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TECHNICAL REPORT OF KA OWF 2030

Underwater Noise Kattegat OWF

ENERGINET

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	Kattegat OWF	Veritasveien 1
Customer:	ENERGINET,	1363 Høvik
	Tonne Kjærsvej 65	Norway
	7000 Fredericia	Tel: +47 67 57 99 00
	Denmark	945 748 931
Customer contact:	Amalie Rasmussen	
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Applicable contract(s) governing the provision of this Report:

Objective:

The objective is to perform an analysis of the propagation of underwater noise from pile-driving based on project assumptions provided by the Client.

Prepared by:	Verified by:	Approved by:
Matias Helleve Engineer	Mohammad Ghasemi Senior Engineer	Øystein Solheim Pettersen Head of Section

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1 LIST OF ABBREVIATIONS

Abbreviation	Definition
DBBC	Double Bubble Curtain
DEA	Danish Energy Authority
HF	High Frequency
HSD	Hydro Sound Damper
KA	Kattegat
LF	Low Frequency
OWF	Offshore Wind Farm
PCW	Phocid Carnivores in Water
SEL	Sound Exposure Level
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
VHF	Very High Frequency

2 EXECUTIVE SUMMARY

In order to accelerate the expansion of Danish offshore wind production, it was decided with the agreement on the Finance Act for 2022 to offer an additional 2 GW of offshore wind for establishment before the end of 2030. In addition, the parties behind the Climate Agreement on Green Power and Heat 2022 of 25 June 2022 (hereinafter Climate Agreement 2022) decided), that areas that can accommodate an additional 4 GW of offshore wind must be offered for establishment before the end of 2030. Most recently, a political agreement was concluded on 30 May 2023, which establishes the framework for the Climate Agreement 2022 with the development of 9 GW of offshore wind, which potentially can be increased to 14 GW or more if the concession winners – i.e. the tenderers who will set up the offshore wind turbines – use the freedom included in the agreement to establish capacity in addition to the tendered minimum capacity of 1 GW per tendered area.

In order to enable the realization of the political agreements on significantly more energy production from offshore wind before the end of 2030, the Danish Energy Agency has drawn up a plan for the establishment of offshore wind farms in three areas in the North Sea, the Kattegat and the Baltic Sea respectively.

The area for Kattegat Offshore Wind Farm (OWF) is located in Kattegat, approximately 20 kilometer east of Djursland and approximately 30 kilometers north of Zealand. The area for the OWF is approximately 122 km^2. The Kattegat OWF will be connected to land via subsea cables making landfall close to Grenaa.

Commissioned by Energinet, DNV's section for noise and vibration has carried out an assessment of the underwater noise generated by installation of foundations of wind turbines for Kattegat (KA) offshore wind farm (OWF).

A study of underwater noise emitted from the installation of wind turbine foundations has been conducted. The study is based on the requirements of the Danish Energy Agency (DEA) for underwater noise emission from the installation of an offshore wind farm. The noise emitted from the installation was modelled using dbSEA modelling software. The cumulative sound exposure noise levels were numerically modelled and calculated for the whole piling sequence for two different hammer types and sequences, and two different pile diameters defined in Section 3. The required noise mitigation and distance-to-threshold (DTT) were calculated for each scenario.

The 13-meter monopile require noise mitigating measures to adhere to DEA's guidelines, specifically for the low frequency auditory weighting (LF) group. The necessary attenuation of the mitigating measures is up to 11 dB. Conversely, the 18-meter monopile needs a reduction of up to 13.3 dB, for the weighting groups low frequency (LF), Phocid Carnivores in Water (PCW) and very high frequency (VHF)

If the distance-to-threshold (DTT) for all scenarios remains under 50 meters, provided that the safe radius r_{safe} exceeds 50 meters, piling can proceed without requiring acoustic deterrent devices. This remains valid when utilizing both a double bubble curtain (DBBC) and a hydro sound damper (HSD), with their combined effect assumed to be at least 18 dB according to [1]

In the absence of mitigating measures, it is assumed that the radius to the pressure thresholds r_{PTS} exceeds the safe radius r_{safe} thus prohibiting piling activities as per DEA's guidelines.

3 INTRODUCTION

In order to accelerate the expansion of Danish offshore wind production, it was decided with the agreement on the Finance Act for 2022 to offer an additional 2 GW of offshore wind for establishment before the end of 2030. In addition, the parties behind the Climate Agreement on Green Power and Heat 2022 of 25 June 2022 (hereinafter Climate Agreement 2022) decided), that areas that can accommodate an additional 4 GW of offshore wind must be offered for establishment before the end of 2030. Most recently, a political agreement was concluded on 30 May 2023, which establishes the framework for the Climate Agreement 2022 with the development of 9 GW of offshore wind, which potentially can be increased to 14 GW or more if the concession winners – i.e. the tenderers who will set up the offshore wind turbines – use the freedom included in the agreement to establish capacity in addition to the tendered minimum capacity of 1 GW per tendered area.

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DNV's Section for noise and vibration, commissioned by Energinet, has carried out an analysis and modelling of underwater noise generated by installation of pile-driven foundations for wind turbine in the Kattegat area, off the Danish east coast.

An example of a wind farm layout for Kattegat OWF is presented in Figure 3-1 and the scenario presented in the figure is a so-called overplanting case using 27 MW turbines. Coordinates can be found in Appendix A.

The modelling follows DEA's guidelines for underwater noise, and its requirement to include two cases. The first case is the reference case, where the calculated results based on installation without use of noise mitigating measures are presented in Chapter 9. The second case is the planned construction case presented in Chapter 10. These scenarios will be described more thoroughly in their respective chapter. Detailed information about the reference case and the planned construction case, can be found in in DEA's guidelines.

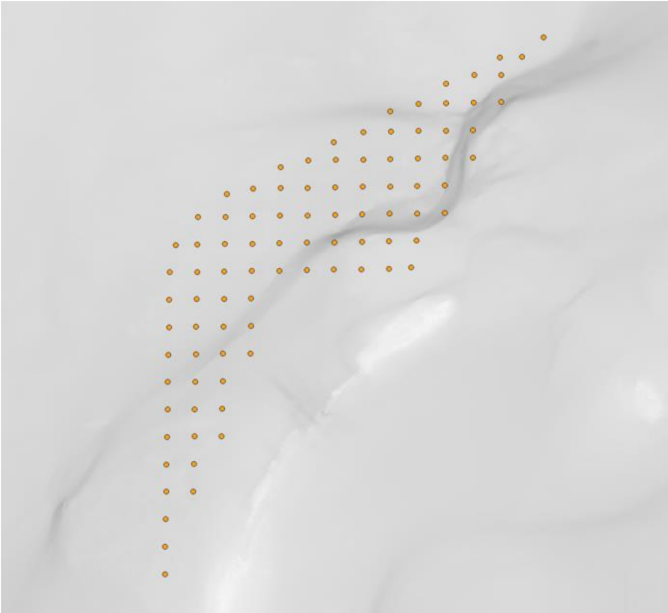

Figure 3-1 OWF Layout

4 MAIN PARTICULARS OF OWF

For the Kattegat OWF the type of foundations, size of turbines and final layout has not been decided. For the purpose of this underwater noise study two scenarios have been established. The Main Particulars and piling sequence detailed below are provided solely as example parameters and are not indicative of those that will be implemented. These parameters are intended to illustrate hypothetical scenarios.

Table 4-1 Main Particulars of OWF

General	
Area	123 km^2
Name of OWF	Kattegat
Nameplate Capacity	15 MW 27 MW
Underwater noise regulation	DEA Guideline for Underwater Noise [2]
Foundation	
Type	Monopiles
Diameter (15 MW)	13 m
Diameter (27 MW)	18 m
Hammer Type 1	
Manufacturer	IHC
Type	S – 4000
Power	4000 kJ
Hammer Type 2	
Manufacturer	Unknown
Type	Unknown
Power	6000 kJ

The hammer sequences are given in

Table 4-2 and Table 4-3 for the 4000 kJ and 6000 kJ hammer respectively.

Table 4-2 – Piling sequence for the 4000 kJ hammer.

Hammer strike energy [kJ]	Number of Blows	Frequency [Blows/min]
400	225	15
1000	75	15
2000	*75*	15
3000	75	15
4000	10050	30

Table 4-3 – Piling sequence for the 6000 kJ hammer.

Hammer strike energy [kJ]	Number of Blows	Frequency [Blows/min]
400	225	15
1000	75	15
2000	*75*	15
3000	75	15
4000	75	15
5000	75	15
6000	6400	30

5 THEORETICAL BACKGROUND AND MODEL ASSUMPTIONS

5.1 Sound Exposure Level (SEL)

The sound exposure level, SEL, is defined as ten times the logarithm to the base 10 of the ratio of the time-integrated sound exposure level E_p to a reference value in ISO 18405:2017 [2]. The convention for underwater noise is to use a reference value of $E_{p,0} = 1\ \mu\text{Pa}^2\ \text{s}$, which was used in this report.

$$L_{E,p} = 10 \log_{10} \frac{E_p}{E_{p,0}} \text{ dB}$$

where

$L_{E,p}$ = Sound exposure level (SEL),

E_p = Time integrated sound exposure level,

$E_{p,0}$ = Reference sound exposure level.

The cumulative sound exposure level (SEL_{cum}) used in this report is defined as

$$L_{E,cum} = 10 \log_{10} \frac{E_{cum}}{E_0} \text{ dB}$$

The values that will be calculated in this report will be the cumulative sound exposure level for the whole hammer sequence. Only one piling sequence is assumed during a 24-hour period. Note that multiple piling operations each day, is not covered in this report.

$$L_{E,cum,24h,xx} = 10 \log_{10} \sum 10^{\frac{L_{E,p}}{10}}$$

5.2 Root-mean-square sound pressure level (SPL)

The rms SPL is defined as the mean of the squared pressure given as

$$p_{rms} = \frac{1}{\Delta t} \int_{t_1}^{t_2} p^2(t)\, dt$$

where

p_{rms} = Mean Squared Pressure,

$\Delta t = t_2 - t_1$ = Time interval.

The associated dB – value is defined as

$$L_{p,rms} = 20 \log_{10} \left(\frac{p_{\text{rms}}}{p_0} \right) \text{ dB}$$

where

$L_{p,rms}$ = Sound Pressure Level (SPL),

p_0 = Reference value. Conventionally 1 µPa for underwater sound.

The threshold for behavioral reactions is determined by the Sound Pressure Level (SPL) within a time interval that corresponds to the average integration time of the mammalian ear, estimated to be 125 ms and further denoted as $L_{p,,rms,125ms}$.

$$L_{p,,rms,125ms} = L_{E,p} + 10 \log_{10}(0.125) = L_{E,p} + 9 \text{ dB}$$

6 REFERENCE SOURCE LEVELS

The source levels were scaled by third octave band frequency SEL levels based on piling of monopile wind turbine generator (WTG), measured at a distance of 750 m as reported in [3]. The scaling is based on hammer strike energy and pile diameter, using the following equation, taken from [3]

$$L_{E,p} = L_{E,p,0} + k_E \log_{10}\left(\frac{E_i}{E_0}\right) + k_d \log_{10}\left(\frac{d_i}{d_0}\right)$$

where

$L_{E,p,0}$ = Unscaled sound exposure level,

k_E = Hammer strength energy scaling coefficient,

k_d = Pile diameter scaling coefficient,

E_i = Hammer Energy,

E_0 = Hammer Energy Reference,

d_i = Pile diameter,

d_0 = Reference Pile Diameter.

The scaling coefficient follows [3] as $k_E = 10$ and $k_D = 16.7$. The reference sound exposure level per third octave band is taken from [4] and shown in Figure 6-1 – SEL 1/3 – Octave band reference values. The blue line is the idealized values which was used. The SEL levels can be linearly scaled for diameter and power.

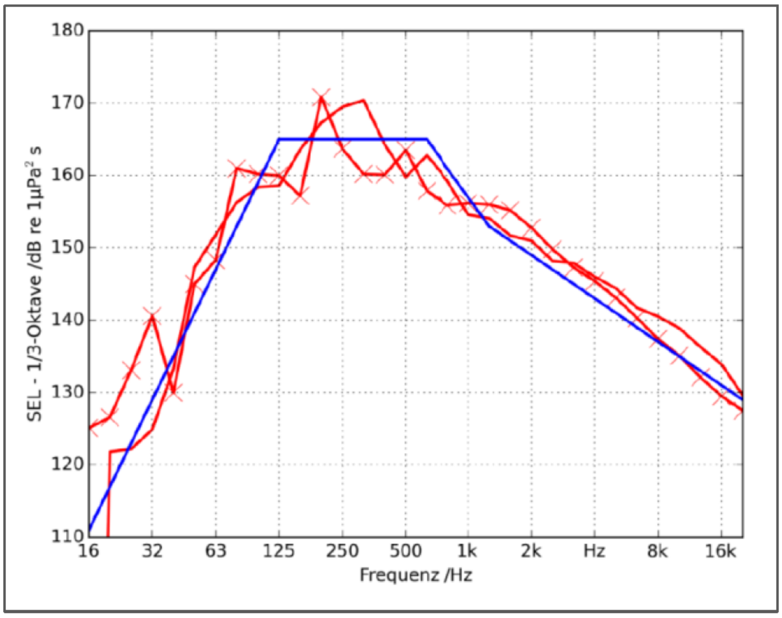

Figure 6-1 – SEL 1/3 – Octave band reference values [4]

The depicted octave band reference values further are back tracked to 1 m using [5], assuming a 4.5 dB increase for each halving of distance. The estimated propagation loss for sound travelling over a distance of 750 meter to 1 meter is calculated to be 43.1 dB, which was added to the scaled SEL values on which the source levels are based. The sound exposure levels outside the frequency band 16 – 20k Hz is unknown. However, the highest values are between 125 Hz and 750 Hz, with decaying values for both sides of this band indicate negligible amplitudes for frequencies outside the 16 – 20k Hz band. The resulting source levels backtracked from 750 m given in SEL's single strike are shown in Figure 5.2

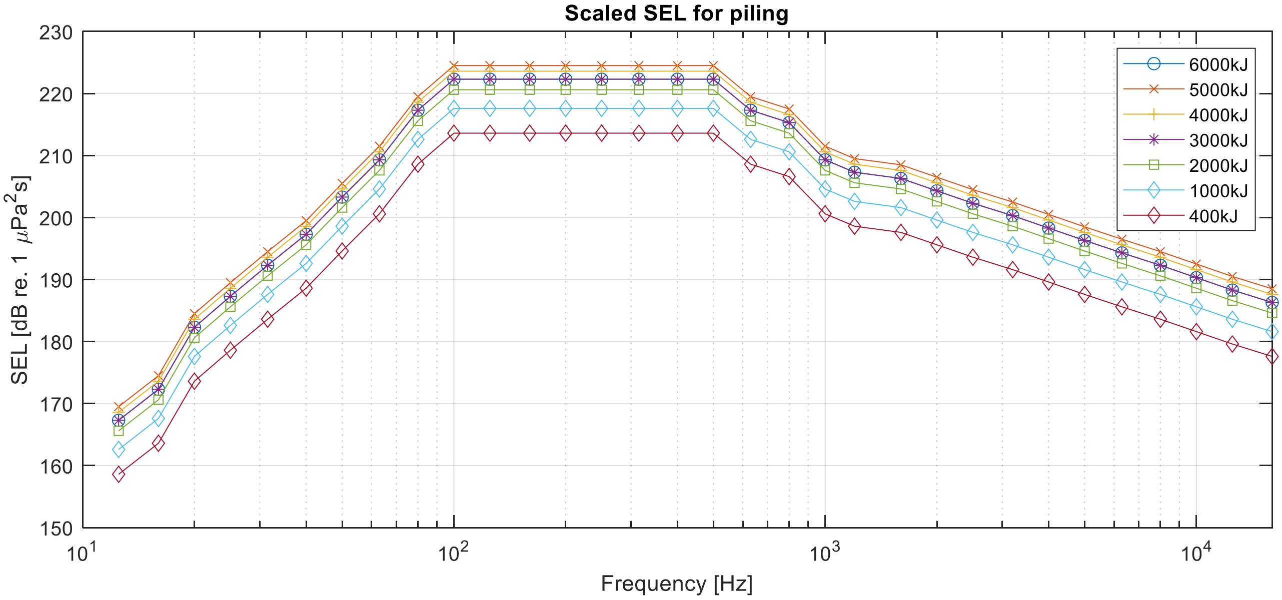

Figure 6-2 - Scaled SEL @ 1 meter for different piling energies.

7 CALCULATION METHODOLOGY

For calculations of sound field from the applicable noise sources, DNV will utilize dBSea, which is developed by Marshall Day Acoustics and provides support for relatively complex scenarios.

Different methods for calculations of the sound field such as ray-tracing, normal modes and parabolic equation can be used depending on the characteristics of the propagation conditions such as the geometry of the site as well as frequency of the sound. These methods can be combined to account for a broader frequency range. In some cases, simple approximations using spherical attenuation or a combination of spherical and cylindrical attenuation, both combined with frequency dependant attenuation can be utilized in calculations of the sound field.

The propagated sound from the piling was modelled using dbSEA, which performs numerical modelling. The sound propagation models used were both normal mode (NM) and acoustic ray-tracing method (RT) complying with DEA's guidelines [6]. The solver utilizes different algorithms in different frequency ranges, i.e., a split solver. The frequency range from 12.5 – 500 Hz is calculated by NM, while RT is used for frequencies f > 500 Hz. The choice of using a split solver is based on [7], and aims to use an optimal solver for each frequency.

A pulse duration of 0.2 seconds is assumed following ISO 18405, to consider a worst-case scenario. Effect of prolonged pulses due to mitigating measures or propagation is not considered.

The source solution is calculated with 36 radial slices and 7000 range points. An example of this is shown in Figure 7-2. The calculation grid is defined to comply with the guidelines [6] which requires a resolution of 20 m resolution in the horizontal plane, and under 1 m resolution in depth resolution. The max length of the transects is ~100km. The values outside the numerical modelling is interpolated. The calculation stops when it reaches the shoreline.

The location of the assumed point source was determined to simulate the worst-case scenarios. The chosen position is based on where the sound is assumed to propagate the farthest. Generally, sound propagates further in deeper waters due to reduced interaction with the seabed and sea surface. In Figure 7-1, darker grey indicates deeper water, suggesting that the eastern points at KA represent the worst case. The specific eastern point was selected based on the proximity to the Natura 2000 areas, which are protected habitats of the relevant protected species.

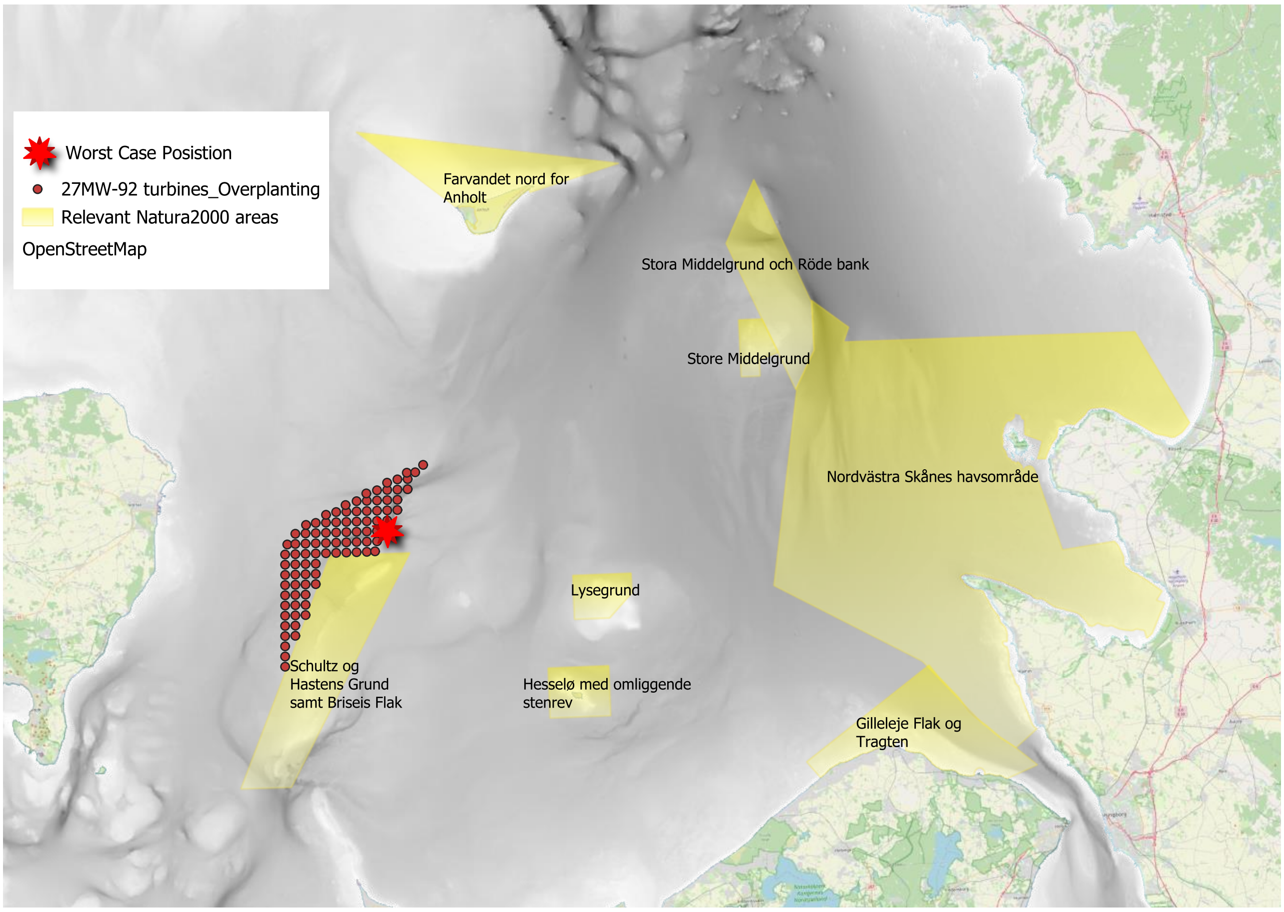

Figure 7-1 - Worst Case Scenario

Due to insufficient research on source modelling for the piling of monopiles, it is assumed that the source behaves as a point source. The point source is further assumed to be at 5 m depth under the assumption that the energy is highest close to the hammer impact, but also considering some lower vibrations at deeper waters.

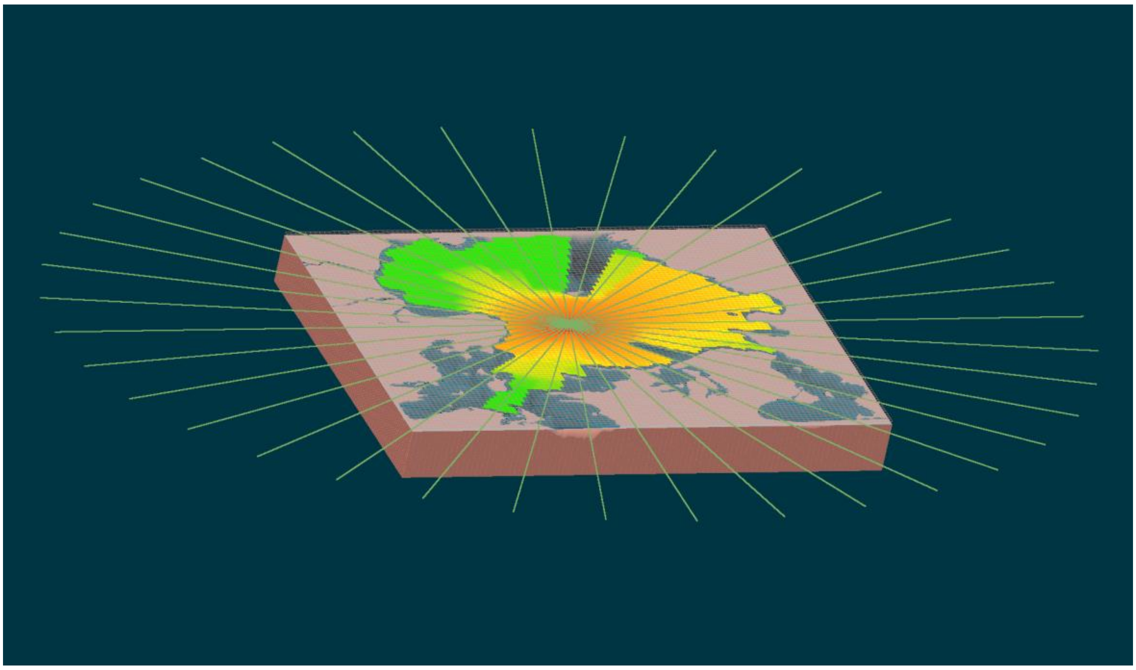

Figure 7-2 Example figure of calculation grid.

8 OCEAN CHARACTERISTICS

Received data from Energinet shows different seabed-substrate compositions. A single seabed composition assumption must be made for the entire calculated area. The seabed composition is estimated to comprise a 2-meter-thick upper layer of sand, followed by an infinite layer of moraine, following received data from Energinet. Note that the uncertainty that stems from the seabed composition is small compared to the magnitude of the calculations.

The sound speed profile (SSP) is calculated using salinity and temperature data from National Oceanic and Atmospheric Administration (NOAA, 2019). The model used for the sound speed estimation is based on MacKenzie [8].

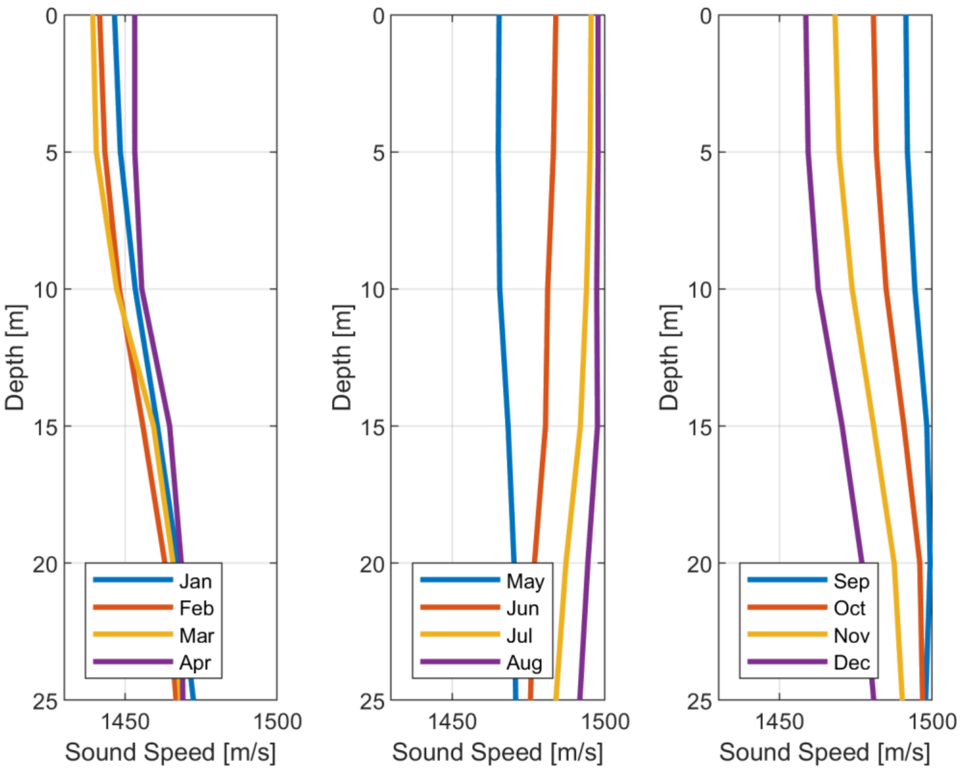

Figure 8-1 - Calculated monthly average sound speed profiles.

Bases on received data, the salinity is decided to be on average 32 ppt. The temperature is assumed to be on average 8 degrees through the water column. The pH value is based on typical values for the relevant area.

- Temperature is assumed to be 8°,
- Salinity(ppt) is given as 32,
- pH value is assumed to be 8

The above factors affect the sound absorption in the sea volume. The sound speed profile for a worst-case scenario was determined by running a test model of one of the scenarios, with two different sound speed profiles. The two sound speed profiles represent the edge cases in the sound speed profile. Determining the worst-case was done by checking the resulting sound levels across the calculated grids for the two sound speed profiles. The mean difference between the two resulting grids was 2.64 dB. The sound speed profile of February resulted in the highest sound levels was considered to represent the worst-case scenario.

In the model, the ocean is assumed to have a calm sea state, which results in lower dispersion and therefore the reflection at the sea surface is close to ideal. This means that the largest possible amount of sound energy is reflected at the surface, resulting in a worst-case scenario.

9 AUDITORY FREQUENCY WEIGHTINGS

Following DEA's guidelines [6], the relevant marine species for Inner Danish waters, including Kattegat, are:

- Low frequency (LF) cetaceans
- High frequency (HF) cetaceans
- Very high frequency (VHF) cetaceans
- Phocid carnivores in water (PCW)

The weighting was conducted using dbSEA, which utilizes the weightings as described in Southall [9].

There are three different types of thresholds which are assessed in this report, the Permanent Threshold Shift (PTS), Temporary Threshold Shift (TTS) and Behavioural Disturbance. The thresholds are described in DEA's guidelines [6].

Table 9-1 – Permanent and temporary threshold shift limits and limits for behavioural disturbance for relevant species.

Species	Weighting	Impact Sounds (I-Type)		
		PTS [dB re 1 µPa] $\mathrm{SEL_{cum}}$ $L_{E,cum,24h,xx}$	TTS [dB re 1 µPa] $\mathrm{SEL_{cum}}$ $L_{E,cum,24h,xx}$	Behavioral Disturbance (BD) [dB re 1 µPa] $L_{\mathrm{p,rms,125\ m}s}$
Harbour porpoise	VHF	155	140	103
White-beaked dolphin Pilot whale	HF	185	170	-
Minke whale	LF	183	168	-
Harbour seal Grey Seal	PCW	185	170	-

10 REFERENCE CASE RESULTS

The reference case is a scenario which represents a practical worst-case scenario without noise mitigating measures. The goal is to determine the magnitude of noise reduction needed for a marine mammal to be able to have a starting position of 200 m from the piling, and still be exposed to less than the PTS criteria.

The $\mathrm{SEL_{cum}}$ has been calculated with appropriate frequency weightings and compared to the PTS levels in Table 9-1, presented with required noise mitigation to comply with the PTS levels. This is calculated for both pile diameters and hammer sequences, and the results are shown in Table 10-1 to Table 10-4.

The position was chose based on the worst-case scenario, shown in Figure 7-1. The maximum required noise reduction by mitigating measures was calculated to be 13.3 dB.

Table 10-1: 6000 kJ 13 m

Species	Weighting	$\mathrm{SEL_{cum}}$ $L_{E,cum,24h,xx}$	Required Noise Mitigation 6000 kJ 13 m [dB]
Harbour porpoise	VHF	153.6	0
White-beaked dolphin	HF	159.8	0
Pilot whale			
Minke whale	LF	194.0	11
Harbour seal	PCW	183	0
Grey seal			

Table 10-2: 6000 kJ 18 m

Species	Weighting	$\mathrm{SEL_{cum}}$ $L_{E,cum,24h,xx}$	Required Noise Mitigation 6000 kJ 18 m [dB]
Harbour porpoise	VHF	156.0	1
White-beaked dolphin	HF	162.2	0
Pilot whale			
Minke whale	LF	196.3	13.3
Harbour seal	PCW	185.3	0.3
Grey seal			

Table 10-3: 4000 kJ 13 m

Species	Weighting	$\mathrm{SEL_{cum}}$ $L_{E,cum,24h,xx}$	Required Noise Mitigation 4000 kJ 13 m [dB]
Harbour porpoise	VHF	153.0	0
White-beaked dolphin	HF	158.9	0
Pilot whale			
Minke whale	LF	192.2	9.2
Harbour seal	PCW	181.4	0
Grey seal			

Table 10-4: 4000 kJ 18 m

Species	Weighting	$\mathrm{SEL_{cum}}$ $L_{E,cum,24h,xx}$	Required Noise Mitigation 4000 kJ 18 m [dB]
Harbour porpoise	VHF	155.3	0.3
White-beaked dolphin	HF	161.3	0
Pilot whale			
Minke whale	LF	194.6	11.6
Harbour seal	PCW	183.8	0
Grey seal			

11 CONSTRUCTION CASE WITH MITIGATION MEASURES

The following represents a realistic scenario of the installation of monopiles in Kattegat OWF. It assumes the piling to be the only active noise source. The goal is to determine a distance-to-threshold (DTT) corresponding to PTS, TTS and BD criteria, denoted as r_{PTS}, r_{TTS} and r_{BD}. The DTT's were calculated with and without noise mitigating measures, based on a model where a marine mammal starts at 50 meters from the source and flees directly away at a speed of 1.5 m/s.

The effect of the double bubble curtain (DBBC) depends on the density and size of the bubbles. According to Bellmann [10] that for a double bubble curtain (DBBC), the effect is assumed to be minimum 8 dB, and the minimum effect from the hydro sound damper (HSD) can be assumed to be 10 dB. These will be the proposed noise mitigating measures during the piling operation. The DEA guidelines state that before any pile driving activity begins, there must be a designated distance within which no animals are present, denoted as r_{safe} ,which shall be assumed. Assuming a use of an acoustic deterrent device (ADD) for 15 minutes, the assumed r_{safe} is 15 minutes times the estimate fleeing speed of an animal of 1.5 m/s, corresponding to 1350 meters. using an acoustic deterrent device (ADD) for 15 minutes, a assumed r_{safe} can be 15 minutes times the estimate fleeing speed of an animal of 1.5 m/s, corresponding to 1350 meters. Appendix B show some example figures of the modelling.

The results are presented in Table 11-1 to Table 11-8. In general, the results indicate that the auditory group LF will have the longest r_{PTS} and r_{TTS}. Note that according to the modelling results the 6000 kJ hammer with a 13 m diameter generates a higher noise level than the 4000 kJ hammer with an 18 m diameter. According to the DEA's guidelines, piling is permitted only if $r_{\mathrm{PTS}} < r_{Safe}$. As shown in Tables 11-1 through 11-8, $r_{\mathrm{PTS}} < r_{\mathrm{safe}}$ for all configurations. Additionally, piling is allowed without the use of an ADD since all r_{PTS} values are less than 50 m, concurring with DEA's guideline of $r_{\mathrm{PTS}} < 200$ m.

Table 11-1: Worst case r_{PTS} and r_{TTS} for relevant species with 6000 kJ hammer and 18 m pile diameter.

Species	Weighting	No damping		DBBC + HSD	
		r_{PTS} [m]	r_{TTS} [m]	r_{PTS} [m]	r_{TTS} [m]
Harbour porpoise	VHF	370	22130	<50	70
White-beaked dolphin Pilot whale	HF	<50	<50	<50	<50
Minke whale	LF	72330	90470	<50	50870
Harbour seal Grey seal	PCW	330	77670	<50	<50

Table 11-2: Worst case r_{BD} for VHF species with 6000 kJ hammer and 18 m pile diameter.

Species	Weighting	No damping	DBBC + HSD
		r_{BD}[m]	r_{BD}[m]
Harbour porpoise	VHF	98219	16516

Table 11-3: Worst case r_{PTS} and r_{TTS} for relevant species for hammer with 6000 kJ and 13 m pile diameter.

Species	Weighting	No damping		DBBC + HSD	
		r_{PTS} [m]	r_{TTS} [m]	r_{PTS} [m]	r_{TTS} [m]
Harbour porpoise	VHF	110	14670	<50	<50
White-beaked dolphin Pilot whale	HF	<50	<50	<50	<50
Minke whale	LF	58750	89330	<50	30290
Harbour seal Grey seal	PCW	<50	69110	<50	<50

Table 11-4: Worst case r_{BD} for VHF species for relevant species for hammer with 6000 kJ and 13 m pile diameter.

Species	Weighting	No damping	DBBC + HSD
		r_{BD}[m]	r_{BD}[m]
Harbour porpoise	VHF	89678	13628

Table 11-5: Worst case r_{PTS} and r_{TTS} for relevant species for hammer with 4000 kJ and 18 m pile diameter.

Species	Weighting	No damping		DBBC + HSD	
		r_{PTS} [m]	r_{TTS} [m]	r_{PTS} [m]	r_{TTS} [m]
Harbour porpoise	VHF	250	14750	<50	70
White-beaked dolphin Pilot whale	HF	<50	<50	<50	<50
Minke whale	LF	57990	90910	<50	29690
Harbour seal Grey seal	PCW	70	65010	<50	<50

Table 11-6: Worst case r_{BD} for VHF species for relevant species for hammer with 4000 kJ and 18 m pile diameter.

Species	Weighting	No damping	DBBC + HSD
		r_{BD} [m]	r_{BD}[m]
Harbour porpoise	VHF	74010	11335

Table 11-7: Worst case r_{PTS} and r_{TTS} for relevant species for hammer with 4000 kJ and 13 m pile diameter

Species	Weighting	No damping		DBBC + HSD	
		r_{PTS} [m]	r_{TTS} [m]	r_{PTS} [m]	r_{TTS} [m]
Harbour porpoise	VHF	90	9950	<50	<50
White-beaked dolphin	HF	<50	<50	<50	<50
Pilot whale					
Minke whale	LF	34990	89350	<50	14370
Harbour seal	PCW	<50	47130	<50	<50
Grey seal					

Table 11-8: Worst case r_{BD} for VHF species for relevant species for hammer with 4000 kJ and 13 m pile diameter.

Species	Weighting	No damping	DBBC + HSD
		r_{BD} [m]	r_{BD}[m]
Harbour porpoise	VHF	50083	9451

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APPENDIX A

Table A-1 Proposed Coordinates of KA OWF

Turbine type : 27MW					
Coordinate system: UTM (North) WGS 84 : Zone 32					
Kattegat					
Total turbines			MW		
92			2484		
User label	**Easting**	**Northing**	**User label**	**Easting**	**Northing**
KG-1	649773	6258345	**KG-47**	633561	6247800
KG-2	646754	6256638	**KG-48**	634760	6247838
KG-3	647953	6256679	**KG-49**	635960	6247876
KG-4	644355	6255355	**KG-50**	637159	6247915
KG-5	645554	6255396	**KG-51**	638359	6247953
KG-6	646754	6255437	**KG-52**	639558	6247993
KG-7	647953	6255479	**KG-53**	640757	6248032
KG-8	641957	6254073	**KG-54**	641957	6248072
KG-9	643156	6254114	**KG-55**	643156	6248112
KG-10	644355	6254154	**KG-56**	633561	6246600
KG-11	645554	6254195	**KG-57**	634760	6246638
KG-12	646754	6254237	**KG-58**	635960	6246676
KG-13	639558	6252794	**KG-59**	637159	6246714
KG-14	640757	6252833	**KG-60**	633561	6245400
KG-15	641957	6252873	**KG-61**	634760	6245437
KG-16	643156	6252913	**KG-62**	635960	6245476
KG-17	644355	6252954	**KG-63**	637159	6245514
KG-18	645554	6252995	**KG-64**	633561	6244200
KG-19	646754	6253036	**KG-65**	634760	6244237
KG-20	637159	6251515	**KG-66**	635960	6244275
KG-21	638359	6251554	**KG-67**	637159	6244314
KG-22	639558	6251593	**KG-68**	633561	6242999
KG-23	640757	6251633	**KG-69**	634760	6243037
KG-24	641957	6251673	**KG-70**	635960	6243075
KG-25	643156	6251713	**KG-71**	633561	6241799
KG-26	644355	6251754	**KG-72**	634760	6241837
KG-27	645554	6251795	**KG-73**	635960	6241875
KG-28	634760	6250238	**KG-74**	633561	6240599
KG-29	635960	6250276	**KG-75**	634760	6240637
KG-30	637159	6250315	**KG-76**	635960	6240675
KG-31	638359	6250354	**KG-77**	633561	6239399
KG-32	639558	6250393	**KG-78**	634760	6239437
KG-33	640757	6250433	**KG-79**	633561	6238199
KG-34	641957	6250473	**KG-80**	634760	6238237
KG-35	643156	6250513	**KG-81**	633561	6236999
KG-36	644355	6250553	**KG-82**	633561	6235798
KG-37	645555	6250594	**KG-83**	633561	6234598
KG-38	634760	6249038	**KG-84**	633815	6248979
KG-39	635960	6249076	**KG-85**	644125	6248172
KG-40	637159	6249115	**KG-86**	636016	6251279
KG-41	638359	6249154	**KG-87**	638366	6252470
KG-42	639558	6249193	**KG-88**	640662	6253619
KG-43	640757	6249232	**KG-89**	643100	6254985
KG-44	641957	6249272	**KG-90**	645541	6256247
KG-45	643156	6249313	**KG-91**	647858	6257422
KG-46	644355	6249353	**KG-92**	648845	6257472

APPENDIX B

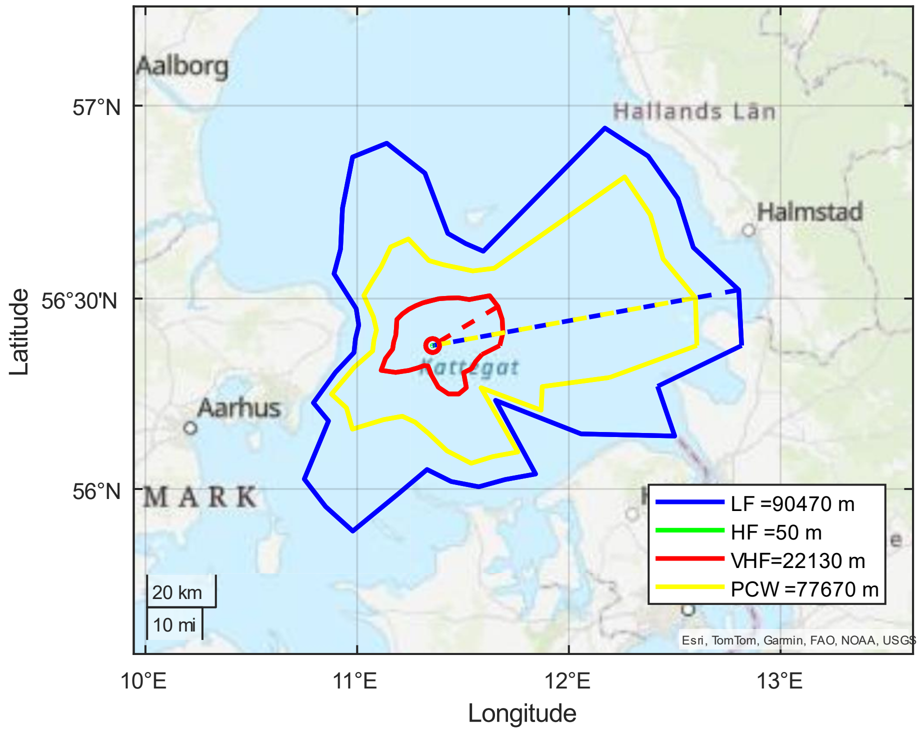

Figure B-1 Noise map with different DTT's for TTS with 6000 kJ Hammer and 18 diameter without damping

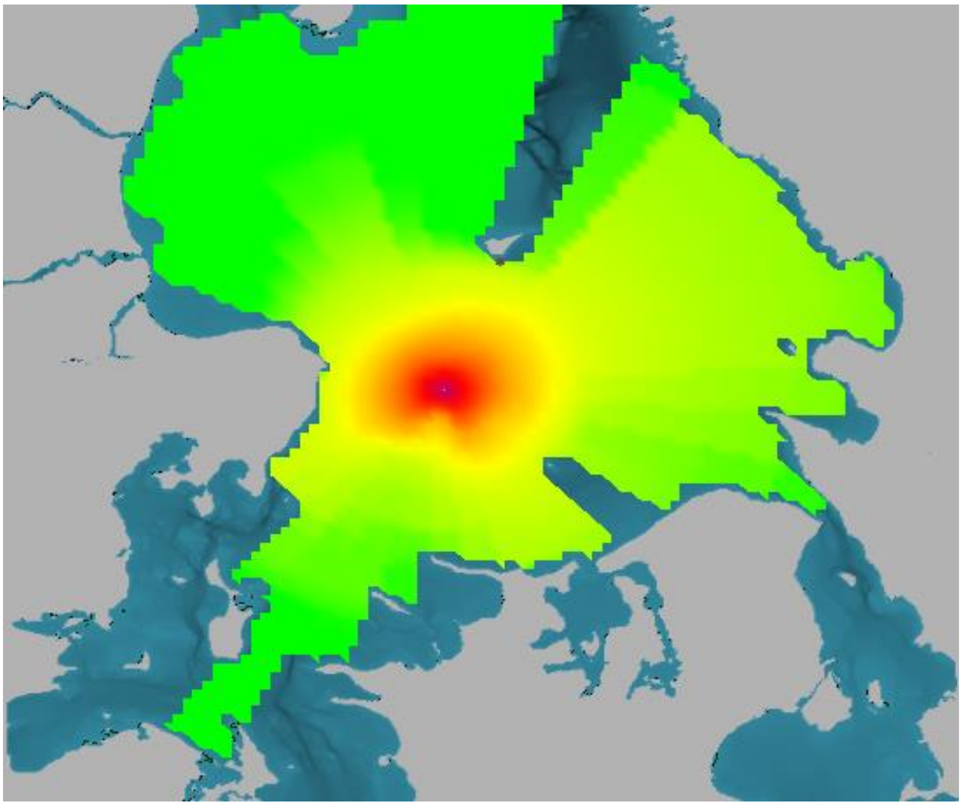

Figure B-2 Visualization of Sound Field

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DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

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