Seagreen Offshore Wind Farm

Offshore Transmission Asset Piling Strategy

April 2020

Project Title	Seagreen Wind Energy Ltd
Document Reference Number	LF000009-CST-OF-PLN-0003

Offshore Transmission Asset Piling Strategy

Marine Licence Offshore Transmission Asset (OTA) Condition 3.2.2.5

Rev	Date	Reason for Issue	Originator	Checker	ECoW	Approver
2.0	30/04/2020	For approval	Carol Sparling SMRU Consulting			

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Consent Plan Overview

Purpose of the Offshore Transmission Asset Piling Strategy

This Piling Strategy is submitted by Seagreen Wind Energy Limited (SWEL) (hereinafter referred to as Seagreen) on behalf of Seagreen Alpha Wind Energy Limited (SAWEL)to address the specific requirements of condition 3.2.2.5 attached to the Offshore Transmission Asset (OTA) Marine Licence granted by the Scottish Ministers under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 on 10 October 2014, as varied in March 2019.

The overall aims and objectives of the OTA Piling Strategy are to provide detailed information on the piling activities for installation of the Seagreen OTA, including setting out the anticipated timing, location, duration and maximum hammer energy to be used. It provides a refined OTA design, with the number of offshore substation platforms (OSPs) reduced from five, as assessed in the 2012 Offshore ES, to two, and a corresponding reduction in the total number of piles from 72 to 24. The maximum pile hammer energy and the duration of piling at each location is increased. Overall, these changes result in reduced environmental effects compared to those reported in the ES and consented in the OTA Marine Licence.

The OTA Piling Strategy also provides information on the mitigation measures which will be applied during the piling process and the monitoring proposed in relation to underwater noise from piling.

All Seagreen Contractors (including their Sub-Contractors) involved in the Seagreen Project are required to comply with this OTA Piling Strategy through conditions of contract.

Structure of the OTA Piling Strategy

The OTA Piling Strategy is structured as follows:

Section 1&2	Provide an overview of the Seagreen Project and the consent requirements that underpin the content of this OTA Piling Strategy. It also sets out the purpose, objectives and scope of the OTA Piling Strategy and sets out the process for making updates and amendments.
Section 3	Details the post-consent consultation for both marine mammals and fish species.
Sections 4	Details the piling parameters in order to fulfil condition 3.2.2.5a and 3.2.2.5b of the OTA Marine Licence.
Section 5	Provides a summary of the revised underwater noise modelling, detailed in Appendix C
Section 6	Summarises the marine mammal impact assessment, detailed in Appendix C
Section 7	Summarises the fish impact assessment, detailed in Appendix C
Section 8	Outlines the marine mammal monitoring plan
Section 9	Outlines fish monitoring
Section 10	Summarises the mitigation and monitoring procedures to be employed during pile-driving, detailed in Appendix D. This fulfils condition 3.2.2.5c of the OTA Marine Licence.
Section 11	Demonstrates compliance with the original application and commitments made.
Section 12	Lists the references made within this OTA Piling Strategy.
Appendices	Appendix A – List of Abbreviations and Definitions
	Appendix B – Change Management Procedure
	Appendix C – Underwater Noise Assessment
	Appendix D – Piling Mitigation Protocol
	Appendix E - Compliance with ES
	Appendix F – Summary of Mitigation Commitments

OTA Piling Strategy Audience

This OTA Piling Strategy will be submitted for approval to the Scottish Ministers/Licensing Authority, in consultation with other stakeholders in relation to monitoring compliance with the specific requirements of the relevant consent conditions

Compliance with this OTA Piling Strategy will be monitored by: Seagreen's Ecological Clerk of Works (ECoW); Seagreen's appointed Contractors, Seagreen's Environmental Manager; and the Marine Scotland Licensing and Operations Team (MS-LOT).

Copies of this OTA Piling Strategy are to be held in the following locations:

- Seagreen's head office;
- Seagreen's construction office and marine coordination centre; and
- at the premises of any Contractor, including the Seagreen ECoW, appointed by Seagreen.
- aboard any vessel engaged in the OTA.

1. Introduction

1.1 Consents and Licences

Seagreen Wind Energy Limited (SWEL, hereafter referred to as 'Seagreen') was awarded Section 36 Consent (S36 Consents) under the Electricity Act 1989 by Scottish Ministers in October 2014 for Seagreen Alpha and Seagreen Bravo Offshore Wind Farms (OWFs), as varied. Marine Licences for Seagreen Alpha and Bravo OWF and the Offshore Transmission Asset (OTA) (the OTA Marine Licence) (together the 'Marine Licences') were also awarded by Scottish Ministers in October 2014, as varied under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009. Together the wind farms Seagreen Alpha and Seagreen Bravo and the OTA collectively comprise 'the Seagreen Project'.

In 2018, following application by Seagreen, the Seagreen Alpha Marine Licence and Seagreen Bravo Marine Licence were varied by Scottish Ministers. Subsequently, in 2019, the OTA Marine Licence was also varied by Scottish Ministers. In 2019, the Bravo Marine Licence was assigned from Seagreen Bravo Wind Energy Limited (SBWEL) to Seagreen Alpha Wind Energy Limited (SAWEL).

This OTA Piling Strategy is seeking to discharge condition 3.2.2.5 of the OTA Marine Licence. A separate Offshore Wind Farm Piling Strategy will be submitted to discharge the Section 36 licence condition requirements.

In June 2019, Seagreen applied for a separate Marine Licence for an alternative installation methodology at the cable landfall. This will involve vibro-piling to install temporary sheet piling at the coastal defences. The Environmental Report (LF000009-CST-OF-REP-0021) accompanying the Marine Licence application concluded no impact and therefore no need for specific mitigation for marine mammals or fish. There is subsequently no requirement for mitigation in the Marine Licence for this activity and therefore it is not considered further in this Piling Strategy (reference 07050/19/0, awarded 12/11/2019)

1.2 Project Description

The Seagreen Project is located in the North Sea, in the outer Firth of Forth and Firth of Tay region and comprises the OWFs (the WTGs, their foundations and associated array cabling), together with associated infrastructure of the OTA (Offshore Substation Platforms (OSP), their foundations and the offshore export cables), to facilitate the export of renewable energy to the national electricity transmission grid. The location of the Seagreen Project is shown in Figure 1.1.

The Seagreen Project will consist of the following key components:

- 150 WTGs; comprising:
- 114 WTGs installed on three legged steel jackets, each installed on suction bucket caissons;
- 36 WTGs installed on up to four legged steel jackets, each installed on pin pile foundations;
- Two OSPs, each installed on 12 pin pile foundations;
- A network of inter-array subsea cables as detailed below;
    - Circa 300km of inter-array cables to connect strings of WTGs on suction bucket caissons together and to connect these WTGs to OSP 1

- Circa 55km of inter-array cables to connect strings of WTGs on piled foundations together and to connect these WTGs to OSP 2; and
- Circa 3km of interconnector cable to connect the two OSPs
- Inter-array cables will be buried where possible and where burial is not possible cable protection will be provided.

- Three subsea export cables, totalling circa 190km in length, to transmit electricity from the OSPs to the landfall at Carnoustie and connecting to the onshore export cables for transmission to the onshore substation and connection to the National Grid network. Export cables will be buried where possible and where burial is not possible cable protection will be provided.

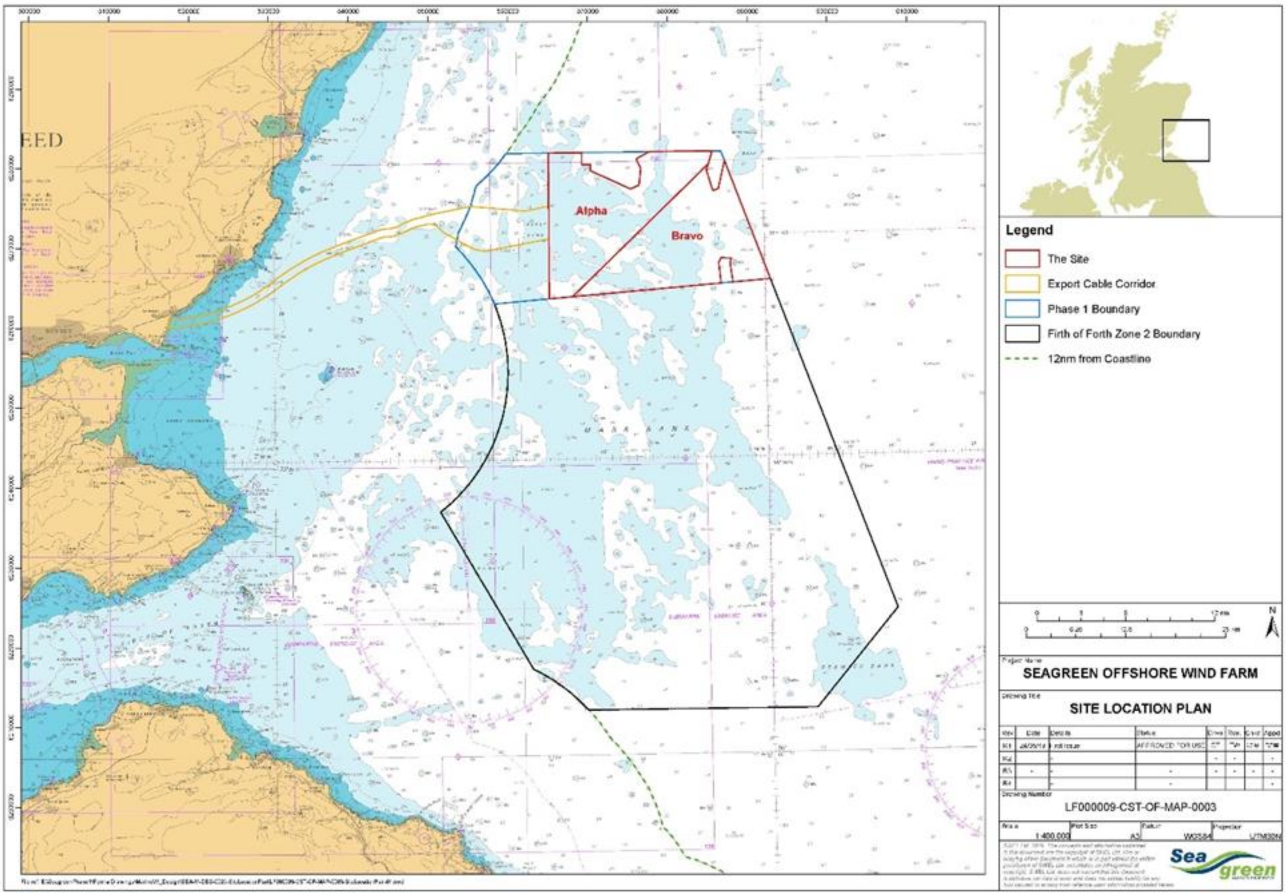

Figure 1.1 Project Location

1.3 Consent and Licence Requirements

This OTA Piling Strategy has been prepared to discharge condition 3.2.2.5 of the OTA Marine Licence, as set out in Table 1-1.

Table 1-1 Consent Conditions to be discharged by this OTA Piling Strategy

Consent Document	Condition Reference	Condition Text	Reference to relevant Section of this OTA Piling Strategy
OTA Marine Licence	Condition 3.2.2.5	In the event that pile foundations are to be used to construct the OSP's, the Licensee must, no later than 6 months prior to the Commencement of the Works, submit a PS, in writing, to the Licensing Authority for their written approval. Such approval may only be granted following consultation by the Licensing Authority with the JNCC, SNH and any such other advisors as may be required at the discretion of the Licensing Authority.	This document
		The PS must include: a) Full details of the proposed method and anticipated duration of pile-driving at all OSP locations;	Section 4
		b) Details of soft-start piling procedures and anticipated maximum piling energy required at each pile location; and	Section 4.3
		c) Details of any mitigation and monitoring to be employed during pile-driving, as agreed by the Licensing Authority.	Appendix D
		The PS must be in accordance with the Application and reflect any surveys carried out after submission of the Application.	Sections 8, 11 and Appendix C
		The PS must demonstrate how the exposure to and / or the effects of underwater noise have been mitigated in respect of the following species: bottlenose dolphin; harbour seal; grey seal; Atlantic salmon; cod; and herring.	Sections 6, 7 and 10
OTA Marine Licence	Condition 3.2.2.17	The Licensee must submit the appropriate completed noise registry form to the Licensing Authority and the JNCC stating, the proposed date(s), location(s) and nature of the piling activities	Section 10

Condition 3.2.2.5 of the OTA Marine Licence specifically relates to the marine mammal species which are qualifying features of nearby European Designated Special Areas of Conservation (SAC) (bottlenose dolphins, harbour seals and grey seals), however, this OTA Piling Strategy also considers harbour porpoise, white-beaked dolphins and minke whales, in order to provide the necessary information to support a subsequent European Species Licence (EPS) application.

1.4 Linkages with other consent plans and Consent Conditions

The OTA Piling Strategy will, so far as is reasonably practicable, be consistent with the EMP, PEMP and CMS consent conditions. These are set out in Table 1-2 with details of the linkages presented and cross referenced as appropriate.

It should be noted that information is not repeated across consent plans, rather, where pertinent information is available in linked consent plans, the relevant consent plans are referred to. The plans are not required for approval of the OTA Piling Strategy but are provided for ease of reference.

Table 1-2 Linkages with other consent plans

Reference	Linkage with the OTA Piling Strategy	Cross-reference in this OTA Piling Strategy
Project Environmental Monitoring Programme (PEMP) (required by S36 Condition 26 and OTA Marine Licence Condition 3.2.1.1)	Sets out measures by which Seagreen will monitor the potential environmental impacts of the OWFs. Seagreen environmental management, mitigation and monitoring commitments have taken account of the results and any recommendations of pre-construction monitoring and will continue to be refined depending on the results of the ongoing programme of construction and monitoring described in the Seagreen PEMP.	Section 8, Section 9 (PEMP and Marine Mammal Monitoring Plan (MMMP))
Environmental Management Plan (EMP) (required by S36 Condition 14 and OTA Marine Licence Condition 3.2.1.2)	Provides the framework for environmental management during construction and operation phases. It sets out the roles and responsibilities of Seagreen personnel and contractors in relation to environmental management measures, to prevent significant adverse impacts on the environment as identified in the ES, during the construction and operation of the Works.	Section 1.5
Construction Method Statement (CMS) (required by S36 Condition 10 and OTA Marine Licence Condition 3.2.2.4)	Details the OTA construction methods, setting out good practice construction measures and how mitigation measures proposed in the ES and ES Addendum are being implemented during construction	Section 4.2.2 - Piling methodology

1.5 Construction management

Full details of the construction management procedures, including environmental compliance, monitoring and reporting and roles and responsibilities are provided in the Offshore Construction Environmental Management Plan (LF000009-CST-OF-PLN-0014 - Offshore CEMP).

1.6 Updates and Amendments

Updates to this OTA Piling Strategy might be required, for example, due to changes to the proposed construction methodology (that require additional management or mitigation measures, or changes to measures already proposed), new environmental sensitivities identified by monitoring prior to construction, or following construction, emerging guidance, or new legislative requirements.

The change management process for any updates required to the OTA Piling Strategy, including resubmission of consent plans for approval, is outlined in Appendix B.

2. Scope and Objectives of the OTA Piling Strategy

The OTA Piling Strategy has four primary functions:

i. to ensure that details of the proposed method and anticipated duration of pile-driving at all locations are provided (condition 3.2.2.5a of the OTA Marine Licence);

ii. to provide details of soft-start piling procedures and anticipated maximum piling energy required at each pile location (condition 3.2.2.5b of the OTA Marine Licence);

iii. to present a revised assessment of predicted impact to key marine mammal and fish species using the refined piling parameters; and

iv. to provide details of any mitigation and monitoring to be employed during pile-driving (condition 3.2.2.5c of the OTA Marine Licence), to demonstrate how the exposure to and/or the effects of underwater noise have been mitigated in respect of the following species: bottlenose dolphin; harbour seal; Atlantic salmon; cod; and herring. In addition, this PS has also considered how exposure to underwater noise will be mitigated for harbour porpoise, white-beaked dolphins and minke whale, in order to support the application for a European Protected Species (EPS) licence.

All Seagreen personnel and Seagreen's Contractors (including their Sub-Contractors) involved in the Seagreen Project must comply with the OTA Piling Strategy.

3. Post Consent Consultation

The post consent consultation that was undertaken with MS-LOT and their statutory advisors SNH as well as Marine Scotland Science (MSS) with regard to the development of this PS and the proposed mitigation and monitoring proposals is summarised in Table 3-1.

Table 3-1 Summary of post consent consultation on the OTA Piling Strategy

Date	Consultee	Description of issue/discussion	Outcome
Conference call 03/07/2019	MS-LOT, MSS, SNH	Discussed significant reduction from worst case pile numbers assessed in 2012 ES and agreed approach to updated assessment for revised OSP piling parameters	Proposed updated noise modelling assessment accepted by consultees
Meeting 11/09/2019	MS-LOT	Discussion of revised wind farm design including a proportion of piled WTG foundations. Discussion of separate OTA Piling Strategy and OWF Piling Strategy documents	Confirmed that previously agreed approach was still relevant and agreed that separate PS documents would be submitted
Meeting 29/10/2019	MS-LOT, MSS, SNH	Presentation of updated noise modelling assessment and discussion of proposed Piling Mitigation Protocol	Agreement from consultees on the noise modelling, the outcome of the assessment and the proposed Piling Mitigation Protocol. Agreement to include assessment of the combined impacts of OTA and OWF piling in the Offshore Wind Farm PS. Agreement that there is no requirement on Seagreen to update noise modelling on the basis of findings from Beatrice OWF noise monitoring.

4. OTA Piling Strategy

Since the consents were granted in 2014, Seagreen have continued with refinement of the Project Design. The number of offshore substation platforms (OSPs) has been reduced from five, as consented, to two. Piling will be required to install the OSP foundations, with up to 12 piles for each OSP jacket, 24 in total. This represents a 66% reduction in the total amount of piling for OSP construction from the total of 72 piles that was assessed in the 2012 ES (Table 13.11, Chapter 13: Marine Mammals). There will be a further significant reduction in the piling required for WTG foundation installation. This will be described in the OWF Piling Strategy.

Following analysis of more detailed information on ground conditions at the OSP locations and due to technological advances in construction methods, the piling will require a hammer energy that is higher than that considered in the ES assessment submitted in support of the original consent application.

This section of the OTA Piling Strategy will provide details of the updated piling parameters (piling method and hammer energy profile, including soft-start details, maximum hammer energy and piling duration) that will be used to install the piled foundations of the two OSPs.

This fulfils condition 3.2.2.5a and 3.2.2.5b of the OTA Marine Licence, which require:

- *Full details of the proposed method and anticipated duration of pile-driving at all locations;*
- *Details of soft-start piling procedures and anticipated maximum piling energy required at each pile location.*

4.1 Geotechnical information

Several geotechnical investigations (GIs) have been performed at the Seagreen site. These include:

- GEMS (2011) – initial GI of the site with several deep boreholes and in situ testing;
- Gardline (2018) – interim GI with several deep boreholes and in situ testing in rock;
- Fugro (2019) – detailed GI across the site including in situ testing at one of the planned OSP locations.

Based on the available geotechnical data, rock is encountered at relatively shallow depths below seabed across much of the site. The rock comprises mudstone, siltstone and sandstone, with the rock uniaxial compressive strength (UCS) across the site ranging from less than 0.5 MPa to approximately 18 MPa. At the planned OSP locations, the rock is generally very weak and considered suitable for driven piles. However, while the rock is generally weak enough to allow piling, it is still substantially stronger than soils. Therefore, a larger hammer energy would be required to install driven piles into rock than would be typical for soils (as was considered in the 2012 offshore ES).

As rock is stronger than soil, pile lengths are typically shorter than piles installed into soil. Shorter piles typically take less time to install than longer piles, though this also depends on the specific ground conditions at the location in question. In addition, with a higher hammer energy, the time to install may be further reduced as fewer hammer blows would be required to reach the target penetration depth.

4.2 Pile parameters

The Seagreen OSP topsides will each be supported by a six leg steel jacket. Each leg will be secured using up to two piles with an outer diameter of up to 3.0m and a maximum penetration of 45.0m. Details of the pile parameters are listed in Table 4-1. For clarity a comparison of the current project design with the worst case design parameters assessed in the original 2012 Offshore ES is also provided.

Table 4-1 OSP pile parameters

Feature	As included in the ES	Revised in this PS	% reduction
Maximum number of piled OSPs	5	2	60%
Maximum number of piles per OSP	24	12	50%
Maximum number of piles total	72	24	66%

4.3 Maximum hammer energy

A hammer with maximum capacity of 2,600 kJ is expected to be utilised, with a maximum operational hammer energy of up to 2,300 kJ (i.e. operating at around 90% efficiency). The duration at the maximum operational energy is expected to range from 0.5 hours to 1.5 hours, depending on pile length and the actual ground conditions encountered.

4.4 Pile installation activities and equipment

4.4.1 Vessel

The OSP jackets will be installed using a floating Heavy Lift Vessel (HLV). The jackets and piles are expected to be transported to the site from the fabrication location by towed barge. The HLV will hold station at the installation using dynamic positioning (DP) or anchor moorings.

The OSP topsides will be installed in a subsequent operation following completion of each jacket installation.

4.4.2 Set-up activities

All pre-installation surveys will be conducted from the HLV. It is not anticipated that any seabed preparation will be required. All debris, boulder and UXO clearance will have been conducted as part of the pre-construction activities, as described in the Construction Method Statement (LF000009-CST-OF-MST-0001).

4.4.3 Pile installation

The OSP jacket will be lifted from the barge and lowered to the seabed at the required location. The piles will then be lifted from the barge and inserted into pile sleeves at the foot of each jacket leg. The piles will then be driven into the seabed to the desired depth using a suitable hydraulic impact hammer. A ‘soft-start’ process will be undertaken (section 4.2.3.3) before ramping up to the required hammer energy, to maintain a steady rate of penetration while minimising damage to the hammer or pile. Piling will be undertaken until pile refusal or the target penetration depth is reached.

If premature refusal occurs, the internal pile plug will be drilled out and a short drill-ahead undertaken. The purpose of this drilling is to reduce installation resistance so that piling can recommence. If refusal occurs once again, the same drill-out and drill-ahead process will need to be repeated until the target penetration is reached.

4.4.4 Soft-start

A pile hammer soft-start is a procedure to mitigate the potential for injury or fatality to marine mammals in the immediate vicinity of the pile. The intention of the soft-start is to allow animals time to move away from the pile location before hammer energies reach levels that could cause injury. During the mitigation soft-start, the pile hammer energy must remain below 500 kJ for a minimum of 20 minutes, in accordance with the JNCC (2010) mitigation guidelines. Following this, the hammer energy can be gradually ramped up as required. The blow rate during the first minute will be approximately 1 blow every 10 seconds, at as low an energy as practicable (≤300 kJ), thereafter increasing to approximately of 40 blows per minute and a maximum of 500 kJ hammer energy over the rest of the soft-start period.

4.4.5 Ramp-up

Following the soft start, the hammer blow energy will be gradually increased during piling until a suitable energy level is reached to maintain a steady rate of pile penetration.

During the piling ramp-up, the rate of hammer blows will remain at approximately 40 blows/minute with the hammer energy adjusted in stages to maintain a steady rate of pile penetration. The pile penetration rate will be monitored by ROV from the installation vessel.

Table 4-2 Indicative piling soft-start and ramp-up profile (see Appendix C for more details)

Stage	Minutes	Hammer energy (kJ)	Blows/min	% Max duration	% max hammer energy
Soft-start	1	Lowest practicable ≤ 300	6	1	13
	19	≤ 500	40	11	22
Ramp-up	20-40	500 – 1,200 linear increase	40	22	52
	40-80	1,200 – 2,000 linear increase	40	44	87
	80-180	2,000 – 2,300 linear increase	40	100	100

4.4.6 Piling locations

The two locations for OSP installation are shown on Figure 4.1. The most northerly of the two OSP locations was chosen to represent a worse case location for modelling of piling noise effects, as this is more central, further from the coast and in slightly deeper water, resulting in greater noise propagation, However, the difference between the two locations would be marginal.

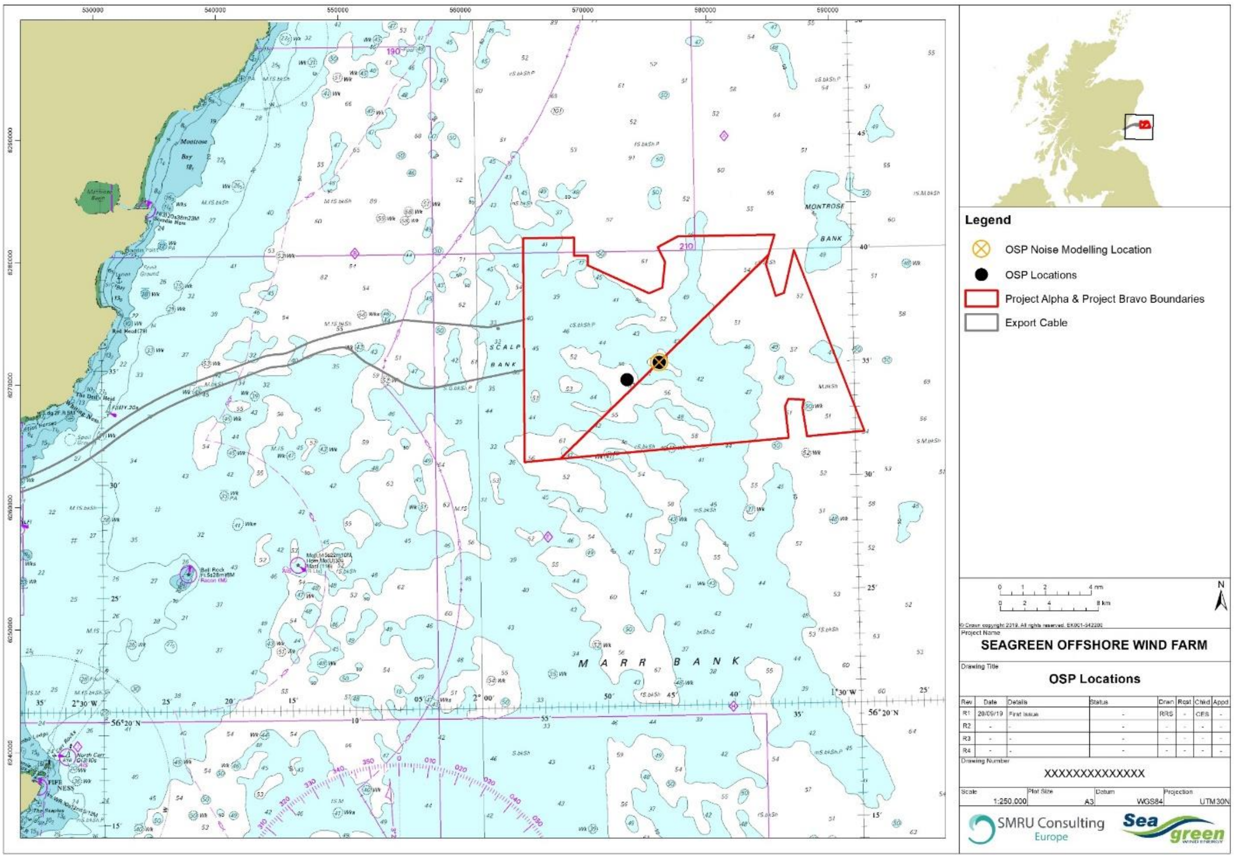

Figure 4.1 OSP locations and location used for noise modelling

4.4.7 **Simultaneous piling**

There are no plans to pile concurrently during the piling operations process.

4.5 Pile installation durations

4.5.1 **Overall piling programme**

OSP jacket 1 installation is currently planned in for May/June 2021 with the topside to follow approximately 8 weeks after jacket installation. OSP jacket 2 is expected to be installed during the period April to July 2023. Jacket installation activities at each location, including installation of piles, are expected to last up to 1 week. These programme timelines are subject to weather delays.

4.5.2 **Individual foundations**

Piling activities are expected to average 1 to 2 hours per pile, including soft start, depending on the pile length and ground conditions. Table 4-3 summarises the estimated durations for OSP installation activities.

Table 4-3 Estimated piling programme for OSPs with driven piles (assuming no relief drilling)

Activity	**Estimated Duration (hours)**
Set-up activities for each OSP location	
HLV and transport barge arrival on site	-
HLV positioning at desired location for installation	2
Lift, upend and place jacket onto seabed	6
Lift piles and insert into pile sleeves	6
Set-up TOTAL	14 hours
Piling activities for each OSP location	
Pre-piling mitigation (acoustic deterrent device (ADD)) deployment)	5 mins (minimum) to 10 mins (maximum) (repeated for any breaks in piling >6 hours (considered unlikely))
Piling, including soft-start, 6 legs with 2 piles per leg. (Assuming average piling duration in average ground conditions and no planned or unplanned breaks in piling)	18[1]
Lift hammer, relocate HLV to next locations and repeat pile installation process to complete OSP piling (6 legs, 12 piles)	12
Piling Duration TOTAL	30 hours (plus a maximum of 10 minutes ADD operation)
Post-piling installation activities for each OSP location	
Perform pile measurement	6
Vessel and transport barge depart from site	-
Post-pile TOTAL	6 hours
TOTAL duration for installation of a single piled OSP foundation	**50 hours [2]**

1. Note: The total of 18 hours of piling for 12 piles is the sum of total piling time required for each OSP location - however, this will be spread out over several days. The maximum number of piles installed within any 24 hour period is four.

2. This figure assumes installation proceeds without interruption due to weather, mechanical issue or other delay.

4.6 Mitigation of Piling Noise

Condition 3.2.2.5c of the OTA Marine Licence sets out the requirement for this OTA Piling Strategy to include: *details of mitigation and monitoring to be employed during piling, as agreed by the Scottish Ministers*. The primary aim of the mitigation is as follows:

- Reducing the risk of instantaneous mortality and injury to marine mammals to negligible levels, and

- Reduce the exposure to and / or the effects of underwater noise on fish species.

A Piling Mitigation Protocol (PMP) has been developed as part of this OTA Piling Strategy (Appendix D). This section briefly outlines the piling mitigation options. The PMP is summarised in Section 10 and the full details can be found in Appendix D.

4.6.1 General mitigation

While the maximum hammer energy will be 2,300 kJ, at each location pile installation will be completed at the lowest practicable hammer energy for the relevant phase of the work, in order to minimise pile and hammer fatigue and minimise the impact zones of injury to marine mammals and fish.

4.6.2 Marine mammals

Soft-start mitigation is required to mitigate the potential for injury or fatality to marine mammals from the underwater noise associated with piling. During the soft-start the piling must remain below 500 kJ for at least 20 minutes, in accordance with the JNCC (2010) mitigation guidelines. ADDs will be used in order to deter marine mammals away from the mitigation zone prior to the soft start.

4.6.3 Fish

The mitigation soft-start and use of ADDs proposed to reduce the risk of injury to marine mammals may also deter hearing-sensitive fish species from the impact zone. Fish may move away from the source on commencement of soft start piling and will continue to do so as piling ramps up. There is also the possibility that hearing sensitive fish species may respond to the acoustic deterrent. The ranges at which injury could occur are described below (Section 5).

5. Underwater noise modelling

In order to fulfil the requirements of the OTA Marine Licence and in light of a refinement of piling parameters since the 2012 application, additional noise modelling has been conducted to inform the development of this Piling Strategy. Appendix C to this OTA Piling Strategy presents the details of the noise modelling conducted by Cefas, the results of the revised noise modelling and an updated assessment to inform the design of the mitigation to be employed during piling. These are summarised in the sections below.

Three model types were run:

(1) SEL_{ss} based on the maximum hammer energy (to inform assessment of the risk of disturbance in marine mammals);
(2) SPL_{peak} based on initial and maximum hammer energies (to assess instantaneous permanent threshold shift (PTS) risk at piling onset and during piling for both marine mammals and fish); and
(3) SEL_{cum} over 24 hours, based on the hammer energy profile presented in Table 4-2 assuming four pin piles are installed in 24 hours (to assess risk of cumulative exposure for both marine mammals and fish).

6. Marine mammal impact assessment

For marine mammals, the risk of PTS-onset was assessed using the updated Southall criteria (Southall *et al.* 2019) which are based on dual criteria: cumulative sound exposure level (SEL_{cum}) and peak sound pressure level (SPL_{peak}). The potential for behavioural impacts (disturbance leading to displacement) was assessed using dose response curves. The dose-response curve adopted for all cetaceans was developed by Graham et al. (2019) from data on harbour porpoises at the Beatrice Offshore Wind Farm. For both species of seal, a dose response curve was derived from Russell et al. (2016) on harbour seal responses at the Lincs Offshore Wind Farm.

6.1 PTS-onset

Appendix C to this OTA Piling Strategy presents the full details of the PTS-onset impact assessment for marine mammals. A summary of the results is presented here.

6.1.1 Instantaneous PTS-onset

For all species the instantaneous PTS-onset impact range at the start of the soft-start was <50 m, which is effectively below the resolution of the noise modelling outputs. The probability of a single individual being within the PTS onset range during the first strike of a single pile was estimated, given the different average species densities in the area (based on Thompson 2015). The probability of a single individual of any marine mammal species being within the 50 m SPL_{peak} PTS-onset impact radius during the first soft-start strike (up to 300 kJ) of a single pile is extremely low (up to 0.00471).

During the first strike at full hammer energy (2300 kJ) the SPL_{peak} PTS-onset radius was also <50 m for minke whale, dolphin species and seal species. For harbour porpoise, the equivalent SPL_{peak} PTS-onset radius was 225 m. The probability of a single individual being within this range is also low (0.09413). This probability is an overestimate since it assumes that animals have not moved out of the impact radius during the soft-start, which is extremely unlikely.

It is also important to note that there will be considerable set-up activity prior to the start of any piling. Evidence from other offshore wind farm sites including Beatrice in the Moray Firth (Graham et al., 2019, Brandt et al., 2018) suggests that this is likely to reduce the probability of marine mammals being within these ranges. Therefore, even in the absence of mitigation methods over and above the soft-start, the probability of a single cetacean being within the SPL_{peak} PTS onset impact range at the start of piling is very low.

6.1.2 Cumulative PTS-onset

For all species other than minke whales, the cumulative PTS onset impact range was <50 m and therefore of negligible magnitude. For minke whales the maximum cumulative PTS onset impact range was 6.75 km which equates to a maximum of 1.95 animals (0.01% of the reference population) (given the different average species densities in the area (based on SCANS III densities, Hammond et al. 2017)) assuming no mitigation in place, other than soft-start, which is considered low magnitude. Therefore, the potential for impact is not considered significant.

6.2 Disturbance

Appendix C to the OTA Piling Strategy presents the details of the disturbance/displacement impact assessment for marine mammals. A summary of the results is provided here.

The number of animals predicted to experience behavioural disturbance for each species, and the proportion of each management unit this represents are provided in Table 3-5 of Appendix C. No significant impacts of behavioural disturbance were predicted for any marine mammal receptor as a result of piling at the worst case OSP location. Given the low number of animals estimated to experience behavioural disturbance, the low proportions of the management units that these represent (up to a maximum of 2.1%), and the short duration of any disturbance (two periods of three days, separated by approximately two years), the impacts are not considered significant.

6.3 Comparison with 2012 Assessment

The results of the worst case OSP assessment (installation of pin piles using a maximum hammer energy of 2,300 kJ) for all marine mammal species were the same or less than those presented in the consented 2012 ES Assessment (Chapter 13: Marine Mammals, Seagreen 2012) for both PTS and behavioural disturbance (see Appendix C of this OTA Piling Strategy).

7. Fish impact assessment

For fish, the most relevant criteria are considered to be those contained in the Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al.* 2014). The species considered in this assessment were: Group 2 (salmon) and Group 3 (cod and herring). The subsea noise model applied the Popper *et al.,* (2014) thresholds for Group 2 and Group 3 species and adopted two metrics in the approach to assessment (SPL_{peak} and SEL_{cum}). The potential for masking and behavioural effects was assessed using qualitative values as there is insufficient scientific data to support recommendations of quantitative criteria (Popper *et al.,* 2014). A highly conservative approach was adopted in the model by assuming that fish are stationary and do not flee the impact zone. This approach, since it is precautionary, is considered likely to lead to an overestimate of the ranges of effect. A summary of the criteria applied in the noise modelling assessment is provided in Table 2-3 of Appendix C.

7.1 Impact Ranges

Instantaneous mortality and hearing impairment arising from the initial, soft-start, hammer strike of 300 kJ was predicted to occur in very close proximity to the pile, over a maximum range of 29 m for all species.

Instantaneous mortality and hearing impairment arising from a hammer strike at maximum energy (2,300 kJ) was predicted to occur over a maximum range of 100 m for all species.

Cumulative exposure (SEL_{cum}) to multiple piles (four piles in a 24-hour period) suggested that mortality could occur out to a range of 804 m for salmon, 1,309 m for cod and herring and 804 m for the eggs/larvae of all species. For all species groups, it was predicted that cumulative exposure could result in recoverable injury out to 2.518 km.

The threshold for temporary threshold shift (TTS) was used to measure impairment and was also used as a proxy for the range at which behavioural displacement (onset of fleeing response) could occur. This range was 24.6 km for all species groups. As discussed above, the ranges modelled using SEL_{cum} are considered to represent a worse-case scenario and are likely to be an overestimate of the extent of effects for each of the thresholds modelled using this metric.

7.2 Fish assessment results

An assessment was undertaken to determine the potential for significant effects on sensitive fish receptors from the revised project design and to compare the conclusions with those presented in the 2012 ES based on the original project design (Appendix C). A summary of this assessment is given here.

Although there is some potential for mortality, injury and behavioural effects in the ranges summarised above, piling at the OSP is predicted to occur over a very short duration (three days per OSP) and overlap with sensitive locations and time periods for the fish species considered is limited. It is therefore concluded that the potential for mortality and impairment and the potential for behavioural effects are negligible. The impact of subsea noise on fish is therefore not considered significant.

7.3 Comparison with 2012 Assessment

The results of the worst case OSP assessment (installation of pin piles using a maximum hammer energy of 2,300 kJ) for all fish species were the same or less than those presented in the consented 2012 ES Assessment (Chapter 12: Natural Fish and Shellfish Resource, Seagreen 2012) for both mortality, auditory injury/impairment and behavioural effects (Appendix C of this OTA Piling Strategy).

8. Marine mammal monitoring

The Seagreen Project PEMP (LF000009-CST-OF-PRG-0003) sets out details of the marine mammal monitoring surveys proposed by Seagreen to better understand the effects of construction activities on marine mammal populations. Full details of the Seagreen Preconstruction Marine Mammal Monitoring Plan are provided in Report LF000009-CST-OF-REP-0024, which has been approved by Marine Scotland. The MMMP is summarised in the Seagreen Project PEMP.

An existing long term acoustic monitoring programme is in place on the east coast of Scotland, the Marine Scotland Science East Coast Marine Mammal Acoustic Study (ECOMMAS). It was agreed with Marine Scotland Science, Scottish Natural Heritage and MS-LOT to co-ordinate with ongoing data collection and to augment this existing programme to realise the full advantage of having a long term existing baseline of cetacean activity across the region and to collect additional data to support the requirements of the Seagreen MMMP.

The ECOMMAS monitoring stations record noise levels and detections of echolocating cetaceans, such as dolphins and porpoises. The configuration of existing stations was not quite optimal in relation to coverage of the coastal area closest to the Seagreen site. The addition of extra monitoring stations between the Stonehaven and Arbroath stations, extending from the coast to the Seagreen site has been agreed and implemented with the initial deployment of cetacean detection devices (CPODs) having taken place in March 2019, in collaboration with MSS. The survey design therefore includes a monitoring station in the shallow, coastal area known to be used by bottlenose dolphins as well as providing a gradient survey design extending to the Seagreen Project Array area for determining any changes in detections of other cetaceans, in relation to construction activities, as well as monitoring noise at a variety of ranges from the construction site. The data collected will provide insights into the actual noise produced during the installation of foundations and will be compared with predicted noise levels from the predictive modelling carried out to inform assessments. In addition, the Seagreen augmentation of the array provides the advantage of monitoring further offshore in deeper areas where ECOMMAS has not previously covered.

9. Fish monitoring

Due to the available evidence and the current understanding within the offshore wind industry of potential impacts in relation to marine fish, generic pre- and post-construction monitoring is not proposed for the Seagreen Project. A review was undertaken of the requirement for marine fish, sandeel and migratory fish monitoring surveys, based on consideration of the predictions made within the 2012 Offshore ES (Seagreen, 2012), the level of certainty in these assessments and the most recently available data including the 2018 Offshore EIA Report (Seagreen, 2018). The conclusions of this review are that the significance of any effects for the majority of potential impacts is considered to be negligible to low and there is a high level of certainty in the impact assessments presented within the 2012 Offshore ES and supported by the more recent assessment in the 2018 Offshore EIA Report. This detailed review is presented in Section 3.4.1 of the marine fish monitoring strategy document (LF000009-CST-OF-REP-0019) and this has been accepted by Marine Scotland, SNH and FTRAG.

With consideration of the above, Seagreen intends to draw on the data collected as part of the Seagreen Marine Mammal Monitoring Plan (MMMP) (LF000009-CST-OF-RPT-0024), which will include underwater noise monitoring through extension of the East Coast Marine Mammal Acoustic Study (ECOMMAS) acoustic arrays, to provide site specific data (see Section 8). As above for marine mammals, the data collected will provide insights into the actual noise produced during the installation of foundations and will be compared with predicted noise levels from the 2012 Offshore ES and 2018 Offshore EIA Report noise modelling studies. In addition, Seagreen will investigate with Marine Scotland the potential for participation in relevant strategic studies, to contribute to the ScotMER diadromous fish programme, with the aim of furthering understanding of Atlantic salmon ecology and behaviour in relation to offshore wind farm construction and operation.

10. Piling Mitigation Protocol

Appendix D to the OTA Piling Strategy details the mitigation methods that will be adhered to during all piling activities at the Seagreen Project. This fulfils condition 3.2.2.5c of the OTA Marine Licence. This section provides a summary of the Piling Mitigation Protocol (PMP).

The PMP does not include the use of Marine Mammal Observers (MMOs) or Passive Acoustic Monitoring (PAM) to monitor the PTS injury zone. This is due to the extremely small instantaneous PTS-onset impact range of <50 m at the start of the soft-start. An increase in construction related activity prior to piling will act as a local scale deterrent and reduce the risk of auditory injury. Incorporating a short period (5 to 10 mins) of ADD deployment prior to the soft-start, to allow marine mammals to be displaced out of the impact zone will reduce this risk even further. The ADD device selected for use is the Lofitech AS seal scarer as it has been shown to have the most consistent effective deterrent ranges for harbour porpoise, seals and minke whales in environments similar to the offshore wind farm construction site.

Prior to commencement of the soft-start, the ADD will be tested. When readiness for piling start is confirmed, the ADD will be activated for a minimum of 5 minutes and a maximum of 10 minutes. The soft-start will then commence and the ADD will be deactivated. The soft-start will then be followed by a gradual ramp-up, until a suitable energy level is reached, to maintain a steady rate of pile penetration. In the event of breaks in piling of <10 minutes, no mitigation is required and the piling can continue from the last hammer energy and strike rate (or lower) used without the need for another ADD deployment. For breaks in piling <6 hours, piling will recommence with a full soft-start and ramp-up in hammer energy, wherever this is safe to do so, but without the need for pre-piling ADD deployment. If the break in piling is >6 hours, then the full piling mitigation procedure of pre-piling ADD deployment, soft-start and ramp-up will be conducted. A schematic diagram of the steps in the piling procedure is provided in Figure 10.1, below.

Appendix D also describes the reporting of piling operations, which will include:

- A record of piling operations detailing date, soft-start duration, piling duration, hammer energy during soft-start and piling and any operational issues for each pile;
- A record of ADD deployment, including start and end times of all periods of ADD activation, any problems with ADD deployment;
- Details of any problems encountered during the piling process including instances of noncompliance with the agreed piling protocol; and
- Any recommendations for amendment of the protocol.

Reports will be provided to MS-LOT/ the Licensing Authority completion of each OSP installation as described the Offshore CEMP (LF000009-CST-OF-PLN-0014). The reports will include any data collected during piling operations, details of ADD deployment, a detailed description of any technical problems encountered and what, if any, actions were taken. Reporting will also include the submission of Noise Registry information as required by the consent.

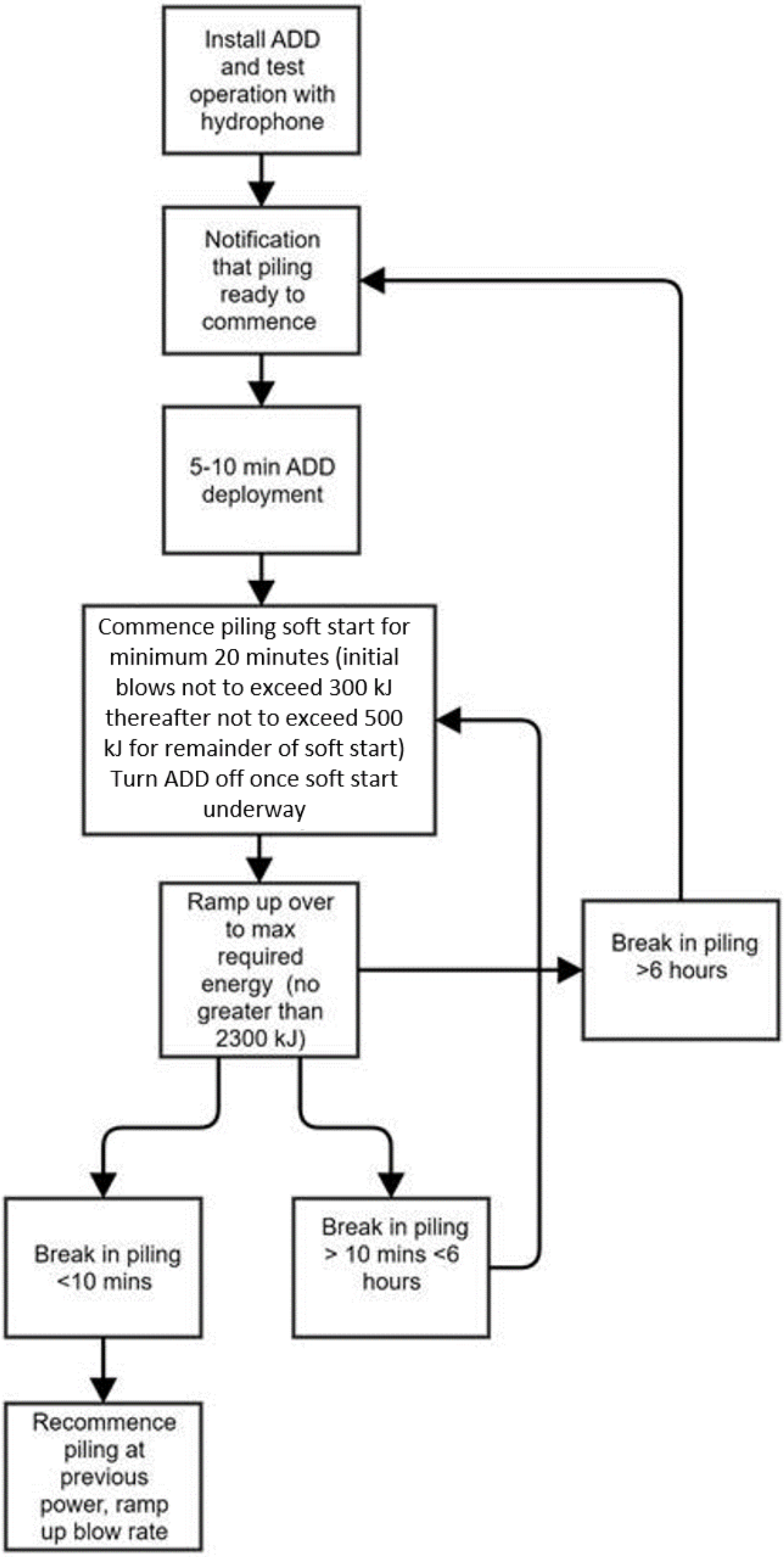

Figure 10.1 Flow diagram of piling procedure

11. Compliance with the ES and ES Addendum

Condition 3.2.2.5 of the OTA Marine Licence requires the Piling Strategy to be in accordance with the Application (including the ES and ES Addendum). Appendices E and F to this document set out information from the 2012 ES, 2013 ES Addendum with regard to:

- Consistency with the construction methods assessed in relation to piling activity; and
- Construction related mitigation and management relevant to the OTA Piling Strategy.

11.1 Compliance with Construction Methods Assessed in the ES and ES Addendum

The ES and ES Addendum for the Seagreen Project described the range of methods that could be applied during the construction of the Development. This was presented as a 'Rochdale Envelope' incorporating a variety of options in relation to the development design and the approach to installation.

Since award of development consent for the Seagreen Project, the design of the project and the approach to installation has been refined, as set out within this OTA Piling Strategy and in other relevant consent plans. To demonstrate compliance with those methods assessed within the ES and ES Addendum, Appendix E provides a tabulated comparison of project construction parameters and methodologies, as presented in the ES and ES Addendum with this OTA Piling Strategy.

11.2 Delivery of Construction-related Mitigation Proposed in the ES and ES Addendum

The ES and ES Addendum for the Seagreen project detailed a number of mitigation commitments specific to construction and installation activities. Appendix F presents the commitments made by Seagreen in the ES and ES Addendum to mitigation measures relevant to construction methods and processes set out in this OTA Piling Strategy. The table provides details of the commitments and a cross-reference to where each commitment is implemented.

A complete register of the mitigation, management and monitoring commitments made in the ES and ES Addendum, required by consent conditions is set out in the commitments register included as part of the Project CEMP.

12. References

Table 12.1 provides a list of Consent Plans that are relevant to this OTA Piling Strategy. It is followed by a list of other reference documents.

Seagreen Document Number	Title
LF000009-CST-OF-PRG-0003	Seagreen Alpha and Seagreen Bravo Offshore Wind Farms Project Environmental Monitoring Programme (PEMP)
LF000009-CST-OF-PLN-0014	Offshore Construction Environmental Management Plan (CEMP)
LF000009-CST-OF-MST-0002	Offshore Transmission Assets Construction Method Statement
LF000009-CST-OF-PRG-0002	Offshore Construction Programme
LF000009-CST-OF-PLN-0001	Offshore Operational Environmental Management Plan
LF000009-CST-OF-PLN-0003	Offshore Wind Farm Piling Strategy
LF000009-CST-OF-MST-0001	Offshore Wind Farm Construction Method Statement
LF000009-CST-OF-PLN-0006	Offshore Vessel Management Plan

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Gardline (2018). Seagreen Alpha and Bravo Offshore Wind Farm –Interim (Phase 2) Geotechnical Surveys 2018 (Seagreen report LF000009-ENG-OF-DTA-0007).

GEMS (2011). Phase 1 Preliminary Geotechnical Survey Factual Report (Seagreen report A4MRSEAG-Z-ENG950-CRP-109).

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Seagreen. 2012. Environmental Statement Volume I. (Seagreen report A4MRSEAG-Z-DEV275-SPR-060).

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Thompson, P. 2015. Annex 3. Framework for a risk-based assessment to underpin the adoption of alternative mitigation measures during piling at the BOWL and MORL Offshore Wind Farms. 28th July 2015. In: Beatrice Offshore Windfarm Ltd. (2015). Beatrice Offshore Wind Farm Piling Strategy. Prepared by RPS, GoBe Consultants Ltd and Brown and May Marine. Report number LF000005. November 2015.

Appendix A – OTA Piling Strategy List of Abbreviations and Definitions

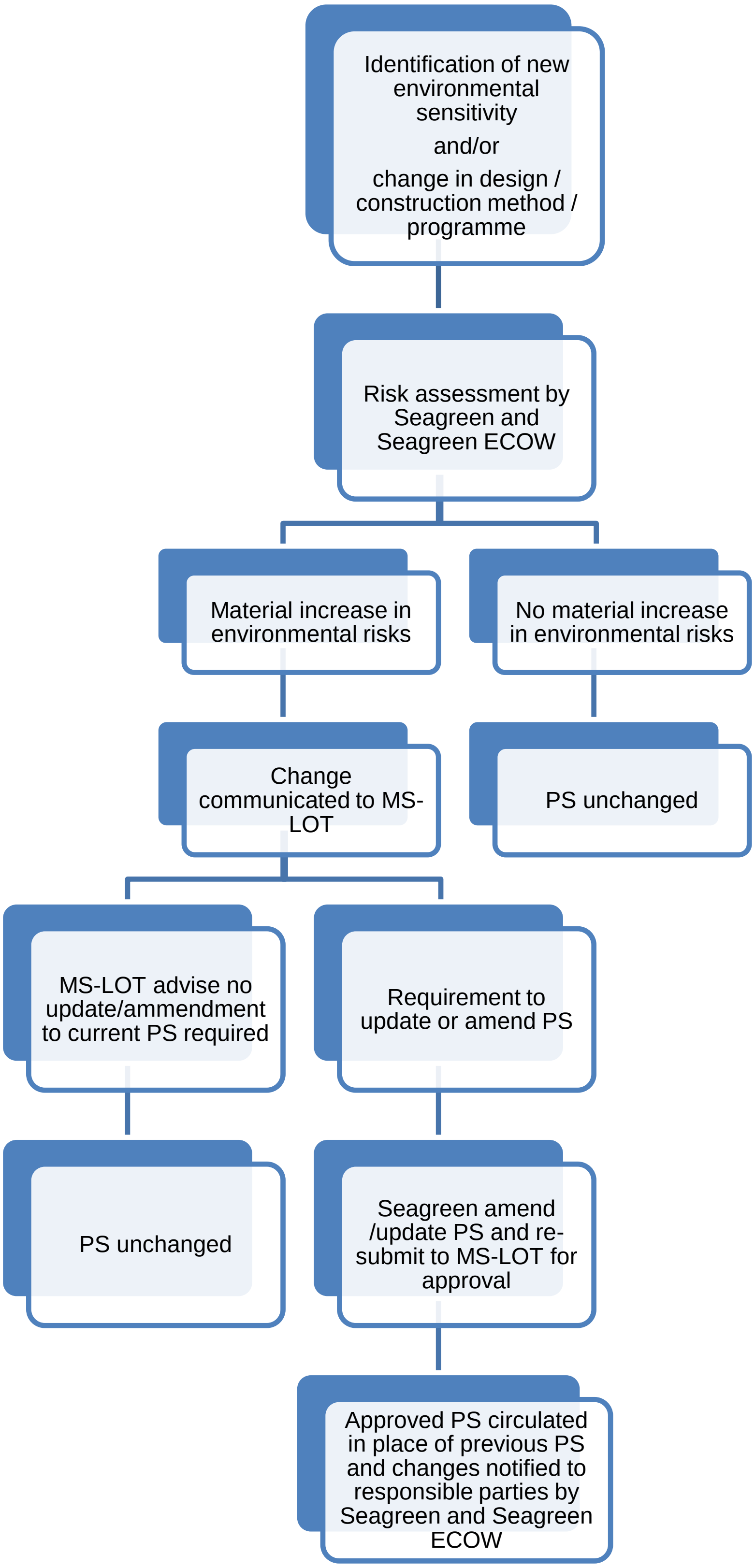
Term	Description
ADD	Acoustic Deterrent Device
Seagreen Alpha Marine Licence	Marine licence granted by the Scottish Ministers under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 in respect of Seagreen Alpha Wind Farm on 10 October 2014 as amended by the revised marine licence granted by the Scottish Ministers on 28 August 2018 (reference 04676/18/0)
Seagreen Bravo Marine Licence	Marine licence granted by the Scottish Ministers under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 in respect of Seagreen Bravo Wind Farm on 10 October 2014 as amended by the revised marine licence granted by the Scottish Ministers on 28 August 2018 (reference 04677/18/0)
Cefas	Centre for Environment, Fisheries and Aquaculture Science. Cefas were contracted to carry out the underwater noise modelling for the noise assessment.
CMS	Construction Method Statement as required under Alpha and Bravo Section 36 Condition 11 and the Offshore Transmission Asset Marine Licence Condition 3.2.2.4
Commitments register	A register that sets out all commitments to manage and mitigate potential environmental impacts made by SWEL
(the) consents	Collective term used to describe the Section 36 consents and Marine Licences issued to SAWEL, SBWEL and SWEL
Construction Environmental Advisor	SWEL's Contractor is required to appoint a Construction Environmental Advisor. The Construction Environmental Advisor will be a full-time resource for the duration of the Contractor's construction works and will be dedicated to delivering the requirements of the consents and wider environmental matters
Contractor	The main CONTRACTOR as appointed by SWEL
Construction Environmental Management Plan (CEMP)	Offshore Construction CEMP as required under Alpha and Bravo Section 36 Condition 14 and the Offshore Transmission Asset Marine Licence Condition 3.2.1.2.
Construction Marine Pollution Contingency Plan (MPCP)	Offshore MPCP, required as part of the CEMP under Offshore Transmission Asset Marine Licence Condition 3.2.1.2.
CoP	Construction Programme as required under Alpha and Bravo Section 36 Condition 9 and the Offshore Transmission Asset Marine Licence Condition 3.2.2.3
CPOD	Acoustic cetacean detection device which is moored at sea for monitoring purposes.
Diadromous fish	Fish species that migrate between fresh and salt water

Term	Description
ECOMMAS	East Coast Marine Mammal Acoustic Study – A Marine Scotland cetacean and noise monitoring study incorporating monitoring on the East Coast of Scotland
ECOW	Ecological Clerk of Works as required under Alpha and Bravo Section 36 Condition 29 and the OTA Marine Licence Condition 3.2.2.12.
EIA	Environmental Impact Assessment
EPS	European Protected Species
ES	Environmental Statement
FTRAG	Forth and Tay Regional Advisory Group, required under Condition 27 of the S36 consent and Condition 3.2.3.9 of the OTA Marine Licence
GI	Ground Investigation
HLV	Heavy lift vessel
HRA	Habitats Regulations Assessment
JNCC	Joint Nature Conservation Committee
Licencing Authority	Marine Scotland acting on behalf of the Scottish Ministers
Licensee	Seagreen Wind Energy Ltd (Seagreen), a company with number 06873902 and having its registered office at No1 Forbury Place, 43 Forbury Road, Reading, United Kingdom RG1 3JH, on behalf of SAWEL and SBWEL
Marine Licences	The three marine licences for the Seagreen Project, comprising the Alpha Marine Licence, the Bravo Marine Licence and the OTA Licence, all as granted by the Scottish Ministers under Section 20(1) of the Marine (Scotland) Act 2010on 10 October 2014 and as subsequently varied, in the case of the Seagreen Alpha Offshore Wind Farm Marine Licence and the Seagreen Bravo Offshore Wind Farm Marine Licence, on 29 August 2018 and, in the case of the OTA Marine Licence, on 6 March 2019
MMMT	Marine Mammals Mitigation Team
MMO	Marine Mammal Observer
MS-LOT	Marine Scotland Licensing and Operations Team
MSS	Marine Scotland Science
OnTW	The Onshore Transmission works, comprising the transmission cable onshore from MLWS to the connection with the UK transmission grid, including the onshore substation at the connection point.
OSP	Offshore Substation Platform
OTA	Offshore Transmission Asset, comprising the OSPs and the transmission cable required to connect the Wind Farm Assets to the OnTW from the OSPs to MHWS at the landfall at Carnoustie

Term	Description
OTA Marine Licence	Marine licence granted by the Scottish Ministers under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 in respect of the Seagreen Offshore Transmission Asset on 10 October 2014 as amended by the revised marine licence granted by the Scottish Ministers on 6th March 2019 (reference 04678/19/0)
OWF	Collective term used to describe the Wind Farm Assets and OTA
PEMP	The Project Environmental Monitoring Programme as required under the Seagreen Alpha and Seagreen Bravo S36 Condition 26 and the Offshore Transmission Assets Marine Licence Condition 3.2.1.1
PMP	Piling Mitigation Protocol
PS	Piling Strategy, as required for approval under Condition 3.2.2.5 of the Marine Licence
PTS	Permanent Threshold Shift (reduction in hearing sensitivity) as a result of auditory injury from exposure to loud noise
S36 Consents	Consents under section 36 of the Electricity Act 1989 granted by the Scottish Ministers on 10 October 2014 in respect of the Seagreen Alpha and Seagreen Bravo offshore wind farms, both as varied by the Scottish Ministers by decision letter issued pursuant to an application under section 36C of the Electricity Act 1989 on 28 August 2018
SAWEL	Seagreen Alpha Wind Energy Limited, a company with registered number 07185533 and having its registered office at No1 Forbury Place, 43 Forbury Road, Reading, United Kingdom RG1 3JH
SAC	Special Area of Conservation
SBWEL	Seagreen Bravo Wind Energy Limited, a company with registered number 07185543 and having its registered office at No1 Forbury Place, 43 Forbury Road, Reading, United Kingdom RG1 3JH
SEL	Sound Exposure Level
SEL_{cum}	Cumulative SEL estimated over a 24 hour period
Site	The area outlined in red and in the figure contained in Part 4 of the OTA Marine Licence
SNH	Scottish Natural Heritage
SSE	Scottish and Southern Energy
Seagreen	Seagreen Wind Energy Limited (SWEL), the parent company of Seagreen Alpha Wind Energy Ltd (SAWEL) and Seagreen Bravo Wind Energy Ltd (SBWEL), (company number 06873902) and having its registered office at No.1 Forbury Place, 43 Forbury Road, Reading, United Kingdom, RG1 3JH.
TTS	Temporary Threshold Shift (reduction in hearing sensitivity) as a result of auditory injury from exposure to loud noise
Wind Farm Assets	The wind turbines and foundations and the array cables connecting wind turbine strings to the OSPs, including any wind or sea conditions monitoring equipment.

Term	Description
Wind Farm Marine Licences	The Alpha Marine Licence and the Bravo Marine Licence
WTG	Wind turbine generator

Appendix B – The OTA Piling Strategy Change Management Procedure



Appendix C Underwater Noise assessment

Project Title	Seagreen Wind Energy Ltd
Document Reference Number	LF000009-CST-OF-PLN-0003

Offshore Transmission Asset Piling Strategy Appendix C: Underwater Noise Assessment

Table of Contents

Glossary

Term	Definition
ADD	Acoustic Deterrent Device – a sound emitting device which is intended to move marine mammals away from a location. In this context used to deter animals away from the location of an activity which could negatively affect them if exposed to it at close proximity.
Permanent Threshold Shift (PTS)	A total or partial permanent reduction in hearing sensitivity at a particular frequency caused by some kind of acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity at that frequency.
Sound Exposure Level (SEL)	The constant sound level over one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
SEL_{cum}	The total SEL generated during a specified period – usually 24 hours
Sound Pressure Level (SPL)	An expression of the sound pressure using the decibel (dB) scale and the standard reference pressures of 1 µPa for water.
SPL_{peak}	The greatest absolute instantaneous sound pressure within a specified time interval and frequency band
Temporary Threshold Shift (TTS)	A temporary reduction in hearing sensitivity at a particular frequency caused by some kind of acoustic trauma.

1. Introduction

In order to fulfil the requirements of Condition 3.2.2.5 of the Offshore Transmission Asset (OTA) Marine Licence, as varied (Ref: 04678/19/0), and in light of a refinement of piling parameters since the 2012 application, it was agreed with Marine Scotland and SNH that additional noise modelling should be undertaken to provide further details of the potential impact of underwater noise on marine mammal and fish species. The approach was agreed with Marine Scotland and SNH on 3 July 2019 to demonstrate that predicted impacts on marine mammals and fish were in accordance with the 2012 ES and application. This appendix to the OTA Piling Strategy presents the results of this updated noise modelling and assessment to inform the design of the mitigation to be employed during piling. Also included is a comparison between the updated assessment and the outcomes of the original assessment to ensure accordance with the Application and no change in impact significance.

2. Assessment Methodology

Underwater noise modelling was undertaken by Cefas using their propagation model (Farcas et al. 2016) and an energy conversion source model. Details of these, and of the assessment criteria applied for fish and marine mammals, are provided below.

2.1 Source model

In the model, the source level estimate for piling was calculated using an energy conversion model (De Jong and Ainslie 2008), whereby a proportion of the expected hammer energy is converted to acoustic energy:

$$\boldsymbol{SLE} = \mathbf{120} + \mathbf{10}\boldsymbol{log}\mathbf{10}\ (\boldsymbol{\beta E c 0 \rho}\ \mathbf{4}\boldsymbol{\pi}\ ) \qquad (1)$$

where E is the hammer energy in joules, SLE is the source level energy for a single strike at hammer energy E, $\boldsymbol{\beta}$ is the acoustic energy conversion efficiency, $c0$ is the speed of sound in seawater in m s-1 , and ρ is the density of seawater in kg m-3 .

This yields an estimate of the source level in units of sound exposure level (dB re 1 µPa^{2}s). This energy is then distributed across the frequency spectrum based on previous measurements of impact piling (Ainslie et al. 2012). Hammer energy profiles for the piling scenarios (see Section 2.5) formed the basis of the source level estimates. Equation 1 was used to compute the source level energies, using an acoustic energy conversion efficiency of 1%, which assumes that 1% of the hammer energy is converted into acoustic energy.

Equation (1) gives the source level energy for a single strike (single-strike Sound Exposure Level (SEL)). The maximal single-pulse SEL, SEL_{ss}, as well as the cumulative SEL (the total SEL generated during a specified period), SEL_{cum}, were computed. The peak sound pressure level (SPL) was calculated using the empirical linear equations linking peak sound pressure levels and sound exposure levels for piling sources found by Lippert et al. (2015).

2.2 Propagation model

The Cefas propagation model (Farcas et al. 2016) is based on a parabolic equation solution to the wave equation (RAM; Collins 1993). This model takes into account the bathymetry, sediment properties, water column properties, and tidal cycle. The model is a quasi-3D model consisting of 360 2D transects extending away from the source at intervals of one degree. Sound propagation is modelled at each discrete frequency in the source spectrum (10 frequencies per 1/3 octave band). Transects are then resampled and integrated over frequency (using the appropriate auditory weightings where needed). Finally, the resulting levels are averaged over depth to produce noise maps.

2.3 Input data

Aside from source levels of piling, the main model inputs were bathymetry, water temperature and salinity (used to compute sound speed), and the acoustic properties of the seabed sediments. Bathymetric data in UTM30N projection was provided to Cefas, covering the area inside the Project Alpha and Project Bravo boundaries. This was supplemented by a more extensive dataset, with a 7.5" resolution and in WGS84 projection, which was downloaded from EMODNET[1] database (http://www.emodnet-bathymetry.eu/data-products) and then converted to UTM30N projection for input to the model.

The bathymetric datasets were interpolated and used to define the model numerical grid with a resolution of 100 m, and a coverage of 500000-750000, 6100000- 6500000 (eastings, northings UTM30N), or approximately 250 km by 400 km, which was more than adequate for the frequency ranges and the spatial scales used in the simulations. The water temperature and salinity data, which are used by the model for calculating the water column sound speed profiles, were taken from a validated, multiyear hindcast model produced by Cefas, known as GETM-ERSEM-BFM. The model provides extensive daily coverage at 0.1 degree spatial resolution and includes 25 depth layers. A seawater temperature of 8°C was used in the modelling which is typical of the April water temperature in the Seagreen project area. The noise model also includes the acoustic properties of the seabed sediments, namely speed of sound, density, and acoustic attenuation, which are used to construct a geoacoustic model of the seafloor. These properties were derived from the seabed core data by correlating the core sediment information with published acoustic properties of various sediment types (Hamilton 1980).

2.4 Piling Location

The two locations where OSPs will be installed are displayed on Figure 2.1. The most northerly of the two OSP locations was chosen to represent a worse case noise modelling location, being more central, furthest from the coast and with slightly deeper water, resulting in greater noise propagation, although the difference between the two locations would be marginal.

[1] The European Marine Observation and Data Network

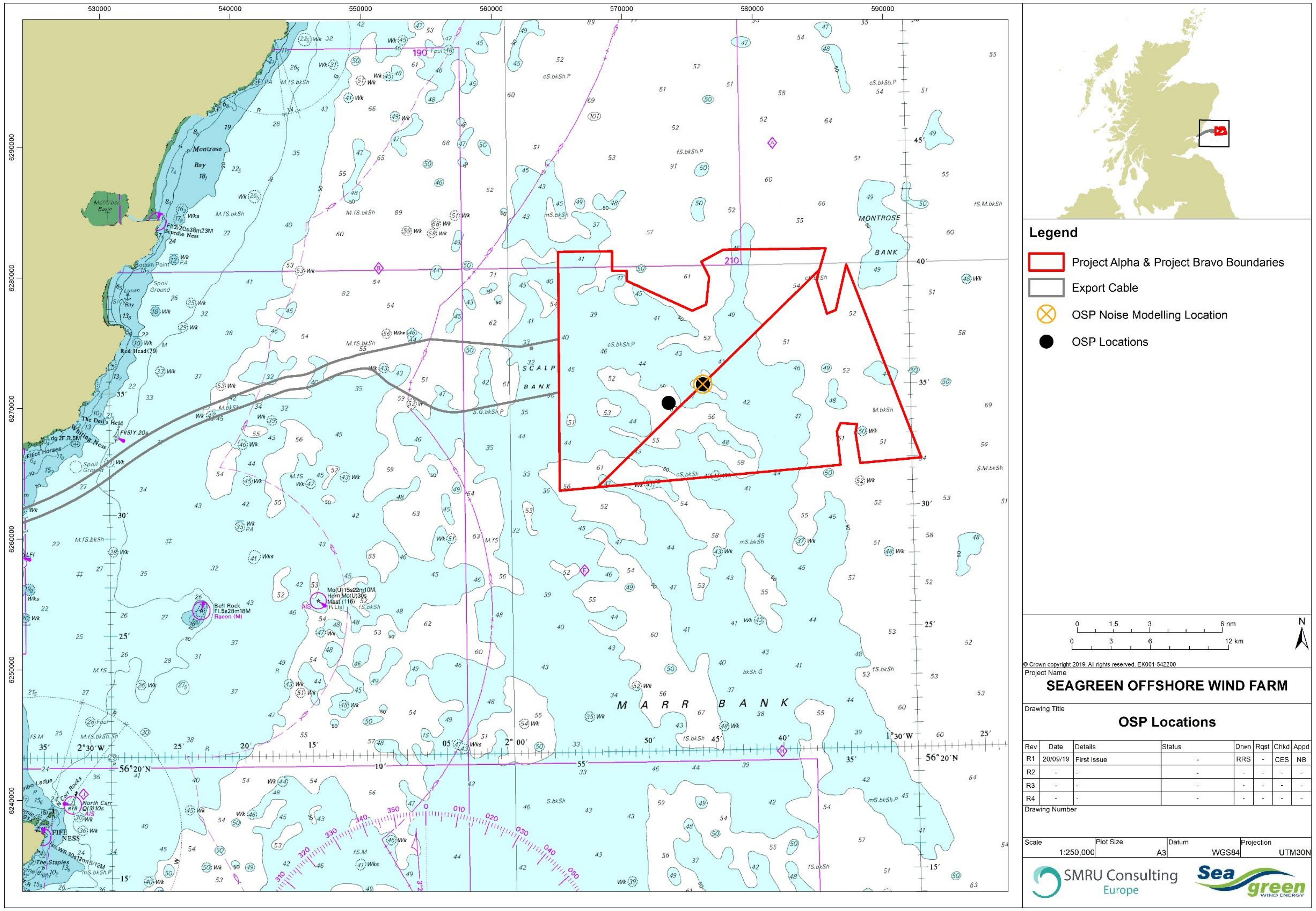


Figure 2.1. OSP locations and location used for noise modelling

2.5 Piling Scenario

Full details of the piling parameters and how they have been derived are given in the Piling Strategy. A hammer energy profile (the rate at which hammer energy increases after the soft start) was developed in light of experience of installing pin piles at Beatrice (BOWL 2018) and informed by available geotechnical information for the Seagreen site. The profile that was modelled was based on the worst case encountered at Beatrice in terms of overall duration and ramp up of energy. At Beatrice, the total piling duration (soft start plus impact piling) ranged from a minimum of 19 minutes up to a maximum of 2 hours and 45 minutes. The duration required to drive a pin pile was most frequently recorded between 61 to 75 minutes. Therefore, to be precautionary, an overall duration of 3 hours was modelled (Table 2-1). The shape of the profile was modelled based on the profiles at Beatrice that reached maximum hammer energy (2299 kJ). This combination of parameters, maximum hammer energy, maximum duration and associated hammer energy profile, are anticipated to represent a worst case in terms of overall noise exposure.

Seagreen is aware that recent noise monitoring at the Beatrice Offshore Wind Farm during piling for jacket installation indicated that the initial pile strikes created more noise than would be predicted based on hammer energy alone. These results have not been fully analysed and are not yet understood and the degree to which these were caused by factors specific to that operation compared to their generality to other projects is unknown. Therefore, it is not considered appropriate or possible to incorporate this into the modelling carried out for this project. This has been agreed in consultation with MS-LOT, MSS and SNH (29/10/2019).

Table 2-1 Modelled piling soft-start and ramp-up details for OSP locations

Stage	Minutes	Hammer energy (kJ)	Blows/min	% Max duration	% max hammer energy
Soft-start	1	Lowest possible ≤ 300	6	1	13
	19	≤ 500	40	11	22
Ramp-up	20-40	500 – 1,200 linear increase	40	22	52
	40-80	1,200 – 2,000 linear increase	40	44	87
	80-180	2,000 – 2,300 linear increase	40	100	100

2.6 Metrics Modelled and Assessment Criteria

2.6.1 Metrics

Three model types were run:

(1) SEL_{ss} based on the maximum hammer energy (to inform assessment of risk of disturbance in marine mammals, see Section 3.2);
(2) SPL_{peak} based on initial and maximum hammer energies (to assess instantaneous permanent threshold shift (PTS) risk at piling onset and during piling, see Section 3.1); and

(3) SEL_{cum} over 24 hours based on the hammer energy profile presented in Table 2-1 assuming four pin piles are installed in 24 hours (to assess risk of cumulative impacts for marine mammals, see Section 3.1, and for fish, see Section 4.1).

2.6.2 Marine Mammal Assessment Criteria

2.6.2.1 PTS Assessment

For marine mammals, the risk of PTS was assessed using the updated Southall criteria (Southall et al. 2019) The Southall criteria are based on both of the dual criteria: cumulative sound exposure level (SEL_{cum}) and peak sound pressure level (SPL_{peak}). To assess the SEL_{cum} criterion, the predictions of received sound level are frequency weighted to reflect the hearing sensitivity of each functional hearing group (Table 2-2). The peak SPL criterion is for unweighted received sound levels.

Table 2-2 Marine mammal PTS thresholds for impulsive noise (Southall et al. 2019)

Species	Species Group	Weighted SEL_{cum} dB re 1 µPa²s	Unweighted SPL_{peak} dB re 1 µPa
Harbour porpoise	VHF[a]	185	202
Minke whale	LF[b]	183	219
White-beaked dolphin	HF[c]	185	230
Bottlenose dolphin			
Harbour seal	PCW[d]	185	218
Grey seal			

[a] very high frequency; [b] Low frequency; [c] High frequency; [d] Phocid carnivores in water

To assess the risk of cumulative PTS, it is necessary to make assumptions of how animals may respond to noise exposure, since any displacement of the animal relative to the noise source will affect the noise exposure incurred.

For this assessment, it was assumed that animals would flee from the pile foundation at the onset of the soft start. Animals were assumed to flee out to a maximum distance of 25 km (after which they were assumed to remain stationary at that distance).

Table 2-3 Fleeing speeds assumed for each marine mammal species/taxon

Species	Harbour Porpoise	Dolphin	Minke Whale	Phocid Seal
Swimming speed (m/s)	1.4	1.52	2.1	1.8
Minimum depth constraint (m)	5	5	10	0

The fleeing model simulates the animal displacement and their noise exposure for a given piling scenario by placing an animal agent in each grid cell of the domain (i.e. every 100 m by 100 m) and allowing them to move on the domain grid according to a set of pre-defined rules. The position of all agents and the cumulated exposure are re-evaluated at constant time intervals (e.g. 5 minutes) and at the end of the piling activity scenario, the total cumulated exposure of all animal agents is mapped back to their starting positions on the grid.

In the case of single location piling, the model assumes that the animal agents are fleeing at constant speeds (Table 2-3), along straight lines away from the pile location, as long as the local water depth exceeds a minimum value (Table 2-3). It should be noted that, as indicated in Table 2-3, these rules do not apply to the seal agents, who are allowed to move in any depths of water and even move to the shore (within the 25 km maximum distance from the pile location), thus stopping their sound exposure.

2.6.2.2 Behavioural Disturbance Assessment

The potential for behavioural impacts (disturbance leading to displacement) was assessed using dose response curves from species specific empirical studies wherever available. The dose-response curve adopted in this assessment for all cetaceans was developed by Graham et al. (2017) and was generated from data on harbour porpoises collected during the first six weeks of piling during Phase 1 of the Beatrice Offshore Wind Farm monitoring program. In the absence of species-specific data on bottlenose dolphins, white-beaked dolphins or minke whales, this dose response curve has been adopted for all cetaceans. For both species of seal, a dose response curve was derived from the data collected and analysed by Russell et al. (2016) on harbour seal responses during several months of piling at the Lincs Offshore Wind Farm.

2.6.2.3 Density and Management Unit Data

Table 2-4 outlines the relevant species-specific density estimates and management unit abundance data for marine mammals used in the assessment. The most appropriate source for the baseline characterisation used to inform the updated assessment is the updated marine mammal baseline characterisation for Seagreen Alpha and Seagreen Bravo. This was presented in the September 2018 application for the Seagreen Optimised Project: Seagreen Alpha and Seagreen Bravo - EIA report - Volume 3 Appendix 10A: Marine Mammal Baseline Technical Report (2018).

Table 2-4 Species specific MU and density estimates taken forward for impact assessment

Species	MU	MU Size	MU Source	Density Estimate	Density Source
Harbour seal	East Coast Scotland	511	August 2016 haul-out count	5x5 km grid cell specific at-sea usage	Russell et al. (2017)
Grey seal	East Coast Scotland	10,891	August 2016 haul-out count	5x5 km grid cell specific at-sea usage	Russell et al. (2017)
Bottlenose dolphin	Coastal East Scotland	195	Cheney et al. (2013)	98 bottlenose dolphins spread evenly across the area inside the 20 m depth contour	Agreed in consultation on Seagreen Optimised project assessment (2017 Scoping Opinion)
Harbour porpoise	North Sea (ICES Assessment Unit)	345,373	SCANS III (Hammond et al. 2017)	SCANS III Block R 0.599 porpoise/km^2	SCANS III (Hammond et al. 2017)
Minke whale	Celtic and Greater North Seas	23,528	IAMMWG (2015)	SCANS III Block R 0.039 whales/km^2	SCANS III (Hammond et al. 2017)
White-beaked dolphin	Celtic and Greater North Seas	36,287	SCANS III (Hammond et al. 2017)	SCANS III Block R 0.243 dolphins/km^2	SCANS III (Hammond et al. 2017)

2.6.3 Fish Assessment Criteria

For fish, the most relevant criteria are considered to be those contained in the recent Sound Exposure Guidelines for Fishes and Sea Turtles (Popper et al. 2014). There is limited understanding of the hearing capabilities of different fish species, however, from the few studies that have been undertaken, it is clear that there are substantial differences in the auditory capability between species. The Popper et al. (2014) guidelines do not group by species but instead broadly group fish into the following categories based on their anatomy and the available information on hearing of other fish species with comparable anatomies:

- Group 1 fish: *fish species with no swim bladder or other gas chamber* (e.g. elasmobranchs and flatfish). These species are less susceptible to barotrauma and are only sensitive to particle motion, not sound pressure.
- Group 2 fish: *fish species with swim bladders but the swim bladder does not play a role in hearing* (e.g. salmonids). These species are susceptible to barotrauma, although hearing only involves particle motion, not sound pressure.
- Group 3 fish[2]: *fish species in which hearing involves a swim bladder or other gas volume* (e.g. Atlantic cod, herring and relatives). These species are susceptible to barotrauma and detect sound pressure as well as particle motion.
- Fish eggs and larvae.

The species considered in this assessment fall under the following criteria: Group 2 (salmon) and Group 3 (cod and herring). The guidelines set out criteria for the effect of sound exposure due to different sources of noise; impulsive noise, including piling, is the source considered for this assessment. The subsea noise model applied the Popper et al. (2014) thresholds for Group 2 and Group 3 species and adopted both SPL_{pk} and SEL_{cum} metrics in the assessment. SPL_{peak} was modelled for both the soft start hammer energy (300 kJ) and the maximum hammer energy (2,300 kJ). A highly conservative approach was adopted in the model by assuming that fish are stationary and do not flee the ensonified area. This approach is very precautionary and is considered to lead to an overestimate of the ranges of effect as fish would be expected to exhibit a fleeing response.

A number of different responses are defined in the Popper et al. (2014) guidelines and thresholds are set as the level at which such changes are likely to be triggered (Table 2-5).

Criteria for masking and behavioural effects are provided as qualitative values as there is insufficient data to determine thresholds. Instead, the criteria are defined in relative terms as a risk level (high, moderate, or low) at three distances from the source: near (i.e. in the tens of metres), intermediate (i.e. in the hundreds of metres) or far (i.e. in the thousands of metres). Such qualitative criteria cannot differentiate between exposures to different noise levels and therefore all sources of noise, no matter how noisy, would theoretically elicit the same assessment result.

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[2] Note that Hawkins and Popper (2017) suggests four hearing groups with Group 3 fish as those with swim bladders that are close, but not intimately connected to the ear (e.g. cod) and Group 4 fish as those which have special structures linking the swim bladder to the ear (e.g. herring). However, for the purpose of setting criteria for subsea noise assessments Popper *et al.*, (2014) groups together the Group 3 and Group 4 fish.

Table 2-5 Criteria for the onset of mortality, impairment and behavioural effects in fish due to impulsive piling (Popper et al., 2014).

Type of animal	Parameter for injury[a]	Mortality /mortal injury	Impairment			Behavioural effects[b]
			Recoverable injury	TTS	Masking[b]	
Group 1: No swim bladder (particle motion detection)	SEL_{cum}	>219	>216	>>186	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
	dB Peak	>213	>213	-		
Group 2: Swim bladder not involved in hearing (particle motion detection)	SEL_{cum}	210	203	>186	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
	dB Peak	>207	>207	-		
Group 3: Swim bladder involved in hearing (pressure detection)	SEL_{cum}	207	203	186	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate
	dB Peak	>207	>207	-		
Eggs and larvae	SEL_{cum}	>210	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low
	dB Peak	>207				

[a] Peak sound pressure level dB re 1µPa; SEL_{cum} dB re 1µPa^2.s All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.

[b] Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.6.4 Significance criteria

The significance of potential impacts has been evaluated using a structured process, based upon the sensitivity of the receptors to the effects generated by the assessed activity, together with the predicted magnitude of the impact. The criteria used to define sensitivity and magnitude for fish and marine mammals were those adopted in the Seagreen Alpha and Seagreen Bravo - EIA report - Volume 1 Chapter 9: Natural Fish and Shellfish Resource and Chapter 10: Marine Mammals (2018). This provides an updated methodology based on advances in best practice and represents an approach for assessment which has been recently agreed with Marine Scotland Science (MSS) and Scottish Natural Heritage (SNH) for both groups of receptors.

Potential impacts identified as major or moderate are generally considered to be significant in EIA terms and mitigation may be required, while impacts identified as minor or negligible are generally considered to be not significant in EIA terms.

2.7 Comparison with 2012 ES Assessment

For both marine mammals and fish, a comparison has been made between the results of the original 2012 ES (Seagreen 2012) and the results of the assessment based on the revised project design parameters presented here. In the 2012 ES, the assessment of OSP foundation piling was included with the assessment of wind turbine generator (WTG) foundation piling. This was undertaken for both Seagreen Alpha and Seagreen Bravo separately and combined. No assessment of OSP foundation piling in isolation was undertaken. The expected duration of piling operations was assessed as two years.

In line with updated guidance and improvements in modelling methodologies, the criteria adopted in the 2012 assessment have been replaced by updated thresholds for both fish and marine mammals (Popper et al. (2014) and Southall et al. (2019)). It is accepted that the proposed increase in hammer energy and duration in the piling scenario assessed here, relative to the piling parameters from the 2012 assessment, would lead to increased potential impact ranges than would result from remodelling the 2012 parameters. Therefore, it was considered unnecessary to directly remodel the 2012 parameters with updated criteria as this would be less precautionary than the assessment presented here.

The revised project design envelope demonstrates that piling at the two OSPs would occur as two discrete short-term events with up to 4 piles installed within each 24-hour period (i.e. a duration of 3 days per OSP). Each pile is predicted to take a maximum of 190 minutes to install, including pre-piling ADD deployment and soft start.

The revised project design envelope represents approximately 60% reduction in terms of the number of piled OSPs compared to the maximum design scenario assessed in the original 2012 ES with two instead of five OSPs to be installed (Table 4.1 in the OTA Piling Strategy). In addition, the maximum number of piles at each OSP has decreased from 24 to 12 (50% decrease). Overall the maximum number of piles to be installed at the OSPs has decreased from 72 to 24 (66% decrease).

3. Marine Mammal Assessment Results

3.1 Auditory Injury

3.1.1 Modelling conservatisms

When considering the modelled estimates of PTS impact ranges, it is important to note the conservatisms in the approach which result in precautionary predictions.

It is highlighted that the PTS onset threshold indicates the level at which the risk of PTS starts to increase, not that all individuals will go onto develop PTS. It is expected that only 18-19% of animals are predicted to experience PTS at the PTS onset threshold level. This was the approach adopted by Donovan et al. (2017) to develop their dose response curve that has been implemented into the SAFESIMM model, based on the data presented in Finneran et al. (2005). Therefore, where PTS onset ranges are provided, it is not expected that all individuals within that range will experience PTS. The number of animals predicted to be within PTS onset ranges are thus overestimates.

It is also important to note that the SEL_{cum} thresholds were determined with the assumption that;

a. the amount of sound energy an animal is exposed to within 24 hours will have the same effect on its auditory system, regardless of whether it is received all at once or in several smaller doses spread over a longer period (called the equal-energy hypothesis); and
b. the sound retains its impulsive character, regardless of the distance to the sound source.

Both assumptions lead to a conservative determination of the impact ranges, as;

a. the magnitude of TTS induced might be influenced by the time interval in-between successive pulses, with some time for TTS recovery in-between pulses (Finneran et al. 2010, Kastelein et al. 2013, Kastelein et al. 2014), therefore recovery is possible in the gaps between individual pile strikes and in the breaks in piling activity; and
b. an impulsive sound will eventually lose its impulsive character while propagating through the water column, therefore becoming non-impulsive (as described in NMFS 2018, Hastie et al. 2019), and then causing a far smaller rate of threshold shift.

In addition, there are data to suggest that the selected swim speeds (Table 2-3) are precautionary and that animals are likely to flee at much higher speeds, at least initially. Minke whales have been shown to flee from ADDs at a mean swimming speed of 4.2 m/s (McGarry et al. 2017). A recent study by Kastelein et al. (2018) reported that a captive harbour porpoise responded to playbacks of piling sounds by swimming at speeds significantly higher than baseline mean swimming speeds, with speeds of up to 1.97 m/s sustained for the 30 minute test period. In another study, van Beest et al. (2018) showed that a harbour porpoise responded to an airgun noise exposure with a fleeing speed of 2 m/s. These recent studies have demonstrated porpoise and minke whale fleeing swim speeds that are greater than that used in the fleeing model, which makes the modelled speeds used in this assessment precautionary.

3.1.2 Auditory injury results

3.1.2.1 Instantaneous PTS onset

The PTS onset impact ranges for marine mammals are presented in

. For all species the instantaneous PTS onset impact range at the start of the soft-start is <50 m, which is effectively below the resolution of the noise modelling outputs. The probability of marine mammals being within 50 m of the pile location at the start of the piling is extremely low (up to 0.00471).

Table 3-1 Instantaneous PTS onset impact ranges at the worst case OSP location

Species	Max Range (m)
Harbour porpoise	<50
Minke whale	<50
White-beaked dolphin	<50
Bottlenose dolphin	<50
Harbour seal	<50
Grey seal	<50

A further calculation was carried out, to estimate the probability of a single individual being within the PTS onset range during the first strike of a single pile, given the different average species densities in the area. The approach taken was based on the method outlined in Thompson (2015). This approach was as follows:

- Use density data to estimate the area around a piling location that should contain 1 individual
- Randomly position that individual within that area and measure the distance to the pile. Repeat 100,000 times.
- Produce a probability density function for distances to the pile for the 100,000 randomly placed individuals.
- Estimate the probability of occurrence in the impact zones of interest at the start of any piling event.

The results show that for harbour porpoise, minke whales and white-beaked dolphins, the probability of a single individual being within the 50 m SPL_{peak} PTS-onset impact radius during the first soft-start strike (300 kJ) of a single pile is extremely low (Table 3-2). The probability of a bottlenose dolphin being within 50 m is 0.000 since their density is restricted to the 20 m depth contour.

For harbour porpoise, the probability of a single individual being within the 225 m SPL_{peak} PTS-onset radius during the first strike of at full hammer energy (2,300 kJ) is also low (0.09413). This probability is an overestimate since it assumes that animals have not moved out of the impact radius during the soft-start, which is extremely unlikely.

It is also important to note that there will be considerable set-up activity prior to the start of any piling. This will include manoeuvring the heavy lift vessel (HLV) into position; the HLV may use include dynamic positioning or the deployment of anchor moorings to maintain position. The OSP jacket will be lifted from the barge and lowered into position, then the piles will be lifted from the barge and inserted into pile sleeves at the foot of each jacket leg. This activity is likely to reduce the probability of marine mammals being within these ranges even further. Therefore, even in the absence of mitigation methods over and above the soft start, the probability of a single cetacean being within the SPLpeak PTS onset impact range is low. Therefore, this is of negligible magnitude

Table 3-2 Probability of animal being present within the SPL_{peak} PTS-onset impact zone during the first strike of a single pile

Species	**Density (#/km²)**	**Area of circle containing 1 individual (km²)**	**Radius of circle containing 1 individual (km)**	**Probability of animal being present within the SPL_{peak} PTS impact during the first strike of a single pile**
SPL_{peak} PTS-onset impact zone: 50 m				
Harbour porpoise	0.599	1.67	0.73	0.00471
Minke whale	0.039	25.64	2.86	0.00029
White-beaked dolphin	0.243	4.12	1.14	0.00183
SPL_{peak} PTS-onset impact zone: 225 m				
Harbour porpoise	0.599	1.67	0.73	0.09413

3.1.2.2 Cumulative PTS onset

For all species other than minke whale, the cumulative PTS onset impact range was <50 m and therefore also of negligible magnitude (Table 3-3). For minke whale, the maximum cumulative PTS onset impact range was 6.75 km which, using the SCANS III block R density of 0.039 whales/km2, equates to a maximum of 1.95 animals (0.01% of MU), assuming no mitigation in place (other than soft start), which is considered low magnitude. Combining the magnitude with the sensitivity assessment resulted in a **Negligible** to **Minor** Adverse impact across the six marine mammal species, which is not significant in EIA terms for the impact of PTS at the worst case OSP location (Table 3-4).

Table 3-3 Cumulative PTS onset impact ranges and areas at the worst case OSP location

Species	Max Range (m)	Area (km^2)	# Animals
Harbour porpoise	<50	<0.01	<1
Minke whale	6,752	50.04	1.95 (0.01% MU)
White-beaked dolphin	<50	<0.01	<1
Bottlenose dolphin	<50	<0.01	0
Harbour seal	<50	<0.01	<1
Grey seal	<50	<0.01	<1

PTS summary

Based on the impact ranges and probabilities presented above, it is considered that there is an extremely low risk of instantaneous PTS occurring to any marine mammals, as a result of the initial hammer blows for OSP foundation installation at the onset of piling. The risk of instantaneous PTS at the maximum hammer energy is also very low for most species. The 20 minute period of ramp up in hammer energy allows time for animals to move away from the piling location, further reducing the risk of auditory injury. Even at maximum hammer energy, the largest impact range for instantaneous PTS onset is 225 m for harbour porpoise. Assuming a swim speed of 1.4 m/s, a porpoise starting right at the pile location at the start of the ramp up, would be 1680 metres away, and well outside the instantaneous PTS range at max hammer energy by the time hammer energy begins to ramp up beyond 500 kJ.

Data collected during windfarm construction have demonstrated that porpoise detections around the piling site decline prior to the start of piling, and it is assumed that this is due to the increase in other construction related activities and vessel presence in advance of the actual piling (Brandt et al. 2018, Graham et al. 2019). Therefore, the presence of construction related vessels in the vicinity prior to the start of piling can act as a local scale deterrent for harbour porpoise and therefore reduce the risk of auditory injury.

Incorporating a short period of ADD deployment prior to the soft start would reduce this risk even further. A period of ADD activation would also mitigate against the risk of elevated noise levels from initial blows as occurred at the Beatrice Offshore Wind Farm, should this also be the case at Seagreen. However, given the results presented by Graham et al. (2019) which suggested that ADD use prior to piling increased levels of disturbance to harbour porpoise above the disturbance caused by piling alone, there is a balance to be found between use of ADD to further reduce an already low risk of PTS and the potential of increasing disturbance. Therefore, it is recommended that ADD use should be up to a maximum of 10 minutes prior to the start of the soft start.

The risk of PTS-onset as a result of cumulative exposure to sound energy emitted over the installation of four pin piles (the maximum number that could be installed within 24 hours) is also very low. For harbour porpoise, dolphin species and seal species, the risk is negligible as the SEL_{cum} PTS-onset range is less than 50 m from the piling location. For minke whales, the SEL_{cum} PTS-onset range is considerably larger with a maximum range of 6.75 km (Figure 3.1). Due to the assumptions necessary to calculate the SEL_{cum} PTS-onset ranges and the conservatisms inherent in these calculations (see section 3.1.1) these calculated ranges are considered to be unrealistically high. Using an average density estimate derived during the summer months when minke whale density is at its highest, the number of animals that would be expected to be within the estimated PTS-onset impact area would be a maximum of two.

Table 3-4 Summary of predicted PTS impact significance on marine mammal receptors

Species	**Magnitude**	**Sensitivity**	**Significance**	
Harbour porpoise	Negligible	Medium	Negligible	**Not significant**
Minke whale	Low	Medium	Minor adverse	**Not significant**
White-beaked dolphin	Negligible	Medium	Negligible	**Not significant**
Bottlenose dolphin	Negligible	Medium	Negligible	**Not significant**
Harbour seal	Negligible	Low	Negligible	**Not significant**
Grey seal	Negligible	Low	Negligible	**Not significant**

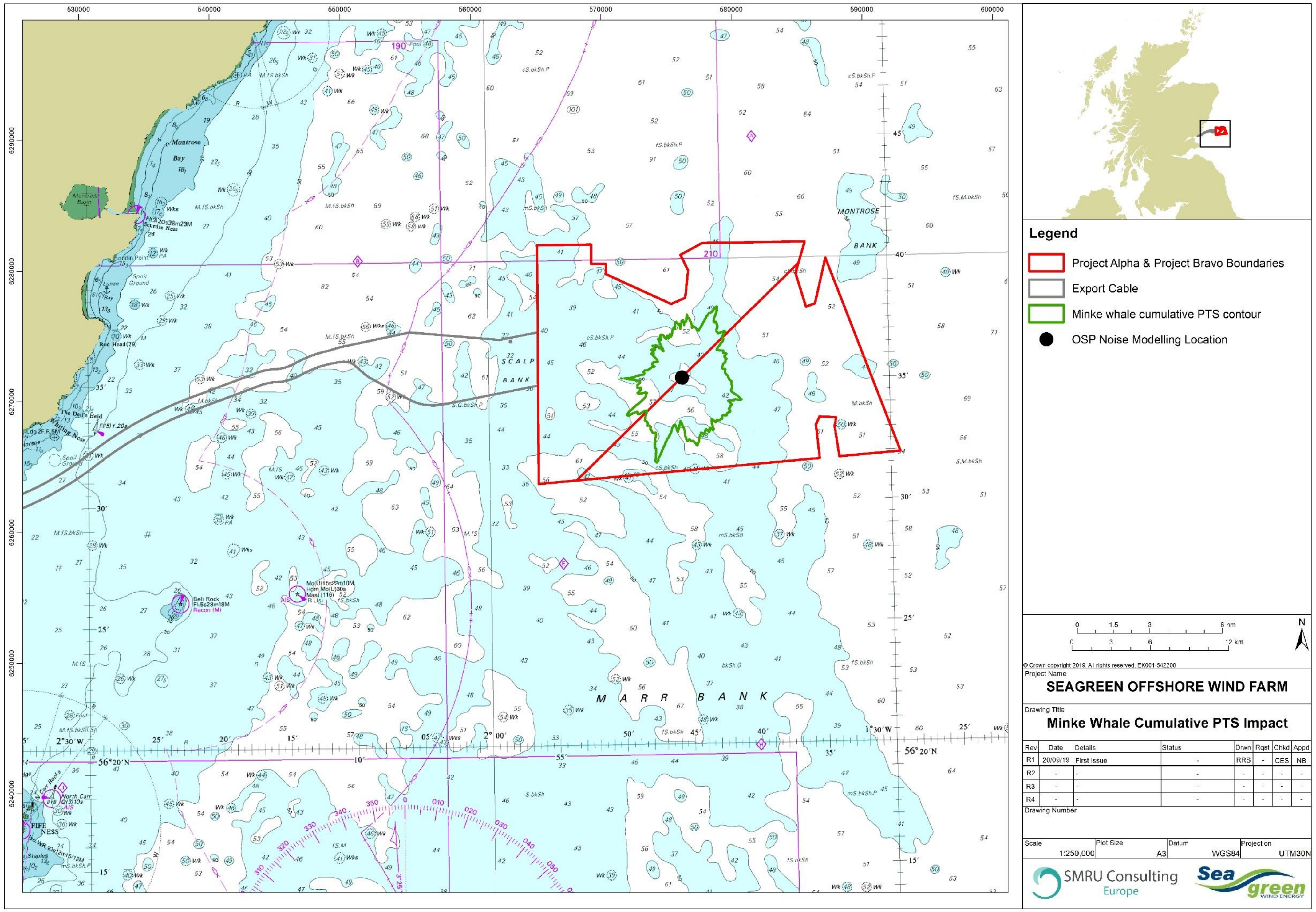


Figure 3.1 SELcum PTS impact area for minke whales at the worst case OSP location

3.2 Disturbance

No significant impacts of behavioural disturbance were predicted for any of the assessed marine mammal receptors as a result of piling at the worst case OSP location. A total of two OSPs will be installed, each with a maximum of 12 pin piles, resulting in a total of 24 pin piles. Given that it is expected that up to 4 piles will be installed per day, this equates to two periods of three days of piling to install the two OSPs. In addition, it is anticipated that the installation of the two OSPs will be separated by a period of approximately two years. Therefore, the duration of any disturbance will be extremely short and each OSP installation should be considered a discrete event with complete recovery between them with no likely cumulative effects.

The number of animals of each species predicted to experience behavioural disturbance and the resulting magnitude and sensitivity assessments are presented in Table 3-5 and the modelled noise contours for the behavioural assessment are presented in Figure 3.2. Affected individuals are expected to move away from the piling location towards areas of lower noise levels. During this time, they are likely to experience reduced foraging opportunities and may be displaced to areas of lower foraging quality. Overall the predicted effect is a short term (days) reduction in foraging efficiency and energy intake.

Given the low number of animals estimated to experience behavioural disturbance, the low proportions of the management units that these represent, and the fact that the disturbance will only be present for a very short duration, the magnitude of effect has been assessed as Negligible across the six marine mammal species. Combined with the sensitivity scores, this results in a **Negligible** significance across all six marine mammal species, which is not significant in EIA terms.

Table 3-5 Number of animals predicted to experience behavioural disturbance at the worst case OSP location at the worst case maximum hammer energy

Species	**# Animals**	**% MU**	**Magnitude**	**Sensitivity**	**Significance**
Harbour porpoise	1,882	0.55%	Negligible	Medium	Negligible
Minke whale	123	0.52%	Negligible	Medium	Negligible
White-beaked dolphin	764	2.10%	Negligible	Medium	Negligible
Bottlenose dolphin	4	2.06%	Negligible	Medium	Negligible
Harbour seal	<1	0.05%	Negligible	Medium	Negligible
Grey seal	49	0.45%	Negligible	Low	Negligible

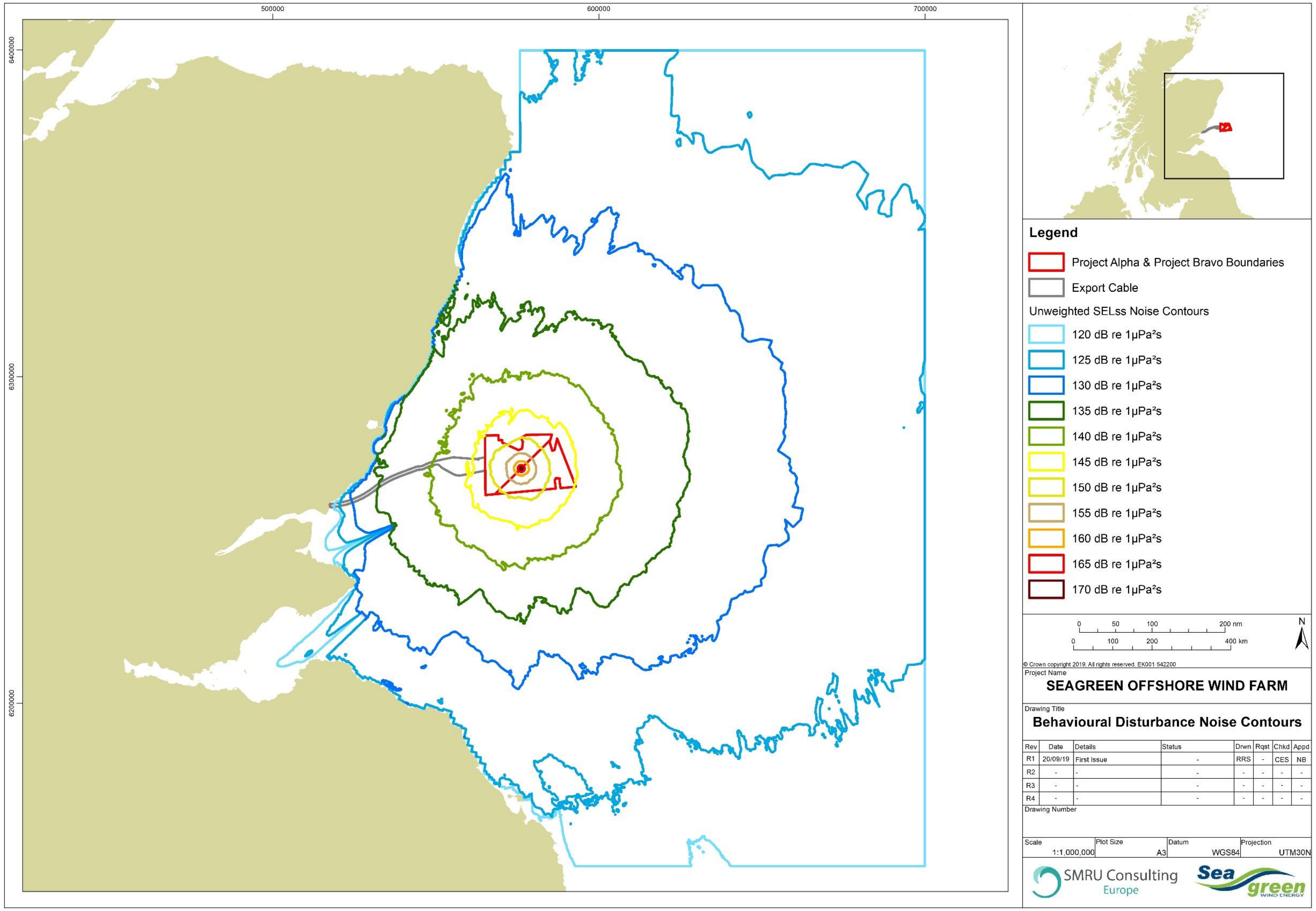


Figure 3.2. Single-strike SEL for a hammer energy of 2,300 kJ (maximum pin pile hammer energy) at the worst case OSP location

3.3 Comparison with 2012 ES Assessment

As stated previously, the 2012 ES Assessment provided impact significance results per species for foundation piling for both the WTGs and OSPs together at Seagreen Alpha and Seagreen Bravo. There is no previous assessment of the OSP installation procedure in isolation to enable a direct comparison. However, a comparison of the outcomes of the assessment between the current worst case OSP location and the 2012 ES Assessment can be made. The results of the worst case OSP assessment (installation of pin piles using a maximum hammer energy of 2,300 kJ) are the same or less than those presented in the consented 2012 ES Assessment (Seagreen 2012)(Table 3-6 for PTS and Table 3-7 for behavioural disturbance). The consented 2012 ES Assessment concluded that PTS and behavioural disturbance was minor or negligible and therefore not significant for all species except harbour seals, which were assessed as moderate and therefore significantly impacted by both PTS and behavioural disturbance. The current worst-case OSP impact assessment concludes that PTS and behavioural disturbance is minor or negligible and therefore not significant across all six marine mammal species, including harbour seals. This represents an overall reduction in impact when considering the reduction in the duration of disturbance.

Table 3-6 Significance of PTS assessment: current worst case OSP assessment and the consented 2012 ES Assessment

Species	**Current worst case OSP Assessment**		**Consented 2012 ES Assessment[3]**	
Harbour porpoise	Negligible	**Not significant**	Minor adverse	**Not significant**
Minke whale	Minor adverse	**Not significant**	Minor adverse	**Not significant**
White-beaked dolphin	Negligible	**Not significant**	Negligible	**Not significant**
Bottlenose dolphin	Negligible	**Not significant**	Minor adverse	**Not significant**
Harbour seal	Negligible	**Not significant**	Moderate adverse	**Significant**
Grey seal	Negligible	**Not significant**	Minor adverse	**Not significant**

[3] Impact significance based on whole wind farm and not just the OSPs

Table 3-7 Significance of behavioural assessment: current worst case OSP assessment and the consented 2012 ES Assessment

Species	Current worst case OSP Assessment		Consented 2012 ES Assessment[4]	
Harbour porpoise	Negligible	**Not significant**	Minor adverse	**Not significant**
Minke whale	Negligible	**Not significant**	Minor adverse	**Not significant**
White-beaked dolphin	Negligible	**Not significant**	Negligible	**Not significant**
Bottlenose dolphin	Negligible	**Not significant**	Minor adverse	**Not significant**
Harbour seal	Negligible	**Not significant**	Moderate adverse	**Significant**
Grey seal	Negligible	**Not significant**	Minor adverse	**Not significant**

3.4 Summary and Conclusions

An assessment of the impact of piling noise resulting from the installation of the OSP foundations has been carried out for the six marine mammal species included in this assessment , including the three marine mammal species noted in Condition 3.2.2.5 of the OTA Marine Licence (Bottlenose dolphin, harbour seal and grey seal). Noise modelling was used to predict the ranges at which instantaneous and cumulative PTS onset could occur and to determine the number of individuals for each species that may be at risk of disturbance.

The risk of instantaneous PTS onset is negligible at the onset of the soft start (<50 m) for all marine mammal species, even in the absence of mitigation methods beyond the soft start itself. The adoption of a 20 minute soft start allows animals to move outside of the maximum instantaneous PTS onset range of 225 m (at maximum hammer energy) for harbour porpoises by the time that hammer energy starts to increase following the soft start. This represents no change or a decrease in impact significance compared to the 2012 ES Assessment. There is a small risk of cumulative PTS onset to a very small number of minke whales on any given piling day, however this risk is still considered to be of low magnitude and is not significant given the number of animals predicted to be impacted, particularly when considering the conservatism in the assessment methodology.

It is suggested that a very short ADD activation period will ensure that the 225 m SPL_{peak} PTS onset range for harbour porpoise (at maximum hammer energy) is free of animals. This will negate the risk of instantaneous PTS to any marine mammal species. However, the duration of any ADD activation period should be kept to a minimum level to not cause disturbance on an unnecessary scale.

The impact of disturbance is negligible for all marine mammal species, particularly in light of the very short construction period for the installation of two OSPs. Therefore, the impact is considered to be not significant across all marine mammal species. In comparison, the 2012 ES assessed impacts as minor or

[4] Impact significance based on whole wind farm and not just the OSPs

negligible for all species, with the exception of harbour seal which was assessed as moderate and therefore significantly impacted by disturbance. This represents no change or a reduction in the level of impact and the impact significance compared to the 2012 ES Assessment.

4. Fish Assessment Results

4.1 Mortality and impairment

The results of noise modelling and assessment against the thresholds presented in Table 2-5 for the scenario of four piles installed within a 24 hour period, including a 20 minute soft start and ramp up to maximum hammer energy for each pile are presented in Table 4-1.

The ranges predicted using the SEL_{cum} criteria for different species are considered to represent a very conservative, worse-case scenario as the modelling assumes that fish will not flee from the ensonified area over the 24-hour piling period and therefore will be exposed to noise for the whole duration of the piling. In practice, it would be expected that hearing sensitive species may move away from the sound source (although not in the egg or larval stages) and therefore the ranges at which mortality and impairment would occur would be lower than those presented here.

Table 4-1 Ranges of effect for injury and impairment to Atlantic salmon, cod and herring arising from piling at the OSP at Seagreen Alpha and Seagreen Bravo. Ranges for peak pressure injury (dB Peak) are presented for both the soft start energy (300 kJ) and full hammer energy (2300 kJ) for comparison. Ranges for SEL_{cum} are for the soft start scenario with piling of 4 piles over a 24 hour period.

Species	Parameter for injury [a]	Mortality and mortal injury	Impairment [b]			Behavioural effects [b,c]
			Recoverable injury	TTS	Masking	
Atlantic salmon	SEL_{cum}	804 m	2,518 m	24.6 km	(N) Moderate	(N) High
	dB Peak (300 kJ)	29 m	29 m	n/a	(I) Low	(I) Moderate
	dB Peak (2300 kJ)	100 m	100 m		(F) Low	(F) Low
Cod	SEL_{cum}	1,309 m	2,518 m	24.6 km	(N) High	(N) High
	dB Peak (300 kJ)	29 m	29 m	n/a	(I) High	(I) High
	dB Peak (2300 kJ)	100 m	100 m		(F) Moderate	(F) Moderate
Herring	SEL_{cum}	1,309 m	2,518 m	24.6 km	(N) High	(N) High
	dB Peak (300 kJ)	29 m	29 m	n/a	(I) High	(I) High
	dB Peak (2300 kJ)	100 m	100 m		(F) Moderate	(F) Moderate
Eggs and larvae (all species)	SEL_{cum}	804 m	(N) Moderate	(N) Moderate	(N) Moderate	(N) Moderate
	dB Peak (300 kJ)	29 m	(I) Low	(I) Low	(I) Low	(I) Low
	dB Peak (2300 kJ)	100 m	(F) Low	(F) Low	(F) Low	(F) Low

[a] Peak sound pressure level dB re 1µPa; SEL_{cum} dB re 1µPa^2.s All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.

[b] Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

[c] The onset of a fleeing response occurs at the threshold for TTS.

4.1.1 Atlantic salmon

As a Group 2 species, salmon is moderately sensitive to subsea noise and Popper et al. (2014) considers that species within this group are of lower sensitivity to subsea noise compared with Group 3 species (e.g. cod and herring). The noise modelling assessment predicted that mortality or mortal injury could occur over a maximum range of 804 m and that recoverable injury could occur over a maximum range of 2,518 m from the source (based on the SEL_{cum} metric) (Table 4-1). Temporary hearing impairment, modelled using the threshold for TTS, could occur over much larger ranges and out to a distance of 24.6 km from the source (Figure 4-1). As discussed previously, these modelled ranges assume a stationary animal and therefore are likely to be very conservative and an overestimate of the effect ranges. The risk of masking is considered to be moderate in the near distance and low in the intermediate to far distance (Table 4-1).

Adult salmon may be exposed to elevated levels of subsea noise during migration towards the Scottish east coast rivers; important salmon rivers in the vicinity of Seagreen Alpha and Seagreen Bravo OWFs and Offshore Transmission Asset (OTA) include the Tweed, Forth, Tay, South Esk and Dee (Marine Scotland 2017)(Figure 4-1). Upstream migration of adults can occur year-round (with a peak in late summer and early autumn) and the modelling suggests that there is potential for mortality or injury within the vicinity of the OSPs during piling. Smolts migrate from the rivers back to the sea around mid-April to end of May (Malcolm et al. 2015) and are likely to move through the area relatively rapidly (Lothian et al. 2018) thereby reducing their exposure to piling noise. Piling at the OSP is predicted to occur over a short duration (3 days each OSP in two separate events) and is currently planned to take place during in May/June 2021 for the first OSP and between April – July 2023 for the second OSP. Therefore, there is potential for an overlap in the migration times of both adult salmon and smolt with the piling activities at the OSPs, although the duration of any overlap is very short.

The most sensitive stage for migrating Atlantic salmon is considered to be the movement of salmon smolts in May from rivers out to sea. This migration occurs over a relative short timeframe with smolts moving quickly through the area at a typical rate of 15 km per day (MSS pers comm). Mortality resulting from cumulative exposure (SEL_{cum} metric) was predicted over an impact range of 804 m; this is based on a 24-hour period of exposure. Given a rate of travel of 15 km a day the assumption of 24-hour exposure is clearly an overestimate since a migrating smolt would only be within this radius of effect for 1 hour 17 minutes. Similarly, recoverable injury is considered unlikely to lead to significant effects on salmon smolts as the risk of this occurring is moderate in the near-field (10s of metres) and low in the intermediate- (100s of metres) and far- (1,000s of metres) fields and any effects on exposed individuals are temporary and reversible. Therefore, the metric that is most relevant to the assessment of effects on smolts is considered to be instantaneous mortality (SPL_{pk}), which was predicted to occur over a range of 100 m from the piling source. Given this range, the number of individuals likely to be affected is negligible in the context of the wider population. An approximate estimate of the density of salmon smolts migrating from east coast of Scotland rivers is 300 smolts per km^2. Assuming, conservatively, that this density also occurs offshore around the Seagreen project, the maximum number of individuals that may occur within the 100 m range (=0.031 km^2) of mortality due to a piling event is estimated as nine.

A total population of smolts from east coast rivers in the vicinity of Seagreen in 2010 can be estimated using data from a study undertaken by Xodus (2012). Based on the area available to smolts within rivers and an estimate of smolt density from the North Esk from 2010, Xodus (2012) estimated the number of smolts from a number of rivers on the east coast of Scotland (including the North Esk, South Esk, Teith, Tay and Tweed) was in the region of 3.7 million (Xodus, 2012). Extrapolating the mortality of individuals over 24 piles, the total mortality of smolts would be 216 individuals or 0.006% of the population. Therefore, the potential impact of piling noise on salmon smolts is considered to be negligible.

The potential for TTS to adults and smolts will occur over a relatively large range, however, individuals within the ensonified area are expected to recover in the short term (days) following cessation of the piling. It is therefore concluded that the potential for mortality and impairment to salmon is of **negligible adverse** significance and **not significant** in EIA terms.

4.1.2 Cod

Cod has an anterior part of the swim bladder that, although not connected to the inner ear, is in close proximity. As a Group 3 species, cod is sensitive to underwater noise, although to a lesser extent than herring. The noise modelling assessment predicted that mortality or mortal injury in adult cod could occur over a maximum range of 1,309 m and that recoverable injury could occur over a maximum range of 2,518 m from the source (based on the SEL_{cum} metric) (Table 4-1). For fish eggs and larvae, the ranges of impact are the same as those described for Group 2 species (i.e. salmon). Temporary hearing impairment in adults and eggs/larvae, modelled using the threshold for TTS, could occur out to a distance of 24.6 km from the source (Figure 4-2). As discussed previously, these modelled ranges assume a stationary animal and therefore are likely to be very conservative and an overestimate of the effect ranges. The risk of masking is considered to be high in the near and intermediate distances and low in the far distance for adult cod (Table 4-1).

Adult and juvenile cod within spawning and nursery grounds, which overlap the Seagreen Alpha and Seagreen Bravo OWF and OTA (Figure 4-2), may suffer temporary hearing impairment (TTS) but are expected to recover in the short term (days) following cessation of the piling. Spawning of cod takes place between January through to April, with peak spawning activity occurring from the last week of January to mid February (Daan et al. 1980). Piling at the OSP is predicted to occur over a short duration (3 days per OSP in two separate events) and is currently planned to take place at some point in May/June 2021 for the first OSP and between April – July 2023 for the second OSP. Therefore, cod spawning activity is likely to be largely unaffected by the short period of piling. Mortality and recoverable injury could occur to both adult cod and larvae in close range to the piling although, notably, the ranges of effect predicted using the SEL_{cum} metric are considered to be highly conservative, as they assume that fish exposed to piling noise remain stationary rather than fleeing the area. It is therefore concluded that the potential for mortality and impairment to cod is of **negligible adverse** significance and **not significant** in EIA terms.

4.1.3 Herring

Herring is particularly sensitive to underwater noise and vibration. Elevations in these during piling could lead to physiological effects and potentially disrupt spawning behaviour, which occurs between July to September off the Scottish east coast. The contours for TTS extend over a maximum total range of 24.6 km (based on SEL_{cum}), although none of the main spawning area to the north mapped by Coull et al. (1998) lies within the TTS contour (Figure 4-3). Recent data from Cefas suggest, however, that some herring may drift south from the main stock and spawning was recorded as close as 6.3 km to the project area. As a consequence, there may be some overlap between the TTS contours and the periphery of the main spawning stock. The maximum potential ranges over which mortality and recoverable injury (based on SEL_{cum}) could occur are within closer ranges (1.3 km and 2.6 km respectively) and therefore unlikely to overlap with key spawning areas, although they would overlap with potential nursery habitat for herring. As shown in Table 4-1, the range of effect for mortality in herring larvae would be 0.8 km and therefore less than the range predicted for adult fish. There is predicted to be a moderate risk of recoverable injury to herring larvae in the near distance and low risk in the intermediate and far distance (Table 4-1).

Piling at the OSP is predicted to occur over a short duration (3 days per OSP in two separate events) and is currently planned to take place at some point in May/June 2021 for the first OSP and between April – July 2023 for the second OSP. The TTS contours may just overlap the peripheral areas of the main spawning stock to the north but the timing of the piling at the OSPs is largely outside the main spawning period (July to September). Adult herring may suffer temporary hearing impairment (TTS), but are expected to recover in the short term (days) following cessation of the piling. Mortality and recoverable injury could occur to both adult herring and larvae in close range to the piling although, notably, the ranges of effect predicted using the SEL_{cum} metric are considered to be highly conservative as they assume that fish exposed to piling noise remain stationary rather than fleeing the area. It is therefore concluded that the potential for mortality and impairment to herring is of **negligible adverse** significance and **not significant** in EIA terms.

4.2 Behavioural effects

The risks of behavioural effects, such as disturbance, are considered to be high in the near distance for all species of fish (Table 2-5). For cod and herring, the risk of behavioural effects is also high in the intermediate distance and reduces to moderate in the far distance. For Atlantic salmon and eggs/larvae the risk is moderate in the intermediate distance and reduces to low in the far distance. Although there are no quantitative metrics for behaviour, Table 4-1 suggests that TTS could occur out to a range of 24.6 km in all three species and a strong behavioural response to this stimulus could result in displacement of individuals. Other effects on behaviour may be less severe and include: startle response, reduction in foraging efficiency, and changes in schooling behaviour. The short duration of piling activity for both OSPs, however, will limit any behavioural effects. Note that displacement is unlikely to occur in eggs/larvae as these will be drifting on currents in their planktonic phase.

4.2.1 Atlantic salmon

Behavioural effects are likely to occur in salmon over the range of tens to hundreds of metres from the piling, with displacement likely to occur as a result. Beyond this range (in the thousands of metres) there is predicted to be a low risk of behavioural effects (Table 4-1). Adult salmon or salmon smolts within the ensonified area during piling at the OSPs could be behaviourally displaced, although there is unlikely to be a barrier to migration as the noise contours do not reach the coast (Figure 4-1). Piling is predicted to occur over a short duration (3 days per OSP in two separate events) and may therefore overlap briefly with migratory activity which occurs in mid-April/end of May (downstream) and late summer/early autumn (upstream) (Section 4.1.1). Any behavioural effects on individuals are expected to be short-lived (during the piling activity only) and affected individuals are expected to recover in the short term (days) following cessation of the piling. It is therefore concluded that the potential for behavioural effects on salmon is of **negligible adverse** significance and **not significant** in EIA terms.

4.2.2 **Cod**

Cod could be affected behaviourally during piling with a high risk of effects occurring in the near and intermediate distance and a moderate risk of effects occurring in the far distance. Cod within the Firth of Forth region during piling at the OSPs could be displaced, however piling is predicted to occur over a short duration (three days per OSP in two separate events). Disruption to spawning behaviour during piling is unlikely as there is limited overlap with the key spawning period (January to April). Any behavioural effects on individuals are therefore expected to be short-lived (during the piling activity only) and affected individuals are expected to recover in the short term (days) following cessation of the piling. It is therefore concluded that the potential for behavioural effects on cod is of **negligible adverse** significance and **not significant** in EIA terms.

4.2.3 **Herring**

Herring could be affected behaviourally during piling with a high risk of effects occurring in the near and intermediate distance and a moderate risk of effects occurring in the far distance. Individuals within the Buchan herring spawning stock could potentially be temporarily displaced from spawning habitat where it overlaps the ensonified area. Piling at the OSP is predicted to occur over a short duration (three days per OSP in two separate events), but there is limited overlap anticipated with the key spawning period (July to September). Any behavioural effects on individuals are expected to be short-lived (during the piling activity only) and affected individuals are expected to recover in the short term (days) following cessation of the piling. It is therefore concluded that the potential for behavioural effects on herring is of **negligible adverse** significance and **not significant** in EIA terms.

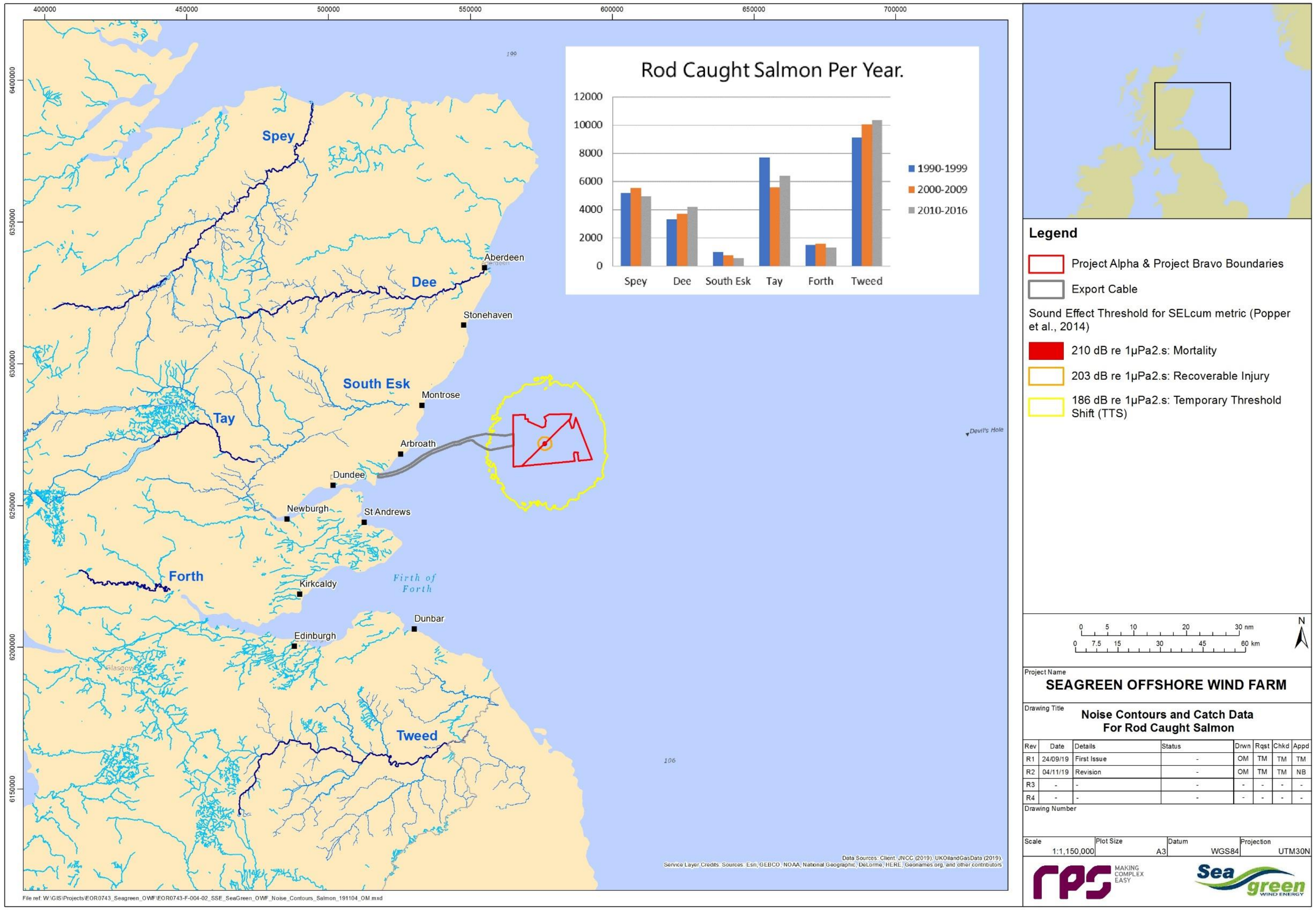
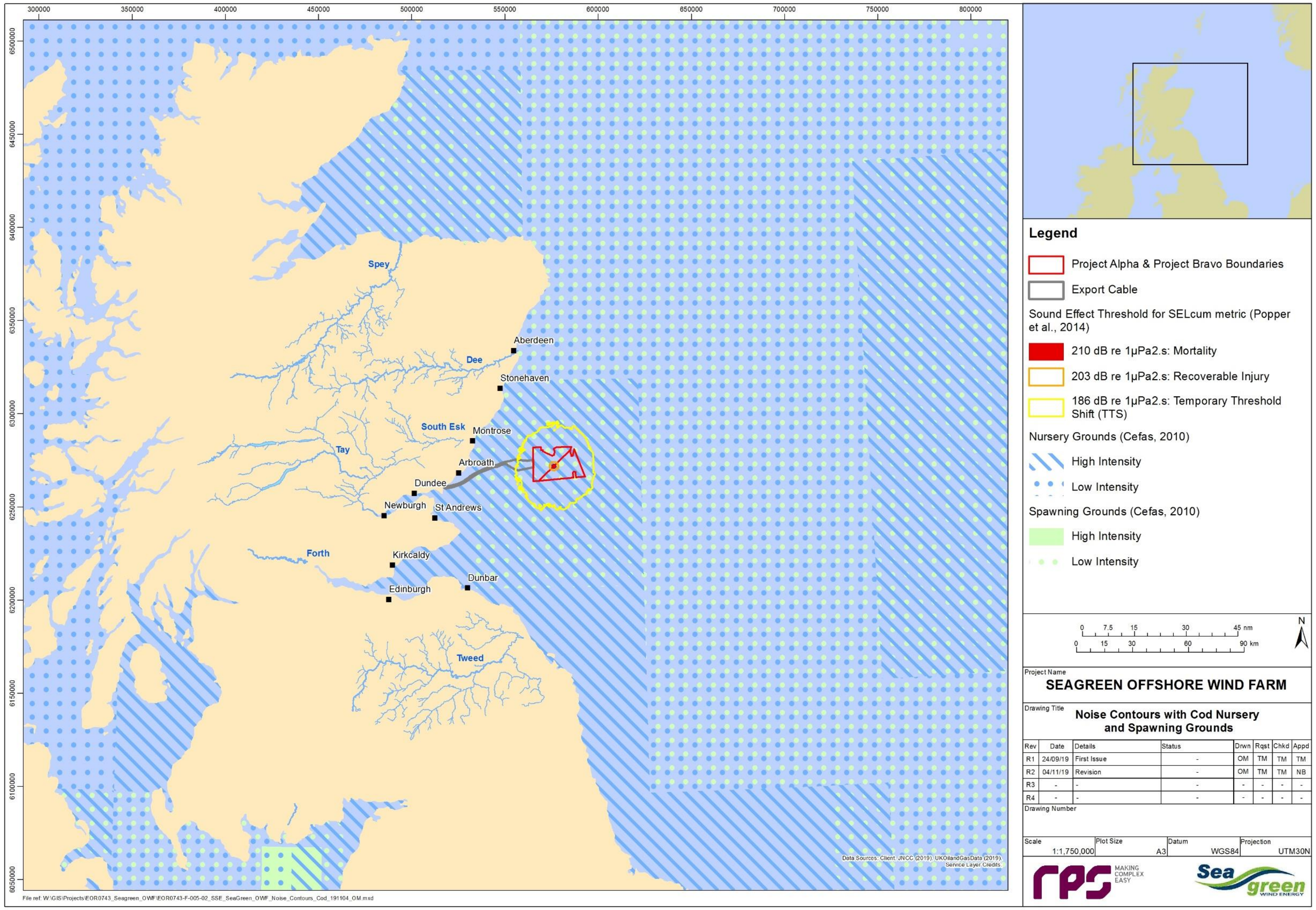


Figure 4-1 Salmon stock assessment and noise contours



Rev	Date	Details	Status	Drwn	Rqst	Chkd	Appd
R1	24/09/19	First Issue	-	OM	TM	TM	TM
R2	04/11/19	Revision	-	OM	TM	TM	NB
R3	-	-	-	-	-	-	-
R4	-	-	-	-	-	-	-

Figure 4-2 Cod spawning and nursery areas and noise contours

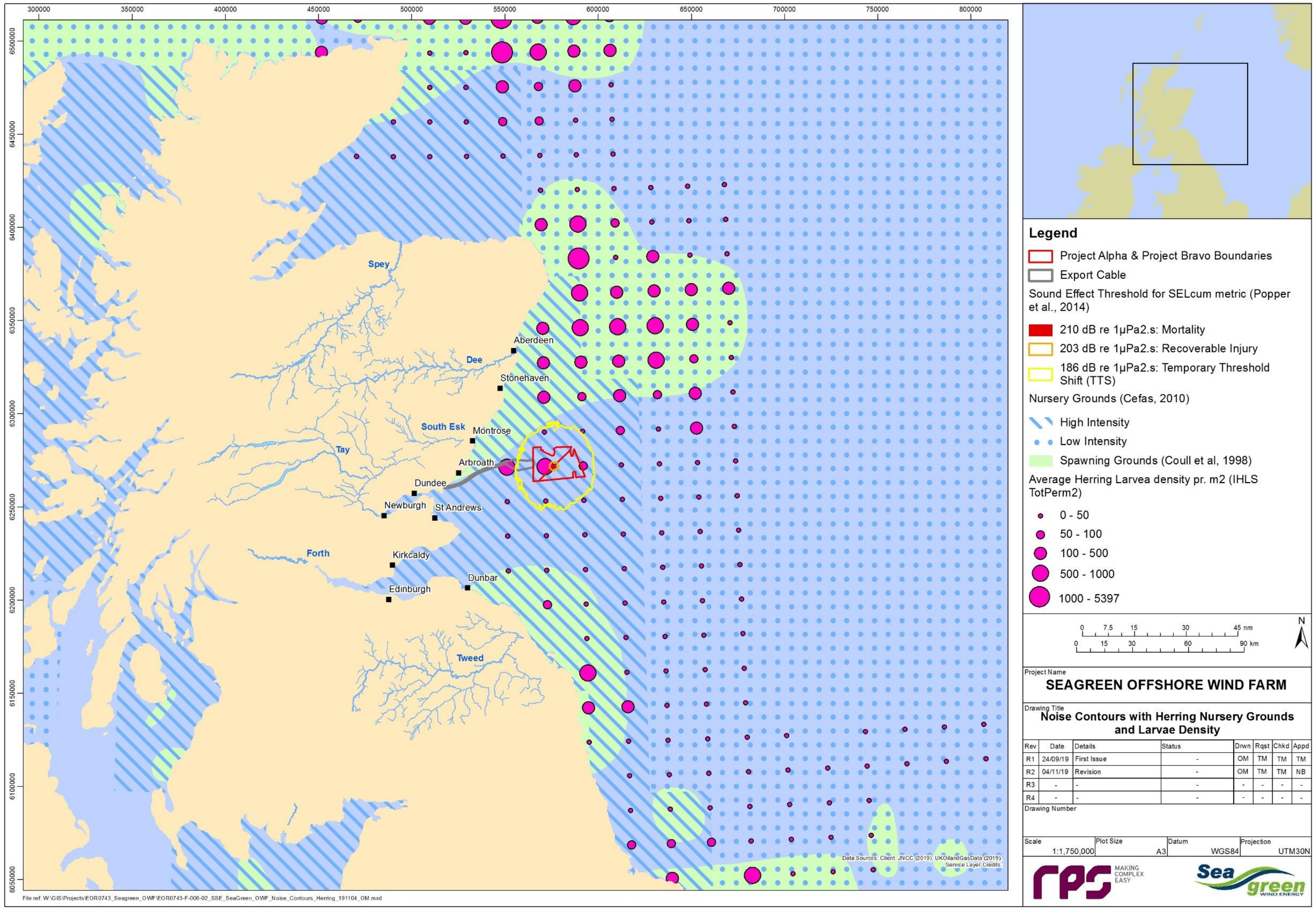


Figure 4-3 Herring spawning and nursery areas and noise contours

4.3 Comparison with 2012 ES Assessment

Injury and impairment ranges presented in the original 2012 ES (Seagreen 2012) were based on a different noise modelling approach and thresholds and are therefore not directly comparable with the results presented here. Therefore, a comparison of the revised design envelope with the 2012 maximum design scenario has been made by referring to the conclusions of the impact assessments for each of the receptors assessed in the 2012 ES and for the revised project design envelope assessed in this document. The 2012 ES assessed the impacts from piling to install wind turbine generator and OSP foundations together, therefore there is no previous assessment of the OSP installation procedure in isolation to enable a direct comparison.

4.3.1 **Atlantic salmon**

In comparison to the 2012 ES there is no difference in the level of significance concluded for the revised project design for mortality and impairment and for behaviour (i.e. negligible significance and Table 4-3). Therefore, there is no change in the conclusions with respect to the impacts of subsea noise from piling on Atlantic salmon from the 2012 ES to the revised project design for installation of the OSPs.

4.3.2 **Cod**

There was no specific assessment of the impact of subsea noise on cod for mortality and impairment in the 2012 ES and therefore a comparison with the current assessment for this species is not possible. The 2012 ES provided an assessment with respect to behavioural effects on cod at Seagreen Alpha only and this was concluded as negligible (Table 4-3). The impact assessment for the revised design also concludes behavioural effects as negligible and therefore, there is no change in the conclusions with respect to the impacts of subsea noise from piling on cod from the 2012 ES to the revised project design for installation of the OSPs.

4.3.3 **Herring**

The 2012 assessment concluded that for piling at the wind farm (including the OSPs), with mitigation in place (soft start piling), the impact on herring would be minor adverse for auditory injury (Table 4-2) and moderate for disturbance (Table 4-3). The impact assessment for the revised design concludes effects would be negligible adverse for auditory injury and negligible for behavioural effects. The significance of effects for the revised project design for piling the OSPs are therefore reduced compared to the significance of effects concluded for the 2012 ES.

Table 4-2 Significance of mortality and impairment assessment for fish species: current worst case OSP assessment and the consented 2012 ES Assessment

Species	**Current worst case OSP Assessment**		**Consented 2012 ES Assessment**[5]	
Atlantic salmon	Negligible	**Not significant**	Negligible	**Not significant**
Cod	Negligible	**Not significant**	Not assessed	**Not significant**
Herring	Negligible	**Not significant**	Minor	**Not significant**

Table 4-3 Significance of behavioural assessment for fish species: current worst case OSP assessment and the consented 2012 ES Assessment

Species	**Current worst case OSP Assessment**		**Consented 2012 ES Assessment**[5]	
Atlantic salmon	Negligible	**Not significant**	Negligible	**Not significant**
Cod	Negligible	**Not significant**	Negligible	**Not significant**
Herring	Negligible	**Not significant**	Moderate	**Not significant**

4.4 Summary and Conclusions

An assessment of the impact of piling noise has been undertaken with respect to the three fish species considered in the Piling Strategy: Atlantic salmon, cod and herring. Noise modelling carried out using the latest guidelines was used to determine the potential ranges at which mortality and impairment could occur. A qualitative risk assessment approach was applied to assess the potential for masking or behavioural effects to occur.

The assessment concluded that there is a risk of mortality and impairment in proximity to the source, whilst temporary auditory injury could occur over greater ranges. The risk of masking and behavioural effects on key species was greater for cod and herring as more hearing sensitive species compared to Atlantic salmon, with the risk assessed as high over a range of hundreds of metres from the source for these two species.

Piling at the OSP is predicted to occur over a very short duration (3 days for each OSP) and therefore it was concluded that the potential for mortality, impairment and behavioural effects would be of negligible significance and not significant in EIA terms for any of the key species (Table 4-2 and Table 4-3). This conclusion is consistent or improved compared with the conclusion presented for the 2012 ES.

[5] Impact significance based on whole wind farm and not just the OSPs

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Appendix D Piling Mitigation Protocol

Project Title	Seagreen Wind Energy Ltd
Document Reference Number	LF000009-CST-OF-PLN-0003

Offshore Transmission Asset Piling Strategy

Appendix D: Piling Mitigation Protocol

Table of Contents

1. Introduction

This Appendix presents the Piling Mitigation Protocol (PMP) that will be adhered to during piling activities for the installation of the two Offshore Substation Platforms (OSPs) for the Seagreen Project. This is provided in compliance with condition 3.2.2.5c of the Offshore Transmission Asset (OTA) Marine Licence. The primary purpose of this PMP is to mitigate the risk of instantaneous mortality or injury to marine mammals during piling for foundation installation at the two OSP locations.

2. Marine Mammal PTS-onset Impact Ranges

Full details of the underwater noise modelling conducted for the OSP pile installation is outlined in Appendix F of the OTA Piling Strategy (PS). The piling soft start will comprise 1 minute of single blows at approximately 10 second intervals at the lowest hammer energy practicable (≤300 kJ), followed by a minimum of 19 minutes ramp up to a maximum of ≤ 500 kJ at approximately of 40 blows/minute. For all marine mammal species, the predicted instantaneous PTS-onset impact range is < 50 m at commencement of the soft-start. This is below the resolution of the noise modelling outputs (Table 2.1).

At maximum hammer energy (2300 kJ), the largest impact range for instantaneous PTS-onset is 225 m for harbour porpoise. Assuming a swim speed of 1.4 m/s, a porpoise starting from the pile location at the start of the ramp up, and moving away in response to the piling noise, would be 1680 metres from the sound source by the end of the soft start period . This would place it well outside the instantaneous PTS-onset range at maximum hammer energy by the time hammer energy begins to ramp up beyond 500 kJ, on completion of the soft start period. For all other marine mammal species, the instantaneous PTS-onset impact range is <50 m for maximum hammer energy.

Table 2.1 Modelled PTS-onset impact ranges at the OSP location

	Instantaneous PTS (SPL_{peak})	
Species	**Max Range (soft-start 300 kJ)**	**Max Range (Max energy 2,300 kJ)**
Harbour porpoise	<50 m	225 m
Minke whale	<50 m	<50 m
White-beaked dolphin	<50 m	<50 m
Bottlenose dolphin	<50 m	<50 m
Harbour seal	<50 m	<50 m
Grey seal	<50 m	<50 m

With consideration of the impact ranges set out in Table 2.1, this PMP does not include the use of Marine Mammal Observers (MMO) or Passive Acoustic Monitoring (PAM), to monitor the PTS injury zone. This is due to the extremely small instantaneous PTS-onset impact range of <50 m at the start of the soft-start. In addition, data collected during wind farm construction have demonstrated that porpoise detections around the piling site decline several hours prior to the start of piling, and it is assumed that this is due to the increase in other construction related activities and vessel presence in advance of the actual piling (Brandt et al. 2018, Graham et al. 2019). Therefore, the presence of construction related vessels in the vicinity prior to the start of piling can act as a local scale deterrent and reduce the risk of auditory injury. Incorporating a short period of Acoustic Deterrent Device (ADD) deployment prior to the soft-start will reduce this risk further by allowing marine mammals to be displaced out of the impact zone prior to commencement of piling. Therefore, this PMP includes ADD use as an additional mitigation measure. It should also be noted that the piling operations will be of very limited duration, each OSP will require a maximum of 12 pin piles, to be installed over a period of approximately three days. This is a significant reduction in piling from that assessed in the ES.

3. Fish

The mitigation soft-start and use of ADDs proposed to reduce the risk of injury to marine mammals may also be useful in deterring hearing-sensitive fish species from the potential impact. Fish may move away from the source on commencement of soft start piling and will continue to do so as piling ramps up. Therefore, no additional mitigation measures are considered necessary to reduce piling noise impacts on fish. This has been accepted by Marine Scotland Licensing Operations Team (MS-LOT), Marine Scotland Science (MSS) and Scottish Natural Heritage (SNH) (meeting 29/10/2019).

4. Acoustic Deterrent Device

This section outlines the application of an ADD for marine mammal mitigation purposes prior to the commencement of the piling soft start.

4.1 ADD choice and specification

The ADD device selected for use is the Lofitech AS seal scarer[1]. This ADD has been shown to have the most consistent effective deterrent ranges for harbour porpoise, seals and minke whales in environments similar to the offshore wind farm construction site (Brandt et al. 2013b, Sparling et al. 2015, McGarry et al. 2017, Gordon et al. 2019). The Lofitech AS seal scarer has been successfully used for marine mammal mitigation purposes at a number of offshore wind farm construction projects in Europe, including the C-Power Thornton Bank offshore wind farm in Belgium (Haelters et al. 2012), the Horns Rev II, Nysted and Dan Tysk offshore wind farms in Denmark (Carstensen et al. 2006, Brandt et al. 2009, Brandt et al. 2011, Brandt et al. 2013a, Brandt et al. 2013b) and on various German sites (Georg Nehls, pers comm). In UK waters the Lofitech device has recently been successfully used for marine mammal mitigation purposes for harbour

[1] http://www.lofitech.no/en/seal-scarer.html

porpoise, harbour and grey seal during piling construction activities at the Dudgeon Offshore Wind Farm, Beatrice Offshore Wind Farm, Race Bank Offshore Wind Farm, Hornsea One Offshore Wind Farm and during UXO detonations at Moray East Offshore Wind Farm. The device is also likely to be used for mitigation at other UK offshore wind farm sites in the near future.

4.2 ADD Deployment procedures

During piling operations, one ADD will be deployed from the deck of the installation vessel, with the control unit and power supply on board the installation vessel in suitable, safe positions on deck. The exact deployment procedure will be agreed once the piling contractor is in place and will follow safe, standard working practices using experienced/trained staff to ensure the equipment is used and deployed correctly within the confines of the installation vessel layout.

Prior to deployment, a vessel survey should be conducted by the contractor’s personnel, to agree the safest and preferred location and method of providing power supply and communications to the ADD device and operator. The transducer part of the ADD should be lowered over the side of the vessel, using an A-frame, or similar, to protect from potential damage from coming into contact with the vessel’s hull. The transducer should be lowered to a sufficient depth so that the hull of the ship does not shadow or block the sound. The weight of the transducer should allow it to maintain position in a vertical orientation but if required additional weights can be attached to the line holding the transducer.

ADDs should be tested for operation before they are activated, using a low sensitivity hydrophone connected to a laptop computer. A variety of free software packages (e.g. PAMGuard, Raven, Audacity) can be used to verify the signal. A calibrated hydrophone such as the RESON TC 4014 would be suitable.

A record of all ADD deployment should be maintained and reports from each OSP installation provided to Seagreen. These reports will include a record of all ADD start and stop times, a record of each verification of ADD activation and a record of any issues with ADD deployment and activation. Incidental sightings of marine mammals around the piling vessel should also be recorded (species, activity and distance/bearing from the vessel recorded) and reported.

5. Roles and Responsibilities

The following section details the key roles and responsibilities for implementing the various elements of this PMP and details how communications between the responsible parties involved in piling operations will be managed during construction.

5.1 Seagreen: Project Manager

The Seagreen Project Manager will require that sufficient resources and processes are put in place by the appointed contractor (and their sub-contractors) to implement this PMP. They will also require that provision is made by the contractor/s for PS compliance and marine mammal mitigation, to form part of construction progress meetings and project inductions.

They will be responsible for ensuring that contractual obligations are established for contractors in relation to the PS and PMP, requiring that all construction personnel and contractors assist and support the

Ecological Clerk of Works (ECoW), as required, for the delivery of the commitments under this PMP. They will require that the specific purpose of this PMP (i.e. to prevent injury to marine mammals) is made clear to all personnel.

5.2 Seagreen: Marine Installation Manager

The piling operations will be the responsibility of the Marine Installation Manager who has the following responsibilities in relation to the PMP:

- Responsible for requiring that sufficient resources and processes are in place across the Marine Installation package to deliver/comply with the PMP;
- Requiring that provision is made for matters relating to the delivery of the PMP to form part of construction progress meetings and Project inductions;
- Requiring that all construction personnel and contractors assist and support the ADD operator and the ECoW where required, in delivering the PMP and monitoring or auditing compliance with the PS;
- Establishing contractual obligations for Key Contractors and Subcontractors in relation to the PS and PMP;
- Reporting to the Seagreen Project Manager on matters related to the PS and PMP; and
- Where necessary, addressing Key Contractor and Subcontractor noncompliance in relation to the PMP.

5.3 OTA Construction Contractor

The OTA Construction Contractor will be required to ensure implementation of and compliance with the PS during construction and installation of the Development and for appropriate liaison with the ADD operator and the ECoW.

5.4 Seagreen: Compliance Manager

The Seagreen Compliance Manager (CM) manages a team responsible for monitoring and reviewing compliance with the project consents and environmental legislation, on behalf of Seagreen (‘Compliance Team’).

The Compliance Team includes the Environment Manager (EM), the Ecological Clerk of Works (ECoW), the Fisheries Liaison Officer (FLO) and any other technical disciplines required, and a supporting Consents team as required.

The Seagreen CM will be responsible for compliance management and monitoring of the PS.

The CM will be responsible for ensuring appropriate technical disciplines are appointed to help support management and monitoring of compliance with the PS.

5.5 Ecological Clerk of Works (ECoW)

The ECoW will be responsible for providing quality assurance of the PS (as required under the S36 Consent and Marine Licences) and providing advice to Seagreen on compliance with the PS.

The ECoW is responsible for communicating the requirements of the PS, monitoring implementation of this PMP and reporting on ongoing compliance with the PS to MS-LOT/ the Licensing Authority throughout the OSP installation.

The ECoW will work with the ADD Operator and more widely with the Seagreen Project team to confirm that the requirements of the PS are understood. They will also undertake site inductions with regard to this PMP and monitor compliance with the PMP. The ECoW will also be responsible for reporting on compliance to MS-LOT / the Licensing Authority.

5.6 ADD operator

A trained and dedicated ADD operator will be responsible for ADD maintenance, operation and reporting. The ADD duties involved would be to deploy the ADD from the installation platform or vessel, to verify the operation of the ADD before deployment, to operate the ADD throughout the pre-piling period (and be available in the case of piling breaks to reactivate), ensure batteries are fully charged and that spare equipment is available in case of any problems, and to record and report on all ADD and piling activity.

6. Full Piling Procedure

6.1 Overview

A schematic diagram of the steps in the piling procedure with the application of this mitigation protocol is provided in Figure 6.1.

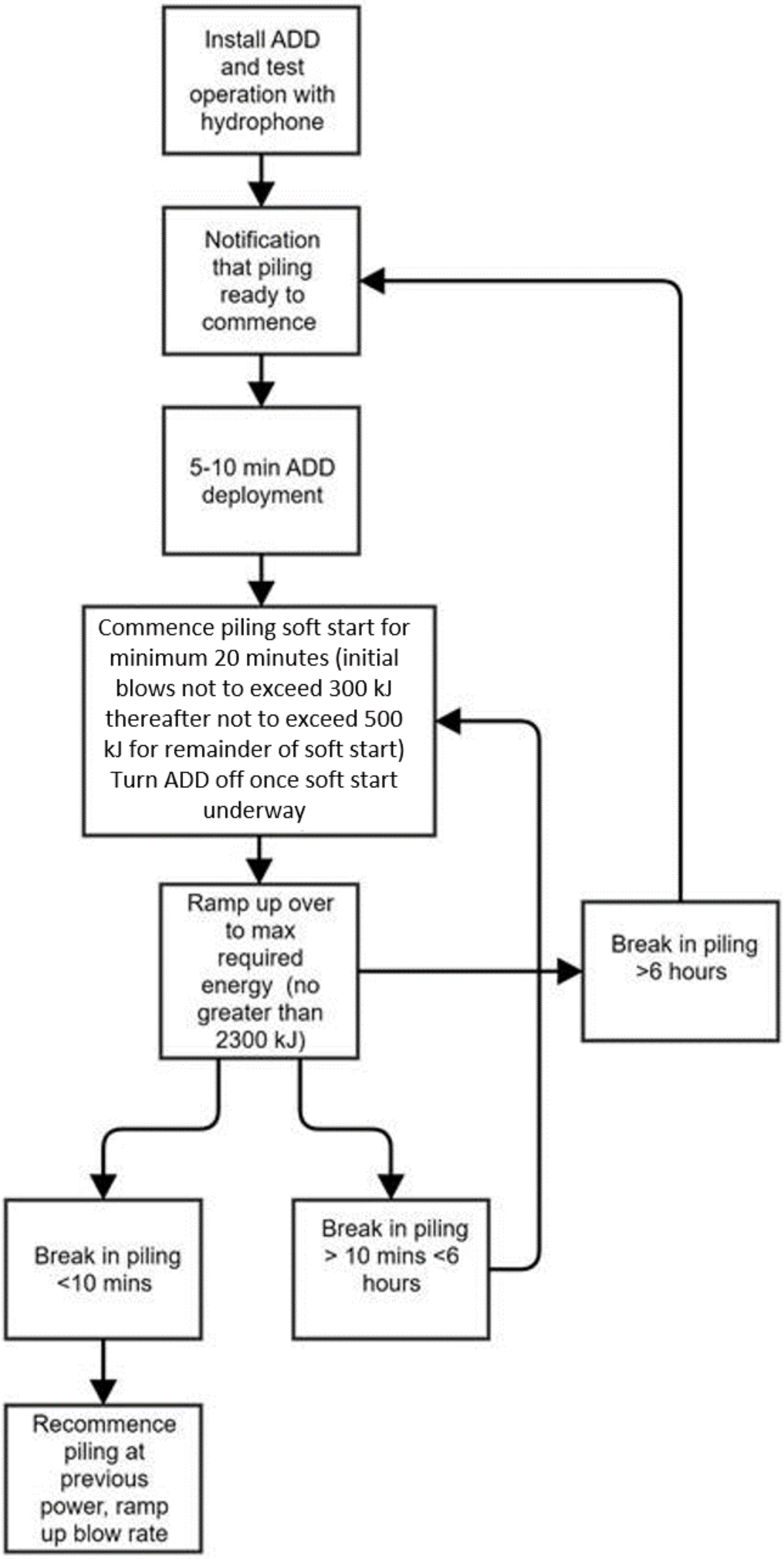

Figure 6.1 Flow diagram of piling procedure

6.2 ADD pre-piling deployment

The ADD operator will test the kit to ensure the ADD is working and will ensure that it is successfully deployed. Following the deployment and testing of the ADD kit, before the commencement of the soft-start procedure, the ADD operator will activate the ADD. The ADD must be activated for at least 5 minutes to ensure that marine mammals have enough time to move out of the potential injury zone. Assuming a swim speed of 1.4 $m.s^{-1}$, a marine mammal starting at the piling location will be 420 m away after 5 minutes. The maximum duration of ADD activation is 10 mins to minimise additional disturbance (mammals are assumed to be 840 m away from the piling location after 10 minutes). When the soft-start commences the ADD operator will deactivate the ADD.

ADD deployment will only be required for the first pile installed in a piling sequence within 24 hours (unless the break between sequential piles exceeds 6 hours – see 6.5).

6.3 Delays in the commencement of piling

Should there be a delay in the commencement of piling, there is a risk of animals moving back into the predicted impact range when the ADD is switched off. However, there is also a risk of habituation as a result of no aversive piling noise commencing after ADD activation. The ADD operator will be notified as soon as practicable of any delay to the commencement of piling and the ADD will therefore be turned off as soon as a delay is communicated. The ADD will not be switched on again until there is confirmation that piling is ready to commence. The ADD will then be reactivated, as set out at 6.2.

6.4 Soft-start and ramp-up

Following the pre-piling deployment of the ADDs, a soft-start procedure will commence. The installation of each OSP foundation pile will involve a minimum 20 minute soft-start procedure. The blow rate during the first minute of the soft start will be approximately 1 blow every 10 seconds, at as low an energy as practicable (≤300 kJ), thereafter increasing to approximately of 40 blows/min and a maximum of 500 kJ hammer energy over the rest of the soft-start period.

Following this, hammer energy will ramp-up gradually until a suitable energy level is reached, to maintain a steady rate of pile penetration. Hammer energy will not be increased above that required to complete each installation – i.e. if ground conditions are such that a lower than maximum hammer energy is sufficient to complete installation, then hammer energy will not be unnecessarily ramped up to the maximum permitted.

6.5 Breaks in piling procedure

In order to minimise ADD use and therefore reduce any unnecessary disturbance to marine mammals, the ADD will not be re-deployed for breaks in piling that are less than 6 hours. This follows advice provided by SNH and MS-LOT on the Moray East Marine Mammal Mitigation Protocol (December 2018). This is based on studies that have shown that harbour porpoise detections remain significantly reduced from baseline up to 6 hours after ADD activation (Brandt et al. 2013b) and has also been shown in more recent studies in Germany where reduced porpoise detection rates were maintained for 28-48 hours after the end of pile driving (Brandt et al. 2018, Rose et al. 2019).

In the event of breaks in piling of <10 minutes, no mitigation is required. The piling can continue from the last hammer energy and strike rate (or lower) used without the need for another ADD deployment.

For breaks in piling <6 hours, piling will recommence with a full soft-start and ramp-up in hammer energy, wherever this is safe to do so, but without the need for pre-piling ADD deployment.

If the break in piling is >6 hours, then the full pilling mitigation procedure of pre-piling ADD deployment, soft-start and ramp-up will be conducted, as set out in Figure 6.1.

7. Communications

A PMP communications protocol will be prepared for implementation on the installation vessel. The communications protocol will include, but not be limited to:

- Procedure to notify ADD operator to set-up equipment, test and deploy ADDs to allow 5 to 10 min activation prior to soft-start commencing;
- Procedure to notify the installation manager that deployment of ADDs and activation for the required time has been successful and soft-start can commence, or if deployment of ADDs and activation has not been successful that soft-start will be delayed;
- Procedure to notify ADD operator that there has been a delay in the onset of the soft-start and that ADD should be turned off;
- Procedure to notify ADD operator that soft-start is successfully underway and the ADDs can be deactivated; and
- Procedure to notify ADD operator that there is a break in piling requiring re-deployment and activation of the ADDs (break in piling over 6 hours).

7.1 Reporting

A record of all piling operations and ADD deployment will be maintained. Reports will include:

- Record of piling operations detailing date, soft-start duration, piling duration, hammer energy during soft-start and piling and any operational issues for each pile;
- Record of ADD deployment, including start and end times of all periods of ADD activation, any problems with ADD deployment;
- Details of any problems encountered during the piling process including instances of noncompliance with the agreed piling protocol; and
- Any recommendations for amendment of the protocol.

Reports will be provided to MS-LOT/ the Licensing Authority completion of each OSP installation as described the Offshore CEMP (LF000009-CST-OF-PLN-0014). The reports will include any data collected during piling operations, details of ADD deployment, a detailed description of any technical problems encountered and what, if any, actions were taken. Reporting will also include the submission of Noise Registry information as required by the consent.

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