Ran OWF - Note on underwater noice emission

Geotechnical survey activities

Ran Vindpark AB

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Contents

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1 Introduction

In connection with Ran Vindpark ABs intentions to establish the Ran offshore wind farm in Sweden, geotechnical survey activities are required to gather necessary information about the seabed, for the installation of foundations and cables.

The purpose of this note is to conduct a screening of the underwater noise emission from proposed geotechnical survey activities, and to evaluate their potential to inflict harmful doses of noise on relevant species of marine mammals and fish.

2 Description of activities

The geotechnical investigations proposed by Ran Vindpark AB, include the following investigation activities within the survey area. The final survey programme has not been made available to NIRAS, and any of the listed investigation activities may not be required. The evaluation of their impact is therefore covered separately.

Activity	Description
Cone Penetration Test (CPT)/Down-hole CPT	Rods are pushed into the seabed soil by hydraulic force, until target depth. As soil resistance increases to the point where this is no longer possible, drilling is required (mostly in mainly sandy soil conditions).
CPTu	The same as for CPT but also the pore pressure will be measured during the process.
Seismic CPT	Similar to CPT which stops in intervals (each meter till target depth) and an energy impulse will be applied on the seabed surface to measure the response at the CPT rods.
Seabed CPT	The same as CPT, but no drilling will be done to reach the shallow soil depth.
Drilling (boreholes)	Boreholes will be drilled to gain core samples to the target depth for lab tests
P-S-Logging	A borehole drill with stops in intervals (here also each meter till target depth). A sensor will be placed in the bore hole and energy impulse will be applied on the seabed surface (similar to sCPT).
Vibrocore	A small sample tube with a soil catcher will be vibrated into the soil. The vibrator is mounted on top of the tube.

In addition to these sources, the survey vessel contributes to the overall noise emission, primarily while holding position during geotechnical activities using a dynamic positioning (DP) system.

From an underwater noise emission perspective, the intended geotechnical investigations can be divided into the following source categories:

1. Drilling (BH, P-S-Logging)
2. Vibrocore
3. CPT – Cone Penetration Tests (CPT, CPTu, sCPT, Seabed CPT)
4. Survey vessel (Dynamic Positioning system (DP))

3 Criteria for evaluating the impact

For the survey area and surroundings, the marine mammal species of interest are harbour seals, grey seals, and harbour porpoise.

Based on the newest scientific literature, species specific frequency weighted $L_{E,cum,24h}$ threshold values (NOAA, 2018), (Southall B. , et al., 2019) for temporary threshold shift (TTS) and permanent threshold shift (PTS) are used, see Table 3.1, where criteria for both impulsive and non-impulsive noise is provided.

In differentiating between impulsive and non-impulsive criteria for PTS and TTS criteria, the following characterisation from (NOAA, 2018) is followed:

- Impulsive: Sounds that are typically transient, brief (duration < 1 s), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay.
- Non-impulsive: Sounds that can be broadband, narrowband, or tonal, brief, or prolonged, continuous, or intermittent, and typically do not have a high peak sound pressure with rapid rise nor decay time.

Source types which fall under the impulsive PTS/TTS criteria include impact pile driving, airguns, explosives, and certain geophysical survey equipment types, such as sparkers and boomers.

For the non-impulsive PTS and TTS criteria, source types include vibratory pile driving, noise from operational wind turbines, vessel noise, geotechnical equipment types and certain geophysical equipment types. Sources involved in this prognosis, are all classified as non-impulsive. The threshold criteria for impulsive noise are only listed for comparison.

Table 3.1: Threshold criteria for marine mammals. PTS and TTS criteria (NOAA, 2018) for hearing group classifications in (Southall B. , et al., 2019). "xx" notation refers to species specific weighted levels.

Species	Swim speed [m/s]	Threshold criteria $L_{E,cum,24h,xx}$ $[dB\ re.1\ \mu Pa^2 s]$			
		PTS		TTS	
		Non-impulsive	impulsive	Non-impulsive	Impulsive
Harbour Porpoise (VHF)	1.5	173 dB	155 dB	153 dB	140 dB
Seal (PCW)	1.5	201 dB	185 dB	181 dB	170 dB

There are currently no scientifically established threshold criteria for the avoidance behaviour effect of activities with non-impulsive noise characteristics for marine mammals. Impact ranges are therefore not directly calculated for the proposed equipment types; however reflections are provided in the respective sections below.

Most fish, detect sound from the infrasonic frequency range (<20 Hz) up to a few hundred Hz (e.g. Salmon, dab, and cod) whereas some fish species with gas-filled structures in connection with the inner ear (e.g. herring) detect sounds up to a few kHz. The main frequency hearing range for fish is therefore overlapping with the frequencies, produces by most of the suggested geotechnical equipment. As for marine mammals there are no studies defining fish behavioural response threshold for continuous noise sources, and the scientific data addressing TTS from such noise sources is limited. The only studies providing a TTS threshold value for fish is from experiments with goldfish. Goldfish is a freshwater hearing specialist with the most sensitive hearing in any fish species.

The marine fish species that can be found in the Ran OWF area all have a less sensitive hearing, compared to the goldfish (Popper, et al., 2014), and using threshold for goldfish will lead to an overestimation of the impact. Empirical data for several of the fish species without a connection between the inner ear and the gas-filled swim bladder (e.g. different flatfish and Salmonidae, that can be found in the project area) showed no TTS in responses to long term continuous noise exposure (Popper, et al., 2014). In a study by Wysocki et al. (2007), rainbow trout exposed to increased continuous noise (up to 150 dB re 1 µPa rms) for nine months in an aquaculture facility, showed no hearing loss nor any negative health effect.

Impact ranges for behavioural avoidance responses and TTS in fish are therefore not directly calculated for the proposed equipment types, however reflections are provided in the respective sections below.

4 Evaluation of geotechnical survey activity impact

In the following sections, each activity type is evaluated for its potential to cause harmful auditory effects on fish and marine mammals, based on available scientific literature.

4.1 Drilling

There are very few measurements of underwater noise from drilling activities (Erbe & McPherson, 2017), but studies where underwater noise from geotechnical drilling activities has been measured, show that the noise is limited to the low-frequency range. Reported source levels are between $SPL_{RMS} = 142 - 145\ dB\ re. 1\ \mu Pa\ @\ 1m$, with primary frequency content located between 30 Hz – 2 kHz (Erbe & McPherson, 2017), see frequency spectrum as measured in Figure 4.1.

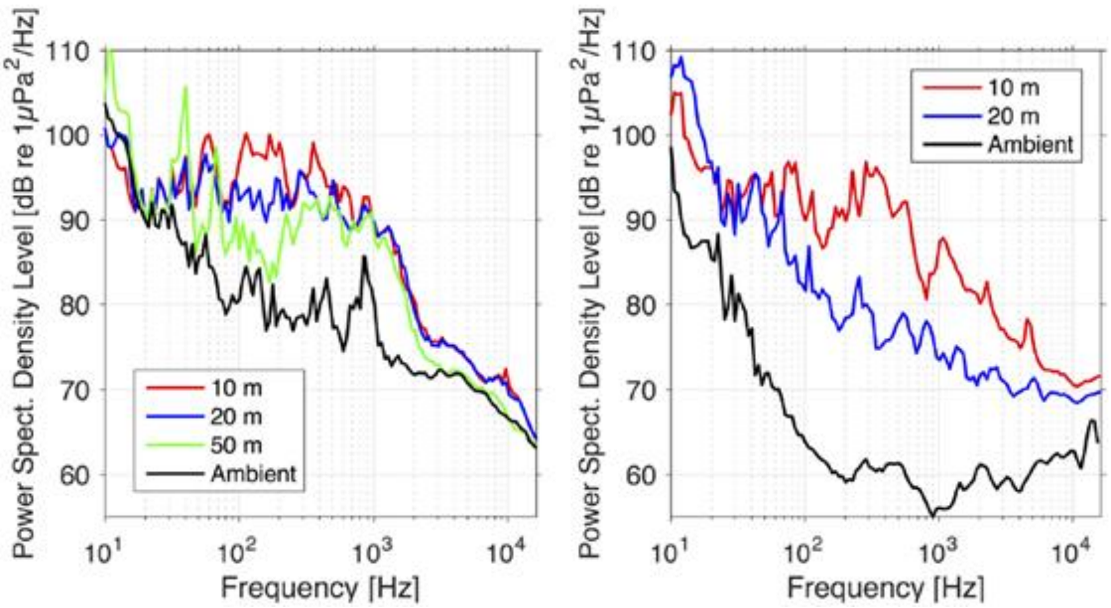


Figure 4.1: Frequency spectrum from underwater noise measurements of shallow water geotechnical drilling at Geraldton (left) and James Price Point (right) (Erbe & McPherson, 2017).

To understand the potential underwater noise emission in metrics relevant for the marine mammals of interest, the frequency spectrum shown in Figure 4.1 was frequency weighted (filtered) with the VHF-weighting curve for harbour porpoise, and PCW-weighting curve for seals, as proposed by NMFS (2018) and Southall et al. (2019). The weighted noise levels should more accurately represent what the marine mammals hear.

Given an unweighted source level of $SPL_{RMS} = 145\ dB\ re.1\ \mu Pa\ @\ 1m$, and based on the reported frequency spectra, the corresponding VHF-weighted source level was assessed to be $SPL_{RMS(VHF)} \approx 110 - 115\ dB\ re.1\ \mu Pa\ @\ 1m$, and PCW-weighted source level of $SPL_{RMS(PCW)} \approx 120 - 125\ dB\ re.1\ \mu Pa\ @\ 1m$.

Drilling is considered a stationary activity, characterized by a non-impulsive continuous noise output. After drilling begins, it continues until completion of the activity. It is therefore considered a predictable noise activity. Frequency wise, it is considered comparable to vessel noise, however with a significantly lower source level. Behaviour effects are therefore considered likely to be less than that of a moving vessel.

The duration of a drilling activity has not been estimated, and a worst case approach is therefore assumed with continuous drilling for 24 hours. For a stationary marine mammal, this would correspond to adding ~50 dB to the source level. For harbour porpoise, the cumulative underwater noise level at 1 m distance would therefore be $SEL_{C24h(VHF)} \approx 160 - 165\ dB\ re.1\ \mu Pa\ @\ 1m$, and for seal $SEL_{C24h(PCW)} \approx 170 - 175\ dB\ re.1\ \mu Pa\ @\ 1m$.

With a PTS threshold criterion for continuous noise of 173 dB, PTS is therefore unlikely to ever occur. For the TTS threshold criteria of 153 dB, it is however possible, that a stationary harbour porpoise could experience TTS at up to 10 m distance. Harbour porpoises are however not stationary, as they constantly hunt for food, and when including an avoidance response in the calculation of the cumulative noise dose, it is unlikely that the harbour porpoise would experience TTS even if located at 1 m distance from the drill at activity onset. For harbour seal, even conservatively assuming stationary behaviour over 24 hours, even the TTS threshold criteria is not met at 1 m distance, and is therefore considered unlikely to occur. The calculated impact ranges for the drilling activity, are summarized in Table 4.1.

Table 4.1: Impact range for drilling activity, assuming fleeing behaviour.

Species	Impact range (m from activity)	
	$SEL_{C24h,<weighting>}$	
	TTS	PTS
Harbour porpoise	< 1 m	< 1 m
Harbour seal	< 1 m	< 1 m

With calculated TTS and PTS impact distances of less than 1 m for both seals and harbour porpoise, it is assessed that auditory injures are unlikely to occur. Behavioural Impact distances for marine mammals are considered likely to be less than that of a moving vessel and is therefore assessed to be negligible.

For fish, no impact distances have been calculated. The frequency content of the drilling noise is within hearing range of fish, however given the low source level of the drilling activity of $SPL_{RMS} = 145\ dB\ re.1\ \mu Pa\ @\ 1m$, it is assessed that underwater noise from drilling activities will have a negligible impact on fish.

If the vessels DP system is active during deployment, retrieval and/or drilling, the impact range will increase. This is covered in section 4.4.

4.2 Vibrocore

Vibrocore equipment may be used to gather core samples. A vibrocorer functions by means of a vibratory hammer driving a hollow steel cylinder into the seabed soil until a target depth is reached, after which the cylinder and vibratory hammer is pulled back up from the seabed and the core can be extracted from within the cylinder.

Measurements of underwater sound emissions from vibrocore equipment with a simultaneously active DP system was investigated in (Reiser, Funk, Rodrigues, & Hannay, 2011). In Figure 4.2 the frequency spectrum of the measured underwater noise emission is provided for the two measurement positions, 207 m (left side plot) and 74 m (right side plot). The duration of a vibrocore activity has not been specified by the client, however has been estimated to be 10 – 45 minutes per deployed location, depending on soil conditions and target depth.

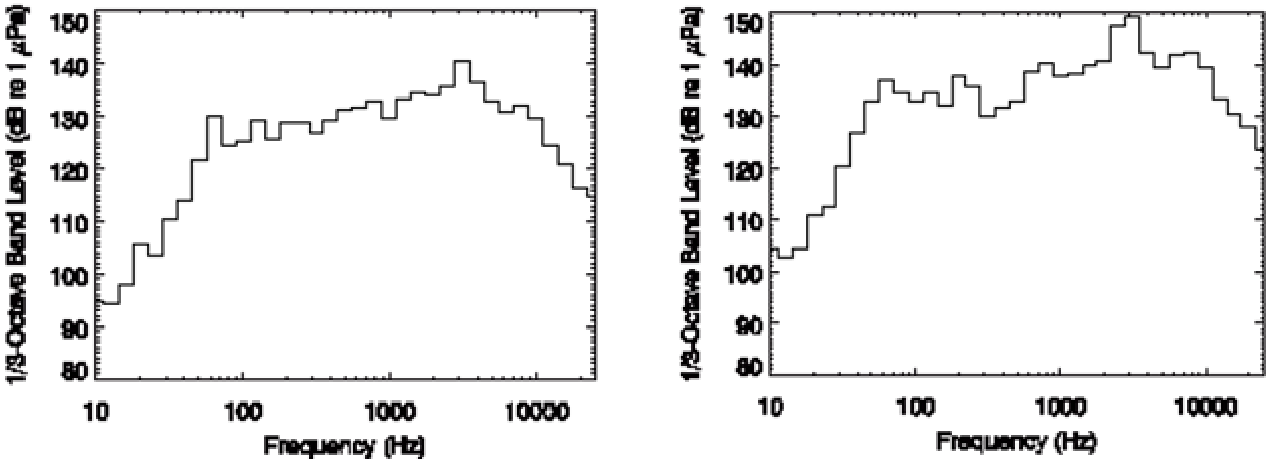


Figure 4.2: Frequency spectrum in 1/3 octave bands from measurement of underwater noise from vibrocore operation at 207 m distance (left) and 74 m (right), (Reiser, Funk, Rodrigues, & Hannay, 2011).

In order to determine impact ranges from the limited information provided in (Reiser, Funk, Rodrigues, & Hannay, 2011), the broadband recorded levels were calculated both unweighted, as well as VHF- and PCW-weighted, based on the 1/3 octave levels presented in Figure 4.2.

In (Reiser, Funk, Rodrigues, & Hannay, 2011), the source level $SPL_{RMS} = 187.4\ dB\ re. 1\ \mu Pa\ @\ 1m$ was also proposed based on a back-calculation from the measurements.

For the 74 m measurement distance, the sound levels are estimated to be:

- Unweighted broadband: $SPL_{RMS} \approx 154\ dB\ @1m$
- VHF-weighted broadband: $SPL_{RMS(VHF)} \approx 139\ dB\ @1m$
- PCW-weighted broadband: $SPL_{RMS(PCW)} \approx 152\ dB\ @1m$

Similarly, for the 207 m measurement distance, the sound levels are estimated to be:

- Unweighted broadband: $SPL_{RMS} \approx 146\ dB\ @1m$
- VHF-weighted broadband: $SPL_{RMS(VHF)} \approx 130\ dB\ @1m$
- PCW-weighted broadband: $SPL_{RMS(PCW)} \approx 144\ dB\ @1m$

Translating this into sound propagation loss factors as a function of distance, it corresponds to approximately 18 dB/decade. The measurement data would suggest, that this approximation is fair both unweighted and PCW-weighted, and slightly conservative VHF-weighted.

Vibrocoring is a stationary activity, with a continuous non-impulsive noise output. It is considered a predictable noise activity in that it does not move during the duration of the activity. Frequency wise, it is considered a broadband signal with significant energy up to 10 kHz. In terms of source level, it is in the same range as cargo, cruise, and containerships, as per reported source levels in (Jiménez-Arranz, Banda, & Cook, 2020). While it is not directly comparable to vessel noise, which is typically considered to have less energy in the higher frequency range, it is instead a stationary non-moving source, and therefore more predictable. Behaviour effects are therefore considered likely to be less than that of a moving cargo, cruise, or container ship.

The duration of the vibrocore activity has not been provided by the client, but from previous experience with geotechnical survey activities and literature (GEO, 2009), NIRAS estimates a conservative operational time up to 1 hour per sample and up to 10 samples taken pr. 24 hour period. For a stationary marine mammal, this would correspond to adding ~36 dB to the source level. For harbour porpoise, the cumulative underwater noise level at 1 m distance would therefore be $SEL_{C24h(VHF)} \approx 166\ dB\ re. 1\ \mu Pa\ @\ 207m$, and for seal $SEL_{C24h(PCW)} \approx 180\ dB\ re. 1\ \mu Pa\ @\ 207m$.

Assuming 18 dB/decade propagation loss, the distance to the PTS threshold criteria for a stationary harbour porpoise is calculated to be ~75 m, and ~900 m to the TTS criteria. For a fleeing harbour porpoise the distances reduce to < 10 m for PTS, and 175 m for TTS.

For seal, assuming stationary behaviour, the corresponding distances are ~200 m for TTS and ~20 m for PTS, while the distances assuming fleeing behaviour are < 10 m for TTS and < 1 m for PTS. The impact ranges calculated for the use of vibrocore, are summarized in Table 4.2.

Table 4.2: Impact range for vibrocore activity, assuming fleeing behaviour

Species	Impact range (m from activity)	
	$SEL_{C24h,<weighting>}$	
	TTS	PTS
Harbour porpoise	175 m	< 10 m
Harbour seal	< 10 m	< 1 m

With calculated PTS impact distances of less than 10 m for harbour porpoise and less than 1 m for seals and with calculated TTS impact distances of 175 m for harbour porpoises and less than 10 m for harbour seals , it is assessed that auditory injures are unlikely to occur. Behavioural Impact distances for marine mammals are considered likely to be less than that of a moving vessel and is therefore assessed to be negligible.

For fish, no impact distances have been calculated. The frequency content of the noise from the vibrocore is within the hearing range of fish, however given the low source level of the vibrocore of $SPL_{RMS} = 154\ dB\ re. 1\ \mu Pa\ @\ 74\ m$, it is assessed that underwater noise from vibrocore will have a negligible impact on fish.

4.3 Cone Penetration Test (CPT)

Two main types of CPT activities have been proposed; CPT and Seismic CPT. Common for both types, a CPT cone is pushed into the seabed, and through sensors mounted in/on the cone, the vibration through the sediment is registered, and provides data on the sediment. With seismic CPT, in addition to the CPT cone, an excitation pulse is generated by a device placed on the seabed nearby, which creates a motion and transfers it into the seabed for further data input. There are different designs, one of which consist of a frame-mounted, cylinder-encapsuled, spring loaded weight that, on release, is accelerated against an end-cap. This creates an impact pulse. The pulse is then structurally transferred through the frame into the seabed. The noise source in this action consists of the noise from the impact itself, as well as from the vibration of the frame.

It has not been possible to acquire underwater noise measurements for this type of equipment, and according to GEO (one of the companies providing such services), no noise measurements have yet been conducted. It is therefore not possible to compare noise levels to any thresholds. A study using a mini-CPT was however found

(Erbe & McPherson, 2017), wherein the noise from the CPT system itself was not possible to measure over the noise from the survey vessel. This is due to the use of a Dynamic Positioning (DP) system on the survey vessel, which maintains vessel position, using thrusters, while the tests are conducted. This is discussed further in section 4.4.

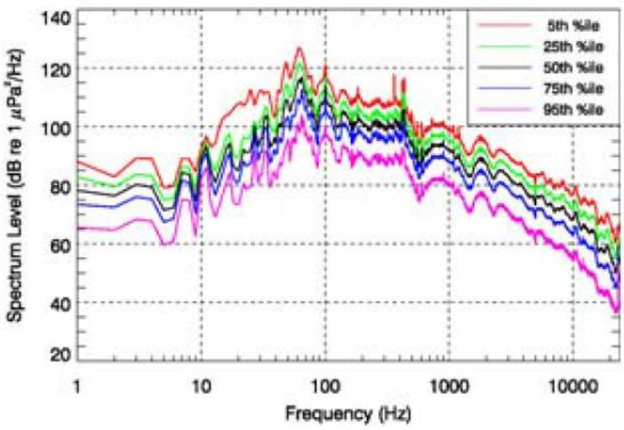
For the seismic source used in seismic CPT tests, noise emission is considered to have two potential sources. The impact of the weight against the endcap, and the vibration of the frame. The impact of the weight against the endcap, occurs inside a closed metallic cylinder, and it is therefore assessed to be effectively attenuated, and insignificant relative to any impact on marine mammals and fish. While the vibration of the frame occurs in direct contact with the water, it is not expected to result in a significant noise emission, rather a low amplitude "ringing" effect. It is not expected to cause any negative impact on marine mammals or fish at any distance. It must however be emphasized, that the above assessment relies only on the supplier's description of the equipment operation, and a qualified guess on the impact.

The CPT and seismic CPT are assessed to cause underwater noise levels at low levels in relation to the marine mammals hearing abilities, however while the CPT systems themselves do not produce significant noise, the survey vessel DP system is expected to be active during CPT tests, and is expected to cause measurable noise levels.

4.4 Vessel noise (Dynamic positioning)

While the geotechnical survey is undertaken, the survey vessel is expected to hold its position using "Dynamic Positioning," (DP mode), where vessel thrusters and propellers counteract the forces applied on the vessel by the environment. This action results in underwater noise emission, as documented by (Reiser, Funk, Rodrigues, & Hannay, 2011). Here, a source noise level of $SPL_{RMS} = 175.9\ dB\ re. 1\ \mu Pa\ @1m$ was back-calculated based on measurements at 207 m and 74 m, and with frequency content as shown in Figure 4.3.

No third octave sound levels were available for the measurements, however based on the frequency spectrum and reported unweighted source level, a VHF-weighted source level is estimated to be $SPL_{RMS(VHF)} \approx 143 - 146\ dB\ re. 1\ \mu Pa\ @1m$, and $SPL_{RMS(PCW)} \approx 153 - 156\ dB\ re. 1\ \mu Pa\ @1m$ for seal.



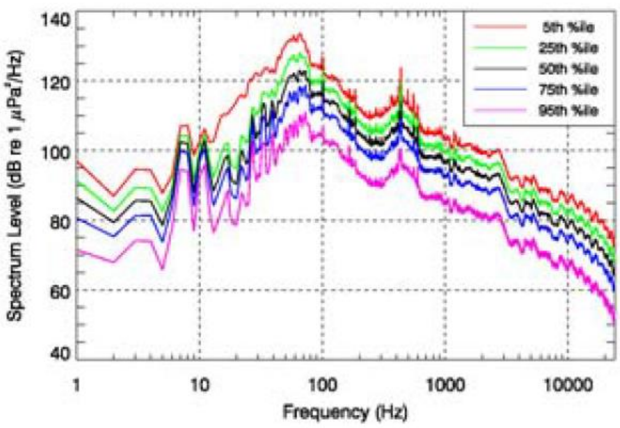


Figure 4.3: Frequency spectrum from measurement of underwater noise from survey vessel "Ocean Pioneer" in DP mode, measured at 207 m distance (left) and 74 m (right) (Reiser, Funk, Rodrigues, & Hannay, 2011).

The duration of the DP system per deployment has not been provided by the client, but from previous experience with geotechnical survey activities and literature (GEO, 2009), NIRAS estimates a conservative operational time up to 1 hour per sample, and a total of 30 minutes of deployment and retrieval. For a stationary marine mammal, this would correspond to adding ~38 dB to the source level. For harbour porpoise, the cumulative underwater noise level at 1 m distance would therefore, in the conservative case be $SEL_{C24h(VHF)} \approx 146 + 38\ dB = 184\ dB\ re. 1\ \mu Pa\ @\ 1m$, and for seal $SEL_{C24h(PCW)} \approx 194\ dB\ re. 1\ \mu Pa\ @\ 1m$. Assuming a conservative 15 dB/decade propagation loss, the distance to the PTS threshold criteria for a stationary harbour porpoise is calculated to be < 10 m, and ~110 m to the TTS criteria. For a fleeing harbour porpoise the distances reduce to < 1 m for PTS, and < 10 m for TTS.

For seal, assuming stationary behaviour, the corresponding distances are < 10 m for TTS and < 1 m for PTS, while the distances assuming fleeing behaviour are < 1 m for TTS and < 1 m for PTS. The impact ranges are summarized in Table 4.3.

Table 4.3: Impact range for Vessel including Dynamic Positioning, assuming fleeing behaviour

Species	Impact range (m from activity)	
	$SEL_{C24h,<weighting>}$	
	TTS	PTS
Harbour porpoise	< 10 m	< 1 m
Harbour seal	< 1 m	< 1 m

With calculated PTS impact distances of less than less than 1 m for both harbour porpoises and seals and with calculated TTS impact distances of less than 10 m for harbour porpoises and less than 1 m for harbour seals, it is assessed that auditory injures are unlikely to occur. Behavioural impact distances for marine mammals are considered likely to be similar to that of a moving vessel and is therefore assessed to be negligible.

For fish, no impact distances have been calculated. The frequency content of the underwater noise from the DP system is within hearing range of fish, however given the low source level of the DP system of $SPL_{RMS} = 175.9\ dB\ re. 1\ \mu Pa\ @\ 1\ m$, it is assessed that underwater noise from the DP system will have a negligible impact on fish.

4.5 Summary

A summary of the evaluated impact ranges is provided in Table 4.4.

Table 4.4: Summary of impact ranges, assuming fleeing behaviour.

Activity type	Harbour porpoise (VHF)		Seal (PCW)	
	PTS	TTS	PTS	TTS
Drilling	< 1 m	< 1 m	< 1 m	< 1 m
Vibrocore	< 10 m	175 m	< 1 m	< 10 m
CPT	-	-	-	-
Vessel (DP)	< 1 m	< 10 m	< 1 m	< 1 m

Overall, the underwater noise impact ranges from the geotechnical survey activities (Drilling, Vibrocore, CPT and DP) are limited for both marine mammals and fish. It is therefore assessed that underwater noise from all of the suggested geotechnical equipment activities have a negligible impact on both marine mammals and fish.

5 References

Erbe, C., & McPherson, C. (2017). Underwater noise from geotechnical drilling and standard penetration testing. The Journal of the Acoustical Society of America 142(EL281).

GEO. (2009). *Anholt/Djursland Offshore Wind Farm, Geotechnical Investigations, Cable Corridors, Geotechnical Report – CPT tests and vibrocores - Report 2.* Kgs. Lyngby, Denmark: GEO.

Jiménez-Arranz, G., Banda, N., & Cook, S. W. (2020). *Review on Existing Data on Underwater Sounds Produced by the Oil and Gas Industry.* Seiche Ltd.

NMFS. (2018). *revision to technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic thresholds for onset of permanent and temporary threshold shifts (83 FR 28824).* Washington, DC: National Oceanic and Atmospheric Administration, U.S. Department of Commerce.: National Marine Fisheries Service.

NOAA. (2018). *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0), NOAA Technical Memorandum NMFS-OPR-59.* Silver Spring, MD 20910, USA: April, National Marine Fisheries Service.

Popper, A., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., . . . Southall, B. L. (2014). Sound exposure guidelines for fishes and sea turtles. ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI.

Reiser, C. M., Funk, D. W., Rodrigues, R., & Hannay, D. (2011). *Marine mammal monitoring and mitigation during marine geophysical surveys by Shell Offshore, Inc. in the Alaskan Chukchi and Beaufort seas, July–October 2010: 90-day report. LGL Rep. P1171E–1.* Rep. from LGL Alaska Research Associates Inc., Anchorage, AK, and JASCO Applied Sciences, Victoria, BC for Shell Offshore Inc, Houston, TX, Nat. Mar. Fish. Serv., Silver Spring, MD, and U.S. Fish and Wild. Serv., Anchorage, AK. 240 pp, plus appendices.

Southall, B. L., Finneran, J. J., Reichmuth, C., Nachtigall, P. E., Ketten, D. R., Bowles, A. E., . . . Tyack, P. L. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals 45(2)*, 125-232, DOI 10.1578/AM.45.2.2019.125.

Southall, B., Finneran, J., Reichmuth, C., Nachtigall, P., Ketten, D., Bowles, A., . . . Tyack, P. (2019). Marine mammal noise exposure criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals, 45(2), 125-323.

Wysocki, L., Davidson, J. I., & Smith, M. (2007). Effects of aquaculture production noise on hearing, growth, and disease resistance of rainbow trout Oncorhynchus mykiss. Aquaculture 272:687–697.