9 September 2019

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MBS Environmental
4 Cook Street, West Perth WA 6005

Attention: **Spencer Shute**

Dear Spencer

Subsea 7 Learmonth Bundle Fabrication Facility
Construction and Operational Underwater Noise: Screening Assessment

This technical letter provides a screening-level assessment of underwater noise impacts associated with the proposed Subsea 7 Learmonth Bundle Fabrication Facility project.

The assessment process involves the following elements:

- Noise assessment criteria for marine fauna species to be assessed, including marine mammals, fishes and sea turtles;
- Major noise sources and their noise source levels associate with the construction and operation of the project;
- Preliminary modelling prediction of underwater noise propagations; and
- The zones of impact estimate for marine fauna species assessed based on criteria set out.

The assessment results show that the noise emissions generated by relevant activities during the construction and operational phase of the project (i.e. predominantly vessel noise associated with rock dumping and the pipeline Bundle launch and tow) are generally low, and it is unlikely that these activities cause significant adverse impacts (i.e. physiological impacts) on relevant marine fauna species assessed (i.e. marine mammals, fishes and sea turtles).

Yours sincerely

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Checked/SS
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1 Marine Noise Impact Assessment Criteria

1.1 Impact of noise on marine fauna species

The effects of noise and the distances over which effects extend depend on the acoustic characteristics of the noise (e.g. level, spectral content, temporal characteristics (e.g. impulsive[1] or non-impulsive/continuous[2]), etc.). The potential impacts of noise on marine fauna species include mortality, physical and hearing damage, masking of communication and other biological important sounds, and alteration of behaviour (Richardson et al, 1995; Hasting and Popper, 2005). In general, underwater noise impacts on marine fauna species may be divided into two categories, behavioural impacts and physiological impacts.

1.1.1 Behavioural impacts

Behavioural responses to noise include changes in vocalisation, resting, diving and breathing patterns, changes in mother-infant relationships, and avoidance of the noise sources. Masking of biologically important sounds may interfere directly with communication and social interaction. Secondary behavioural effects such as inhibited reproduction cycles and other changes in behaviour may also occur.

1.1.2 Physiological impacts

Physiological effects of underwater noise are primarily associated with the auditory system which is likely to be most sensitive to noise. The exposure of the auditory system to a high level of noise for a specific duration can cause a reduction in the animal's hearing sensitivity, or an increase in hearing threshold. If the noise exposure is below some critical sound energy level, the hearing loss is generally only temporary, and this effect is called temporary hearing threshold shift (TTS). If the noise exposure exceeds the critical sound energy level, the hearing loss can be permanent, and this effect is called permanent hearing threshold shift (PTS).

In a broader sense, physiological impacts also include non-auditory physiological effects. Other physiological systems of marine animals potentially affected by noise include the vestibular system, reproductive system, nervous system, liver or organs with high levels of dissolved gas concentrations and gas filled spaces. Noise at high levels may cause concussive effects, physical damage to tissues and organs, cavitation or result in rapid formation of bubbles in venous system due to massive oscillations of pressure.

1.2 Marine mammals

Marine animals do not hear equally well at all frequencies within their functional hearing range. Based on the hearing range and sensitivities, Southall et al (2019) have categorised marine mammal species (i.e. cetaceans and pinnipeds) into six underwater hearing groups: low-frequency (LF), high-frequency (HF), very high-frequency (VHF) cetaceans, Sirenians (SI), Phocid carnivores in water (PCW) and Other marine carnivores in water (OCW).

The potential noise effects on animals depend on how well the animals can hear the noise. Frequency weighting is a method of quantitatively compensating for the differential frequency response of sensory systems (Southall et al, 2007 & 2019).

When developing updated scientific recommendations in marine mammal noise exposure criteria, Southall et

[1] Impulsive noise is typically very short (with seconds) and intermittent with rapid time and decay back to ambient levels. E.g. noise from pile driving, seismic airguns and seabed survey sonar signals.

[2] Non-impulsive or continuous noise refers to a noise event with pressure level remains above ambient levels during an extended period of time (minutes to hours), but varies in intensity with time. E.g. noise from marine vessels.

al (2019) adopt the auditory weighting functions as expressed in the equation below, which are based on the quantitative method by Finneran (2015 & 2016) and are in consistent with the U.S. National Oceanic and Atmospheric Administration (NOAA) technical guidance (NMFS, 2016 & 2018).

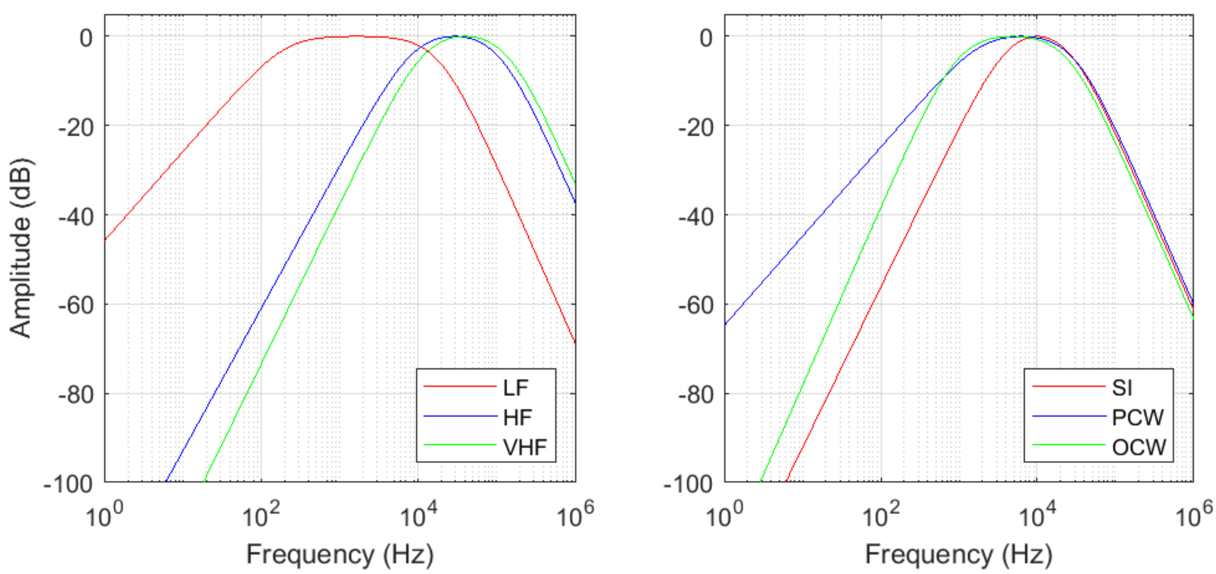
$$W(f) = C + 10log10\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\} \qquad (2.1)$$

Table 1 lists the auditory weighting parameters for the six hearing groups. The corresponding auditory weighting functions for all hearing groups are presented in **Figure 1.**

Table 1 Parameters for the auditory weighting functions

Marine mammal hearing group	*a*	*b*	*f_1 (Hz)*	*f_2 (Hz)*	*C (dB)*
Low-frequency cetaceans (LF)	1.0	2	200	19,000	0.13
High-frequency cetaceans (HF)	1.6	2	8,800	110,000	1.20
Very high-frequency cetaceans (VHF)	1.8	2	12,000	140,000	1.36
Sirenians (SI)	1.8	2	4,300	25,000	2.62
Phocid carnivores in water (PCW)	1.0	2	1,900	30,000	0.75
Other marine carnivores in water (OCW)	2.0	2	940	25,000	0.64

Figure 1 Auditory weighting functions - LF, HF, VHF, SI, PCW and OCW



1.2.1 Noise impact criteria for marine mammals

There have been extensive scientific studies and research efforts to develop quantitative links between marine noise and impacts on marine fauna species. For example, Southall et al (2007 & 2019) have proposed noise exposure criteria associated with various sound types, including impulsive noise (e.g. piling noise and seismic airgun noise) and non-impulsive noise (e.g. vessel and drilling noise)) for certain marine mammal species (i.e. cetaceans and sirenians and carnivores), based on review of expanding literature on marine mammal hearing and on physiological and behavioural responses to anthropogenic sounds.

The newly updated scientific recommendations in marine mammal noise exposure criteria (Southall et al, 2019) propose PTS-onset and TTS-onset criteria for both impulsive noise and non-impulsive noise events. The PTS-onset and TTS-onset criteria for impulsive noise incorporate a dual-criteria approach based on both peak sound pressure level (SPL) and cumulative sound exposure level (SEL) within a 24-hour period (SEL_{24hr}). However, the PTS-onset and TTS-onset criteria for non-impulsive noise, such as noise from marine vessels that is applicable for this project, as outlined in **Table 2** are based on cumulative SEL within a 24-hour period (SEL_{24hr}) only.

For behavioural changes, the widely used assessment criterion for the onset of possible behavioural disruption in marine mammals is root-mean-square (RMS) SPL of 120 dB re 1µPa for non-impulsive noise (NMFS, 2013), as shown in **Table 3.**

Table 2 PTS- and TTS-onset threshold levels for marine mammals exposed to non-impulsive noise

Marine mammal hearing group	PTS and TTS threshold levels – non-impulsive noise	
	Injury (PTS) onset	**TTS onset**
	SEL_{24hr}, dB re 1µPa^2·S (weighted)	SEL_{24hr}, dB re 1µPa^2·S (weighted)
Low-frequency cetaceans (LF)	199	179
High-frequency cetaceans (HF)	198	178
Very high-frequency cetaceans (VHF)	173	153
Sirenians (SI)	206	186
Phocid carnivores in water (PCW)	201	181
Other marine carnivores in water (OCW)	219	199

Table 3 The behavioural disruption threshold level for marine mammals – non-impulsive noise

Marine mammal hearing group	Behavioural disruption threshold levels, non-impulsive noise RMS SPL, dB re 1µPa
All hearing groups	120

1.3 Fishes and sea turtles

In general, limited scientific data are available regarding the effects of sound for fishes and sea turtles. As such, assessment procedures and subsequent regulatory and mitigation measures are often severely limited in their relevance and efficacy. To reduce regulatory uncertainty for all stakeholders by replacing precaution with scientific facts, the U.S. National Oceanic and Atmospheric Administration (NOAA) convened an international panel of experts to develop noise exposure criteria for fishes and sea turtles in 2004, primarily based on published scientific data in the peer-reviewed literature. The panel was organized as a Working Group (WG) under the ANSI-Accredited Standards Committee S3/SC 1, Animal Bioacoustics, which is sponsored by the Acoustical Society of America.

The outcomes of the WG are broadly applicable sound exposure guidelines for fishes and sea turtles (Popper *et al*., 2014), considering the diversity of fish and sea turtle species, the different ways they detect sound, as well as various sound sources and their acoustic characteristics. The sound exposure criteria for sound sources relevant to the project, i.e. non-impulsive noise from marine vessels, are presented in **Table 4**.

Table 4 Noise exposure criteria for shipping and continuous sounds – fishes and sea turtles

Type of animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recovery injury	TTS	Masking	
Fish: no swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder is not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB rms for 48h	158 dB rms for 48h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) High	(N) Moderate (I) Moderate (F) Low

Notes: rms sound pressure levels (RMS SPL) dB re 1 μPa. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

1.4 Zones of bioacoustics impact

The received noise levels within and around the project area can be predicted using known source levels in combination with models of sound propagation transmission loss between the source and the receiver locations. Zones of impact can be determined by comparison of the predicted received levels to the noise exposure criteria.

Predicted zones of impact define the environmental footprint of the noise generating activities and indicate the locations within which the activities may have an adverse impact on a marine fauna species, either behaviourally or physiologically. This information can be used to assess the risk (likelihood) of potential adverse noise impacts, by combining the acoustic zones of impact with ecological information such as habitat significance and migratory routes in the affected area.

2 Underwater Noise Modelling Predictions

2.1 Underwater noise assessment scenarios and source levels

A list of modelling scenarios with relevant major noise-generating equipment are developed and outlined as in in **Table 5** below, based on relevant information provided in regards to construction and operational activities of the proposed project.

Table 5 Potential major scenarios to be assessed and relevant noise sources

Activities / Scenarios		Major underwater noise sources
Construction phase	Launchway construction, involving minor back-hoe/excavation work, rock armour/concrete mattress dumping	Marine barge/vessel (e.g. TSHD) for rock armour dumping
Operational phase	The pipeline Bundle launch and tow using the Controlled Depth Tow Method (CDTM)	Leading tugs (x2), e.g. Anchor Handling Tugs (AHTs) SIEM AHTS VS491 CD Trailing tug (x1), ROV Command Vessel (x1), e.g. MMA Pinnacle

Construction phase

The construction phase of the project involves the launchway construction, including minor back-hoe work, rock armour dumping and placement of pre-fab concrete panels. It is understood the rock armour dumping is to be vessel based operation, and is expected to be the major noise generating activities as the vessel is operating with propellers and thrusters inducing cavitation noise underwater, as well as the splash, tumble and grinding of rocks during the placement process.

It is assumed the rock armour dumping is to be undertaken on a trailing suction hopper dredger (TSHD) with a typical overall RMS source level of 182 dB re 1µPa @ 1m (Wyatt, 2008).

Operational phase

The operational phase of the project involves the launch and tow of the pipeline Bundle using two leading tugs (e.g. anchor handling tugs (AHTs)), one trailing tug and one ROV command vessel.

The major noise emissions from the operational phase of the projects are expected to be from the cavitation noise generated by propellers and thrusters, with energy predominantly below 1 kHz.

The AHTs, trailing tug and command vessel have typical RMS source levels of 184 dB re 1µPa @ 1m (Wyatt, 2008), with an overall combined source level for the operational scenario as 190 dB re 1µPa @ 1m. The assumed overall noise level represent the worst case noise emissions, considering only two leading tugs to be on high power operations, with the expected low power operations for both trailing gut and ROV support vessel, as well as the distances between vessels.

2.2 Preliminary modelling prediction methodology

Underwater noise propagation models predict the sound transmission loss between noise sources and receivers. Providing the source level (*SL*) of the noise source is known, the predicted transmission loss (*TL*) is then used to predict the received level (*RL*) at the receiver location as:

$$RL = SL - TL \tag{1}$$

The transmission loss between the noise source and the receiver may be described by a logarithmic relationship with an attenuation factor *N*:

$$TL = N*log10(R) \tag{2}$$

Where *R* is the distance between the noise source and the receiver.

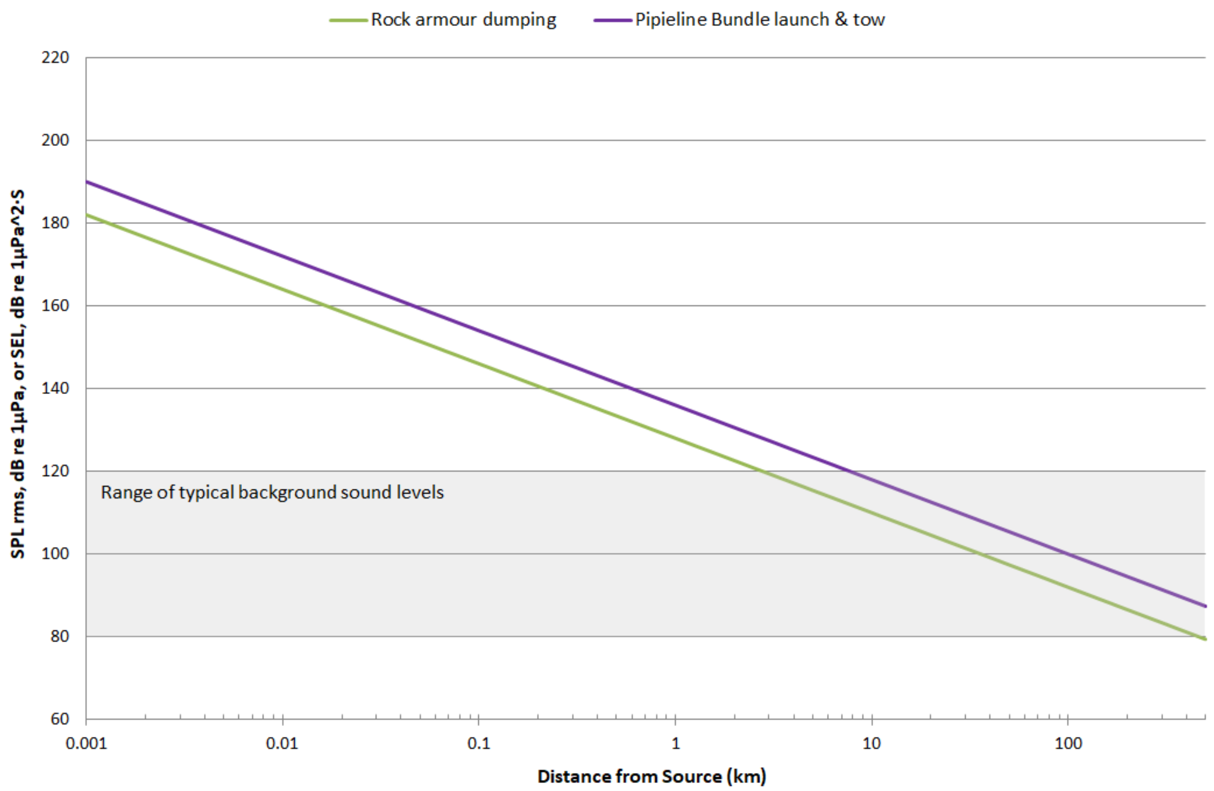
In shallow water environment (with water depths up to a few hundred meters), noise propagation is highly dependent on the properties of the bottom and the surface as well as the properties of the fluid. Parameters such as depth and the bottom properties can vary with distance from the source. Sound energy at low frequencies may be transferred directly into the sea floor, rather than propagating through the water. Overall, the transmission loss in shallow water is a combination of cylindrical spreading effects, bottom interaction effects (absorption) at lower frequencies and scattering losses at high frequencies. Considering the very shallow water environment with the Gulf of Exmouth, it is expected strong interaction between sound field and seabed, and the attenuation factor *N* is assumed to be 18 for this study which is overall close to spherical spreading loss.

The predicted overall received noise levels with distance from the two modelling scenarios are presented in **Figure 2** below. The typical range of background noise levels 80 – 120 dB re 1µPa are also highlighted in the figure.

For the cumulative SEL calculations, two exposure scenarios are considered, i.e. a 24-hr continuous exposure scenario which represents the worst case consideration, and a 0.5-hr continuous exposure which is more realistic exposure duration as well as for comparison purpose.

Typical spectral curve patterns are used for the non-impulsive vessel noise for their relevant frequency-weighted SEL calculations.

Figure 2 Overall noise level attenuation with distance (with an attenuation factor of 18) to typical background levels



2.3 Estimated zones of impact

Table 6 and **Table 7** below present the zones of cumulative impact for marine mammals based on 24-hour and half an hour continuous exposure respectively, from the two modelling scenarios during both construction phase (i.e. rock armour dumping) and operational phase (i.e. pipeline Bundle launch and tow) of the project as proposed in **Section 2.1**.

2.3.1 Construction phase

For the construction scenario of the project, i.e. the rock armour dumping scenario and affected marine animals stay at the fixed distance from the source over the entire 24-hour period, LF cetaceans have the highest PTS-onset and TTS-onset impact zones among all marine mammal hearing groups, with the PTS-onset zone up to 30 m and TTS-onset zone up to 400 m from the source location.

However, with a decreased exposure period, the zones of impact will be reduced significantly. For an exposure period of half an hour, the PTS-onset zone is predicted to be less than 10 m from the construction scenario noise source for LF cetaceans, and TTS-onset zone within 20 m. For marine mammals of other hearing groups, they have relatively lower impact zones and nearly no PTS-onset and TTS-onset are predicted to occur for the rest of five hearing groups due to such the short duration exposure. This exposure period is more realistic for the characteristics of the rock dumping activity scenario and marine animal dynamic movements.

As presented in **Table 8**, potential behavioural disturbance from the non-impulsive noise emissions from construction phase scenario of the project is predicted to occur for marine mammals of all hearing groups up to 2.2 km from the rock dumping locations.

2.3.2 Operational phase

For the operational scenario of the project, i.e. the pipeline Bundle launch or tow continuous operation and affected marine animals stay at the fixed distance from the source over the entire 24-hour period, LF cetaceans have the highest PTS-onset and TTS-onset impact zones among all marine mammal hearing groups, with the PTS-onset zone up to 70 m and TTS-onset zone up to 900 m from the source location.

With a decreased exposure period, the zones of impact will be reduced significantly. For an exposure period of half an hour, the PTS-onset zone is predicted to be less than 10 m from the noise source for LF cetaceans, and TTS-onset zone within 70 m. For marine mammals of other hearing groups, they have relatively lower impact zones and nearly no PTS-onset is predicted to occur for the rest of five hearing groups due to such the short duration exposure. This exposure period is more realistic for impact assessment purpose, considering the operational characteristics of the modelling scenario and marine animal dynamic movements.

Potential behavioural disturbance from the non-impulsive noise emissions from operational scenario of the project is predicted to occur for marine mammals of all hearing groups up to 8.0 km from the vessel locations.

Table 6 Zones of cumulative impact from non-impulsive noise for PTS and TTS – marine mammals - 24 hours exposure duration. (C) – Construction scenario; (O) – Operational scenario

Marine mammal hearing group	Zones of impact – maximum horizontal perpendicular distances from source to cumulative impact threshold levels			
	Injury (PTS) onset		TTS onset	
	Criteria – Weighted SEL_{24hr} dB re 1 $\mu Pa^2 \cdot s$	Maximum threshold distance, m	Criteria – Weighted SEL_{24hr} dB re 1 $\mu Pa^2 \cdot s$	Maximum threshold distance, m
Low-frequency cetaceans (LF)	199	30 (C) 70 (O)	179	400 (C) 900 (O)
High-frequency cetaceans (HF)	198	- (C) <10 (O)	178	<10 (C) 40 (O)
Very high-frequency cetaceans (VHF)	173	<10 (C) 30 (O)	153	60 (C) 400 (O)
Sirenians (SI)	206	- (C) <10 (O)	186	<10 (C) 50 (O)
Phocid carnivores in water (PCW)	201	<10 (C) 20 (O)	181	70 (C) 300 (O)
Other marine carnivores in water (OCW)	219	- (C) <10 (O)	199	<10 (C) 30 (O)

Note: a dash indicates the threshold is not reached.

Table 7 Zones of cumulative impact from non-impulsive noise for PTS and TTS – marine mammals – 0.5 hours exposure duration. (C) – Construction scenario; (O) – Operational scenario

Marine mammal hearing group	Zones of impact – maximum horizontal perpendicular distances from source to cumulative impact threshold levels			
	Injury (PTS) onset		TTS onset	
	Criteria – Weighted SEL_{24hr} dB re 1 μPa^2·s	Maximum threshold distance, m	Criteria – Weighted SEL_{24hr} dB re 1 μPa^2·s	Maximum threshold distance, m
Low-frequency cetaceans (LF)	199	<10 (C) (O)	179	20 (C) 70 (O)
High-frequency cetaceans (HF)	198	- (C) (O)	178	<10 (C) 20(O)
Very high-frequency cetaceans (VHF)	173	- (C) <10 (O)	153	<10 (C) 30(O)
Sirenians (SI)	206	- (C) (O)	186	<10 (C) (O)
Phocid carnivores in water (PCW)	201	- (C) <10 (O)	181	<10 (C) 20(O)
Other marine carnivores in water (OCW)	219	- (C) (O)	199	<10 (C) (O)

Note: a dash indicates the threshold is not reached.

Table 8 Zones of immediate impact from non-impulsive noise for behavioural disturbance – marine mammals. (C) – Construction scenario; (O) – Operational scenario

Type of animal	Zones of impact – maximum horizontal distances from source to impact threshold levels	
	Behavioural disturbance	
	Criteria - RMS SPL, dB re 1μPa	Maximum threshold distance, m
Marine mammals	120	2,200 (C) 8,000 (O)

As indicated in **Table 4**, the non-impulsive marine vessel noise emissions from both construction and operational scenarios have low physiological impacts (both mortality and recovery injury) at near field on fish and sea turtle species, and moderate to low behavioural impacts at immediate and far field on fish and sea turtle species.

3 Conclusions

The screening level assessment results show that the noise emissions generated by relevant activities during the construction and operational phase of the project are generally low, and it is unlikely that these activities cause significant adverse impacts (i.e. physiological PTS and TTS impacts) on relevant marine fauna species assessed (i.e. marine mammals, fishes and sea turtles).

For marine mammals, the threshold distances of the potential behavioural response are predicted to be approximately 2.2 km and 8.0 km from the source locations for the construction and operational assessment scenario respectively. For fish and sea turtle species, potential risks of behavioural impacts at immediate and far field from the noise source locations during construction and operational phase of the project are expected to be moderate to low.

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