



Morven Hawthorn Pit Grid Connection Project

Preliminary Environmental Information Report

Volume 2, Annex 5.1: Underwater Sound Technical
Report

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Executive Summary

This Technical Report presents an assessment of the potential noise and effect on marine fauna during the Morven Hawthorn Pit Grid Connection Project (hereafter 'MHPGC Project') in the North Sea undertaken by Subacoustech Environmental Ltd..

Various noise sources relating to the expected activities have been considered in this assessment including geophysical surveys, geotechnical investigations, route preparation and cable installation, vessel movements and clearance of unexploded ordnance (UXO). No dedicated noise reduction mitigation was considered for any of the noise-making activities.

The predicted noise model used in this assessment considers a wide range of input parameters including the noise level at the source, its frequency content, seabed properties, and the speed of sound through the water. Full account has also been taken of the bathymetry in the areas surrounding the chosen modelling location.

When considering the non-UXO related activities, the largest impacts were calculated for marine mammals during noise from the cable laying vessel and the ultra-short baseline (USBL) acoustic positioning system. Maximum auditory injury onset ranges covering all the non-UXO sources were predicted up to 150m when considering a receptor that flees away from the noise. For species of fish, impacts are predicted to be much smaller.

The noise from UXO clearance is expected to be much louder, with maximum marine mammal auditory injury onset ranges predicted up to 18km for harbour porpoises when considering the clearance of the largest UXO charge weight (697kg). For fish and sea turtles, injury ranges of between 80 and 340m are predicted for the same UXO clearance scenario.

It is worth reiterating that the modelling calculations and predicted impact ranges will produce results that are indicative of the onset of effects on receptors during the noise making activities and should not be considered as absolute ranges of guaranteed effect.

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Terminology

Auditory Injury (AUD INJ)	Noise threshold that represents the onset level of a permanent impairment hearing caused by acoustic trauma. AUD INJ results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity.
Cumulative Sound Exposure Level (SEL_{cum} or $L_{E,p,t}$)	Single value for the collected, combined total of sound exposure over a specified time or multiple instances of a noise source.
Decibel (dB)	A customary scale commonly used (in various ways) for reporting levels of sound. The dB represents a ratio/comparison of a sound measurement (e.g., sound pressure) over a fixed reference level. The dB symbol is followed by a reference value (e.g., re 1μPa).
Peak pressure	The highest pressure above or below ambient that is associated with a sound wave.
Peak Sound Pressure level (SPL_{peak} or $L_{p,pk}$)	The highest (zero-peak) positive or negative sound pressure, in decibels.
Root Mean Square (RMS)	The square root of the arithmetic average of a set of squared instantaneous values. Used for presentation of an average sound pressure level.
Single Pulse Sound Exposure Level, (SEL_{sp} or $L_{E,p,sp}$)	Calculation of the sound exposure level representative of a single noise impulse, typically a pile strike.
Sound Exposure Level (SEL or $L_{E,p,t}$)	The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level, and is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
Sound Pressure Level (SPL or L_p)	The sound pressure level is an expression of sound pressure using the decibel (dB) scale; the standard frequency pressures of which are 1μPa for water and 20μPa for air.
Temporary Threshold Shift (TTS)	Onset threshold level for a temporary reduction of hearing acuity caused by exposure to sound over time.
Unweighted sound level	Sound levels which are “raw” or have not been adjusted in any way, for example to account for the hearing ability of a species.
Weighted sound level	A sound level which has been adjusted with respect to a “auditory weighting function” or “weighting envelope” in the frequency domain, typically to make an unweighted level relevant to a particular species.

Acronyms

AUD INJ	Auditory Injury
BOEM	Bureau of Ocean Energy Management
CLV	Cable Lay Vessel
EMODnet	European Marine Observation and Data Network
HF	High-Frequency Cetaceans
ISO	International Organisation for Standardisation
LF	Low-Frequency Cetaceans
MBES	Multi-Beam Echosounder
MHPGC	Morven Hawthorn Pit Grid Connection
NEQ	Net Explosive Quantity
NMFS	National Marine Fisheries Service
NMPi	National Marine Plan Interactive
NOAA	National Oceanic and Atmospheric Administration
NPL	National Physical Laboratory
PE	Parabolic Equation
PEIR	Preliminary Environmental Information Report
PPV	Peak Particle Velocity
PW	Phocid Pinnipeds
RMS	Root Mean Square
SBES	Single Beam Echosounder
SBP	Sub-Bottom Profiler
sCPT	Seismic Cone Penetration Testing
SE	Sound Exposure
SEL ($L_{E,p}$)	Sound Exposure Level
SEL _{cum} ($L_{E,p,t}$)	Cumulative Sound Exposure Level
SEL _{sp} ($L_{E,p,sp}$)	Single Pulse Sound Exposure Level
SNH	Scottish Natural Heritage
SPL (L_p)	Sound Pressure Level
SPL _{peak} ($L_{p,pk}$)	Peak Sound Pressure Level
SPL _{RMS} ($L_{p,RMS}$)	Root Mean Square Sound Pressure Level
SSS	Side-Scan Sonar
TNT	Trinitrotoluene (explosive)
TTS	Temporary Threshold Shift
UHRS	Ultra-High Resolution Seismic
UK	United Kingdom
USBL	Ultra-Short Baseline
UXO	Unexploded Ordnance
VHF	Very High-Frequency Cetaceans

Units

dB	Decibel (sound pressure)
dB re 1μPa	Decibels referenced to 1 micropascal (sound pressure)
Hz	Hertz (frequency)
kg	Kilogram (mass)
kgm ³	Kilogram metres cubed (density)
kHz	Kilohertz (frequency)
km	Kilometre (distance)
m	Metre (distance)
mm s ⁻¹	Millimetres per second (particle motion)
m s ⁻¹	Metres per second (speed)
Pa	Pascal (pressure)
Pa ² s	Pascal squared seconds (acoustic energy)
s	Second (duration)
s ⁻¹	Inverse second / per second (frequency)
μPa	Micropascal (pressure)

1 Introduction

1.1 Project overview

This technical report presents the underwater noise modelling of the noise producing activities related to all phases of the Morven Hawthorn Pit Grid Connection Project (hereafter 'MHPGC Project'). It forms **Volume 2, Annex 5.1: Underwater Sound Technical Report, of the Preliminary Environmental Information Report (PEIR)** prepared for the MHPGC Project.

The MHPGC Project is proposed to be developed in the North Sea, connecting the offshore substation platform(s) (OSPs) within Morven North Offshore Wind Array Project or Morven South Offshore Wind Array Project (hereafter 'Morven North and Morven South') located within Scottish offshore waters, transiting through English offshore and inshore waters, to Mean High Water Springs (MHWS) at landfall. The potential noise impacts on marine fauna in the region surrounding these noise-producing activities have been assessed using detailed underwater noise modelling.

This report provides the results and findings of the detailed modelling assessment of the noise-producing activities. The modelling has been used to predict the sound pressure levels and sound exposure levels likely to be generated during these activities and make assessments with regards to impacts on marine species in the region.

1.2 Study area

A single location within the MHPGC Project Preliminary Environmental Information Report (PEIR) Red Line Boundary along the cable corridor has been used for modelling all the considered noise sources, representative of the cable corridor as a whole. The location situated in Farne Deep, is a deeper water area approximately 35km east of the Northumberland coast at Boulmer, and represents a worst-case option with regards to noise transmission as it is located in the deepest water. The modelling location and the area used for modelling (extending 100km around the modelling location), is shown in Figure 1-1, which also shows the MHPGC Project PEIR Red Line Boundary and surrounding bathymetry.

1.3 Noise sources

There are various expected noise sources relating to the MHPGC Project works which have been considered in this study, covering various surveys, cable installation, vessel noise, and clearance of unexploded ordnance (UXO). These include:

- Geophysical survey activities including:
 - Single Beam Echosounder (SBES).
 - Sub-Bottom Profiler (SBP) chirp system.
 - Ultra-High Resolution Seismic (UHRS) sparker system.
 - High Frequency Sub-Bottom Profiler.
 - Ultra Short Baseline (USBL) Acoustic Positioning transponder and transceiver.
- Pre-construction geotechnical investigations including:
 - Seismic Cone Penetration Testing (sCPT).
 - Vibro-coring, including borehole drilling.
- Route preparation and cable installation activities including:

- Cable lay vessel (CLV) assumed to be approximately 140m in length with dynamic positioning, also covering noise from the pre-lay grapnel run, boulder clearance, sandwave levelling/pre-sweep, jetting, trenching, ploughing, cable protection and trenchless technique breakout in shallow water.
- Rock cutting, covering cutter suction dredging.
- Dredging using a backhoe system.
- Vessel movements including:
 - Medium support vessels measuring between 50m and 100m in length.
 - Small support vessels measuring less than 50m in length.
- UXO clearance, covering the following methods and charge weights, all considered without mitigation:
 - Low-order and low-yield donor charges (0.08, 0.5, 2 × 0.75, and 4 × 0.75kg).
 - High-order donor charges (1.2kg and 3.5kg).
 - High-order UXO clearances (136kg, 270kg, 431kg, and 697kg).

It is worth noting that while noise from high-order clearance has been assessed, consent is only currently being sought for low-order clearance.

In addition to the listed geophysical survey activities, high frequency sources such as Multi-Beam Echosounders (MBES) and Side-Scan Sonar (SSS) are also expected to be utilised as part of the MHPGC Project, however the operating frequencies of these sources are in excess of what can be perceived by the marine fauna under consideration (> 200kHz), and as such have not been included in this noise modelling assessment. A magnetometer or gradiometer is also expected to be used, however this equipment does not generate underwater noise.

1.4 Document overview

This report presents a detailed assessment of the potential underwater noise resulting from works related to the MHPGC Project in the North Sea, and covers the following:

- Section 2: Review of background information on measuring and assessing underwater noise.
- Section 3: Discussion of the modelling approach, input parameters and assumptions for the noise modelling undertaken.
- Sections 4 and 5: Presentation of the detailed underwater noise modelling and interpretation of the results using suitable noise metrics and criteria for non-UXO activities and UXO clearance, respectively.
- Section 6: Summary and conclusions.

Plots showing the modelled levels of underwater noise from each noise source are presented in Appendix A. Impact ranges using further criteria (non-impulsive thresholds for impulsive sources) are presented in Appendix B.

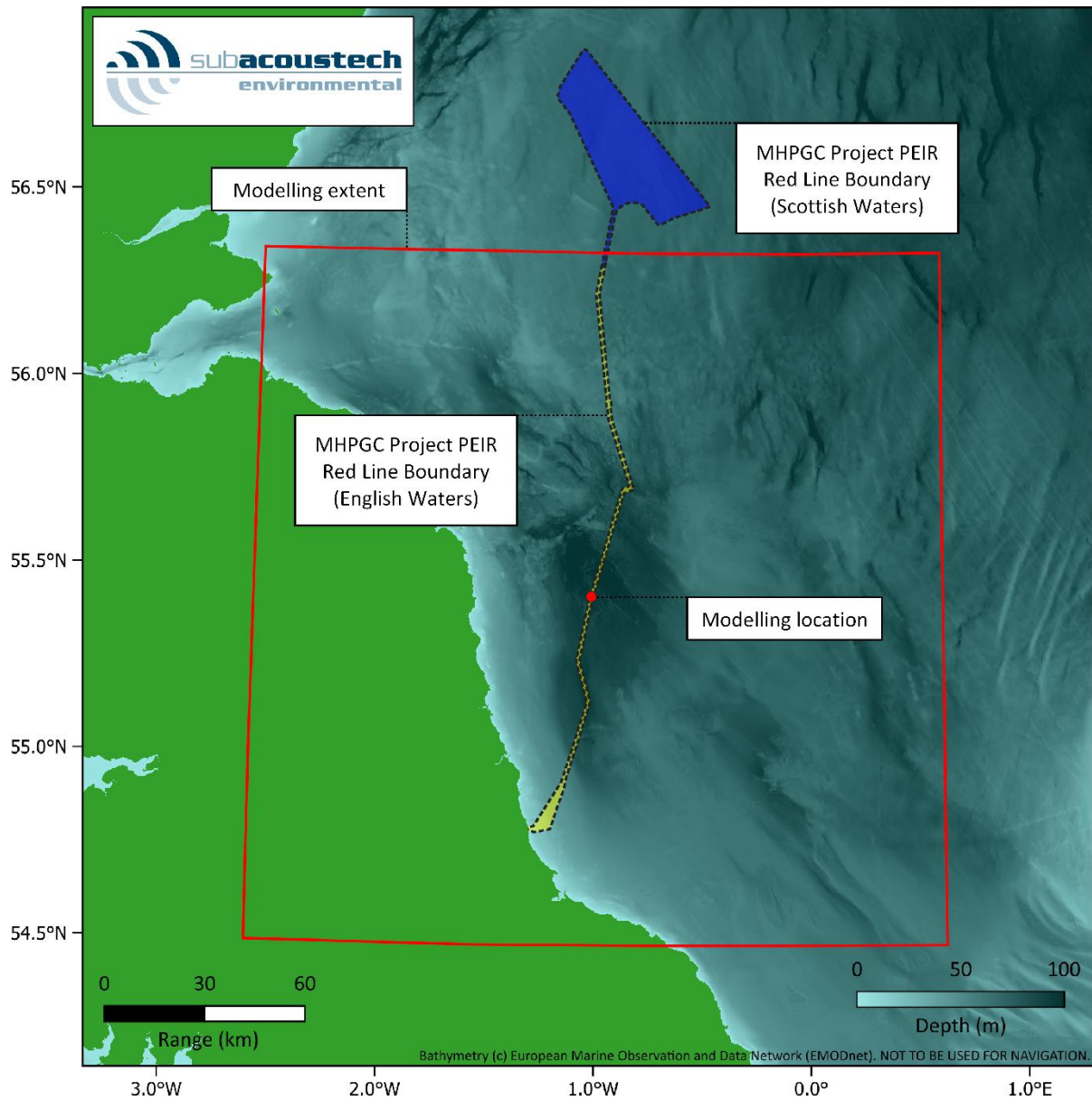


Figure 1-1: Modelling area overview, showing MHPGC Project, modelling location and surrounding bathymetry in the North Sea (WGS 84 / UTM Zone 30N).

2 Underwater noise concepts

Sound travels much faster in water (approximately $1,500\text{ms}^{-1}$ faster than in air (343ms^{-1}), as water is relatively incompressible and has a higher density than air. This affects the way in which sound measurements are expressed between the two mediums, which means that underwater sound levels are not directly comparable to airborne sound levels. This is noted for context; this report does not contain or include any reference to airborne sound levels.

2.1 Units of measurement

Sound measurements are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound. The dB scale represents a ratio, and therefore, it is used with a reference unit, which is the base from which the ratio is expressed. The fundamental definition of the dB scale is given in Equation 1:

$$\text{Sound pressure level } (L_p) = 20 \log_{10} \left(\frac{P}{P_{ref}} \right) \quad \text{Equation 1}$$

where P is pressure, measured in Pascals (Pa), and P_{ref} is the reference pressure, given as $1\mu\text{Pa}$ ($1 \times 10^{-6}\text{Pa}$) as defined in the International Organisation for Standardisation (ISO) 18405:2017 for underwater noise. Noise can be quantified using various metrics depending on the nature of the sound, as discussed below.

2.1.1 Sound Pressure Level

Sound Pressure Level (SPL or L_p) is a measure of the pressure variation caused by sound waves, expressed in decibels (dB), as seen in Equation 1. Variations of L_p are used depending on the noise source being measured. Unless otherwise defined, all L_p noise levels in this report are referenced to $1\mu\text{Pa}$.

2.1.1.1 Mean Squared Sound Pressure level

For continuous, non-impulsive noise sources such as drilling or dredging, an unweighted sound pressure level, averaged over a measurement period, known as a root mean squared (RMS) sound pressure level (SPL_{RMS} or $L_{p,\text{RMS}}$), can be used to represent the noise levels. The RMS period must be specified (e.g. $L_{p,\text{RMS},125\text{ms}}$), as the mean level can vary significantly depending on the measurement duration.

2.1.1.2 Peak Sound Pressure level

Transient, impulsive pressure waves, such as are generated from UXO clearance are usually expressed using the peak sound pressure level (SPL_{peak} or $L_{p,\text{pk}}$). This is calculated using the maximum pressure variation from positive to zero, representing the peak change in pressure as the transient wave propagates.

2.1.2 Sound Exposure Level

Sound Exposure Level (SEL or $L_{E,p}$) is a measure of Sound Exposure (SE), which represent the total acoustic energy of a sound event in dB, accounting for both the sound's intensity and duration. $L_{E,p}$ provides a way to quantify the total energy in a sound, making it useful for assessing the impact of both continuous and transient sounds. Variations of $L_{E,p}$ are used depending on the noise source being measured. For context, $L_{E,p}$ can be compared $L_{p,\text{RMS}}$ using Equation 2:

$$L_{E,p} = L_{p,\text{RMS}} + 10 \times \log_{10} T \quad \text{Equation 2}$$

where the $L_{p,\text{RMS}}$ is a measure of the average level of broadband noise and the $L_{E,p}$ sums the cumulative broadband noise energy. For continuous sounds shorter than one second, the $L_{E,p}$ is lower than the $L_{p,\text{RMS}}$. For durations longer than one second, the $L_{E,p}$ exceeds the $L_{p,\text{RMS}}$ (e.g., a 10-second sound results in a 10dB higher SEL and a 100-second sound gives a 20dB higher SEL). Unless otherwise defined, all $L_{E,p}$ noise levels in this report are referenced to $1\mu\text{Pa}^2\text{s}$.

2.1.2.1 Single Pulse Sound Exposure Level

Single Pulse Sound Exposure Level (SEL_{sp} or $L_{E,p,sp}$) refers to the total acoustic energy from a single, loud, short duration noise event (such as a blast or impact) measured over a specified duration. This can be expressed using Equation 3:

$$L_{E,p,sp} = 10 \times \log_{10} \left(\frac{\int_0^T p^2(t) dt}{p_{ref}^2 T_{ref}} \right) \quad \text{Equation 3}$$

where p is the acoustic pressure in Pascals, T is the total duration of sound in seconds, and t is time in seconds.

2.1.2.2 Cumulative Sound Exposure Level

A cumulative Sound Exposure Level (SEL_{cum} or $L_{E,p,t}$) accounts for the exposure from multiple impulses or pile strikes over time, where the number of impulses replaces the T in Equation 3, leading to Equation 4:

$$L_{E,p,t} = L_{E,p,sp} + 10 \times \log_{10} X \quad \text{Equation 4}$$

where X is the total number of impulses or strikes.

2.2 Properties of sound

2.2.1 Impulsive and non-impulsive sound

Sound can be categorised loosely into two types: impulsive and non-impulsive. These can be defined as:

- Non-impulsive: a steady-state sound. It does not necessarily have to have a long duration.
 - Examples: vibropiling, drilling, pingers (with a short inter-pulse interval).
- Impulsive: a sound with a high peak sound pressure, short duration, fast rise-time and broad frequency content at the source.
 - Examples: seismic airguns, explosives, impact piling.

These differences are important when considering the potential for auditory injury, as impulsive noise is more injurious than non-impulsive noise (Henderson and Hamernik, 1986; Hastie *et al.*, 2019). Due to the differences between impulsive and non-impulsive noise sources, different metrics are appropriate:

- Impulsive: Use $L_{p,pk}$, $L_{E,p,sp}$ or $L_{E,p,t}$.
- Non-impulsive: Use $L_{p,RMS}$ or $L_{E,p,t}$.

Objective categorisation of a noise as impulsive or non-impulsive is not always clear. This is particularly the case if sound is travelling over large distances. For example, when an impulsive sound propagates through an environment, the energy within the sound wave will scatter and dissipate, and it will become less impulsive with distance. This is important to consider regarding auditory injury and impact range calculations, as noise will become less injurious if it becomes less impulsive.

Research to define a range-dependent transition from impulsive to non-impulsive noise for various noise sources has been a significant field of study (see, for example, Martin *et al.*, 2020). Although the situation is complex, Hastie *et al.* (2019) concluded that an impulsive piling sound can be considered effectively non-impulsive at a range of 3.5km from the source using some metrics. However, the recent study by Matei *et al.* (2024) concludes that there is still insufficient evidence to clearly define a transition point suitable for an assessment such as this. It is, however, reasonable to presume there is a fully impulsive region close to many of the nominally impulsive sources, and a fully non-impulsive region at some greater distance, and a transition region in between. Matei *et al.* (2024) makes it clear that there is a substantial reduction in impulsiveness within the first 5km. However, due to the uncertainty in identifying a transition point, no presumption of such a change has been made in this report, although it is reasonable to assume that the sound can be considered not fully impulsive where injury

onset ranges are calculated above 5km. Where applicable, results in respect of both impulsive and non-impulsive criteria (see section 2.3.1 for marine mammals) have been presented in this report.

Some noise sources, including the UHRS and USBL systems, do not clearly fall into either category as they have some characteristics relevant to both impulsive and non-impulsive groups. Tougaard (2021) goes into some detail on these (pulse length, speed of onset, range of frequency content) in the context of marine mammal injury, all of which are necessary for a sound to be considered fully impulsive. Where this is the case, results have been provided based on both impulsive and non-impulsive criteria.

2.2.2 Particle motion

The motion of the particles that make up a medium is an important component of sound. Particle motion is present wherever there is sound, and it describes the back-and-forth movement of particles in water, which in the context of underwater noise, are caused by a sound wave passing through the water column. This back-and-forth movement means that, unlike sound pressure at a single point, particle motion always contains directional information (Hawkins and Popper, 2017). Regarding quantifying particle motion, it is usually defined in reference to the velocity of the particle (often a peak particle velocity (PPV)), but sometimes the related acceleration or displacement of the particle is used.

It has been identified by several researchers that many fish species (e.g., Popper and Hawkins, 2019; Nedelec *et al.*, 2016; Radford *et al.*, 2012), as well as marine invertebrates (see section 2.3.3) are sensitive to particle motion. However, sound pressure metrics are still preferred and more widely used than particle motion due to a lack of supporting data (Popper and Hawkins, 2018). There continue to be calls for additional research on the levels of and effects on marine receptors with respect to levels of particle motion.

2.3 Analysis of environmental effects: Assessment criteria

It has become increasingly evident that noise from human activities in and around underwater environments can have an impact on the marine species in the area. The extent to which intense underwater sound might cause adverse impacts in species is dependent upon the incident sound level, source frequency, duration of exposure, and/or repetition rate of an impulsive sound (see, for example, Hastings and Popper, 2005). As a result, scientific interest in the hearing abilities of aquatic species has increased. Studies are primarily based on evidence from high level sources of underwater noise such as seismic airguns, impact piling and blasting as these sources are likely to have the greatest immediate environmental impact and therefore the clearest observable effects, although interest in chronic noise exposure is increasing.

The impacts of underwater sound on marine species can be broadly summarised as follows:

- Physical traumatic injury and fatality.
- Auditory injury (either permanent or temporary).
- Disturbance and behavioural responses.

The following sections discuss the underwater noise criteria used in this study with respect to species of marine mammals and fish that may be present in the North Sea surrounding the MHPGC Project.

The main metrics and criteria that have been used in this study to inform the assessment of environmental effects come from two key papers covering underwater noise and its effects:

- National Marine Fisheries Service (NMFS) (2024) marine mammal exposure criteria.
- Popper *et al.* (2014) sound exposure guidelines for fishes and sea turtles.

These include the most commonly used and authoritative criteria for assessing environmental effects for use in impact assessments, at the time of writing.

2.3.1 *Marine mammals*

The NMFS (2024) paper is the latest reference for marine mammal hearing and injury thresholds at the time of writing. It updates weightings and thresholds from the previously most-used and recognised guidance documents, Southall *et al.* (2019) and NMFS (2018).

The NMFS (2024) guidance categorises marine mammals into groups of similar species and applies filters to the unweighted noise to approximate the hearing sensitivities of the receptor in question. The hearing groups given by NMFS (2024) are summarised in Table 2-1 and the relevant auditory weighting functions are shown in Figure 2-1. Further groups for sirenians and otariid pinnipeds are given, but these have not been included in this study as they are not commonly found in the area in the North Sea.

Table 2-1: Marine mammal hearing groups (from NMFS, 2024).

Hearing group	Generalised hearing range	Example species
Low-frequency cetaceans (LF)	7Hz to 36kHz	Baleen whales (including minke whales)
High-frequency cetaceans (HF)	150Hz to 160kHz	Dolphins, toothed whales, beaked whales, bottlenose whales (including bottlenose dolphin)
Very high-frequency cetaceans (VHF)	200Hz to 165kHz	True porpoises (including harbour porpoise)
Phocid pinnipeds (PW)	40Hz to 90kHz	True seals (including harbour seals)

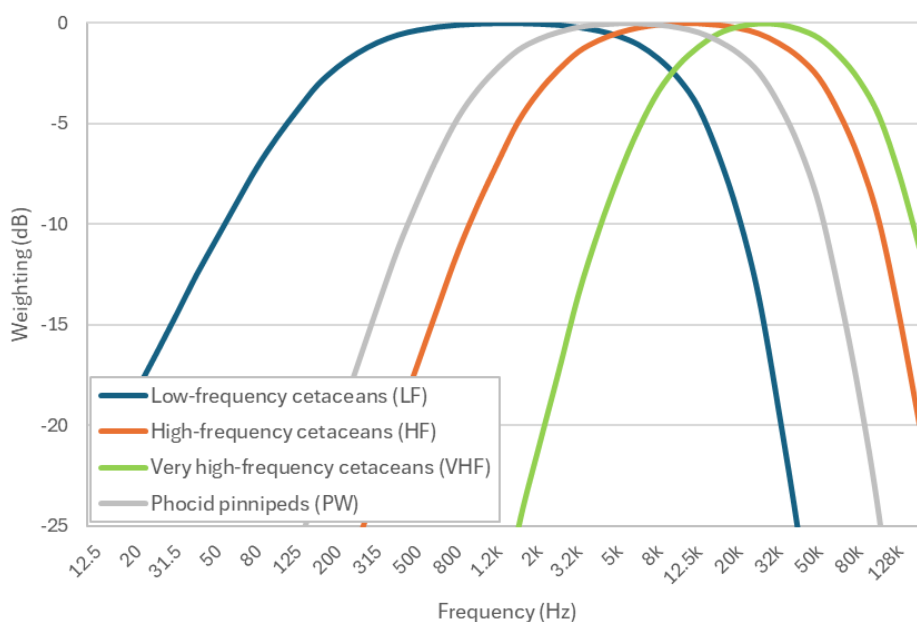


Figure 2-1: Auditory weighting functions for low-frequency cetaceans (LF), high-frequency cetaceans (HF), very high-frequency cetaceans (VHF), and phocid carnivores in water (PW) (from NMFS, 2024).

Like the preceding NMFS (2018) and Southall *et al.* (2019) guidance, NMFS (2024) considers the nature of the sound in the context of whether it is an impulsive or non-impulsive source (see section 2.2.1 for details). Although the use of impact ranges derived using the impulsive criteria are recommended for all but clearly defined non-impulsive sources, it should be recognised that where calculated ranges are beyond 5km (see section 2.2.1; Matei *et al.*, 2024), the sound is expected to be beyond the fully impulsive region and the real impact range is likely to be somewhere between those calculated based on the impulsive and non-impulsive impact criteria (Lucke *et al.*, 2024). Therefore, if the modelled impact range of an impulsive noise has been predicted to be greater than 5km, it is unlikely to be ‘fully impulsive’ and the non-impulsive impact range should also be considered. Both impulsive and non-impulsive criteria have been presented in this study.

Table 2-2 and Table 2-3 present the impulsive and non-impulsive criteria set out in NMFS (2024) for auditory injury (AUD INJ) and temporary threshold shift (TTS) in marine mammals used for this study. The NMFS (2024) paper does not include TTS criteria for all the metrics and categories, however the remaining $L_{p,pk}$ and $L_{E,p,24h,wt d}$ criteria have been derived from Finneran (2024), which was in itself used to create the methodology and criteria used by NMFS (2024) and is also presented as an appendix in the same report.

Table 2-2: Unweighted $L_{p,pk}$ criteria for AUD INJ and TTS onset in marine mammals (NMFS, 2024).

NMFS (2024) Unweighted $L_{p,pk}$ (dB re $1\mu\text{Pa}$)	Impulsive	
	AUD INJ	TTS
Low-frequency cetaceans (LF)	222	216
High frequency cetaceans (HF)	230	224
Very high-frequency cetaceans (VHF)	202	196
Phocid pinnipeds (PW)	223	217

Table 2-3: Weighted $L_{E,p,24h,wt d}$ criteria for AUD INJ and TTS onset in marine mammals (NMFS, 2024).

NMFS (2024) Weighted $L_{E,p,24h,wt d}$ (dB re $1\mu\text{Pa}^2\text{s}$)	Impulsive		Non-impulsive	
	AUD INJ	TTS	AUD INJ	TTS
Low-frequency cetaceans (LF)	183	168	197	177
High frequency cetaceans (HF)	193	178	201	181
Very high-frequency cetaceans (VHF)	159	144	181	161
Phocid pinnipeds (PW)	183	168	195	175

Where $L_{E,p,t}$ thresholds are required for marine mammals, a fleeing animal model has been used. This assumes that a receptor, when exposed to high noise levels, will swim away from the noise source. The speed relevant to different species or species groups is dependent on the jurisdiction in which the assessment is undertaken. As works are taking place in both English and Scottish waters, two sets of swim speeds have been considered due to regulator preference, alongside a worst-case stationary receptor calculation.

In England, a constant swim speed of 3.25ms^{-1} has been assumed for the LF cetaceans group (Blix and Folkow, 1995), based on data for minke whale, and for other receptors, a constant rate of 1.5ms^{-1} has been assumed for fleeing, which is a cruising speed for a harbour porpoise (Otani *et al.*, 2000).

In Scotland, the following swim speeds have been used for marine mammals:

- 2.1ms^{-1} for LF cetaceans (LF) (Scottish Natural Heritage; SNH, 2016).
- 1.52ms^{-1} for HF cetaceans (Bailey and Thompson, 2006).
- 1.4ms^{-1} for VHF cetaceans (SNH, 2016).
- 1.8ms^{-1} for PW (SNH, 2016).

These swim speeds are considered worst case assumptions as marine mammals are expected to be able to swim much faster under stress conditions (Kastelein *et al.* 2018), especially at the start of any noisy process when the receptor will be closest.

Limited data is available for behavioural disturbance on species of marine mammal. To take this into account, the National Oceanic and Atmospheric Administration (NOAA) (2005) Level B (behavioural disturbance) harassment criterion for impulsive noise on marine mammals has been included to cover disturbance effects from the various activities across the MHPGC Project. This criterion is 160dB re $1\mu\text{Pa}$ ($L_{p,RMS}$) for non-explosive impulsive or intermittent noise sources and 120dB re $1\mu\text{Pa}$ ($L_{p,RMS}$) for continuous noise sources.

2.3.2 Fish and sea turtles

The Popper *et al.* (2014) guidelines are recognised as a suitable reference for underwater noise impacts on marine fauna (aside from marine mammals) in UK waters. Popper *et al.* (2014) provides a summary of research

and guidelines for fish and sea turtle exposure to sound and uses categories that are representative of the species present in the North Sea around the MHPGC Project.

The Popper *et al.* (2014) guidelines present criteria dependent on the type of noise source, species of marine fauna and their hearing capabilities, and impact type. Noise sources considered in the guidance include explosions, pile driving, seismic airguns, sonar, and shipping and continuous noise. For this study, criteria for explosions, low-frequency sonar, mid-frequency sonar and shipping and continuous noise have been used.

For each sound source, the marine fauna are categorised into groups covering fish, sea turtles and eggs and larvae. Due to their diversity and quantity, fish are categorised further into three groups depending on their hearing capabilities, which can be indicated by whether they possess a swim bladder or not, and whether the swim bladder is involved in its hearing.

Popper *et al.* (2014) provides separate criteria, depending on the species and noise source, for various impacts associated with noise exposure. These are mortality and potential mortal injury, impairment (split into recoverable injury, TTS, and masking), and behavioural effects.

Depending on the noise source, quantitative criteria are given in appropriate metrics ($L_{p,pk}$, $L_{p,RMS}$), which can then be used as thresholds for the onsets of listed impacts. Where insufficient data is available, Popper *et al.* (2014) also gives a description of relative risk. This summarises the effect of the noise as having either a high, moderate or low relative risk of an effect on an individual in either near (tens of metres), intermediate (hundreds of metres), or far (thousands of metres) from the source.

The thresholds and relative risk descriptions given by Popper *et al.* (2014) used in this study are reproduced in Table 2-4 to Table 2-7, covering explosions (for UXO clearance), low-frequency sonar and mid-frequency sonar (for various geophysical survey activities), and shipping and continuous noise sources. It is worth noting that the Popper *et al.* (2014) criteria use the SPL_{peak} and SPL_{RMS} notation. To keep consistency with the NMFS (2024) criteria in section 2.3.1, this report will present the ISO 18405:2017 notation ($L_{p,pk}$, and $L_{p,RMS}$, respectively) when considering Popper *et al.* (2014).

For noise sources within the high-frequency sonar category (i.e., frequencies exceeding 10kHz), Popper *et al.* (2014) do not provide assessment criteria for fish and sea turtles due to their relatively low-frequency hearing ranges. As such, these sources have not been assessed for fish and sea turtles.

Table 2-4: Recommended guidelines for explosions according to Popper et al. (2014) for species of fish, sea turtles and eggs and larvae (N = near-field, I = intermediate-field, F = far-field).

Receptor	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: no swim bladder	229 – 234dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	N/A	(N) High (I) Moderate (F) Low
Fish: swim bladder not involved in hearing	229 – 234dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	N/A	(N) High (I) Low (F) Low
Fish: swim bladder involved in hearing	229 – 234dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	N/A	(N) High (I) Low (F) Low
Sea turtles	229 – 234dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	N/A	(N) High (I) Low (F) Low
Eggs and larvae	> 13mms ⁻¹ peak velocity	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	N/A	(N) High (I) Low (F) Low

Table 2-5: Recommended guidelines for low-frequency sonar according to Popper et al. (2014) for species of fish, sea turtles and eggs and larvae (N = near-field, I = intermediate-field, F = far-field).

Receptor	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: no swim bladder	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	> 193dB $L_{p,RMS}$	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Fish: swim bladder not involved in hearing	> 193dB $L_{p,RMS}$	> 193dB $L_{p,RMS}$	> 193dB $L_{p,RMS}$	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Fish: swim bladder involved in hearing	> 193dB $L_{p,RMS}$	> 193dB $L_{p,RMS}$	> 193dB $L_{p,RMS}$	(N) Moderate (I) Low (F) Low	> 197dB $L_{p,RMS}$
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low

Table 2-6: Recommended guidelines for mid-frequency sonar according to Popper *et al.* (2014) for species of fish, sea turtles and eggs and larvae (N = near-field, I = intermediate-field, F = far-field).

Receptor	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: no swim bladder	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	N/A	N/A	N/A
Fish: swim bladder not involved in hearing	> 210dB $L_{p,RMS}$	> 210dB $L_{p,RMS}$	N/A	N/A	N/A
Fish: swim bladder involved in hearing	> 210dB $L_{p,RMS}$	> 210dB $L_{p,RMS}$	> 210dB $L_{p,RMS}$	(N) Low (I) Low (F) Low	> 209dB $L_{p,RMS}$
Sea turtles	N/A	N/A	N/A	N/A	N/A
Eggs and larvae	N/A	N/A	N/A	N/A	N/A

Table 2-7: Recommended guidelines for shipping and continuous noise according to Popper *et al.* (2014) for species of fish, sea turtles and eggs and larvae (N = near-field, I = intermediate-field, F = far-field).

Receptor	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: no swim bladder	(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 not involved in hearing	(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	(N) Low (I) Low (F) Low	170dB $L_{p,RMS,48h}$	158dB $L_{p,RMS,12h}$	(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
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

It is important to note that, despite the evidence that many fish are sensitive to particle motion (see section 2.2.2), the Popper *et al.* (2014) guidance defines noise impacts in terms of sound pressure or sound pressure-associated functions (i.e., $L_{E,p,t}$).

It has been suggested that the criteria set out by Popper *et al.* (2014) could have been derived from unmeasured particle motion, as well as sound pressure. Whilst this may be true, sound pressure remains the preferred metric in the criteria due to a lack of data surrounding particle motion (Popper and Hawkins, 2018), particularly regarding the ability to predict the consequences of the particle motion of a noise source, and the sensitivity of fish to a specific particle motion value. Therefore, as stated by Popper and Hawkins (2019): “since there is an immediate need for updated criteria and guidelines on potential effects of anthropogenic sound on fishes, we recommend, as do our colleagues in Sweden (Andersson *et al.*, 2017), that the criteria proposed by Popper *et al.* (2014) should be used.”

2.3.3 *Marine invertebrates*

A review by Solé *et al.* (2023) highlights the increasing evidence that some types of anthropogenic noise can negatively impact a variety of marine invertebrate taxa. These impacts include changes in behaviour, physiology, and rate of mortality, as well as physical impairment, at the individual, population, or ecosystem level. Much of the damage from exposure to noise comes from vibration of the invertebrate body (André *et al.*, 2016) caused by the passage of sound.

Comparatively, the studies described by Solé *et al.* (2023) show a general inconsistency in the way noise impacts have been quantified for marine invertebrates. For example, Hubert *et al.* (2021) notes behavioural changes in blue mussels to 150 and 300Hz tones, whereas Spiga *et al.* (2016) describes behavioural changes in the same species at $L_{E,p,sp}$ of 153.47dB re 1µPa. These inconsistencies make it difficult to generate accurate thresholds for the onset of any impact for species. A notable exception is the cephalopods group, in which several studies, mainly by Solé *et al.* (2013, 2018, 2019) and André *et al.* (2011) show a consistent threshold for auditory damage on various species of cephalopod at 157dB re 1µPa. While further research is needed even on this group to ensure accurate thresholds which are satisfactory to regulators, the current state of research on cephalopods sets a goal for the research required for other marine invertebrate groups, if they are to be used usefully as impact thresholds.

The meta-analysis conducted by Solé *et al.* (2023) also reveals inconsistencies in the responses of taxonomically near species of marine invertebrates to the effect of anthropogenic noise. For example, Fields *et al.* (2019) demonstrates low mortality of zooplankton during seismic airguns, whereas for the same noise source, McCauley *et al.* (2017) showed mass mortality of krill larvae. Clearly, the effect of noise on one species may not necessarily be applicable on another species despite being taxonomically near, which again makes it difficult to generate a generalised impact threshold that can confidently be applied to different taxonomic groups of marine invertebrates.

In its current state, research on the effects of anthropogenic noise on marine invertebrates is emerging, but more slowly than for marine mammals and fish. At this time, this research is in too early a stage to be used to accurately generate impact thresholds which would be satisfactory to regulators. The data available could potentially be referenced for some species but with caution, as there are still considerable gaps in the knowledge that would enable reliable conclusions for the impact of noise for most species. However, due to the degree of uncertainty, benthic species will not be considered further.

3 Underwater noise modelling methodology

To estimate the underwater noise levels likely to arise during the construction, operation, maintenance and decommissioning of the MHPGC Project, predictive noise modelling has been undertaken. The methods described in this section, and used within this report, meet the requirements set by the National Physical Laboratory (NPL) Good Practice Guide 133 for underwater noise measurement (Robinson *et al.*, 2014).

Modelling of underwater noise is complex and can be approached in several different ways. To estimate the noise levels generated by the noise-making activities, Subacoustech have chosen to utilise the dBSea modelling software (Pedersen, 2017), currently version 3.0, which is a widely-used acoustic model for underwater noise and uses various numerical solvers to calculate underwater noise. For this project, two different solvers were used:

- A parabolic equation (PE) method for lower frequencies.
 - Widely used within the underwater acoustics community but has computational limitations at high frequencies.
- A ray tracing method for higher frequencies.
 - More computationally efficient at higher frequencies but is not suited to low frequencies (Etter, 1991).

Modelling has been undertaken using a frequency range from 12.5Hz up to 100kHz, with the split between the low and high frequency solvers differing between the noise sources, depending on the frequency spectrum of the source.

The dBSea model incorporates bathymetry data and noise sources, with user-defined seabed and water properties (e.g. sound speed, temperature, salinity). Using selected numerical solvers, the software calculates 1/3rd octave band noise levels between 12.5Hz and 100kHz at set distances across the defined area, considering inputted environmental parameters and source characteristics. Where peak ($L_{p,pk}$) levels have been modelled, a methodology that also incorporates a time-domain element has been used.

3.1 Input parameters

3.1.1 Modelling locations

A single, representative modelling location has been chosen in an area of deep water in the Farne Deep along the MHPGC Project PEIR Red Line Boundary, as illustrated in Figure 1-1. Details of this location are given in Table 3-1.

Table 3-1: Summary of the underwater noise modelling location used for this assessment.

Modelling location	Latitude	Longitude	Water depth
Farne Deep	55.43872°N	1.02933°W	90.1m

The depths in the water column used for modelling vary with each source with the SBES, SBP chirp, UHRS sparker, high-frequency SBP, USBL acoustic positioning, support vessels and CLV source positions located just below the sea surface, and the UXO clearance, sCPT, vibro-core, rock cutting and dredging sources located at the seabed.

3.1.2 Bathymetry

The bathymetry data used in the modelling was obtained from The European Marine Observation and Data Network (EMODnet, 2024 dataset), which has a resolution of 30 arc-seconds. The bathymetry used for modelling covers an area exceeding 100km in range around the chosen modelling location (Figure 1-1). Smaller areas have been used for the $L_{p,pk}$ modelling due to smaller predicted impact ranges and the higher level of processing required, this is illustrated in the noise plots presented in Appendix A.

3.1.3 Seabed properties

Characteristics of the seabed were based on data from the British Geological Society (BGS)¹. The seabed at the modelling location is assumed to be comprised of a 10m sediment layer of sand and slightly gravelly sand, which is above a bedrock layer of sandstone. Geo-acoustic properties for the seabed were based on available data from Jensen *et al.* (1994, 2011), which are provided in Table 3-2.

Table 3-2: Details of the seabed geo-acoustic properties at the modelling location.

Material	Compressive sound speed profile in substrate	Density profile in substrate	Attenuation profile in substrate
Sediment: Sand / Slightly gravelly sand	1,680ms ⁻¹	1,920kgm ³	0.76dB/wavelength
Bedrock: Sandstone	3,000ms ⁻¹	2,500kgm ³	0.1dB/wavelength

3.1.4 Sound speed profile

The speed of sound in water through the water column has been calculated at the modelling location using the average annual temperature and salinity and the equation from Mackenzie (1981), based on data sourced from Marine Scotland's National Marine Plan Interactive (NMPI) tool². The resulting profile is shown in Figure 3-1.

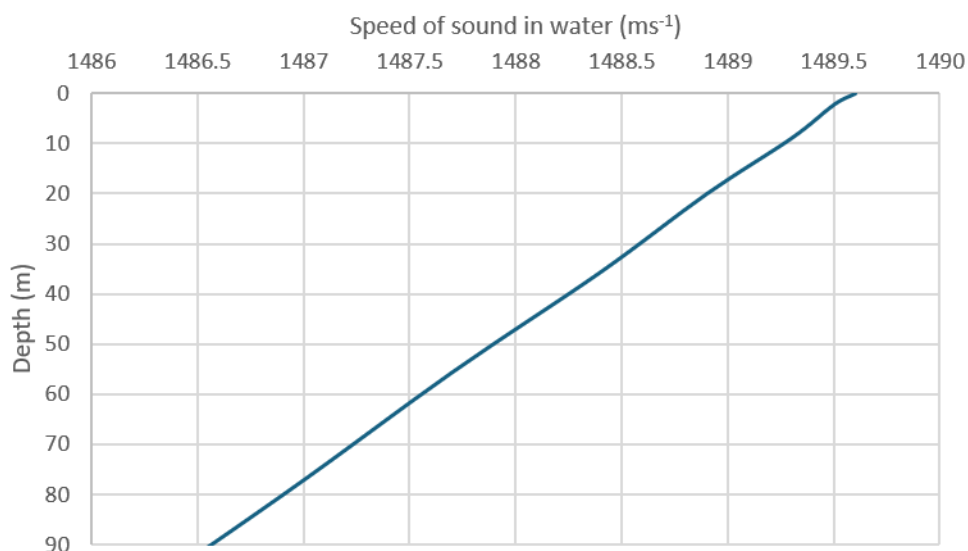


Figure 3-1: Sound speed profile used for modelling at Farne Deep.

3.1.5 Noise sources

The following sections detail the noise-making activities expected during the MHPGC Project covering pre-construction and construction phases.

3.1.5.1 Non-UXO activities

The main (non-UXO clearance) noise-producing activities proposed for the MHPGC Project are summarised in Table 3-3; where sources are directional, off-axis reductions have been applied to the apparent source levels. Further sources including MBES, SSS, and magnetometer/gradiometer have not been considered further due to either operating at frequencies inaudible to marine fauna (MBES operates between 200 and 400kHz and SSS operates between 300 and 600kHz) or not generating any noise (magnetometer/gradiometer).

¹ https://mapapps2.bgs.ac.uk/geoindex_offshore/home.html

² <https://marinescotland.atkinsgeospatial.com/nmpi/>

Where information specific to the MHPGC Project was not available, assumptions have been made based on Subacoustech Environmental's measurement database, similar manufacturer specification sheets and assumptions made for previous modelling at the MHPGC Project.

The combined empirically-derived source levels, alongside the numerical sound propagation modelling approach, are designed to provide a conservative fit to measured data and are not necessarily suitable for other modelling.

Table 3-3: Summary of the sound source characteristics and apparent source levels used to model the MHPGC Project activities.

Source	Sound type	Operating frequency	Source level @ 1 m	Repetition rate	Reference
SBES	Continuous	20kHz - 40kHz	188dB re 1 μ Pa ² s ($L_{p,RMS}$)	0.3 - 1.5 s ⁻¹	East and Mason (2023); multiple product specification sheets.
SBP chirp	Continuous	200Hz - 14kHz	186dB re 1 μ Pa ² s ($L_{p,RMS}$)	15 s ⁻¹	Midforth <i>et al.</i> (2017); Multiple product specification sheets.
UHRS sparker	Impulsive	50Hz - 4.0kHz	219dB re 1 μ Pa ($L_{p,pk}$) 140dB re 1 μ Pa ² s ($L_{E,p,sp}$)	0.5 s ⁻¹	East and Mason (2023); RPS (2024).
High frequency SBP	Continuous	85kHz - 115kHz	191dB re 1 μ Pa ² s ($L_{p,RMS}$)	40 s ⁻¹	East and Mason (2023); multiple product specification sheets.
sCPT	Impulsive ³	40Hz - 8.0kHz	120dB re 1 μ Pa ² s ($L_{p,RMS}$)	-	Reiser <i>et al.</i> (2011); BOEM (2023); Chorney <i>et al.</i> (2011); Tetra Tech (2014).
Vibro-coring	Continuous	20Hz - 20kHz	187dB re 1 μ Pa ² s ($L_{p,RMS}$)	-	Reiser <i>et al.</i> (2011).
USBL acoustic positioning	Impulsive	21kHz - 31kHz	191dB re 1 μ Pa ($L_{p,pk}$) 172dB re 1 μ Pa ² s ($L_{E,p,sp}$)	1 s ⁻¹	East and Mason (2023).
Rock cutting	Continuous	30Hz - 2.0kHz	186dB re 1 μ Pa ² s ($L_{p,RMS}$)	-	Collett and Mason (2015); Wyatt <i>et al.</i> (2008).
Dredging	Continuous	100Hz - 2.0kHz	179dB re 1 μ Pa ² s ($L_{p,RMS}$)	-	Nedwell <i>et al.</i> (2008); Wyatt <i>et al.</i> (2008).
Medium support vessel	Continuous	5Hz - 3.2kHz	184dB re 1 μ Pa ² s ($L_{p,RMS}$)	-	Nedwell and Brooker (2009).
Small support vessel	Continuous	5Hz - 3.2kHz	160dB re 1 μ Pa ² s ($L_{p,RMS}$)	-	Midforth <i>et al.</i> (2017).
CLV	Continuous	5Hz - 3.2kHz	197dB re 1 μ Pa ² s ($L_{p,RMS}$)	-	Nedwell <i>et al.</i> (2010); Ross (1993); Kevin <i>et al.</i> (2014); Hale (2018); Nedwell <i>et al.</i> (2003); Barham and Mason (2019); Nedwell <i>et al.</i> (2012).

³ Due to the low predicted levels expected from sCPT activities, the time domain methodology has not been used to calculate $L_{p,pk}$ for this source.

Figure 3-2 presents the 1/3rd octave spectrum used for modelling, adjusted to achieve the source levels in Table 3-3. Figure 3-3 and Figure 3-4 present the scaled time histories for impulsive sources (UHRS sparker and USBL acoustic positioning) that have been used to model $L_{p,pk}$ impacts.

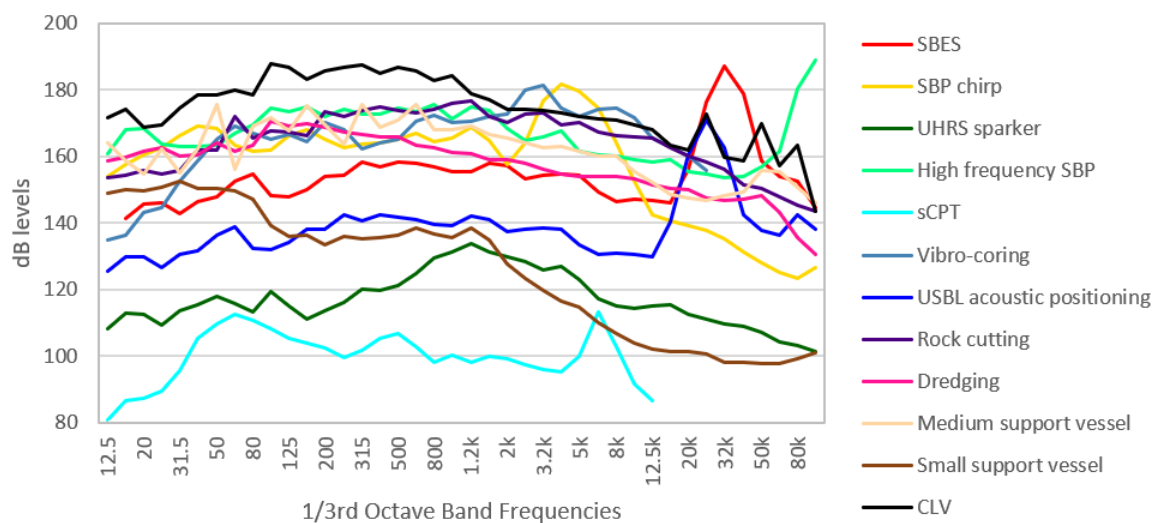


Figure 3-2: Source spectra containing 1/3rd octave band levels used to model the various non-UXO noise sources.

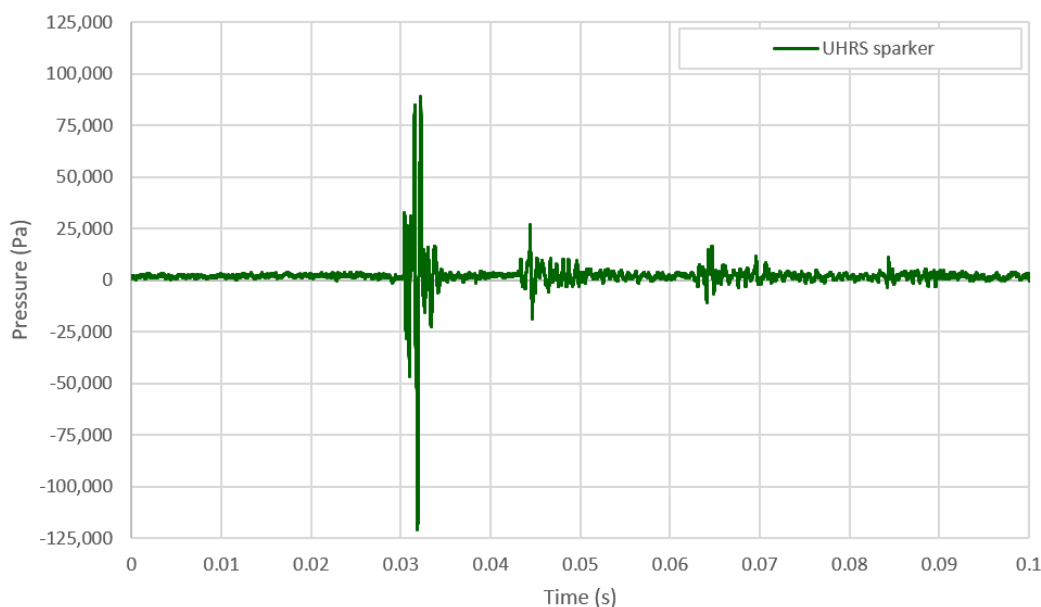


Figure 3-3: Scaled source time history of a single pulse used to model the UHRS sparker activity; used for modelling $L_{p,pk}$ noise levels only.

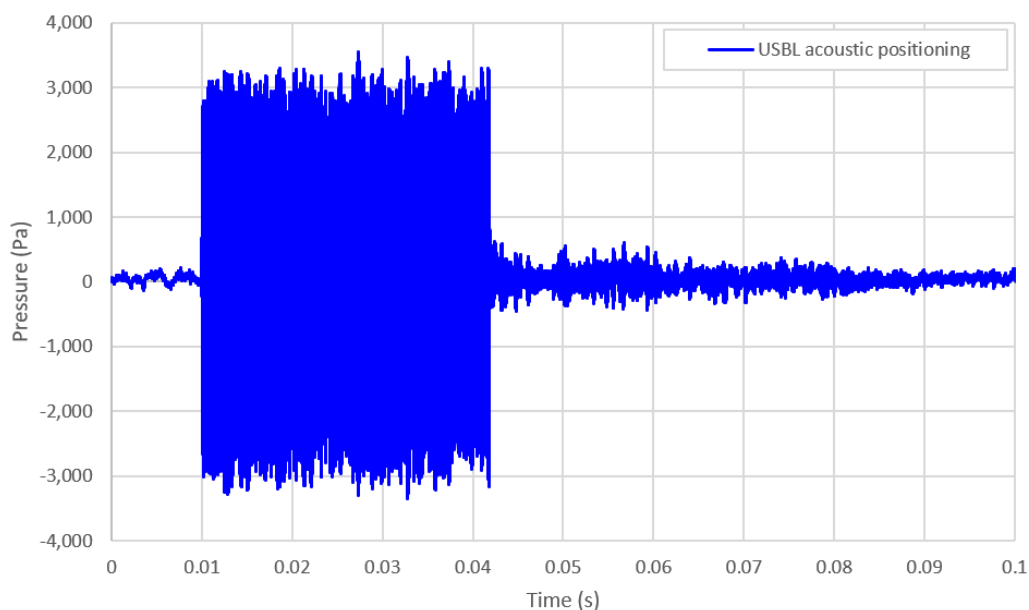


Figure 3-4: Scaled source time history of a single pulse used to model the USBL acoustic positioning; used for modelling $L_{p,pk}$ noise levels only.

As a worst case, it has been assumed that all sources are operational for up to 24 hours a day when considering $L_{E,p,t}$. The NMFS (2024) guidance limits the exposure calculation to this period, but it does not restrict the operation lasting for longer than this period. Although most noise sources are expected to be moving, this movement has not been included in the modelling as it is impossible to know whether it will change position towards or away from a receptor. The receptor, however, will still be presumed to move away from the source (see section 2.3.1).

3.1.5.2 UXO clearance

To carry out detailed noise modelling of UXO clearance, source spectra and estimated source levels for $L_{p,pk}$ and $L_{E,p,sp}$ must be used. The various detonation charge weights have been provided based on the net equivalent quantity (NEQ) of Trinitrotoluene (TNT). Where multiple detonations are considered in a short space of time, the charge weight has been considered in aggregate. The range of charge configurations considered for modelling UXO clearance are detailed in Table 3-4.

Table 3-4: UXO charge weights and clearance methods modelled.

Method	Charge weight (kg; NEQ)	Notes
Low-order and low-yield donor charge configurations	0.08	Maximum size of donor charge used for the low-order clearance technique.
	0.5	Maximum size of clearing shot used to neutralise any residual explosive material.
	2 × 0.75 (1.5 total)	Charge configuration for the low-yield technique anticipated for most UXO sizes.
	4 × 0.75 (3.0 total)	Maximum charge configuration for the low-yield technique (German ground mines).
High-order donor charge configurations	1.2	Most common donor charge for high-order UXO clearance
	3.5	Single barracuda blast-fragmentation charge for high-order UXO clearance.
High-order UXO clearance	136	Depth charge.
	270	German SC500 Aerial Bomb
	431	British Mark A Ground Mine
	697	Maximum UXO size (German "Luftmine B" Ground Mine)

For this study, estimation of the source noise level has been based on measured data, from Subacoustech Environmental's underwater noise measurement library. In order to model specified charge weights, adjustments to the predicted source levels have been included based on calculations from Soloway and Dahl (2014). No consideration has been given to mitigation or noise abatement systems in this modelling.

It is also worth noting that the levels used for modelling largely agree with the levels in Robinson *et al.* (2022), which presented measurement data from high-order UXO clearance and individual scare charges during construction of the Neart na Gaoithe wind farm in the Firth of Forth, Scotland.

A summary of the unweighted apparent source levels ($L_{p,pk}$ and $L_{E,p,sp}$), calculated at 1m from the detonation based on the measured noise levels and the equations described above, are given in Table 3-5.

Table 3-5: Summary of the apparent source levels used for modelling.

Apparent source level	Unweighted $L_{p,pk}$ @ 1 m	Unweighted $L_{E,p,sp}$ @ 1 m
0.08kg	245.5dB re 1μPa	224.4dB re 1μPa ² s
0.5kg	251.5dB re 1μPa	229.5dB re 1μPa ² s
2 × 0.75kg	255.1dB re 1μPa	232.5dB re 1μPa ² s
4 × 0.75kg	257.3dB re 1μPa	234.5dB re 1μPa ² s
1.2kg	254.3dB re 1μPa	231.9dB re 1μPa ² s
3.5kg	257.8dB re 1μPa	234.9dB re 1μPa ² s
136kg	266.1dB re 1μPa	237.3dB re 1μPa ² s
270kg	268.3dB re 1μPa	239.2dB re 1μPa ² s
431kg	269.8dB re 1μPa	240.5dB re 1μPa ² s
697kg	271.4dB re 1μPa	241.8dB re 1μPa ² s

As with the previous section, the source levels provide a conservative fit to measured data based on the modelled transmission loss, and are not necessarily suitable for other modelling.

Also required for the detailed noise modelling is a source spectrum. For the UXO clearance noise in this study this is based on Midforth (2024) for the low-order and donor charge configurations and Mason *et al.* (2020) for the high-order clearance, both from unmitigated UXO detonations recorded by Subacoustech in the North Sea. From this, 1/3rd octave levels and the single pulse waveforms were created achieving the levels given in Table 3-5. These levels are presented in Figure 3-5 to Figure 3-7.

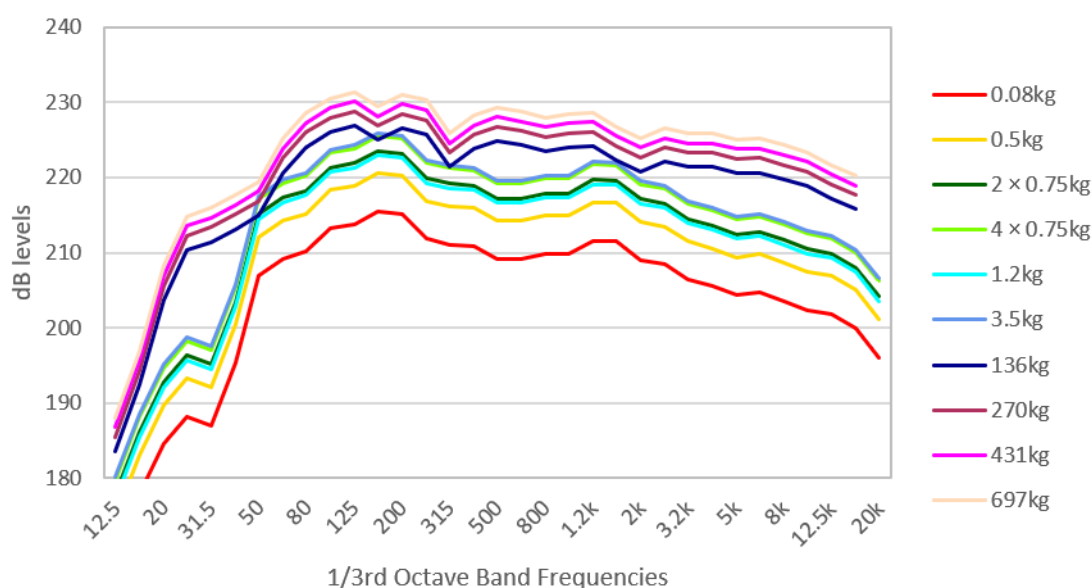


Figure 3-5: Source spectra containing 1/3rd octave band levels used to model the various UXO clearance charge weights.

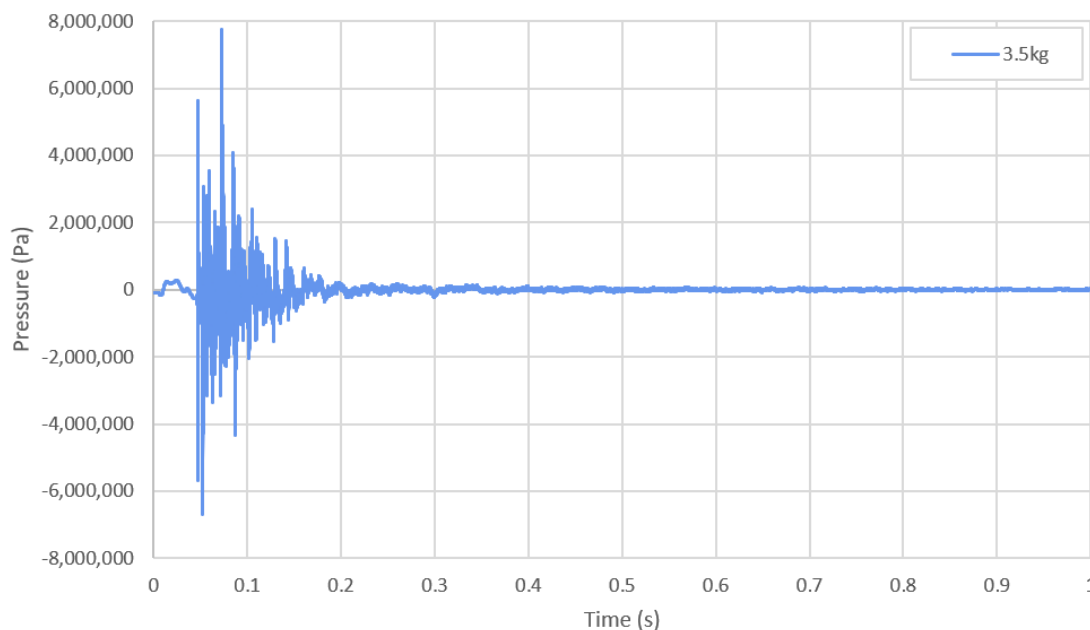


Figure 3-6: Scaled source time history used to model the largest donor charge NEQ (3.5kg) used for modelling $L_{p,pk}$ noise levels only; other charge weights use the same time history scaled using Soloway and Dahl (2014).

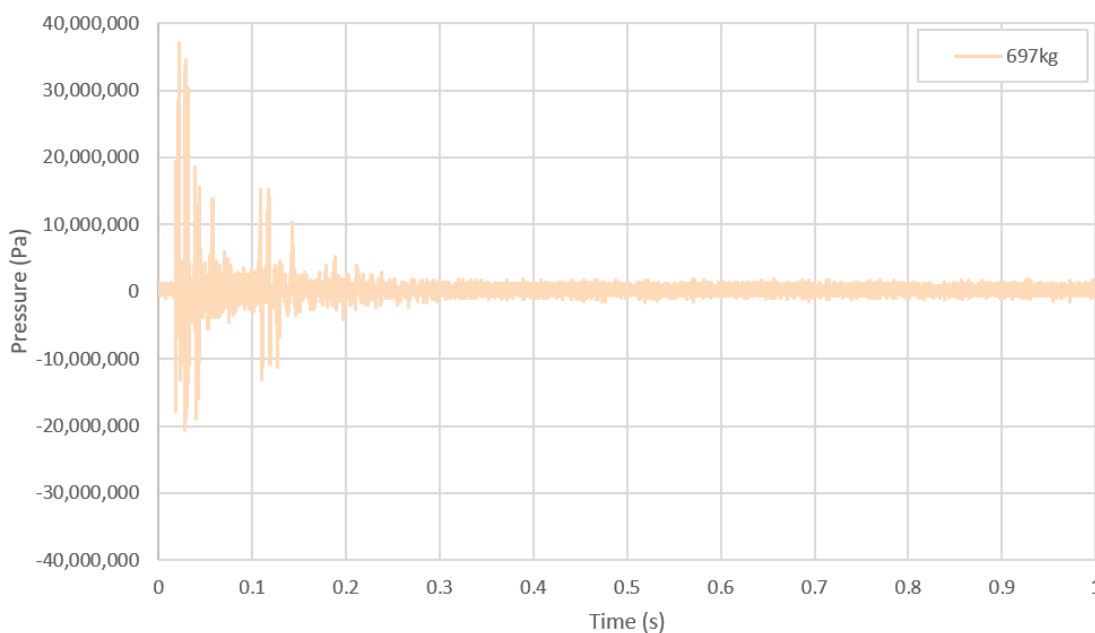


Figure 3-7: Scaled source time history used to model the largest high-order UXO clearance NEQ (697kg) used for modelling $L_{p,pk}$ noise levels only; other charge weights use the same time history scaled using Soloway and Dahl (2014).

It should be noted that the modelling software is unable to back-calculate the raw time-domain waveforms (Figure 3-6 and Figure 3-7) to obtain a source waveform for peak level calculations. As such an adjustment of the overall pressure level has been carried out to derive the source input to the model. It is acknowledged that this approach is based on an estimation of the near-field propagation, however due to limitations in the modelling software and solvers this is the best available methodology.

In addition to the source levels (Table 3-5), it is useful to look at the potential levels at range from the noise sources. The level at 1km is commonly used as a reference position in UXO clearance noise monitoring, as

recommended in NPL (2020), and has been presented here. These levels have the added advantage of being comparable with other modelling or measurements (as valid measurements can be taken at this range), where the source level (at 1m) may not. A summary of the modelled unweighted levels at a range of 1km are given in Table 3-6.

Table 3-6: Summary of the predicted unweighted noise levels at a range of 1km for the considered UXO clearance scenarios.

Predicted levels at 1km range	Unweighted $L_{p,pk}$ @ 1km (dB re 1 μ Pa)			Unweighted $L_{E,p,sp}$ @ 1km (dB re 1 μ Pa ² s)		
	Maximum level	Mean level	Minimum level	Maximum level	Mean level	Minimum level
0.08kg	195.1	193.7	192.5	180.3	178.9	177.6
0.5kg	201.1	199.7	198.5	185.4	184.0	182.7
2 × 0.75kg	204.7	203.3	202.1	188.4	187.0	185.7
4 × 0.75kg	206.9	205.5	204.3	190.4	189.0	187.7
1.2kg	203.9	202.5	201.3	187.8	186.4	185.1
3.5kg	207.4	206.0	204.8	190.8	189.4	188.1
136kg	215.8	213.9	212.2	193.4	191.9	190.5
270kg	218.0	216.1	214.4	195.3	193.8	192.4
431kg	219.5	217.6	215.9	196.6	195.1	193.7
697kg	221.1	219.2	217.5	197.9	196.4	195.0

4 Underwater noise modelling results (non-UXO activities)

The following sections present the results of the dBSea underwater noise modelling for the non-UXO activities for the MHPGC Project, assessed using the criteria from NMFS (2024) and NOAA (2005) for marine mammals (section 2.3.1) and from Popper *et al.* (2014) for fish (section 2.3.2). Results for UXO clearance are given in section 5.

For $L_{E,p,t}$ criteria, results have been presented using swim speeds recommended by both English and Scottish regulators, as well as for stationary receptors as a comparison. The faster a receptor is able to swim from the noise, the lower the modelled impact range is calculated to be. All impact ranges have been calculated based on the maximum noise level in the water column as a worst-case.

The maximum impact ranges are predicted for the CLV when considering the LF cetacean hearing group and USBL acoustic positioning when considering the VHF cetacean hearing group. This is due to the difference in the peak frequency components of each source. All impact ranges for AUD INJ onset fall below 150m when considering a fleeing receptor, due to either the directionality and narrow frequency bands of the geophysical survey sources considered, or the low levels and non-impulsive nature of the continuous sources.

The predicted unweighted noise levels are presented as noise plots in Appendix A, showing the varying transmission of noise with water depth and any interaction with nearby land. Additional impact ranges covering the non-impulsive criteria for impulsive noise sources (as per section 2.2.1) are given in Appendix B.

Due to the complexity in acoustic conditions at close range to the source, estimated impact ranges are limited to a resolution of 10m from the source. As such, predicted ranges smaller than this have been presented as "< 10m".

4.1 Single Beam Echosounder (SBES)

Table 4-1 to Table 4-4 present the modelled impact ranges for SBES noise, with maximum predicted ranges calculated for VHF cetaceans, however all AUD INJ onset ranges for marine mammals were predicted to be less than 10m when considering a fleeing receptor. The noise from SBES falls within the high-frequency sonar category in Popper *et al.* (2014), hence no impact ranges have been presented for fish.

Table 4-1: Predicted impact ranges associated with SBES noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		SBES (English swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	720m	560m	420m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	20m	10m	10m

Table 4-2: Predicted impact ranges associated with SBES noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		SBES (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing $2.1ms^{-1}$)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing $1.52ms^{-1}$)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing $1.4ms^{-1}$)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	740m	580m	440m
PW pinnipeds (Fleeing $1.8ms^{-1}$)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	20m	10m	10m

Table 4-3: Predicted impact ranges associated with SBES noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		SBES (stationary receptors)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary $0ms^{-1}$)	AUD INJ (197dB)	50m	40m	30m
	TTS (177dB)	770m	590m	430m
HF cetaceans (Stationary $0ms^{-1}$)	AUD INJ (201dB)	110m	90m	80m
	TTS (181dB)	1.1km	950m	790m
VHF cetaceans (Stationary $0ms^{-1}$)	AUD INJ (181dB)	1.2km	1.0km	840m
	TTS (161dB)	2.9km	2.8km	2.5km
PW pinnipeds (Stationary $0ms^{-1}$)	AUD INJ (195dB)	160m	140m	110m
	TTS (175dB)	1.4km	1.2km	1.1km

Table 4-4: Predicted impact ranges associated with SBES noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		SBES		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	2.6km	2.4km	2.1km

4.2 Sub-Bottom Profiler (SBP) chirp

The predicted impact ranges from SBP chirp noise are summarised in Table 4-5 to Table 4-9, with maximum predicted ranges calculated for the VHF cetacean hearing group. All predicted AUD INJ onset ranges using the NMFS (2024) non-impulsive criteria fall below 10m when considering fleeing receptors.

Table 4-5: Predicted impact ranges associated with SBP chirp noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		SBP chirp (English swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing $3.25ms^{-1}$)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	30m	20m	10m
HF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	660m	500m	290m
PW pinnipeds (Fleeing $1.5ms^{-1}$)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	150m	80m	40m

Table 4-6: Predicted impact ranges associated with SBP chirp noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		SBP chirp (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	60m	30m	20m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	740m	560m	340m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	110m	60m	30m

Table 4-7: Predicted impact ranges associated with SBP chirp noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		SBP chirp (stationary receptors)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	410m	260m	190m
	TTS (177dB)	6.6km	5.4km	4.6km
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	160m	120m	90m
	TTS (181dB)	4.5km	2.7km	2.1km
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	880m	720m	520m
	TTS (161dB)	11km	8.9km	7.8km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	490m	330m	240m
	TTS (175dB)	8.3km	6.2km	5.2km

Table 4-8: Predicted impact ranges associated with SBP chirp noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		SBP chirp		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	12km	11km	9.2km

Table 4-9: Predicted impact ranges associated with SBP chirp noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for mid-frequency sonar.

Popper et al. (2014) criteria		SBP chirp		
Unweighted $L_{p,RMS}$ (Mid-frequency sonar)		Maximum range	Mean range	Minimum range
> 210dB		< 10m	< 10m	< 10m
> 209dB		< 10m	< 10m	< 10m

4.3 Ultra-High Resolution Seismic (UHRS) sparker

Table 4-10 to Table 4-16 present the modelled impact ranges for UHRS sparker noise, which has been assessed using the various impulsive criteria sets for marine mammals and both low-frequency and mid-frequency sonar criteria for fish due to the frequency components present during the activity. Maximum AUD INJ onset ranges are calculated for VHF cetaceans using the $L_{p,pk}$ criteria (10m), however noise from UHRS sparker activity showed a rapid attenuation resulting in small impact ranges. Impact ranges using the NMFS (2024) and NOAA (2005) non-impulsive criteria are presented in section B.1 of Appendix B.

Table 4-10: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		UHRS sparker		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	< 10m	< 10m	< 10m
	TTS (216dB)	< 10m	< 10m	< 10m
HF cetaceans	AUD INJ (230dB)	< 10m	< 10m	< 10m
	TTS (224dB)	< 10m	< 10m	< 10m
VHF cetaceans	AUD INJ (202dB)	10m	10m	< 10m
	TTS (196dB)	30m	30m	20m
PW pinnipeds	AUD INJ (223dB)	< 10m	< 10m	< 10m
	TTS (217dB)	< 10m	< 10m	< 10m

Table 4-11: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wt d}$ criteria for impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria Weighted $L_{E,p,24h,wt d}$ (Impulsive)		UHRS sparker (English swim speeds)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (159dB)	< 10m	< 10m	< 10m
	TTS (144dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m

Table 4-12: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wt d}$ criteria for impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria Weighted $L_{E,p,24h,wt d}$ (Impulsive)		UHRS sparker (Scottish swim speeds)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (159dB)	< 10m	< 10m	< 10m
	TTS (144dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m

Table 4-13: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wt d}$ criteria for impulsive noise, assuming stationary receptors.

NMFS (2024) criteria Weighted $L_{E,p,24h,wt d}$ (Impulsive)		UHRS sparker (stationary receptor)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	50m	30m	20m
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (159dB)	< 10m	< 10m	< 10m
	TTS (144dB)	90m	70m	60m
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	30m	20m	20m

Table 4-14: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from an impulsive or intermittent (non-explosive) noise source.

NOAA (2005) criteria		UHRS sparker		
Unweighted $L_{p,RMS}$ (Impulsive)		Maximum range	Mean range	Minimum range
Level B	160dB	< 10m	< 10m	< 10m

Table 4-15: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for low-frequency sonar.

Popper et al. (2014) criteria		UHRS sparker		
Unweighted $L_{p,RMS}$ (Low-frequency sonar)		Maximum range	Mean range	Minimum range
> 193dB		< 10m	< 10m	< 10m
> 197dB		< 10m	< 10m	< 10m

Table 4-16: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for mid-frequency sonar.

Popper et al. (2014) criteria		UHRS sparker		
Unweighted $L_{p,RMS}$ (Mid-frequency sonar)		Maximum range	Mean range	Minimum range
> 210dB		< 10m	< 10m	< 10m
> 209dB		< 10m	< 10m	< 10m

4.4 High Frequency Sub-Bottom Profiler (SBP)

Table 4-17 to Table 4-20 present the modelled impact ranges for high frequency SBP noise, all AUD INJ onset ranges are predicted to be less than 10m. The noise from high frequency SBP falls within the high-frequency sonar category in Popper et al. (2014), as such no impact ranges have been presented for fish.

Table 4-17: Predicted impact ranges associated with high frequency SBP noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		High frequency SBP (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing $3.25ms^{-1}$)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	80m	20m	10m
HF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	160m	100m	60m
PW pinnipeds (Fleeing $1.5ms^{-1}$)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	30m	20m	10m

Table 4-18: Predicted impact ranges associated with high frequency SBP noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		High frequency SBP (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	150m	40m	20m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	160m	110m	60m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	20m	10m	10m

Table 4-19: Predicted impact ranges associated with high frequency SBP noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		High frequency SBP (stationary receptors)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	500m	320m	220m
	TTS (177dB)	7.5km	6.4km	5.8km
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	70m	60m	50m
	TTS (181dB)	1.1km	870m	640m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	430m	340m	250m
	TTS (161dB)	2.9km	2.6km	2.2km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	240m	190m	150m
	TTS (175dB)	5.7km	4.6km	3.7km

Table 4-20: Predicted impact ranges associated with high frequency SBP noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		High frequency SBP		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	16km	14km	12km

4.5 Seismic Cone Penetration Testing (sCPT)

Table 4-21 to Table 4-26 present the modelled impact ranges for sCPT, which has been assessed using the various impulsive criteria sets for marine mammals. Due to lack of suitable classification information in Popper *et al.* (2014) and the low level of noise produced by sCPT activity, sCPT noise has been assessed using the continuous noise criteria for fish in this study, although due to the low noise levels predicted from sCPT activity, all impact ranges are predicted to be less than 10m including any of the other source classifications in Popper *et al.* (2014).

For completeness, impact ranges using the NMFS (2024) and NOAA (2005) non-impulsive criteria are presented in section B.2 of Appendix B.

Table 4-21: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		sCPT		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	< 10m	< 10m	< 10m
	TTS (216dB)	< 10m	< 10m	< 10m
HF cetaceans	AUD INJ (230dB)	< 10m	< 10m	< 10m
	TTS (224dB)	< 10m	< 10m	< 10m
VHF cetaceans	AUD INJ (202dB)	< 10m	< 10m	< 10m
	TTS (196dB)	< 10m	< 10m	< 10m
PW pinnipeds	AUD INJ (223dB)	< 10m	< 10m	< 10m
	TTS (217dB)	< 10m	< 10m	< 10m

Table 4-22: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wt d}$ criteria for impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria Weighted $L_{E,p,24h,wt d}$ (Impulsive)		sCPT (English swim speeds)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing $3.25ms^{-1}$)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (159dB)	< 10m	< 10m	< 10m
	TTS (144dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing $1.5ms^{-1}$)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m

Table 4-23: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wt d}$ criteria for impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria Weighted $L_{E,p,24h,wt d}$ (Impulsive)		sCPT (Scottish swim speeds)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing $2.1ms^{-1}$)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing $1.52ms^{-1}$)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing $1.4ms^{-1}$)	AUD INJ (159dB)	< 10m	< 10m	< 10m
	TTS (144dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing $1.8ms^{-1}$)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m

Table 4-24: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wt d}$ criteria for impulsive noise, assuming stationary receptors.

NMFS (2024) criteria Weighted $L_{E,p,24h,wt d}$ (Impulsive)		sCPT (stationary receptor)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary $0ms^{-1}$)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m
HF cetaceans (Stationary $0ms^{-1}$)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Stationary $0ms^{-1}$)	AUD INJ (159dB)	< 10m	< 10m	< 10m
	TTS (144dB)	< 10m	< 10m	< 10m
PW pinnipeds (Stationary $0ms^{-1}$)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m

Table 4-25: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from an impulsive or intermittent (non-explosive) noise source.

NOAA (2005) criteria		sCPT		
Unweighted $L_{p,RMS}$ (Impulsive)		Maximum range	Mean range	Minimum range
Level B	160dB	< 10m	< 10m	< 10m

Table 4-26: Predicted impact ranges associated with sCPT noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for low-frequency sonar.

Popper et al. (2014) criteria		sCPT		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
170dB (48 hours)		< 10m	< 10m	< 10m
158dB (12 hours)		< 10m	< 10m	< 10m

4.6 Vibro-coring

The predicted impact ranges from vibro-coring noise are summarised in Table 4-27 to Table 4-31, with maximum predicted ranges calculated for VHF cetaceans, however all AUD INJ onset ranges are predicted to be smaller than 10m for fleeing receptors.

Table 4-27: Predicted impact ranges associated with vibro-coring noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		Vibro-coring (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing $3.25ms^{-1}$)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	50m	30m	20m
HF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	10m	< 10m	< 10m
VHF cetaceans (Fleeing $1.5ms^{-1}$)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	950m	570m	320m
PW pinnipeds (Fleeing $1.5ms^{-1}$)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	270m	130m	70m

Table 4-28: Predicted impact ranges associated with vibro-coring noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		Vibro-coring (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing $2.1ms^{-1}$)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	110m	50m	30m
HF cetaceans (Fleeing $1.52ms^{-1}$)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	10m	< 10m	< 10m
VHF cetaceans (Fleeing $1.4ms^{-1}$)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	1.1km	630m	360m
PW pinnipeds (Fleeing $1.8ms^{-1}$)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	200m	100m	50m

Table 4-29: Predicted impact ranges associated with vibro-coring noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		Vibro-coring (stationary receptors)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	520m	340m	250m
	TTS (177dB)	7.5km	6.2km	5.5km
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	180m	140m	110m
	TTS (181dB)	3.9km	2.8km	2.2km
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	980m	760m	570m
	TTS (161dB)	8.5km	7.6km	6.8km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	630m	410m	300m
	TTS (175dB)	7.9km	6.8km	6.0km

Table 4-30: Predicted impact ranges associated with vibro-coring noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		Vibro-coring		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	13km	12km	11km

Table 4-31: Predicted impact ranges associated with vibro-coring noise at the MHPGC Project for species of fish using the Popper *et al.* (2014) $L_{p,RMS}$ criteria for continuous noise.

Popper <i>et al.</i> (2014) criteria		Vibro-coring		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
170dB (48 hours)		20m	10m	10m
158dB (12 hours)		120m	80m	60m

4.7 Ultra Short Baseline (USBL) acoustic positioning

The modelled impact ranges from USBL acoustic positioning activities are presented in Table 4-32 to Table 4-36, which has been assessed using the various impulsive criteria sets for marine mammals. The noise from high frequency SBP falls within the high-frequency sonar category in Popper *et al.* (2014), and as such no impact ranges have been presented for fish. Maximum predicted ranges are calculated for VHF cetaceans due to the frequency components for the USBL acoustic positioning noise. Maximum AUD INJ onset ranges are predicted up to 150m when considering a fleeing receptor assuming the Scottish swim speeds. Impact ranges using the NMFS (2024) and NOAA (2005) non-impulsive criteria are presented in section B.3 of Appendix B.

Table 4-32: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria		USBL acoustic positioning		
Unweighted $L_{p,pk}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	< 10m	< 10m	< 10m
	TTS (216dB)	< 10m	< 10m	< 10m
HF cetaceans	AUD INJ (230dB)	< 10m	< 10m	< 10m
	TTS (224dB)	< 10m	< 10m	< 10m
VHF cetaceans	AUD INJ (202dB)	< 10m	< 10m	< 10m
	TTS (196dB)	< 10m	< 10m	< 10m
PW pinnipeds	AUD INJ (223dB)	< 10m	< 10m	< 10m
	TTS (217dB)	< 10m	< 10m	< 10m

Table 4-33: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		USBL acoustic positioning (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (159dB)	140m	90m	70m
	TTS (144dB)	1.4km	1.2km	1.1km
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m

Table 4-34: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		USBL acoustic positioning (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (193dB)	< 10m	< 10m	< 10m
	TTS (178dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (159dB)	150m	100m	70m
	TTS (144dB)	1.4km	1.2km	1.1km
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (183dB)	< 10m	< 10m	< 10m
	TTS (168dB)	< 10m	< 10m	< 10m

Table 4-35: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		USBL acoustic positioning (stationary receptor)		
Weighted $L_{E,p,24h,wtd}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (183dB)	80m	60m	50m
	TTS (168dB)	580m	430m	340m
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (193dB)	70m	60m	60m
	TTS (178dB)	500m	410m	340m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (159dB)	2.5km	2.2km	2.1km
	TTS (144dB)	4.9km	4.4km	4.1km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (183dB)	210m	170m	150m
	TTS (168dB)	1.3km	1.1km	830m

Table 4-36: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from an impulsive or intermittent (non-explosive) noise source.

NOAA (2005) criteria		USBL acoustic positioning		
Unweighted $L_{p,RMS}$ (Impulsive)		Maximum range	Mean range	Minimum range
Level B	160dB	< 10m	< 10m	< 10m

4.8 Rock cutting

Table 4-37 to Table 4-41 present the modelled impact ranges for rock cutting noise (including cutter suction dredging), with maximum predicted ranges calculated for the LF cetacean hearing group. All AUD INJ onset ranges are predicted to be less than 10m for fleeing receptors.

Table 4-37: Predicted impact ranges associated with rock cutting noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		Rock cutting (English swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	100m	20m	10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	130m	80m	50m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	90m	40m	20m

Table 4-38: Predicted impact ranges associated with rock cutting noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		Rock cutting (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	180m	50m	20m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	140m	90m	50m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	60m	30m	20m

Table 4-39: Predicted impact ranges associated with rock cutting noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		Rock cutting (stationary receptors)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	520m	320m	220m
	TTS (177dB)	6.3km	5.8km	5.4km
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	80m	70m	60m
	TTS (181dB)	2.0km	1.5km	1.1km
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	430m	330m	260m
	TTS (161dB)	5.6km	5.0km	4.5km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	370m	250m	190m
	TTS (175dB)	5.5km	4.9km	4.4km

Table 4-40: Predicted impact ranges associated with rock cutting noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		Rock cutting		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	15km	14km	12km

Table 4-41: Predicted impact ranges associated with rock cutting noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for continuous noise.

Popper <i>et al.</i> (2014) criteria Unweighted $L_{p,RMS}$ (Continuous)	Rock cutting		
	Maximum range	Mean range	Minimum range
170dB (48 hours)	20m	10m	< 10m
158dB (12 hours)	190m	80m	50m

4.9 Dredging

Modelled impact ranges based on the predicted noise levels from dredging noise are presented in Table 4-42 to Table 4-46. All AUD INJ and TTS onset ranges are predicted to be less than 10m for fleeing receptors when considering the NMFS (2024) non-impulsive criteria.

Table 4-42: Predicted impact ranges associated with dredging noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Dredging (English swim speeds)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table 4-43: Predicted impact ranges associated with dredging noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Dredging (Scottish swim speeds)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table 4-44: Predicted impact ranges associated with dredging noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Dredging (stationary receptors)		
		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	120m	80m	70m
	TTS (177dB)	2.8km	2.1km	1.6km
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	200m	160m	130m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	60m	60m	50m
	TTS (161dB)	1.4km	950m	710m
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	40m	40m	30m
	TTS (175dB)	960m	740m	550m

Table 4-45: Predicted impact ranges associated with dredging noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		Dredging		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	10km	8.5km	7.8km

Table 4-46: Predicted impact ranges associated with dredging noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for continuous noise.

Popper et al. (2014) criteria		Dredging		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
170dB (48 hours)		< 10m	< 10m	< 10m
158dB (12 hours)		50m	30m	20m

4.10 Medium support vessel

Table 4-47 to Table 4-51 present the modelled impact ranges for vessel noise from medium support vessels (measuring 50 – 100m in length), with maximum predicted ranges calculated for LF cetaceans, however all AUD INJ onset ranges are predicted to be less than 10m for fleeing receptors.

Table 4-47: Predicted impact ranges associated with medium support vessel noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		Medium support vessel (English swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	20m	10m	10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table 4-48: Predicted impact ranges associated with medium support vessel noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		Medium support vessel (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	40m	10m	10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table 4-49: Predicted impact ranges associated with medium support vessel noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		Medium support vessel (stationary receptors)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	360m	200m	140m
	TTS (177dB)	4.9km	4.1km	3.4km
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	30m	30m	20m
	TTS (181dB)	690m	460m	310m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	110m	100m	80m
	TTS (161dB)	2.0km	1.7km	1.6km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	130m	100m	80m
	TTS (175dB)	2.6km	2.3km	1.9km

Table 4-50: Predicted impact ranges associated with medium support vessel noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		Medium support vessel		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	12km	11km	9.4km

Table 4-51: Predicted impact ranges associated with medium support vessel noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for continuous noise.

Popper et al. (2014) criteria		Medium support vessel		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
170dB (48 hours)		10m	< 10m	< 10m
158dB (12 hours)		100m	50m	40m

4.11 Small support vessel

Table 4-52 to Table 4-56 present the modelled impact ranges for vessel noise from small support vessels (measuring less than 50m in length), all impact ranges are predicted to be smaller than those predicted for medium support vessels (section 4.10).

Table 4-52: Predicted impact ranges associated with small support vessel noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		Small support vessel (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table 4-53: Predicted impact ranges associated with small support vessel noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		Small support vessel (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table 4-54: Predicted impact ranges associated with small support vessel noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtg}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		Small support vessel (stationary receptors)		
Weighted $L_{E,p,24h,wtg}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	50m	30m	30m
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	20m	20m	10m

Table 4-55: Predicted impact ranges associated with small support vessel noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		Small support vessel		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	420m	210m	130m

Table 4-56: Predicted impact ranges associated with small support vessel noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for continuous noise.

Popper et al. (2014) criteria		Small support vessel		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
170dB (48 hours)		< 10m	< 10m	< 10m
158dB (12 hours)		< 10m	< 10m	< 10m

4.12 Cable lay vessel (CLV)

The predicted impact ranges from CLV noise are summarised in Table 4-57 to Table 4-61, with maximum predicted ranges calculated for the LF cetacean hearing group. Maximum AUD INJ onset ranges are predicted out to 10m using the NMFS (2024) non-impulsive criteria assuming a fleeing receptor.

Table 4-57: Predicted impact ranges associated with CLV noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		CLV (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	10m	< 10m	< 10m
	TTS (177dB)	1.2km	810m	580m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	400m	260m	160m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	710m	490m	290m

Table 4-58: Predicted impact ranges associated with CLV noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		CLV (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	10m	< 10m	< 10m
	TTS (177dB)	1.8km	1.5km	1.2km
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	440m	290m	180m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	570m	360m	190m

Table 4-59: Predicted impact ranges associated with CLV noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		CLV (stationary receptors)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	1.8km	1.5km	1.2km
	TTS (177dB)	19km	17km	14km
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	160m	130m	100m
	TTS (181dB)	3.3km	2.8km	2.4km
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	770m	600m	450m
	TTS (161dB)	8.3km	6.5km	5.6km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	930m	700m	510m
	TTS (175dB)	12km	11km	9.5km

Table 4-60: Predicted impact ranges associated with CLV noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		CLV		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	27km	24km	19km

Table 4-61: Predicted impact ranges associated with CLV noise at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,RMS}$ criteria for continuous noise.

Popper et al. (2014) criteria		CLV		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
170dB (48 hours)		170m	70m	40m
158dB (12 hours)		550m	350m	230m

5 Underwater noise modelling results (UXO clearance)

The results of the UXO clearance dBSea underwater noise modelling are presented in this section, covering low-order clearance, low-yield donor charges, high-order donor charges and high-order UXO clearance

Consent is being sought for low-order UXO clearance only. Information relating to high-order UXO clearance is provided for context and information purposes only, and does not form part of the consent applications. Should high-order UXO clearance be required, this would be subject to a separate Marine Licence application.

Results are presented in terms of the NMFS (2024) marine mammal criteria (section 2.3.1) and the Popper *et al.* (2014) criteria for fish and sea turtles (section 2.3.2). It should be noted that the NOAA (2005) Level B harassment criteria have not been included for UXO clearance, as it is specifically for non-explosive impulsive noise.

With regards to UXO detonation noise and the $L_{E,p,t}$ criteria given in NMFS (2024), the detonations modelled for this section are all considered single pulse ($L_{E,p,sp}$), as such swim speed is not considered. All impact ranges have been calculated based on the maximum noise level in the water column. No consideration has been given to mitigation or noise abatement systems in this modelling.

The maximum AUD INJ onset ranges are predicted to be between 1.9km for the smallest charge weight (0.08kg; VHF cetacean, $L_{E,p,sp}$), out to 18km for the largest charge weight (697kg; VHF cetacean, $L_{p,pk}$). When considering the impacts on fish and sea turtles using the Popper *et al.* (2014) criteria, mortality and potential mortal injury ranges are predicted between 80 and 340m for the largest charge weight (697kg). The modelled impact ranges for all the considered UXO clearance activities are presented in Table 5-1 to Table 5-30 across sections 5.1 to 5.3.

The predicted unweighted UXO clearance noise levels are presented as noise plots in Appendix A (section A.2), showing the varying transmission of noise with water depth and any interaction with nearby land. Additional impact ranges covering the non-impulsive criteria for impulsive noise sources (as per section 2.2.1) are given in Appendix B (section 0).

As with the previous section, estimated impact ranges are limited to a resolution of 10m from the source, due to the complexity in acoustic conditions at very close range to the source. As such, predicted ranges smaller than this have been presented as "< 10m".

5.1 Low-order and low-yield donor charge

5.1.1 0.08kg NEQ

Table 5-1: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.08kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria		0.08kg NEQ		
Unweighted $L_{p,pk}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	10m	10m	10m
	TTS (216dB)	20m	20m	20m
HF cetaceans	AUD INJ (230dB)	< 10m	< 10m	< 10m
	TTS (224dB)	< 10m	< 10m	< 10m
VHF cetaceans	AUD INJ (202dB)	340m	230m	170m
	TTS (196dB)	830m	650m	550m
PW pinnipeds	AUD INJ (223dB)	10m	10m	< 10m
	TTS (217dB)	20m	20m	20m

Table 5-2: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.08kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for impulsive noise.

NMFS (2024) criteria		0.08kg NEQ		
Weighted $L_{E,p,sp,wtd}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	590m	410m	280m
	TTS (168dB)	4.3km	3.8km	3.4km
HF cetaceans	AUD INJ (193dB)	30m	30m	20m
	TTS (178dB)	350m	260m	200m
VHF cetaceans	AUD INJ (159dB)	1.9km	1.3km	1.0km
	TTS (144dB)	7.4km	6.3km	5.8km
PW pinnipeds	AUD INJ (183dB)	260m	190m	150m
	TTS (168dB)	2.6km	2.0km	1.7km

Table 5-3: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.08kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria		0.08kg NEQ		
Unweighted $L_{p,pk}$ (Explosions)		Maximum range	Mean range	Minimum range
229dB (Upper bound)		< 10m	< 10m	< 10m
234dB (Lower bound)		< 10m	< 10m	< 10m

5.1.2 0.5kg NEQ

Table 5-4: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.5kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria		0.5kg NEQ		
Unweighted $L_{p,pk}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	20m	20m	20m
	TTS (216dB)	70m	60m	40m
HF cetaceans	AUD INJ (230dB)	< 10m	< 10m	< 10m
	TTS (224dB)	20m	20m	20m
VHF cetaceans	AUD INJ (202dB)	830m	650m	550m
	TTS (196dB)	2.9km	1.9km	1.5km
PW pinnipeds	AUD INJ (223dB)	20m	20m	20m
	TTS (217dB)	50m	40m	40m

Table 5-5: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.5kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for impulsive noise.

NMFS (2024) criteria		0.5kg NEQ		
Weighted $L_{E,p,sp,wtd}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	1.1km	890m	690m
	TTS (168dB)	7.8km	7.2km	6.5km
HF cetaceans	AUD INJ (193dB)	70m	60m	50m
	TTS (178dB)	800m	590m	450m
VHF cetaceans	AUD INJ (159dB)	3.4km	2.7km	2.1km
	TTS (144dB)	9.6km	8.8km	8.1km
PW pinnipeds	AUD INJ (183dB)	650m	430m	310m
	TTS (168dB)	4.9km	4.1km	3.6km

Table 5-6: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.5kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria Unweighted $L_{p,pk}$ (Explosions)	0.5kg NEQ		
	Maximum range	Mean range	Minimum range
229dB (Upper bound)	10m	10m	< 10m
234dB (Lower bound)	< 10m	< 10m	< 10m

5.1.3 $2 \times 0.75\text{kg NEQ}$ (1.5kg total)

Table 5-7: Predicted impact ranges associated with low-order or low-yield donor charge noise ($2 \times 0.75\text{kg NEQ}$) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		$2 \times 0.75\text{kg NEQ}$		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	40m	30m	30m
	TTS (216dB)	90m	90m	80m
HF cetaceans	AUD INJ (230dB)	10m	10m	10m
	TTS (224dB)	30m	30m	20m
VHF cetaceans	AUD INJ (202dB)	1.7km	1.3km	1.1km
	TTS (196dB)	4.1km	3.3km	2.6km
PW pinnipeds	AUD INJ (223dB)	30m	30m	30m
	TTS (217dB)	80m	80m	80m

Table 5-8: Predicted impact ranges associated with low-order or low-yield donor charge noise ($2 \times 0.75\text{kg NEQ}$) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtg}$ criteria for impulsive noise.

NMFS (2024) criteria Weighted $L_{E,p,sp,wtg}$ (Impulsive)		$2 \times 0.75\text{kg NEQ}$		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	1.8km	1.4km	1.1km
	TTS (168dB)	11km	10km	9.3km
HF cetaceans	AUD INJ (193dB)	110m	90m	80m
	TTS (178dB)	1.3km	970m	750m
VHF cetaceans	AUD INJ (159dB)	4.5km	3.7km	3.2km
	TTS (144dB)	11km	11km	9.7km
PW pinnipeds	AUD INJ (183dB)	910m	710m	540m
	TTS (168dB)	6.7km	5.9km	5.4km

Table 5-9: Predicted impact ranges associated with low-order or low-yield donor charge noise ($2 \times 0.75\text{kg NEQ}$) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria Unweighted $L_{p,pk}$ (Explosions)	$2 \times 0.75\text{kg NEQ}$		
	Maximum range	Mean range	Minimum range
229dB (Upper bound)	20m	10m	10m
234dB (Lower bound)	< 10m	< 10m	< 10m

5.1.4 $4 \times 0.75\text{kg NEQ}$ (3.0kg total)

Table 5-10: Predicted impact ranges associated with low-order or low-yield donor charge noise ($4 \times 0.75\text{kg NEQ}$) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		$4 \times 0.75\text{kg NEQ}$		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	70m	50m	40m
	TTS (216dB)	320m	120m	110m
HF cetaceans	AUD INJ (230dB)	20m	20m	20m
	TTS (224dB)	40m	30m	30m
VHF cetaceans	AUD INJ (202dB)	2.6km	1.8km	1.5km
	TTS (196dB)	5.1km	4.5km	3.8km
PW pinnipeds	AUD INJ (223dB)	40m	40m	40m
	TTS (217dB)	110m	100m	90m

Table 5-11: Predicted impact ranges associated with low-order or low-yield donor charge noise ($4 \times 0.75\text{kg NEQ}$) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for impulsive noise.

NMFS (2024) criteria Weighted $L_{E,p,sp,wt,d}$ (Impulsive)		$4 \times 0.75\text{kg NEQ}$		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	2.3km	1.9km	1.6km
	TTS (168dB)	13km	12km	11km
HF cetaceans	AUD INJ (193dB)	160m	120m	100m
	TTS (178dB)	1.8km	1.3km	1.0km
VHF cetaceans	AUD INJ (159dB)	5.1km	4.4km	3.9km
	TTS (144dB)	13km	12km	11 m
PW pinnipeds	AUD INJ (183dB)	1.3km	980m	760m
	TTS (168dB)	7.9km	7.3km	6.6km

Table 5-12: Predicted impact ranges associated with low-order or low-yield donor charge noise ($4 \times 0.75\text{kg NEQ}$) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria Unweighted $L_{p,pk}$ (Explosions)		$4 \times 0.75\text{kg NEQ}$		
		Maximum range	Mean range	Minimum range
229dB (Upper bound)		20m	20m	20m
234dB (Lower bound)		10m	10m	10m

5.2 High-order donor charge

5.2.1 1.2kg NEQ

Table 5-13: Predicted impact ranges associated with high-order donor charge noise (1.2kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		1.2kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	30m	30m	30m
	TTS (216dB)	80m	80m	80m
HF cetaceans	AUD INJ (230dB)	10m	10m	10m
	TTS (224dB)	20m	20m	20m
VHF cetaceans	AUD INJ (202dB)	1.4km	1.1km	870m
	TTS (196dB)	3.5km	2.9km	2.5km
PW pinnipeds	AUD INJ (223dB)	30m	30m	20m
	TTS (217dB)	80m	80m	80m

Table 5-14: Predicted impact ranges associated with high-order donor charge noise (1.2kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for impulsive noise.

NMFS (2024) criteria		1.2kg NEQ		
Weighted $L_{E,p,sp,wt,d}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	1.7km	1.3km	1.0km
	TTS (168dB)	10km	9.5km	8.8km
HF cetaceans	AUD INJ (193dB)	100m	90m	70m
	TTS (178dB)	1.2km	880m	680m
VHF cetaceans	AUD INJ (159dB)	4.4km	3.5km	2.9km
	TTS (144dB)	11km	10km	9.3km
PW pinnipeds	AUD INJ (183dB)	850m	640m	490m
	TTS (168dB)	6.2km	5.5km	4.9km

Table 5-15: Predicted impact ranges associated with high-order donor charge noise (1.2kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria		1.2kg NEQ		
Unweighted $L_{p,pk}$ (Explosions)		Maximum range	Mean range	Minimum range
229dB (Upper bound)		10m	10m	10m
234dB (Lower bound)		< 10m	< 10m	< 10m

5.2.2 3.5kg NEQ

Table 5-16: Predicted impact ranges associated with high-order donor charge noise (3.5kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria		3.5kg NEQ		
Unweighted $L_{p,pk}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	70m	70m	70m
	TTS (216dB)	330m	150m	130m
HF cetaceans	AUD INJ (230dB)	20m	20m	20m
	TTS (224dB)	40m	40m	40m
VHF cetaceans	AUD INJ (202dB)	2.9km	2.1km	1.6km
	TTS (196dB)	5.3km	4.7km	4.1km
PW pinnipeds	AUD INJ (223dB)	50m	40m	40m
	TTS (217dB)	120m	110m	90m

Table 5-17: Predicted impact ranges associated with high-order donor charge noise (3.5kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for impulsive noise.

NMFS (2024) criteria		3.5kg NEQ		
Weighted $L_{E,p,sp,wt,d}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	2.4km	2.0km	1.7km
	TTS (168dB)	14km	13km	11km
HF cetaceans	AUD INJ (193dB)	170m	130m	100m
	TTS (178dB)	1.9km	1.4km	1.1km
VHF cetaceans	AUD INJ (159dB)	5.2km	4.6km	4.1km
	TTS (144dB)	13km	12km	11km
PW pinnipeds	AUD INJ (183dB)	1.5km	1.0km	810m
	TTS (168dB)	8.3km	7.6km	6.9km

Table 5-18: Predicted impact ranges associated with high-order donor charge noise (3.5kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria Unweighted $L_{p,pk}$ (Explosions)	3.5kg NEQ		
	Maximum range	Mean range	Minimum range
229dB (Upper bound)	20m	20m	20m
234dB (Lower bound)	10m	10m	10m

5.3 High-order UXO clearance

5.3.1 136kg NEQ

Table 5-19: Predicted impact ranges associated with high-order UXO clearance (136kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		136kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	370m	230m	180m
	TTS (216dB)	950m	730m	600m
HF cetaceans	AUD INJ (230dB)	80m	70m	40m
	TTS (224dB)	330m	140m	110m
VHF cetaceans	AUD INJ (202dB)	7.5km	6.4km	5.0km
	TTS (196dB)	20km	17km	15km
PW pinnipeds	AUD INJ (223dB)	360m	190m	150m
	TTS (217dB)	760m	620m	540m

Table 5-20: Predicted impact ranges associated with high-order UXO clearance (136kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtg}$ criteria for impulsive noise.

NMFS (2024) criteria Weighted $L_{E,p,sp,wtg}$ (Impulsive)		136kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	3.5km	2.9km	2.4km
	TTS (168dB)	17km	15km	13km
HF cetaceans	AUD INJ (193dB)	290m	230m	180m
	TTS (178dB)	3.1km	2.4km	1.9km
VHF cetaceans	AUD INJ (159dB)	7.6km	6.6km	6.0km
	TTS (144dB)	16km	15km	14km
PW pinnipeds	AUD INJ (183dB)	2.2km	1.7km	1.4km
	TTS (168dB)	11km	9.9km	9.1km

Table 5-21: Predicted impact ranges associated with high-order UXO clearance (136kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria Unweighted $L_{p,pk}$ (Explosions)	136kg NEQ		
	Maximum range	Mean range	Minimum range
229dB (Upper bound)	80m	80m	80m
234dB (Lower bound)	30m	30m	30m

5.3.2 270kg NEQ

Table 5-22: Predicted impact ranges associated with high-order UXO clearance (270kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		270kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	430m	340m	290m
	TTS (216dB)	1.7km	1.1km	870m
HF cetaceans	AUD INJ (230dB)	90m	90m	80m
	TTS (224dB)	370m	250m	180m
VHF cetaceans	AUD INJ (202dB)	11km	9.3km	6.5km
	TTS (196dB)	28km	24km	21km
PW pinnipeds	AUD INJ (223dB)	420m	310m	240m
	TTS (217dB)	1.2km	880m	780m

Table 5-23: Predicted impact ranges associated with high-order UXO clearance (270kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for impulsive noise.

NMFS (2024) criteria Weighted $L_{E,p,sp,wt,d}$ (Impulsive)		270kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	4.4km	3.8km	3.4km
	TTS (168dB)	19km	18km	14km
HF cetaceans	AUD INJ (193dB)	430m	300m	230m
	TTS (178dB)	4.0km	3.2km	2.6km
VHF cetaceans	AUD INJ (159dB)	8.4km	7.4km	6.6km
	TTS (144dB)	18km	16km	15km
PW pinnipeds	AUD INJ (183dB)	2.8km	2.2km	1.8km
	TTS (168dB)	13km	12km	11km

Table 5-24: Predicted impact ranges associated with high-order UXO clearance (270kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria Unweighted $L_{p,pk}$ (Explosions)		270kg NEQ		
		Maximum range	Mean range	Minimum range
229dB (Upper bound)		100m	100m	90m
234dB (Lower bound)		50m	40m	40m

5.3.3 431kg NEQ

Table 5-25: Predicted impact ranges associated with high-order UXO clearance (431kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria Unweighted $L_{p,pk}$ (Impulsive)		431kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	600m	450m	350m
	TTS (216dB)	2.0km	1.5km	990m
HF cetaceans	AUD INJ (230dB)	110m	100m	100m
	TTS (224dB)	420m	320m	280m
VHF cetaceans	AUD INJ (202dB)	14km	12km	11km
	TTS (196dB)	36km	31km	27km
PW pinnipeds	AUD INJ (223dB)	570m	360m	310m
	TTS (217dB)	1.7km	1.3km	920m

Table 5-26: Predicted impact ranges associated with high-order UXO clearance (431kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wd}$ criteria for impulsive noise.

NMFS (2024) criteria		431kg NEQ		
Weighted $L_{E,p,sp,wd}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	5.0km	4.5km	4.1km
	TTS (168dB)	21km	19km	15km
HF cetaceans	AUD INJ (193dB)	560m	370m	280m
	TTS (178dB)	4.6km	3.8km	3.0km
VHF cetaceans	AUD INJ (159dB)	8.9km	8.1km	7.3km
	TTS (144dB)	19km	17km	15km
PW pinnipeds	AUD INJ (183dB)	3.2km	2.7km	2.1km
	TTS (168dB)	14km	13km	12km

Table 5-27: Predicted impact ranges associated with high-order UXO clearance (431kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria		431kg NEQ		
Unweighted $L_{p,pk}$ (Explosions)		Maximum range	Mean range	Minimum range
229dB (Upper bound)		120m	110m	100m
234dB (Lower bound)		80m	60m	40m

5.3.4 697kg NEQ

Table 5-28: Predicted impact ranges associated with high-order UXO clearance (697kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{p,pk}$ criteria for impulsive noise.

NMFS (2024) criteria		697kg NEQ		
Unweighted $L_{p,pk}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (222dB)	770m	640m	540m
	TTS (216dB)	2.9km	2.1km	1.6km
HF cetaceans	AUD INJ (230dB)	230m	120m	100m
	TTS (224dB)	600m	410m	340m
VHF cetaceans	AUD INJ (202dB)	18km	15km	14km
	TTS (196dB)	47km	40km	35km
PW pinnipeds	AUD INJ (223dB)	700m	530m	420m
	TTS (217dB)	2.4km	1.7km	1.4km

Table 5-29: Predicted impact ranges associated with high-order UXO clearance (697kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wd}$ criteria for impulsive noise.

NMFS (2024) criteria		697kg NEQ		
Weighted $L_{E,p,sp,wd}$ (Impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (183dB)	5.9km	5.3km	4.8km
	TTS (168dB)	23km	20km	16km
HF cetaceans	AUD INJ (193dB)	680m	470m	340m
	TTS (178dB)	5.1km	4.4km	3.9km
VHF cetaceans	AUD INJ (159dB)	9.5km	8.7km	8.0km
	TTS (144dB)	20km	18km	16km
PW pinnipeds	AUD INJ (183dB)	3.9km	3.2km	2.6km
	TTS (168dB)	15km	14km	12km

Table 5-30: Predicted impact ranges associated with high-order UXO clearance (697kg NEQ) at the MHPGC Project for species of fish using the Popper et al. (2014) $L_{p,pk}$ criteria for explosions.

Popper et al. (2014) criteria		697kg NEQ		
Unweighted $L_{p,pk}$ (Explosions)		Maximum range	Mean range	Minimum range
229dB (Upper bound)		340m	150m	120m
234dB (Lower bound)		80m	80m	80m

6 Summary and conclusions

Subacoustech Environmental Ltd This Technical Report presents an underwater noise modelling assessment undertaken by Subacoustech Environmental Ltd. concerning noise-making activities during the MHPGC Project in the North Sea to connect the OSPs within Morven North or Morven South located within Scottish offshore waters, transiting through English offshore and inshore waters, to MHWS at landfall. The expected noise sources modelled in this assessment cover various geophysical and geotechnical surveys, cable installation, vessel noise and UXO clearance.

The level of underwater noise generated by the different activities was predicted using the dBSea underwater noise modelling software (v3.0) utilising a combined PE and ray tracing modelling approach, with a time-domain element included to model peak levels. The modelling considers a wide array of input parameters including the equipment source level, sound frequency content, seabed properties and the sound speed profile through the water column. Full account is also taken of the bathymetry in the areas surrounding the representative modelling location.

The modelled noise levels of the various activities have been interpreted using the noise criteria from NMFS (2024) and NOAA (2005) for marine mammals, and from Popper *et al.* (2014) for fish and sea turtles. Marine Invertebrates have also been considered, however currently no relevant criteria exist to assess these. No noise abatement systems have been included.

The largest predicted (non-UXO) impact ranges were calculated for CLV noise when considering the LF cetacean hearing group, and for USBL acoustic positioning when considering the VHF cetacean hearing group. All AUD INJ onset impact ranges are predicted to fall below 150m when considering a fleeing receptor, with the greatest impacts caused by the USBL acoustic positioning system. Impacts on fish are predicted to be much lower than those predicted for marine mammals.

Considering the noise from UXO clearance, the maximum AUD INJ onset ranges are predicted out to 18km for VHF cetaceans when considering the largest charge weight (697kg NEQ) using the NMFS (2024) $L_{p,pk}$ criteria. For fish and sea turtles, the mortality and potential mortal injury criteria from Popper *et al.* (2014) is met at ranges between 80 and 340m for the largest charge weight considered.

By its nature, mathematical modelling will produce results that indicate a precise range at which a criterion will be reached, but this does not reflect the inherent uncertainty in the physical processes, including many that change constantly under real world conditions. While the results present specific ranges at which each impact threshold is met based on the modelling results, the resulting ranges should be taken as indicative in determining where environmental effects may occur in receptors during the proposed activities.

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Appendix A Noise plots

A.1 Non-UXO activities

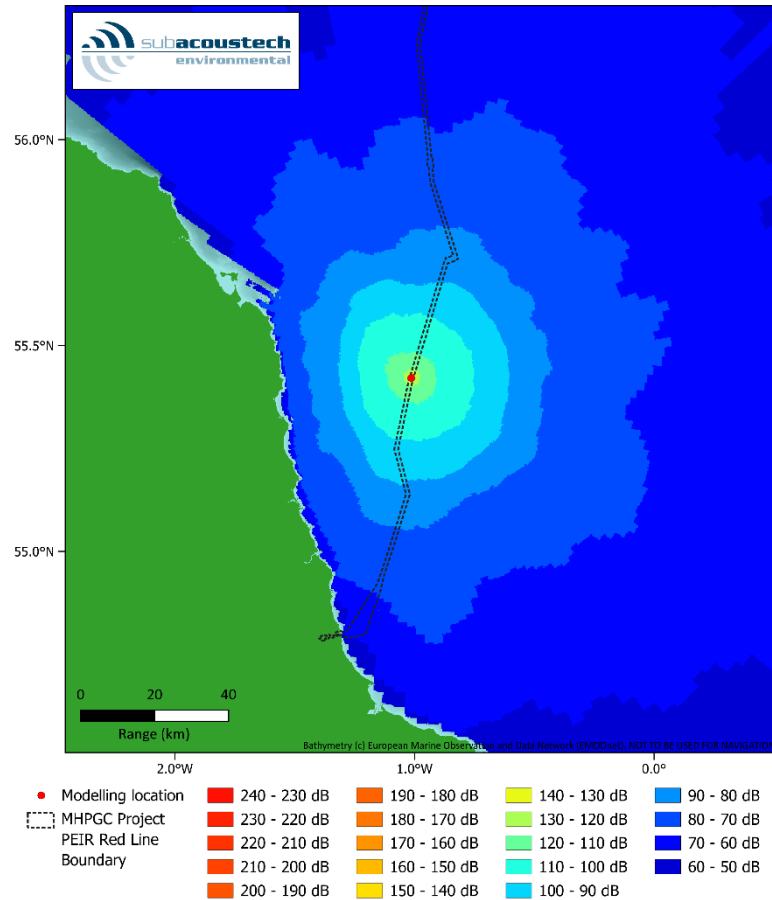


Figure A 1: Plot showing the modelled unweighted $L_{p,RMS}$ for SBES noise.

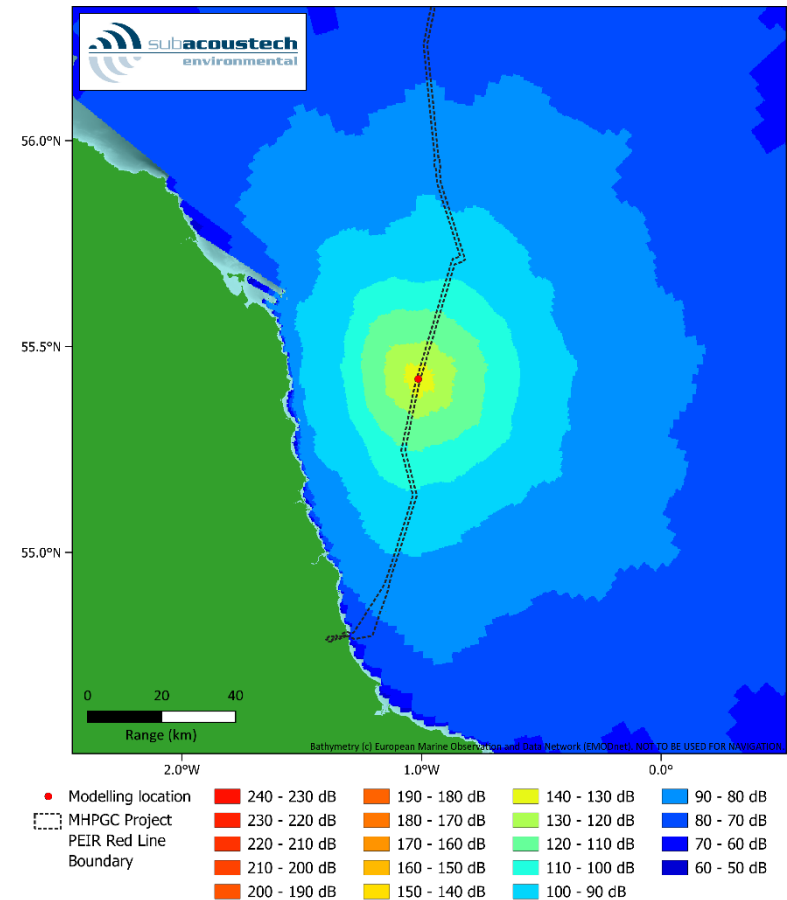


Figure A 2: Plot showing the modelled unweighted $L_{p,RMS}$ for SBP chirp noise.

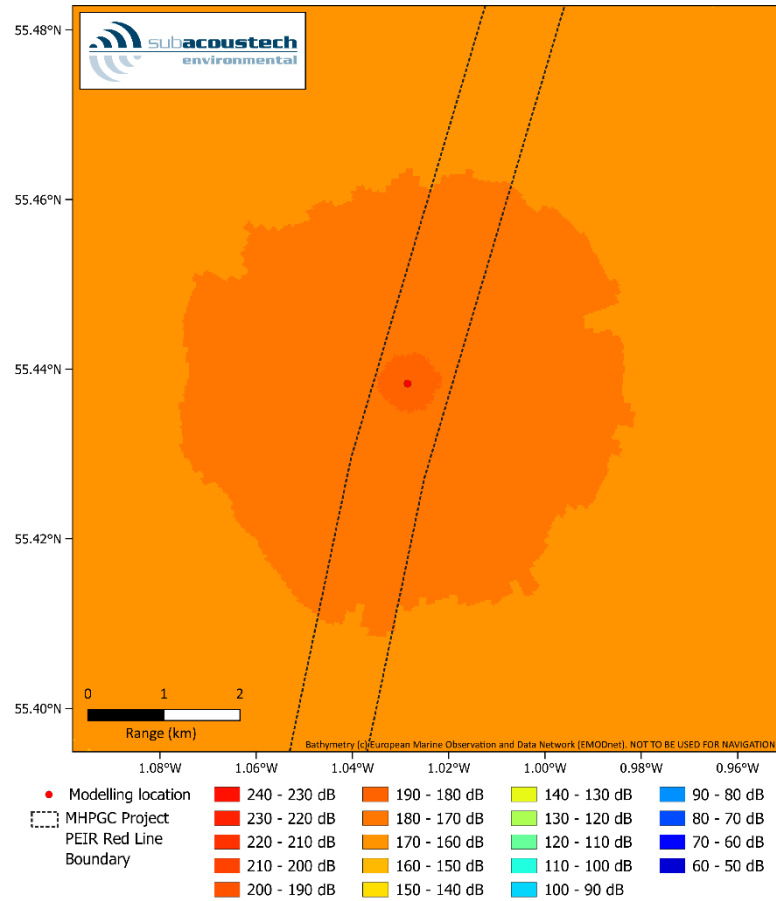


Figure A 3: Plot showing the modelled unweighted $L_{p,pk}$ for UHRS sparker noise (note the difference in scale between the $L_{E,p,sp}$ and the $L_{p,pk}$ UHRS sparker plots as discussed in section 3.1.2).

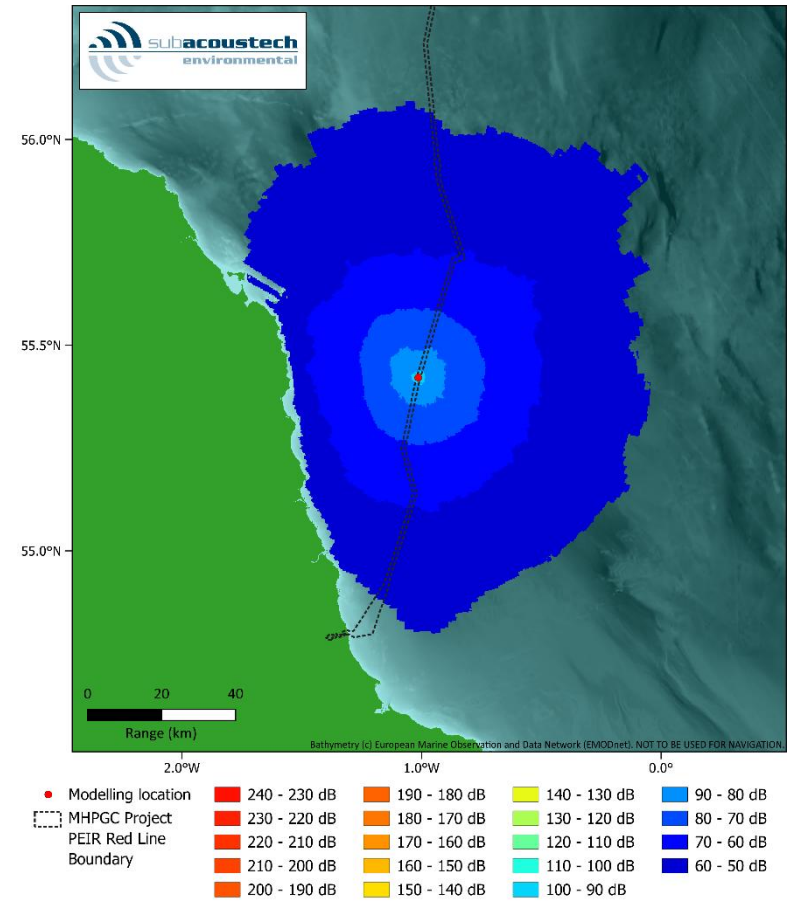


Figure A 4: Plot showing the modelled unweighted $L_{E,p,sp}$ for UHRS sparker noise (note the difference in scale between the $L_{E,p,sp}$ and the $L_{p,pk}$ UHRS sparker plots as discussed in section 3.1.2).

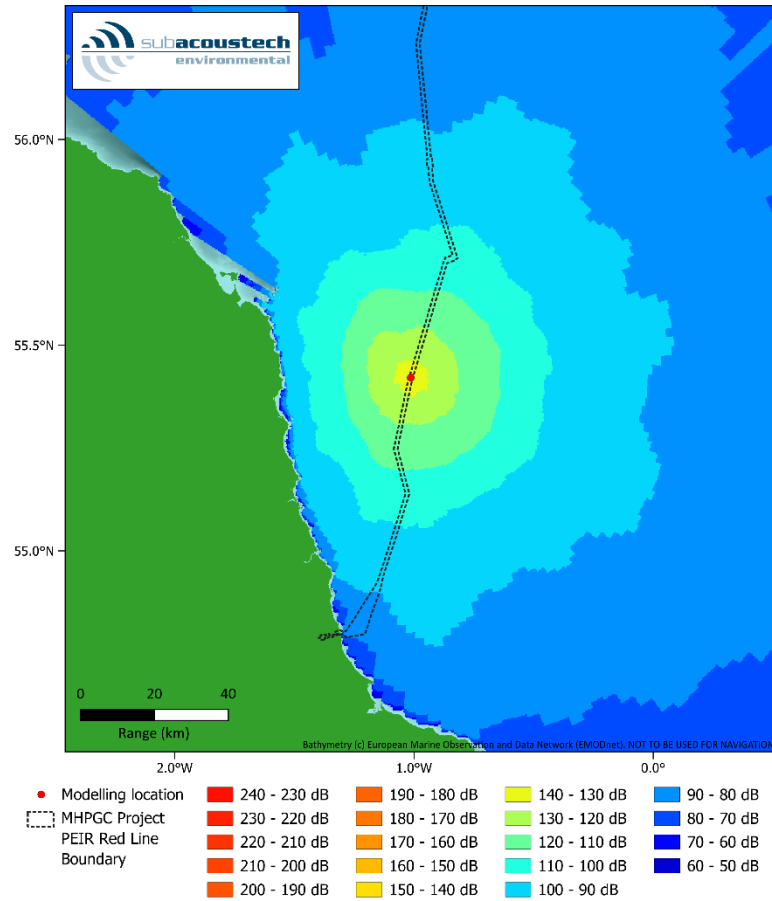


Figure A 5: Plot showing the modelled unweighted $L_{p,RMS}$ for high-frequency SBP noise.

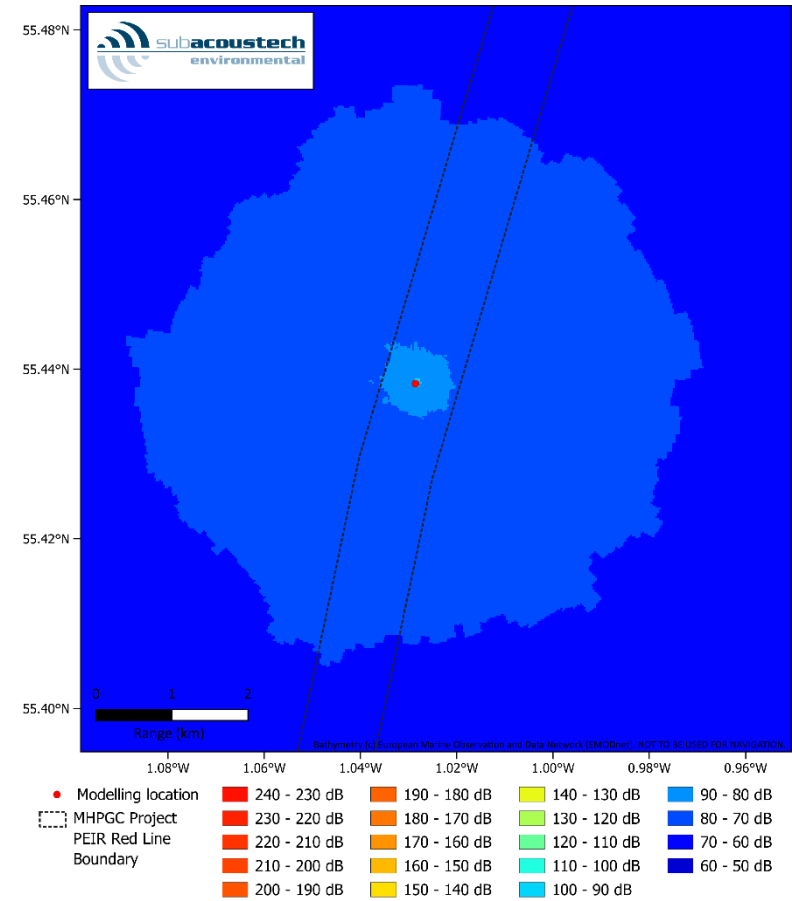


Figure A 6: Plot showing the modelled unweighted $L_{p,pk}$ for sCPT noise (note the difference in scale between the $L_{p,RMS}$ and the $L_{p,pk}$ sCPT plots as discussed in section 3.1.2).

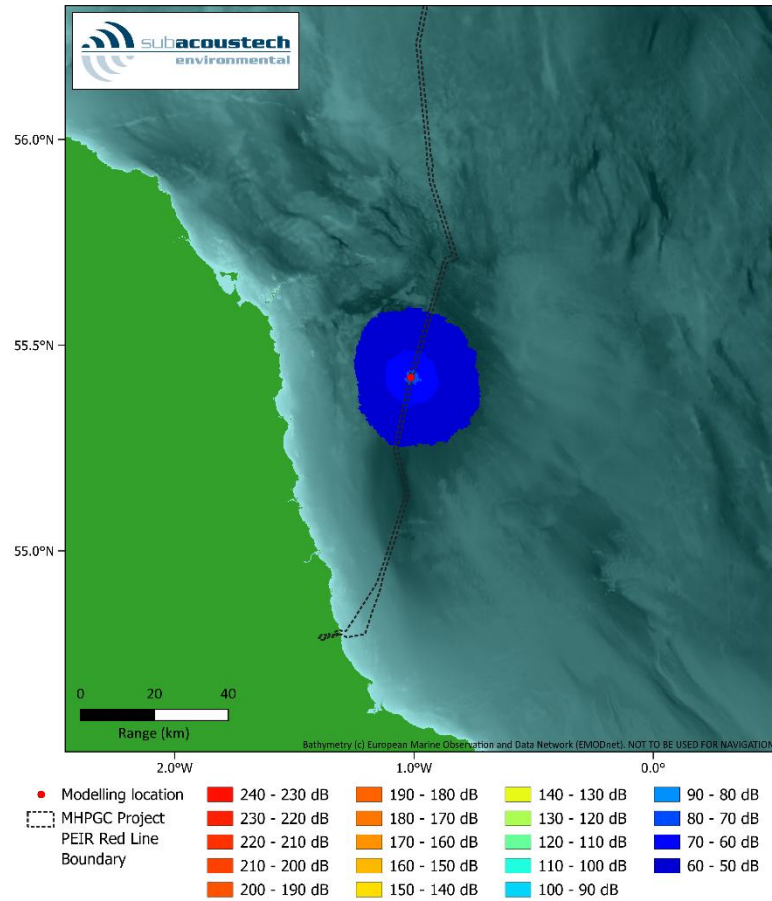


Figure A 7: Plot showing the modelled unweighted $L_{p,RMS}$ for SCPT noise (note the difference in scale between the $L_{p,RMS}$ and the $L_{p,pk}$ SCPT plots as discussed in section 3.1.2).

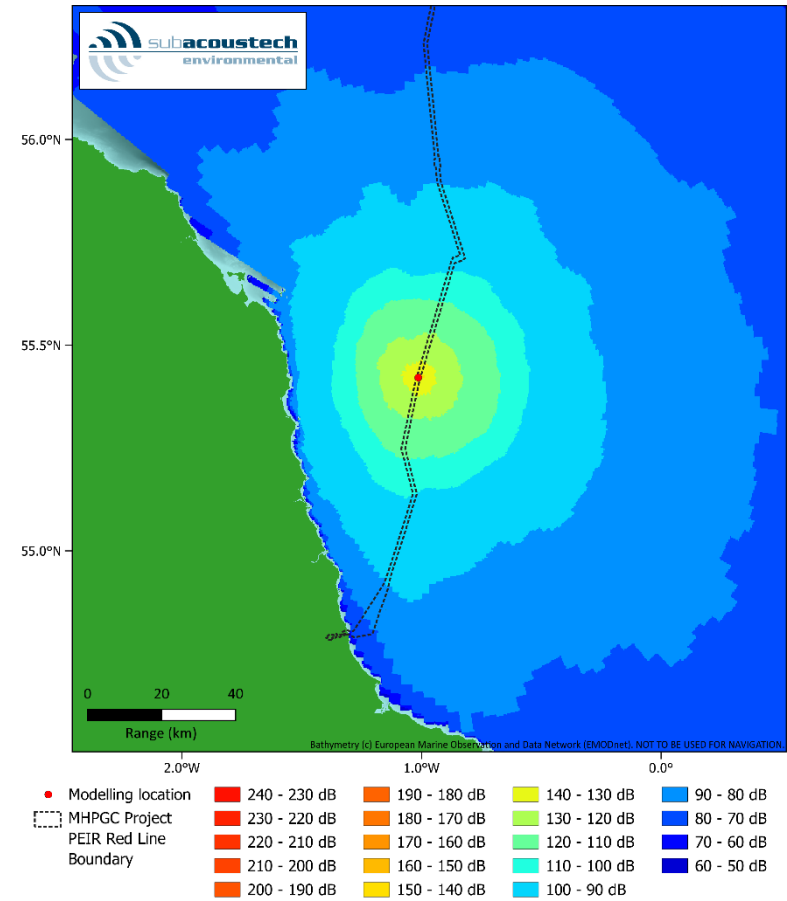


Figure A 8: Plot showing the modelled unweighted $L_{p,RMS}$ for vibro-coring noise.

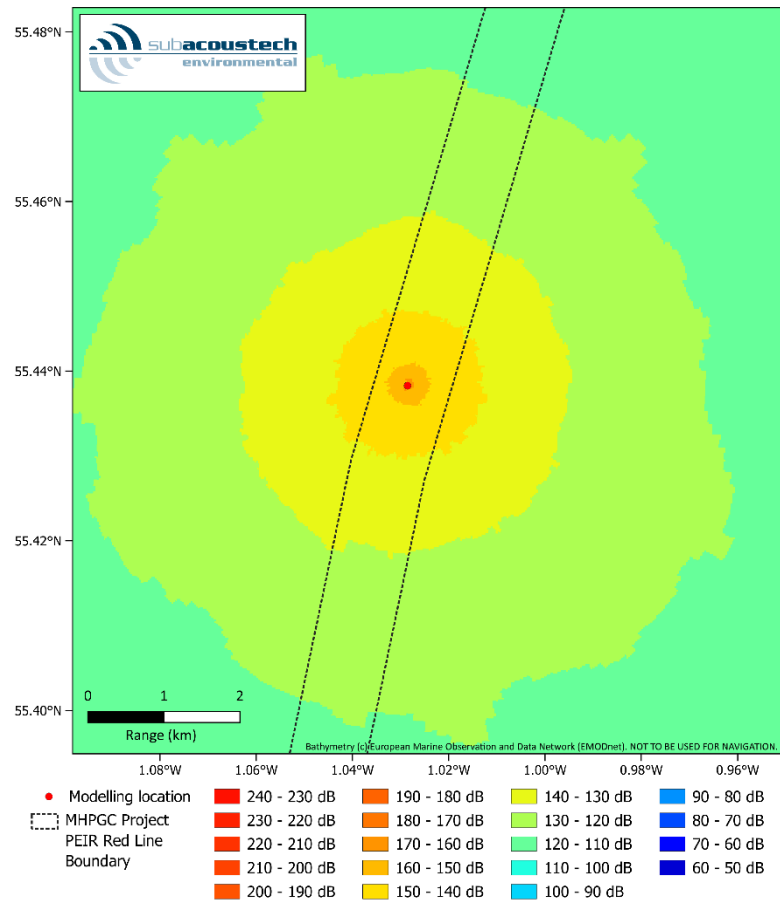


Figure A 9: Plot showing the modelled unweighted $L_{p,pk}$ for USBL acoustic positioning noise (note the difference in scale between the $L_{E,p,sp}$ and the $L_{p,pk}$ USBL acoustic positioning plots as discussed in section 3.1.2).

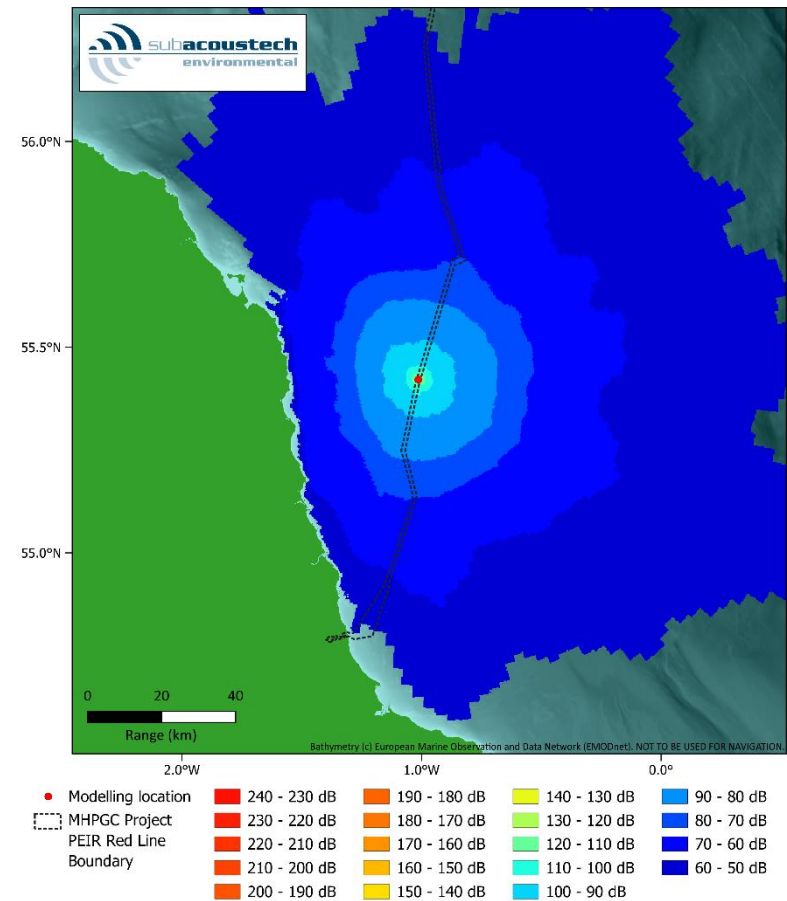


Figure A 10: Plot showing the modelled unweighted $L_{E,p,sp}$ for USBL acoustic positioning noise (note the difference in scale between the $L_{E,p,sp}$ and the $L_{p,pk}$ USBL acoustic positioning plots as discussed in section 3.1.2).

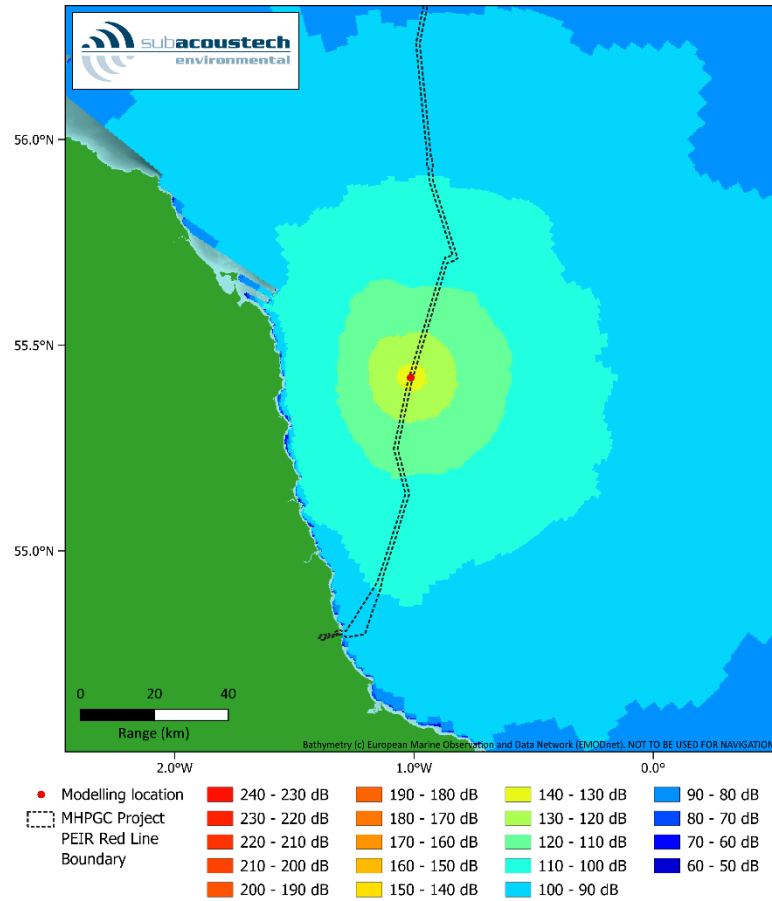


Figure A 11: Plot showing the modelled unweighted $L_{p,RMS}$ for rock cutting noise.

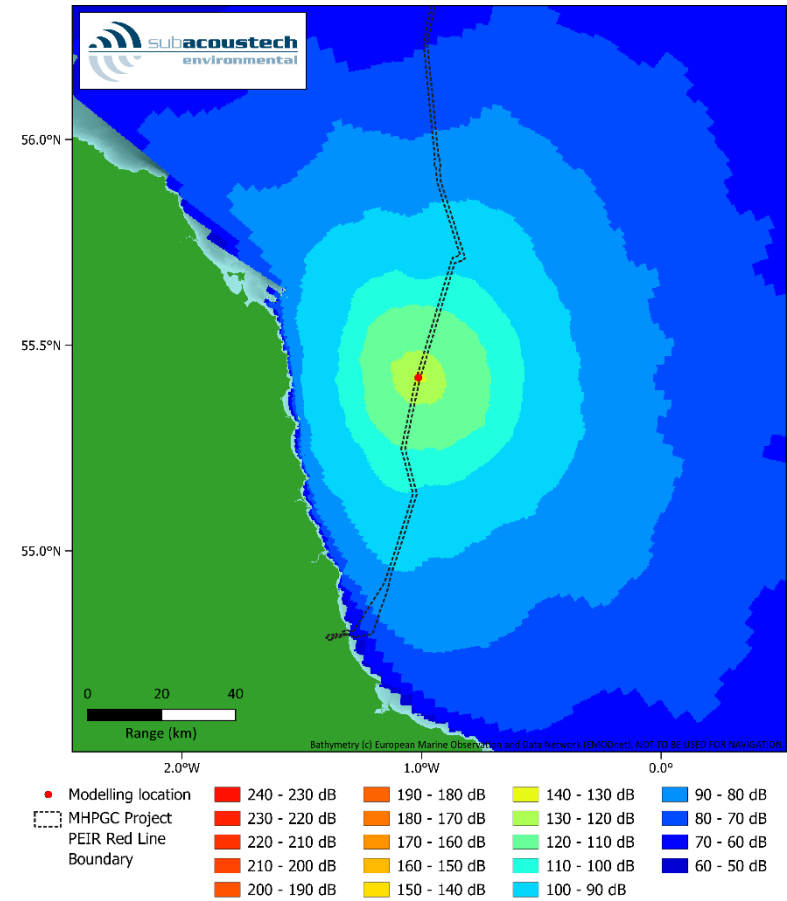


Figure A 12: Plot showing the modelled unweighted $L_{p,RMS}$ for dredging noise.

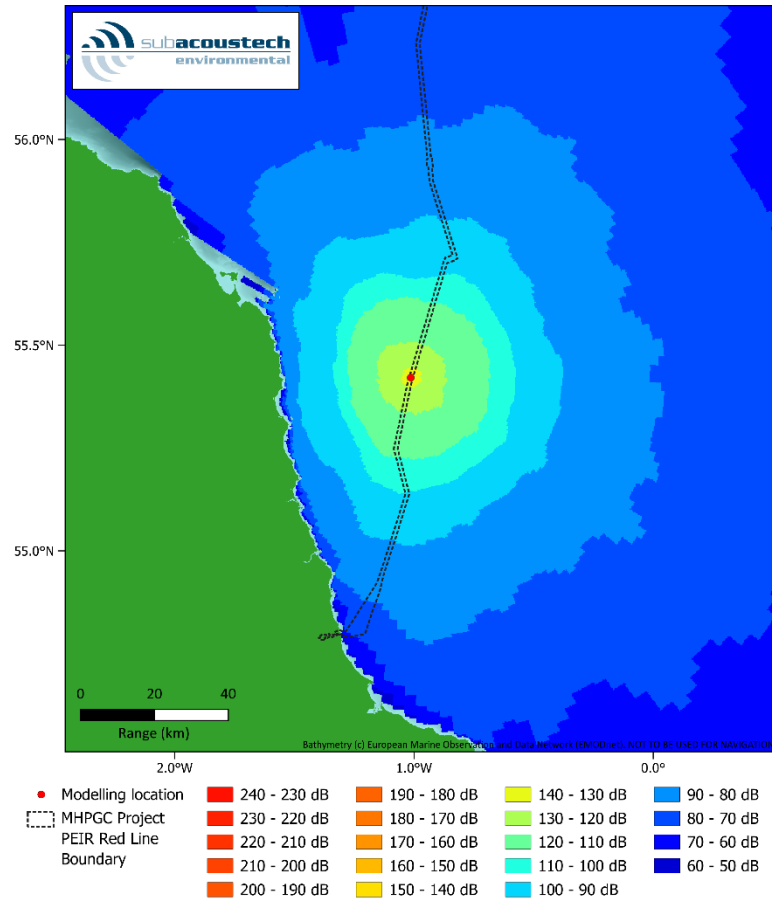


Figure A 13: Plot showing the modelled unweighted $L_{p,RMS}$ for medium support vessel noise.

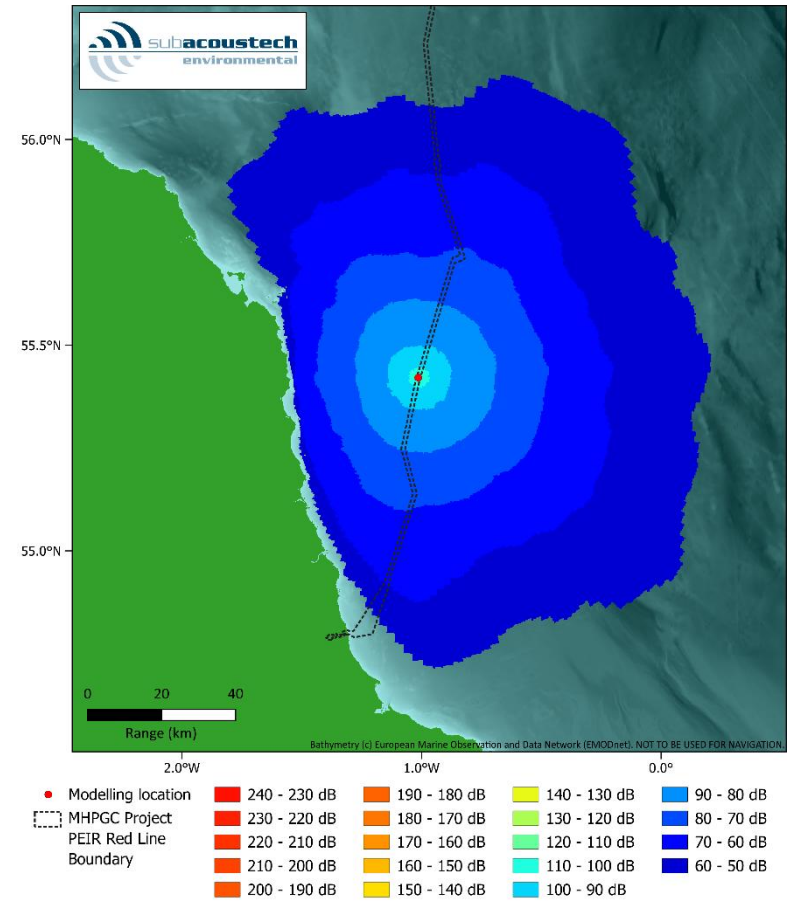


Figure A 14: Plot showing the modelled unweighted $L_{p,RMS}$ for small support vessel noise.

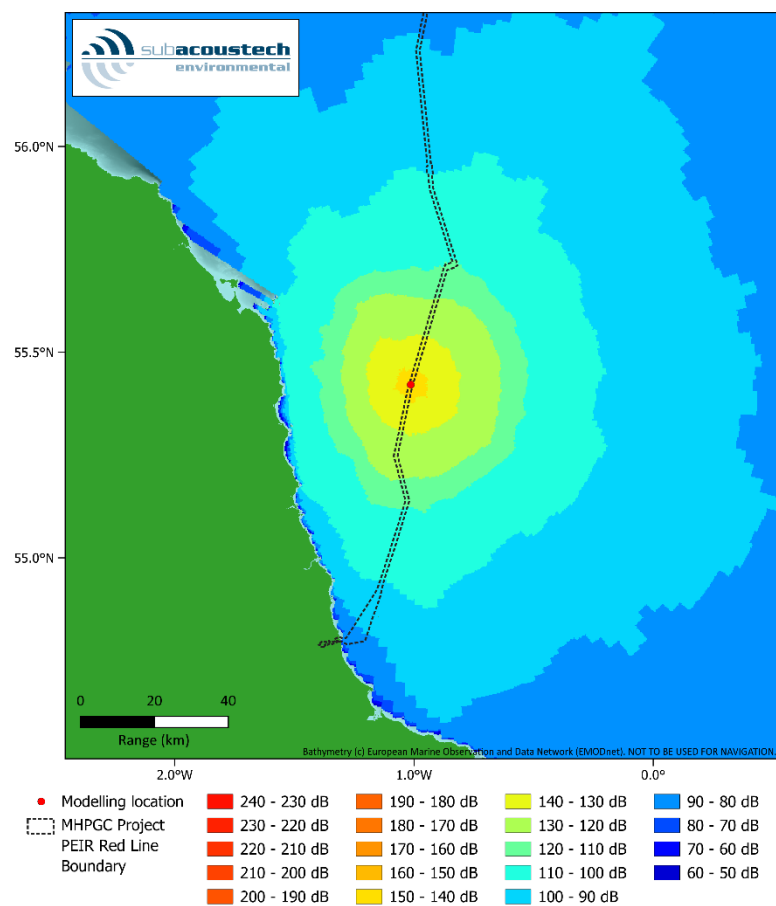


Figure A 15: Plot showing the modelled unweighted $L_{p,RMS}$ for CLV noise.

A.2 UXO clearance

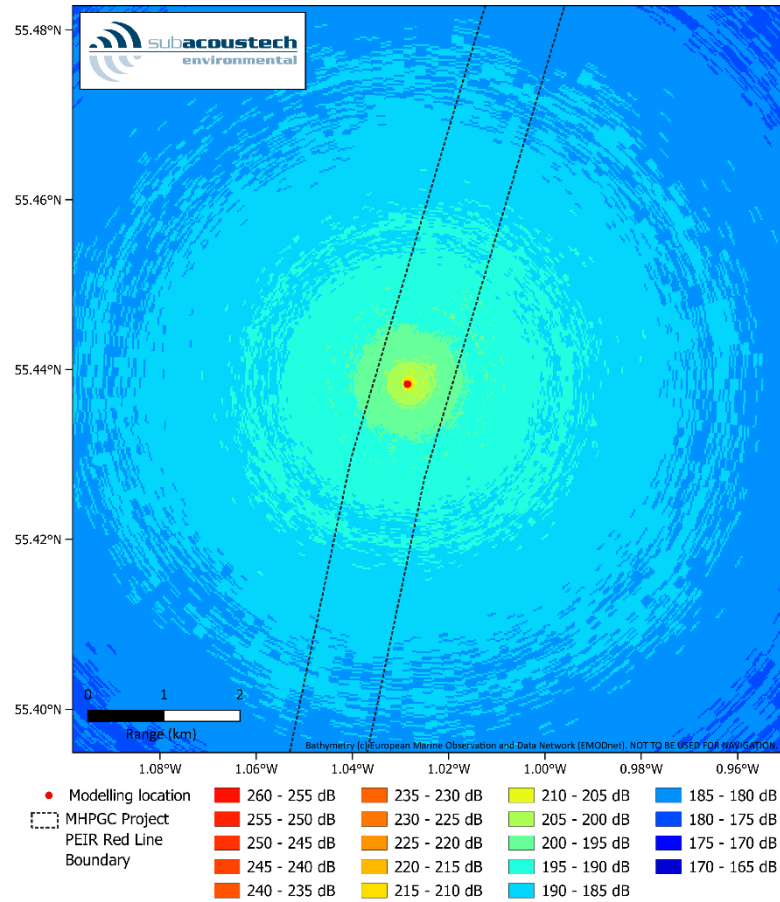


Figure A 16: Plot showing the modelled unweighted $L_{p,pk}$ for a low-order or low-yield donor charge (0.08kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

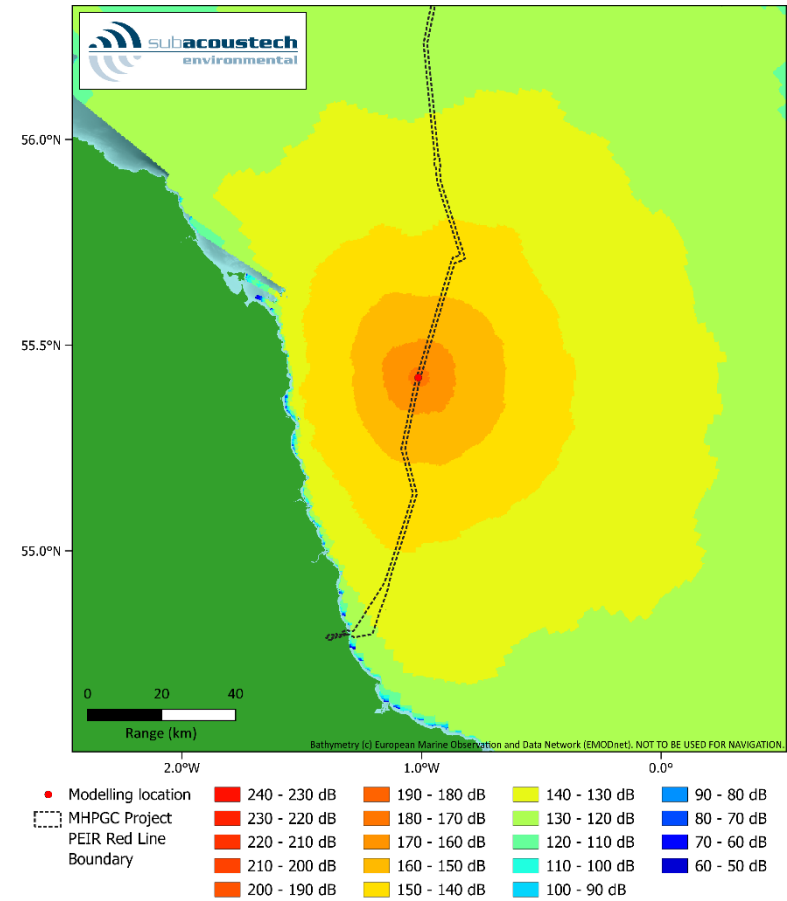


Figure A 17: Plot showing the modelled unweighted $L_{E,p,sp}$ for a low-order or low-yield donor charge (0.08kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

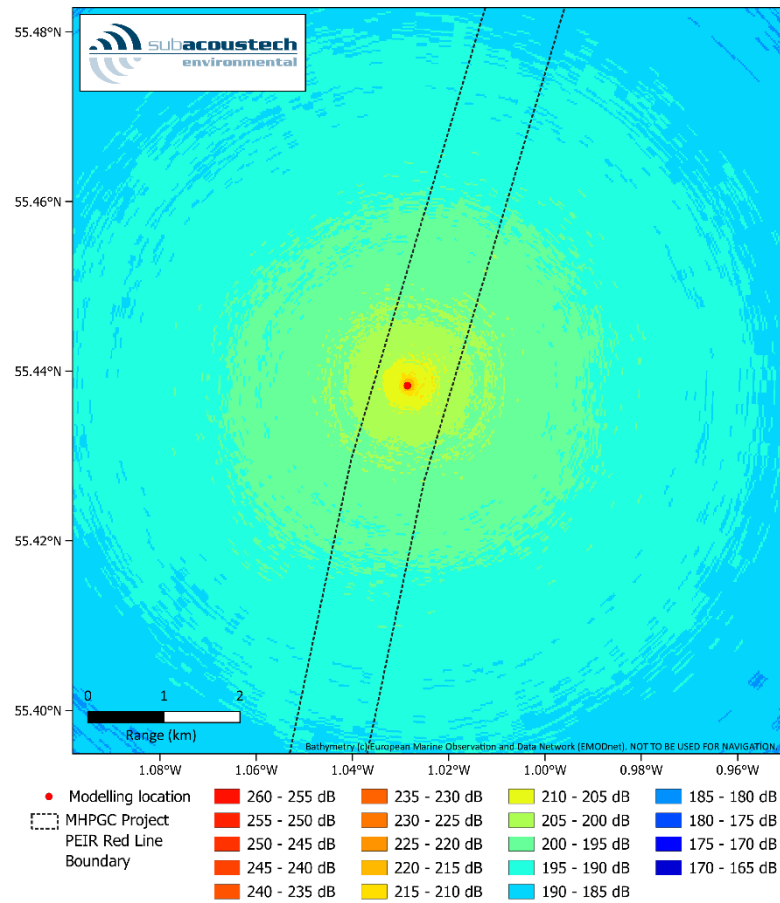


Figure A 18: Plot showing the modelled unweighted $L_{p,pk}$ for a low-order or low-yield donor charge (0.5kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

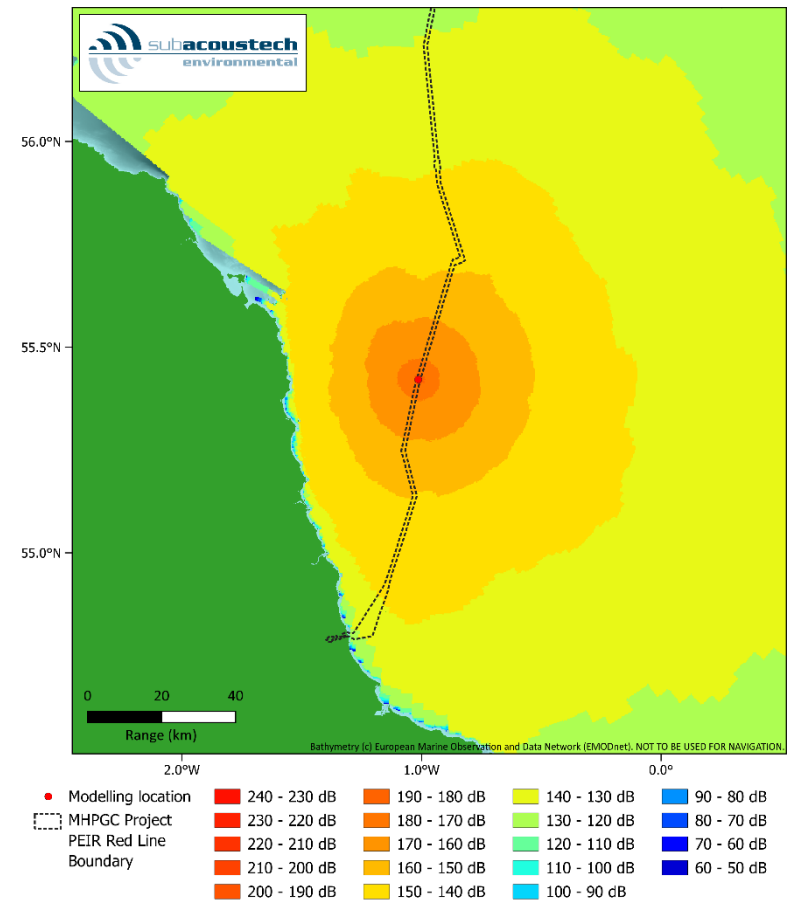


Figure A 19: Plot showing the modelled unweighted $L_{E,p,sp}$ for a low-order or low-yield donor charge (0.5kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

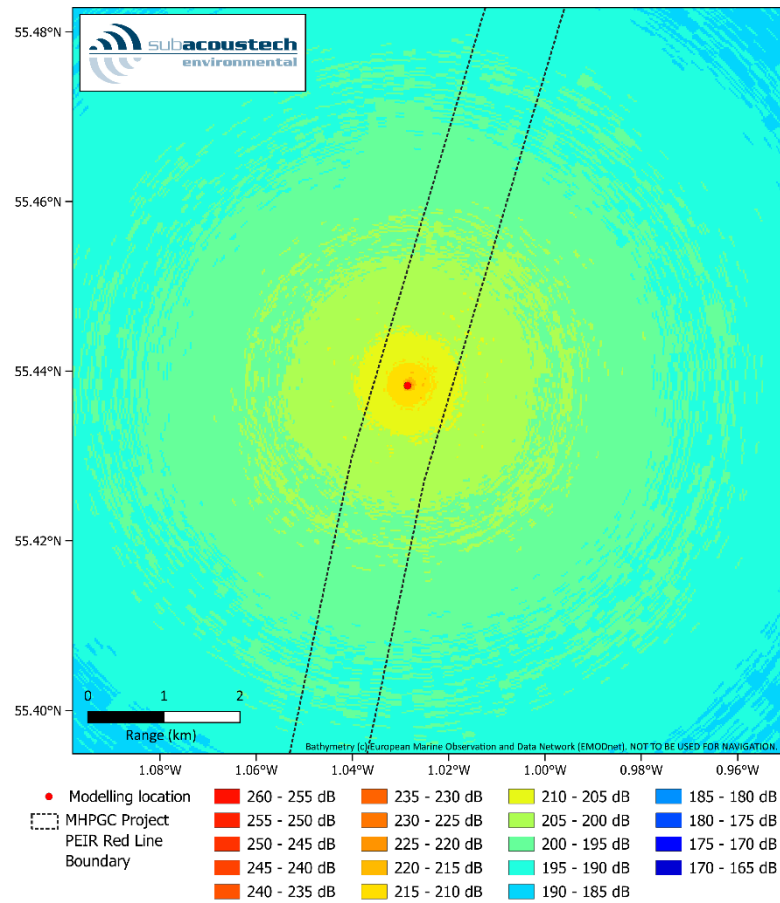


Figure A 20: Plot showing the modelled unweighted $L_{p,pk}$ for a low-order or low-yield donor charge ($2 \times 0.75\text{kg NEQ}$) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

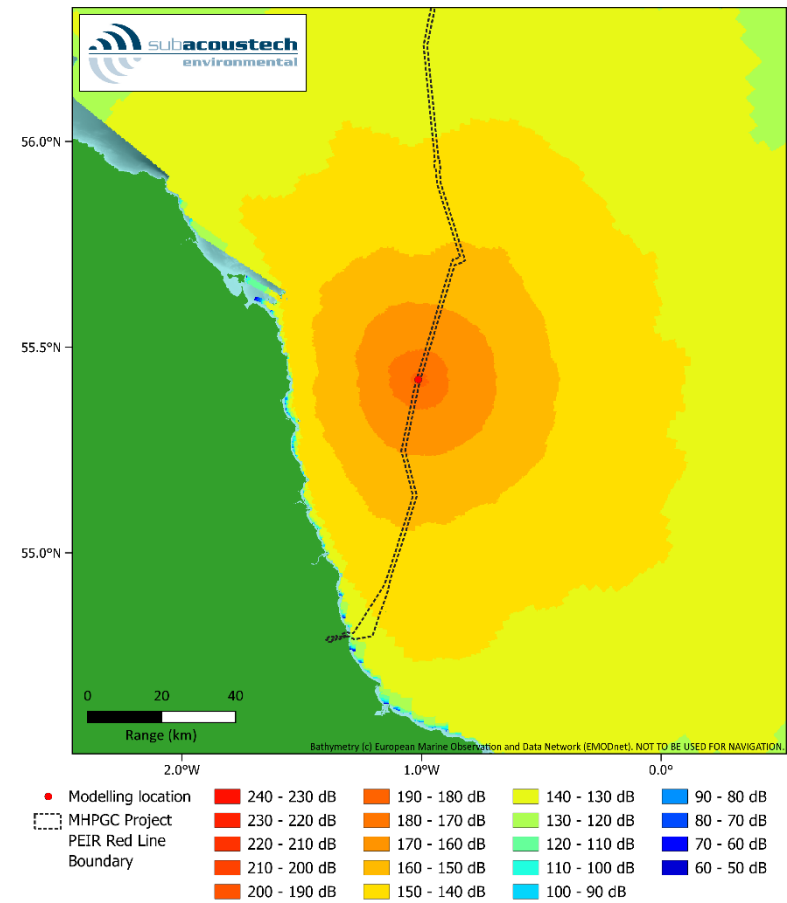


Figure A 21: Plot showing the modelled unweighted $L_{E,p,sp}$ for a low-order or low-yield donor charge ($2 \times 0.75\text{kg NEQ}$) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

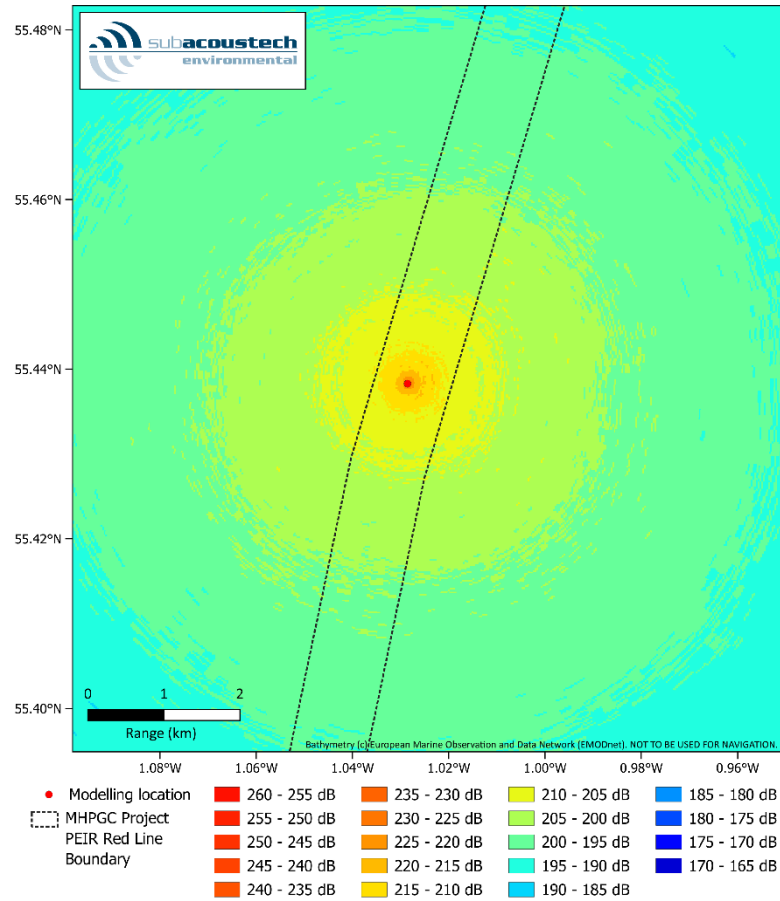


Figure A 22: Plot showing the modelled unweighted $L_{p,pk}$ for a low-order or low-yield donor charge ($4 \times 0.75\text{kg NEQ}$) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

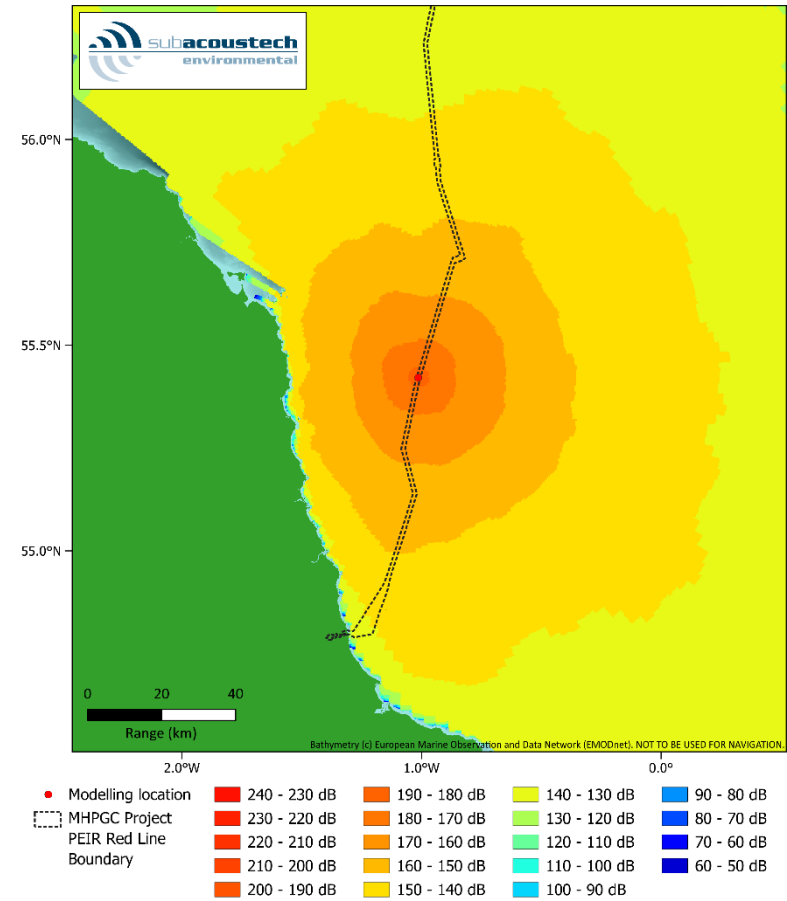


Figure A 23: Plot showing the modelled unweighted $L_{E,p,sp}$ for a low-order or low-yield donor charge ($4 \times 0.75\text{kg NEQ}$) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

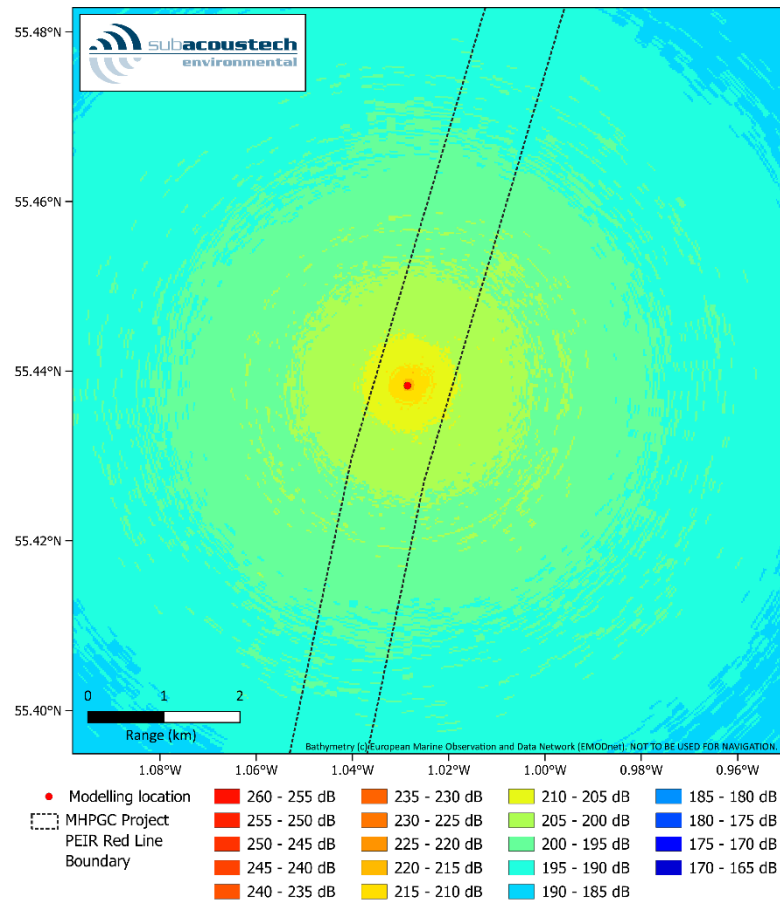


Figure A 24: Plot showing the modelled unweighted $L_{p,pk}$ for a high-order donor charge (1.2kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

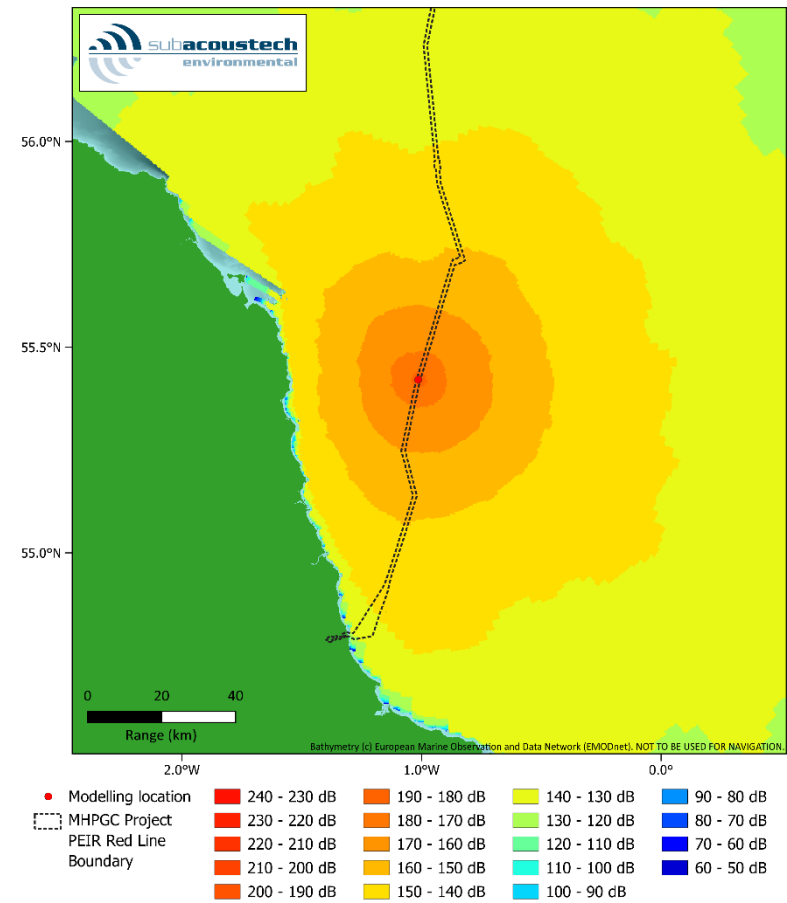


Figure A 25: Plot showing the modelled unweighted $L_{E,p,sp}$ for a high-order donor charge (1.2kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

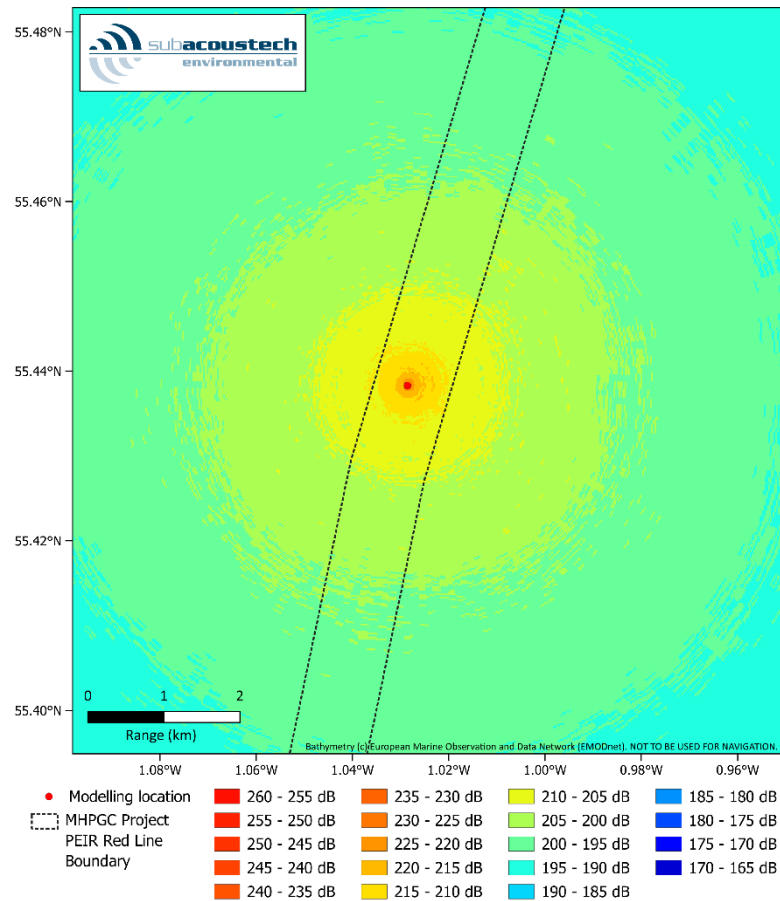


Figure A 26: Plot showing the modelled unweighted $L_{p,pk}$ for a high-order donor charge (3.5kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

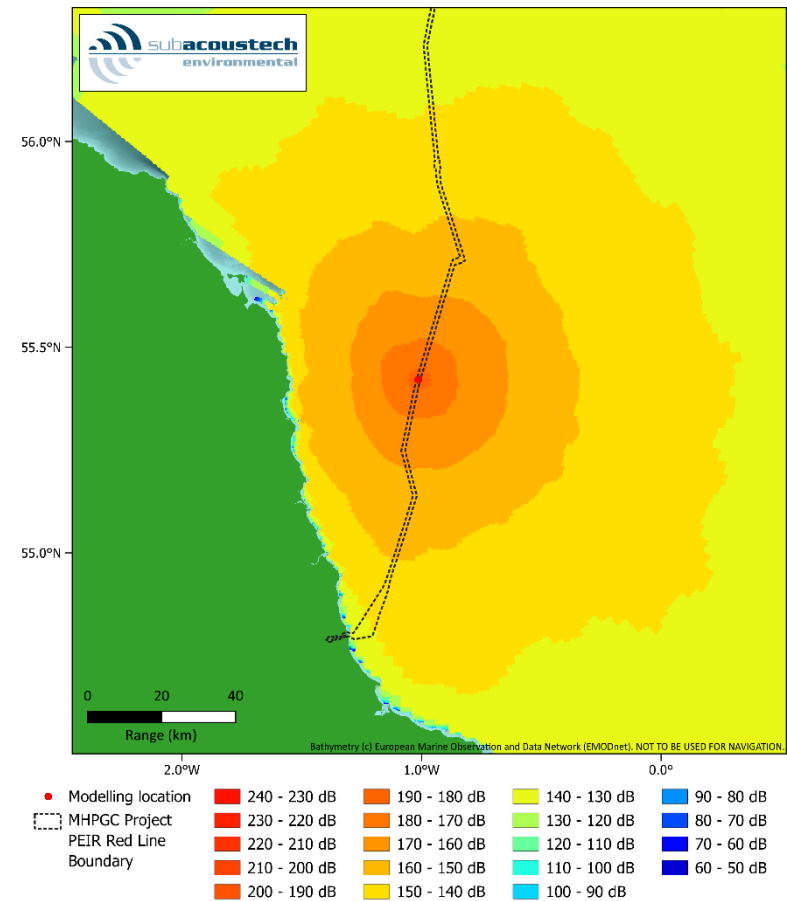


Figure A 27: Plot showing the modelled unweighted $L_{E,p,sp}$ for a high-order donor charge (3.5kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

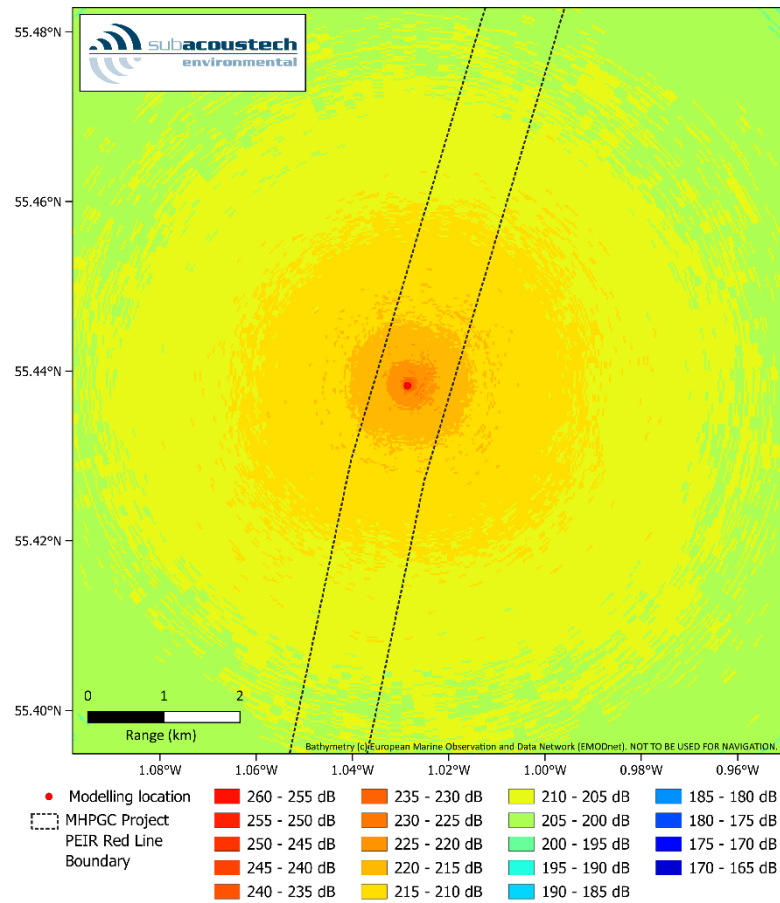


Figure A 28: Plot showing the modelled unweighted $L_{p,pk}$ for a high-order UXO clearance (136kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

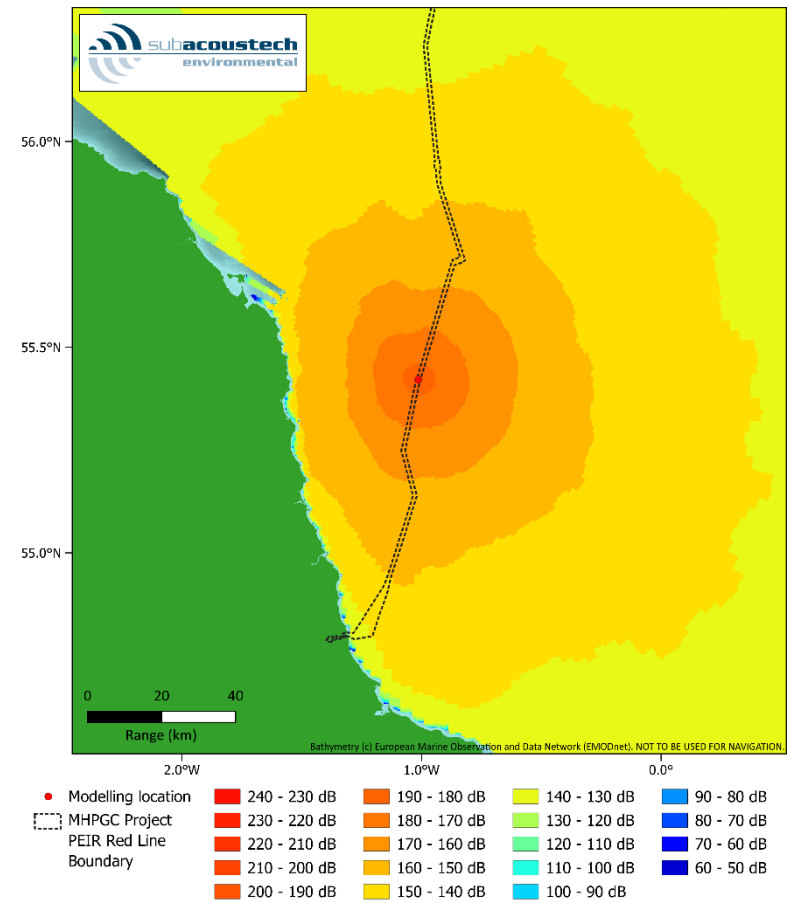


Figure A 29: Plot showing the modelled unweighted $L_{E,p,sp}$ for a high-order UXO clearance (136kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

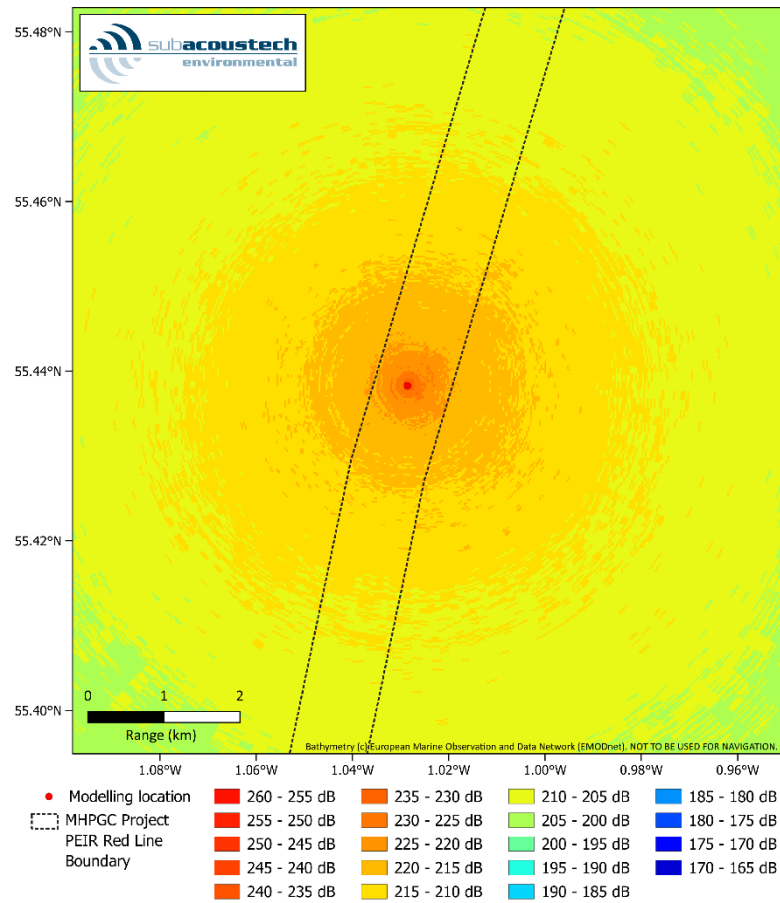


Figure A 30: Plot showing the modelled unweighted $L_{p,pk}$ for a high-order UXO clearance (270kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

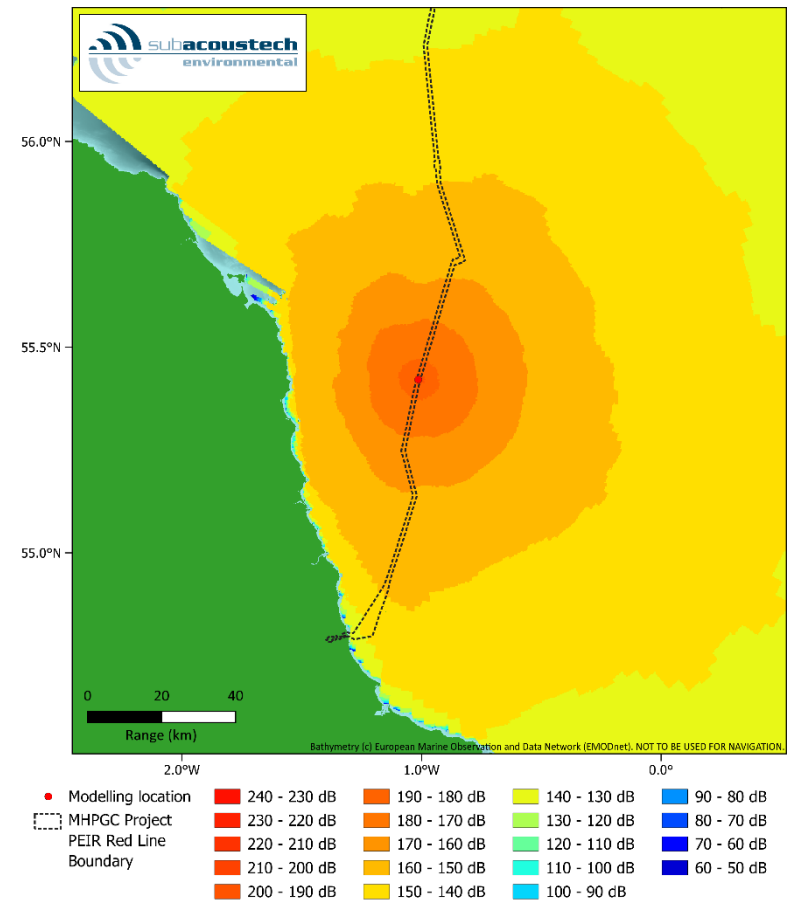


Figure A 31: Plot showing the modelled unweighted $L_{E,p,sp}$ for a high-order UXO clearance (270kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

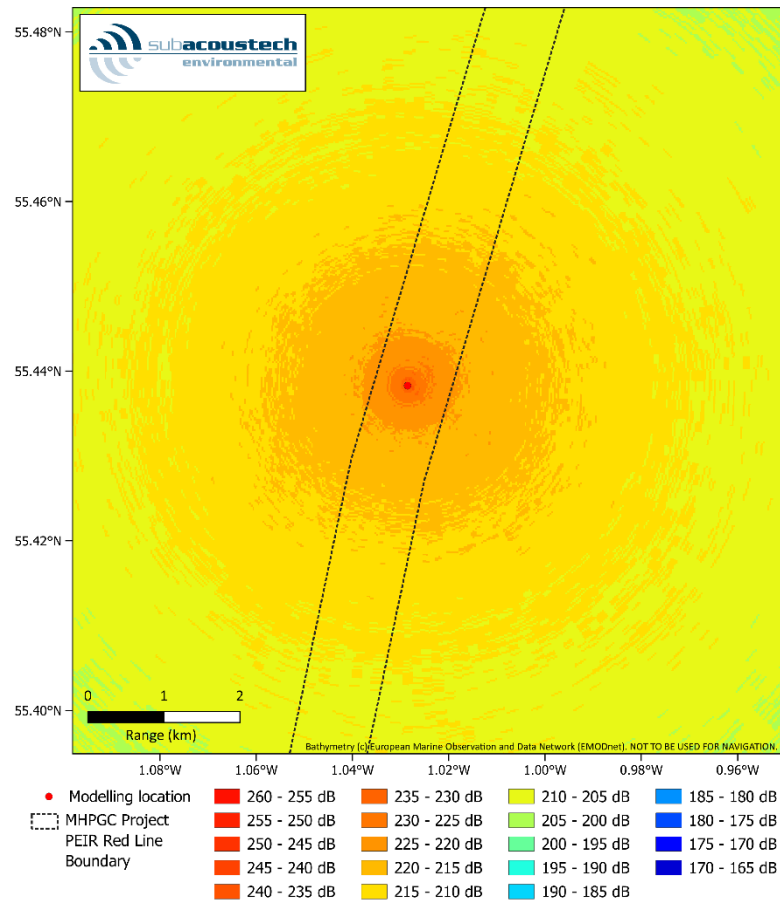


Figure A 32: Plot showing the modelled unweighted $L_{p,pk}$ for a high-order UXO clearance (431kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

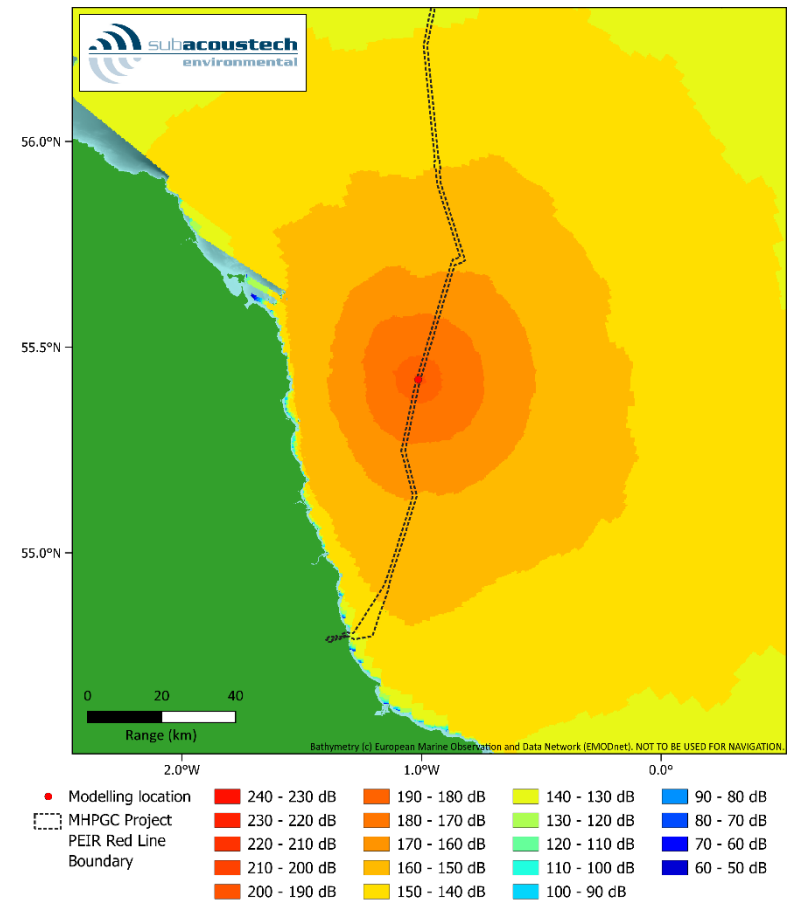


Figure A 33: Plot showing the modelled unweighted $L_{E,p,sp}$ for a high-order UXO clearance (431kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

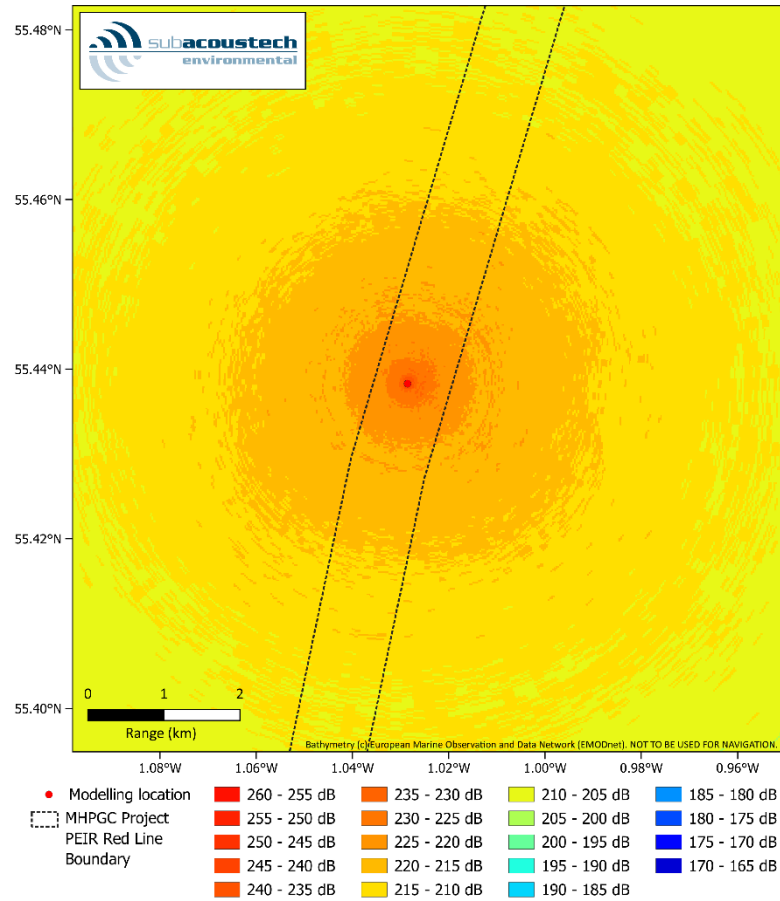


Figure A 34: Plot showing the modelled unweighted $L_{p,pk}$ for a high-order UXO clearance (697kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

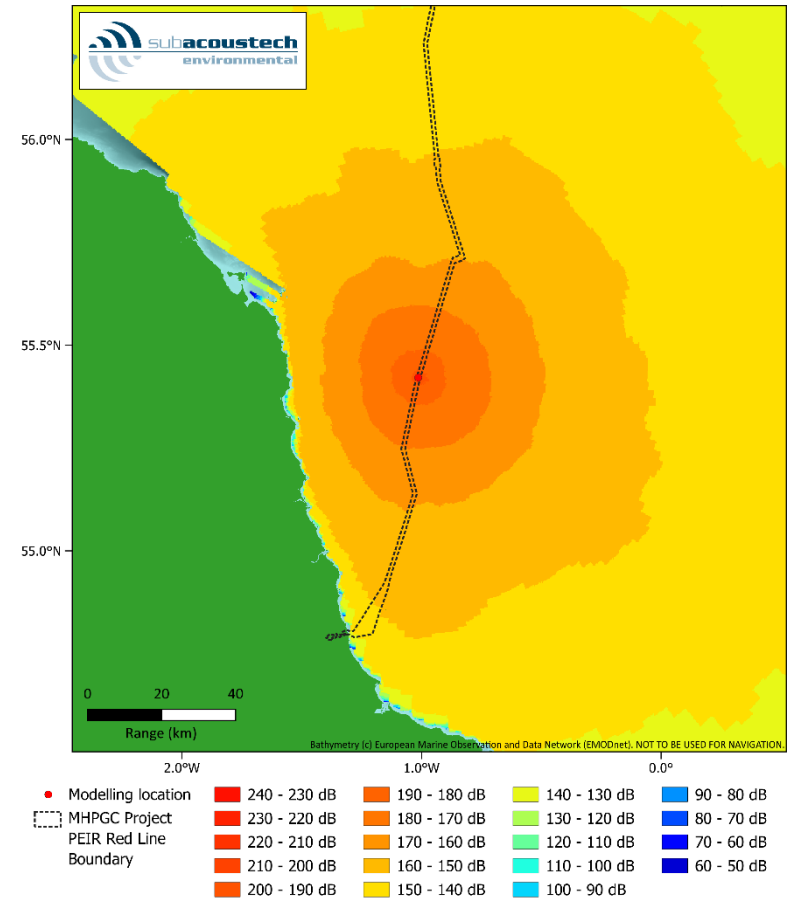


Figure A 35: Plot showing the modelled unweighted $L_{E,p,sp}$ for a high-order UXO clearance (697kg NEQ) (note the difference in scale and legend between the $L_{E,p,sp}$ and the $L_{p,pk}$ UXO plots as discussed in section 3.1.2).

Appendix B Non-impulsive noise results

The following section presents noise modelling results for the impulsive noise sources in sections 4 and 5, using the non-impulsive noise criteria from NMFS (2024) and NOAA (2005). This follows the discussion in section 2.2.1, regarding impulsive and non-impulsive noise classification and the potential for impulsive sources to become non-impulsive at range. Almost all ranges are predicted to be less than 10m.

B.1 Ultra-High Resolution Seismic (UHRs) sparker

Table B 1: Predicted impact ranges associated with UHRs sparker noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		UHRs sparker (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 2: Predicted impact ranges associated with UHRs sparker noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		UHRs sparker (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 3: Predicted impact ranges associated with UHRs sparker noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		UHRs sparker (stationary receptors)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 4: Predicted impact ranges associated with UHRS sparker noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		UHRS sparker		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	40m	20m	< 10m

B.2 Seismic Cone Penetration Testing (sCPT)

Table B 5: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		sCPT (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 6: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		sCPT (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 7: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		sCPT (stationary receptors)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	< 10m	< 10m	< 10m
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 8: Predicted impact ranges associated with sCPT noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		sCPT		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	< 10m	< 10m	< 10m

B.3 Ultra Short Baseline (USBL) acoustic positioning

Table B 9: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using English swim speeds.

NMFS (2024) criteria		USBL acoustic positioning (English swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 3.25ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.5ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	80m	60m	40m
PW pinnipeds (Fleeing 1.5ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 10: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming fleeing receptors using Scottish swim speeds.

NMFS (2024) criteria		USBL acoustic positioning (Scottish swim speeds)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Fleeing 2.1ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	< 10m	< 10m	< 10m
HF cetaceans (Fleeing 1.52ms ⁻¹)	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	< 10m	< 10m	< 10m
VHF cetaceans (Fleeing 1.4ms ⁻¹)	AUD INJ (181dB)	< 10m	< 10m	< 10m
	TTS (161dB)	90m	60m	50m
PW pinnipeds (Fleeing 1.8ms ⁻¹)	AUD INJ (195dB)	< 10m	< 10m	< 10m
	TTS (175dB)	< 10m	< 10m	< 10m

Table B 11: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,24h,wtd}$ criteria for non-impulsive noise, assuming stationary receptors.

NMFS (2024) criteria		USBL acoustic positioning (stationary receptors)		
Weighted $L_{E,p,24h,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (197dB)	< 10m	< 10m	< 10m
	TTS (177dB)	180m	130m	110m
HF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (201dB)	30m	20m	20m
	TTS (181dB)	350m	280m	240m
VHF cetaceans (Stationary 0ms ⁻¹)	AUD INJ (181dB)	370m	290m	250m
	TTS (161dB)	2.2km	2.0km	1.9km
PW pinnipeds (Stationary 0ms ⁻¹)	AUD INJ (195dB)	40m	40m	40m
	TTS (175dB)	620m	480m	400m

Table B 12: Predicted impact ranges associated with USBL acoustic positioning noise at the MHPGC Project for marine mammals using the NOAA (2005) $L_{p,RMS}$ criteria for Level B harassment from a continuous noise source.

NOAA (2005) criteria		USBL acoustic positioning		
Unweighted $L_{p,RMS}$ (Continuous)		Maximum range	Mean range	Minimum range
Level B	120dB	1.0km	860m	690m

UXO clearance

B.3.1 Low-order and low-yield donor charge

Table B 13: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.08kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for non-impulsive noise.

NMFS (2024) criteria		0.08kg NEQ		
Weighted $L_{E,p,sp,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	120m	50m	40m
	TTS (177dB)	1.3km	1.0km	810m
HF cetaceans	AUD INJ (201dB)	< 10m	< 10m	< 10m
	TTS (181dB)	210m	160m	130m
VHF cetaceans	AUD INJ (181dB)	50m	50m	40m
	TTS (161dB)	1.4km	970m	730m
PW pinnipeds	AUD INJ (195dB)	40m	30m	30m
	TTS (175dB)	900m	700m	530m

Table B 14: Predicted impact ranges associated with low-order or low-yield donor charge noise (0.5kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for non-impulsive noise.

NMFS (2024) criteria		0.5kg NEQ		
Weighted $L_{E,p,sp,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	310m	120m	80m
	TTS (177dB)	2.6km	2.2km	1.8km
HF cetaceans	AUD INJ (201dB)	20m	20m	20m
	TTS (181dB)	550m	360m	270m
VHF cetaceans	AUD INJ (181dB)	110m	100m	80m
	TTS (161dB)	2.8km	2.1km	1.6km
PW pinnipeds	AUD INJ (195dB)	90m	70m	60m
	TTS (175dB)	2.0km	1.5km	1.3km

Table B 15: Predicted impact ranges associated with low-order or low-yield donor charge noise (2×0.75 kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for non-impulsive noise.

NMFS (2024) criteria		2×0.75 kg NEQ		
Weighted $L_{E,p,sp,wtd}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	380m	190m	120m
	TTS (177dB)	3.8km	3.4km	2.9km
HF cetaceans	AUD INJ (201dB)	30m	30m	20m
	TTS (181dB)	800m	590m	450m
VHF cetaceans	AUD INJ (181dB)	170m	150m	120m
	TTS (161dB)	3.8km	3.0km	2.5km
PW pinnipeds	AUD INJ (195dB)	140m	100m	90m
	TTS (175dB)	2.9km	2.4km	2.0km

Table B 16: Predicted impact ranges associated with low-order or low-yield donor charge noise ($4 \times 0.75\text{kg}$ NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for non-impulsive noise.

NMFS (2024) criteria Weighted $L_{E,p,sp,wtd}$ (Non-impulsive)		4 × 0.75kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	440m	250m	160m
	TTS (177dB)	4.9km	4.4km	4.0km
HF cetaceans	AUD INJ (201dB)	50m	40m	30m
	TTS (181dB)	1.0km	830m	640m
VHF cetaceans	AUD INJ (181dB)	230m	200m	160m
	TTS (161dB)	4.5km	3.7km	3.2km
PW pinnipeds	AUD INJ (195dB)	190m	140m	110m
	TTS (175dB)	3.7km	3.2km	2.6km

B.3.2 High-order donor charge

Table B 17: Predicted impact ranges associated with high-order donor charge noise (1.2kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for non-impulsive noise.

NMFS (2024) criteria Weighted $L_{E,p,sp,wtd}$ (Non-impulsive)		1.2kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	370m	170m	110m
	TTS (177dB)	3.6km	3.1km	2.6km
HF cetaceans	AUD INJ (201dB)	30m	30m	20m
	TTS (181dB)	750m	540m	400m
VHF cetaceans	AUD INJ (181dB)	160m	140m	110m
	TTS (161dB)	3.6km	2.8km	2.2km
PW pinnipeds	AUD INJ (195dB)	120m	100m	80m
	TTS (175dB)	2.7km	2.2km	1.8km

Table B 18: Predicted impact ranges associated with high-order donor charge noise (3.5kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wtd}$ criteria for non-impulsive noise.

NMFS (2024) criteria Weighted $L_{E,p,sp,wtd}$ (Non-impulsive)		3.5kg NEQ		
		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	460m	260m	170m
	TTS (177dB)	5.1km	4.6km	4.2km
HF cetaceans	AUD INJ (201dB)	50m	40m	30m
	TTS (181dB)	1.2km	880m	680m
VHF cetaceans	AUD INJ (181dB)	250m	220m	170m
	TTS (161dB)	4.6km	3.8km	3.4km
PW pinnipeds	AUD INJ (195dB)	200m	150m	120m
	TTS (175dB)	3.9km	3.3km	2.8km

B.3.3 High-order UXO clearance

Table B 19: Predicted impact ranges associated with high-order UXO clearance (136kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for non-impulsive noise.

NMFS (2024) criteria		136kg NEQ		
Weighted $L_{E,p,sp,wt,d}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	550m	360m	240m
	TTS (177dB)	7.1km	6.3km	5.7km
HF cetaceans	AUD INJ (201dB)	90m	70m	60m
	TTS (181dB)	2.1km	1.6km	1.2km
VHF cetaceans	AUD INJ (181dB)	660m	470m	350m
	TTS (161dB)	6.8km	5.7km	5.2km
PW pinnipeds	AUD INJ (195dB)	340m	240m	190m
	TTS (175dB)	5.5km	4.9km	4.5km

Table B 20: Predicted impact ranges associated with high-order UXO clearance (270kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for non-impulsive noise.

NMFS (2024) criteria		270kg NEQ		
Weighted $L_{E,p,sp,wt,d}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	660m	470m	330m
	TTS (177dB)	8.5km	7.9km	7.2km
HF cetaceans	AUD INJ (201dB)	110m	90m	80m
	TTS (181dB)	2.8km	2.1km	1.6km
VHF cetaceans	AUD INJ (181dB)	840m	630m	480m
	TTS (161dB)	7.5km	6.5km	5.9km
PW pinnipeds	AUD INJ (195dB)	490m	330m	250m
	TTS (175dB)	7.1km	6.1km	5.5km

Table B 21: Predicted impact ranges associated with high-order UXO clearance (431kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for non-impulsive noise.

NMFS (2024) criteria		431kg NEQ		
Weighted $L_{E,p,sp,wt,d}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	780m	570m	420m
	TTS (177dB)	9.9km	9.1km	8.5km
HF cetaceans	AUD INJ (201dB)	140m	110m	90m
	TTS (181dB)	3.2km	2.5km	2.0km
VHF cetaceans	AUD INJ (181dB)	1.2km	800m	600m
	TTS (161dB)	8.3km	7.1km	6.4km
PW pinnipeds	AUD INJ (195dB)	630m	410m	300m
	TTS (175dB)	7.7km	6.9km	6.2km

Table B 22: Predicted impact ranges associated with high-order UXO clearance (697kg NEQ) at the MHPGC Project for marine mammals using the NMFS (2024) $L_{E,p,sp,wt,d}$ criteria for non-impulsive noise.

NMFS (2024) criteria		697kg NEQ		
Weighted $L_{E,p,sp,wt,d}$ (Non-impulsive)		Maximum range	Mean range	Minimum range
LF cetaceans	AUD INJ (197dB)	920m	710m	530m
	TTS (177dB)	11km	11km	9.6km
HF cetaceans	AUD INJ (201dB)	170m	130m	110m
	TTS (181dB)	3.8km	3.0km	2.4km
VHF cetaceans	AUD INJ (181dB)	1.6km	1.0km	740m
	TTS (161dB)	8.5km	7.7km	6.9km
PW pinnipeds	AUD INJ (195dB)	730m	510m	380m
	TTS (175dB)	8.5km	7.8km	7.2km