Environmental Impact Assessment Report (EIAR)

Volume 6 of 6: Appendices

(Appendix 8.20) Underwater Noise Modelling Report

Document no: 32105801/EIARA8.20
Version: Final

December 2025

PAGE LEFT INTENTIONALLY BLANK

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

Issy Morgan, Fergus Midforth

25th July 2025

**Subacoustech Environmental Report No.
P293R0302**

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

Document No.	Date	Written	Approved	Distribution
P293R0301	07/05/2025	I Morgan	F Midforth	L Kennedy (Tobin)
P293R0302	25/07/2025	I Morgan	F Midforth	L Kennedy (Tobin)

> **This report is a controlled document. The report documentation page lists the version number, record of changes, referencing information, abstract and other documentation details.**

Disclaimer

This report, with its associated works and services, has been designed solely to meet the requirements agreed between Subacoustech Environmental and the Client or Sponsor (contracting parties) detailed in the report documentation page. If used for any other circumstances, some or all the results may not be valid, and we can accept no liability for such use. Such circumstances include any use by third parties, or changes to any project parameters, including (but not limited to) site location, planned works, applicable legislation occurring after completion of this report. In case of doubt, please consult Subacoustech Environmental Limited.

Copyright Notice

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

Executive Summary

An assessment of the likely effect on fish of underwater noise from the construction and operation of a planned Raw Water Intake and Pumping Station (RWI&PS) in Parteen Basin, Ireland has been undertaken by Subacoustech Environmental Ltd. The assessment covers a baseline noise assessment undertaken in Parteen Basin, predictions of the noise generated from secant piling and vibropiling required during the Construction Phase, and predictions of the noise of the RWI&PS once it is operational. Detailed numerical modelling of the relevant noise sources was used to generate noise contours, which were then used to predict the likely ranges to the relevant noise exposure criteria for fish.

The results have been interpreted using the guidelines provided in Popper *et al.* (2014) for fish. These interpretations are based on worst-case parameters with no implemented mitigation measures. Bony fish, such as bream sp., perch sp., minnow sp., carp sp., roach sp. are unlikely to be at risk of recoverable injury at any distance from the secant piling or noise from the RWI&PS at any capacity. These fish species are however predicted to be at risk of recoverable injury if they are within 60 m from the vibropiling activities. It should be noted that the risk of mortality across all activities for all fish species assessed is low, however, the risk of masking is high within hundreds of metres of all activities assessed for all fish species, including lampreys and salmon.

Note that the modelling calculations and predicted impact ranges will produce results that should be considered indicative of the onset of effects on receptors during the works and should not be considered as absolute ranges.

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

List of Contents

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

Terminology

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 second symbol identifying the specific reference value (e.g., re 1 µPa).
Peak pressure	The highest pressure above or below ambient that is associated with a sound wave.
Peak-to-peak pressure	The sum of the highest positive and negative pressures that are associated with a sound wave.
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.
Sound Exposure Level (SEL or $L_{E,p}$)	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. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
Sound Exposure Level, cumulative (SEL_{cum})	Single value for the collected, combined total of sound exposure over a specified time or multiple instances of a noise source.
Sound Exposure Level, single strike (SEL_{ss})	Calculation of the sound exposure level representative of a single noise impulse, typically a pile strike.
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 1 µPa for water and 20 µPa for air.
Sound Pressure Level Peak (SPL_{peak} or $L_{p,pk}$)	The highest (zero-peak) positive or negative sound pressure, in decibels.
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.

Units

dB	Decibel (sound pressure)
Hz	Hertz (frequency)
kHz	Kilohertz (frequency)
km^2	Square kilometres (area)
m	Metre (distance)
mm^{-1}	Millimetres per second (particle velocity)
m^{-1}	Metres per second (speed)
Pa	Pascal (pressure)
Pa^{2}s	Pascal squared seconds (acoustic energy)
µPa	Micropascal (pressure)

Acronyms

PPV	Peak Particle Velocity
RMS	Root Mean Square
SE	Sound Exposure
SEL ($L_{E,p}$)	Sound Exposure Level
SEL$_{cum}$	Cumulative Sound Exposure Level
SEL$_{ss}$	Single Strike Sound Exposure Level
SPL	Sound Pressure Level
SPL$_{peak}$ (L_{p-pk})	Peak Sound Pressure Level
SPL$_{peak-to-peak}$	Peak-to-peak Sound Pressure Level
SPL$_{RMS}$ (L_p)	Root Mean Square Sound Pressure Level

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

1 Introduction

1.1 Project Overview

1. Subacoustech Environmental was commissioned by TOBIN to carry out underwater noise modelling for the construction and operation of the planned Raw Water Intake and Pumping Station (RWI&PS) in Parteen Basin, Ireland.

2. As part of Ireland's Eastern and Midlands Region Water Supply Project, a RWI&PS is proposed on the eastern bank of Parteen Basin, south of Lough Derg in County Tipperary. Construction will involve installing a secant pile wall by drilling boreholes to bedrock, filling them with concrete, and inserting reinforced steel cages to form intersecting primary and secondary piles. Additionally, sheet piles may be installed nearby to retain material for the piling platform, likely requiring vibropiling. Once operational, a raw water abstraction consent of 300 million litres per day (Mld) is being sought to cover the operational requirements of providing up to 280Mld of treated water in 2050, with a provision of a further 20Mld to allow for potential future sustainability reductions from existing supply volumes.

3. The secant piling, vibropiling, as well as the RWI&PS when it is operational will generate noise in Parteen Basin, and therefore, an underwater noise assessment is required to consider the potential impact from the noise generated on fish residing here. This report provides the results of a detailed modelling assessment for secant piling and vibropiling associated with the construction works, as well as the RWI&PS once operational. The modelling has been used to predict the sound pressure levels generated during these noise-generating activities in the region, and the potential impact of these noise levels on fish.

4. Trenchless construction is proposed for tunnelling beneath a number of watercourses along the Proposed Project. The trenchless construction will generate vibration in the substrate, which has the potential to be transmitted to the riverbed and watercourse itself. The calculation of this is extremely complex. However, in Subacoustech's experience the potential impact is related to the depth below the riverbed, and is generally far enough below to not contribute any detectable vibration in the substrate, much less any level that could lead to injury or disturbance to fish, or damage to nests or redds. The rotational nature of the vibration source in trenchless construction, the drill, is not impulsive, and impulsivity is most likely to lead to higher risk of adverse impact. Due to the very low risk of any impacts in this situation, the trenchless construction has been scoped out of any further assessment.

5. In October 2021, an underwater noise survey was undertaken by Subacoustech in Parteen Basin to establish an underwater noise baseline in the area of the planned RWI&PS. This report presents both the details and findings of the underwater noise survey in addition to the results and analysis of the construction and operation underwater noise modelling.

1.2 Noise Sources

6. Underwater noise sources that could impact marine fauna, and have therefore been included in the assessment include:

- Secant piling

- Vibropiling

- Operational Noise of the RWI&PS

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

7. Details of the input parameters used for the modelling of each of these sources in the assessment are presented in Section 4.1.5.

1.3   Document Overview

8. This report presents a detailed assessment of the potential underwater noise from the construction and operation of the RWI&PS in Parteen Basin, and covers the following:

- Section 2: Review of background information on the units for measuring and assessing underwater noise

- Section 3: Description and discussion of underwater noise monitoring undertaken at Parteen Basin

- Section 4: Discussion of the modelling approach, input parameters and assumptions for the noise modelling undertaken

- Section 5: Presentation of detailed noise modelling and interpretation of the results using suitable noise metrics and criteria

- Section 6: Summary and conclusions

2   Underwater Noise Concepts

9. Sound travels much faster in water (approximately 1,500 ms^{-1}) than in air (343 ms^{-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

10. 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:

(1)

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

where P is pressure, measured in Pascals (Pa), and P_{ref} is the reference pressure, also measured in Pa. For underwater noise, a reference pressure of 1 µPa (1x10^{-6} Pa) is used as defined in ISO 18405:2017. Noise can be quantified using various metrics depending on the nature of the sound, as discussed below.

2.1.1   Sound Pressure Level

11. 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 SPL are used depending on the noise source being measured. Unless otherwise defined, all SPL noise levels in this report are referenced to 1 µPa.

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

2.1.1.1 Level of the Mean Squared Sound Pressure

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

2.1.1.2 Level of the Peak Sound Pressure

13. Transient, impulsive pressure waves, such as generated from impact piling are usually expressed using level of the peak sound pressure (SPL$_{peak}$ or $L_{p,pk}$). This is calculated using the maximum pressure variation from positive to zero, representing the peak change in pressure as the transient wave propagates. A further variation of this is the peak-to-peak sound pressure level (SPL$_{peak-peak}$ or $L_{p,pk-pk}$) which considers the maximum pressure variation from positive to negative. For a symmetrically distributed wave, the peak-to-peak pressure is twice the peak level, or 6 dB higher.

2.1.2 *Sound Exposure Level*

14. Sound Exposure Level (SEL) is a measures Sound Exposure (SE), which represent the total acoustic energy of a sound event in decibels (dB), accounting for both the sound's intensity and duration. SEL 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 SEL are used depending on the noise source being measured. For context, SEL can be compared SPL using Equation 2:

(2)

$$L_{E,p} = L_p + 10 \times \log_{10} T$$

where the L_p 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 SEL is lower than the SPL. For durations longer than one second, the SEL exceeds the SPL (e.g., a 10-second sound results in a 10 dB higher SEL and a 100-second sound gives a 20 dB higher SEL). Unless otherwise defined, all $L_{E,p}$ noise levels in this report are referenced to 1 μPa^{2}s.

2.1.2.1 Single Strike Sound Exposure Level

15. Single strike Sound Exposure Level (SEL$_{ss}$ or $L_{E,p,ss}$) 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:

(3)

$$L_{E,p,ss} = 10 \times \log_{10} \left(\frac{\int_0^T p^2(t)dt}{p^2{}_{ref} T_{ref}} \right)$$

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

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

2.1.2.2   Cumulative Sound Exposure Level

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

(4)

$$L_{E,cum} = L_{E,p,ss} + 10 \times \log_{10} X$$

where $L_{E,p,ss}$ is the SEL$_{ss}$ and X is the total number of impulses or strikes.

2.2   Properties of Sound

2.2.1   *Impulsive vs Non-impulsive*

17. Sound can be categorized 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.

    o   Examples: vibropiling, drilling

- Impulsive: a sound with a high peak sound pressure, short duration, fast rise-time and broad frequency content at the source.

    o   Examples: seismic airguns, explosives, impact piling

18. These differences are crucial for assessing auditory injury, as impulsive sound is typically more harmful than non-impulsive sound. Different metrics are needed to describe these distinct sound sources:

- Impulsive: Use SPL$_{peak}$ ($L_{p,pk}$) or SEL$_{cum}$ ($L_{E,p,ss}$ or $L_{E,cum}$)

- Non-impulsive: Use SPL$_{rms}$ ($L_{p,rms}$) or SEL$_{cum}$ ($L_{E,cum}$)

2.2.2   *Particle Motion*

19. Particle motion, a key component of sound, describes the back-and-forth movement of particles in a medium, such as water, caused by sound waves. Unlike sound pressure, particle motion contains directional information (Hawkins and Popper, 2017). It is typically quantified by peak particle velocity (PPV), though acceleration or displacement can also be used. Research shows many fish species and marine invertebrates are sensitive to particle motion (e.g., Popper and Hawkins, 2019; Nedelec *et al.,* 2016, Radford *et al.,* 2012, Sole *et al.,* 2023), but sound pressure metrics are still more commonly used due to limited data (Popper and Hawkins, 2018). Calls for further research on particle motion levels and effects continue.

2.3   Analysis of Environmental Effects: Assessment Criteria

20. Over the past 20 years, it has become clear that human-generated underwater noise impacts marine species. The severity of these effects depends on factors like sound level, frequency, exposure duration, and repetition rate (Hastings and Popper, 2005). As a result, research on aquatic species' hearing abilities has grown, with studies focused on high-level noise sources such as seismic airguns, impact piling, and blasting, which have the most immediate environmental effects, though interest in chronic noise exposure is rising.

21. 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)

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

- Behavioural responses

22. The following sections outline the underwater noise criteria used in this study for fish species in Parteen Basin.

2.3.1   *Fish*

2.3.1.1   Popper *et al.* (2014): Mortality, injury and behavioural effects

23. The Popper *et al.* (2014) guidelines are a reliable reference for underwater noise impacts on marine fauna, excluding marine mammals. Unlike previous studies based on limited or irrelevant data, Popper *et al.* (2014) provides updated research and guidelines, using fish categories that include species found in the UK.

24. Popper *et al.* (2014) provides specific criteria for common anthropogenic underwater sound sources. If a source is not listed, it is common practice to use the criteria which is the best fit to the source required in the assessment. Across all sources, marine faunae are categorized into sea turtles, eggs and larvae, and fish. Fish are further divided into three groups based on their hearing capabilities, determined by the presence and role of a swim bladder:

- Fish: no swim bladder

- Fish: swim bladder not involved in hearing

- Fish: swim bladder involved in hearing.

25. Popper *et al.* (2014) then provides impact thresholds for each marine faunae category related to sound exposure, including:

- Mortality and potential mortal injury: immediate or delayed death

- Impairment, such as:

    o   Recoverable injury: injuries unlikely to result in mortality.

    o   Temporary Threshold Shift (TTS): short or long-term changes in hearing sensitivity that may or may not reduce fitness.

    o   Masking: Reduction in sound detectability due to the simultaneous presence of another sound

- Behavioural effects: substantial change in behaviour for the animals exposed to a sound (long or short term)

26. Despite emerging evidence of fish sensitivity to particle motion (see Section 2.2.2), the Popper *et al.* (2014) criteria provide a quantitative criterion as thresholds for impact onsets in terms of sound pressure related functions (e.g., SPL_{peak}, SPL_{rms}, SEL_{ss}, SEL_{cum}).

27. Since drilling (associated with secant piling), vibropiling and operational pump noise are all continuous noise source, this study uses the criteria from Popper *et al.* (2014) for shipping and continuous sounds as a proxy, summarized in Table 2-1.

28. Popper *et al.* (2014) only provides a quantitative criterion for fish with a swim bladder involved in hearing for recoverable injury and TTS as data is insufficient for other impacts, and other fish categories. Therefore, to assess the other fish categories (fish with no swim bladder and fish with a swim bladder not involved in hearing), Popper *et al.* (2014) provides a relative risk associated with various impacts, which describes the risk of an effect on a receptor occurring in either the near-field (tens of meters), intermediate-field (hundreds of meters) or far-field (thousands of meters) from the sound source, as high, moderate or low.

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

Due to the extent of Parteen Basin, the potential risk in the near-field distance (tens of metres) and intermediate field distance (hundreds of metres) is relevant in this study, and thus, only the risk associated with these distances has been considered.

Table 2-1: Recommended guidelines for shipping and continuous sounds according to Popper et al. (2014) for speices of fish, sea turtles and eggs and larvae (N = Near-field; I = Intermediate-field; F = Far-field).

Popper *et al.* (2014) criteria for Shipping and Continuous sounds					
Type of fish	**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	$170\ L_{p,48h}$	$158\ L_{p,12h}$	((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

2.3.2   *Marine Invertebrates*

29. A review by Sole *et al.* (2023) highlights growing evidence that certain anthropogenic noises harm marine invertebrates, affecting behaviour, physiology, mortality rates, and causing physical impairment at individual, population, or ecosystem levels. Much of this damage results from vibrations of the invertebrate's body caused by sound (André *et al.*, 2016).

30. Studies reviewed by Sole *et al.* (2023) show inconsistency in quantifying noise impacts on marine invertebrates. For example, Hubert *et al.* (2021) reports behavioural changes in blue mussels at 150-300 Hz tones, while Spiga *et al.* (2016) notes a behavioural change at $L_{E,p,ss}$ 153.47 dB re 1 μPa. These inconsistencies make it challenging to develop accurate thresholds. A notable exception is cephalopods, where studies (e.g., Sole *et al.,* 2019, 2018, 2013a; André *et al.*, 2011) show consistent auditory damage at 157 dB re 1 μPa, providing a benchmark for other groups. However, further research is needed for more accurate thresholds.

31. Furthermore, Sole *et al.* (2023) highlights inconsistencies in the responses of taxonomically similar marine invertebrates to anthropogenic noise. For instance, Fields *et al.* (2019) reports low mortality in zooplankton exposed to seismic airguns, while McCauley *et al.* (2017) observes mass mortality in krill larvae from the same source. This suggests that noise impacts vary by species, complicating the development of generalized impact thresholds for marine invertebrates.

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

32. For now, research on the effects of anthropogenic noise on marine invertebrates is emerging, but at a slower pace than for marine mammals and fish. Currently, the data is insufficient to establish reliable impact thresholds for regulatory use. However, convincing evidence of noise impacts exists, and while some species' data may be referenced, caution is needed due to significant knowledge gaps.

3 Baseline Noise Levels in Parteen Basin

3.1 Methodology

33. Underwater noise measurements were sampled over two weeks in October 2021 to establish a baseline in Parteen Basin surrounding the proposed location for the RWI&PS. Both attended and unattended survey methods were used concurrently through the survey period.

34. An unattended, fixed-position, long term monitor was installed to monitor temporal noise level variation. Attended short-term monitoring using boat-based instrumentation was utilised to monitor snapshots of spatial noise level variation in the area.

3.1.1 *Unattended Long-Term Monitoring*

35. Long-term unattended monitoring was undertaken by deploying a Wildlife Acoustics SM3M long-term acoustic recording device (serial number SM3M2210) on a single line mooring. The mooring was configured such that in the water column (6 m depth at the deployment location) the monitor was situated 1 m above a 25 kg weight with a 30 cm buoy at the surface. The mooring was deployed close to the proposed water works (location 2.1 shown in Figure 3-1) with the monitor recording continuously for two weeks before being recovered. Calm conditions on the lough led to very little surface movement contributing to any mooring noise being detected at the hydrophone.

36. The SM3M monitor was end-to-end calibrated before and after the survey, and no drift in calibration was noted.

3.1.2 *Attended Short-Term Monitoring*

37. Immediately following the deployment of the long-term monitor, attended monitoring of underwater noise was undertaken using drifting measurements along two transects in the Parteen Basin. The first transect began at the Parteen Weir and headed north towards Killaloe. Each location used for this transect is shown in Figure 3-1 as '1.X'. The second transect was across the Parteen Basin directly out from the location of the long-term monitor and proposed water works. Each location used for this transect is shown in Figure 3-1 as '2.X'. The attended monitoring was repeated two weeks later using the same measurement locations, prior to the recovery of the long-term monitor. All measurements of underwater noise were made using a Subacoustech pre-amp with variable gain, a National Instruments USB-6216 data acquisition device and a Reson TC-4014 hydrophone (serial number 4005037).

38. For each spot measurement, the water depth was measured and the hydrophone positioned to sit in the middle of the water column. During noise measurements the survey boat's engines and depth sounders were turned off before the monitoring equipment was deployed and allowed to drift with the current of the river. Drifting measurements minimise the flow of water over the hydrophone and thus reduce flow-induced noise on the measurements. Ten to thirty-second measurements were recorded and verified in real-time before recovering the equipment, restarting the boat's engines, and repositioning the boat at the next location along the transect.
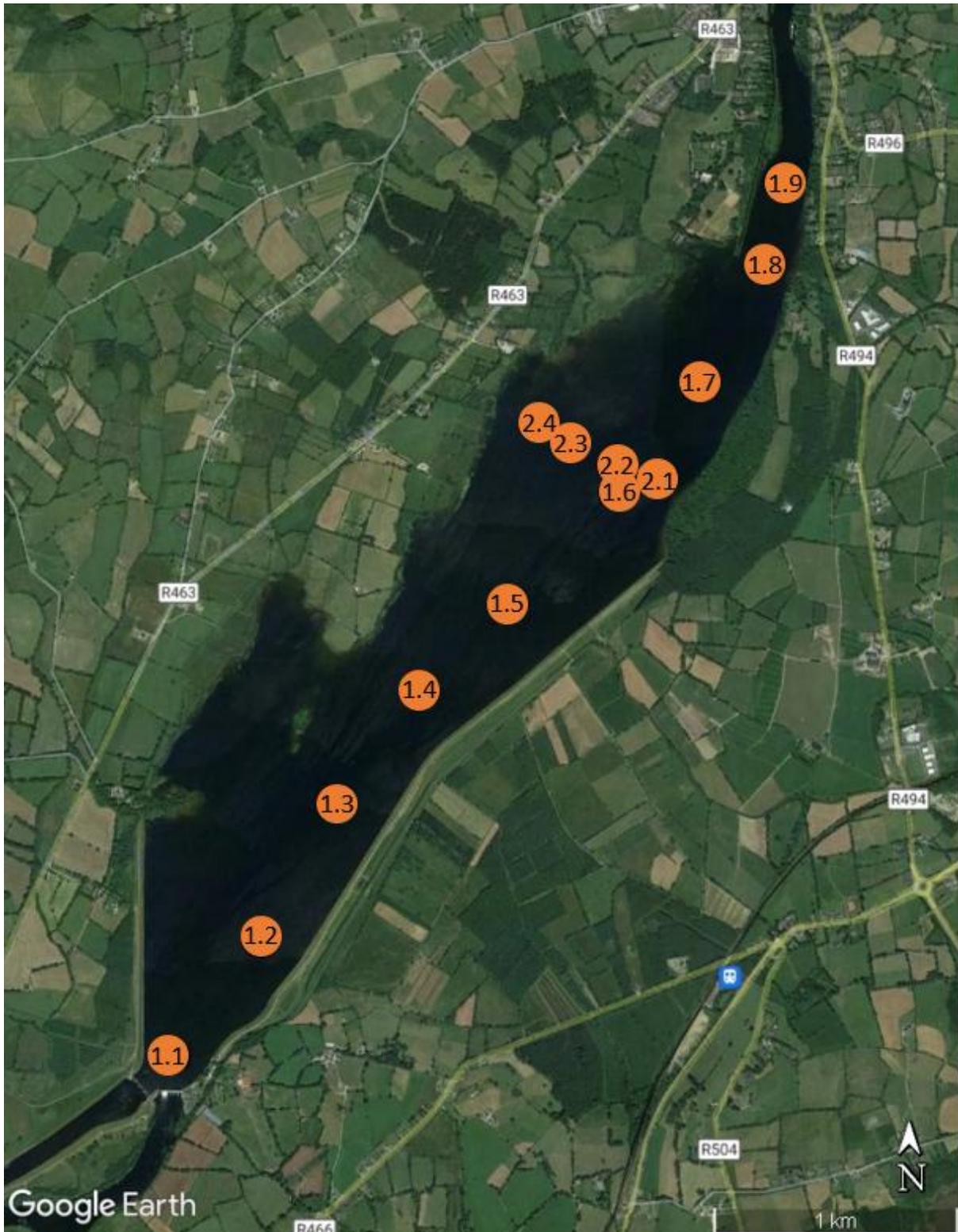
CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

Figure 3-1 Measurement locations during underwater noise surveys in Parteen Basin

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

3.2   Baseline Noise Results

3.2.1   *Long-Term Monitoring*

39. The results for the unattended long-term monitor are presented in Figure 3-2 and Table 3-1. The monitor was deployed at 08:50 on 6th October 2021 and recovered at 10:00 on 20th October 2021.

40. Figure 3-2 shows the broadband SPL$_{RMS}$ level for every minute over the two-week monitoring period. Peaks in noise occur mostly during daylight hours where river traffic from small fishing vessels is present in the vicinity of the monitor.

41. Table 3-1 shows the minimum, maximum, and mean one-minute $L_{p, RMS}$ recorded for each day in the two-week monitoring period. The lowest daily mean $L_{p, RMS}$ for a full day of recording was 92.2 dB, which occurred on 15th October. The highest daily mean $L_{p, RMS}$ for a full day of recording was 97.7 dB, which occurred on 19th October. The minimum daily $L_{p, RMS}$ was consistently 91.7 dB - 91.9 dB. This minimum noise level that can be seen in Figure 3-2 is attributed to noise from the machinery at the weir, which can be heard in recordings at the position of the long-term monitor and provides a continuous lower limit for the broadband noise level.

42. Figure 3-3 shows the frequency data as a Power Spectral Density (PSD) for one hour of monitoring between 03:00 and 04:00 on 16th October 2021. The PSD shows the frequency information captured over the hour-long sample period. This sample has been presented as an example of a quiet period where the recorded data shows no acoustic features that would be consistent with noisy events such as passing river traffic or rain. The peaks in frequency shown between 100 Hz and 1 kHz occur throughout all recordings, both attended and unattended. The broadband level is low however these peaks are audible and are consistent with constant turbine noise at the weir.

43. A spectrogram for each day of monitoring by the long-term monitor is shown in Annex A. These plots show the frequency characteristics of the noise recorded. The figures in the annex show that the underwater noise comprises mostly of low frequency noise below 1 kHz. Such noise is consistent with the frequency characteristics of a small boat engine.

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment
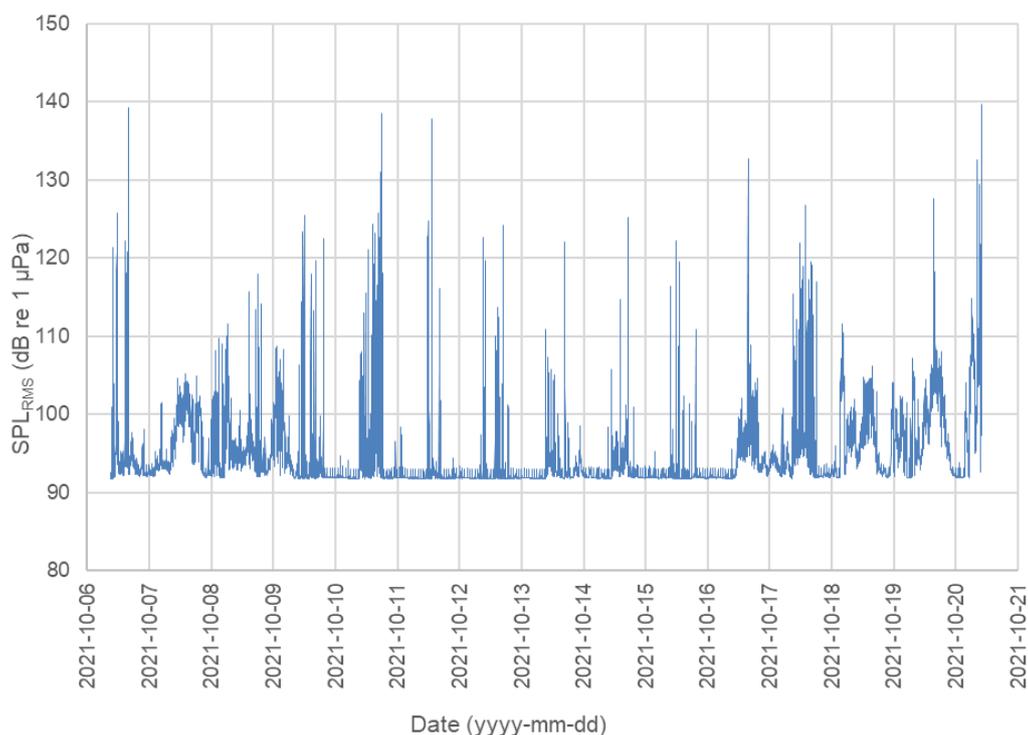
Figure 3-2 $L_{p, RMS}$ for each minute of continuous monitoring from the unattended long-term monitor

Table 3-1 The minimum, maximum and mean $L_{p, RMS}$ (1-minute) values for each day of continuous monitoring from the unattended long-term monitor

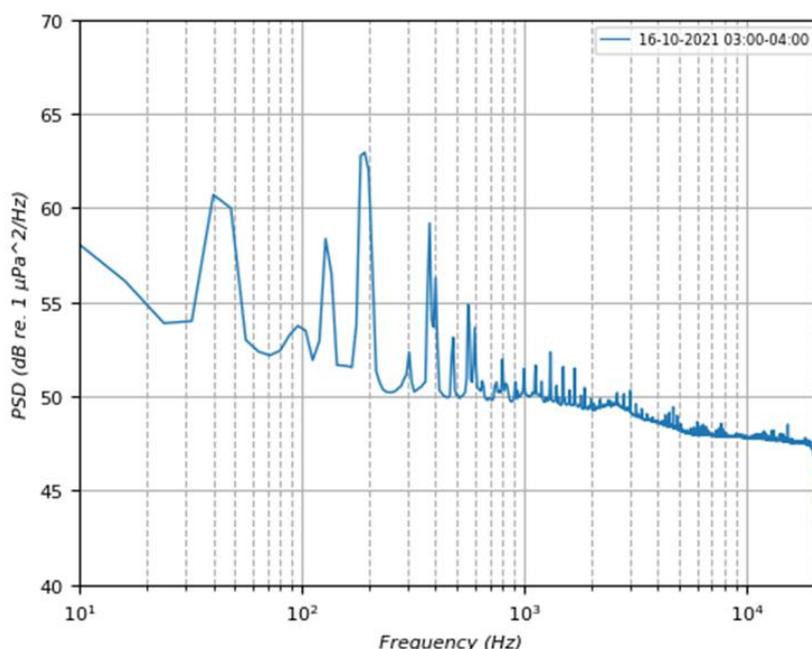| Date	SPL$_{RMS}$ (dB re 1 µPa)		
	Min	Max	Mean
06/10/2021	91.7	139.3	94.6
07/10/2021	91.9	105.2	96.1
08/10/2021	91.8	117.9	95.6
09/10/2021	91.7	125.4	94.4
10/10/2021	91.7	138.6	94.2
11/10/2021	91.7	137.9	92.5
12/10/2021	91.7	124.2	92.3
13/10/2021	91.7	122.0	92.7
14/10/2021	91.7	125.2	92.6
15/10/2021	91.7	122.2	92.2
16/10/2021	91.7	132.7	93.9
17/10/2021	91.8	126.8	94.8
18/10/2021	91.8	111.5	96.3
19/10/2021	91.8	127.7	97.7
20/10/2021	91.8	138.3	99.5

Figure 3-3 Power Spectral Density (PSD) for one hour of monitoring between 03:00 and 04:00 on 16th October from the unattended long-term monitor

3.2.2 Short-Term Monitoring

44. A summary of the results from the short-term attended measurements on 6th October 2021 and 20th October 2021 is presented in Table 3-2 and Table 3-3 respectively. Table 3-2 shows results from locations on the northeast-southwest transect. Table 3-3 shows results from transect taken directly across the water from the proposed water works location. All measurement locations are shown in Figure 3-1. Position 1.1 is consistently 25-35 dB louder than noise levels at all other locations. Location 1.1 is approximately 20 meters away from the Parteen Weir where hydroelectric turbines were operational throughout both survey days. The noise recorded at this position contained features that are mechanical in nature and are consistent with that of audible operational underwater turbines.

Table 3-2 The maximum, minimum, and mean $L_{p, RMS}$ values for each location on each day of attended monitoring for the northeast-southwest transect

Measurement Location	6th October 2021 $L_{p, RMS}$ (dB re 1 µPa)			20th October 2021 $L_{p, RMS}$ (dB re 1 µPa)		
	Min	Max	Mean	Min	Max	Mean
1.1	135.7	137.4	136.4	132.2	134.0	133.3
1.2	105.4	110.2	106.9	113.3	114.3	113.8
1.3	103.8	113.9	105.4	108.2	108.8	108.4
1.4	103.1	113.6	104.7	110.8	115.9	111.5
1.5	103.0	109.6	104.5	112.4	113.0	112.8
1.6	101.5	109.9	103.4	110.8	112.1	111.1
1.7	108.6	111.5	110.0	101.1	110.6	106.3
1.8	108.6	111.1	109.5	106.3	113.3	109.7
1.9	N/A	N/A	N/A	106.0	118.3	107.3

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

Table 3-3 The maximum, minimum, and mean $L_{p, RMS}$ values for each location on each day of attended monitoring for the transect crossing the lough

Measurement Location	6th October 2021 $L_{p, RMS}$ (dB re 1 µPa)			20th October 2021 $L_{p, RMS}$ (dB re 1 µPa)		
	Min	Max	Mean	Min	Max	Mean
2.1	104.2	111.5	106.6	102.0	102.2	102.1
2.2	104.2	110.2	105.1	106.7	108.1	107.4
2.3	103.2	109.7	104.9	107.4	111.7	111.0
2.4	104.7	109.6	107.0	103.8	106.7	104.3

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment
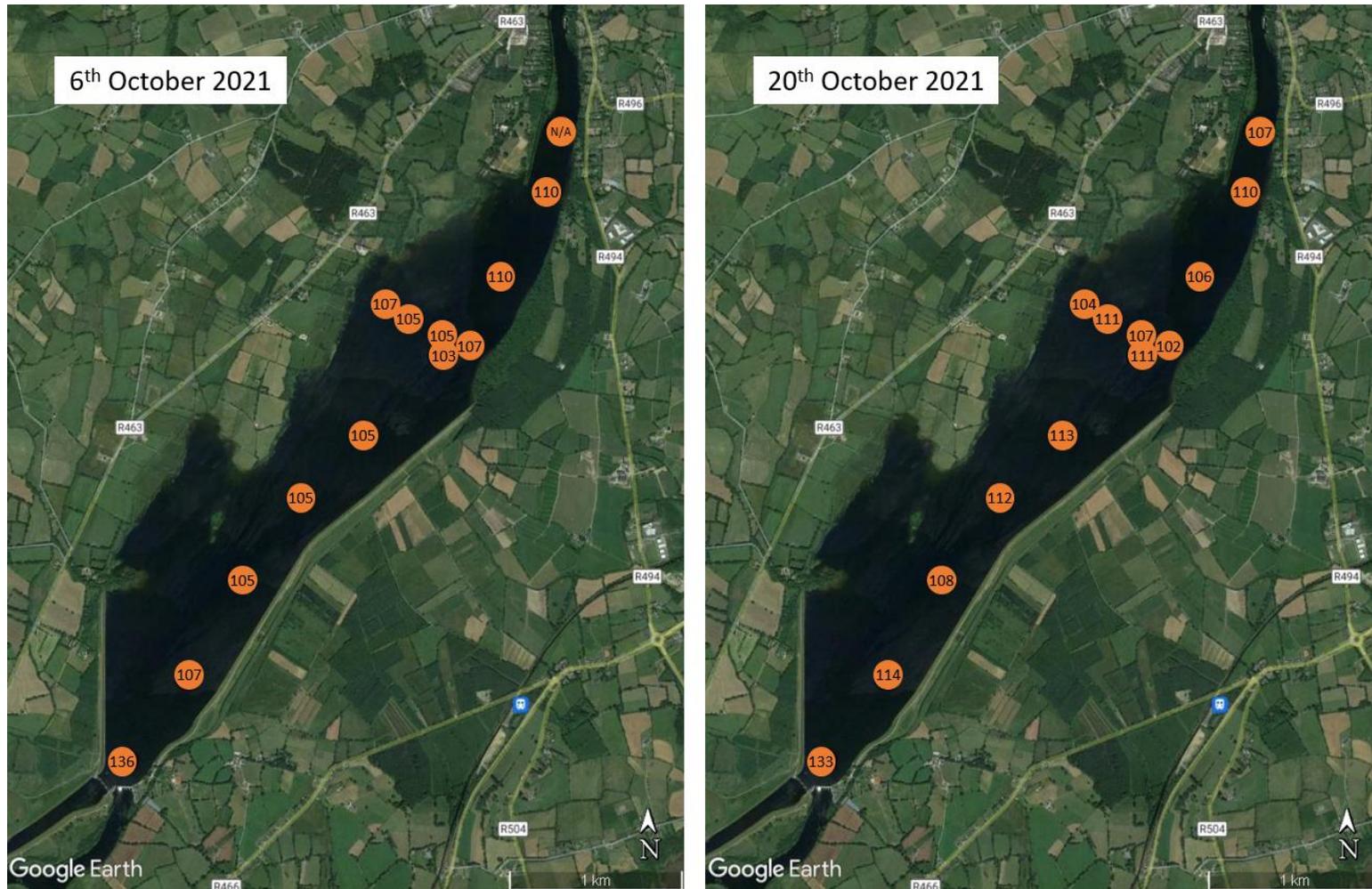
Figure 3-4 Average dB L$_{p, RMS}$ levels from attended measurements on 6th and 20th October 2021

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

3.3   Baseline Underwater Noise Summary

45. Baseline noise levels in the Parteen Basin were monitored by Subacoustech for 14 days between 6th and 20th October 2021 using an unattended long-term underwater noise recorder in the vicinity of the location proposed for the RWI&PS. In addition to this monitoring, attended spot measurements were taken which covered a large area within Parteen Basin.

46. The daily mean noise levels recorded by the long-term monitor were between 92.2 dB and 97.7 dB $L_{p, RMS}$.

47. The maximum noise level recorded during the spot measurements was 137.4 dB within 20 m of Parteen Weir.

4   Underwater Noise Modelling: Methodology

48. Modelling of underwater noise is complex and can be approached in several different ways. Measurements are only possible at limited locations, so modelling has been undertaken to provide a more comprehensive set of results. To estimate the noise levels generated by secant piling, vibropiling and the operational pumps, Subacoustech have chosen to utilise the dBSea noise modelling software, which uses various numerical solvers to calculate underwater noise. This assessment uses two different solvers:

- A parabolic equation (PE) method for lower frequencies (12.5 Hz to 250 Hz)

    o   Widely used within the underwater acoustics community but has computational limitations at high frequencies.

- A ray tracing method for higher frequencies (315 Hz to 100 kHz).

    o   More computationally efficient at higher frequencies but is not suited to low frequencies (Etter, 1991).

49. These solvers account for a wide array of environmental input parameters within the study area, including bathymetry, sediment data and sound speed, as well as the characteristics of the noise source, such as source frequency content, to ensure as detailed results as possible. The input parameters used in this study are described in the following sections.

4.1   Input Parameters

4.1.1   Modelling Location

50. All activities were modelled at the proposed location for the RWI&PS, at a single, representative modelling location. For all noise sources, the depth of the source was modelled at mid-water depth. Details of the noise source locations used are presented in Table 4-1.

Table 4-1: Details of the modelling locations. Eastings/Northings are in WGS84, UTM Zone 29N.

Modelling location	Easting (m)	Northing (m)
Raw Water Intake & Pumping Station (All Sources)	537410	5848288

4.1.2   Bathymetry

51. Bathymetry of Parteen Basin for the modelling was provided by TOBIN and covers a total area of approximately 3.5 km^2.

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

4.1.3   Bed Properties

52. At the modelling location, the bed was assumed to consist entirely of mud. Geo-acoustic properties were taken from Jensen *et al.* (1994, 2011) as listed in Table 4-2.

Table 4-2: Bed geo-acoustic properties of the area.

Material	Compressive sound speed profile in substrate (m/s)	Density profile in substrate (kg/m³)	Attenuation profile in substrate (dB/wavelength)
Mud	1700	1500	1

4.1.4   Sound Speed Profile

53. The speed of sound in the water has been calculated for the average annual temperature and salinity for the modelling location using the Mackenzie (1981) equation. The resulting profile is shown in Figure 4-1.
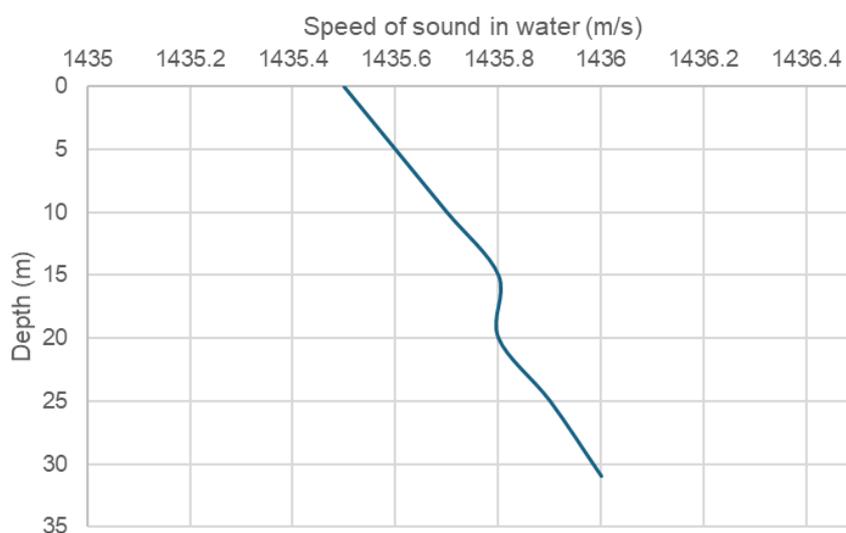

Figure 4-1: Sound speed profile used for detailed modelling of the area.

4.1.5   Noise Sources

54. According to the information provided, the following noise sources were modelled. The source levels used in modelling for each activity are presented in Table 4-3.

- Secant piling

55. Secant piling consists of borehole drilling, which generates the most noise associated with this piling method. Therefore, drilling noise was used to represent the anticipated worst-case noise generated by this piling technique. Source levels for drilling noise were calculated from measurements taken by Subacoustech in the River Mersey, Liverpool during rotary drilling (Mason and Midforth, 2019), which were taken in a similar, enclosed environment to Parteen Basin.

- Vibropiling

56. Limited information was available regarding the equipment specifications associated with the anticipated vibropiling. Therefore, vibropiling source levels were calculated from measurements in the River Thames, London during the installation of sheet pile retaining wall (Midforth and East, 2016) which were taken in a

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

similar, enclosed environment to Parteen Basin. This measurement scenario was deemed representative of possible vibropiling activities which may take place in Parteen Basin and therefore were considered suitable to use for modelling.

- Operational RWI&PS

57. The RWI&PS is anticipated to have capacity for the following:

    o Expected abstraction rate: 280 Mld

    o Maximum abstraction rate: 300 Mld

58. The operational RWI&PS noise therefore consists of two modelling scenarios; the expected abstraction rate, which represents a realistic scenario, and a maximum abstraction rate, which represents a worst-case scenario for this noise source. Source levels for operational pump noise was based on measurements taken at an existing RWI&PS in Loch Duntelchaig, Inverness (Nedwell *et al*., 2009). The recorded levels of the pumps were scaled up to reflect the anticipated capacity of the RWI&PS to be installed in Parteen Basin.

Table 4-3: Summary of the calculated $L_{p,rms}$ source levels for the drilling, vibropiling and the operational pumps.

Equipment	Estimated source level @ 1 m ($L_{p,rms}$ dB re 1 µPa)
Secant Piling (Drilling)	156.6
Vibropiling	187.5
Operational Pump (Max Capacity)	123.6
Operational Pump	120.6

59. Using this measured data, the spectrums (measured at various distances from the source) containing 1/3rd octave levels were obtained, and were then shifted to represent an estimated source spectrum, based on the calculated source levels in Table 4-3. The 1/3rd octave source spectrums used for modelling is shown in Figure 4-2 for drilling, Figure 4-3 for vibropiling and Figure 4-4 for operational pump noise.
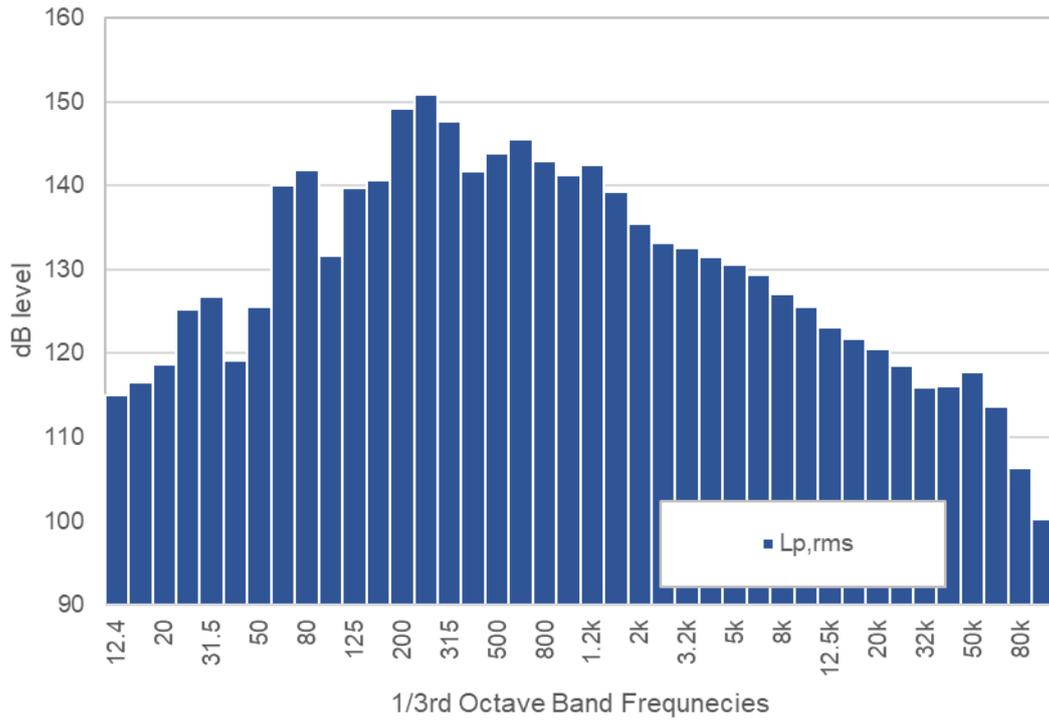
CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

Figure 4-2: The L$_{p,rms}$ source spectrums containing 1/3rd octave band levels used to model secant piling (drilling).

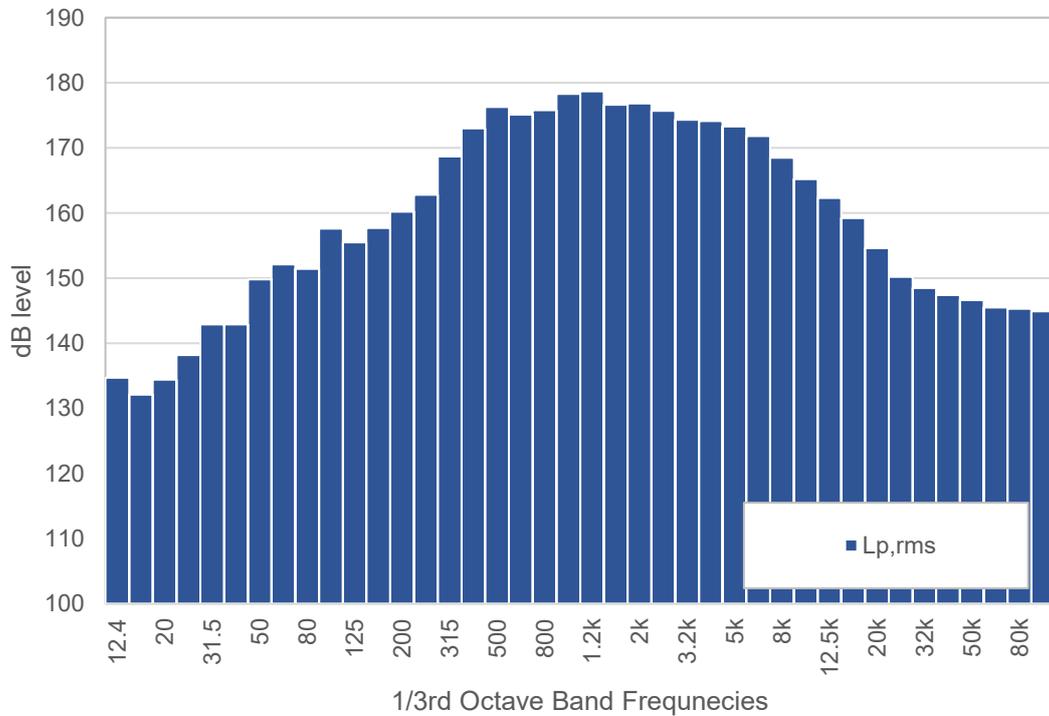*Figure 4-3: The L$_{p,rms}$ source spectrum containing 1/3rd octave band levels used to model the vibropiling.*

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment
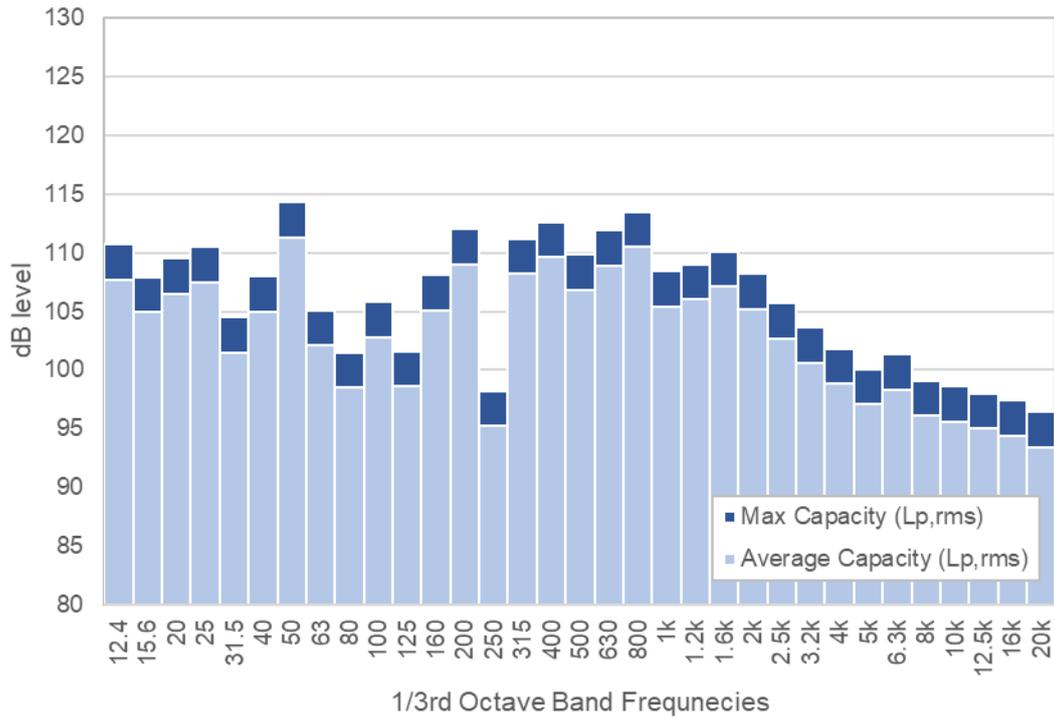

Figure 4-4: The $L_{p,rms}$ source spectrum containing 1/3rd octave band levels used to model operational pump noise.

5 Underwater Noise Modelling: Results

60. The distribution of noise from all noise generating activities are presented as noise contour plots in the following section. These noise contours are then interpreted using the Popper *et al.* (2014) guidelines to predict the likely range at which the thresholds for shipping and continuous sounds would be exceeded by fish.

61. Any impact range noted as *NE* indicates that no exceedance is expected for the given criteria based on the results of the modelling.

5.1 Secant Piling (Drilling)

5.1.1 *Predicted Noise Levels*

62. The distribution of noise from the secant piling (drilling) is presented as a noise contour plot in Figure 5-1. These plots show the maximum predicted noise level in the water column.
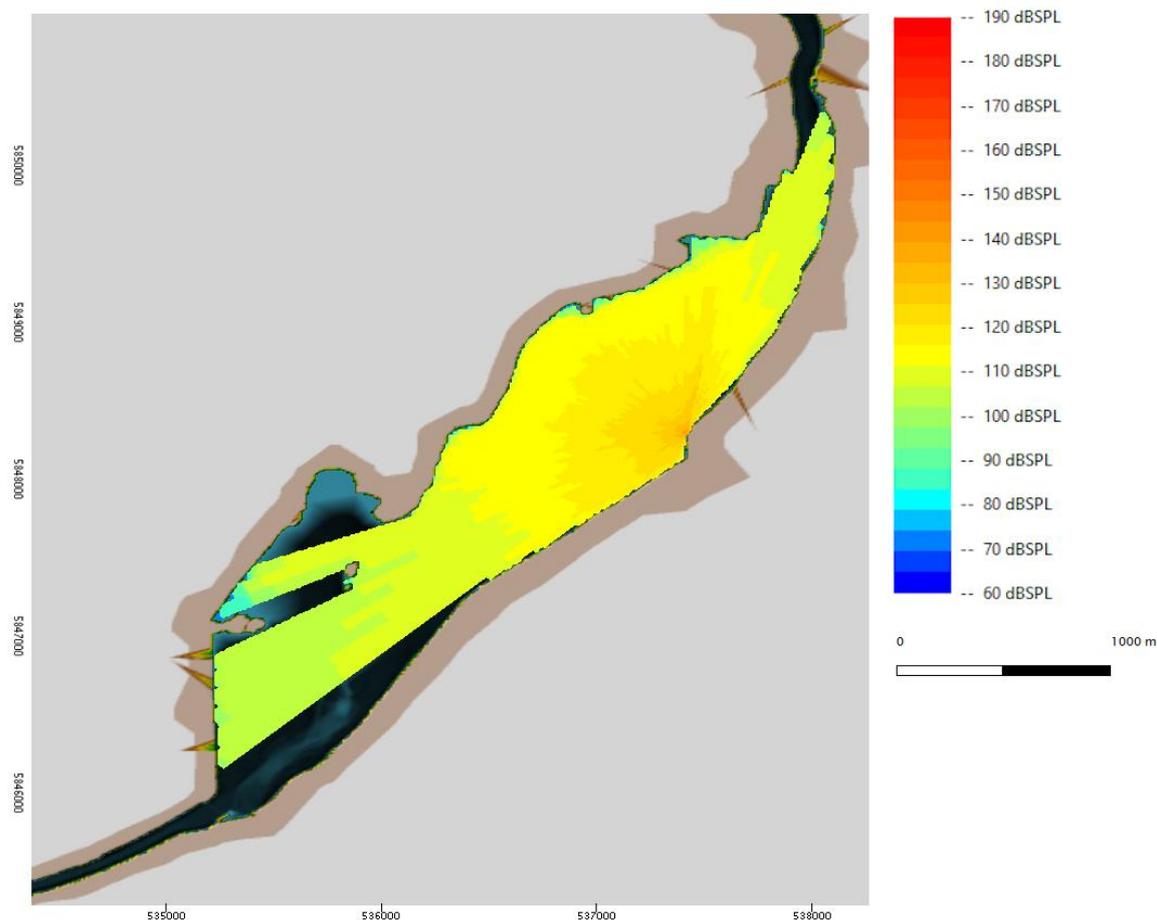
Figure 5-1: L$_{p,RMS}$ noise level contours predicted for secant piling (drilling).

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

5.1.2   Interpretation: Fish Assessment

63. Based on the results for the $L_{p,rms}$ metric, it is unlikely that animals will exceed any threshold for fish with a
swim bladder involved in hearing at any range from the secant piling (drilling) activities. These details are
provided in Table 5-1.

*Table 5-1: Estimated impact ranges for the secant piling (drilling) activities using the Popper et al. (2014) $L_{p,rms}$
fish criteria for shipping and continuous sounds.*

Popper *et al*. (2014) criteria $L_{p,rms}$ (Continuous sounds)		Estimated impact range (m)		
		Maximum	**Mean**	**Minimum**
Fish: swim bladder involved in hearing	**Recoverable injury**	NE	NE	NE
	TTS	NE	NE	NE

64. Across all species of fish, the relative risk of mortality and potential mortal injury, as well as recoverable
injury associated secant piling is low in both the near-field and intermediate field distance. Of all the
potential impacts, the impact associated with the highest relative risk for all species of fish is masking, which
is deemed as high in the near-field and intermediate field. These details are presented in Table 5-2.

*Table 5-2: The relative risk of impacts on fish in the near-field (N) and intermediate field (I) for the secant piling
(drilling) activities using the Popper et al. (2014) $L_{p,rms}$ fish criteria for shipping and continuous sounds.*

Popper *et al*. (2014) criteria for Shipping and Continuous sounds					
Type of fish	**Mortality and potential mortal injury**	**Impairment**			**Behaviour**
		Recoverable injury	**TTS**	**Masking**	
Fish: no swim bladder	(N) Low (I) Low	(N) Low (I) Low	(N) Moderate (I) Low	(N) High (I) High	(N) Moderate (I) Moderate
Fish: swim bladder not involved in hearing	(N) Low (I) Low	(N) Low (I) Low	(N) Moderate (I) Low	(N) High (I) High	(N) Moderate (I) Moderate
Fish: swim bladder involved in hearing	(N) Low (I) Low	n/a	n/a	((N) High (I) High	(N) High (I) Moderate

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment

5.2   Vibropiling

5.2.1   Predicted Noise Levels

65.   The distribution of noise from the vibropiling is presented as a noise contour plot in Figure 5-2. These plots show the maximum predicted noise level in the water column.
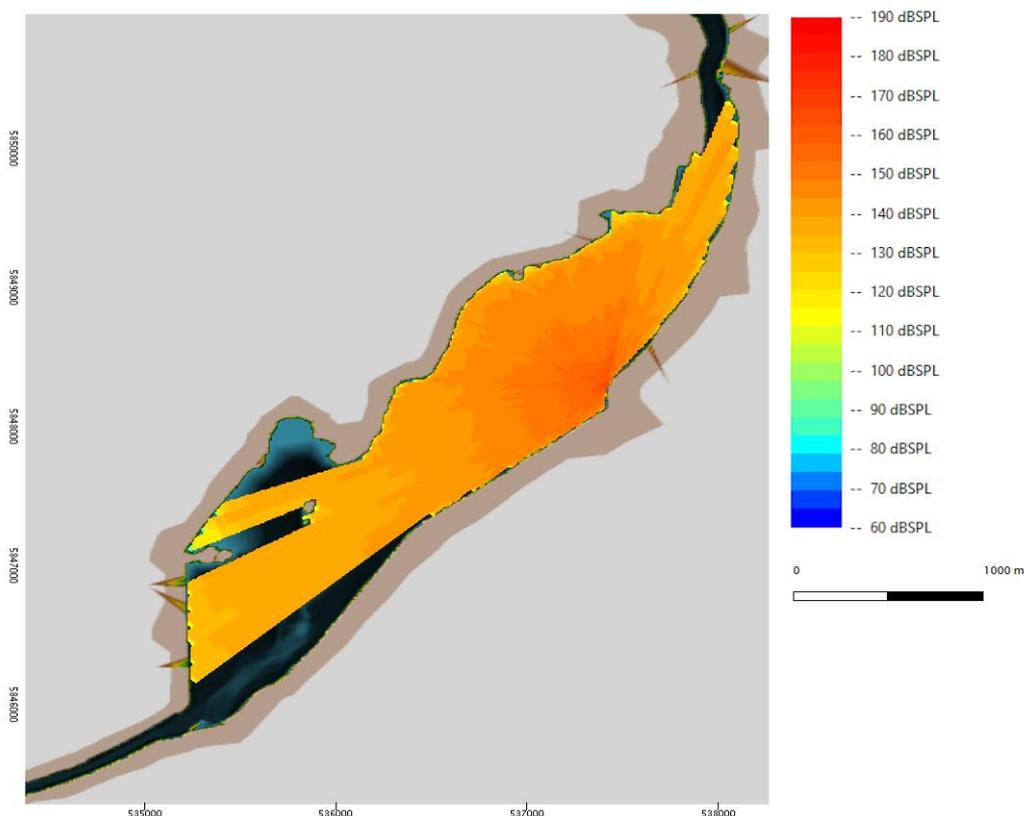

Figure 5-2: L$_{p,RMS}$ noise level contours predicted for vibropiling.

5.2.2   Interpretation: Fish Assessment

66.   Based on the results for the $L_{p,rms}$ metric, animals within 60 m of the vibropiling activities may exceed the recoverable injury threshold for fish with a swim bladder involved in hearing. These details, along with TTS impact ranges are provided in Table 5-3.

Table 5-3: Estimated impact ranges for the vibropiling activities using the Popper et al. (2014) L$_{p,rms}$ fish criteria for shipping and continuous sounds.

Popper *et al.* (2014) criteria L$_{p,rms}$ (Continuous sounds)		Estimated impact range (m)		
		Maximum	**Mean**	**Minimum**
Fish: swim bladder involved in hearing	**Recoverable injury**	60	30	< 10
	TTS	520	210	< 10

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

67. Across all species of fish, the relative risk of mortality and potential mortal injury, as well as recoverable injury associated vibropiling is low in both the near-field and intermediate field distance. Of all the potential impacts, the impact associated with the highest relative risk for all species of fish is masking, which is deemed as high in the near-field and intermediate field. These details are presented in Table 5-4.

Table 5-4: The relative risk of impacts on fish in the near-field (N) and intermediate field (I) for the vibropiling activities using the Popper et al. (2014) $L_{p,rms}$ fish criteria for shipping and continuous sounds.

Popper *et al.* (2014) criteria for Shipping and Continuous sounds					
Type of fish	**Mortality and potential mortal injury**	**Impairment**			**Behaviour**
		Recoverable injury	**TTS**	**Masking**	
Fish: no swim bladder	(N) Low (I) Low	(N) Low (I) Low	(N) Moderate (I) Low	(N) High (I) High	(N) Moderate (I) Moderate
Fish: swim bladder not involved in hearing	(N) Low (I) Low	(N) Low (I) Low	(N) Moderate (I) Low	(N) High (I) High	(N) Moderate (I) Moderate
Fish: swim bladder involved in hearing	(N) Low (I) Low	n/a	n/a	((N) High (I) High	(N) High (I) Moderate

5.3 Operational Pumps

5.3.1 *Predicted Noise Levels*

68. The distribution of noise from the operational pump noise at expected capacity and maximum capacity is presented as noise contour plots in Figure 5-3 and Figure 5-4 respectively. These plots show the maximum predicted noise level in the water column.

69. At the expected capacity, noise levels are predicted to return to the minimum recorded baseline level of 92.2 dB at 400 m from the RWI&PS, and the maximum recorded baseline level of 97.7 dB at 200 m from the RWI&PS.

70. At the maximum capacity, noise levels are predicted to return to the minimum recorded baseline level of 92.2 dB at 550 m from the RWI&PS, and the maximum recorded baseline level of 97.7 dB at 380 m from the RWI&PS.
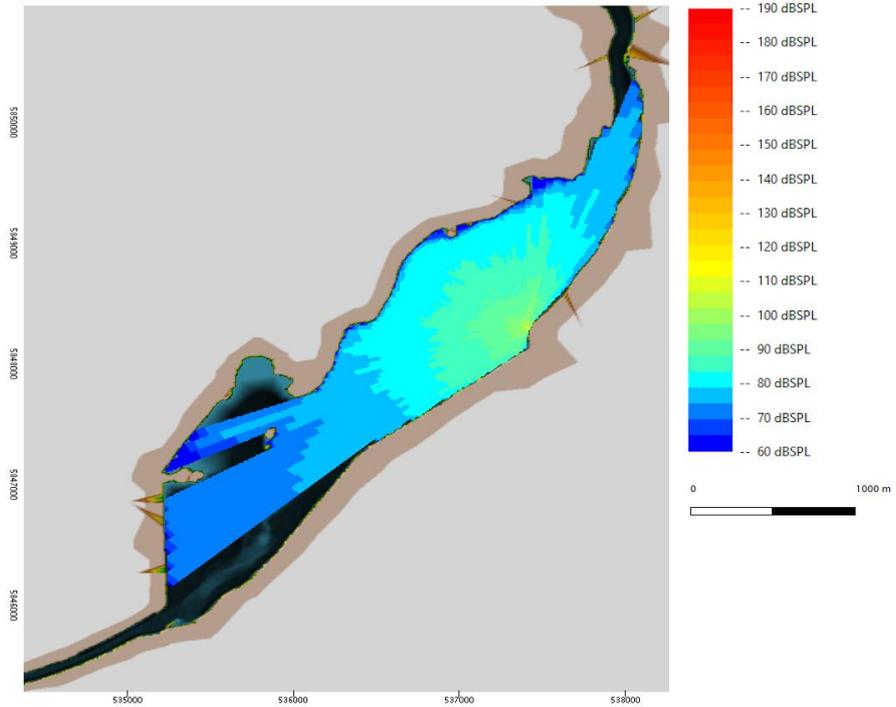
Figure 5-3: L$_{p,RMS}$ noise level contours predicted for operational pump noise at expected capacity.
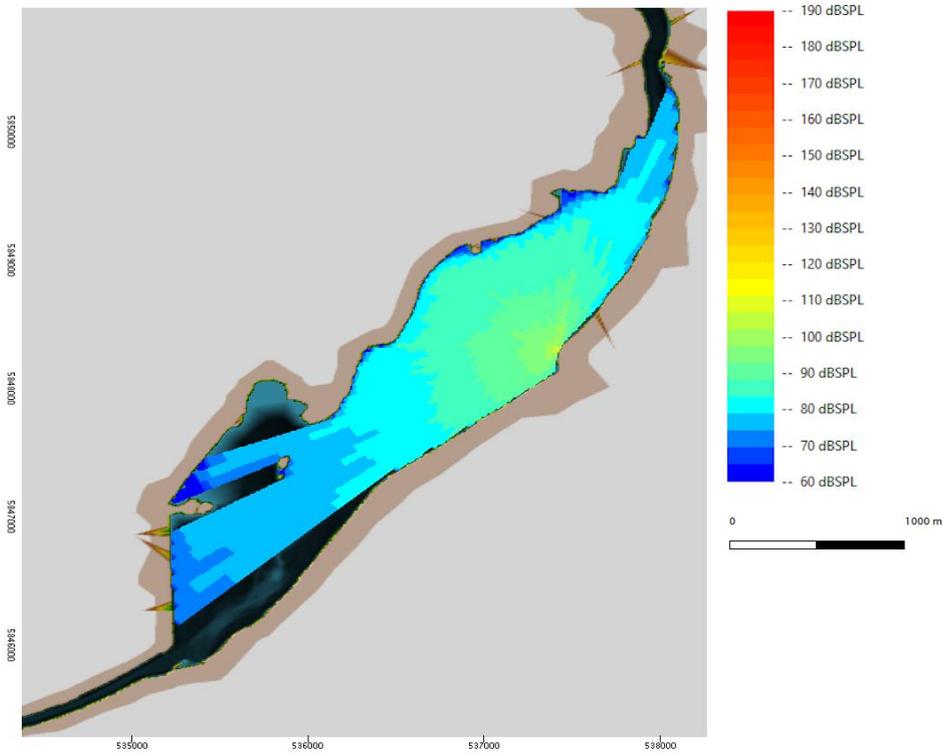
Figure 5-4: L$_{p,RMS}$ noise level contours predicted for operational pump noise at maximum capacity.

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

5.3.2   Interpretation: Fish Assessment

71.   Based on the results for the $L_{p,rms}$ metric, it is unlikely that animals will exceed any threshold for all fish
species at any range from the RWI&PS when operating at any capacity. These details are provided in Table
5-5.

Table 5-5: Estimated impact ranges for the operational pump noise using the Popper et al. (2014) $L_{p,rms}$ fish criteria for shipping and continuous sounds.

Popper *et al.* (2014) criteria $L_{p,rms}$ (Continuous sounds)		Estimated impact range (m)					
		Expected Capacity			Maximum Capacity		
		Maximum	Mean	Minimum	Maximum	Mean	Minimum
Fish: swim bladder involved in hearing	Recoverable injury	NE	NE	NE	NE	NE	NE
	TTS	NE	NE	NE	NE	NE	NE

72.   Across all species of fish, the relative risk of mortality and potential mortal injury, as well as recoverable
injury associated with operational pump noise is low in both the near-field and intermediate field distance.
Of all the potential impacts, the impact associated with the highest relative risk for all species of fish is
masking, which is deemed as high in the near-field and intermediate field. These details are presented in
Table 5-6.

Table 5-6: The relative risk of impacts on fish in the near-field (N) and intermediate field (I) for the operational pump noise using the Popper et al. (2014) $L_{p,rms}$ fish criteria for shipping and continuous sounds.

Popper *et al.* (2014) criteria for Shipping and Continuous sounds					
Type of fish	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: no swim bladder	(N) Low (I) Low	(N) Low (I) Low	(N) Moderate (I) Low	(N) High (I) High	(N) Moderate (I) Moderate
Fish: swim bladder not involved in hearing	(N) Low (I) Low	(N) Low (I) Low	(N) Moderate (I) Low	(N) High (I) High	(N) Moderate (I) Moderate
Fish: swim bladder involved in hearing	(N) Low (I) Low	n/a	n/a	((N) High (I) High	(N) High (I) Moderate

6   Conclusion

73. Subacoustech Environmental has undertaken an underwater noise monitoring survey to establish baseline noise levels in Parteen Basin, Ireland, along with an underwater noise modelling study for the construction and operation of the planned RWI&PS in the area. The construction works are anticipated to involve secant piling to construct a secant pile wall, as well as the installation of sheet piles nearby via vibropiling.

74. Baseline noise levels at the location of the RWI&PS were found to vary between 92.2 dB and 97.7 dB re 1 μPa $L_{p, RMS}$. The maximum level monitored in Parteen Basin was 137.4 dB re 1 μPa $L_{p,RMS}$ within 20 m of Parteen Weir.

75. The level of underwater noise generated by the works was estimated using a combined parabolic equation and ray tracing modelling approach. The modelling considers a wide array of input parameters including the equipment source level, sound frequency content, bed properties and the sound speed profile in the water column. Full account is also taken of the bathymetry in the area.

76. The modelled noise levels were then interpreted in accordance with the guidelines outlined in Popper *et al.* (2014) for fish in relation to continuous sounds. According to this guidance, fish with a swim bladder involved in hearing are unlikely to exceed the criteria for recoverable injury or TTS for noise associated with secant piling and operational pumps at any capacity.

77. During vibropiling, the recoverable injury threshold is likely to be exceeded within 60 m, and the TTS criteria exceeded within 520 m for fish with a swim bladder. It is noted that the criteria found in Popper *et al.* (2014) for assessing recoverable injury and TTS onset in fish with a swim bladder are for RMS noise exposure over 48 and 12 hours respectively. Noise from vibropiling activities will not occur continuously over 48 or 12 hours and so the results of this modelling should be treated as conservative in nature.

78. Across all activities, the relative risk of morality for all fish species is considered low in the near-field (tens of metres) and intermediate field (hundreds of metres), however, the risk of masking is considered high across both fields, and the risk of behavioural changes is considered moderate. There is also a moderate risk of TTS for fish with no swim bladder, or a swim bladder not involved in hearing, in the near field from all sources.

79. 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 ranges should be taken as indicative in determining where environmental effects may occur in receptors during the proposed operations.
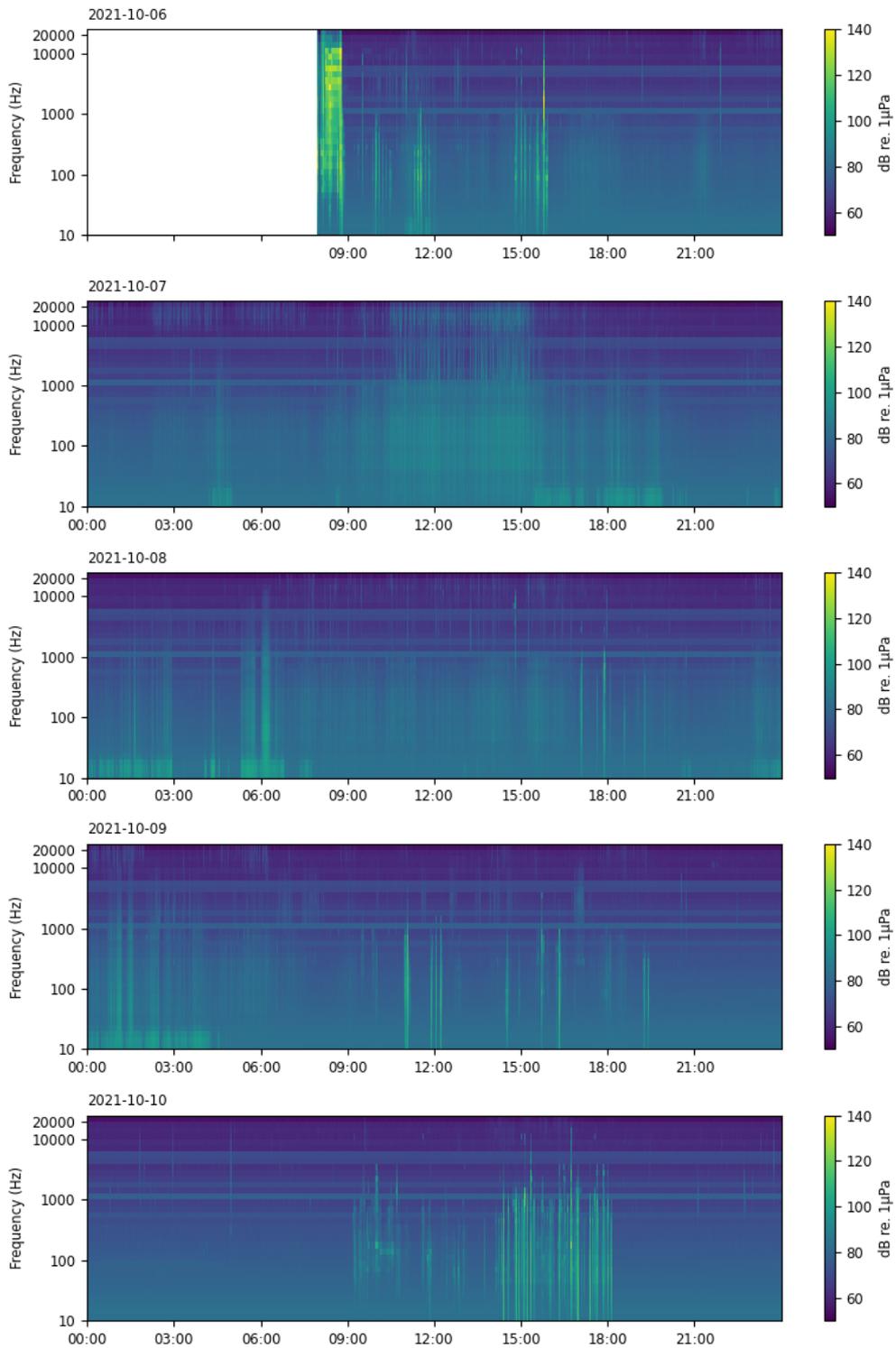
Annex A   Spectrogram Results at the Long-Term Monitor

*Figure 6-1 Five spectrograms showing 1/3rd octave frequency bands over each day between 6th and 10th
October*

Figure 6-2 Five spectrograms showing 1/3rd octave frequency bands over each day between 11th and 15th October

Figure 6-3 Five spectrograms showing 1/3rd octave frequency bands over each day between 16th and 20th October

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
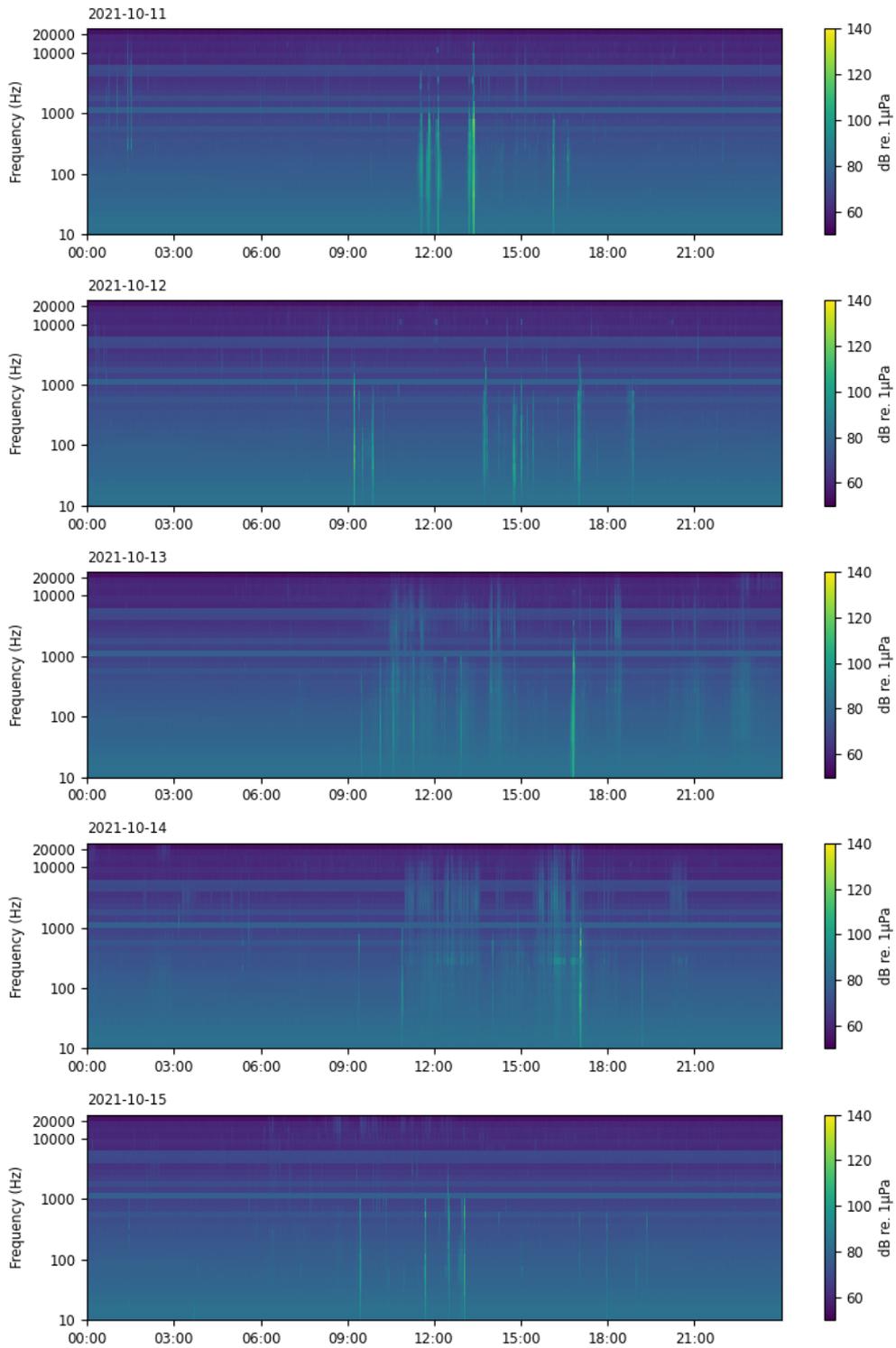Modelling Assessment

References

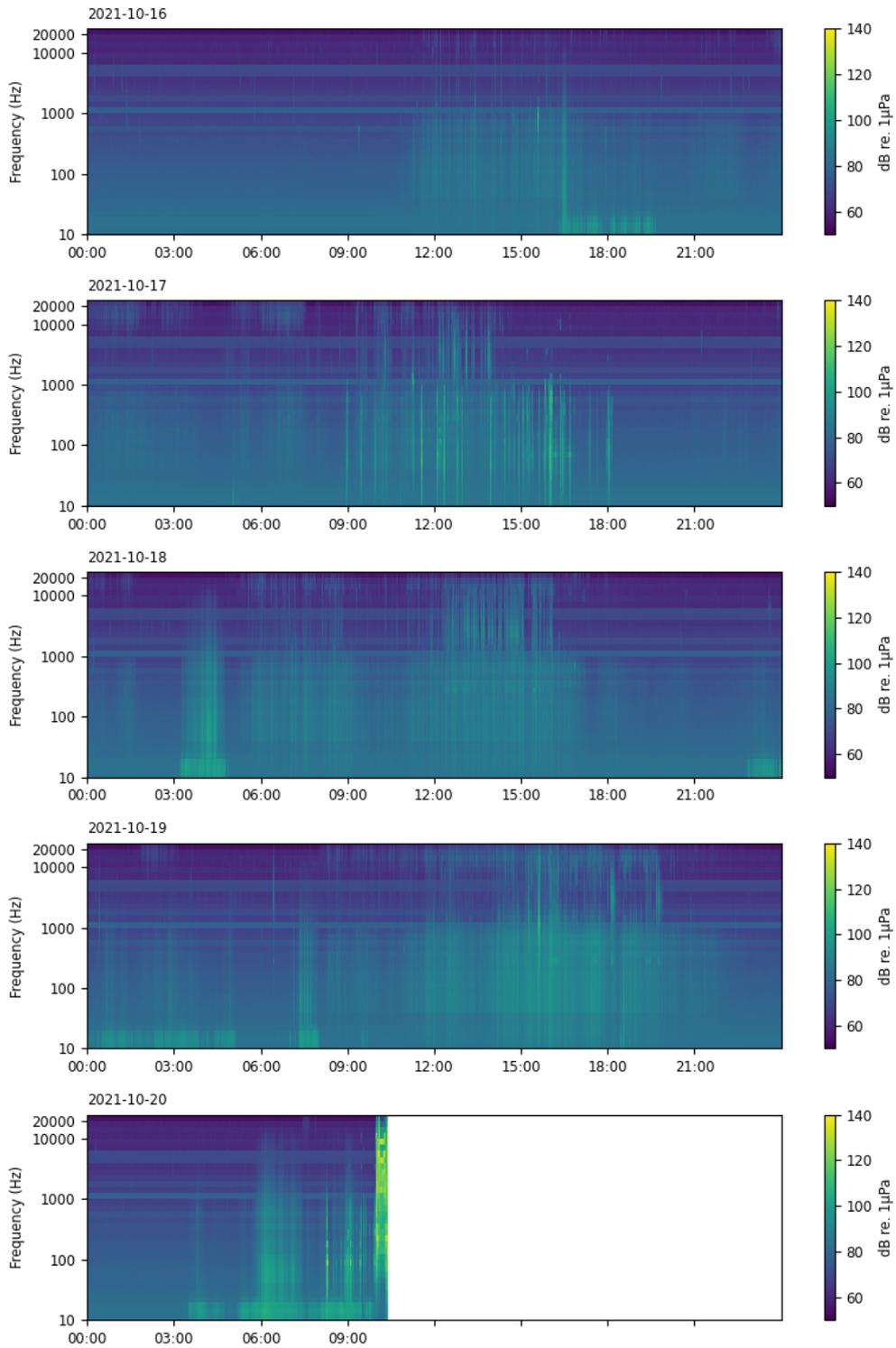Etter P C (1991). *Underwater acoustic modelling: Principles, techniques and applications.* Elsevier Science Publishers Ltd, Essex. ISBN 1-85166-528-5.

Hastings M C, Popper A N (2005). *Effects of sound on fish.* Report to the California Department of Transport, under Contract No. 43A01392005, January 2005.

Hawkins A D, Popper A N (2017). A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES J. Mar. Sci. 74 (3), 635–651. doi: 10.1093/icesjms/fsw205

Jensen F B, Kuperman W A, Porter M B, Schmidt H (1994). *Computational Ocean Acoustics.* Woodbury NW, AIP Press.

Jensen F B, Kuperman W A, Porter M B, Schmidt H (2011). *Computational Ocean Acoustics.* Modern Acoustics and Signal Processing. Springer-Verlag, NY. ISBN: 978-1-4419-8678-8.

Mackenzie K V (1981). *Nine-term equation for the sound speed in the oceans*. J. Acoust. Soc. Am. 70(3), pp 807-812.

Mason and Midforth (2019). *12 Quays Birkenhead, Underwater Noise during Rotary Drilling*. Subacoustech Report Ref P265R0204.

Midforth and East (2016). *Monitoring of underwater noise prior to and during piling operations at Blackfriars and Victoria Embankment*. Subacoustech Report Ref E541R0201.

Nedwell, Brooker and Barham (2009). *Modelling and Measurement of Underwater Noise Associated with the Construction and Operation of a Water Intake in the River Ewe, Scottish Highlands*. Subacoustech Report Ref E210R0103.

Popper A N, Hawkins A D, Fay R R, Mann D A, Bartol S, Carlson T J, Coombs S, Ellison W T, Gentry R L, Halvorsen M B, Løkkeborg S, Rogers P H, Southall B L, Zeddies D G, Tavolga W N (2014). *Sound exposure guidelines for Fishes and Sea Turtles.* Springer Briefs in Oceanography DOI 10. 1007/978-3-319-06659-2.

Popper A N, Hawkins A D (2018). *The importance of particle motion to fishes and invertebrates.* J. Acoust. Soc. Am. 143, 470 – 486.

Popper A N, Hawkins A D (2019). *An overview in fish bioacoustics and the impacts of anthropogenic sounds on fishes.* Journal of Fish Biology, 1-22. DOI: 10.111/jfp.13948.

Radford C A, Montgomery J C, Caiger P, Higgs D M (2012). *Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts.* Journal of Experimental Biology, 215, 3429 – 3435.

Solé M, Kaifu K, Mooney T A, Nedelec S L, Olivier F, Radford A N, Vazzana M, Wale M A, Semmens J M, Simpson S D, Buscaino G, Hawkins A, Aguilar de Soto N, Akamatsu T, Chauvaud L, Day R D, Fitzgibbon Q, McCauley R D,

CLASSIFICATION: UNRESTRICTED

The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise
Modelling Assessment

Document Information

- This is a controlled document.
- Any electronic copy not stored on Subacoustech Environmental's system is considered uncontrolled.
- Amendment shall be by whole document revision and re-issue.
- Requests for changes to this document or its classification should be sent to Subacoustech Environmental.

Document No.	Draft	Date	Details of change
P293R0300	01	02/05/2025	Initial writing and internal review
P293R0301	-	07/05/2025	Issue to client
P293R0302	-	25/07/2025	Address minor comments and include survey details

Originator's current report number	P293R0302
Originator's name and location	I Morgan; Subacoustech Environmental Ltd.
Contract number and period covered	P293; May 2025
Sponsor's name and location	L Kennedy; Tobin
Report classification and caveats in use	UNRESTRICTED
Date written	May 2025
Pagination	Cover + vi + 17
References	
Report title	The Construction and Operation of a Raw Water Intake and Pumping Station, Parteen Basin: Underwater Noise Modelling Assessment
Translation/Conference details (if translation, give foreign title/if part of a conference, give conference particulars)	
Title classification	UNRESTRICTED
Author(s)	Issy Morgan, Fergus Midforth
Descriptors/keywords	
Abstract	
Abstract classification	UNRESTRICTED