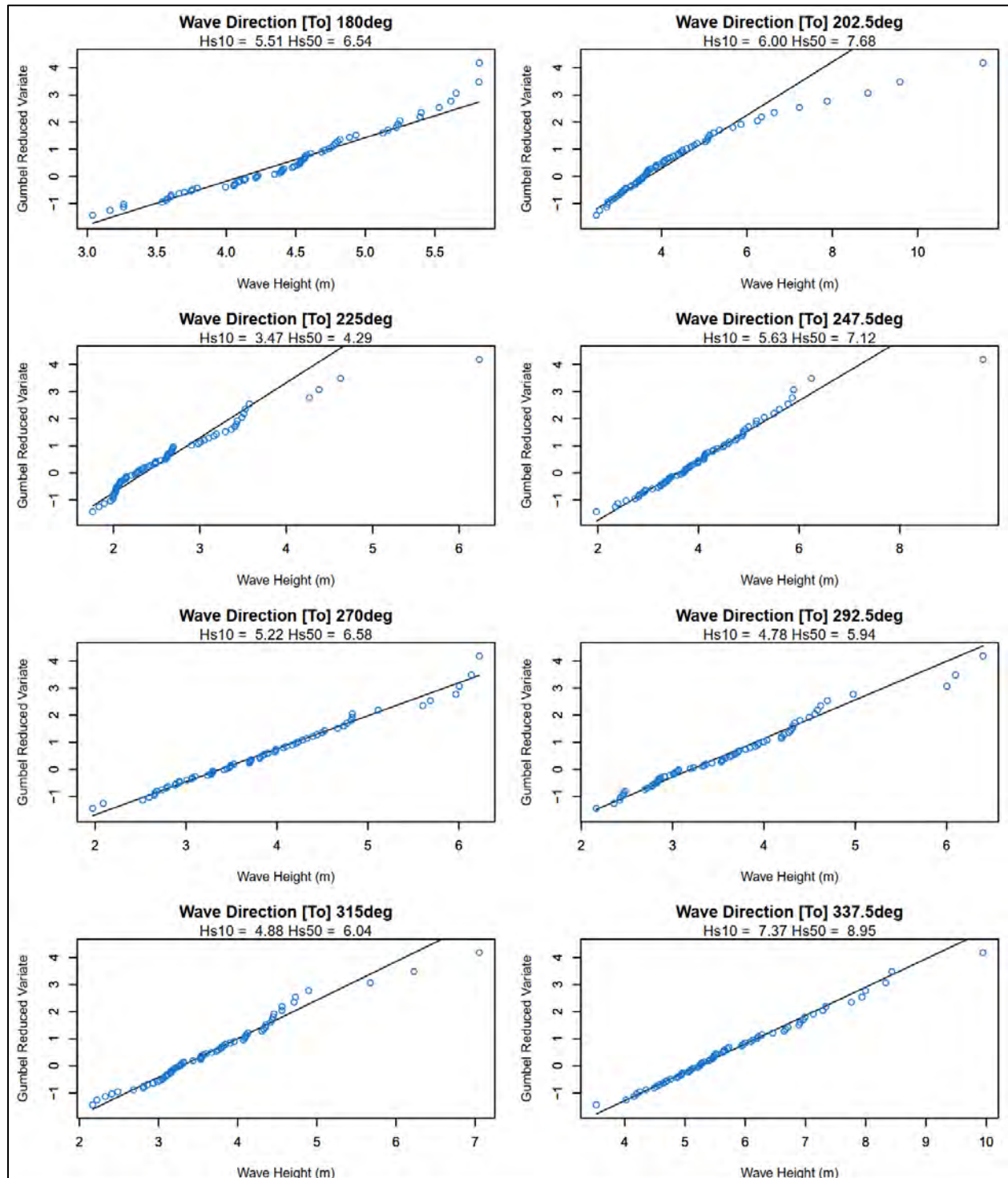



Figure 8: Extreme value analysis on wave data – for Source Point offshore location [1]


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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	20.8	24.02	5.51	6.54
23	NNE	21.23	24.95	6	7.68
45	NE	21.23	24.75	3.47	4.29
68	ENE	23.51	28.64	5.63	7.12
90	E	21.25	25.37	5.22	6.58
113	ESE	20.84	24.4	4.78	5.94
135	SE	19.9	22.92	4.88	6.04
158	SSE	20.38	23.47	7.37	8.95
180	S	21.13	24.72	7.6	9.21
203	SSW	20.77	24.01	7.9	9.8
225	SW	20.92	24.05	6.26	7.55
248	WSW	22.17	25.94	4.17	4.93
270	W	21.66	24.81	3.32	3.95
293	WNW	20.9	23.55	3.3	3.92
315	NW	20.87	23.53	3.58	4.3
338	NNW	20.62	23.46	4	4.84

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.

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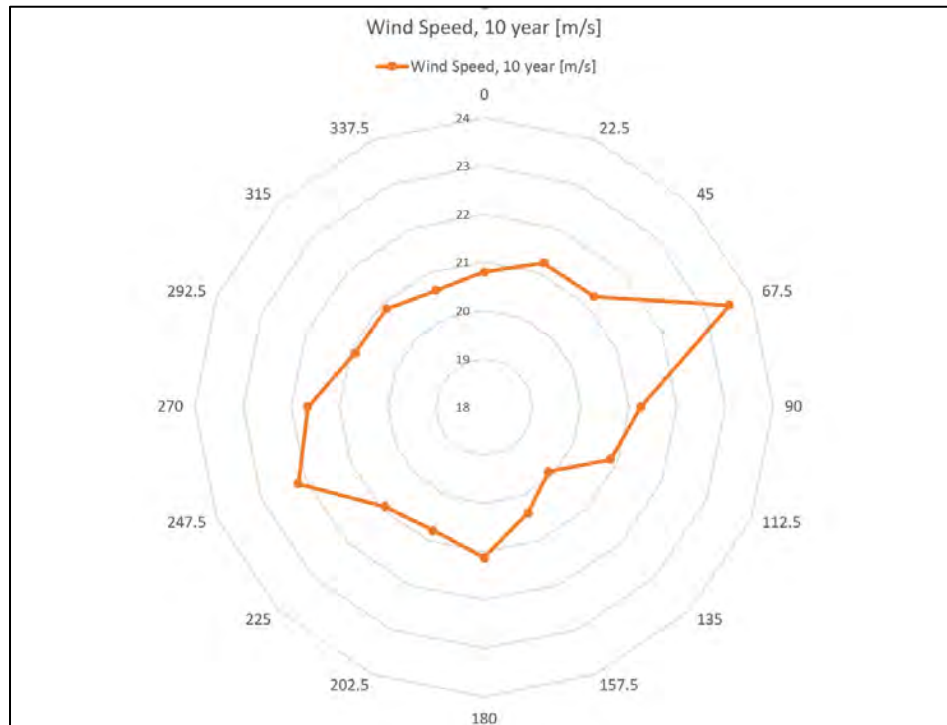


Figure 9 Maximum wind speed at 10 year return period and direction [from]- for Source Point offshore location [1]

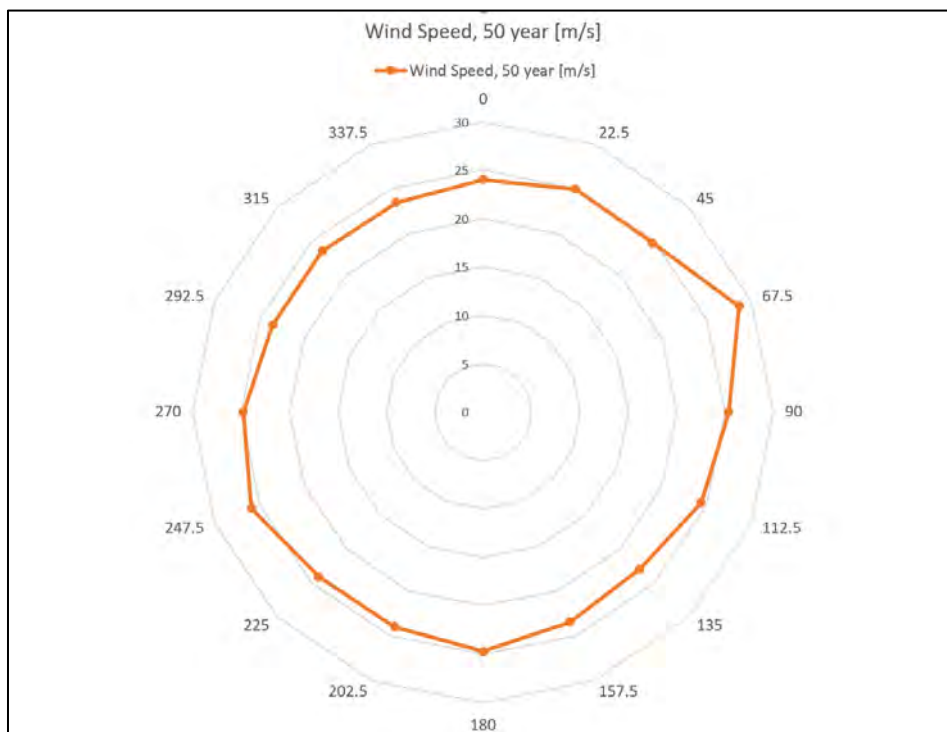


Figure 10 Maximum wind speed at 50 year return period and direction [from]- for Source Point offshore location [1]




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

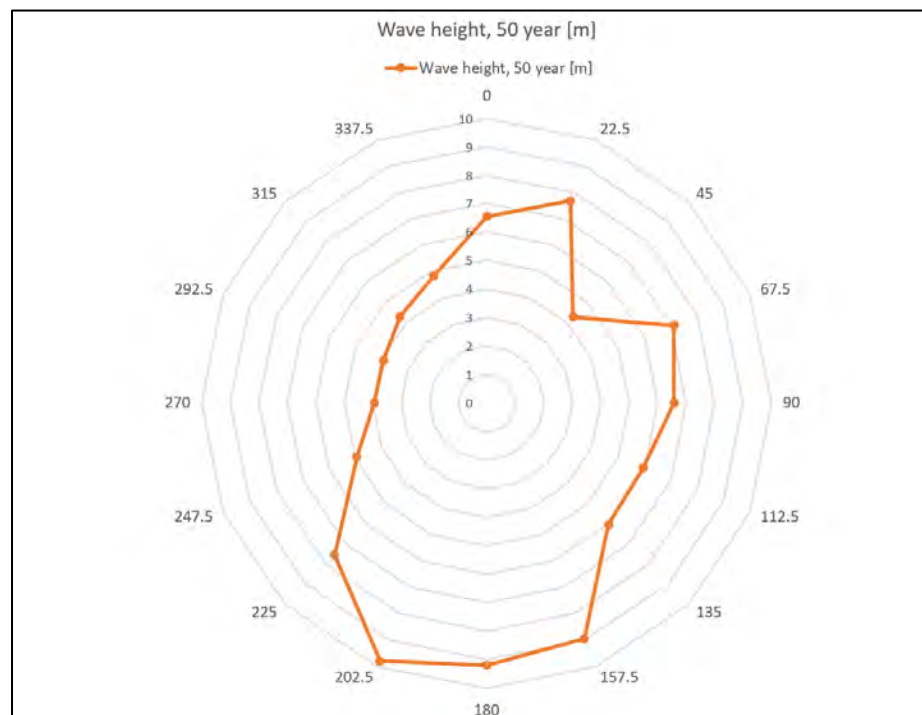



Figure 12 Maximum wave height at 50 year return period and direction [from]- for Source Point offshore location [1]



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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	7.98_14.77
23	NNE	5.57_15.5
45	NE	4.5_14
68	ENE	7.35_15.3
90	E	7.8_13.2
113	ESE	7.42_14.15
135	SE	8.5_13.9
158	SSE	8.3_15
180	S	8.9_15
203	SSW	8.3_16
225	SW	8_14
248	WSW	5.5_12.3
270	W	4.7_12.1
293	WNW	4.8_12
315	NW	5.1_13.5
338	NNW	5.2_14.2

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 location.

#### 4.4 Wave modeling results

The results of the wave modeling are presented in Figure 13 to Figure 15 for directions from south, southwest, and southeast 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.

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The reference locations within St. Margaret’s Bay are presented in Figure 1. The predicted wave and wind conditions for each location are presented in the following sections.

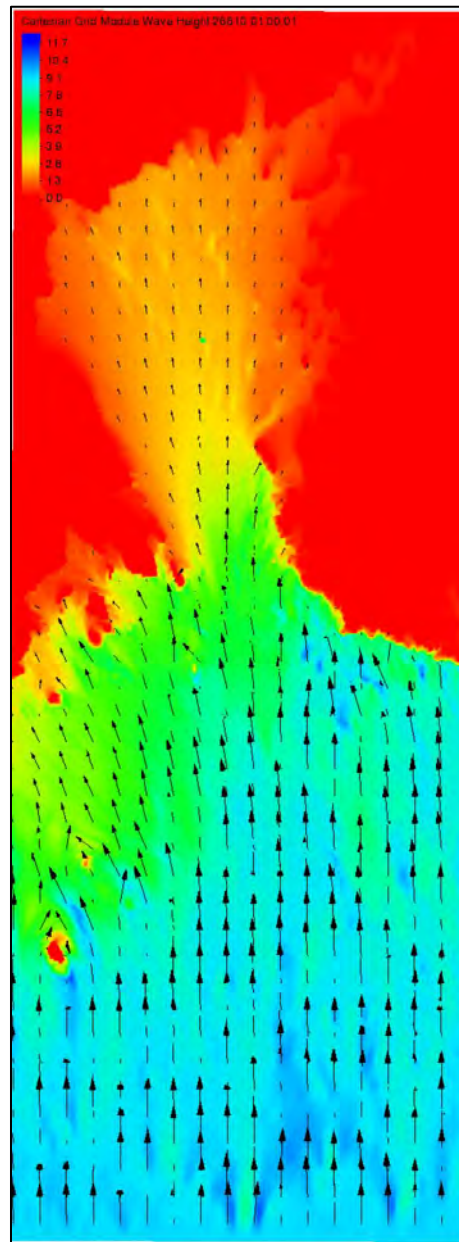



Figure 13 Wave modeling results for direction [From] 180 deg- S

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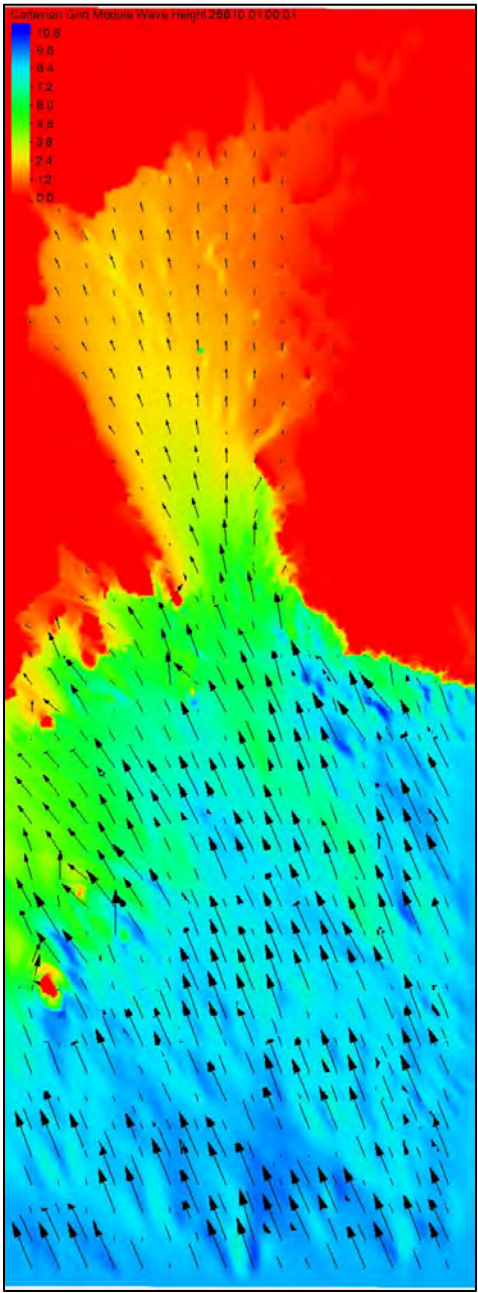



Figure 14 Wave modeling results for direction [From] 158 deg- SSE

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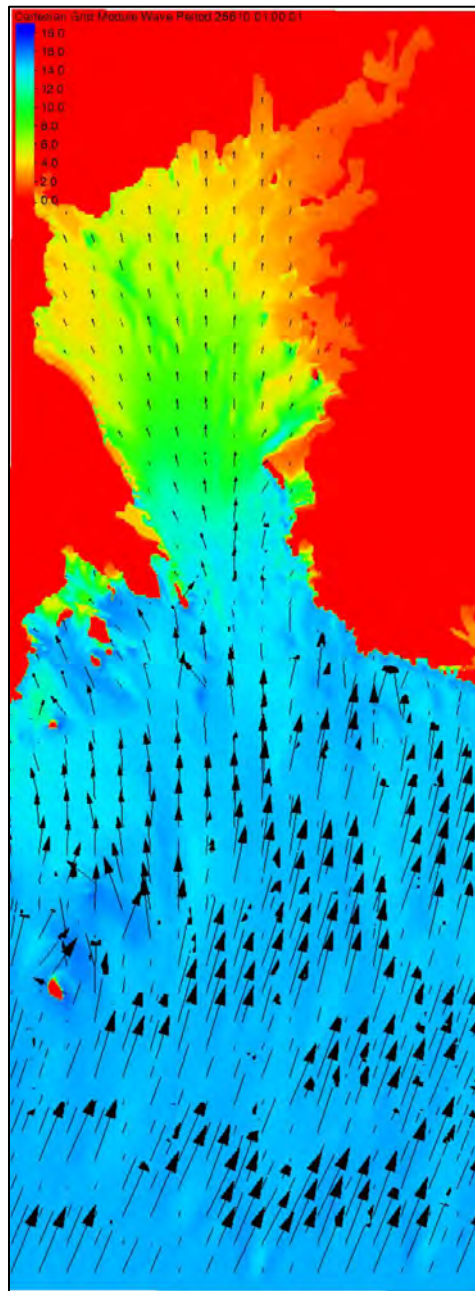



Figure 15 Wave modeling results for direction [From] 203 deg- SSW


#### 4.4.1 Wave/wind conditions for St. Margaret’s Bay- Reference Location 1

The recommended wave and wind results from the STWave model, for the St. Margaret’s Bay- Reference Location 1, summarized in Table 3. Note that the results in Table 3 indicates significant wave height ( $H_s$ ) and peak period ( $T_P$ ) for the location. These represent the extreme wave conditions at this coordinate: 44° 32.554'N, 63° 58.175'W.

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**Table 3 Recommended wave and wind design conditions for St. Margaret's Bay- Reference Location 1**

Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	Hs (m)	Tp (s)
10yr wave/wind	0	N	20.8	1.34	3.65
	23	NNE	21.23	0.72	3.04
	45	NE	21.23	0.56	2.22
	68	ENE	23.51	0.48	2.1
	90	E	21.25	0.53	2.05
	113	ESE	20.84	0.46	2.1
	135	SE	19.9	0.71	3.27
	158	SSE	20.38	1.5	4.36
	180	S	21.13	3.35	10.3
	203	SSW	20.77	2.41	11.32
	225	SW	20.92	1.28	8.9
	248	WSW	22.17	0.87	2.8
	270	W	21.66	0.93	2.85
	293	WNW	20.9	0.75	2.83
	315	NW	20.87	1.1	3.95
	338	NNW	20.62	1.3	3.66
50yr wave/wind	0	N	24.02	1.6	3.9
	23	NNE	24.95	0.9	3.28
	45	NE	24.75	0.66	2.37
	68	ENE	28.64	0.6	2.3
	90	E	25.37	0.65	2.2
	113	ESE	24.4	0.56	2.26
	135	SE	22.92	0.8	3.32
	158	SSE	23.47	1.75	4.62
	180	S	24.72	3.43	10.2
	203	SSW	24.01	2.51	10.7
	225	SW	24.05	1.37	7.8
	248	WSW	25.94	1.04	3
	270	W	24.81	1.1	3.02
	293	WNW	23.55	0.85	3
	315	NW	23.53	1.27	4.16
	338	NNW	23.46	1.51	3.9

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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.

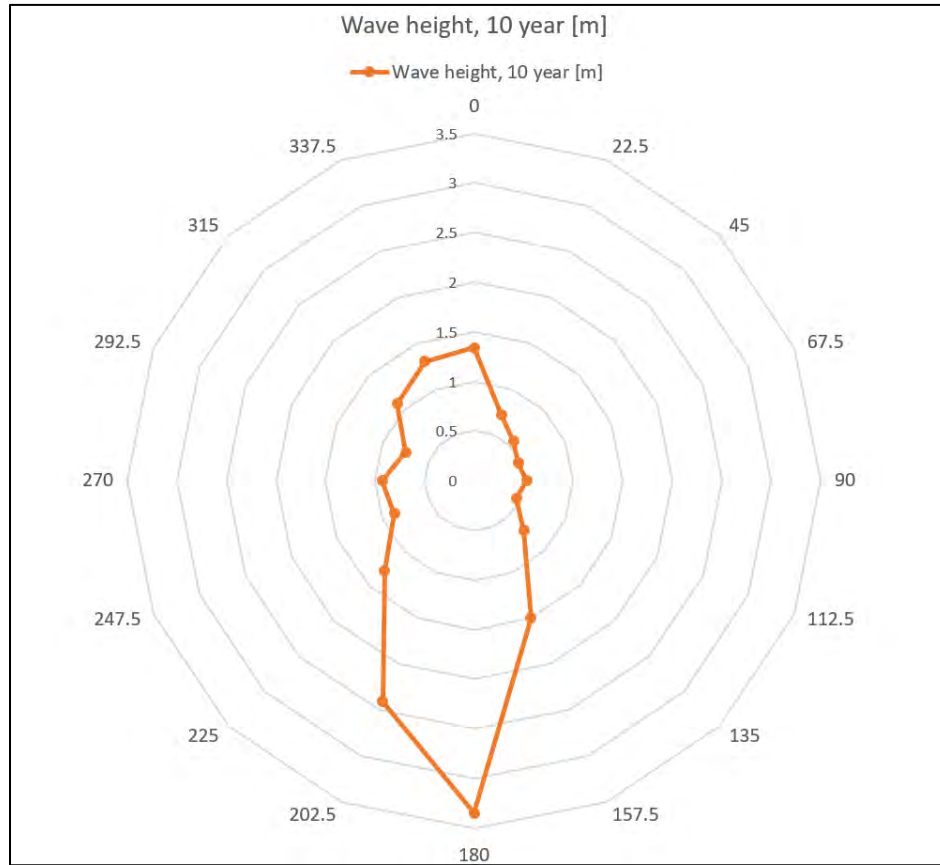



Figure 16 Maximum wave height at 10 year return period and direction [from]- St. Margaret's Bay- Reference Location 1



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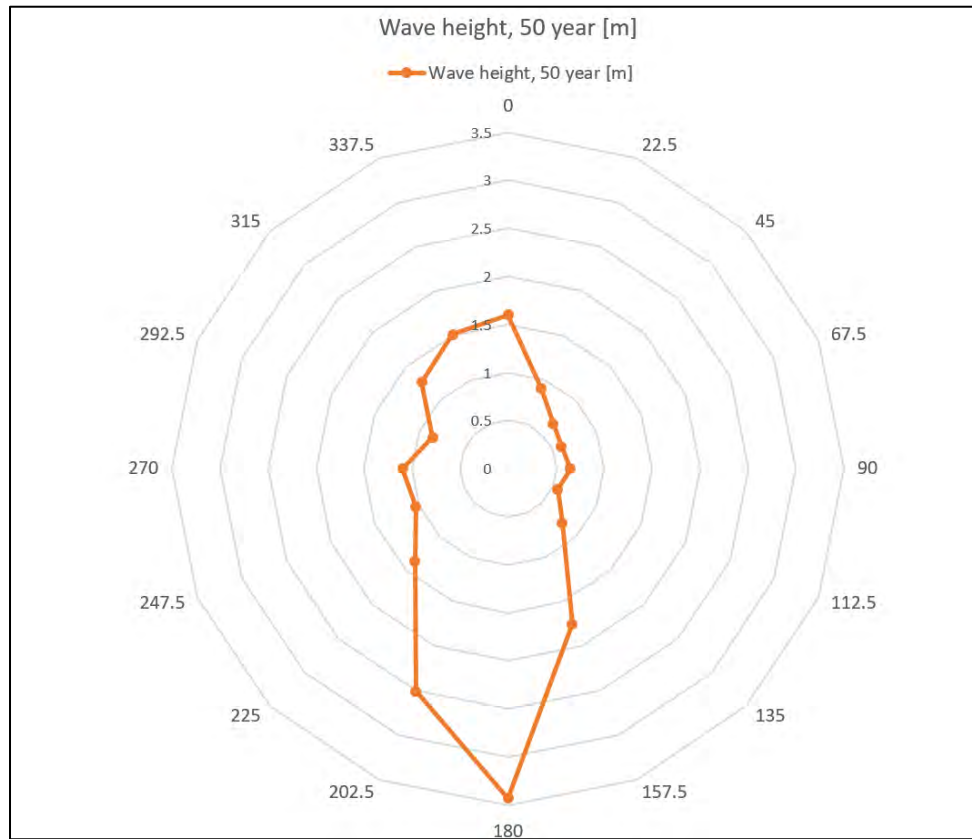



Figure 17 Maximum wave height at 50 year return period and direction [from]- St. Margaret's Bay- Reference Location 1

#### 4.4.2 Wave/wind conditions for St. Margaret's Bay- Reference Location 2

The recommended wave and wind results from the STWave model, for the St. Margaret's Bay- Reference Location 2, 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 location. These represent the extreme wave conditions at this coordinate: 44° 35.071'N, 63° 59.153'W.


Table 4 Recommended wave and wind design conditions for St. Margaret's Bay- Reference Location 2

Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	$H_s$ (m)	$T_p$ (s)
10yr wave/wind	0	N	20.8	1.1	3.2
	23	NNE	21.23	0.9	3.3
	45	NE	21.23	0.9	3
	68	ENE	23.51	0.93	2.95
	90	E	21.25	0.85	2.8
	113	ESE	20.84	0.62	2.64
	135	SE	19.9	0.75	2.8

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	158	SSE	20.38	1.48	4.34
	180	S	21.13	2.24	8.15
	203	SSW	20.77	0.73	2.84
	225	SW	20.92	0.8	3.17
	248	WSW	22.17	0.93	3.07
	270	W	21.66	1.04	3.05
	293	WNW	20.9	0.77	2.92
	315	NW	20.87	0.92	3.5
	338	NNW	20.62	1.01	3.22
50yr wave/wind	0	N	24.02	1.3	3.4
	23	NNE	24.95	1.07	3.53
	45	NE	24.75	1.07	3.17
	68	ENE	28.64	1.16	3.22
	90	E	25.37	1.04	3
	113	ESE	24.4	0.75	2.9
	135	SE	22.92	0.88	3
	158	SSE	23.47	1.73	4.6
	180	S	24.72	2.35	7.9
	203	SSW	24.01	0.87	3.04
	225	SW	24.05	0.95	3.4
	248	WSW	25.94	1.12	3.3
	270	W	24.81	1.22	3.24
	293	WNW	23.55	0.88	3.1
	315	NW	23.53	1.05	3.66
	338	NNW	23.46	1.18	3.41

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.

Title	Wind and Wave Conditions – St. Margaret's Bay			
Revision	C	Date Last Revised	2020-03-24	
DSA Project	CMAR-19EXM	Client Project / Reference	N/A	

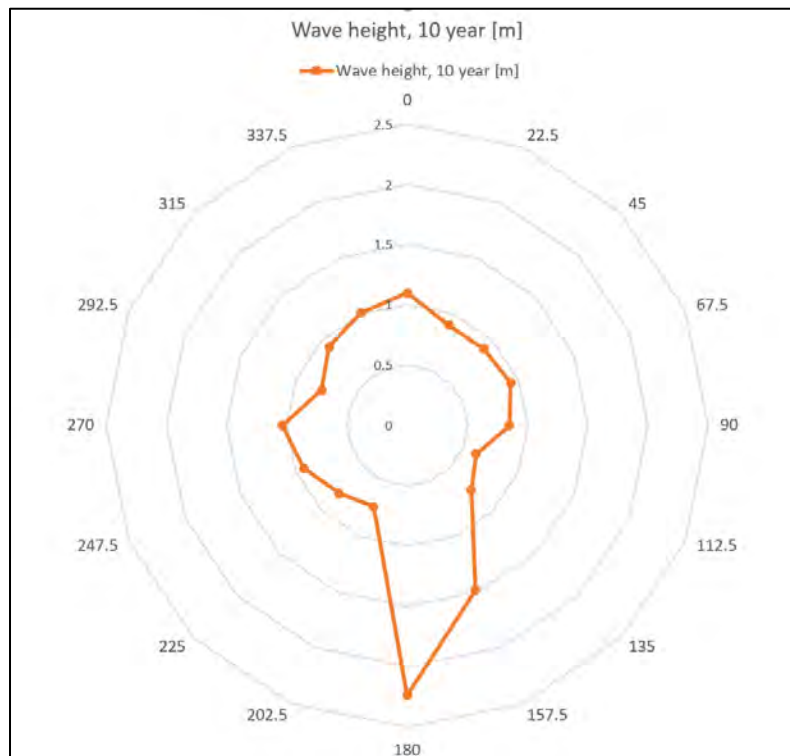


Figure 18 Maximum wave height at 10 year return period and direction [from]- St. Margaret's Bay- Reference Location 2

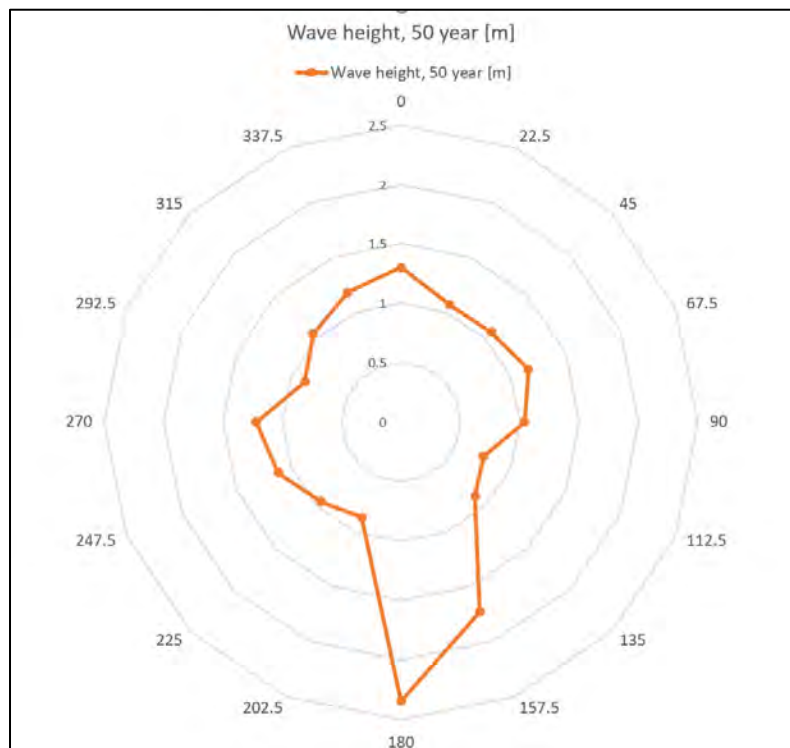


Figure 19 Maximum wave height at 50 year return period and direction [from]- St. Margaret's Bay- Reference Location 2