C2 - Restricted

ESB 400 KV CROSS SHANNON CABLE PROJECT

Site Investigation Works- Risk Assessment for Annex IV Species

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REPORT

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1 INTRODUCTION

1.1 Overview

The Cross Shannon 400 kV Cable Project (Capital Project Reference 0970) involves the laying of a new 400 kV cable across the Shannon Estuary (in the seabed) between the Moneypoint 400 kV Electricity Substation in the townland of Carrowdotia South County Clare and Kilpaddoge 220/110 kV Electricity Substation in the townland of Kilpaddoge County Kerry. The connection at Moneypoint will be at the existing substation on ESB lands. The connection at Kilpaddoge requires an extension of 5,500m^2 to the existing substation on ESB lands.

These upgrades are part of EirGrid Group Strategy 2020-2025 which aims to transform the power system in Ireland with the primary goal being to lead the transition of Ireland's electricity sector to low carbon-renewable energy. Key to the new strategy is upgrading the power system so that it can handle world-leading levels of renewable energy, supplied through a combination of offshore and onshore wind, along with solar energy.

At times of medium to high wind generation output, it is expected that the south-west of Ireland will export the excess generation to areas where it is needed. This will create large power flows from the west and south-west towards the east coast. To be able to facilitate this and to utilise the existing 400 kV network better, a system reinforcement across the Shannon is required, which is the Cross Shannon 400 kV cable circuit (Capital Project Reference CP0970). This reinforcement forms part of the 'regional solution' consisting of a suite of reinforcement projects designed to maximise the capabilities of the existing network.

This report will discuss the proposed geophysical and geotechnical site investigation works (SI works) and the potential impact on Annex IV cetacean species within the Shannon Estuary. At the time of submission, the marine surveys are expected to comprise geophysical surveys only, however, assessment of a geotechnical survey has been included here, as this might be proposed at a later stage. These surveys are summarised in Section 2 of this report.

1.2 Purpose of the Report

This risk assessment and associated subsea noise technical report (Appendix A) has been prepared by RPS, on behalf of the ESB, to provide information on the SI works proposed to be undertaken for the Cross Shannon 400 kV Cable project in support of a cetacean derogation application to NPWS.

In May 2019, the Government of Ireland declared a Climate and Biodiversity Emergency in the Dáil[1] and has committed to increasing the proportion of electricity generated from renewable sources to 80% by 2030. The proposed SI works fall under Regulation 54(2) (c) as high levels of renewable generation are currently being integrated into the southwest of Ireland. At times of medium to high wind generation output, it is expected that the southwest of Ireland will export the excess generation to areas where it is needed. This will create large power flows from the west and southwest towards the east coast. To be able to facilitate this and to utilise the existing 400 kV network better, a system reinforcement across the Shannon is required, which is the Cross Shannon 400 kV cable circuit (Capital Project Reference CP0970). This reinforcement forms part of the 'regional solution' consisting of a suite of reinforcement projects designed to maximise the capabilities of the existing network. The project is therefore critical to ensuring that Ireland meets its renewable energy and climate action targets.

The proposed SI works are critical to the development of the Cross Shannon 400 kV project, and therefore, qualify under Regulation 54(2)(c). The proposed SI works will provide the necessary engineering information to inform the design of the marine cable, which is imperative to Ireland achieving its renewable energy targets.

This report has been prepared on the basis that a derogation application will only be required for relevant Annex IV marine species due to the potential, in the absence of mitigation measures, for underwater noise from the geophysical and geotechnical equipment and vessels to impact on cetacean species. However,

[1] Report entitled 'Climate Change: A Cross-Party Consensus on Climate Action': Motion – Dáil Éireann (32nd Dáil) – Thursday, 9 May 2019 – Houses of the Oireachtas

based on the assessment below, the potential for injury or disturbance to occur to Annex IV cetacean and turtle species as a result of the SI works is considered to be low. This risk will be further reduced by the implementation of mitigation. This report provides the required level of detail to the NPWS on the effects of the SI works on relevant Annex IV species in order to allow them to make a decision on the application for derogation.

1.3 Statement of Authority

The technical competence of the authors is outlined below:

Gareth McElhinney is Technical Director in the Environmental Services Business Unit in RPS. He has over 24 years' experience. He holds an honours degree in Civil Engineering (B.E.) from NUI, Galway, a postgraduate diploma in Environmental Sustainability from NUI, Galway, and a Master's in Business Studies from the Irish Management Institute/ UCC. Gareth is also a Chartered Engineer and Project Management Professional with the Project Management Institute (PMI-PMP). He has managed the delivery of numerous environmental projects including marine and terrestrial projects that have required environmental impact assessment, appropriate assessment, and Annex IV species reports.

Aoife Edgely is a Principal Scientist in the Environmental Services Business Unit in RPS. She has over 13 years' experience in the marine science field and is a Chartered Environmentalist and a Full Member of the Institute of Environmental Sciences. Aoife holds an honours degree in Environmental Science from Trinity College Dublin and a Master's in Marine Environmental Protection from Bangor University, Wales. Aoife has delivered the environmental assessments for a wide range of marine and coastal projects, including environmental impact assessment, appropriate assessment and Annex IV species reports.

Rachael Shaw is a Project Scientist in the Environmental Services Business Unit in RPS. She holds a Bachelor's Degree in Marine Science from the University of Galway and Master's Degree in Climate Change and Managing the Marine Environment from Heriot-Watt University Edinburgh. She has over three years' experience working in consultancy, assisting on a wide range of projects from offshore renewable energy projects to flood relief schemes, including marine and terrestrial surveys. She is a qualifying CIEEM member.

2 Project Description

2.1 Site Location

The proposed development will involve the installation and operation of an additional cable crossing of the Shannon Estuary between the existing transmission substation on the site of the existing electricity generating station at ESB Moneypoint (north side of the Shannon estuary, near Killimer in County Clare) and a new 400/220 kV transformer at the transmission substation at Kilpaddoge (south side of the Shannon estuary near Tarbert in County Kerry) (Figure 2.1).

Moneypoint is located on the northern shore of the Shannon Estuary in Co. Clare, approximately 3 km west of Killimer and 6 km south-east of Kilrush.

Kilpaddoge is located in north County Kerry adjacent to Tarbert. The immediate area surrounding the existing Kilpaddoge 220/110 kV substation within this landbank can be categorised as predominantly rural or on the fringes of ribbon development associated with Tarbert.

The proposed SI works will be conducted within the Shannon Estuary which handles up to 1,000 ships carrying 12 million tons of cargo per annum (SIFP, 2020). A car and passenger ferry also operates between Killimer, Co. Clare, and Tarbert, Co. Kerry all year-round. Fishing activity also takes place in the estuary. Additionally, a large number of pleasure crafts exist year-round in the estuary.

The sediment found within this area of the Shannon Estuary is mainly sand to fine/medium gravel, and maximal depths are c. 60 m (assuming high tide).

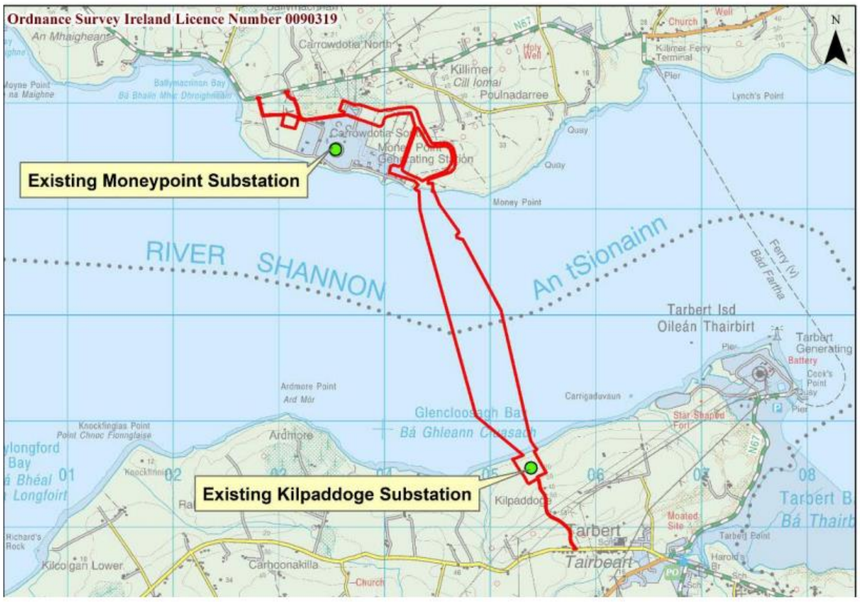

Figure 2.1 Project location map

The Foreshore Licence Area (98.15 ha) is highlighted in red on Figure 2.2 which also shows the proposed submarine cable corridor.

Figure 2.2 Foreshore Licence Area

2.2 Description of the SI Works

2.2.1 Overview

In order to provide a reliable basis for design and development the following surveys and investigations (collectively, the SI works) are considered necessary. The aim of the site investigation is to acquire data to a high quality and specification for the site as summarised below and described in the following sections. The SI works may also incorporate visual surveys (e.g., drop down video, remotely operated vehicle (ROV), etc.) pending the development of the project's ground model.

- Marine Site Investigation Works:
  - Marine Geophysical Surveys.
  - Visual surveys - including potential ROV deployment (note that impacts related to ROV are considered under Marine Geotechnical Investigations).
  - Marine Geotechnical Investigations, including potential ROV deployment.

It should be noted that all locations are provisional only and subject to change on-site due to the presence of obstructions/ refusals at individual locations.

It is noted that the requirement for additional and more refined works may arise as the SI works progress and are analysed. This may include areas of particular interest using more targeted techniques and/or refined vibrocore/CPT locations and quantities.

2.2.2 Marine Geophysical Surveys

The geophysical survey scope is intended to provide significant seabed and sub-seabed information to assist in the consenting, design, and construction phases of the project. It is therefore foreseen to gather, as a minimum, detailed information on:

- Water depths, reduced to LAT, throughout the defined survey area.
- The nature of any seabed features, obstructions, sediments, and shallow geological conditions throughout the defined survey areas.
- The nature of the sub-seabed conditions and horizons down to circa 50m below seabed level (bsbl).

- Seabed conditions/ hazards to any project equipment which may need to be located on the seabed.
- Seabed habitats to identify sensitive marine habitats which will need to be avoided during geotechnical sampling.
- Archaeological features within the development area.

The foreseen scope of marine SI works will consist of primarily non-intrusive survey methods, in that they will not physically interact with the seabed, such as multi beam echosounder (MBES) and sub-bottom profiler (SBP) surveys. No side scan sonar or ultrashort baseline (USBL) positioning system will be deployed.

A single vessel of <30 m length will be using a MBES and SBP, and a smaller vessel may be used in nearshore / shallower water areas.

A brief description of the geophysical survey methods has been provided in the subsequent sections. The exact technical specifications of the equipment to be used will not be known until the survey contract has been awarded. However, a description of the typical equipment and survey parameters is described. Typical acoustic properties of equipment are provided in Section 2.2.5.

2.2.2.1 Multibeam Echo Sounder

Full 100% coverage with 25% overlap of the area concerned associated with the survey and area classification will be required. Surveys shall identify the level, nature, and detailed coverage of the seabed to ensure identification of features on the seabed within the area shown, identify potential large upstanding archaeological features and guide habitat mapping with the backscatter function if available. Processing of data sets shall include processing for archaeological indicators. The area shall be surveyed in such a way as to produce a comprehensive data set required to enable the generation of multiple sections through the survey area in any direction.

A remote sensing acoustic device which will be either attached to the vessel(s) hull at the bow or mounted on a side pole. It is proposed that a Reson Teledyne Seabat or similar will be used, swath width will be optimised to provide 100% seafloor coverage with typical swath widths of 3 to 6 times water depth depending on arrangement of equipment hardware. MBES survey may be performed throughout the entire area which is to be 98.15 ha.

2.2.2.2 Sub-bottom Profiling

A typical sub bottom profiling (SBP) survey will be completed using a multi-channel seismic reflection system such as a Boomer, Chirp or Sparker system. Five SBP run lines parallel to the RPL within the redline corridor and 20 SBP run lines ~200m apart perpendicular to the RPL shall be conducted during the survey.

The geophysical SBP survey shall identify the bed level and the nature, thickness, and location of the sub surface strata to rock head.

The survey shall include both items detailed below:

1. Completion of specified runs.
2. Completion of a Free Line Survey.

SBP are acoustic devices for imaging sections of the seabed. The images are used to produce profiles beneath the seafloor, enabling delimitation of major sedimentary interfaces. They are either mounted on the vessel / pole or towed behind the vessel. It is proposed an Innomar SES 2000 Compact or similar will be used and will be performed throughout the entire area which is estimated to be 98.15 ha.

2.2.3 Marine Geotechnical Investigations

The aim of the geotechnical survey is to provide sufficient geotechnical data to allow the characterisation of the sub-seabed strata and composition of the seabed and the level of rock head (including follow on coring to confirm rock head).

The works will include the following:

- Cone penetration testing
- Vibrocore

Normal industry standards for performance of all positioning, drilling, sampling, SPT testing, CPTu testing, laboratory testing and analysis and reporting will apply. A USBL will be used during the geotechnical surveys for positioning in deeper water. Material sampling, in situ testing, data logging, laboratory testing and reporting (factual and interpretative) will be required.

The final quantity, location, and specification of equipment will be determined following interpretation of the geophysical survey data and considering environmental constraints (i.e., proximity to sensitive receptors). The final proposed locations will be subject to environmental conditions. The geotechnical survey will be undertaken from a single geotechnical vessel (up to 80 m in length, or alternatively a JUB for shallower water).

2.2.3.1 Cone Penetration Testing

Cone penetration testing (CPT) is an in-situ testing method to determine the properties of soil to determine the geological condition of the seabed and aid in geotechnical design.

CPT samples will be taken every 400 m along each RPL line along the route. The final sampling locations will be determined based upon interpretation of the geophysical data and selected based on the preliminary engineering design. Some locations may need to be avoided due to environmental reasons including sensitive archaeological features or unsuitable substrate types.

2.2.3.2 Vibrocore Sampling

Vibrocore sampling is a technique for collecting core samples of seabed sediments. A vibrating mechanism is attached to a metallic core which is driven into the sediment by gravity and the energy from the vibrations. A “soil log” is collected which will is typically examined directly after recovery for shear strength and is later examined at a lab.

Vibrocore samples will be taken every 400m along each RPL line along the route. The final sampling locations will be determined based upon interpretation of the geophysical data and selected based on the preliminary engineering design. Some locations may need to be avoided due to environmental reasons including sensitive archaeological features or unsuitable substrate types.

2.2.3.3 Ultra Short Baseline

The Ultra Short Baseline (USBL) is a method of underwater acoustic positioning to accurately determine and log the 3D position of towed subsea equipment and sensors. USBL systems employ a transceiver fixed to the hull of the survey vessel in combination with transponders on the towed equipment. Triangulation is achieved using acoustic signals transmitted and detected at regular intervals from which bearing, depth and distance can be calculated. The USBL in this study is based on a generic model using data from systems made by Edgetech, ORE offshore, Sonardyne & Ixblue. The USBL is used along with deployed equipment when the exact position relative to the vessel is needed, such as during the geotechnical survey for the vibrocoring and CPT.

2.2.4 ROV Deployment

An ROV are underwater machines that can be used to explore a wide range of depths underwater while being operated by someone at the surface i.e. on board a vessel. They record images and/or videos and can collect samples to assess the seabed prior to intrusive survey techniques i.e. geotechnical surveys. For the SI works a suitable ROV might be deployed to investigate seabed anomalies from a Dynamic Positioning (DP) vessel, should they be found. The associated vessel and USBL closely matches the equipment for the vessel-borne geotechnical survey and is covered under that assessment.

2.2.5 Marine Noise Level Summary

All survey works that involve the use of acoustic instrumentation will follow the *Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters* (DAHG, 2014).

A summary of the noise sources, for the main activities proposed to be undertaken as part of the project surveys is included in Table 2-1 (see Appendix A: Subsea Noise Technical Report for further detail).

Table 2-1 Summary of Noise Sources and Activities Included in the Subsea Noise Assessment

Equipment	Source level [SPL]	Primary frequencies (-20 dB width)	Source model details	Impulsive/non-impulsive
Geophysical Survey				
Survey vessel, geophysical survey, <30 m length	173 dB SPL	10-2,000 Hz	(Wittekind, 2014; Simard, et al., 2016; Heitmeyer, 2001)	Non-impulsive
Multibeam echosounder	210 dB SPL (ping rate dependent, equivalent spherical level)	400,000 Hz – 800,000 Hz	Source levels based on von Hann windowed FM or CW pulses at max SPL as given by manufacturer.	Impulsive to 260 m, then non-impulsive*
Sub-bottom profiler Based on: "Innomar SES 2000 Compact"	192-195 dB SPL (ping rate and depth dependent, off-axis level)	Primary: 85,000 – 115,000 Hz Secondary: 2,000 – 22,000 Hz	Source levels based on von Hann windowed FM or CW pulses at max SPL as given by manufacturer. Soft start as given by manufacturer (Innomar)	Impulsive to 260 m, then non-impulsive
Geotechnical Survey				
DP vessel, geotechnical & ROV survey, <80 m length	196 dB SPL	10-12,500 Hz	(Wittekind, 2014; Simard, et al., 2016; Heitmeyer, 2001)	Non-impulsive
Tug to assist positioning jack-up barge	195 dB SPL	10-16,000 Hz	(Wittekind, 2014; Simard, et al., 2016; Heitmeyer, 2001)	Non-impulsive
Vibro-coring / drilling & CPT	189 dB SPL	50 – 16,000 Hz	Based on recorded levels	Non-impulsive
USBL (positioning)	190 dB SPL 215 dB L_P	20,000 – 31,500 Hz	Generic USBL based on models from Edgetech, ORE offshore, Sonardyne & Ixblue	Impulsive to 260 m, then non-impulsive
Sonar (high-resolution sonar used during the ROV survey to detect fine detail on the sediment surface).	190 dB SPL	700,000 – 3,000,000 Hz **Not audible to animals**	Based on ARIS sonars	Impulsive to 260 m, then non-impulsive

2.2.6 Duration of works

The intention is to begin survey activities as soon as feasible following issue of a derogation licence from NPWS, with a phased programme of investigations, capitalising on suitable weather windows over this time period. This phased approach will progress the overall development towards detailed design stage. A separate derogation licence will be applied for as part of each phase of the proposed SI works. The geophysical SI works will be carried out initially, but an assessment of a geotechnical survey has been included here as this might be proposed at a later stage. The exact mobilisation dates will not be known until the process of procuring a contractor is complete.

The exact dates for the surveys are to be determined pending the appointment of survey contractors the estimated durations are subject to change based on variables such as weather conditions onsite, unforeseen seabed conditions, unforeseen obstructions etc. ESB will consult with relevant stakeholders where appropriate prior to the commencement of the surveys.

2.3 General Survey Requirements

2.3.1 Vessels

All vessels will be fit for purpose, certified and capable of safely undertaking all required survey work. Marine vessels will be governed by the provisions of the Sea Pollution Act 1991, as amended, including the requirements of MARPOL. In addition, all vessels will adhere to published guidelines and best working practices such as: the National Maritime Oil/HNS Spill Contingency Plan (NMOSCP), Marine Pollution Contingency Plan (MPCP), Chemicals Act 2008 (No. 13 of 2008), Chemicals (Amendment) Act 2010 (No. 32 of 2010) and associated regulations.

Vessels shall have a Health, Safety and Environmental Managements system which should conform to the requirements of the latest International Maritime Organization (IMO), Safety of Life at Sea (SOLAS) and environmental requirements for their classification and with any national requirement of the territorial or continental / EEZ waters to be operated in.

The SI works will be undertaken from vessels in accordance with the relevant guidelines required to manage the risk to marine mammals from man-made sound sources in Irish waters.

3 RISK ASSESSMENT FOR ANNEX IV SPEICES

3.1 Legislative Context

Under Article 12 and 13 of the Habitats Directive, Member States must establish systems of strict protection for animal and plant species which are particularly threatened, and which are listed on Annex IV of the Directive. Article 16 provides for derogations from these legal protections under certain, specific, circumstances. Article 12, 13 and 16 of the Habitats Directive are transposed into Irish law by Regulations 51, 52 and 54 of the European Communities (Birds and Natural Habitats) Regulations 2011, as amended.

Annex IV species are afforded strict protection throughout their range, both inside and outside of designated protected areas. It is an offence to:

- Deliberately capture or kill any specimen of these species in the wild;
- Deliberately disturb these species particularly during the period of breeding, rearing, hibernation and migration;
- Deliberately take or destroy eggs of these species in the wild;
- Damage or destroy a breeding or resting place of such an animal[2];
- Deliberately pick, collect, cut, uproot, or destroy any specimen of [plant] species in the wild; or
- Keep, transport, sell, exchange, offer for sale or offer for exchange any specimen of [animal or plant] species taken in the wild, other than those taken legally as referred to in Article 12(2) of the Directive[3].

The granting of another statutory consent (e.g., planning permission; MARA licence) does not remove the obligation to obtain a derogation licence in the event of the consented works being likely to not conform with the strict protections afforded to Annex IV species. As such, an application for derogation may have to be made to the Minister for Housing, Local Government & Heritage via the National Parks and Wildlife Service (NPWS) under Regulation 54, in addition to an application for development consent. If satisfied that an application meets the criteria for derogation, the Minister may grant a derogation licence, which may be subject to such conditions, restrictions, limitations, and requirements as the Minister considers appropriate, and these will be specified in the licence.

3.2 Relevant Annex IV Marine Species

This report has been prepared on the basis that a derogation application will only be required for relevant marine species due to the potential, in the absence of mitigation measures, for underwater noise from the geophysical and geotechnical equipment and vessels to impact on these species.

Bat species are not considered as part of this derogation application as the proposed SI works including access/egress from each potential landfall zone will not result in any direct or indirect impacts on any structure or feature which could be used by roosting bats. Therefore, there is no likelihood of the SI works resulting in any bats being captured or killed and disturbed during periods of breeding, rearing or hibernation. No breeding site or resting place of such animals will be damaged or destroyed during the SI works. Any artificial lighting, if used, will be localised to either the vessels or JUB. Therefore, there is no likelihood of any significant disturbance or displacement of foraging, commuting, or migrating bats and the proposed SI works will conform with the strict protections afforded to bat species.

There will be no interaction with otter holts or couches as the intrusive sampling will take place within the marine environment. As otter tends to forage within 80 m of the shoreline (NPWS, 2009), it is considered unlikely that there will be interaction between marine survey activity and otters foraging in coastal waters. Therefore, the proposed SI works will conform with the strict protections afforded to otter.

[2] Including any action resulting in damage to, or destruction of, a breeding or resting place of an animal. Breeding or resting places are protected even when the animals are not using them.

[3] National Parks and Wildlife Service (2021) Guidance on the Strict Protection of Certain Animal and Plant Species under the Habitats Directive in Ireland.

All cetacean species and marine turtle species are listed under Annex IV of the Habitats Directive and have the potential to occur in the Shannon Estuary. Therefore, these Annex IV species will be considered further.

3.3 Methodology

This risk assessment for Annex IV marine species has had regard to the following guidance:

- European Commission (2021) Guidance document on the strict protection of species of community interest under the Habitats Directive. C. (2021) 7301 final. Brussels.
- (Mullen, E., Marnell, F. & Nelson, B. 2021) Strict Protection of Animal Species. National Parks and Wildlife Service Guidance Series, No. 2. National Parks and Wildlife Service, Department of Housing. Local Government and Heritage.
- NPWS (2021) Guidance on the Strict Protection of Certain Animal and Plant Species under the Habitats Directive in Ireland. National Parks and Wildlife Service Guidance Series, No. 2. Department of Housing. Local Government and Heritage.

This risk assessment for Annex IV marine species broadly follows the methodology structure outlined in (Mullen et al., 2021), as follows:

3.3.1.1 Test 1: Reasons for Seeking Derogation

Reasons set out in Regulations 54(2) (a)- (e) below;

(a) *In the interests of protecting wild flora and fauna and conserving natural habitats;*

(b) *To prevent serious damage, in particular to crops, livestock, forests, fisheries and water and other types of property;*

(c) *In the interests of public health and public safety, or for other imperative reasons of overriding public interest, including those of a social or economic nature and beneficial consequences of primary importance for the environment;*

(d) *For the purpose of research and education, of re-populating and reintroducing these species and for the breeding operations necessary for these purposes, including artificial propagation of plants, or;*

(e) *To allow, under strictly supervised conditions, on a selective basis and to a limited extent, the taking or keeping of certain specimens of the species to the extent specified therein, which are referred to in the First Schedule. If it cannot be clearly demonstrated that one or more of the reasons set out above apply, a derogation licence cannot be granted by the Minister.*

In May 2019, the Government of Ireland declared a Climate and Biodiversity Emergency in the Dáil[4] and has committed to increasing the proportion of electricity generated from renewable sources to 80% by 2030. The proposed SI works fall under Regulation 54(2) (c): as high levels of renewable generation are currently being integrated into the southwest of Ireland. At times of medium to high wind generation output, it is expected that the southwest of Ireland will export the excess generation to areas where it is needed. This will create large power flows from the west and southwest towards the east coast. To be able to facilitate this and to utilise the existing 400 kV network better, a system reinforcement across the Shannon is required, which is the Cross Shannon 400 kV cable circuit (Capital Project Reference CP0970). This reinforcement forms part of the ‘regional solution’ consisting of a suite of reinforcement projects designed to maximise the capabilities of the existing network. The project is therefore critical to ensuring that Ireland meets its renewable energy and climate action targets.

The proposed SI works are critical to the development of the Cross Shannon 400 kV project, and therefore, qualify under Regulation 54(2)(c). The proposed SI works will provide the necessary engineering information to inform the design of the marine cable, which is imperative to Ireland achieving its renewable energy targets.

[4] Report entitled 'Climate Change: A Cross-Party Consensus on Climate Action': Motion – Dáil Éireann (32nd Dáil) – Thursday, 9 May 2019 – Houses of the Oireachtas

3.3.1.2 Test 2: There is No Satisfactory Alternative

Derogation from the Strict Protection provisions of the Directive must be seen as the last resort in any situation. It must therefore be clear that there is no other satisfactory solution to the situation presented by the proposal or project in question Applicants for a derogation licence should include full details of the alternatives examined and should set out objective reasons demonstrating why these alternatives are not satisfactory. If there is a satisfactory alternative then the application has failed the second test and a derogation licence cannot be issued.

With regards to alternatives considered, there are no alternatives to undertaking site investigations. This information is critical to the engineering design of the project. Best practice methods and equipment will be used to carry out the SI works which will be undertaken in accordance with standard operating procedures by competent contractors. Appointed survey contractors will be required to use methods and equipment which aligns with the parameters of the standard equipment described in the project description above and assessed in this report.

3.3.1.3 Test 3: Favourable Conservation Status

In each case, consideration must be given to whether granting a derogation licence would be detrimental to the maintenance of the populations of the species in question at a favourable conservation status in their natural range (Regulation 54(2)). Annex IV species must be maintained at Favourable Conservation Status or restored to favourable status if this is not the case at present. The net result of granting a derogation licence must be neutral or positive for the species in question.

If a derogation licence is likely to have a significant negative effect on the population concerned (or the prospects of this population) or is likely to have a significant negative effect at the biogeographical level within Ireland, then a derogation licence cannot be considered. If a derogation is issued it may have conditions, restrictions, limitations or requirements attached. All derogation licences are also subject to the Animal Health and Welfare Act 2013. At the completion of the process the Minister will state reasons for issuing (or refusing to issue) the licence. This statement will include the reasons it was decided there was an absence of suitable alternatives and refer to any relevant technical, legal and scientific reports used in making the decision.

The potential effects of the proposed SI works on relevant Annex IV cetacean and turtle species are discussed in Section 3.4 and 3.5 below. With the implementation of the mitigation measures outlined in this report, the impacts to Annex IV species will be neutral. Once the SI works are complete, there is no further potential for impacts to Annex IV species.

3.4 Evidence Base

3.4.1 Desk study sources

The following sources were consulted during the desk study in February 2025:

- Irish Whale and Dolphin Group Sightings Log https://iwdg.ie/browsers/sightings.php/;
- Distribution records for Annex IV species held online by the NBDC www.biodiversityireland.ie.
- NPWS (2019) The Status of EU Protected Habitats and Species in Ireland. Volume 3: Species Assessments. Unpublished Report, National Parks and Wildlife Service. Department of Culture, Heritage and the Gaeltacht, Dublin.
- Giralt Paradell, O., Cañadas, A., Bennison, A., Todd, N., Jessopp, M., Rogan, E. (2024). Aerial surveys of cetaceans and seabirds in Irish waters: Occurrence, distribution and abundance in 2021-2023. Department of the Environment, Climate & Communications and Department of Housing, Local Government & Heritage, Ireland. 260pp.
- IWDG (2015). Species profiles https://iwdg.ie/species/ .

3.4.2 Desk study results

Twenty-five species of cetacean have been recorded in the waters around Ireland. The Irish Whale and Dolphin Group (IWDG) holds 13 records of cetacean sightings within the inner and outer Shannon Estuary including Moneypoint for the period February 2024 to February 2025 (IWDG, 2025).

Species recorded include:

- Bottlenose dolphin (*Tursiops truncatus*)
- Common dolphin (*Delphinus delphis*)
- Harbour porpoise (*Phocoena phocoena*)
- Humpback whale (*Megaptera novaeangliae*)

No other cetacean species was recorded in the Shannon Estuary between February 2024 to February 2025.

Within the Shannon Estuary bottlenose dolphins were noted as the most frequently recorded species (24 sightings recorded between February 2024 and February 2025) with one common dolphin sighting recorded over the same time period. Five harbour porpoises were also sighted over the same time period (IWDG, 2025).

In November 2024, a humpback whale was identified off the coast of Killimer in the Shannon Estuary. The juvenile whale has been sighted feeding and breaching within the Shannon Estuary and as far up as Moneypoint (IWDG, 2025). Phase II of the Irish ObSERVE programme (2021-2023) was conducted to investigate the occurrence, distribution and abundance of key marine species in Ireland's offshore and coastal regions. These aerial surveys included four offshore areas and coastal waters. The Shannon Estuary is within the coastal survey stratum 6B.

Common dolphin, harbour porpoise and bottlenose dolphin are the most frequently sighted species throughout the Phase II ObSERVE survey programme (Giralt Paradell et al., 2024).

According to Giralt Paradell et al (2024), abundance estimates were typically lower for the coastal strata but high densities were derived from stratum 6B for bottlenose dolphins. Harbour porpoise was the second most frequently sighted cetacean and was recorded in the coastal strata including 6B. Common dolphin showed a preference for continental shelf waters in both coastal and offshore areas. Common dolphin was recorded in the coastal strata including 6B. There were no confirmed records of humpback whale during the Phase II surveys, although three records of unidentified large whales (>10m) were recorded. These sightings were recorded in the slope waters of the Porcupine Basin off the west coast of Ireland (Giralt Paradell et al., 2024).

According to the most recent Article 17 conservation assessment, bottlenose dolphin, common dolphin and harbour porpoise are deemed as being in favourable conservation condition, while the status of humpback whale is unknown (NPWS, 2019).

Management Unit (MU) boundaries, defined by the Inter Agency Marine Mammal Working Group (IAMMWG, 2015; 2022), refer to geographical areas in which the animals of a particular cetacean species are found, to which management of human activities is applied. These geographical areas are delineated based on the best scientific knowledge of the population structure of the species while taking into account jurisdictional boundaries or divisions which are already used for manging human activities (IAMMWG, 2023).

The following sections provide more detail on the most commonly recorded cetacean species within and around the Shannon Estuary.

3.4.2.1 Bottlenose dolphin

The Shannon Estuary is one of the most important areas for bottlenose dolphins in Ireland, and the species is a qualifying interest of the Lower River Shannon SAC. In addition, the IAMMWG Shannon Estuary (SHE) management unit (MU) is one of two management units in the Republic of Ireland recognised for bottlenose dolphin (IAMMWG, 2023). The SHE MU bottlenose dolphin is considered a distinct inshore population in western Irish waters (IAMMWG, 2023). Bottlenose dolphins are found throughout the estuary, but regular concentrations occur off Kilcredaun Head in the outer estuary and Tarbert-Killimer which is associated with foraging behaviour (Rogan et al., 2000). Previous surveys in 2002 (Ingram and Rogan, 2001), 2007 (Englund et al., 2007), 2010 (Berrow et al., 2010) and in 2018 (Rogan et al., 2018) have confirmed high site fidelity of dolphins within the Shannon Estuary.

The population of bottlenose dolphins in the Shannon Estuary is estimated at around 145 individuals with only 80 adults (Baker *et al*., 2018 in MERC, 2021). Rogan et al (2000) recorded bottlenose dolphins in the estuary all year round with a peak from May to September and noted the presence of neo-natal calves from July to September as evidence of a well-defined breeding season in the Shannon Estuary between June and September, with the peak calving period occurring in August (Ingram, 2000).In 2010, a cetacean desktop literature review was conducted to inform the Moneypoint Windfarm development planning application. This review noted that neonatal calves were recorded from July to September 2010 (same time period noted in Rogan et al., 2000 above), highlighting that the area is an important nursery area.

Large groups of bottlenose dolphins were frequently observed in the narrow waters at Kilcredaun and in the mouth of the estuary. This area has been identified as a 'Critical Area' for bottlenose dolphin within the Shannon Estuary (Ingram and Rogan, 2002). A second critical area was identified further east into the estuary around Moneypoint and Tarbert/ Killimer. Both of these areas are located in deep parts of the estuary within fast tidal currents (Ingram and Rogan, 2002). There are no density estimates for the Lower River Shannon Estuary SAC but equating the abundance of 145 individuals to the surface area of this SAC (683 km^2)[5] would give an estimate of 0.212 animals per km^2. Density estimates are available for the coastal waters along the west coast of Ireland, including coastal stratum 6B of the ObSERVE Phase II aerial project (Giralt Paradell et al., 2024). These data suggest that bottlenose dolphin occurs in densities of between 0.011 to 0.242 animals per km^2 (Giralt Paradell et al., 2024).

According to (Giralt Paradell et al., 2024), bottlenose dolphin was one of the most frequently sighted species throughout the survey. Bottlenose dolphins were observed occasionally in the coastal strata (6B) however abundance estimates were lower in the coastal strata in comparison to others. Mean group size varied between the strata but did not change between the seasons ranging from 3.9 to 4.2 individuals in summer to 4.4 in winter.

Bottlenose dolphins face threats such as underwater noise, interactions with fisheries through bycatch, industrial and agricultural pollutant contamination, disturbance from marine industrial activities, and harmful algal blooms (IWDG, 2015a).

3.4.2.2 Common dolphin

Common dolphins are frequently recorded off the western seaboard of Ireland with peak counts during summer (Wall et al., 2013), including off Loop and Kerry Heads. Common dolphins are present all year round in Irish waters. Although the highest concentrations are seen over the continental shelf and in deeper waters, they are frequently observed in shallow inshore waters off the southwest coasts and around the Aran Islands (IWDG, 2015b). However, very few sightings of common dolphin have been recorded in the Shannon Estuary with only one sighting between February 2023 and February 2024 (IWDG, 2025).

According to Giralt Paradell et al., (2024), the data recorded from coastal stratum 6B suggests that common dolphin occurs in densities of between 0.265 to 5.553 animals per km^2. Common dolphins showed interannual variability with more sightings during the summer of 2021 than in 2022, mean group sizes were also larger in the summer (7.2) compared to winter (6.7) (Giralt Paradell et al., 2024). Species were seen in all strata including stratum 6B. Common dolphins showed a preference for continental shelf waters, where they occurred both in coastal and offshore areas. Sightings in deeper waters beyond the continental shelf occurred occasionally, primarily in the Rockall and Porcupine basins (Giralt Paradell et al., 2024).

Common dolphins face threats such as underwater noise, interactions with fisheries through bycatch, ship strikes, chemical and plastic pollution (IWDG, 2015b). Common dolphins have been assigned to a single MU, the Celtic & Greater North Seas MU, which covers the Shannon Estuary (IAMMWG, 2022). From the lack of recorded sightings of common dolphin within the Shannon Estuary, it is likely that they largely avoid the area. As a result, it is considered unlikely for common dolphin to be encountered within the SI works area during operations.

3.4.2.3 Harbour porpoise

Harbour porpoise is widespread around the Irish coast (Wall et al., 2013) and the IAMMWG Celtic and Irish Seas (CIS) MU is recognised for the management of harbour porpoise in Celtic and Irish waters (IAMMWG,

[5] https://eunis.eea.europa.eu/sites/IE0002165 accessed February 2025

2023). Abundance of harbour porpoise in the CIS MU is estimated at 62,517 animals (IAMMWG, 2022). However, very few sightings of harbour porpoise have been recorded within the Shannon Estuary, with five recorded sightings between February 2024 and February 2025 (IWDG, 2025). According to (Giralt Paradell et al., 2024), the data recorded from coastal stratum 6B suggests that harbour porpoise occurs in coastal waters along the west coast of Ireland in densities of between 0.043 to 0.21 animals per km^2. Violent interactions have been recorded between bottlenose dolphins and harbour porpoise (Ross and Wilson, 1996; Gross et al., 2020) and suggested reasons for this aggression include interspecies territoriality, defence of group members, food competition, feeding interference and object-orientated play (Gross et al., 2020). From the lack of recorded sightings of harbour porpoise within the Shannon Estuary, it is likely that they largely avoid the area. As a result, it is considered unlikely for harbour porpoise to be encountered within the SI works area during operations.

3.4.2.4 Humpback whale

Irish sightings of humpback whales are mainly off the west and south coast of Ireland, with sightings increasing in summer to peak in September, declining after this period (NBDC, 2025b, Berrow et al., 2010). According to (Paradell et al., 2024), there were no confirmed sightings of humpback during the survey however three unidentified large whales were noted which could potentially be humpback whales. These recordings were sighted off the Porcupine Basin slope waters. The population is not part of a MU.

In November 2024, one juvenile humpback whale was recorded within the Shannon Estuary, feeding and breaching regularly. As of February 2025, the juvenile whale remains within the estuary and has been seen as far inshore as Moneypoint and Tarbert.

3.4.2.5 Turtle Species

Four Annex IV species of turtle are known to occur in Ireland: leatherback turtle (*Dermochelys coriacea*), loggerhead turtle (*Caretta caretta*), Kemp's Ridley turtle (*Lepidochelys kempii*) and hawksbill turtle (*Eretmochelys imbricata*). Leatherback turtle has been reported on a number of occasions around the Irish coastline and in the Irish Sea, most recently in 2025. Between 2000 and 2025, 1060 observations of leatherback turtles were recorded in Irish waters (NBDC, 2025c). Leatherbacks are known to have an 'atypical migration pattern', as while they must return to tropical waters to breed and reach preferred nesting grounds, they are known to spend the summer months in productive temperate waters, like Ireland's, feeding on jellyfish and sea squirts (Doyle, 2007). A leatherback turtle at the mouth of the Shannon Estuary about 2 miles east of Loop Head, Co. Clare was reported to IWDG in June 2007[6]. Most records of leatherback turtle are reported in coastal waters, and rarely within estuaries.

Loggerhead turtle has been recorded all along the west coast of Ireland[7] and between 2000 and 2025, 45 observation of loggerhead turtles were recorded in Irish waters (NBDC, 2025d), however, only one loggerhead turtle has been observed in the vicinity of the Shannon Estuary at Kilbaha, Loop Head in 1998 (NBDC, 2025d).

Other turtle species have been less commonly observed in Irish waters. The last record of hawksbill turtle (*Eretmochelys imbricata*) in Ireland was in 1983[8] off the coast of Cork, and the closest recorded sighting of Kemps Ridley turtle (*Lepidochelys kempii*) was in 1992 at Banna Strand in Co. Kerry (NBDC, 2025e). Kemps Ridley turtle has been recorded all along the west coast of Ireland and between 2000 and 2025, 3 observations of Kemps Ridley turtles were recorded in Irish waters (NBDC, 2025e).

It can, therefore, be concluded that the occurrence of turtles in Irish waters is rare, with the leatherback and loggerhead turtles the most common species. These species are most commonly observed in coastal waters and are not generally found in estuaries. No turtle sightings have been recorded in the vicinity of the proposed SI works in the Shannon Estuary.

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[6] Leatherback Turtles now arrived | Irish Whale and Dolphin Group (iwdg.ie).

[7] https://maps.biodiversityireland.ie/Map/Terrestrial/Species/128438 Accessed online 20 March 2025

[8] https://maps.biodiversityireland.ie/Species/128441 Accessed online 20 March 2025

3.4.3 Desk study summary

The above section discusses the species most likely to be found within the Shannon Estuary based on desk-based research. However, all cetaceans are considered in the examination of impacts and are assessed in Section 3.5 below, grouped according to hearing frequency (see Table 3-1).

3.5 Examination of Impacts to Strict Protections for Annex IV Species

With respect to cetaceans, the following potential routes to impact are associated with the proposed marine SI works:

- Underwater noise; and
- Collision risk with survey vessels.

3.5.1 Underwater Noise Impacts

3.5.1.1 Underwater noise assessment

An underwater (subsea) noise assessment was carried out using indicative noise sources for the marine SI works. The assessment and results are presented in the accompanying Subsea Noise Technical Report in Appendix A.

When assessing the potential impact of underwater noise sources on the marine environment a range of variables such as source level, frequency, duration, and directivity were considered. Increasing the distance from the sound source usually results in attenuation with distance. The factors that affect the way noise propagates underwater include water column depth, pressure, temperature gradients, salinity, as well as water surface and seabed type and thickness. When sound encounters the seabed the amount of noise/sound reflected back depends on the composition of the seabed, i.e., mud or other soft sediment will reflect less than rock. The sediment within this region of the Shannon Estuary is mainly sand to fine/medium gravel, and maximal depths are c. 60 m (assuming high tide).

Assessment Criteria

The NPWS/DAHG "Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters" 2014 (Department of Arts, Heritage and the Gaeltacht, 2014) contains the following statement:

"It is therefore considered that anthropogenic sound sources with the potential to induce TTS in a receiving marine mammal contain the potential for both (a) disturbance, and (b) injury to the animal."

This states that TTS constitutes an injury and should thus be the main assessment criteria[9]. However, the guidance goes on to specify the use of thresholds from a 2007 publication (Southall, 2007), which has since been superseded (Southall, et al., 2019; National Oceanic and Atmospheric Administration, 2024) and no longer represents best available science, nor reflects best practice internationally. Thus, the following excerpt from the guidance is relevant:

"The document will be subject to periodic review to allow its efficacy to be reassessed, to consider new scientific findings and incorporate further developments in best practice."

As there has been no such update to date, but the guidance clearly states its intention to consider new scientific findings, we have applied the latest guidance (National Oceanic and Atmospheric Administration, 2024), reflecting the current best available method for assessing impact from noise on marine mammals. This means that it is "AUD INJ" (previously "PTS") that is the criteria for injury, not "TTS".

Auditory injury (AUD INJ) in cetaceans can be defined as the area where the sound level is sufficient to cause permanent hearing loss in an animal. At even closer ranges, and for very high intensity sound sources

[9] Injury being the qualifying limit in the Irish Wildlife Act 1976, section 23, 5c : https://www.irishstatutebook.ie/eli/1976/act/39/enacted/en/print#sec23

(e.g., underwater explosions), physical trauma or acute mortal injuries are possible. TTS involves short term changes (minutes to few hours) in hearing sensitivity which may, or may not, reduce fitness and survival. Impairment of hearing may affect the ability of animals to capture prey and avoid predators, and also cause deterioration in communication between individuals, affecting growth, survival, and reproductive success. After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure.

Cetacean species can be split into functional hearing groupings, according to their frequency-specific hearing sensitivity (NOAA, 2024). Minke, fin and humpback whales are considered low frequency cetaceans (LF), common, bottlenose and Risso's dolphin are considered high frequency cetaceans (HF), and harbour porpoise a very high frequency cetacean (VHF). See Table 3-1 below for a list of cetacean species contained within each functional hearing group.

Table 3-1 Functional Hearing Groups for Marine Mammal Species

NOAA (2024) Hearing Group Name	Species Included in Group
Low-frequency cetaceans (LF)	Baleen whales (minke, fin and humpback whale).
High-frequency cetaceans (HF)	Most toothed whales and dolphins (bottlenose, common and Risso's dolphin, killer, and pilot whales).
Very high-frequency cetaceans (VHF)	Certain toothed whales and porpoises (harbour porpoise).
Other marine carnivores in water (OCW)	Includes sea lions, walrus, otters.
Phocid carnivores in water (PCW)	Earless seals (including harbour and grey seal).

A summary of the equipment likely to be used in the SI Works is presented in Table 4.1 of the accompanying Subsea Noise Technical Report.

Should the noise levels from sources provided in the accompanying Subsea Noise Technical Report exceed the thresholds (Table 3-2 below), there is the potential for underwater noise generated during the geophysical survey to result in injury and/or disturbance to Annex IV cetacean species in the vicinity of the SI works.

Both the criteria for impulsive and non-impulsive sound are relevant given the nature of the sound sources used during the SI Works. The relevant AUD INJ and TTS criteria proposed by NOAA (2024) are summarised in Table 3-2 which addresses peak pressure levels (L_p) and sound exposure levels (SEL).

Table 3-2 AUD INJ and TTS thresholds (National Oceanic and Atmospheric Administration, 2024)

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		AUD INJ	TTS	AUD INJ	TTS
Low frequency (LF) cetaceans	L_P, (unweighted)	222	216	-	-
	SEL, (weighted)	183	168	197	177
High frequency (HF) cetaceans	L_P, (unweighted)	230	224	-	-
	SEL, (weighted)	193	178	201	181
Very high frequency (VHF) cetaceans	L_P, (unweighted)	202	196	-	-
	SEL, (weighted)	159	144	181	161
Phocid carnivores in water (PCW)	L_P, (unweighted)	223	217	-	-
	SEL, (weighted)	183	168	195	175
Other marine carnivores in water (OCW)	L_P, (unweighted)	230	224	-	-
	SEL, (weighted)	185	170	199	179
	L_P, (unweighted)	225	219	-	-

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		AUD INJ	TTS	AUD INJ	TTS
Sirenians (SI) (NOAA only)	SEL, (weighted)	186	171	186	180

Assessment Results – Geophysical Survey

To assess the impacts of the geophysical survey for MBES and SBP, two depth scenarios were assessed in order to understand underwater impacts in different depths within the Shannon Estuary. The deep scenario considered a depth of 60 m, while the shallow scenario assessed depth <20 m. The results have been summarised below to present the 'worst-case scenario', and it should be noted that no mitigation (i.e. soft-start measures, or marine mammal observers) has been applied at this stage.

Geophysical: Deep, no mitigation

- LF group (minke, fin and humpback whale), auditory injury and TTS could occur <10 m from the sound source. Behavioural disturbance could occur out to 2 km.
- HF group (bottlenose/common dolphin), auditory injury and TTS could occur <10 m from the sound source. Behavioural disturbance could occur out to 8 km.
- VHF group (harbour porpoise), auditory injury could occur within 210 m of the sound source, while TTS could occur within 280 m. Behavioural disturbance could occur out to 2 km.

Geophysical: Shallow, no mitigation

- LF group (minke, fin and humpback whale), auditory injury and TTS could occur <10 m from the sound source. Behavioural disturbance could occur out to 3 km.
- HF group (bottlenose/common dolphin), auditory injury and TTS could occur <10 m from the sound source. Behavioural disturbance could occur greater than 10 km.
- VHF group (harbour porpoise), auditory injury could occur within 240 m of the sound source, while TTS could occur within 350 m. Behavioural disturbance could occur out to 2 km

The geophysical survey could give rise to risk ranges for both TTS and auditory injury of <10 m for all hearing groups except the VHF group, where auditory injury could occur within 240 m of the sound source and TTS within 350 m (worst-case scenario: shallow, no mitigation applied). Therefore, for harbour porpoise (VHF group) the maximum area of impact for auditory injury would be 0.18 km^2 (based on a radius of 240 m). This range is mainly determined by the parametric SBP. The baseline characterisation showed that harbour porpoise is unlikely to be encountered in the Shannon Estuary and therefore, the risk of auditory injury is very low. Coastal densities of harbour porpoise (i.e. outside the Shannon Estuary) were predicted to be in the region of 0.043 to 0.21 animals per km^2 (Giralt Paradell et al., 2024) and applying the highest estimate, the maximum number of animals affected would be <1 individual. Any potential injury to harbour porpoise can be compared against the population of the CIS MU of 62,517 animals and therefore, in the unlikely event of injury to harbour porpoise, this would constitute a very small proportion of the MU population (i.e. 0.001%). As discussed previously, it is unlikely that harbour porpoise will occur within the Shannon Estuary.

The HF hearing group (which includes bottlenose dolphins) has minimal starting ranges to avoid auditory injury at <10 m for all geophysical survey sources. Therefore, the maximum area of impact would be 0.001 km^2 (based on a radius of 10 m). Bottlenose dolphin is known to occur within the Shannon Estuary and the population of this species has an estimated size of 145 animals with an estimated density of 0.212 animals per km^2. Applying this estimate, there is considered to be low risk of encountering an animal(s) within the impacted area (i.e. 0.0003 animals within 0.001 km^2 = 0.0002% of the MU). Therefore, whilst any effects to individuals are compared against a relatively small population size and could therefore be meaningful in this respect, the risk is considered to be low due to the small impact ranges predicted.

The density of humpback whale within the Shannon Estuary can be assumed to be 0.004 animals per km^2 (based on 1 individual against the surface area of the SAC, 683 km^2). Similar to bottlenose dolphin, the geophysical survey impact ranges for humpback whale are very low (< 10 m), giving a maximum area of impact of 0.001 km^2. However, as only one animal has been sighted within the Shannon Estuary, it is assumed on a precautionary basis, that one individual has the potential to be affected, within an area of 0.001 km^2. Therefore, whilst any effects to individuals are compared against a relatively small population size and could therefore be meaningful in this respect, the risk is considered to be low due to the small impact ranges predicted.

Behavioural disturbance effects range from 2 km to 10 km for the geophysical survey. Behavioural disturbance thresholds assume that no other vessels are present, which is not the case within the Shannon Estuary. In reality, behavioural disturbance effects will extend only as far as the next vessel transiting through the estuary. Given that only geophysical survey vessel will be used during operations, it is considered likely that any behavioural effects will short term and intermittent, and that cetaceans will be habituated to behavioural disturbance, in line with the background level of vessel activity within the estuary. There is anticipated to be high potential for the rapid recovery of populations to baseline levels upon completion of the surveys such that there are no implications in the long-term for cetacean populations. Therefore, the risk of behavioural disturbance to cetaceans is considered to be low.

Assessment Results – Geotechnical Survey

To assess the impacts of the geotechnical survey, two depth scenarios were assessed i.e. deep which included a DP vessel up to 80 m in length, USBL, vibrocoring, CPT and ROV operations, and shallow which included a tug/JUB vessel up to 15 m, vibrocoring and CPT. The results have been summarised below to present the ‘worst-case scenario’, and it should be noted that no mitigation has been applied at this stage.

Geotechnical: Deep, no mitigation

- LF group (minke, fin and humpback whale), auditory injury could occur <20 m from the sound source, while TTS could occur within 1 km. Behavioural disturbance could occur greater than 10 km.
- HF group (bottlenose/common dolphin), auditory injury could occur <10 m from the sound source, while TTS could occur within 50 m. Behavioural disturbance could occur greater than 10 km.
- VHF group (harbour porpoise), auditory injury could occur within 250 m of the sound source, while TTS could occur within 3 km. Behavioural disturbance could occur greater than 10 km.

Geotechnical: Shallow, no mitigation

- LF group (minke, fin and humpback whale), auditory injury could occur <10 m from the sound source, while TTS could occur within 2 km. Behavioural disturbance could occur greater than 10 km.
- HF group (bottlenose/common dolphin), auditory injury could occur <10 m from the sound source, while TTS could occur within 60 m. Behavioural disturbance could occur greater than 10 km.
- VHF group (harbour porpoise), auditory injury could occur <10 m from the sound source, while TTS could occur within 3 km. Behavioural disturbance could occur greater than 10 km.

While worst-case scenario assessment (deep geotechnical, no mitigation) results for geotechnical survey works show ranges exceeding auditory injury thresholds for harbour porpoise (VHF) out to 250 m and TTS thresholds out to 3 km, the principal noise is related to the DP-enabled survey vessel itself. The Lower Shannon Estuary is a busy shipping area, and Moneypoint is one of six terminals within the Shannon Estuary that handle up to 1,000 ships carrying 12 million tons of cargo per annum (Clare County Council, 2023). Moneypoint accepts on average six to eight shipments per year. Cetacean species, and in particular, bottlenose dolphins, are likely to be habituated to marine traffic, and the low increase in vessel traffic as a result of the proposed surveys.

As discussed previously, it is unlikely that harbour porpoise will occur within the Shannon Estuary, however, as a precautionary measure, the maximum number of individuals with the potential to be injured by the geotechnical SI works has been calculated. The maximum area of impact for auditory injury would be 0.20 km^2 (based on a radius of 250 m). The baseline characterisation showed that harbour porpoise is unlikely to be encountered in the Shannon Estuary and therefore, the risk of auditory injury is very low. Coastal densities of harbour porpoise (i.e. outside the Shannon Estuary) were predicted to be in the region of 0.043 to 0.21 animals per km^2 (Giralt Paradell et al., 2024) and applying the highest estimate, the maximum number of animals affected would be <1 individual. Any potential injury to harbour porpoise can be compared against the population of the CIS MU of 62,517 animals and therefore, in the unlikely event of injury to harbour porpoise, this would constitute a very small proportion of the MU population (i.e. 0.001%).

The HF hearing group (which includes bottlenose dolphins) has minimal starting ranges to avoid auditory injury at <10 m from the geotechnical survey vessel. Therefore, the maximum area of impact would be 0.001 km^2 (based on a radius of 10 m). Bottlenose dolphin is known to occur within the Shannon Estuary and the population of this species has an estimated size of 145 animals with an estimated density of 0.212 animals per km^2. Applying this estimate, there is considered to be low risk of encountering an animal(s) within the impacted area (i.e. 0.0003 animals within 0.001 km^2 = 0.0002% of the MU). Therefore, whilst any effects to individuals are compared against a relatively small population size and could therefore be meaningful in this respect, the risk is considered to be low due to the small impact ranges predicted.

The density of humpback whale within the Shannon Estuary can be assumed to be 0.004 animals per km^2 (based on 1 individual against the surface area of the SAC, 683 km^2). Similar to bottlenose dolphin, the geophysical survey impact ranges for humpback whale are very low (< 10 m), giving a maximum area of impact of 0.001 km^2. However, as only one animal has been sighted within the Shannon Estuary, it is assumed on a precautionary basis, that one individual has the potential to be affected, within an area of 0.001 km^2. Therefore, whilst any effects to individuals are compared against a relatively small population size and could therefore be meaningful in this respect, the risk is considered to be low due to the small impact ranges predicted.

Behavioural disturbance effects may be greater than 10 km for the geotechnical survey. Behavioural disturbance thresholds assume that no other vessels are present, which is not the case within the Shannon Estuary. In reality, behavioural disturbance effects will extend only as far as the next vessel transiting through the estuary. Given that a maximum of two survey vessels will be used during geotechnical operations, it is considered likely that any behavioural effects will short term and intermittent, and that cetaceans will be habituated to behavioural disturbance, in line with the background level of vessel activity within the estuary. There is anticipated to be high potential for the rapid recovery of populations to baseline levels upon completion of the surveys such that there are no implications in the long-term for cetacean populations. Therefore, the risk of behavioural disturbance to cetaceans is considered to be low.

3.5.1.2 Mitigation

The mitigation measures proposed will reduce the impact of auditory injury and TTS on cetaceans from the proposed SI works (reproduced from Section 7 in the accompanying Subsea Noise Technical Report).

Geophysical surveys

The geophysical survey could give rise to risk ranges for both TTS and auditory injury of <10 m for all hearing groups except the VHF group, where auditory injury could occur within 240 m of the sound source and TTS within 350 m (worst-case scenario: shallow, no mitigation applied).

Given the risk of exceedance of the auditory injury thresholds significant ranges, the following mitigation, in line with DAHG (2024), will be applied to limit risks to animals, by establishing their likely absence from the zone of injury prior to commencement of the noisy activity (pre-start monitoring) and by providing enough time for them to vacate the area (soft start).

A qualified and experienced marine mammal observer (MMO) will be appointed to monitor for marine mammals within the monitored zone i.e. 500 m radial distance of the sound source intended for use. The 500 m pre-start-up survey will be conducted at least 30 minutes before the sound-producing activity, i.e. those activities described in Section 2.2 are due to commence. Sound-producing activity shall not commence until at least 30 minutes have elapsed with no marine mammals detected within the monitored zone (500 m) by the MMO. In commencing sound producing activities using the equipment listed above, a 20-minute soft start procedure must be used. Once the soft start procedure commences, there is no requirement to halt or discontinue the procedure at night-time, nor if weather or visibility conditions deteriorate nor if marine mammals occur within a 500 m radial distance, of the sound source. If there is a break in sound output for a period greater than 30 minutes (e.g., due to equipment failure, shut-down, survey line or station change) then all pre-start monitoring and a subsequent soft start procedure (where appropriate following pre-start monitoring) must be undertaken, in cognisance of DAHG (2014). These measures will ensure that impacts on cetaceans will be reduced to the lowest possible level to ensure there is no significant risk to marine mammals from impulsive noise.

The absence of a USBL for the geophysical surveys, means that the risk ranges for threshold exceedance are lower than for other geophysical surveys where a USBL would be used to determine the location of towed equipment i.e., for towfish deployment (SSS or towed SBP). USBLs are relatively loud at frequencies of greatest sensitivity for the HF and VHF groups, so the absence of this device for the geophysical survey decreases the noise at these critical frequencies. The choice to use a hull mounted parametric SBP means that the main sound energy is either very high frequency noise (attenuates rapidly) or very focused (the secondary interference beam characteristic of a parametric SBP), leading to limited effect ranges.

Given the risk ranges for the VHF group of 240 m for auditory injury, and 350 m for TTS, the following soft start is proposed for geophysical survey, in cognisance with DAHG (2014):

- Using the inbuilt ramp-up of the parametric SBP for a 20-minute period, auditory risk ranges are reduced to 170m and TTS risk ranges are reduced to 260 m for the VHF group (i.e. harbour porpoise).

Harbour porpoise is not expected to be present within the Shannon Estuary (see Section 3.4.2.3). Risk ranges for other hearing groups (HF; bottlenose dolphin and LF; humpback whale) are <10 m without soft start applied, however, the above soft start will be applied as a precautionary measure.

Geotechnical surveys

For the shallow geotechnical survey, auditory injury risk ranges for all hearing groups are <10 m from the sound source. Risk ranges for exceedance of TTS thresholds are within 60 m for the HF group to within 3 km for the VHF group. TTS risk ranges for LF group are within 2 km.

For the deep geotechnical survey, ROV operations and using a USBL, the auditory injury ranges are within 250 m for the VHF group, 20 m for the LF group and less than 10 m for the remaining hearing groups. Risk ranges for TTS are within 50 m for HF group, within 3 km for VHF group and within 1 km for the LF group.

The principal noise during the geotechnical SI works is the vessel itself, and the noise of the modelled DP vessel is similar to the large vessels frequently navigating the same area in the Shannon Estuary. The similarity of the noise produced by this activity to the existing vessel noise in the area means that while the activity is assessed as having potential to cause auditory injury/TTS, this does not constitute a substantial change to the existing underwater noise environment. Therefore, the noise from the vessel itself is likely to deter animals beyond the predicted injury and TTS zones. For TTS and behavioural disturbance effects, the ranges of effect are also localised and any effects that do occur will be short-term and reversible.

For geotechnical SI works a qualified and experienced MMO will be appointed to monitor for marine mammals within the monitored zone i.e. 500 m radial distance of the sound source intended for use. The 500 m pre-start-up survey will be conducted at least 30 minutes before the sound-producing activity, i.e. those activities described in Section 2.2 are due to commence. Sound-producing activity shall not commence until at least 30 minutes have elapsed with no marine mammals detected within the monitored zone (500 m) by the MMO.

These measures will ensure that impacts on cetaceans will be reduced to the lowest possible level to ensure there is no significant risk to marine mammals from noise-producing survey works.

3.5.1.3 Underwater noise assessment conclusion

For the geophysical survey, given the use of a parametric SBP and the absence of a USBL/HiPAP device, the risk ranges for the VHF hearing group of TTS is within 350 m and auditory injury within 240 m of the sound source. The remaining hearing groups (HF and LF) have risk ranges for TTS and auditory injury <10 m without the application of any mitigation measures. With the implementation of a 20-minute soft-start of the parametric SBP, TTS risk range is reduced to within 260 m and auditory injury is less than 170 m of the sound source for VHF hearing group. With this reduced injury range, a maximum injury risk zone of 0.09 km^2 for harbour porpoise is predicted, with an estimated <1 individual affected, which constitutes a very small proportion of the MU population (i.e. <0.001%). For bottlenose dolphin, an estimated 0.0002% of the MU is predicted to be affected. An MMO will be in place to ensure no marine mammals are detected within 500 m of the vessel prior to works commencing.

For the geotechnical SI works, risk ranges for the VHF hearing group for auditory injury are within 250 m of the sound source and TTS is within 3 km. Risk ranges for auditory injury for HF hearing group are less than 10 m of the sound source and within 60 m for TTS. For LF hearing group auditory injury and TTS risk ranges are within 20 m of the sound source and 2 km respectively. As stated above, the principal noise associated with the geotechnical surveys is the vessel itself, and cetaceans within the Shannon Estuary are expected to be habituated to vessel noise. It is expected that the presence of the vessel will act as a deterrent, giving cetaceans time to move away from the vessel prior to works commencing, and an MMO will be in place to ensure no marine mammals are detected within 500 m of the vessel prior to works commencing.

As stated above, behavioural disturbance effects were modelled out to >10 km of the sound source, however, the available thresholds for behavioural disturbance assume that no other vessels are present, and do not take into account habituation of species to survey vessels. Behavioural effects are therefore expected to be short term and intermittent, with rapid recovery of populations to baseline levels upon completion of the surveys such that there are no implications in the long-term for cetacean populations.

3.5.2 Collision Risk

Vessel strikes are a known cause of mortality in cetaceans (Laist et al., 2001). Non-lethal collisions have also been documented (Laist et al., 2001; Van Waerebeek et al., 2007). Injuries from such collisions can be divided into two broad categories: blunt trauma from impact and lacerations from propellers. Injuries may result in individuals becoming vulnerable to secondary infections or predation.

It is expected that only one vessel will be operating at any one time. The geotechnical SI works will be carried out a separate campaign to the geophysical SI works, and therefore, there will be no overlap. Visual inspection surveys (including potential ROV deployment) may also be carried out as a separate survey campaign.

During geophysical surveys, the vessel will be travelling in a predefined trajectory and at a low speed of typically 4 knots during surveying, with a transit speed of 10 knots. It is considered that this low survey speed will allow animals to predict the movement of the vessels and therefore avoid collisions. During geotechnical sampling, the survey vessel(s) will be stationary for extended periods throughout their operations which will reduce the potential for collision with these vessels.

It is expected that animals in the Shannon Estuary are likely habituated to marine traffic transiting within the estuary. As stated in Section 2.1, the Shannon Estuary handles up to 1,000 ships per annum, a car and passenger ferry operates between Killimer and Tarbert all year-round while fishing activity and recreational activity is common throughout the year. It is, therefore, reasonable to assume that cetaceans in the area are exposed to vessel traffic on a regular basis and may exhibit some habituation. In addition, the increase in vessel traffic at any one time is considered to be very low (i.e. one vessel operating). On this basis it is predicted that collisions between survey vessels and cetaceans will be extremely unlikely and there is no likelihood of significant effects occurring.

4 Summary & Conclusion

In summary, the potential for injury or disturbance to occur to Annex IV cetacean species as a result of the SI works is considered to be low. This risk will be further reduced by the implementation of mitigation, as outlined in this document and in cognisance of the Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters (DAHG, 2014).

It is concluded that the SI works will not deliberately capture or kill any cetacean or turtle species listed under Annex IV of the Habitats Directive. The SI works will not disturb Annex IV cetacean or turtle species during periods of breeding or migration, and breeding or resting places of such Annex IV species will not be damaged or destroyed with the inclusion of the mitigation measures stated above in Section 3.5.1.2. The conservation status of the Annex IV cetacean or turtle species will not be impacted by the proposed SI works. The habitat available to Annex IV cetacean or turtle species will also continue to be sufficiently large to maintain its populations on a long-term basis.

Following the assessment of the evidence base and available information on Annex IV cetacean and turtle species, it is concluded that the SI works comply with the system of strict protections afforded by Article 12 of the Habitats Directive and Regulations 51 and 52 of the European Communities (Birds and Natural Habitats) Regulations 2011, as amended.

It is concluded that the proposed SI works will not give rise to significant impacts to marine species listed under Annex IV of the Habitats Directive.

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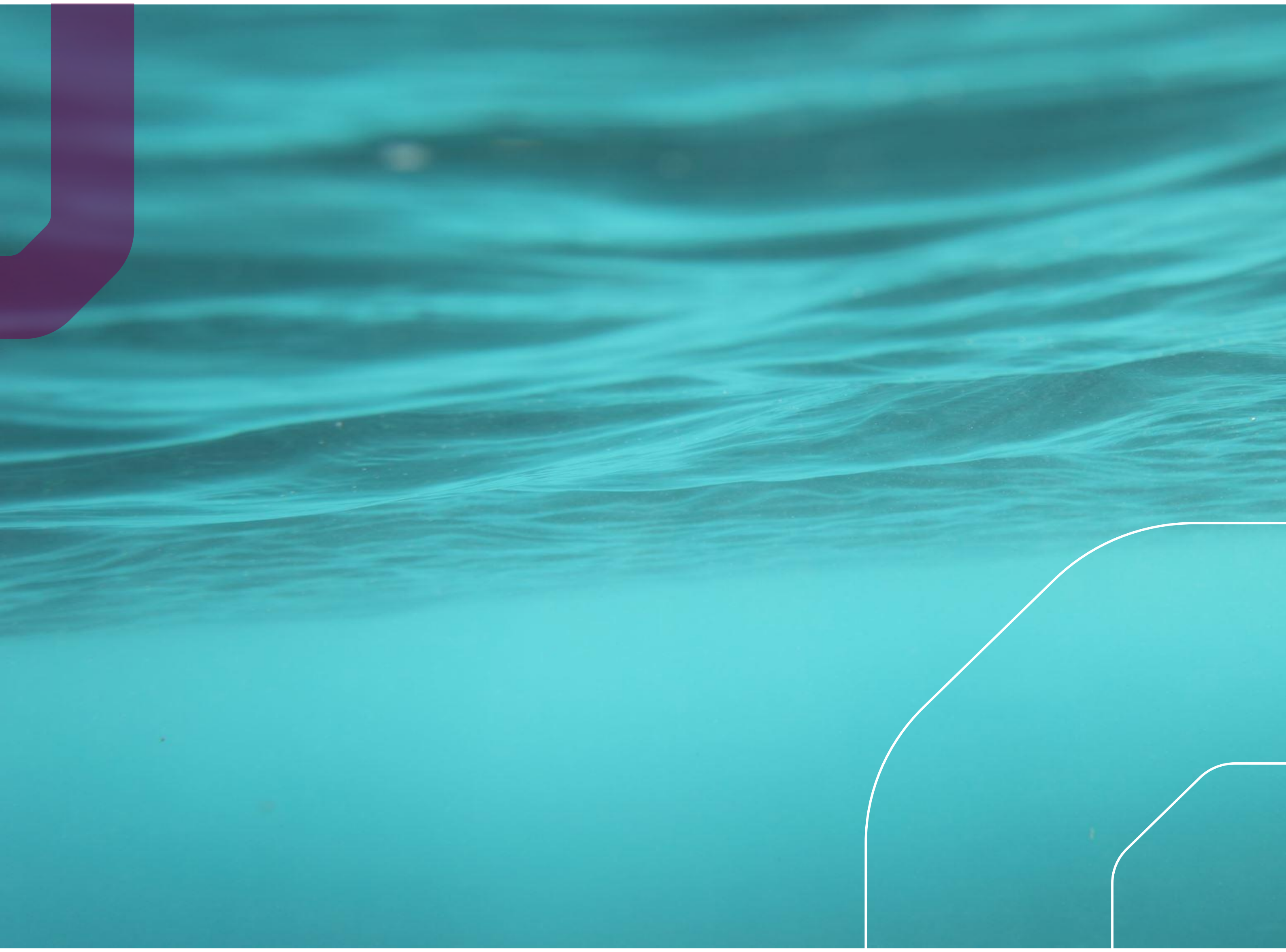
Appendix A
Subsea Noise Technical Report

C2 - Restricted

ESB CROSS SHANNON CABLE PROJECT

Survey Works – Subsea Noise



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REPORT

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1 INTRODUCTION

1.1 Overview

The Cross Shannon 400 kV Cable Project involves the laying of a new 400 kV cable across the Shannon Estuary (in the seabed) between the Moneypoint 400 kV Electricity Substation in the townland of Carrowdotia South County Clare and Kilpaddoge 220/110 kV Electricity Substation in the townland of Kilpaddoge County Kerry. The connection at Moneypoint will be at the existing substation on ESB lands. The connection at Kilpaddoge requires an extension of 5,500 m^2 to the existing substation on ESB lands.

The proposed development will involve the installation and operation of an additional cable crossing of the Shannon Estuary between the existing transmission substation on the site of the existing electricity generating station at ESB Moneypoint (north side of the Shannon estuary, near Killimer in County Clare) and a new 400/220 kV transformer at the transmission substation at Kilpaddoge (south side of the Shannon estuary near Tarbert in County Kerry).

ESB intends to undertake a survey campaign in the marine area at Moneypoint to inform the engineering design of the proposed Shannon Estuary 400 kV Cable Project. The marine surveys will mainly be a geophysical survey, but an assessment of a geotechnical survey has been included here as this might be proposed at a later stage.

Where anomalies in the seabed are found, a remotely operated vehicle (ROV) might be deployed from a dynamic positioning (DP) vessel to survey for archaeological interests.

1.2 Purpose of the Report

This Subsea Noise Technical Report presents the results of a desktop study considering the potential for Momentary, Brief and Temporary effects[1] of underwater noise on the marine environment from the site investigation works, which include geophysical and geotechnical surveys to map the application area (hereafter referred to as “the Project”). The site forms a single contiguous area of approximately 9 km^2, or a ~1.3 km wide band of 6 km length along the north edge of the Shannon Estuary, near the Moneypoint power station, 5 km south-east of Kilrush, Co. Clare.

The activities necessary to complete the Project emit noise that has the potential to have adverse effects on marine life. At close ranges from a noise source with high noise levels, permanent hearing injury or brief hearing impairment may occur to marine species, while at a very close range gross physical trauma is possible. At long ranges (several kilometres), the introduction of any additional noise could, for the duration of the activity, potentially cause behavioural changes. For example, changes to the ability of species to communicate and to determine the presence of predators, food, underwater features and obstructions.

This report provides an overview of the potential effects due to underwater noise from the Project on the surrounding marine environment based on the NMFS/NOAA 2024 and Popper et al. 2014 framework for assessing impact from noise on marine mammals and fishes and well as an assessment of likely ranges for behavioural effects.

Consequently, the primary purpose of the subsea noise assessment is to predict the likely range of onset of injury as given in the relevant guidance (AUD INJ) and ranges to potential behavioural effects due to anthropogenic noise as a result of the Project.

1.3 Statement of Authority

This report has been prepared by RPS on behalf of the ESB. The technical competence of the authors is outlined below:

Rasmus Sloth Pedersen is a Senior Scientist with RPS. He holds a master’s degree in biology, biosonar and marine mammal hearing from University of Southern Denmark. Rasmus has over 10 years’ experience

[1] Effects are defined in accordance with the EPA Guidelines on the information to be contained in Environmental Impact Assessment Reports (2022), Table 3.4 Description of Effects, pp.50-52.

as a marine biologist and over 8 years' experience with underwater noise modelling and marine noise impact assessments. Rasmus has co-developed commercially available underwater noise modelling software, as well as developed multiple source models for e.g. impact piling, seismic airgun arrays and sonars. Rasmus is a member of the Institute of Acoustics and a chartered scientist with the Institution of Environmental Sciences.

John Mahon is a Senior Associate in Acoustics with RPS. He holds a BA BAI in Mechanical Engineering from Trinity College Dublin (2004) and a PhD in Acoustics and Vibration from Trinity College Dublin (2008). He is a Chartered Engineer with Engineers Ireland. John has 20 years' experience in environmental projects including planning applications and environmental impact assessments for a wide range of strategic infrastructure projects.

Gareth McElhinney is a Technical Director in the Environmental Services Business Unit in RPS. He has over 24 years' experience. He holds an honours degree in Civil Engineering (B.E.) from NUI, Galway, a postgraduate diploma in Environmental Sustainability from NUI, Galway, and a Master's in Business Studies from the Irish Management Institute/ UCC. Gareth is also a Chartered Engineer. He has managed the delivery of numerous environmental projects including marine and terrestrial projects that have required environmental impact assessment, appropriate assessment and Annex IV species reports.

Sean Mansfield is a Scientist in Acoustics with RPS. He holds a BA (Hons) in Music Technology from Maynooth University and a Postgraduate Diploma in Acoustics and Noise Control from the Institute of Acoustics. He has over two years' experience working in a wide range of environmental areas, including road, rail, offshore wind, industrial, flood relief, underwater noise, and bat acoustics analysis projects. He is an associate member of the Institute of Acoustics and the Institution of Environmental Sciences.

2 ASSESSMENT CRITERIA

2.1 General

To determine the potential spatial range of injury and disturbance, assessment criteria have been developed based on a review of available evidence including national and international guidance and scientific literature. The following sections summarise the relevant assessment criteria and describe the evidence base used to derive them.

Underwater noise has the potential to affect marine life in different ways depending on its noise level and characteristics. Assessment criteria generally separate sound into two distinct types, as follows:

- **Impulsive sounds** which are typically transient, momentary (less than one second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay (ANSI, 2005; ANSI, 1986; NIOSH, 1998). This category includes sound sources such as seismic surveys, impact piling and underwater explosions. Additionally included here are sounds under 1 second in duration with a weighted kurtosis over 40 (see note below*).
- **Non-impulsive** (and continuous) sounds which can be broadband, narrowband or tonal, momentary, brief or prolonged, continuous or intermittent and typically do not have a high peak sound pressure with rapid rise/decay time that impulsive sounds do (ANSI, 1995; NIOSH, 1998).This category includes sound sources such as continuous vibro-piling, running machinery, some sonar equipment and vessels. Additionally included here are sounds over 1 second in duration with a weighted kurtosis under 40 (see note below*).

* Note that the European Guidance: “Monitoring Guidance for Underwater Noise in European Seas, Part II: Monitoring Guidance Specifications” (MSFD Technical Subgroup on Underwater Noise, 2014) includes sonar as impulsive sources (see Section 2.2 in the reference). However, the guidance suggests that *“all loud sounds of duration less than 10 seconds should be included”* as impulsive.

This contradicts research on impact from impulsive sounds suggesting that a limit for “impulsiveness” can be set at a kurtosis[2] of 40 (Martin, et al., 2020). See examples in Appendix A, Impulsiveness.

This latter criterion (kurtosis >40) has been used for classification of impulsive versus non-impulsive for sonars and similar sources. The justification for departing from the MSFD criterion is that the Southall et al. 2019, NOAA 2024 and the Popper et al. 2014 frameworks thresholds are based on the narrower definition of impulsive as given in “Impulsive sounds” above.

There is scope for some sounds to be classified as both impulsive and non-impulsive, depending on the criteria applied. Examples are pulses from sonar-like sources that can contain very rapid rise times (<0.5 ms), sweep a large frequency range and have high kurtosis. However, given that the scientific work carried out to identify impulsive thresholds were done with “pure” impulses (from a near instantaneous event), sonar-like sounds are sometimes not included in this, impulsive, category. This argument ignores that sounds used for establishing the non-impulsive thresholds (often narrowband slowly[3] rising pulses), are markedly less impulsive (lower kurtosis, narrower bandwidth) than what is sometimes seen in pulses from sonar-like sources and are thus also not representative for all sonar-like pulses.

Given impulsive sound’s tendency to become less impulsive with increased range, a minimal range can be established where the noise is no longer impulsive (here kurtosis <40 is used as the criterion) (Appendix A, Impulsiveness). This range is established using raytracing with sources placed at multiple depths to account for variation in final source setup.

The acoustic assessment criteria for marine mammals and fish in this report has followed the latest international guidance (based on the best available scientific information), that are widely accepted for assessments in the UK, Europe and worldwide (Southall, et al., 2019; Popper, et al., 2014; National Oceanic and Atmospheric Administration, 2024).

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[2] Statistical measure of the asymmetry of a probability distribution.

[3] Slowly in this context is >10 ms – slow relative to the integration time of the auditory system of marine mammals.

2.2 Impact Assessment Criteria

2.2.1 Effects on Marine Animals

Underwater noise has the potential to affect marine life in different ways depending on its noise level and characteristics. Richardson *et al.* (1995) defined four zones of noise influence which vary with distance from the source and level, to which an additional zone has been added "zone of temporary hearing loss". These are:

- **The zone of audibility**: This is defined as the area within which the animal can detect the sound. Audibility itself does not implicitly mean that the sound will affect the animal.
- **The zone of masking**: This is defined as the area within which sound can interfere with the detection of other sounds, such as communication or echolocation clicks. This zone is very hard to estimate due to a paucity of data relating to how animals detect sound in relation to masking levels (for example, humans can hear tones well below the numeric value of the overall sound level). Continuous sounds will generally have a greater masking potential than intermittent sound due to the latter providing some relative quiet between sounds. Masking only occurs if there is near-overlap in sound and signal, such that a loud sound at e.g., 1000 Hz will not be able to mask a signal at 10,000 Hz[4].
- **The zone of responsiveness**: This is defined as the area within which the animal responds either behaviourally or physiologically. The zone of responsiveness is usually smaller than the zone of audibility because, as stated previously, audibility does not necessarily evoke a reaction. For most species, there is very little data on response, but for species like harbour porpoise there exists several studies showing a relationship between received level and probability of response (Graham IM, 2019; Sarnoci´nska J, 2020; BOOTH, 2017; Benhemma-Le Gall A, 2021). This zone is quantified here with the use of behavioural thresholds (Table 2-2, section 2.2.2.1 & Table 2-3, section 2.2.3).
- **The zone of temporary hearing loss**: The area where the sound level is sufficient to cause the auditory system to lose sensitivity temporarily, causing loss of "acoustic habitat" (the volume of water that can be sensed acoustically by the animal). This hearing loss is typically classified as Temporary Threshold Shift ("TTS", see section 2.2.2 & 2.2.3).
- **The zone of injury / permanent hearing loss**: This is the area where the sound level is sufficient to cause permanent hearing loss in an animal. This hearing loss is typically classified as Auditory Injury ("AUD INJ", see section 2.2.2 & 2.2.3). At even closer ranges, and for very high intensity sound sources (e.g., underwater explosions), physical trauma or acute mortal injuries are possible.

For this study, it is the zones of injury (here "AUD INJ") that are of primary interest, along with estimates of behavioural impact ranges. To determine the potential spatial range of injury and behavioural change, a review has been undertaken of available evidence, including international guidance and scientific literature. The following sections summarise the relevant thresholds for onset of effects and describe the evidence base used to derive them.

Irish Guidance Interpretation

We note that the NPWS/DAHG "Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters" 2014 (Department of Arts, Heritage and the Gaeltacht, 2014) contains the following statement:

"It is therefore considered that anthropogenic sound sources with the potential to induce TTS in a receiving marine mammal contain the potential for both (a) disturbance, and (b) injury to the animal."

[4] The exact limit of how near a noise can get to the signal in frequency before causing masking will depend on the receivers' auditory frequency resolution ability, but for most practical applications noise and signal frequencies will need to be within 1/3rd octave to start to have a masking effect.

This states that TTS constitutes an injury and should thus be the main assessment criteria[5]. However, the guidance goes on to specify the use of thresholds from a 2007 publication (Brandon L. Southall, 2007), which has since been superseded (Southall, et al., 2019; National Oceanic and Atmospheric Administration, 2024) and no longer represents best available science, nor reflects best practice internationally. Thus, the following excerpt from the guidance is relevant:

"The document will be subject to periodic review to allow its efficacy to be reassessed, to consider new scientific findings and incorporate further developments in best practice."

As there has been no such update to date, but the guidance clearly states its intention to consider new scientific findings, we have applied the latest guidance (National Oceanic and Atmospheric Administration, 2024), reflecting the current best available method for assessing impact from noise on marine mammals. This means that it is "AUD INJ" (previously "PTS") that is the criteria for injury, not "TTS".

2.2.2 Thresholds for Marine Mammals

The zone of injury in this study is classified as the distance over which a fleeing marine mammal can suffer AUD INJ leading to non-reversible auditory injury. Injury thresholds are based on a dual criteria approach using both un-weighted L_P (maximal instantaneous SPL) and marine mammal hearing weighted SEL. The hearing weighting function is designed to represent the sensitivity for each group within which acoustic exposures can have auditory effects. The categories include:

- **Low Frequency (LF) cetaceans**: Marine mammal species such as baleen whales (e.g. minke whale *Balaenoptera acutorostrata*).
- **High Frequency (HF) cetaceans**: Marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales (e.g., bottlenose dolphin *Tursiops truncatus* and white-beaked dolphin *Lagenorhynchus albirostris*).
- **Very High Frequency (VHF) cetaceans**: Marine mammal species such as true porpoises, river dolphins and pygmy/dwarf sperm whales and some oceanic dolphins, generally with auditory centre frequencies above 100 kHz) (e.g., harbour porpoise *Phocoena phocoena*).
- **Phocid Carnivores in Water (PCW)**: True seals, earless seals (e.g., harbour seal *Phoca vitulina* and grey seal *Halichoreus grypus*); hearing in air is considered separately in the group PCA.
- **Other Marine Carnivores in Water (OCW)**: Including otariid pinnipeds (e.g., sea lions and fur seals), sea otters and polar bears; in-air hearing is considered separately in the group Other Marine Carnivores in Air (OCA).
- **Sirenians (SI)**: Manatees and dugongs.

These weightings are used in this study and are shown in Figure 2-1. It should be noted that not all of the above hearing groups of marine mammals will be present in the Project area, but all hearing groups are presented in this report for completeness.

[5] Injury being the qualifying limit in the Irish Wildlife Act 1976, section 23, 5c : https://www.irishstatutebook.ie/eli/1976/act/39/enacted/en/print#sec23

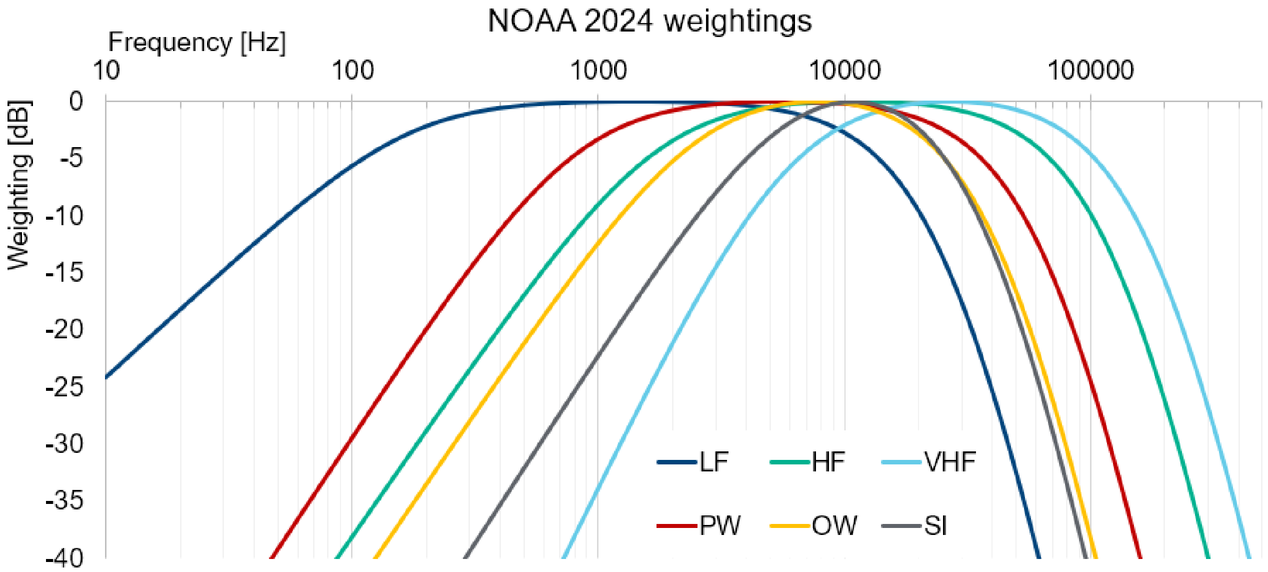

Figure 2-1 Auditory weighting functions for seals, whales and sirenians (National Oceanic and Atmospheric Administration, 2024).

The criteria for impulsive and non-impulsive sound are relevant for this study, given the nature of the sound sources used during the Project. The relevant AUD INJ and TTS criteria proposed by NOAA 2024 are summarised in Table 2-1.

Table 2-1 AUD INJ and TTS thresholds (National Oceanic and Atmospheric Administration, 2024)

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		AUD INJ	TTS	AUD INJ	TTS
Low frequency (LF) cetaceans	L_P, (unweighted)	222	216	-	-
	SEL, (weighted)	183	168	197	177
High frequency (HF) cetaceans	L_P, (unweighted)	230	224	-	-
	SEL, (weighted)	193	178	201	181
Very high frequency (VHF) cetaceans	L_P, (unweighted)	202	196	-	-
	SEL, (weighted)	159	144	181	161
Phocid carnivores in water (PCW)	L_P, (unweighted)	223	217	-	-
	SEL, (weighted)	183	168	195	175
Other marine carnivores in water (OCW)	L_P, (unweighted)	230	224	-	-
	SEL, (weighted)	185	170	199	179
Sirenians (SI) (NOAA only)	L_P, (unweighted)	225	219	-	-
	SEL, (weighted)	186	171	186	180

2.2.2.1 Disturbance to Marine Mammals

The noise thresholds for disturbance of marine mammals are not as mature as the AUD INJ and TTS thresholds and several different approaches exist. A conservative but realistic approach based on a review of Danish and UK guidance documents, as well as scientific reviews has been applied.

The general approach reflects the approach recommended by the Danish guidance (Danish Centre for Environment and Energy, 2021), by a review submitted to the JNCC (Joint Nature Conservation Committee) of the UK (Nedwell, et al., 2007) and by a review for Natural Resources Wales (Sinclair, et al., 2023). These all recommend or acknowledge the use of a weighted received level along with a hearing group specific threshold.

Using 21 suitable studies from these reports, we have arrived at hearing group specific thresholds (Table 2-2) to determine behavioural disturbance levels for non-impulsive noise (here understood to be noise with a kurtosis <40). These thresholds are compared to the range where the hearing group weighted received level exceeds the relevant threshold.

Table 2-2 Disturbance criteria for marine mammals used in this assessment, based on Danish, UK and USA guidance.

Effect	Non-Impulsive Threshold [SPL]	Impulsive Threshold
Low frequency (LF) cetaceans	118	160 dB SEL single impulse or 1-second SEL (NOAA level B-harassment)
High frequency (HF) cetaceans	92	
Very high frequency (VHF) cetaceans	95	
Phocid carnivores in water (PCW)	108	
Other marine carnivores in water (OCW)	110	

Given the considerable variation in the data (up to 40 dB where both mild disturbance and severe disturbance was included), we have opted to select a conservative value of either the 10th percentile value or the minimal value, whichever is greater[6] (Figure 2-2).

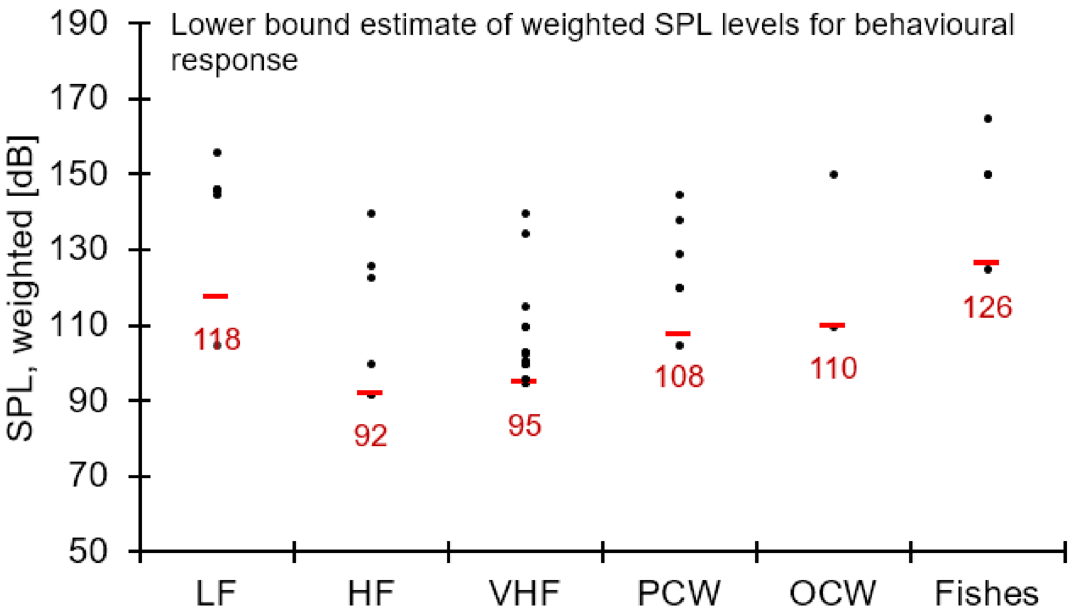

Figure 2-2 Data and behavioural disturbance thresholds. Red lines/values are 10th percentile values or the minimal value, whichever is greater.

[6] Where there is large data variation, the 10th percentile of the equivalent normal distribution can get smaller than the minimal value, in these cases we have used the minimal value observed to cause disturbance.

2.2.3 Injury and Disturbance to Fishes

The injury criteria used in this noise assessment are given in Table 2-3 and Table 2-4 for impulsive noises (L_P) and continuous noise (SEL) respectively. L_P and SEL criteria presented in the tables are unweighted.

It's important to clarify that this lack of weighting for fishes reflects a lack of scientific consensus about the best method for applying frequency dependence to received levels for fishes, rather than a statement that fishes can hear all frequencies equally. Thus, fishes generally cannot hear above 10 kHz, and if they can, the sensitivity is generally very poor (Figure 2-3, (Nedwell, et al., 2004)).

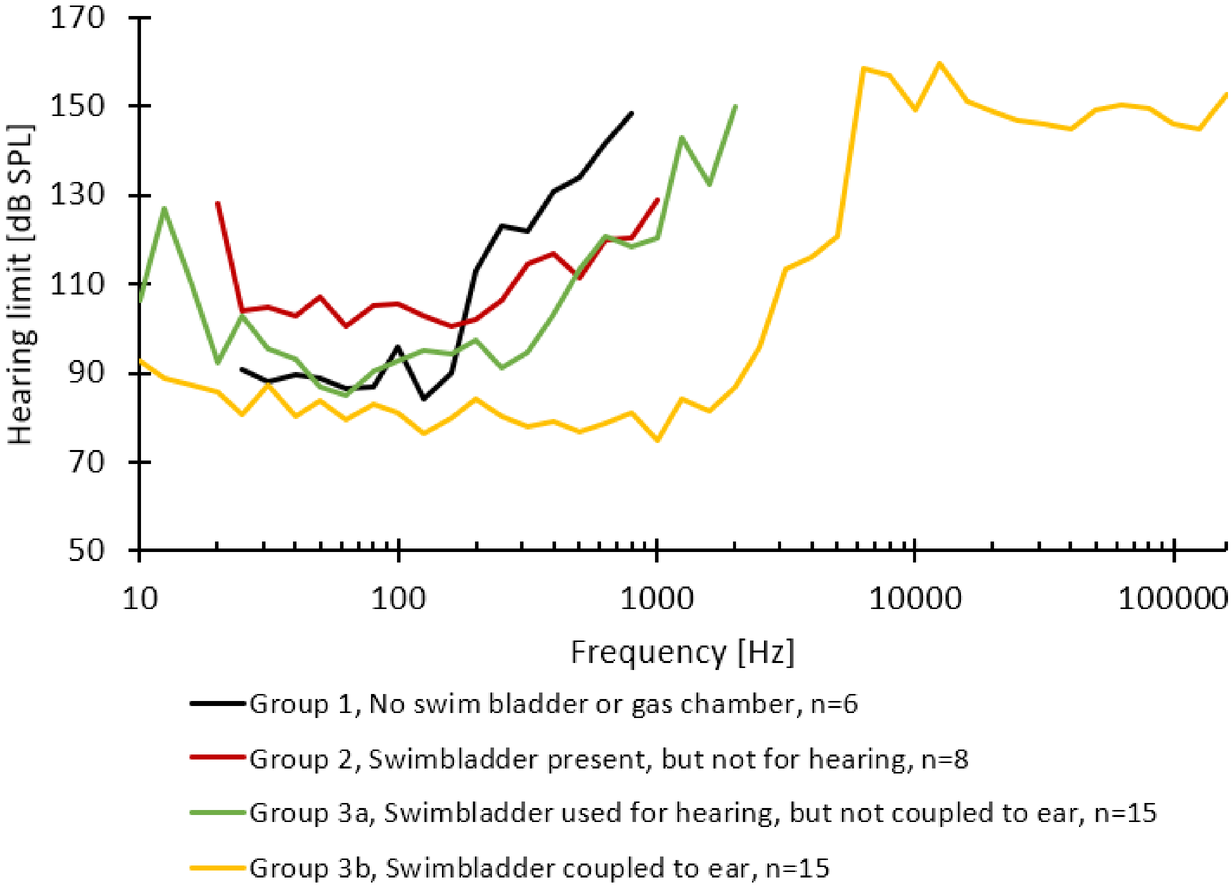

Figure 2-3 Generalised hearing thresholds for fishes grouped by the presence of a swim bladder and its role in hearing.

Physiological effects relating to injury criteria are described below (Popper, et al., 2014):

- **Mortality and potential mortal injury**: Either immediate mortality or tissue and/or physiological damage that is sufficiently severe (e.g., a barotrauma) that death occurs sometime later due to decreased fitness. Mortality has a direct effect upon animal populations, especially if it affects individuals close to maturity.

- **Recoverable injury ("AUD INJ" in tables and figures)**: Tissue damage and other physical damage or physiological effects, that are recoverable, but which may place animals at lower levels of fitness, may render them more open to predation, impaired feeding and growth, or lack of breeding success, until recovery takes place.

The AUD INJ term is used here to describe this more serious impact, even though it is not strictly permanent for fish. This is to better reflect the fact that this level of impact is perceived as serious and detrimental to the fish.

- **Temporary Threshold Shift (TTS)**: Short term changes (minutes to few hours) in hearing sensitivity may, or may not, reduce fitness and survival. Impairment of hearing may affect the ability of animals to capture prey and avoid predators, and also cause deterioration in communication between individuals, affecting growth, survival, and reproductive success. After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure.

Popper et al. 2014 does not set out specific TTS limits for L_P and for disturbance limits for impulsive noise for fishes. Therefore publications “Washington State Department of Transport Biological Assessment Preparation for Transport Projects Advanced Training Manual” (WSDOT, 2020) and “Canadian Department of Fisheries and Ocean Effects of Seismic energy on Fish: A Literature review” (Worcester, 2006) on effects of seismic noise on fish are used to determine limits for these:

- The criteria presented in the Washington State Department of Transport Biological Assessment Preparation for Transport Projects Advanced Training Manual (WSDOT, 2020). The manual suggests an un-weighted sound pressure level of 150 dB SPL (assumed to be duration of 95 % of energy) as the criterion for onset of behavioural effects, based on work by (Hastings, 2002). Sound pressure levels in excess of 150 dB SPL are expected to cause temporary behavioural changes, such as elicitation of a startle response, disruption of feeding, or avoidance of an area. The document notes that levels exceeding this threshold are not expected to cause direct permanent injury but may indirectly affect the individual fish (such as by impairing predator detection). It is important to note that this threshold is for onset of potential effects, and not necessarily an ‘adverse effect’ threshold. The threshold is implemented here as either single impulse SEL or 1 second SEL, whichever is greater.
- The report from the Canadian Department of Fisheries and Ocean “Effects of Seismic energy on Fish: A Literature review on fish” (Worcester, 2006) found large differences in response between experiments. Onset of behavioural response varied from 107-246 dB L_P, the 10^{th} percentile level for behavioural response was 160 dB L_P (rounded to nearest 5 dB to reflect large variation in data).

Thus, the behavioural threshold for fishes for impulsive sound is 160 dB L_P, and for non-impulsive sound 150 dB SPL.

Note that while there are multiple groups of fish presented, we have used the thresholds of the more sensitive group for all fish thus covering all fishes (203/186 AUD INJ/TTS for impulsive sound & 222/204 AUD INJ/TTS for non-impulsive sound). These lower thresholds also cover “Eggs and Larvae”.

Table 2-3 Criteria for onset of injury to fish and sea turtles due to impulsive noise. For this assessment the lowest threshold for any group is used for all groups (shown in bold).

Type of Animal	Unit	Mortality and Potential Mortal Injury [dB]	Recoverable Injury (AUD INJ) [dB]	TTS [dB]	Behavioural [dB]
Fish: no swim bladder (particle motion detection) Example: Sharks.	SEL	219[1]	216[1]	186[1]	150[3]
	L_P	213[1]	213[1]	193[2]	160[2]
Fish: where swim bladder is not involved in hearing (particle motion detection). Example: Salmonoids.	SEL	210[1]	203[1]	186[1]	150[3]
	L_P	207[1]	207[1]	193[2]	160[2]
Fish: where swim bladder is involved in hearing (primarily pressure detection). Example: Gadoids (cod-like).	SEL	207[1]	**203[1]**	**186**	**150[3] [SPL]**
	L_P	207[1]	**207[1]**	**193[2]**	**160[2]**
Sea turtles	SEL	210[1]	(*Near*) High* (*Mid*) Low (*Far*) Low	-	-
	L_P	207[1]		-	-

Eggs and larvae	SEL	210[1]	(*Near*) Moderate (*Mid*) Low (*Far*) Low	-	-
	L_P	207[1]		-	-

[1] (Popper et al. 2014) table 7.4, [2] (Worcester, 2006), [3] (WSDOT, 2020)

* Indicate (range) and risk of effect, e.g., "(Near) High", meaning high risk of that effect when near the source.

Where Popper et al. 2014 present limits as ">" 207 or ">>" 186, we have ignored the "greater than" and used the threshold level as given.

Relevant thresholds for non-impulsive noise for fishes relating to AUD INJ, TTS, and behaviour are given in Table 2-4.

Table 2-4 Criteria for fish (incl. sharks) due to non-impulsive noise from Popper et al. 2014, Table 7.7.

Type of Animal	Unit	Mortality and Potential Mortal Injury [dB]	Recoverable Injury (AUD INJ) [dB]	TTS [dB]	Behavioural [dB]
All fishes	SEL	(*Near*) Low (*Mid*) Low (*Far*) Low	222†	204†	126 [SPL]*

*Based on review in Section 2.2.2.1, also Figure 2-2.

†Based on 48 hours of 170 dB SPL and 12 hours of 158 dB SPL

3 SITE, SURVEY METHOD AND ENVIRONMENT

3.1 Site Location

Moneypoint is located on the northern shore of the Shannon Estuary in Co. Clare, approximately 3 km west of Killimer and 6 km south-east of Kilrush. The Project involves the laying of a new cable across the Shannon Estuary (in the seabed) between the Moneypoint 400 kV Electricity Substation in the townland of Carrowdotia South County Clare and Kilpaddoge 220/110 kV Electricity Substation in the townland of Kilpaddoge County Kerry. The connection at Moneypoint will be at the existing substation on ESB lands. The connection at Kilpaddoge requires an extension of 5,500m² to the existing substation on ESB lands. The Project location is shown in Figure 3-1.

The sediment is mainly sand to fine/medium gravel, and maximal depths are c. 60 m (assuming high tide).

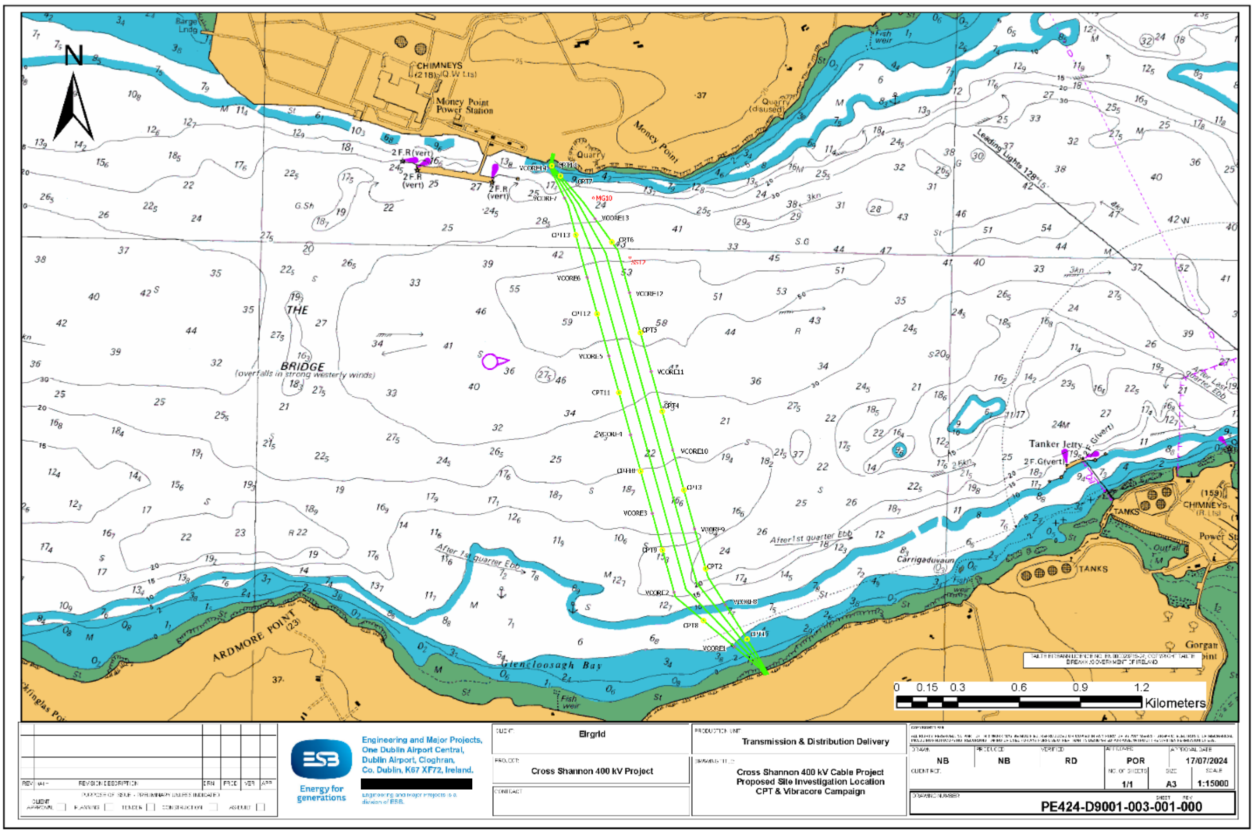

Figure 3-1 Site Investigation Survey Area

3.2 Surveys

Three activities are covered by this assessment; a geophysical survey for depths, sediment structure and properties as derived by acoustic means, a geotechnical survey using invasive methods to characterise the sediment and remotely operated vehicle (ROV) deployment to investigate seabed anomalies.

3.2.1 Geophysical Survey

A single vessel of <30 m length will be using a multibeam echosounder (MBES) and a parametric sub-bottom profiler (P-SBP). No side scan sonar nor ultrashort baseline (USBL) positioning system will be deployed. The vessel is assumed to move at c. 4 knots while surveying.

For surveying shallower areas, a smaller vessel or autonomous unmanned vehicle might be used, this will have lower noise emissions than the larger vessel and thus be covered under this assessment too.

3.2.2 Geotechnical Survey

For the geotechnical survey, two systems are modelled:

1. A single vessel of up to 80 m length using DP thrusters and a USBL for positioning is assumed for deeper water.
2. A jackup barge is assumed for shallower water, an associated tug vessel (<15 m length) is assumed to position the barge. No USBL positioning devices will be deployed for this system.

3.2.3 ROV deployment

From a DP vessel, a suitable ROV might be deployed to investigate seabed anomalies, should they be found. The associated vessel and USBL closely matches the equipment for the vessel-borne geotechnical survey and is covered under that assessment.

3.3 Environment

3.3.1 Water Properties

Water properties were determined from historical data for the area. Where values differ between e.g. seasons and tidal states, the values resulting in the lowest transmission loss were chosen for a more conservative assessment (more noise at range). Thus, this also covers seasonal variation.

- Temperature: 20 degrees – data from seatemperature.net for water temperatures near Shannon town. A higher temperature is more conservative.
- Salinity: Set at 30 psu - lowest, most conservative value observed 2007-2011 (INFOMAR, 2012).
- Soundspeed profile: Assumed uniform given high mixing as a result of tidal flows. A uniform soundspeed profile is conservative compared to the likely downward refracting soundspeed profiles seen during summer months (higher temperature in the surface leads to higher soundspeeds). No significant halocline is expected due to the relative proximity to the sea and distance to the River Shannon outflow into the estuary.

3.3.2 Sediment Properties

Sediment properties are taken from EMODnet[7] "Folk 7-class Classification" and nautical charts[8]. A sediment model (Ainslie, 2010) was used to derive the acoustic properties of the sediments from the grain size. An "acoustically harder" sediment (higher density and soundspeed) will be conservative, in that it will improve sound propagation in the water column. Therefore, while it is expected to find finer, acoustically softer sediments present, these will have higher transmission losses and will thus be covered by the more conservative assumption of the coarser sediment.

Table 3.1 Sediment properties

Sediment type (Folk 7)	ISO (14688-1:2017)	Density [kg/m³]	Soundspeed [m/s]	Grain size [mm] (nominal)
Coarse sediment (Gravel/sandy gravel/gravelly sand)	Fine gravel	2595	2034	2.8

[7] https://emodnet.ec.europa.eu/ sediment model "Folk 7-class" classification.

[8] https://fishing-app.gpsnauticalcharts.com/i-boating-fishing-web-app/fishing-marine-charts-navigation.html

4 SOURCE NOISE LEVELS

Underwater noise sources are usually quantified in dB scale with values generally referenced to 1 µPa pressure amplitude as if measured at a hypothetical distance of 1 m from the source (called the Source Level). In practice, it is not usually possible to measure at 1 m from a source, but the metric allows comparison and reporting of different source levels on a like-for-like basis. In reality, for a large sound source, this imagined point at 1 m from the acoustic centre does not exist. Furthermore, the energy is distributed across the source and does not all emanate from this imagined acoustic centre point. Therefore, the stated sound pressure level at 1 m does not occur for large sources. For such large source, in the acoustic near field (i.e. close to the source), the sound pressure level will be significantly lower than the value predicted by the back-calculated source level (SL).

4.1 Source Models

The noise sources and activities investigated during the subsea noise assessment study are summarised in Table 4.1.

Source levels for the active equipment were combined to produce a “combined” source that represents the total noise emissions from the activity.

Note that as source levels have all been converted to 1-second SPL equivalents, the levels vary depending on the location to reflect changes in depth and sediment properties (repetition rate of emitted pulses and sediment absorption affects the modelled source level).

Multibeam echosounders have been included in the assessment even though their main frequencies lie well above the hearing range of the VHF hearing group. This is because, given the way the signals are produced some spectral leakage (energy “leakage” into other frequencies due to the acoustic properties of the transducer) will occur, resulting in significant acoustic energy to frequencies audible to both dolphins and porpoises.

As sonars and echosounder have narrow beams and therefore “sweep” through the water body, they are harder to model for expected received level. For the assessment, the energy in the beam has been converted to an equivalent spherical source (of lower spherical SPL than the in-beam level) to ensure that a randomly positioned receiver would receive the same energy as one occasionally “hit” by a beam. Note that while extremely narrow beams (0.1-1 degree) are often stated for sonars and echosounders, this is the width of the beam where the received level drops by a set amount, usually 3 dB (if stated at all). There is a significant amount of acoustic energy outside the beam, which has been included in the assessment.

The parametric sub-bottom profilers have quite narrow beams directed vertically down, with levels attenuating rapidly as the angle away from vertical increases. For exposure modelling [dB SEL], the source level at an angle corresponding to the specular reflection of the sediment[9], has been used for the assessment. This means there will be a cone within which we will underpredict the impact for animals. As risk ranges tend to be larger than the radius of this cone, and animals will be able to hear the vessel approaching with time to evade this cone, this does not translate to an increased risk for the animals.

For the peak pressure level [dB L_P], propagation modelling using the actual directivity of common SBPs has been used to model the peak pressures at range.

[9] There is still reflection at steeper angles, but also a large loss to the sediment, meaning rapid attenuation, with increasing number of surface-bottom reflections.

Table 4.1 Summary of Noise Sources and Activities Included in the Subsea Noise Assessment

Equipment	Source level [SPL]	Primary frequencies (-20 dB width)	Source model details	Impulsive/non-impulsive
Survey vessel, geophysical survey, <30 m length	173 dB SPL	10-2,000 Hz	(Wittekind, 2014; Simard, et al., 2016; Heitmeyer, 2001)	Non-impulsive
DP vessel, geotechnical & ROV survey, <80 m length	196 dB SPL	10-12,500 Hz	(Wittekind, 2014; Simard, et al., 2016; Heitmeyer, 2001)	Non-impulsive
Tug to assist positioning jackup barge	195 dB SPL	10-16,000 Hz	(Wittekind, 2014; Simard, et al., 2016; Heitmeyer, 2001)	Non-impulsive
Multibeam echosounder	210 dB SPL (ping rate dependent, equivalent spherical level)	400,000 Hz – 800,000 Hz	Source levels based on von Hann windowed FM or CW pulses at max SPL as given by manufacturer.	Impulsive to 260 m, then non-impulsive*
Sub-bottom profiler Based on: “Innomar SES 2000 Compact”	192-195 dB SPL (ping rate and depth dependent, off-axis level)	Primary: 85,000 – 115,000 Hz Secondary: 2,000 – 22,000 Hz	Source levels based on von Hann windowed FM or CW pulses at max SPL as given by manufacturer. Soft start as given by manufacturer (Innomar)	Impulsive to 260 m, then non-impulsive
USBL	190 dB SPL 215 dB L_P	20,000 – 31,500 Hz	Generic USBL based on models from Edgetech, ORE offshore, Sonardyne & Ixblue	Impulsive to 260 m, then non-impulsive
Vibro-coring / drilling & CPT	189 dB SPL	50 – 16,000 Hz	Based on recorded levels	Non-impulsive
Sonar	190 dB SPL	700,000 – 3,000,000 Hz **Not audible to animals**	Based on ARIS sonars	Impulsive to 260 m, then non-impulsive

* Using criteria for impulsiveness as laid out in section 2.1.

4.2 Vessels

An ensemble model, consisting of a combination of numerical models (Wittekind, 2014; MacGillivray, et al., 2021) and empirical models (Heitmeyer, 2001; Simard, et al., 2016; Chion, et al., 2019; Liefvendahl, et al., 2015; Audoly, et al., 2015) was used to calculate representative source band levels of the vessels. Where we did not have exact representative vessels. the 90th percentile value of the ensemble model distribution[10] was used as a conservative estimate.

4.2.1 Geophysical Survey

A vessel of up to 30 m length assumed, travelling at a max speed of 4 knots during the survey. Band levels are presented in Figure 4-1, the broadband level is 173 dB SPL.

[10] The 90th percentile value of the normal distribution fitted to the model.

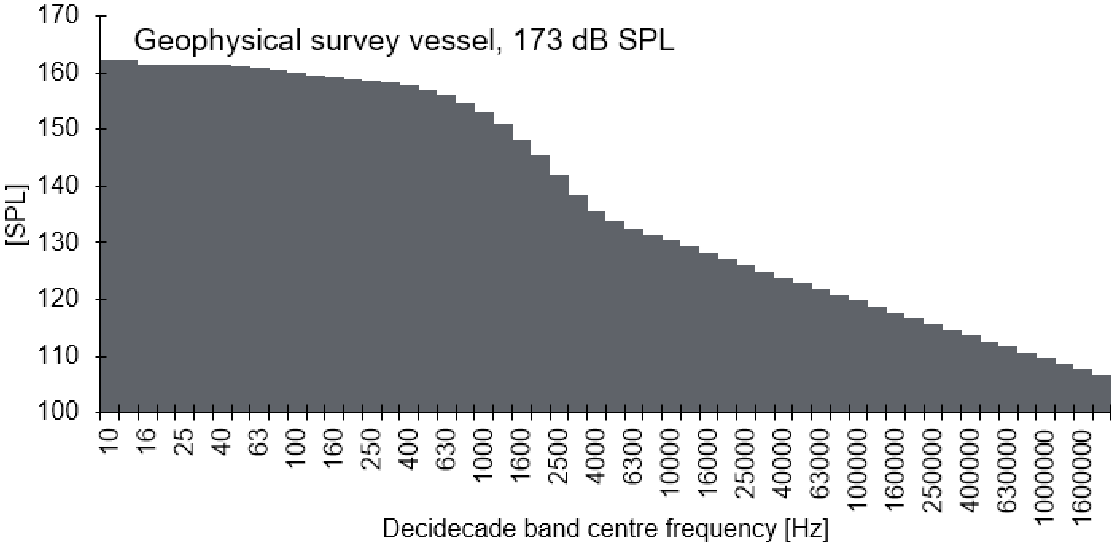

Figure 4-1. Source band levels for the geophysical survey vessel.

4.2.2 Geotechnical Survey – DP Vessel

A vessel of up to 80 m length assumed, travelling above the propeller cavitation speed (important for noise emissions). Band levels are presented in Figure 4-2, the broadband level is 196 dB SPL.

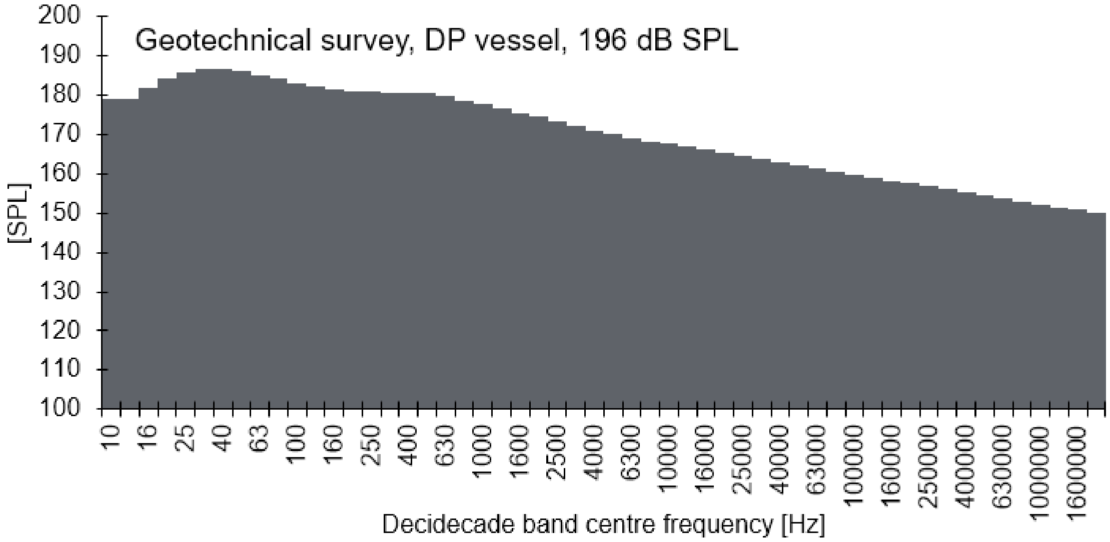

Figure 4-2. Source band levels for the geotechnical survey DP vessel.

4.2.3 Geotechnical Survey – Tug for Positioning of Jackup Barge

A vessel of up to 15 m length assumed, travelling above the propeller cavitation speed (important for noise emissions). Band levels are presented in Figure 4-3, the broadband level is 195 dB SPL.

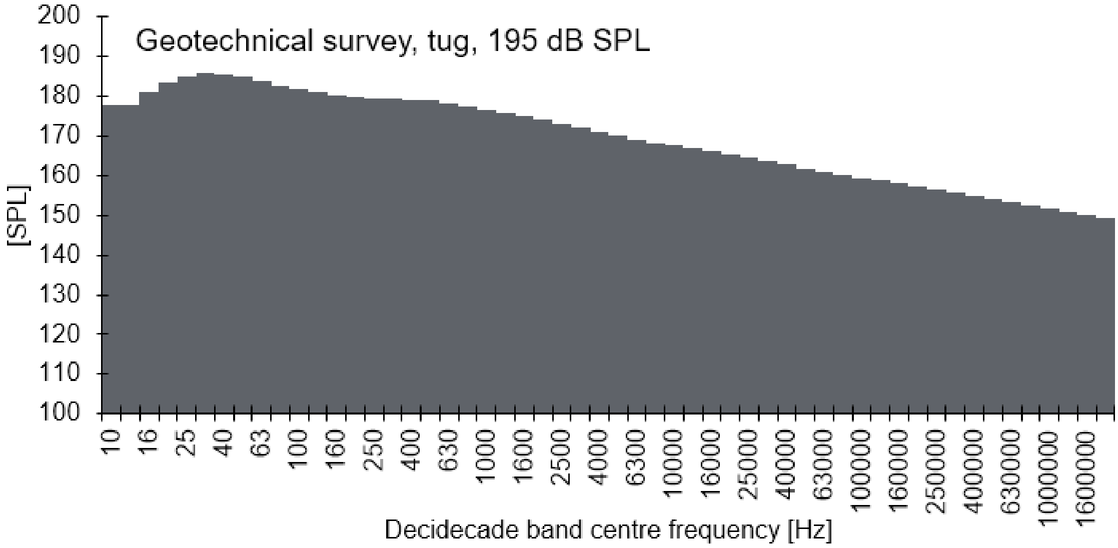

Figure 4-3. Source band levels for the geotechnical survey tug.

4.3 MBES

The MBES source is based off a generic model using data from 24 MBES systems. The system is specified to have nominal frequencies from 400 kHz to 800 kHz. The broadband level is 210 dB SPL, with band levels given in Figure 4-4

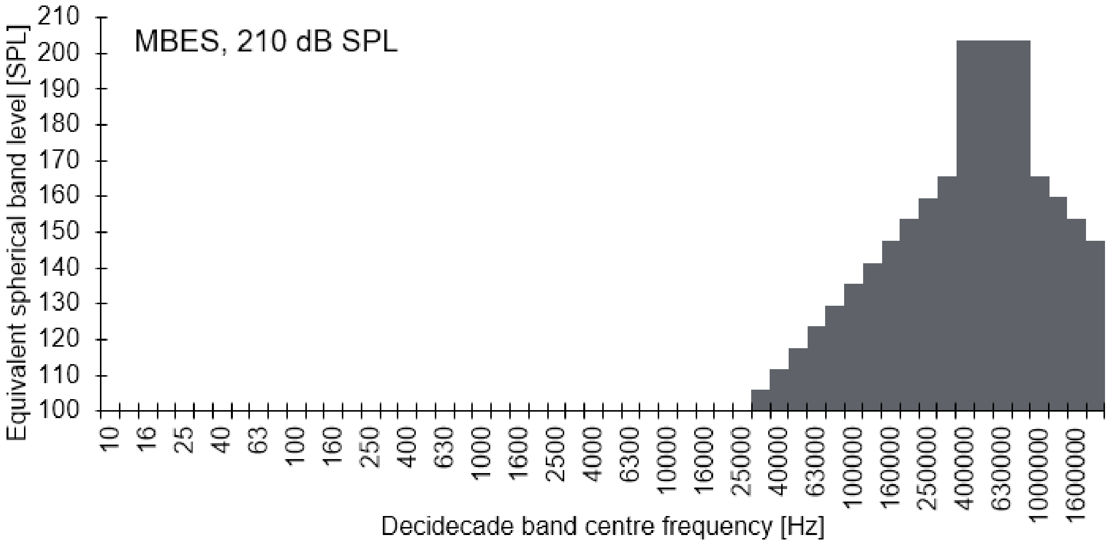

Figure 4-4. Source band levels for the MBES given as spherical equivalent levels.

4.4 Sub-bottom Profiler, Parametric

The sub-bottom profiler (SBP) will be a parametric type that uses beams of two higher frequencies (85-115 kHz) to generate a very narrow lower frequency beam (using constructive/destructive interference between the higher frequencies) to penetrate the sediment. The hull-mounted Innomar SES 2000 Compact is representative for the survey. The broadband level is 192-195 dB SPL (varying with depth) with the higher frequencies being at 192-195 dB SPL and the lower frequencies at 135-148 dB SPL (Figure 4-5).

The SBP does not use all these frequencies simultaneously but has been assessed against the potential spread of frequencies that might be emitted.

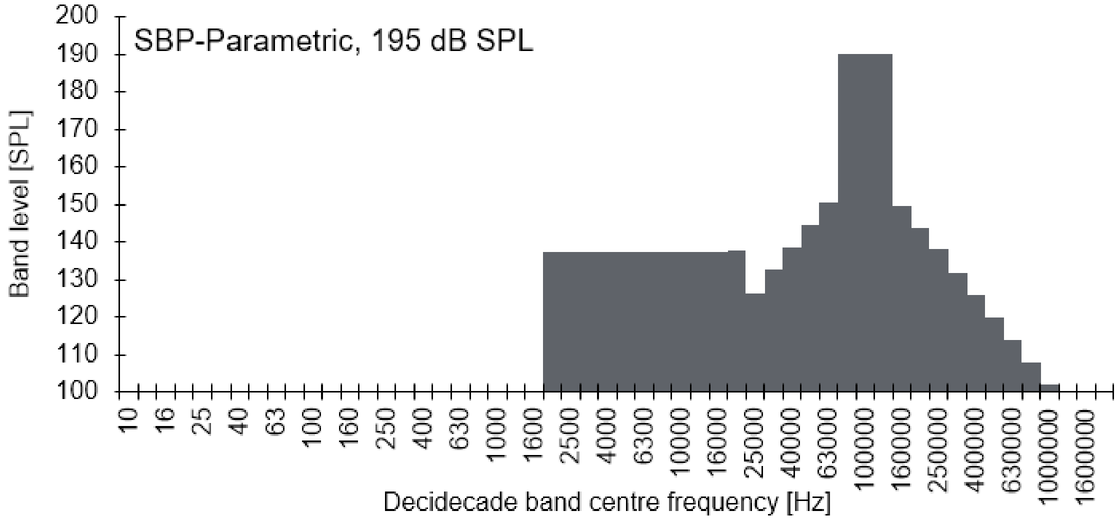

Figure 4-5. Source band levels for the parametric SBP.

Note that during SBP-only soft starts, the source levels of the main frequencies will be 20, 40 & 75 % of the levels given in Figure 4-5 (c. -7, -4 & -1.25 dB), while the secondary frequencies will be in steps of 10, 20, 37.5 % of full level (-10, -7 & -4.25 dB). This ramp-up will occur over 20-minutes with each step lasting 6 min 40 seconds each. Band levels for in-built soft start given in Figure 4-6.

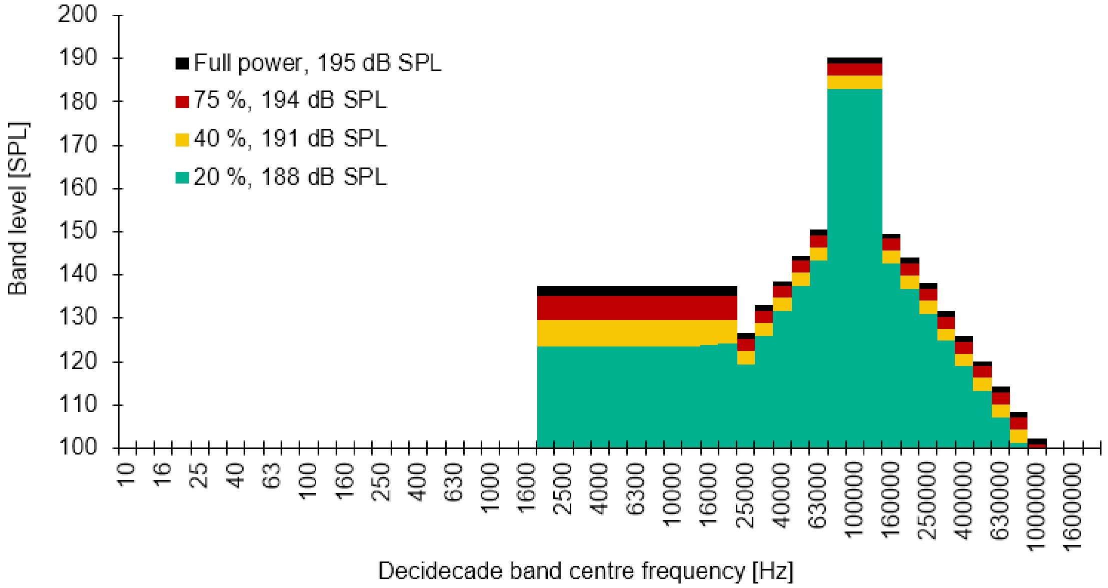

Figure 4-6. Soft start procedure for parametric SBP when using inbuilt 20 min ramp-up.

4.5 USBL

The USBL is based on a generic model using data from systems made by Edgetech, ORE offshore, Sonardyne & Ixblue. The band levels are given in Figure 4-7 and the broadband level is 190 dB SPL.

The USBL is used along with deployed equipment when the exact position relative to the vessel is needed, such as during the geotechnical survey for the Vibrocoring and CPT.

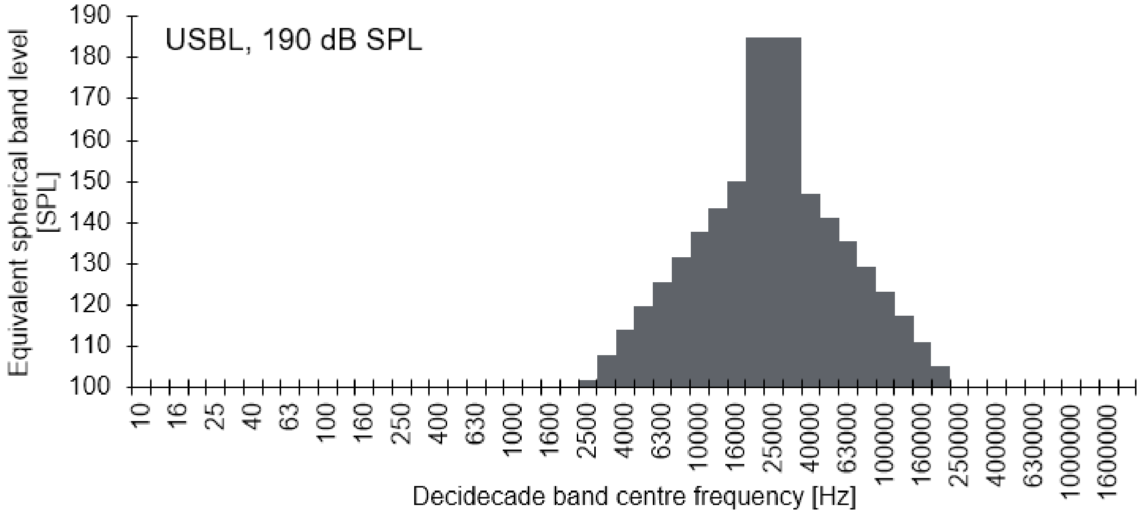

Figure 4-7. Source band levels for the USBL.

4.6 Vibrocoring & CPT

Source band levels for vibrocoring and CPT are based on recordings from these types of activities (Bureau of Ocean Energy Management; Center for Marine Acoustics, 2023; Erbe, et al., 2017)

Band levels are given in Figure 4-8, with a broadband level for vibrocoring of 189 dB SPL and for CPT 157 dB SPL.

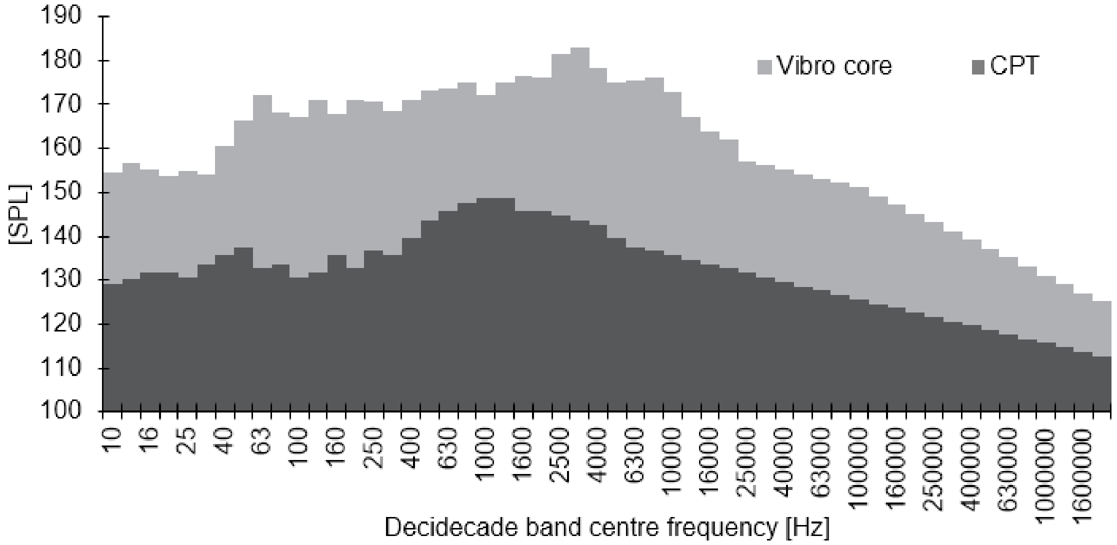

Figure 4-8. Source band levels for Vibrocoring and CPT.

4.7 High-resolution Sonar

A high-resolution sonar, lowest nominal frequency >700 kHz is based on a generic model using data from ARIS[11] (the likely supplier). The band levels are given in Figure 4-9 and the broadband level is 190 dB SPL.

The high-res sonar is used during the ROV survey to detect fine detail on the sediment surface.

Note that this source is only included for completeness, as it is inaudible to animals (compare with weightings in section 2.2.2 and section 2.2.3).

[11] http://www.soundmetrics.com/Products/ARIS-Sonars

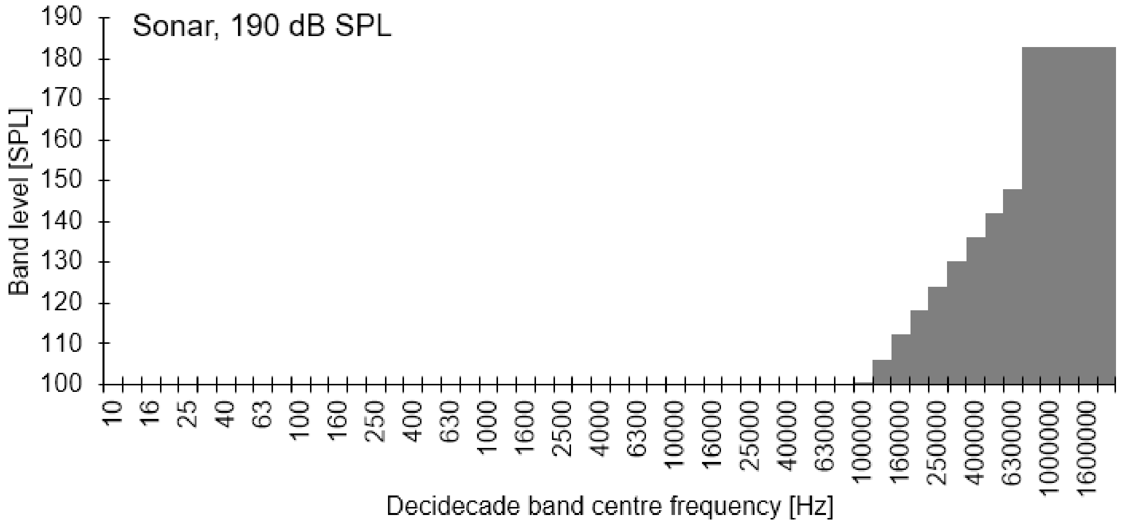

Figure 4-9. Source band levels for the high-res sonar.

4.8 Combined Sources

In the following sections, the four combined source configuration are given for clarity. These represent the sources as modelled and thus account for overlap in noise emissions between sources.

4.8.1 Geophysical Survey – Deep

Equipment active:

- Geophysical Survey vessel up to 30 m length
- MBES
- Sub-bottom profiler, Parametric (depth to 60 m)

Broadband level of 195 dB SPL, with band levels shown in Figure 4-10.

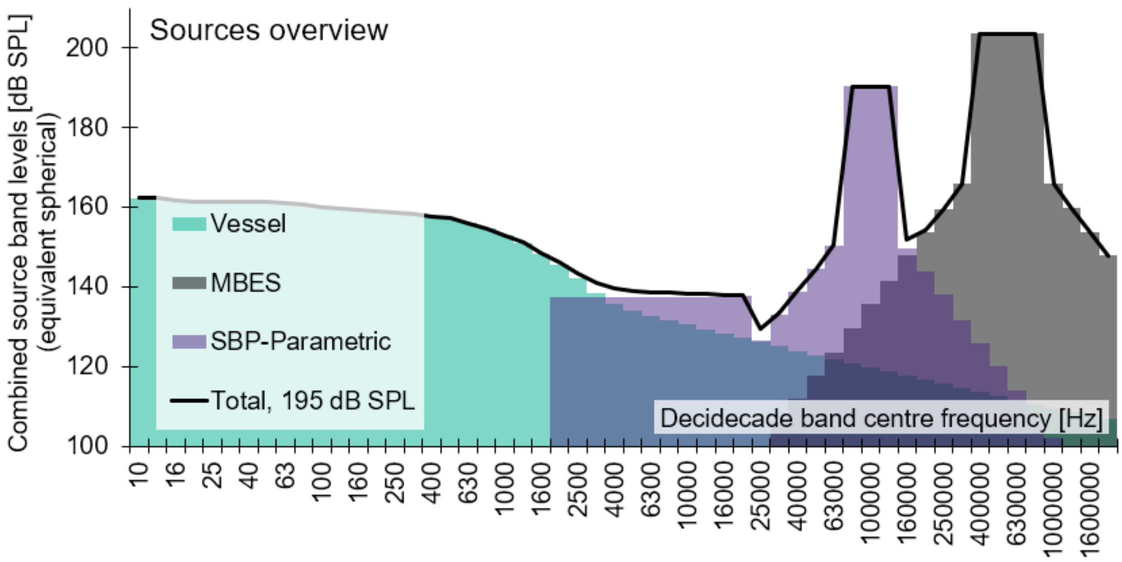

Figure 4-10. Source band levels for geophysical survey – deeper water.

4.8.2 Geophysical Survey – Shallow

Equipment active:

- Geophysical Survey vessel up to 30 m length
- MBES
- Sub-bottom profiler, Parametric (depth <20 m)

Broadband level of 192 dB SPL, with band levels shown in Figure 4-11.

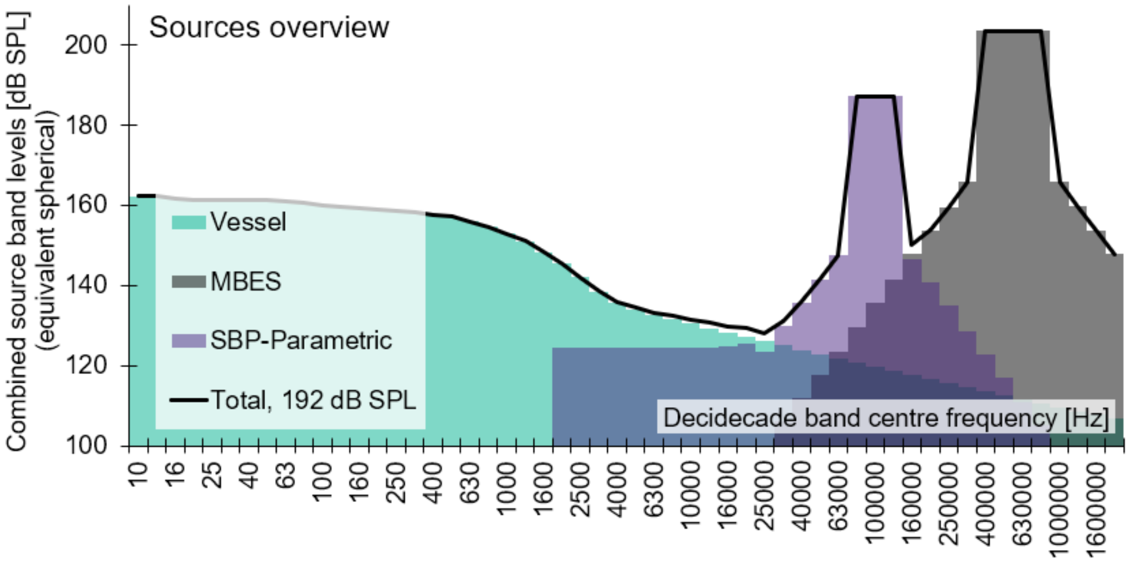

Figure 4-11. Source band levels for geophysical survey – shallow water.

4.8.3 Geophysical Survey – Soft Start with MBES

- Equipment active:
    - Geophysical Survey vessel up to 30 m length
    - MBES

  Equipment not active:
    - Sub-bottom profiler, Parametric (depth <20 m)

  Broadband level of 173 dB SPL, with band levels shown in Figure 4-12.

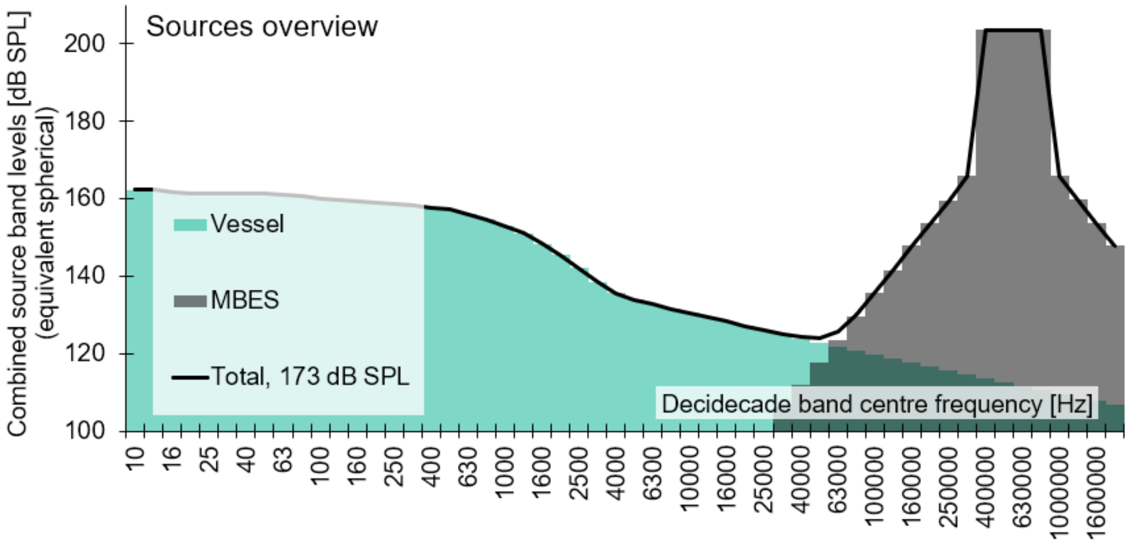

Figure 4-12. Source band levels for geophysical survey – soft start.

4.8.4 Geophysical Survey – Soft Start with Parametric SBP only

- Equipment active:
  - Geophysical Survey vessel up to 30 m length
  - Parametric SBP, ramping up as 20 %, 40 % & 75 % of full energy for primary frequencies.
    6 min, 40 sec on each step.
    secondary frequencies ramp up as 10 %, 20 % & 37.5 % of full energy (double the reduction of the primary bands)

  Equipment not active:
  - MBES

Broadband level of 188-194 dB SPL, with band levels shown in Figure 4-13.

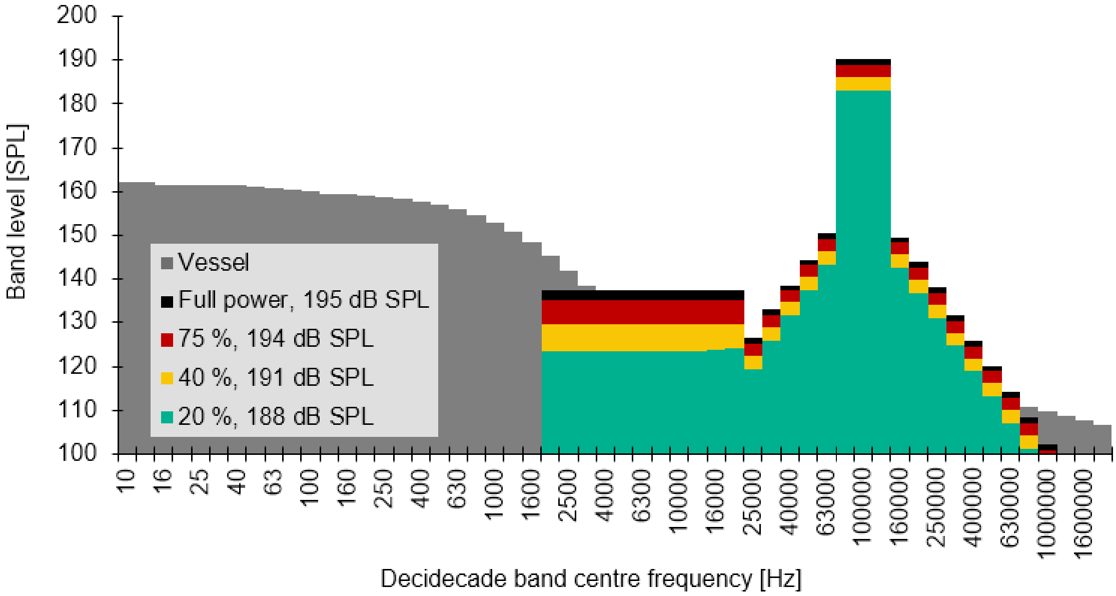

Figure 4-13. Soft start levels for parametric SBP-only soft start.

4.8.5 Geotechnical Survey – Deep & ROV Operations

Equipment active:

- Geotechnical Survey, DP vessel up to 80 m length
- Vibrocoring & CPT
- USBL
- High-resolution sonar (only active during ROV operations, not audible to animals)

Broadband level of 198 dB SPL, with band levels shown in Figure 4-14.

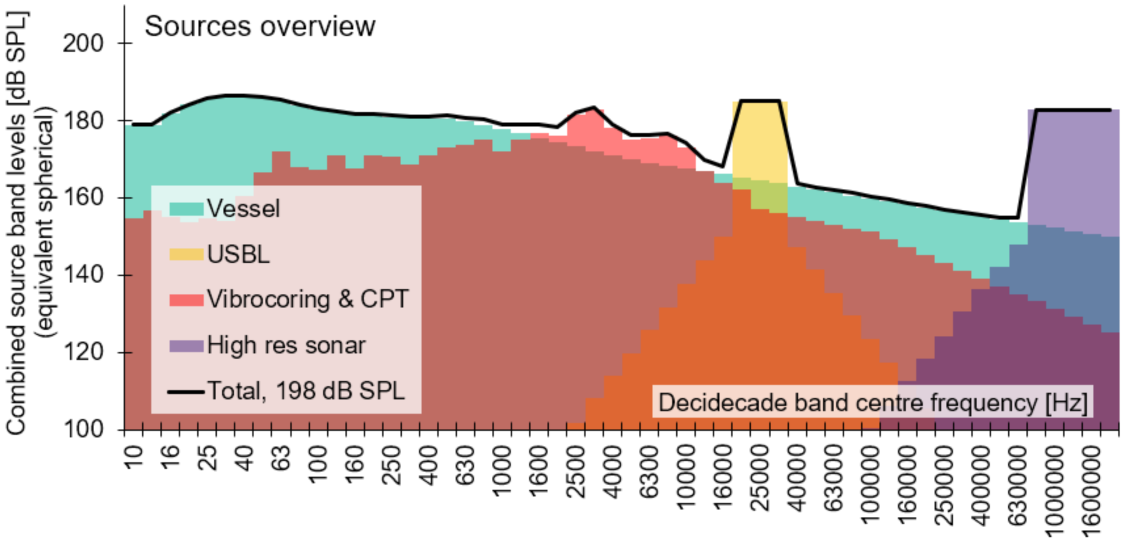

Figure 4-14. Source band levels for geotechnical survey – deeper water and ROV operations.

4.8.6 Geotechnical Survey – Shallow

Equipment active:

- Geotechnical Survey, tug for positioning, up to 15 m length.
- Vibrocoring & CPT

Broadband level of 196 dB SPL, with band levels shown in Figure 4-15.

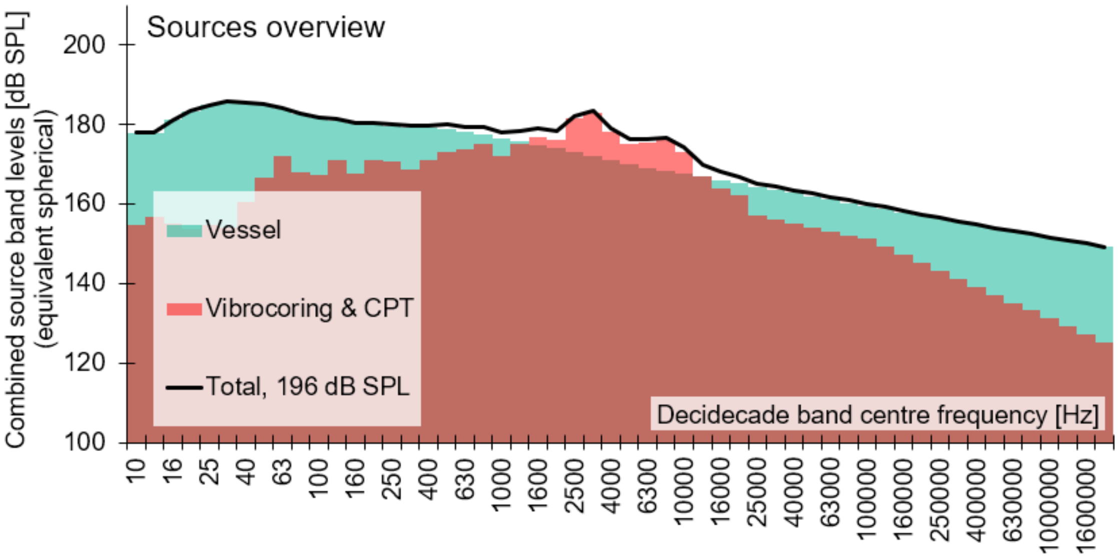

Figure 4-15. Source band levels for geotechnical survey – shallow water.

5 SOUND PROPAGATION MODELLING METHODOLOGY

There are several methods available for modelling the propagation of sound between a source and receiver, ranging from very simple models which simply assume spreading according to a 10×$\log_{10}$(range) or 20×$\log_{10}$(range) relationship, to full acoustic models (e.g., ray tracing, normal mode, parabolic equation, wavenumber integration and energy flux models). In addition, semi-empirical models are available which lie somewhere in between these two extremes in terms of complexity (e.g., (Rogers, 1981; Weston, 1971)).

For simpler scenarios, such as this one, where the sediment is relatively uniform and mostly flat, or where great detail in the sound field is not needed, the speed of these simpler models is preferred over the higher accuracy of numerical models and are routinely used for these types of assessments. For this assessment, we have used the Weston model (Weston, 1971), which is suitable to depths of c. 200 m and generally softer sediments.

This model will tend to underestimate the transmission losses (leading to estimates greater than actual impact), primarily due to the omission of surface roughness, wind effects and shear waves in the sediment.

Validation examples of the model can be found in Appendix B

5.1 Modelling Assumptions

The main assumptions made for the modelling are:

1. Animals fleeing the area will not return within a 24-hour period.
2. Animals flee for up to 2 hours, after which they will be up to 10.8 km and 3.6 km away for marine mammals and fish, respectively.
3. Results assume a transition from impulsive (kurtosis >40) to non-impulsive (kurtosis <40) at some distance from the source. For this assessment, the transition occurs before 260 m from the source. After the transition to non-impulsive noise, the noise is assessed against the non-impulsive thresholds.

   This assumption is also applicable for the assessment of behavioural disturbance.
4. Sources are modelled as point sources.
5. Modelling is done for high tide, being the tidal state with the least transmission loss.

5.2 Exposure Calculations (dB SEL)

To compare modelled levels with the two impact assessment frameworks (NOAA 2024 & Popper et al. 2014) it is necessary to calculate received levels as exposure levels (SEL), weighted for marine mammals and unweighted for fishes. For ease of implementation, sources have generally been converted to an SPL source level, meaning converting to SEL from SPL or from a number of events.

To convert from SPL to SEL, the following relation can be used:

$$SEL = \text{SPL} + 10 \cdot Log_{10}(t_2 - t_1) \quad (1)$$

Or, where it is inappropriate to convert SEL from one event to SEL cumulative by relating to the number of events as:

$$SEL_{\ n\ events} = SEL_{single\ event} + 10 \cdot Log_{10}(n) \quad (2)$$

And SPL from SEL:

$$SPL = SEL_{single\ event} + 10 \cdot Log_{10}\left(\frac{n}{t_2 - t_1}\right) \quad (3)$$

As an animal swims away from the sound source, the noise it experiences will become progressively more attenuated; the cumulative, fleeing SEL is derived by logarithmically adding the SEL to which the mammal is exposed as it travels away from the source. This calculation is used to estimate the approximate minimum start distance for an animal in order for it to be exposed to sufficient sound energy to result in the exceedance of a threshold, or to check if a set exclusion zone is sufficient for an activity (e.g. will an exclusion zone of 500 m be sufficient to prevent exceeding an AUD INJ threshold). It should be noted that the sound exposure calculations are based on the simplistic assumption that the animal will continue to swim away at a constant speed. The real-world situation is more complex and the animal is likely to move in a more varied manner. Reported swim speeds are summarised in Table 5-1 along with the source papers for the assumptions.

For this assessment, a swim speed of 1.5 m/s for marine mammals, and 0.5 m/s for fishes (including sharks) is assumed.

For very long fleeing durations, the ambient sound itself can exceed the thresholds, e.g., an ambient sound level of 122.4 dB, weighted for the VHF group, will exceed the non-impulsive TTS threshold of 161 dB SEL after 2 hours' exposure[12]. For this assessment, we consider fleeing durations of 2 hours (7200 seconds, allowing 10800 m of fleeing), meaning that weighted levels of 122.4 dB SPL will exceed the VHF group's non-impulsive TTS threshold in the fleeing model.

Table 5-1 Swim speed examples from literature

Species	Hearing Group	Swim Speed (m/s)	Source Reference
Harbour porpoise	VHF	1.5	Otani *et al.,* 2000
Harbour seal	PCW	1.8	Thompson, 2015
Grey seal	PCW	1.8	Thompson, 2015
Minke whale	LF	2.3	Boisseau *et al.,* 2021
Bottlenose dolphin	HF	1.52	Bailey and Thompson, 2010
White-beaked dolphin	HF	1.52	Bailey and Thompson, 2010
Basking shark	Fish (unweighted)	1.0	Sims, 2000
All other fish groups	Fish (unweighted)	0.5	Popper *et al.,* 2014
Sea turtles	Fish (unweighted)	0.56-0.84 & 0.78-2.8	(F, et al., 1997; SA, 2002)

[12] 122.4 dB SPL + 10*$\log_{10}$(3600 seconds) = 161 dB SEL, TTS non-impulsive threshold for the VHF group is 161 dB SEL.

6 RESULTS AND ASSESSMENT

6.1 Assumptions and Notes on Results

The results should be read while keeping the following in mind:

- Results are rounded up to the nearest two significant digits. This can lead to apparent overlaps in risk ranges.
- The modelling resolution of 10 metres means that, were results are lower than this, "<10" is stated to mean "below 10 metres".
- As the impulsive noise transitions to non-impulsive noise with increased ranges, the appropriate behavioural threshold for the assessment changes from 160 dB to 92-126 dB (a likely >10-fold increase in range). This means that there are large ranges of disturbance, but these should be considered in relation to, for example, the radiated noise from common vessels, which will exceed this threshold to ranges of 500-10000 m (assuming 160-180 dB SPL source level).
- Animals are modelled as fleeing in straight lines. Where sites are very confined, the maximal modelled risk ranges will be restricted by line-of-sight ranges (and cut short where they meet land). To mitigate this, maximal ranges are included in the results.
- Modelling assumes a maximal fleeing time of 7200 seconds (2 hours). This allows for 10.8 km of fleeing for marine mammals (3.6 km for fish).
- Modelling is limited to a range of 15 km from the site boundary.
- Where behavioural disturbance ranges are over 10 km, ">10000 m" is reported.
- Soft starts using one kind of pulsed noise might serve as a deterrent for another kind of pulsed noise (e.g. an MBES for an SBP using similar pulses).

6.2 Results Tables

6.2.1 Geophysical Survey – Deep

The behavioural disturbance ranges are between 500 m and 8300 m depending on the hearing group. These ranges should be considered in relation to normal vessel noise in the area, where any vessels closer to the animal than the survey vessel will tend to "drown out" the noise from the survey vessel. The exception to this is a closer range where the higher frequencies from the MBES and P-SBP are still relevant (higher frequencies attenuate rapidly at higher frequencies, see Appendix A).

Exceedances of the TTS thresholds are <10 m for all hearing groups except the VHF group (porpoises), which has risk ranges to 280 m for exceedance of the TTS threshold.

Exceedances of AUD INJ thresholds are <10 m for all hearing groups except the VHF group (porpoises), which has risk range to 210 m for exceedance of the AUD INJ threshold.

Using the SBP ramp-up procedure as soft start reduces the VHF TTS ranges to 260 m and the AUD INJ ranges to 130 m.

Table 6-1. Threshold exceedance ranges for Geophysical Survey – Deep.

Condition		LF	HF	VHF	PW	OW	Fishes
Behavioural disturbance range	90th percentile range [m]	2000	6600	2100	2300	500	1200
	Maximal range [m]	2100	8300	2200	2600	500	1200
TTS,1 seconds' exposure	90th percentile range [m]	<10	<10	220	<10	<10	<10
	Maximal range [m]	<10	<10	220	<10	<10	<10
AUD INJ,1 seconds' exposure	90th percentile range [m]	<10	<10	30	<10	<10	<10
	Maximal range [m]	<10	<10	30	<10	<10	<10
TTS, sound exposure, fleeing receiver	90th percentile range [m]	<10	<10	270	<10	<10	<10

	Maximal range [m]	<10	<10	280	<10	<10	<10
AUD INJ, sound exposure, fleeing receiver	90th percentile range [m]	<10	<10	210	<10	<10	<10
	Maximal range [m]	<10	<10	210	<10	<10	<10
TTS, sound exposure, fleeing receiver, 20-minute soft start, SBP and vessel only	90th percentile range [m]	<10	<10	260	<10	<10	<10
	Maximal range [m]	<10	<10	260	<10	<10	<10
AUD INJ, sound exposure, fleeing receiver, 20-minute soft start, SBP and vessel only	90th percentile range [m]	<10	<10	130	<10	<10	<10
	Maximal range [m]	<10	<10	130	<10	<10	<10

6.2.2 Geophysical Survey – Shallow

The behavioural disturbance ranges are between 810 m and >10000 m depending on the hearing group. These ranges should be considered in relation to normal vessel noise in the area, where any vessels closer to the animal than the survey vessel will tend to “drown out” the noise from the survey vessel. The exception to this is a closer range where the higher frequencies from the MBES and P-SBP are still relevant (higher frequencies attenuate rapidly at higher frequencies, see Appendix A).

Exceedances of the TTS thresholds are <10 m for all hearing groups except the VHF group (porpoises), which has risk ranges to 350 m for exceedance of the TTS threshold.

Exceedances of AUD INJ thresholds are <10 m for all hearing groups except the VHF group (porpoises), which has risk range to 240 m for exceedance of the AUD INJ threshold.

Using a soft start with the MBES as soft start reduces TTS ranges for the VHF group to 70 m, and the AUD INJ ranges to <10 m.

Using the SBP ramp-up procedure as soft start reduces the VHF TTS ranges to 260 m and the AUD INJ ranges to 170 m.

Table 6-2. Threshold exceedance ranges for Geophysical Survey – Shallow.

Condition		LF	HF	VHF	PW	OW	Fishes
Behavioural disturbance range	90th percentile range [m]	3100	7100	2000	3400	810	1600
	Maximal range [m]	3400	>10000	2200	4100	850	1800
TTS,1 seconds’ exposure	90th percentile range [m]	<10	<10	290	<10	<10	<10
	Maximal range [m]	<10	<10	290	<10	<10	<10
AUD INJ,1 seconds’ exposure	90th percentile range [m]	<10	<10	40	<10	<10	<10
	Maximal range [m]	<10	<10	40	<10	<10	<10
TTS, sound exposure, fleeing receiver	90th percentile range [m]	<10	<10	340	<10	<10	<10
	Maximal range [m]	<10	<10	350	<10	<10	<10
AUD INJ, sound exposure, fleeing receiver	90th percentile range [m]	<10	<10	240	<10	<10	<10
	Maximal range [m]	<10	<10	240	<10	<10	<10
TTS, sound exposure, fleeing receiver, 20-minute soft start, MBES and vessel only	90th percentile range [m]	<10	<10	70	<10	<10	<10
	Maximal range [m]	<10	<10	70	<10	<10	<10
AUD INJ, sound exposure, fleeing receiver, 20-minute soft start, MBES and vessel only	90th percentile range [m]	<10	<10	<10	<10	<10	<10
	Maximal range [m]	<10	<10	<10	<10	<10	<10
TTS, sound exposure, fleeing receiver, 20-minute soft start, SBP and vessel only	90th percentile range [m]	<10	<10	260	<10	<10	<10
	Maximal range [m]	<10	<10	260	<10	<10	<10
AUD INJ, sound exposure, fleeing receiver, 20-minute soft start, SBP and vessel only	90th percentile range [m]	<10	<10	170	<10	<10	<10
	Maximal range [m]	<10	<10	170	<10	<10	<10

6.2.3 Geotechnical Survey – Deep & ROV Operations

The behavioural disturbance ranges are between 7100 m and >10000 m depending on the hearing group. These ranges should be considered in relation to normal vessel noise in the area, where any larger vessels significantly closer to the animal than the survey vessel will tend to “drown out” the noise from the survey vessel.

Exceedances of the TTS thresholds are <50 m for the HF hearing group (dolphins), but with larger ranges for the PW group (seals) at 600-700 m, for the LF group (whales) at 860-1100 m and for the VHF group (porpoises) at 2600-2900 m. The OW group (otters) and fishes have TTS risk ranges of 150-160 m.

Exceedances of AUD INJ thresholds are <20 m for all hearing groups except the VHF group (porpoises), which has risk range to 250 m for exceedance of the AUD INJ threshold.

Table 6-3. Threshold exceedance ranges for Geotechnical Survey – Deep.

Condition		LF	HF	VHF	PW	OW	Fishes
Behavioural disturbance range	90th percentile range [m]	7100	7100	7100	7100	7100	7100
	Maximal range [m]	>10000	>10000	>10000	>10000	>10000	>10000
TTS,1 seconds’ exposure	90th percentile range [m]	20	<10	780	10	<10	<10
	Maximal range [m]	20	<10	780	10	<10	<10
AUD INJ,1 seconds’ exposure	90th percentile range [m]	<10	<10	30	<10	<10	<10
	Maximal range [m]	<10	<10	30	<10	<10	<10
TTS, sound exposure, fleeing receiver	90th percentile range [m]	860	40	2600	600	160	150
	Maximal range [m]	1100	50	2900	700	160	150
AUD INJ, sound exposure, fleeing receiver	90th percentile range [m]	20	<10	250	<10	<10	<10
	Maximal range [m]	20	<10	250	<10	<10	<10

6.2.4 Geotechnical Survey - Shallow

The behavioural disturbance ranges are between 7100 m and >10000 m depending on the hearing group. These ranges should be considered with respect to normal vessel noise in the area, where any larger vessels significantly closer to the animal than the survey vessel will tend to “drown out” the noise from the survey vessel.

Exceedances of the TTS thresholds are <60 m for the HF hearing group (dolphins), but with larger ranges for the PW group (seals) at 1100-1400 m, for the LF group (whales) at 1400-1800 m, the VHF group (porpoises) at 2200-2800 m and for the OW group (otters) at <120 m. The fishes have TTS risk ranges <10 m.

Exceedances of AUD INJ thresholds are <10 m for all hearing groups.

Table 6-4. Threshold exceedance ranges for Geotechnical Survey – Shallow.

Condition		LF	HF	VHF	PW	OW	Fishes
Behavioural disturbance range	90th percentile range [m]	7100	7100	7100	7100	7100	7100
	Maximal range [m]	>10000	>10000	>10000	>10000	>10000	>10000
TTS,1 seconds’ exposure	90th percentile range [m]	<10	<10	<10	<10	<10	<10
	Maximal range [m]	<10	<10	<10	<10	<10	<10
AUD INJ,1 seconds’ exposure	90th percentile range [m]	<10	<10	<10	<10	<10	<10
	Maximal range [m]	<10	<10	<10	<10	<10	<10
TTS, sound exposure, fleeing receiver	90th percentile range [m]	1400	40	2200	1100	90	<10
	Maximal range [m]	1800	60	2800	1400	120	<10

AUD INJ, sound exposure, fleeing receiver	90th percentile range [m]	<10	<10	<10	<10	<10	<10
	Maximal range [m]	<10	<10	<10	<10	<10	<10

6.3 Summary of Results

6.3.1 Geophysical Survey

The behavioural disturbance thresholds are generally exceeded to multiple kilometres. Depending on the presence of other vessels in the area and the habituation of the animals the actual ranges to disturbance are likely to be significantly smaller.

The geophysical survey has risk ranges for both TTS and AUD INJ below 10 m for all hearing groups except the VHF group, which has risk of TTS exceedance to 350 m, and risk of AUD INJ exceedance to 240 m.

The absence of a positioning device, USBL, means that the risk ranges for threshold exceedances are lower than for other geophysical surveys where a towfish is deployed (SSS or towed SBP) which would require a USBL to determine the location of the towfish. USBLs are relatively loud at frequencies of greatest sensitivity for the HF and VHF groups, so the absence of this device decreases the noise at these critical frequencies. The choice to use a hull mounted parametric SBP means that the main sound energy is either very high frequency noise (attenuates rapidly) or very focused (the secondary interference beam characteristic of a parametric SBP), leading to limited effect ranges.

6.3.2 Geotechnical Survey & ROV Operations

The behavioural disturbance thresholds of all hearing groups are exceeded to the extent of the modelled area (within 10 km from the surveyed area). Depending on the presence of larger vessels in the area and the habituation of the animals the actual ranges to disturbance are likely to be significantly smaller.

Risk ranges for exceedance of TTS thresholds extend only to short ranges of 40-60 m for the HF group (common dolphin and bottlenose dolphin are in this group).

TTS threshold exceedance risk for the OW (amphibious mammals, e.g. otter) and fishes have ranges of 90-160 m.

TTS risk ranges for the PW (seals) and LF (baleen whales) groups extend from 600-1800 m.

For the VHF group the TTS thresholds exceedance risk ranges are from 2200-2900 m.

For the shallow geophysical, using a jackup barge, with no USBL, the AUD INJ risk ranges for all hearing groups are <10 m.

For the deep geotechnical and the ROV operations, using a USBL, the AUD INJ ranges are up to 250 m for the VHF group (porpoises), 20 m for the LF group (baleen whales) and <10 m for the remaining hearing groups.

7 MITIGATION

7.1 Geophysical Survey

Given the TTS exceedance risk range of 350 m and the AUD INJ exceedance risk range of up to 240 m for the VHF group, the following mitigation is proposed:

A. Before start of the geophysical survey, a 20-minute period where the MBES is active, but not the parametric SBP, will serve as a soft start to allow animals to swim away, and provided good reduction in risk ranges for the VHF hearing group.

   This reduces TTS exceedance risk ranges to 70 m and AUD INJ range to <10 m for the VHF groups (and all other groups).

B. Another soft start option – using the inbuilt ramp-up of the parametric SBP and no MBES – is less efficient at reducing risk ranges for the VHF hearing group, but might prove relevant.

   This reduces TTS exceedance risk ranges to 260 m and AUD INJ range to 170 m for the VHF groups (and <10 m for all other groups).

7.2 Geotechnical Survey

While this activity has substantial ranges to exceedance of TTS thresholds, the principal noise is the vessel itself and the approach of the vessel will serve as a suitable soft start. The noise of the modelled DP-enabled vessel is similar to the larger vessels frequently navigating in the same area and thus, trying to implement a specific soft start or mitigation procedure for this activity is not a practical or sensible solution. Rather, this assessment shows the potential impact of large vessels in general and may be seen as an argument for more silent vessels.

8 CONCLUSIONS

8.1 Geophysical Survey

Given the use of a parametric sub-bottom profiler and the absence of a USBL/HiPAP device, the risks for the VHF hearing group (porpoises) of TTS (temporary hearing impairment) is 350 m and AUD INJ (auditory injury) to 280 m. The remaining hearing groups have risk ranges for TTS and AUD INJ <10 m.

Thus, if there is a likelihood of encountering porpoises during the survey, the survey should implement mitigation as suggested in section 7.1 (soft start). If this mitigation is implemented, risk of exceeding the TTS threshold of the VHF group is brought within 260 m or 70 m depending on choice of mitigation method.

Given the implementation of the suggested mitigation, effects of noise from the geophysical survey against the auditory thresholds is assessed as being not significant.

8.2 Geotechnical Survey & ROV Operations

The modelled vessels for the geotechnical survey have noise emissions typical of larger vessels, though with somewhat more noise at higher frequencies due to the thrusters of the DP systems. While there is likely exceedance of the TTS thresholds to significant ranges for seals, porpoises and baleen whales (600-2900 m), the TTS threshold exceedance ranges for the HF group (dolphins) are below 60 m.

The AUD INJ threshold exceedances ranges are only above 20 m for the VHF group with a range of 250 m.

Mitigation for this activity is not practical nor sensible as the noise is similar to the existing larger vessels in the area.

The similarity of the noise produced by this activity to the existing vessel noise in the area means that while the activity is assessed as having potential to cause TTS to significant ranges, this does not constitute a substantial change to the existing environment.

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Appendix A – Acoustic Concepts and Terminology

Sound travels through water as vibrations of the fluid particles in a series of pressure waves. The waves comprise a series of alternating compressions (positive pressure variations) and rarefactions (negative pressure fluctuations). Because sound consists of variations in pressure, the unit for measuring sound is usually referenced to a unit of pressure, the Pascal (Pa). The unit usually used to describe sound is the decibel (dB) and, in the case of underwater sound, the reference unit is taken as 1 µPa, one micro-pascal, whereas airborne sound is usually referenced to a pressure of 20 µPa. To convert from a sound pressure level referenced to 20 µPa to one referenced to 1 µPa, a factor of 20 log (20/1) i.e. 26 dB has to be added to the former quantity. Thus, a sound pressure of 60 dB re 20 µPa is the same as 86 dB re 1 µPa, although care also needs to be taken when converting from in air sound to in water sound levels due to the different sound speeds and densities of the two mediums resulting in a conversion factor of approximately 62 dB for comparing intensities (watt/m²), see Table 9-1 , below.

Table 9-1: Comparing sound quantities between air and water.

	Constant intensity		Constant pressure	
Properties	**Air**	**Water**	**Air**	**Water**
Soundspeed (C) [m/s]	340	1500	340	1500
Density (ρ) [kg/m³]	1.293	1026	1.293	1026
Acoustic impedance (Z=C·ρ) [kg/(m²·s) or (Pa·s)/m³]	440	1539000	440	1539000
Sound intensity (I=p²/Z) [Watt/m²]	1	1	22.7469	0.0065
Sound pressure (p=(I*Z)^½) [Pa]	21	1241	100	100
Particle velocity (I/p) [m/s]	0.04769	0.00081	0.22747	0.00006
dB re 1 µPa²	146.4	**181.9**	160.0	**160.0**
dB re 20 µPa²	**120.4**	155.9	**134.0**	134.0
Difference dB re 1 µPa² & dB re 20 µPa²	**61.5**		**26.0**	

All underwater sound pressure levels in this report are described in dB re 1 µPa². In water, the sound source strength is defined by its sound pressure level in dB re 1 µPa², referenced back to a representative distance of 1m from an assumed (infinitesimally small) point source. This allows calculation of sound levels in the far-field. For large, distributed sources, the actual sound pressure level in the near-field will be lower than predicted.

There are several descriptors used to characterise a sound wave. The difference between the lowest pressure deviation (rarefaction) and the highest pressure deviation (compression) from ambient is the peak to peak (or pk-pk) sound pressure (L_{P-P} for the level in dB), Note that L_{P-P} can be hard to measure consistently, as the maximal duration between the lowest and highest pressure deviation is not standardised. The difference between the highest deviation (either positive or negative) and the ambient pressure is called the peak pressure (L_P for the level in dB). Lastly, the average sound pressure is used as a description of the average amplitude of the variations in pressure over a specific time window (SPL for the level in dB). SPL is equal to the L_{eq} when the time window for the SPL is equal to the time window for the total duration of an event. The cumulative sound energy from pressure is the integrated squared pressure over a given period (SEL for the level in dB). These descriptions are shown graphically in Figure 9-1 and reflect the units as given in ISO 18405:2017, “Underwater Acoustics – Terminology”.

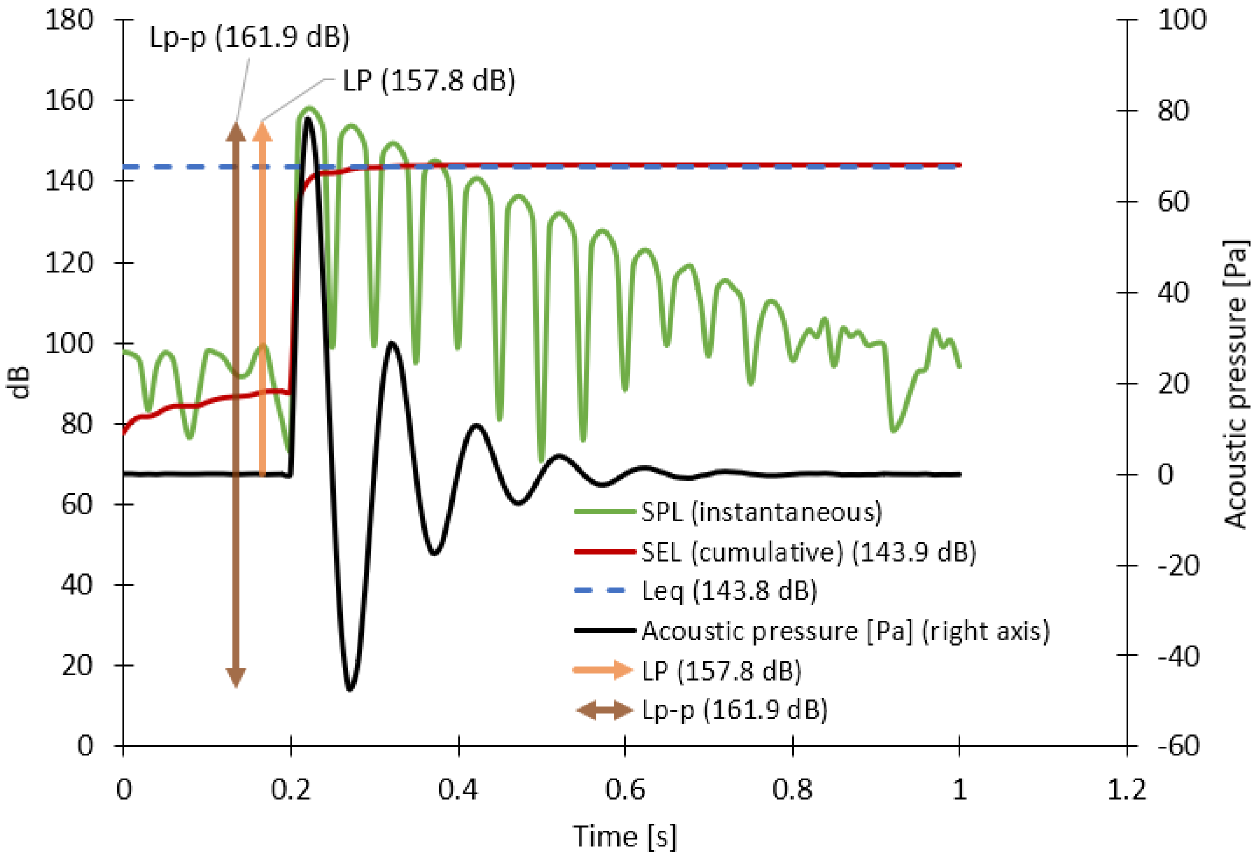

Figure 9-1: Graphical representation of acoustic wave descriptors.

The sound pressure level (SPL[13]) is defined as follows (ISO 18405:2017, 3.2.1.1):

$$SPL = 10 \cdot Log_{10}\left(\frac{\overline{p^2}}{1 \cdot 10^{-12} Pa}\right) \quad (1)$$

Here $\overline{p^2}$ is the arithmetic mean of the squared pressure values. Note that L_P is simply the instantaneous SPL (ISO 18405:2017, 3.2.2.1).

The peak sound pressure level, L_P, is the instantaneous decibel level of the maximal deviation from ambient pressure and is defined in (ISO 18405:2017, 3.2.2.1) and can be calculated as:

$$L_P = 10 \cdot Log_{10}\left(\frac{max(p^2)}{1 \cdot 10^{-12} Pa}\right)$$

Another useful measure of sound used in underwater acoustics is the Exposure Level, or SEL. This descriptor is used as a measure of the total sound energy of a single event or a number of events (e.g. over the course of a day). This allows the total acoustic energy contained in events lasting a different amount of time to be compared on a like for like basis. Historically, use was primarily made of SPL and L_P metrics for assessing the potential effects of sound on marine life. However, the SEL is increasingly being used as it allows exposure duration and the effect of exposure to multiple events over e.g. a 24-hour period to be taken into account. The SEL is defined as follows (ISO 18405:2017, 3.2.1.5):

$$SEL = 10 \cdot Log_{10}\left(\frac{\int_{t_1}^{t_2} p(t)^2 dt}{1 \cdot 10^{-12} Pa}\right) \quad (2)$$

To convert from SEL to SPL the following relation can be used:

[13] Equivalent to the commonly seen "RMS-level".

$$SEL = \mathrm{SPL} + 10 \cdot Log_{10}(t_2 - t_1) \quad (3)$$

Converting from a single event to multiple events for SEL:

$$SEL_{n\ events} = SEL_{single\ event} + 10 \cdot Log_{10}(n) \quad (4)$$

The frequency, or pitch, of the sound is the rate at which these oscillations occur and is measured in cycles per second, or Hertz (Hz). When sound is measured in a way which approximates to how a human would perceive it using an A-weighting filter on a sound level meter, the resulting level is described in values of dB(A). However, the hearing faculties of marine mammals and fish are not the same as humans, with marine mammals hearing over a wider range of frequencies, fish over a typically smaller range of frequencies and both with different sensitivities. It is therefore important to understand how an animal's hearing varies over the entire frequency range to assess the effects of sound on marine life. Consequently, use can be made of frequency weighting scales to determine the level of the sound in comparison with the auditory response of the animal concerned. A comparison between the typical hearing response curves for fish, humans and marine mammals is shown in Figure 9-2. Note that hearing thresholds are sometimes shown as audiograms with sound level on the y axis rather than sensitivity, resulting in the graph shape being the inverse of the graph shown. It is also worth noting that some fish are sensitive to particle velocity rather than pressure, although paucity of data relating to particle velocity levels for anthropogenic sound sources means that it is often not possible to quantify this effect. Marine reptiles (mostly sea turtles) have relatively poor hearing underwater, lacking a good acoustic coupling mechanism from the sea water to the inner ear.

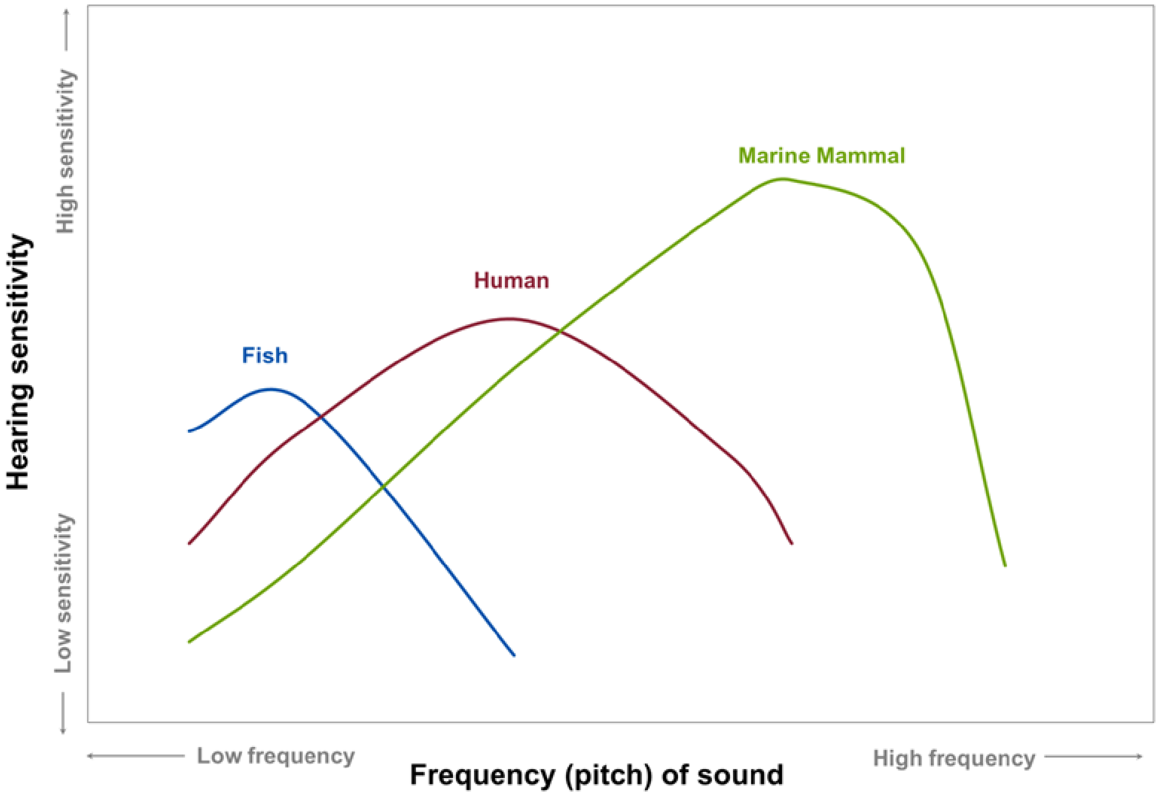

Figure 9-2: Comparison between hearing thresholds of different marine animals and humans.

Impulsiveness

The impulsiveness of a source can be estimated from the kurtosis of the weighted signal (as suggested by Matin et al. in "Techniques for distinguishing between impulsive and non-impulsive sound in the context of regulating sound exposure for marine mammals", Journal of the Acoustical Society of America, 2020)

The consequence of this is that the same equipment can be both impulsive and non-impulsive, depending o marine mammal presence and the local environment.

Below is an example of a hull mounted echo sounder at 15 m depth and at 250 m depth.

In shallow water the ping rate can be high as reflections from the sediment return quickly, but the single pulse duration is usually shorter as less energy in the signal is required due to the short range the pulse must travel. This leads to high repetition rate (decreases kurtosis) and shorter pulses (increases kurtosis). Figure 9-3 shows an example where this leads to a non-impulsive source, to be compared to the thresholds for non-impulsive noise.

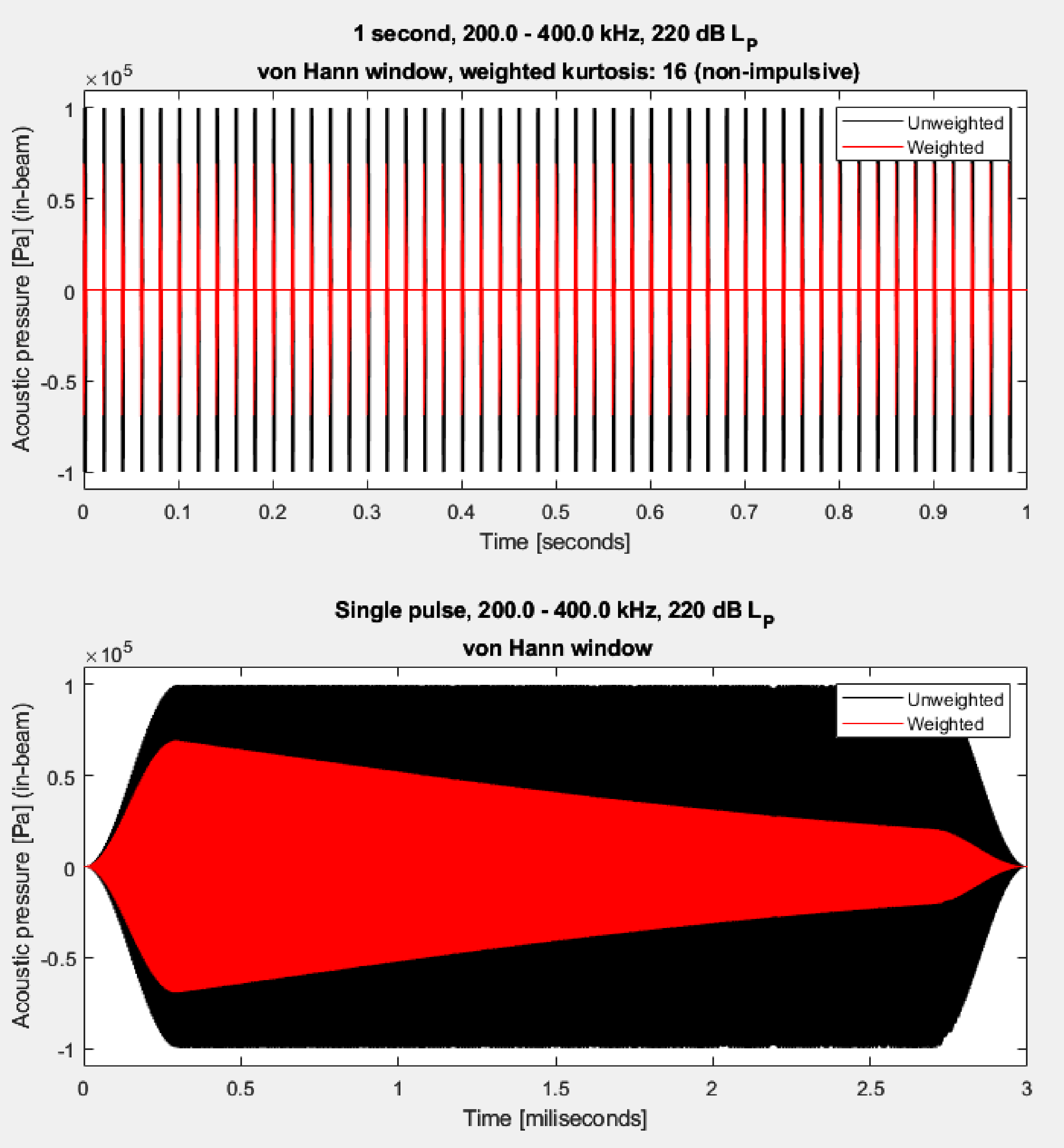

Figure 9-3. Example of a multibeam echosounder at 15 m depth (achieving 50 ping/sec) with a 3 ms ping duration. VHF-weighted kurtosis of 16 – non-impulsive.

In deeper water, the ping rate will usually be slower as echoes take longer to return to the sediment and the pulses will be longer to increase the energy in the pulses and make their echoes easier to detect. This leads to low repetition rate (increases kurtosis) and longer pulses (decreases kurtosis). Figure 9-4 shows an example where this combination resulted in an impulsive source, to be compared to the thresholds for impulsive noise.

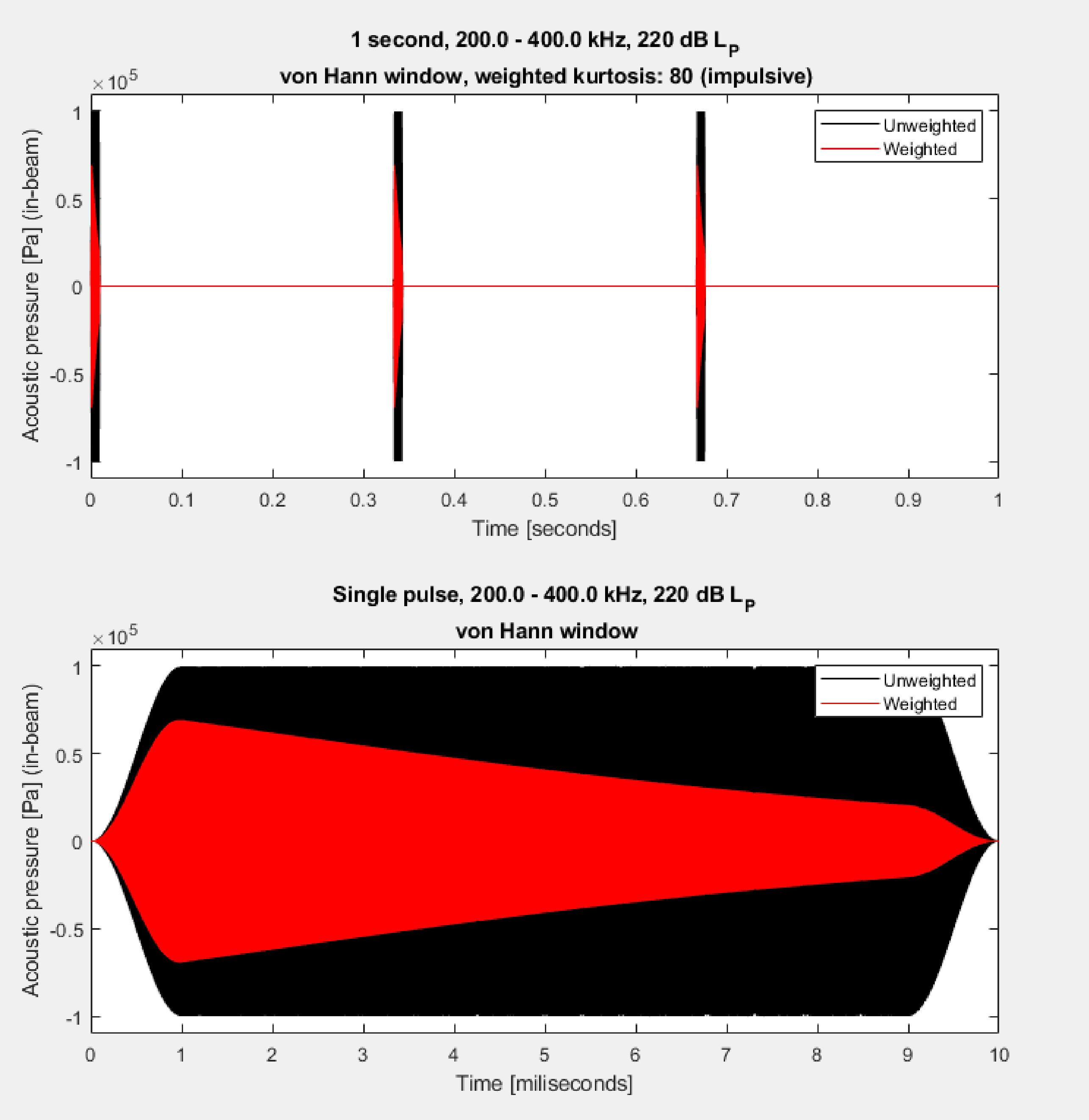

Figure 9-4. Example of a multibeam echosounder at 250 m depth (achieving 3 ping/sec) with a 10 ms ping duration. VHF-weighted kurtosis of 80 – impulsive.

With range, due to multiple reflections and scattering, the kurtosis will decrease with increased range, for shallow water this decrease will be quicker than for deeper water, compare Figure 9-5 & Figure 9-6, where a kurtosis <40 is reached at c. 200 m in 20 m depth, but at over 1000 m at 200 m depth.

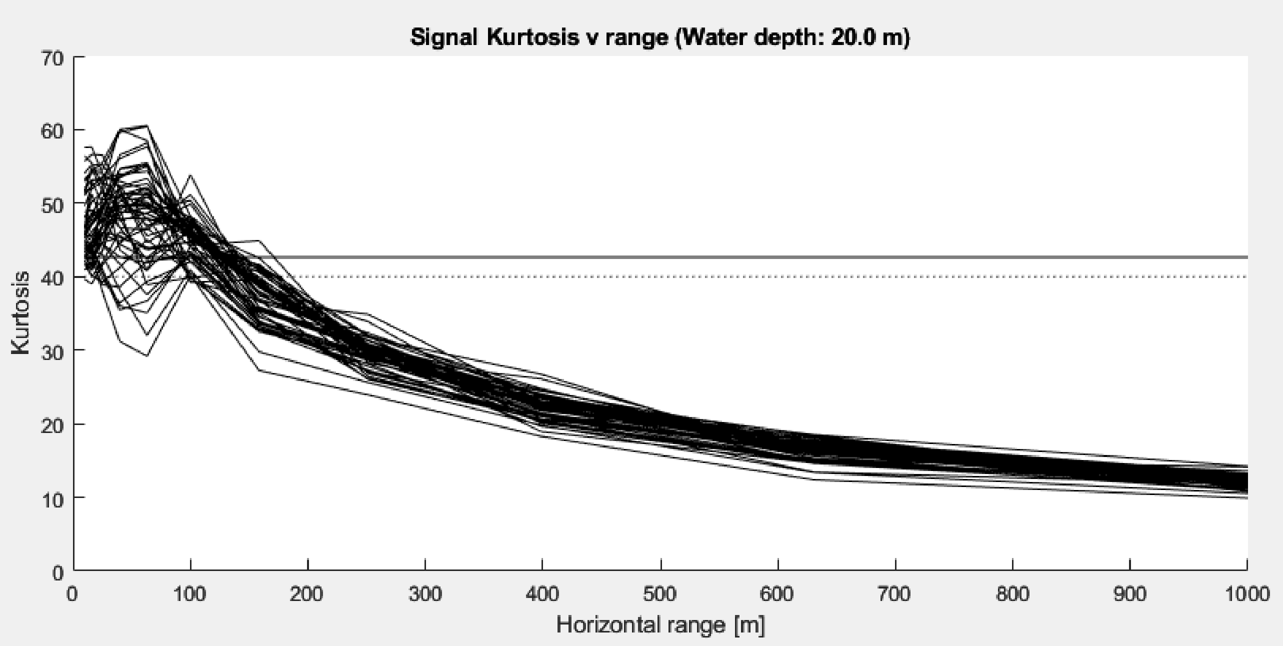

Figure 9-5. Example of USBL signal kurtosis decreasing with range at 20 m depth. Multiple lines are various combinations of source and receiver depths.

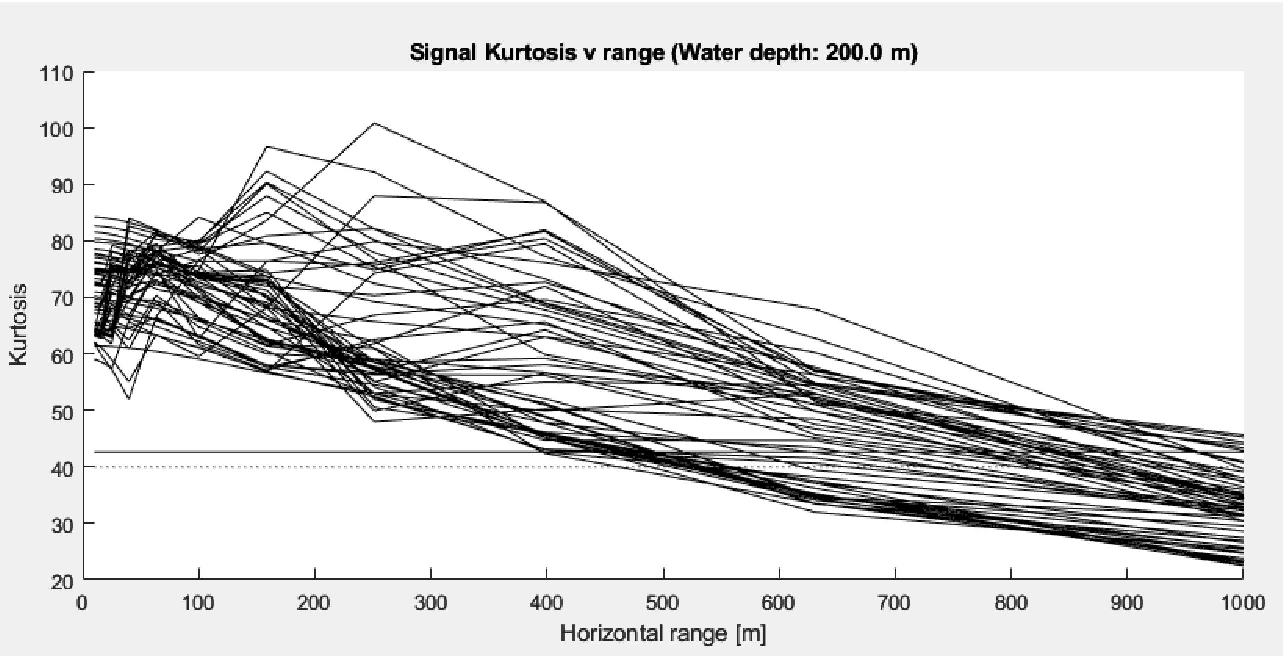

Figure 9-6. Example of USBL signal kurtosis decreasing with range at 200 m depth. Multiple lines are various combinations of source and receiver depths.

Review of Sound Propagation Concepts

Increasing the distance from the sound source usually results in the level of sound getting lower, due primarily to the spreading of the sound energy with distance, analogous to the way in which the ripples in a pond spread after a stone has been thrown in.

The way that the sound spreads will depend upon several factors such as water column depth, pressure, temperature gradients, salinity, as well as water surface and seabed conditions. Thus, even for a given locality, there are temporal variations to the way that sound will propagate. However, in simple terms, the sound energy may spread out in a spherical pattern (close to the source, with no boundaries) or a cylindrical pattern (much further from the source, bounded by the surface and the sediment), although other factors mean that decay in sound energy may be somewhere between these two simplistic cases.

In acoustically shallow waters[14] in particular, the propagation mechanism is coloured by multiple interactions with the seabed and the water surface (Lurton, 2002; Etter, 2013; Urick, 1983; Brekhovskikh and Lysanov 2003, Kinsler et al., 1999). Whereas in deeper waters, the sound will propagate further without encountering the surface or bottom of the sea, in shallower waters the sound is reflected many times by the surface and sediment.

At the sea surface, the majority of sound is reflected back into the water due to the difference in acoustic impedance (i.e. sound speed and density) between air and water. However, scattering of sound at the surface of the sea is an important factor with respect to the propagation of sound from a source. In an ideal case (i.e. for a perfectly smooth sea surface), the majority of sound wave energy will be reflected back into the sea. However, for rough waters, much of the sound energy is scattered (Eckart, 1953; Fortuin, 1970; Marsh, Schulkin, and Kneale, 1961; Urick and Hoover, 1956). Scattering can also occur due to bubbles near the surface such as those generated by wind or fish or due to suspended solids in the water such as particulates and marine life. Scattering is more pronounced for higher frequencies than for low frequencies and is dependent on the sea state (i.e. wave height). However, the various factors affecting this mechanism are complex. Generally, the scattering effect at a particular frequency depends on the physical size of the roughness in relation to the wavelength of the frequency of interest.

As surface scattering results in differences in reflected sound, its effect will be more important at longer ranges from the source sound and in acoustically shallow water (i.e. where there are multiple reflections between the source and receiver). The degree of scattering will depend upon the water surface smoothness/wind speed, water depth, frequency of the sound, temperature gradient, grazing angle and range from source. Depending upon variations in the aforementioned factors, significant scattering could occur at sea state 3 or more for higher frequencies (e.g. 15 kHz or more). It should be noted that variations in propagation due to scattering will vary temporally (primarily due to different sea-states/wind speeds at different times) and that more sheltered areas (which are more likely to experience calmer waters) could experience surface scattering to a lesser extent, and less frequently, than less sheltered areas which are likely to encounter rougher waters. However, over shorter ranges (e.g. within 10-20 times the water depth) the sound will experience fewer reflections and so the effect of scattering should not be significant. Consequently, over the likely distances over which injury will occur, this effect is unlikely to significantly affect the injury ranges presented in this report, and not including this effect will overestimate the impact.

When sound waves encounter the seabed, the amount of sound reflected will depend on the geoacoustic properties of the seabed (e.g. grain size, porosity, density, sound speed, absorption coefficient and roughness) as well as the grazing angle (see Figure 9-7[15]) and frequency of the sound (Cole, 1965; Hamilton, 1970; Mackenzie, 1960; McKinney and Anderson, 1964; Etter, 2013; Lurton, 2002; Urick, 1983). Thus, seabeds comprising primarily of mud or other acoustically soft sediment will reflect less sound than acoustically harder seabeds such as rock or sand. This effect also depends on the profile of the seabed (e.g. the depth of the sediment layers and how the geoacoustic properties vary with depth below the sea floor). The sediment interaction is less pronounced at higher frequencies (a few kHz and above) where interaction is primarily with the top few cm of the sediment (related to the wavelength). A scattering effect (similar to that which occurs at the surface) also occurs at the seabed (Essen, 1994; Greaves and Stephen, 2003; McKinney and Anderson, 1964; Kuo, 1992), particularly on rough substrates (e.g. pebbles and larger).

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[14] Acoustically, shallow water conditions exist whenever the propagation is characterised by multiple reflections with both the sea surface and seabed (Etter, 2013). Consequently, the depth at which water can be classified as acoustically deep or shallow depends upon numerous factors including the sound speed gradient, water depth, sediment type, frequency of the sound and distance between the source and receiver.

[15] The density of "rays" indicate difference in effective propagation angle from the source, with acoustically harder sediments (gravel) having better reflection at steeper angles leading to more "rays" being effectively propagated (no significant bottom attenuation) in the waveguide. Beam shape indicated in left chart, with the black line showing the same received level.

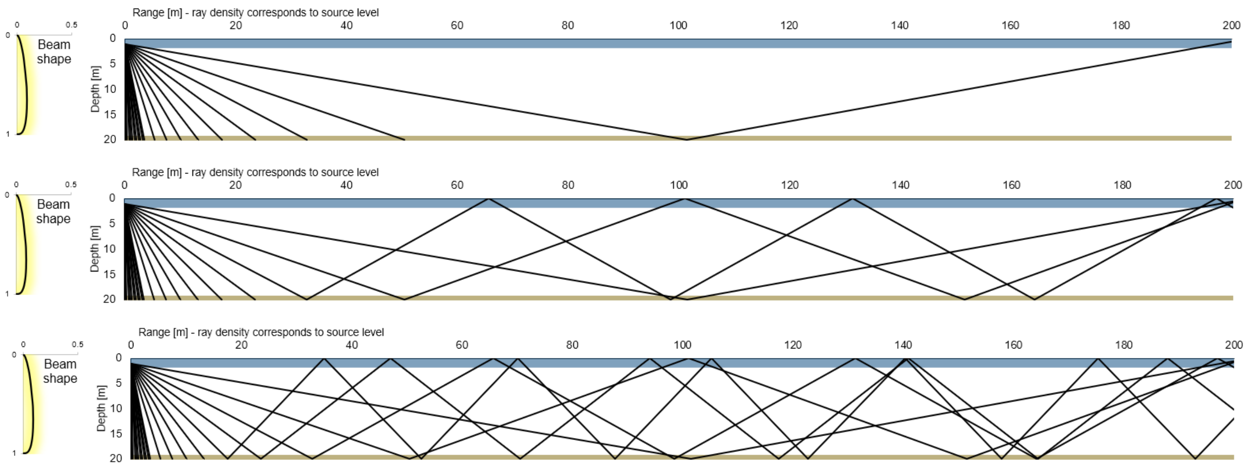


Figure 9-7: Schematic of the effect of sediment on sources with narrow beams. Sediments range from fine silt (top panel), sand (middle panel), and gravel (lower panel).

These sediment effects mean that the directivity of equipment such as sub-bottom profilers have a profound effect on the effective source level – the apparent source level to a far-away receiver.

A parametric SBP such as the "Innomar Medium" or "Standard" sub-bottom profiler use two higher frequencies ("primary frequencies") to generate an interference pattern at lower frequencies ("secondary frequencies"). This means that the secondary beam can be made extraordinarily narrow, e.g. 5 degrees at -10 dB (Figure 9-8), versus c. 50 degrees for a chirper/pinger type, leading to a much smaller sound impact – even when a parametric sub-bottom profiler has higher sound output within the main beam. We account for these differences in beam pattern by including the sediment reflection loss at high incidence angles (Figure 9-7) to reduce the effective source level accordingly.

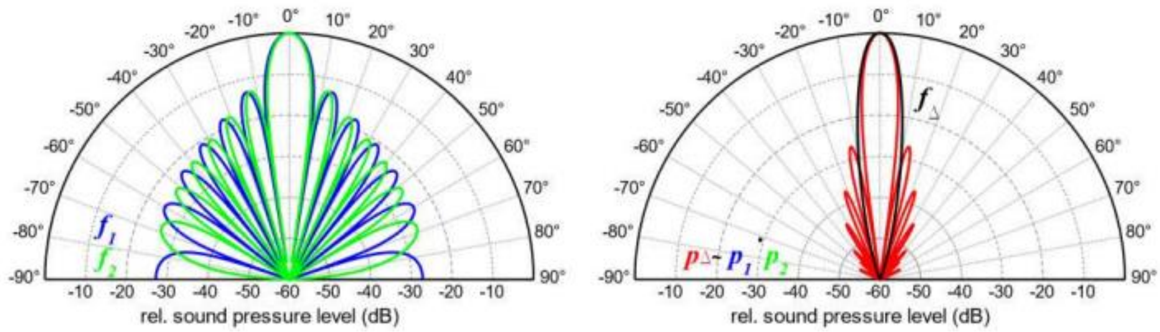


Figure 9-8. Example of a beam pattern on an Innomar SES 2000. Primary frequencies left (f1 & f2), the interference pattern between the primary frequencies means that the beam pattern for the secondary frequency (right plot) is very narrow (Source: Innomar technical note TN-01).

Another phenomenon is the waveguide effect which means that shallow water columns do not allow the propagation of low frequency sound (Urick, 1983; Etter, 2013). The cut-off frequency of the lowest mode in a channel can be calculated based on the water depth and knowledge of the sediment geoacoustic properties. Any sound below this frequency will not propagate far due to energy losses through multiple reflections. The cut-off frequency as a function of water depth is shown in Figure 9-9 for a range of seabed types. Thus, for a water depth of 10m (i.e. shallow waters typical of coastal areas and estuaries) the cut-off frequency would be approximately 70Hz for sand, 115Hz for silt, 155Hz for clay and 10Hz for bedrock.

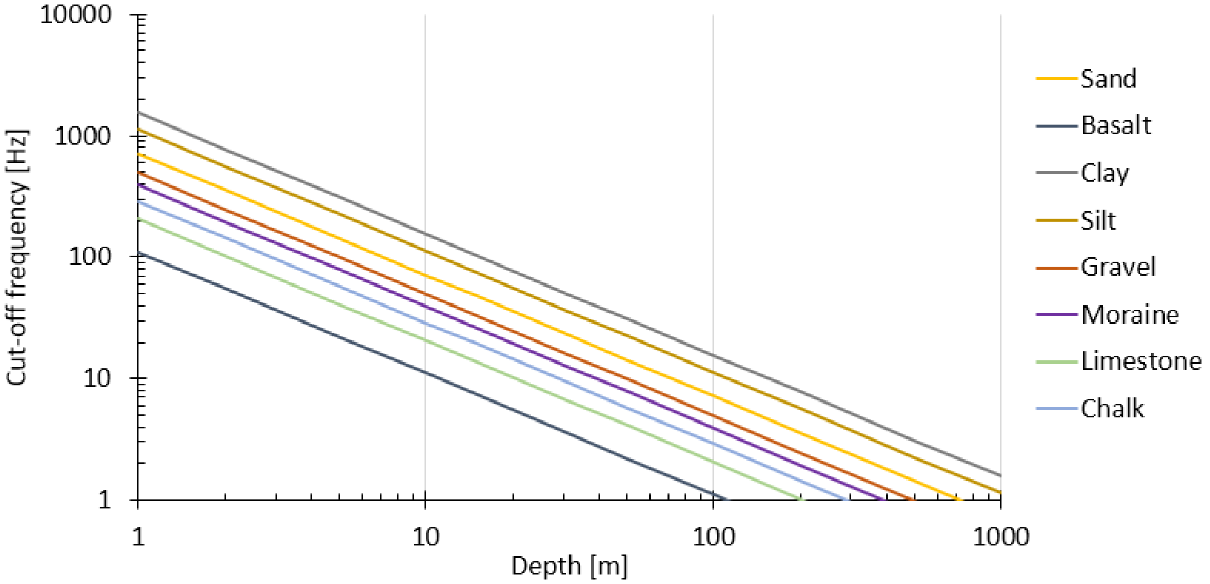


Figure 9-9: Lower cut-off frequency as a function of depth for a range of seabed types.

Changes in the water temperature and the hydrostatic pressure with depth mean that the speed of sound varies throughout the water column. This can lead to significant variations in sound propagation and can also lead to sound channels, particularly for high-frequency sound. Sound can propagate in a duct-like manner within these channels, effectively focussing the sound, and conversely, they can also lead to shadow zones. The frequency at which this occurs depends on the characteristics of the sound channel but, for example, a 25m thick layer would not act as a duct for frequencies below 1.5 kHz. The temperature gradient can vary throughout the year and thus there will be potential variation in sound propagation depending on the season.

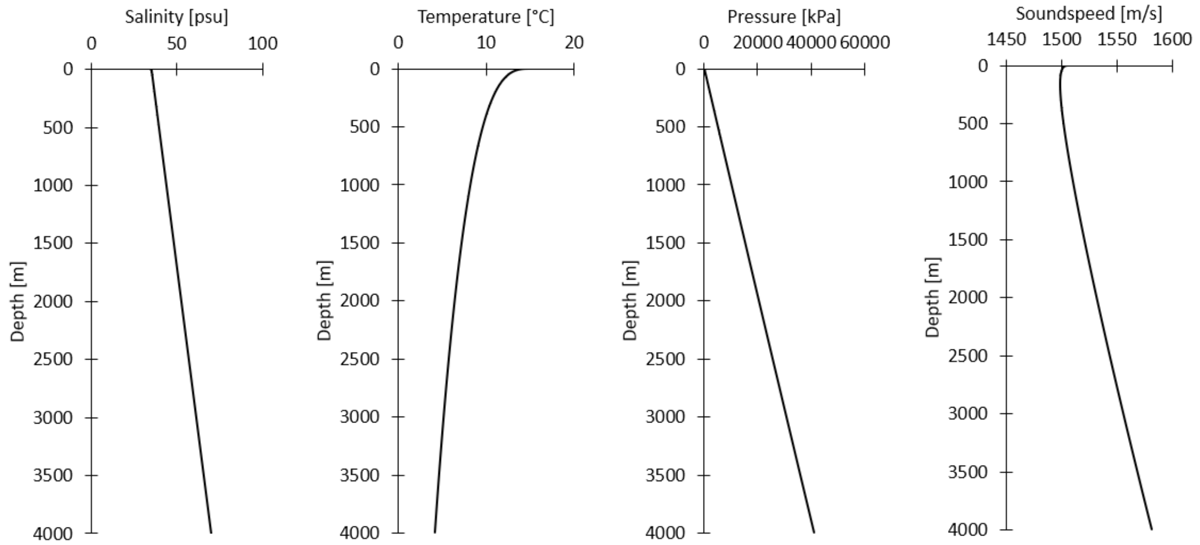


Figure 9-10: Soundspeed profile as a function of salinity, temperature and pressure.

Wind can make a significant difference to the soundspeed in the uppermost layers as the introductions of bubbles decreases the soundspeed and refracts (bends) the sound towards the surface, where the increased roughness and bubbles from the wind will cause increased transmission loss.

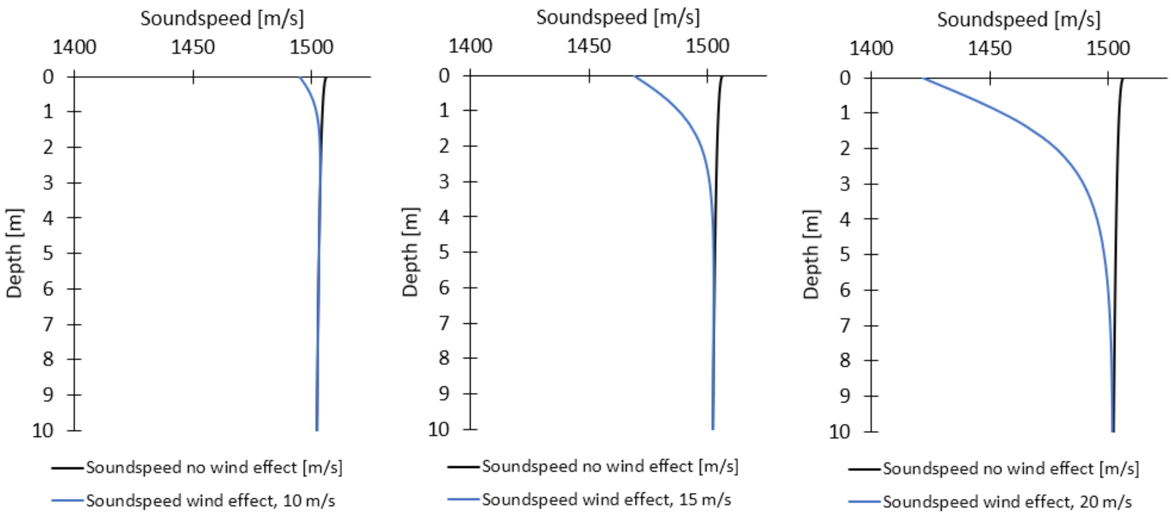


Figure 9-11: Effect of wind (at 10 m height) on upper portion of soundspeed profile.

Sound energy can also be absorbed due to interactions at the molecular level converting the acoustic energy into heat. This is another frequency dependent effect with higher frequencies experiencing much higher losses than lower frequencies. This is shown in Figure 9-12 where the variation of the absorption (sometimes called volume attenuation) is shown for various salinities and temperatures. As the effect is proportional to the wavelength, colder water, with slower soundspeed/period and being slightly more viscous, will have more absorption. Higher salinity slightly decreases absorption at low frequencies (mostly due to increase in soundspeed and wavelength/period), but much higher absorption at higher frequencies where interaction with pressure sensitive molecules of magnesium sulphite and boric acid increase the conversion acoustic energy to heat.

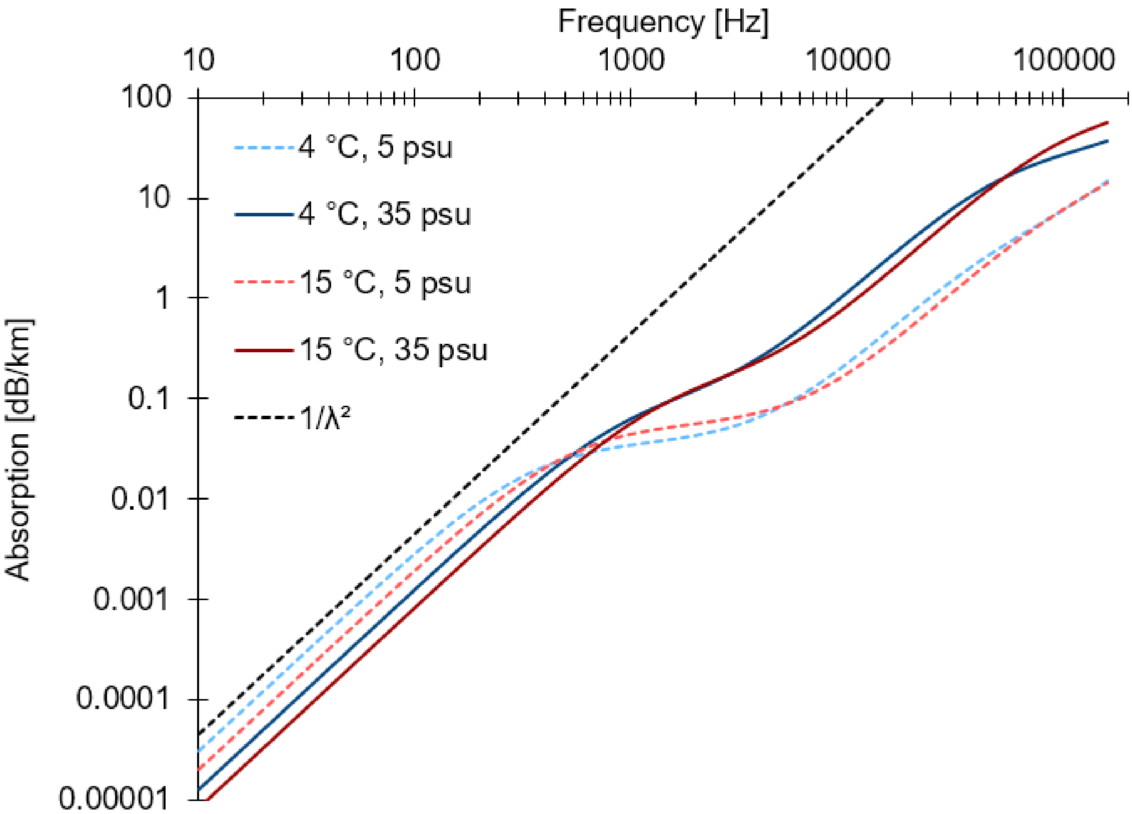


Figure 9-12: Absorption loss coefficient (dB/km) for various salinities and temperature.

Appendix B – Weston Propagation Model Validation

The Weston 1971-1976 sound propagation model was first published in 1971 as “Intensity-Range Relations in Oceanographic Acoustics” by D. E. Weston in the Journal of Sound and Vibration, with an update in 1976 as “Propagation in Water With Uniform Sound Velocity but Variable-Depth Lossy Bottom” by D.E. Weston in the Journal of Sound and Vibration.

The model presents a pragmatic approach to sound propagation modelling by splitting propagation into four distinct regions dependent on the given range, water depth and wavelength, and has be made range-dependent for both depth, soundspeed and sediment properties.

This appendix presents a few testcases with known solutions compared to this implementation of the Weston propagation model.

Comparison to normal modes, ray-tracing and parabolic equation models

Source:

Sertlek H. Ö. & Ainslie M. A (2003), “Propagation loss model comparisons on selected scenarios from the Weston memorial workshop”. 1st International Conference and Exhibition on Underwater Acoustics.

Case 1

Depth 100 m, max range 40 km.

This is a simple semi-deep waveguide which might be considered representative for parts of the continental shelf.

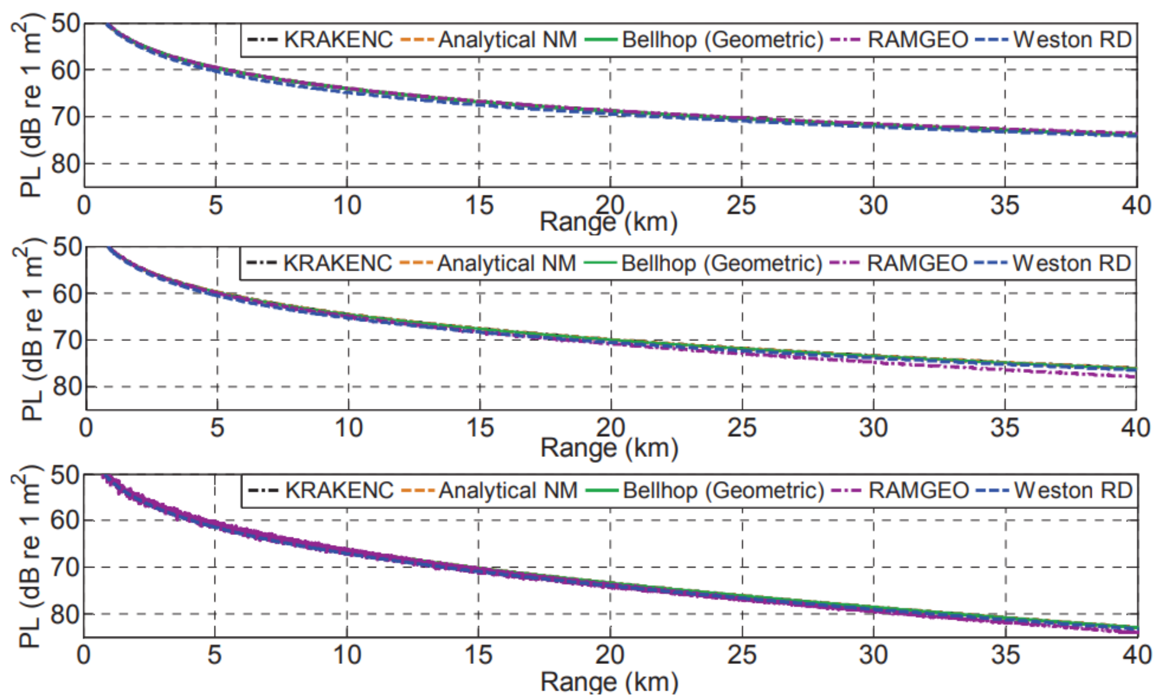


Figure 5. Depth-averaged (over receiver depth)PL vs range for Case 1 (f=250 Hz (top), f=1 kHz (middle), f=3.5 kHz (bottom)). Source depth = 30 m.

Case 2

Depth 100 m to 5 km then sloping up to 30 m at 7 km. Remaining at 30 m depth to 40 km range.

The step up at 5 km range tests the models' ability to calculate the effect of slowly changing depths in an upslope environment. Note that for 250 Hz (top panel in figure below) the Weston model underestimates the loss after c. 20 km, leading to a higher received level. The ray-tracer (Bellhop) shows the same result. This is expected as the Weston model relies on approximations made from ray-theory to specify the transitions between propagation regions.

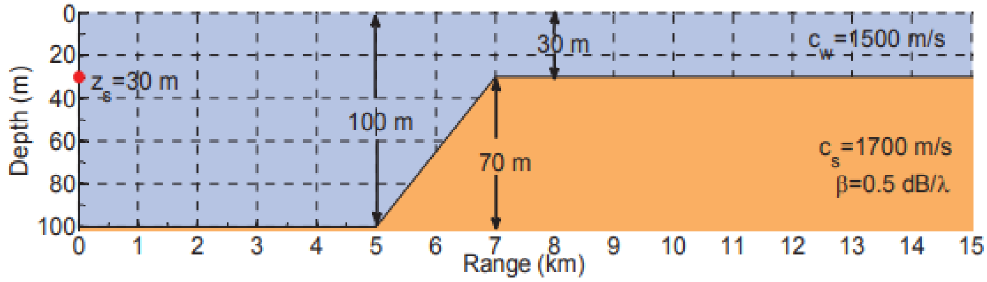


Figure 6. The bathymetry of Case 4

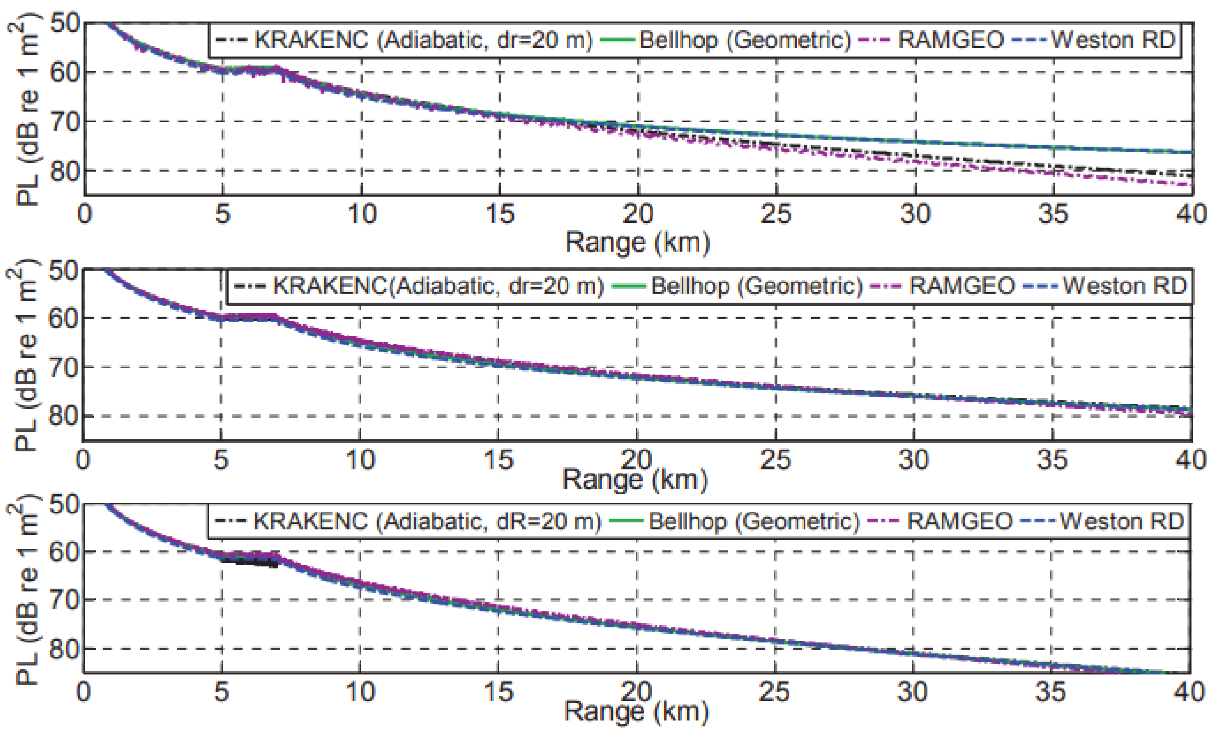


Figure 7. Depth-averaged (over receiver depth)PL vs range for Case 4 (f=250 Hz (top), f=1 kHz (middle), f=3.5 kHz (bottom)). Source depth = 30 m.

Case 3

Depth 100 m to 5 km, then sloping up to 30 m at 7 km. Remaining at 30 m depth to 7 km, then sloping down to 100 m depth at 10 km.

The “bump” scenario represents a shallow bank between two deeper sections. It tests the models’ ability to transition between different regions of propagation. There is excellent agreement between the Weston model and the numerical models.

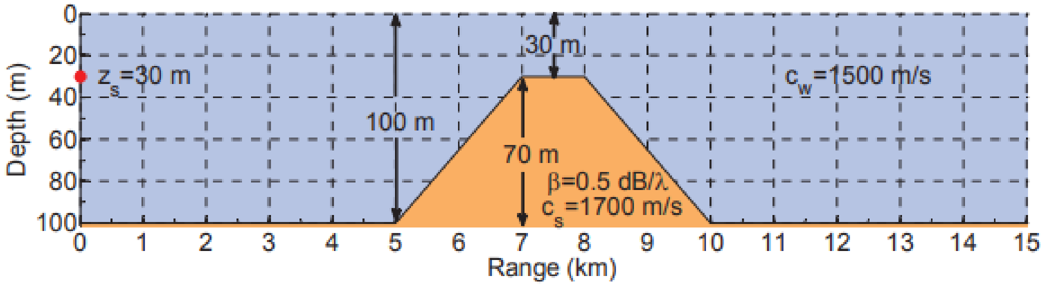


Figure 8. The bathymetry of Case 9

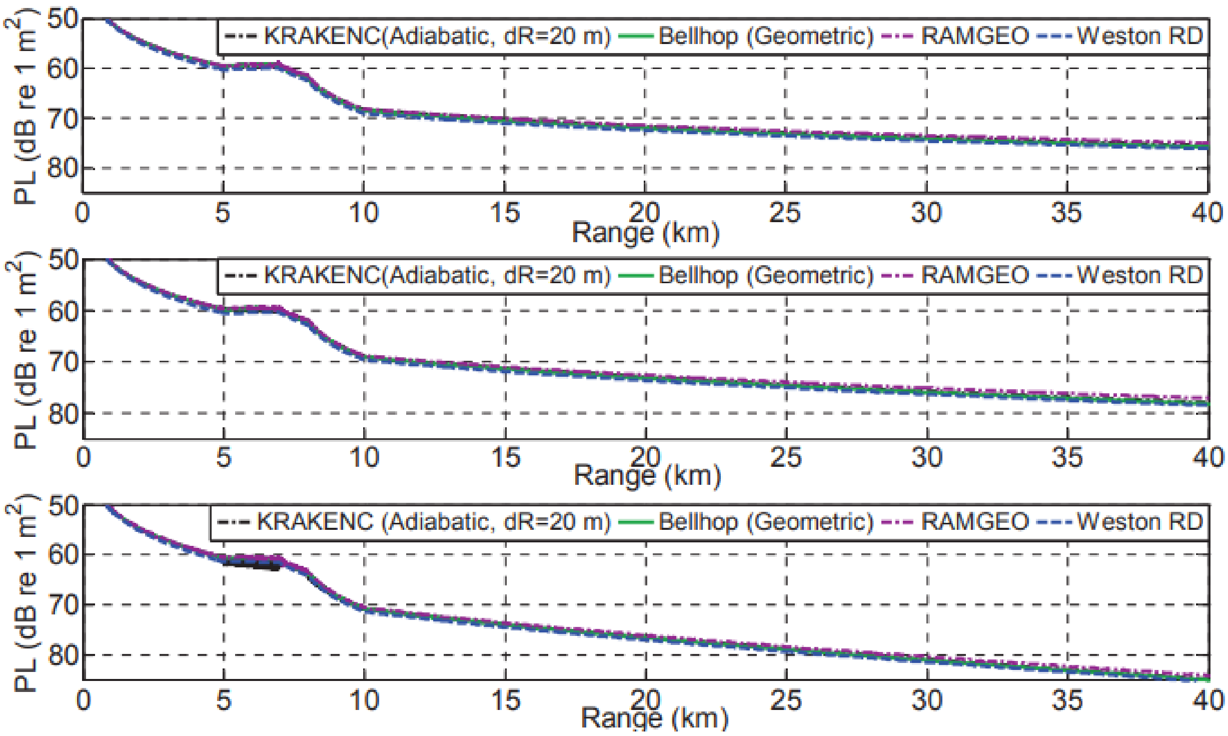


Figure 9. Depth-averaged (over receiver depth) PL vs range for Case9 (f=250 Hz (top), f=1 kHz (middle), f=3.5 kHz (bottom)). Source depth = 30 m.

Broadband comparison with various commercial models

Source:

Bas Binnerts, Christ de Jong, Ilkka Karasalo, Martin Östberg, Thomas Folegot, Dominique Clorennec, Michael A. Ainslie, Graham Warner, Lian Wang (2109), "Model Benchmarking Results For Ship Noise In Shallow Water", JOMOPANS.

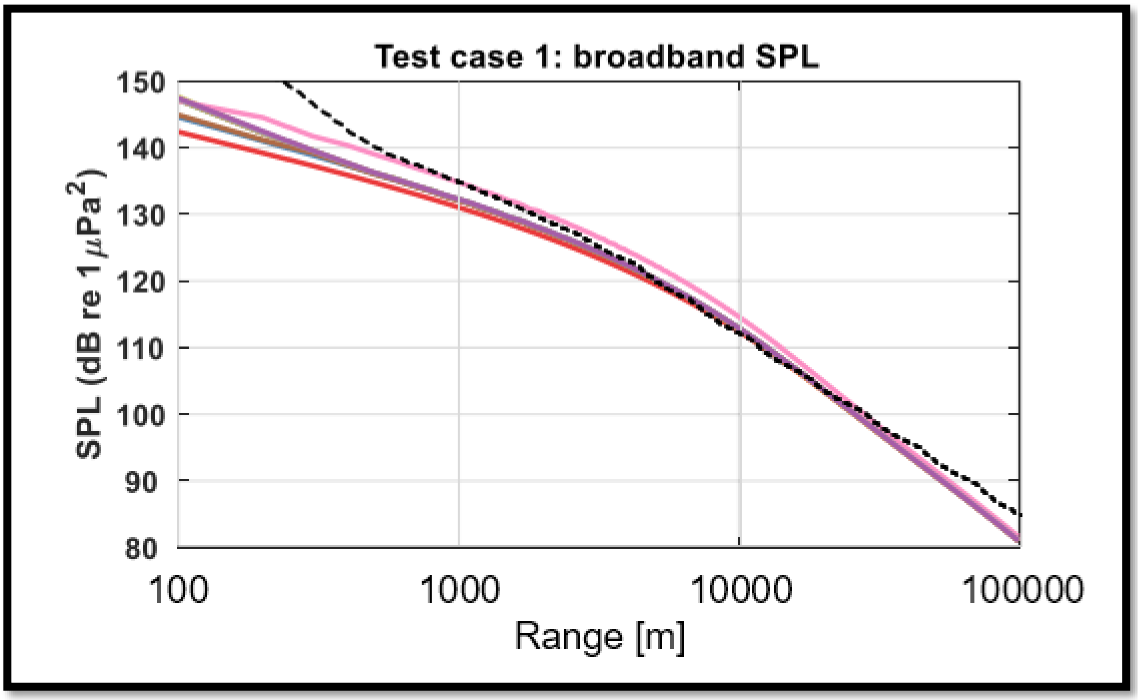
Two cases are investigated, both with a vessel source model used as the source and from 10 Hz to 20 kHz.

Case 1

50 m depth to 100 km range.

Broadband levels versus range

The Weston model matches the general losses well at ranges over c. 500 m.



Case 2

100 m depth to 5 km, then upslope to 30 m depth at 7 km. Remaining at 30 m depth to 50 km range.

Broadband levels versus range

The Weston model matches the general losses well at ranges over c. 500 m.