16 Underwater Noise

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16 Underwater Noise

16.1 Executive Summary

16.1.1 As part of the Proposed Development there is a requirement for a new extended slipway and a new landing jetty to be constructed on the south-east of Faray, this would include works below the Mean High Water Spring (MHWS). This chapter provides an assessment of underwater noise impacts below MHWS only.

16.1.2 The Proposed Development comprises:

- A new extended slipway to replace the existing facility. The extant slipway is c.20 m long by 3.5 m wide, though this was originally longer. This would be upgraded (i.e. extended and widened) to a maximum 36 m long and 8 m wide. The design of the slipway would be sufficient to enable access by larger vessels with the bow or stern gate and would be built to a standard design for the Orkney Islands to allow access for local vessels.
- A new landing jetty to accommodate abnormal loads. The jetty would comprise a causeway up to 55 m long and 10 m wide, terminating in square structure for docking measuring up to 20 m by 20 m. The square docking structure would likely be constructed on site from sheet piles. The causeway would be in-filled and capped-off with concrete batched onsite.

16.1.3 The new extended slipway and landing jetty are shown in Figure 3.3.

16.1.4 The works would likely involve sheet piling for the new landing jetty. Piling causes high-amplitude, impulsive sounds that can result in a range of impacts to marine mammals, from behavioural changes to masking auditory cues used for navigation, communication and foraging and injury, such as physical damage to hearing systems. As such, the potential impacts of underwater noise from piling to marine mammals required assessment.

16.1.5 Based on data sources such as SCANS-III (Hammond et al, 2017) and the Special Committee on Seals (SCOS) (2019), along with site specific data from the Orkney Wildlife Information and Records Centre (OWIRC), the following marine mammals are likely to be present within the Proposed Development area and were scoped into the underwater noise assessment:

- Pinnipeds (grey seal and harbour seal);
- Low-frequency cetaceans (baleen whales);
- Mid-frequency cetaceans (common dolphin, bottlenose dolphin, Atlantic white-sided dolphin, orca, long-finned pilot whale, minke whale, Risso's dolphin, white-beaked dolphin); and,
- High-frequency cetaceans (harbour porpoise).

16.1.6 This chapter describes the assessment carried out to assess the impact of underwater sound generated by sheet pile driving activity on marine mammals in the proximity to Faray.

16.1.7 Underwater noised modelling was undertaken by HR Wallingford. Three impact thresholds were assessed, with the modelling identifying the area where these thresholds would be exceeded:

- Potential for permanent impacts, known as Permanent Threshold Shift (PTS). PTS is where permanent impacts to hearing sensitivity could occur (note this is any permanent change to hearing sensitivity, not just total loss of hearing).
- Potential for temporary impacts, known as Temporary Threshold Shift (TTS). TTS is where temporary injury would occur, i.e. temporary impacts to hearing sensitivity which will return to normal overtime.

- Potential for behavioural changes. At sound levels lower than those that can cause injury, impacts may also occur due to behavioural disturbance to marine mammals. Possible behavioural changes may include startle response, extended cessation or modification of vocal behaviour, brief cessation of reproductive behaviour or brief separation of females and dependent offspring.

16.1.8 From this, the number of individuals that could potentially be impacted was identified and impacts to local, regional and population levels of each species determined.

16.1.9 The modelling assumed that a soft-start procedure is in place, as per the JNCC piling protocol (2010), to allow for marine mammals to vacate the area. However, the modelling results are conservative estimates as, in line with the piling protocol, a pre-piling search of an established 500 m mitigation zone around the operations would be undertaken to ensure the area is clear of marine mammals prior to the soft-start commencing. If there is a pause in the piling operations for a period of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated before piling recommences. Therefore, the number of animals potentially within the areas of TTS and PTS exceedance would be less than those calculated within the assessment.

16.1.10 The modelling shows that, with the use of standard mitigation (i.e. soft-start), mid-frequency cetaceans are predicted to receive dosages that are below the threshold for both the TTS and PTS. Thus, effects to mid-frequency cetaceans were assessed as **negligible and not significant**.

16.1.11 During installation of a single pile using standard mitigation measures, which includes a 20 minute soft start period at the start of pile driving, seals are predicted to receive a cumulative sound exposure level (SELcum) dosage that exceeds TTS within a distance of 1,980 m (1.35 km^2 area). No exceedance above the level for PTS is predicted for seals. Harbour seals are not likely to be within the area in any great numbers, therefore the effect is **negligible and not significant**. However, the area that exceeds TTS has the potential to impact a significant percentage of the local grey seal population, although regionally and nationally the percentage of grey seal population potentially experiencing TTS is predicted to be below 1%. As such, the significance of effect to grey seals was initially assessed as moderate and significant.

16.1.12 Low-frequency cetaceans (baleen whales) are predicted to have the largest extent of impact, exceeding PTS and TTS thresholds within a distance of 3,030 m (7.65 km^2) and 12,950 m (15.90 km^2) respectively. This assumes the low-frequency cetaceans swim directly away from the noise source and results in the potential for PTS <0.01% of the regional population. Using a modified fleeing method for low-frequency cetaceans, whereby they are assumed to flee to the nearest exit, results in marginally smaller distance for PTS of 2,770 m (TTS remains the same), and the area the impact for PTS reduces to 2.3 km^2 instead of 7.65 km^2. Again, this results in PTS to less than 0.01% of the regional population. However, the shallow water depth in the region means that there is a low likelihood of low-frequency whales being present in much of the area affected by the noise. At MHWS, approximately 3 km^2 and 10 km^2 of the area is less than 10 m and 20 m deep respectively. The area at which PTS is exceeded is limited to these shallower waters and, thus, effects from PTS are considered to be negligible and not significant.

16.1.13 TTS impact would affect 0.01% of the population. In reality, the result is likely to lie somewhere between the two fleeing methods. Overall, taking into account the fact that the area is relatively shallow, the effect to low-frequency cetaceans, assuming standard mitigation and fleeing via the nearest exit, was deemed to be **minor and not significant**.

16.1.14 High-frequency cetaceans (harbour porpoise) are predicted to have the second largest extent of impact, exceeding PTS and TTS thresholds within a distance of 340 m (0.01 km^2) and 3,080 m (8.60 km^2) respectively. This assumes the high-frequency cetaceans are swimming directly away from the noise source and results in the potential for TTS to more than 1% of the local population. Using a modified fleeing method for high-frequency cetaceans, whereby they are assumed to flee to the nearest exit, results in marginally smaller distances for PTS and TTS (30 m and 3,070 m), and in terms of total area the impact is 7.9 km^2 instead of 8.6 km^2 for TTS.

16.1.15 Overall, for harbour porpoise using either the swim directly away or the quickest escape method for fleeing, the PTS thresholds are only expected to be exceeded within the standard 500 m mitigation zone. As a pre-piling search will be undertaken to ensure the mitigation zone is clear of marine mammals prior to piling commencing, PTS to an individual is not expected to occur. Furthermore, due to the pre-piling search of the mitigation zone, the number of individuals impacted is a conservative estimate. None the less, as TTS could occur to >1% of the local population, the overall significance of effect (due to TTS) was deemed to be **moderate and significant**.

16.1.16 As there is the potential for moderate impacts to both local grey seal and harbour porpoise populations, the use additional mitigation has been investigated. Namely, the use of a bubble curtain.

16.1.17 The use of a bubble curtain results in no exceedance of the PTS threshold for any marine mammal species. In addition to standard mitigation, the predicted distances for TTS for seals is also zero. As such the residual effect to grey seals is **negligible and not significant**.

16.1.18 For low-frequency cetaceans, the addition of a bubble curtain results in a maximum distance of 3,030 m for TTS, reducing slightly to 2,760 m if the animals are assumed to swim to the nearest exit. This results in the potential for TTS to <0.001% of the regional population. Thus, residual effect to low-frequency cetaceans is **minor and not significant**.

16.1.19 Using a bubble curtain, the impact distance for TTS to harbour porpoise result in a maximum distance of 50 m and 300 m for the ‘nearest exit’ and ‘swim directly away’ fleeing methods, respectively, which is within the standard 500 m mitigation zone. The residual effect to harbour porpoises using bubble curtain mitigation is, therefore, deemed to be **minor and not significant**.

16.1.20 Behavioural disturbance of the marine mammals is predicted to occur over a larger area compared to the areas of potential injury described above. Under standard mitigation (soft-start only) the maximum distance within which low-level disturbance (140 dB re 1µPa) may occur for marine mammals is predicted to be approximately 19 km, covering an area of 26.6 km^2. High-level disturbance is predicted to occur at a distance of up to 3.4 km (8.0 km^2). Using the bubble curtain mitigation option reduces this to 4 km (9.1 km^2) and 0.42 km (0.1 km^2) for low-level and high-level disturbance, respectively. Although the areas are quite large, behavioural impacts are temporary and reversible and the percentage of marine mammals impacted at regional and population levels is low; <1% of all species when the bubble curtain is applied. As such the residual effects from behavioural disturbance are deemed to be **negligible and not significant** for all marine mammal species assessed.

16.2 Introduction

16.2.1 This chapter describes and evaluates impacts from underwater noise to marine mammals associated with sheet piling of the new landing jetty. It documents the baseline conditions, includes an assessment of the likely effects of underwater noise below Mean High Water Springs (MHWS) on ecological features above a certain value, and defines mitigation measures where significant effects are predicted.

16.2.2 As part of the Proposed Development there is a requirement for a new extended slipway and a new landing jetty to be constructed on the south-east of Faray, this would include works below the MHWS. Under the Marine (Scotland) Act 2010, an application for a marine licence will be submitted to Marine Scotland (MS-LOT) for the construction works below MHWS. The structures are illustrated in Figure 3.3.

16.2.3 Initial information suggests that the new landing jetty would be constructed using 0.6 m wide PU-28 sheet piles which are likely to be installed using a 30 kJ pile driving hammer. Because these are to be installed beyond mean low water, there is the possibility for underwater sound to be introduced into the surrounding water. Marine mammals use sound for a variety of reasons (foraging, orientation and navigation, communication, detection and predator avoidance) and are, therefore, potentially susceptible to elevated levels of anthropogenic underwater noise. Piling causes high-amplitude, impulsive sounds that can result in a range of impacts to marine mammals, from behavioural changes to masking auditory cues used for navigation, communication and foraging and injury, such as physical damage to hearing systems. It is therefore necessary to assess the potential noise impacts on marine mammals.

16.2.4 The specific objectives of this chapter are to:

- Describe the ecological baseline conditions below MHWS.
- Define the scope of the underwater noise assessment.
- Assess the magnitude of the impacts and significance of effect on marine mammals in the area due to underwater noise emitted during the pile driving activity. The assessment draws upon detailed numerical modelling of underwater sound propagation carried out by HR Wallingford and includes the presence of standard mitigation measures.
- Provide additional mitigation measures to address potential significant effects and assess any residual impacts.
- Provide an impact assessment to accompany the marine licence application.
- Provide MS-LOT and NatureScot (previously Scottish Natural Heritage, SNH) with the relevant information to determine whether a European Protected Species (EPS) and/or seal licence is required for the piling activities.

16.2.5 This chapter has been authored by HR Wallingford and ITPE and is supported by the following appendices:

- Appendix 16.1 – Underwater noise modelling figures
- Appendix 16.2 – Behavioural disturbance assessment

Statement of Competence

16.2.6 The underwater noise modelling has been carried out by HR Wallingford in accordance with National Oceanic and Atmospheric Administration (NOAA) and Marine Scotland Guidelines. This chapter has been prepared by Thomas Benson of HR Wallingford and Gemma Tait of ITPE.

16.2.7 Thomas Benson (MRes, PhD) has 15 years of experience working at HR Wallingford as a physical oceanographer, specialising in underwater acoustics, hydrodynamics and agent-based modelling of marine species. HR Wallingford is a world-renowned independent research, engineering and consultancy organisation founded in 1947 by the Department of Scientific and Industrial Research as a publicly funded facility for carrying out hydraulic research and development for the UK government. In 1982 the company was privatised but still retained a special status as a not-for-profit distributing company where any profits are reinvested back into the company in order to fund further research.

16.2.8 Gemma Tait (MA, MSc) is a Principal Environmental Consultant at ITPE, an EIA specialist with over 10 years' experience.

Proposed development

16.2.9 As discussed in Chapters 3 and 12, the following construction works would include works below MHWS.

New Extended Slipway

16.2.10 A new extended slipway would be required to replace the existing facility. This item would need to be replaced regardless of the Proposed Development as the current slipway is badly damaged and access to the island is still required for agricultural purposes. The new extended slipway would be built in the same location as the existing slipway. It would be refurbished and extended to allow for preliminary site works to be undertaken. The design of the slipway would be sufficient to enable access by larger vessels with the bow or stern gate and would be built to a standard design for the Orkney Islands to allow access for local vessels. The extant slipway is c.20 m long by 3.5 m wide, though this was originally longer. This would be upgraded to a maximum 36 m long and 8 m wide.

16.2.11 Piling will not be required for the extended slipway, thus it has been scoped out of the underwater noise assessment.

New Landing Jetty

16.2.12 The new landing jetty is necessary because of the dimensions of the turbine components mean that a slipway is unsuitable for delivery. The jetty has, therefore, been designed to accommodate vessels which transport the turbine components. The jetty would comprise a causeway up to 55 m long and 10 m wide, terminating in square structure for docking measuring up to 20 m by 20 m. The square docking structure would likely be constructed on site from sheet piles, this would result in piling activities below MHWS. The causeway would be in-filled and capped-off with concrete batched onsite.

16.2.13 Localised dredging will be required for the construction of both the slipway and the jetty, in addition there is the potential for dredging to allow for vessel access to the jetty to be required. Dredging is subject to a separate marine licence application. Chapter 17 assesses the potential impacts of the proposed dredging activities.

16.3 Legislation, Policy and Guidelines

16.3.1 Relevant legislation, policy and guidance documents have been reviewed and taken into account as part of this assessment. Of particular relevance are:

- Council Directive 2014/89/EU establishing a framework for maritime spatial planning (Marine Spatial Planning Directive);
- Council Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive, MSFD);
- Council Directive 92/43/EEC on the Conservation of Natural Habitats and Wild Flora and Fauna (the Habitats Directive);
- Marine (Scotland) Act 2010;
- The Marine Strategy Regulations 2010;
- Scotland's National Marine Plan (NMP) (Scottish Government, 2015);

- The Pilot Pentland Firth and Orkney Waters Marine Spatial Plan (Scottish Government, 2016);
- The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) (the Habitats Regulations);
- The protection of Marine European Protected Species from injury and disturbance, guidance for Scottish Inshore Waters (Marine Scotland, 2020);
- The Protection of Seals (Designation of Haul-Out Sites) (Scotland) Order 2014;
- The Wildlife and Countryside Act 1981 (as amended) (WCA);
- The statutory protocol for minimising the risk of injury to marine mammals from piling noise written by the Joint Nature Conservation Committee (JNCC piling protocol) (JNCC, 2010);
- Guidance by the National Oceanic and Atmospheric Administration on the criteria for underwater noise impacts on marine mammals (Southall et al, 2007; NOAA, 2016);
- The Good Practice Guide No. 133 for Underwater Noise Measurement by the National Physics Laboratory (NPL, 2014); and
- An evaluation of the effectiveness of Acoustic Deterrent Devices and other non-lethal measures on marine mammals has also been published (Marine Scotland, 2014).

Legislation

Marine Strategy Framework Directive

16.3.2 Under the Marine Strategy Regulations 2010, which ratify the MSFD into UK law, the Secretary of State and devolved authorities must take necessary measures to achieve or maintain "good environmental status". Good environmental status is defined within the regulations as: *"the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations, i.e.…Anthropogenic inputs of substances and energy, including noise, into the marine environment do not cause pollution effects"*.

Marine Licence

16.3.3 Under the Marine (Scotland) Act 2010, an application for a marine licence will be submitted to MS-LOT for the Proposed Development construction works below the MHWS, namely the new extended slipway and new landing jetty (as shown in Figure 3.3).

16.3.4 In line with the Marine Licensing (Pre-application Consultation) (Scotland) Regulations 2013, a pre-application consultation event will be held for the application. Comments received will be considered and detailed within a pre-application consultation report which will accompany the application.

Marine Mammal Protection

<u>Cetaceans</u>

16.3.5 Under Regulation 39(1) of the Habitats Regulations, it is an offence to:

- Deliberately or recklessly capture, injure, or kill a wild animal of a European Protected Species (EPS);
- Deliberately or recklessly –
  - Harass a wild animal or group of wild animals of an EPS;

- Disturb such an animal while it is occupying a structure or place which it uses for shelter or protection;
- Disturb such an animal while it is rearing or otherwise caring for its young;
- Obstruct access to a breeding site or resting place of such an animal, or otherwise to deny the animal use of the breeding site or resting place;
- Disturb such an animal in a manner that is, or in circumstances which are, likely to significantly affect the local distribution or abundance of the species to which it belongs;
- Disturb such an animal in a manner that is, or in circumstances which are, likely to impair its ability to survive, breed or reproduce, or rear or otherwise care for its young; or
- Disturb such an animal while it is migrating or hibernating

16.3.6 Under Regulation 39(2), it is an offence to deliberately or recklessly disturb any dolphin, porpoise or whale (cetacean). Underwater noise, such as piling, has the potential to cause such disturbance.

16.3.7 Marine EPS are species which are listed in Annex IV of the Habitats Directive whose natural range includes any area in Scottish inshore waters. They include all species of cetaceans. EPS likely to be within the Proposed Development area are detailed in Section 16.6. A number of cetaceans are also listed as Priority Marine Features (PMFs) under Scotland's NMP.

16.3.8 Where an activity has the potential to disturb an EPS, suitable mitigation must be in place to avoid or reduce the potential for injury and or/disturbance. If, despite the use of alternatives and/or mitigation measures, an activity remains likely to result in injury, death or disturbance of marine EPS, the activity may still be able to go ahead under an EPS licence.

Seals

Under the Marine (Scotland) Act, it is an offence to kill, injure or take a live seal except to alleviate suffering, or where Marine Scotland has issued a licence to do so. It is also an offence to intentionally or recklessly harass seals at significant haul-out sites under the Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014. Underwater noise, such as piling, as the potential to cause such disturbance.

Both grey and harbour seals have the potential to be within the Proposed Development area, see Section 16.6. Both species are listed under Annex II and Annex V of the Habitats Directive and are listed as PMFs under Scotland's NMP.

Planning Policy

Scottish NMP

16.3.9 The Scottish NMP sets out strategic policies for the sustainable development of Scotland's marine resources out to 200 nautical miles, taking into account various EU Directives on marine management, including those listed above, and the Marine (Scotland) Act 2010. The following General Policies of the NMP are applicable to this assessment (Scottish Government, 2015):

- GEN 9 Natural heritage: *"Development and use of the marine environment must:*

  (a) Comply with legal requirements for protected areas and protected species.

  (b) Not result in significant impact on the national status of Priority Marine Features.

  (c) Protect and, where appropriate, enhance the health of the marine area".
- GEN 13 Noise: *"Development and use in the marine environment should avoid significant adverse effects of man-made noise and vibration, especially on species sensitive to such effects".*
- GEN 18 Engagement: *"Early and effective engagement should be undertaken with the general public and all interested stakeholders to facilitate planning and consenting processes".*

- GEN 21 Cumulative impacts: *"Cumulative impacts affecting the ecosystem of the marine plan area should be addressed in decision making and plan implementation".*

Pilot Pentland Firth and Orkney Waters Marine Spatial Plan

16.3.10 To satisfy the requirements of the Scottish NMP, the planning policy for Orkney is covered under the Pilot Pentland Firth and Orkney Waters Marine Spatial Plan (Scottish Government, 2016) developed by a collaboration between Marine Scotland, Orkney Islands Council and Highland Council. This planning policy, referred to hereon as 'the Plan', sets out an integrated planning policy framework to guide marine development, activities and management decisions, whilst ensuring the quality of the marine environment is protected.

16.3.11 Under General Policy 8A (Noise) of the Plan, it is a requirement that applications for a marine development or an activity that is likely to have significant noise impacts (on sensitive species and/or people) include a noise impact assessment or supporting information to describe the duration, type and level of noise expected to be generated at all stages of the development (construction, operation, decommissioning). In particular, the assessment must consider whether the level of surface or underwater noise has the potential to affect an EPS. As noted above, where an activity has the potential to result in disturbance to an EPS, the activities may be permitted to go ahead under an EPS licence.

16.3.12 The Plan requires that mitigation measures are in place to minimise the adverse impacts associated with the duration and level of significant noise activity. It suggests that measures could include Marine Mammal Observers (MMO) and Passive Acoustic Monitoring (PAM), location of noise generating devices away from sensitive receptors, controlling noise generating activities during sensitive periods (i.e. breeding, rearing, migration), eliminating or controlling noise at source by enclosing or insulating the noise and routing ship movements away from sensitive receptors where feasible. These are in line with the requirements of the JNCC (2010) piling protocol.

16.3.13 Cumulative effects of noise in the marine environment and on local communities must also be assessed as detailed in the Plan.

16.3.14 In addition, the Plan states that, as part of the data collection to monitor noise for the MSFD, MS-LOT sends records on activities that may generate underwater noise (piling, explosives and Acoustic Deterrent Devices) to the Joint Nature Conservation Committee (JNCC) to contribute to a Noise Registry that will be the national recording programme for anthropogenic noise in the marine environment.

16.3.15 It is acknowledged in the Plan that, for some species, there is limited information on the effect that noise can have and there is ongoing research to fill some of these knowledge gaps.

Guidance

Standards for reporting underwater sound

16.3.16 A general background on underwater sound and the accepted terminology and metrics are provided in The Good Practice Guide No. 133 for Underwater Noise Measurement by the National Physics Laboratory (NPL, 2014). The reader is referred to this document for details of terminology related to underwater noise used in this chapter, not already described in this chapter.

General guidance on carrying out an assessment of marine EPS

16.3.17 The assessment described in this chapter follows Marine Scotland's guidance for Scottish Inshore Waters in relation to '*The Protection of Marine European Protected Species from Injury and Disturbance*' (Marine Scotland, 2020). The document describes how to plan a development or activity that has potential to kill, injure or disturb a marine EPS and the process for gaining a licence, if needed.

Criteria for underwater noise impacts on marine mammals

The latest NOAA (2016) guidance criteria have been used for assessing impacts of underwater noise on marine mammals in this assessment. These criteria underpin the impact assessment in terms of sensitivity of the mammals to underwater sound (and hence the significance of the effect) and, therefore, are described in detail in this section.

16.4 Consultation

Summary of consultation

16.4.1 A summary of consultation undertaken to date is provided in Table 16.1, full details are provided in Appendix 4.4.

Table 16.1 – Consultation Relevant to the marine assessment

Consultee	Summary of consultation	Key consultee comments	Applicant action
MS-LOT	Meeting held on 4 December 2020 to provide a summary of the project and agree scope of assessment	▪ Liaison with JNCC required to agree scope assessment and underwater noise assessment methodology.	▪ JNCC contacted on 22 December 2020, see below.
JNCC	Technical note and summary of underwater noise assessment methodology shared on 22 December 2020 in order to agree scope and methodology of assessment	▪ JNCC's remit is offshore waters so cannot advise on the application; NatureScot would be better placed in this instance.	▪ Information shared with NatureScot on 07 January 2020
NatureScot	Technical note and summary of underwater noise assessment methodology shared on 07 January 2021 in order to agree scope and methodology of assessment	▪ Impact assessment appears sufficient and is SELcum based. If impact piling is used SPL_{pk} and SELs may also need to be considered ▪ It is noted that the assessment looks at disturbance in a qualitative manner, considering individual disturbed is also recommended ▪ Recommend including baleen whales within the assessment. Depending on the noise levels, sound could propagate significant distances and there are regular sightings of baleen whales including	▪ Peak SPL has been considered, as required, within the assessment ▪ This has been included within the assessment ▪ Given that the works are within a relatively enclosed bay with maximum depths of 25m at MHWS (with large areas less than 10m deep), it is highly unlikely that baleen whales

Consultee	Summary of consultation	Key consultee comments	Applicant action
		humpback, minke and fin whale in the relatively shallow waters in and around Orkney	would be within a close enough range from the piling activity to be adversely impacted. However, these have been included in the assessment since there is potential for sound to propagate through the Faray Sound into deeper water. Sperm and fin whales have been included in the assessment. Minke whales is a mid-frequency cetacean, which have also been scoped into the assessment. Further details are provided in Section 16.6.

16.5 Assessment Methodology and Significance Criteria

Summary

16.5.1 The assessment of impacts from underwater sound from pile driving on marine mammals in the region has been undertaken in line with the methodology outlined in Chapter 4: Approach to EIA. The terms 'impact' and 'effect' are defined as:

- Impact – Actions resulting in changes to an ecological feature. For example, underwater noise associated with sheet piling activities.
- Effect – Outcome to an ecological feature from an impact. For example, behavioural changes or damage to a marine mammal's hearing as a result of the underwater noise.

16.5.2 Impacts in relation to underwater sound from pile driving, are assessed here using the cumulative sound exposure level metric (SEL_{cum}). The potential effect of the noise impact on the marine mammals in the region is to damage the animals' hearing (Permanent Threshold Shift, PTS or Temporary Threshold Shift, TTS) and may also lead to behavioural changes at lower sound levels.

The sensitivity of the different receptors (i.e. the marine mammal hearing groups) is very important for assessing the relative magnitude of the noise impact. Here the sensitivity is defined using the NOAA (2016) criteria for TTS and PTS using the M-weighted SEL_{cum} metric (as described in the following section on the *Background to Underwater Sound*). These criteria are the updated version of the criteria set originally by Southall et al (2007) and are generally now regarded as the best guidance.

Background to Underwater Sound

Sound in the Underwater Environment

16.5.3 Underwater sound propagates through water as a pressure wave and, due to the low impedance and absorption characteristics of water, it can travel further and faster than sound in air. The amount of sound generated by anthropogenic sources in the marine environment has been increasing due to the growth in a number of areas e.g. shipping activity and construction of more offshore and coastal facilities. There is a concern that the increased levels of underwater sound will adversely impact on marine life and, as discussed in Section 16.3, there are numerous pieces of legislation in place to ensure marine mammals aren't disturbed by underwater noise.

16.5.4 The propagation of sound underwater is affected by the frequency of sound emitted and the physical properties of the water and seabed. Water depth is a key factor altering the propagation of underwater sound. In shallow water (less than about 200 m deep) propagated sound will dissipate more quickly than in deeper water due to numerous interactions with the surface and the bed, although this is also frequency dependant. The seabed type will alter the rate of transmission loss (TL) of propagated sound, with softer muddy sediments tending to absorb sound whereas hard rocky surfaces will cause reflection and hence less absorption. The vertical profiles of temperature and salinity through the water column are also important, particularly in deep water, because these affect the speed of sound and thus the degree to which the sound is refracted up or down as it propagates horizontally away from the source.

16.5.5 As sound propagates away from a source it loses energy and so eventually the sound level drops to the same intensity as the ambient level at which point it becomes indistinguishable from the background and can no longer effectively be heard. The ambient sound is a combination of all natural sounds such as wind, waves, rain, animals and other common sources of man-made sound in the area, such as shipping. The term *ambient sound* can be used to describe all sound not associated with the development or activity being assessed in the present study.

Acoustic Metrics and Units

16.5.6 The unit of sound pressure is the pascal (Pa) and is commonly described in terms of decibels (dB) relative to a reference pressure, which for underwater sound is 1 µPa (expressed as dB re 1µPa). The use of a logarithmic scale means that a 6 dB increase in the underwater sound level equates to a doubling of the intensity.

16.5.7 The frequency spectrum of underwater sound is also important in terms of potential impacts. The power spectral density for different anthropogenic sources of sound can vary greatly. For example, seismic airguns generally have most energy in the lower frequency range, from the low tens of Hertz (Hz) up to a few hundred Hz, whereas the range of high frequency sonar, for example, is generally much higher, in the thousands to millions of Hz. Knowing the frequency range of the acoustic source being assessed means that the potential adverse impacts on marine life can be assessed realistically, as hearing ranges of different species can be taken into account.

Sound Pressure Level (SPL)

16.5.8 Most commonly, underwater sound is expressed as the root mean square (RMS) of the sound pressure level (SPL) over a stated interval. This is a time-averaged value for the pressure, which is most useful for assessing continuous sound sources such as drilling or shipping sounds, rather than impulsive sounds such as pile driving or seismic surveying. This is calculated from the following:

$$SPL = 20 \log_{10} \frac{P}{P_{ref}} \quad (1)$$

16.5.9 Where P is the sound pressure and P_{ref} is the reference pressure (1 µPa).

16.5.10 The SPL is described as the received level (RL) which is the sound pressure level at a distance from a source with a source level (SL) minus the transmission loss (TL). For Environmental Impact Assessment (EIA) purposes the RL is the more useful metric as this will provide the sound level a receptor is being exposed to. Models are usually required to simulate both the source level and the transmission loss.

Sound Exposure Level (SEL)

16.5.11 The sound exposure level (SEL) is a measure of sound energy in a pulse that takes into account both the peak and the duration of the sound and is, therefore, useful for describing impulsive sounds, such as those emitted by seismic airguns or by pile driving. SEL is calculated by integrating the square of the pressure waveform over the duration of the pulse. The duration of the pulse is defined as the region of the waveform containing the central 90 % of the energy (E_{90}) of the pulse. The calculation is given by:

$$E_{90} = \int_{t5}^{t95} P^2(t)dt \quad (2)$$

16.5.12 This is usually expressed as dB re 1 µPa²s and is calculated as follows:

$$SEL = 10 \log_{10} \left[\frac{E_{90}}{E_0}\right] \quad (3)$$

16.5.13 where E_0 is the reference value of 1 Pa²s.

16.5.14 Since the SEL is the time integral of the sound, it can also be related to the RMS SPL by the time duration T over which the RMS was calculated, as:

$$SEL = SPL + 10 \log_{10}(\mathrm{T}) \quad (4)$$

Cumulative Sound Exposure Level (SEL_{cum})

16.5.15 SEL is also used to express the amount of sound over time to which a receptor is exposed, this can be called the SEL *dose* or the cumulative SEL (SEL_{cum}).

16.5.16 For a sequence of pulses, the cumulative SEL is calculated as:

$$SEL_{cum} = 10 \log_{10} \left(\sum_{p=1}^{N_p} 10^{\frac{SEL_p}{10}}\right) \quad (5)$$

16.5.17 For a sequence of equal intensity SEL exposures, this simplifies to:

$$SEL_{cum} = SEL + 10 \log_{10}(\mathrm{N_p}) \quad (6)$$

16.5.18 Where N_p is the number of pulses.

Power Spectral Density and Third-octaves

16.5.19 It is important to model the frequency spectrum emanating from a source because different marine species are more sensitive to certain portions of the sound spectrum. Modelling of the full range of frequencies is usually carried out by modelling discrete frequencies at third-octave intervals. The broadband sound is then calculated by integrating the sound energy across the bandwidth (Δbf) for each third-octave frequency and then summing across all the bands, written as:

$$SEL_{bb} = \sum_{f=1}^{N_f} SEL_f + 10 \log_{10}(\Delta b_f) \quad (7)$$

16.5.20 Where SEL_{bb} is the broadband sound exposure level, and SEL_f is the sound exposure level at each discrete frequency, f.

Potential Impacts of Sound on Marine Fauna

16.5.21 Underwater sound from anthropogenic activities has the potential to have adverse impacts on fish, marine reptiles (sea turtles) and marine mammals. The potential impacts on these animals range from causing discomfort by changing the acoustic environment, causing the animals to retreat from an area (i.e. behavioural response), to causing physical injury. Generally physical injury is caused by either a large and sudden change in pressure causing barotrauma e.g. bursting of swim-bladder or blood vessels, or by the cumulative amount of sound that an animal is exposed to. The latter is usually associated with temporary threshold shift i.e. a temporary increase in the threshold at which an animal can hear. For all of the available impact criteria, assessment of the effects is related to the SPL in the far-field rather than to the associated particle motion in the near-field area of the sound source.

Lethal Effects

16.5.22 Mortality from underwater sound (primarily only a concern for fish species) is usually associated with being very close to the acoustic source due to the high peak pressure levels, particularly from pulsed sounds such as seismic sources or pile driving. Severe injury which leads to death of the individual is also possible within a certain distance from the acoustic source. These injuries are associated with the rapid and large changes in pressure that an animal is exposed to rather than whether they can hear the sound.

Hearing Threshold Shift

Exposure to high levels of underwater sound can also cause impairment in sound detection capabilities of marine species. The impairment can be a temporary threshold shift (TTS) where normal detection would return after a length of time dependant on the intensity of the sound and the duration for which an animal was exposed, or the impairment can be a permanent threshold shift (PTS) where no recovery is possible.

Marine Mammal Threshold Shift Criteria

16.5.23 The hearing frequency range of marine mammals is wide, and each species will differ slightly in the frequency of greatest sensitivity. In general, baleen whales such as the blue, humpback and southern right whale hear the lowest frequencies; dolphins and toothed whales hear mid-high frequencies; and porpoises and their relatives are most sensitive to high frequencies. Pinnipeds have different hearing abilities dependent on whether they are underwater or not, with a greater hearing range underwater than in air (Babushina et al, 1991; Kastak and Schusterman, 1999; Reichmuth, et al, 2013). Pinnipeds can also be split into otariids, such as sea lions and fur seals, and phocids which are the true seals (grey or harbour seal in UK waters), as research has shown that they have markedly different hearing ranges (Hemilä et al, 2006; Kastelein et al, 2009; Reichmuth et al, 2013).

16.5.24 The response of marine mammal species to underwater sound, and the potential physical impact of anthropogenic sound, has been the subject of scientific study for several decades, although the results are often uncertain due to the difficulties of identifying behavioural responses to sound in the open sea (Weilgart, 2007; Boyd et al, 2011). The US Marine Mammal Criteria Group within NOAA developed criteria for the impacts of underwater sound on marine mammals which allow an assessment of behavioural response to be made based on the best scientific knowledge at that time (Southall et al, 2007).

16.5.25 Southall et al (2007) divided marine mammals into four distinct groups based on their known, or assumed, auditory ranges – low-frequency cetaceans, mid-frequency cetaceans, high frequency cetaceans and pinnipeds (in air and in water). For each mammal group, the hearing range of the animals was accounted for using weighting factors (or M-weightings) to the received level sound at each centre frequency (f) of the third-octave sound spectrum.

16.5.26 For impulsive sound sources, such as seismic survey airguns or pile drivers, the zero-to-peak (referred to as peak) SPL close to the source may be high enough to cause injury or mortality for marine animals. The work of Southall et al (2007), therefore, also determined impact criteria based on peak sound pressure level of impulsive sound using unweighted broadband values.

16.5.27 The criteria of Southall et al (2007) were not originally meant to become guidance for carrying out acoustic impact assessments for estuarine or offshore developments but they became accepted as industry standard for doing so (NOAA, 2013). It was also acknowledged that the work of Southall et al (2007) was limited to the few marine mammal species which had been studied up to that point. As such, NOAA developed new impact criteria into a guidance document which is designed to be used for assessing impacts of anthropogenic sound on marine mammals (NOAA, 2016). These latest guidelines have been used to carry out the marine mammal's assessment detailed in this chapter.

16.5.28 The NOAA guidance for assessing the impact of underwater acoustics on marine mammals updated the auditory weighting functions defined by Southall et al (2007) and split the pinnipeds into phocids and otariids rather than accounting for different hearing in air and water (NOAA, 2016). The estimated functional hearing bandwidth for each of the hearing groups under the NOAA (2016) guidelines are shown in Table 16.2.

Table 16.2 – Marine Mammal Hearing Groups and Hearing Ranges

Hearing group	*Mammals represented*	*Hearing range (Hz)*	
		Lower limit	*Upper limit*
Low-frequency cetaceans	Baleen whales	7	35,000
Mid-frequency cetaceans	Dolphins, toothed whales, beaked whales, bottlenose whales	150	160,000
High-frequency cetaceans	True porpoises, Kogia, river dolphins, cephalorhynchid, Lagenorhynchus cruciger and L. australis	275	160,000
Phocid pinnipeds	True seals	50	86,000
Otariid pinnipeds	Sea lions and fur seals	60	39,000

16.5.29 The form of the updated auditory weighting functions for the hearing groups is written below:

$$M(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\} \quad (8)$$

16.5.30 Where M(f) is the weighted frequency. The constants for the above auditory weighting function for each mammal hearing group are given in Table 16.3 and the resultant weighting curves are plotted in Appendix 16.11, Figure 16.1:

Table 16.3 – Summary of Weighting and Exposure Function Parameters (NOAA,2016)

Hearing group	a	b	f1 (Hz)	f2 (Hz)	C (dB)
Low-frequency cetaceans	1.0	2	200	19,000	0.13
Mid-frequency cetaceans	1.6	2	8,800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds	1.0	2	1,900	30,000	0.75
Otariid pinnipeds	2.0	2	940	25,000	0.64

16.5.31 The guidelines of NOAA (2016) also determine impact criteria based on peak sound pressure level for impulsive sound using unweighted broadband values for both TTS and PTS thresholds (with PTS calculated as 6 dB greater than TTS for each mammal hearing group). The SEL_{cum} and peak SPL criteria for TTS and PTS for each mammal functional hearing group are given in Table 16.4 for impulsive sounds.

16.5.32 In general, for impacts on marine mammals from small to medium sized piling operations (such as those proposed for carrying out the landing jetty installation for the current work), the SEL_{cum} metric is most likely to result in the greatest impact because of the importance of the duration of the sound dosage on any potential damage to the animals' hearing. The modelling carried out in the present assessment therefore focuses on the SEL_{cum} metric although the peak SPL is also considered later in this chapter.

Table 16.4 – Impact Criteria for Marine Mammals and Impulsive Sounds (NOAA,2016)

Hearing group	TTS threshold		PTS threshold	
	Peak SPL (dB re 1µPa)	SEL_{cum} (dB re 1µPa^{2}s)	Peak SPL (dB re 1µPa)	SEL_{cum} (dB re 1µPa^{2}s)
Low-frequency cetaceans	213	168	219	183
Mid-frequency cetaceans	224	170	230	185
High-frequency cetaceans	195	140	202	155
Phocid pinnipeds	212	170	218	185
Otariid pinnipeds	226	140	232	203

Behavioural Response Thresholds in Marine Mammals

16.5.33 At sound levels lower than those that can cause injury, impacts may also occur due to behavioural disturbance to marine mammals. The area within which behavioural response occurs can be large and, hence, has potential to disturb a large number of individuals. Possible behavioural changes may include startle response, extended cessation or modification of vocal behaviour, brief cessation of reproductive behaviour or brief separation of females and dependent offspring. It should be noted that for the present study, piling will not occur during seal breeding season, but assessing disturbance is still a requirement (JNCC, 2010). To assess the possibility of a disturbance resulting from the pile driving noise, it is necessary to consider the likelihood that the sound could cause significant disturbance and also the likelihood and number of marine mammals that could potentially be exposed to that sound (i.e. expected animal density in the area).

16.5.34 Differences between location, piling equipment, species and even individuals within a species mean it is not yet possible to accurately quantify the sound level at which mammals will respond. Southall et al. (2007) states that "*behavioural reactions to acoustic exposure are generally more variable, context-dependent, and less predictable than effects of noise exposure on hearing or physiology*". Furthermore, they suggest that the only feasible way to assess whether a particular sound might cause disturbance is to compare the circumstances of the situation with empirical studies using a ranking system to assess the severity of the behavioural response (from 0 to 9). The more severe the response (higher score), the lower the amount of time that the animals will tolerate the noise before they could be negatively impacted.

16.5.35 The JNCC guidance (JNCC, 2010) defines disturbance as when there is a risk of animals incurring sustained or chronic disruption of behaviour or when animals are displaced from an area, with subsequent redistribution being significantly different from that occurring due to natural variation. The JNCC guidance also indicates that a score of 5 or more on the Southall et al. (2007) behavioural response severity scale could be significant.

16.5.36 Southall et al. (2007) presents a summary of observed behavioural responses, with associated response score, due to multiple pulsed sound, although the data are primarily based on responses to seismic airgun noise and mainly for low-frequency cetaceans. Low frequency cetaceans, other than bow-head whales, were typically observed to respond significantly at a received level of 140 – 160 dB re 1 µPa (rms). It should be noted that the sound level spectrum generated by seismic air-guns is generally concentrated below a frequency of about 1 kHz, and therefore low-frequency cetaceans are relatively sensitive to this type of noise source. Pile driving noise tends to be spread across a much broader frequency range and so the energy at lower frequencies will be less for the same broadband SPL.

16.5.37 Southall et al (2007) also states that there are few reliable studies available for pinnipeds, mid-frequency or high-frequency cetaceans. However, they refer to a study of mid-frequency cetaceans in which some significant response was observed at a sound pressure level of 120 - 130 dB re 1µPa (rms), but the majority of the observed cetaceans did not display significant behavioural disturbance until exposed to an SPL of 170 – 180 dB re 1µPa (rms). Even at these levels some mid-frequency cetaceans within the same study were observed to have no behavioural response.

16.5.38 For pinnipeds, a study using ringed, bearded and spotted seals (Harris et al, 2001) observed onset of a significant response at a received rms SPL of 160 – 170 dB re 1 µPa, although larger numbers of animals showed no response at noise levels of up to 180 dB re 1 µPa. Only at much higher sound pressure levels in the range of 190 – 200 dB re 1 µPa (rms) were significant numbers of seals found to exhibit a significant response. More recently, field studies investigating changes in seal densities during pile driving have suggested a single strike SEL threshold for behavioural avoidance of between 130 dB re 1 μPa^2s and 155 dB re 1 μPa^2s (Russell et al, 2016; Whyte, 2020). Assuming a pulse length of between 100 ms and 150 ms (typical for a wind farm monopile), this would equate to an rms range of approximately 138 dB re 1 µPa to 164 dB rms.

16.5.39 For high-frequency cetaceans there is a general lack of reliable behavioural response data (South et al, 2007). However, significant behavioural reactions have been observed for a single harbour porpoise to pulsed sound at received sound pressure levels above 174 dB re 1 µPa (peak-peak) or a SEL of 145 dB re 1 μPa^2s, equivalent to an estimated rms sound pressure level of 166 dB re 1 µPa (Lucke et al, 2008).

16.5.40 The need to define threshold criteria for EIA purposes has meant that previous underwater noise studies have tended to take a precautionary approach to defining the thresholds for behavioural response. Two such studies (Kongsberg, 2010; Marine Scotland, 2015a) based the thresholds on the findings of the High Energy Seismic Survey workshop on the effects of seismic (i.e. pulsed) sound on marine mammals (HESS, 1997), which concluded that mild behavioural disturbance would most likely occur at rms sound levels greater than 140 dB re 1 µPa (rms), although acknowledged there was significant uncertainty. A second, higher threshold of 160 dB re 1 µPa (rms) is often used to define a higher level disturbance, based on the US National Marine Fisheries Service guidance (NMFS, 2005) for Level B harassment threshold for marine mammals.

16.5.41 Based on the above discussion, for the purposes of this study, a precautionary threshold level for behavioural disturbance of 140 dB re 1 µPa (rms) is adopted to indicate the onset of low level marine mammal disturbance effects for all mammal groups for impulsive sound. In line with other assessments, a higher threshold of 160 dB re 1 µPa (rms) is used to define higher level disturbance.

Consultation

16.5.42 As detailed in Chapter 4, MS-LOT and NatureScot were consulted on the scope of the underwater noise assessment.

Scope of assessment

16.5.43 It is anticipated that sheet piling will be required for construction of the landing jetty and, since the installation will be beyond mean low water, underwater sound is likely to be introduced into the surrounding environment. Thus, it is necessary to assess the potential noise impacts on marine mammals. Sheet piling of the landing jetty is considered to be the only activity to present the potential for significant underwater noise impacts to marine mammals and, as such, is the focus of this assessment.

16.5.44 Faray is surrounded by the Faray and Holm of Faray Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI), with the qualifying interest being grey seals. The site supports the second largest grey seal breeding colony in the UK (JNCC, 2020). In addition to grey seals, other marine mammals such as whales, porpoises and dolphins have the potential to be impacted. The marine mammals included within the assessment are detailed in Sections 16.6 and 16.7. To summarise the following have been scoped into the assessment -

- Phocid pinnipeds: grey seals and harbour seals;
- Low-frequency cetaceans: baleen whales;

- Mid-frequency cetaceans: common dolphin, bottlenose dolphin, Atlantic white-sided dolphin, orca, long-finned pilot whale, minke whale, Risso's dolphin, white-beaked dolphin; and,
- High-frequency cetaceans: harbour porpoise.

16.5.45 It is highly unlikely that low frequency cetaceans (baleen whales) would be in the immediate vicinity of the pile driving activity due to the shallow water depth. The maximum water depth during MHWS at the new landing jetty is about 4.5 m. The water depth in the relatively enclosed bay area opposite the new landing jetty is also only up to 25 m at MHWS (with large areas less than 10 m deep). It is therefore considered very unlikely that baleen whales would be within a close enough range from the piling activity to be impacted. However, it is possible that noise may propagate through the Faray Sound into deeper water. Therefore low-frequency cetaceans have been included in the underwater noise assessment.

16.5.46 Otariid pinnipeds (sea lions and fur seals) are highly unlikely to be within the area (SCOS, 2019), as they are not native to UK waters (SCOS, 2019), so these have been excluded from the assessment.

16.5.47 Noise created by piling will predominantly travel through the water column. Sound reduces much more quickly in air than water, thus additional impacts to seals and otters from piling when they are on land is highly unlikely. Therefore, airborne noise from construction of the landing jetty has been scoped out of the assessment.

16.5.48 Airborne noise from construction works associated with the onshore wind farm aspects of the Proposed Development is assessed in Chapter 8. This includes potential impacts to seals and otters.

Study Area

16.5.49 The new landing jetty will be situated on the south-east end of the island of Faray. As discussed in Chapter 8, the Proposed Development site is within the Faray and Holm of Faray SAC and SSSI, shown in Figure 8.1. The area considered in the underwater noise modelling is also shown in Appendix 16.1, Figure 16.2.

Assessment of the Magnitude of Impact from Underwater Sound

16.5.50 The level of impact caused by underwater sound emitted from the pile driving activity proposed for installing the new landing jetty was assessed by using a numerical model of underwater sound propagation to predict the likely sound levels in the region.

16.5.51 The modelling undertaken for assessing the impacts due to underwater noise was carried out by HR Wallingford.

Underwater Sound Propagation Model Description

16.5.52 To account for the complexity of underwater sound propagation, the numerical modelling tool UnaCorda (HR Wallingford, 2012, 2013a, 2013b; Rossington et al, 2013) was used to predict sound propagation from the installation of the piles. This model is used to predict the propagation of underwater sound from one or more point sources throughout the water column and for 360° around each sound source. Underwater sound is assessed for third-octave frequencies of sound across the spectrum from 10 Hz to 25 kHz and the outputs from the model are presented as ‘sound maps’ for each frequency showing the transmission loss (TL) or received level (RL) from the source in decibels (dB).

16.5.53 UnaCorda uses a parabolic equation approach based on the Range dependent Acoustic Model (RAM) which has been modified to be computationally efficient and to produce 3D sound maps, rather than just results along a single line. Being a range dependent model, it takes into account changes in bathymetry, sediment type and speed of sound profile with distance from the source. The model is used to predict the TL for discrete frequencies, allowing differences in attenuation that come with different wavelengths to be included in the model. The seabed sediment type is taken into account using known absorption coefficients for different sediment types.

16.5.54 The model has been validated against laboratory and field measurements (HR Wallingford, 2013a, 2013b) and used successfully on a wide range of previous pile driving noise impact assessments, including offshore renewable energy installations (HR Wallingford, 2015a), bridge building (HR Wallingford, 2020) and harbour infrastructure construction works (HR Wallingford, 2015b).

Model Set Up

16.5.55 The underwater sound propagation model (UnaCorda) requires various input data, listed as:

- A sound source level spectrum for the pile driving activity undertaken;
- Source locations and bathymetry to take into account the spatially varying water depth; and,
- Geophysical bed parameters to simulate sound absorption by the seabed material.

<u>Pile Driving Source Level and Duration</u>

16.5.56 Impact piling would likely be required to install the sheet piles for constructing the new landing jetty. The new landing jetty would be constructed using 0.6 m wide PU-28 sheet piles (154 in total) which are to be installed using a 30 kJ pile driving hammer (SL30). The size of the outer piled section of the landing jetty would be a maximum of 20 m x 20 m, and the overall length of sheet piled wall is estimated to be 92 m (154 sheet piles) including returns. Based on information provided by the Applicant for a similar structure, the piles are likely to be 14 m in length and driven to 2 m minimum embedment to refusal in rock. The number of piles pitched and then driven over a two day cycle is estimated to be between 12 and 18 piles, installed during daylight hours.

16.5.57 Using this information, and assuming it would take approximately half an hour to prepare and pitch each pile, it is estimated that it would take approximately 40 minutes on average to drive each pile to refusal depth. The strike rate of the SL30 hammer is quoted as 84 blows per minute (BSP, 2015). This equates to a total of 3,360 blows for each pile installation.

16.5.58 In terms of duration for the full works to be completed, it is estimated from the above that the number of days when piles would be driven should be around 18 to 21 days in total. Including downtime, this equates to approximately 4 weeks total construction time. This is just the period when piles are being driven; the actual marine works would take longer as there would be other activities taking place in the marine environment including setting up of temporary works, piling gates, installation of walings and tie rods (works involving divers), formation of the causeway bund and placing of rock armour. Additionally, there would be the works associated with the construction of the new slipway.

16.5.59 Using the hammer energy specified above, the source level of the sound emitted during pile driving can be estimated. In the past, various authors have related the source level from impact piling to the pile diameter (e.g. Nedwell et al, 2007). More recent methods for calculating source level energy (SLE) have identified that the hammer energy (E) of the pile driver is a more reliable indicator of source level. An example of this is by De Jong and Ainslie (2008), who developed the following empirical relationship:

$$E = \frac{4\pi}{\rho_0 c_0} 10^{(SL_E - 120)/10} \quad (9)$$

16.5.60 Where: E = pile driver hammer energy (J); ρ_0 = water density (1027 kg/m^3 for seawater); c_0 = speed of sound (~1500 m/s in seawater); and SL_E = energy related RMS source level (dB re 1µPa^{2}m^{2}s).

16.5.61 Rearranging Equation 9 in terms of SL_E gives the following:

$$SL_E = 10.log_{10}\left(\frac{E\rho_0 c_0}{4\pi}\right) + 120 \quad (10)$$

16.5.62 Assuming a 30 kJ hammer would be used, if it is further assumed that all of the hammer energy is converted to sound, the SL_E calculated from Equation 10 would be 216 dB re 1µPa^{2}m^{2}s. However, field measurements from other studies (De Jong and Ainslie, 2008; Ainslie et al, 2012) have shown that only a small fraction of the total hammer energy is converted into sound with values in the range of 0.3 % to 10 %, with an average of around 1 %. More recently, there has been growing consensus amongst various authors that the conversion factor is more likely to be lower, at about

0.5 % (Dahl et al, 2015; Marine Scotland, 2019). In the present study, a hammer energy conversion factor of 0.5 % has been used for assessing behavioural effects, resulting in a SL_E of 193 dB re 1µPa^{2}m^{2}s. For assessing injury to mammals (TTS and PTS), a more precautionary value of 1 % was applied in the current study to the 30 kJ hammer energy, resulting in a source level (SL_E) for percussive piling of 196 dB re 1µPa^{2}m^{2}s.

In addition to the overall broadband sound level, it is necessary to know the power spectrum of sound levels at different frequencies. *S*uitable sound spectra for sheet piling are *not available* in *the* literature. Instead, a spectrum was derived using *the* methodology described in a prev*ious assessment of* sheet piling noise in Cromerty Firth (Subacoustech, 2018). In that study, a source level spectrum for a 2 m diameter pile was scaled according to *the* hammer energy *that was to be used for driving the piles*. *In the present study, t*he source level spectrum *from the Cromerty Firth study* was scaled to *provide the* broadband source levels of 19*3* dB 1µPa^{2}m^{2}s and *196 dB re 1µPa^{2}m^{2}s (see previous paragraph)*. The resultant *source level* spectra were used in the UnaCorda sound propagation modelling.

<u>Model Geometry and Pile Location</u>

16.5.63 The UnaCorda model uses an unstructured mesh (with triangular elements) onto which detailed bathymetry of the area around Faray was interpolated (Appendix 16.1, Figure 16.2). One pile location was modelled and located at the furthest offshore point of the new landing jetty, at the easternmost corner, the position of which is given in Table 16.5. The unstructured mesh allows a spatially non-uniform mesh resolution to be defined. A maximum resolution (smaller mesh spacing) of 2 m was defined at the sound source, with gradually decreasing resolution (larger mesh spacing) away from the source up to a maximum mesh spacing of 20 m in areas affected by sound. The water level was set to +3.6 m CD, representing MHWS (which will generally be the worst case in terms of sound propagation distance).

16.5.64 The 3D model set up includes a vertical resolution of 21 horizontal sigma planes spaced uniformly between the seabed and the sea surface. The individual planes do not represent a constant depth, but rather a proportion of the water column position across the whole model domain.

Table 16.5 – Modelled Pile Location (British National Grid Coordinate System)

Pile Location	***Easting (m)***	***Northing (m)***
East corner of new landing jetty	353430	1035872

<u>Bed Sediment Characterisation</u>

16.5.65 The geo-acoustic properties of the seabed sediment influence how sound is refracted and attenuated as it propagates away from the sound source. In the absence of local geotechnical data, the acoustic properties of the seabed within the near-field area have been estimated based on literature of the area.

16.5.66 The geology in the local region around the island of Faray consists largely of sandstone bedrock referred to as Old Red Sandstone (McKirdy, 2010). It is likely that there is a layer of sand of varied thickness over the sandstone bedrock. However, a detailed survey of the local bed deposits was not available for this study. Therefore, although the acoustic properties for sandstone (Table 16.6) are unlikely to be representative of the whole area, the properties of this type of bed material mean that it can be considered a worst case in terms of sound propagation distance and it was therefore applied across the whole domain.

Table 16.6 – Bed Parameters Used in the Underwater Noise Model

Physical property	Value
Density (kg/m^3)	2,450
Sound speed (m/s)	3,500
Attenuation coefficient (dB/λ)	0.2

Fleeing Mammal Model

16.5.67 An important factor to consider when calculating the cumulative sound exposure level (SEL_{cum}) metric is that mammals have the ability to swim away from an acoustic source if the sound levels are not tolerable. Hence it is now common practice (Lepper et al, 2007) to assume that as soon as piling is initiated, the mammals affected by the sound swim in a straight line away from the source. As the individuals move away into quieter water, the instantaneous SEL generally reduces with range. The SEL_{cum} for each individual is therefore considerably less than if they were assumed to remain stationary. A value of swim speed for all mammal species as a whole is usually taken to be 1.5 m/s (e.g. Lepper et al, 2007; RSK Environmental, 2012) as it represents an approximate speed at the lower end of the range and so includes harbour porpoise which are generally the slowest swimmers, and this value has been assumed in this study.

Agent-based Model Description

16.5.68 HydroBoids is an agent-based model (ABM) developed at HR Wallingford for predicting the movement of fish (or other mobile marine animals) and consequences of behaviours in response to stimuli such as sound or properties of the water (Rossington and Benson, 2019). In the model, individuals are represented as quasi-Lagrangian points in a three dimensional underwater space in which they are able to swim according to programmed, species specific behaviours. Depending on the type of assessment, the animals can also be carried by time-varying currents calculated offline using a 3D hydrodynamic model.

16.5.69 Each modelled individual is assigned a swim speed and can be assigned multiple behaviours (e.g. schooling, light avoidance or predator-prey interactions). Of particular importance for the present study, a feature of the ABM is that the simulated agents are able to actively avoid shallow water and land boundaries. In the event of an agent finding itself stranded at the end of a particular model time step, they iteratively reattempt the movement for that step, each time modifying their heading in small increments, until they successfully remain in the water column and within the model domain at the end of the step. This simulates avoidance behaviour and allows the modelled animals to swim away from the noise source without getting stuck on the shoreline. The model is described in more detail by Rossington and Benson (2019).

16.5.70 In the particular case of seals, it is assumed that the animals are able to leave the water at the shoreline, thus reducing the time that they are exposed to the underwater sound. Since it is assumed that the seals swim directly away from the pile, then some modelled seals will leave the water close to the new landing jetty. Although it is unlikely that seals will actually leave the water so close to the new landing jetty during the piling, it is also unlikely that seals will be in this region between the pile and the shoreline due to local disturbance during setting up of the pile and also during the pre-piling search within the marine mammal mitigation area.

Cumulative Sound Exposure Levels for Fleeing Mammals

16.5.71 For each mammal hearing group, the group specific M-weighting function was applied to the source spectrum (see Appendix 16.1, Figure 16.1) and the weighted spectrum model results from UnaCorda were used to calculate the instantaneous spatial SEL for that hearing group.

16.5.72 In the agent-based model simulations, agents (i.e. mammal individuals) were placed at the vertices of the computational model mesh (approximately 5 m resolution within the area of the bay). The cumulative sound exposure level (SEL_{cum}) was then calculated as the agents of each hearing group swam away from the noise source. At each model time interval, the instantaneous M-weighted SEL at each animal's position was added cumulatively (as described previously in paragraph 16.5.17). This procedure was carried out for the duration of the Hydroboids simulation (or shorter for seals reached the shoreline) to give the total SEL_{cum} for each animal. Interpolation of the final SEL_{cum} values at the start position for all animals then allowed contour plots of potential impacts to be generated in terms of the exceedance criteria for PTS and TTS.

Estimation of peak SPL

16.5.73 For underwater pile driving noise or other activities where there are multiple sound impulses over an extended period of (e.g. seismic surveys), the SEL_{cum} metric is usually the greater of the two metrics in terms of distance to TTS or PTS for mammals. This is due to the cumulative effect of integrating the energy dosage over time using SEL_{cum} metric. The potential impacts on mammals are, therefore, primarily assessed in this chapter in terms of the SEL_{cum} metric. However, following the guidance of Southall el al (2007) consideration of peak SPL should also be given. This is provided below.

16.5.74 Sound propagation models generally are only able to predict the propagation of sound energy (i.e. SEL) and are not capable of resolving the time component of the sound impulse. They are, therefore, not capable of modelling the peak in the sound pressure. The peak SPL is dependent on the type of pile driving equipment and also the peak reduces relative to the sound energy due to spreading of the pulse as it travels away from the source of the sound. Previous research has shown that there is a relationship, albeit an empirical one, between the SEL and peak SPL (Lippert et al, 2015). Generally, the empirical relationship between SEL and peak SPL is site specific and therefore, to be accurate, it requires in situ sound measurements from the development site in question recorded whilst the piling equipment is in use. Clearly this is not possible for an EIA for a proposed development, where the construction works have not yet started, such as the present study. Despite this, an estimate of the peak SPL was calculated for the present study under the assumption that the empirical constants were similar to those calculated by Lippert et al, 2015 for a study of pile driving during construction of three offshore wind farms. The three cases showed similar linear relationships between SEL and peak SPL, with the worst case used for the present study, written as:

$$\text{peak SPL} = 1.43\ \text{SEL}_{ss} - 44.0 \qquad (11)$$

16.5.75 This approach is considered to be the only available option for assessing the impact due to peak SPL in this instance.

Behavioural response thresholds

16.5.76 Based on the earlier discussion on behavioural response (see paragraphs 16.5.4 to 16.5.8), thresholds of 140 dB re 1µPa (rms) and 160 dB re 1µPa (rms) were applied to be representative of low level and high level disturbance, respectively. Because the response criteria metric uses rms SPL, it was necessary to convert the modelled single strike SEL by assuming a typical sound impulse duration of 100 ms and applying Equation 4 (on paragraph 0).

Assessment of Effects

16.5.77 Significance of effects has been determined using the methods outlined in Chapter 4. To summarise, as shown in Table 4.1, the magnitude of the impact and sensitivity of receptor are considered in order to determine if the effects are of major, moderate, minor or negligible significance. Table 4.1 has been repeated in Table 16.7 below for reference.

Table 16.7 - Guide to the Inter-Relationship between Magnitude of Impact and Sensitivity of Receptor

		Sensitivity of Receptor / Receiving Environment to Change			
		High	**Medium**	**Low**	**Negligible**
Magnitude of Impact/Change	**High**	major	moderate to major	minor to moderate	negligible
	Medium	moderate to major	moderate	minor	negligible
	Low	minor to moderate	minor	negligible to minor	negligible
	Negligible	negligible	negligible	negligible	negligible

Magnitude of impact

16.5.78 The magnitude of the direct impact of the sound on marine mammals is quantified here as the maximum distance from the pile driver that the SEL_{cum} threshold for PTS or TTS is exceeded for each marine mammal receptor hearing group.

16.5.79 Impact magnitude has been categorised with reference to the definitions in Table 16.8, this is based on the methods used in Chapter 8.

Table 16.8 – Impact Magnitude

Magnitude of impact	Definition
Negligible	Detectable impact but reversible. Not expected to affect the conservation status of the nature conservation designation, habitat or species under consideration In terms of noise modelling, this has been defined as below the TTS and PTS thresholds.
Low	Detectable impacts, and may be irreversible, but either of sufficiently small scale or of short-term duration to have no material impact on the conservation status of the nature conservation designation, habitat or species population. In terms of noise modelling, this has been defined as behavioural changes and/or TTS to less than 1% of the local marine mammal population, with no potential for PTS.
Medium	Detectable impact on the status of the nature conservation designation, habitat or species population in the medium term but is reversible/replaceable given time, and not a threat to the long-term integrity of the feature In terms of noise modelling, this has been defined as TTS to more than 1% and/or PTS to less than 1% of the local marine mammal population.

Magnitude of impact	Definition
High	Irreversible impact on the status of the nature conservation designation, habitat or species and likely to threaten the long-term integrity of the feature. Not reversible or replaceable. In terms of noise modelling, this has been defined as PTS to more than 1% of the local marine mammal population.

16.5.80 In terms of timing, frequency and duration of the impact, it is estimated that it will take approximately four weeks for the entire piling activity to be completed, with pile driving occurring during daylight hours only. Each pile will take approximately 40 minutes to drive to refusal depth, with about half an hour preparation time between piles. Because of the limited duration of the works the impact of the works and resultant effects are considered temporary (reversible).

16.5.81 Because of the limited duration of the piling activity, indirect impacts are likely to be **negligible**, although the feeding behaviour of the animals may change temporarily due to the requirement for them to search for food in other areas.

<u>Sensitivity of receptor</u>

16.5.82 In terms of sensitivity, all marine mammals are classified as having a high sensitivity to piling as they are afforded some level of protection (as outlined in Section 16.3 and 16.6) with the activities resulting in a range of impacts, from behavioural changes to injury or even death.

Requirements for Mitigation

16.5.83 Standard mitigation measures have been adopted based on the guidelines of the JNCC piling protocol (2010). This is a basic requirement of the Pilot Pentland Firth and Orkney Waters Marine Spatial Plan (Scottish Government, 2016). See Section 16.8 for further details.

16.5.84 In addition to the standard mitigation, further mitigation, such as Acoustic Deterrent Devices (ADDs), bubble curtains and piling cushions, may be required. See Section 16.10 for further details.

Assessment of Residual Effect Significance

16.5.85 Where a moderate to major effect was identified, further investigation of effects using appropriate additional mitigation measures, such as piling cushions, was undertaken and the residual impact identified.

Limitations to Assessment

16.5.86 There are a number of limitations to the modelling methodology and data availability which mean that a relatively conservative approach has been adopted, these are:

- A detailed map of bed deposits in the area was not available for parameterising the sound absorption parameters for the underwater noise model. It was, therefore, conservatively assumed that the bed consisted of sandstone which is known to form the bedrock in this region (McKirdy, 2010). A sandy or muddy bed layer, if present, would result in greater attenuation of the sound and, hence, could result in lower impacts than predicted in this study.
- The precise behaviour of the animals in response to the sound is not known and simplified assumptions have, therefore, been made in the model as to swim speed and direction. However, the assumptions made are considered the best-estimate of how animals might behave.

- The underwater sound model does not account for the water level change over time due to tides. Instead, the model assumes a fixed water level representative of MHWS. This is considered to be conservative (worst case) since sound tends to travel a longer distance in deeper water due to fewer interactions with the bed and water surface. The new landing jetty is located in an area that almost dries out at low tide, with the water depth reducing to less than 2 m during MLWS. Therefore, if piling occurs close to low water, the propagated sound levels are expected to be lower than modelled, resulting in reduced impacts on marine mammals compared to those predicted in this assessment.

16.6 Baseline Conditions

Background noise

16.6.1 Based on previous studies of noise data relating to other sites in UK waters, background underwater noise levels in the area are likely to be low (Brooker et al, 2012; Marine Scotland, 2015b). Generally the unweighted average background levels in UK coastal waters away from shipping lanes has been measured to be in the range of 92 dB to 132 dB, with the main sources of noise being due to the sea-state and occasional vessel movements (i.e. engine and propellor noise). The background levels are unlikely to exceed threshold levels for PTS or TTS however, it may cause short term behavioural changes to mammals.

Cetaceans

16.6.2 In terms of marine mammals likely to occur within the wider area, data from the latest Small Cetaceans in European Atlantic waters and the North Sea (SCANS) report (SCANS-III), as reported by Hammond et al (2017) has been used. A primary aim of SCANS-III was to provide robust large-scale estimates of cetacean abundance to inform the MSFD assessment of GES in European Atlantic waters in 2018. The report provides design-based estimates of abundance of the following cetaceans species: harbour porpoise, bottlenose dolphin, Risso's dolphin, white-beaked dolphin, white-sided dolphin, common dolphin, striped dolphin, pilot whale, all beaked whale species combined, sperm whale, minke whale and fin whale (Hammond et al, 2017).

16.6.3 Faray is located within SCANS-III block S (measuring 40,383 km^2, shown in Appendix 16.1, Figure 16.3). Marine mammal abundance and density within SCANS-III area S, along with the wider JNCC (2015) Marine Mammal Management Unit (MMMU) populations, are provided in Table 16.9. Species recorded within 10km of Faray are provided in Table 16.10. This shows a number of species that Hammond et al (2017) do not list as being present within SCANS-III block S. Densities for these species have been estimated based on neighbouring blocks and the MMMU populations provided. Where MMMU data is not available, representative data from SCANS-III has been used.

16.6.4 For baleen whales, the SCANS-III ship survey data for fin whale and sperm whale was used, these blocks are shown in blue in Appendix 16.1, Figure 16.3. The closest area, block 8, was assumed for the purposes of this assessment. MMMU data is not available for baleen whales, therefore representative data assuming all ship survey blocks has been used.

16.6.5 Note, there is no overall estimate for the orca population available, however, local sightings have been included in Table 16.10.

16.6.6 There is no humpback whale data provided in ether Hammond et al (2017) or JNCC (2015). However, JNCC's atlas of cetacean distribution in north-west Europe waters (Reid et al, 2003) shows no sightings of humpback whales in the waters surrounding Orkney, the closet sighting are between Shetland and the Faroe Islands and in the central north sea off the coast of Peterhead.

Table 16.9 – Cetacean abundance and density within SCANS-III block S (Hammond et al, 2017; JNCC, 2015)

Species	Legal / Conservation status	SCANS-III Block S (Hammond et al, 2017)		Wider MMMU population (JNCC, 2015)
		Abundance	Density (animals/km^2)	
Harbour porpoise *Phocoena phocoena*	EPS Annex II species Schedule 5 of the WCA PMF	6,147	0.152	227,298
Bottlenose dolphin *Tursiops truncatus*	EPS Annex II species Schedule 5 of the WCA PMF	151	0.004	195[1]
White-beaked dolphin *Lagenorhynchus albirostris*	EPS Schedule 5 of the WCA PMF	868	0.021	15,895
Minke whale *Balaenoptera acutorostrata*	EPS Schedule 5 of the WCA PMF	383	0.010	23,528
Orca *Orcinus orca*	EPS Schedule 5 of the WCA PMF	N/A	N/A	N/A
Atlantic white-sided dolphin[2] *Lagenorhynchus acutus*	EPS Schedule 5 of the WCA PMF	1,366	0.034	69,293
Common dolphin[3] *Delphinus delphis*	EPS Schedule 5 of the WCA PMF	4,679	0.116	56,556
Pilot whale[4] *Globicephala melaena*	EPS Schedule 5 of the WCA PMF	1,733	0.043	1,812[5]
Risso's dolphin[4] *Grampus griseus*	EPS Schedule 5 of the WCA PMF	440	0.011	8,818[6]
Sperm whale[7]	EPS Schedule 5 of the WCA PMF	9,599	0.060	13,518[8]
Fin whale[7]	EPS Schedule 5 of the WCA PMF	820	0.005	18,142[8]

[1] Note the MMMU includes the Moray Firth SAC which is designated for bottlenose dolphins, actual sightings within the Faray area are low as highlighted in Table 16.10.
[2] Representative abundance data from adjacent SCANS-III block, T, has been assumed. Density has then been calculated based on this representative abundance data and area of block S.

Species	Legal / Conservation status	SCANS-III Block S (Hammond et al, 2017)		Wider MMMU population (JNCC, 2015)
		Abundance	Density (animals/km^2)	
[3] Representative abundance data from nearest SCANS-III block, J, has been assumed. Density has then been calculated based on this representative abundance data and area of block S. [4] Representative abundance from adjacent SCANS-III block, K, has been assumed. Density has then been calculated based on this representative abundance data and area of block S. [5] MMMU abundance data not available, combined abundance of pilot whale in UK and Irish waters (SCANS-III blocks J and K) used as representative population data. [6] MMMU abundance data not available, combined abundance of Risso's dolphin in UK and Irish waters (SCANS-III blocks E, H, J and K) used as representative population data. [7] Representative abundance and density data from nearest SCANS-III block, 8, has been assumed. [6] MMMU abundance data not available, total abundance from SCANS-III ship surveys used as representative population data.				

16.6.7 Data provided by the Orkney Wildlife Information and Records Centre (OWIRC) include records of nine cetacean species from locations within 10 km of the site boundary, dating from within the last 10 years, as summarised in Table 16.10. The listed species can be grouped into the mammal hearing groupings of Southall et al (2007) described previously in Section 16.3, as indicated in the last column of Table 16.10.

16.6.8 Species density has been calculated using the same method as the SCANS-III data (Hammond et al, 2017), where the sightings have been compared against the study area of 10 km (c.314km^2).

16.6.9 The sensitivity of these groups is deemed to be high as outlined in paragraph 16.5.82.

Table 16.10 – Key Protected Cetacean Species recorded within 10km of Faray

Species	Legal / Conservation status	Existing Records	Density (animals/km^2)	Hearing group
Harbour porpoise *Phocoena phocoena*	EPS Annex II of the Habitats Directive Schedule 5 of the WCA	72 records, 1 record south of Faray and 67 records in Warness sound, eday.	0.229	High-frequency cetacean
Orca *Orcinus orca*	EPS Schedule 5 of the WCA PMF	17 records, 2013, x3 Calf Sound , east side of Eday, c.4.0km east; x1 record, 9 records -Fall of Warness Eday, c.5.5km south, 4 off Sanday, 1 each off Egilsay, Rousay, Papa Westray and Green Holm; all >5km from faray.	0.054	Mid-frequency cetaceans

Species	Legal / Conservation status	Existing Records	Density (animals/km^2)	Hearing group
Atlantic white-sided dolphin *Lagenorhynchus acutus*	EPS Schedule 5 of the WCA PMF	Single records, Warness Sound 5km south of Faray, 2014.	0.003	
Bottlenose dolphin *Tursiops truncatus*	EPS Annex II of the Habitats Directive Schedule 5 of the WCA PMF	Single record, Westray 2009.	0.003	
Common dolphin *Delphinus delphis*	EPS Schedule 5 of the WCA PMF	Single record, 2014, Sound of Faray, c.0.5km east	0.003	
Long-finned pilot whale *Globicephala melaena*	EPS Schedule 5 of the WCA PMF	Single record, Twiness Westray 4.5km north-west 2012	0.003	
Minke whale *Balaenoptera acutorostrata*	EPS Schedule 5 of the WCA PMF	24 records, 20 off Warness sound, Eday. Other records Eday, Westray, Sanday, Egilsay all >5km from Faray.	0.076	
Risso's dolphin *Grampus griseus*	EPS Schedule 5 of the WCA PMF	14 records, 9 Warness Sound Eday. 3 records Sanday and a single records iat Rapness, Westray in 2017. All records > 5km from faray.	0.045	
White-beaked dolphin *Lagenorhynchus albirostris*	EPS Schedule 5 of the WCA PMF	4 records between 2009 and 2015, 3 off Warness Sound and one of Westray all > 5km from Faray.	0.013	

Pinnipeds

16.6.10 The Proposed Development partially overlaps the Faray and Holm of Faray SAC and SSSI, which is designated for grey seals. The site is of particular importance to breeding seals, supporting the second-largest breeding colony in the UK and is one of the most important breeding and haul out sites for grey seal in Orkney. As discussed in Chapter 8, the overall 2018 UK grey seal population was estimated at c.152,000 (SCOS, 2019). The Orkney population was estimated at c.23,849 animals, representing c.43.6 % of the Scottish population (54,741) and a significant 36.5 % of the UK total (SCOS, 2019). Specifically, for the Faray and Holm of Faray SAC, and indicating its importance to the Orcadian grey seal population, the SAC accounted for c.15% (c.3,578 animals) of Orkney grey seal pup production in 2010 (Russel *et al.*, 2019).

16.6.11 In addition to the Faray and Holm of Faray SAC and SSSI, there are three sites designated for grey or harbour seals within a 15km radius of the Proposed Development (see Table 16.11). There are also a number of designated seal haul outs within 10km of the Proposed Development, as detailed in Appendix 8.3.

16.6.12 Harbour seals are noted to forage in a range of 40-50 km (SCOS, 2019), therefore have the potential to be within the area. The overall 2018 UK harbour seal population was estimated at 45,800 with the Scottish Population (26,900) representing c.59% of the UK total (SCOS, 2019).

16.6.13 Grey seals widely forage and frequently travel over 100 km between haul out sites (SCOS, 2019), therefore seals from the wider Scotland population, including those supported by the Muckle and Little Green Holm SSSI, have the potential to be within the Proposed Development area.

Table 16.11 – Designated Sites (seals) within 10 km of the Proposed Development

Site	Designation	Distance to Site	Species Designation
Faray and Holm of Faray	SAC	Partly overlaps with the site	Grey seal
	SSSI	Partly overlaps with the site	Grey seal
Sanday	SAC	10.7 km east	Harbour seal
East Sanday Coast	SSSI	11.4 km east	Harbour seal
Muckle and Little Green Holm	SSSI	7.8 km south	Grey seal

16.6.14 Data provided by OWIRC include four records of grey seals from locations within 10 km of the site boundary and dating from within the last 10 years. No records of harbour seals were recorded.

16.6.15 As documented in Chapter 8, Appendix 8.3 and shown on Figure 8.4, grey seals were recorded all around the Faray coastline, with animals apparently present on any suitable haul-out surface. 1,480 animals recorded with counts varying between 43 (April) and 406 (August); an average of 182.

16.6.16 Only one harbour seal was noted during the site seal survey (in June 2019), with all other animals being grey seals. While harbour seals are present in the area, the survey results indicate that Faray is unlikely to be of any particular importance to this species.

16.6.17 The abundance and density of grey and harbour seals is provided in Table 16.12. This has been calculated using the same method as the SCANS-III data (Hammond et al, 2017), using the seal survey data provided in Appendix 8.3. The seal survey area covered the island and a 500m radius around the island offshore, equating to c.5.26km^2. The abundance was assumed to be an average of the daily counts recorded (182) as the 1,461 animals recorded were in relation to sightings not individuals. The total UK population from SCOS (2019) is also provided.

Table 16.12 – Grey seals and harbour seal abundance and density

Species	Legal / Conservation status	Seal survey area		UK population (SCOS, 2019)	Hearing group
		Abundance	Density (animals/km^2)		
Grey seal *Halichoerus grypus*	Annex II & V of the Habitats Directive PMF	182	35	152,000	Phocid pinnipeds
Harbour seal *Phoca vitulina*	Annex II & V of the Habitats Directive PMF	1	0.190	45,800	

16.7 Receptors Brought Forward for Assessment

16.7.1 The assessment focuses on the three hearing groups with the specific species present based on both regional and site specific data, as discussed in Section 16.6:

- Phocid pinnipeds (grey seals and harbour seals);
- High-frequency cetaceans (harbour porpoise, also known as common porpoise); and
- Mid-frequency cetaceans (common dolphin, bottlenose dolphin, Atlantic white-sided dolphin, orca, long-finned pilot whale, minke whale, Risso's dolphin, white-beaked dolphin);
- Low-frequency cetaceans (baleen whales).

16.7.2 Otters are not included in the modelling assessment as their hearing abilities are not included in standard guidance. They are also unlikely to be far from the shore in deep water, so it is assumed that they will be able to escape quickly from the underwater noise onto dry land. Further details on otters are provided in Chapter 8.

16.7.3 There were no low frequency cetaceans (i.e. baleen whales) recorded in the region due to the shallow water depths, however there have been sightings of baleen whales in deeper water away from Faray (see Table 16.9) and some noise could propagate through Faray Sound to the northeast into deeper water. Therefore low-frequency cetaceans have been included in the assessment. There are no otariid pinniped species (i.e. sea lions and fur seals) native to the UK. This hearing group has, therefore, been excluded from the assessment.

16.8 Standard Mitigation

16.8.1 A range of standard mitigation measures, in accordance with the JNCC piling protocol (2010), have already been put in place as part of the iterative design process to minimise the potential risks to marine mammals, and in particular local grey seals, in the area. The standard measures, as detailed in JNCC (2010), built into design are listed below:

- **Mitigation zone:** implementation of a mitigation zone where the area is monitored either visually and/or acoustically (via Passive Acoustic Monitoring, PAM) for marine mammals prior to piling commencing. Monitoring should be undertaken by a suitably qualified MMO / PAM operative. The extent of the mitigation zone should be agreed with the consenting authority prior to the works taking place. The minimum is a 500 m radius, which has been assumed for this assessment.

- **Pre-piling search and delayed start:** the mitigation zone should be monitored visually by the MMO and/or acoustically via PAM for a period of at least 30 minutes. Piling should not commence if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection.
- **Avoid piling at night or in poor visibility:** piling activities should not commence during periods of darkness, poor visibility (e.g. fog) or a rough sea state where it is not conductive to visual mitigation as there is a greater risk of failing to detect a marine mammal within the mitigation zone.
- **Soft-start:** the piling activities should employ a soft-start, where the piling power is gradually ramped up incrementally until full power is achieved. This is to allow for any marine mammals within the area to move away from the noise source and will reduce the likelihood of exposing marine fauna to sounds which can cause injury. The soft-start period should be a minimum of 20 minutes. If a marine mammal enters the area during the soft start then, wherever possible, the piling should cease, or at the least the power should not be increased until the marine mammal exits the mitigation zone and there is no further marine mammal detection for 20 minutes. When piling at full power, there is no requirement to cease piling or reduce the power if a marine mammal is detected in the mitigation zone as it is deemed to have entered "voluntarily". JNCC (2010) does recognise in the piling protocol that it may not be technically possible to stop piling at full power until the pile is in position.
- **Break in piling activity:** If there is a pause in the piling operations for a period of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated before piling recommences. If a watch has been kept during the piling operation, the MMO or PAM operative should be able to confirm the presence or absence of marine mammals, and it may be possible to commence the soft-start immediately. However, if there has been no watch, the complete pre-piling search and soft-start procedure should be undertaken.

16.8.2 The soft start procedure is included in the standard mitigation modelling presented in this chapter. It is not possible to build the mitigation zone into the model as it needs to assume the presence of marine mammals within close proximity to the piling source in order to determine the potential zone of impact.

16.8.3 Due to the Proposed Development overlapping with Faray and Holm of Faray SAC and SSSI, there is a project commitment to avoid construction during the grey seal breeding season, which extends from mid-September-December (see Chapter 8). Seal densities across Faray are discussed in Chapter 8. Breeding use within Scammalin Bay (the location of the landing jetty) is not fully understood, this is due to careful avoidance of surveying during the breeding season to minimise disturbance to grey seals (as per consultation with NatureScot on survey scope). However, the majority of haul-out use of the island is to the north, away from the landing area, which is already subject to regular use by the farmer.

16.8.4 As per Table 3.2, the sheet piling operations are scheduled to commence on 1 May at the earliest. Piling would last a maximum of 21 days and will not take place any later than 15 August. This will ensure piling is out with the breeding season and for a month prior where seals are expected to be returning to the island for breeding purposes.

16.8.5 The piling schedule will be included within the CEMP and construction marine licence application to ensure piling operations do not occur past 15 August or during the breeding period itself.

16.9 Likely Effects

16.9.1 The results from the fleeing mammal model are used in this section to assess the magnitude of the impact and the resulting significance of effect on the receptors brought forward for assessment.

Construction Noise

16.9.2 The magnitude of impact due to underwater sound during construction of the new landing jetty is presented in this section for standard mitigation. The magnitude of the impacts is first assessed using the cumulative sound exposure level (SEL_{cum}) threshold criteria for injury (PTS and TTS) for marine mammals in the different hearing groups for phocid pinnipeds, low-frequency cetaceans, mid-frequency cetaceans and high-frequency cetaceans. The PTS and TTS injury impacts are then reassessed using the peak SPL metric to determine which metric gives the worst impact. Finally, behavioural disruption is assessed using the rms SPL.

Injury to mammals (SEL_{cum})

16.9.3 For phocid pinnipeds (grey seals and harbour seals) the modelled SEL_{cum} dosage received during the installation of a single sheet pile using standard mitigation is presented in Appendix 16.1, Figure 16.4. Similar plots are provided for low-frequency cetaceans (Appendix 16.1, Figure 16.5) mid-frequency cetaceans (Appendix 16.1, Figure 16.6) and high-frequency cetaceans (Appendix 16.1, Figure 16.7). On each of these plots a contour indicating the threshold for PTS and TTS is drawn (if exceeded). The maximum distances to the PTS and TTS threshold for each mammal hearing group are presented in Table 16.13 and the corresponding area of exceedance has been tabulated in Table 16.14. The latter is useful when considering the likely density of mammals in the area and hence numbers of individuals that may be affected, as detailed in the subsequent sections.

16.9.4 The model results plotted in Appendix 16.1, Figure 16.4 to Figure 16.7 show the SEL_{cum} dosage for mammals using the assumption that the animals swim directly away from the pile driver. For pinnipeds, it is further assumed that the animals leave the water when they reach the shoreline. For cetaceans, the animals clearly cannot leave the water and some animals, therefore, may become temporarily trapped against the shoreline, before swimming along the coast due to land avoidance behaviour in the model. This simplified behaviour is considered a worst case scenario for cetaceans since they are likely to be more aware of the available exit routes. As such, for low- and high-frequency cetaceans (baleen whales and harbour porpoise) additional model simulations were undertaken whereby the mammals were assumed to exit the area of noise via their nearest exit route (i.e. northwards through the Sound of Faray, or westwards past Fers Ness). The SEL_{cum} results for these 'quickest escape' model scenarios are plotted in Appendix 16.1, Figure 16.8 and Figure 16.9.

Table 16.13 – Maximum Distances to PTS and TTS Impact Thresholds using the SEL_{cum} metric (Standard Mitigation)

Hearing group	Maximum distance to threshold (m)	
	PTS	TTS
Phocid Pinnipeds	0	1,980
Low-frequency cetaceans	3,030	12,950
Low-frequency cetaceans (quickest escape)	2,770	12,950
Mid-frequency cetaceans	0	0
High-frequency cetaceans	340	3,080
High-frequency cetaceans (quickest escape)	30	3,070

Table 16.14 – Area of PTS and TTS Impact using the SEL_{cum} metric (Standard Mitigation)

Hearing group	Area of threshold exceedance (km^2)	
	PTS	TTS
Phocid Pinnipeds	0	1.35
Low-frequency cetaceans	7.65	15.90
Low-frequency cetaceans (quickest escape)	2.31	15.29
Mid-frequency cetaceans	0	0
High-frequency cetaceans	0.01	8.60
High-frequency cetaceans (quickest escape)	<0.01	7.85

Pinnipeds

16.9.5 Using the area of threshold exceedance in Table 16.14, and the baseline data provided in Section 16.6, the number of grey and harbour seals that could potentially be effected can be calculated. The results are shown in Table 16.16. From this, the significance of effect can be determined, as per the methodology outlined in Section 16.5.

16.9.6 Harbour seals are not likely to be within the area in any great numbers, therefore the effect is **negligible and not significant**. The potential impacts to grey seals are discussed below.

16.9.7 Using the standard mitigation (i.e. soft-start), for seals the modelled maximum start distance within which the TTS criteria is exceeded is 1,980 m, with the area of TTS threshold exceedance being 1.35km^2. This has the potential to temporarily impact a significant percentage of the local grey seal population, 26% (Table 16.16), resulting in a **moderate and significant** effect. On a larger, regional and national population level, the percentage of population with the potential for TTS is <0.1%.

16.9.8 For PTS, there is no exceedance predicted for seals.

16.9.9 The overall effect is, therefore, assessed as **moderate and significant** as there is the potential for TTS to greater than 1% of the local population, but there will be no potential for PTS. This is a conservative assessment as, although the modelling takes soft-start into consideration, a 500 m mitigation zone would also be implemented within which a pre-piling search would be undertaken to ensure the area is clear of marine mammals prior to piling commencing. Thus, the number of grey seals that could potentially experience TTS will be less than that calculated Table 16.16. It should also be noted that no construction work will take place between 15th of September and 31st of December inclusive to avoid grey seal breeding. Furthermore, the piling operations will be completed by 15th August at the latest.

Low-frequency cetaceans

16.9.10 Using the area of threshold exceedance in Table 16.14, and the baseline data provided in Section 16.6, the number of baleen whales (specifically, sperm whales and fin whales) that could potentially be effected can be calculated. The results are shown in Table 16.17. From this, the significance of effect can be determined, as per the methodology outlined in Section 16.5. Note, there is no population data available for humpback wales, therefore, they could not be included in the assessment. However, as noted in Section 16.6, this species has not been recorded within the area (Reid et al, 2003).

16.9.11 Of all the mammal hearing groups, low-frequency cetaceans are predicted to be impacted at the furthest distance from the pile. Under standard mitigation (i.e. soft-start), the distance to TTS is predicted to be almost 13 km, with the area of TTS threshold exceedance being 15.90km^2. Assuming the mammals swim away from the noise, the distance to PTS is predicted to be 3,030 m (7.65 km^2), but reduces to 2,770 m (2.31 km^2) under the assumption that they swim immediately to the nearest exit.

16.9.12 There were no OWIRC records of baleen whales within 10 km of Faray, thus the assessment is based on the regional and national sperm and fin whale populations only (see Table 16.17). The maximum number of individuals within the area of TTS and PTS exceedance is <1 for both sperm whales and fin whales, representing TTS to 0.01% and PTS to <0.01% of the regional populations and TTS and PTS to <0.01% of the national populations.

16.9.13 The likelihood of baleen whales being within the bay area is very low due to the shallow water depths (see Figure 16.2); at MHWS, approximately 3 km^2 and 10 km^2 of the area is less than 10 m and 20 m deep respectively. As outlined above, a pre-piling search will be undertaken to ensure the area is clear of marine mammals prior to piling commencing. Thus, the number of individuals that could potentially experience TTS will be less than that calculated in Table 16.17. Assuming baleen whales escape via the quickest route, the area of PTS exceedance is limited to the shallower areas of the bay (see Appendix 16.1, Figure 16.8), therefore, with standard mitigation in place, PTS to an individual is not expected to occur. As such, the overall effect is assessed as **minor and not significant**.

Mid-frequency cetaceans

16.9.14 For mid-frequency cetaceans no exceedance of TTS or PTS is predicted (see Table 16.14 and Appendix 16.1, Figure 16.6). The effect using standard mitigation is, therefore, **negligible and not significant** for this hearing group.

High-frequency cetaceans

16.9.15 Using the area of threshold exceedance in Table 16.14, and the baseline data provided in Section 16.6, the number of harbour porpoise potentially effected can be calculated. The results are shown in Table 16.18. From this, the significance of effect can be determined, as per the methodology outlined in Section 16.5. Note, the highest density for harbour porpoise was assumed in order to represent the worst case, this was based on the OWIRC records within 10 km of Faray.

16.9.16 High-frequency cetaceans (harbour porpoise) are predicted to be subject to the second largest impact after low-frequency cetaceans. Under the assumption that they swim directly away from the noise, the modelled maximum start distance, assuming soft-start, for PTS is 340 m (0.01 km^2). This distance is within the standard 500 m mitigation zone and, considering the fact that the area will undergo a pre-piling search to ensure the area is clear of marine mammals prior to piling commencing, the effect is deemed to be **negligible and not significant** for harbour porpoise with regard to PTS.

16.9.17 The modelled maximum distance to TTS threshold is considerably larger for this mammal group, at 3,080 m (8.60km^2). This has the potential to impact >1% of the local population, therefore the significance of TTS effect was initially assessed as **moderate and significant.** On a larger regional (SCANS-III block S) and national (MMMU) scale, the percentage at risk of TTS is <1%.

16.9.18 This is a conservative assessment as the implementation of the 500 m mitigation zone will ensure the area is clear of marine mammals prior to piling commencing. Thus, the number of harbour porpoise that could potentially experience PTS or TTS will be less than that calculated in Table 16.18. None the less, as there is the potential for TTS to more than 1% of the local population, the overall significance of effect to harbour porpoises, assuming they swim directly away from the source, is deemed to be **moderate and significant**.

16.9.19 Under the assumption that the high-frequency cetaceans swim to their nearest exit, the impacts in terms of maximum distance are slightly shorter, with PTS and TTS distances of 30 m (<0.01km^2) and 3,070 m (7.85 km^2) respectively. The reason for the similarity of the TTS contours is due to the restricted distance to the shoreline within the bay opposite the new landing jetty which limits the extent of the impact.

16.9.20 For TTS exceedance, the area using the nearest exit method is only slightly reduced, at 7.85 km^2 compared to 8.60 km^2 for swimming directly away. Thus, there is still the potential for TTS to more than 1% of the local population.

Overall for harbour porpoise using either the swim directly away or the quickest escape method for fleeing, the PTS thresholds are only expected to be exceeded within the standard 500 m mitigation zone. As a pre-piling search will be undertaken to ensure the mitigation zone is clear of marine mammals prior to soft-start commencing, PTS to an individual is not expected to occur. Furthermore, due to the pre-piling search of the mitigation zone, the species numbers provided in Table 16.18 are conservative with less individuals than those calculated likely to experience TTS. None the less, as TTS could occur to >1% of the local population, the overall significance of effect (due to TTS) is conservatively deemed to be **moderate and significant**.

Injury to mammals (Peak SPL)

16.9.21 The impacts using standard mitigation were also assessed using the empirically derived peak SPL metric (see paragraph 16.5.74), applied to the modelled SEL_{ss}. For all mammals, the distances to the TTS and PTS threshold (Table 16.15) were found to be considerably smaller using the peak SPL metric, apart from PTS for seals which was predicted to be at 10 m using the peak SPL metric (as opposed to zero for SEL_{cum}). The maximum distance to impact using the peak SPL was predicted to be greatest for high frequency cetaceans, with ranges for PTS and TTS of up to 120 m and 370 m, respectively. These distances are within the standard 500 m mitigation zone and, considering the fact that the area will undergo a pre-piling search and the soft start procedure will be used, the effect using the peak SPL metric will be **negligible and not significant** to all marine mammals. Due to these results, the SEL_{cum} metric is considered most appropriate for assessing the overall impacts on mammals in the present assessment.

Table 16.15 – Maximum Distances to PTS and TTS Impact Thresholds using the peak SPL metric (Standard Mitigation)

Hearing group	Maximum distance to threshold (m)	
	PTS	TTS
Phocid Pinnipeds	10	30
Low-frequency cetaceans	10	25
Mid-frequency cetaceans	0	0
High-frequency cetaceans	120	370

Table 16.16 Estimated number of pinnipeds effected (PTS and TTS)

Species	Density	Maximum number of pinnipeds predicted to be within the area of threshold exceedance (density x area of exceedance)	Percentage of population impacted					
			Local Faray population		Wider population			
					Scottish population		UK population	
			Population	% potentially effected	Population	% potentially effected	Population	% potentially effected
PTS								
N/A								
TTS								
Grey Seal	35	46.74	182	26%	54,741	0.085%	152,000	0.031%
Harbour Seal	0.190	0.257	1	26%	26,900	0.001%	45,800	0.0006%

Table 16.17 Estimated number of baleen whales effected (PTS and TTS)

Species	Density	Maximum number of baleen whales predicted to be within the area of threshold exceedance (density x area of exceedance)	Percentage of population impacted					
			Local Faray population		Wider population			
					SCANS-III Block 8 population		SCANS-III total population	
			Population	% potentially effected	Population	% potentially effected	Population	% potentially effected
PTS								
Sperm whale (quickest escape)	0.060	0.954	-	-	9,599	0.010%	13,518	0.007%
Fin whale (quickest escape)	0.005	0.080	-	-	820	0.010%	18,142	<0.001%
TTS								
Sperm whale (quickest escape)	0.060	0.917	-	-	9,599	0.010%	13,518	0.007%
Fin whale (quickest escape)	0.005	0.076	-	-	820	0.009%	18,142	<0.001%

Table 16.18– Estimated number of harbour porpoise effected (PTS and TTS)

Species	Density	Maximum number of harbour porpoise predicted to be within the area of threshold exceedance (density x area of exceedance)	Percentage of population impacted					
			Local Faray population		Wider population			
					SCANS-III Block S population		MMMU population	
			Population	% potentially effected	Population	% potentially effected	Population	% potentially effected
PTS								
Harbour porpoise	0.229	0.002	72	0.003%	6,147	<0.001%	227,298	<0.001%
Harbour porpoise (quickest escape)	0.229	<0.002	72	<0.003%	6,147	<0.001%	227,298	<0.001%
TTS								
Harbour porpoise	0.229	1.967	72	2.74%	6,147	0.032%	227,298	0.001%
Harbour porpoise (quickest escape)	0.229	1.799	72	2.50%	6,147	0.029%	227,298	0.001%

Behavioural disturbance

16.9.23 Disturbance was assessed using thresholds of 140 dB re 1µPa (rms) and 160 dB re 1µPa (rms), plotted in Appendix 16.1, Figure 16.10. The thresholds are considered to be the same for all marine mammal species. Maximum distances to these thresholds from the pile are provided in Table 16.19.

Table 16.19 – Maximum Distances to Disturbance Threshold and Area of Disturbance for all Mammal Hearing Groups using the rms SPL Metric (Standard Mitigation)

Disturbance level	Maximum distance to threshold (m)	Area of disturbance (km^2)
Low	19,000	26.62
High	3,400	7.99

16.9.24 As per the TTS and PTS threshold assessments, the area of behavioural disturbance and the baseline data provided in Section 16.6 have been used to calculate the number of individuals that could be disturbed from the piling activities, as shown in Appendix 16.2.

16.9.25 Given the distances involved, along with the temporary and reversible nature of disturbance impacts, percentage of population impacted has been calculated at a regional and national scale only. Again, it should be noted that the number of individuals, and resultant percentage of population effected, are conservative as a pre-piling search of the mitigation zone would be completed to ensure the area was clear of marine mammals prior to the operations commencing.

16.9.26 The percentage of grey seal population disturbed on a regional scale is <1% for high disturbance and 1.68% for low disturbance. The percentage of populations disturbed for all other marine mammals is <1% at a regional and national scale. A higher percentage of local populations could be impacted, due to the area at which behavioural disturbance could occur, however, in consideration of the temporary and reversible nature of the impacts the effect is deemed to be **minor and not significant**.

Operational Noise

16.9.27 Operational noise will be limited to occasional vessel movements during maintenance visits. Some behavioural changes are likely during these visits, with mammals tending to avoid the vessels within a distance of approximately 200 m to 500 m (as already described in Chapter 8). However, the disturbance will be of a very short duration and the sound source levels relatively low, and so the magnitude of impact during operation is therefore regarded as **negligible and not significant**.

Decommissioning

The Applicant is seeking in-perpetuity consent for the Proposed Development. In the event of decommissioning, or replacement of turbines, it is anticipated that the effects would be less than that of construction as piling would not be required for decommissioning. Decommissioning would be undertaken in line with best practice processes and methods at that time and will be managed through an agreed Decommissioning Environmental Management Plan.

16.10 Additional Mitigation and Enhancement

16.10.1 The impacts and potential effects using standard mitigation measures described in the Section 16.8 and 16.9 indicated that there is the potential for moderate and significant effects to grey seals and harbour porpoise. As noted in Section 16.9, this is a conservative estimate as a pre-piling search of the mitigation zone would be undertaken prior to operations commencing.

16.10.2 Various forms of mitigation are available to reduce impacts on marine mammals. The most common take two forms, either to reduce the sound pressure levels being emitted from the pile driving (e.g. using pile driving cushions or bubble curtains), or attempting to displace the animals from the immediate area (e.g. through the use of deterrents or a longer soft start period).

16.10.3 Pile driving cushions or padding can be used between the head of the pile and the hammer. This reduces wear on the hammer and can also reduce the source sound level. Research into the sound reduction achieved is limited (e.g. Laughin, 2006; Deng et al, 2016). Cushions tend to reduce the high-frequency (above 1 kHz) sound in the source level spectrum whereas bubble curtains are effective at lower frequencies.

16.10.4 Bubble curtains can be an effective method for reducing underwater noise. Compressed air is injected through a perforated ring laid on the seabed around the pile, creating a ring of air bubbles which rise to the surface. The difference in impedance between water and air results in sound being absorbed and scattered as it passes from the water into the air bubbles (Koschinski and Lüdermann, 2013).

16.10.5 Koschinski and Lüdermann (2013) reviews several studies which used bubble curtains to mitigate piling noise. Reductions of the broadband SEL resulting from the bubble curtains were found to be between 11 dB re 1µPa^{2}s and 15 dB re 1µPa^{2}s, but varied with distance from the pile. In the present study, to account for the presence of a bubble curtain, the reductions for each frequency as reported in Elmer and Savery (2014) for experiments using the Big Bubble Curtain at the FINO3 research platform, were applied to the standard source level spectrum.

16.10.6 Cushions are more likely to reduce the potential impacts on high-frequency cetaceans, whereas bubble curtains may be more suited to reducing impacts on low-frequency cetaceans. However, both mitigations measures are likely to reduce the impacts for either of these mammal groups. Pinnipeds have a wider hearing range making them sensitive to both low and high frequencies (see Appendix 16.1, Figure 16.1) and therefore the impacts are likely to be reduced for seals by using either a bubble curtain or cushion.

16.10.7 The use of both a cushion and bubble curtain were modelled with bubble curtain providing the greatest reduction in impacts and effects. As such modelling outputs and assessment of the bubble curtain, only, should it be required, are presented in this Chapter.

Modified Source Levels for Mitigation Options

Source Level Spectrum with Bubble Curtain

16.10.8 Bubble curtains can be an effective method for reducing underwater noise. Compressed air is injected through a perforated ring laid on the seabed around the pile, creating a ring of air bubbles which rise to the surface. The difference in impedance between water and air results in sound being absorbed and scattered as it passes from the water into the air bubbles (Koschinski and Lüdermann, 2013).

16.10.9 Koschinski and Lüdermann (2013) reviews several studies which used bubble curtains to mitigate piling noise. Reductions of the broadband SEL resulting from the bubble curtains were found to be between 11 dB re 1µPa^{2}s and 15 dB re 1µPa^{2}s, but varied with distance from the pile. In the present study, to account for the presence of a bubble curtain, the reductions for each frequency as reported in Elmer and Savery (2014) for experiments using the Big Bubble Curtain at the FINO3 research platform, were applied to the standard source level spectrum (Appendix 16.1, Figure 16.11).

16.11 Residual Effects

Construction noise (with Bubble Curtain)

16.11.1 This section presents the potential impacts of piling with the use of a bubble curtain, in addition to standard mitigation, should it be deemed required for the project.

Injury to mammals (SEL_{cum})

16.11.2 For phocid pinnipeds the modelled SEL_{cum} dosage received during the installation of a single sheet pile using bubble curtain mitigation is presented in Appendix 16.1, Figure 16.12. Similar plots are provided for low-frequency cetaceans (Appendix 16.1, Figure 16.13), mid-frequency cetaceans (Appendix 16.1, Figure 16.14) and high-frequency cetaceans (Appendix 16.1, Figure 16.15). Similar plots are provided for low- and high-frequency cetaceans under the assumption of escaping via the nearest exit route (Appendix 16.1, Figure 16.16 and Figure 16.17). The maximum distances to the PTS and TTS threshold for each mammal hearing group are presented in Table 16.20 and the corresponding area of exceedance has been tabulated in Table 16.21.

16.11.3 With the use of the bubble curtain, there is no PTS predicted for any hearing group.

Table 16.20 – Maximum Distances to PTS and TTS Impact Thresholds using the SEL_{cum} metric (with Bubble Curtain)

Hearing group	Maximum distance to threshold (km)	
	PTS	TTS
Phocid Pinnipeds	0	0
Low-frequency cetaceans	0	3,030
Low-frequency cetaceans (quickest escape)	0	2,760
Mid-frequency cetaceans	0	0
High-frequency cetaceans	0	300
High-frequency cetaceans (quickest escape)	0	50

Table 16.21 – Area of PTS and TTS Impact using the SEL_{cum} metric (with Bubble Curtain)

Hearing group	Area of threshold exceedance (km2)	
	PTS	TTS
Phocid Pinnipeds	0	0
Low-frequency cetaceans	0	7.63
Low-frequency cetaceans (quickest escape)	0	3.33
Mid-frequency cetaceans	0	0
High-frequency cetaceans	0	0.01
High-frequency cetaceans (quickest escape)	0	<0.01

Pinnipeds

16.11.4 Using the bubble curtain reduces the magnitude of the modelled impacts compared to standard mitigation (i.e. soft-start only) due to underwater sound levels. For seals the maximum start distance within which TTS is exceeded is reduced from 1,980 m to zero. Thus, the residual effect following the addition of bubble curtain mitigation is assessed as **negligible and not significant**.

Low-frequency cetaceans

16.11.5 Low-frequency cetaceans (baleen whales) are predicted to have the largest reduction in impact due to the addition of the bubble curtain. Under the assumption that they swim directly away from the noise, the maximum start distance for TTS reduces from 12,950 m to 3,030 m, equating to a reduction in area from 15.9km^2 to 7.63km^2. For PTS, the maximum distance to PTS threshold is reduced from 3,030 m to zero.

16.11.6 Under the revised assumption that the low-frequency cetaceans swim to their nearest exit (Appendix 16.1, Figure 16.16), the reduction in maximum distance TTS threshold distance is marginally greater compared to the more simple fleeing method, reducing from 12,950 m to 2,760 m and the area of impact reducing from to 15.3 km^2 to 3.3 km^2 .

16.11.7 This would result in a reduction in the percentage of local population potentially affected, to <0.01% of the regional and national sperm whale and fin whale populations. As noted above, a search of the mitigation zone would be undertaken to ensure the area is clear of marine mammals prior to piling commencing thus individuals within the zone of TTS exceedance would be even less. Thus, in consideration of standard and additional mitigation measures, the residual effect is deemed to be **minor and not significant** overall.

<u>Mid-Frequency Cetaceans</u>

16.11.8 For mid-frequency cetaceans no exceedance of either the PTS or TTS threshold was predicted for standard mitigation and, therefore, no further reduction was possible, so, again effects are **negligible and not significant**.

<u>High-Frequency Cetaceans</u>

16.11.9 Under the assumption that harbour porposie swim directly away from the noise, the maximum start distance for PTS reduces from 340 m to zero. Furthermore, the maximum distance to TTS threshold is reduced, from 3,080 m to 300 m (and to 50 m under the revised assumption that the high-frequency cetaceans swim to their nearest exit (Appendix 16.1, Figure 16.17)

16.11.10 In terms of area of impact, for TTS the area is 0.01 km under the assumption that they swim directly away, reducing to almost zero (<0.01km) if the animals are assumed to swim to the nearest. Therefore, the TTS areas for both fleeing methods using the bubble curtain are considerably smaller than the TTS areas for the equivalent runs with standard mitigation, which had values of 8.6 km^2 and 7.9 km^2 respectively. This would result in a reduction in the percentage of local population potentially affected to <0.01%. As noted above, a search of the mitigation zone would be undertaken to ensure the area is clear of marine mammals prior to piling commencing. Thus, in consideration of standard and additional bubble curtain mitigation, the residual effect is deemed to be **minor and not significant** overall.

Injury to mammals (Peak SPL)

16.11.11 The residual impacts using bubble curtain mitigation were re-assessed using the empirically derived peak SPL metric (see paragraph 16.5.74). For all mammals, except high-frequency cetaceans, the distances to the PTS and TTS threshold were predicted to be zero. Thus, effects are considered to be **negligible and not significant.**

For high-frequency cetaceans (harbour porpoise) the PTS and TTS thresholds were exceeded with the bubble curtain in place for the peak SPL metric, at distances of up to approximately 10 m and 25 m respectively (as opposed to the equivalent SEL_{cum} distance of zero). This distance is within the standard 500m mitigation zone and also likely to be partly within the area inside the bubble curtain. The residual effect is therefore still deemed to be ***minor and not significant*** for harbour porpoise with regard to both PTS and TTS when using the bubble curtain mitigation.

Table 16.22 – Maximum Distances to PTS and TTS Impact Thresholds using the peak SPL metric (Standard Mitigation)

Hearing group	Maximum distance to threshold (m)	
	PTS	TTS
Phocid Pinnipeds	0	0
Low-frequency cetaceans	0	0
Mid-frequency cetaceans	0	0
High-frequency cetaceans	10	25

Behavioural disturbance

16.11.12 Disturbance was assessed using thresholds of 140 dB re 1µPa (rms) and 160 dB re 1µPa (rms), plotted in Appendix 16.1, Figure 16.18. The thresholds are considered to be the same for all mammals species. Maximum distances to these thresholds from the pile are provided in Table 16.23.

Table 16.23 – Maximum Distances to Disturbance Threshold and Area of Disturbance for all Mammal Hearing Groups using the rms SPL Metric (with Bubble Curtain)

Disturbance level	Maximum distance to threshold (m)	Area of disturbance (km^2)
Low	4,000	9.11
High	420	0.11

16.11.13 The number of individuals potentially disturbed significantly reduces for all marine mammal species (see Appendix 16.2). Thus, effects reduce from minor to **negligible and not significant**.

Operational Noise

16.11.14 The additional mitigation measures only apply to construction noise and therefore operational noise is not assessed in this section (refer to paragraph 16.9.27).

Decommissioning

The Applicant is seeking in-perpetuity consent for the Proposed Development. In the event of decommissioning, or replacement of turbines, it is anticipated that the effects would be less than that of construction as piling would not be required for decommissioning. Decommissioning would be undertaken in line with best practice processes and methods at that time and will be managed through an agreed Decommissioning Environmental Management Plan.

16.12 Cumulative Assessment

There are no other planned developments in the area. Therefore, there are considered to be no cumulative effects.

16.13 Summary

16.13.1 An assessment was carried out of the potential impacts on marine mammals from underwater noise generated during pile driving operations to install the new landing jetty at the island of Faray.

16.13.2 The key species in the area under consideration were assessed according to three hearing groups:

- Phocid Pinnipeds (seals);
- Low-frequency cetaceans (baleen whales);

- Mid-frequency cetaceans (common dolphin, bottlenose dolphin, Atlantic white-sided dolphin, orca, long-finned pilot whale, minke whale, Risso's dolphin, white-beaked dolphin); and,
- High-frequency cetaceans (harbour porpoise).

16.13.3 Underwater noise modelling was undertaken which calculated the area at which PTS and TTS thresholds for each hearing group would be exceeded. The modelling assumes that a soft-start procedure is in place, as per the JNCC piling protocol (2010), to ensure marine mammals can vacate the area. However, the modelling results are conservative estimates as, in line with the piling protocol, a search of an established 500 m zone around the operations would be undertaken to ensure the area is clear of marine mammals prior to the soft-start commencing. Therefore, the number of animals potentially within the areas of TTS and PTS exceedance will be less than those calculated.

16.13.4 During installation of a single pile using standard mitigation measures, which includes a 20 minute soft start period at the start of pile driving, seals are predicted to receive a cumulative sound exposure level (SEL_{cum}) dosage that exceeds TTS within a distance of 1,980 m (1.35 km^2 area). No exceedance above the level for PTS is predicted for seals. Harbour seals are not likely to be within the area in any great numbers, therefore the effect is **negligible and not significant**. However, the area that exceeds TTS has the potential to impact a significant percentage of the local grey seal population, although regionally and nationally the percentage of grey seal population potentially experiencing TTS is predicted to be below 1%. As such, the significance of effect to grey seals was initially assessed as **moderate and significance**.

16.13.5 Low-frequency cetaceans (baleen whales) are predicted to have the largest extent of impact, exceeding PTS and TTS thresholds within a distance of 3,030 m (7.65 km^2) and 12,950 m (15.90 km^2) respectively. This assumes the low-frequency cetaceans swim directly away from the noise source and results in the potential for PTS <0.01% of the regional population. Using a modified fleeing method for low-frequency cetaceans, whereby they are assumed to flee to the nearest exit, results in marginally smaller distance for PTS of 2,770 m (TTS remains the same), and the area the impact for PTS reduces to 2.3 km^2 instead of 7.65 km^2. Again, the results in PTS to less than 0.01% of the regional population. However, the shallow water depth in the region means that there is a low likelihood of low-frequency whales being present in much of the area affected by the noise. At MHWS, approximately 3 km^2 and 10 km^2 of the area is less than 10 m and 20 m deep respectively. The area at which PTS is exceeded is limited to these shallower waters and, thus, effects from PTS are considered to be **negligible and not significant**.

16.13.6 TTS impact would affect 0.01% of the population. In reality, the result is likely to lie somewhere between the two fleeing methods. Overall, taking into account the fact that the area is relatively shallow, the effect to low-frequency cetaceans, assuming standard mitigation and fleeing via the nearest exit, was deemed to be **minor and not significant**.

16.13.7 Mid-frequency cetaceans (which include a wide range of species found locally, including dolphins), are less impacted by underwater noise than the other mammal groups, and are predicted to receive dosages that are below threshold for both the TTS and PTS. Thus, effects were assessed as **negligible and not significant**.

16.13.8 High-frequency cetaceans (harbour porpoise) are predicted to have the second largest extent of impact, exceeding PTS and TTS thresholds within a distance of 340 m (0.01 km^2) and 3,080 m (8.60 km^2) respectively. This assumes the high-frequency cetaceans are swimming directly away from the noise source and results in the potential for TTS to more than 1% of the local population. Using a modified fleeing method for high-frequency cetaceans, whereby they are assumed to flee to the nearest exit, results in marginally smaller distances for PTS and TTS (30 m and 3,070 m), and in terms of total area the impact is 7.9 km^2 instead of 8.6 km^2 for TTS.

16.13.9 Overall, for harbour porpoise using either the swim directly away or the quickest escape method for fleeing, the PTS thresholds are only expected to be exceeded within the standard 500 m mitigation zone. As a pre-piling search will be undertaken to ensure the mitigation zone is clear of marine mammals prior to piling commencing, PTS to an individual is not expected to occur. Furthermore, due to the pre-piling search of the mitigation zone, the number of individuals impacted is a conservative estimate. None the less, as TTS could occur to >1% of the local population, the overall significance of effect (due to TTS) was deemed to be **moderate and significant**.

16.13.10 As there is the potential for moderate impacts to both local grey seal and harbour porpoise populations, the use of additional mitigation has been investigated. Namely, the use of a bubble curtain.

16.13.11 The use of a bubble curtain, in addition to standard mitigation, results in no exceedance of the PTS threshold for any marine mammal hearing group. The predicted distances for TTS for seals also reduces to zero when both standard mitigation and the bubble curtain are applied. As such the residual effect to grey seals is **negligible and not significant**.

16.13.12 For low-frequency cetaceans, the addition of a bubble curtain results in a maximum distance of 3,030 m for TTS, reducing slightly to 2,760 m if the animals are assumed to swim to the nearest exit. This results in the potential for TTS to <0.001% of the regional population. Thus residual effect to low-frequency cetaceans is **minor and not significant**.

16.13.13 Using a bubble curtain, the impact distance for TTS to harbour porpoise reduce to a maximum distance of 50 m and 300 m for the 'nearest exit' and 'swim directly away' fleeing methods, respectively, which is within the standard 500 m mitigation zone. The residual effect to harbour porpoises using bubble curtain mitigation is, therefore, deemed to be **minor and not significant.**

16.13.14 Behavioural disturbance of the marine mammals is predicted to occur over a larger area compared to the areas of potential injury described above. Under standard mitigation (soft-start only) the maximum distance within which low-level disturbance (140 dB re 1µPa) may occur for marine mammals is predicted to be approximately 19 km, covering an area of 26.6 km^2. High-level disturbance is predicted to occur at a distance of up to 3.4 km (8.0 km^2). Using a pile driving cushion, the low-level and high-level disturbance distances are reduced to 6.5 km (10.9 km^2) and 2.7 km (2.5 km^2), respectively. The distances are reduced more when using the bubble curtain mitigation option, to 4 km (9.1 km^2) and 0.42 km (0.1 km^2). Although the areas are quite large, behavioural impacts are temporary and reversible and the percentage of marine mammals impacted at regional and population levels is low; <1% of all species when the bubble curtain is applied. As such the effects from behavioural disturbance are deemed to be **negligible and not significant** for all marine mammal species assessed.

Table 16.24 – Summary of Effects

Description of Effect	Significance of Potential Effect		Mitigation Measure	Significance of Residual Effect	
	Significance	Beneficial/ Adverse		Significance	Beneficial/ Adverse
Construction					
Damage to hearing in local seal population	Moderate and significant	Adverse	Use of a bubble curtain	Negligible and not significant	Adverse
Damage to hearing in local low-frequency cetaceans population	Minor and not significant	Adverse	Use of a bubble curtain	Minor and not significant	Adverse
Damage to hearing in local mid-frequency cetaceans population	Negligible and not significant	Adverse	Use of a bubble curtain	Negligible and not significant	Adverse
Damage to hearing in local high-frequency cetaceans population	Moderate and significant	Adverse	Use of a bubble curtain	Minor and not significant	Adverse
Operation					
Vessel movements during maintenance visits	Negligible and not significant	Adverse	None considered		
Decommissioning					
The Applicant is seeking in-perpetuity consent for the Proposed Development. In the event of decommissioning, or replacement of turbines, it is anticipated that the levels of effect would be less as piling would not be required for removal. Decommissioning would be undertaken in line with best practice processes and methods at that time and will be managed through an agreed Decommissioning Environmental Management Plan.					

Table 16.25 – Summary of Cumulative Effects

Receptor	Effect	Cumulative Developments	Significance of Cumulative Effect	
			Significance	Beneficial/ Adverse
Marine mammals	Hearing loss and behavioural disturbance	None in the area	No effect	N/A

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