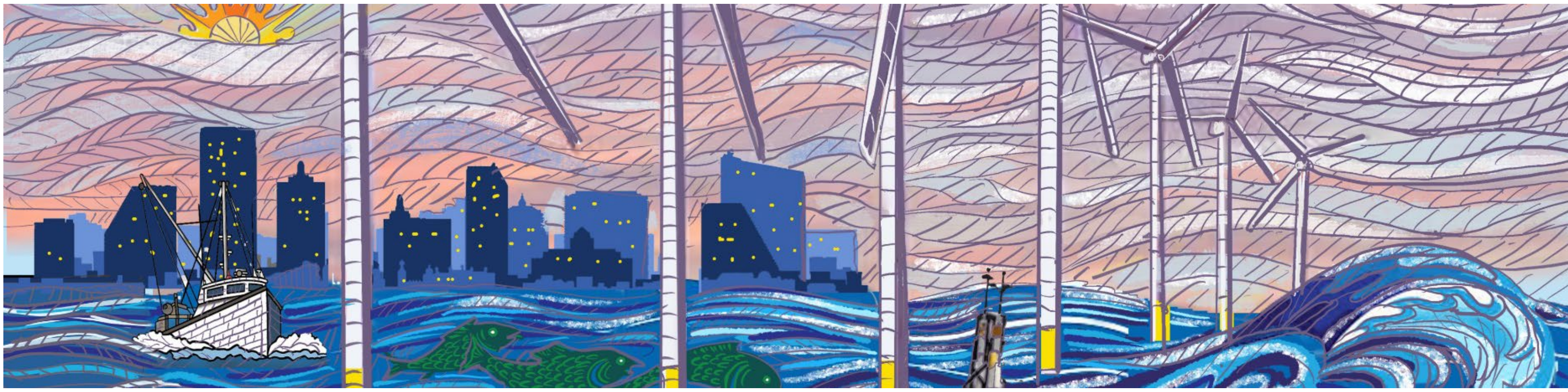

Appendix II-B2

Metocean Design Basis

Redacted Version - Confidential and/or Privileged Information Removed

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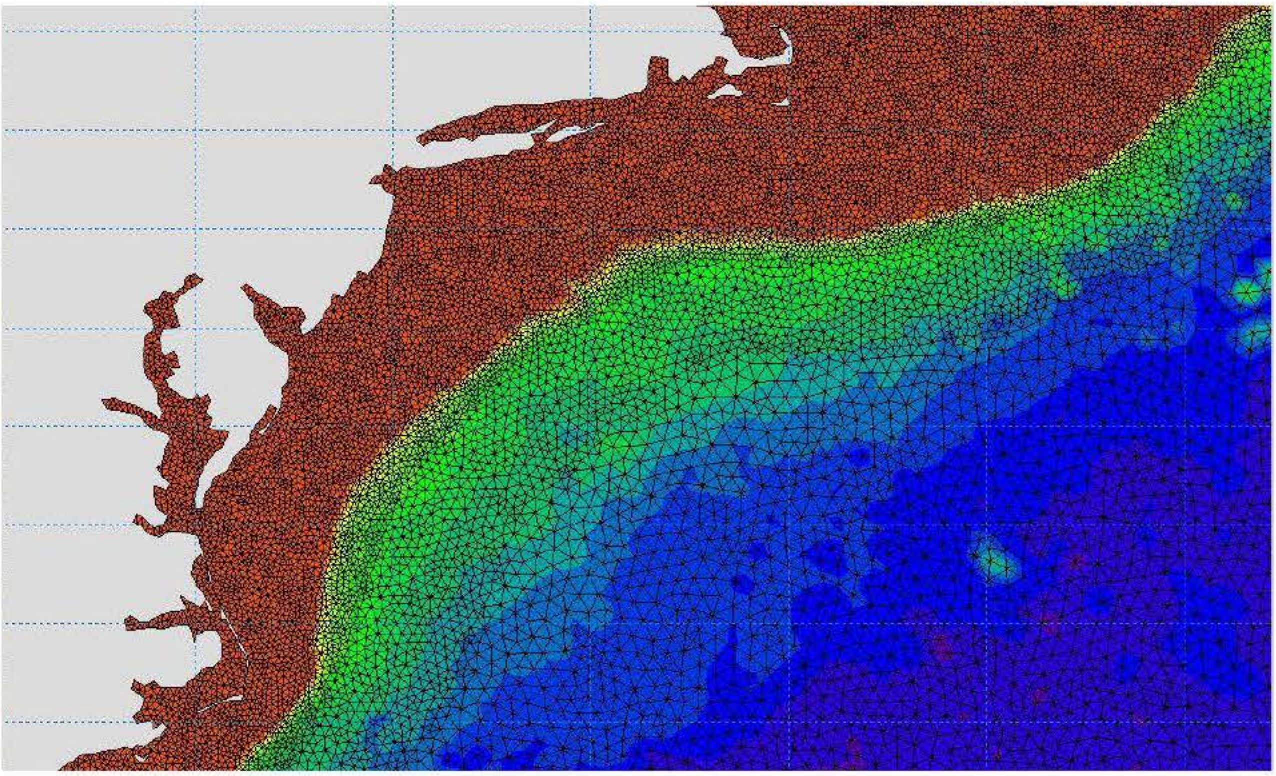
ATLANTIC SHORE OFFSHORE WIND FARM
VOLUME 2 - METOCEAN DESIGN BASIS



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Made by	**FHD**
Checked by	**JAN**
Approved by	**AOP**
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2	15.07.2020	FHD	JAN	AOP	Issued for comments

CONTENTS

Glossary

A	Weibull scale parameter
H_s	Significant wave height, occasionally denoted H_{m0}
H_{max}	Maximum wave height
k	Weibull shape parameter
MWD	Total mean wave direction
T_p	Peak wave period
T_{Hmax}	Associated wave period for maximum wave height
U	Mean wind speed
U_{10}	10-minute mean wind speed at 10 meter above mean sea level
U_{135}	10-minute mean wind speed at 135 meter above mean sea level
WIN	Wind direction
γ	Weibull offset parameter
HAT (Highest Astronomical Tide) LAT (Lowest Astronomical Tide)	Highest Astronomical Tide & Lowest Astronomical Tide The highest and lowest levels respectively which can be predicted to occur irrespective of the meteorological conditions but depending on astronomical constellations; these levels will not be reached every year. HAT and LAT are not the extreme levels which can be reached, as storm surges may cause considerably higher and lower levels to occur.
MHHW (Mean Higher High Water)	The average height of the highest tide recorded at a tide station each day during the recording period.
MHW (Mean High Water)	The tidal datum representing the average of all the daily tidal high-water heights observed over a period of 19 years.
NAVD88 (North American Vertical Datum of 1988)	The vertical datum for orthometric heights established for vertical control surveying in the United States of America.
MSL (Mean Sea Level)	Mean height of the surface of the sea for all stages of the tide over a 19-year period.
MTL (Mean Tide Level)	Arithmetic mean of mean high water and mean low water levels
MLW (Mean Low Water)	The tidal datum representing the average of all the daily tidal low-water heights observed over a period of 19 years.
MLLW Mean Lower Low Water	Lowest of the two low tides per day (or the one low tide) averaged over a 19-year period.

1. INTRODUCTION

This document provides supporting information and methodologies employed to develop the metocean design criteria which will be used for the pre-FEED design of the Atlantic Shore Offshore Wind Farm.

The report is provided as a two-volume document:

Volume 1 – Metocean Analysis
Volume 2 – Metocean Design Basis

Volume 1 presents metocean design criteria for operational and extreme conditions in a concise tabular format for the project locations provided in Table 1-1.

Volume 2, this document, presents the full background information including descriptions of the data sets and methodologies employed to develop the metocean design criteria presented in the Volume 1 of this document.

Table 1-1 Locations used in the analysis

Location	Coordinate	Water Depth
P1	39.30 °N, 74.10 °W	26.25 m
P2	39.55 °N, 74.00 °W	24.25 m

Present metocean study does not constitute a full wind study, which is required for wind turbine design. The analysis of the wind data carried out in this study is solely intended for foundation design. In the next design phase where wind and wave loads are expected to be combined during the load iteration process, ensuring that the support structure is designed appropriately for the respective turbine loads, the consistency of the wind information used in the full wind study and metocean study should be ensured.

2. DEFINITIONS

2.1 Directional Presentations

Standard oceanographic convention is used for the presentation of directions, namely that the direction of wind and waves are presented as the direction from where it originates (or coming from), while the direction of currents are presented as the direction to where it flows toward (or going to).

2.2 Standards

The analyses have been carried out in accordance with the following technical standards:

- IEC 61400-3: Design requirements for offshore wind turbines (ref. [1])
- DNVGL-ST-0437: Loads and site conditions for wind turbines, 2016, (ref. [2])
- DNVGL-RP-C205: Environmental Conditions and Environmental Loads, 2017, (ref. [3])

2.3 Reference Level and Unit Systems

If not specifically stated otherwise, all elevations and measures are given in metres and SI units.

All the elevations are based on the level relative to mean sea level (MSL).

2.4 Scaling

The wind data at 10 m MSL used in the analysis is the hindcast time series provided by Oceanweather Inc. (OWI). However, the wind data at 135 m MSL has been obtained by scaling the mean wind speeds provided for 10 m MSL.

Power law profile, with an exponent of 0.14 in accordance with IEC 61400-1 (ref. [1]) has been applied to the wind speeds at 10 m MSL, U_{10}:

$$U_{135\,m\,MSL} = U_{10}\left(\frac{135m\,MSL}{10m\,MSL}\right)^{0.14}$$

The value of wind shear exponent has been adopted as 0.11 while scaling the extreme wind speeds (ref. [1]).

Further, in accordance with the work scope, 1-hour mean wind speeds have been converted to 10-min averaged values by applying the formula recommended in ref. [3] :

$$U(T) = U_{10}\left(1 - 0.047 ln\frac{T}{T_{10}}\right)$$

Here T is averaging period and T=60 minutes, T_{10} = averaging period of 10-min, and U_{10} is the 10-min mean wind speed.

Considering that the wind directions are received only for 10 m MSL, the wind directions used in the present metocean assessment are assumed to be valid for both elevations.

3. SOURCE OF TIMESERIES

The primary data used in the analysis is the hindcast time series from the GROW Fine East Coast Model (GFEC) provided by Oceanweather Inc. (OWI).

The closest grid points from the GFEC database to the project site locations are 20428, 20430 and 20928. These grid points are presented in Table 3-1 including coordinates, and water depths.

Key parameters such as maximum wave height, wind speed at 135 m MSL, turbulence intensity, water level and current velocity have not been provided for the grid point 20428. Hence the time series data at the grid points 20430 (P1) and 20928 (P2) are assessed to be more representative and adopted for the present metocean analysis.

Table 3-1 Details of the grid points where timeseries extracted for the metocean analysis

Grid Point	Chosen for assessment	Coordinate	Water Depth	Reference used in Assessment
20428	÷	39.30 °N, 74.20 °W	20.50 m	Not used
20430	✓	39.30 °N, 74.10 °W	26.25 m	P1
20928	✓	39.55 °N, 74.00 °W	24.25 m	P2

Continuous period operational wind and wave parameters at a 1-hour time step from Jan-01-1979 to Dec-31-2018, 151 tropical storms from Jan-01-1924 to Dec-31-2018 at a 15-minute time step and 52 extratropical storms from Jan-01-1957 to Dec-31-2018 at a 15-minute time step have been received for the analysis. Current and water level data have been provided only in the hindcasts of tropical and extra-tropical storms. Hence, any analyses involving operational current and operational water level have not be carried out at the present stage of the project. A brief overview for the content of received timeseries for the grid points 20430 and 20928 are presented in Table 3-2.

More information about the standard GFEC hindcast including history, methodology, validation, and sample outputs are provided in ref. [4].

Table 3-2 Content of the received timeseries

Type of Time series	Continuous	Tropical Storms	Extra-Tropical Storms
Duration	1979-2018	1924-2018	1957-2018
Wind Direction	X	X	X
Wind Speed-10 m MSL	X	X	X
Wind Speed-135 m MSL (*)	÷	-	-
Turbulence Intensity-135 m MSL	X	-	-
Significant wave height-Total Sea	X	X	X
Maximum wave height-Total Sea	X	-	-
Peak period-Total Sea	X	X	X
Mean Wave Direction-Total Sea	X	X	X
Surge Height	-	X	X
Current Speed	-	X	X
Current Direction	-	X	X
Air temperature-10 m MSL	X	-	-
Air density-10 m MSL	X	-	-

(*): Received data has inconsistency and until the clarification is received Ramboll has applied scaling (Please see Section 2.4)

The locations of the grid points versus project site locations are indicated in Fig. 3-1.

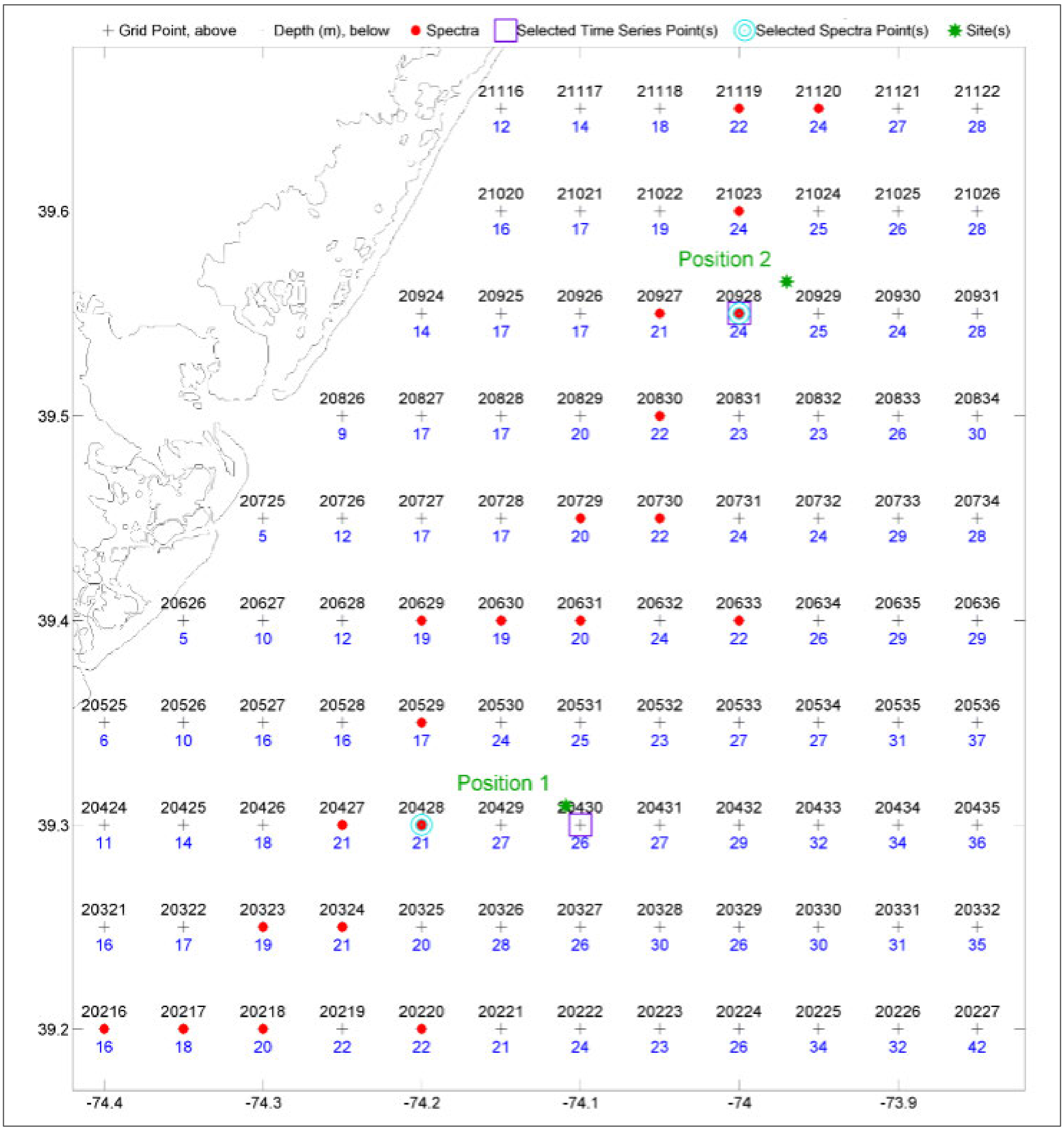

Figure 3-1 GFEC Grid Points and Project Site Positions, ref. [4]

4. SUMMARY OF DELIVERABLES

Following metocean design criteria for operational and extreme conditions are derived for the project locations P1 and P2:

Wind
Analysis are performed for the elevations of 10 m MLS and 135 m MSL unless otherwise stated:

- Wind roses – plot and tabulated values
- Probability scatter tables between mean wind speed and wind direction
- Per 12 wind directions and omni: Extreme wind speeds at the elevations of 10 m MSL and 135 m MSL for the return periods of 1, 10, 50, 100, 500 and 1000 years (averaging time:1-hour, 10-min, 1-min and 3-sec)
- Weibull fit parameters – Per 12 wind directions and omni
- Turbulence intensity values binned as function of wind speed (only for 135 m MSL)
- Wind direction versus total mean wave direction scatter tables conditioned on hub height wind speeds
- Annual and monthly statistics for air density and air temperature (average, min, max) - (only for 135 m MSL)

Wave
- Wave roses – plot and tabulated values (for total sea state and its components: swell and wind-sea)
- Extreme Hs for return periods of 1, 10, 50, 100, 500 and 1000 years. Associated values of Tp, Hmax, THmax and maximum wave crest (Cmax)
- Probability scatter tables of Hs-Tp for 12 wind and 12 wave directions and omni (only for total sea state)
- Probability scatter tables of Hs-U_{135} for 12 wind directions and Omni
- Probability scatter table of Hs and Mean Wave Direction (MWD) (only for total sea state)
- Probability scatter table of Hs and Wind Direction (only for total sea state)
- Weibull fit parameters parameters – per 12 wind and wave directions and omni
- Wave breaking analysis

Water Level
- Tidal analysis of water level time series
- Annual and monthly statistics for high and low water levels (average, min, max)
- Extreme total water levels (high and low) for return periods of 1, 10, 50, 100 and 1000 years
- Annual and monthly extreme total water levels (high and low) for return periods of 1, 10, 50 and 100 years

Current
- Roses for depth-averaged, surface and bottom currents (total) – plot and tabulated values
- Annual total extreme depth-averaged, surface and bottom current speeds for return periods of 1, 10, 50, 100 years for per 12 current directions and omni direction
- Monthly omni-directional total extreme depth-averaged, surface and bottom current speeds for return periods of 1, 10, 50 and 100 years

5. METHODOLOGY

5.1 General

Scatter tables are produced detailing operational and extreme conditions for the locations P1 and P2. The analyses are made by using various tools from the MIKE Zero program packages (ref. [5]) as well as Ramboll's in-house tools.

Directional analyses are performed for omni and per 12 wind and mean wave directions centered around 0º, 30º, 60º, 90º, 120º, 150º, 180º, 210º, 240º, 270º, 300º and 330º.

Following bin sizes are adopted through the scatter tables:

- Significant wave height, Hs (0.5 m)
- Peak period, Tp (1 s)
- Mean wind speed, U (1 m/s)

In order to make scatter tables reader friendly, colour order for the scatter tables are introduced: Three shades of blue and green have been used for the locations P1 and P2 respectively.

5.2 Interpretation of Operational Conditions

5.2.1 Wind and wave roses

[redacted]

5.2.2 Scatter tables

[redacted]

- [redacted]
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5.3 Interpretation of Extreme Conditions

5.3.1 Extreme value analysis

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6. WAVE BREAKING

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

7. REFERENCES

[1] IEC 61400-3: Wind Turbines – Part 3: Design Requirements for Offshore Wind Turbines, 2009-02.

[2] DNVGL-ST-0437: Loads and site conditions for wind turbines. DNVGL, November 2016

[3] DNV-RP-C205. Environmental Conditions and Environmental Loads. Det Norske Veritas. April 2017.

[4] GROW-FINE U.S. East Coast: Global Reanalysis of Ocean Waves – U.S. East Coast, Project Description. July 2019.

[5] http://www.mikebydhi.com

[6] http://www.co-ops.nos.noaa.gov/benchmarks/8534720.html

[7] ISO 19901-1:2015. Petroleum and natural gas industries - Specific requirements for offshore structures - Part 1: Metocean design and operating considerations