Submitted to:

Hantie Plomp
Triplo4 Sustainable Solutions

Tel: +27 (0)32 946 3213

E-mail: hantie@triplo4.com
Website: www.triplo4.com

Submitted by:

Tim Mason
Subacoustech Environmental Ltd
Unit 2, Muira Industrial Estate
William Street
Southampton
SO14 5QH
United Kingdom

Tel: +44 (0)23 80 236 330

E-mail: tim.mason@subacoustech.com
Website: www.subacoustech.com

Underwater noise assessment – Port of Richard's Bay

Tim Mason, Fergus Midforth

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Declaration of Independence

Underwater Noise Impact Assessment

I, Tim Mason, declare that I and my co-authors are independent consultants and have no business, financial, personal, or other interest in the proposed Powership Project in Port of Richard’s Bay, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application, or appeal. There are no circumstances that compromise the objectivity of my performing such work.

Tim Mason

Principal Consultant, Subacoustech Environmental Limited

Glossary

Term	Definition
Decibel (dB)	A customary scale commonly used (in various ways) for reporting levels of sound. A difference of 10 dB corresponds to a factor of 10 in sound power. The actual sound measurement is compared to a fixed reference level and the "decibel" value is defined to be 10 $\log_{10}$(actual/reference) where (actual/reference) is a power ratio. Because sound power is usually proportional to sound pressure squared, the decibel value for sound pressure is 20 $\log_{10}$(actual pressure/reference pressure). The standard reference for underwater sound is 1 micro pascal (µPa). 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.
Permanent Threshold Shift (PTS)	A permanent total or partial loss of hearing sensitivity caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the air, and thus a permanent reduction of hearing acuity.
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)	The constant sound level acting for one second, which has the same amount of acoustic energy, 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 Pressure Level (SPL)	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.
Temporary Threshold Shift (TTS)	Temporary reduction of hearing acuity because of exposure to sound over time. Exposure to high levels of sound over relatively short time periods could cause the same level of TTS as exposure to lower levels of sound over longer time periods.
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 "weighting envelope" in the frequency domain, typically to make an unweighted level relevant to a particular species. Examples of this are the dB(A), where the overall sound level has been adjusted to account for the hearing ability of humans, or the filters used by Southall *et al*. (2019) for marine mammals.

1 Introduction

Karpowership SA (Pty) Ltd has proposed the installation of a gas to power project in the Port of Richard’s Bay, KwaZulu Natal, South Africa.

The project entails the generation of electricity by two Powerships, one comprising 21 gas engines and two steam turbines, and one comprising six gas engines and one steam turbine. A Floating Storage Regasification Unit (FSRU) will act as the storage and regasification facility. A Liquefied Natural Gas Carrier will supply the Liquefied Natural Gas (LNG) to the FSRU over a one to two day period approximately every 20 - 30 days or potentially less frequently. From the Powership, power will be distributed via a transmission cable to a switching-station (Project). The average load on the Powerships is predicted to be 327 MW.

As part of the EIA process, Subacoustech Environmental Ltd have been contracted by Triplo4 Sustainable Solutions to assess the impact of underwater noise on the environment during the construction and operational phases of the Project.

The assessment is based on requirements that arose out of the Minister’s Appeal decisions dated 1 August 2022 and comments received from Interested and Affected Parties during the initial EIA phase (2021), in order to address the environmental impacts of noise by the Project in both the marine and terrestrial environments. The effect of noise in the terrestrial environment is dealt with in a separate report.

Ideally, an assessment of Project noise would measure noise impacts on an actual Powership, FSRU and associated vessels operating in the Port of Richard’s Bay. As there are no Powerships and FSRU’s in operation (none can be established before obtaining environmental authorisation) at the Port of Richard’s Bay and in order to provide a scientifically reliable report on which an assessment of Project noise impacts on the environment can be determined by environmental specialists, interested and affected parties and the DFFE, Subacoustech has employed the following internationally accepted study protocol for projects of this nature, to assess the noise impacts of the Project in the Port of Richard’s Bay:

1. Conduct a study of the existing underwater noise soundscape (baseline) in the Port of Richard’s Bay (see section 3);
2. Conduct an underwater noise study and assessment of a Powership of a similar class to that intended for deployment to the Project in Richard’s Bay, at a Port where such a Powership is in operation and where port conditions are comparable (see section 4 and Appendix C);
3. Conduct an assessment of an FSRU in terms of its noise outputs based on the FSRU equipment specifications (see section 6);
4. Extrapolate the results using established scientific methods to account for differences in the port specifics at different power output levels, from studies 1, 2 and 3 above to the Port of Richard’s Bay to predict how actual noise effects from the Project will interact with the existing sound levels present in the Port of Richard’s Bay (see section 6).

Subacoustech visited the Port of Richard’s Bay on 15th to 17th November 2021 to sample an indicative underwater noise baseline within the port, harbour entrance channel, and wider bay area.

Subacoustech visited Sekondi Naval Base, Ghana, on 3rd to 6th September 2022 to sample underwater noise around an operational Powership, selected for its similarity with those proposed to be deployed (sister ship) in South Africa. Based on the maximum power output of the Osman Khan (470 MW), the harbour design and technical parameters considered, this Powership is of the same design class to study, in order to determine relevant noise information for the South African Project.

Subacoustech has also assessed noise aspects of an FSRU, typical to that which will be used by the Project in the Port of Richard’s Bay.

This report provides a summary of the recorded noise levels at both sites along with an assessment of the potential impact of underwater noise from an operational Powership installed in the Port of Richard’s Bay, and during the construction phase for its associated infrastructure. It provides technical input to the marine ecology report (Ref B4, Marine Ecology, Oct. 2022), part of the Gas to Power Powership Project at the Port of Richard’s Bay Environmental Impact Assessment, where the significance of impacts on specific species present in Port of Richard’s Bay are considered directly, and should be read in conjunction with the detailed baseline underwater noise report (Appendix C, Background Noise Monitoring – Port of Richard’s Bay, Subacoustech Ref. P292R0501), although this is summarised in section 3.

2 Underwater acoustics terminology

2.1 Units of measurement

Sound measurements underwater are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound. A logarithmic scale is used because, rather than equal increments of sound having an equal increase in effect, typically each doubling of sound level will cause a roughly equal increase of "loudness."

Any quantity expressed in this scale is termed a "level." If the unit is sound pressure, expressed on the dB scale, it will be termed a "sound pressure level."

The fundamental definition of the dB scale is given by:

$$Level = 10 \times \log_{10}\left(\frac{Q}{Q_{ref}}\right)$$

where Q is the quantity being expressed on the scale, and Q_{ref} is the reference quantity.

The dB scale represents a ratio. It is therefore used with a reference unit, which expresses the base from which the ratio is expressed. The reference quantity is conventionally smaller than the smallest value to be expressed on the scale so that any level quoted is positive. For example, a reference quantity of 20 µPa is used for sound in air since that is the lower threshold of human hearing.

When used with sound pressure, the pressure value is squared. So that variations in the units agree, the sound pressure must be specified as units of Root Mean Square (RMS) pressure squared. This is equivalent to expressing the sound as:

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

For underwater sound, a unit of 1 µPa is typically used as the reference unit (P_{ref}); a Pascal is equal to the pressure exerted by one Newton over one square metre, one micropascal equals one millionth of this.

2.2 Sound pressure level (SPL)

The SPL is normally used to characterise noise of a continuous nature such as drilling, boring, continuous wave sonar, or background sea and river noise levels. To calculate the SPL, the variation in sound pressure is measured over a specific period to determine the RMS level of the time-varying sound. The SPL can therefore be considered a measure of the average level of sound over the measurement period. It is often presented as a single figure overall broadband noise level, e.g. 95.0 dB SPL_{RMS} re 1 µPa. Unless stated otherwise, all SPL_{RMS} values in this report are referenced to 1 µPa.

Based on the equation above (20 x $\log_{10}(P_{RMS}/P_{ref})$), a doubling of sound pressure (P_{RMS}) is equivalent to a 6 dB increase in sound pressure level (SPL_{RMS}). However this requires two coherent noise sources – that is, two sources operating perfectly in synchronisation. In practice two noise sources rarely operate coherently and so this leads to an increase or decrease of 3 dB per doubling or halving of sound pressure, i.e. 10 x $\log_{10}(P_{RMS}/P_{ref})$.

2.3 Sound Exposure Level (SEL)

The Sound Exposure Level (SEL) form of analysis has been used to develop criteria for assessing injury ranges for fish and marine mammals from various noise sources (Popper *et al*., 2014; Southall *et al*., 2019; Southall *et al*., 2007).

The SEL sums the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound and the duration it is present in the acoustic environment. Sound Exposure (SE) is defined by the equation:

$$SE = \int_{0}^{T} p^2(t)dt$$

where p is the acoustic pressure in Pascals, T is the total duration of sound in seconds, and t is time in seconds. The SE is a measurement of acoustic energy and has units of Pascal squared seconds (Pa^{2}s).

To express the SE on a logarithmic scale by means of a dB, it must be compared with a reference acoustic energy level ($p^2{}_{ref}$) and a reference time (T_{ref}). The SEL is then defined by:

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

By selecting a common reference pressure (p_{ref}) of 1 µPa for assessments of underwater noise, the SEL and SPL can be compared using the expression:

$$SEL = SPL + 10 \times \log_{10} T$$

where the SPL is a measure of the average level of broadband noise and the SEL sums the cumulative broadband noise energy.

This means that, for continuous sounds of less than one second, the SEL will be lower than the SPL. For periods greater than one second, the SEL will be numerically greater than the SPL (i.e., for a continuous sound of 10 seconds duration, the SEL will be 10 dB higher than the SPL; for a sound of 100 seconds duration the SEL will be 20 dB higher than the SPL, and so on).

Unless otherwise defined, all SEL noise levels in this report are referenced to 1 µPa^{2}s.

3 Underwater noise measured in Port of Richard’s Bay, South Africa

The complete baseline underwater noise report for Port of Richard’s Bay, Subacoustech document ref P292R0501, is provided separately. This section shows a summary of the results sampled during November 2021, presented in the complete report.

3.1 Overview

Noise in the harbour during the survey was always controlled by machinery onboard ships docked at one of the terminals, when in their vicinity. Outside the harbour, i.e. south of the sandbar and on the Harbour Entrance Channel east out of the harbour, the ambient noise was generally dominated by snapping noise from marine wildlife, likely to be fish, shrimp and other crustaceans, unless a ship was passing into or out of the port with direct ‘line of sight’. No ship-related noise was observed beyond one kilometre or so of the nearest dock, unless a ship was in motion nearby. This indicates that the noise at this distance had reduced to below the level of background noise.

The highest underwater noise levels were measured nearby the Coal Terminal, and these occurred where a bulk carrier vessel was passing during measurements. The measured noise level here were up to 134.4 dB SPL_{RMS} (129.7 dB SPL_{RMS} on average during measurements). Other high noise levels were detected in the vicinity of the Bulk Cargo Quay, especially the jetty extending from its east end. The levels here were generally high because of the vessels at the terminals on either side. Please see Figure 3-1 for the port layout.

Figure 3-1 – Average dB SPL_{RMS} baseline levels from attended measurements in Port of Richard’s Bay between 15th and 17th November 2021 (including proposed location of the Powerships)

Outside the harbour, noise levels from berthed vessels were substantially attenuated by distance, and the ships were not audible. Underwater noise levels outside the harbour varied between 112 dB and 123 dB SPL$_{RMS}$.

These measured noise levels are shown with locations in the assessment in section 6, as well as in the detailed baseline noise report.

3.2 Monitoring of specific vessels

There was an opportunity on site to take measurements directly of three bulk carrier vessels, to sample representative underwater noise levels of typical ships transiting to the terminals. The *Mineral Subic*, the *Golden Magnum* and the *Freedom* were measured as they passed the survey boat. Measurements were made at multiple distances from the vessels as they passed.

Repeated 10 s samples were taken at various distances from the vessels. By nature, the measurements were only possible from one side of the vessels. These distances are approximated from the side of the moving vessel, travelling at approximately 4-5 knots.

All measurements of the vessels were taken on 16th November. Measurements of the *Mineral Subic* (vessel port side) were taken at approximately Location 8. Measurements of the *Golden Magnum* were taken at approximately Location 5, (vessel port side). *Freedom* was situated at the north end of the Coal Terminal with measurements taken off its starboard.

Table 3-1 The average SPL$_{RMS}$ levels recorded at distances from moving and berthed vessels, 10s samples

Distance	**Dir.**	**SPL$_{RMS}$ (dB re 1 µPa)**		
		***Mineral Subic* (approaching dock)**	***Golden Magnum* (leaving, fully laden)**	***Freedom* (berthed, loading)**
400	Approach / static	-	-	124.0
300		144.4	-	-
200		140.1	-	126.0
120		-	140.9	-
100		142.8	141.4	130.5
80		-	142.4	-
50		142.6	-	132.3
100	Away	147.3	141.9	-
200		146.4	138.8	-
300		147.7	138.1	-
400		144.7	-	-

4 Underwater noise measured in Sekondi, Ghana

The Karadeniz Powership Osman Khan is a 470 MW capacity Khan class Powership currently installed in Sekondi Naval Base, Ghana. The Powership features 24 gas powered engines, each engine capable of producing 18.3 MW of electricity. The underwater noise survey was undertaken to measure the in-water noise produced by operational plant onboard the Powership.

Figure 4-1 – Satellite image of Osman Khan Powership in Ghana, © Google Earth

The Karadeniz Powership Osman Khan is larger in design specification, engine complement and electricity output to the Khan Class Powership that will be used in the Port of Richard's Bay and considerably greater than the Shark class Powership.

Both the Osman Khan and the proposed Powerships to be installed at Port of Richard's Bay have built-in noise attenuation devices which limit the escape of both airborne and underwater noise from the ship. Anti-vibration mountings are fitted to engines and alternators, and rotating machinery (e.g. air compressors and pumps) are designed with resilient isolation mountings. These restrict the passage of structure-borne noise from the machinery to and out of the hull, which will be the primary source of noise transmission to the surrounding water. The exhaust gas flues include silencers to reduce noise emission. The integrated mitigation methods will minimise the environmental noise produced by the Powerships.

Underwater noise was measured using two techniques: the first technique used was static monitoring where a single long-term monitor was deployed and recorded continuously for the entire duration of the study from a single appropriate position that did not interfere with the passage of traffic in the port, nor was influenced by noise from other moored vessels. The second technique used was attended monitoring where measurements were taken at various receptor locations around Sekondi Naval Base harbour using a vessel-based mobile measurement survey where underwater noise levels were sampled at multiple distances, positions and Powership power outputs in line with and moving away from the ship's hull.

4.1 Static monitoring

4.1.1 Equipment

- Hydrophone: Ocean Sonics icListen SB2 digital hydrophone s/n: 1433
- Sensitivity: -169.0 dB re. 1V/µPa
- Sample rate: 128 kHz
- Bit-depth: 24 bit
- Recording: Continuous uncompressed WAV format

4.1.2 Procedure

A static monitor was installed within Sekondi Naval Base approximately 80m from the centre of the Powership. The location was selected to measure varying noise from the hull in front of the ship, as the operating conditions (power output) changed with time.

The static monitor was moored to the seabed on a single line mooring and floated approximately 2 m above the seabed to reduce influence of any sound reflections from the surface or seabed.

The monitoring was undertaken using a high-sensitivity hydrophone suitable for the measurement of background noise levels in this environment. The transducer used at the static monitor was a low-noise OceanSonics icListen SB2 digital hydrophone. This measurement station sampled continuously over a period of approximately 72 hours day and night. This continuous monitoring allows for a comparison of noise levels during different levels of energy production by the Powership.

4.1.3 Static measurement conditions and results

The static underwater noise monitor measured continuously from installation on the morning of 3rd September to the morning of 6th September 2022. The results of this monitoring are shown in Figure 4-2.

The chart in Figure 4-2 shows the variation in noise with time, plotted alongside the power output of the Powership in 15-minute steps. The changes in sound level clearly correspond with the change in Powership load.

Closer inspection of the values shows that the noise output responds very closely to the standard acoustic principle that a doubling in power of the main driver of the sound (in this case, this is the power output in MW of the generating engines) will increase the sound output by approximately 3 dB, and similarly a halving in generating power will reduce the sound output by approximately 3 dB (see the first equation in section 2.1).

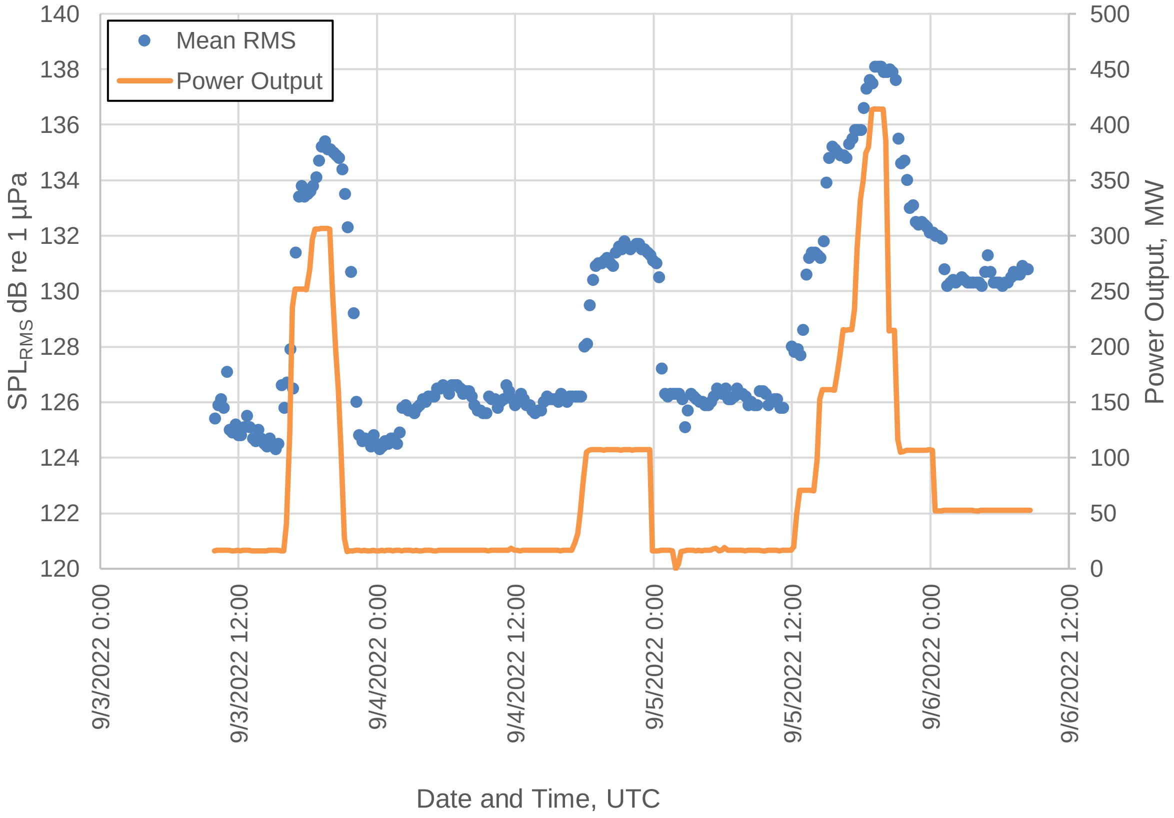

Figure 4-2 - Mean measured SPL$_{RMS}$ noise levels recorded by the static monitor and Powership power output over the same time period

To demonstrate this, at 04/09/2022 12:00 the measured noise level was approximately 126 dB SPL$_{RMS}$ at a power output of 16.6 MW. Shortly afterwards, the power output increased to 107 MW, a multiple of 6.5. Acoustic theory would predict an increase in noise output of 8 dB [10*log(6.5)], whereas the actual increase is approximately 6 dB, a notably close reading. (The larger increase at the start of monitoring is predicted 12.6 dB increase against a measured 10.7 dB increase.)

The slightly lower measured noise increase is likely to be a result of the monitor being relatively close to the ship, with many of the engines significantly further away (i.e. those closer to the front and rear) from the monitoring location on the 300 m ship and therefore making a relatively lower contribution to the overall noise than purely the power output would suggest. It is expected that the prediction would be even closer to the theory where the measurement location was further from the ship into the harbour (thus each engine is closer to the same distance from the measurement position), which is relevant to predictions later in this report (see section 6).

4.2 Attended boat-based monitoring

4.2.1 Equipment

- Hydrophone: Reson TC4014 s/n: 4005034
- Sensitivity: -185.5 dB re. 1V/µPa
- Pre-amplifier: Subacoustech 4 channel amplifier
- DAQ: National Instruments USB-6216
- Recording: 10 second samples – Subacoustech uncompressed SUB format.

4.2.2 Procedure

An attended survey was carried out by Subacoustech's specialist acoustic consultants on board a survey vessel. A series of spot measurements were taken at numerous positions around the Powership, as well as outside the harbour wall towards open water.

The spot measurements were taken along a series of lines at varying selected distances away from the Powership. Measurements were taken at multiple locations (minimum three distributed points) at 50, 100, 200 and 400 m away from the hull inside the harbour, and 720 m on one operating condition. The same methodology was applied outside the harbour wall at 120 m and 200 m away from the hull, and 850 m on one operating condition. It was not possible to sample closer to the ship than this outside of the harbour because of the size of the seawall itself. The greatest number of measurements were taken to concentrate on the time period when the Powership was operating at the highest power output.

4.2.3 Vessel-based measurement conditions and results

Spot measurements were recorded during different operating conditions for the Powership on fixed-distance lines. Figure 4-3 shows the underwater noise levels averaged over each line, recorded when the ship was producing power with one engine (approximately 18 MW), 14 engines (250 MW) and 23 engines (420 MW). The single engine generation scenario used engine 24, located at the south-eastern end of the Powership. All measurements are logarithmic averaged decibel SPL_{RMS} re 1 µPa.

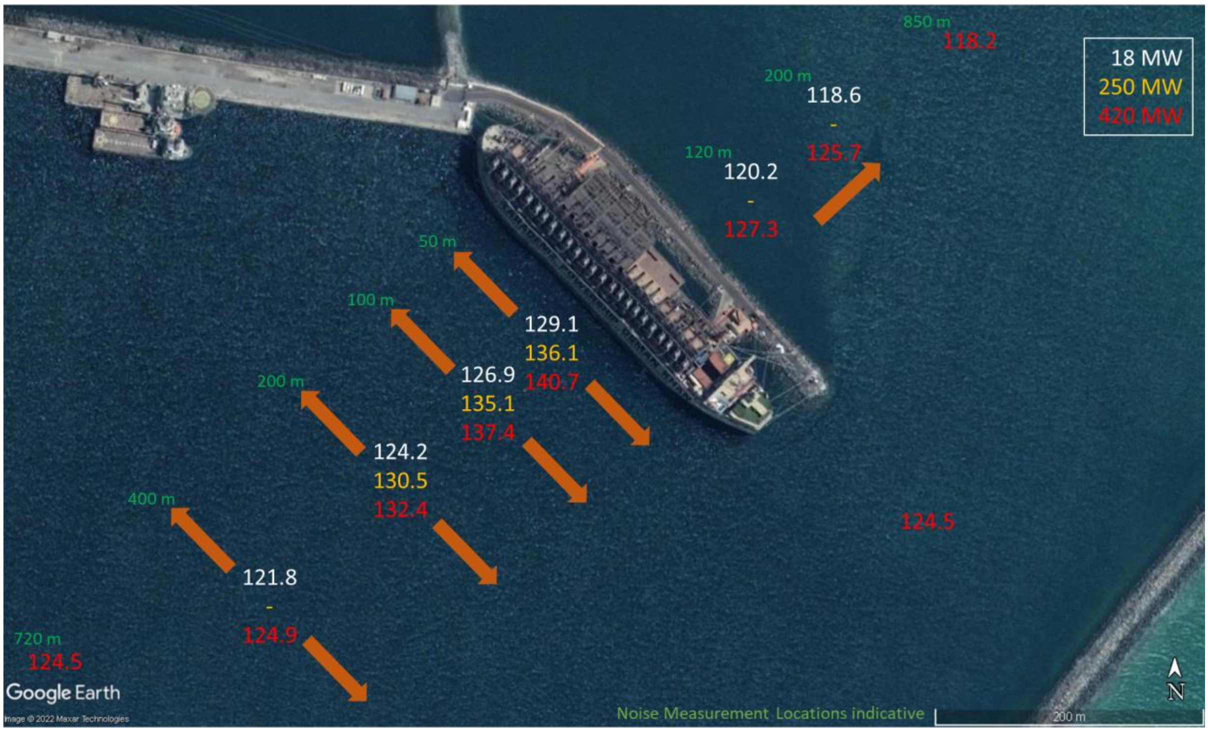

Figure 4-3 – Average of underwater noise measurements sampled along lines at the Osman Khan Powership in Ghana under various operating conditions

A more detailed summary of measurements taken is shown in Appendix B.

These measurements showed a clear audibility of the Powership inside the harbour. Increasing the power output of the Powership had a direct effect on the measured noise, which attenuated clearly with distance from the ship within the harbour. The noise level measured off the end of the ship at the entrance to the harbour was significantly lower than that of the same distance to the side. By listening subjectively to the noise behind the jetty (i.e. to the north-east) in real time, the Powership itself did not appear audible even at the closest distance, and the increased noise levels close to the seawall were produced by the sound of what are believed to be snapping shrimp, which is common in shallow waters. This was also noted in the harbour, where noise from the shrimp increased close to the harbour sides.

Figure 4-4 shows the frequency spectra from the two sides of the jetty at approximately the same distances[1], with the Powership operating at the highest power available. Although the noise adjacent to the Powership in the harbour was the only audible noise source, on the other side of the harbour wall the frequency spectrum shows a different characteristic, demonstrating a different type of noise.

On this basis, noise from sources inside the harbour do not appear to affect the underwater environment on the other side of the harbour wall barrier. Thus, the harbour wall is regarded to be effective in significantly reducing noise transmission.

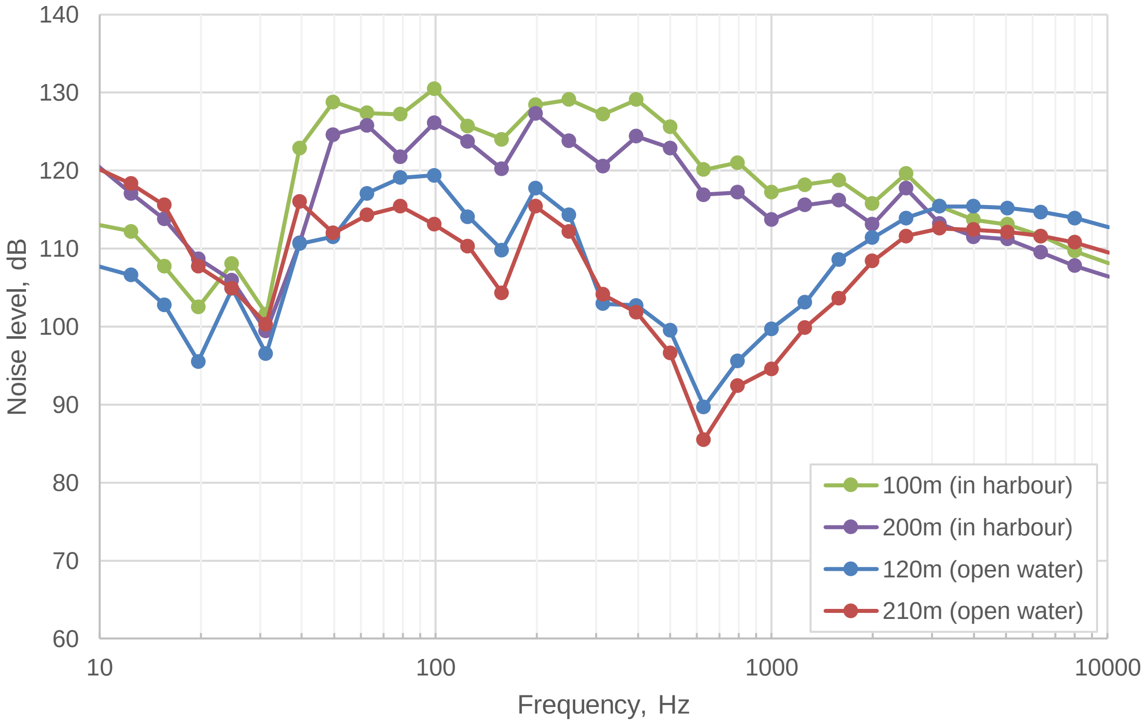

Figure 4-4 – Frequency spectra for underwater noise measured inside and outside the harbour

The design of the harbour in Ghana, along with water depth and environmental conditions, will impact how noise propagates away from the Powership. As such, some variation is to be expected in a different harbour environment, such as that in South Africa. However, the effect of the harbour and environment on the noise measured in Ghana is considered to be negligible for the comparison to that which would be experienced in Port of Richard's Bay, which is much larger and more open. Slight variations may be caused by the temperature or salinity of the water, the depth of the water and the surroundings (hard walls in a partially enclosed harbour). These will be considered in order below.

The temperature and salinity of the water affects the sound speed in the water and the sound absorption of the water. In shallow water[2], it is assumed that the water is well mixed, with the variation in salinity and temperature with depth being insignificant. Over the distances being considered (less than a

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[1] Slight vessel drift is unavoidable during measurements when the survey vessel shuts down to eliminate noise contamination from engine noise.

[2] All water depths in Ghana and Port of Richard's Bay are acoustically shallow.

kilometre[3]), these will have a negligible impact on the sound, at considerably less than 1 dB variance. This principle will also lead to a negligible seasonal difference.

The water depth in Ghana is around 8-10 m; in Richard’s Bay the depth around the vessels to be installed is approximately 14-20 m around the location of the Powership and auxiliary vessels. In terms of underwater sound propagation, these locations are both relatively shallow. Again, over the distances under consideration, the differences in depth will have a negligible impact on the noise attenuation.

Hard sea walls could lead to a reverberant condition, where sound from a noise source reflects off hard surface and interacts with the sound field in the space, potentially increasing the noise levels. Whilst most of the hard surfaces around the vessels (especially the adjacent sea wall and breakwater) will lead to some reflections, the space is large enough such that any reverberant effect will be small. In any case this would lead to slightly higher noise levels being measured in Ghana, where the harbour is smaller and has more hard surfaces (primarily the jetty) closer to the Powership than at the proposed port in South Africa, although Richard’s Bay also has numerous hard surfaces. The measurements in Ghana and conditions are therefore considered to be precautionary (that is, potentially lead to slightly greater noise levels) for the noise data and assessment, but any differences due to the environment can be considered negligible in practice.

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[3] Noise levels were found to be negligibly above background noise (i.e. <1 dB) within one kilometer of the measured Powership at 420 MW.

5 Assessment of environmental effects

Over the last 20 years it has become increasingly evident from focused research 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 blasting or impact piling, as these sources have the greatest immediate environmental impact and therefore the clearest observable effects, although interest and understanding of chronic noise exposure is increasing rapidly.

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

- Auditory injury (either permanent or temporary); and
- Disturbance.

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

- Southall *et al*. (2019) marine mammal exposure criteria; and
- Popper *et al*. (2014) sound exposure guidelines for fishes and sea turtles.

At the time of writing it is widely accepted amongst experts that these include the most up-to-date and authoritative criteria for assessing environmental effects for use in impact assessments.

The following sections discuss the underwater noise criteria used in this study with respect to species categories of marine mammals and fish present in South African waters in the Project location.

5.1 Marine mammals

The Southall *et al*. (2019) paper is effectively an update of the previous Southall *et al.* (2007) paper and provides identical thresholds to those from the National Marine Fisheries Service (NMFS) (2018) guidance for marine mammals. No equivalent dedicated South African guidance exists.

The Southall *et al*. (2019) guidance groups 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 Southall *et al*. (2019) are summarised in Table 5-1 and Figure 5-1.

Table 5-1 Marine mammal hearing groups (from Southall et al., 2019)

Hearing group	Generalised hearing range	Example species
Low-frequency cetaceans (LF)	7 Hz to 35 kHz	Baleen whales (e.g. Humpback whale, Southern Right Whale, Bryde's Whale)
High-frequency cetaceans (HF)	150 Hz to 160 kHz	Dolphins, toothed, beaked, bottlenose whales (Heaviside's dolphin, Dusky dolphin)
Very high-frequency cetaceans (VHF)	275 Hz to 160 kHz	True porpoises (including harbour porpoise) (none)
Phocid carnivores in water (PCW)	50 Hz to 86 kHz	True seals (non-resident or semi-resident)
Otariid and other carnivores in water (OCW)	60 Hz to 39 kHz	Fur seals and sea lions, otters (Cape Fur Seal)

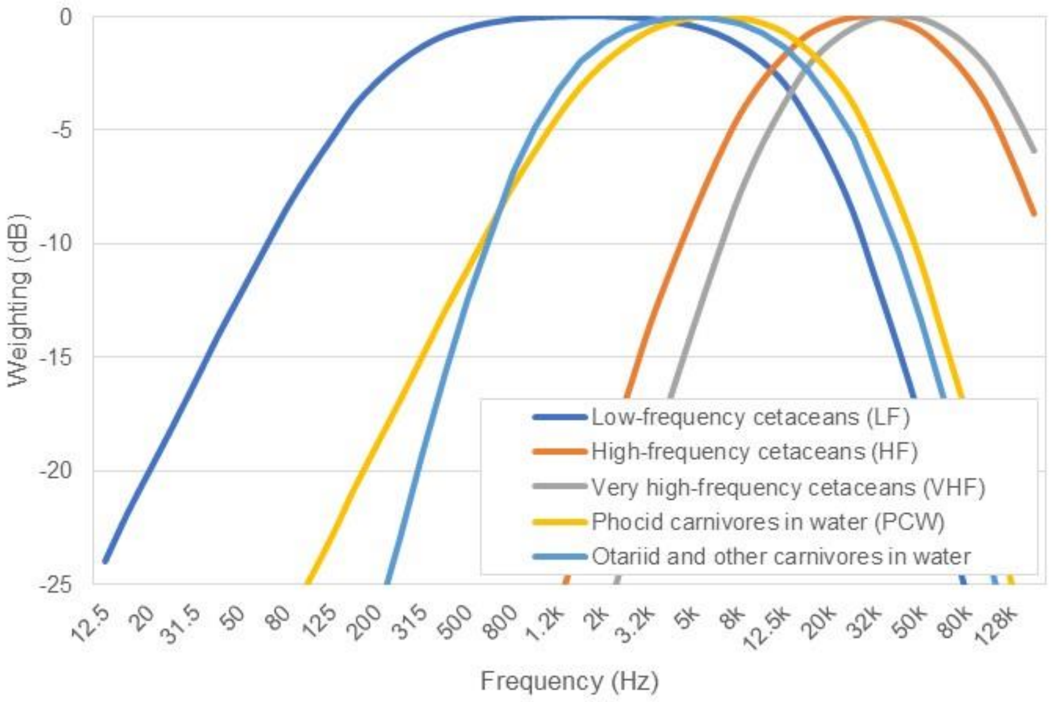

Figure 5-1 Auditory weighting functions for low-frequency cetaceans (LF), high-frequency cetaceans (HF), very high-frequency cetaceans (VHF), phocid carnivores in water (PCW), and other carnivores (inc. otariid) in water (from Southall et al., 2019)

Southall *et al*. (2019) also gives individual criteria based on whether the noise source is considered impulsive or non-impulsive. Southall *et al*. (2019) categorises impulsive noises as having high peak sound pressure, short duration, fast rise-time and broad frequency content at source, and non-impulsive sources as steady-state noise. A non-impulsive, often continuous, noise does not necessarily have to have a long duration. As all noise sources for this project are of a non-impulsive type, especially operation of the Powerships, impulsive noise criteria will be not considered further.

Southall *et al*. (2019) presents cumulative weighted sound exposure criteria (SEL_{cum}, i.e., can include the accumulated exposure of multiple pulses) for both permanent threshold shift (PTS), where unrecoverable (but incremental) hearing damage may occur, and temporary threshold shift (TTS), where a temporary reduction in hearing sensitivity may occur in individual receptors.

Table 5-2 Non-impulsive SEL_{cum} criteria for PTS and TTS in marine mammals (Southall et al., 2019)

Southall *et al*. (2019)	**Weighted SEL_{cum} (dB re 1 µPa^{2}s)**	
	Non-impulsive	
	PTS	**TTS**
Low-frequency cetaceans (LF)	199	179
High-frequency cetaceans (HF)	198	178
Very high-frequency cetaceans (VHF)	173	153
Phocid carnivores in water (PCW)	201	181
Other carnivores in water (OCW)	219	199

Where SEL_{cum} exposure thresholds are required, a moving animal model is typically used for marine mammals. This assumes that a receptor, when exposed to high noise levels, will swim away from the noise source. Continuous noise sources cannot be guaranteed to make a species react in this way, although the likelihood of a species remaining static close to the source for the duration is highly unlikely. However, this assumption will be used as a worst-case scenario.

5.2 Fish

5.2.1 Noise impact criteria

The large number of, and variation in, fish species led to a greater challenge in production of a generic range of criteria, for the assessment of noise impacts. Whereas previous studies applied broad criteria based on limited studies of fish that are not present in the waters relevant to a particular country (e.g., McCauley *et al*., 2000) or measurement data not intended to be used as criteria (Hawkins *et al*., 2014), the publication of Popper *et al*. (2014) provides an authoritative summary of the research and guidelines for fish exposure to sound and uses categories for fish that are representative of general fish species, according to its anatomy crucial to hearing. This also includes sea turtles.

The Popper *et al*. (2014) study groups species of fish by whether they possess a swim bladder, and whether it is involved in its hearing; a group for fish eggs and larvae is also included. The guidance also gives specific criteria (as unweighted SPL_{rms} values) for shipping and continuous noise sources, based on the available research. These are summarised in Table 5-3.

Table 5-3 Criteria for recoverable injury and TTS in species of fish from continuous noise sources (Popper et al., 2014)

Type of animal	Impairment	
	Recoverable injury	TTS
Fish: swim bladder involved in hearing	170 dB SPL_{RMS} for 48 hrs	158 dB SPL_{RMS} for 12 hrs

Where insufficient data are available, Popper *et al*. (2014) also gives qualitative criteria that summarise the effect of the noise as having either a high, moderate or low effect on an individual in either the near-field (tens of metres), intermediate-field (hundreds of metres), or far-field (thousands of metres). These qualitative effects are reproduced in Table 5-4; no distinction is made for the age of the fish for this type of noise. These also make no consideration of the actual noise level produced by the source.

Table 5-4 Summary of the qualitative effects on fish from continuous noise from Popper et al. (2014) (N = Near-field; I = Intermediate-field; F = Far-field)

Type of animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking[4]	
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 is 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	See Table 5-3	See Table 5-3	(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

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[4] Masking is the inability of a species to hear a sound due to the relatively high level of another noise source.

Although most species are likely to move away from a sound that is loud enough to cause harm (Dahl *et al*., 2015; Popper *et al*., 2014), some may seek protection in the sediment and others may dive deeper in the water column. Neither are likely based on the level of noise seen in Ghana.

5.2.2 Vibration

The term 'vibration' is often used alongside 'noise' and in this context generally refers to the rapid movement of a surface. In reference to this project, vibration could refer to the minute back-and-forth movement of the ship's hull in the water, which itself acts as a sound radiator to generate the noise in the surrounding water, in the same way that a loudspeaker vibrates to generate sound in the air. In this case the noise in the water itself is important, and the assessment will focus on this; the vibration of the hull itself is simply the mechanism by which noise is transmitted into the water, it is not the critical aspect. The assessment will therefore focus on waterborne noise.

6 Powership noise impact in and around the Port of Richard's Bay

6.1 Noise levels from ships to be installed at Port of Richard's Bay

Three vessels are proposed to be installed in the Port of Richard's Bay, on the east side of the harbour, with one further vessel visiting intermittently during the Project term. The vessels are as follows:

- Two Powerships,
    - one 21 engine Khan class Powership (installed capacity 415.6 MW)
    - one 6 engine Shark class Powership (installed capacity 125.4 MW)
- Two auxiliary vessels:
    - one FSRU (floating fuel storage) and
    - one Liquefied Natural Gas Carrier (LNGC) ship that will dock next to the FSRU and will be present intermittently.

The average load on the Powerships is predicted to be 327 MW and cannot exceed 450 MW at any point. The two auxiliary vessels are primarily storage vessels and have very little machinery active when in port, especially in comparison to the Powership. During periodic regasification operations, the total load on the FSRU will be less than 4 MW. Locations are shown in Figure 6-1.

In order to calculate the effects of underwater noise in Richard's Bay from the introduction of the Powerships, the measured noise levels from the Khan class Powership have been combined with the noise levels from the smaller Shark class Powership proposed at the Break Bulk quay. These have then been overlaid with the baseline noise measured at Richard's Bay calculate a potential increase.

A number of worst-case assumptions have been made:

- It has been assumed that the Powerships are both operating at full rated power. This will not be the case as the maximum contracted capacity will be 450 MW.
- The highest noise levels were shown in section 4.2 to be from the sides of the ships, whereas most areas of surrounding water are face the ends of the Powerships.
- The largest Powership will be situated in a partially enclosed space, which will somewhat restrict the sound.
- A small, shallow opening exists at the west side of the sand bar by the proposed location of the Powerships, and it is assumed that this allows free passage of sound, when in fact significant attenuation of sound from the Powerships will occur.
- It has been assumed that both auxiliary storage ships (FSRU and LNGC) are present and operating with the equivalent of one engine running (based on the Powership measurements). This could be considered an unrealistic worst case as the engines running to power the FSRU and LNGC are significantly smaller in power rating (maximum 4 MW compared with 18.3 MW for one engine operating on the Powership) and the LNGC is expected to be present in port for approximately 2 days every 4-6 weeks (depending on power dispatch demanded from the Powership).
- When transiting in and out of port, the LNGC is reasonably expected to generate the same noise level as any other large container or bulk carrier vessel of a type that frequently transits the port.

In the Port of Richard's Bay, the largest Powership is capable of operating at up to 416 MW with 21 engines (Khan class), next to a second smaller Powership capable of operating at up to 125 MW with 6 engines (Shark class). For the larger ship, the noise level from the Powership in Ghana operating at 420 MW will be used. This will be combined with the measurements in Ghana at 250 MW power output, divided by two, which is equivalent to a reduction in noise of approximately 3 dB, i.e. 10*log(2).

All calculated noise levels are based on the distance of each source to the relevant receiver position. Attenuations are based on the measurements in Ghana directly where available or using the best fit from the measurements at 420 MW (approximately 14.log(R) geometric attenuation).

Calculated noise levels with the Powerships and auxiliary vessels are shown in Figure 6-1. All decibel noise values in Figure 6-1 below are combined with simple logarithmic addition, where the contributing noise added to the baseline noise equals the total combined levels, e.g. (by the Powership) 125.0 dB + 137.6 dB = 137.9 dB.

Noise levels shaded in red in Figure 6-1 denote an increase in the baseline of over 10 dB, which could occur nearby to the ships. Noise levels shaded in yellow denote an increase in the baseline of 3-10 dB. Noise levels remain unshaded for increases of less than 3 dB.

Based on measurements taken during the baseline monitoring exercise at Port of Richard's Bay, it is demonstrable that the noise levels shown (that represent the effect of Powership operations) will be exceeded any time a container or bulk carrier vessel transits into or out of the port, since noise levels from those existing operations were measured to be higher (see section 3.2).

The increase of over 10 dB on the south side of the sand bar is expected to be a significant overestimate, due to the worst-case assumptions explained earlier in this section. As there should be no 'line of sight' to the larger Powership and the passage of sound will be restricted by the shallow water at the west end of the sand bar, the actual contribution is expected to be of the order of 6 dB lower than those predictions. To provide a precautionary assessment however, this worst-case calculation has been used.

As these noise levels are significantly lower than any noise level that would lead to the lower TTS onset threshold (see following sections 6.1 and 6.1.2), detailed underwater noise modelling would not provide any additional insight or benefit and has not been undertaken.

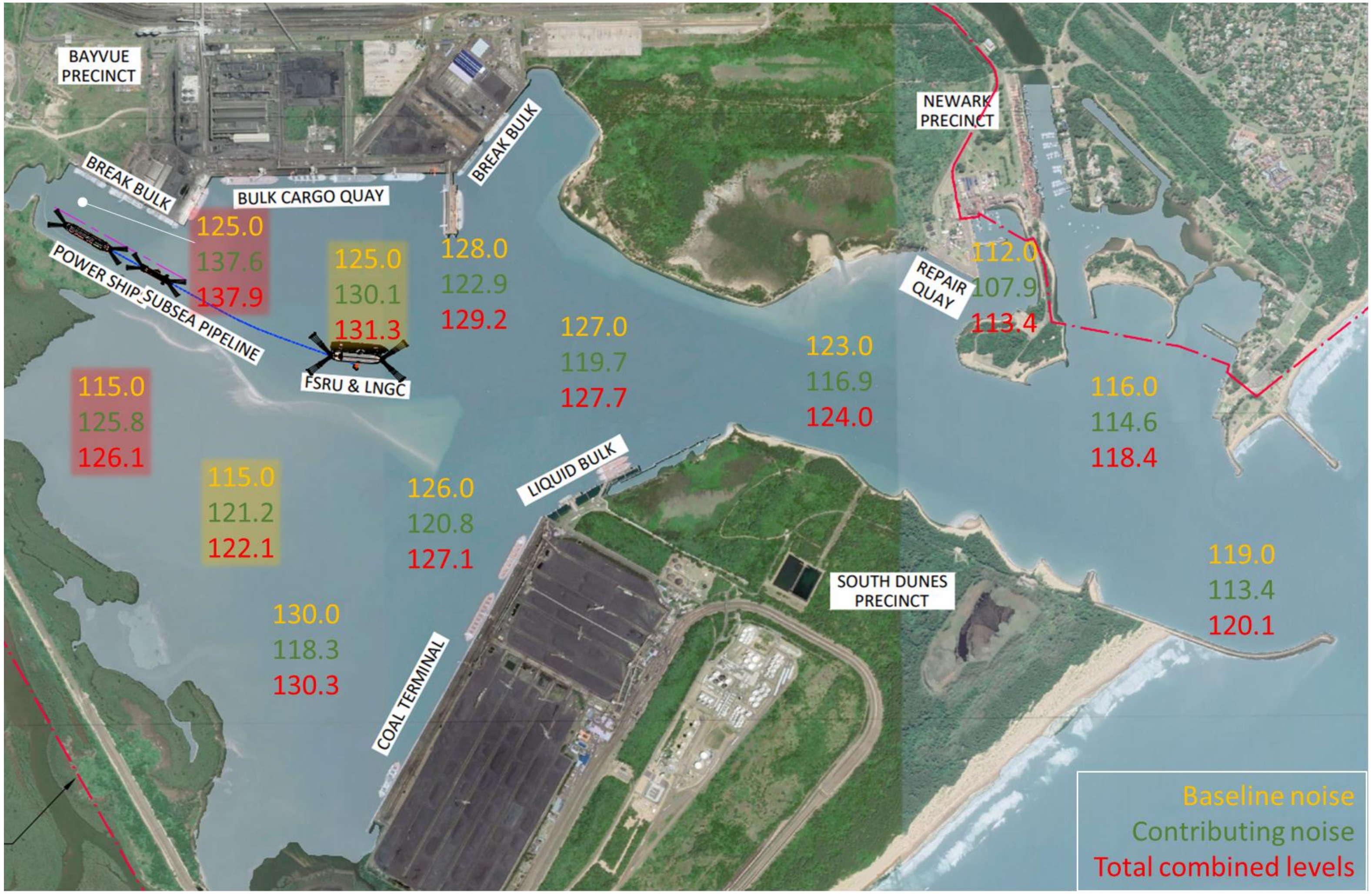

Figure 6-1 Calculated noise levels based on the introduction of a Powership and auxiliary vessels operating at full power. "Contributing noise" is the noise at each location exclusively from the Powership and auxiliary vessels in isolation. "Total combined levels" is the total noise level on site as a result of addition of the Powerships and auxiliary vessels to the existing baseline noise level.

6.1.1 Impact of underwater noise on marine mammals

The impact assessment of underwater noise on marine mammals will be undertaken using the criteria presented in the Southall *et al.* (2019) guidelines described in section 5.1. In order to correctly assess the impact on various species, the underwater noise must be appropriately weighted to account for the differing hearing sensitivities of each species.

The effect of the weighting is shown in Figure 6-2 to Figure 6-5 below, using the 420 MW output, 200 m spectrum (in harbour), shown in Figure 4-4, as a basis. Each chart shows how the perception of sound changes for the relevant hearing insensitivities of each species group.

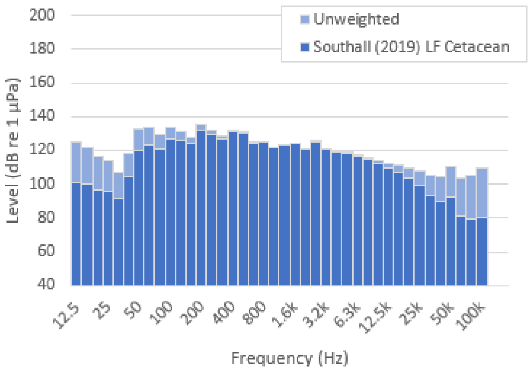

Figure 6-2 Powership frequency with effect of Southall et al. (2019) weighting, LF cetacean

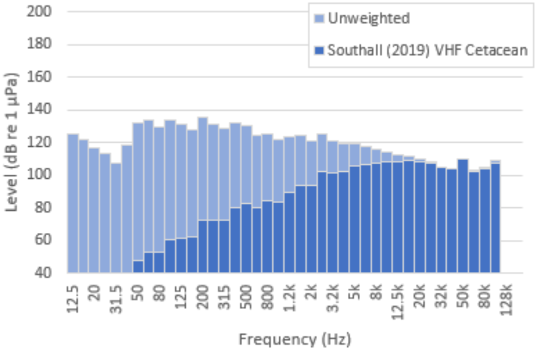

Figure 6-3 Powership frequency with effect of Southall et al. (2019) weighting, VHF cetacean

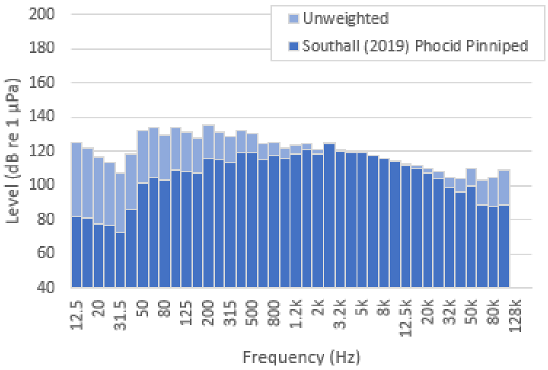

Figure 6-4 Powership frequency with effect of Southall et al. (2019) weighting, phocid pinniped

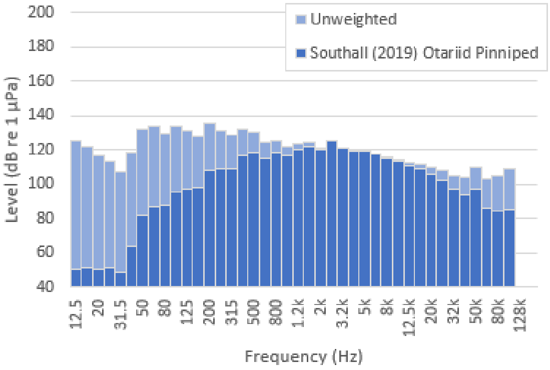

Figure 6-5 Powership frequency with effect of Southall et al. (2019) weighting, otariid pinniped and other marine carnivores

To present a worst-case scenario, it has been assumed that the Powerships will operate at maximum capacity for 24 hours a day; as noted earlier, Powership operation in Port of Richard's Bay is limited to 16.5 hours a day and will not be operating at maximum installed capacity.

Table 6-1 TTS thresholds for marine mammals exposed to the Powership continuously for 24 hr/day, based on TTS thresholds defined in Southall et al. (2019)

	TTS threshold	Range to meet TTS onset
Low-frequency cetaceans (LF)	179 dB SEL$_{cum}$	350 m
High-frequency cetaceans (HF)	178 dB SEL$_{cum}$	<50 m
Very high-frequency cetaceans (VHF)	153 dB SEL$_{cum}$	850 m
Phocid carnivores in water (PCW)	181 dB SEL$_{cum}$	70 m
Other carnivores in water (OCW)	199 dB SEL$_{cum}$	<50 m

Only LF cetaceans (baleen whales) and VHF cetaceans (porpoises) have calculated impact ranges in excess of 200 m. The largest range, for VHF cetaceans, would require an individual to remain in 'line of sight' of the Powership within the above range for a full 24-hour period to be exposed to noise sufficient to produce the onset of TTS symptoms, even under the worst-case scenario conditions described above. To produce PTS onset, the most sensitive species (VHF cetaceans) would need to remain within approximately 50 m of the Powership for an entire day under maximum load (much closer for the other species categories), and as such there is no reasonable expectation of this. This species group is not expected to be present at the Port of Richard's Bay, and the risk of any large baleen species (LF cetaceans) in this restricted space is very low.

Based on the above, particularly the high durations of exposure required and full power operation in excess of expected maximum load for the entire duration, no impact is expected on any marine mammal species from the installation of the Powership in the Port of Richard's Bay.

As the noise levels produced by the ships associated with this project are also not substantially different to the noise levels produced by ships typically using the harbour, no significant disturbance effect to marine mammals as a result of underwater noise outside of the normal operational port noise is anticipated, except potentially if directly adjacent to the ships.

More information is provided in the marine ecology report Ref. B4, Marine Ecology, Oct 2022.

6.1.2 Impact of underwater noise on fish

The assessment of underwater noise on fish is simpler than for marine mammals; based on the Guidelines in Popper *et al.* (2014) (see section 5.2) no weighting is applied or required to calculate the impact thresholds. The exposure criterion for TTS to the most sensitive species of fish is 158 dB SPL_{RMS}, to which a fish must be exposed for 12 hours.

The calculated noise levels in the Port of Richard's Bay shown in Figure 6-1 do not reach this threshold in any position. All noise measurements at any range from the Ghanian Powership were at least 10 dB below this value. No risk to fish in the Port of Richard's Bay is expected as a result of underwater noise from the Powership installation. More information is provided in the marine ecology report Ref. B4, Marine Ecology, Oct 2022.

6.2 Construction noise sources

Table 6-2 provides a summary of the various noise producing sources expected to be present during the construction of the infrastructure required for the Powerships and supporting vessels.

Table 6-2 Summary of the possible noise making activities

Activity	**Description**
Vibropiling	This will be required to install the first stage of the piled anchors for the Powerships and FSRU
Drilling	Drilling will be necessary to install the piles for the remainder of the required depth into bedrock
Rock clearance	Potentially required on site for installation of pipelines

The NPL Good Practice Guide 133 for underwater noise measurements (Robinson *et al*., 2014) indicates that under certain circumstances, a high-level modelling approach is considered acceptable. Such an approach has been used for these noise sources, which are variously either quiet (e.g. drilling) compared to high intensity impulsive noise sources, or where detailed modelling would imply unjustified accuracy. The overview of modelling presented here is considered entirely sufficient and there would be little benefit in using a more detailed model to include frequency or bathymetric dependence.

For the purposes of identifying the greatest noise levels, subsea noise levels have been predicted using a modelling approach based on measured data from Subacoustech Environmental's own underwater noise measurement database, scaled to relevant parameters for the site and to the specific noise sources used. The calculation of underwater noise transmission loss for the non-impulsive sources is based on an empirical analysis of the noise measurements taken along transects around these sources by Subacoustech Environmental. The predictions use the following principle fitted to the measured data, where R is the range from the source, N is the transmission loss, and α is the absorption loss.

$$Recieved\ level = Source\ level\ (SL) - N\log_{10} R - \alpha R$$

All SEL$_{cum}$ criteria use the same assumptions as presented in section 5, and ranges smaller than 50 m have not been presented. It should be noted that this modelling approach does not rely on bathymetry or any other environmental conditions, and as such can be applied to any location at, or surrounding, the port. Due to the relatively low noise levels produced and their distribution, any bathymetric or other conditions will lead to a negligible effect on the results.

For SEL$_{cum}$ calculations, the duration the noise is present also needs to be considered, with the duration of vibropiling planned to be no more than two hours in a day. In practice, this will be in intervals of 15 minutes on and 15 minutes off. The period for which drilling will occur is not known, so a precautionary 12 hours in any day has been applied.

To account for the weightings required for modelling using the Southall *et al*. (2019) criteria (see section 5.1), reductions in source level have been applied to the various noise sources based on the measured frequency spectra.

6.2.1 Drilling and vibro-piling

Vibropiling noise is generated in the piles through the coupling to the piling hammer. 1/3rd octave band source noise levels are based on measurements taken by Subacoustech of the vibropiling of piles in a harbour. This used a PVE Dieseko 2350VM pile vibrator (centrifugal force 2900 kN, dynamic weight 6600 kg). The proposed vibro hammer to be used in Port of Richard's Bay is an ICE 1412C vibro hammer (centrifugal force 2300 kN, dynamic weight 6400 kg). Therefore the noise output from the previously measured hammer should be similar, if potentially slightly worse than for the proposed vibro hammer. The source level (i.e. theoretical noise level at 1 m from the noise source, used for calculations) was calculated to be 184.0 dB SPL$_{RMS}$.

Source levels used for drilling are based on 1/3rd octave band measurements undertaken by Subacoustech of underwater drilling. The project was drilling anchor sockets in rock for a tidal turbine, similar to the requirement for the anchor piles in the Port of Richard's Bay, although the bedrock here is deeper than the surface rock for the tidal turbine. The source level was calculated to be 168.8 dB SPL$_{RMS}$ and will represent a precautionary prediction as it is based on bedrock closer to the water.

The simple modelling is based on a simple geometric spreading model of the form $N\log_{10} R - \alpha R$ where R is the range and values for N and α are based on approximations from field measurements taken by Subacoustech. Due to the distances to be considered within the Port of Richard's Bay and the source noise levels for the sources, this will provide sufficient accuracy without the need for complex modelling.

The ranges for vibropiling have been calculated for both a stationary and moving animal and are based on 2 hours of operation in any 24 hour period. For drilling, the calculations have assumed a stationary animal and drilling being undertaken for up to 12 hours in a given 24-hour period.

Threshold	**Criteria SEL$_{cum}$ (weighted)**	**Vibropiling (2 hours)**		**Drilling, stationary (12 hours)**
		Stationary animal	**Moving animal (1.5 m/s)**	
LF Cetaceans TTS	179 dB re 1 µPa^{2}s	200 m	<50 m	110 m
HF Cetaceans TTS	178 dB re 1 µPa^{2}s	<50 m	<50 m	<50 m
VHF Cetaceans TTS	153 dB re 1 µPa^{2}s	520 m	<50 m	130 m
PCW Pinnipeds TTS	181 dB re 1 µPa^{2}s	120 m	<50 m	<50 m
OCW Mammals TTS	199 dB re 1 µPa^{2}s	<50 m	<50 m	<50 m

Table 6-3 TTS ranges to Southall et al. (2019) SEL$_{cum}$ criteria for vibropiling and drilling operations

The impact ranges during vibropiling are smaller than those for the operation of Powerships and auxiliary vessels, even though the vibropiling itself is a louder source, as the calculations assume a two-hour maximum vibropiling operation, whereas the Powerships could operate (in theory) for 24 hours a day as a worst case. This leads to the difference in noise exposure.

The PTS impact ranges for all marine mammal species and noise types are less than 50 m. All impacts are expected to be negligible where the individual does not remain static and within the vicinity, e.g. <520 m at most for VHF cetaceans, from the vibropiling for two hours. As noted previously, VHF cetaceans are not expected in this location.

Based on the 158 dB SPL_{RMS} threshold for TTS in fish from continuous noise sources, all impact ranges will be less than 50 m. This also requires 12 hours continuous exposure to an individual.

6.2.2 Rock breaking

The pipeline is laid onto the seabed and, whilst no dredging is required, an option is available for the requirement to clear some of the hard rock substrate that may protrude above the level seabed under the route of the pipeline at the Powerships, to avoid the risk of the pipeline 'riding' on a rock outcrop which would create portions of pipeline that are unsupported by the seabed. The equipment required will depend on the portion of rock (if any) that requires flattening out, but a mechanical breaker is expected. The potential rock to be levelled is in shallow water north of the Powerships and north of the location of the FSRU.

The shallow water right next to land in which the rock breaking will take place is beneficial to reduction of underwater noise levels, as noise is more readily attenuated in the shallower water. For prediction of noise transmission, Subacoustech have previously measured rock breaking using a 4.2 tonne, 10.4 kJ hydraulic hammer, which had a calculated source noise level of 175.1 dB SPL_{RMS} at 1 m.

The duration in a day that this hammer may be used for is expected to be less than 6 hours, and will not be prolonged due to the relatively small area of rock that would need to be levelled, and the intermittent nature of this equipment. However, a precautionary 6 hours a day has been applied to the noise predictions.

Threshold	**Criteria SEL_{cum} (weighted)**	**Rock breaking (6 hours)**	
		Stationary animal	**Moving animal (1.5 m/s)**
LF Cetaceans TTS	179 dB re 1 µPa²s	360 m	<50 m
HF Cetaceans TTS	178 dB re 1 µPa²s	80 m	<50 m
VHF Cetaceans TTS	153 dB re 1 µPa²s	950 m	<50 m
PCW Pinnipeds TTS	181 dB re 1 µPa²s	220 m	<50 m
OCW Mammals TTS	199 dB re 1 µPa²s	<50 m	<50 m

Table 6-4 TTS ranges to Southall et al. (2019) SEL_{cum} criteria for rock breaking operations

The maximum distance for potential TTS onset for VHF cetaceans is 950 m, where there is line of sight. As previously, this would still require a marine mammal to remain present for the entire duration, presuming six hours of rock breaking. This species is not expected in this location. Any other species group would need to be considerably closer.

A fish would also need to remain in the near vicinity (<50 m) of the breaking for an extended period to reach the requirements for TTS exposure.

6.3 Mitigation

As described in section 4, the proposed Powership has noise mitigation built into the design of the ship, reducing any potential noise emission from the machinery on board. Specifically for the control of underwater noise, this includes resilient anti-vibration mounts for machinery that minimise the transfer of structure-borne noise to the hull to escape to the surrounding water. The assessment in section 6.1

following measurements in Ghana demonstrates that these have been largely effective. As the increase in noise in Port of Richard’s Bay is not predicted to significantly affect the wider bay or species of marine mammal and fish in it, no further noise mitigation devices to the ship are required.

Construction noise considered in section 6.2 has been shown to affect VHF cetaceans (porpoises) at potentially any location in the port with line of sight, if they remain in the port for a precautionary duration of six hours. However porpoises are not expected to be present in the Port of Richard’s Bay. Most likely to be present are the HF cetaceans (dolphins), which are considerably less sensitive to the adverse effects of noise. These would need to remain extremely close to any of the noise sources to obtain a noise exposure sufficient to lead to TTS. Therefore, application of any additional noise mitigation is not deemed to be appropriate.

7 Conclusions

A Powership and FSRU is proposed to be installed at the Port of Richard’s Bay, South Africa, to support the local electricity supply. It is recognised that these ships will generate noise in the water when operational and that underwater noise could have an impact on marine life in the area if it were to reach certain thresholds as described in this report.

A noise impact assessment has been undertaken to identify any significant risks from underwater noise. To assist in this process, a baseline noise survey has been carried out in the Port of Richard’s Bay, which identified noise levels to which the harbour and surrounding area are already exposed.

A survey was also carried out at the location of a large Khan class Powership in Ghana, of a similar class specification, albeit larger, to that of the Powerships planned at the Port of Richard’s Bay. This was to sample the noise levels that such a vessel produces at various distances and power outputs. In addition an FSRU with a single engine running was assessed. This data was applied to the baseline data using standard methodology to calculate the noise levels that would be present if all proposed ships were installed and operated at a maximum capacity.

The results of the assessment showed that after installing two Powerships and an FSRU, with all operating at maximum output, the background noise could increase by just over 10 dB directly adjacent to the ships, in the restricted section of the port by the Break Bulk quay. This is equivalent to a noise level of 137.9 dB SPL_{RMS} re 1 µPa. This is a worst-case scenario, with the Powerships maximum permitted output (450 MW) significantly lower than the maximum capacity (total ~540 MW) on which this has assessment has been conducted. For context, large cargo vessels passed frequently in Richard’s Bay during the baseline survey and, for example, a bulk carrier typical of the type accessing the harbour produced noise levels of 141-143 dB SPL_{RMS} re 1 µPa at 100 m from its side as it passed, and one reaching over 147 dB SPL_{RMS} re 1 µPa at it passed at this distance, being significantly higher than that which will be produced by Powership operations.

Any risk to marine mammals or fish, as per the guidelines in Southall *et al.* (2019) and Popper *et al.* (2014) respectively, will be negligible. The lower order of effect defined in the guidelines, temporary threshold shift (TTS), would only occur when marine mammals of the most sensitive species (VHF cetaceans, i.e. porpoises) remained within 850 m of the Powerships operating at maximum capacity for a full 24 hours. These are not expected to be present. All other species had a TTS impact range of less than 350 m from the Powerships with the same worst-case assumptions.

The effect on baseline noise will be negligible where the Powership is operating at a low power, which was found to be typical during the survey of the operational Powership in Ghana.

Predictions of the noise outside of the port will be less than 3 dB above baseline with the Powerships operating at maximum power, although this is expected to be an overestimation in practice.

An assessment of the underwater noise due to construction was also undertaken, primarily to consider the potential impacts of vibropiling and drilling for Powership mooring piles, and breaking rock on the pipeline route. As per the guidelines in Southall *et al.* (2019) and Popper *et al.* (2014), any impacts would require an individual marine mammal to remain within 520 m of vibropiling for its entire duration of 2 hours in a day, or within 950 m from rock breaking for 6 hours. This range is for the VHF cetacean marine mammal category (porpoises), which are not present in this location. Other marine mammal groups are less sensitive, and would need to be within 400 m for a significant period.

Fish would need to remain within 50 m of the activity. Impacts from any other noise source are significantly lower.

Any risk to marine mammals or fish, as per the guidelines in Southall *et al.* (2019) and Popper *et al.* (2014), will be negligible. This condition of extended presence of marine mammals close to the ships in the port and maximum output is highly unlikely to occur in practice, especially considering that the Powership operations are only permitted for 16.5 hours per day. The most sensitive species of fish would need to remain directly adjacent to the Powership for the same full 24 hour period.

Based on this assessment, no significant underwater noise impacts on fish or marine mammals are predicted as a result of the operation of the Powership in Port of Richard’s Bay as it will not materially change existing underwater noise associated with the port. No additional noise mitigation is deemed necessary, and this project is thus supported from an underwater noise assessment perspective.

The effects of underwater noise, as well as other impacts, on the marine ecology at Port of Richard’s Bay are considered further in the Marine Ecology report Ref. B4, Marine Ecology, Oct. 2022.

Polycentric Approach

A specialist integrative workshop and weekly meetings were held to consider specialist requirements, eliminate potential gaps between the various specialist assessments and ensure a holistic assessment of environmental and socio-economic impacts with appropriate mitigations based on the significance of assessed impacts.

This report provides further context on the assessment of environmental effects of noise on marine mammals and fish species in and around underwater environments.

The underwater noise assessment was provided to all Specialists conducting assessments for the proposed Gas to Power Powership project at the Port of Richard’s Bay. This report was specifically highlighted, for consideration, to the Specialists conducting the following studies:

- Marine ecology and fisheries;
- Coastal and Estuary;
- Ambient Noise (South-African Context);
- Avifauna (Marine and Terrestrial) – impacts on birds;
- Biodiversity;
- Socio-Economic, including Small Scale Fishers; and
- Sustainability.

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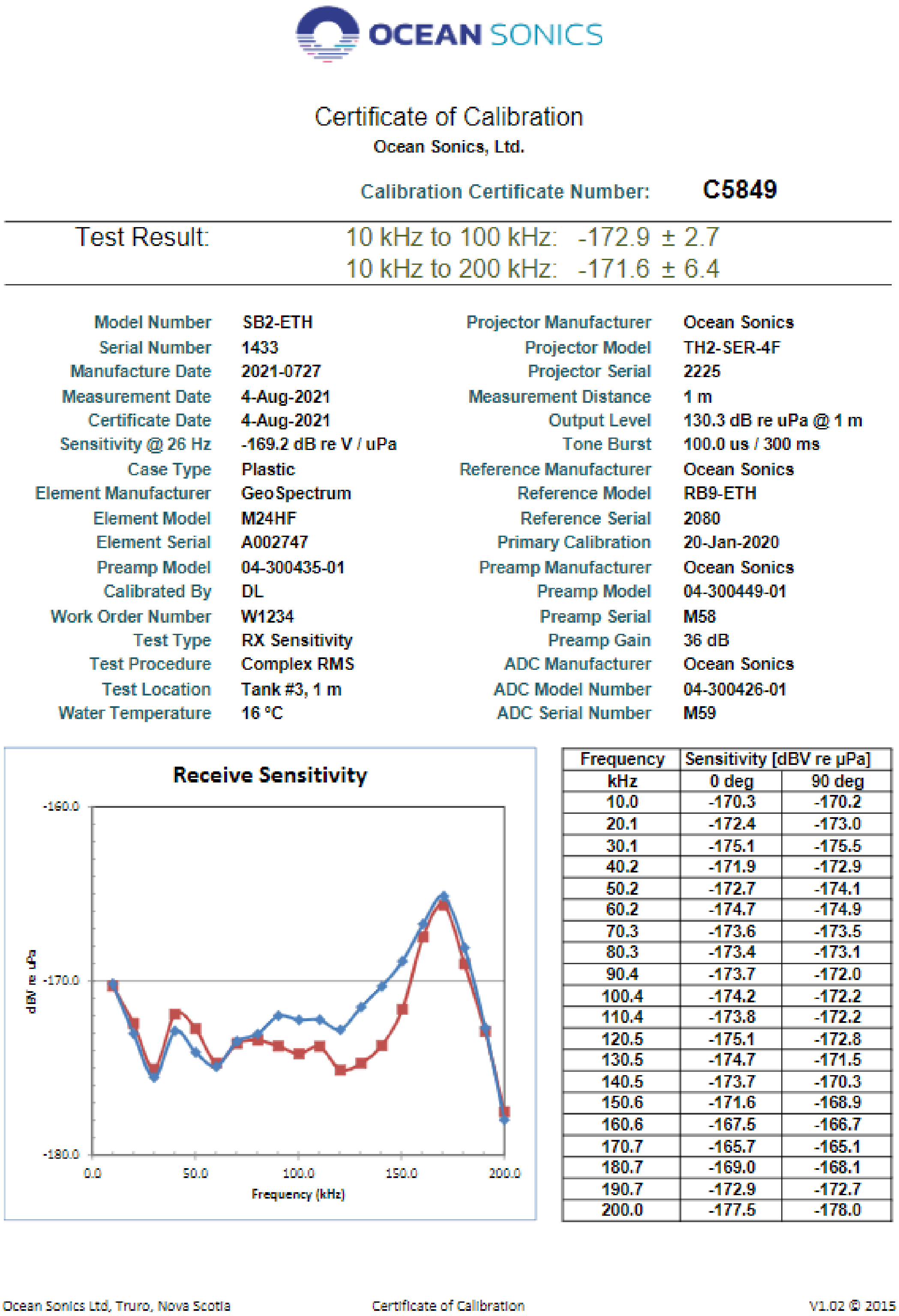
Appendix A Calibration Certificates



OCEAN SONICS

Certificate of Calibration
Ocean Sonics, Ltd.

Calibration Certificate Number: **C5849**

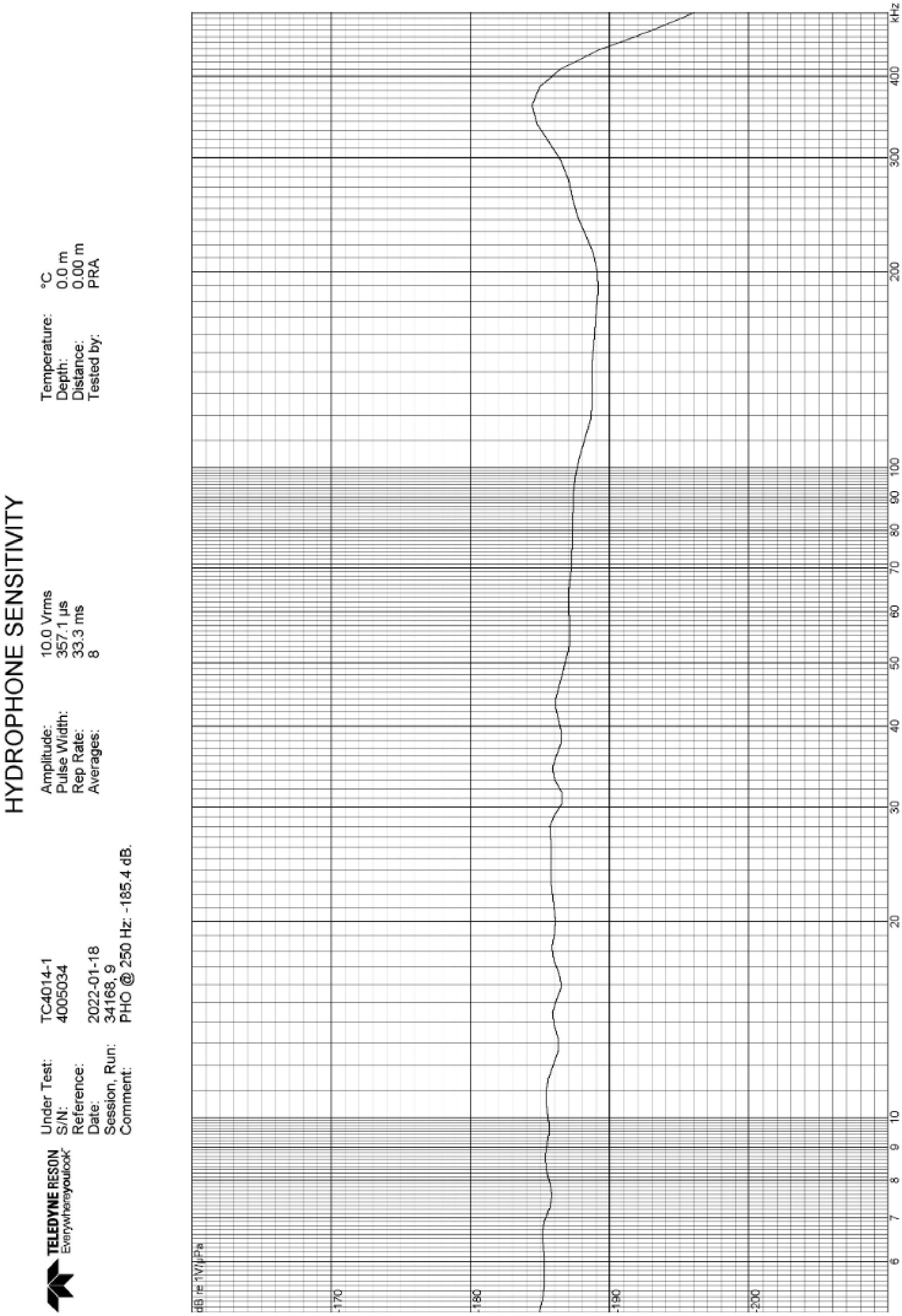
Test Result: 10 kHz to 100 kHz: -172.9 ± 2.7
10 kHz to 200 kHz: -171.6 ± 6.4

Model Number	SB2-ETH	Projector Manufacturer	Ocean Sonics
Serial Number	1433	Projector Model	TH2-SER-4F
Manufacture Date	2021-0727	Projector Serial	2225
Measurement Date	4-Aug-2021	Measurement Distance	1 m
Certificate Date	4-Aug-2021	Output Level	130.3 dB re uPa @ 1 m
Sensitivity @ 26 Hz	-169.2 dB re V / uPa	Tone Burst	100.0 us / 300 ms
Case Type	Plastic	Reference Manufacturer	Ocean Sonics
Element Manufacturer	Geo Spectrum	Reference Model	RB9-ETH
Element Model	M24HF	Reference Serial	2080
Element Serial	A002747	Primary Calibration	20-Jan-2020
Preamp Model	04-300435-01	Preamp Manufacturer	Ocean Sonics
Calibrated By	DL	Preamp Model	04-300449-01
Work Order Number	W1234	Preamp Serial	M58
Test Type	RX Sensitivity	Preamp Gain	36 dB
Test Procedure	Complex RMS	ADC Manufacturer	Ocean Sonics
Test Location	Tank #3, 1 m	ADC Model Number	04-300426-01
Water Temperature	16 °C	ADC Serial Number	M59

Frequency	Sensitivity [dBV re µPa]	
kHz	0 deg	90 deg
10.0	-170.3	-170.2
20.1	-172.4	-173.0
30.1	-175.1	-175.5
40.2	-171.9	-172.9
50.2	-172.7	-174.1
60.2	-174.7	-174.9
70.3	-173.6	-173.5
80.3	-173.4	-173.1
90.4	-173.7	-172.0
100.4	-174.2	-172.2
110.4	-173.8	-172.2
120.5	-175.1	-172.8
130.5	-174.7	-171.5
140.5	-173.7	-170.3
150.6	-171.6	-168.9
160.6	-167.5	-166.7
170.7	-165.7	-165.1
180.7	-169.0	-168.1
190.7	-172.9	-172.7
200.0	-177.5	-178.0

Ocean Sonics Ltd, Truro, Nova Scotia Certificate of Calibration V1.02 © 2015

Figure A.1 - Calibration certificate for static monitor transducer in Sekondi, icListen SB2 (serial number #1433)



HYDROPHONE SENSITIVITY

Under Test: TC4014-1
S/N: 4005034
Reference:
Date: 2022-01-18
Session, Run: 34168, 9
Comment: PHO @ 250 Hz: -185.4 dB.

Amplitude: 10.0 Vrms
Pulse Width: 357.1 µs
Rep Rate: 33.3 ms
Averages: 8

Temperature: °C
Depth: 0.0 m
Distance: 0.00 m
Tested by: PRA

Figure A.2 - Calibration certificate for attended monitor transducer in Sekondi, Teledyne Reson TC-4014-1 (serial number #4005034)

Appendix B Detailed underwater noise measurements of Osman Khan

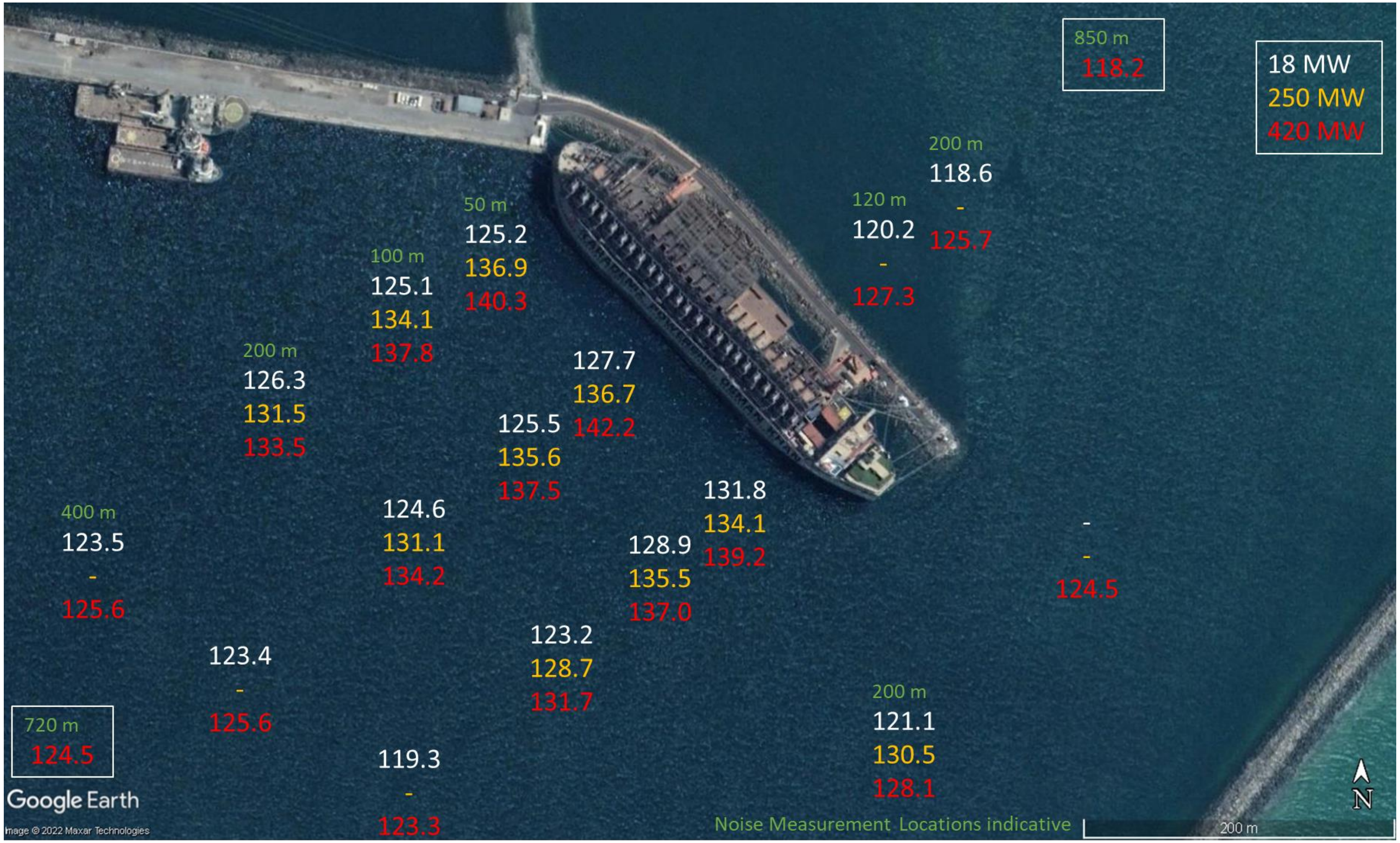


Figure B.1 – Underwater noise levels and approx. locations around the Osman Khan Powership, Ghana, at various power outputs, dB SPL$_{RMS}$ re 1 µPa

Appendix C Port of Richard’s Bay baseline noise survey

This is provided in a separate file, EIA Ref. B1, Subacoustech reference P292R0501, Dec 2021.

Appendix D Specialist Report Requirements

Table D-1 outlines the requirements of the Specialist Reports as per the NEMA EIA Regulations, 2014 (as amended). According to Appendix 6 (1) "A specialist report prepared in terms of these Regulations must contain …" the information outlined in Table D-1 below.

Table D-1 Prescribed contents of the Specialist Reports (Appendix 6 of the EIA Regulations, 2014)

Relevant section in GNR. 982	Requirement description	Relevant section in this report
(a) details of—	(i) the specialist who prepared the report; and	Appendix E
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Appendix E
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	p2
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 1
(cA)	an indication of the quality and age of base data used for the specialist report;	Section 3, 4
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 6
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 4
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 5
(f)	details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Section 3
(g)	an identification of any areas to be avoided, including buffers;	n/a
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 6
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge; Note: Uncertainties should be qualified within the report – there will always be uncertainties due to ?? and gaps in knowledge should also be qualified – a gap is to record that not all knowledge can be obtained for a study.	Section 4,5
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Section 6
(k)	any mitigation measures for inclusion in the EMPr;	Section 6
(l)	any conditions for inclusion in the environmental authorisation;	n/a
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	n/a
(n) a reasoned opinion—	(i) whether the proposed activity, activities or portions thereof should be authorised;	n/a
	(iA) regarding the acceptability of the proposed activity or activities; and	Section 6
	(ii) if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance,	Section 6

	management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	n/a
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	n/a
(q)	any other information requested by the competent authority.	n/a
(2)	Where a government notice gazetted by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	n/a

Appendix E Specialist Credentials

Mr Timothy I Mason *BEng (Hons.) MIOA*

Project Role:	**Underwater Acoustics - Project Manager and Principal Acoustician**

Personal Information

Surname:	Mason
Forenames:	Timothy Irving
Date of Birth:	9th August 1980
Current Employer:	Subacoustech Environmental Ltd.
Position:	Principal Acoustic Consultant
Address:	Unit 2 Muira Industrial Estate, William Street, Southampton, Hants. SO14 5QH, UK
Telephone:	+44 (0) 2380 236330
E-mail:	tim.mason@subacoustech com

Qualifications/Professional Memberships

Degree: BEng(Hons) Engineering Acoustics and Vibration

Institute of Sound and Vibration Research, University of Southampton (2001), UK

Member of the Institute of Acoustics (MIOA), UK

Experience

Continuous post-graduate acoustic consultancy experience since 2001 in design and impact assessment of both underwater and traditional airborne noise situations. Joined Subacoustech Environmental in 2011. Responsible for project management and QA in addition to technical consultancy and reporting. Acts as an expert witness for planning enquiries with respect to underwater noise and its effects on marine life. Experienced in a wide range of acoustic disciplines in addition to underwater noise modelling and monitoring; other disciplines includes road, rail and construction noise impacts, industrial noise mapping and control, planning and architectural acoustics, vibration and noise nuisance. Delivered presentations on underwater noise impacts at national and international conferences and has been invited to speak on underwater noise at the Royal Society.

Relevant Project Experience

Client: RWE, Ørsted, SPR, Innogy, Royal Haskoning, GoBe, others

Environmental Impact Assessments and Regulatory Enquiries for Offshore Wind Farms, Technical lead

Leading the underwater noise EIAs for the majority of offshore wind farm projects in UK waters, including Seagreen Alpha, Inch Cape and Moray Firth, Awel y Môr, Hornsea Projects 1 to 4, East Anglia 3, 2 and 1 North, Rampion 2, Sofia, Galloper, Dogger Bank A&B, Triton Knoll, Norfolk Boreas and Norfolk Vanguard, and many others.

Client: Blue Gem Wind/Total, MarineSpace

Environmental Impact Assessments for Erebus Floating Offshore Wind Farm, Technical lead

Undertaking the underwater noise assessment for the Erebus Offshore Wind Farm, in Welsh waters, one of the few floating turbine wind farms in the UK. Multiple turbine foundation types were under consideration requiring innovative use of modelling for an unusual EIA report.

Client: Royal Haskoning, Arcadis, Buro Happold

Underwater noise assessments of river and coastal redevelopment projects: container terminals, military docks

Conducted the assessments, including underwater noise modelling, for impact on species of fish and marine mammal in river and coastal waters for multiple types of projects with a variety of noise sources, including foundation impact and vibro piling, land based breaking, and operational noise.

Client: Bureau of Ocean Energy Management, USA – RODEO project

Monitoring and analysis of noise from the Block Island wind farm and Coastal Virginia Demonstrator, USA

Planned and led simultaneous airborne and underwater, onshore and offshore, noise and vibration monitoring surveys during construction and operation of the Block Island Offshore Windfarm and Coastal Virginia Offshore Wind, USA. The study is thought to be the most comprehensive of its kind in the world. ***Client: Royal Haskoning, GoBe, Ørsted*** **Estimation of UXO clearance, underwater noise impact** As part of offshore development, calculation of the underwater noise transmission and its potential impact on marine wildlife as a result of detonation from clearance of unexploded ordnance in UK waters. ***Client: RWE Innogy, Ørsted*** **Monitoring of piling, Gwynt y Môr OWF, Wales; Burbo Bank Extension, Liverpool Bay** Carried out measurement surveys and assessment of underwater noise propagation at two offshore wind farms in Liverpool Bay during the installation of foundation piles off the north coast of Wales.
Supplementary training/information
SAMSA Medical Certificate (exp. November 2023) BOSIET/FOET (expires July 2024) Certificate of Compressed Air Emergency Breathing System (exp. July 2024) CSCS card: Professional Qualified Person (valid until February 2025)

Report documentation page

- This is a controlled document.
- Additional copies should be obtained through the Subacoustech Environmental librarian.
- If copied locally, each document must be marked "Uncontrolled copy".
- Amendment shall be by whole document replacement.
- Proposals for change to this document should be forwarded to Subacoustech Environmental.

Document No.	Draft	Date	Details of change
P292R1000	01	18/09/22	First draft
P292R1001	-	14/10/22	First issue
P292R1002	-	18/10/22	Minor updates

Originator's current report number	P292R1002
Originator's name and location	T Mason; Subacoustech Environmental Ltd.
Contract number and period covered	P292; August 2022 – October 2022
Sponsor's name and location	H Plomp, Triplo4
Report classification and caveats in use	FOR ISSUE
Date written	September 2022
Pagination	Cover + i + 38
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Report title	Underwater noise assessment – Port of Richard's Bay
Translation/Conference details (if translation, give foreign title/if part of a conference, give conference particulars)	
Title classification	Unclassified
Author(s)	Tim Mason, Fergus Midforth
Descriptors/keywords	
Abstract	
Abstract classification	Unclassified; Unlimited distribution

environmental affairs
Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

	(For official use only)
File Reference Number:	
NEAS Reference Number:	DEA/EIA/14/12/16/3/3/2007
Date Received:	02 November 2020

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

PROJECT TITLE

The Proposed Gas to Power Powership Project at the Port of Richards Bay, Umhlathuze Local Municipality, King Cetshwayo District, Kwazulu-Natal.

Kindly note the following:

1. This form must always be used for applications that must be subjected to Basic Assessment or Scoping & Environmental Impact Reporting where this Department is the Competent Authority.
2. This form is current as of 01 September 2018. It is the responsibility of the Applicant / Environmental Assessment Practitioner (EAP) to ascertain whether subsequent versions of the form have been published or produced by the Competent Authority. The latest available Departmental templates are available at https://www.environment.gov.za/documents/forms.
3. A copy of this form containing original signatures must be appended to all Draft and Final Reports submitted to the department for consideration.
4. All documentation delivered to the physical address contained in this form must be delivered during the official Departmental Officer Hours which is visible on the Departmental gate.
5. All EIA related documents (includes application forms, reports or any EIA related submissions) that are faxed; emailed; delivered to Security or placed in the Departmental Tender Box will not be accepted, only hardcopy submissions are accepted.

Departmental Details

Postal address:
Department of Environmental Affairs
Attention: Chief Director: Integrated Environmental Authorisations
Private Bag X447
Pretoria
0001

Physical address:
Department of Environmental Affairs
Attention: Chief Director: Integrated Environmental Authorisations
Environment House
473 Steve Biko Road
Arcadia

Queries must be directed to the Directorate: Coordination, Strategic Planning and Support at:
Email: EIAAdmin@environment.gov.za

1. SPECIALIST INFORMATION

Specialist Company Name:	Subacoustech Environmental Limited			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	n/a (UK based)	Percentage Procurement recognition	n/a (UK based)
Specialist name:	Tim Mason			
Specialist Qualifications:	BEng(Hons) Acoustic Engineering			
Professional affiliation/registration:	Member of the Institute of Acoustics (UK) (MIOA)			
Physical address:	Unit 2 Muira Industrial Estate, William Street, Southampton, Hampshire, UK			
Postal address:	Unit 2 Muira Industrial Estate, William Street, Southampton, Hampshire, UK			
Postal code:	SO14 5QH	Cell:	n/a	
Telephone:	+44 2380 236330	Fax:	n/a	
E-mail:	tim.mason@subacoustech.com			

2. DECLARATION BY THE SPECIALIST

I, Tim Mason, declare that –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Signature of the Specialist

Subacoustech Environmental Limited

Name of Company:

31/10/2022

Date

3. UNDERTAKING UNDER OATH/ AFFIRMATION

I, Tim Mason, swear under oath / affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Signature of the Specialist

Subacoustech Environmental Limited

Name of Company

31/10/2022

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Woolfe

ature of the Commissioner of Oaths FIONA WOOLFE

31st October 2022.

Da

Signed before me, Fiona Woolfe, notary public of England and Wales, having an office at 39 Granadiers Road, Winchester, Hants, SO22 6GU by Timothy Mason, whose identity I verified by sight of his original UK passport with number 542493480, on this 31st October 2022.