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## Project UpWind

Contract No.:  
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"Integrated Wind Turbine Design"

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# Upwind Design Basis

## (WP4: Offshore Foundations and Support Structures)

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## Purpose of the document

The following design basis shows the data for two different offshore sites in the Dutch North Sea – namely *Ijmuiden Munitiestortplaats* and *K13*. The Ijmuiden site is considered to be a shallow location with 21.4m water depth. The K13 site has a water depth of 25m and is therefore also a shallow location. However, for studies related to deep water sites, the site data is correlated to a 50m site in the Dutch North Sea. It was found that the normal sea states are similar, but for the extremes different values are obtained by using the Argoss database. Thus, K13 is divided into two different sites, a *K13-shallow* and a *K13-deep* site.

STATUS, CONFIDENTIALITY AND ACCESSIBILITY							
Status			Confidentiality			Accessibility	
<b>S0</b>	Approved/Released	<b>X</b>	<b>R0</b>	General public	<b>X</b>	Private web site	
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<b>S3</b>	Draft for comments		<b>R3</b>	Restricted to WP members + PL			
<b>S4</b>	Under preparation		<b>R4</b>	Restricted to Task members +WPL+PL			

PL: Project leader    WPL: Work package leader    TL: Task leader

## Remark

The following design basis can be used within work package 4 of the UpWind project only. Any other usage has to be communicated and released by the author.

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## **A. Ijmuiden Shallow Water Site**

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## **Abstract**

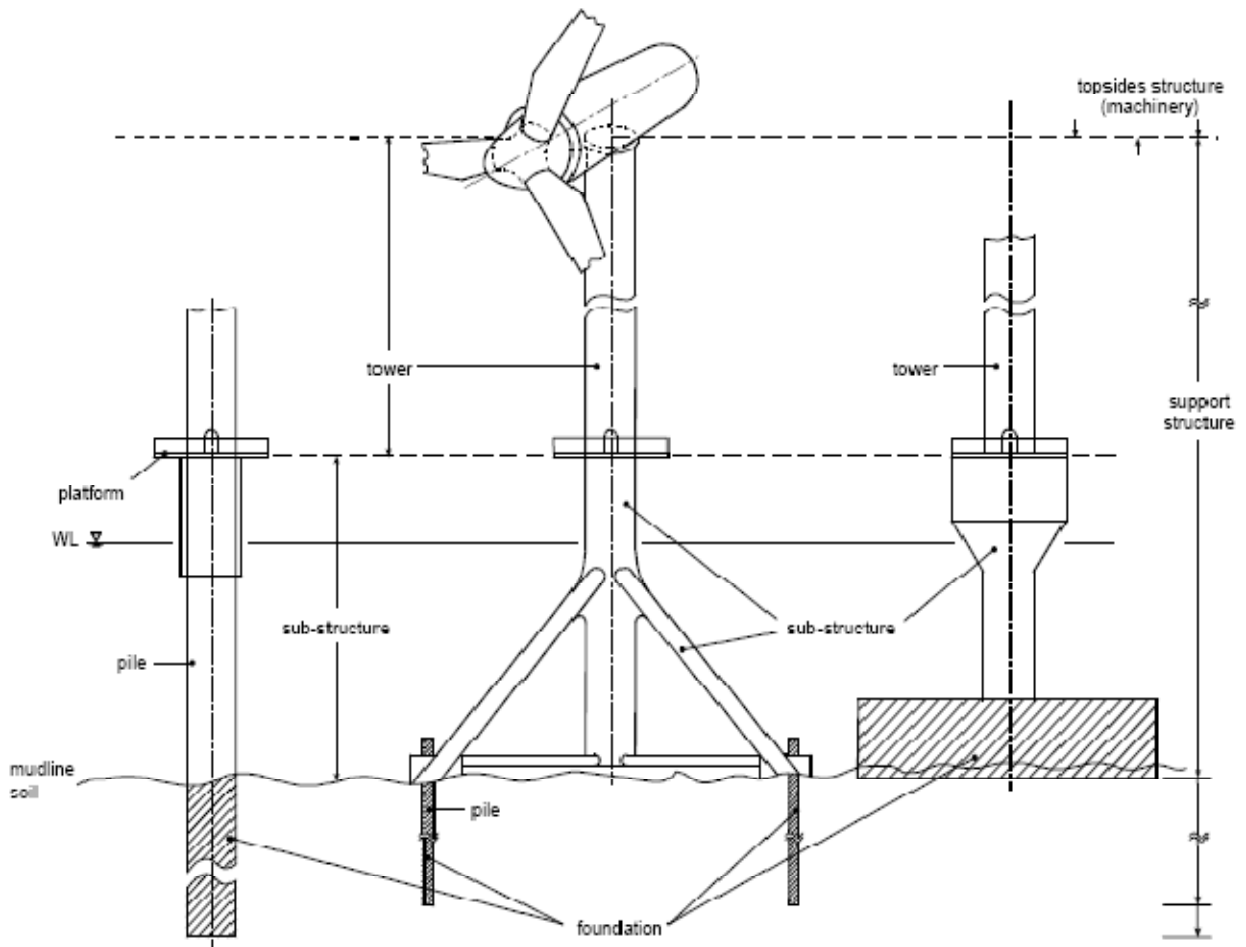
The presented design basis gives a summarized overview of relevant design properties for a later offshore wind turbine design procedures within work package 4. The described offshore site is located in the Dutch North Sea and has a water depth of 21m. Therefore it will be chosen as shallow site within the work package for further design studies.

Besides information about climate properties like wind and wave definitions, other load properties are specified according to a current design guideline. Here the guideline of the Germanischer Lloyd and IEC is chosen. Finally the relevant design load cases according to the guideline are listed, which have to be fulfilled for a suitable support structure design.

## A.1. General remarks and definitions

The relevant design parameters and methods within this design basis are taken from the IEC-61400-3 standard [1]. Further standards are quoted when used.

An offshore wind turbine (OWT) as examined in this design basis, consists of a wind turbine and its support structure, see Figure 1. The support structure is divided into two parts: the tower and the sub-structure. The tower is directly connected to the wind turbine. The sub-structure of OWT consists of a kind of transition piece (e. g. a jacket) connecting the tower with the foundation. The actual foundation is either realised with piles or is part of the transition piece (e.g. gravity foundation).



**Figure 1:** Definition of an offshore wind turbine [2]

The intention of this design basis is to give the necessary definitions for designing a support structure in a fictive wind farm. The met-ocean conditions are, however, uniform at all fictive locations and only one support structure will be designed applicable to all positions.

## A.2. Project description

The following design basis is based on a location in the Dutch North Sea, close to the already build *Noordzeewind OWEZ* project near *Egmond aan Zee*. The climate information are obtained from the wave and wind data published by *Rijkswaterstaat* for the location “*IJmuiden Munitiestortplaats*” [3] and from the project design basis of OWEZ wind farm [9]. This site will be denoted in the following as *IJ-geul IJ5* (see Figure 2). The coordinates of the Ijmuiden site (YM6) are  $52^{\circ}33'00''$  east and  $4^{\circ}03'30''$  north, and the water depth is 21.4m MSL. These data are available as 3-hour average values for a period of 22 years (January 1979 - December 2000).

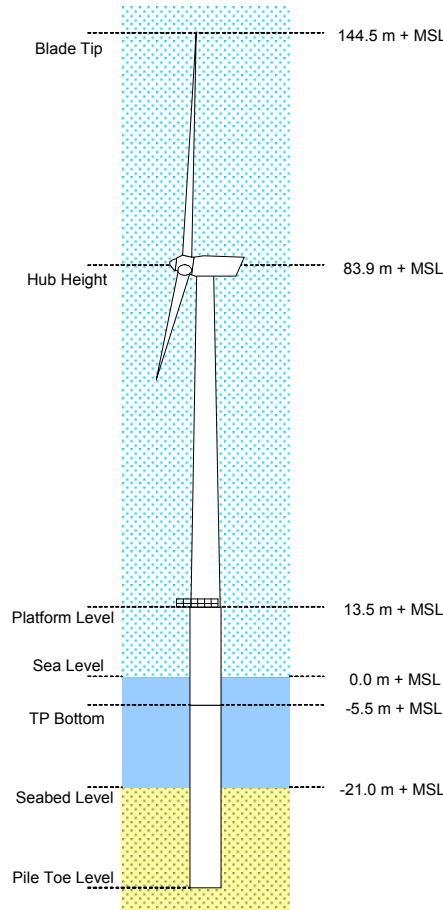


**Figure 2:** Locations for which *Rijkswaterstaat* measures wind and wave data [4]

## A.3. Structural definitions and limitations

### A.3.1 Tower and sub-structure design

The shallow water site has a mean water level (MSL) of 21.4 as shown in Figure 3. As described in the following, the platform level was found at 13.5m. By using a standard tower of 68m and a vertical offset in the nacelle of 2.4m, the support structure design results finally in a hub height of 83.9m above MSL. The monopile penetration depth in Figure 3 is shown exemplary, not as final solution.



**Figure 3:** Schematic dimensions of the reference design for the shallow water location

#### A.3.1.1. Platform

The platform is placed at the base of the tower. The determination of the height is based on the GL standard [2] with the expression

$$z_{platform} = LAT + \Delta z_{tide} + \Delta z_{surge} + \Delta z_{air} + \xi^* \quad \text{and} \quad \xi^* = \delta \cdot H_{S,50max}$$

By applying  $\delta = 0.65$ ,  $LAT = -1.4m$ , a tidal range of  $\Delta z_{tide} = 2.4m$ , a storm surge of  $\Delta z_{surge} = 1.0m$ , an air gap of  $\Delta z_{air} = 1.5m$  and a 50years extreme wave height of  $H_{S,50max} = 15.01m$ , the platform level is found at 14.5m LAT or 13.5m MSL.

### A.3.1.2. Tower

On top of the transition piece the tower is flanged. Table 1 shows the dimensions of the tower used for the load calculations. The tower is split into two sections, each 34m, resulting in a total tower height of 68m. At three stages flanges are placed, namely as link to the transition piece, as connection of the two tower sections and at the tower top as link to the nacelle. They are considered as added masses in the load calculations.

**Table 1:** Dimensions tower design

Hub height, 81.5 m	Section	Height of section to MSL	Outer diameter at section-top	Outer diameter at section-bottom	Section wall thickness	Flange mass]
	[-]	[m]	[m]	[m]	[mm]	[kg]
6. ---	81.5	77.5	4.000	4.118	30	1000 (at 81.5m)
5. ---	77.5	65.5	4.118	4.329	20	0
4. ---	65.6	55.5	4.329	4.565	22	0
3. ---	55.5	45.5	4.565	4.800	24	0
2. ---	45.5	33.5	4.800	5.082	28	1400 (at 45.5m)
1. ---	33.5	23.5	5.082	5.318	30	0
	23.5	13.5	5.318	5.600	32	1900 (at 13.5m)

### A.3.1.3. Other secondary structures

Other secondary structures are not pre-defined in detail here. However, structures like the J-tube, which is used to protect and align the cabling from the turbine to land and to cross the scour protection, shall be analysed on the same loads by waves, current and the scour of the monopile.

## A.3.2. Corrosion

Corrosion is only taken into account from the splash zone downwards. Therefore no internal volumes or corrosion in air is studied in detail.

Within the splash zone (+4.53m MSL to -3.18m MSL), the following corrosion allowance is used:

- Corrosion rate according to DNV standard [8]: 0.3mm/year
- Applicable corrosion period: 20 years (reference period)
- Applicable corrosion allowance: 20 x 0.3mm =6.0mm

Below the splash zone (-3.18m MSL to 3m below sea bed), the following corrosion allowance is used:

- Applicable corrosion allowance: 3.0mm (20 years)

For fatigue calculations, half of the corrosion allowance has to be taken into account. For extreme calculations, the full allowance.

## A.4. Environmental conditions

### A.4.1. Sea water

For the sea water, the following values are assumed (see Table 2):

**Table 2:** Quantities of sea water

Water density	1025 kg/m <sup>3</sup>
Water salinity	3.5 ‰
Water temperature (min/max)	0°C / 22°C

### A.4.2. Water depths

The water depth within the assumed wind park is taken as 21.4m MSL. The value does not include any scour effect.

### A.4.3. Water levels

Beside wind and wave measurements, there is also measured water level and surge data available for the Ijmuiden site. For the full duration of 22 years, the following extreme values are found (see Table 3).

**Table 3:** Measured water levels at the location (scheme according to [2])

HSWL	+ 2.4m MSL		
HAT	+ 1.4m MSL		
MSL	0m		
LAT (CD)	- 1.1m MSL		
LSWL	- 2.1m MSL		
A	+ 1.0m MSL		
B	2.4m		
C	- 1.0m MSL		
			<p>HSWL highest still water level  HAT highest astronomical tide  MSL mean sea level  LAT lowest astronomical tide  CD chart datum (often equal to LAT)  LSWL lowest still water level  A positive storm surge  B tidal range  C negative storm surge  D maximum crest elevation  E minimum trough elevation</p>

Besides the water depths and water level, the splash zone has to be determined for later studies. According to DNV [8], the splash zone is determined as

$$\text{Upper limit: } SZ_U = HAT + 0.6 \cdot (1/3) \cdot H_{s,\max}(100\text{years}) = +4.53\text{m MSL}$$

$$\text{Lower limit: } SZ_L = LAT - 0.4 \cdot (1/3) \cdot H_{s,\max}(100\text{years}) = -3.18\text{m MSL}$$

with  $H_{s,\max}(100\text{years}) = 15.64\text{m}$ ,  $HAT = 1.4\text{m}$  and  $LAT = -1.1\text{m}$ .

### A.4.4. Currents

The values for the currents are taken from the *Noordzeewind OWEZ project*, which is close to the studied location. For normal current loads an average value of 0.6m/s at surface level is taken and for the extreme case of 1.2m/s, respectively.

**Table 4:** Current velocities according to load situation

Load situation	Current at MSL [m/s]
Normal current	0.6
Extreme current	1.2

### A.4.5. Wave parameters

#### A.4.5.1. Scatter diagram

In the offshore industry wave climate data is generally expressed in a 2-dimensional scatter diagram giving the number of occurrences of each combination of significant wave height  $H_s$  and peak spectral period  $T_p$ . For offshore wind turbine design the 2-D scatter diagram must be expanded to include  $V_w$  as a third dimension. To derive the 3-D scatter diagram, the parameters  $H_s$  and  $T_p$  and  $V_w$  will be used.

The wind and wave data is subsequently gathered in bins. The  $V_w$  bins cover 2 m/s, the  $H_s$  bins cover 0.5 m and the  $T_p$  bins span 1.0 s. The binning of the  $V_w$  data is done in such a way that the wind speed bin corresponding to for example  $V_w = 2$  m/s contains all wind speed observations ranging from  $\geq 1$  m/s to  $< 3$  m/s. The bin  $H_s = 2$  m contains all wave height observations between  $\geq 1.75$  m and  $< 2.25$  m, while the bin  $T_p = 2$  s includes all wave period observations from  $\geq 1.5$  s to  $< 2.5$  s. Subsequently, the occurrence of all combinations of  $V_w$ ,  $H_s$  and  $T_p$  is counted. The data is gathered per wind speed bin and entered in a scatter diagram giving the frequency of occurrences of each combination of  $H_s$  and  $T_p$  for that wind speed bin as a percentage value. This is illustrated in Table 5 for  $V_w = 10$  m/s. The wind speeds used here are at hub height.

**Table 5:** Part of a 3-D scatter diagram for  $V_w = 10$  m/s

Vw = 9-11 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6														0,00000
	5,5														0,00000
	5														0,00000
	4,5														0,00000
	4														0,00002
	3,5												0,00008	0,00005	0,00002
	3										0,00017	0,00012	0,00009		0,00039
2,5									0,00002	0,00058	0,00103	0,00044	0,00005	0,00210	
2								0,00002	0,00232	0,00748	0,00205	0,00012	0,00002	0,01201	
1,5								0,00320	0,02532	0,01370	0,00087	0,00009		0,04320	
1								0,00180	0,03424	0,03173	0,00314	0,00011		0,07102	
0,5								0,00003	0,01076	0,01447	0,00260	0,00022	0,00003	0,02814	
<0,25								0,00002	0,00031	0,00011	0,00003			0,00047	
		0,00000	0,00000	0,00000	0,00005	0,01288	0,05203	0,06202	0,02512	0,00426	0,00089	0,00022	0,00002	0,00000	0,15748

A diagram as shown in Table 5 is produced for each wind speed bin. The full set of scatter diagrams make up the 3-D scatter diagram. These are given in the appendix.

#### A.4.5.2. Extreme values

The values for the extreme wave conditions are taken from the *Noordzeewind OWEZ project*, which is close to the studied location and where detailed studies about the extreme values were performed. The relation between wave height and return period was found to be:

$$H_{s,3hrs}(T_{return}) = 0.479 \cdot \ln(x) + 6.0626$$

In Table 6 different significant wave height values for different periods of occurrence are given. To obtain the maximum wave height the following relationship is used:

$$H_{max} = 1.86H_s$$

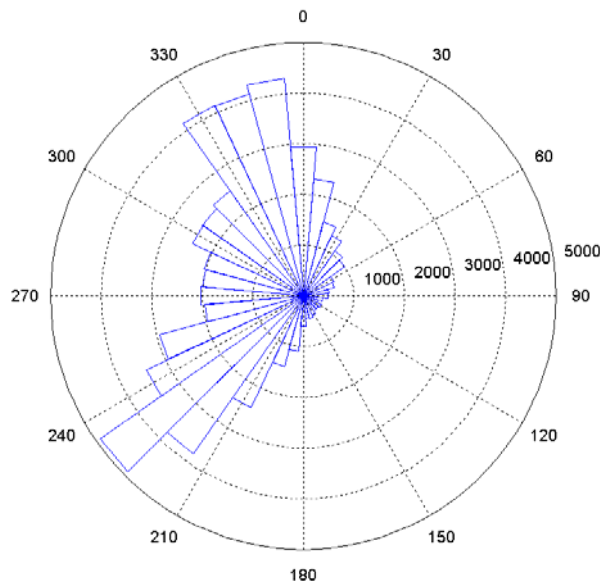
The factor 1.86 can be used for the given location, as the water depths are relative shallow. For deeper water sites this factor should be higher (close to 2).

**Table 6:** Extreme wave heights as a function of the return period

$T_{return}$ [yr]	$H_s$ [m]	$T_p$ [s]	$H_{max}$ [m]
1	6.06	9.7	11.27
5	6.83	10.3	12.70
10	7.25	10.7	13.49
50	8.07	11.3	15.01
100	8.41	11.6	15.64

#### A.4.5.3. Wave directions

The 3-D scatter diagram does not take directionality into account. Therefore a different diagram is produced giving the spreading of wave directions per wave height bin. First,  $\theta_{wave;full}$  is gathered in bins of  $30^\circ$ . Subsequently,  $H_s$  and  $\theta_{wave;full}$  are sorted to obtain the number of occurrences of each wave direction per wave height bin. Figure 4 shows the wave rose for all measured values. In this figure  $0^\circ$  corresponds with north. It can be seen that the dominant wave directions are between north north west (NNW) and west south west (WSW). The probability of occurrence is given as total value on the radial axes. The full series of wave roses sorted for each wave height are given in the appendix.



**Figure 4:** Wave rose for the measurement location

#### A.4.5.4. Breaking waves

According to the studies of the near located *Noordzeewind OWEZ* project, the effect of breaking waves will be neglected. Breaking waves will not occur, although the wave height is near breaking. The gentle increase in seabed level towards the shore in this region of the Dutch North Sea may cause some shoaling, but no offshore bars are present to initiate breaking.

### A.4.6. Wind parameters

#### A.4.6.1. Wind distributions

In Figure 5, the wind speed distribution of the IJmuiden site at 80m height can be seen. The measured wind data was firstly translated from the reference height of 10 m to the hub height. A hub height of 80 m above MSL is assumed. According to GL the wind speed at hub height can be found with

$$V_{hub} = \frac{V(z)}{\left(\frac{z}{z_{hub}}\right)^\alpha}$$

with:

- $V_{hub}$  = wind speed at hub height
- $V(z)$  = wind speed at elevation  $z$
- $z$  = elevation for which wind speed is given
- $z_{hub}$  = hub height
- $\alpha$  = wind shear exponent ( $\alpha = 0.14$  for roughness length of 0.002 m)

The relevant Weibull parameters are  $A= 10.61$  m/s and  $k=2.08$ , which leads to an annual mean wind speed of 9.29m/s.

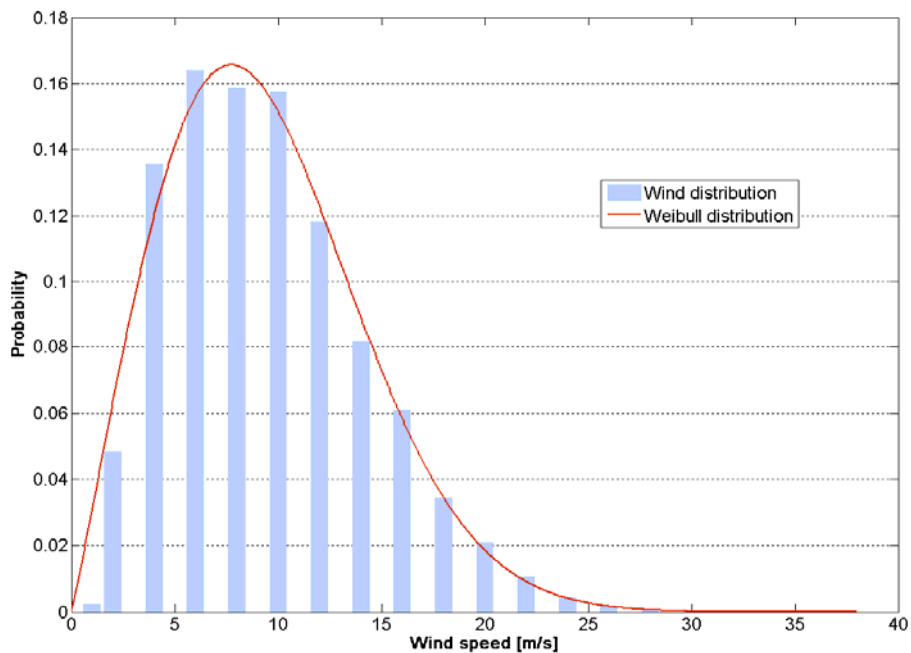
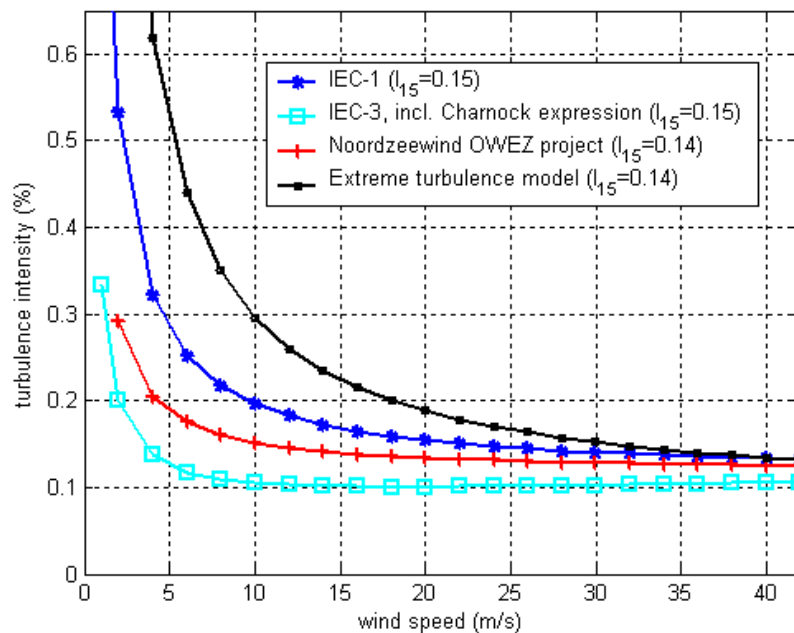


Figure 5: Wind speed distribution for the measurement location

#### A.4.6.2. Turbulence intensity

For the turbulence intensity, different distributions were compared. As shown in Figure 6, the standard curves for IEC-1 and IEC-3 are shown for a reference turbulence intensity of 0.15. Besides, a distribution based on the assumptions of the *Noordzeewind OWET project* is shown, where again an IEC-3 distribution was assumed, but with a different reference intensity and taken wake into account. As the IEC-1 curve is too conservative, but the IEC-3 one probably optimistic, the distribution from the *Noordzeewind OWET project* will be chosen as a good compromise, also for the consideration of wake effects. The distribution can be described by the following relation (with  $I_{15}=0.14$  and  $a=5$ )

$$I(U) = \frac{(15 + aU)}{(1 + a)U} \cdot I_{15}$$



**Figure 6:** Turbulence intensity according to IEC

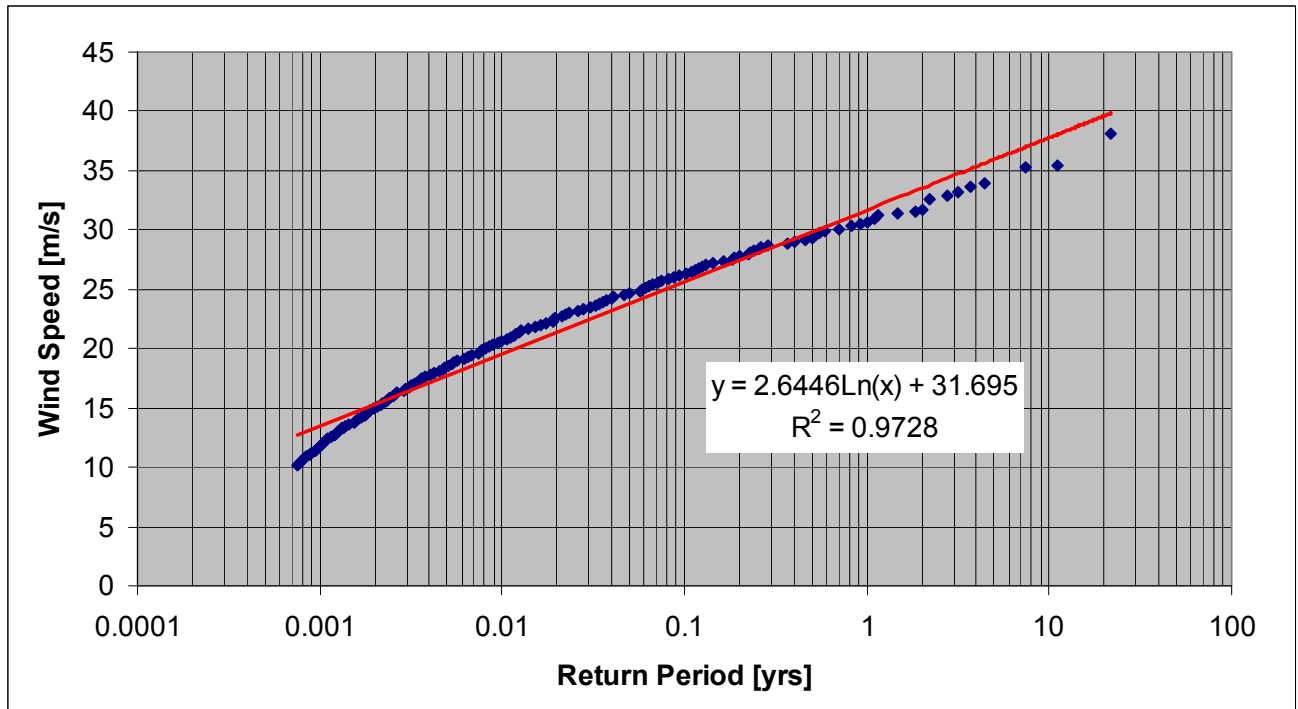
For later extreme load calculations, a further extreme turbulence distribution has to be defined. Based on the normal turbulence model described in the expression above (*Noordzeewind OWET project*), an extreme turbulence distribution is calculated according to the IEC-3 standard. The curvature is also shown in Figure 6.

All turbulence values are again listed for each wind speed bin in A.7. Appendix.

#### A.4.6.3. Extreme values

From the measured wind data the extreme wind speeds can be determined. The extreme wind speed is determined as the maximum wind speed that occurs with a certain return period (as seen in Figure 7). The resulting equation can be found as follows:

$$V_{hub,10\min}(T_{return}) = 2.6446 \cdot \ln(x) + 31.695$$



**Figure 7:** Determining the maximum wind speed

Table 7 shows the maximum wind speed at hub height as a function of the return period. The values averaged 10-min wind speeds, where the original 3-hrs stationary situations were converted with a factor 0.9 according to IEC.

**Table 7:** Extreme wind speeds as a function of the return period

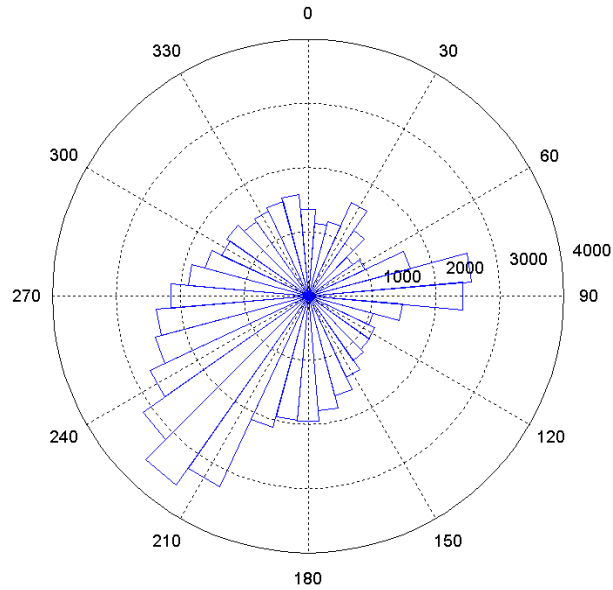
$T_{\text{return}}$ [yr]	$V_w$ [m/s]
1	31.70
5	35.95
10	37.78
50	42.04
100	43.87

If the here determined values are compared to the results of the *Noordzeewind OWEZ project* and *Rijkswaterstaat* for the location “*IJmuiden Munitiestortplaats*”, the values correspond well, where a 50 years extreme wind speed of 41.9m/s was found in 70m height.

#### A.4.6.4. Wind directions

The 3-D scatter diagram does not take directionality into account. Therefore a different diagram is produced giving the spreading of wind directions per wind speed bin. First,  $\theta_{\text{wind},\text{full}}$  is gathered in bins of 2m/s. Subsequently,  $V_w$  and  $\theta_{\text{wind},\text{full}}$  are sorted to obtain the number of occurrences of each wind direction per wind speed bin. Figure 8 shows the wind rose for all measured values. In this figure  $0^\circ$  corresponds with north. It can be seen that the dominant wind directions comes from west south west (WSW), which agrees with the main wave directions. However, especially in cases of low wind speed the wind tend to come from eastern directions as well. The full series of wind roses sorted for each wind speed is given in A.7. Appendix.

## Upwind Design Basis – Ijmuiden Shallow Water Site



**Figure 8:** Wind rose for the measurement location

### A.4.7. Wind-wave-directionality

As for some support structure types and environmental conditions the effect of wind- and wave-misalignment can be important, in the following the directional scatter of the measured wind and wave directions is shown. Here the wind speed values correspond to 10-min average values, and the wave heights to 3hrs respectively. The binning is done corresponding to the former described wind and wave scatters. The binning of the  $V_w$  data is done in such a way that the wind speed bin corresponding to for example  $V_w = 2$  m/s contains all wind speed observations ranging from  $\geq 1$  m/s to  $< 3$  m/s. The directional bins at NNE ( $30^\circ$ ) contain all observations between  $\geq 15^\circ$  and  $< 45^\circ$ .

**Table 8:** Directional scatter diagram for all wind speeds

All windspeeds	Wave direction												
	000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000° N	0,03366	0,00170	0,00034	0,00020	0,00011	0,00012	0,00009	0,00034	0,00075	0,00143	0,00317	0,02145	0,06337
030° NNE	0,03837	0,01053	0,00092	0,00025	0,00016	0,00017	0,00006	0,00017	0,00044	0,00103	0,00166	0,00922	0,06298
060° ENE	0,01691	0,02156	0,00852	0,00152	0,00050	0,00020	0,00008	0,00020	0,00034	0,00059	0,00068	0,00305	0,05416
090° E	0,02073	0,02297	0,02129	0,01335	0,00562	0,00221	0,00123	0,00115	0,00148	0,00149	0,00177	0,00745	0,10075
120° ESE	0,00611	0,00320	0,00238	0,00352	0,00709	0,00891	0,00481	0,00370	0,00299	0,00221	0,00230	0,00537	0,05259
150° SSE	0,00373	0,00131	0,00112	0,00092	0,00143	0,00526	0,01265	0,01839	0,00784	0,00380	0,00341	0,00628	0,06612
180° S	0,00282	0,00054	0,00023	0,00044	0,00051	0,00128	0,00952	0,03651	0,01870	0,00655	0,00515	0,00635	0,08859
210° SSW	0,00226	0,00045	0,00030	0,00022	0,00034	0,00042	0,00283	0,04712	0,05990	0,01290	0,00689	0,00619	0,13981
240° WSW	0,00207	0,00023	0,00023	0,00022	0,00031	0,00037	0,00068	0,01173	0,05972	0,02674	0,01683	0,01090	0,13004
270° W	0,00232	0,00031	0,00019	0,00008	0,00012	0,00009	0,00023	0,00143	0,01529	0,02997	0,03263	0,01708	0,09975
300° WNW	0,00440	0,00020	0,00011	0,00006	0,00002	0,00005	0,00016	0,00050	0,00339	0,00773	0,02126	0,03548	0,07336
330° NNW	0,01308	0,00051	0,00012	0,00012		0,00006	0,00014	0,00019	0,00121	0,00244	0,00736	0,04323	0,06847
	0,14647	0,06353	0,03576	0,02089	0,01621	0,01915	0,03248	0,12142	0,17204	0,09688	0,10313	0,17205	1,00000

Percentage of time [%]

90° + from wind direction

90° - from wind direction

A diagram as shown in Table 8 is produced for each wind speed bin, as shown as an example for  $V=10\text{m/s}$  in Table 9. The full set of those directional scatter diagrams are given in A.7. Appendix.

**Table 9:** Part of the 3-D directional scatter diagram for V = 10 m/s

Vw 9-11 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00733	0,00033	0,00003					0,00003	0,00003	0,00008	0,00030	0,00344	0,01156
030°	NNE	0,00678	0,00232	0,00014	0,00005	0,00002					0,00002	0,00008	0,00070	0,01010
060°	ENE	0,00375	0,00544	0,00165	0,00036	0,00009	0,00003	0,00002	0,00002	0,00002	0,00006	0,00005	0,00031	0,01181
090°	E	0,00205	0,00467	0,00470	0,00327	0,00129	0,00016	0,00006	0,00005	0,00002	0,00003	0,00002	0,00020	0,01650
120°	ESE	0,00016	0,00023	0,00028	0,00087	0,00187	0,00193	0,00054	0,00023	0,00003	0,00006	0,00008	0,00003	0,00632
150°	SSE	0,00006	0,00012	0,00006	0,00006	0,00025	0,00126	0,00289	0,00336	0,00054	0,00020	0,00006	0,00003	0,00891
180°	S	0,00008	0,00002	0,00003	0,00008	0,00008	0,00019	0,00207	0,00820	0,00359	0,00078	0,00025	0,00016	0,01551
210°	SSW	0,00009	0,00006		0,00003	0,00005	0,00002	0,00034	0,00688	0,00829	0,00238	0,00115	0,00044	0,01972
240°	WSW	0,00008	0,00003	0,00003	0,00002	0,00006	0,00005	0,00009	0,00199	0,00940	0,00535	0,00297	0,00098	0,02105
270°	W	0,00006	0,00002	0,00003		0,00002	0,00002	0,00006	0,00020	0,00252	0,00389	0,00530	0,00229	0,01440
300°	WNW	0,00050		0,00003					0,00003	0,00045	0,00114	0,00338	0,00569	0,01122
330°	NNW	0,00191	0,00005	0,00003	0,00002				0,00003	0,00008	0,00023	0,00095	0,00709	0,01039
		0,02285	0,01328	0,00702	0,00474	0,00372	0,00364	0,00610	0,02101	0,02497	0,01422	0,01458	0,02136	0,15748

Percentage of time [%]

90° + from wind direction  
 90° - from wind direction

As for some simulations the full set of wind and wave directionalities is too detailed, a reduced form can be determinate, where the opposite direction of wind and waves are merged (see Table 10)

**Table 10:** Reduced directional scatter V = 10 m/s

Vw 9-11 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00947	0,00857	0,00369	0,00093	0,00062	0,00378	0,02707
030°	NNE	0,00722	0,00926	0,00843	0,00247	0,00129	0,00115	0,02982
060°	ENE	0,00395	0,00748	0,01109	0,00579	0,00317	0,00137	0,03285
090°	E	0,00224	0,00493	0,00726	0,00719	0,00663	0,00266	0,03091
120°	ESE	0,00120	0,00050	0,00079	0,00207	0,00532	0,00765	0,01753
150°	SSE	0,00487	0,00356	0,00072	0,00051	0,00126	0,00838	0,01930
		0,02895	0,03430	0,03198	0,01896	0,01829	0,02500	0,15748

### A.4.8. Further meteorological - oceanographical parameters

#### A.4.8.1. Temperature

The temperatures of water and air are illustrated in Table 11 according to [5]. For later fatigue calculations the mean values has to be taken.

**Table 11:** Air and water temperatures

Water temperature at the surface [°C]		Air temperature [°C]	
Mean	10	Mean	15.0
Standard deviation	5	Extremes	-20 to +50
Maximum	22		
Minimum	0		
Yearly amplitude	7		

#### A.4.8.2. Ice

It is very unlikely that sea ice occurs. Therefore it will not be taken into account. However, icing at the structure is possible and will be dimensioned according to [2]. This leads to the following values:

- Atmospheric ice formation with a thickness of 30mm
- Ice formation due to sea water spray with a thickness of 100mm from MSL to HSWL
- Ice formation due to sea water spray from HSWL up to 60m above MSL with a thickness decreasing linearly to 30mm
- Density of ice of 900 kg/m<sup>3</sup>

#### A.4.8.3. Maritime growths

For design purposes, marine growth has to be assumed. The density has to be taken as 1100 kg/m<sup>3</sup>. The thickness has to be taken according to DNV standard [8] to be:

**Table 12:** Assumptions for marine growths

Level [m]	Thickness [mm]
MSL to MSL-10	50
MSL-10 to seabed	45

### A.4.9. Soil conditions

#### A.4.9.1. Soil profiles

Two different soil profile configurations will be assumed in the wind farm area – namely a soft and hard one. The profiles are defined as follows:

**Table 13:** Soil conditions for the soft profile

Depths [m]	$\gamma'$ [N/m <sup>3</sup> ]	$\Phi$ [°]	$C_u$ [Pa]
0-3	10000	36	-
3-5	10000	33	-
5-7	10000	26	60000
7-10	10000	37	-
10-15	10000	35	-
15-50	10000	37.5	-

$\gamma'$  – effective soil unit weight  
 $\phi$  – angle of internal friction  
 $C_u$  – undrained shear strength

**Table 14:** Soil conditions for the hard profile

Depths [m]	$\gamma'$ [N/m <sup>3</sup> ]	$\Phi$ [°]	$C_u$ [Pa]
0-3	10000	38	-
3-5	10000	35	-
5-7	10000	38	-
7-10	10000	38	-
10-15	10000	42	-
15-50	10000	42.5	-

$\gamma'$  – effective soil unit weight  
 $\phi$  – angle of internal friction  
 $C_u$  – undrained shear strength

*A.4.9.2. Scour*

If no scour protection is planned, an additional depth in relation to scour effects has to be assumed in accordance to the outer diameter of the water piercing members,  $D$ , to be  $(2.5 \cdot D)$  according to [2].

However, in this study scour protection is assumed, by what no water depths variations due to scour are taken into account.

## A.5. Structural load assumptions

### A.5.1. Modelling of the structure

For the determination of the wave loads, the following values for the hydrodynamic coefficients can be assumed according to [2]. For other than monopile designs, the following hydrodynamic coefficients have to be re-calculated.

**Table 15:** Recommended hydrodynamic coefficients

Reynolds number	smooth cylinder		rough cylinder	
	$C_D$	$C_M$	$C_D$	$C_M$
$\leq 2 \cdot 10^5$	1.2	2.0	1.2	2.0
$> 2 \cdot 10^5$	0.7	1.6	1.1	2.0

For the load calculations in this study, the following coefficients are taken. Both values are increased from their usual values to account ladders, corrosion protection devices, J-tube, marine growths.

**Table 16:** Assumed hydrodynamic coefficients

Fatigue loading		Extreme loading	
Drag coefficient, $C_D$ [-]	Inertia coefficient, $C_D$ [-]	Drag coefficient, $C_D$ [-]	Inertia coefficient, $C_D$ [-]
0.95	2.15	1.11	1.77

For later load calculations, both fatigue and ultimate load cases, partial safety factors have to be added according the type of case. Table 17 summarize these values according to [2].

**Table 17:** Partial safety factors for loads according to [1]

Unfavourable loads			Favourable <sup>12</sup> loads
Type of design situation (see Tables 1 and 2)			All design situations
Normal (N)	Abnormal (A)	Transport and erection (T)	
1,35*	1,1	1,5	0,9
<p>* For design load case DLC 1.1, given that loads are determined using statistical load extrapolation at prescribed wind speeds between <math>V_{in}</math> and <math>V_{out}</math>, the partial load factor for normal design situations shall be <math>\gamma_f = 1,25</math>.</p> <p>If for normal design situations the characteristic value of the load response <math>F_{gravity}</math> due to gravity can be calculated for the design situation in question, and gravity is an unfavourable load, the partial load factor for combined loading from gravity and other sources may have the value:</p>			

## A.5.2. Load assumptions

### A.5.2.1. Fatigue load cases

For fatigue considerations, the different load setups from the scatter diagram have to be taken. The reduced (lumped) scatter is shown in Table 18.

The lumping is done damage equivalent based on the method described in Kühn [7]. The peakness for the JONSWAP wave spectrum is considered to be constant, with a value of 3.3, which is realistic for North Sea sites. The turbulence intensity is based on the assumptions of chapter A.4.6.1. Wind distributions

**Table 18:** Lumped scatter diagram of the given offshore site (sorted Wind bins)

V [ms]	TI [%]		Hs [m]	Tp [m]	Peakness [-]	f [%]	occ./year [hrs]
	normal	extreme					
2	29,2	88,5	0,91	5,83	3,3	0,04839	423,9
4	20,4	61,9	0,97	5,65	3,3	0,13541	1186,2
6	17,5	44	1,03	5,46	3,3	0,16407	1437,3
8	16	35	1,14	5,39	3,3	0,15875	1390,7
10	15,2	29,6	1,33	5,5	3,3	0,15748	1379,5
12	14,6	26	1,57	5,79	3,3	0,11817	1035,2
14	14,2	23,5	1,84	6,15	3,3	0,08157	714,6
16	13,9	21,5	2,2	6,64	3,3	0,06080	532,6
18	13,6	20	2,56	7	3,3	0,03455	302,6
20	13,4	18,8	2,96	7,41	3,3	0,02098	183,8
22	13,3	17,9	3,34	7,86	3,3	0,01059	92,8
24	13,1	17	3,63	8,21	3,3	0,00412	36,1
26	12	16,5	4,14	8,7	3,3	0,00185	16,2
28	11,9	15,8	4,32	8,95	3,3	0,00056	4,9
30	11,8	15,3	4,59	9,05	3,3	0,00020	1,8
32	11,8	14,8	5,09	9,54	3,3	0,00006	0,5
34-42	11,7	14,14	4,82	9,42	3,3	0,00003	0,3

**Table 19:** Lumped scatter diagram of the given offshore site (Weibull fit Wind bins)

V [ms]	TI [%]		Hs [m]	Tp [m]	Peakness [-]	f [%]	occ./year [hrs]
	normal	extreme					
2	29,2	99,3	1,07	6,03	3,3	0,06239	546,5
4	20,4	53,1	1,1	5,88	3,3	0,11898	1042,2
6	17,5	37,1	1,18	5,76	3,3	0,15494	1357,3
8	16	30	1,31	5,67	3,3	0,16479	1443,5
10	15,2	25,4	1,48	5,74	3,3	0,15130	1325,4
12	14,6	22,3	1,7	5,88	3,3	0,12285	1076,2
14	14,2	20,1	1,91	6,07	3,3	0,08932	782,5
16	13,9	18,5	2,19	6,37	3,3	0,05858	513,1
18	13,6	17,2	2,47	6,71	3,3	0,03480	304,8
20	13,4	16,1	2,76	6,99	3,3	0,01878	164,5
22	13,3	15,3	3,09	7,4	3,3	0,00922	80,8
24	13,1	14,6	3,42	7,8	3,3	0,00413	36,2
26	12	14	3,76	8,14	3,3	0,00168	14,8
28	11,9	13,5	4,17	8,49	3,3	0,00063	5,5
30	11,8	13,1	4,46	8,86	3,3	0,00021	1,9
32	11,8	12,7	4,79	9,12	3,3	0,00007	0,6
34-42	11,7	12,3	4,9	9,43	3,3	0,00003	0,2

## A.5.2.2. Extreme load cases

For the different extreme design load cases, different values for the wind speed, wave height and wave period have to be determined. Table 20 gives an overview.

**Table 20:** Extreme wave conditions according to [1]

$H_{s,50}$ [m]	7.60
$H_{smax,50}$ [m]	14.14
$H_{sred,50}$ [m]	10.03
$H_{s,1}$ [m]	5.65
$H_{smax,1}$ [m]	10.51
$H_{sred,1}$ [m]	7.46
$V_{ref} = V_{50}$ [m/s]	42.04
$V_1$ [m/s]	31.70

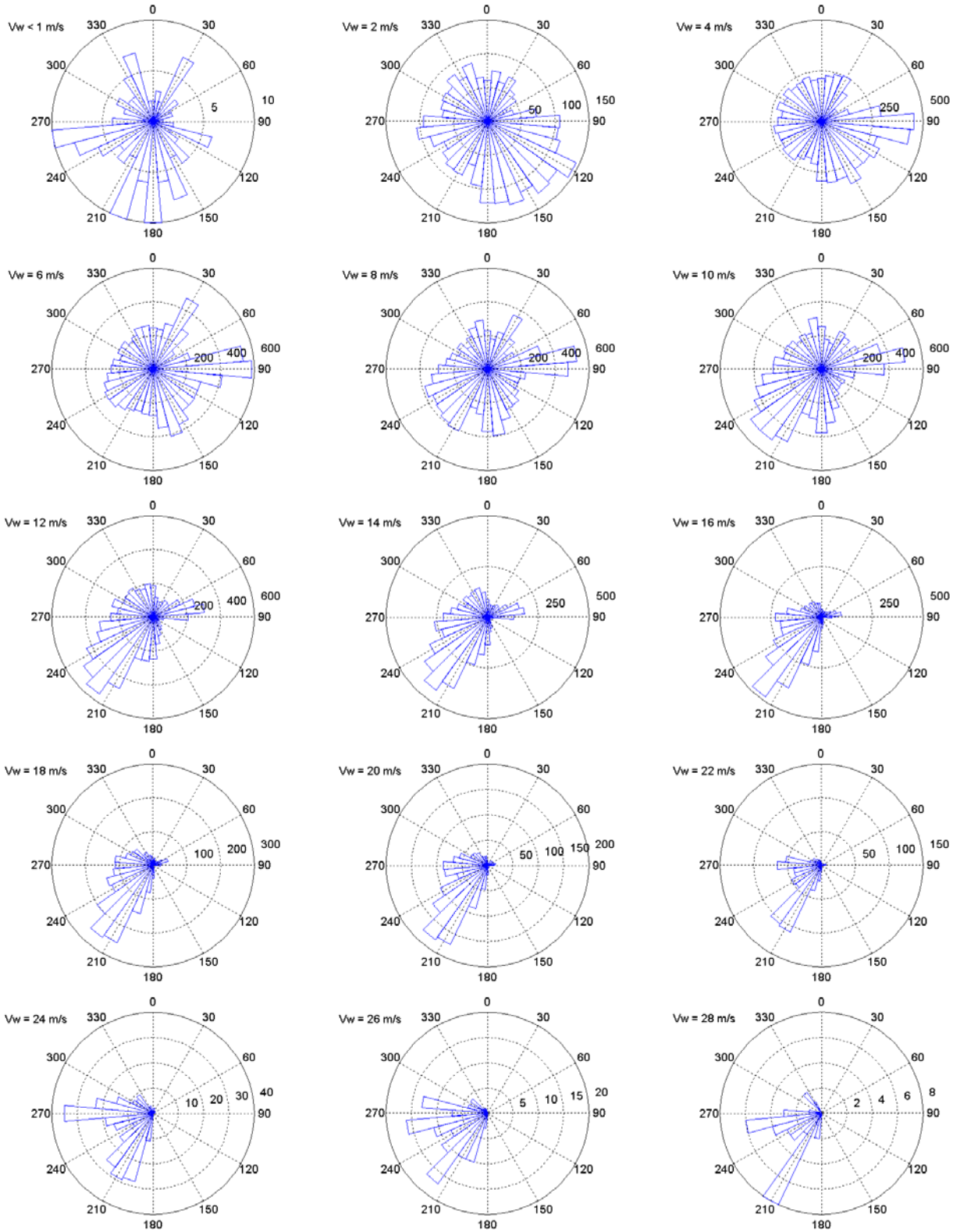
The periods combined with the above mentioned extreme wave heights have to be calculated following the formula [1]:

$$11.1\sqrt{H_s(V)/g} \leq T \leq 14.3\sqrt{H_s(V)/g}$$

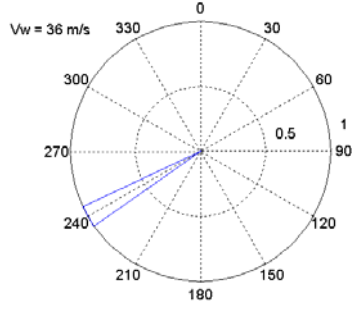
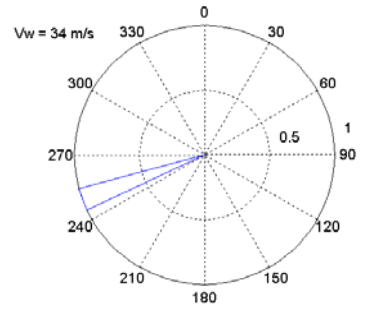
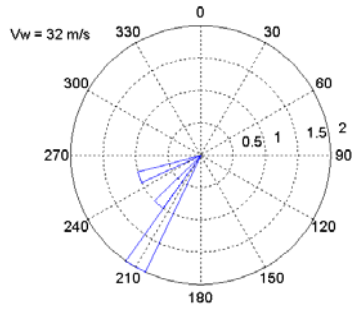
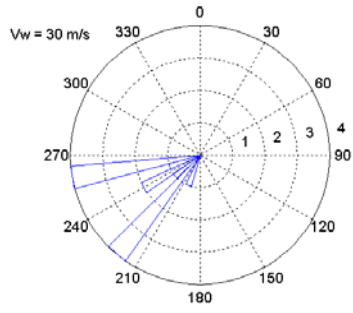


## A.7. Appendix

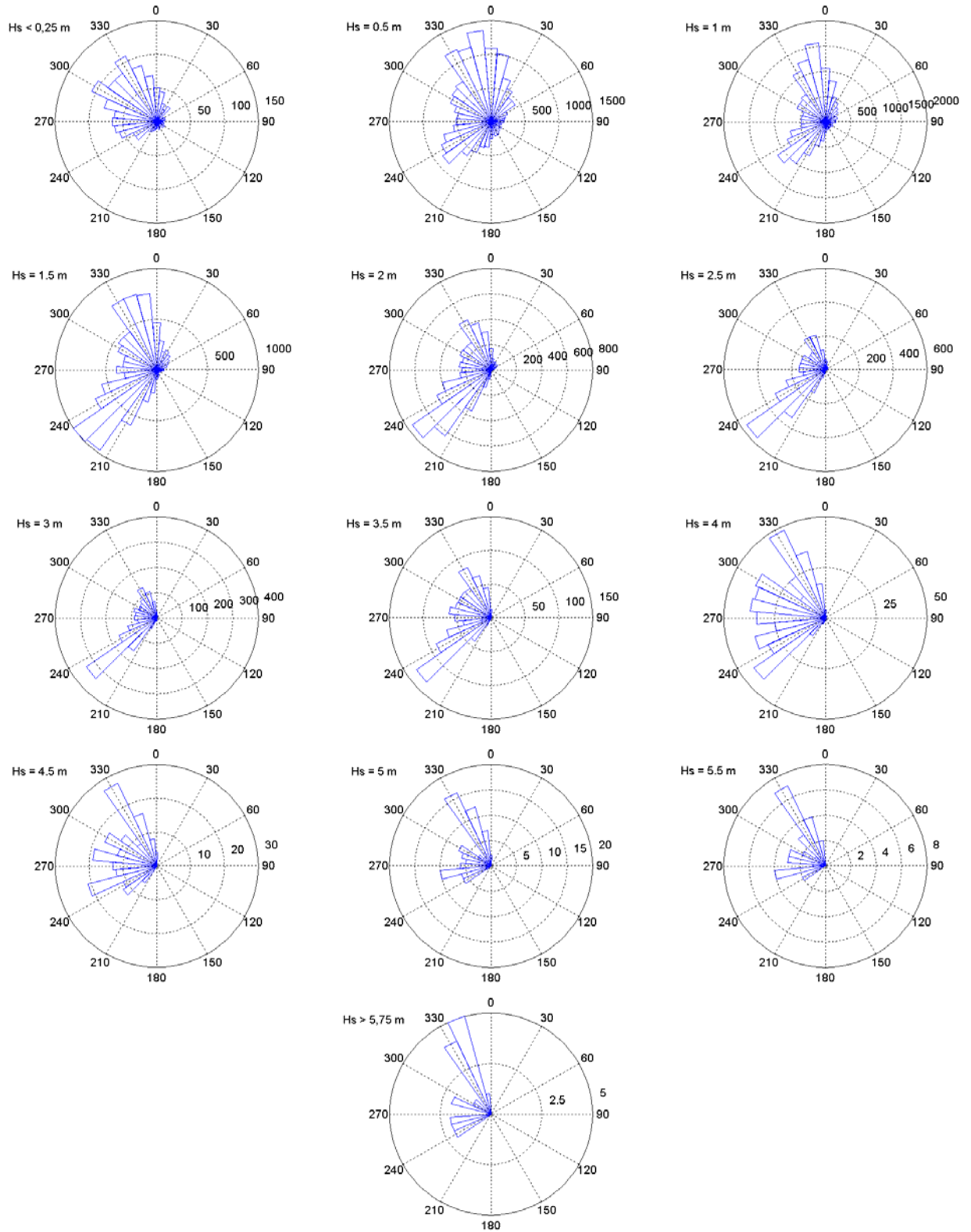
### A. Wind roses



# Upwind Design Basis – Ijmuiden Shallow Water Site



**B. Wave roses**



C. Scatter diagrams (V-Hs-Tz)

all windspeeds		Tp [s]																				
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5								
Hs [m]	9,5														0,00000							
	9														0,00000							
	8,5														0,00000							
	8														0,00000							
	7,5														0,00000							
	7													0,00002	0,00002							
	6,5													0,00003	0,00005	0,00008						
	6													0,00008	0,00008	0,00006	0,00022					
	5,5													0,00026	0,00023		0,00050					
	5													0,00025	0,00086	0,00026	0,00002	0,00138				
	4,5													0,00162	0,00131	0,00017		0,00310				
	4													0,00002	0,00081	0,00495	0,00107	0,00003	0,00688			
	3,5													0,00008	0,00744	0,00639	0,00068	0,00003	0,01462			
	3													0,00541	0,01862	0,00367	0,00037	0,00005	0,02812			
	2,5													0,00093	0,03403	0,01745	0,00185	0,00017	0,00002	0,05447		
	2													0,00005	0,02305	0,06597	0,00950	0,00106	0,00016	0,09980		
1,5													0,01053	0,10658	0,05587	0,00768	0,00128	0,00017	0,00005	0,18216		
1													0,00574	0,10290	0,12729	0,04607	0,00938	0,00112	0,00016	0,00003	0,00002	0,29270
0,5													0,00030	0,07001	0,12780	0,06984	0,02209	0,00408	0,00098	0,00026	0,00006	0,29542
<0,25													0,00003	0,00537	0,01257	0,00250	0,00006					0,02053
		0,00000	0,00000	0,00000	0,00033	0,08112	0,25384	0,33020	0,22961	0,07496	0,02316	0,00555	0,00106	0,00017	1,00000							

Vw < 1 m/s		Tp [s]																		
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5						
Hs [m]	9,5														0,00000					
	9														0,00000					
	8,5														0,00000					
	8														0,00000					
	7,5														0,00000					
	7														0,00000					
	6,5														0,00000					
	6														0,00000					
	5,5														0,00000					
	5														0,00000					
	4,5														0,00000					
	4														0,00000					
	3,5														0,00000					
	3														0,00000					
	2,5														0,00000					
	2														0,00000					
1,5														0,00003	0,00008	0,00008	0,00019			
1														0,00003	0,00011	0,00036	0,00009	0,00002	0,00002	0,00062
0,5														0,00002	0,00006	0,00042	0,00056	0,00019	0,00006	0,00131
<0,25														0,00006	0,00020	0,00002				0,00028
		0,00000	0,00000	0,00000	0,00002	0,00012	0,00065	0,00072	0,00062	0,00023	0,00002	0,00002	0,00000	0,00000	0,00240					

Vw = 1-3 m/s		Tp [s]																					
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5									
Hs [m]	9,5														0,00000								
	9														0,00000								
	8,5														0,00000								
	8														0,00000								
	7,5														0,00000								
	7														0,00000								
	6,5														0,00000								
	6														0,00000								
	5,5														0,00000								
	5														0,00000								
	4,5														0,00000								
	4														0,00000								
	3,5														0,00000								
	3														0,00000								
	2,5														0,00002								
	2														0,00002	0,00002	0,00005	0,00008					
1,5														0,00002	0,00006	0,00016	0,00005	0,00002	0,00030				
1														0,00005	0,00020	0,00092	0,00065	0,00019	0,00006	0,00005	0,00212		
0,5														0,00002	0,00056	0,00275	0,00462	0,00204	0,00023		0,00002	0,01024	
<0,25														0,00002	0,00061	0,00269	0,00065	0,00002				0,00003	0,03167
		0,00000	0,00000	0,00000	0,00003	0,00324	0,01392	0,01515	0,01103	0,00400	0,00078	0,00016	0,00008	0,00002	0,04839								

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw = 3-5 m/s		Tp [s]																
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5				
Hs [m]	9,5															0,00000		
	9															0,00000		
	8,5															0,00000		
	8															0,00000		
	7,5															0,00000		
	7															0,00000		
	6,5															0,00000		
	6															0,00000		
	5,5															0,00000		
	5															0,00000		
	4,5															0,00000		
	4										0,00002	0,00003				0,00005		
	3,5									0,00002						0,00002		
	3									0,00002	0,00005	0,00003	0,00002			0,00011		
	2,5									0,00005	0,00012	0,00008	0,00006			0,00031		
	2									0,00008	0,00030	0,00053	0,00023	0,00005		0,00118		
1,5									0,00005	0,00090	0,00305	0,00190	0,00051	0,00005	0,00646			
1									0,00026	0,00352	0,01216	0,01456	0,00381	0,00064	0,00005	0,03500		
0,5									0,00002	0,01403	0,03153	0,02641	0,00977	0,00163	0,00026	0,00009	0,00002	0,08376
<0,25									0,00208	0,00544	0,00098	0,00002						0,00852
		0,00000	0,00000	0,00000	0,00002	0,01638	0,04054	0,04054	0,02775	0,00806	0,00177	0,00034	0,00002	0,00000		0,13541		

Vw = 5-7 m/s		Tp [s]																
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5				
Hs [m]	9,5															0,00000		
	9															0,00000		
	8,5															0,00000		
	8															0,00000		
	7,5															0,00000		
	7															0,00000		
	6,5															0,00000		
	6															0,00000		
	5,5															0,00000		
	5															0,00000		
	4,5															0,00000		
	4															0,00000		
	3,5											0,00005				0,00005		
	3										0,00005	0,00005	0,00003			0,00012		
	2,5										0,00006	0,00026	0,00011	0,00002		0,00002	0,00047	
	2										0,00012	0,00101	0,00070	0,00030	0,00008	0,00002	0,00222	
1,5										0,00023	0,00358	0,00694	0,00230	0,00033	0,00003	0,01341		
1										0,00082	0,01237	0,02481	0,01431	0,00272	0,00017	0,00005	0,00003	0,05528
0,5										0,02145	0,03864	0,02005	0,00534	0,00103	0,00034	0,00005	0,00002	0,08701
<0,25										0,00173	0,00310	0,00065	0,00003					0,00551
		0,00000	0,00000	0,00000	0,00011	0,02400	0,05433	0,04922	0,02769	0,00706	0,00134	0,00025	0,00005	0,00003		0,16407		

Vw = 7-9 m/s		Tp [s]																	
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5					
Hs [m]	9,5															0,00000			
	9															0,00000			
	8,5															0,00000			
	8															0,00000			
	7,5															0,00000			
	7															0,00000			
	6,5															0,00000			
	6															0,00000			
	5,5															0,00000			
	5															0,00000			
	4,5															0,00000			
	4															0,00000			
	3,5												0,00002			0,00002			
	3											0,00005	0,00002			0,00006			
	2,5											0,00006	0,00012		0,00005	0,00023			
	2											0,00002	0,00014	0,00037	0,00014	0,00005	0,00002	0,00073	
1,5											0,00054	0,00235	0,00114	0,00020			0,00423		
1											0,00123	0,01011	0,01061	0,00156	0,00016	0,00003	0,02369		
0,5											0,00179	0,02745	0,03385	0,00817	0,00058	0,00006	0,00005	0,07194	
<0,25											0,00009	0,01845	0,02791	0,00821	0,00112	0,00020	0,00008	0,00005	0,05611
		0,00000	0,00000	0,00000	0,00009	0,02080	0,05760	0,05290	0,02238	0,00390	0,00082	0,00019	0,00006	0,00000		0,15875			

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw = 9-11 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00000
	4,5															0,00000
	4											0,00002				0,00002
	3,5										0,00008	0,00005	0,00002			0,00014
	3									0,00017	0,00012	0,00009				0,00039
	2,5						0,00002	0,00058	0,00103	0,00044	0,00005					0,00210
	2					0,00002	0,00232	0,00748	0,00205	0,00012	0,00002					0,01201
1,5					0,00320	0,02532	0,01370	0,00087	0,00009						0,04320	
1				0,00180	0,03424	0,03173	0,00314	0,00011							0,07102	
0,5			0,00003	0,01076	0,01447	0,00260	0,00022	0,00003	0,00003						0,02814	
<0,25			0,00002	0,00031	0,00011	0,00003									0,00047	
		0,00000	0,00000	0,00000	0,00005	0,01288	0,05203	0,06202	0,02512	0,00426	0,00089	0,00022	0,00002	0,00000	0,15748	

Vw = 11-13 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00000
	4,5															0,00000
	4												0,00002			0,00002
	3,5										0,00003	0,00003				0,00006
	3									0,00002	0,00005	0,00012	0,00012	0,00002		0,00033
	2,5									0,00008	0,00056	0,00053	0,00008			0,00124
	2						0,00008	0,00229	0,00212	0,00037						0,00485
1,5						0,00002	0,00425	0,01425	0,00204	0,00009					0,02064	
1					0,00289	0,03344	0,01066	0,00020							0,04719	
0,5				0,00067	0,01902	0,01699	0,00068	0,00002							0,03738	
<0,25			0,00002	0,00232	0,00361	0,00042	0,00006								0,00642	
		0,00000	0,00000	0,00002	0,00300	0,02556	0,05517	0,02803	0,00498	0,00115	0,00023	0,00003	0,00000	0,00000	0,11817	

Vw = 13-15 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00000
	4,5															0,00000
	4															0,00000
	3,5															0,00000
	3															0,00000
	2,5															0,00000
	2															0,00000
1,5															0,00000	
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00065	0,00734	0,03246	0,03145	0,00759	0,00170	0,00034	0,00003	0,00000	0,08157	

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw = 15-17 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5														0,00000	
	9														0,00000	
	8,5														0,00000	
	8														0,00000	
	7,5														0,00000	
	7														0,00000	
	6,5														0,00000	
	6														0,00000	
	5,5													0,00003	0,00003	0,00003
	5											0,00002	0,00003			0,00005
	4,5										0,00006	0,00006	0,00005			0,00017
	4									0,00002	0,00019	0,00025	0,00002			0,00047
	3,5								0,00003	0,00045	0,00096	0,00025				0,00170
	3								0,00072	0,00350	0,00086	0,00006				0,00513
	2,5							0,00030	0,01101	0,00462	0,00033					0,01625
	2					0,00002	0,00622	0,01493	0,00078	0,00002						0,02196
1,5					0,00078	0,00997	0,00269	0,00005							0,01349	
1				0,00002	0,00086	0,00058	0,00002								0,00146	
0,5				0,00003	0,00006										0,00009	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00005	0,00171	0,01706	0,02940	0,00941	0,00241	0,00064	0,00012	0,00000	0,06080	

Vw = 17-19 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5														0,00000	
	9														0,00000	
	8,5														0,00000	
	8														0,00000	
	7,5														0,00000	
	7														0,00000	
	6,5														0,00000	
	6														0,00000	
	5,5													0,00002	0,00002	0,00002
	5										0,00002	0,00002	0,00002			0,00003
	4,5										0,00005	0,00026	0,00006	0,00002		0,00014
	4								0,00002	0,00008	0,00078	0,00026				0,00037
	3,5								0,00000	0,00143	0,00149	0,00006				0,00114
	3								0,00191	0,00540	0,00040					0,00299
	2,5							0,00022	0,00860	0,00296	0,00006					0,00772
	2							0,00255	0,00588	0,00014						0,01184
1,5					0,00008	0,00103	0,00047								0,00857	
1					0,00006	0,00009	0,00002								0,00157	
0,5															0,00017	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00014	0,00389	0,01689	0,01000	0,00278	0,00067	0,00014	0,00003	0,03455	

Vw = 19-21 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5														0,00000	
	9														0,00000	
	8,5														0,00000	
	8														0,00000	
	7,5														0,00000	
	7														0,00000	
	6,5														0,00000	
	6														0,00000	
	5,5													0,00003	0,00003	0,00003
	5											0,00002	0,00008			0,00009
	4,5											0,00020	0,00012			0,00033
	4										0,00022	0,00044	0,00002			0,00067
	3,5									0,00019	0,00107	0,00023				0,00149
	3								0,00003	0,00240	0,00135	0,00006				0,00199
	2,5								0,00162	0,00434	0,00033					0,00384
	2								0,00011	0,00453	0,00148	0,00002				0,00628
1,5								0,00064	0,00118	0,00006					0,00613	
1					0,00002	0,00017	0,00005								0,00188	
0,5															0,00023	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00092	0,00740	0,00846	0,00299	0,00095	0,00022	0,00003	0,02098	

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw = 21-23 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5													0,00002	0,00002
	6												0,00002	0,00002	0,00003
	5,5										0,00003	0,00008			0,00011
	5									0,00002	0,00016	0,00003			0,00020
	4,5									0,00033	0,00023				0,00056
	4								0,00026	0,00128	0,00003	0,00002			0,00159
	3,5								0,00184	0,00109					0,00292
	3							0,00065	0,00249	0,00036					0,00350
	2,5						0,00006	0,00078	0,00056						0,00140
	2						0,00008	0,00016							0,00023
1,5						0,00002	0,00002							0,00003	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00016	0,00160	0,00515	0,00306	0,00045	0,00014	0,00003	0,01059	

Vw = 23-25 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7												0,00002		0,00002
	6,5												0,00002	0,00002	0,00002
	6										0,00002	0,00002			0,00003
	5,5										0,00009	0,00003			0,00012
	5									0,00009	0,00023				0,00033
	4,5									0,00050	0,00014				0,00064
	4								0,00019	0,00076	0,00003				0,00098
	3,5								0,00079	0,00050					0,00129
	3							0,00008	0,00040	0,00006					0,00054
	2,5							0,00008	0,00006						0,00014
	2							0,00002							0,00002
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00017	0,00145	0,00191	0,00051	0,00006	0,00002	0,00412	

Vw = 25-27 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5													0,00002	0,00002
	6												0,00003		0,00003
	5,5										0,00008				0,00008
	5									0,00008	0,00014				0,00022
	4,5									0,00031	0,00005				0,00036
	4								0,00003	0,00058	0,00005				0,00065
	3,5								0,00026	0,00014					0,00040
	3							0,00003	0,00002	0,00003					0,00008
	2,5							0,00002							0,00002
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00005	0,00031	0,00114	0,00031	0,00003	0,00002	0,00185	

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw = 27-29 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6											0,00005			0,00005
	5,5														0,00000
	5										0,00003	0,00003			0,00006
	4,5										0,00012	0,00005			0,00017
	4									0,00005	0,00016	0,00003			0,00023
	3,5									0,00002					0,00002
	3									0,00003					0,00003
	2,5														0,00000
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00009	0,00031	0,00016	0,00000	0,00000	0,00056	

Vw = 29-31 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6												0,00002		0,00002
	5,5											0,00002			0,00002
	5										0,00003	0,00002			0,00005
	4,5										0,00003	0,00005			0,00008
	4										0,00003				0,00003
	3,5														0,00000
	3														0,00000
	2,5														0,00000
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00009	0,00009	0,00002	0,00000	0,00020	

Vw = 31-33 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6													0,00002	0,00002
	5,5														0,00000
	5														0,00000
	4,5											0,00002	0,00002		0,00003
	4														0,00000
	3,5														0,00000
	3														0,00000
	2,5									0,00002					0,00002
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00000	0,00000	0,00002	0,00003	0,00000	0,00006	

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw 33-35 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5											0,00002				0,00002
	5															0,00000
	4,5															0,00000
	4															0,00000
	3,5															0,00000
	3															0,00000
	2,5															0,00000
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00000	0,00000	0,00002	

Vw =35-37 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00000
	4,5															0,00000
	4															0,00000
	3,5															0,00000
	3															0,00000
	2,5															0,00000
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00000	0,00002	

Vw > 37 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00000
	4,5															0,00000
	4															0,00000
	3,5															0,00000
	3															0,00000
	2,5															0,00000
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	

D. Scatter diagrams ( $V - \theta_{wind} - \theta_{wave}$ )

All windspeeds		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,03366	0,00170	0,00034	0,00020	0,00011	0,00012	0,00009	0,00034	0,00075	0,00143	0,00317	0,02145	0,06337
030°	NNE	0,03837	0,01053	0,00092	0,00025	0,00016	0,00017	0,00006	0,00017	0,00044	0,00103	0,00166	0,00922	0,06298
060°	ENE	0,01691	0,02156	0,00852	0,00152	0,00050	0,00020	0,00008	0,00020	0,00034	0,00059	0,00068	0,00305	0,05416
090°	E	0,02073	0,02297	0,02129	0,01335	0,00562	0,00221	0,00123	0,00115	0,00148	0,00149	0,00177	0,00745	0,10075
120°	ESE	0,00611	0,00320	0,00238	0,00352	0,00709	0,00891	0,00481	0,00370	0,00299	0,00221	0,00230	0,00537	0,05259
150°	SSE	0,00373	0,00131	0,00112	0,00092	0,00143	0,00526	0,01265	0,01839	0,00784	0,00380	0,00341	0,00628	0,06612
180°	S	0,00282	0,00054	0,00023	0,00044	0,00051	0,00128	0,00952	0,03651	0,01870	0,00655	0,00515	0,00635	0,08859
210°	SSW	0,00226	0,00045	0,00030	0,00022	0,00034	0,00042	0,00283	0,04712	0,05990	0,01290	0,00689	0,00619	0,13981
240°	WSW	0,00207	0,00023	0,00023	0,00022	0,00031	0,00037	0,00068	0,01173	0,05972	0,02674	0,01683	0,01090	0,13004
270°	W	0,00232	0,00031	0,00019	0,00008	0,00012	0,00009	0,00023	0,00143	0,01529	0,02997	0,03263	0,01708	0,09975
300°	WNW	0,00440	0,00020	0,00011	0,00006	0,00002	0,00005	0,00016	0,00050	0,00339	0,00773	0,02126	0,03548	0,07336
330°	NNW	0,01308	0,00051	0,00012	0,00012	0,00006	0,00014	0,00019	0,00121	0,00244	0,00736	0,04323	0,06847	
		0,14647	0,06353	0,03576	0,02089	0,01621	0,01915	0,03248	0,12142	0,17204	0,09688	0,10313	0,17205	1,00000

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw < 1 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00005				0,00002			0,00002				0,00003	0,00011
030°	NNE	0,00003							0,00002		0,00003	0,00002	0,00006	0,00016
060°	ENE	0,00002								0,00005	0,00002		0,00003	0,00011
090°	E		0,00002					0,00002					0,00002	0,00005
120°	ESE	0,00009						0,00002	0,00000	0,00002	0,00002	0,00002	0,00002	0,00017
150°	SSE	0,00009	0,00002		0,00002		0,00002		0,00002	0,00002	0,00003	0,00002	0,00005	0,00026
180°	S	0,00009	0,00002		0,00005		0,00002		0,00002			0,00003	0,00012	0,00034
210°	SSW	0,00016							0,00002			0,00006	0,00006	0,00030
240°	WSW	0,00006	0,00002			0,00002		0,00002			0,00002	0,00005	0,00011	0,00028
270°	W	0,00008									0,00002	0,00011	0,00003	0,00023
300°	WNW	0,00008									0,00005		0,00003	0,00016
330°	NNW	0,00012								0,00002		0,00003	0,00006	0,00023
		0,00087	0,00006	0,00000	0,00006	0,00003	0,00003	0,00005	0,00008	0,00009	0,00017	0,00033	0,00062	0,00240

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 1-3 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00086	0,00011	0,00005		0,00006	0,00006	0,00002	0,00008	0,00014	0,00017	0,00045	0,00115	0,00314
030°	NNE	0,00104	0,00011	0,00009	0,00003		0,00003		0,00002	0,00009	0,00025	0,00028	0,00103	0,00297
060°	ENE	0,00061	0,00017	0,00006		0,00002	0,00003	0,00002	0,00005	0,00012	0,00012	0,00016	0,00058	0,00193
090°	E	0,00126	0,00034	0,00009	0,00009	0,00008	0,00006	0,00016	0,00012	0,00026	0,00028	0,00030	0,00138	0,00443
120°	ESE	0,00129	0,00036	0,00017	0,00016	0,00008	0,00017	0,00026	0,00023	0,00042	0,00045	0,00072	0,00163	0,00594
150°	SSE	0,00096	0,00026	0,00012	0,00014	0,00009	0,00012	0,00025	0,00031	0,00059	0,00054	0,00082	0,00159	0,00582
180°	S	0,00098	0,00008	0,00005	0,00002	0,00005	0,00009	0,00009	0,00030	0,00064	0,00067	0,00103	0,00129	0,00527
210°	SSW	0,00058	0,00009	0,00002	0,00002	0,00003	0,00003	0,00002	0,00016	0,00048	0,00042	0,00059	0,00135	0,00378
240°	WSW	0,00042	0,00003	0,00005	0,00002		0,00006	0,00003	0,00017	0,00039	0,00045	0,00098	0,00114	0,00373
270°	W	0,00042	0,00008	0,00002	0,00002	0,00003	0,00003	0,00003	0,00019	0,00040	0,00048	0,00104	0,00142	0,00415
300°	WNW	0,00062	0,00003		0,00002		0,00002	0,00002	0,00011	0,00033	0,00034	0,00053	0,00137	0,00338
330°	NNW	0,00103	0,00008	0,00005			0,00006	0,00002	0,00026	0,00026	0,00054	0,00154	0,00384	
		0,01006	0,00174	0,00076	0,00050	0,00044	0,00072	0,00095	0,00174	0,00414	0,00445	0,00744	0,01546	0,04839

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw 3-5 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00417	0,00028	0,00009	0,00008		0,00002	0,00003	0,00008	0,00025	0,00058	0,00082	0,00369	0,01008
030°	NNE	0,00546	0,00084	0,00016	0,00005	0,00005	0,00003		0,00009	0,00019	0,00030	0,00050	0,00277	0,01042
060°	ENE	0,00188	0,00075	0,00034	0,00008	0,00012	0,00003	0,00002	0,00006	0,00005	0,00017	0,00022	0,00081	0,00453
090°	E	0,00572	0,00300	0,00149	0,00093	0,00092	0,00070	0,00044	0,00051	0,00062	0,00059	0,00070	0,00289	0,01853
120°	ESE	0,00266	0,00100	0,00051	0,00053	0,00065	0,00124	0,00098	0,00120	0,00117	0,00079	0,00090	0,00218	0,01381
150°	SSE	0,00148	0,00033	0,00042	0,00025	0,00020	0,00065	0,00162	0,00222	0,00218	0,00134	0,00120	0,00254	0,01442
180°	S	0,00107	0,00028	0,00006	0,00014	0,00014	0,00020	0,00089	0,00201	0,00250	0,00143	0,00135	0,00257	0,01265
210°	SSW	0,00068	0,00006	0,00006	0,00005	0,00006	0,00008	0,00034	0,00096	0,00235	0,00194	0,00131	0,00187	0,00977
240°	WSW	0,00081	0,00005	0,00006	0,00008	0,00006	0,00006	0,00012	0,00059	0,00188	0,00154	0,00229	0,00299	0,01053
270°	W	0,00084	0,00009	0,00006	0,00002	0,00002	0,00002	0,00008	0,00023	0,00095	0,00156	0,00263	0,00361	0,01010
300°	WNW	0,00131	0,00012	0,00008	0,00003	0,00002	0,00003	0,00008	0,00012	0,00064	0,00095	0,00202	0,00495	0,01034
330°	NNW	0,00216	0,00020	0,00003	0,00005		0,00006	0,00006	0,00011	0,00037	0,00051	0,00126	0,00541	0,01024
		0,02825	0,00700	0,00338	0,00227	0,00224	0,00313	0,00465	0,00820	0,01314	0,01170	0,01520	0,03626	0,13541

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 5-7 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00566	0,00036	0,00011	0,00006	0,00002	0,00003	0,00002	0,00006	0,00016	0,00033	0,00073	0,00418	0,01171
030°	NNE	0,01034	0,00163	0,00012	0,00005	0,00003	0,00003	0,00003	0,00008	0,00030	0,00050	0,00308	0,01622	
060°	ENE	0,00361	0,00176	0,00064	0,00020	0,00011	0,00003		0,00005	0,00006	0,00011	0,00011	0,00072	0,00739
090°	E	0,00702	0,00527	0,00306	0,00215	0,00121	0,00081	0,00037	0,00026	0,00047	0,00045	0,00053	0,00227	0,02388
120°	ESE	0,00148	0,00112	0,00087	0,00087	0,00135	0,00222	0,00143	0,00115	0,00093	0,00068	0,00044	0,00124	0,01380
150°	SSE	0,00076	0,00031	0,00025	0,00020	0,00030	0,00082	0,00249	0,00471	0,00299	0,00120	0,00101	0,00170	0,01674
180°	S	0,00037	0,00008	0,00006	0,00005	0,00009	0,00023	0,00124	0,00341	0,00339	0,00180	0,00159	0,00162	0,01394
210°	SSW	0,00044	0,00011	0,00008	0,00003	0,00003	0,00006	0,00047	0,00243	0,00397	0,00226	0,00157	0,00140	0,01283
240°	WSW	0,00047	0,00005	0,00008	0,00005	0,00011	0,00008	0,00009	0,00103	0,00344	0,00313	0,00314	0,00285	0,01450
270°	W	0,00064	0,00002	0,00005		0,00006		0,00002	0,00026	0,00148	0,00233	0,00342	0,00361	0,01188
300°	WNW	0,00076	0,00005		0,00002			0,00003	0,00014	0,00045	0,00075	0,00226	0,00599	0,01044
330°	NNW	0,00263	0,00009		0,00005			0,00002	0,00002	0,00022	0,00044	0,00096	0,00633	0,01075
		0,03417	0,01084	0,00532	0,00372	0,00331	0,00432	0,00621	0,01355	0,01762	0,01377	0,01625	0,03498	0,16407

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 7-9 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00642	0,00028		0,00005	0,00002	0,00002	0,00003		0,00008	0,00016	0,00047	0,00345	0,01097
030°	NNE	0,00854	0,00246	0,00012	0,00005	0,00002	0,00005		0,00002	0,00005	0,00009	0,00023	0,00107	0,01269
060°	ENE	0,00376	0,00369	0,00131	0,00034	0,00009	0,00006	0,00002	0,00003	0,00005	0,00009	0,00009	0,00044	0,00997
090°	E	0,00387	0,00502	0,00411	0,00296	0,00140	0,00039	0,00017	0,00020	0,00008	0,00014	0,00019	0,00067	0,01919
120°	ESE	0,00040	0,00047	0,00045	0,00092	0,00205	0,00240	0,00128	0,00078	0,00034	0,00017	0,00014	0,00026	0,00966
150°	SSE	0,00034	0,00023	0,00025	0,00019	0,00050	0,00142	0,00299	0,00470	0,00140	0,00044	0,00026	0,00037	0,01308
180°	S	0,00019	0,00006	0,00002	0,00006	0,00009	0,00036	0,00247	0,00604	0,00417	0,00142	0,00073	0,00054	0,01615
210°	SSW	0,00026	0,00005	0,00006	0,00006	0,00005	0,00005	0,00047	0,00381	0,00632	0,00246	0,00160	0,00096	0,01615
240°	WSW	0,00016	0,00003		0,00005	0,00003	0,00003	0,00014	0,00159	0,00546	0,00389	0,00369	0,00232	0,01737
270°	W	0,00020	0,00006	0,00002	0,00005		0,00002	0,00002	0,00014	0,00204	0,00288	0,00490	0,00322	0,01353
300°	WNW	0,00070							0,00002	0,00053	0,00106	0,00247	0,00513	0,00991
330°	NNW	0,00269	0,00005	0,00002	0,00002					0,00005	0,00022	0,00103	0,00602	0,01008
		0,02755	0,01240	0,00635	0,00473	0,00425	0,00478	0,00758	0,01731	0,02055	0,01300	0,01580	0,02447	0,15875

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw 9-11 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00733	0,00033	0,00003					0,00003	0,00003	0,00008	0,00030	0,00344	0,01156
030°	NNE	0,00678	0,00232	0,00014	0,00005	0,00002					0,00002	0,00008	0,00070	0,01010
060°	ENE	0,00375	0,00544	0,00165	0,00036	0,00009	0,00003	0,00003	0,00002	0,00002	0,00006	0,00005	0,00031	0,01181
090°	E	0,00205	0,00467	0,00470	0,00327	0,00129	0,00016	0,00006	0,00005	0,00002	0,00003	0,00002	0,00020	0,01650
120°	ESE	0,00016	0,00023	0,00028	0,00087	0,00187	0,00193	0,00054	0,00023	0,00003	0,00006	0,00008	0,00003	0,00632
150°	SSE	0,00006	0,00012	0,00006	0,00006	0,00025	0,00126	0,00289	0,00336	0,00054	0,00020	0,00006	0,00003	0,00891
180°	S	0,00008	0,00002	0,00003	0,00008	0,00008	0,00019	0,00207	0,00820	0,00359	0,00078	0,00025	0,00016	0,01551
210°	SSW	0,00009	0,00006		0,00003	0,00005	0,00002	0,00034	0,00688	0,00829	0,00238	0,00115	0,00044	0,01972
240°	WSW	0,00008	0,00003	0,00003	0,00002	0,00006	0,00005	0,00009	0,00199	0,00940	0,00535	0,00297	0,00098	0,02105
270°	W	0,00006	0,00002	0,00003		0,00002	0,00002	0,00006	0,00020	0,00252	0,00389	0,00530	0,00229	0,01440
300°	WNW	0,00050		0,00003					0,00003	0,00045	0,00114	0,00338	0,00569	0,01122
330°	NNW	0,00191	0,00005	0,00003	0,00002				0,00003	0,00008	0,00023	0,00095	0,00709	0,01039
		0,02285	0,01328	0,00702	0,00474	0,00372	0,00364	0,00610	0,02101	0,02497	0,01422	0,01458	0,02136	0,15748

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 11-13 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00509	0,00023	0,00003	0,00002					0,00005	0,00003	0,00006	0,00236	0,00787
030°	NNE	0,00294	0,00162	0,00012		0,00002	0,00002	0,00002		0,00002	0,00002		0,00020	0,00496
060°	ENE	0,00204	0,00468	0,00154	0,00022	0,00003						0,00002	0,00008	0,00860
090°	E	0,00067	0,00235	0,00319	0,00226	0,00042	0,00008	0,00002				0,00003	0,00002	0,00902
120°	ESE	0,00003	0,00002	0,00009	0,00016	0,00067	0,00070	0,00023	0,00009	0,00003	0,00002			0,00204
150°	SSE	0,00003	0,00002	0,00002	0,00005	0,00003	0,00067	0,00152	0,00173	0,00011	0,00002	0,00002	0,00002	0,00422
180°	S	0,00003	0,00002		0,00005	0,00003	0,00008	0,00140	0,00649	0,00177	0,00037	0,00012	0,00003	0,01039
210°	SSW	0,00003	0,00005	0,00002	0,00002	0,00005	0,00006	0,00042	0,00918	0,00795	0,00173	0,00047	0,00006	0,02002
240°	WSW	0,00005	0,00003	0,00002	0,00002	0,00002	0,00006	0,00011	0,00222	0,01041	0,00465	0,00198	0,00037	0,01993
270°	W	0,00005	0,00003				0,00002		0,00020	0,00201	0,00408	0,00445	0,00135	0,01218
300°	WNW	0,00025						0,00003	0,00008	0,00030	0,00110	0,00350	0,00479	0,01005
330°	NNW	0,00123	0,00002							0,00008	0,00033	0,00101	0,00624	0,00890
		0,01243	0,00905	0,00502	0,00277	0,00126	0,00168	0,00375	0,01999	0,02271	0,01234	0,01165	0,01552	0,11817

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 13-15 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00241	0,00009	0,00002					0,00006	0,00002	0,00003	0,00014	0,00151	0,00428
030°	NNE	0,00190	0,00090	0,00008	0,00002	0,00003	0,00002	0,00002				0,00005	0,00016	0,00316
060°	ENE	0,00092	0,00272	0,00140	0,00023	0,00002	0,00002				0,00002		0,00006	0,00538
090°	E	0,00014	0,00145	0,00243	0,00107	0,00023				0,00002				0,00534
120°	ESE		0,00002		0,00002	0,00037	0,00023	0,00006		0,00003				0,00073
150°	SSE		0,00002		0,00002	0,00003	0,00019	0,00056	0,00084	0,00002	0,00003	0,00002		0,00171
180°	S			0,00002		0,00002	0,00006	0,00064	0,00404	0,00126	0,00008	0,00005	0,00002	0,00618
210°	SSW		0,00002	0,00003	0,00002	0,00002	0,00005	0,00039	0,00717	0,00790	0,00100	0,00012	0,00003	0,01674
240°	WSW	0,00003						0,00005	0,00180	0,00857	0,00299	0,00093	0,00011	0,01448
270°	W	0,00002	0,00002	0,00002				0,00002	0,00009	0,00185	0,00400	0,00355	0,00076	0,01031
300°	WNW	0,00008								0,00026	0,00076	0,00229	0,00322	0,00661
330°	NNW	0,00081	0,00003							0,00005	0,00023	0,00067	0,00487	0,00666
		0,00630	0,00526	0,00398	0,00137	0,00072	0,00056	0,00173	0,01402	0,01997	0,00913	0,00781	0,01073	0,08157

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

## Upwind Design Basis – Ijmuiden Shallow Water Site

Vw 15-17 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00076	0,00002	0,00002						0,00002	0,00002	0,00008	0,00103	0,00193
030°	NNE	0,00092	0,00040	0,00003	0,00002					0,00002	0,00003		0,00008	0,00149
060°	ENE	0,00022	0,00142	0,00076	0,00008	0,00002						0,00003	0,00003	0,00255
090°	E		0,00058	0,00128	0,00042	0,00006	0,00002					0,00002		0,00236
120°	ESE					0,00005	0,00002		0,00002		0,00002			0,00009
150°	SSE						0,00003	0,00008	0,00025	0,00037				0,00073
180°	S							0,00003	0,00031	0,00308	0,00075			0,00417
210°	SSW	0,00002	0,00002	0,00003		0,00002	0,00002	0,00022	0,00795	0,00846	0,00054	0,00002		0,01728
240°	WSW					0,00002		0,00002	0,00128	0,00815	0,00258	0,00051	0,00003	0,01258
270°	W	0,00002						0,00005	0,00160	0,00375	0,00348	0,00050		0,00940
300°	WNW	0,00006								0,00016	0,00048	0,00171	0,00199	0,00440
330°	NNW	0,00028								0,00002	0,00011	0,00037	0,00303	0,00381
		0,00227	0,00243	0,00212	0,00051	0,00019	0,00016	0,00079	0,01274	0,01916	0,00753	0,00622	0,00669	0,06080

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 17-19 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00056							0,00002	0,00002	0,00003	0,00005	0,00039	0,00106
030°	NNE	0,00030	0,00016	0,00002								0,00002	0,00006	0,00054
060°	ENE	0,00003	0,00072	0,00062	0,00002							0,00002		0,00140
090°	E		0,00019	0,00048	0,00014					0,00002				0,00082
120°	ESE											0,00002		0,00002
150°	SSE						0,00002	0,00006	0,00009					0,00017
180°	S					0,00002	0,00002	0,00019	0,00160	0,00033				0,00215
210°	SSW					0,00002	0,00005	0,00003	0,00443	0,00563	0,00011		0,00002	0,01028
240°	WSW							0,00002	0,00050	0,00548	0,00121	0,00025	0,00002	0,00747
270°	W								0,00005	0,00093	0,00255	0,00165	0,00017	0,00535
300°	WNW									0,00014	0,00058	0,00149	0,00129	0,00350
330°	NNW	0,00017								0,00002	0,00003	0,00019	0,00138	0,00179
		0,00106	0,00106	0,00112	0,00016	0,00003	0,00008	0,00030	0,00669	0,01255	0,00451	0,00367	0,00333	0,03455

Percentage of time [%]

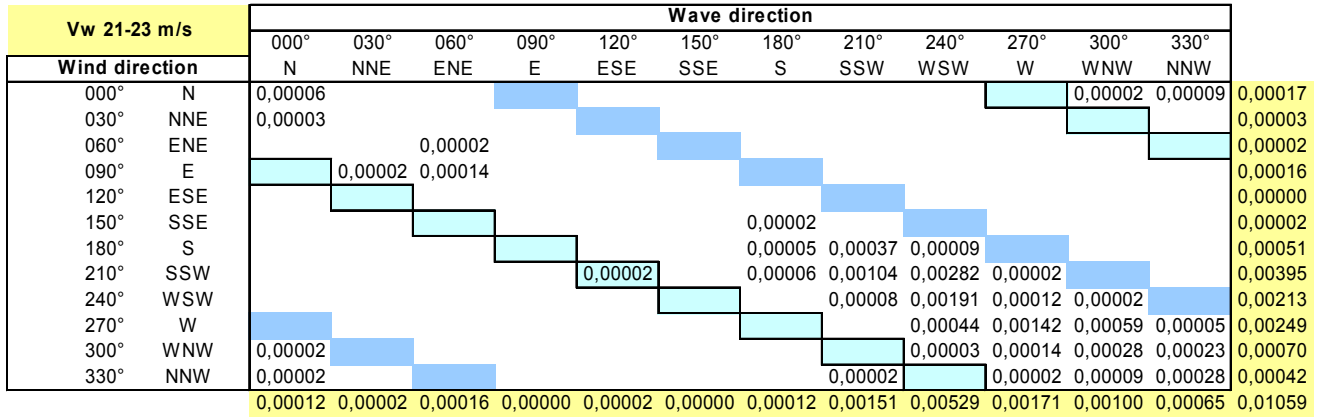
90° + from wind direction  
90° - from wind direction

Vw 19-21 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00026									0,00002	0,00005	0,00012	0,00045
030°	NNE	0,00008	0,00009	0,00003									0,00002	0,00022
060°	ENE	0,00006	0,00022	0,00017										0,00045
090°	E		0,00008	0,00033	0,00006									0,00047
120°	ESE									0,00002				0,00002
150°	SSE						0,00002		0,00003					0,00005
180°	S							0,00017	0,00079	0,00012				0,00109
210°	SSW					0,00002	0,00002	0,00008	0,00247	0,00420	0,00005			0,00683
240°	WSW								0,00042	0,00358	0,00059	0,00003		0,00462
270°	W							0,00002		0,00061	0,00196	0,00109	0,00008	0,00375
300°	WNW	0,00003								0,00008	0,00020	0,00101	0,00068	0,00201
330°	NNW	0,00003								0,00003	0,00003	0,00017	0,00078	0,00104
		0,00047	0,00039	0,00053	0,00006	0,00002	0,00003	0,00026	0,00372	0,00863	0,00285	0,00235	0,00168	0,02098

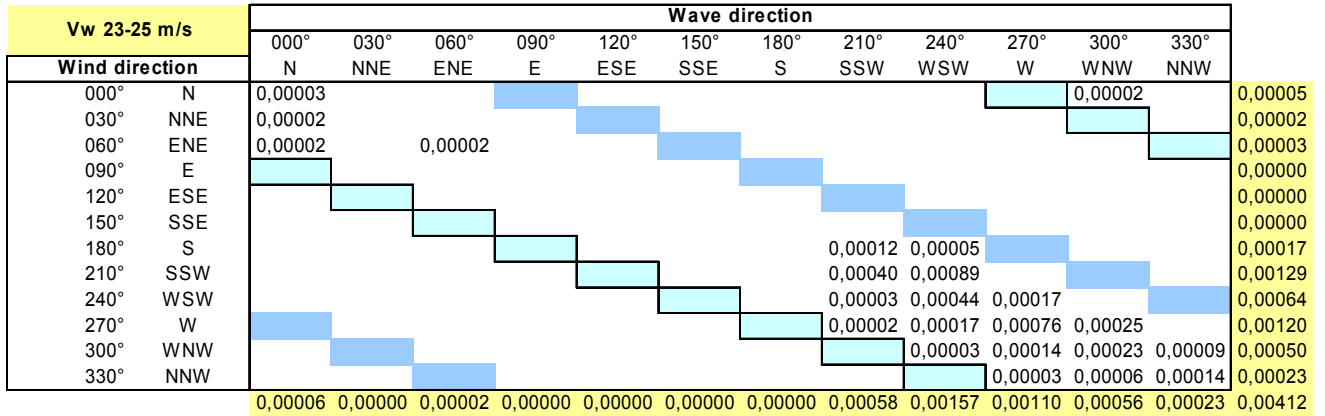
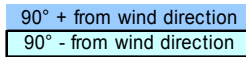
Percentage of time [%]

90° + from wind direction  
90° - from wind direction

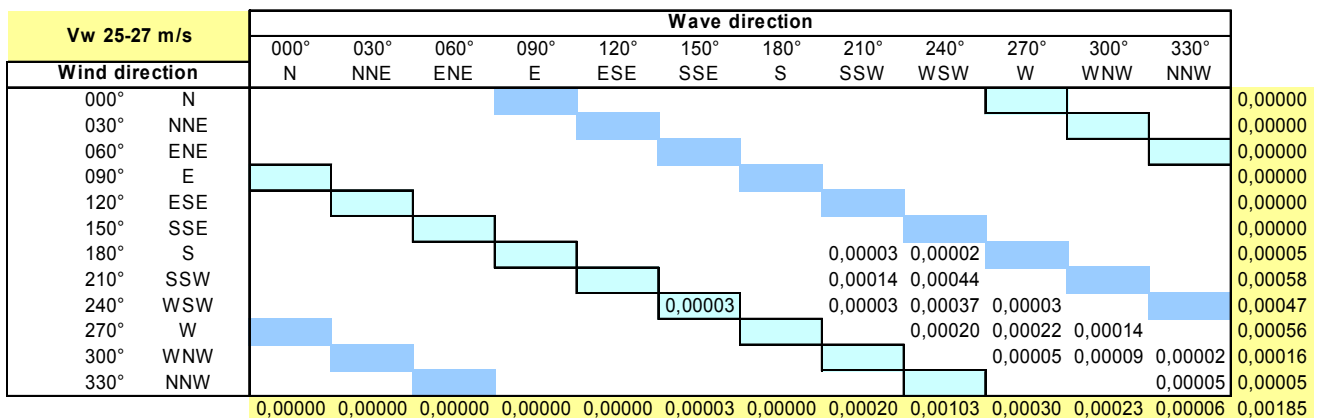
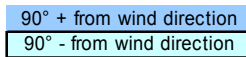
## Upwind Design Basis – Ijmuiden Shallow Water Site



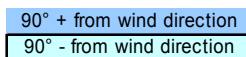
Percentage of time [%]



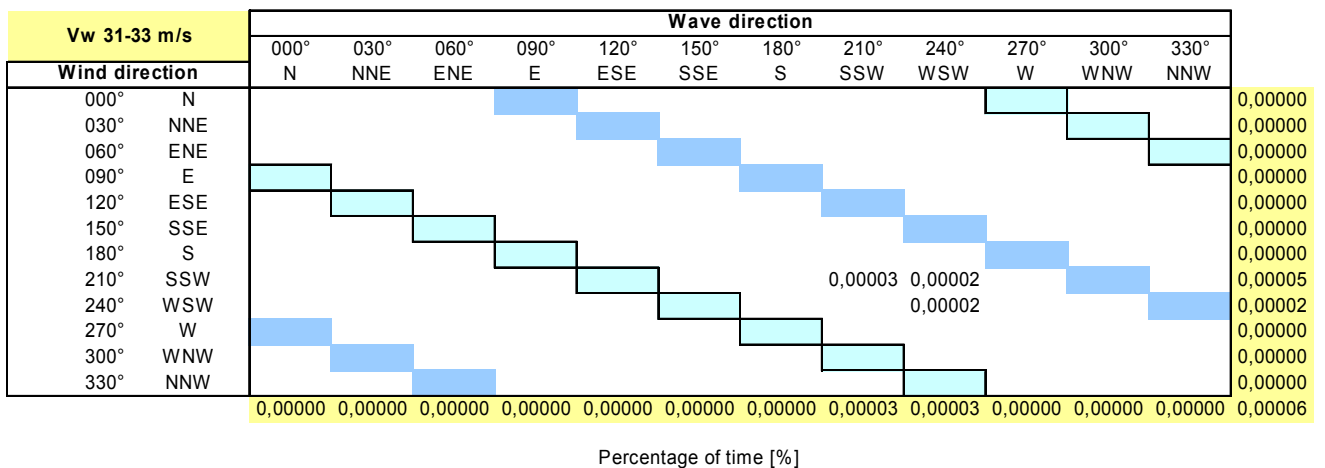
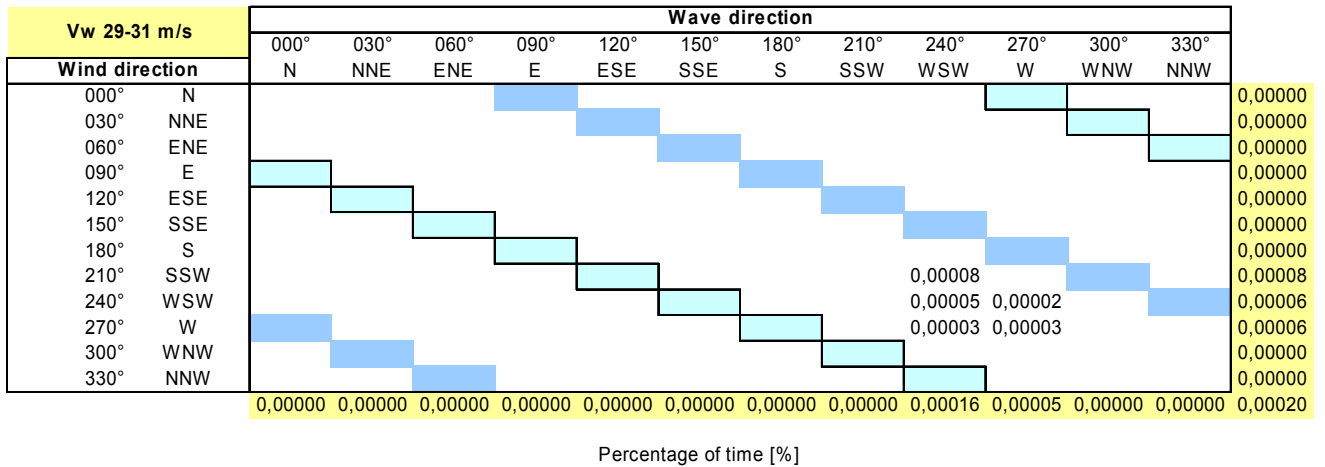
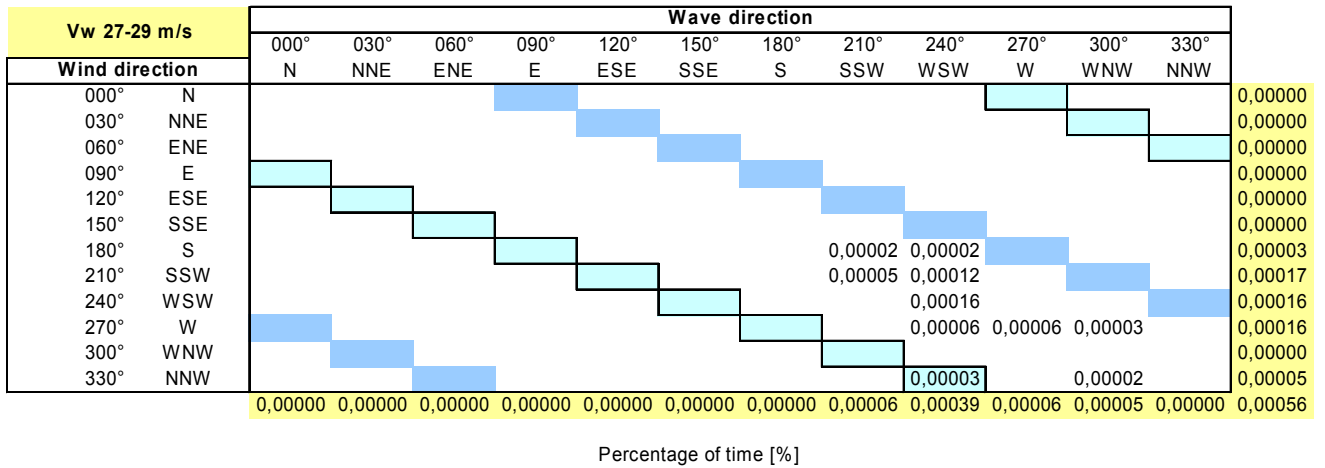
Percentage of time [%]



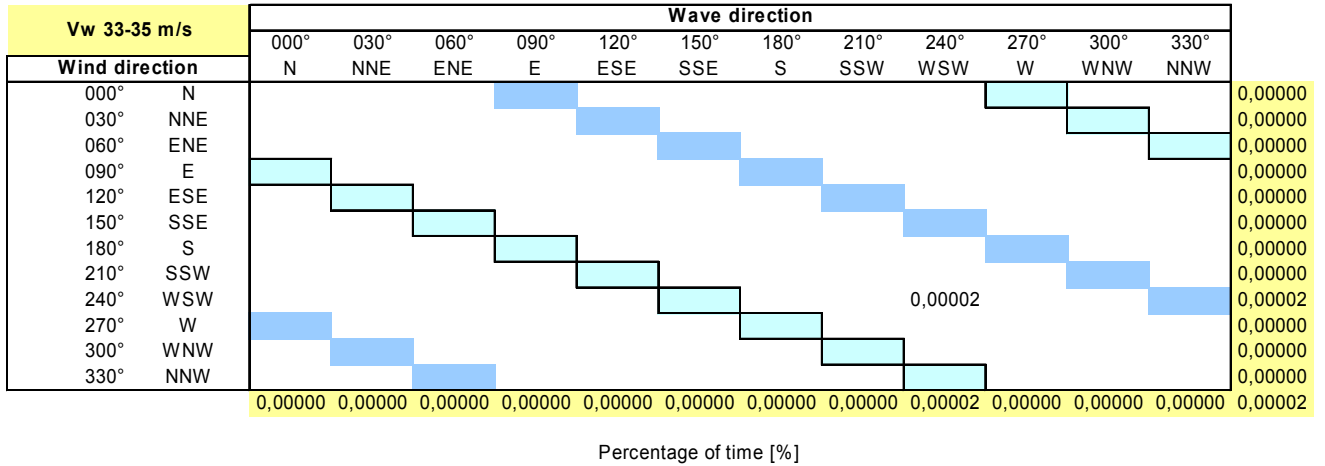
Percentage of time [%]



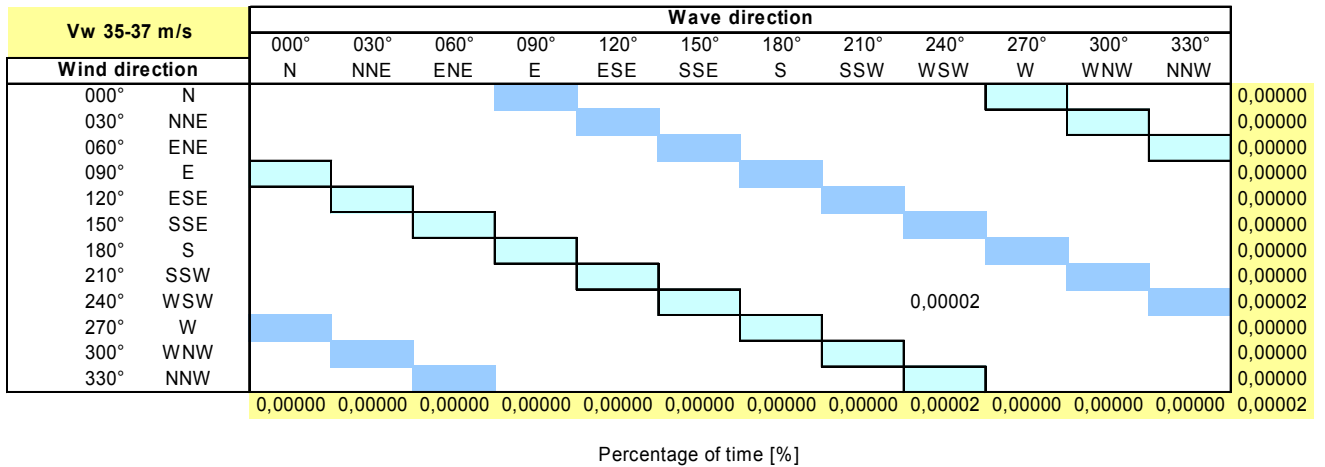
## Upwind Design Basis – Ijmuiden Shallow Water Site



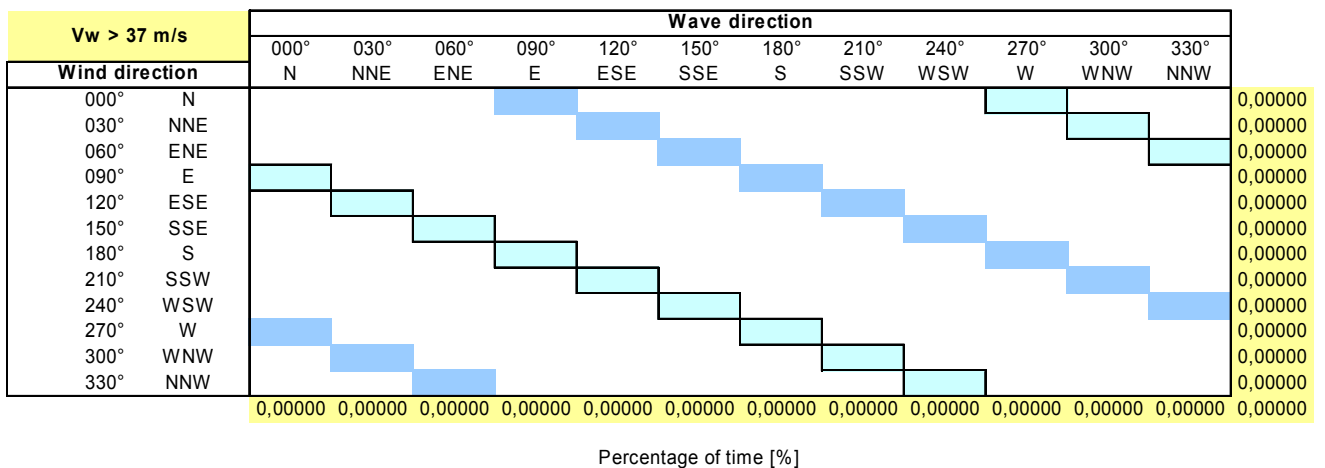
## Upwind Design Basis – Ijmuiden Shallow Water Site



90° + from wind direction  
90° - from wind direction



90° + from wind direction  
90° - from wind direction



90° + from wind direction  
90° - from wind direction

**E. Reduced scatter diagrams ( $V - \theta_{wind} - \theta_{wave}$ )**

All windspeeds		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,04609	0,03909	0,02002	0,00862	0,00894	0,02920	0,15196
030°	NNE	0,04352	0,05827	0,06155	0,01439	0,00905	0,01601	0,20279
060°	ENE	0,01974	0,03372	0,06882	0,02907	0,01832	0,01453	0,18420
090°	E	0,02451	0,02587	0,03825	0,04489	0,04015	0,02683	0,20050
120°	ESE	0,01548	0,00761	0,00887	0,01352	0,03067	0,04981	0,12595
150°	SSE	0,02960	0,02039	0,01030	0,00728	0,01220	0,05483	0,13460
		0,17894	0,18495	0,20780	0,11777	0,11934	0,19120	1,00000

Vw < 1 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00014	0,00005		0,00005	0,00005	0,00017	0,00045
030°	NNE	0,00019	0,00003		0,00003	0,00008	0,00012	0,00045
060°	ENE	0,00009	0,00002	0,00005	0,00003	0,00006	0,00014	0,00039
090°	E	0,00009	0,00002		0,00002	0,00011	0,00005	0,00028
120°	ESE	0,00019		0,00002	0,00006	0,00002	0,00005	0,00033
150°	SSE	0,00022	0,00003	0,00003	0,00005	0,00005	0,00012	0,00050
		0,00092	0,00014	0,00009	0,00023	0,00036	0,00065	0,00240

Vw 1-3 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00194	0,00056	0,00087	0,00086	0,00159	0,00260	0,00842
030°	NNE	0,00163	0,00037	0,00068	0,00072	0,00090	0,00244	0,00675
060°	ENE	0,00107	0,00042	0,00062	0,00059	0,00115	0,00180	0,00566
090°	E	0,00187	0,00073	0,00078	0,00087	0,00145	0,00289	0,00859
120°	ESE	0,00219	0,00073	0,00092	0,00096	0,00132	0,00319	0,00932
150°	SSE	0,00230	0,00067	0,00103	0,00095	0,00146	0,00325	0,00966
		0,01101	0,00348	0,00490	0,00495	0,00787	0,01618	0,04839

Vw 3-5 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00616	0,00264	0,00291	0,00222	0,00232	0,00647	0,02273
030°	NNE	0,00649	0,00196	0,00275	0,00233	0,00191	0,00474	0,02019
060°	ENE	0,00283	0,00145	0,00233	0,00187	0,00269	0,00389	0,01506
090°	E	0,00708	0,00384	0,00313	0,00310	0,00426	0,00722	0,02862
120°	ESE	0,00502	0,00244	0,00240	0,00230	0,00359	0,00840	0,02416
150°	SSE	0,00532	0,00286	0,00300	0,00215	0,00266	0,00866	0,02465
		0,03290	0,01520	0,01652	0,01397	0,01744	0,03939	0,13541

Vw 5-7 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00730	0,00390	0,00372	0,00224	0,00243	0,00607	0,02565
030°	NNE	0,01128	0,00420	0,00425	0,00263	0,00213	0,00457	0,02906
060°	ENE	0,00417	0,00288	0,00422	0,00348	0,00347	0,00367	0,02189
090°	E	0,00804	0,00582	0,00506	0,00493	0,00523	0,00669	0,03576
120°	ESE	0,00370	0,00246	0,00226	0,00232	0,00404	0,00946	0,02423
150°	SSE	0,00590	0,00513	0,00345	0,00188	0,00227	0,00885	0,02749
		0,04038	0,02439	0,02294	0,01748	0,01957	0,03931	0,16407

Upwind Design Basis – Ijmuiden Shallow Water Site

Vw 7-9 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00912	0,00638	0,00426	0,00168	0,00131	0,00437	0,02711
030°	NNE	0,00927	0,00633	0,00655	0,00266	0,00190	0,00213	0,02884
060°	ENE	0,00408	0,00534	0,00681	0,00437	0,00390	0,00285	0,02735
090°	E	0,00426	0,00543	0,00624	0,00602	0,00649	0,00429	0,03273
120°	ESE	0,00238	0,00126	0,00132	0,00215	0,00467	0,00779	0,01957
150°	SSE	0,00602	0,00498	0,00171	0,00086	0,00179	0,00781	0,02316
		0,03512	0,02971	0,02689	0,01773	0,02005	0,02924	0,15875

Vw 9-11 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00947	0,00857	0,00369	0,00093	0,00062	0,00378	0,02707
030°	NNE	0,00722	0,00926	0,00843	0,00247	0,00129	0,00115	0,02982
060°	ENE	0,00395	0,00748	0,01109	0,00579	0,00317	0,00137	0,03285
090°	E	0,00224	0,00493	0,00726	0,00719	0,00663	0,00266	0,03091
120°	ESE	0,00120	0,00050	0,00079	0,00207	0,00532	0,00765	0,01753
150°	SSE	0,00487	0,00356	0,00072	0,00051	0,00126	0,00838	0,01930
		0,02895	0,03430	0,03198	0,01896	0,01829	0,02500	0,15748

Vw 11-13 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00652	0,00674	0,00185	0,00047	0,00022	0,00247	0,01826
030°	NNE	0,00341	0,01084	0,00810	0,00176	0,00053	0,00034	0,02498
060°	ENE	0,00219	0,00694	0,01196	0,00488	0,00204	0,00051	0,02853
090°	E	0,00073	0,00258	0,00520	0,00633	0,00490	0,00146	0,02120
120°	ESE	0,00054	0,00019	0,00042	0,00128	0,00417	0,00549	0,01209
150°	SSE	0,00278	0,00176	0,00020	0,00039	0,00106	0,00692	0,01311
		0,01618	0,02904	0,02773	0,01510	0,01291	0,01720	0,11817

Vw 13-15 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00305	0,00420	0,00131	0,00011	0,00020	0,00159	0,01045
030°	NNE	0,00230	0,00809	0,00801	0,00103	0,00022	0,00025	0,01989
060°	ENE	0,00100	0,00453	0,00997	0,00324	0,00095	0,00019	0,01986
090°	E	0,00017	0,00156	0,00431	0,00507	0,00378	0,00076	0,01565
120°	ESE	0,00014	0,00002	0,00030	0,00078	0,00266	0,00345	0,00734
150°	SSE	0,00137	0,00089	0,00006	0,00028	0,00072	0,00506	0,00837
		0,00803	0,01927	0,02395	0,01050	0,00852	0,01129	0,08157

Vw 15-17 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00107	0,00310	0,00078	0,00002	0,00008	0,00106	0,00610
030°	NNE	0,00115	0,00837	0,00854	0,00059	0,00003	0,00009	0,01877
060°	ENE	0,00023	0,00269	0,00891	0,00266	0,00058	0,00006	0,01514
090°	E	0,00002	0,00062	0,00288	0,00417	0,00356	0,00051	0,01176
120°	ESE	0,00006	0,00002	0,00016	0,00050	0,00176	0,00201	0,00450
150°	SSE	0,00053	0,00037	0,00002	0,00011	0,00040	0,00311	0,00454
		0,00306	0,01517	0,02128	0,00804	0,00641	0,00684	0,06080

Vw 17-19 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00075	0,00162	0,00034	0,00003	0,00006	0,00040	0,00320
030°	NNE	0,00033	0,00459	0,00565	0,00011	0,00003	0,00012	0,01083
060°	ENE	0,00005	0,00121	0,00610	0,00123	0,00026	0,00002	0,00887
090°	E		0,00023	0,00143	0,00269	0,00165	0,00017	0,00618
120°	ESE			0,00014	0,00058	0,00151	0,00129	0,00352
150°	SSE	0,00023	0,00009	0,00002	0,00003	0,00019	0,00140	0,00196
		0,00135	0,00775	0,01367	0,00467	0,00370	0,00341	0,03455

Upwind Design Basis – Ijmuiden Shallow Water Site

Vw 19-21 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00044	0,00079	0,00012	0,00002	0,00005	0,00012	0,00154
030°	NNE	0,00016	0,00257	0,00423	0,00005	0,00002	0,00003	0,00705
060°	ENE	0,00006	0,00064	0,00375	0,00059	0,00003		0,00507
090°	E	0,00002	0,00008	0,00093	0,00202	0,00109	0,00008	0,00422
120°	ESE	0,00003		0,00009	0,00020	0,00101	0,00068	0,00202
150°	SSE	0,00003	0,00003	0,00003	0,00003	0,00017	0,00079	0,00109
		0,00073	0,00411	0,00916	0,00291	0,00236	0,00171	0,02098

Vw 21-23 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00011	0,00037	0,00009		0,00002	0,00009	0,00068
030°	NNE	0,00009	0,00104	0,00282	0,00002	0,00002		0,00398
060°	ENE		0,00008	0,00193	0,00012	0,00002		0,00215
090°	E		0,00002	0,00058	0,00142	0,00059	0,00005	0,00264
120°	ESE	0,00002		0,00003	0,00014	0,00028	0,00023	0,00070
150°	SSE	0,00003	0,00002		0,00002	0,00009	0,00028	0,00044
		0,00025	0,00152	0,00544	0,00171	0,00101	0,00065	0,01059

Vw 23-25 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00003	0,00012	0,00005		0,00002		0,00022
030°	NNE	0,00002	0,00040	0,00089				0,00131
060°	ENE	0,00002	0,00003	0,00045	0,00017			0,00067
090°	E		0,00002	0,00017	0,00076	0,00025		0,00120
120°	ESE			0,00003	0,00014	0,00023	0,00009	0,00050
150°	SSE				0,00003	0,00006	0,00014	0,00023
		0,00006	0,00058	0,00159	0,00110	0,00056	0,00023	0,00412

Vw 25-27 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N		0,00003	0,00002				0,00005
030°	NNE		0,00014	0,00044				0,00058
060°	ENE		0,00003	0,00037	0,00003		0,00003	0,00047
090°	E			0,00020	0,00022	0,00014		0,00056
120°	ESE				0,00005	0,00009	0,00002	0,00016
150°	SSE						0,00005	0,00005
		0,00000	0,00020	0,00103	0,00030	0,00023	0,00009	0,00185

Vw 27-29 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N		0,00002	0,00002				0,00003
030°	NNE		0,00005	0,00012				0,00017
060°	ENE			0,00016				0,00016
090°	E			0,00006	0,00006	0,00003		0,00016
120°	ESE							0,00000
150°	SSE			0,00003		0,00002		0,00005
		0,00000	0,00006	0,00039	0,00006	0,00005	0,00000	0,00056

Vw 29-31 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE			0,00008				0,00008
060°	ENE			0,00005	0,00002			0,00006
090°	E			0,00003	0,00003			0,00006
120°	ESE							0,00000
150°	SSE							0,00000
		0,00000	0,00000	0,00016	0,00005	0,00000	0,00000	0,00020

Upwind Design Basis – Ijmuiden Shallow Water Site

Vw 31-33 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE		0,00003	0,00002				0,00005
060°	ENE			0,00002				0,00002
090°	E							0,00000
120°	ESE							0,00000
150°	SSE							0,00000
		0,00000	0,00003	0,00003	0,00000	0,00000	0,00000	0,00006

Vw 33-35 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE							0,00000
060°	ENE			0,00002				0,00002
090°	E							0,00000
120°	ESE							0,00000
150°	SSE							0,00000
		0,00000	0,00000	0,00002	0,00000	0,00000	0,00000	0,00002

Vw 35-37 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE							0,00000
060°	ENE			0,00002				0,00002
090°	E							0,00000
120°	ESE							0,00000
150°	SSE							0,00000
		0,00000	0,00000	0,00002	0,00000	0,00000	0,00000	0,00002

Vw > 37 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE							0,00000
060°	ENE							0,00000
090°	E							0,00000
120°	ESE							0,00000
150°	SSE							0,00000
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000



## **B. K13 Shallow Water Site**

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## **Abstract**

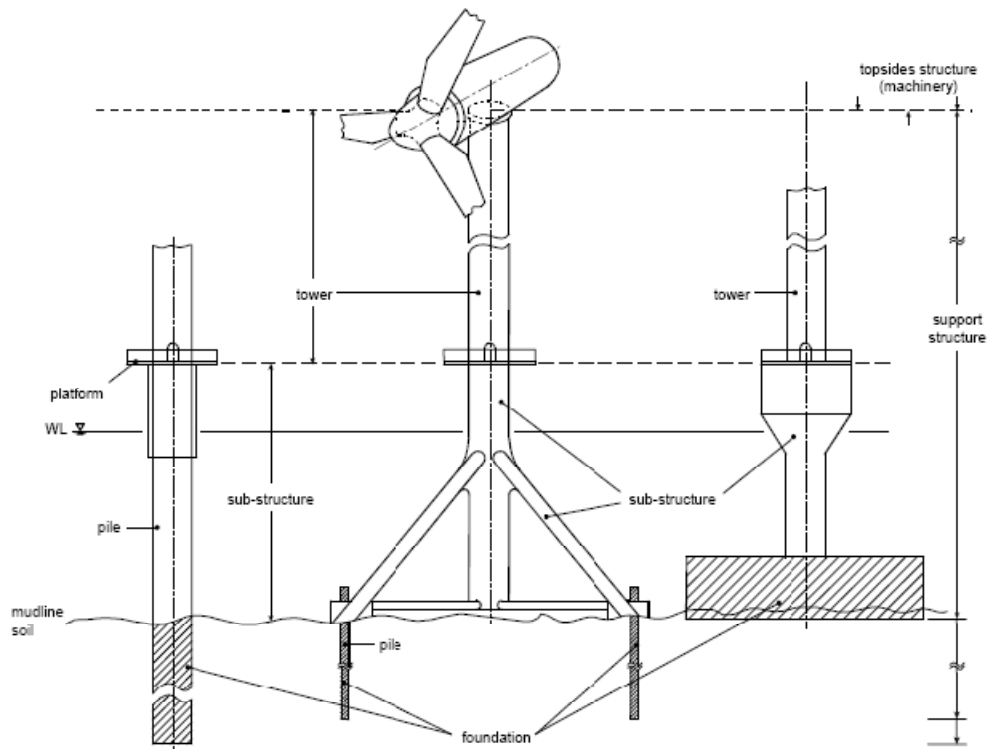
The presented design basis gives a summarized overview of relevant design properties for a later offshore wind turbine design procedures within work package 4. The described offshore site is located in the Dutch North Sea and has a water depth of 25m. Therefore it will be chosen as shallow site within the work package for further design studies.

Besides information about climate properties like wind and wave definitions, other load properties are specified according to a current design guideline. Here the guideline of the Germanischer Lloyd and IEC is chosen. Finally the relevant design load cases according to the guideline are listed, which have to be fulfilled for a suitable support structure design.

## B.1. General remarks and definitions

The relevant design parameters and methods within this design basis are taken from the IEC-61400-3 standard [1]. Further standards are quoted when used.

An offshore wind turbine (OWT) as examined in this design basis, consists of a wind turbine and its support structure, see Figure 9. The support structure is divided into two parts: the tower and the sub-structure. The tower is directly connected to the wind turbine. The sub-structure of OWT consists of a kind of transition piece (e. g. a jacket) connecting the tower with the foundation. The actual foundation is either realised with piles or is part of the transition piece (e.g. gravity foundation).



**Figure 9:** Definition of an offshore wind turbine [2]

The intention of this design basis is to give the necessary definitions for designing a support structure in a fictive wind farm. The met-ocean conditions are, however, uniform at all fictive locations and only one support structure will be designed applicable to all positions.

## B.2. Project description

The following design basis is based on a location in the Dutch North Sea. The climate information is obtained from the wave and wind data published by Rijkswaterstaat for the location “K13” [3]. This site will be denoted in the following as K13 (see Figure 10). The coordinates of K13 are  $53^{\circ}13'04''$  north and  $3^{\circ}13'13''$  east, and the site has a water depth of 25m. These data are available as 3-hour average values for a period of 22 years (January 1979 - December 2000).



Figure 10: Locations for which *Rijkswaterstaat* measures wind and wave data [4]

## B.3. Structural definitions and limitations

### B.3.1. Turbine

The turbine that will be used for the design of the support structure will be the UpWind Reference Turbine which is based on the NREL generic 5.0 MW turbine. The parameters of relevance to the preliminary design are listed in Table 21.

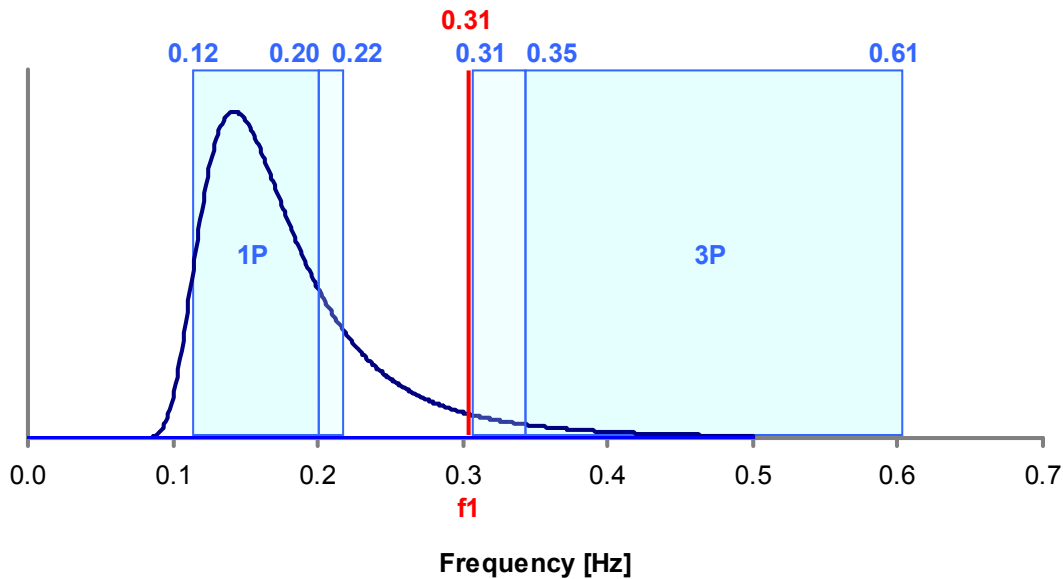
**Table 21:** Turbine parameters for the NREL 5.0MW

<i>Turbine parameter</i>	<i>Value</i>	<i>Unit</i>
Rated power	5.0	MW
Rotor diameter	126	m
Mass of rotor and nacelle	350	ton
Cut-in wind speed	3	m/s
Rated wind speed	11.4	m/s
Cut-out wind speed	25	m/s
Nominal rotor speed	12.1	rpm
Lower bound rotor speed	6.9	rpm
Upper bound rotor speed	12.1	rpm

Many additional parameters are required to determine the turbine behavior. These are not listed here as they are implemented in the Bladed model of the reference turbine.

### B.3.2. Allowable frequency range

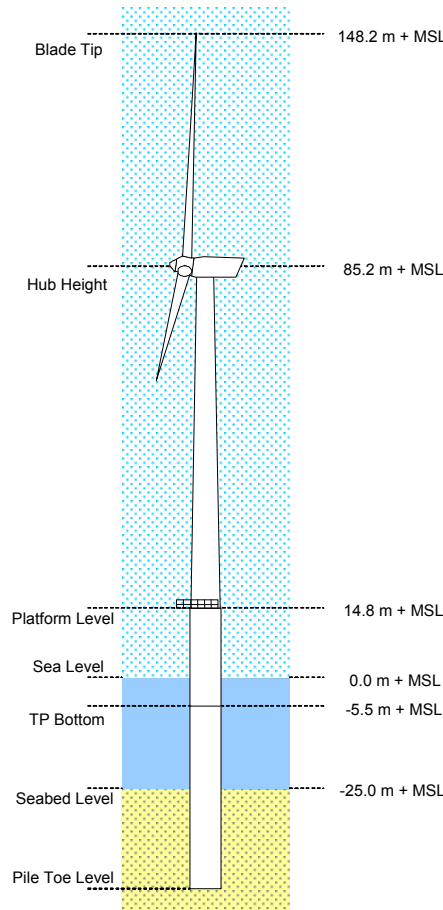
The rotor frequency range (1P) lies between 0.115 Hz and 0.202 Hz. The support structure natural frequency is to be within the soft-stiff range in between the 1P and 3P frequency ranges. A safety margin of 10% on the maximum and minimum rotor speed is adopted, which means that the allowable frequency is between 0.222 Hz and 0.31 Hz.



**Figure 11:** Allowable natural frequency range for the support structure

### B.3.3. Tower and sub-structure design

The shallow water site has a mean water level (MSL) of 25m as shown in Figure 12. As described in the following, the platform level was found at 14.76m. By using a standard tower of 68m, the support structure design results finally in a hub height of 85.16m above MSL. The monopile penetration depth in Figure 12 is shown exemplary, not as final solution.



**Figure 12:** Schematic dimensions of the reference design for the shallow water location

#### B.3.1.1. Platform

The platform is placed at the base of the tower. The determination of the height is based on the GL standard [2] with the expression

$$z_{platform} = LAT + \Delta z_{tide} + \Delta z_{surge} + \Delta z_{air} + \xi^* \quad \text{and} \quad \xi^* = \delta \cdot H_{S,50max}$$

By applying  $\delta = 0.65$ ,  $LAT = -1.06m$ , a tidal range of  $\Delta z_{tide} = 2.22m$ , a storm surge of  $\Delta z_{surge} = 2.13m$ , an air gap of  $\Delta z_{air} = 1.5m$  and a 50years extreme wave height of  $H_{S,50max} = 15.33m$ , the platform level is found at 15.82m LAT or 14.76m MSL.

### B.3.1.2. Tower

On top of the transition piece the tower is flanged. Table 22 shows the dimensions of the tower used for the load calculations. The tower is split into two sections, each 34m, resulting in a total tower height of 68m. At three stages flanges are placed, namely as link to the transition piece, as connection of the two tower sections and at the tower top as link to the nacelle. They are considered as added masses in the load calculations.

**Table 22:** Dimensions tower design

Hub height, 85.16 m	Section	Height of section to MSL	Outer diameter at section-top	Outer diameter at section- bottom	Section wall thickness	Flange mass]
	[-]	[m]	[m]	[m]	[mm]	[kg]
6	82.76	77.76	4.000	4.118	30	1000 (at 82.76m)
5	77.76	68.76	4.118	4.329	20	0
4	68.76	58.76	4.329	4.565	22	0
3	58.76	48.76	4.565	4.800	24	0
2	48.76	36.76	4.800	5.082	28	1400 (at 48.76m)
1	36.76	26.76	5.082	5.318	30	0
	26.76	14.76	5.318	5.600	32	1900 (at 14.76m)

### B.3.1.3. Other secondary structures

Other secondary structures are not pre-defined in detail here. However, structures like the J-tube, which is used to protect and align the cabling from the turbine to land and to cross the scour protection, shall be analysed on the same loads by waves, current and the scour of the monopile.

## B.3.2. Corrosion

Corrosion is only taken into account from the splash zone downwards. Therefore no internal volumes or corrosion in air is studied in detail.

Within the splash zone (+4.53m MSL to -3.18m MSL), the following corrosion allowance is used:

- Corrosion rate according to DNV standard [8]: 0.3mm/year
- Applicable corrosion period: 20 years (reference period)
- Applicable corrosion allowance: 20 x 0.3mm =6.0mm

Below the splash zone (-3.18m MSL to 3m below sea bed), the following corrosion allowance is used:

- Applicable corrosion allowance: 3.0mm (20 years)

For fatigue calculations, half of the corrosion allowance has to be taken into account. For extreme calculations, the full allowance.

## B.4. Environmental conditions

### B.4.1. Sea water

For the sea water, the following values are assumed (see Table 23):

**Table 23:** Quantities of sea water

Water density	1025 kg/m <sup>3</sup>
Water salinity	3.5 ‰
Water temperature (min/max)	0°C / 22°C

### B.4.2. Water depths

The water depth within the assumed wind park is taken as 25m MSL. The value does not include any scour effect.

### B.4.3. Water levels

Beside wind and wave measurements, there is also measured water level and surge data available for the K13 site. Table 24 shows the water level values for the full duration of 22 years<sup>1</sup>. The 50 year positive storm surge is 2.13 m, while the 50 year negative storm surge is -1.31 m.

**Table 24:** Measured water levels at the location (scheme according to [2])

HSWL	+ 3.29 m MSL	<p>           HSWL highest still water level            HAT highest astronomical tide            MSL mean sea level            LAT lowest astronomical tide            CD chart datum (often equal to LAT)            LSWL lowest still water level            A positive storm surge            B tidal range            C negative storm surge            D maximum crest elevation            E minimum trough elevation         </p>
HAT	+ 1.16 m MSL	
MSL	0 m	
LAT (CD)	- 1.06 m MSL	
LSWL	- 2.37 m MSL	
A	+ 2.13 m MSL	
B	2.22 m	
C	- 1.31 m MSL	

Besides the water depths and water level, the splash zone has to be determined for later studies. According to DNV [1][8], the splash zone is determined as

$$\text{Upper limit: } SZ_U = HAT + 0.6 \cdot (1/3) \cdot H_{s,max}(100 \text{ years}) = +4.61 \text{ m MSL}$$

$$\text{Lower limit: } SZ_L = LAT - 0.4 \cdot (1/3) \cdot H_{s,max}(100 \text{ years}) = -3.50 \text{ m MSL}$$

with  $H_{s,max}(100 \text{ years}) = 16.05 \text{ m}$ ,  $HAT = 1.4 \text{ m}$  and  $LAT = -1.1 \text{ m}$ .

### B.4.4. Currents

Currents are considered to consist of sub surface currents, mainly driven by tide and wind generated near surface currents. The near surface current is described by the following current profile:

$$U_w(z) = U_w(0) \left(1 + z/20\right)$$

<sup>1</sup> LAT is taken as the lowest elevation due to tide in the period 1979 – 2001. HAT is taken as the highest elevation due to tide in the period 1979 – 2001.

The subsurface current is given by a power law description:

$$U_{ss}(z) = U_{ss}(0) \left[ \frac{z+d}{d} \right]^{1/7}$$

In these equations  $U_{ss}(0)$  and  $U_w(0)$  are respectively the subsurface and near surface currents measured at the sea surface. The currents are given as a function of the height  $z$  above the sea surface and  $d$  is the water depth.

The values for the currents are taken from the *Noordzeewind OWEZ project*, which is close to the studied location. For normal current loads an average value of 0.6 m/s at surface level is taken and for the extreme case of 1.2 m/s, respectively as shown in Table 25.

**Table 25:** Current velocities according to load situation

Load situation	Current at MSL [m/s]
Normal current	0.6
Extreme current	1.2

For the Normal Current Model (NCM) the tide and storm surge induced sub surface are not included [1].

The Extreme Current Model is defined as the appropriate site-specific combination of sub surface currents, wind generated currents and breaking wave surf induced currents (if any) with recurrence periods of 1 and 50 years [1]. For lack of information the extreme current is assumed to consist of 0.6 m/s near surface and 0.6 m/s subsurface current, both measured at the sea surface.

## B.4.5. Wave parameters

### B.4.5.1. Scatter diagram

In the offshore industry wave climate data is generally expressed in a 2-dimensional scatter diagram giving the number of occurrences of each combination of significant wave height  $H_s$  and peak spectral period  $T_p$ . For offshore wind turbine design the 2-D scatter diagram must be expanded to include  $V_w$  as a third dimension. To derive the 3-D scatter diagram, the parameters  $H_s$  and  $T_p$  and  $V_w$  will be used.

The wind and wave data is subsequently gathered in bins. The  $V_w$  bins cover 2 m/s, the  $H_s$  bins cover 0.5 m and the  $T_p$  bins span 1.0 s. The binning of the  $V_w$  data is done in such a way that the wind speed bin corresponding to for example  $V_w = 2$  m/s contains all wind speed observations ranging from  $\geq 1$  m/s to  $< 3$  m/s. The bin  $H_s = 2$  m contains all wave height observations between  $\geq 1.75$  m and  $< 2.25$  m, while the bin  $T_p = 2$  s includes all wave period observations from  $\geq 1.5$  s to  $< 2.5$  s. Subsequently, the occurrence of all combinations of  $V_w$ ,  $H_s$  and  $T_p$  is counted. The data is gathered per wind speed bin and entered in a scatter diagram giving the frequency of occurrences of each combination of  $H_s$  and  $T_p$  for that wind speed bin as a percentage value. This is illustrated in Table 26 for  $V_w = 10$  m/s. The wind speeds used here are at hub height.

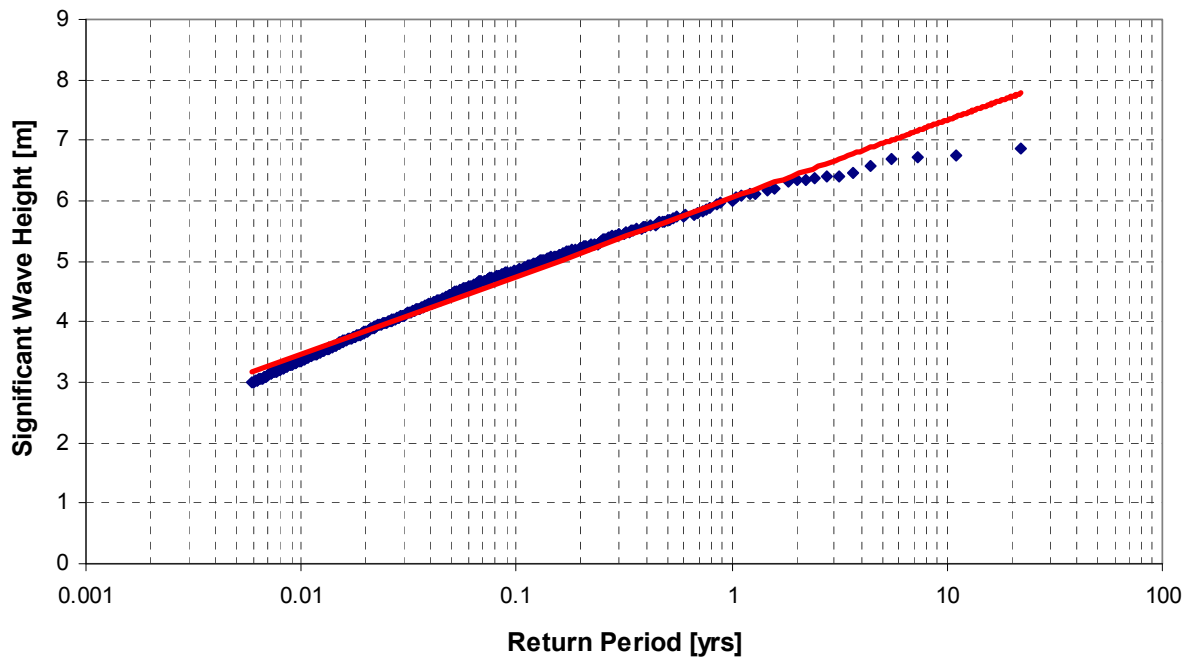
**Table 26:** Part of a 3-D scatter diagram for  $V_w = 10$  m/s

Vw = 7-9 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5														0,00000	
	9														0,00000	
	8,5														0,00000	
	8														0,00000	
	7,5														0,00000	
	7														0,00000	
	6,5														0,00000	
	6														0,00000	
	5,5														0,00000	
	5														0,00000	
	4,5														0,00000	
	4														0,00000	
	3,5									0,00002	0,00003	0,00002		0,00000	0,00006	
3									0,00003	0,00019	0,00009	0,00009	0,00002	0,00042		
2,5									0,00003	0,00053	0,00087	0,00053	0,00012	0,00003	0,00212	
2									0,00101	0,00387	0,00238	0,00068	0,00002		0,00796	
1,5									0,00072	0,01356	0,01333	0,00288	0,00026	0,00003	0,03078	
1									0,00051	0,01845	0,02934	0,00736	0,00098	0,00020	0,05685	
0,5									0,00002	0,01036	0,02131	0,00638	0,00126	0,00020	0,00011	0,03967
<0,25									0,00054	0,00067	0,00014	0,00002				0,00137
		0,00000	0,00000	0,00000	0,00002	0,01142	0,04114	0,05046	0,02640	0,00751	0,00191	0,00028	0,00005	0,00005	0,13923	

A diagram as shown in Table 26 is produced for each wind speed bin. The full set of scatter diagrams make up the 3-D scatter diagram. These are given in Appendix C. Scatter diagrams (V-Hs-Tz).

**B.4.5.2. Extreme values**

From the measured wave data the extreme wave heights can be determined. The extreme wave height is determined as the maximum value that occurs with a certain return period (as seen in Figure 13).



**Figure 13:** Determining the maximum wave height

The relation between wave height and return period was found to be:

$$H_{s,3hrs}(T_{return}) = 0.5605 \cdot \ln(x) + 6.0457$$

In Table 27 different significant wave height values for different periods of occurrence are given. To obtain the maximum wave height the following relationship is used:

$$H_{\max} = 1.86H_s$$

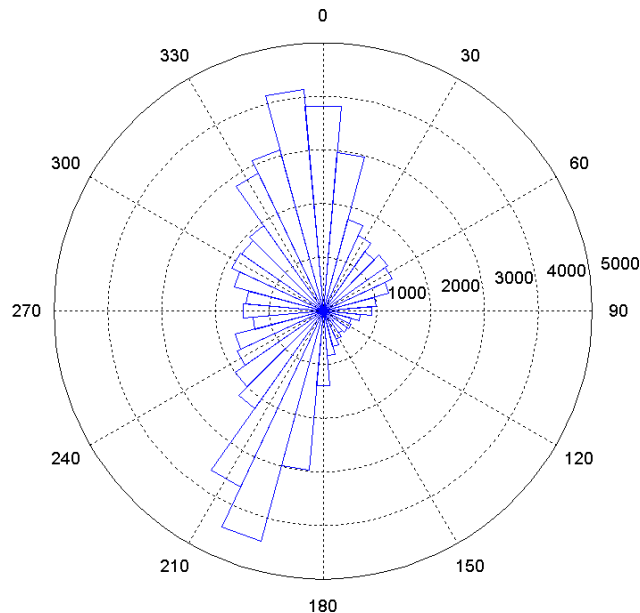
The factor 1.86 is chosen for the given location. However, as the water depth is relatively large, this factor might be changed to a higher value (close to 2).

**Table 27:** Extreme wave heights as a function the return period

$T_{\text{return}}$ [yr]	$H_s$ [m]	$T_p$ [s]	$H_{\max}$ [m]
1	6.05	10.12	11.25
5	6.95	10.54	12.93
10	7.34	10.69	13.65
50	8.24	10.97	15.33
100	8.63	11.05	16.05

#### B.4.5.3. Wave directions

The 3-D scatter diagram does not take directionality into account. Therefore a different diagram is produced giving the spreading of wave directions per wave height bin. First,  $\theta_{\text{wave;full}}$  is gathered in bins of  $30^\circ$ . Subsequently,  $H_s$  and  $\theta_{\text{wave;full}}$  are sorted to obtain the number of occurrences of each wave direction per wave height bin. Figure 14 shows the wave rose for all measured values. In this Figure  $0^\circ$  corresponds with north. It can be seen that the dominant wave directions between north north west (NNW) and west south west (WSW). The probability of occurrence is given as total value on the radial axes. The full series of wave roses sorted for each wave height are given in the appendix.



**Figure 14:** Wave rose for the measurement location

**B.4.5.4. Breaking waves**

The effect of breaking waves will be neglected. Breaking waves will not occur as the wave height is significantly less than the breaking limit.

**B.4.6. Wind parameters**

**B.4.6.1. Wind distributions**

In Figure 15, the wind speed distribution of the K13 site at hub height can be seen. The measured wind data was first translated from the reference height of 10 m to the hub height. A conversion factor of 0.9 is used to obtain the 10-minute wind speed from the 1-hour average wind speed. The wind speed at hub height can be found with [8]:

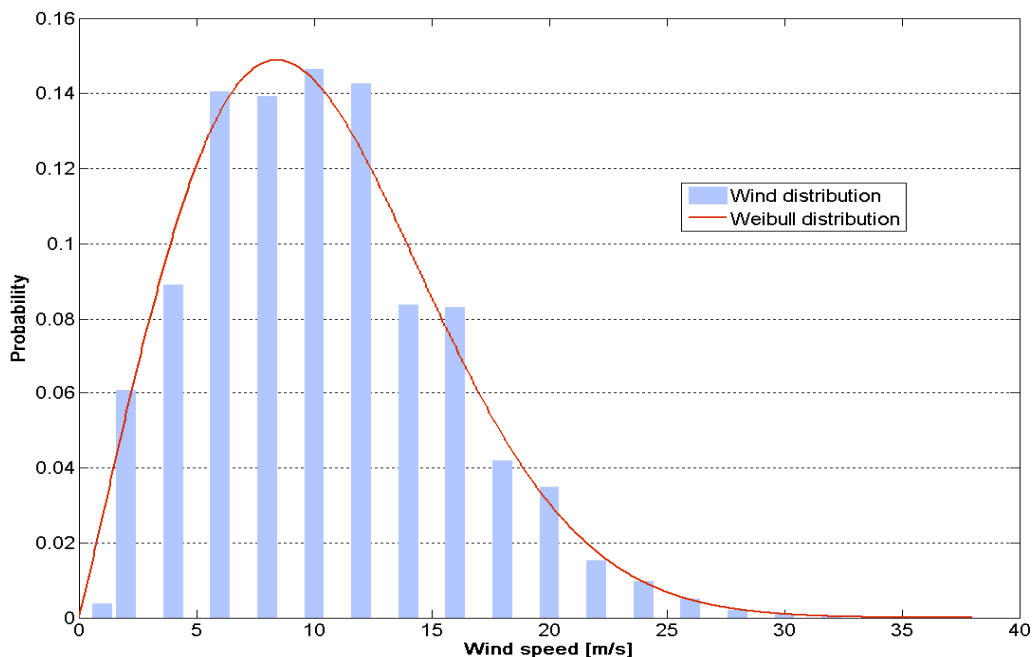
$$V(z) = V(z_{ref}) \frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_{ref}}{z_0}\right)} \text{ Figure 15}$$

with:

- $V(z)$  = wind speed at elevation  $z$
- $V(z_{ref})$  = wind speed at elevation  $z_{ref}$
- $z_{ref}$  = elevation for which wind speed is given
- $z_0$  = roughness length, 0.002 m for offshore conditions

**B.4.6.2. Wind distributions**

The relevant Weibull parameters are  $A= 11.68$  m/s and  $k= 2.04$ , which leads to an annual mean wind speed of 10.05 m/s.

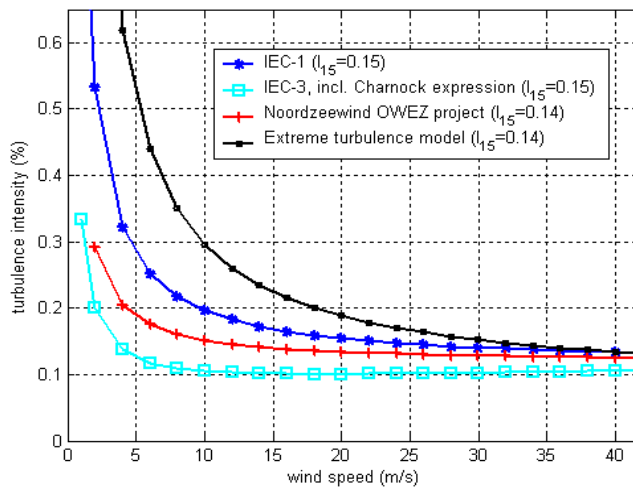


**Figure 15:** Wind speed distribution for the measurement location

### B.4.6.3. Turbulence intensity

For the turbulence intensity, different distributions were compared. As shown in Figure 16, the standard curves for IEC-1 and IEC-3 are shown for a reference turbulence intensity of 0.15. Besides, a distribution based on the assumptions of the *Noordzeewind OWEZ project* is shown [9], where again an IEC-3 distribution was assumed, but with a different reference intensity and taking wake effects into account. As the IEC-1 curve is too conservative, but the IEC-3 one probably optimistic, the distribution from the *Noordzeewind OWEZ project* will be chosen as a good compromise, also for the consideration of wake effects. The distribution can be described by the following relation (with  $I_{15} = 0.14$  and  $a = 5$ )

$$I(U) = \frac{(15 + aU)}{(1 + a)U} \cdot I_{15}$$



**Figure 16:** Turbulence intensity according to IEC

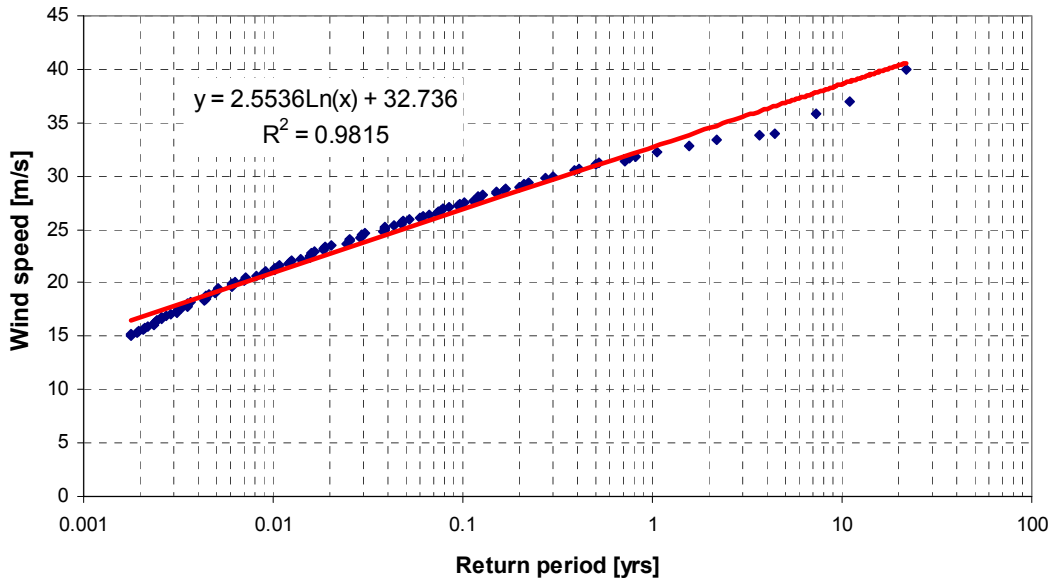
For later extreme load calculations, a further extreme turbulence distribution has to be defined. Based on the normal turbulence model described in the expression above (*Noordzeewind OWEZ project*), an extreme turbulence distribution is calculated according to the IEC-3 standard for class IC. The curvature is also shown in Figure 16. All turbulence values are again listed for each wind speed bin in B.7. Appendix.

### B.4.6.4. Extreme values

From the measured wind data the extreme wind speeds can be determined. The extreme wind speed is determined as the maximum wind speed that occurs with a certain return period (as seen in Figure 17). The resulting equation can be found as follows:

$$V_{hub,10min}(T_{return}) = 2.5536 \cdot \ln(x) + 32.736$$

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**Figure 17:** Determining the maximum wind speed

Table 28 shows the maximum wind speed at hub height as a function of the return period. The values averaged 10-min wind speeds, where the original 3-hrs stationary situations were converted with a factor 0.9 according to IEC.

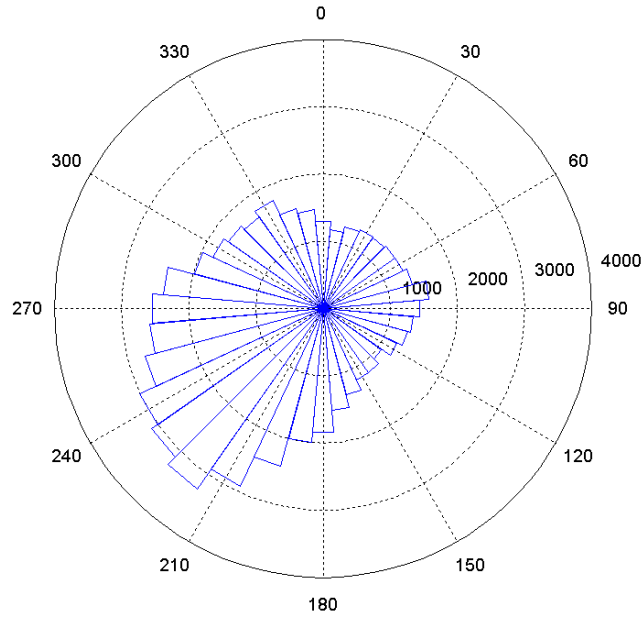
**Table 28:** Extreme wind speeds as a function of the return period

$T_{return}$ [yr]	$V_w$ (10min) [m/s]
1	32.74
5	36.85
10	38.62
50	42.73
100	44.50

### B.4.6.5. Wind directions

The 3-D scatter diagram does not take directionality into account. Therefore a different diagram is produced giving the spreading of wind directions per wind speed bin. First,  $\theta_{wind,full}$  is gathered in bins of 2m/s. Subsequently,  $V_w$  and  $\theta_{wind,full}$  are sorted to obtain the number of occurrences of each wind direction per wind speed bin. Figure 18 shows the wind rose for all measured values. In this Figure  $0^\circ$  corresponds with north. It can be seen that the dominant wind directions comes from west south west (WSW), which agrees with the main wave directions. However, especially in cases of low wind speed the wind tends to come from eastern directions as well. The full series of wind roses sorted for each wind speed is given in B.7. Appendix.

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**Figure 18:** Wind rose for the measurement location

### B.4.7. Wind-wave-directionality

As for some support structure types and environmental conditions the effect of wind- and wave-misalignment can be important, in the following the directional scatter of the measured wind and wave directions is shown. Here the wind speed values correspond to 10-min average values, and the wave heights to 3hrs respectively. The binning is done corresponding to the former described wind and wave scatters. The binning of the  $V_w$  data is done in such a way that the wind speed bin corresponding to for example  $V_w = 2$  m/s contains all wind speed observations ranging from  $\geq 1$  m/s to  $< 3$  m/s. The directional bins at NNE ( $30^\circ$ ) contain all observations between  $\geq 15^\circ$  and  $< 45^\circ$ .

**Table 29:** Directional scatter diagram for all wind speeds

All windspeeds		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,03839	0,00504	0,00093	0,00028	0,00011	0,00025	0,00058	0,00089	0,00070	0,00095	0,00188	0,01143	0,06143
030°	NNE	0,02819	0,01846	0,00422	0,00081	0,00028	0,00044	0,00065	0,00073	0,00054	0,00042	0,00103	0,00408	0,05984
060°	ENE	0,01299	0,02210	0,01739	0,00319	0,00081	0,00065	0,00067	0,00067	0,00050	0,00044	0,00073	0,00201	0,06214
090°	E	0,00779	0,01036	0,02462	0,01454	0,00359	0,00160	0,00115	0,00079	0,00048	0,00045	0,00068	0,00210	0,06818
120°	ESE	0,00571	0,00510	0,00821	0,01199	0,01052	0,00554	0,00314	0,00138	0,00087	0,00050	0,00079	0,00193	0,05569
150°	SSE	0,00534	0,00336	0,00322	0,00414	0,00607	0,01034	0,01384	0,00443	0,00110	0,00107	0,00165	0,00249	0,05706
180°	S	0,00675	0,00263	0,00198	0,00210	0,00213	0,00470	0,02792	0,02117	0,00436	0,00252	0,00275	0,00453	0,08353
210°	SSW	0,00639	0,00229	0,00151	0,00098	0,00103	0,00208	0,01790	0,06882	0,01322	0,00633	0,00583	0,00762	0,13401
240°	WSW	0,00652	0,00196	0,00095	0,00070	0,00058	0,00109	0,00621	0,04693	0,03393	0,01756	0,01120	0,01034	0,13796
270°	W	0,00778	0,00137	0,00081	0,00022	0,00033	0,00044	0,00218	0,01352	0,01989	0,02697	0,02750	0,01618	0,11718
300°	WNW	0,01224	0,00148	0,00042	0,00014	0,00023	0,00030	0,00107	0,00445	0,00554	0,00885	0,02083	0,03029	0,08583
330°	NNW	0,02870	0,00180	0,00047	0,00019	0,00028	0,00025	0,00107	0,00182	0,00143	0,00216	0,00625	0,03274	0,07717
		0,16678	0,07596	0,06472	0,03928	0,02595	0,02767	0,07639	0,16560	0,08257	0,06822	0,08113	0,12573	1,00000

Percentage of time [%]

90° + from wind direction

90° - from wind direction

A diagram as shown in Table 29 is produced for each wind speed bin, as shown as an example for  $V=10$ m/s in Table 30. The full set of those directional scatter diagrams are given in the appendix.

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**Table 30:** Part of the 3-D directional scatter diagram for V = 10 m/s

Vw 9-11 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00639	0,00086	0,00014	0,00003	0,00002		0,00006	0,00003	0,00009	0,00014	0,00025	0,00229	0,01030
030°	NNE	0,00454	0,00328	0,00075	0,00012	0,00003	0,00006				0,00011	0,00054	0,00944	
060°	ENE	0,00151	0,00414	0,00257	0,00039	0,00019	0,00005	0,00008	0,00002	0,00006	0,00003	0,00009	0,00022	0,00933
090°	E	0,00058	0,00185	0,00383	0,00268	0,00067	0,00014	0,00005	0,00003	0,00005	0,00003	0,00006	0,00014	0,01010
120°	ESE	0,00044	0,00078	0,00159	0,00190	0,00190	0,00082	0,00047	0,00011	0,00009	0,00003	0,00003	0,00012	0,00828
150°	SSE	0,00026	0,00023	0,00044	0,00072	0,00109	0,00180	0,00241	0,00036	0,00017	0,00006	0,00022	0,00012	0,00789
180°	S	0,00051	0,00022	0,00020	0,00028	0,00067	0,00096	0,00493	0,00331	0,00051	0,00025	0,00036	0,00053	0,01274
210°	SSW	0,00039	0,00019	0,00017	0,00016	0,00025	0,00031	0,00282	0,00711	0,00246	0,00124	0,00089	0,00112	0,01709
240°	WSW	0,00065	0,00014	0,00014	0,00011	0,00016	0,00012	0,00112	0,00639	0,00496	0,00288	0,00188	0,00176	0,02031
270°	W	0,00065	0,00009	0,00008	0,00003	0,00005	0,00005	0,00040	0,00205	0,00243	0,00303	0,00392	0,00313	0,01591
300°	WNW	0,00173	0,00008		0,00002	0,00002	0,00003	0,00009	0,00070	0,00086	0,00123	0,00322	0,00473	0,01269
330°	NNW	0,00496	0,00011	0,00005	0,00002	0,00002	0,00003	0,00020	0,00026	0,00026	0,00036	0,00098	0,00521	0,01246
		0,02262	0,01196	0,00994	0,00644	0,00504	0,00439	0,01263	0,02038	0,01195	0,00929	0,01201	0,01991	0,14654

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

As for some simulations the full set of wind and wave directionalities is too detailed, a reduced form can be determinate, where the opposite direction of wind and waves are merged (see Table 31)

**Table 31:** Reduced directional scatter V = 10 m/s

Vw 9-11 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01190	0,00442	0,00095	0,00070	0,00129	0,00378	0,02304
030°	NNE	0,00775	0,01058	0,00338	0,00152	0,00128	0,00204	0,02654
060°	ENE	0,00336	0,01069	0,00773	0,00341	0,00232	0,00215	0,02965
090°	E	0,00168	0,00403	0,00638	0,00577	0,00470	0,00345	0,02601
120°	ESE	0,00272	0,00166	0,00254	0,00317	0,00516	0,00571	0,02097
150°	SSE	0,00784	0,00096	0,00092	0,00115	0,00230	0,00717	0,02035
		0,03525	0,03234	0,02189	0,01573	0,01705	0,02430	0,14654

**B.4.8. Further meteorological - oceanographical parameters**

**B.4.8.1. Temperature**

The temperatures of water and air are illustrated in Table 32 according to [5]. For later fatigue calculations the mean values has to be taken.

**Table 32:** Air and water temperatures

Water temperature at the surface [°C]		Air temperature [°C]	
Mean	10	Mean	15.0
Standard deviation	5	Extremes	-20 to +50
Maximum	22		
Minimum	0		
Yearly amplitude	7		

**B.4.8.2. Ice**

It is very unlikely that sea ice occurs. Therefore it will not be taken into account. However, icing at the structure is possible and will be dimensioned according to [2]. This leads to the following values:

- Atmospheric ice formation with a thickness of 30mm
- Ice formation due to sea water spray with a thickness of 100mm from MSL to HSWL

- Ice formation due to sea water spray from HSWL up to 60m above MSL with a thickness decreasing linearly to 30mm
- Density of ice of 900 kg/m<sup>3</sup>

#### B.4.8.3. Maritime growths

For design purposes, marine growth has to be assumed. The density has to be taken as 1100 kg/m<sup>3</sup>. Table 33 shows the thickness as determined according to DNV standard [8].

**Table 33:** Assumptions for marine growths

Level [m]	Thickness [mm]
MSL -2 to -40	100

### B.4.9. Soil conditions

#### B.4.9.1. Soil profiles

Two different soil profile configurations will be assumed in the wind farm areal – namely a soft and hard one. The profiles are defined as follows:

**Table 34:** Soil conditions for the soft profile

Depths [m]	$\gamma'$ [N/m <sup>3</sup> ]	$\Phi$ [°]	$C_u$ [Pa]
0-3	10000	36	-
3-5	10000	33	-
5-7	10000	26	60000
7-10	10000	37	-
10-15	10000	35	-
15-50	10000	37.5	-

$\gamma'$  – effective soil unit weight  
 $\phi$  – angle of internal friction  
 $C_u$  – undrained shear strength

**Table 35:** Soil conditions for the hard profile

Depths [m]	$\gamma'$ [N/m <sup>3</sup> ]	$\Phi$ [°]	$C_u$ [Pa]
0-3	10000	38	-
3-5	10000	35	-
5-7	10000	38	-
7-10	10000	38	-
10-15	10000	42	-
15-50	10000	42.5	-

$\gamma'$  – effective soil unit weight  
 $\phi$  – angle of internal friction  
 $C_u$  – undrained shear strength

#### B.4.9.2. Scour

If no scour protection is planned, an additional depth in relation to scour effects has to be assumed in accordance to the outer diameter of the water piercing members, D, to be (2.5·D) according to [2]. However, in this study scour protection is assumed, by what no water depths variations due to scour are taken into account.

## B.5. Structural load assumptions

### B.5.1. Modelling of the structure

For the determination of the wave loads, the following values for the hydrodynamic coefficients can be assumed according to [2]. For other than monopile designs, the following hydrodynamic coefficients have to be re-calculated.

**Table 36:** Recommended hydrodynamic coefficients

Reynolds number	smooth cylinder		rough cylinder	
	$C_D$	$C_M$	$C_D$	$C_M$
$\leq 2 \cdot 10^5$	1.2	2.0	1.2	2.0
$> 2 \cdot 10^5$	0.7	1.6	1.1	2.0

For the load calculations in this study, the following coefficients are taken. Both values are increased from their usual values to account ladders, corrosion protection devices, J-tube, marine growths.

**Table 37:** Assumed hydrodynamic coefficients

Fatigue loading		Extreme loading	
Drag coefficient, $C_D$ [-]	Inertia coefficient, $C_D$ [-]	Drag coefficient, $C_D$ [-]	Inertia coefficient, $C_D$ [-]
0.95	2.15	1.11	1.77

For later load calculations, both fatigue and ultimate load cases, partial safety factors have to be added according the type of case. Table 38 summarize these values according to [2].

**Table 38:** Partial safety factors for loads according to [1]

Unfavourable loads			Favourable loads
Type of design situation			All design situations
Normal (N)	Abnormal (A)	Transport and erection (T)	
1.35	1.1	1.5	0.9

## B.5.2. Load assumptions

### B.5.2.1. Fatigue load cases

For fatigue considerations, the different load setups from the scatter diagram have to be taken. The reduced (lumped) scatter is shown in **Table 39**.

The lumping was done damage equivalent based on the method described in Kühn [7]. The peakness for the JONSWAP wave spectrum is considered to be different between fatigue and extreme load cases, which is realistic for North Sea sites. The turbulence intensity is based on the assumptions of B.4.6.1. Wind distributions.

Depending on the Weibull fit, to different probability distributions are possible. The first one is based on the real sorted wind bins based on the simulations, where the second one is based on the Weibull distribution parameters at this site ( $A= 11.31$  m/s and  $k= 1.97$ ).

**Table 39:** Lumped scatter diagram of the given offshore site (sorted wind bins)

V [ms]	TI [%]		Hs [m]	Tp [m]	Peakness [-]		f [%]	occ./year [hrs]
	normal	extreme			Fatigue	Extreme		
2	29,2	99,3	1,07	6,03	1	3,3	0,06071	531,8
4	20,4	53,1	1,1	5,88	1	3,3	0,08911	780,6
6	17,5	37,1	1,18	5,76	1	3,3	0,14048	1230,6
8	16	30	1,31	5,67	1	3,3	0,13923	1219,7
10	15,2	25,4	1,48	5,74	1	3,3	0,14654	1283,7
12	14,6	22,3	1,7	5,88	1	3,3	0,14272	1250,2
14	14,2	20,1	1,91	6,07	1	3,3	0,08381	734,2
16	13,9	18,5	2,19	6,37	1	3,3	0,08316	728,5
18	13,6	17,2	2,47	6,71	1	3,3	0,04186	366,7
20	13,4	16,1	2,76	6,99	1	3,3	0,03480	304,8
22	13,3	15,3	3,09	7,4	1	3,3	0,01534	134,4
24	13,1	14,6	3,42	7,8	1	3,3	0,00974	85,3
26	12	14	3,76	8,14	1	3,3	0,00510	44,7
28	11,9	13,5	4,17	8,49	1	3,3	0,00202	17,7
30	11,8	13,1	4,46	8,86	1	3,3	0,00096	8,4
32	11,8	12,7	4,79	9,12	1	3,3	0,00050	4,4
34-42	11,7	12,3	4,9	9,43	1	3,3	0,00019	1,6

**Table 40:** Lumped scatter diagram of the given offshore site (Weibull fit wind bins)

V [ms]	TI [%]		Hs [m]	Tp [m]	Peakness [-]		f [%]	occ./year [hrs]
	normal	extreme			Fatigue	Extreme		
2	29,2	99,3	1,07	6,03	1	3,3	0,05395	472,6
4	20,4	53,1	1,1	5,88	1	3,3	0,10177	891,5
6	17,5	37,1	1,18	5,76	1	3,3	0,13431	1176,6
8	16	30	1,31	5,67	1	3,3	0,14768	1293,7
10	15,2	25,4	1,48	5,74	1	3,3	0,14288	1251,6
12	14,6	22,3	1,7	5,88	1	3,3	0,12459	1091,4
14	14,2	20,1	1,91	6,07	1	3,3	0,09917	868,7
16	13,9	18,5	2,19	6,37	1	3,3	0,07259	635,9
18	13,6	17,2	2,47	6,71	1	3,3	0,04910	430,1
20	13,4	16,1	2,76	6,99	1	3,3	0,03079	269,7
22	13,3	15,3	3,09	7,4	1	3,3	0,01793	157,1
24	13,1	14,6	3,42	7,8	1	3,3	0,00972	85,1
26	12	14	3,76	8,14	1	3,3	0,00491	43,0
28	11,9	13,5	4,17	8,49	1	3,3	0,00231	20,2
30	11,8	13,1	4,46	8,86	1	3,3	0,00101	8,9
32	11,8	12,7	4,79	9,12	1	3,3	0,00042	3,6
34-42	11,7	12,3	4,9	9,43	1	3,3	0,00024	2,1

**B.5.2.2. Extreme load cases**

For the different extreme design load cases, different values for the wind speed, wave height and wave period have to be determined. Table 41 gives an overview.

**Table 41:** Extreme wave conditions according to [1]

$H_{s,50}$ [m]	8.24
$H_{smax,50}$ [m]	15.33
$H_{sred,50}$ [m]	9.06
$H_{s,1}$ [m]	6.05
$H_{smax,1}$ [m]	11.25
$H_{sred,1}$ [m]	6.66
$V_{ref} = V_{50}$ [m/s]	42.73
$V_1$ [m/s]	32.74

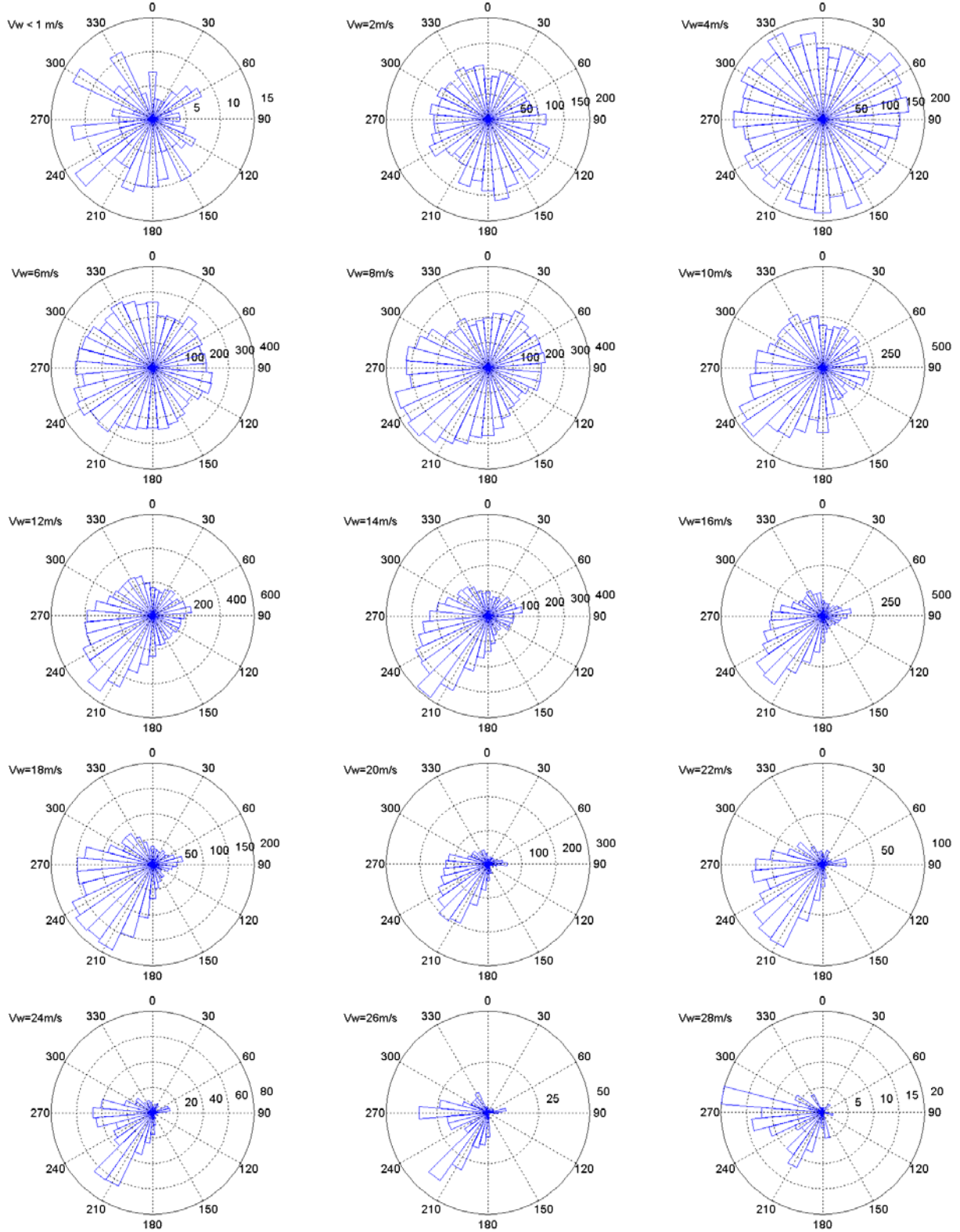
The periods combined with the above mentioned extreme wave heights have to be calculated following the formula [1]:

$$11.1\sqrt{H_s(V)/g} \leq T \leq 14.3\sqrt{H_s(V)/g}$$

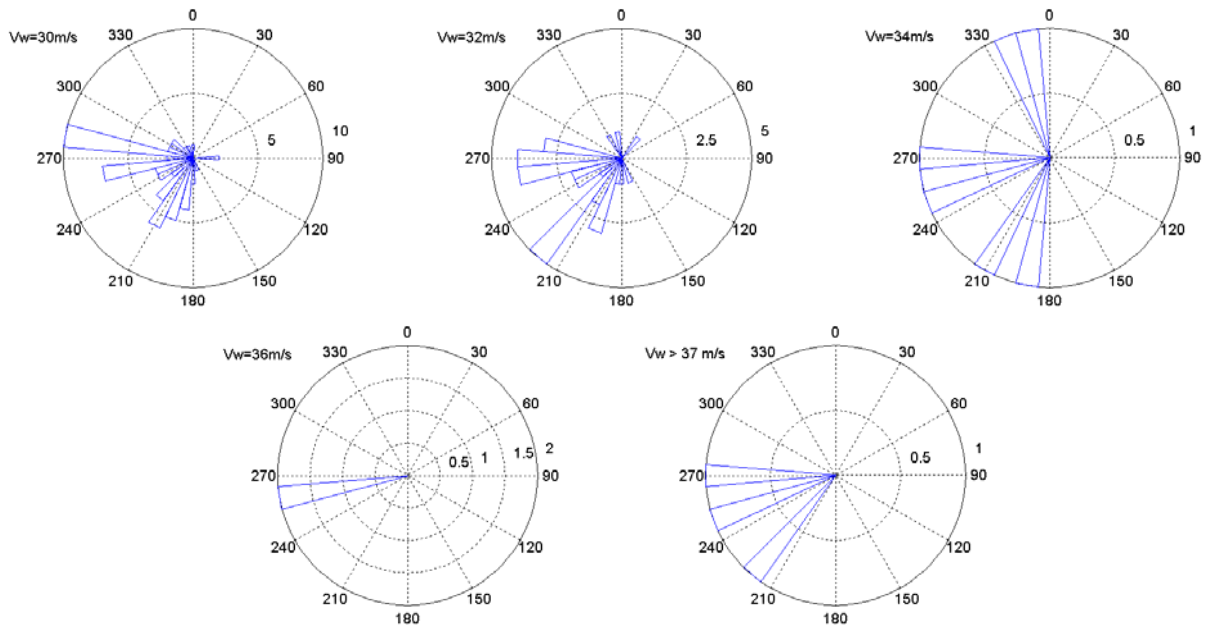


## B.7. Appendix

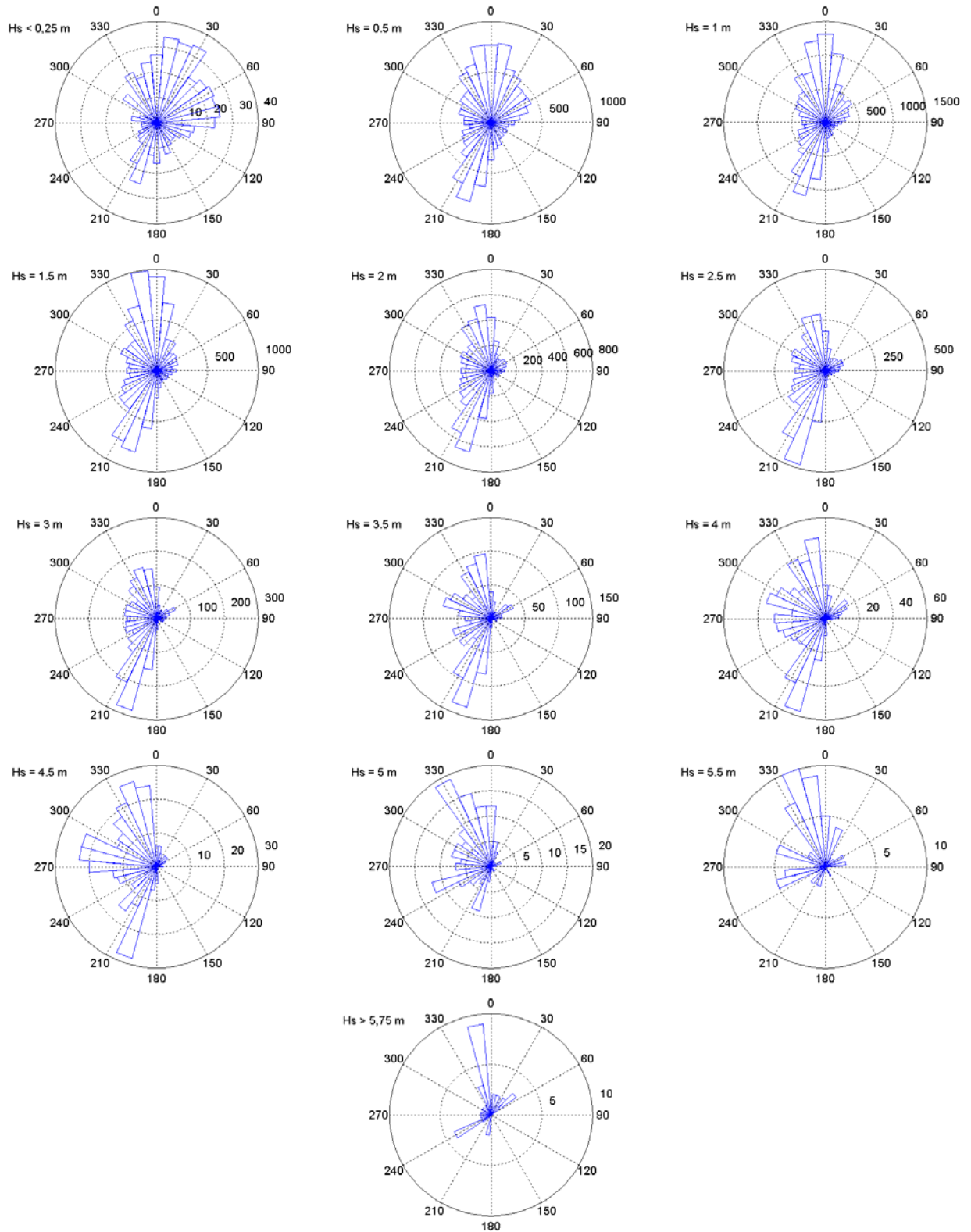
### A. Wind roses



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**B. Wave roses**



C. Scatter diagrams (V-Hs-Tz)

all windspeeds		Tp [s]																	
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5					
Hs [m]	9,5														0,00000				
	9														0,00000				
	8,5														0,00000				
	8														0,00000				
	7,5														0,00000				
	7													0,00003	0,00003				
	6,5										0,00002	0,00009	0,00005		0,00016				
	6										0,00019	0,00014	0,00005		0,00037				
	5,5										0,00008	0,00061	0,00033	0,00005	0,00106				
	5										0,00084	0,00138	0,00031	0,00006	0,00260				
	4,5										0,00011	0,00342	0,00132	0,00014	0,00002	0,00501			
	4										0,00003	0,00240	0,00663	0,00087	0,00019	0,00002	0,01013		
	3,5										0,00058	0,01269	0,00709	0,00078	0,00008	0,00002	0,02123		
	3										0,00002	0,01058	0,02576	0,00478	0,00045	0,00003	0,00006	0,04167	
	2,5										0,00098	0,05074	0,02189	0,00263	0,00050	0,00011	0,00002	0,07686	
	2										0,00006	0,03047	0,07924	0,01285	0,00255	0,00028		0,12547	
1,5										0,00649	0,11598	0,06449	0,01419	0,00252	0,00014	0,00002	0,00003	0,20385	
1										0,00313	0,08888	0,12814	0,04869	0,00978	0,00143	0,00011	0,00003	0,00003	0,28022
0,5										0,00008	0,04740	0,10613	0,05166	0,01355	0,00241	0,00082	0,00017	0,00003	0,22225
<0,25																			0,00910
		0,00000	0,00000	0,00000	0,00008	0,05276	0,20716	0,32844	0,26795	0,10207	0,03279	0,00681	0,00151	0,00042	1,00000				

Vw < 1 m/s		Tp [s]															
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5			
Hs [m]	9,5														0,00000		
	9														0,00000		
	8,5														0,00000		
	8														0,00000		
	7,5														0,00000		
	7														0,00000		
	6,5														0,00000		
	6														0,00000		
	5,5														0,00000		
	5														0,00000		
	4,5														0,00000		
	4														0,00000		
	3,5													0,00002	0,00002		
	3														0,00000		
	2,5											0,00002			0,00002		
	2											0,00003	0,00002		0,00005		
1,5											0,00003	0,00022	0,00016	0,00005	0,00003	0,00048	
1											0,00003	0,00017	0,00056	0,00030		0,00106	
0,5											0,00022	0,00067	0,00079	0,00028	0,00003	0,00002	0,00201
<0,25												0,00011					0,00011
		0,00000	0,00000	0,00000	0,00000	0,00022	0,00081	0,00100	0,00106	0,00048	0,00011	0,00005	0,00000	0,00002	0,00373		

Vw = 1-3 m/s		Tp [s]																	
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5					
Hs [m]	9,5														0,00000				
	9														0,00000				
	8,5														0,00000				
	8														0,00000				
	7,5														0,00000				
	7														0,00000				
	6,5														0,00000				
	6														0,00000				
	5,5														0,00000				
	5														0,00000				
	4,5														0,00000				
	4											0,00002			0,00002				
	3,5											0,00002			0,00002				
	3											0,00003	0,00002		0,00005				
	2,5											0,00003	0,00003	0,00005	0,00003	0,00014			
	2											0,00003	0,00022	0,00030	0,00030	0,00006	0,00090		
1,5											0,00005	0,00048	0,00207	0,00261	0,00058	0,00005	0,00583		
1											0,00002	0,00096	0,00618	0,00913	0,00278	0,00034	0,00003	0,01944	
0,5											0,00299	0,01257	0,01213	0,00406	0,00067	0,00022	0,00009	0,00003	0,03276
<0,25											0,00023	0,00114	0,00017	0,00002					0,00156
		0,00000	0,00000	0,00000	0,00000	0,00324	0,01472	0,01899	0,01549	0,00639	0,00149	0,00031	0,00008	0,00000	0,06071				

## Upwind Design Basis – K13 Shallow Water Site

Vw = 3-5 m/s		Tp [s]															
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5			
Hs [m]	9,5														0,00000		
	9														0,00000		
	8,5														0,00000		
	8														0,00000		
	7,5														0,00000		
	7														0,00000		
	6,5														0,00000		
	6														0,00000		
	5,5														0,00000		
	5														0,00000		
	4,5														0,00000		
	4														0,00000		
	3,5										0,00002				0,00002		
	3									0,00003					0,00003		
	2,5									0,00003	0,00006	0,00008	0,00006	0,00002	0,00002	0,00006	
	2									0,00003	0,00007	0,00005	0,00009	0,00002		0,00025	
1,5									0,00005	0,00138	0,00460	0,00339	0,00075	0,00005	0,01022		
1									0,00011	0,00330	0,01193	0,01237	0,00282	0,00048	0,00003	0,00002	0,03105
0,5									0,00530	0,01846	0,01451	0,00418	0,00073	0,00023	0,00002		0,04345
<0,25									0,00047	0,00165	0,00039	0,00003					0,00254
		0,00000	0,00000	0,00000	0,00000	0,00588	0,02346	0,02831	0,02159	0,00778	0,00179	0,00025	0,00005	0,00002	0,08911		

Vw = 5-7 m/s		Tp [s]																
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5				
Hs [m]	9,5														0,00000			
	9														0,00000			
	8,5														0,00000			
	8														0,00000			
	7,5														0,00000			
	7														0,00000			
	6,5														0,00000			
	6														0,00000			
	5,5														0,00000			
	5														0,00000			
	4,5														0,00000			
	4														0,00000			
	3,5														0,00000			
	3										0,00002				0,00002			
	2,5										0,00002	0,00006	0,00002	0,00003	0,00012			
	2										0,00002	0,00020	0,00023	0,00025	0,00014	0,00003	0,00002	0,00089
1,5										0,00037	0,00194	0,00182	0,00078	0,00008	0,00002		0,00501	
1										0,00031	0,00548	0,01073	0,00378	0,00078			0,02108	
0,5										0,00034	0,00985	0,02616	0,01422	0,00249	0,00031	0,00003	0,00002	0,05342
<0,25										0,01112	0,02805	0,01402	0,00324	0,00061	0,00023			0,05726
		0,00000	0,00000	0,00000	0,00000	0,01209	0,03985	0,04643	0,03033	0,00896	0,00243	0,00028	0,00005	0,00006	0,14048			

Vw = 7-9 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6														0,00000
	5,5														0,00000
	5														0,00000
	4,5														0,00000
	4														0,00000
	3,5														0,00000
	3														0,00000
	2,5														0,00000
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00002	0,01142	0,04114	0,05046	0,02640	0,00751	0,00191	0,00028	0,00005	0,00005	0,13923

## Upwind Design Basis – K13 Shallow Water Site

		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00000
	4,5										0,00002					0,00002
	4									0,00002	0,00003	0,00002				0,00009
	3,5									0,00006	0,00020	0,00005	0,00002			0,00033
	3									0,00008	0,00044	0,00039	0,00009			0,00100
	2,5									0,00003	0,00208	0,00205	0,00062	0,00003		0,00482
	2									0,00002	0,00306	0,01031	0,00358	0,00047	0,00002	0,01745
1,5									0,00092	0,02380	0,01464	0,00117	0,00011	0,00002	0,04066	
1									0,00078	0,02377	0,02700	0,00366	0,00033	0,00005	0,00002	0,05561
0,5									0,00002	0,00871	0,01423	0,00244	0,00039	0,00012	0,00002	0,02596
<0,25									0,00026	0,00026	0,00008					0,00061
		0,00000	0,00000	0,00000	0,00002	0,00975	0,03920	0,05642	0,03116	0,00776	0,00188	0,00028	0,00005	0,00003	0,14654	

		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00000
	4,5											0,00002			0,00002	0,00003
	4										0,00006	0,00005	0,00005			0,00016
	3,5										0,00003	0,00012	0,00034	0,00016	0,00005	0,00070
	3										0,00036	0,00151	0,00112	0,00014		0,00313
	2,5										0,00011	0,00460	0,00460	0,00078	0,00006	0,01016
	2										0,00585	0,01888	0,00250	0,00008		0,02731
1,5										0,00199	0,03296	0,01129	0,00020		0,04645	
1										0,00084	0,02011	0,01821	0,00115	0,00009	0,00005	0,04046
0,5										0,00002	0,00532	0,00751	0,00110	0,00014	0,00005	0,01414
<0,25										0,00006	0,00009	0,00003				0,00019
		0,00000	0,00000	0,00000	0,00002	0,00622	0,02971	0,05827	0,03646	0,00908	0,00244	0,00040	0,00009	0,00002	0,14272	

		Tp [s]															
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5			
Hs [m]	9,5															0,00000	
	9															0,00000	
	8,5															0,00000	
	8															0,00000	
	7,5															0,00000	
	7															0,00000	
	6,5															0,00000	
	6															0,00000	
	5,5														0,00002	0,00002	
	5											0,00002				0,00002	
	4,5											0,00002	0,00003			0,00005	
	4											0,00003	0,00020	0,00012	0,00006	0,00042	
	3,5											0,00042	0,00059	0,00020	0,00002	0,00123	
	3											0,00086	0,00238	0,00079	0,00006	0,00409	
	2,5											0,00005	0,00708	0,00412	0,00022	0,00002	0,01148
	2											0,00002	0,00563	0,01540	0,00095	0,02199	
1,5											0,00107	0,02017	0,00439		0,02563		
1											0,00023	0,00770	0,00625	0,00020	0,01439		
0,5											0,00002	0,00201	0,00216	0,00020	0,00439		
<0,25											0,00005	0,00003			0,00008		
		0,00000	0,00000	0,00000	0,00002	0,00229	0,01098	0,03231	0,02792	0,00790	0,00182	0,00047	0,00009	0,00002	0,08381		

## Upwind Design Basis – K13 Shallow Water Site

Vw = 15-17 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6											0,00002				0,00002
	5,5															0,00000
	5											0,00006				0,00006
	4,5										0,00009	0,00012	0,00002			0,00023
	4									0,00005	0,00050	0,00017	0,00005			0,00076
	3,5								0,00003	0,00100	0,00112	0,00028				0,00243
	3						0,00002	0,00159	0,00465	0,00142						0,00767
	2,5					0,00031	0,01341	0,00524	0,00009							0,01905
	2				0,00002	0,00868	0,01798	0,00040	0,00002							0,02710
	1,5				0,00098	0,01417	0,00254									0,01769
1				0,00017	0,00350	0,00224	0,00003								0,00594	
0,5					0,00002	0,00112	0,00100	0,00008							0,00221	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00002	0,00129	0,00549	0,02549	0,03557	0,01134	0,00324	0,00065	0,00006	0,00000	0,08316	

Vw = 17-19 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6													0,00002		0,00002
	5,5															0,00000
	5													0,00002	0,00002	0,00003
	4,5										0,00002	0,00008	0,00006	0,00006		0,00019
	4										0,00025	0,00022	0,00006			0,00053
	3,5								0,00002	0,00020	0,00078	0,00019	0,00002			0,00120
	3								0,00006	0,00154	0,00148	0,00006				0,00314
	2,5								0,00185	0,00516	0,00050	0,00002				0,00753
	2								0,00025	0,01010	0,00247	0,00002	0,00002			0,01285
	1,5								0,00384	0,00683	0,00012					0,01080
1						0,00033	0,00300	0,00048							0,00381	
0,5					0,00006	0,00090	0,00047								0,00143	
<0,25					0,00019	0,00016									0,00034	
		0,00000	0,00000	0,00000	0,00000	0,00025	0,00138	0,00756	0,01933	0,00950	0,00303	0,00058	0,00017	0,00005	0,04186	

Vw = 19-21 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5															0,00008
	4,5															0,00040
	4										0,00003	0,00026	0,00009	0,00002		0,00073
	3,5										0,00002	0,00039	0,00033			0,00193
	3										0,00042	0,00124	0,00026			0,00456
	2,5										0,00014	0,00294	0,00148			0,00969
	2										0,00313	0,00635	0,00022			0,01104
	1,5										0,00012	0,00930	0,00162			0,00471
1										0,00002	0,00168	0,00297	0,00005		0,00110	
0,5										0,00008	0,00084	0,00019			0,00047	
<0,25										0,00006	0,00023	0,00017			0,00008	
		0,00000	0,00000	0,00000	0,00000	0,00012	0,00034	0,00282	0,01573	0,01139	0,00336	0,00092	0,00011	0,00002	0,03480	

## Upwind Design Basis – K13 Shallow Water Site

Vw = 21-23 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5													0,00002		0,00002
	6											0,00002		0,00002		0,00003
	5,5											0,00003	0,00006	0,00002		0,00011
	5											0,00006	0,00019	0,00011	0,00002	0,00037
	4,5											0,00002	0,00042	0,00023	0,00005	0,00072
	4											0,00031	0,00103	0,00005		0,00138
	3,5											0,00012	0,00264	0,00101		0,00378
	3											0,00151	0,00328	0,00009		0,00488
	2,5											0,00003	0,00282	0,00048		0,00333
	2											0,00019	0,00037			0,00056
	1,5											0,00006	0,00002			0,00008
1											0,00008				0,00008	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00008	0,00028	0,00484	0,00674	0,00261	0,00051	0,00025	0,00003	0,01534	

Vw = 23-25 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5														0,00002	0,00002
	6													0,00002	0,00002	0,00003
	5,5													0,00002	0,00009	0,00005
	5													0,00008	0,00030	0,00003
	4,5													0,00003	0,00059	0,00020
	4													0,00058	0,00134	0,00002
	3,5													0,00012	0,00260	0,00051
	3													0,00098	0,00132	0,00006
	2,5													0,00003	0,00048	0,00009
	2													0,00003	0,00008	
	1,5													0,00002		
1													0,00002			
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00009	0,00166	0,00462	0,00260	0,00061	0,00011	0,00005	0,00974	

Vw = 25-27 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5														0,00003	0,00002
	6													0,00002	0,00005	0,00006
	5,5													0,00011	0,00012	0,00023
	5													0,00016	0,00020	0,00002
	4,5													0,00002	0,00070	0,00008
	4													0,00002	0,00051	0,00092
	3,5													0,00006	0,00110	0,00025
	3													0,00019	0,00042	
	2,5													0,00011		
	2															0,00000
	1,5															0,00000
1															0,00002	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00039	0,00205	0,00202	0,00040	0,00022	0,00002	0,00510		

## Upwind Design Basis – K13 Shallow Water Site

		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
<b>Hs [m]</b>	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5													0,00002		0,00002
	6													0,00002	0,00002	0,00002
	5,5											0,00002	0,00002	0,00003		0,00005
	5										0,00003	0,00012	0,00003			0,00019
	4,5										0,00022	0,00016				0,00037
	4										0,00003	0,00051	0,00008			0,00062
	3,5										0,00016	0,00034				0,00050
	3										0,00019	0,00005				0,00023
	2,5										0,00002	0,00002				0,00003
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00039	0,00115	0,00037	0,00006	0,00003	0,00202	

		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
<b>Hs [m]</b>	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5														0,00002	0,00002
	6															0,00000
	5,5												0,00006	0,00003		0,00009
	5											0,00002	0,00008	0,00002		0,00011
	4,5											0,00016	0,00006			0,00022
	4											0,00025	0,00002			0,00026
	3,5											0,00011	0,00012			0,00023
	3											0,00002				0,00002
	2,5											0,00002				0,00002
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00014	0,00054	0,00022	0,00005	0,00002	0,00096	

		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
<b>Hs [m]</b>	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5														0,00002	0,00002
	6															0,00006
	5,5												0,00005	0,00002		0,00005
	5												0,00009	0,00005		0,00014
	4,5												0,00017			0,00017
	4												0,00002	0,00002		0,00003
	3,5															0,00000
	3															0,00002
	2,5															0,00000
	2															0,00000
	1,5															0,00002
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00000	0,00003	0,00028	0,00014	0,00002	0,00002	0,00050	

# Upwind Design Basis – K13 Shallow Water Site

Vw 33-35 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5										0,00002	0,00003				0,00005
	5										0,00003	0,00002				0,00005
	4,5										0,00002					0,00002
	4															0,00000
	3,5															0,00000
	3															0,00000
	2,5															0,00000
	2															0,00000
1,5															0,00000	
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00006	0,00005	0,00000	0,00000	0,00011	

D. Scatter diagrams (V -  $\theta$ wind -  $\theta$ wave)

All windspeeds		Wave direction												
Wind direction		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,03839	0,00504	0,00093	0,00028	0,00011	0,00025	0,00058	0,00089	0,00070	0,00095	0,00188	0,01143	0,06143
030°	NNE	0,02819	0,01846	0,00422	0,00081	0,00028	0,00044	0,00065	0,00073	0,00054	0,00042	0,00103	0,00408	0,05984
060°	ENE	0,01299	0,02210	0,01739	0,00319	0,00081	0,00065	0,00067	0,00067	0,00050	0,00044	0,00073	0,00201	0,06214
090°	E	0,00779	0,01036	0,02462	0,01454	0,00359	0,00160	0,00115	0,00079	0,00048	0,00045	0,00068	0,00210	0,06818
120°	ESE	0,00571	0,00510	0,00821	0,01199	0,01052	0,00554	0,00314	0,00138	0,00087	0,00050	0,00079	0,00193	0,05569
150°	SSE	0,00534	0,00336	0,00322	0,00414	0,00607	0,01034	0,01384	0,00443	0,00110	0,00107	0,00165	0,00249	0,05706
180°	S	0,00675	0,00263	0,00198	0,00210	0,00213	0,00470	0,02792	0,02117	0,00436	0,00252	0,00275	0,00453	0,08353
210°	SSW	0,00639	0,00229	0,00151	0,00098	0,00103	0,00208	0,01790	0,06882	0,01322	0,00633	0,00583	0,00762	0,13401
240°	WSW	0,00652	0,00196	0,00095	0,00070	0,00058	0,00109	0,00621	0,04693	0,03393	0,01756	0,01120	0,01034	0,13796
270°	W	0,00778	0,00137	0,00081	0,00022	0,00033	0,00044	0,00218	0,01352	0,01989	0,02697	0,02750	0,01618	0,11718
300°	WNW	0,01224	0,00148	0,00042	0,00014	0,00023	0,00030	0,00107	0,00445	0,00554	0,00885	0,02083	0,03029	0,08583
330°	NNW	0,02870	0,00180	0,00047	0,00019	0,00028	0,00025	0,00107	0,00182	0,00143	0,00216	0,00625	0,03274	0,07717
		0,16678	0,07596	0,06472	0,03928	0,02595	0,02767	0,07639	0,16560	0,08257	0,06822	0,08113	0,12573	1,00000

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw < 1 m/s		Wave direction												
Wind direction		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00006		0,00002						0,00002		0,00002	0,00006	0,00017
030°	NNE	0,00009			0,00002	0,00002	0,00002			0,00002		0,00002		0,00017
060°	ENE	0,00005	0,00002	0,00003	0,00002		0,00006		0,00003			0,00006	0,00002	0,00028
090°	E	0,00003	0,00003		0,00002			0,00003	0,00002				0,00005	0,00017
120°	ESE	0,00012	0,00008					0,00003	0,00002				0,00003	0,00028
150°	SSE	0,00011	0,00002				0,00002	0,00005	0,00005		0,00003		0,00005	0,00031
180°	S	0,00020	0,00003	0,00002	0,00003		0,00002	0,00002		0,00005	0,00003	0,00002	0,00005	0,00045
210°	SSW	0,00012	0,00003	0,00002		0,00002		0,00002	0,00003	0,00002		0,00003	0,00014	0,00042
240°	WSW	0,00017	0,00005		0,00002	0,00002		0,00002	0,00002	0,00002	0,00003	0,00002	0,00009	0,00044
270°	W	0,00016	0,00002	0,00002		0,00002			0,00002	0,00002	0,00002	0,00002	0,00006	0,00036
300°	WNW	0,00014	0,00002	0,00002			0,00002		0,00006	0,00002		0,00003	0,00006	0,00036
330°	NNW	0,00011	0,00002	0,00003				0,00002	0,00005			0,00003	0,00008	0,00033
		0,00137	0,00030	0,00014	0,00009	0,00006	0,00012	0,00017	0,00028	0,00014	0,00011	0,00026	0,00068	0,00373

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 1-3 m/s		Wave direction												
Wind direction		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00201	0,00033	0,00006	0,00006		0,00005	0,00017	0,00020	0,00016	0,00019	0,00030	0,00073	0,00425
030°	NNE	0,00185	0,00036	0,00031	0,00016	0,00006	0,00008	0,00025	0,00012	0,00005	0,00016	0,00030	0,00072	0,00440
060°	ENE	0,00165	0,00084	0,00025	0,00014	0,00011	0,00014	0,00016	0,00016	0,00006	0,00009	0,00009	0,00045	0,00414
090°	E	0,00180	0,00045	0,00053	0,00023	0,00020	0,00019	0,00023	0,00022	0,00012	0,00012	0,00016	0,00042	0,00468
120°	ESE	0,00142	0,00061	0,00037	0,00033	0,00023	0,00039	0,00042	0,00025	0,00028	0,00014	0,00026	0,00054	0,00524
150°	SSE	0,00146	0,00064	0,00040	0,00033	0,00020	0,00036	0,00061	0,00067	0,00016	0,00033	0,00048	0,00054	0,00618
180°	S	0,00156	0,00056	0,00023	0,00026	0,00012	0,00022	0,00059	0,00093	0,00061	0,00020	0,00040	0,00093	0,00663
210°	SSW	0,00118	0,00039	0,00028	0,00008	0,00002	0,00014	0,00030	0,00054	0,00033	0,00030	0,00047	0,00115	0,00516
240°	WSW	0,00109	0,00044	0,00023	0,00008	0,00006	0,00014	0,00039	0,00048	0,00034	0,00047	0,00045	0,00118	0,00535
270°	W	0,00124	0,00026	0,00014	0,00008	0,00011	0,00008	0,00030	0,00050	0,00037	0,00022	0,00070	0,00107	0,00507
300°	WNW	0,00151	0,00048	0,00006	0,00003	0,00005	0,00003	0,00014	0,00037	0,00025	0,00031	0,00053	0,00112	0,00488
330°	NNW	0,00219	0,00034	0,00006	0,00005	0,00006	0,00011	0,00012	0,00028	0,00016	0,00023	0,00025	0,00087	0,00473
		0,01896	0,00569	0,00294	0,00182	0,00123	0,00191	0,00367	0,00473	0,00288	0,00275	0,00439	0,00974	0,06071

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

## Upwind Design Basis – K13 Shallow Water Site

Vw 3-5 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00367	0,00072	0,00016	0,00003	0,00005	0,00008	0,00008	0,00022	0,00005	0,00019	0,00026	0,00126	0,00675
030°	NNE	0,00336	0,00142	0,00045	0,00011	0,00003	0,00005	0,00009	0,00020	0,00026	0,00009	0,00016	0,00081	0,00703
060°	ENE	0,00310	0,00180	0,00079	0,00045	0,00011	0,00009	0,00022	0,00020	0,00019	0,00023	0,00023	0,00061	0,00803
090°	E	0,00185	0,00132	0,00104	0,00065	0,00048	0,00026	0,00037	0,00020	0,00012	0,00014	0,00023	0,00065	0,00734
120°	ESE	0,00137	0,00086	0,00082	0,00051	0,00034	0,00064	0,00051	0,00030	0,00020	0,00011	0,00026	0,00050	0,00642
150°	SSE	0,00124	0,00068	0,00048	0,00048	0,00033	0,00048	0,00109	0,00084	0,00025	0,00026	0,00030	0,00064	0,00708
180°	S	0,00165	0,00056	0,00036	0,00030	0,00019	0,00022	0,00100	0,00126	0,00070	0,00045	0,00036	0,00103	0,00806
210°	SSW	0,00168	0,00045	0,00031	0,00012	0,00008	0,00011	0,00058	0,00120	0,00065	0,00051	0,00076	0,00104	0,00750
240°	WSW	0,00140	0,00034	0,00016	0,00008	0,00008	0,00014	0,00042	0,00112	0,00070	0,00051	0,00100	0,00151	0,00745
270°	W	0,00180	0,00042	0,00019	0,00006	0,00005	0,00014	0,00017	0,00089	0,00051	0,00054	0,00104	0,00187	0,00768
300°	WNW	0,00213	0,00037	0,00017		0,00003	0,00011	0,00023	0,00048	0,00048	0,00053	0,00093	0,00247	0,00795
330°	NNW	0,00308	0,00031	0,00019	0,00002	0,00003		0,00023	0,00037	0,00020	0,00036	0,00061	0,00243	0,00782
		0,02633	0,00926	0,00512	0,00282	0,00179	0,00232	0,00499	0,00728	0,00432	0,00394	0,00614	0,01481	0,08911

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 5-7 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00666	0,00112	0,00012	0,00006	0,00002	0,00003	0,00009	0,00020	0,00017	0,00014	0,00036	0,00222	0,01120
030°	NNE	0,00534	0,00271	0,00062	0,00008	0,00008	0,00008	0,00011	0,00017	0,00014	0,00006	0,00017	0,00082	0,01038
060°	ENE	0,00308	0,00310	0,00188	0,00061	0,00008	0,00012	0,00017	0,00019	0,00009	0,00002	0,00014	0,00044	0,00991
090°	E	0,00179	0,00221	0,00226	0,00191	0,00054	0,00037	0,00019	0,00014	0,00014	0,00012	0,00019	0,00044	0,01030
120°	ESE	0,00131	0,00134	0,00162	0,00140	0,00143	0,00109	0,00065	0,00036	0,00022	0,00012	0,00014	0,00044	0,01011
150°	SSE	0,00128	0,00065	0,00067	0,00079	0,00089	0,00135	0,00204	0,00115	0,00023	0,00023	0,00036	0,00056	0,01020
180°	S	0,00128	0,00059	0,00048	0,00050	0,00030	0,00068	0,00222	0,00241	0,00075	0,00056	0,00059	0,00096	0,01132
210°	SSW	0,00134	0,00067	0,00039	0,00017	0,00022	0,00025	0,00165	0,00317	0,00135	0,00093	0,00120	0,00152	0,01286
240°	WSW	0,00176	0,00054	0,00017	0,00022	0,00009	0,00014	0,00112	0,00313	0,00199	0,00145	0,00191	0,00222	0,01475
270°	W	0,00232	0,00034	0,00025		0,00002	0,00003	0,00040	0,00187	0,00118	0,00149	0,00212	0,00366	0,01367
300°	WNW	0,00283	0,00030	0,00012	0,00006	0,00011	0,00006	0,00025	0,00095	0,00079	0,00086	0,00210	0,00450	0,01293
330°	NNW	0,00566	0,00056	0,00011	0,00005	0,00005	0,00008	0,00022	0,00033	0,00033	0,00037	0,00106	0,00404	0,01285
		0,03463	0,01412	0,00870	0,00585	0,00381	0,00429	0,00912	0,01406	0,00739	0,00636	0,01033	0,02182	0,14048

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 7-9 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00638	0,00081	0,00022	0,00005	0,00003	0,00008	0,00005	0,00006	0,00006	0,00006	0,00012	0,00143	0,00935
030°	NNE	0,00562	0,00327	0,00073	0,00014	0,00003	0,00003	0,00006	0,00008	0,00003	0,00006	0,00012	0,00070	0,01087
060°	ENE	0,00215	0,00409	0,00260	0,00051	0,00023	0,00006	0,00003	0,00008	0,00008	0,00003	0,00008	0,00022	0,01016
090°	E	0,00126	0,00208	0,00302	0,00208	0,00062	0,00033	0,00014	0,00017	0,00002	0,00002	0,00003	0,00031	0,01008
120°	ESE	0,00070	0,00087	0,00168	0,00173	0,00165	0,00089	0,00056	0,00023	0,00003	0,00006	0,00006	0,00019	0,00865
150°	SSE	0,00075	0,00078	0,00067	0,00082	0,00093	0,00138	0,00199	0,00072	0,00017	0,00012	0,00014	0,00033	0,00880
180°	S	0,00110	0,00039	0,00045	0,00036	0,00037	0,00075	0,00320	0,00280	0,00079	0,00072	0,00078	0,00061	0,01232
210°	SSW	0,00114	0,00028	0,00020	0,00017	0,00014	0,00048	0,00213	0,00512	0,00188	0,00112	0,00129	0,00168	0,01563
240°	WSW	0,00117	0,00031	0,00016	0,00008	0,00011	0,00030	0,00103	0,00471	0,00283	0,00252	0,00230	0,00202	0,01753
270°	W	0,00124	0,00017	0,00008	0,00002	0,00008	0,00005	0,00040	0,00207	0,00182	0,00240	0,00356	0,00294	0,01482
300°	WNW	0,00252	0,00016	0,00003	0,00003	0,00002	0,00002	0,00016	0,00070	0,00078	0,00120	0,00196	0,00437	0,01193
330°	NNW	0,00406	0,00028	0,00003	0,00003	0,00005		0,00006	0,00022	0,00017	0,00025	0,00053	0,00341	0,00908
		0,02808	0,01349	0,00986	0,00602	0,00426	0,00436	0,00982	0,01695	0,00866	0,00856	0,01098	0,01820	0,13923

Percentage of time [%]

90° + from wind direction
90° - from wind direction

## Upwind Design Basis – K13 Shallow Water Site

Vw 9-11 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00639	0,00086	0,00014	0,00003	0,00002		0,00006	0,00003	0,00009	0,00014	0,00025	0,00229	0,01030
030°	NNE	0,00454	0,00328	0,00075	0,00012	0,00003	0,00006					0,00011	0,00054	0,00944
060°	ENE	0,00151	0,00414	0,00257	0,00039	0,00019	0,00005	0,00008	0,00002	0,00006	0,00003	0,00009	0,00022	0,00933
090°	E	0,00058	0,00185	0,00383	0,00268	0,00067	0,00014	0,00005	0,00003	0,00005	0,00003	0,00006	0,00014	0,01010
120°	ESE	0,00044	0,00078	0,00159	0,00190	0,00190	0,00082	0,00047	0,00011	0,00009	0,00003	0,00003	0,00012	0,00828
150°	SSE	0,00026	0,00023	0,00044	0,00072	0,00109	0,00180	0,00241	0,00036	0,00017	0,00006	0,00022	0,00012	0,00789
180°	S	0,00051	0,00022	0,00020	0,00028	0,00067	0,00096	0,00493	0,00331	0,00051	0,00025	0,00036	0,00053	0,01274
210°	SSW	0,00039	0,00019	0,00017	0,00016	0,00025	0,00031	0,00282	0,00711	0,00246	0,00124	0,00089	0,00112	0,01709
240°	WSW	0,00065	0,00014	0,00014	0,00011	0,00016	0,00012	0,00112	0,00639	0,00496	0,00288	0,00188	0,00176	0,02031
270°	W	0,00065	0,00009	0,00008	0,00003	0,00005	0,00005	0,00040	0,00205	0,00243	0,00303	0,00392	0,00313	0,01591
300°	WNW	0,00173	0,00008		0,00002	0,00002	0,00003	0,00009	0,00070	0,00086	0,00123	0,00322	0,00473	0,01269
330°	NNW	0,00496	0,00011	0,00005	0,00002	0,00002	0,00003	0,00020	0,00026	0,00026	0,00036	0,00098	0,00521	0,01246
		0,02262	0,01196	0,00994	0,00644	0,00504	0,00439	0,01263	0,02038	0,01195	0,00929	0,01201	0,01991	0,14654

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 11-13 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00586	0,00047	0,00012	0,00002			0,00005	0,00003	0,00005	0,00014	0,00019	0,00121	0,00814
030°	NNE	0,00348	0,00317	0,00067	0,00009	0,00002		0,00006	0,00002		0,00003	0,00009	0,00023	0,00787
060°	ENE	0,00090	0,00341	0,00302	0,00053	0,00003	0,00008			0,00002	0,00003	0,00002	0,00003	0,00806
090°	E	0,00030	0,00159	0,00389	0,00260	0,00045	0,00016	0,00008	0,00002	0,00003	0,00002		0,00003	0,00915
120°	ESE	0,00022	0,00039	0,00103	0,00233	0,00224	0,00089	0,00026	0,00011	0,00005	0,00003	0,00002	0,00008	0,00764
150°	SSE	0,00016	0,00023	0,00034	0,00054	0,00142	0,00229	0,00198	0,00040	0,00009	0,00002	0,00014	0,00014	0,00775
180°	S	0,00023	0,00017	0,00011	0,00022	0,00023	0,00086	0,00502	0,00311	0,00040	0,00012	0,00011	0,00036	0,01095
210°	SSW	0,00036	0,00017	0,00005	0,00008	0,00011	0,00050	0,00375	0,01153	0,00249	0,00093	0,00045	0,00062	0,02103
240°	WSW	0,00016	0,00008	0,00003	0,00005	0,00005	0,00008	0,00087	0,00776	0,00566	0,00325	0,00156	0,00093	0,02047
270°	W	0,00026	0,00005	0,00002	0,00002	0,00002	0,00005	0,00030	0,00244	0,00367	0,00422	0,00473	0,00187	0,01762
300°	WNW	0,00076	0,00003	0,00002			0,00003	0,00011	0,00067	0,00084	0,00148	0,00319	0,00521	0,01234
330°	NNW	0,00412	0,00011		0,00002	0,00003	0,00002	0,00014	0,00014	0,00016	0,00025	0,00118	0,00555	0,01171
		0,01681	0,00986	0,00929	0,00649	0,00459	0,00493	0,01262	0,02623	0,01346	0,01052	0,01167	0,01627	0,14272

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 13-15 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00257	0,00033	0,00003	0,00002			0,00005	0,00005	0,00003	0,00003	0,00011	0,00073	0,00394
030°	NNE	0,00168	0,00151	0,00025	0,00002		0,00003	0,00003	0,00002	0,00002		0,00005	0,00008	0,00367
060°	ENE	0,00023	0,00215	0,00205	0,00030	0,00003	0,00002						0,00002	0,00479
090°	E	0,00008	0,00030	0,00277	0,00165	0,00031	0,00009	0,00003				0,00002	0,00005	0,00529
120°	ESE	0,00006	0,00017	0,00064	0,00140	0,00121	0,00033	0,00002	0,00002			0,00002	0,00000	0,00386
150°	SSE	0,00005	0,00008	0,00014	0,00022	0,00047	0,00104	0,00112	0,00014	0,00002		0,00002	0,00002	0,00330
180°	S	0,00014	0,00003	0,00005	0,00008	0,00014	0,00040	0,00327	0,00187	0,00026	0,00006	0,00009	0,00006	0,00646
210°	SSW	0,00012	0,00008	0,00006	0,00009	0,00008	0,00006	0,00230	0,00946	0,00135	0,00053	0,00037	0,00011	0,01462
240°	WSW	0,00012	0,00003	0,00006	0,00002		0,00009	0,00047	0,00537	0,00448	0,00222	0,00100	0,00040	0,01426
270°	W	0,00005		0,00002	0,00002			0,00008	0,00114	0,00236	0,00322	0,00299	0,00086	0,01072
300°	WNW	0,00034					0,00006	0,00020	0,00059	0,00089	0,00207	0,00296	0,00711	
330°	NNW	0,00180			0,00002	0,00005	0,00002		0,00011	0,00006	0,00006	0,00040	0,00328	0,00580
		0,00725	0,00467	0,00607	0,00381	0,00229	0,00208	0,00742	0,01835	0,00918	0,00702	0,00712	0,00856	0,08381

Percentage of time [%]

90° + from wind direction
90° - from wind direction

## Upwind Design Basis – K13 Shallow Water Site

Vw 15-17 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00250	0,00023	0,00005	0,00002		0,00002	0,00002	0,00006	0,00005	0,00003	0,00019	0,00086	0,00401
030°	NNE	0,00123	0,00120	0,00012	0,00003		0,00003	0,00002	0,00006		0,00002	0,00002	0,00005	0,00277
060°	ENE	0,00017	0,00159	0,00204	0,00012	0,00002	0,00002	0,00002				0,00002		0,00398
090°	E	0,00008	0,00040	0,00336	0,00128	0,00022	0,00003	0,00003					0,00002	0,00541
120°	ESE	0,00006	0,00002	0,00033	0,00145	0,00107	0,00030	0,00012					0,00002	0,00336
150°	SSE	0,00002	0,00003	0,00006	0,00016	0,00053	0,00082	0,00114	0,00005	0,00002	0,00002		0,00003	0,00286
180°	S	0,00008	0,00005		0,00003	0,00006	0,00031	0,00324	0,00208	0,00016	0,00008	0,00003		0,00611
210°	SSW	0,00003	0,00003	0,00002	0,00011	0,00008	0,00008	0,00179	0,01084	0,00128	0,00040	0,00023	0,00012	0,01501
240°	WSW		0,00002		0,00005	0,00002	0,00003	0,00039	0,00753	0,00492	0,00212	0,00078	0,00011	0,01594
270°	W	0,00002	0,00002	0,00002			0,00002	0,00002	0,00093	0,00272	0,00398	0,00317	0,00042	0,01131
300°	WNW	0,00020	0,00002			0,00002		0,00019	0,00037	0,00081	0,00250	0,00233		0,00646
330°	NNW	0,00138	0,00008				0,00002	0,00002	0,00005	0,00012	0,00040	0,00386		0,00593
		0,00577	0,00367	0,00599	0,00324	0,00201	0,00165	0,00680	0,02176	0,00955	0,00758	0,00734	0,00781	0,08316

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 17-19 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00110	0,00008						0,00003	0,00002		0,00002	0,00028	0,00152
030°	NNE	0,00044	0,00061	0,00011	0,00002		0,00002	0,00002	0,00003	0,00002			0,00003	0,00128
060°	ENE	0,00008	0,00058	0,00098	0,00005								0,00002	0,00170
090°	E	0,00003	0,00008	0,00148	0,00058	0,00006	0,00003							0,00226
120°	ESE	0,00002		0,00012	0,00058	0,00019	0,00009	0,00008					0,00002	0,00109
150°	SSE	0,00002	0,00002	0,00002	0,00006	0,00017	0,00053	0,00065	0,00003				0,00006	0,00156
180°	S		0,00003	0,00006	0,00003	0,00002	0,00011	0,00188	0,00121	0,00005	0,00005	0,00002		0,00345
210°	SSW			0,00002		0,00003	0,00006	0,00101	0,00610	0,00054	0,00012	0,00008	0,00006	0,00803
240°	WSW		0,00002		0,00002		0,00002	0,00020	0,00350	0,00302	0,00079	0,00017	0,00011	0,00784
270°	W	0,00003		0,00002				0,00011	0,00056	0,00142	0,00260	0,00182	0,00019	0,00674
300°	WNW	0,00005	0,00003				0,00002			0,00019	0,00062	0,00165	0,00103	0,00358
330°	NNW	0,00050								0,00003	0,00008	0,00036	0,00187	0,00283
		0,00226	0,00143	0,00280	0,00132	0,00047	0,00086	0,00397	0,01146	0,00527	0,00426	0,00411	0,00366	0,04186

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 19-21 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00058	0,00008					0,00002			0,00003	0,00006	0,00020	0,00096
030°	NNE	0,00026	0,00053	0,00016	0,00003		0,00002		0,00002				0,00008	0,00109
060°	ENE	0,00006	0,00031	0,00064	0,00005	0,00002								0,00107
090°	E		0,00005	0,00151	0,00042	0,00002								0,00199
120°	ESE			0,00002	0,00025	0,00019	0,00005	0,00002						0,00051
150°	SSE				0,00002	0,00005	0,00020	0,00051	0,00002					0,00079
180°	S			0,00002		0,00002	0,00009	0,00128	0,00087	0,00006				0,00233
210°	SSW	0,00003					0,00005	0,00089	0,00652	0,00048	0,00009	0,00005	0,00003	0,00814
240°	WSW							0,00017	0,00376	0,00278	0,00073	0,00008		0,00753
270°	W					0,00003			0,00051	0,00138	0,00222	0,00157	0,00008	0,00580
300°	WNW								0,00006	0,00020	0,00045	0,00121	0,00075	0,00268
330°	NNW	0,00044					0,00005	0,00002	0,00002	0,00002	0,00003	0,00031	0,00104	0,00190
		0,00137	0,00096	0,00233	0,00076	0,00028	0,00044	0,00292	0,01178	0,00493	0,00356	0,00328	0,00218	0,03480

Percentage of time [%]

90° + from wind direction
90° - from wind direction

## Upwind Design Basis – K13 Shallow Water Site

Vw 21-23 m/s		Wave direction													
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW		
000°	N	0,00030	0,00002							0,00002		0,00002	0,00009	0,00044	
030°	NNE	0,00016	0,00020	0,00002		0,00002			0,00002					0,00040	
060°	ENE	0,00002	0,00005	0,00025										0,00031	
090°	E			0,00050	0,00026									0,00076	
120°	ESE				0,00006	0,00003	0,00005							0,00014	
150°	SSE						0,00003	0,00009	0,00002					0,00014	
180°	S						0,00002	0,00002	0,00003	0,00047	0,00059			0,00112	
210°	SSW							0,00005	0,00037	0,00302	0,00302	0,00014	0,00009	0,00002	0,00369
240°	WSW								0,00002	0,00002	0,00171	0,00121	0,00025	0,00005	0,00325
270°	W									0,00025	0,00086	0,00109	0,00072	0,00002	0,00292
300°	WNW	0,00003								0,00005	0,00006	0,00019	0,00067	0,00037	0,00137
330°	NNW	0,00016								0,00002		0,00002	0,00009	0,00051	0,00079
		0,00065	0,00026	0,00076	0,00034	0,00006	0,00017	0,00095	0,00566	0,00229	0,00163	0,00156	0,00100	0,01534	

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 23-25 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00020	0,00002	0,00002									0,00003	0,00026
030°	NNE	0,00012	0,00016	0,00003						0,00002			0,00002	0,00034
060°	ENE		0,00002	0,00026	0,00002									0,00030
090°	E			0,00023	0,00009	0,00002								0,00034
120°	ESE				0,00006	0,00003	0,00002							0,00011
150°	SSE						0,00002	0,00014						0,00016
180°	S						0,00005	0,00042	0,00033					0,00079
210°	SSW							0,00016	0,00219	0,00012	0,00005		0,00002	0,00254
240°	WSW								0,00087	0,00053	0,00016	0,00002		0,00157
270°	W								0,00012	0,00056	0,00089	0,00048	0,00002	0,00207
300°	WNW									0,00003	0,00008	0,00050	0,00023	0,00084
330°	NNW	0,00014						0,00002			0,00002	0,00002	0,00023	0,00042
		0,00047	0,00019	0,00054	0,00017	0,00005	0,00008	0,00073	0,00352	0,00126	0,00118	0,00101	0,00054	0,00974

Percentage of time [%]

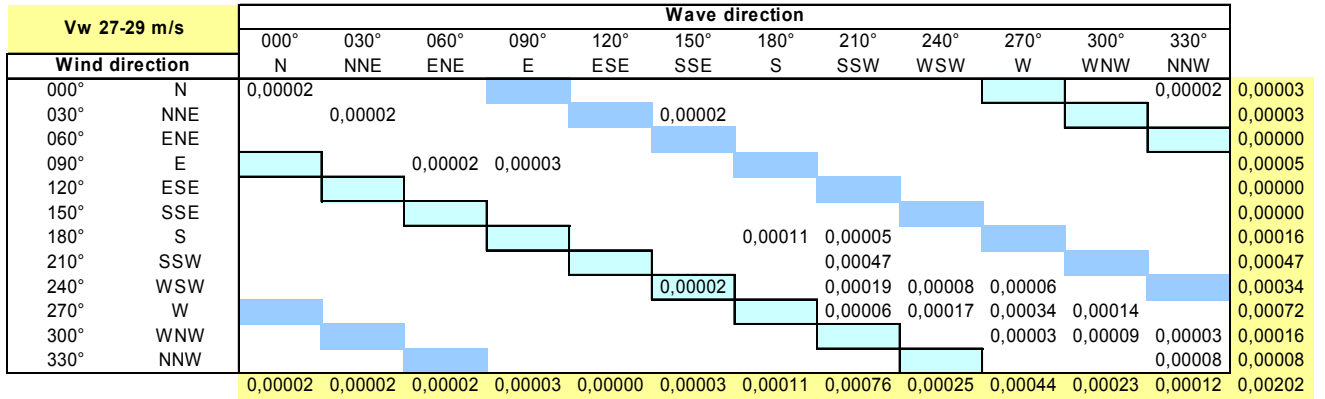
90° + from wind direction  
90° - from wind direction

Vw 25-27 m/s		Wave direction													
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW		
000°	N	0,00006												0,00006	
030°	NNE	0,00002	0,00005					0,00002						0,00008	
060°	ENE		0,00003	0,00003	0,00002		0,00002							0,00009	
090°	E			0,00017	0,00006									0,00023	
120°	ESE													0,00000	
150°	SSE							0,00002						0,00002	
180°	S							0,00022	0,00026					0,00048	
210°	SSW								0,00118	0,00009				0,00140	
240°	WSW								0,00025	0,00031	0,00012			0,00068	
270°	W								0,00008	0,00030	0,00048	0,00034	0,00002	0,00121	
300°	WNW									0,00002	0,00005	0,00014	0,00016	0,00048	
330°	NNW	0,00006								0,00002		0,00002	0,00003	0,00023	0,00036
		0,00014	0,00008	0,00020	0,00008	0,00002	0,00002	0,00036	0,00180	0,00075	0,00076	0,00053	0,00037	0,00510	

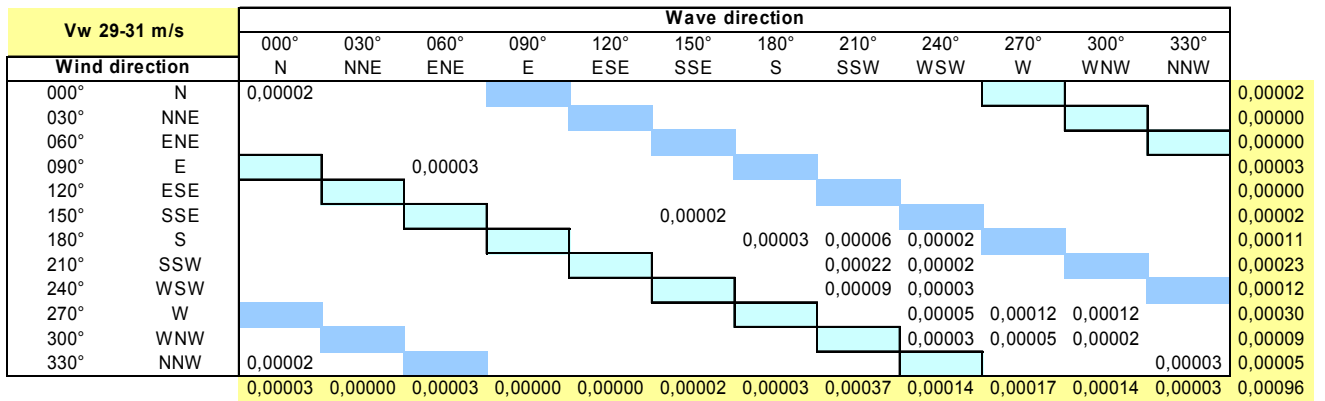
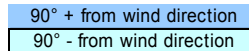
Percentage of time [%]

90° + from wind direction  
90° - from wind direction

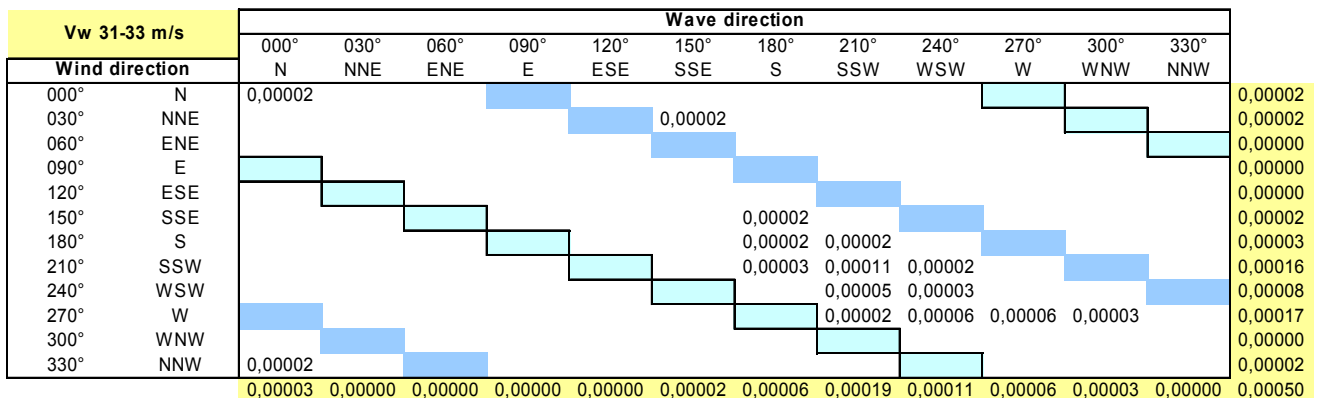
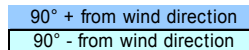
## Upwind Design Basis – K13 Shallow Water Site



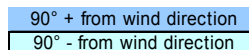
Percentage of time [%]



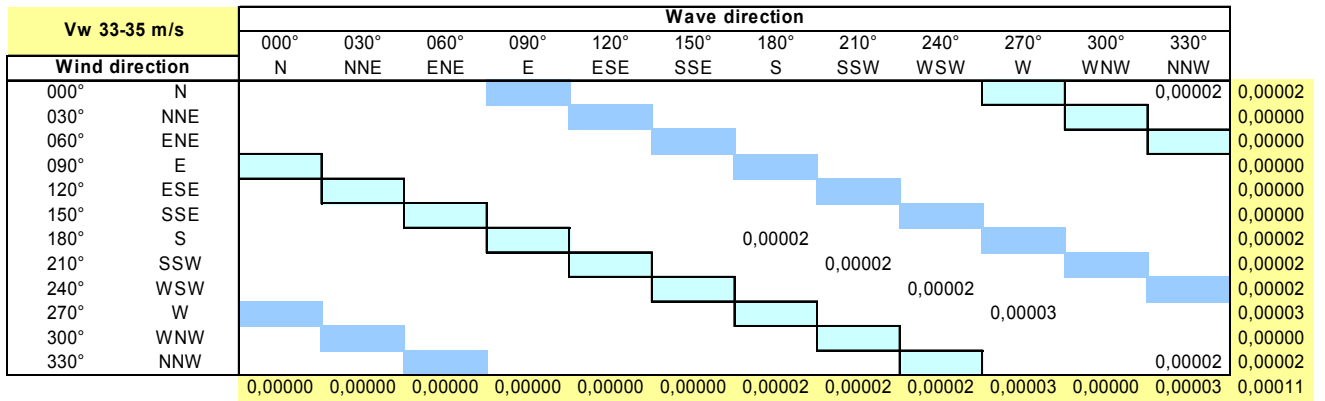
Percentage of time [%]



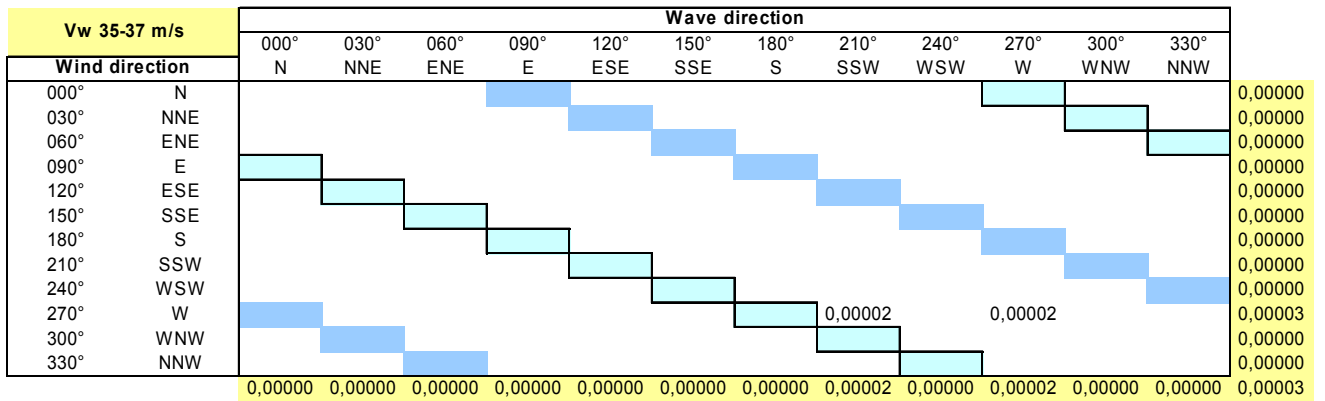
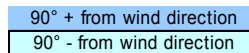
Percentage of time [%]



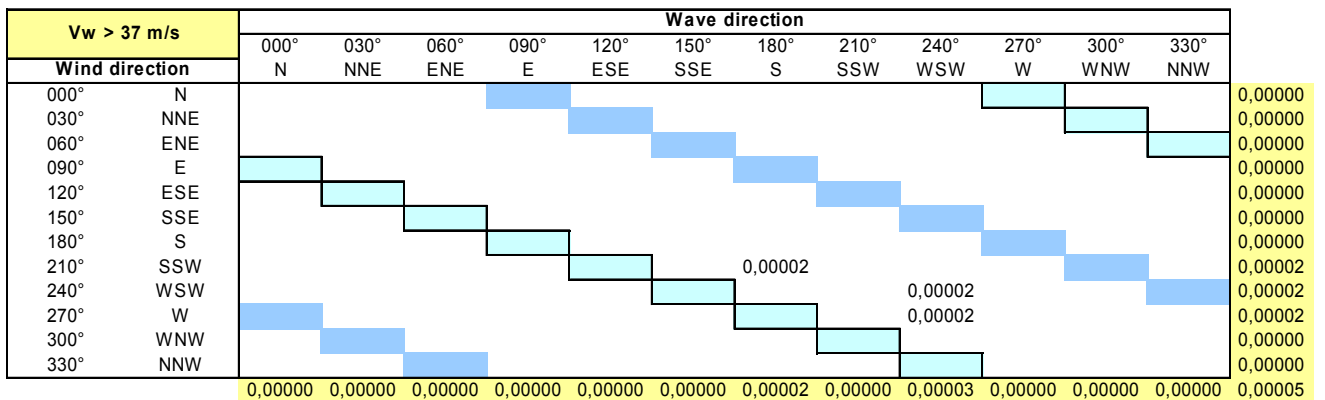
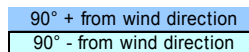
## Upwind Design Basis – K13 Shallow Water Site



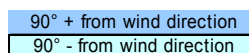
Percentage of time [%]



Percentage of time [%]



Percentage of time [%]



**E. Reduced scatter diagrams ( $V - \theta_{wind} - \theta_{wave}$ )**

All windspeeds		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,07364	0,02973	0,00796	0,00585	0,00688	0,02091	0,14496
030°	NNE	0,05314	0,09030	0,01949	0,00854	0,00817	0,01422	0,19385
060°	ENE	0,02638	0,07166	0,05276	0,02189	0,01332	0,01409	0,20010
090°	E	0,01890	0,02604	0,04581	0,04219	0,03211	0,02031	0,18535
120°	ESE	0,02217	0,01241	0,01504	0,02148	0,03237	0,03805	0,14152
150°	SSE	0,04895	0,01142	0,00622	0,00756	0,01425	0,04583	0,13422
		0,24317	0,24155	0,14729	0,10750	0,10708	0,15340	1,00000

Vw < 1 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00028	0,00003	0,00009	0,00006	0,00003	0,00012	0,00062
030°	NNE	0,00023	0,00006	0,00005	0,00002	0,00008	0,00016	0,00059
060°	ENE	0,00023	0,00011	0,00005	0,00006	0,00009	0,00017	0,00072
090°	E	0,00022	0,00008	0,00003	0,00003	0,00006	0,00011	0,00053
120°	ESE	0,00030	0,00017	0,00003		0,00003	0,00011	0,00064
150°	SSE	0,00028	0,00012	0,00003	0,00003	0,00003	0,00014	0,00064
		0,00154	0,00058	0,00028	0,00020	0,00033	0,00081	0,00373

Vw 1-3 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00432	0,00202	0,00106	0,00072	0,00082	0,00193	0,01087
030°	NNE	0,00358	0,00142	0,00096	0,00068	0,00084	0,00208	0,00957
060°	ENE	0,00328	0,00191	0,00089	0,00078	0,00072	0,00191	0,00949
090°	E	0,00358	0,00143	0,00117	0,00065	0,00117	0,00176	0,00975
120°	ESE	0,00348	0,00171	0,00096	0,00081	0,00107	0,00208	0,01013
150°	SSE	0,00439	0,00193	0,00078	0,00093	0,00100	0,00188	0,01090
		0,02263	0,01042	0,00582	0,00457	0,00562	0,01165	0,06071

Vw 3-5 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00639	0,00275	0,00126	0,00096	0,00086	0,00258	0,01481
030°	NNE	0,00571	0,00327	0,00168	0,00084	0,00103	0,00201	0,01453
060°	ENE	0,00513	0,00347	0,00184	0,00128	0,00142	0,00235	0,01548
090°	E	0,00420	0,00283	0,00187	0,00140	0,00180	0,00292	0,01503
120°	ESE	0,00425	0,00201	0,00168	0,00115	0,00157	0,00372	0,01437
150°	SSE	0,00565	0,00221	0,00112	0,00112	0,00126	0,00355	0,01490
		0,03133	0,01653	0,00944	0,00675	0,00793	0,01713	0,08911

Vw 5-7 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01025	0,00432	0,00152	0,00126	0,00126	0,00390	0,02252
030°	NNE	0,00843	0,00672	0,00250	0,00124	0,00166	0,00268	0,02324
060°	ENE	0,00613	0,00695	0,00414	0,00229	0,00222	0,00292	0,02465
090°	E	0,00470	0,00456	0,00383	0,00353	0,00286	0,00450	0,02397
120°	ESE	0,00504	0,00294	0,00275	0,00244	0,00378	0,00608	0,02304
150°	SSE	0,00919	0,00269	0,00134	0,00145	0,00235	0,00604	0,02305
		0,04374	0,02819	0,01608	0,01221	0,01414	0,02612	0,14048

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Vw 7-9 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01073	0,00406	0,00152	0,00118	0,00131	0,00286	0,02167
030°	NNE	0,00894	0,00874	0,00285	0,00149	0,00159	0,00289	0,02651
060°	ENE	0,00437	0,00919	0,00566	0,00314	0,00272	0,00260	0,02769
090°	E	0,00305	0,00450	0,00493	0,00451	0,00429	0,00362	0,02490
120°	ESE	0,00394	0,00196	0,00252	0,00302	0,00369	0,00546	0,02058
150°	SSE	0,00686	0,00199	0,00104	0,00123	0,00165	0,00512	0,01789
		0,03789	0,03044	0,01853	0,01458	0,01524	0,02255	0,13923

Vw 9-11 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01190	0,00442	0,00095	0,00070	0,00129	0,00378	0,02304
030°	NNE	0,00775	0,01058	0,00338	0,00152	0,00128	0,00204	0,02654
060°	ENE	0,00336	0,01069	0,00773	0,00341	0,00232	0,00215	0,02965
090°	E	0,00168	0,00403	0,00638	0,00577	0,00470	0,00345	0,02601
120°	ESE	0,00272	0,00166	0,00254	0,00317	0,00516	0,00571	0,02097
150°	SSE	0,00784	0,00096	0,00092	0,00115	0,00230	0,00717	0,02035
		0,03525	0,03234	0,02189	0,01573	0,01705	0,02430	0,14654

Vw 11-13 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01117	0,00378	0,00068	0,00050	0,00053	0,00243	0,01909
030°	NNE	0,00765	0,01489	0,00320	0,00114	0,00067	0,00135	0,02890
060°	ENE	0,00193	0,01125	0,00873	0,00386	0,00165	0,00112	0,02853
090°	E	0,00093	0,00409	0,00761	0,00684	0,00520	0,00210	0,02677
120°	ESE	0,00135	0,00120	0,00193	0,00384	0,00544	0,00621	0,01997
150°	SSE	0,00639	0,00089	0,00059	0,00082	0,00277	0,00800	0,01946
		0,02943	0,03609	0,02274	0,01700	0,01625	0,02120	0,14272

Vw 13-15 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00602	0,00227	0,00037	0,00019	0,00034	0,00120	0,01039
030°	NNE	0,00414	0,01106	0,00168	0,00064	0,00050	0,00028	0,01829
060°	ENE	0,00082	0,00754	0,00660	0,00254	0,00103	0,00053	0,01905
090°	E	0,00023	0,00143	0,00515	0,00488	0,00331	0,00100	0,01601
120°	ESE	0,00048	0,00039	0,00123	0,00229	0,00330	0,00328	0,01097
150°	SSE	0,00297	0,00033	0,00022	0,00030	0,00093	0,00436	0,00910
		0,01467	0,02302	0,01524	0,01083	0,00941	0,01064	0,08381

Vw 15-17 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00583	0,00243	0,00025	0,00016	0,00028	0,00118	0,01013
030°	NNE	0,00306	0,01213	0,00142	0,00056	0,00033	0,00028	0,01778
060°	ENE	0,00058	0,00913	0,00695	0,00229	0,00082	0,00016	0,01993
090°	E	0,00014	0,00135	0,00610	0,00526	0,00339	0,00048	0,01672
120°	ESE	0,00040	0,00022	0,00070	0,00226	0,00359	0,00264	0,00982
150°	SSE	0,00255	0,00017	0,00012	0,00030	0,00093	0,00471	0,00879
		0,01257	0,02543	0,01554	0,01081	0,00935	0,00946	0,08316

Vw 17-19 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00299	0,00135	0,00012	0,00008	0,00005	0,00039	0,00498
030°	NNE	0,00146	0,00674	0,00068	0,00014	0,00011	0,00017	0,00930
060°	ENE	0,00028	0,00409	0,00400	0,00086	0,00017	0,00014	0,00954
090°	E	0,00017	0,00064	0,00291	0,00317	0,00188	0,00022	0,00899
120°	ESE	0,00016	0,00003	0,00031	0,00120	0,00184	0,00114	0,00467
150°	SSE	0,00117	0,00005	0,00005	0,00014	0,00053	0,00246	0,00439
		0,00622	0,01290	0,00807	0,00558	0,00457	0,00451	0,04186

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Vw 19-21 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00187	0,00095	0,00008	0,00003	0,00008	0,00030	0,00330
030°	NNE	0,00118	0,00706	0,00064	0,00012	0,00005	0,00017	0,00922
060°	ENE	0,00023	0,00408	0,00342	0,00078	0,00009		0,00860
090°	E		0,00056	0,00289	0,00264	0,00159	0,00011	0,00779
120°	ESE	0,00002	0,00006	0,00022	0,00070	0,00140	0,00079	0,00319
150°	SSE	0,00100	0,00003	0,00002	0,00005	0,00036	0,00124	0,00269
		0,00429	0,01274	0,00726	0,00432	0,00356	0,00261	0,03480

Vw 21-23 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00076	0,00061	0,00002	0,00002	0,00003	0,00012	0,00156
030°	NNE	0,00053	0,00324	0,00016	0,00009	0,00003	0,00005	0,00409
060°	ENE	0,00003	0,00176	0,00146	0,00025	0,00005	0,00002	0,00356
090°	E		0,00025	0,00135	0,00135	0,00072	0,00002	0,00369
120°	ESE	0,00003	0,00005	0,00006	0,00025	0,00070	0,00042	0,00151
150°	SSE	0,00025	0,00003		0,00002	0,00009	0,00054	0,00093
		0,00160	0,00593	0,00305	0,00198	0,00162	0,00117	0,01534

Vw 23-25 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00062	0,00034	0,00002			0,00008	0,00106
030°	NNE	0,00028	0,00235	0,00017	0,00005		0,00003	0,00288
060°	ENE		0,00089	0,00079	0,00017	0,00002		0,00187
090°	E		0,00012	0,00079	0,00098	0,00050	0,00002	0,00241
120°	ESE			0,00003	0,00014	0,00053	0,00025	0,00095
150°	SSE	0,00030			0,00002	0,00002	0,00025	0,00058
		0,00120	0,00370	0,00180	0,00135	0,00106	0,00062	0,00974

Vw 25-27 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00028	0,00026					0,00054
030°	NNE	0,00014	0,00123	0,00009		0,00002		0,00148
060°	ENE		0,00028	0,00034	0,00014		0,00002	0,00078
090°	E		0,00008	0,00047	0,00054	0,00034	0,00002	0,00145
120°	ESE		0,00002	0,00005	0,00014	0,00016	0,00012	0,00048
150°	SSE	0,00008	0,00002		0,00002	0,00003	0,00023	0,00037
		0,00050	0,00188	0,00095	0,00084	0,00054	0,00039	0,00510

Vw 27-29 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00012	0,00005				0,00002	0,00019
030°	NNE		0,00048				0,00002	0,00050
060°	ENE		0,00019	0,00008	0,00006		0,00002	0,00034
090°	E		0,00006	0,00019	0,00037	0,00014		0,00076
120°	ESE				0,00003	0,00009	0,00003	0,00016
150°	SSE						0,00008	0,00008
		0,00012	0,00078	0,00026	0,00047	0,00023	0,00016	0,00202

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Vw 29-31 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00005	0,00006	0,00002				0,00012
030°	NNE		0,00022	0,00002				0,00023
060°	ENE		0,00009	0,00003				0,00012
090°	E			0,00008	0,00012	0,00012		0,00033
120°	ESE			0,00003	0,00005	0,00002		0,00009
150°	SSE	0,00002					0,00005	0,00006
		0,00006	0,00037	0,00017	0,00017	0,00014	0,00005	0,00096

Vw 31-33 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00003	0,00002					0,00005
030°	NNE	0,00003	0,00011	0,00002			0,00002	0,00017
060°	ENE		0,00005	0,00003				0,00008
090°	E		0,00002	0,00006	0,00006	0,00003		0,00017
120°	ESE							0,00000
150°	SSE	0,00003						0,00003
		0,00009	0,00019	0,00011	0,00006	0,00003	0,00002	0,00050

Vw 33-35 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00002					0,00002	0,00003
030°	NNE		0,00002					0,00002
060°	ENE			0,00002				0,00002
090°	E				0,00003			0,00003
120°	ESE							0,00000
150°	SSE						0,00002	0,00002
		0,00002	0,00002	0,00002	0,00003	0,00000	0,00003	0,00011

Vw 35-37 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE							0,00000
060°	ENE							0,00000
090°	E		0,00002		0,00002			0,00003
120°	ESE							0,00000
150°	SSE							0,00000
		0,00000	0,00002	0,00000	0,00002	0,00000	0,00000	0,00003

Vw > 37 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE	0,00002						0,00002
060°	ENE			0,00002				0,00002
090°	E			0,00002				0,00002
120°	ESE							0,00000
150°	SSE							0,00000
		0,00002	0,00000	0,00003	0,00000	0,00000	0,00000	0,00005

## Upwind Design Basis – K13 Shallow Water Site

## **C. K13 Deep Water Site**

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## **Abstract**

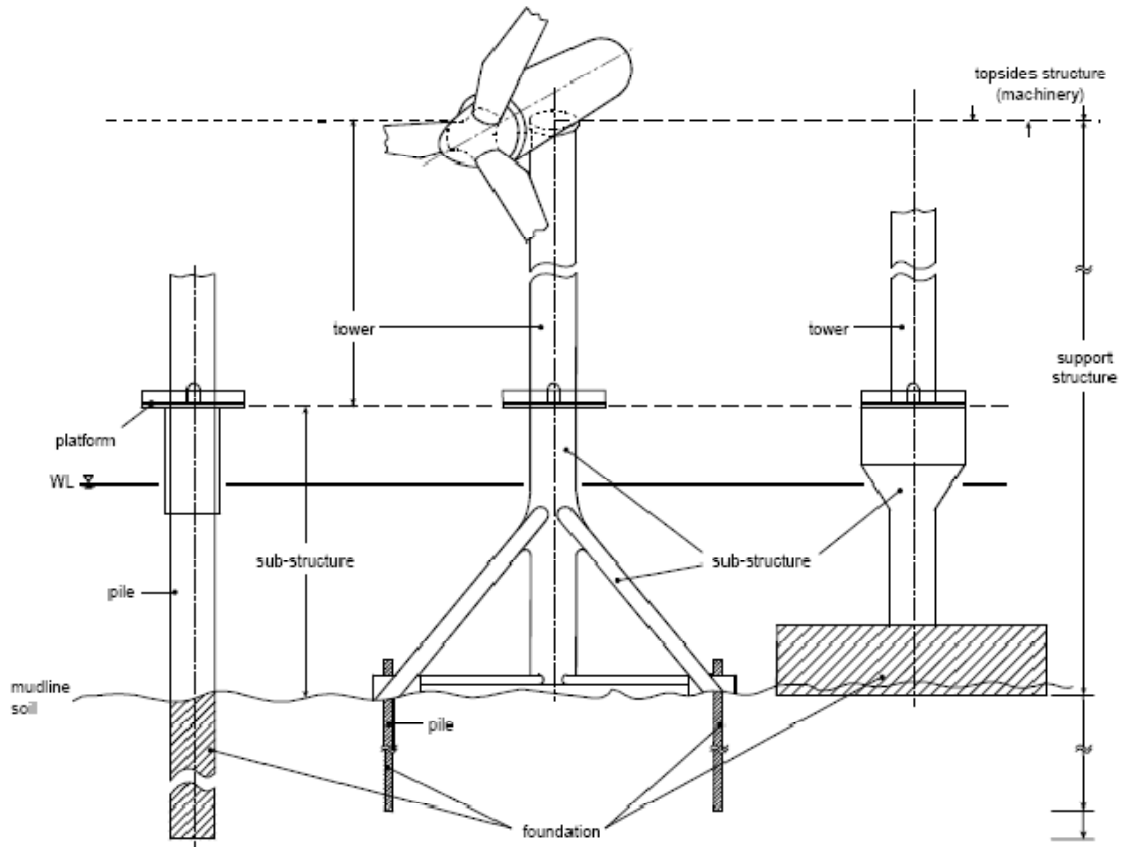
The presented design basis gives a summarized overview of relevant design properties for a later offshore wind turbine design procedure within work package 4. The described offshore site is located in the Dutch North Sea. With an assumed water depth of 50 m it has been chosen as deep water site within the work package for further design studies.

Besides information about climate properties like wind and wave definitions, other load properties are specified according to a current design guideline. Here the guideline of the Germanischer Lloyd and IEC is chosen. Finally the relevant design load cases according to the guideline are listed, which have to be fulfilled for a suitable support structure design.

## C.1. General remarks and definitions

The relevant design parameters and methods within this design basis are taken from the IEC-61400-3 standard [1]. Further standards are quoted when used.

An offshore wind turbine (OWT) as examined in this design basis, consists of a wind turbine and its support structure, see Figure 19. The support structure is divided into two parts: the tower and the sub-structure. The tower is directly connected to the wind turbine. The sub-structure of OWT consists of a kind of transition piece (e. g. a jacket) connecting the tower with the foundation. The actual foundation is either realised with piles or is part of the transition piece (e.g. gravity foundation).

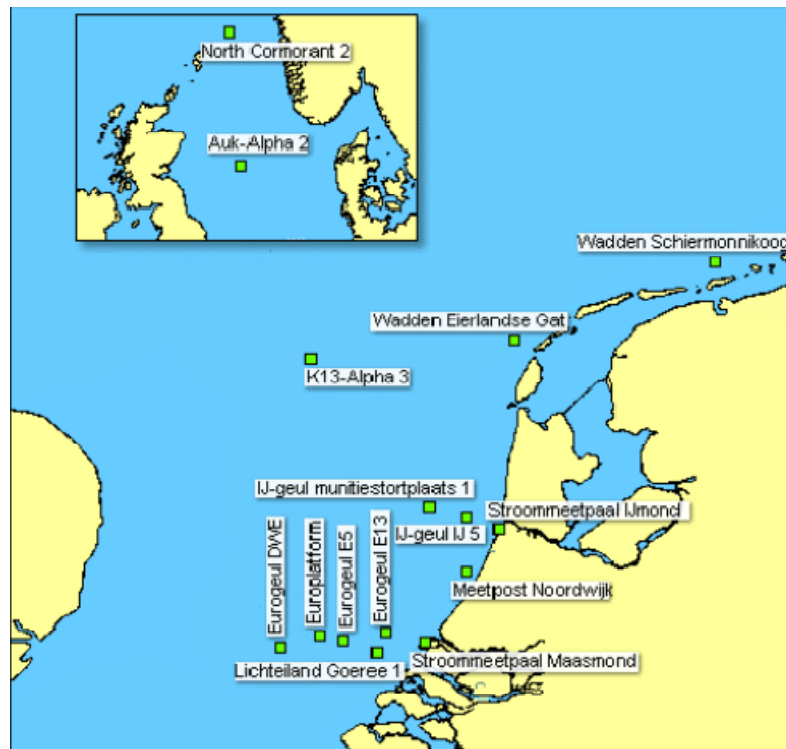


**Figure 19:** Definition of an offshore wind turbine [2]

The intention of this design basis is to give the necessary definitions for designing a support structure in a fictive wind farm. The met-ocean conditions are, however, uniform at all fictive locations and only one support structure will be designed applicable to all positions.

## C.2. Project description

The following design basis is based on a location in the Dutch North Sea. The climate information is obtained from the wave and wind data published by *Rijkswaterstaat* for the location “K13” [3]. This site will be denoted in the following as *K13-Alpha 3* (see Figure 20). The coordinates of *K13* are 53°13'04” north and 3°13'13” east, and for the water depth a value of 50 m is taken. These data are available as 3-hour average values for a period of 22 years (January 1979 - December 2000). As the actual water depth at the *K13* platform is significantly less than 50 m an additional data source was used to obtain extreme wave data to verify that the waves are not depth limited. The Argoss [10] database was consulted to obtain the extreme significant wave heights as function of the return period for a location at 53°55'N and 03° 05'E, where the actual water depth is approximately 50 m.



**Figure 20:** Locations for which *Rijkswaterstaat* measures wind and wave data [4]

### C.3. Structural definitions and limitations

#### C.3.1. Turbine

The turbine that will be used for the design of the jacket structure will be the UpWind Reference Turbine which is based on the NREL generic 5.0 MW turbine. The parameters of relevance to the preliminary design are listed in Table 42.

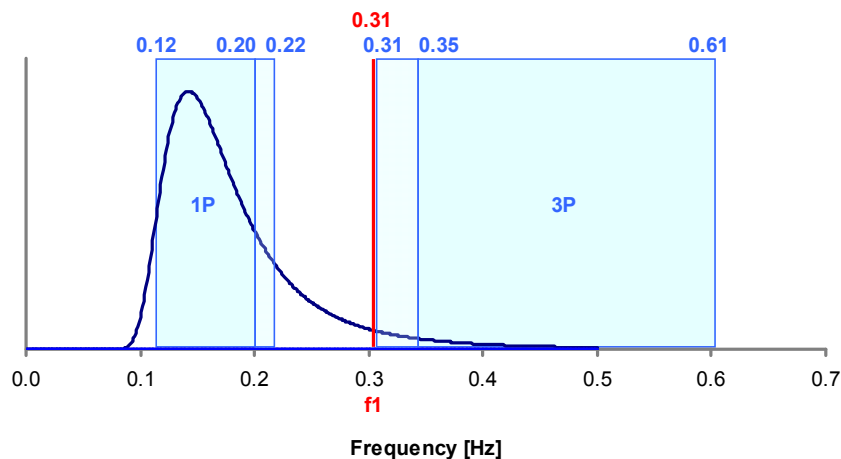
**Table 42:** Turbine parameters for the NREL 5.0MW.

<i>Turbine parameter</i>	<i>Value</i>	<i>Unit</i>
Rated power	5.0	MW
Rotor diameter	126	m
Mass of rotor and nacelle	350	ton
Cut-in wind speed	3	m/s
Rated wind speed	11.4	m/s
Cut-out wind speed	25	m/s
Nominal rotor speed	12.1	rpm
Lower bound rotor speed	6.9	rpm
Upper bound rotor speed	12.1	rpm

Many additional parameters are required to determine the turbine behaviour. These are not listed here as they are implemented in the Bladed model of the reference turbine.

#### C.3.2. Allowable frequency range

The rotor frequency range (1P) lies between 0.115 Hz and 0.202 Hz. The support structure natural frequency is to be within the soft-stiff range in between the 1P and 3P frequency ranges. A safety margin of 10% on the maximum and minimum rotor speed is adopted, which means that the allowable frequency is between 0.222 Hz and 0.31 Hz.



**Figure 21:** Allowable natural frequency range for the support structure

### C.3.3. Tower and sub-structure design

The deep water site has a mean water level (MSL) of 50.0 as shown in Figure 22. As described in the following, the bottom of the transition piece is found at 16.15 m. The height of the concrete transition piece is 4.0 m. This sets the interface level at 20.15 m. The hub vertical offset is 2.4 m. By using a standard tower of 68 m, the support structure design results finally in a hub height of 90.55 m above MSL.

#### C.3.3.1. Transition piece

The concrete transition is located the base of the tower. The determination of the elevation of the bottom of the transition piece is based on the GL standard [2] with the expression

$$z_{TP;bottom} = LAT + \Delta z_{tide} + \Delta z_{surge} + \Delta z_{air} + \zeta^* \quad \text{and} \quad \zeta^* = \delta \cdot H_{50,max}$$

By applying  $\delta = 0.65$ ,  $LAT = -1.06m$ , a tidal range of  $\Delta z_{tide} = 2.22m$ , a storm surge of  $\Delta z_{surge} = 2.13m$ , an air gap of  $\Delta z_{air} = 1.5m$  and a 50 years extreme wave height of  $H_{50,max} = 17.48m$ , the level of the bottom of the transition piece is found at  $17.21m + LAT$  or  $16.15m + MSL$ .

#### C.3.3.2. Tower

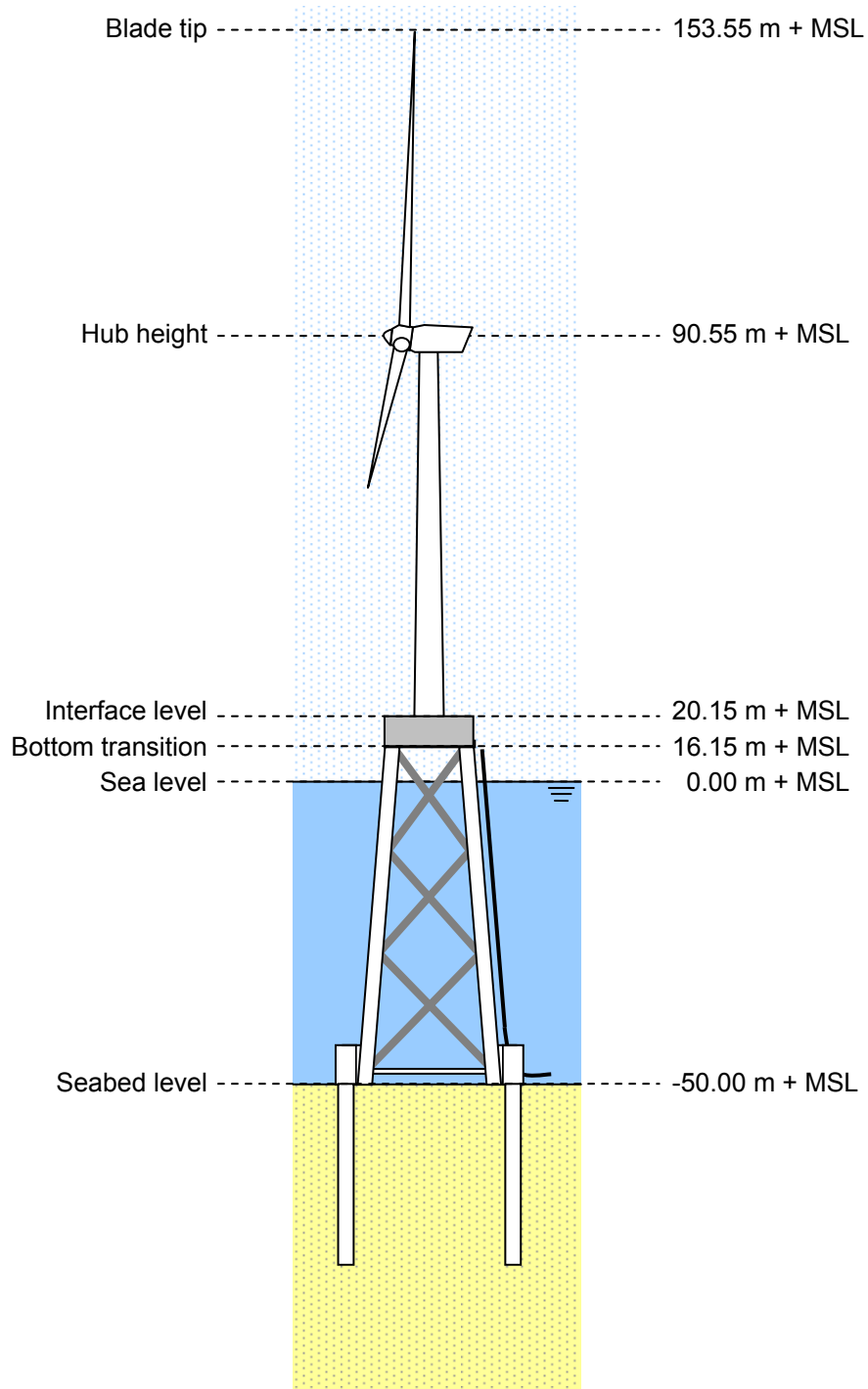
On top of the transition piece the tower is flanged. Table 43 shows the dimensions of the tower used for the load calculations. The tower is split into two sections, each 34m, resulting in a total tower height of 68m. At three stages flanges are placed, namely as link to the transition piece, as connection of the two tower sections and at the tower top as link to the nacelle. They are considered as concentrated masses in the load calculations. The total tower mass is 218 tons, including flange masses, but excluding equipment in the tower.

**Table 43:** Dimensions tower design

Hub height, 90.55 m	Section	Height of section to MSL	Outer diameter at section-top	Outer diameter at section- bottom	Section wall thickness	Flange mass]
	[-]	[m]	[m]	[m]	[mm]	[kg]
6	88.15	83.15	4.000	4.118	30	1000 (at 88.15m)
5	83.15	74.15	4.118	4.329	20	0
4	74.15	64.15	4.329	4.565	22	0
3	64.15	54.15	4.565	4.800	24	0
2	54.15	42.15	4.800	5.082	28	1400 (at 54.15m)
1	42.15	32.15	5.082	5.318	30	0
	32.15	20.15	5.318	5.600	32	1900 (at 20.15m)

The schematic dimensions of the jacket structure are shown in Figure 22.

## Upwind Design Basis – K13 Deep Water Site



**Figure 22:** Schematic dimensions of the reference design for the deep water location

### C.3.3.3. Other secondary structures

Other secondary structures are not pre-defined in detail here. However, structures like the J-tube, which is used to protect and align the cabling from the turbine to land and to cross the scour protection, shall be analysed on the same loads by waves, current and the scour of the monopile.

### C.3.4. Corrosion

Corrosion is only taken into account from the splash zone downwards. Therefore no internal volumes or corrosion in air is studied in detail.

Within the splash zone (+4.84 m MSL to -3.51 m MSL), the following corrosion allowance is used:

- Corrosion rate according to DNV standard [8]: 0.3mm/year
- Applicable corrosion period: 20 years (reference period)
- Applicable corrosion allowance:  $20 \times 0.3\text{mm} = 6.0\text{mm}$

The legs are assumed to be flooded, so both internal and external corrosion allowance is assumed in the splash zone for the legs.

As all members are fully submerged below the splash zone, cathodic protection can be relied on to prevent the structure from corroding in this zone.

For fatigue calculations, half of the corrosion allowance has to be taken into account. For extreme calculations, the full allowance should be applied.

## C.4. Environmental conditions

### C.4.1. Sea water

For the sea water, the following values are assumed (see Table 44):

**Table 44:** Properties of seawater

Description	Value	Unit
Water density	1025 kg/m <sup>3</sup>	kg/m <sup>3</sup>
Water salinity	3.5	%
Water temperature (min/max)	0 / 22	°C

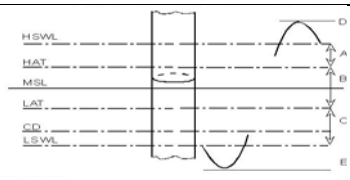
### C.4.2. Water depths

The water depth within the assumed wind park is taken as 50.0 m MSL. The value does not include any scour effect.

### C.4.3. Water levels

Beside wind and wave measurements, there is also measured water level and surge data available for the K13 site. Table 45 shows the water level values for the full duration of 22 years<sup>2</sup>. The 50 year positive storm surge is 2.13 m, while the 50 year negative storm surge is -1.31 m.

**Table 45:** Measured water levels at the location (scheme according to [2])

HSWL	+ 3.29 m MSL		
HAT	+ 1.16 m MSL		
MSL	0 m		
LAT (CD)	- 1.06 m MSL		
LSWL	- 2.37 m MSL		
A	+ 2.13 m MSL		
B	2.22 m		
C	- 1.31 m MSL		
			HSWL highest still water level HAT highest astronomical tide MSL mean sea level LAT lowest astronomical tide CD chart datum (often equal to LAT) LSWL lowest still water level A positive storm surge B tidal range C negative storm surge D maximum crest elevation E minimum trough elevation

Besides the water depths and water level, the splash zone has to be determined for later studies. According to DNV [8], the splash zone is determined as

$$\text{Upper limit: } SZ_U = HAT + 0.6 \cdot \frac{1}{3} \cdot H_{\max}(100 \text{ years}) = +4.84 \text{ m MSL}$$

$$\text{Lower limit: } SZ_L = LAT - 0.4 \cdot \frac{1}{3} \cdot H_{\max}(100 \text{ years}) = -3.51 \text{ m MSL}$$

with  $H_{s,\max}(100 \text{ years}) = 18.41 \text{ m}$ ,  $HAT = 1.16 \text{ m}$  and  $LAT = -1.06 \text{ m}$ .

<sup>2</sup> LAT is taken as the lowest elevation due to tide in the period 1979 – 2001. HAT is taken as the highest elevation due to tide in the period 1979 – 2001.

### C.4.4. Currents

Currents are considered to consist of sub surface currents, mainly driven by tide and wind generated near surface currents. The near surface current is described by the following current profile [1]:

$$U_w(z) = U_w(0)(1 + z/20)$$

The subsurface current is given by a power law description [1]:

$$U_{ss}(z) = U_{ss}(0) \left[ (z + d) / d \right]^{1/7}$$

In these equations  $U_{ss}(0)$  and  $U_w(0)$  are respectively the subsurface and near surface currents measured at the sea surface. The currents are given as a function of the height  $z$  above the sea surface and  $d$  is the water depth.

The values for the currents are taken from the *Noordzeewind OWEZ project*, which is close to the studied location. For normal current loads an average value of 0.6 m/s at surface level is taken and for the extreme case of 1.2 m/s, respectively as shown in Table 46.

**Table 46:** Current velocities according to load situation

Load situation	Current at MSL [m/s]
Normal current	0.6
Extreme current	1.2

For the Normal Current Model (NCM) the tide and storm surge induced sub surface are not included [1].

The Extreme Current Model is defined as the appropriate site-specific combination of sub surface currents, wind generated currents and breaking wave surf induced currents (if any) with recurrence periods of 1 and 50 years [1]. For lack of information the extreme current is assumed to consist of 0.6 m/s near surface and 0.6 m/s subsurface current, both measured at the sea surface.

### C.4.5. Wave parameters

#### C.4.5.1. Scatter diagram

In the offshore industry wave climate data is generally expressed in a 2-dimensional scatter diagram giving the number of occurrences of each combination of significant wave height  $H_s$  and peak spectral period  $T_p$ . For offshore wind turbine design the 2-D scatter diagram must be expanded to include  $V_w$  as a third dimension. To derive the 3-D scatter diagram, the parameters  $H_s$  and  $T_p$  and  $V_w$  will be used.

The wind and wave data is subsequently gathered in bins. The  $V_w$  bins cover 2 m/s, the  $H_s$  bins cover 0.5 m and the  $T_p$  bins span 1.0 s. The binning of the  $V_w$  data is done in such a way that the wind speed bin corresponding to for example  $V_w = 2$  m/s contains all wind speed observations ranging from  $\geq 1$  m/s to  $< 3$  m/s. The bin  $H_s = 2$  m contains all wave height observations between  $\geq 1.75$  m and  $< 2.25$  m, while the bin  $T_p = 2$  s includes all wave period observations from  $\geq 1.5$  s to  $< 2.5$  s. Subsequently, the occurrence of all combinations of  $V_w$ ,  $H_s$  and  $T_p$  is counted. The data is gathered per wind speed bin and entered in a scatter diagram giving the frequency of occurrences of each combination of  $H_s$  and  $T_p$  for that wind speed bin as a percentage value. This is illustrated in Table 47 for  $V_w = 10$  m/s. The wind speeds used here are at hub height.

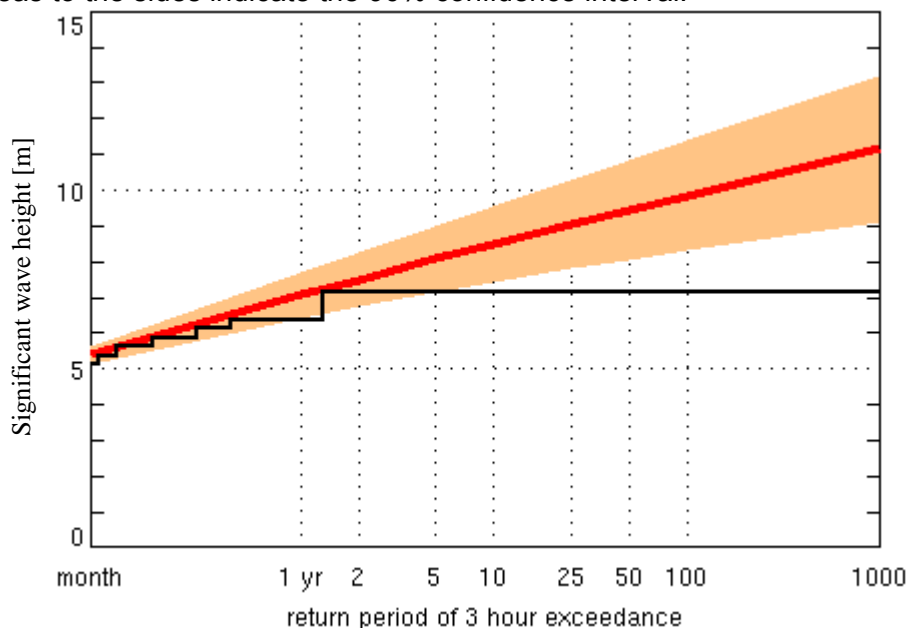
**Table 47:** Part of a 3-D scatter diagram for  $V_w = 10$  m/s

Vw = 9-11 m/s		Tp [s]															
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5			
Hs [m]	9,5														0,00000		
	9														0,00000		
	8,5														0,00000		
	8														0,00000		
	7,5														0,00000		
	7														0,00000		
	6,5														0,00000		
	6														0,00000		
	5,5														0,00000		
	5														0,00000		
	4,5											0,00002			0,00002		
	4									0,00002	0,00002	0,00002	0,00002	0,00002	0,00002	0,00008	
	3,5									0,00006	0,00016	0,00005	0,00002			0,00028	
3									0,00040	0,00037	0,00009				0,00093		
2,5									0,00003	0,00204	0,00191	0,00061	0,00003		0,00462		
2									0,00002	0,00302	0,01006	0,00353	0,00047	0,00002	0,01711		
1,5									0,00089	0,02336	0,01448	0,00114	0,00009	0,00002	0,03999		
1									0,00076	0,02344	0,02666	0,00366	0,00033	0,00005	0,00002	0,05492	
0,5									0,00002	0,00866	0,01416	0,00244	0,00039	0,00012	0,00002	0,00003	0,02584
<0,25									0,00026	0,00026	0,00008						0,00061
		0,00000	0,00000	0,00000	0,00002	0,00969	0,03876	0,05559	0,03069	0,00751	0,00177	0,00028	0,00005	0,00003	0,14440		

A diagram as shown in Table 47 is produced for each wind speed bin. The full set of scatter diagrams make up the 3-D scatter diagram. These are given in Appendix C. Scatter diagrams (V-Hs-Tz).

**C.4.5.2. Extreme values**

The extreme wave data has been taken from hindcast data from the Argoss database [10]. The data is valid for a locations centred on 53°55'N and 03° 05'E. The local water depth is approximately 50 m. The red line in Figure 23 shows the significant wave height as a function of the return period. The shaded orange areas to the sides indicate the 90% confidence interval.



**Figure 23:** Maximum significant wave height

The relation between wave height and return period was found to be:

$$H_{s,3hrs}(T_{return}) = 0.6127 \cdot \ln(x) + 7.042$$

In Table 48 different significant wave height values for different periods of occurrence are given. To obtain the maximum wave height the following relationship is used:

$$H_{max} = 1.86H_s$$

The factor 1.86 is chosen for the given location. However, as the water depth is relatively large, this factor might be changed to a higher value (close to 2). The wave period associated with the maximum wave height should be within the limits indicated below [1]:

$$11.1\sqrt{H_s / g} \leq T \leq 14.3\sqrt{H_s / g}$$

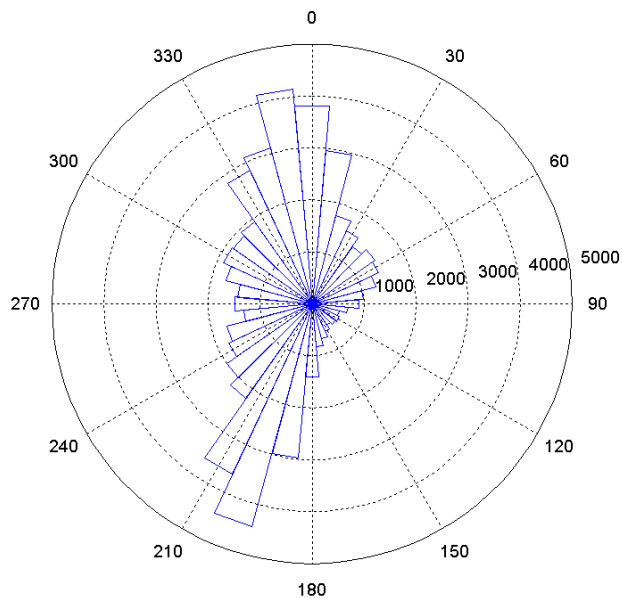
Assuming the lower limit to give the most severe loading conditions, the wave periods associated with the maximum wave heights are listed in the rightmost column of Table 48.

**Table 48:** Extreme wave heights as a function the return period

$T_{return}$ [yr]	$H_{s,max}$ [m]	$H_{max}$ [m]	$T(H_{max})$ [s]
1	7.1	13.21	9.44
5	8.1	15.07	10.09
10	8.5	15.81	10.33
50	9.4	17.48	10.87
100	9.9	18.41	11.15

#### C.4.5.3. Wave directions

The 3-D scatter diagram does not take directionality into account. Therefore a different diagram is produced giving the spreading of wave directions per wave height bin. First,  $\theta_{wave,full}$  is gathered in bins of 30°. Subsequently,  $H_s$  and  $\theta_{wave,full}$  are sorted to obtain the number of occurrences of each wave direction per wave height bin. Figure 24 shows the wave rose for all measured values. In this figure 0° corresponds with north. It can be seen that the dominant wave directions between north north west (NNW) and west south west (WSW). The probability of occurrence is given as total value on the radial axes. The full series of wave roses sorted for each wave height are given in Appendix B. Wave roses.



**Figure 24:** Wave rose for the measurement location

#### C.4.5.4. Breaking waves

The effect of breaking waves will be neglected. Breaking waves will not occur as the wave height is significantly less than the breaking limit.

## C.4.6. Wind parameters

### C.4.6.1. Wind shear profile

In Figure 25, the wind speed distribution of the K13 site at 90.55 m height can be seen. The measured wind data was first translated from the reference height of 10 m to the hub height at 90.55 m + MSL. A conversion factor of 0.9 is used to obtain the 10-minute wind speed from the 1-hour average wind speed. The wind speed at hub height can be found with [8]:

$$V(z) = V(z_{ref}) \frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_{ref}}{z_0}\right)}$$

with:

$V(z)$  = wind speed at elevation  $z$

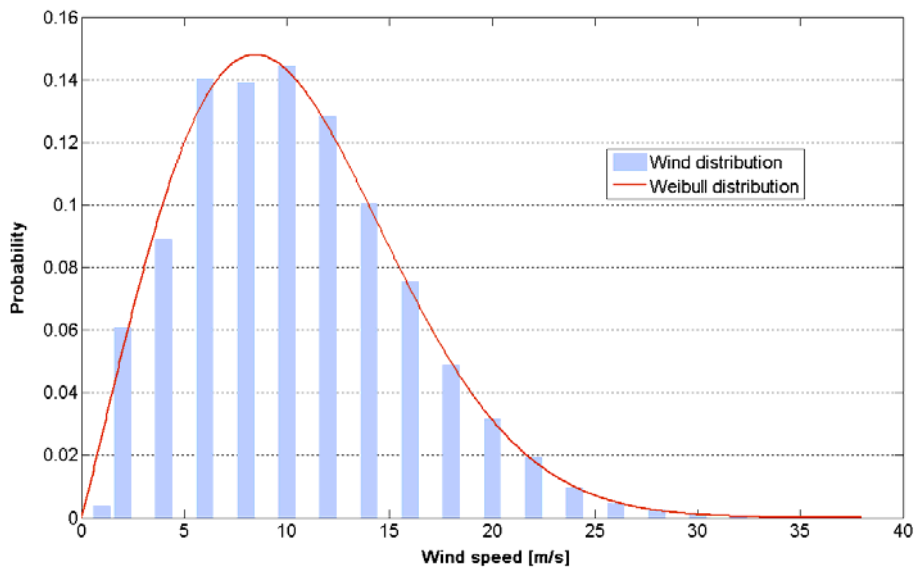
$V(z_{ref})$  = wind speed at elevation  $z_{ref}$

$z_{ref}$  = elevation for which wind speed is given

$z_0$  = roughness length, 0.002 m for offshore conditions

### C.4.6.2. Wind distributions

The relevant Weibull parameters are  $A = 11.75$  m/s and  $k = 2.04$ , which leads to an annual mean wind speed of 10.05 m/s.

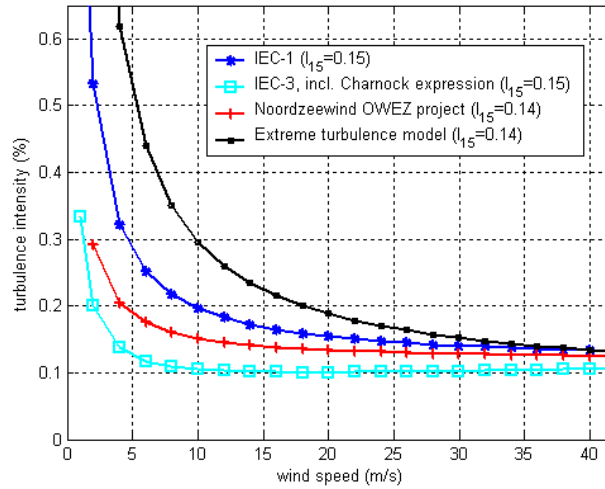


**Figure 25:** Wind speed distribution for the measurement location

### C.4.6.3. Turbulence intensity

For the turbulence intensity, different distributions were compared. As shown in Figure 26, the standard curves for IEC-1 and IEC-3 are shown for a reference turbulence intensity of 0.15. Besides, a distribution based on the assumptions of the *Noordzeewind OWEZ project* is shown [9], where again an IEC-3 distribution was assumed, but with a different reference intensity and taking wake effects into account. As the IEC-1 curve is too conservative, but the IEC-3 one probably optimistic, the distribution from the *Noordzeewind OWEZ project* will be chosen as a good compromise, also for the consideration of wake effects. The distribution can be described by the following relation (with  $I_{15} = 0.14$  and  $a = 5$ )

$$I(U) = \frac{(15 + aU)}{(1 + a)U} \cdot I_{15}$$



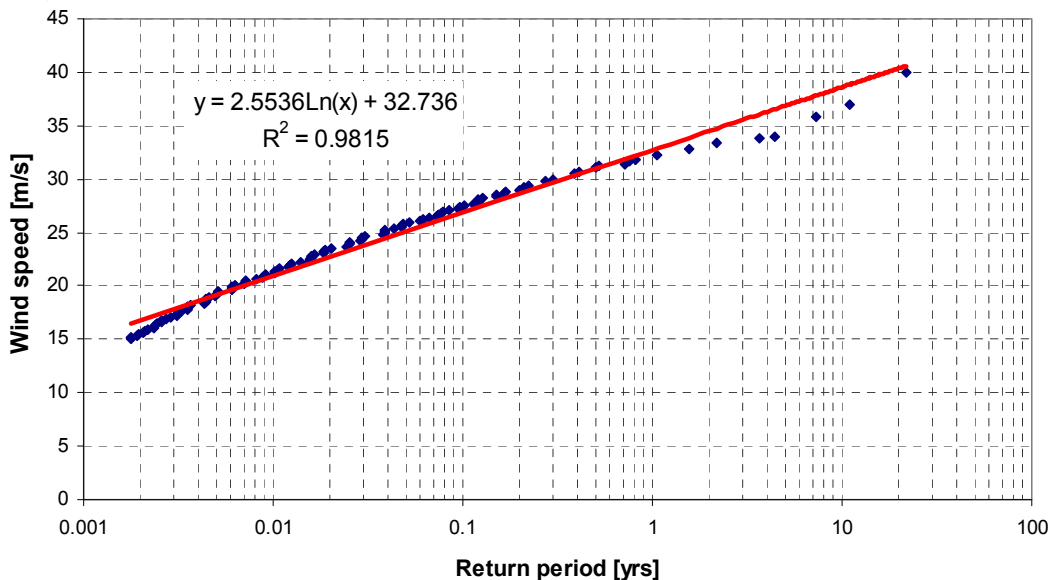
**Figure 26:** Turbulence intensity according to IEC

For later extreme load calculations, a further extreme turbulence distribution has to be defined. Based on the normal turbulence model described in the expression above (*Noordzeewind OWEZ project*), an extreme turbulence distribution is calculated according to the IEC-3 standard for class IC. The curvature is also shown in Figure 26. All turbulence values are again listed for each wind speed bin in C.6. Appendix.

#### C.4.6.4. Extreme values

From the measured wind data the extreme wind speeds can be determined. The extreme wind speed is determined as the maximum wind speed that occurs with a certain return period (as seen in Figure 27). The resulting equation can be found as follows:

$$V_{hub,10min}(T_{return}) = 2.5536 \cdot \ln(x) + 32.736$$



**Figure 27:** Determining the maximum wind speed

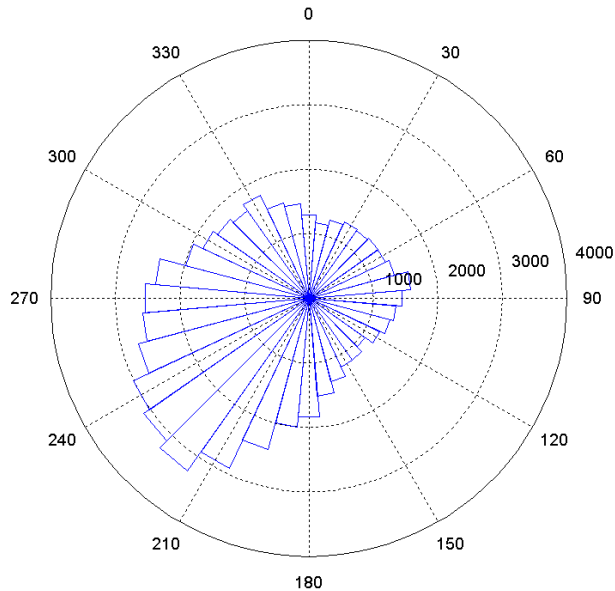
Table 49 shows the maximum wind speed at hub height as a function of the return period. The values averaged 10-min wind speeds, where the original 3-hrs stationary situations were converted with a factor 0.9 according to IEC.

**Table 49:** Extreme wind speeds as a function of the return period

$T_{return}$ [yr]	$V_w$ (10min) [m/s]
1	32.74
5	36.85
10	38.62
50	42.73
100	44.50

**C.4.6.5. Wind directions**

The 3-D scatter diagram does not take directionality into account. Therefore a different diagram is produced giving the spreading of wind directions per wind speed bin. First,  $\theta_{wind,full}$  is gathered in bins of 2m/s. Subsequently,  $V_w$  and  $\theta_{wind,full}$  are sorted to obtain the number of occurrences of each wind direction per wind speed bin. Figure 28 shows the wind rose for all measured values. In this figure 0° corresponds with north. It can be seen that the dominant wind directions comes from west south west (WSW), which agrees with the main wave directions. However, especially in cases of low wind speed the wind tends to come from eastern directions as well. The full series of wind roses sorted for each wind speed is given in C.6. Appendix.



**Figure 28:** Wind rose for the measurement location

**C.4.7. Wind-wave-directionality**

As for some support structure types and environmental conditions the effect of wind- and wave-misalignment can be important, in the following the directional scatter of the measured wind and wave directions is shown. Here the wind speed values correspond to 10-min average values, and the wave heights to 3hrs respectively. The binning is done corresponding to the former described wind and wave scatters. The binning of the  $V_w$  data is done in such a way that the wind speed bin corresponding to for example  $V_w = 2$  m/s contains all wind speed observations ranging from  $\geq 1$  m/s to  $< 3$  m/s. The directional bins at NNE ( $30^\circ$ ) contain all observations between  $\geq 15^\circ$  and  $< 45^\circ$ .

**Table 50: Directional scatter diagram for all wind speeds**

All windspeeds		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,03839	0,00504	0,00093	0,00028	0,00011	0,00025	0,00058	0,00089	0,00070	0,00095	0,00188	0,01143	0,06143
030°	NNE	0,02819	0,01846	0,00422	0,00081	0,00028	0,00044	0,00065	0,00073	0,00054	0,00042	0,00103	0,00408	0,05984
060°	ENE	0,01299	0,02210	0,01739	0,00319	0,00081	0,00065	0,00067	0,00067	0,00050	0,00044	0,00073	0,00201	0,06214
090°	E	0,00779	0,01036	0,02462	0,01454	0,00359	0,00160	0,00115	0,00079	0,00048	0,00045	0,00068	0,00210	0,06818
120°	ESE	0,00571	0,00510	0,00821	0,01199	0,01052	0,00554	0,00314	0,00138	0,00087	0,00050	0,00079	0,00193	0,05569
150°	SSE	0,00534	0,00336	0,00322	0,00414	0,00607	0,01034	0,01384	0,00443	0,00110	0,00107	0,00165	0,00249	0,05706
180°	S	0,00675	0,00263	0,00198	0,00210	0,00213	0,00470	0,02792	0,02117	0,00436	0,00252	0,00275	0,00453	0,08353
210°	SSW	0,00639	0,00229	0,00151	0,00098	0,00103	0,00208	0,01790	0,06882	0,01322	0,00633	0,00583	0,00762	0,13401
240°	WSW	0,00652	0,00196	0,00095	0,00070	0,00058	0,00109	0,00621	0,04693	0,03393	0,01756	0,01120	0,01034	0,13796
270°	W	0,00778	0,00137	0,00081	0,00022	0,00033	0,00044	0,00218	0,01352	0,01989	0,02697	0,02750	0,01618	0,11718
300°	WNW	0,01224	0,00148	0,00042	0,00014	0,00023	0,00030	0,00107	0,00445	0,00554	0,00885	0,02083	0,03029	0,08583
330°	NNW	0,02870	0,00180	0,00047	0,00019	0,00028	0,00025	0,00107	0,00182	0,00143	0,00216	0,00625	0,03274	0,07717
		0,16678	0,07596	0,06472	0,03928	0,02595	0,02767	0,07639	0,16560	0,08257	0,06822	0,08113	0,12573	1,00000

Percentage of time [%]

90° + from wind direction

90° - from wind direction

A diagram as shown in Table 50 is produced for each wind speed bin, as shown as an example for  $V=10$ m/s in Table 51. The full set of those directional scatter diagrams are given in C.6. Appendix.

**Table 51: Part of the 3-D directional scatter diagram for  $V = 10$  m/s**

Vw 9-11 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00638	0,00084	0,00014	0,00003	0,00002		0,00006	0,00003	0,00009	0,00014	0,00025	0,00229	0,01027
030°	NNE	0,00453	0,00325	0,00075	0,00012	0,00003	0,00006					0,00011	0,00054	0,00940
060°	ENE	0,00149	0,00392	0,00247	0,00037	0,00019	0,00005	0,00008	0,00002	0,00006	0,00003	0,00009	0,00022	0,00899
090°	E	0,00058	0,00185	0,00383	0,00268	0,00067	0,00014	0,00005	0,00003	0,00005	0,00003	0,00006	0,00014	0,01010
120°	ESE	0,00044	0,00078	0,00159	0,00190	0,00190	0,00082	0,00047	0,00011	0,00009	0,00003	0,00003	0,00012	0,00828
150°	SSE	0,00026	0,00023	0,00044	0,00072	0,00109	0,00180	0,00241	0,00036	0,00017	0,00006	0,00022	0,00012	0,00789
180°	S	0,00051	0,00022	0,00020	0,00028	0,00067	0,00096	0,00493	0,00331	0,00051	0,00025	0,00036	0,00053	0,01274
210°	SSW	0,00039	0,00019	0,00017	0,00016	0,00025	0,00031	0,00282	0,00711	0,00246	0,00124	0,00089	0,00112	0,01709
240°	WSW	0,00064	0,00014	0,00012	0,00011	0,00016	0,00011	0,00109	0,00597	0,00462	0,00278	0,00185	0,00173	0,01932
270°	W	0,00065	0,00009	0,00008	0,00003	0,00005	0,00005	0,00040	0,00204	0,00243	0,00303	0,00392	0,00313	0,01590
300°	WNW	0,00173	0,00008		0,00002	0,00002	0,00003	0,00009	0,00070	0,00086	0,00117	0,00314	0,00467	0,01249
330°	NNW	0,00467	0,00009	0,00005	0,00002	0,00002	0,00003	0,00020	0,00026	0,00026	0,00036	0,00096	0,00502	0,01195
		0,02226	0,01168	0,00983	0,00642	0,00504	0,00437	0,01260	0,01994	0,01160	0,00913	0,01188	0,01963	0,14440

Percentage of time [%]

90° + from wind direction

90° - from wind direction

As for some simulations the full set of wind and wave directionalities is too detailed, a reduced form can be determinate, where the opposite direction of wind and waves are merged (see Table 52)

**Table 52: Reduced directional scatter V = 10 m/s**

Vw 9-11 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01188	0,00440	0,00095	0,00070	0,00129	0,00378	0,02301
030°	NNE	0,00773	0,01055	0,00338	0,00152	0,00128	0,00204	0,02649
060°	ENE	0,00330	0,01005	0,00728	0,00330	0,00229	0,00210	0,02831
090°	E	0,00168	0,00401	0,00638	0,00577	0,00470	0,00345	0,02599
120°	ESE	0,00272	0,00166	0,00254	0,00311	0,00509	0,00565	0,02077
150°	SSE	0,00754	0,00095	0,00092	0,00115	0,00229	0,00698	0,01983
		0,03486	0,03162	0,02143	0,01556	0,01692	0,02400	0,14440

### C.4.8. Further meteorological - oceanographical parameters

#### C.4.8.1. Temperature

The temperatures of water and air are illustrated in Table 53 according to [5]. For later fatigue calculations the mean values must be applied.

**Table 53: Air and water temperatures**

Water temperature at the surface [°C]		Air temperature [°C]	
Mean	10	Mean	15.0
Standard deviation	5	Extremes	-20 to +50
Maximum	22		
Minimum	0		
Yearly amplitude	7		

#### C.4.8.2. Ice

It is very unlikely that sea ice occurs. Therefore it will not be taken into account. However, icing at the structure is possible and will be dimensioned according to [2]. This leads to the following values:

- Atmospheric ice formation with a thickness of 30mm
- Ice formation due to sea water spray with a thickness of 100mm from MSL to HSWL
- Ice formation due to sea water spray from HSWL up to 60m above MSL with a thickness decreasing linearly to 30mm
- Density of ice of 900 kg/m<sup>3</sup>

#### C.4.8.3. Marine growth

For design purposes, marine growth has to be assumed. The density has to be taken as 1100 kg/m<sup>3</sup>. Table 54 shows the thickness as determined according to DNV standard [8].

**Table 54: Assumptions for marine growths**

Level [m]	Thickness [mm]
MSL -2 to -40	100

### C.4.9. Soil conditions

#### C.4.9.1. Soil profiles

Two different soil profile configurations will be assumed in the wind farm areal – namely a soft and hard one. The soil parameters are given in terms of the effective soil unit weight  $\gamma'$ , the angle of internal

friction  $\phi$  and the undrained shear strength  $c_u$ . The soft profile is defined as listed in Table 55. The hard profile is given in Table 56.

**Table 55:** Soil conditions for the soft profile

Depths [m]	$\gamma'$ [N/m <sup>3</sup> ]	$\phi$ [°]	$C_u$ [Pa]
0-3	10000	36	-
3-5	10000	33	-
5-7	10000	26	60000
7-10	10000	37	-
10-15	10000	35	-
15-50	10000	37.5	-

**Table 56:** Soil conditions for the hard profile

Depths [m]	$\gamma'$ [N/m <sup>3</sup> ]	$\phi$ [°]	$C_u$ [Pa]
0-3	10000	38	-
3-5	10000	35	-
5-7	10000	38	-
7-10	10000	38	-
10-15	10000	42	-
15-50	10000	42.5	-

#### C.4.9.2. Scour

If no scour protection is planned, an additional depth in relation to scour effects has to be assumed in accordance to the outer diameter of the water piercing members,  $D$ , to be  $(2.5 \cdot D)$  according to [2]. However, in this study scour protection is assumed, which implies that no water depth variations due to scour are taken into account.

## C.5. Structural load assumptions

### C.5.1. Modelling of the structure

For later load calculations, both fatigue and ultimate load cases, partial safety factors have to be added according the type of case. Table 57 summarizes these values according to [1].

**Table 57:** Partial safety factors for loads according to [1]

Unfavourable loads			Favourable loads
Type of design situation			All design situations
Normal (N)	Abnormal (A)	Transport and erection (T)	
1.35	1.1	1.5	0.9

### C.5.2. Load assumptions

#### C.5.2.1. Design load cases

Load calculations will be performed on the basis of the Design Load Cases (DLCs) as formulated in the IEC [1]. From the recommended load cases a set of governing load cases is collected in order to reduce computation efforts. These load cases are listed in Table 58. A full description of the design load cases is given in IEC-3 [1].

**Table 58:** Design load cases used for the reference design

DLC	Description	Type
DLC 1.2	Power production	FLS
DLC 1.6	Power production in 50 year sea state	ULS
DLC 2.2	Safety system fault	ULS
DLC 2.3	Generator cut-out	ULS
DLC 6.1a	Idling in storm	ULS
DLC 6.2a	Idling in storm during grid loss	ULS
DLC 6.4	Idling	FLS
DLC 7.2	Idling after fault	FLS

#### C.5.2.2. Fatigue load cases

For fatigue considerations, the different load setups from the scatter diagram have to be taken. The reduced (lumped) scatter is shown in Table 59.

The lumping was done damage equivalent based on the method described in Kühn [7]. For the fatigue load case 1.2, a Pierson-Moskowitz spectrum is applied (corresponding to fully developed waves) with a peakness factor of 1.0. For all other load cases, a peakness factor of 3.3 is applied. The turbulence intensity is based on the assumptions of section C.4.6.3. Turbulence intensity.

**Table 59:** Lumped scatter diagram of the given offshore site (sorted wind bins)

V [ms]	TI[%]		Hs [m]	Tp [m]	Peakness [-]		f [%]	occ./year [hrs]
	normal	extreme			Fatigue	Extreme		
2	29,2	99,3	1,07	6,03	1	3,3	0,06071	531,8
4	20,4	53,1	1,1	5,88	1	3,3	0,08911	780,6
6	17,5	37,1	1,18	5,76	1	3,3	0,14048	1230,6
8	16	30	1,31	5,67	1	3,3	0,13923	1219,7
10	15,2	25,4	1,48	5,74	1	3,3	0,14440	1264,9
12	14,6	22,3	1,7	5,88	1	3,3	0,12806	1121,8
14	14,2	20,1	1,91	6,07	1	3,3	0,10061	881,3
16	13,9	18,5	2,19	6,37	1	3,3	0,07554	661,7
18	13,6	17,2	2,47	6,71	1	3,3	0,04878	427,3
20	13,4	16,1	2,76	6,99	1	3,3	0,03151	276,1
22	13,3	15,3	3,09	7,4	1	3,3	0,01924	168,6
24	13,1	14,6	3,42	7,8	1	3,3	0,00977	85,6
26	12	14	3,76	8,14	1	3,3	0,00474	41,6
28	11,9	13,5	4,17	8,49	1	3,3	0,00243	21,3
30	11,8	13,1	4,46	8,86	1	3,3	0,00093	8,2
32	11,8	12,7	4,79	9,12	1	3,3	0,00053	4,6
34-42	11,7	12,3	4,9	9,43	1	3,3	0,00019	1,6

**Table 60:** Lumped scatter diagram of the given offshore site (sorted wind bins)

V [ms]	TI[%]		Hs [m]	Tp [m]	Peakness [-]		f [%]	occ./year [hrs]
	normal	extreme			Fatigue	Extreme		
2	29,2	99,3	1,07	6,03	1	3,3	0,05330	466,9
4	20,4	53,1	1,1	5,88	1	3,3	0,10076	882,6
6	17,5	37,1	1,18	5,76	1	3,3	0,13327	1167,5
8	16	30	1,31	5,67	1	3,3	0,14693	1287,1
10	15,2	25,4	1,48	5,74	1	3,3	0,14258	1249,0
12	14,6	22,3	1,7	5,88	1	3,3	0,12476	1092,9
14	14,2	20,1	1,91	6,07	1	3,3	0,09969	873,3
16	13,9	18,5	2,19	6,37	1	3,3	0,07329	642,0
18	13,6	17,2	2,47	6,71	1	3,3	0,04981	436,4
20	13,4	16,1	2,76	6,99	1	3,3	0,03139	275,0
22	13,3	15,3	3,09	7,4	1	3,3	0,01839	161,1
24	13,1	14,6	3,42	7,8	1	3,3	0,01003	87,8
26	12	14	3,76	8,14	1	3,3	0,00509	44,6
28	11,9	13,5	4,17	8,49	1	3,3	0,00241	21,2
30	11,8	13,1	4,46	8,86	1	3,3	0,00107	9,4
32	11,8	12,7	4,79	9,12	1	3,3	0,00044	3,9
34-42	11,7	12,3	4,9	9,43	1	3,3	0,00026	2,3

**C.5.2.3. Extreme load cases**

For the different extreme design load cases, different values for the wind speed, wave height and wave period have to be determined. Table 61 gives an overview. For the extreme load cases a JONSWAP spectrum is used, with a peak enhancement factor of 3.3.

**Table 61:** Extreme wave conditions according to [1]

Parameter	Value	Unit
$H_{s,50}$	9.40	m
$H_{max,50}$	17.48	m
$H_{red,50}$	10.34	m
$H_{s,1}$	7.10	m
$H_{max,1}$	13.21	m
$H_{red,1}$	7.81	m
$V_{ref} = V_{50}$	42.73	m/s
$V_1$	32.74	m/s

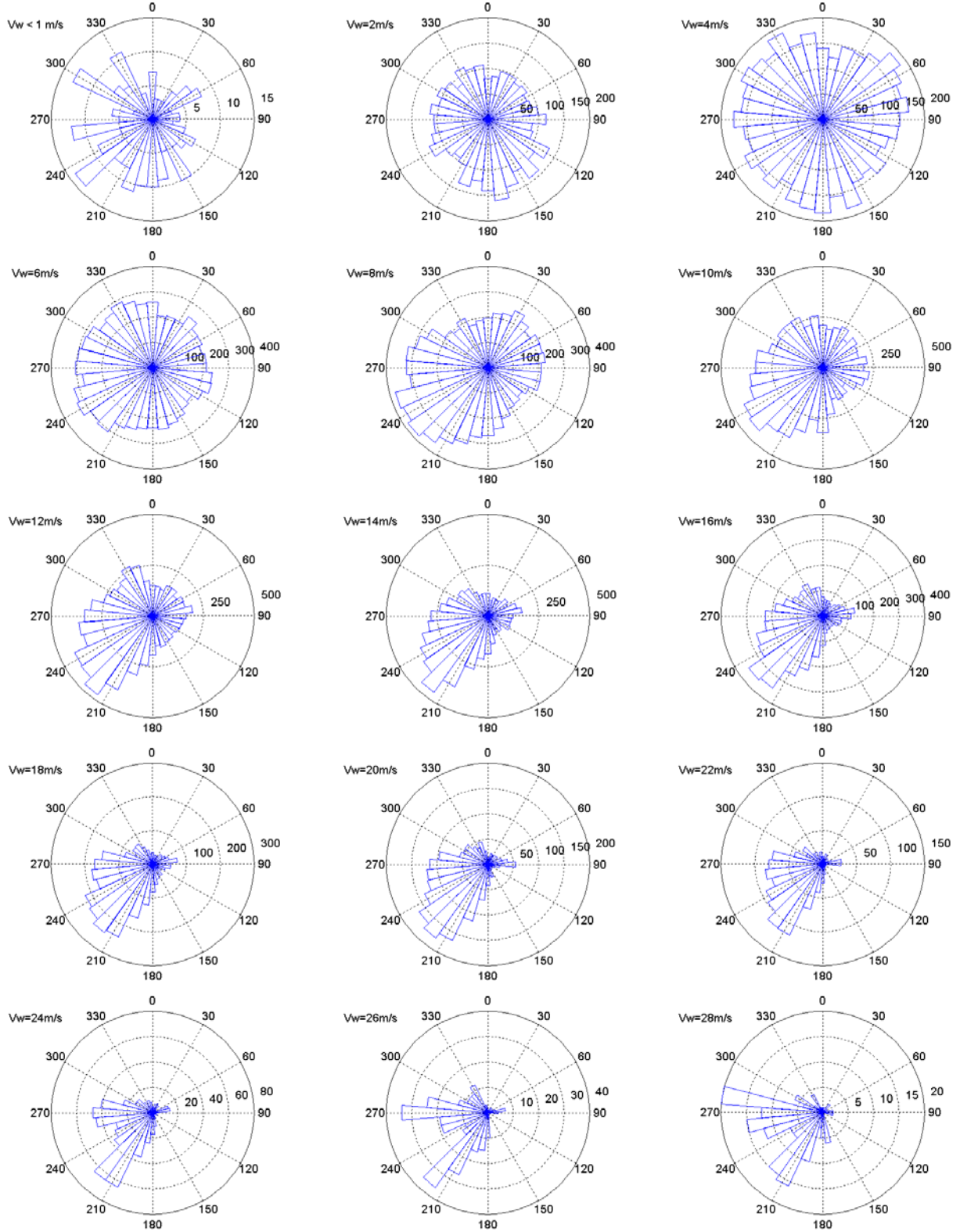
The periods combined with the above mentioned extreme wave heights have to be calculated following the equation [1]:

$$11.1\sqrt{H_s(V)/g} \leq T \leq 14.3\sqrt{H_s(V)/g}$$

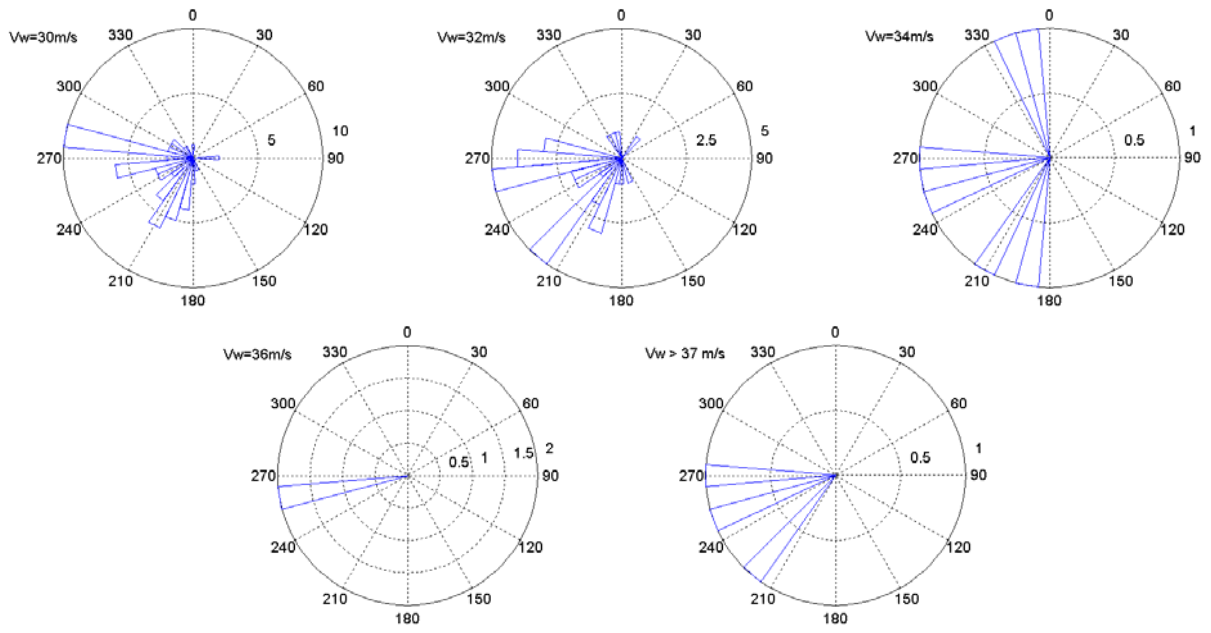


## C.6. Appendix

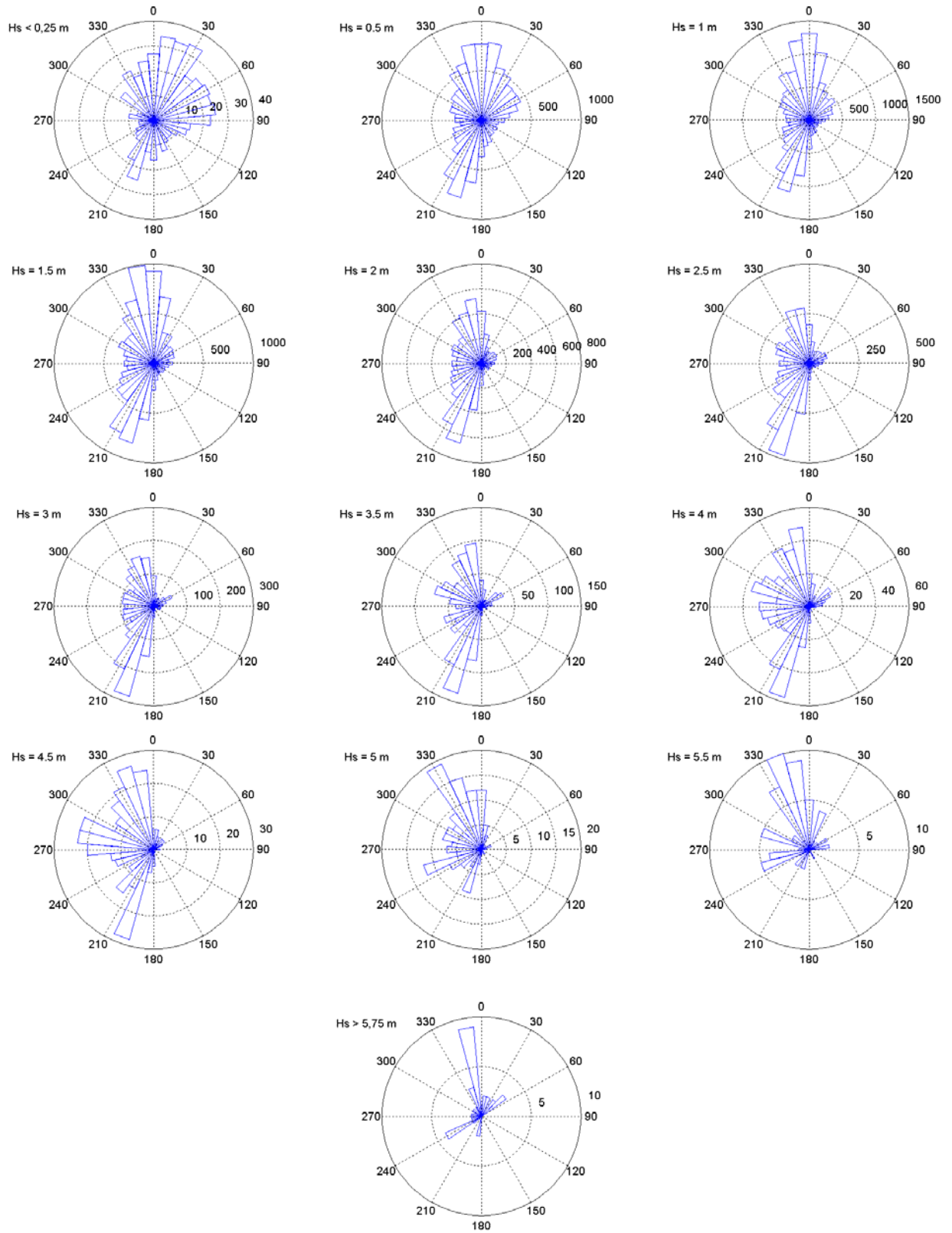
### A. Wind roses



# Upwind Design Basis – K13 Deep Water Site



**B. Wave roses**



Upwind Design Basis – K13 Deep Water Site

C. Scatter diagrams (V-Hs-Tz)

all windspeeds		Tp [s]															
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5			
Hs [m]	9,5														0,00000		
	9														0,00000		
	8,5														0,00000		
	8														0,00000		
	7,5														0,00000		
	7													0,00003	0,00003		
	6,5											0,00002	0,00009	0,00005	0,00016		
	6											0,00019	0,00014	0,00005	0,00037		
	5,5										0,00008	0,00061	0,00033	0,00005	0,00106		
	5										0,00084	0,00138	0,00031	0,00006	0,00260		
	4,5										0,00011	0,00342	0,00132	0,00014	0,00002	0,00501	
	4								0,00003	0,00240	0,00663	0,00087	0,00019	0,00002	0,01013		
	3,5								0,00058	0,01269	0,00709	0,00078	0,00008	0,00002	0,02123		
	3								0,00002	0,01058	0,02576	0,00478	0,00045	0,00003	0,00006	0,04167	
	2,5								0,00098	0,05074	0,02189	0,00263	0,00050	0,00011	0,00002	0,07686	
	2								0,00006	0,03047	0,07924	0,01285	0,00255	0,00028	0,00002	0,00000	0,12547
1,5								0,00649	0,11598	0,06449	0,01419	0,00252	0,00014	0,00002	0,00003	0,20385	
1								0,00313	0,08888	0,12814	0,04869	0,00978	0,00143	0,00011	0,00003	0,00003	0,28022
0,5								0,00008	0,04740	0,10613	0,05166	0,01355	0,00241	0,00082	0,00017	0,00003	0,22225
<0,25								0,00224	0,00560	0,00120	0,00006						0,00910
		0,00000	0,00000	0,00000	0,00008	0,05276	0,20716	0,32844	0,26795	0,10207	0,03279	0,00681	0,00151	0,00042	1,00000		

Vw < 1 m/s		Tp [s]															
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5			
Hs [m]	9,5														0,00000		
	9														0,00000		
	8,5														0,00000		
	8														0,00000		
	7,5														0,00000		
	7														0,00000		
	6,5														0,00000		
	6														0,00000		
	5,5														0,00000		
	5														0,00000		
	4,5														0,00000		
	4														0,00000		
	3,5													0,00002	0,00002		
	3														0,00000		
	2,5											0,00002			0,00002		
	2											0,00003	0,00002		0,00005		
1,5											0,00003	0,00022	0,00016	0,00005	0,00003	0,00048	
1											0,00003	0,00017	0,00056	0,00030	0,00106		
0,5											0,00022	0,00067	0,00079	0,00028	0,00003	0,00002	0,00201
<0,25											0,00011						0,00011
		0,00000	0,00000	0,00000	0,00000	0,00022	0,00081	0,00100	0,00106	0,00048	0,00011	0,00005	0,00000	0,00002	0,00373		

Vw = 1-3 m/s		Tp [s]																
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5				
Hs [m]	9,5														0,00000			
	9														0,00000			
	8,5														0,00000			
	8														0,00000			
	7,5														0,00000			
	7														0,00000			
	6,5														0,00000			
	6														0,00000			
	5,5														0,00000			
	5														0,00000			
	4,5														0,00000			
	4														0,00000			
	3,5														0,00002			
	3														0,00002			
	2,5														0,00005			
	2														0,00003	0,00002		
1,5														0,00003	0,00003	0,00005	0,00003	
1														0,00003	0,00030	0,00006	0,00090	
0,5														0,00005	0,00048	0,00207	0,00583	
<0,25														0,00002	0,00096	0,00618	0,00913	0,01944
		0,00000	0,00000	0,00000	0,00000	0,00324	0,01472	0,01899	0,01549	0,00639	0,00149	0,00031	0,00008	0,00000	0,06071			

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Vw = 3-5 m/s		Tp [s]															
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5			
Hs [m]	9,5														0,00000		
	9														0,00000		
	8,5														0,00000		
	8														0,00000		
	7,5														0,00000		
	7														0,00000		
	6,5														0,00000		
	6														0,00000		
	5,5														0,00000		
	5														0,00000		
	4,5														0,00000		
	4														0,00000		
	3,5										0,00002				0,00002		
	3									0,00003					0,00003		
	2,5									0,00003	0,00006	0,00008	0,00006	0,00002		0,00002	
	2									0,00009	0,00037	0,00075	0,00020	0,00009		0,00009	
1,5									0,00005	0,00138	0,00460	0,00339	0,00075	0,00005	0,01022		
1									0,00011	0,00330	0,01193	0,01237	0,00282	0,00048	0,00003	0,00002	0,03105
0,5									0,00530	0,01846	0,01451	0,00418	0,00073	0,00023	0,00002		0,04345
<0,25									0,00047	0,00165	0,00039	0,00003					0,00254
		0,00000	0,00000	0,00000	0,00000	0,00588	0,02346	0,02831	0,02159	0,00778	0,00179	0,00025	0,00005	0,00002	0,08911		

Vw = 5-7 m/s		Tp [s]																
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5				
Hs [m]	9,5														0,00000			
	9														0,00000			
	8,5														0,00000			
	8														0,00000			
	7,5														0,00000			
	7														0,00000			
	6,5														0,00000			
	6														0,00000			
	5,5														0,00000			
	5														0,00000			
	4,5														0,00000			
	4														0,00000			
	3,5											0,00002			0,00002			
	3										0,00002				0,00003			
	2,5										0,00002	0,00020	0,00023	0,00025	0,00014	0,00003	0,00002	0,00089
	2										0,00037	0,00194	0,00182	0,00078	0,00008	0,00002		0,00501
1,5										0,00031	0,00548	0,01073	0,00378	0,00078			0,02108	
1										0,00034	0,00985	0,02616	0,01422	0,00249	0,00031	0,00003	0,00002	0,05342
0,5										0,01112	0,02805	0,01402	0,00324	0,00061	0,00023			0,05726
<0,25										0,00062	0,00165	0,00039						0,00266
		0,00000	0,00000	0,00000	0,00000	0,01209	0,03985	0,04643	0,03033	0,00896	0,00243	0,00028	0,00005	0,00006	0,14048			

Vw = 7-9 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6														0,00000
	5,5														0,00000
	5														0,00000
	4,5														0,00000
	4														0,00000
	3,5														0,00000
	3														0,00000
	2,5														0,00000
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00002	0,01142	0,04114	0,05046	0,02640	0,00751	0,00191	0,00028	0,00005	0,00005	0,13923

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Vw = 9-11 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5														0,00000	
	9														0,00000	
	8,5														0,00000	
	8														0,00000	
	7,5														0,00000	
	7														0,00000	
	6,5														0,00000	
	6														0,00000	
	5,5														0,00000	
	5														0,00000	
	4,5											0,00002			0,00002	
	4									0,00002	0,00002	0,00002	0,00002	0,00002	0,00002	0,00008
	3,5									0,00006	0,00016	0,00005	0,00002			0,00028
	3								0,00006	0,00040	0,00037	0,00009				0,00093
	2,5							0,00003	0,00204	0,00191	0,00061	0,00003				0,00462
2					0,00002	0,00302	0,01006	0,00353	0,00047	0,00002					0,01711	
1,5				0,00089	0,02336	0,01448	0,00114	0,00009	0,00002	0,00002	0,00002				0,03999	
1			0,00076	0,02344	0,02666	0,00366	0,00033	0,00005	0,00002				0,00002		0,05492	
0,5		0,00002	0,00866	0,01416	0,00244	0,00039	0,00012	0,00002	0,00003						0,02584	
<-0,25			0,00026	0,00026	0,00008										0,00061	
		0,00000	0,00000	0,00000	0,00002	0,00969	0,03876	0,05559	0,03069	0,00751	0,00177	0,00028	0,00005	0,00003	0,14440	

Vw = 11-13 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6														0,00000
	5,5														0,00000
	5														0,00000
	4,5										0,00002				0,00003
	4										0,00006	0,00005	0,00005		0,00016
	3,5								0,00002	0,00011	0,00034	0,00011	0,00005		0,00062
	3								0,00033	0,00132	0,00100	0,00012			0,00277
	2,5						0,00009	0,00411	0,00412	0,00076	0,00006				0,00915
2						0,00482	0,01615	0,00241	0,00008					0,02346	
1,5					0,00166	0,02847	0,01048	0,00023	0,00002					0,04086	
1			0,00081	0,01885	0,01689	0,00110	0,00008	0,00005						0,03778	
0,5		0,00002	0,00498	0,00683	0,00104	0,00014	0,00005							0,01305	
<-0,25			0,00006	0,00009	0,00003									0,00019	
		0,00000	0,00000	0,00000	0,00002	0,00585	0,02744	0,05135	0,03232	0,00832	0,00232	0,00034	0,00009	0,00002	0,12806

Vw = 13-15 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6														0,00000
	5,5														0,00002
	5										0,00002	0,00002			0,00003
	4,5										0,00002	0,00003	0,00000		0,00005
	4										0,00003	0,00022	0,00012	0,00006	0,00044
	3,5									0,00002	0,00044	0,00064	0,00025	0,00002	0,00135
	3									0,00090	0,00260	0,00093	0,00008		0,00451
	2,5							0,00006	0,00762	0,00474	0,00025	0,00002			0,01269
2						0,00002	0,00670	0,01839	0,00109					0,02619	
1,5					0,00143	0,02511	0,00535							0,03189	
1			0,00028	0,00929	0,00792	0,00025	0,00002							0,01775	
0,5		0,00002	0,00240	0,00292	0,00026									0,00560	
<-0,25			0,00005	0,00003										0,00008	
		0,00000	0,00000	0,00000	0,00002	0,00272	0,01369	0,04005	0,03253	0,00891	0,00205	0,00053	0,00009	0,00002	0,10061

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		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5															0,00000
	5											0,00006				0,00006
	4,5										0,00009	0,00012	0,00002			0,00023
	4									0,00005	0,00050	0,00017	0,00005			0,00076
	3,5								0,00002	0,00089	0,00106	0,00028				0,00224
	3							0,00002	0,00145	0,00437	0,00134					0,00717
	2,5							0,00022	0,01204	0,00495	0,00009					0,01730
	2						0,00002	0,00775	0,01621	0,00037	0,00002					0,02436
1,5						0,00079	0,01296	0,00236							0,01611	
1				0,00012	0,00316	0,00199	0,00003								0,00530	
0,5			0,00002	0,00101	0,00090	0,00006									0,00199	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00002	0,00114	0,00487	0,02299	0,03211	0,01062	0,00310	0,00064	0,00006	0,00000	0,07554	

		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5														0,00000	
	9														0,00000	
	8,5														0,00000	
	8														0,00000	
	7,5														0,00000	
	7														0,00000	
	6,5													0,00002	0,00002	
	6											0,00002			0,00002	
	5,5													0,00002	0,00002	
	5											0,00002	0,00008	0,00005	0,00003	0,00017
	4,5										0,00022	0,00022	0,00006		0,00050	
	4								0,00002	0,00020	0,00078	0,00019	0,00002		0,00120	
	3,5								0,00008	0,00156	0,00145	0,00005			0,00313	
	3								0,00193	0,00532	0,00054	0,00002			0,00781	
	2,5								0,00034	0,01137	0,00272	0,00002	0,00002		0,01447	
	2								0,00476	0,00857	0,00016				0,01349	
1,5								0,00051	0,00417	0,00065				0,00534		
1					0,00011	0,00124	0,00072							0,00207		
0,5					0,00030	0,00025	0,00002							0,00056		
<0,25														0,00000		
		0,00000	0,00000	0,00000	0,00000	0,00040	0,00201	0,01000	0,02262	0,00996	0,00302	0,00058	0,00016	0,00005	0,04878	

		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5														0,00000
	6														0,00000
	5,5												0,00006	0,00002	0,00008
	5											0,00003	0,00023	0,00011	0,00037
	4,5											0,00037	0,00030		0,00067
	4											0,00039	0,00115	0,00025	0,00179
	3,5									0,00012	0,00264	0,00137	0,00002		0,00415
	3									0,00260	0,00572	0,00023			0,00856
	2,5									0,00011	0,00831	0,00152			0,00994
	2									0,00002	0,00154	0,00275	0,00005		0,00436
1,5									0,00008	0,00082	0,00017			0,00107	
1						0,00006	0,00022	0,00017						0,00045	
0,5						0,00006	0,00002							0,00008	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00012	0,00033	0,00264	0,01395	0,01033	0,00316	0,00086	0,00012	0,00000	0,03151

## Upwind Design Basis – K13 Deep Water Site

Vw = 21-23 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5													0,00002	0,00002
	6												0,00002	0,00002	0,00003
	5,5											0,00003	0,00006	0,00002	0,00011
	5										0,00005	0,00022	0,00011	0,00003	0,00040
	4,5									0,00003	0,00047	0,00026	0,00005		0,00081
	4									0,00034	0,00110	0,00006			0,00151
	3,5									0,00014	0,00300	0,00121			0,00436
	3									0,00210	0,00401	0,00011			0,00622
	2,5									0,00005	0,00390	0,00062			0,00457
	2									0,00034	0,00062				0,00096
1,5									0,00012	0,00003				0,00016	
1						0,00009								0,00009	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00009	0,00051	0,00680	0,00801	0,00294	0,00059	0,00025	0,00005	0,01924

Vw = 23-25 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5													0,00002	0,00002
	6												0,00002	0,00002	0,00003
	5,5											0,00002	0,00008	0,00005	0,00002
	5										0,00009	0,00028	0,00003		0,00016
	4,5										0,00003	0,00059	0,00020	0,00002	0,00040
	4										0,00058	0,00135	0,00002		0,00084
	3,5										0,00012	0,00261	0,00051		0,00194
	3										0,00098	0,00134	0,00006		0,00325
	2,5										0,00003	0,00048	0,00009		0,00238
	2										0,00003	0,00008			0,00061
1,5										0,00002				0,00011	
1										0,00002				0,00002	
0,5										0,00002				0,00002	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00009	0,00166	0,00465	0,00263	0,00058	0,00011	0,00005	0,00977

Vw = 25-27 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5													0,00003	0,00002
	6												0,00002	0,00005	0,00005
	5,5											0,00012	0,00012		0,00025
	5											0,00012	0,00020	0,00002	0,00034
	4,5											0,00002	0,00065	0,00008	0,00075
	4											0,00002	0,00050	0,00078	0,00129
	3,5											0,00006	0,00103	0,00022	0,00131
	3											0,00019	0,00039		0,00058
	2,5											0,00011			0,00011
	2														0,00000
1,5														0,00000	
1											0,00002			0,00002	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00039	0,00193	0,00177	0,00042	0,00022	0,00002	0,00474

## Upwind Design Basis – K13 Deep Water Site

Vw = 27-29 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7													0,00002	0,00002
	6,5												0,00002		0,00002
	6											0,00002	0,00002	0,00002	0,00005
	5,5										0,00003	0,00012	0,00003		0,00019
	5									0,00025	0,00017				0,00042
	4,5								0,00003	0,00056	0,00008				0,00067
	4								0,00017	0,00048					0,00065
	3,5								0,00028	0,00008					0,00036
	3							0,00002	0,00005						0,00006
	2,5														0,00000
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00053	0,00140	0,00039	0,00006	0,00003	0,00243	

Vw = 29-31 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7													0,00002	0,00002
	6,5														0,00000
	6											0,00005	0,00003		0,00008
	5,5									0,00002	0,00008	0,00002			0,00011
	5									0,00016	0,00006				0,00022
	4,5									0,00025	0,00002				0,00026
	4									0,00011	0,00012				0,00023
	3,5									0,00002					0,00002
	3														0,00000
	2,5														0,00000
	2														0,00000
1,5														0,00000	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00012	0,00054	0,00020	0,00005	0,00002	0,00093	

Vw = 31-33 m/s		Tp [s]													
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5	
Hs [m]	9,5														0,00000
	9														0,00000
	8,5														0,00000
	8														0,00000
	7,5														0,00000
	7														0,00000
	6,5													0,00002	0,00002
	6											0,00006	0,00002		0,00008
	5,5											0,00005			0,00005
	5										0,00009	0,00005			0,00014
	4,5										0,00017				0,00017
	4									0,00002	0,00002				0,00003
	3,5														0,00000
	3									0,00003					0,00003
	2,5														0,00000
	2														0,00000
1,5														0,00002	
1														0,00000	
0,5														0,00000	
<0,25														0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00000	0,00005	0,00028	0,00016	0,00002	0,00002	0,00053

## Upwind Design Basis – K13 Deep Water Site

Vw 33-35 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5										0,00002	0,00003				0,00005
	5										0,00003	0,00002				0,00005
	4,5										0,00002					0,00002
	4															0,00000
	3,5															0,00000
	3															0,00000
	2,5															0,00000
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00006	0,00005	0,00000	0,00000	0,00011	

Vw =35-37 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6															0,00000
	5,5											0,00002				0,00002
	5											0,00002				0,00002
	4,5															0,00000
	4															0,00000
	3,5															0,00000
	3															0,00000
	2,5															0,00000
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00003	0,00000	0,00000	0,00003	

Vw > 37 m/s		Tp [s]														
		< 0,5	1	2	3	4	5	6	7	8	9	10	11	>11,5		
Hs [m]	9,5															0,00000
	9															0,00000
	8,5															0,00000
	8															0,00000
	7,5															0,00000
	7															0,00000
	6,5															0,00000
	6											0,00002	0,00002			0,00003
	5,5															0,00000
	5															0,00000
	4,5															0,00000
	4															0,00000
	3,5											0,00002				0,00002
	3															0,00000
	2,5															0,00000
	2															0,00000
	1,5															0,00000
1															0,00000	
0,5															0,00000	
<0,25															0,00000	
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00002	0,00002	0,00000	0,00005	

D. Scatter diagrams (V -  $\theta$ wind -  $\theta$ wave)

All windspeeds		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,03839	0,00504	0,00093	0,00028	0,00011	0,00025	0,00058	0,00089	0,00070	0,00095	0,00188	0,01143	0,06143
030°	NNE	0,02819	0,01846	0,00422	0,00081	0,00028	0,00044	0,00065	0,00073	0,00054	0,00042	0,00103	0,00408	0,05984
060°	ENE	0,01299	0,02210	0,01739	0,00319	0,00081	0,00065	0,00067	0,00067	0,00050	0,00044	0,00073	0,00201	0,06214
090°	E	0,00779	0,01036	0,02462	0,01454	0,00359	0,00160	0,00115	0,00079	0,00048	0,00045	0,00068	0,00210	0,06818
120°	ESE	0,00571	0,00510	0,00821	0,01199	0,01052	0,00554	0,00314	0,00138	0,00087	0,00050	0,00079	0,00193	0,05569
150°	SSE	0,00534	0,00336	0,00322	0,00414	0,00607	0,01034	0,01384	0,00443	0,00110	0,00107	0,00165	0,00249	0,05706
180°	S	0,00675	0,00263	0,00198	0,00210	0,00213	0,00470	0,02792	0,02117	0,00436	0,00252	0,00275	0,00453	0,08353
210°	SSW	0,00639	0,00229	0,00151	0,00098	0,00103	0,00208	0,01790	0,06882	0,01322	0,00633	0,00583	0,00762	0,13401
240°	WSW	0,00652	0,00196	0,00095	0,00070	0,00058	0,00109	0,00621	0,04693	0,03393	0,01756	0,01120	0,01034	0,13796
270°	W	0,00778	0,00137	0,00081	0,00022	0,00033	0,00044	0,00218	0,01352	0,01989	0,02697	0,02750	0,01618	0,11718
300°	WNW	0,01224	0,00148	0,00042	0,00014	0,00023	0,00030	0,00107	0,00445	0,00554	0,00885	0,02083	0,03029	0,08583
330°	NNW	0,02870	0,00180	0,00047	0,00019	0,00028	0,00025	0,00107	0,00182	0,00143	0,00216	0,00625	0,03274	0,07717
		0,16678	0,07596	0,06472	0,03928	0,02595	0,02767	0,07639	0,16560	0,08257	0,06822	0,08113	0,12573	1,00000

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw < 1 m/s		Wave direction												
Wind direction		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00006		0,00002						0,00002		0,00002	0,00006	0,00017
030°	NNE	0,00009			0,00002	0,00002	0,00002			0,00002		0,00002		0,00017
060°	ENE	0,00005	0,00002	0,00003	0,00002		0,00006		0,00003			0,00006	0,00002	0,00028
090°	E	0,00003	0,00003		0,00002			0,00003	0,00002				0,00005	0,00017
120°	ESE	0,00012	0,00008					0,00003	0,00002				0,00003	0,00028
150°	SSE	0,00011	0,00002				0,00002	0,00005	0,00005		0,00003		0,00005	0,00031
180°	S	0,00020	0,00003	0,00002	0,00003		0,00002	0,00002		0,00005	0,00003	0,00002	0,00005	0,00045
210°	SSW	0,00012	0,00003	0,00002		0,00002		0,00002	0,00003	0,00002		0,00003	0,00014	0,00042
240°	WSW	0,00017	0,00005		0,00002	0,00002		0,00002	0,00002	0,00002	0,00003	0,00002	0,00009	0,00044
270°	W	0,00016	0,00002	0,00002		0,00002			0,00002	0,00002	0,00002	0,00005	0,00006	0,00036
300°	WNW	0,00014	0,00002	0,00002			0,00002		0,00006	0,00002		0,00003	0,00006	0,00036
330°	NNW	0,00011	0,00002	0,00003				0,00002	0,00005			0,00003	0,00008	0,00033
		0,00137	0,00030	0,00014	0,00009	0,00006	0,00012	0,00017	0,00028	0,00014	0,00011	0,00026	0,00068	0,00373

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 1-3 m/s		Wave direction												
Wind direction		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00201	0,00033	0,00006	0,00006		0,00005	0,00017	0,00020	0,00016	0,00019	0,00030	0,00073	0,00425
030°	NNE	0,00185	0,00036	0,00031	0,00016	0,00006	0,00008	0,00025	0,00012	0,00005	0,00016	0,00030	0,00072	0,00440
060°	ENE	0,00165	0,00084	0,00025	0,00014	0,00011	0,00014	0,00016	0,00016	0,00006	0,00009	0,00009	0,00045	0,00414
090°	E	0,00180	0,00045	0,00053	0,00023	0,00020	0,00019	0,00023	0,00022	0,00012	0,00012	0,00016	0,00042	0,00468
120°	ESE	0,00142	0,00061	0,00037	0,00033	0,00023	0,00039	0,00042	0,00025	0,00028	0,00014	0,00026	0,00054	0,00524
150°	SSE	0,00146	0,00064	0,00040	0,00033	0,00020	0,00036	0,00061	0,00067	0,00016	0,00033	0,00048	0,00054	0,00618
180°	S	0,00156	0,00056	0,00023	0,00026	0,00012	0,00022	0,00059	0,00093	0,00061	0,00020	0,00040	0,00093	0,00663
210°	SSW	0,00118	0,00039	0,00028	0,00008	0,00002	0,00014	0,00030	0,00054	0,00033	0,00030	0,00047	0,00115	0,00516
240°	WSW	0,00109	0,00044	0,00023	0,00008	0,00006	0,00014	0,00039	0,00048	0,00034	0,00047	0,00045	0,00118	0,00535
270°	W	0,00124	0,00026	0,00014	0,00008	0,00011	0,00008	0,00030	0,00050	0,00037	0,00022	0,00070	0,00107	0,00507
300°	WNW	0,00151	0,00048	0,00006	0,00003	0,00005	0,00003	0,00014	0,00037	0,00025	0,00031	0,00053	0,00112	0,00488
330°	NNW	0,00219	0,00034	0,00006	0,00005	0,00006	0,00011	0,00012	0,00028	0,00016	0,00023	0,00025	0,00087	0,00473
		0,01896	0,00569	0,00294	0,00182	0,00123	0,00191	0,00367	0,00473	0,00288	0,00275	0,00439	0,00974	0,06071

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

## Upwind Design Basis – K13 Deep Water Site

Vw 3-5 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00367	0,00072	0,00016	0,00003	0,00005	0,00008	0,00008	0,00022	0,00005	0,00019	0,00026	0,00126	0,00675
030°	NNE	0,00336	0,00142	0,00045	0,00011	0,00003	0,00005	0,00009	0,00020	0,00026	0,00009	0,00016	0,00081	0,00703
060°	ENE	0,00310	0,00180	0,00079	0,00045	0,00011	0,00009	0,00022	0,00020	0,00019	0,00023	0,00023	0,00061	0,00803
090°	E	0,00185	0,00132	0,00104	0,00065	0,00048	0,00026	0,00037	0,00020	0,00012	0,00014	0,00023	0,00065	0,00734
120°	ESE	0,00137	0,00086	0,00082	0,00051	0,00034	0,00064	0,00051	0,00030	0,00020	0,00011	0,00026	0,00050	0,00642
150°	SSE	0,00124	0,00068	0,00048	0,00048	0,00033	0,00048	0,00109	0,00084	0,00025	0,00026	0,00030	0,00064	0,00708
180°	S	0,00165	0,00056	0,00036	0,00030	0,00019	0,00022	0,00100	0,00126	0,00070	0,00045	0,00036	0,00103	0,00806
210°	SSW	0,00168	0,00045	0,00031	0,00012	0,00008	0,00011	0,00058	0,00120	0,00065	0,00051	0,00076	0,00104	0,00750
240°	WSW	0,00140	0,00034	0,00016	0,00008	0,00008	0,00014	0,00042	0,00112	0,00070	0,00051	0,00100	0,00151	0,00745
270°	W	0,00180	0,00042	0,00019	0,00006	0,00005	0,00014	0,00017	0,00089	0,00051	0,00054	0,00104	0,00187	0,00768
300°	WNW	0,00213	0,00037	0,00017		0,00003	0,00011	0,00023	0,00048	0,00048	0,00053	0,00093	0,00247	0,00795
330°	NNW	0,00308	0,00031	0,00019	0,00002	0,00003		0,00023	0,00037	0,00020	0,00036	0,00061	0,00243	0,00782
		0,02633	0,00926	0,00512	0,00282	0,00179	0,00232	0,00499	0,00728	0,00432	0,00394	0,00614	0,01481	0,08911

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 5-7 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00666	0,00112	0,00012	0,00006	0,00002	0,00003	0,00009	0,00020	0,00017	0,00014	0,00036	0,00222	0,01120
030°	NNE	0,00534	0,00271	0,00062	0,00008	0,00008	0,00008	0,00011	0,00017	0,00014	0,00006	0,00017	0,00082	0,01038
060°	ENE	0,00308	0,00310	0,00188	0,00061	0,00008	0,00012	0,00017	0,00019	0,00009	0,00002	0,00014	0,00044	0,00991
090°	E	0,00179	0,00221	0,00226	0,00191	0,00054	0,00037	0,00019	0,00014	0,00014	0,00012	0,00019	0,00044	0,01030
120°	ESE	0,00131	0,00134	0,00162	0,00140	0,00143	0,00109	0,00065	0,00036	0,00022	0,00012	0,00014	0,00044	0,01011
150°	SSE	0,00128	0,00065	0,00067	0,00079	0,00089	0,00135	0,00204	0,00115	0,00023	0,00023	0,00036	0,00056	0,01020
180°	S	0,00128	0,00059	0,00048	0,00050	0,00030	0,00068	0,00222	0,00241	0,00075	0,00056	0,00059	0,00096	0,01132
210°	SSW	0,00134	0,00067	0,00039	0,00017	0,00022	0,00025	0,00165	0,00317	0,00135	0,00093	0,00120	0,00152	0,01286
240°	WSW	0,00176	0,00054	0,00017	0,00022	0,00009	0,00014	0,00112	0,00313	0,00199	0,00145	0,00191	0,00222	0,01475
270°	W	0,00232	0,00034	0,00025		0,00002	0,00003	0,00040	0,00187	0,00118	0,00149	0,00212	0,00366	0,01367
300°	WNW	0,00283	0,00030	0,00012	0,00006	0,00011	0,00006	0,00025	0,00095	0,00079	0,00086	0,00210	0,00450	0,01293
330°	NNW	0,00566	0,00056	0,00011	0,00005	0,00005	0,00008	0,00022	0,00033	0,00033	0,00037	0,00106	0,00404	0,01285
		0,03463	0,01412	0,00870	0,00585	0,00381	0,00429	0,00912	0,01406	0,00739	0,00636	0,01033	0,02182	0,14048

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 7-9 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00638	0,00081	0,00022	0,00005	0,00003	0,00008	0,00005	0,00006	0,00006	0,00006	0,00012	0,00143	0,00935
030°	NNE	0,00562	0,00327	0,00073	0,00014	0,00003	0,00003	0,00006	0,00008	0,00003	0,00006	0,00012	0,00070	0,01087
060°	ENE	0,00215	0,00409	0,00260	0,00051	0,00023	0,00006	0,00003	0,00008	0,00008	0,00003	0,00008	0,00022	0,01016
090°	E	0,00126	0,00208	0,00302	0,00208	0,00062	0,00033	0,00014	0,00017	0,00002	0,00002	0,00003	0,00031	0,01008
120°	ESE	0,00070	0,00087	0,00168	0,00173	0,00165	0,00089	0,00056	0,00023	0,00003	0,00006	0,00006	0,00019	0,00865
150°	SSE	0,00075	0,00078	0,00067	0,00082	0,00093	0,00138	0,00199	0,00072	0,00017	0,00012	0,00014	0,00033	0,00880
180°	S	0,00110	0,00039	0,00045	0,00036	0,00037	0,00075	0,00320	0,00280	0,00079	0,00072	0,00078	0,00061	0,01232
210°	SSW	0,00114	0,00028	0,00020	0,00017	0,00014	0,00048	0,00213	0,00512	0,00188	0,00112	0,00129	0,00168	0,01563
240°	WSW	0,00117	0,00031	0,00016	0,00008	0,00011	0,00030	0,00103	0,00471	0,00283	0,00252	0,00230	0,00202	0,01753
270°	W	0,00124	0,00017	0,00008	0,00002	0,00008	0,00005	0,00040	0,00207	0,00182	0,00240	0,00356	0,00294	0,01482
300°	WNW	0,00252	0,00016	0,00003	0,00003	0,00002	0,00002	0,00016	0,00070	0,00078	0,00120	0,00196	0,00437	0,01193
330°	NNW	0,00406	0,00028	0,00003	0,00003	0,00005		0,00006	0,00022	0,00017	0,00025	0,00053	0,00341	0,00908
		0,02808	0,01349	0,00986	0,00602	0,00426	0,00436	0,00982	0,01695	0,00866	0,00856	0,01098	0,01820	0,13923

Percentage of time [%]

90° + from wind direction
90° - from wind direction

## Upwind Design Basis – K13 Deep Water Site

Vw 9-11 m/s		Wave direction													
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW		
000°	N	0,00638	0,00084	0,00014	0,00003	0,00002		0,00006	0,00003	0,00009	0,00014	0,00025	0,00229	0,01027	
030°	NNE	0,00453	0,00325	0,00075	0,00012	0,00003	0,00006					0,00011	0,00054	0,00940	
060°	ENE	0,00149	0,00392	0,00247	0,00037	0,00019	0,00005	0,00008	0,00002	0,00006	0,00003	0,00009	0,00022	0,00899	
090°	E	0,00058	0,00185	0,00383	0,00268	0,00067	0,00014	0,00005	0,00003	0,00005	0,00003	0,00006	0,00014	0,01010	
120°	ESE	0,00044	0,00078	0,00159	0,00190	0,00190	0,00190	0,00082	0,00047	0,00011	0,00009	0,00003	0,00003	0,00012	0,00828
150°	SSE	0,00026	0,00023	0,00044	0,00072	0,00109	0,00180	0,00241	0,00036	0,00017	0,00006	0,00022	0,00012	0,00789	
180°	S	0,00051	0,00022	0,00020	0,00028	0,00067	0,00096	0,00493	0,00331	0,00051	0,00025	0,00036	0,00053	0,01274	
210°	SSW	0,00039	0,00019	0,00017	0,00016	0,00025	0,00031	0,00282	0,00711	0,00246	0,00124	0,00089	0,00112	0,01709	
240°	WSW	0,00064	0,00014	0,00012	0,00011	0,00016	0,00011	0,00109	0,00597	0,00462	0,00278	0,00185	0,00173	0,01932	
270°	W	0,00065	0,00009	0,00008	0,00003	0,00005	0,00005	0,00040	0,00204	0,00243	0,00303	0,00392	0,00313	0,01590	
300°	WNW	0,00173	0,00008		0,00002	0,00002	0,00003	0,00009	0,00070	0,00086	0,00117	0,00314	0,00467	0,01249	
330°	NNW	0,00467	0,00009	0,00005	0,00002	0,00002	0,00003	0,00020	0,00026	0,00026	0,00036	0,00096	0,00502	0,01195	
		0,02226	0,01168	0,00983	0,00642	0,00504	0,00437	0,01260	0,01994	0,01160	0,00913	0,01188	0,01963	0,14440	

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 11-13 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00529	0,00048	0,00012	0,00002			0,00003	0,00003	0,00005	0,00012	0,00017	0,00103	0,00734
030°	NNE	0,00322	0,00300	0,00059	0,00009	0,00002		0,00006	0,00002		0,00003	0,00009	0,00020	0,00733
060°	ENE	0,00084	0,00333	0,00260	0,00050	0,00003	0,00006			0,00002	0,00003	0,00002	0,00002	0,00744
090°	E	0,00028	0,00138	0,00320	0,00247	0,00045	0,00014	0,00006	0,00002	0,00003			0,00002	0,00806
120°	ESE	0,00022	0,00037	0,00089	0,00191	0,00190	0,00079	0,00025	0,00009	0,00003	0,00003		0,00008	0,00656
150°	SSE	0,00016	0,00023	0,00031	0,00051	0,00121	0,00205	0,00166	0,00039	0,00009		0,00014	0,00012	0,00689
180°	S	0,00023	0,00017	0,00011	0,00019	0,00020	0,00068	0,00398	0,00260	0,00039	0,00011	0,00008	0,00033	0,00907
210°	SSW	0,00034	0,00017	0,00003	0,00008	0,00009	0,00045	0,00317	0,01002	0,00212	0,00082	0,00042	0,00059	0,01831
240°	WSW	0,00017	0,00008	0,00005	0,00005	0,00005	0,00009	0,00082	0,00678	0,00530	0,00303	0,00145	0,00089	0,01876
270°	W	0,00026	0,00005	0,00002		0,00002	0,00005	0,00028	0,00227	0,00325	0,00359	0,00414	0,00174	0,01566
300°	WNW	0,00076	0,00003	0,00002			0,00003	0,00009	0,00061	0,00073	0,00128	0,00274	0,00462	0,01090
330°	NNW	0,00439	0,00012		0,00002	0,00003	0,00002	0,00012	0,00012	0,00014	0,00023	0,00112	0,00543	0,01174
		0,01616	0,00943	0,00793	0,00583	0,00400	0,00437	0,01055	0,02294	0,01215	0,00929	0,01036	0,01506	0,12806

Percentage of time [%]

90° + from wind direction
90° - from wind direction

Vw 13-15 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00316	0,00033	0,00003	0,00002			0,00006	0,00005	0,00003	0,00005	0,00012	0,00092	0,00476
030°	NNE	0,00196	0,00171	0,00033	0,00002		0,00003	0,00003	0,00002	0,00002		0,00005	0,00011	0,00426
060°	ENE	0,00031	0,00244	0,00257	0,00034	0,00003	0,00003						0,00003	0,00576
090°	E	0,00009	0,00050	0,00345	0,00177	0,00031	0,00011	0,00005			0,00002	0,00002	0,00006	0,00638
120°	ESE	0,00006	0,00019	0,00078	0,00182	0,00156	0,00042	0,00003	0,00003	0,00002		0,00003		0,00493
150°	SSE	0,00005	0,00008	0,00017	0,00025	0,00067	0,00128	0,00143	0,00016	0,00002	0,00002	0,00002	0,00003	0,00415
180°	S	0,00014	0,00003	0,00005	0,00011	0,00017	0,00058	0,00431	0,00238	0,00028	0,00008	0,00012	0,00009	0,00834
210°	SSW	0,00014	0,00008	0,00008	0,00009	0,00009	0,00011	0,00288	0,01097	0,00173	0,00064	0,00040	0,00014	0,01734
240°	WSW	0,00012	0,00003	0,00006	0,00002		0,00009	0,00054	0,00677	0,00518	0,00254	0,00114	0,00048	0,01697
270°	W	0,00005		0,00002	0,00003			0,00009	0,00132	0,00278	0,00384	0,00358	0,00098	0,01269
300°	WNW	0,00034						0,00008	0,00026	0,00070	0,00115	0,00260	0,00361	0,00874
330°	NNW	0,00184			0,00002	0,00005	0,00002	0,00002	0,00012	0,00008	0,00008	0,00048	0,00359	0,00628
		0,00826	0,00538	0,00753	0,00448	0,00288	0,00266	0,00952	0,02207	0,01083	0,00840	0,00856	0,01005	0,10061

Percentage of time [%]

90° + from wind direction
90° - from wind direction

## Upwind Design Basis – K13 Deep Water Site

Vw 15-17 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00249	0,00022	0,00005	0,00002		0,00002	0,00002	0,00006	0,00003	0,00003	0,00019	0,00086	0,00397
030°	NNE	0,00118	0,00110	0,00011	0,00002		0,00003	0,00002	0,00006		0,00002	0,00002	0,00005	0,00260
060°	ENE	0,00016	0,00148	0,00185	0,00012	0,00002	0,00002					0,00002		0,00366
090°	E	0,00005	0,00034	0,00308	0,00112	0,00019	0,00003	0,00003					0,00002	0,00485
120°	ESE	0,00006	0,00002	0,00031	0,00137	0,00095	0,00025	0,00009					0,00002	0,00306
150°	SSE	0,00002	0,00003	0,00006	0,00014	0,00050	0,00076	0,00096	0,00005		0,00002		0,00002	0,00255
180°	S	0,00008	0,00003		0,00003	0,00005	0,00030	0,00286	0,00188	0,00012	0,00008	0,00003		0,00546
210°	SSW	0,00002	0,00003	0,00002	0,00008	0,00006	0,00006	0,00162	0,00918	0,00110	0,00037	0,00020	0,00012	0,01286
240°	WSW		0,00002		0,00005	0,00002	0,00003	0,00031	0,00677	0,00425	0,00184	0,00072	0,00011	0,01409
270°	W	0,00002	0,00002	0,00002			0,00002	0,00002	0,00082	0,00246	0,00341	0,00291	0,00037	0,01005
300°	WNW	0,00020	0,00002			0,00002	0,00002	0,00019	0,00037	0,00081	0,00250	0,00233		0,00646
330°	NNW	0,00138	0,00008				0,00002	0,00002	0,00002	0,00005	0,00012	0,00040	0,00386	0,00593
		0,00565	0,00338	0,00549	0,00294	0,00179	0,00151	0,00596	0,01902	0,00838	0,00669	0,00698	0,00775	0,07554

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 17-19 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00104	0,00009						0,00003	0,00003		0,00002	0,00028	0,00149
030°	NNE	0,00047	0,00070	0,00012	0,00003		0,00002	0,00002	0,00003	0,00002			0,00003	0,00143
060°	ENE	0,00009	0,00068	0,00115	0,00005			0,00002					0,00002	0,00201
090°	E	0,00006	0,00014	0,00176	0,00072	0,00009	0,00003							0,00280
120°	ESE	0,00002		0,00014	0,00065	0,00031	0,00014	0,00011					0,00002	0,00138
150°	SSE	0,00002	0,00002	0,00002	0,00008	0,00020	0,00059	0,00082	0,00003	0,00002			0,00008	0,00187
180°	S		0,00005	0,00006	0,00003	0,00003	0,00012	0,00224	0,00142	0,00008	0,00005	0,00002		0,00409
210°	SSW	0,00002	0,00002	0,00002	0,00003	0,00005	0,00008	0,00117	0,00773	0,00072	0,00016	0,00011	0,00006	0,01013
240°	WSW		0,00002		0,00002		0,00002	0,00028	0,00426	0,00369	0,00104	0,00023	0,00011	0,00966
270°	W	0,00003		0,00002				0,00011	0,00065	0,00168	0,00310	0,00202	0,00022	0,00782
300°	WNW	0,00005	0,00003				0,00002			0,00019	0,00056	0,00160	0,00093	0,00338
330°	NNW	0,00045								0,00003	0,00008	0,00034	0,00182	0,00272
		0,00224	0,00173	0,00328	0,00160	0,00068	0,00100	0,00478	0,01416	0,00644	0,00498	0,00434	0,00356	0,04878

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 19-21 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°		330°
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00058	0,00008									0,00005	0,00017	0,00087
030°	NNE	0,00025	0,00051	0,00011	0,00003		0,00002						0,00008	0,00100
060°	ENE	0,00006	0,00028	0,00056	0,00005	0,00002								0,00096
090°	E		0,00003	0,00138	0,00040	0,00002								0,00184
120°	ESE			0,00002	0,00023	0,00019	0,00003	0,00002						0,00048
150°	SSE				0,00002	0,00005	0,00020	0,00047	0,00002					0,00075
180°	S			0,00002		0,00002	0,00008	0,00118	0,00079	0,00005				0,00213
210°	SSW	0,00003					0,00002	0,00075	0,00577	0,00045	0,00009	0,00002	0,00003	0,00716
240°	WSW							0,00014	0,00328	0,00246	0,00070	0,00005		0,00663
270°	W						0,00003		0,00050	0,00110	0,00202	0,00142	0,00009	0,00516
300°	WNW								0,00006	0,00017	0,00044	0,00117	0,00073	0,00257
330°	NNW	0,00048						0,00005	0,00002	0,00002	0,00003	0,00033	0,00106	0,00198
		0,00140	0,00090	0,00208	0,00073	0,00028	0,00037	0,00260	0,01044	0,00425	0,00328	0,00302	0,00216	0,03151

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

## Upwind Design Basis – K13 Deep Water Site

Vw 21-23 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00037	0,00002					0,00002		0,00002	0,00003	0,00003	0,00012	0,00061
030°	NNE	0,00019	0,00022	0,00006		0,00002			0,00003					0,00051
060°	ENE	0,00002	0,00008	0,00034										0,00044
090°	E		0,00002	0,00062	0,00030									0,00093
120°	ESE			0,00008	0,00003	0,00006								0,00017
150°	SSE					0,00003	0,00014	0,00002						0,00019
180°	S				0,00002	0,00002	0,00005	0,00058	0,00065	0,00002				0,00132
210°	SSW					0,00008	0,00050	0,00378	0,00017	0,00009	0,00005			0,00467
240°	WSW						0,00002	0,00005	0,00219	0,00154	0,00031	0,00008		0,00418
270°	W								0,00028	0,00114	0,00137	0,00093	0,00002	0,00373
300°	WNW	0,00003								0,00005	0,00008	0,00026	0,00076	0,00166
330°	NNW	0,00016								0,00002		0,00002	0,00009	0,00054
		0,00076	0,00033	0,00103	0,00039	0,00006	0,00023	0,00128	0,00702	0,00296	0,00208	0,00194	0,00117	0,01924

Percentage of time [%]

90° + from wind direction  
90° - from wind direction

Vw 23-25 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00020	0,00002	0,00002									0,00003	0,00026
030°	NNE	0,00012	0,00016	0,00003					0,00002				0,00002	0,00034
060°	ENE		0,00002	0,00026	0,00002									0,00030
090°	E			0,00023	0,00009	0,00002								0,00034
120°	ESE				0,00006	0,00003	0,00002							0,00011
150°	SSE					0,00002	0,00014							0,00016
180°	S					0,00005	0,00042	0,00034						0,00081
210°	SSW						0,00019	0,00221	0,00012	0,00005			0,00002	0,00258
240°	WSW							0,00087	0,00053	0,00014	0,00002			0,00156
270°	W							0,00012	0,00056	0,00089	0,00048	0,00002		0,00207
300°	WNW								0,00005	0,00008	0,00048	0,00023		0,00084
330°	NNW	0,00014					0,00002			0,00002	0,00002	0,00002	0,00022	0,00040
		0,00047	0,00019	0,00054	0,00017	0,00005	0,00008	0,00076	0,00355	0,00128	0,00117	0,00100	0,00053	0,00977

Percentage of time [%]

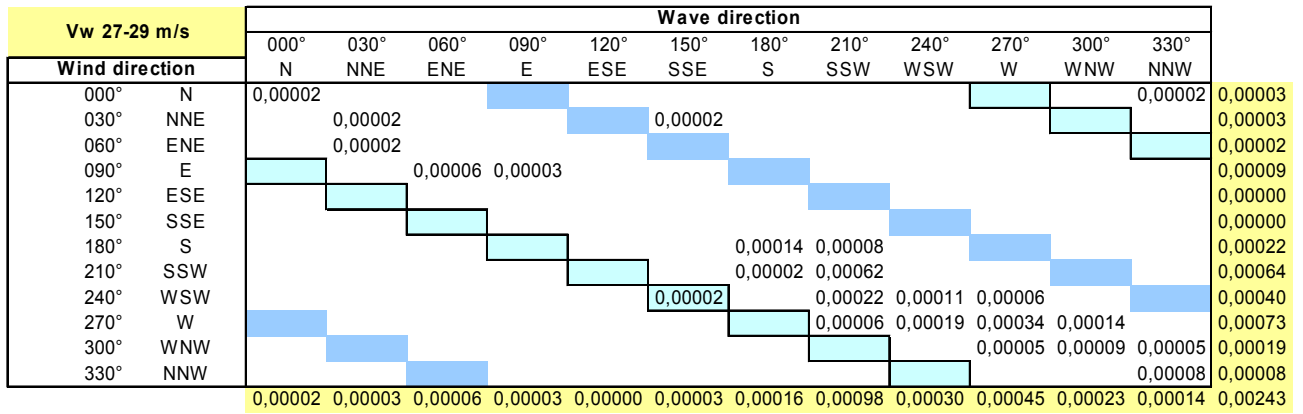
90° + from wind direction  
90° - from wind direction

Vw 25-27 m/s		Wave direction												
		000°	030°	060°	090°	120°	150°	180°	210°	240°	270°	300°	330°	
Wind direction		N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	
000°	N	0,00006												0,00006
030°	NNE	0,00002	0,00005					0,00002						0,00008
060°	ENE		0,00002	0,00003	0,00002		0,00002							0,00008
090°	E			0,00012	0,00006									0,00019
120°	ESE													0,00000
150°	SSE						0,00002							0,00002
180°	S						0,00019	0,00023						0,00042
210°	SSW					0,00002		0,00009	0,00103	0,00009				0,00123
240°	WSW							0,00022	0,00028	0,00014				0,00064
270°	W							0,00008	0,00028	0,00048	0,00034	0,00002		0,00120
300°	WNW								0,00002	0,00005	0,00012	0,00017	0,00011	0,00047
330°	NNW	0,00006							0,00002		0,00002	0,00003	0,00025	0,00037
		0,00014	0,00006	0,00016	0,00008	0,00002	0,00002	0,00031	0,00159	0,00070	0,00076	0,00054	0,00037	0,00474

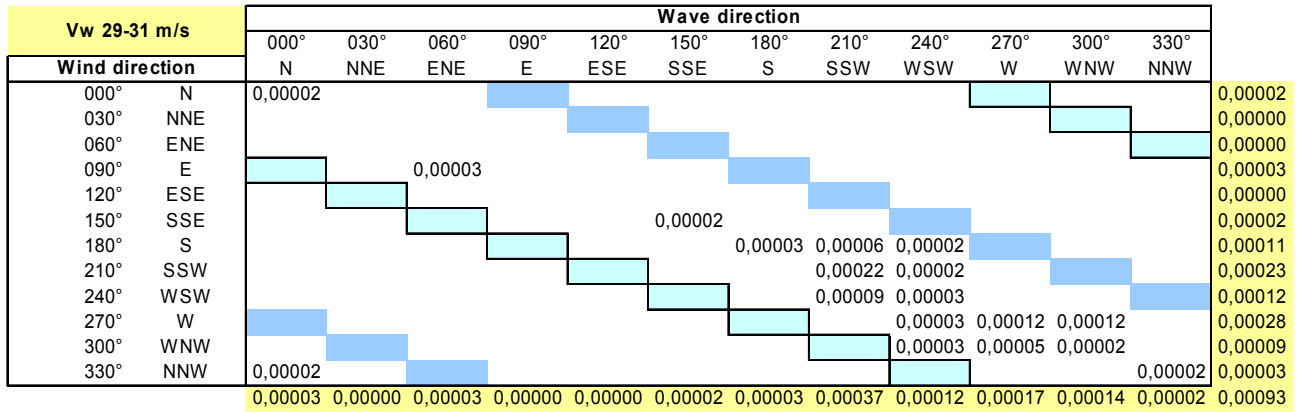
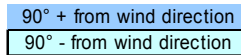
Percentage of time [%]

90° + from wind direction  
90° - from wind direction

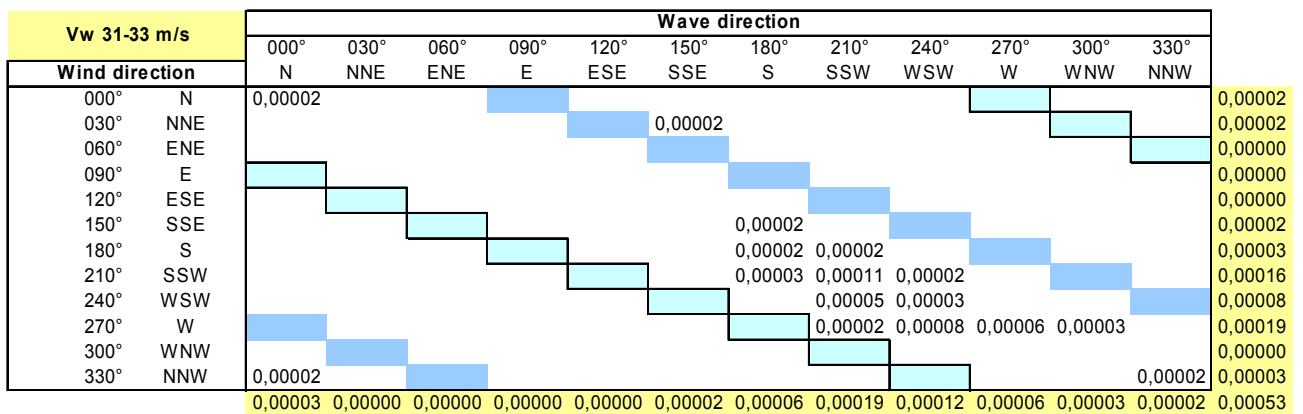
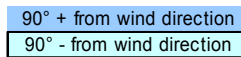
## Upwind Design Basis – K13 Deep Water Site



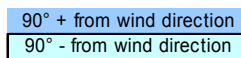
Percentage of time [%]



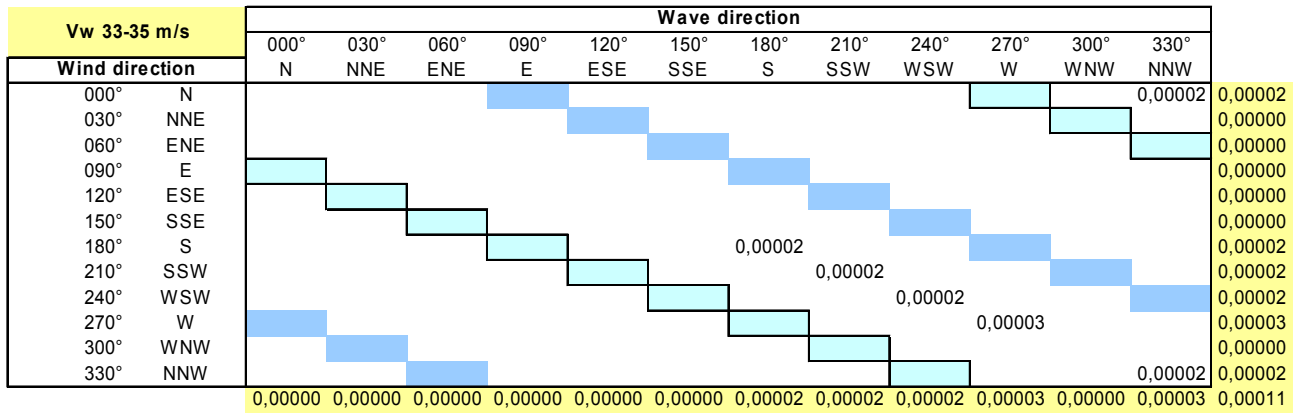
Percentage of time [%]



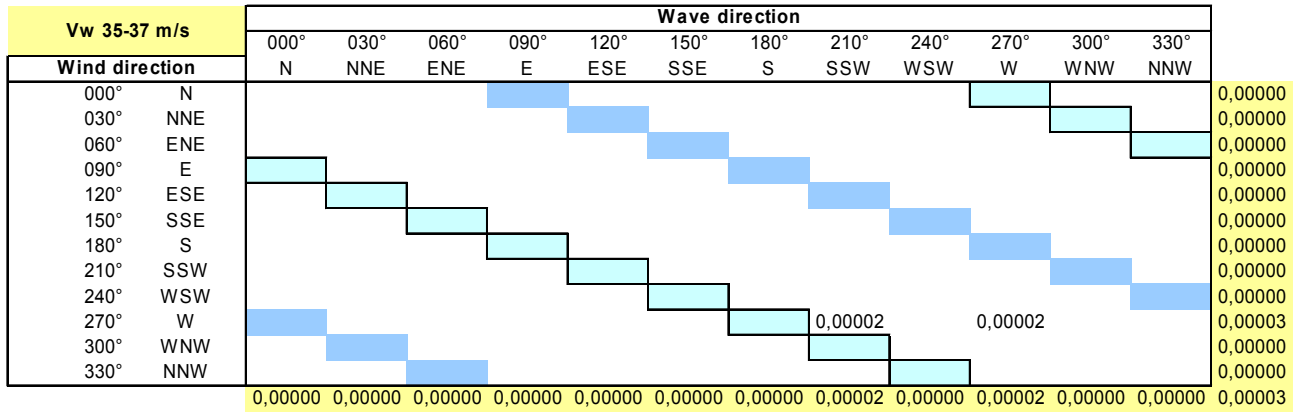
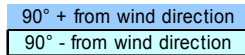
Percentage of time [%]



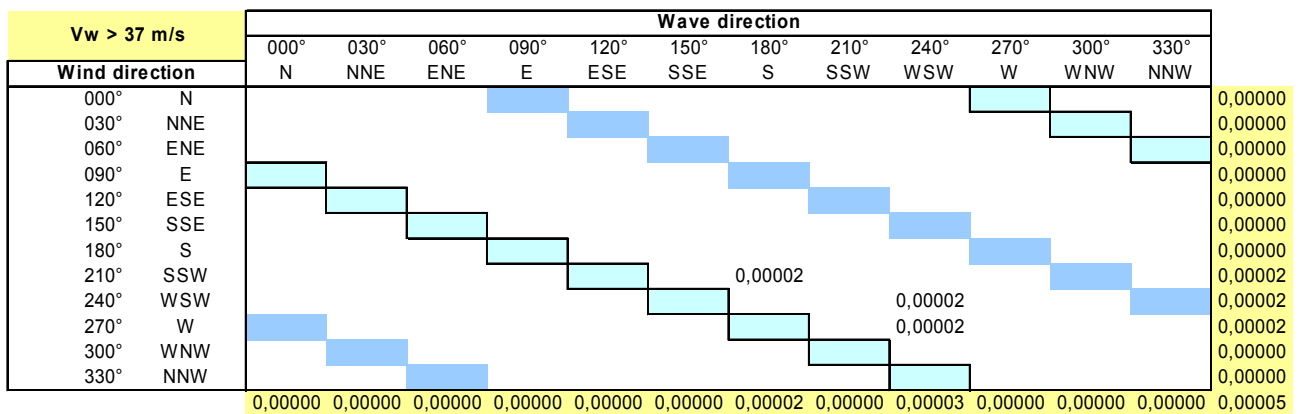
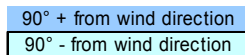
## Upwind Design Basis – K13 Deep Water Site



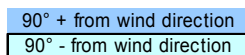
Percentage of time [%]



Percentage of time [%]



Percentage of time [%]



**E. Reduced scatter diagrams ( $V - \theta_{wind} - \theta_{wave}$ )**

All windspeeds		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,07364	0,02973	0,00796	0,00585	0,00688	0,02091	0,14496
030°	NNE	0,05314	0,09030	0,01949	0,00854	0,00817	0,01422	0,19385
060°	ENE	0,02638	0,07166	0,05276	0,02189	0,01332	0,01409	0,20010
090°	E	0,01890	0,02604	0,04581	0,04219	0,03211	0,02031	0,18535
120°	ESE	0,02217	0,01241	0,01504	0,02148	0,03237	0,03805	0,14152
150°	SSE	0,04895	0,01142	0,00622	0,00756	0,01425	0,04583	0,13422
		0,24317	0,24155	0,14729	0,10750	0,10708	0,15340	1,00000

Vw < 1 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00028	0,00003	0,00009	0,00006	0,00003	0,00012	0,00062
030°	NNE	0,00023	0,00006	0,00005	0,00002	0,00008	0,00016	0,00059
060°	ENE	0,00023	0,00011	0,00005	0,00006	0,00009	0,00017	0,00072
090°	E	0,00022	0,00008	0,00003	0,00003	0,00006	0,00011	0,00053
120°	ESE	0,00030	0,00017	0,00003		0,00003	0,00011	0,00064
150°	SSE	0,00028	0,00012	0,00003	0,00003	0,00003	0,00014	0,00064
		0,00154	0,00058	0,00028	0,00020	0,00033	0,00081	0,00373

Vw 1-3 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00432	0,00202	0,00106	0,00072	0,00082	0,00193	0,01087
030°	NNE	0,00358	0,00142	0,00096	0,00068	0,00084	0,00208	0,00957
060°	ENE	0,00328	0,00191	0,00089	0,00078	0,00072	0,00191	0,00949
090°	E	0,00358	0,00143	0,00117	0,00065	0,00117	0,00176	0,00975
120°	ESE	0,00348	0,00171	0,00096	0,00081	0,00107	0,00208	0,01013
150°	SSE	0,00439	0,00193	0,00078	0,00093	0,00100	0,00188	0,01090
		0,02263	0,01042	0,00582	0,00457	0,00562	0,01165	0,06071

Vw 3-5 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00639	0,00275	0,00126	0,00096	0,00086	0,00258	0,01481
030°	NNE	0,00571	0,00327	0,00168	0,00084	0,00103	0,00201	0,01453
060°	ENE	0,00513	0,00347	0,00184	0,00128	0,00142	0,00235	0,01548
090°	E	0,00420	0,00283	0,00187	0,00140	0,00180	0,00292	0,01503
120°	ESE	0,00425	0,00201	0,00168	0,00115	0,00157	0,00372	0,01437
150°	SSE	0,00565	0,00221	0,00112	0,00112	0,00126	0,00355	0,01490
		0,03133	0,01653	0,00944	0,00675	0,00793	0,01713	0,08911

Vw 5-7 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01025	0,00432	0,00152	0,00126	0,00126	0,00390	0,02252
030°	NNE	0,00843	0,00672	0,00250	0,00124	0,00166	0,00268	0,02324
060°	ENE	0,00613	0,00695	0,00414	0,00229	0,00222	0,00292	0,02465
090°	E	0,00470	0,00456	0,00383	0,00353	0,00286	0,00450	0,02397
120°	ESE	0,00504	0,00294	0,00275	0,00244	0,00378	0,00608	0,02304
150°	SSE	0,00919	0,00269	0,00134	0,00145	0,00235	0,00604	0,02305
		0,04374	0,02819	0,01608	0,01221	0,01414	0,02612	0,14048

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Vw 7-9 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01073	0,00406	0,00152	0,00118	0,00131	0,00286	0,02167
030°	NNE	0,00894	0,00874	0,00285	0,00149	0,00159	0,00289	0,02651
060°	ENE	0,00437	0,00919	0,00566	0,00314	0,00272	0,00260	0,02769
090°	E	0,00305	0,00450	0,00493	0,00451	0,00429	0,00362	0,02490
120°	ESE	0,00394	0,00196	0,00252	0,00302	0,00369	0,00546	0,02058
150°	SSE	0,00686	0,00199	0,00104	0,00123	0,00165	0,00512	0,01789
		0,03789	0,03044	0,01853	0,01458	0,01524	0,02255	0,13923

Vw 9-11 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,01188	0,00440	0,00095	0,00070	0,00129	0,00378	0,02301
030°	NNE	0,00773	0,01055	0,00338	0,00152	0,00128	0,00204	0,02649
060°	ENE	0,00330	0,01005	0,00728	0,00330	0,00229	0,00210	0,02831
090°	E	0,00168	0,00401	0,00638	0,00577	0,00470	0,00345	0,02599
120°	ESE	0,00272	0,00166	0,00254	0,00311	0,00509	0,00565	0,02077
150°	SSE	0,00754	0,00095	0,00092	0,00115	0,00229	0,00698	0,01983
		0,03486	0,03162	0,02143	0,01556	0,01692	0,02400	0,14440

Vw 11-13 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00954	0,00328	0,00067	0,00044	0,00045	0,00204	0,01641
030°	NNE	0,00680	0,01321	0,00274	0,00103	0,00062	0,00124	0,02563
060°	ENE	0,00184	0,01019	0,00796	0,00361	0,00154	0,00106	0,02619
090°	E	0,00089	0,00372	0,00650	0,00607	0,00460	0,00194	0,02372
120°	ESE	0,00132	0,00110	0,00166	0,00322	0,00464	0,00552	0,01747
150°	SSE	0,00633	0,00087	0,00054	0,00076	0,00250	0,00762	0,01863
		0,02671	0,03237	0,02008	0,01512	0,01436	0,01943	0,12806

Vw 13-15 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00767	0,00278	0,00039	0,00025	0,00042	0,00159	0,01310
030°	NNE	0,00501	0,01277	0,00215	0,00075	0,00054	0,00039	0,02161
060°	ENE	0,00098	0,00924	0,00781	0,00289	0,00117	0,00064	0,02273
090°	E	0,00028	0,00182	0,00625	0,00566	0,00390	0,00115	0,01907
120°	ESE	0,00051	0,00048	0,00149	0,00297	0,00418	0,00403	0,01367
150°	SSE	0,00333	0,00036	0,00026	0,00036	0,00121	0,00492	0,01044
		0,01778	0,02745	0,01835	0,01288	0,01143	0,01271	0,10061

Vw 15-17 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00544	0,00219	0,00020	0,00016	0,00026	0,00117	0,00943
030°	NNE	0,00283	0,01038	0,00123	0,00048	0,00028	0,00026	0,01546
060°	ENE	0,00047	0,00826	0,00610	0,00201	0,00076	0,00016	0,01775
090°	E	0,00011	0,00118	0,00555	0,00453	0,00310	0,00044	0,01490
120°	ESE	0,00037	0,00022	0,00068	0,00218	0,00347	0,00260	0,00952
150°	SSE	0,00238	0,00017	0,00011	0,00028	0,00090	0,00464	0,00848
		0,01160	0,02240	0,01388	0,00963	0,00877	0,00926	0,07554

Vw 17-19 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00328	0,00159	0,00017	0,00008	0,00006	0,00040	0,00558
030°	NNE	0,00166	0,00846	0,00087	0,00022	0,00016	0,00019	0,01156
060°	ENE	0,00039	0,00496	0,00484	0,00110	0,00023	0,00014	0,01167
090°	E	0,00020	0,00079	0,00345	0,00381	0,00212	0,00025	0,01062
120°	ESE	0,00019	0,00003	0,00033	0,00121	0,00191	0,00109	0,00476
150°	SSE	0,00129	0,00005	0,00006	0,00016	0,00054	0,00249	0,00459
		0,00702	0,01588	0,00972	0,00658	0,00502	0,00456	0,04878

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Vw 19-21 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00176	0,00087	0,00006		0,00006	0,00025	0,00300
030°	NNE	0,00103	0,00628	0,00056	0,00012	0,00002	0,00014	0,00815
060°	ENE	0,00020	0,00356	0,00302	0,00075	0,00006		0,00759
090°	E		0,00053	0,00249	0,00243	0,00143	0,00012	0,00700
120°	ESE	0,00002	0,00006	0,00019	0,00067	0,00135	0,00076	0,00305
150°	SSE	0,00100	0,00003	0,00002	0,00005	0,00037	0,00126	0,00272
		0,00400	0,01134	0,00633	0,00401	0,00330	0,00254	0,03151

Vw 21-23 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00096	0,00067	0,00003	0,00005	0,00005	0,00017	0,00193
030°	NNE	0,00068	0,00403	0,00023	0,00009	0,00006	0,00008	0,00518
060°	ENE	0,00006	0,00227	0,00188	0,00031	0,00008	0,00002	0,00462
090°	E		0,00030	0,00176	0,00166	0,00093	0,00002	0,00467
120°	ESE	0,00003	0,00005	0,00008	0,00034	0,00079	0,00054	0,00184
150°	SSE	0,00030	0,00003		0,00002	0,00009	0,00058	0,00101
		0,00204	0,00734	0,00398	0,00247	0,00201	0,00140	0,01924

Vw 23-25 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00062	0,00036	0,00002			0,00008	0,00107
030°	NNE	0,00031	0,00236	0,00017	0,00005		0,00003	0,00292
060°	ENE		0,00089	0,00079	0,00016	0,00002		0,00185
090°	E		0,00012	0,00079	0,00098	0,00050	0,00002	0,00241
120°	ESE			0,00005	0,00014	0,00051	0,00025	0,00095
150°	SSE	0,00030			0,00002	0,00002	0,00023	0,00056
		0,00123	0,00373	0,00182	0,00134	0,00104	0,00061	0,00977

Vw 25-27 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00025	0,00023					0,00048
030°	NNE	0,00012	0,00107	0,00009		0,00002		0,00131
060°	ENE		0,00023	0,00031	0,00016		0,00002	0,00072
090°	E		0,00008	0,00040	0,00054	0,00034	0,00002	0,00138
120°	ESE		0,00002	0,00005	0,00012	0,00017	0,00011	0,00047
150°	SSE	0,00008	0,00002		0,00002	0,00003	0,00025	0,00039
		0,00045	0,00165	0,00086	0,00084	0,00056	0,00039	0,00474

Vw 27-29 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00016	0,00008				0,00002	0,00025
030°	NNE	0,00002	0,00064				0,00002	0,00067
060°	ENE		0,00023	0,00011	0,00006		0,00002	0,00042
090°	E		0,00006	0,00025	0,00037	0,00014		0,00082
120°	ESE				0,00005	0,00009	0,00005	0,00019
150°	SSE						0,00008	0,00008
		0,00017	0,00101	0,00036	0,00048	0,00023	0,00017	0,00243

Vw 29-31 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00005	0,00006	0,00002				0,00012
030°	NNE		0,00022	0,00002				0,00023
060°	ENE		0,00009	0,00003				0,00012
090°	E			0,00006	0,00012	0,00012		0,00031
120°	ESE			0,00003	0,00005	0,00002		0,00009
150°	SSE	0,00002					0,00003	0,00005
		0,00006	0,00037	0,00016	0,00017	0,00014	0,00003	0,00093

Upwind Design Basis – K13 Deep Water Site

Vw 31-33 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00003	0,00002					0,00005
030°	NNE	0,00003	0,00011	0,00002			0,00002	0,00017
060°	ENE		0,00005	0,00003				0,00008
090°	E		0,00002	0,00008	0,00006	0,00003		0,00019
120°	ESE							0,00000
150°	SSE	0,00003					0,00002	0,00005
		0,00009	0,00019	0,00012	0,00006	0,00003	0,00003	0,00053

Vw 33-35 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N	0,00002					0,00002	0,00003
030°	NNE		0,00002					0,00002
060°	ENE			0,00002				0,00002
090°	E				0,00003			0,00003
120°	ESE							0,00000
150°	SSE						0,00002	0,00002
		0,00002	0,00002	0,00002	0,00003	0,00000	0,00003	0,00011

Vw 35-37 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE							0,00000
060°	ENE							0,00000
090°	E		0,00002		0,00002			0,00003
120°	ESE							0,00000
150°	SSE							0,00000
		0,00000	0,00002	0,00000	0,00002	0,00000	0,00000	0,00003

Vw > 37 m/s		Wave direction						
		000°	030°	060°	090°	120°	150°	
Wind direction		N	NNE	ENE	E	ESE	SSE	
000°	N							0,00000
030°	NNE	0,00002						0,00002
060°	ENE			0,00002				0,00002
090°	E			0,00002				0,00002
120°	ESE							0,00000
150°	SSE							0,00000
		0,00002	0,00000	0,00003	0,00000	0,00000	0,00000	0,00005

## References

- [1] IEC TC88 WG3: *Design requirements for offshore wind turbines*, CDV, 2007
- [2] Germanischer Lloyd (GL-COWT): *Guideline for the Certification of Offshore Wind Turbines, Rules and Guidelines, IV - Industrial Services, Part 2 Guideline for the Certification of Offshore Wind Turbines*; 2005
- [3] Ministerie van Verkeer en Waterstaat: *Monitoring van de Waterstaatkundige Toestand des Lands (MWTL), data IJmuiden site (YM6)*; [www.golfklimaat.nl](http://www.golfklimaat.nl)
- [4] Braam, H. and Eecen, P.J: *Assessment of wind and wave data measured at IJmuiden Munitiestortplaats*; ECN-C-05-060, 2005
- [5] Bundesamt für Seeschifffahrt und Hydrographie (BSH): *Standard-Design of Offshore Wind Turbines*; 2007
- [6] IEC 61400-1: *Wind turbines - Design requirements*, 3rd edition; 2005
- [7] Kühn, M., *Dynamics and Design Optimisation of Offshore Wind Energy Conversion Systems*, PhD thesis; DUWIND 2001.002, 2001
- [8] DNV, *Design of offshore wind turbine structures*; 2004
- [9] *NoordzeeWind (OWEZ) Project*; 2005
- [10] Argoss website: [www.waveclimate.com](http://www.waveclimate.com)