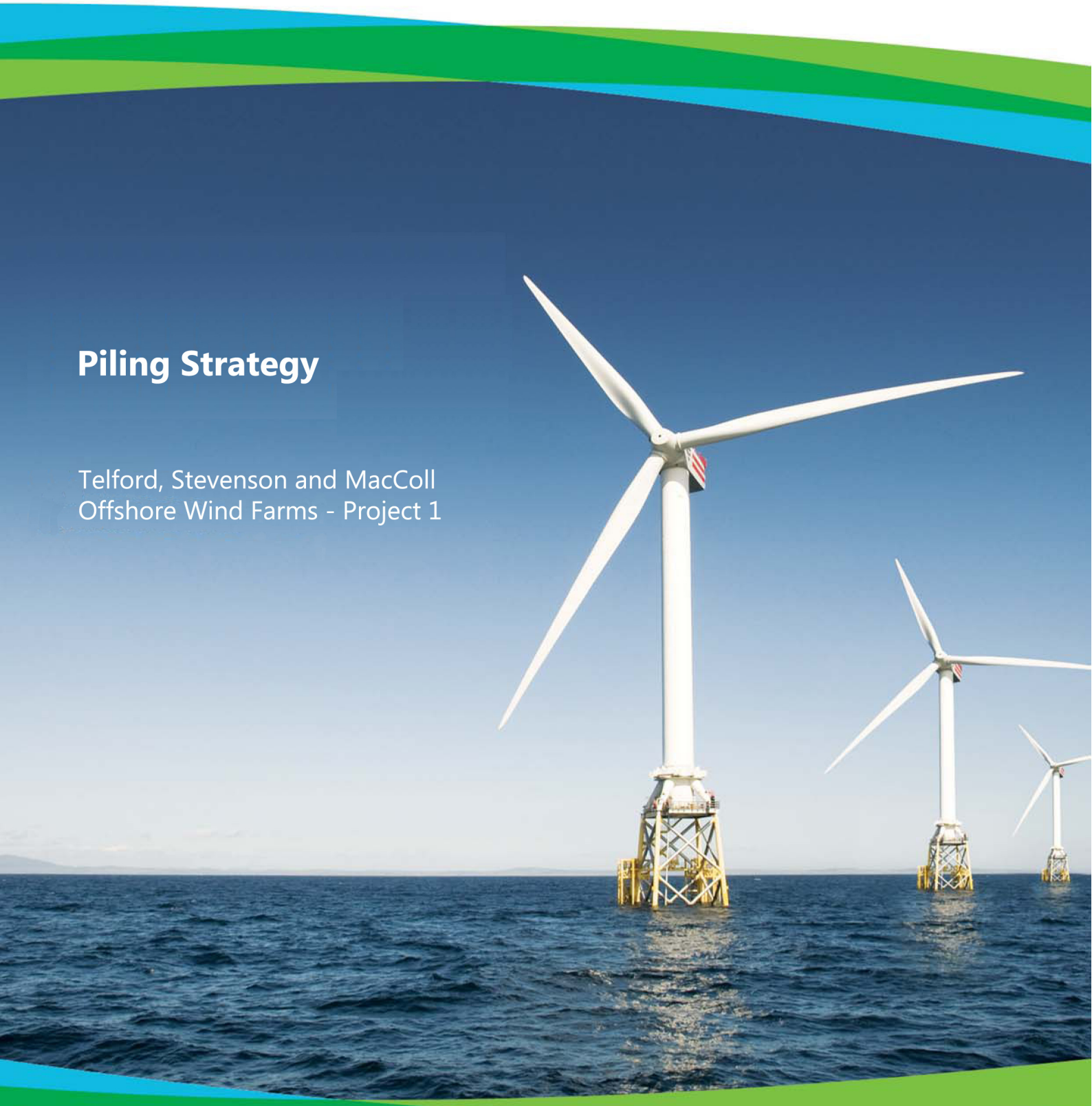
moray offshore renewables ltd

Developing Wind Energy In The Outer Moray Firth



Piling Strategy

Telford, Stevenson and MacColl
Offshore Wind Farms - Project 1

edp renewables

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List of Abbreviations

ADD	Acoustic Deterrent Device
ASFB	Association of Salmon Fishery Boards
BOWL	Beatrice Offshore Wind Ltd
CfD	Contract for Difference
CMS	Construction Method Statement
CoP	Construction Programme
DDD	Drive-Drill-Drive
DECC	Department of Energy and Climate Change
ECoW	Ecological Clerk of Works
EDA	Eastern Development Area
EMP	Environmental Management Plan
ES	Environmental Statement
FEED	Front End Engineering Design
HE	Highest Expected
JNCC	Joint Nature Conservation Committee
ML	Most Likely
MFRAG	Moray Firth Regional Advisory Group
MFRAG – MM Subgroup	Moray Firth Regional Advisory Group – Marine Mammals Subgroup
MMO	Marine Mammal Observer
MMMP	Marine Mammal Monitoring Programme
MORL	Moray Offshore Renewables Limited
MS-LOT	Marine Scotland Licensing Operations Team
MSS	Marine Scotland Science
OFTI	Offshore Transmission Infrastructure
OSP	Offshore Substation Platform

PAM	Passive Acoustic Monitoring
PEMP	Project Environmental Monitoring Programme
PIF	Pile Installation Frame
PS	Piling Strategy
ROV	Remotely Operated Vehicle
SEL	Sound Exposure Level
SNCB	Statutory Nature Conservation Body
SNH	Scottish Natural Heritage
WTG	Wind Turbine Generator
WDC	Whale and Dolphin Conservation

Executive Summary

This Piling Strategy (PS) has been prepared by Moray Offshore Renewables Limited (MORL) to inform the Marine Scotland Licensing Operations Team (MS-LOT) and relevant stakeholders of the intended scope of MORL's PS for Project 1 and to seek agreement that the information provided meets the requirements of condition 11 of the Section 36 consents in respect of the first phase of development of the Telford, Stevenson and MacColl sites (i.e. Project 1). The aim of this document is to detail the underwater noise assessments undertaken for Project 1, outline mitigation that has been determined appropriate and describe how mitigation has been incorporated into the PS to minimise the impacts of underwater noise on key natural heritage receptors. This document is designed to sit alongside other consent condition documents such as the Construction Method Statement (CMS), Construction Program (CoP) and Environmental Management Plan (EMP) for which approval will be sought at a later date.

The PS has been developed with the aim of ensuring potential effects, with respect to the species identified in condition 11, i.e. bottlenose dolphins, harbour seals, Atlantic salmon, cod and herring, are no worse than assessed in the MORL (2012) Environmental Statement (ES) and are not considered significant. MORL has included harbour porpoise in the considerations for mitigation and monitoring in this document at request from the MFRAG-MM Subgroup (see Table 1.1 for details) and as a recognition that this is the most common EPS within the site.

Consultation already undertaken with stakeholders is presented within this document and it is anticipated that ongoing consultation with key stakeholders will be required throughout the pre-construction phase and will continue during piling operations. The information provided in the PS is accurate at the time of submission. Should any significant changes occur to the information provided then the PS will be updated or amended from time to time as necessary and will be submitted to MS-LOT for approval in terms of condition 11.

This document has been produced for MS-LOT approval and presents the PS for Project 1 which complies with and on approval will meet the requirements of the consent condition 11 of the Section 36 consents as they apply to Project 1. A separate PS document will be provided to discharge condition 3.2.2.5 of the Offshore Transmission Infrastructure Marine Licence. A PS will also be submitted in respect condition 11 of the Section 36 consents for Phase 2 works.

As required by the condition 11 of the Section 36 consents as far as reasonably practicable the PS will be consistent with the following documents (to be submitted at a later date):

- Environmental Management Plan (EMP);
- Project Environmental Monitoring Plan (PEMP); and
- Construction Method Statement (CMS).

1 Introduction

1.1 Project Background

In March 2014 Section 36 consents were granted for three offshore wind farms (Telford, Stevenson and MacColl) within the Moray Offshore Renewables Limited (MORL) Eastern Development Area (EDA) (see Figure 1). Marine Licences for the three wind farms were granted in September 2014.

MORL plans to develop the three sites within the EDA in two phases. This Piling Strategy (PS) relates to phase 1 only (referred to as Project 1). The exact boundary of the phased approach is currently being refined but it is likely that both phases will include a proportion of all three of the consented wind farms. The PS therefore takes into account all relevant conditions relating to the three sites, discussed in Section 1.2.1.

The MORL (2012) Environmental Statement (MORL ES) which accompanied the applications provided a description of the project parameters. The design envelope assessed in the MORL ES was based on a maximum of 339 wind turbine generators (WTGs) installed on four legged jackets; i.e. the assessments for the three wind farm sites together were modelled on a maximum of 1,356 piles (excluding additional piles required for up to eight offshore substation platforms (OSPs)). To address concerns relating to potential ornithological impacts the Section 36 consents reduced the total number of WTGs permitted in the EDA to 186 (which would represent a maximum of 744 piles). Additionally, MORL subsequently reduced the maximum number of OSPs to two (MORL (2014) Modified Offshore Transmission Infrastructure ES). Project 1 will comprise up to 100 WTGs. This PS has been prepared in respect of Project 1 and separate PSs will be provided for the OSPs as required by the OfTI Marine Licence and for any subsequent Phase 2 works.

The MORL ES considered a maximum hammer energy of 1080 kJ to drive piles up to the target depth (using a hammer of 1200 kJ capacity). However post-consent site investigations (discussed further in Section 2.2) indicate that in a worst case scenario higher energies may be required for a small proportion of the pile installation duration for up to 39% of piling locations. Consultation with the regulator and stakeholders has taken place prior to submitting this document (see Table 1.1) and underwater noise modelling has been undertaken, taking into account this new information (Appendices 1 and 4 for marine mammals and fish species, respectively). The potential effects on marine mammals and fish associated with this possible change have been re-assessed (provided in Appendix 3 and Appendix 5, respectively). For marine mammals and key fish species assessments were undertaken to validate that the potential effects of the Piling Strategy are within those effects predicted in the MORL ES.

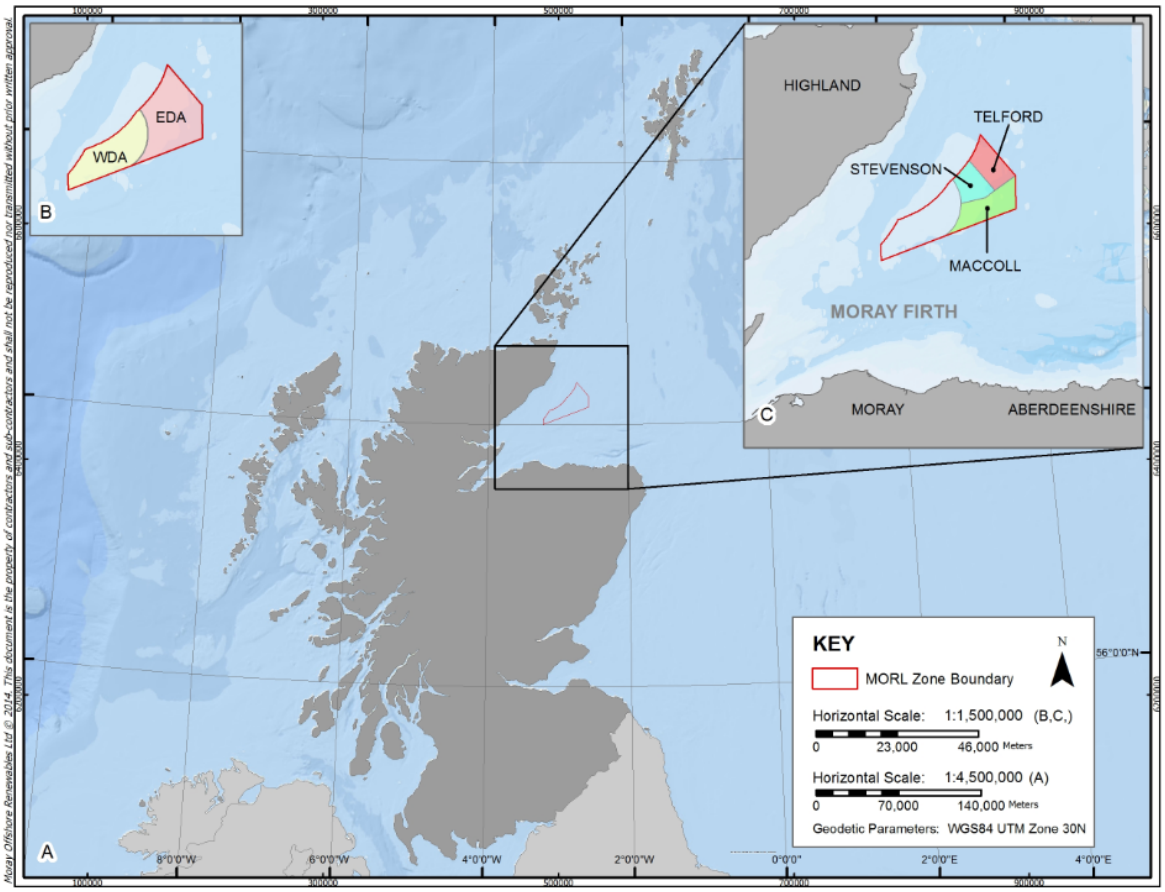

Figure 1: A. Location of the MORL zone; B. Location of the EDA and WDA; and C. Location of the three consented wind farms (Telford, Stevenson and MacColl) where Project 1 will be located.

1.2 Purpose of Piling Strategy

Submission of a PS six months prior to construction is a consent condition for the three consented sites (see Section 1.2.1). Following the grant of the consents MORL carried out significant additional geophysical and geotechnical surveys in 2014 within the EDA (see Section 2.2 below) which enables MORL to accelerate the submission of the PS. Approval of the PS will support MORL reaching Project Definition for Project 1 which will be used to support the processes necessary to ensure that Project 1 can be built. This includes supporting any bid for a Contract for Difference (CfD) as well as inclusion in contractors' scopes of work in MORL's ongoing procurement processes.

The PS demonstrates that effects of the planned piling works for Project 1 are within those assessed in the MORL ES (see Section 4). Where possible, the PS aims to further reduce or mitigate any potential effects on key receptors.

The Front End Engineering Design (FEED) and contractor procurement processes are currently ongoing and therefore the detailed construction programme and sequencing will be provided in the Construction Method Statement (CMS) and Construction Programme (CoP) documents which will be submitted no later than 6 months before construction.

The PS will be updated or amended as necessary to ensure that as far as practicable it is consistent with the PEMP, Environmental Mitigation Plan (EMP) and CMS as discussed in Section 1.4.

The PS outlines the methodologies currently being considered for the pile installation process, including potential variations to the approach and discusses how monitoring and mitigation will be built into the construction methodology in order to minimise the impact of underwater noise from piling. Although associated construction activities around the piling process have not yet been finalised, the pile driving work is expected to be largely consistent. Finalised construction methodologies will be provided in detail within the CMS.

This document is structured in such a way that the main PS document provides an overview of pile installation options, programme, piling mitigation, and monitoring associated with piling activities for Project 1. Full discussion of impact assessments and mitigation techniques are provided in the following appendices:

- Appendix 1 (Underwater Noise Modelling – Marine Mammals) outlines the predicted source and received sound exposure levels (SELs) for a maximum single pulse and cumulative SELs over 24 hours as well as the received levels weighted to take into account the hearing capabilities of relevant marine mammal species . The noise modelling takes into account the piling strategy scenarios detailed in Section 3.
- Appendix 2 (Piling Protocol) provides a reasoned justification and protocol for mitigating the effects on marine mammals as discussed and agreed with the MFRAG-MM Subgroup (details of consultation are provided within Section 1.5 of this PS).
- Appendix 3 (Marine Mammals Assessment) provides an updated assessment for marine mammals taking into account updated project information and underwater noise modelling (Appendix 1) as well as the piling protocol (Appendix 2) in order to validate that the potential effects are within those predicted in the MORL ES and therefore assess whether the potential effects of the PS cause any significant change to the conclusions of the ES.
- Appendix 4 (Underwater Noise Modelling - Fish) provides the outputs of the noise modelling for relevant fish species. The noise modelling takes into account the piling strategy scenarios detailed in Section 3.
- Appendix 5 (Fish Assessment) provides an updated fish assessment taking into account updated project information and underwater noise modelling (Appendix 4) in order to validate that the potential effects are within those predicted in the MORL ES and therefore assess whether the potential effects of the PS cause any significant change to the conclusions of the ES.
- Appendix 6 (Acoustic Deterrent Device Procedure) provides information on the procedure which will be followed during the deployment of Acoustic Deterrent Devices (ADDs), including the role of the ADD operator, testing and maintenance and coordination of deployment and activation of devices.
- Appendix 7 (Phased Piling Mitigation Strategy) provides details on a phased mitigation strategy for marine mammals which will be followed over a period(s) of up to 28 days during the piling campaign at Project 1 to monitor the effectiveness of mitigation methods.

1.2.1 Relevant Consent Conditions

This document has been produced to meet the requirements of condition 11 of the Telford, Stevenson and MacColl Section 36 consents in relation to Project 1. Condition 11 reads as follows:

> *"In the event that pile foundations are to be used, the Company must, no later than 6 months prior to the Commencement of the Development, submit a Piling Strategy ("PS"), in writing, to the Scottish Ministers for their written approval. Such approval may only be granted following consultation by the Scottish Ministers with the JNCC, SNH and any such other advisors as may be required at the discretion of the Scottish Ministers. The Development must, at all times, be constructed in accordance with the approved PS (as updated and amended from time to time by the Company). Any updates or amendments made to the PS by the Company must be submitted, in writing, by the Company to the Scottish Ministers for their written approval.*
>
> *The PS must include:*
>
> *a. Full details of the proposed method and anticipated duration of pile-driving at all locations;*
>
> *b. Details of soft start piling procedures and anticipated maximum piling energy required at each pile location; and*
>
> *c. Details of mitigation and monitoring to be employed during pile-driving, as agreed by the Scottish Ministers.*
>
> *The PS must be in accordance with the ES and reflect any surveys carried out after submission of the Application. 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; Atlantic salmon; cod; and herring.*
>
> *The PS must, so far as reasonably practicable, be consistent with the EMP, the PEMP and the CMS."*

In addition, Consent Condition 33 of the Section 36 consents includes the following seasonal restriction to mitigate potential impacts on herring from piling which has been incorporated in the PS:

> "*In the event that pile foundations are to be used, the Company must undertake herring surveys every year during the months of August and September commencing the first August and September following the date of this consent, up until, and including, the last August and September prior to Commencement of the Development, unless otherwise agreed in writing by the Scottish Ministers. The methodology of the herring surveys must be agreed, in writing, by the Scottish Ministers, following consultation with Marine Scotland Science, prior to the surveys commencing. The results of the herring surveys will be used to better inform the knowledge of spawning behaviour / characteristics of the Orkney / Shetland herring stock, thus allowing the Company to devise mitigation options to minimise noise impacts from piling activity on all life stages of herring and to inform the Company's PS (if a PS is required).*
>
> *Following the results of the herring surveys undertaken in the last August and September prior to the Commencement of the Development, the Company must submit, in writing, its mitigation strategy to minimise the noise impacts on herring from piling activity, to the Scottish Ministers for their written approval. Once the Scottish Ministers have provided*

their written approval, the mitigation must be deployed during the annual herring spawning period (August and September) in any year of construction involving piling. Failing any agreement on mitigation, a piling restriction not exceeding sixteen (16) days within the months of August and September will take place in the area marked 'mitigation zone', as shown on the Telford Wind Farm Fish Mitigation and Monitoring Plan in Figure 2, in any year of construction involving piling. The sixteen (16) days are not necessarily to be consecutive. The relevant sixteen (16) days of piling restrictions will be notified to the Company by the Scottish Ministers, in writing, at least 90 days prior to the first day of piling restriction."

1.3 General Approach

The PS is informed by project engineering parameters (in order to include piling methodologies and programme) and environmental sensitivities as identified through the baseline surveys undertaken (and updated through pre-construction survey results where applicable).

This PS aims to mitigate potential significant effects on the receptors' population taking into account the assessments presented in the ES. The PS is also designed to demonstrate how mitigation measures have been incorporated into pile driving requirements which installation contractors will have to adhere to and incorporate into their CMS.

This PS contains piling methodologies, construction mitigation and monitoring methods which will aim to mitigate potential effects associated with piling activities, in particular underwater noise, with respect to harbour seals, bottlenose dolphins, harbour porpoise, Atlantic salmon, cod and herring, using an approach appropriate for the proposed development. The construction programme will take into account the restrictions on piling as set out in condition 33 and the steps to minimise the duration of piling activities in developing the final construction programme are set out in section 3.4.

PS implementation will be executed by the Foundation Installation Contractor and monitored by the Ecological Clerk of Works (ECoW). Monitoring reports will be provided to the Scottish Ministers on PS compliance at timescales to be determined by the Scottish Ministers.

1.4 Document Control

Agreement of the PS with Scottish Ministers is an important factor influencing project financial decisions. This PS is being submitted for approval at an early stage of the construction planning process so that agreed mitigation measures can be included within contractors' scopes of work. As previously discussed the PS may be updated or amended as further information on seabed conditions, chosen technology, construction methods and environmental sensitivities becomes available during the pre-construction period.

Any updates made to this document will be recorded using the document tracker provided at the beginning of this document. The need to update the PS document will be identified through MORL's change management system (to be detailed in the EMP), which records changes to the Project and details the process required to record and implement the change successfully.

Any changes to the PS will be submitted in writing to the Scottish Ministers as soon as reasonably practicable for approval, prior to enacting the proposed changes, as required by the Section 36 consents.

1.5 Stakeholder Consultations

The Moray Firth Regional Advisory Group (MFRAG) has been set up to discuss and manage topics relating to the development of MORL and Beatrice Offshore Wind Ltd (BOWL) and provide advice to the Scottish Ministers. The MFRAG includes the following key stakeholders for the PS:

- Marine Scotland;
    - Marine Scotland Science (MSS)
    - Marine Scotland Licencing Operations Team (MS-LOT)
- Scottish Natural Heritage (SNH);
- Whale and Dolphin Conservation (WDC);
- Association of Salmon Fishery Boards (ASFB);
- Joint Nature Conservation Committee (JNCC); and
- Moray Firth Offshore Wind Developers: MORL and BOWL.

In addition, the MFRAG Marine Mammals (MFRAG-MM) Subgroup has been set up (including MS-LOT, MSS, SNH, JNCC and WDC) to allow detailed discussions related to marine mammals.

The approach to mitigation for potential impacts on marine mammals associated with piling activities has been discussed and agreed with the MFRAG-MM. The approach to monitoring for marine mammals (Marine Mammal Monitoring programme, MMMP) is also being discussed with the pre-construction and construction monitoring (general principles) scope of works now also agreed within the MFRAG-MM and will be outlined in PEMP as part of the requirements of the Section 36 consents' condition 26. A brief outline of the monitoring and how it relates to mitigation is provided in Section 0 below.

Fish ecology is also discussed in the MFRAG meetings and to date, no issues have been discussed which are expected to impact on this PS. Nonetheless MORL has met with MSS to discuss fish in the context of piling activities prior to issuing of this document. Issues relating to monitoring of fish will be addressed in the PEMP.

Table 1.1 provides a summary of post-consent consultation undertaken to date which is of relevance to the development of the PS.

Table 1.1 Stakeholder consultation of relevance to the PS since consent determination

Consultee	Scope of Consultation / Consultation Response	Date	MORL Comments
MS-LOT & MSS meeting	Overview and update of the project provided by MORL. MORL outlined that piling restrictions in relation to daylight and visibility could	15/01/2015	These topics were further discussed with MSS and MS-LOT on 05/03/15 and within MFRAG-MM Subgroup on the 30/03/15.

Consultee	Scope of Consultation / Consultation Response	Date	MORL Comments
	significantly increase the piling programme. MS-LOT stated that the JNCC piling guidelines are only a guide and that an increase in the duration of the piling programme could be detrimental in terms of potential disturbance impacts. Outline of approach to piling provided by MORL. MORL raised the possibility of requiring an increase in the maximum hammer energy depending on detailed analysis of the 2014 site investigations. MS-LOT confirmed that the PS was the appropriate document process in which to consider the impact of any such change.		A review of mitigation strategies (draft Marine Mammal Piling Mitigation Strategy: Removal of Restriction on Commencement of Piling at Night / During Low Visibility) was provided to MSS and MS-LOT on 26/01/15. The information provided in this PS supersedes the information provided on the 26/01/15.
MS-LOT & MSS (in writing)	MORL provided the draft Marine Mammal Piling Mitigation Strategy: Removal of Restriction on Commencement of Piling at Night / During Low Visibility.	26/01/2015	This was discussed during the meeting on 05/03/15. Document now superseded by the Piling Protocol (Appendix 2).
MS-LOT (in writing)	MS-LOT feedback on the draft Marine Mammal Piling Mitigation Strategy confirming acceptance in principle subject to agreeing the PS.	03/03/2015	Feedback has been taken into consideration in Appendix 2
MS-LOT & MSS meeting	Meeting to discuss marine mammal mitigation and approach to piling. The appropriate mitigation zones were discussed as well as the use of soft start to reduce the injury zone. MS-LOT indicated that the SNCBs were receptive to considering the use of ADDs.	05/03/2015	Mitigation zones are discussed in Section 3.5.3.3 and Appendix 2. The protocol for use of ADD mitigation is also discussed in Appendix 2.
MS-LOT, MSS, SNH, JNCC, WDC MFRAG-MM meeting	The key activities associated with pile-driving operations, the limitations of the JNCC guidelines and the benefits of ADDs were discussed. The SNCBs outlined that ADDs have not been used on their own without Passive Acoustic Monitoring (PAM) and Marine	30/03/2015	Appendix 2 outlines the mitigation protocol associated with this PS. Monitoring is discussed briefly in Section 0 and will be

Consultee	Scope of Consultation / Consultation Response	Date	MORL Comments
	Mammal Observers (MMOs) as mitigation before. Agreed marine mammal impact assessment to be revisited following changes to project parameters. It was confirmed that the MORL PS will present anticipated maximum hammer energies and piling durations in zones across Project 1 in line with the different ground conditions.		addressed in detail in the PEMP. Revised assessment provided in Appendix 3. Required hammer energies in relation to ground conditions is discussed in Section 3.3.1.
SNH & JNCC (in writing)	Feedback on the draft Construction MMMP and mitigation proposals following the meeting on the 30/03/15. SNH/JNCC requested further discussion on the timescales for analysis of data from construction monitoring; measurement of pile-driving noise and marine mammal monitoring. It was confirmed that the size of mitigation zone(s) for MORL and BOWL will be agreed via the MFRAG-MM subgroup meetings.	24/04/2015	Monitoring is discussed briefly in Section 0 and will be addressed in detail in the PEMP. The scope of the PEMP will be agreed with MS-LOT in consultation with relevant stakeholders (including SNH and JNCC). Mitigation zones are discussed in Section 3.5.3.3 and in further detail in Appendix 2.
MS-LOT, MSS, SNH, JNCC, WDC MFRAG-MM meeting	Protocol for Mitigating Effects on Marine Mammals During Piling at the BOWL and MORL Wind Farms issued to MFRAG-MM Subgroup.	01/06/2015	Final Piling Protocol included in Appendix 2.
MS-LOT, MSS, SNH, JNCC, WDC MFRAG-MM meeting	Piling protocol, revised construction MMMP and MMMP annual report issued to MFRAG-MM Subgroup.	11/06/2015	Final Piling Protocol included in Appendix 2.
MS-LOT, MSS, SNH, JNCC, WDC MFRAG-MM meeting	Meeting to discuss monitoring and mitigation. It was agreed that the piling mitigation protocol should include: • 10-15 minutes ADD deployment. • 20 minutes soft start ≤500 kJ in total and remove specified staged energy requirements.	19/06/2015	Further comments on Piling Protocol provided by SNH and JNCC on the 07/08/2015 and 09/09/2015 (see below).

Consultee	Scope of Consultation / Consultation Response	Date	MORL Comments
	• No intermittent use of ADD during breaks, ADD to be deployed 10-15 minutes prior to piling recommencing. It was agreed that the aim of the mitigation is avoiding instantaneous death and injury and does not try to mitigate cumulative noise impacts or disturbance. MORL proposed that using MMOs and PAM as back up mitigation would conflict the purpose of using ADD (i.e. allowing 24/7 operation) but monitoring would be undertaken of the effectiveness of ADD. Stakeholders confirmed that harbour seal and harbour porpoise should be the key focus of monitoring of mitigation. The PS is submitted to discharge consent conditions and not as a report to provide detailed information on other topics.		These mitigation parameters have been incorporated in Section 3.5.3 and Appendix 2. Appendix 2 provides further justification of the mitigation protocol associated with this PS. Harbour porpoise has been considered in this PS.
MS-LOT, MSS, SNH, JNCC, WDC (in writing)	Revised protocol issued to MFRAG-MM Subgroup.	31/07/15	Piling Protocol updated and final version included in Appendix 2.
SNH (in writing)	Response to the draft Piling Protocol: SNH is content that the mitigation protocol can be referred to, and used to inform, the piling strategy. SNH is content with ADD deployment during pre-piling for a period of not less than 10 minutes and not more than 15 minutes. SNH is satisfied with the way the impact zone has been calculated.	07/08/15	The Piling protocol provided in Appendix 2 is as agreed with SNH.
JNCC (in writing)	Response to the draft Piling Protocol: JNCC recognise that there is evidence that certain ADDs provide a level of mitigation that may be comparable to that of MMO/PAM for seals and harbour porpoise (noting that this is currently under discussion in much more detail via ORJIP) but state that a full suite of ADD, MMO	09/09/15	Piling Protocol updated to state that ADD deployment would be of 15 minutes. An overview of monitoring of mitigation is provided in Section 0.

Consultee	Scope of Consultation / Consultation Response	Date	MORL Comments
	and PAM is preferred. It is stated that a 15 minute deployment of ADD is preferred. JNCC state that any mitigation devised for the piling protocol should also other species of cetacean found within the Moray Firth in order to satisfy European Protect Species (EPS) licencing.		The PS addresses the requirements of condition 11 of the Section 36 Consents. An EPS licence application will be submitted at a later date setting out details of the risk for the EPS together with appropriate mitigation.
MS-LOT, MSS, SNH, JNCC (meeting)	A meeting was held with key PS stakeholders (with the exception of WDC who was briefed separately) to discuss the results of additional noise modelling and the revised marine mammal assessment. The overall approach to the PS was also discussed. MSS and the SNCBs agreed that the level of information MORL proposed to submit in terms of WTG locations and soil profile characterisations provided them with sufficient information for the PS. JNCC expressed an interest in having further discussion/'walk through' of assessment once complete.	11/09/2015	Following this meeting MS-LOT also confirmed that the approach of MORL in setting out the piling activities in terms of soil profiles rather than specific locations met the requirements of condition 11. A further meeting to discuss the PS with MS and SNCBs will be organised following submission of this document to MS-LOT.
MS-LOT, MSS, SNH, JNCC, WDC (in writing)	Revised protocol issued to MFRAG-MM Subgroup. The main updates were revision of ADD deployment (15 minutes as per JNCC response of the 09/09/15 above), update on risk injury area and provision of separate project's risk assessments (MORL and BOWL) as well as cumulative (in light of SNH comments of the 07/08/15 and comments provided at the meeting of the 11/09/15).	09/10/15	Piling Protocol updated and final version included in Appendix 2.
Scottish Fishermen's Federation (SFF) (meeting)	A meeting was held between MORL and SFF. MORL provided an overview of the PS contents and how it related to fish species (herring, cod and salmon). SFF were content with MORL's approach to the PS and added that they would not expect that salmon would be found on the Project 1 area.	26/10/15	Conservative assumption was followed in the validation of salmon assessments that salmon would be present within Project 1 area in line with MORL's ES assessment methodology (full

Consultee	Scope of Consultation / Consultation Response	Date	MORL Comments
			methodology details in Appendix 5 Fish Assessment). MORL will continue to engage with the fishing industry through the Moray Firth Commercial Fisheries Working Group (MFCFWG). Further information on the planned construction activities, including piling programme, will also be facilitated through the appointment of a Fisheries Liaison Officer (FLO) and Notices to Mariners prior / during to construction.
MSS (meeting)	A meeting was held with MSS to discuss piling activities, the results of additional site investigations, underwater noise modelling and the revised assessment for key fish species (cod, herring and salmon). MSS were in agreement with the modelling and assessment approach and advised that a clear comparison between the most recent results and the MORL ES should be presented.	29/10/15	Comments taken into account in Appendix 4 (Underwater Noise Modelling – Fish) and Appendix 5 (Fish Assessment).
MS-LOT, MSS, SNH, JNCC, WDC (in writing)	A voting request was issued by the MFRAG-MM Subgroup chair on the Piling Protocol. The majority of the MFRAG-MM Subgroup agreed that the Piling Protocol was the group's agreed position (six organisations voted yes and JNCC abstained from voting). Given different opinions expressed on the Piling Protocol a report was produced by the group's secretariat detailing the MFRAG-MM Subgroup advice to MS-LOT.	29/10/15	Piling Protocol included in Appendix 2.
WDC, MSS (meeting)	A meeting was held with WDC and MSS to discuss piling activities, the results of additional site investigations, underwater noise modelling and the revised marine mammal assessment. MORL offered to meet again with WDC after the submission of the PS should WDC feel it would assist in the review.	20/11/15	A further meeting to discuss the PS with WDC will be organised following submission of this document to MS-LOT if required. MORL will provide information on the predicted piling timescales for Project 1 to

Consultee	Scope of Consultation / Consultation Response	Date	MORL Comments
			researchers at the Cetacean Research and Rescue Unit (CRRU).
MS-LOT, MSS (meeting)	A meeting was held with MS-LOT and MSS to discuss MORL's proposed herring mitigation. Discussions included proposed desk studies, survey methodologies and approach for data analysis in order to identify the 16 days piling restriction within Telford and Stevenson sites or remove the piling restriction if not required.	29/11/16	Further details on survey and assessment methodologies will be provided within the PEMP.

1.6 Relevant Guidance and Legislation

The following legislation applies to the consents granted for MORL:

- Marine and Coastal Access Act 2009;
- Marine (Scotland) Act 2010;
- Electricity Act 1989, Section 36.

The following European legislation is also applicable and was taken into consideration during the consenting process:

- Marine Strategy Framework Directive;
- Habitats Directive.

The following guidance documents have been considered during the preparation of this PS:

- JNCC (2010) guidance;
- The Marine Scotland website[1] provides guidance on the Marine Strategy Regulations (2010)- Noise registry; and
- Marine Scotland (2014) EPS Guidelines.

1.7 Additional Consents and Licences

[1] http://www.gov.scot/Topics/marine/Licensing/marine/guidance/noise-registry

An EPS licence to disturb cetaceans will be required for pile driving. The information provided in Appendices 2 and 3 will be used in the applications for the EPS licences.

1.8 Other Relevant Documentation

Table 1.2 outlines other MORL documents which will include information that can be considered alongside the PS and its appendices described in Section 1.2. These documents will be submitted no later than 6 months prior to construction.

Table 1.2 MORL Documents

Document Name	Information Contained within Document
Construction Method Statement (CMS)	Construction methodology once the final details are known.
Construction Programme (CoP)	Final programme in relation to the CMS.
Environmental Management Plan (EMP)	Mitigation and monitoring for the project, which will include the piling mitigation outlined in this PS and Appendix 2.
Development Specification and Layout Plan (DSLP)	The final layout taking into account the layout criteria described in Section 2.1 of this PS.
Vessel Management Plan (VMP)	Document will provide further details of vessels and management measures for the project, including those involved in pile installation.

2 Engineering Background

As described in Section 1, elements of the construction works will be refined during FEED and following selection of key contractors and therefore this PS describes the process with built-in flexibility where required.

A specific supplier of WTG substructures cannot at this stage be confirmed. Similarly, vessel operators and installation contractors are yet to be confirmed. As a result the following areas of flexibility are required within the limits of the Rochdale Envelope:

- Layout (see Section 2.1);
- Pile parameters (see Section 3.1);
- Equipment (see Section 3.2);
- Vessels (see Section 3.2.1);
- Pile installation methodology, including hammer energies (see Section 3.2); and
- Piling Programme (see Section 3.4).

In addition, the PS aims to provide maximum and likely scenarios for details, such as hammer energy, which (as is the case for all piling activities offshore) will not be fully known until piling commences.

2.1 Development Plan/ Layout

The consented Rochdale Envelope allows MORL to use 6 to 8 MW turbines. Procurement is still ongoing and therefore the turbine selected for Project 1 cannot be confirmed at this stage. Further, the capacity of Project 1 will only be known once MORL enters into a CfD. As a result, the layout and detail of all WTG locations is not available. Detailed information on the project layout will be provided in the Development Specification and Layout Plan (Section 36 consents, condition 12) and the PS will be updated accordingly as required. The layout will be based on the following spacing parameters:

- Downwind 1,200 to 1,720 m;
- Crosswind 1,050 to 1,376 m;
- Turbines or rows within the windfarm array may be removed;
- WTGs orientated into the dominant wind direction; and
- Minimum spacing between MORL and BOWL is 10 x rotor diameter. The minimum rotor diameter proposed is 150 m), therefore the minimum possible spacing would be 1500 m.

The layout is also dependent on several factors including:

- Seabed geological conditions;
- Seabed bathymetric conditions;
- Seabed obstructions (micro–siting constraint);
- Physical and spatial constraints; and
- Environmental issues (micro–siting constraint).

The layout may be in a grid or diamond formation as shown in Figure 2 and Figure 3, respectively. As noted in the MORL ES analysis of the wind resource may require that some rows of turbines are "removed" from the array layout or individual turbines removed or repositioned. Although layout cannot at this stage be confirmed, MORL has been able to determine the likely proportion of foundations in each soil type present across the site, which has informed the underwater noise modelling.

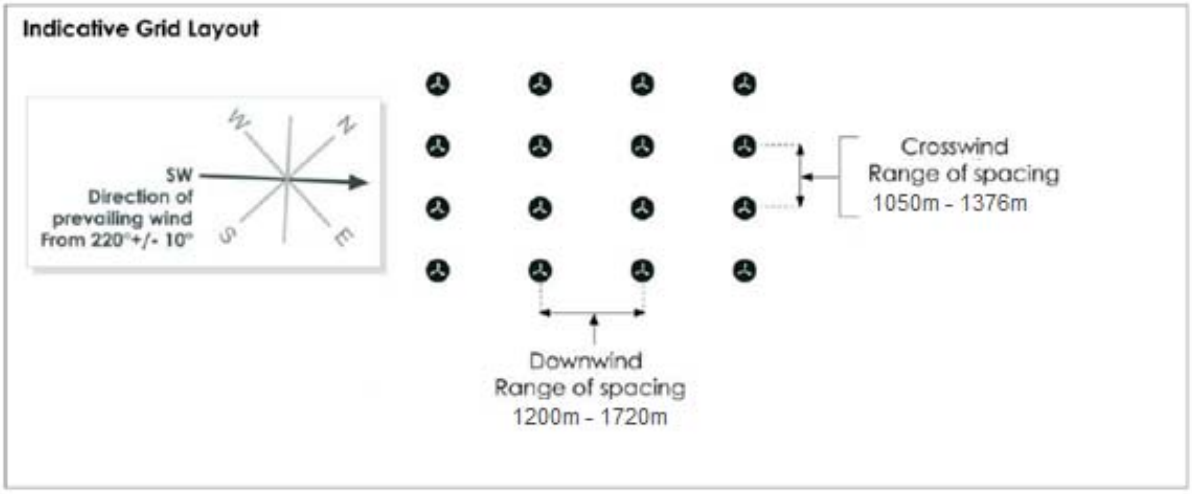

Figure 2: Indicative grid layout

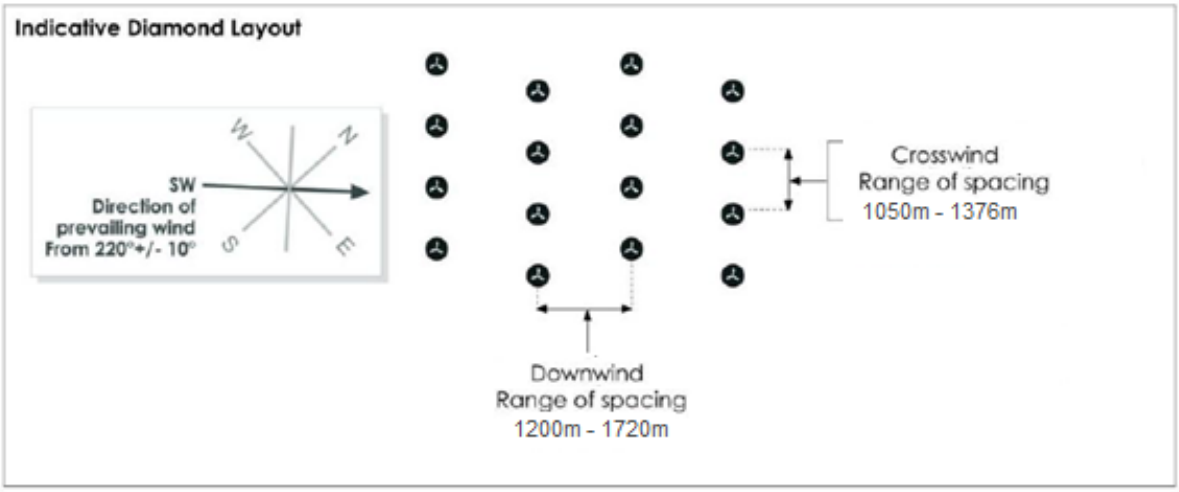

Figure 3: Indicative diamond layout

2.2 Geotechnical and Geophysical Survey Results

A seismic survey of sub-bottom geology in the EDA was undertaken between May and September 2010. The survey provided data covering the entire EDA, including the three proposed wind farm areas and a small buffer outside of the EDA.

The results show that within the EDA, the thickness of sandy marine sediments is highly variable. In the Telford Wind Farm the marine sediment veneer was found to be typically 1 to 3 m thick, increasing to 10 to 30 m in the central southern part of the site, and very thin or absent over the shallowest area in the western part of the site. In the Stevenson Wind Farm the marine sediment veneer is typically 1 to 3 m thick, but very thin or absent over the bathymetric highs in central and eastern parts of the site. In the MacColl Wind Farm the marine sediment veneer is typically 1 to 3 m thick, increasing to 5 m in the western part and 10 to 30 m at the north eastern edge of the site. The marine deposits in the three sites overlay glacial tills (compacted poorly sorted mixtures of fine and coarse material). Where the surface veneer is sufficiently thin, glacial till is exposed at the seabed surface.

In order to assess the pile driving characteristics within the EDA, 45 boreholes have been taken across the site during geotechnical investigations in 2010 and 2014. These samples coupled with geophysical seismic surveys have been used to create a detailed 'ground model' which has been used to characterise and predict subsurface soil conditions across the EDA.

Geotechnical investigations have indicated that the soils across the EDA are heterogeneous and laterally variable. This variability has been captured in the generation of six 'characteristic' design soil profiles with parameters selected covering the expected soil conditions within the EDA (see Table 2.1). The drivability of pin piles in each profile is discussed in Section 3.3.1.

Table 2.1: Soil Profiles

Soil profile	Soil type	Estimated proportion of EDA (%)
1	sand/clay	32
2	clay/sand	17
3	clay/sand/clay	8
4	Sand	21
5	Clay	8
6	sand/clay/sand	14

3 Piling Strategy

3.1 Pile Parameters

The WTG supporting foundation and substructure will be a steel lattice 'jacket' structure comprised of three or four braced legs each with a 'grouted' or mechanical connection to driven tubular pin-piles. The jacket type and therefore the number of piles (three or four) will be determined by MORL as part of the FEED engineering process which will progress through 2016. It is anticipated that a single jacket type will be selected for Project 1. There will be up to four design variants for the selected jacket type across Project 1 to accommodate water depth variation. Pile size (length and/or diameter) will also vary across the site depending on the particular soil condition at each of the wind turbine locations.

Table 3.1 provides the expected worst case for key parameters of the piles and jacket bases.

Table 3.1: Pile parameters

Feature	Parameter
Pile diameter (maximum)	2.5 m
Maximum number of piles per WTG	4
Maximum embedded length of pile	55 m
Maximum distance between piles within a jacket foundation	40 m

3.2 Pile Installation Activities and Equipment

3.2.1 Vessel Requirements

Piling will be undertaken from either a large jack up platform (JUP) or from a floating heavy lift vessel (HLV). Dynamic positioning may be used to ensure the installation vessel is in the correct position either throughout the site operation or prior to anchoring or jacking up.

Piles and jackets can be either loaded directly onto the installation vessel during a port call or be delivered directly to the vessel using a typical offshore platform supply vessel (PSV) or tugged barge (Figure 4).

Figure 4: Example Jack Up Platform and Supply Vessel with pin piles

3.2.2 Construction Methodology

Jacket pin -piles will be driven into the seabed either prior to jacket installation (pre-piled) or through sleeves / guides in the jacket following its installation (post piled). The pile driving characteristics remain consistent whichever construction methodology selected.

The following sections outline the characteristic operations and equipment involved in either methodology.

3.2.2.1 Pre-piling option

The installation vessel will travel to the WTG location from the selected port or a previous piling location. Once on site, the vessel will jack up as shown in Figure 5 or alternatively deploy anchors.

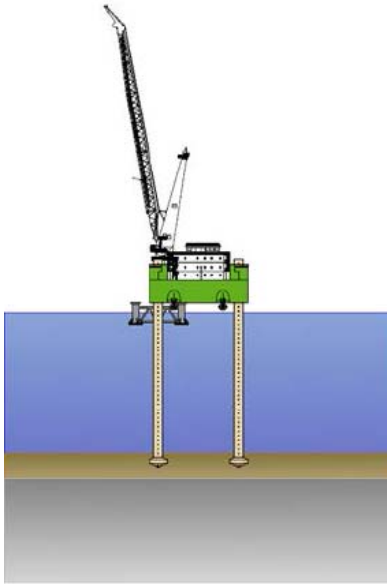

Figure 5: Installation vessel (jack up)

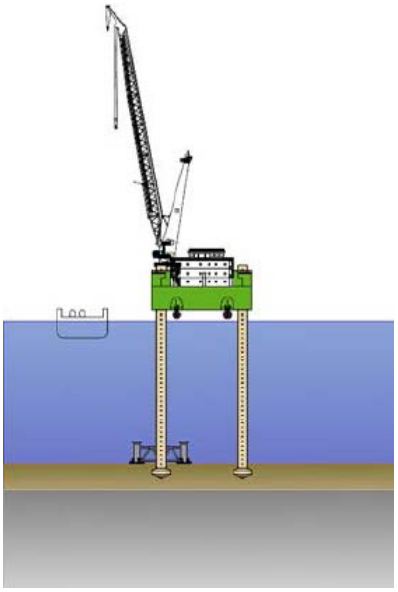

Figure 6: Deployment of the PIF

A Pile Installation Frame (PIF) is placed on the seabed and used as a template to ensure the piles are installed to fit with the jacket structure. The PIF is levelled using the PIF feet as required (shown in Figure 6). Figure 7 provides photographs of a typical PIF in transport and preparation for lowering.

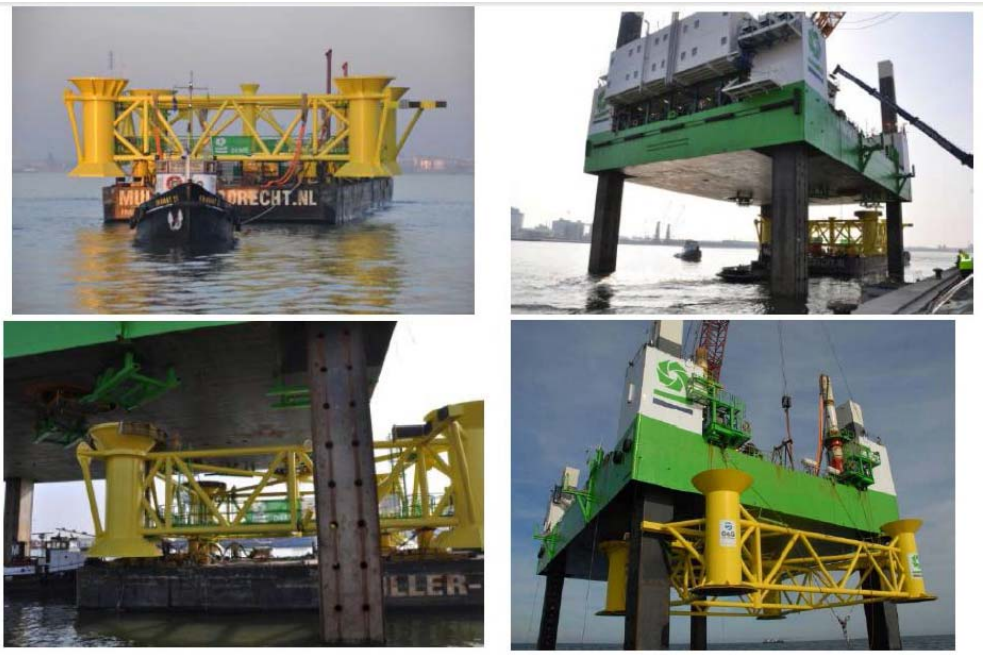

Figure 7: Transport and lowering of the PIF (from Thornton Bank II)

With the PIF in place, the installation vessel uses a crane to upend the piles and place them into the four sleeves of the PIF, ready for pile driving (Figure 8). Once lifted into position in the piling template the pile will typically self-penetrate the seabed for up to 3 m under its own weight.

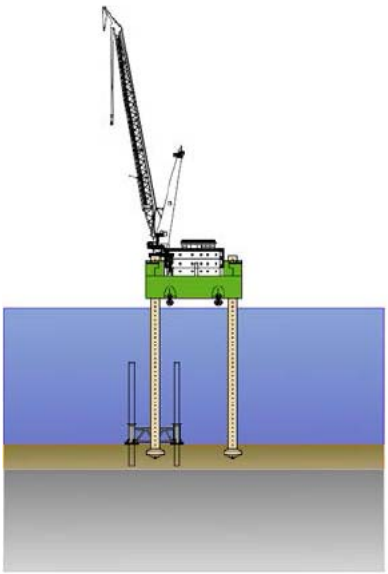

Figure 8: Pile placement

Once in position the piles are then driven to the target depth using a hydraulic piling hammer and / or seabed drilling as required, dependant on the soil conditions as discussed later in further detail (Section 3.3).

Following installation of the piles the PIF is recovered from the seabed, leaving between 2 and 12 m of the pile proud of the seabed. The steel jacket is lowered onto the pre-installed piles, (Figure 9) interfacing with the pile 'stick up' where a connection is made using a cementitious grout or other mechanical connection. This operation may occur either immediately after pile installation using the same vessel or may be done at a later date with an alternative vessel.

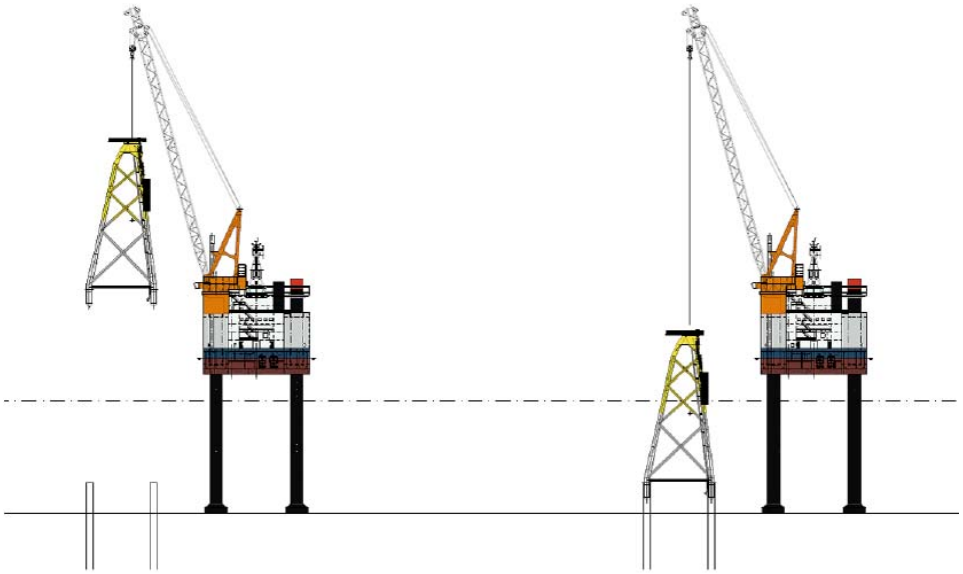

Figure 9: Jacket installation onto pre installed piles

3.2.2.2 Post-piling option

Unlike the pre-piling methodology, installation of the piles occurs after the placement of the jacket onto the seabed. Here piles are driven / drilled through the jacket structure which is already lifted into position thus removing the need for a PIF. Piles can either be installed through sleeves on the jacket at the seabed (Figure 10) or can be driven through the jacket structure from the surface (Figure 11).

Unlike the pre-piling method pile installation must be conducted at the same time, and therefore usually by the same installation vessel, as the jacket installation.

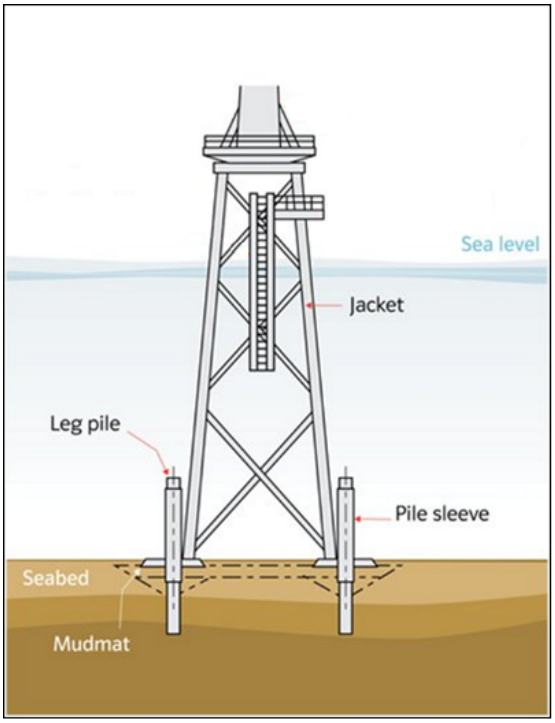

Figure 10: Piles driven through jacket sleeves above seabed

Figure 11: Photograph of post pile installation from surface

3.3 Pile Driving

Whether using a pre-piling or post piling construction methodology the method for installing the foundation piles into the seabed remains largely unchanged.

Once positioned either in a PIF or in the jacket, the piles are driven to the target depth using a hydraulic piling hammer. The piling hammer is placed on top of the pile either directly or with an intermediate pile 'follower'. The pile follower is a temporary extension to the pile that allows the pile top to be driven below the level of the piling template. Figure 12 shows a typical hydraulic piling hammer with follower.

Figure 12: Typical piling hammer with follower

Once the hammer is in position and following the deployment of ADD mitigation (see Section 3.5.3.2), the pile driving commences.

Soft start mitigation procedure (discussed in Section 3.3.3 and 3.5.3.4) is required to mitigate the potential for injury or fatality to marine mammals from the underwater noise associated with pile driving (as discussed in Appendix 2). Typically during the main piling operation, the rate of hammer blows remain constant (blows/minute) with the blow energy required adjusted by the hammer operator to maintain a steady rate of pile penetration. The rate of penetration will be constantly monitored, for example with subsea cameras (ROV or fixed onto the piling template).

During the operation, piling on a single pile may be paused or suspended for a number of reasons, including undertaking 'relief drilling' of the soil in the centre of the pile to aid installation in stiff soils. Other possible causes include poor weather, breakages of equipment, unexpected refusal or a need for pile adjustment. The restart procedure would depend on the duration of the break, as discussed in Section 3.5.3.5.

This section describes the pile driving process in relation to the following:

- Pile Driving energies;
- Hammer energy ramp to maintain pile movement;
- Soft start mitigation (embedded within the hammer energy ramp up);
- Final procedure to reach target depth; and
- Potential for simultaneous pile driving.

3.3.1 Hammer Energies and Driveability

Characteristic site geotechnical information (see Section 2.2) has been used to complete pile drivability assessments, designed to provide a forecast of the anticipated hammer energies for pile driving at pile locations across the Project 1 area. This analysis has been undertaken using a preliminary estimate of the pile geometries for the WTG foundations as the exact length will be determined during the FEED engineering stage of the project. It should be noted that although piling energy can be predicted with a moderately high level of confidence there are site specific characteristics (such as boulders) which may affect piling energy, the effects of which cannot be predicted prior to piling commencing. As the precise hammer energies required will not be known until piling is underway this document considers the likely maximum (i.e. highest expected) requirements to account for all eventualities. The PS also provides information on the most probable energies to provide more detail on the most likely scenario as well as the worst case scenario.

The pile driving methodology proposed, with the associated piling hammer energies, is designed to minimise risk to environmental receptors whilst satisfying the engineering requirements necessary to successfully complete the work and reduce the risk of pile refusal. Increases in anticipated rates of pile refusal and the need to use drilling rather than piling at higher blow energies will extend the overall construction programme.

The pile drivability assessment predicts the hammer energies required through each individual piling sequence. These assessments reflect the variation in blow energy during the driving operation, where only sufficient energy is used to maintain steady rate of penetration, and is usually characterised by progressively increasing energy, or 'ramp –up', as the pile is driven deeper before reaching a maximum energy level required at each piling location. Minimising the hammer energy protects the integrity of both the pile and hammer, and also acts to reduce unnecessary activity at full hammer energy, therefore minimising the impact zones for injury of fish and marine mammals.

For each of the characteristic soil profiles, 'most probable' and 'highest expected' maximum pile driving energies have been predicted from the drivability analysis (Table 3.2).

Table 3.2 Most probable and highest expected maximum hammer energy for each of the six predicted soil profiles

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6
Estimated % of WTG	32%	17%	8%	21%	8%	14%
Most Probable (kJ)	660	1800	636	1020	900	1140
Highest Expected (kJ)	1020	2250	996	1020	1800	1800

The driveability analysis has indicated that it is most likely that at five of the six Soil Profiles discussed in Section 2.2 piles can be driven to the target penetration depth using up to 1140 kJ, which can be achieved using a 1200 kJ hammer at maximum efficiency of 95% and a maximum blow rate of 40 per minute. For piles driven in Soil Profile 2 (the hardest predicted

soil profile) refusal before target depth has been reached is likely unless larger hammer energies can be employed.

For the worst case analysis (i.e. Highest Expected scenario), piles driven at three of the six Soil Profiles are expected to reach the target depth using less than 1080 kJ, however piles driven in Profiles 2, 5, and 6 potentially encounter early refusal at this blow energy level.

It is likely that the depth of soil penetration required for pile design in the 'hard' soil conditions will be less than is currently modelled for the drivability analysis, as shorter piles than those used in the modelling in Appendices 1 and 4 would have sufficient stability. However, the analysis indicates that between approximately 17% and 39% of locations will require piling hammer energies in excess of 1080 kJ for a small proportion of the pile installation duration in order for piles to be driven successfully, with the potential for maximum hammer energies of up to 2250 kJ required for the most extreme locations. It is expected that an increased piling energy to 2250 kJ would provide sufficient pile driving capacity to ensure design depth can be reached on all piles, minimising risk associated with potential pile refusal. The use of a 2250 kJ hammer energy has been discussed with key stakeholders (see Table 1.1) and taken into account in the piling protocol provided in Appendix 2, with revised noise modelling provided in Appendices 1 and 4, and updated marine mammal and fish impact assessments provided in Appendices 3 and 5 respectively. For all pile driving, the pile will only be driven using the upper end of the hammer energy for a short period (if at all) in the latter period of pile driving.

3.3.2 Ramp Up

As indicated in section 3.3.1 from an engineering perspective, hammer blow energy is gradually increased during the piling operation to a sufficient level to maintain a steady rate of pile penetration. This 'ramp up' in blow energy generally follows an initial 5 to 6 single blows at a low rate (approximately 1 blow per 10 seconds) using as low an energy as practically possible to check hammer operation and initially embed the pile. Hammer energy is then increased / adjusted to maintain a steady rate of pile penetration until the target depth is reached.

The ramp up is incorporated with the mitigation soft start (see Section 3.3.3, Section 3.5.3.4 and Appendix 2), where piling must remain below 500 kJ for 20 minutes, in accordance with the JNCC (2010) mitigation guidelines, following which further increases in energy levels can made as required).

Table 3.3 provides the estimate of the blow energies, calculated by MORL's geotechnical consultant, required in the worst case driving results for Soil Profile 2 (the hardest driving conditions). As can be seen, the blow energy follows a ramp up, gradually increasing as the pile gains increasing depth, up to a maximum hammer energy of 2250 kJ for Soil Profile 2 and 1020 kJ for Soil Profile 1 (Highest Expected scenarios). The estimated number of blows for Profile 2 which are above the consented 1080 kJ hammer energy represents 44% of the total estimated number of blows for the highest expected and 32% for the most probable. The maximum number of WTGs expected to require hammer energies over 1080 kJ for a small portion of the piling activities represents 39% for the Highest Expected scenario (comprised of Soil Profiles 2, 5 and 6) of the total WTGs in Project 1 (see Section 3.3.1 and Table 3.2).

The results of the Pile Drivability Analysis indicate that for the most challenging soil profile (Soil Profile 2), on the Highest Expected scenario, energies in excess of the consented 1080 kJ would only be required within approximately the last 1.5 hours of pile driving (within an overall period of 6.5 hours pile driving).The actual ramp up of hammer energy and blow rates will be

dependent on monitoring pile penetration progress while piling is underway subject to complying with the protocol in Appendix 2.

Table 3.3 Estimated ramp up (blow counts per hammer energy) for the softest and hardest soil profiles

	Blow counts per hammer energy			
	Profile 1 (most common)		Profile 2 (hardest predicted)	
Hammer Energy	Most Probable	Highest Expected	Most Probable	Highest Expected
300	7850	7500	5900	5060
360	-	-	600	660
420	1400	880	-	-
540	1120	970	890	1440
660	1710	640	-	-
720	-	-	820	1290
840	-	960	-	-
900	-	-	920	820
1020	-	1270	-	-
1200	-	-	1080	1440
1350			2110	1160
1620			440	930
1800			730	850
2250				3000

3.3.3 Soft Start Mitigation

During the 20 minute period required for soft start mitigation (see Section 3.5.3.4), hammering ramp up (as discussed in Section 3.3.2) will not exceed 500 kJ.

On completion of the soft start period, the ramp up of hammer energy will be increased in line with engineering requirements set out in 3.3.2.To reiterate, a key aim of the piling contractor is to install the pile using the lowest energy possible to minimise fatigue on the pile and hammer. This is compatible with minimising effects on marine mammals and fish ecology.

3.3.4 Pile refusal and Relief Drilling

As indicated in Section 3.3.1, pile drivability analysis has identified the potential risk that pile refusal may occur at some locations before reaching the required depth. The ability to drive the piles with hammer energies up to 2250 kJ reduces the risk of pile refusal, however, if premature pile refusal is encountered an additional relief drilling operation may be required in order to allow the pile to be driven further. Pile refusal is likely to be the result of increased soil friction to a level where penetration can no longer be achieved. This pile friction can be reduced by removing the soil from the inside of the pile, known as "relief drilling".

The Drive-Drill-Drive (DDD) operational sequence consists of the following steps (see Table 3.4):

- driving the pile until pile refusal;
- removal of the soil inside the pile by a custom built drilling tool; and
- driving the pile until target depth.

Table 3.4: Operations and durations for drill drive drill

Typical operational sequence for DDD method (four pile jacket scenario)																				
Operation	**Time**																			
Positioning and jacking up																				
Deploy piling template																				
Pile 1			Drive		Drill						Restrike									
Pile 2					Drive		Drill						Restrike							
Pile 3							Drive		Drill						Restrike					
Pile 4									Drive		Drill						Restrike			
Transfer pile for following location																				
Jacking down and transit																				

3.3.5 Potential Simultaneous Piling

Within the ES MORL made a commitment to limit piling to a maximum of two simultaneous piling events in each of the EDA offshore wind farm sites (i.e. Stevenson, Telford and MacColl), therefore six in total. For Project 1 MORL is committed to limiting the number of concurrent piling activities to three within the project boundary. Of these three, the commitment remains to have a maximum of two simultaneous piling events within any wind farm site.

Given that the spacing between the WTGs within wind farm sites will be over 1 km there will be no navigational safety issues for simultaneous piling.

The spacing between BOWL and MORL infrastructure will be over 1.5 km and therefore there will be no safety issues with simultaneous piling.

3.3.6 After Pile Driving

Once piling has been completed, a number of construction tasks are required before the vessels can move to the next WTG location, depending on the construction methodology being utilised. However as discussed in Section 3.4.1, a minimum planned break of around 15.5 hours is expected.

3.4 Piling Base Case Programme

It is anticipated that the installation of WTG foundations and support structures for Project 1 will be completed within a 24 month period. During this timeframe both pile installation and jacket installation activities for up to 100 WTGs will be completed (jacket installation is not covered by the PS and will be detailed in the CMS). This construction period will commence no earlier than 2017.

As detailed in Table 3.5, during this 24 month period there will be an aggregated duration of approximately 3 months of actual pile driving (noise generation) activity, based on up to 22 hours of pile driving each WTG (assuming no concurrent piling which would reduce the pile driving duration). The additional time in the programme is conservative and allows for:

- Sequencing and seasonal work scheduling;
- The time for pile installation activities other than the driving operation (vessel movements, relief drilling activities, setup etc);
- Jacket installation;
- Operational downtime as a result of weather, equipment failures, and other unforeseen issues; and
- Time to implement mitigation, such as seasonal herring restrictions.

The intensity of pile driving activities within the 24 month period will vary significant depending on the operational sequencing, season (related to weather downtime) and construction methodology. The durations set out in Table 3.6 show for a typical pile installation operation (excluding weather downtime etc) the time spent pile driving within the general installation activities. Here it can be seen that of the 65.25 hours estimated for installing piles for a single WTG, 22 hours (or approximately one third of the time) involves pile driving. The occurrence of weather downtime, changes to construction methodology, inclusion of drilling activities into these activities will further reduce the intensity of pile driving within the overall programme.

3.4.1 Piling Timescales

The overall timing of construction activities for the WTG foundation installation can vary significantly depending on a number of factors, including the construction methodology, operational sequence, vessel capabilities, however the overall time taken for driving each pile (i.e. period when the piling hammer is in use) will generally only vary with soil conditions. In addition to predicting hammer blow energies, the pile driveability analysis provides an estimate for the duration of pile driving required for a pile in each of the six soil profiles discussed in Section 2.2. Table 3.5 gives the typical estimated driving durations for a typical pile in each of the characteristic soil profiles.

Table 3.5: Estimated pile driving duration per pile for different soil profiles

Soil Profile	Most Probable Duration (hours)	Highest Expected Duration (hours)
1	5.0	5.1
2	5.5	6.5
3	3.9	4.5
4	5.2	Continuous sand profile and therefore only 'most probable' is applicable
5	5.1	5.4
6	5.1	5.2

For operational reasons the pile driving duration (for each pile) may not be continuous as, depending on the construction methodology, driving may be suspended on a single pile prior to achieving target depth (to undertake relief drilling, commence piling an adjacent pile, add a pile follower or other intervention) before returning to finish driving to depth. Notwithstanding this potential variation, it is anticipated that the maximum aggregated timescale for driving the piles at a single WTG location in a given 24 hour period is not likely to exceed 16 hours, or the equivalent time of three 'average' piles fully driven. This is the basis of the cumulative SEL calculations as detailed in Appendix 1 (Underwater Noise Modelling).

With the above considerations in mind, indicative average operational timescales for the pile installation works are presented in Table 3.6, relating to the pre-piling process described in Section 3.1. This table illustrates the overall pile installation duration and the proportion of time within which pile driving will occur. The constraints around the overall programme for piling are discussed in Section 3.4.2.

Table 3.6: Approximate operational timescales – pile installation (excluding weather or operational downtime)

Task	Average Duration (hours)	
	3-pile	4-pile
Set-up activities for each WTG location		
Sailing to site, jack up/anchor and preparation	7.5	
Lift, install, position and level Pile Installation Frame (PIF)	4	
Lift, upend and place piles into PIF	5	6
Deploy and activate ADD 15 minutes prior to piling start	0.25	
Set up total	*16.75*	*17.75*

Task	Average Duration (hours)	
	3-pile	**4-pile**
Pile installation operations for each WTG location		
Total (aggregate) time for Pile Driving including soft starts – note this will be discontinuous and these timings do not include planned or unplanned breaks in piling activity. Assumes average expected soil conditions (Section 2.2)	16	22*
Other activities (total) in between operation of pile hammer including, soil plug removal, lifting hammer between piles alignment checks etc. This assumes no relief drilling required – this should be considered as a minimum.	8	10
Pile installation total	*24*	*32*
Post-pile installation activities for each WTG location **		
Perform pin pile measurement	1	
Recover PIF to Heavy Lift Vessel (HLV) deck or Jack Up Platform (JUP)	1	
Transfer next pin pile from delivery vessel	7	8
Vessel jack down / pick up anchors and move from location	5.5	
Post-pile driving total	*14.5*	*15.5*
Total duration for installation piles for a single WTG **	**55.25**	**65.25**

* Note: three piles would only be driven in any 24 hour period.

** Assumes only pile installation activities during these works, if jacket installation (on to pre piles) is undertaken by the same vessel the overall duration will increase.

Section 3.5.3.5 outlines the protocol for restarting piling following breaks in relation to the need for ADD deployment and soft start mitigation. As shown in Table 3.6, there will be approximately 15.5 hours of post-pile driving activities plus time to move to the next location, and pre-piling activities. Therefore a full start up procedure (see Section 3.3) will be required at the start of piling a new WTG location.

3.4.2 Construction Programme Constraints

Construction of each wind farm (i.e. Telford, Stevenson or MacColl) must commence in accordance with Condition 2 of the Section 36 consent or as directed by the Scottish Ministers.

Condition 33 of the Section 36 consents for the Telford and Stevenson wind farms requires that there is no piling within the mitigation zone in these sites during any year of construction involving piling for a maximum period of 16 days (not necessarily consecutive days) in August

and September. In addition to consent condition 33, MORL will undertake not to pile using hammer energies over 1080 kJ outwith the herring mitigation zone (where there is no seasonal restriction) during this maximum 16-day period.

The base case is for one piling vessel operating at one time, however there could be up to three vessels operating in Project 1 which would reduce the piling duration for Project 1. Of the three vessels operating in Project 1, a maximum of two would be located in any one of the three EDA sites (i.e. Telford, Stevenson or MacColl) in accordance with commitments made in the ES.

3.5 Piling Mitigation Measures / Procedures

3.5.1 Herring

3.5.1.1 Seasonal Restrictions

As discussed previously, consent condition 33 places seasonal restrictions on piling within the mitigation zone within the Telford and Stevenson sites. During these periods there must be no piling for a maximum of 16 days in August and September. Herring surveys were carried out by BOWL during 2014 and 2015 (see BOWL, 2016). The results of the surveys show strong evidence that the main herring spawning grounds (Orkney-Shetland herring stock) are further north than considered in the MORL ES assessments and beyond the area of potential impact from piling noise at Project 1. Nevertheless it is acknowledged that the concentrations of herring spawning may vary in their spatial extent over the years and therefore MORL will carry out desk studies and surveys to assess the requirement for a piling restriction in order to mitigate effects on herring spawning. The piling restriction of up to a maximum of 16 days, if required, will be determined based on the results of the desk-studies and surveys and through consultation with MSS and MS-LOT. Further details on the scope of surveys and assessment will be presented within the PEMP.

In addition to consent condition 33, MORL will undertake not to pile outwith the herring mitigation zone using hammer energies over 1080 kJ during this maximum 16-day period.

3.5.2 Shipping

3.5.2.1 Safety Zones

In accordance with the Electricity (Offshore Generating Stations) (Safety Zones) (Application Procedures and Control of Access) Regulations 2007, it is expected that a 500 m safety zone around each renewable energy installation will be applied for under Section 95 of the Energy Act 2004 during the period of construction works for Telford, Stevenson and MacColl. In order to minimise disruption to navigation by users of the sea, safety zones are expected to be established around such areas of the total site that have activities actually taking place at a given time. As such the safety zones are expected to follow the construction activity throughout the different areas of the site as construction work is undertaken. The exact locations are to be determined at a later stage and would be notified to mariners. Safety Zones in place on the Project will be implemented and communicated through standard protocol (i.e. Notice to Mariners).

3.5.3 Underwater Noise – Marine Mammals and Fish

Mitigation is aimed at reducing the risk of fatality and injury during the initial piling strikes for marine mammals (cumulative noise exposure and disturbance are not considered part of the main objectives of mitigation for marine mammals as detailed within the Annex of Appendix 2). Condition 11 of the Section 36 consent states that mitigation must be provided to minimise effects on Atlantic salmon, cod, herring, harbour seal, and bottlenose dolphin.

MORL has included harbour porpoise in the considerations for mitigation and monitoring in this document at request from the MFRAG-MM Subgroup (please see Table 1.1 for details) and as a recognition that this is the most common EPS within the site.

An assessment of the potential risk to different mammal species in the absence of any piling mitigation was carried out for the following species; harbour seal, grey seal, harbour porpoise, minke whale and bottlenose dolphin. The assessment highlighted that the risk of instantaneous death or injury at the start of an individual piling event is extremely low (please see Annex 3 within Appendix 2 Piling Protocol for further details on the risk assessment).

Of the piling process outlined in Section 3.3, the following key mitigation processes will be undertaken:

- Deploy ADD for 15 minutes prior to piling as agreed with JNCC and SNH (see Table 1.1);
- Employ a soft start when commencing piling with blow energies remaining at less than 500 kJ for 20 minutes;
- Minimise hammer energies at levels sufficient for pile driving, resulting in an energy ramp up throughout the piling operation.

These are considered in detail in the Piling Protocol (Appendix 2). A phased piling mitigation will also be employed for a period not exceeding 28 days during the piling campaign at Project 1, where a combination of MMOs, PAM and ADD are deployed. The phased piling mitigation strategy details are provided within Appendix 7. A summary of the piling mitigation is provided below.

3.5.3.1 Optimise Hammer Energies

MORL will use the minimum practical hammer energy for each pile which will reduce the underwater noise impacts below those assessed. The assessment is based on the maximum capacity of the required hammer but in reality, the hammer will not be used at full capacity for the majority of the activity, if at all (Section 3.3).

3.5.3.2 Acoustic Deterrent Devices

Piling at any time of day or night and in reduced visibility condition is essential for the financial viability of Project 1 and therefore the mitigation for marine mammals has been designed to avoid reliance on visual surveys by MMOs. It is proposed that ADDs are used instead, to displace marine mammals from the mitigation impact zones (see Section 3.5.3.3) with the aim of removing animals from an area where there is potential for injury or fatality to be caused by piling noise. The ADDs will be selected to have sound levels and frequencies which are appropriate to the hearing capabilities of the key marine mammal species present at the site to stimulate a disturbance response and cause the animals to leave the mitigation impact zones. Appendix 2 provides further detail on the use of ADDs.

The ADDs will be deployed at the piling site for a period of 15 minutes prior to piling (as agreed with the MFRAG-MM Subgroup), to allow marine mammals to be displaced out of the impact zones. ADD deployment is determined by the size of the injury zone at each pile (based on predicted hammer energies) and the animal's swimming speed (see Appendix 2).

The 20 minute soft start mitigation (see Section 3.5.3.4) would commence after the ADD deployment has been completed.

Selection of ADD will be based upon available evidence on effective displacement of key receptors for each site. The duration of ADD use is aimed at balancing the key objective of dispersing animals from the injury zone against any risks of habituation to the ADD source or significantly increasing disturbance effects (Appendix 2).

Further information is included within ADD Procedure in Appendix 6. A detailed method statement will be produced and included in the PS once the Substructures and Foundations EPCI contractors and the ADD operators have been appointed. Any updates to the PS will be submitted to MS-LOT for approval.

3.5.3.3 Mitigation Impact Zones

A mitigation zone must be identified which ensures that no marine mammals are within a range which may cause injury or fatality when piling starts. For the marine mammal species relevant to the Project 1, the maximum range at which instantaneous injury might occur is 60 m based on the conservative underwater noise modelling described in Appendix 2, Annex 1.

In order to be precautionary, MORL will use ADD for 15 minutes (as described in Section 3.5.3.2). Based on a conservative swim speed of 1.5 m/s for all marine mammal species this will provide a mitigation zone around 1350 m which far exceeds the minimum 500 m mitigation zone identified in the JNCC piling guidelines. It was determined through consultation (MFRAG-MM Subgroup Meeting (19/06/2015) and further written feedback received from the SNCBs, see Table 1.1) that deploying an ADD for 15 minutes would be sufficient to allow a marine mammal to travel twice the radius of the likely impact zone at all locations.

3.5.3.4 Soft Start

Soft start will commence with 5-6 single blows at a low rate using as low an energy as practically possible (as detailed in Section 3.3.2). The soft start will then continue for a minimum of 20 minutes, in accordance with JNCC guidelines (as mentioned in Section 3.3.3). During this time the hammer energy will start at an energy of 300 kJ or less and will not exceed 500 kJ. The aim of the soft start is to allow marine mammals to move away from the piling activity before the noise reaches a level that could potentially result in injury or fatality. Soft start will also provide mitigation for effects on fish.

3.5.3.5 Protocol for Planned or Unplanned Breaks

Appendix 2 provides an outline of the approach following a planned or unplanned break, dependent on the duration of the break. In the event of breaks in piling of less than 10 minutes no additional mitigation would be required (i.e. the piling may continue from the hammer energy and frequency last used).

For breaks in piling of greater than 10 minutes there are two possible outcomes:

- Where duration of break is either unknown, or known to be less than 2.5 hours:
    - Deploy ADD for the 15 minute period prior to piling recommencing;

  - Initiate piling with approximately 5 - 6 single blows at low energy; and
  - Continue to ramp up hammer energy to the levels required to maintain pile movement at approximately 2.5 cm/blow.
- If the break is greater than 2.5 hours, or if the break occurs during the soft start procedure described:
  - Re-start piling mitigation procedure as outlined previously in this section (Sections 3.5.3.2, 3.5.3.3, and 3.5.3.4).

Change over between piles of one WTG foundation is expected to be between 0.5 to 2 hours and therefore ADD will be deployed for 15 minutes prior to piling commencing and then energy ramp up will be undertaken to levels required to maintain pile movement at approximately 2.5 cm/blow. Mitigation soft start will not be required unless breaks are longer than 2.5 hours as outlined above.

3.5.3.6 Phased Piling Mitigation

The 'Phased Piling Mitigation Strategy', will comprise of two stages:

- Stage 1 implements mitigation recommended in the JNCC (2010) protocol as outlined in the JNCC 2010 guidelines for minimising the risk of injury to marine mammals from piling noise, requiring the use of MMOs and PAM operators;
- Stage 2 follows the Piling Mitigation Protocol as set out in Appendix 2, using ADDs and soft start with the addition of MMOs and a PAM operator to record a log of visual and acoustic detections of marine mammals during this stage.

Following the phased mitigation period, mitigation will be implemented in accordance with the Piling Protocol (Appendix 2) for the remainder of the piling operations. Monitoring will be undertaken to determine the effectiveness of each mitigation method and data collected over the phased mitigation period will be provided to MS-LOT. Data collected will provide a record of passive acoustic detections and sightings (or lack thereof) within each stage. Data will be presented to MS-LOT using JNCC marine mammal data recording forms, and as a report summarising the observations.

Full details of the phased mitigation strategy are provided in Appendix 7.

3.6 Monitoring and Validation of Assessment Results

3.6.1 Underwater Noise Monitoring

Under the Marine Strategy Regulations (2010), there is a requirement to monitor loud, low to mid frequency (10Hz to 10kHz) impulsive noise. MORL is committed to undertaking noise monitoring during piling in order to validate the results and conclusions drawn from pre-construction noise modelling and underwater noise assessments for fish ecology and marine mammals. Full details of underwater noise monitoring methods, as agreed with stakeholders, will be provided within the PEMP. A summary of MORL's expected approach to during piling noise monitoring is provided below.

3.6.1.1 Aims of Monitoring

Predictions on the SEL and propagation behaviour of underwater noise based on detailed modelling have been made both during the ES and then updated within Appendices 1 and 4 of this document. The results of the modelling have been used to inform subsequent receptor led assessments into the impact of underwater noise on bottlenose dolphin, harbour porpoise and harbour seal (Appendix 3) as well as cod, herring and Atlantic salmon (Appendix 5). In order to validate the results of the noise modelling and the associated impact assessments, underwater noise monitoring will be undertaken during piling.

Underwater noise monitoring will aim to validate the noise modelling (presented in Appendices 1 and 4). The noise measurements will produce data which will determine whether observed underwater noise SEL generated during piling is as predicted through modelling. The monitoring will also seek to determine whether noise propagation assumptions used in the model and subsequent results remain valid when compared to those observed during piling.

The results of underwater noise monitoring can then be used to validate or inform the rationale for the proposed mitigation to be implemented during piling. Where there is a significant deviation between underwater noise levels recorded and the conclusions made within MORL's noise modelling, stakeholders will be informed and consulted to determine an appropriate response.

3.6.1.2 Data Collection

Underwater noise measurements would be collected using seabed mounted noise recorders, similar to those used by Merchant *et al.* 2014 to monitor ship noise and by MSS as part of the East Coast Passive Acoustic Monitoring programme. Monitoring would be undertaken using a combination of shorter term near-field deployments of noise recorders around initial piling sites and longer term (medium and far-field) deployments.

For the near-field deployments, noise recorders would be mounted on the seabed at a suitable (and safe) distance from the source of noise (pile). Underwater noise levels would be recorded during piling and the results used to validate conclusions of SEL within the predicted marine mammal injury zone and near-field area.

Medium and far-field noise recorders will be deployed at increasing distances from the pile with the aim to validate predictions of noise propagation behaviour and SEL over a wider range, focusing on validating conclusions made for sensitive areas.

3.6.2 Mitigation Monitoring for Marine Mammals

MORL is committed to undertaking sufficient pre-construction monitoring of marine mammals in order to validate population and distribution conclusions as well as to provide further information to ensure proposed mitigation methods are appropriate. Further detail will be set out in the PEMP.

Details of marine mammal mitigation to be implemented during piling are provided in Appendix 2 (Piling Protocol), Appendix 6 (ADD Procedure) and Appendix 7 (Phased Piling Mitigation Strategy) of this PS. During construction monitoring by noise recorders (data recorders) will focus on validating that the ADD based mitigation protocol is appropriate, operating effectively and providing the level of protection predicted through pre-construction impact assessment (Appendix 3) and risk assessments (Appendix 2). This monitoring will also be tied into noise monitoring results to assess whether conclusions made in predicting the size of injury zones are valid.

A full description of monitoring methods would be provided in the PEMP, the following summarises the intended approach:

3.6.2.1 Harbour Seals

Following discussions within MFRAG-MM Subgroup it was agreed that whilst there is limited opportunity for dedicated work during construction, broader scale tracking work under Work Package (WP) 1.3 of the MMMP (harbour seal responses to pile-driving, Thompson 2015) may provide opportunistic evidence of responses to ADDs should harbour seal be in near field areas during a soft start. Any other focussed work outside the construction area would need to build upon recent MS funded work by Sea Mammal Research Unit (SMRU), most likely through the Offshore Renewables Joint Industry Programme (ORJIP).

Further details will be discussed and agreed through the MFRAG-MM subgroup and provided to MS-LOT as part of the construction MMMP scope, which will also be reported within the PEMP.

3.6.2.2 Harbour Porpoise

<u>Aims of Monitoring</u>

Data gathered will be used to validate conclusions made with respect to harbour porpoise responses to the use of ADD and soft start procedures as well as the time predicted for harbour porpoise to return to the area of displacement during periods of piling inactivity. The validation of predictions regarding the 'flee response' and return times will provide evidence to support the rationale used to design the mitigation protocol. The aim of the monitoring will be to provide evidence as to the effectiveness of the mitigation implemented.

<u>Data Collection</u>

It is anticipated that fine-scale data from animals within 100 m of the source of noise would not be robust enough to draw conclusions as the sample size is expected to be very small, although, it may be possible to attain observational evidence to support conclusions. Monitoring (using passive acoustic monitoring data loggers) is expected to be more effective at measuring medium-scale responses of animals between 100 m and 1,000 m from the source of sound. If animals exhibit responses over this scale, it can then be confidently inferred that avoidance responses at less than 100 m would be the same or stronger.

Monitoring of harbour porpoise responses would be undertaken in two phases, each consisting of seabed mounted passive acoustic monitoring data loggers placed around a pile site. Multiple data loggers would be deployed, with the first being 500m from the pile location and subsequent loggers placed at increased distances. It is anticipated that three or four data loggers would be appropriate to obtain data at the necessary scale. Sampling sites for data loggers will be selected to provide:

- Graduated distances for each piling sequence; and
- Variations in baseline abundance through the consideration of harbour porpoise habitat preference.

Phase 1 of the construction monitoring programme would be undertaken at the start of the piling campaign. Phase 2 of the construction monitoring would be undertaken part way through the piling campaign to allow a comparison of response and return times observed at the start of the piling campaign.

To avoid interference with piling operations, it is expected that data loggers would be deployed by a separate vessel 1-2 weeks prior to installation of the pile. Devices and or/device moorings will be fitted with transponders so that construction vessels working within the wind farm site can locate and avoid the devices. Recovery of the devices would be via a separate vessel after piling has been completed once it is safe to do so.

Reporting

Results of the monitoring programme will be reported to key stakeholders within an agreed timescale after the completed collection of the data results. This will ensure that if results are significantly different to those predicted through modelling, appropriate action can be taken at an early stage.

Reporting of the results of phase 2 of the monitoring programme will be compared with the results of phase 1 and submitted to stakeholders within an agreed timeframe after the completed collection of phase 2 data.

3.6.3 Mitigation Monitoring for Fish

Mitigation for fish species identified within condition 11 has been discussed with stakeholders during the determination period (i.e. in advance of project consents award) and post consent. MORL is committed to undertaking seasonal restrictions on piling within the Stevenson and Telford wind farm sites during the herring spawning period (subject to the conclusions of any herring spawning surveys carried out in the Moray Firth as mentioned in Section 3.5.1.1). Soft start will also be employed (as discussed in Section 3.5.3.4) and in addition MORL will not undertake any piling using hammer energies over 1080 kJ during this period in any of the three EDA sites outwith the herring mitigation zone. No further mitigation for fish has been proposed. Monitoring for fish ecology will be agreed as part of the PEMP.

3.6.4 Compliance Monitoring

3.6.4.1 Underwater Noise

Monitoring of underwater noise will be done via a noise register, which is requirement of the Marine Licence. This monitoring will also be captured in the PEMP and will aim to ensure the hammer energies and noise levels remain within agreed limits. Marine Strategy Framework Regulations requires completion of a noise registry form or database at the application stage which allows applicants to provide details on the proposed work. Completion of a 'close-out'

form, which allows licensees to provide details of the actual dates and locations where the activities occurred, is required at quarterly intervals or after each phase of foundation installation.

3.6.4.2 Marine Mammal and Fish Mitigation

Monitoring of ADD deployment (marine mammal mitigation) and soft start implementation (marine mammal and fish mitigation) will be undertaken during piling. It is anticipated that an independent ADD operator, positioned on the installation vessel, would be used to deploy the ADD in accordance with the protocol outlined in Appendix 2. Compliance reports to demonstrate ADD operation and soft start protocols would be undertaken in accordance with agreed methods would be submitted to JNCC and MSS on a regular basis.

3.6.4.3 Herring Mitigation

In order to comply with the seasonal restriction on piling within the Stevenson and Telford wind farms, if required, MORL will provide evidence to the Scottish Ministers that Condition 33 of the Stevenson and Telford Marine Licences has be complied with, to show that piling has not been undertaken on the up to 16 days of the herring spawning period within the herring mitigation zone. In addition, MORL will not exceed 1080 kJ on these days on any other part of the sites within the EDA. Evidence for this will be provided through environmental reporting systems which will be defined within the EMP.

Further details on compliance monitoring will be provided within the PEMP.

4 Validation of Project 1 Effects Within MORL ES Assessments

As discussed in Section 1.1, the design envelope for the EDA assessed in the MORL ES was based on a maximum of 339 wind turbine generators (WTGs) installed on four legged jackets i.e. 1,356 piles (excluding additional piles required for up to eight offshore substation platforms).

The EIA was undertaken on this basis and the outcomes of the marine mammal impact assessment and the fish impact assessment were deemed to be acceptable.

The Section 36 consent reduced the total number of WTGs in the EDA to 186 (which would represent a maximum of 744 piles) in order to mitigate potential effects on birds during operation. This will also reduce the effects on marine mammals and fish. Project 1 will have a maximum of 100 WTGs (up to 400 piles), leaving the remainder of the consented capacity for a second phase of development.

Table 4.1 provides a summary of the Project 1 parameters considered in this PS compared with the Rochdale Envelope parameters assessed in the MORL ES.

Table 4.1 Comparison of parameters used in the MORL ES and the assessment for Project 1

	Rochdale Envelope provided in the ES	Project 1
Project Description		
WTG Foundations	Up to 339 WTG Foundations – 1356 no. of piles[2]	Up to 100 WTG Foundations – 400 no. of piles.
Foundation type	Jackets or GBSs.	Jackets – three or four legged.
Simultaneous piling	Maximum 6 simultaneous piling events across Telford, Stevenson and McColl OWFs.	Most likely scenario is represented by a single piling vessel, but with the potential for up to three vessels as a result of construction delays.
Piling duration	Maximum of 5 years 3.25 hours pile driving per pile, and 2 piles per 24 hours.	Piling duration dependent on soil profiles. Modelled worst case of 6.5 hours of piling for Soil Profile 2, with three piles in a 24 hour period. Piling campaign up to two years (average of five hours per pile and in the order of 84 days[3] of piling in total).

[2] Consented projects: up to 186 WTG (744 piles).

[3] See Section 3.4 for more details on piling base case programme.

	Rochdale Envelope provided in the ES	Project 1
Piling energies	All assessment based on worst case, which included up to 2 hours of 1080 kJ.	Predicted blow energies dependent on soil profiles – 61 % of WTG predicted to be below 1080 kJ; 39 % of WTG may require higher energies (>1080 kJ) for last up to 1.5 hours of piling.

4.1 Marine Mammals

Appendix 3 provides estimates of the number of individuals for each marine mammal species that are predicted to experience the onset of Permanent Threshold Shift (PTS) during the Project 1 development taking into account the varying hammer energies for each Soil Profile as shown in Table 3.2. A summary of the results from Appendix 3 is provided in Table 4.2 alongside the numbers of individuals predicted to experience the onset of PTS according to the assessment in the MORL ES. It can be seen that the revised assessment represents a significant reduction of potential effects on marine mammals.

In addition, a reduction on the number of simultaneous piling events (from six to three) is also considered for Project 1.

Table 4.2 Estimated number of individuals receiving Permanent Threshold Shift (PTS) onset for marine mammal species assuming the highest blow energy is required for pile installation at all locations. HE – Highest Expected scenario, ML – Most Likely scenario.

Soil type	% of WTG locations present	Bottlenose dolphin (198 dB)		Harbour porpoise (198 dB)		Grey seal (186 dB)		Harbour seal (186 dB)	
		HE	ML	HE	ML	HE	ML	HE	ML
1	32%	0.00	0.00	0.28	0.28	16	13	14	11
2	17%	0.01	0.00	0.74	0.33	25	16	23	14
3	8%	0.00	0.00	0.07	0.07	4	4	4	3
4	21%	0.00	0.00	0.33	0.33	12	12	11	11
5	8%	0.01	0.00	0.35	0.16	12	8	11	7
6	14%	0.01	0.00	0.61	0.27	20	13	19	11
Total number for Project 1		**0.03**	**0.00**	**2.38**	**1.44**	**89**	**66**	**82**	**57**
ES (Scenario A)		**0.06**		**6.4**		**170**		**121**	
Percentage reduction		**50%**	**~100%**	**62.8%**	**77.5%**	**47.6%**	**61.2%**	**32.2%**	**52.9%**

4.2 Fish

Appendix 4 provides underwater noise modelling based on the parameters of this PS and provides a comparison with the assessment presented in the MORL ES.

As a result of the updated project parameters for Project 1 (outlined in Table 4.1), Appendix 5 shows there have been some increases in spatial extent of areas of risk for displacement/injury for the key fish species (cod, salmon and herring) under both the MP and HE scenarios when compared to those predicted in the MORL ES. However the findings of the geotechnical survey (Section 2.2) show that only a limited proportion of locations (17% under the MP scenario) may require hammer energies above 1080kJ and that these would only be required at the latter period of pile driving (up to approximately 1.5 hours) (Section 3.3). As a result the majority of piling activity will have a lower effect overall than those predicted by the conservative underwater noise modelling.

In addition, Project 1 will be a maximum of 100 WTG foundations which is significantly less than assessed in the MORL ES. This would also reduce the overall predicted effects of the Project in terms of temporal duration compared to that assessed previously.

MSS is currently undertaking research regarding the potential effects of underwater noise generated during piling on salmon. In addition, further research has been undertaken examining the migratory behaviour of adult salmon which has a potential bearing on their

exposure to underwater noise. However, at the time of writing the results from this work were unavailable and cannot therefore be used to inform this assessment.

A summary of the results from Appendix 5 is provided in Table 4.3 and shows that the increase in maximum blow energy from a maximum of 1080 kJ to up to 2250 kJ for Project 1 is not considered to cause a significant change to the conclusions of the ES and demonstrates that the effects of Project 1 are within the overall effects predicted in the ES.

Table 4.3 Summary of the Fish assessment provided in Appendix 5

	Rochdale Envelope provided in the ES	**Project 1**
Assessment Approach		
Noise modelling	Subacoustech noise modelling dB_{ht} (*Species*) metric.	Subacoustech noise modelling dB_{ht} (*Species*) metric. Subsequent comparison against MORL 2012 ES assessment.
Impact Assessment criteria	Subacoustech noise modelling dB_{ht} (Species) metric.	Subacoustech noise modelling dB_{ht} (Species) metric. Subsequent comparison against MORL 2012 ES assessment.
Residual Effects		
Herring	Minor: no significant effects	Minor: no significant effects
Cod	Minor: no significant effects	Minor: no significant effects
Salmon	Minor: no significant effects	Minor: no significant effects

5 References

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moray offshore renewables ltd

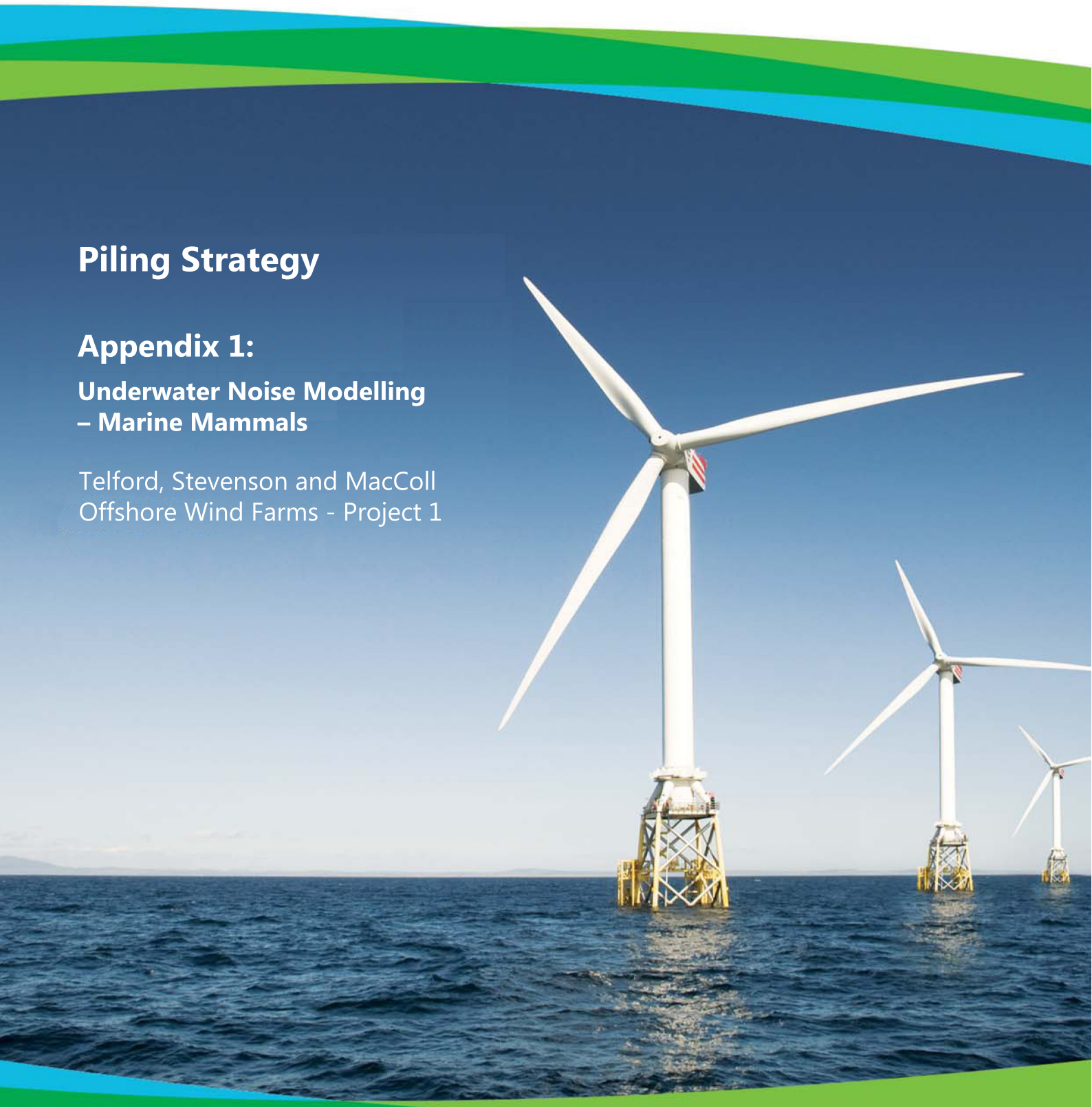
Developing Wind Energy In The Outer Moray Firth

Piling Strategy

Appendix 1:

Underwater Noise Modelling – Marine Mammals

Telford, Stevenson and MacColl Offshore Wind Farms - Project 1



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APPENDIX 1 Underwater Noise Modelling – Marine Mammals

Produced by Cefas on behalf of Moray Offshore Renewables Ltd	
Produced by	Dr Nathan Merchant, Dr Adrian Farcas, Rebecca Faulkner
Reviewed by	Dr Nathan Merchant
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Legal Review

Reviewed by	Company
Patricia Hawthorn	Shepherd and Wedderburn

Moray Offshore Renewables Ltd Approvals

Offshore Consents Manager	Head of Development	Project Director
Catarina Rei	Sarah Pirie	Oscar Diaz
[redacted]	[redacted]	[redacted]

Ecological Clerk of Works Approval

Company	Name	Signature
Royal Haskoning DHV	Benjamin King	[redacted]

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Executive Summary

This report presents an assessment of the noise levels which may be generated during the construction of the MORL offshore wind farm (Project 1) in the Moray Firth. Since the Environmental Statement (ES) (MORL, 2012) was completed, a more detailed assessment of the engineering requirements for the piling operation has been carried out, including the hammer energies which will be needed to install the piles. This assessment considers the potential effects of noise on marine mammals at the site in light of this new information, in the context of the predictions made previously for the ES.

Source levels of impact piling were modelled based on hammer energy profiles for five possible piling scenarios (most likely and highest expected scenarios for the three soil profiles best represented within the development area). These source levels were then input into an acoustic propagation model - which took into account sediment, bathymetry and water column properties at the site – to produce noise maps of received levels throughout the Moray Firth. These predictions were combined with noise exposure thresholds for marine mammals (harbour porpoise, bottlenose dolphins, and grey and harbour seals) obtained from the peer-reviewed literature. Effect zones were then mapped for temporary and permanent auditory impairment.

Although the maximum hammer energy for one of the modelled piling profiles was higher than in the ES (2,250 kJ, compared to 1,080 kJ), the noise levels predicted were lower, due to a more realistic source level model being used, informed by recent peer-reviewed studies of impact piling noise. As a consequence, the predicted effect zones for marine mammals were smaller in a like-for-like comparison with the ES predictions. More detailed analysis of the noise results in relation to marine mammals, based on the results of this modelling, are provided in Appendix 3.

1 Introduction

This report provides an updated assessment of the noise levels which may be generated during the construction of the MORL offshore wind farm (Project 1). The work presented takes into account more detailed site investigations and updated pile drivability assessment and engineering requirements. This updated underwater noise assessment is based on realistic expected worst case scenarios that have reduced significantly from those outlined in the ES. This document will highlight differences between this assessment and the ES and place them into context.

As part of the Piling Strategy (PS) condition for the MORL windfarm (condition 11 of the Section 36 consents), MORL is required to provide the following information:

> *"In the event that pile foundations are to be used, the Company must, no later than 6 months prior to the Commencement of the Development, submit a Piling Strategy ("PS"), in writing, to the Scottish Ministers for their written approval. Such approval may only be granted following consultation by the Scottish Ministers with the JNCC, SNH and any such other advisors as may be required at the discretion of the Scottish Ministers. The Development must, at all times, be constructed in accordance with the approved PS (as updated and amended from time to time by the Company). Any updates or amendments made to the PS by the Company must be submitted, in writing, by the Company to the Scottish Ministers for their written approval.*
>
> *The PS must include:*
>
> *a. Full details of the proposed method and anticipated duration of pile-driving at all locations;*
>
> *b. Details of soft-start piling procedures and anticipated maximum piling energy required at each pile location; and*
>
> *c. Details of mitigation and monitoring to be employed during pile-driving, as agreed by the Scottish Ministers.*
>
> *The PS must be in accordance with the ES and reflect any surveys carried out after submission of the Application. 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; Atlantic salmon; cod; and herring.*
>
> *The PS must, so far as is reasonably practicable, be consistent with the EMP, the PEMP and the CMS."*

The marine mammal species to be assessed as part of the PS are therefore bottlenose dolphin (*Tursiops truncatus*) and harbour seal (*Phoca vitulina*). In this assessment we additionally include harbour porpoise (*Phocoena phocoena*) and grey seal (*Halichoerus grypus*). Harbour porpoise was included following a request from the Statutory Nature Conservation Bodies (SNCBs) that this species should be considered in the Piling Protocol (see Appendix 2) and therefore also in the PS. The noise exposure criteria for the harbour seal apply equally to the grey seal (see Section 2.2), a position that is supported by the scientific literature (Southall *et al*., 2007; NOAA, 2015) and by the Offshore Renewables Joint Industry Group (ORJIP), and therefore the results provided for harbour seal will also be applicable to grey seal. However, this report will refer only to harbour seals as this is the species identified in the piling strategy condition.

The effect zones predicted for each species were used in the updated marine mammal assessments which are presented in Appendix 3 of the PS.

The report is structured as follows:

- Section 2: Methodology and background information on the MORL site; details the noise exposure criteria that were applied, the procedure for source level modelling, and the specifics of the acoustic propagation modelling used to produce the noise maps and effect zones;
- Section 3: Results showing noise maps and effect zones predicted;
- Section 4: Conclusions discussing outcomes of the assessment;
- Appendix A: All noise maps produced for the five piling scenarios considered;
- Appendix B: All effect zone maps produced.

2 Methodology

2.1 The MORL Site

To provide context to the noise maps and effect zones presented below, a map of the bathymetry (

Figure 2.1) is provided (in the context of the Eastern Development Area, EDA (MORL site) where Project 1 will be located), which strongly affects sound propagation in shallow water environments such as the Moray Firth.

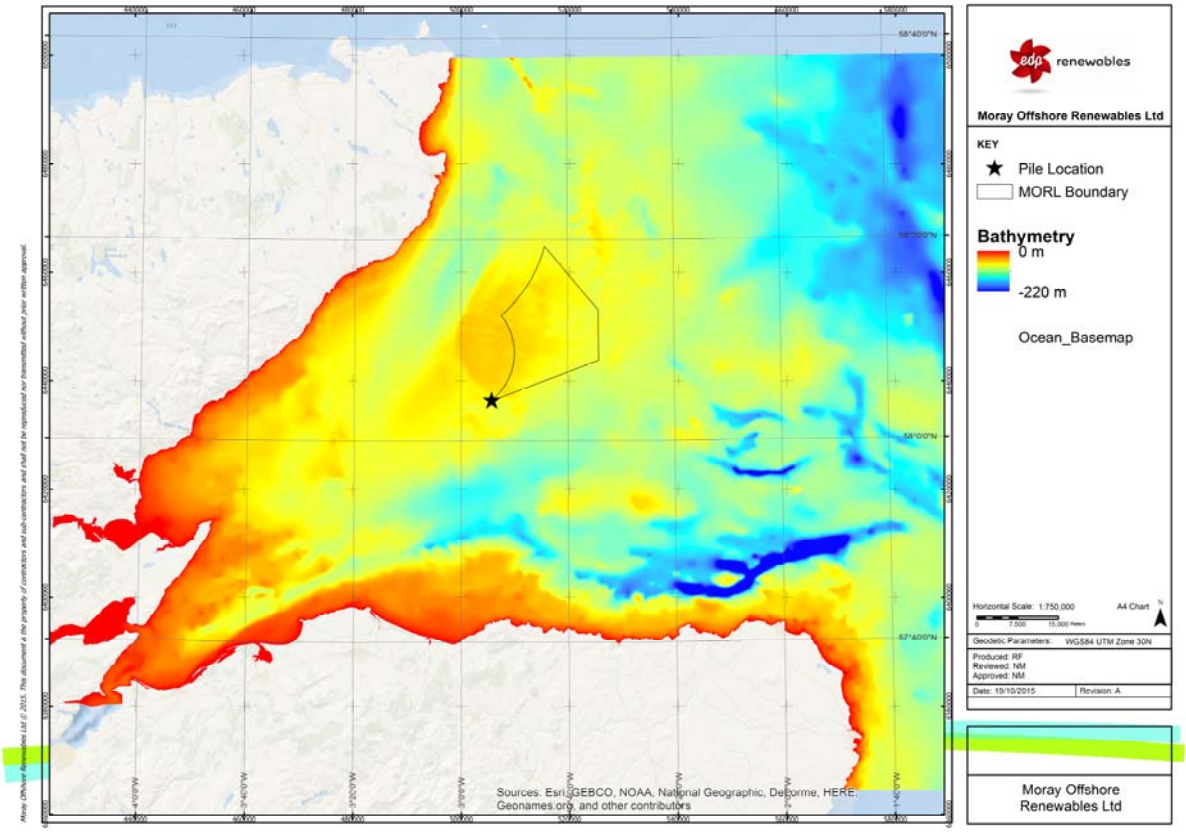

Figure 2.1. Bathymetry of Moray Firth, with MORL EDA boundary and modelled pile location.

2.1.1 Piling Location Assessed

Figure 2.1 shows the modelled piling location for marine mammals. This location was selected for being the nearest location to the Special Areas of Conservation (SACs) in the inner Moray Firth (Moray Firth SAC for bottlenose dolphins and Dornoch Firth and Morrich More SAC for harbour seals).

Note that no cumulative noise assessment with the adjacent proposed wind farm (BOWL) was undertaken, and that cumulative in the context of this report relates to cumulative sound exposure from piling at Project 1 only.

2.2 Noise Exposure Criteria

The first thorough review of marine mammal noise exposure studies which attempted to define noise exposure thresholds was carried out by Southall *et al*. (2007). The review sought to provide guidance on the likely severity of marine mammal responses to anthropogenic noise depending on the received sound level and sound type. This paper has been very influential, and has formed the basis of many environmental impact assessments and scientific studies conducted since its publication. Recently, the U.S. National Oceanic and Atmospheric Administration (NOAA) updated its marine mammal noise exposure criteria to reflect recent advances in the field (NOAA, 2013, 2015) including the Southall *et a*l. (2007) paper and more recent studies. These recommendations are currently in draft form and the subject of public consultation. Indeed, the most recent iteration of this document (NOAA, 2015) differs substantially from the last (NOAA, 2013), and so it was considered preferable to use the Southall criteria in this assessment, both for consistency with the ES and because the NOAA criteria presented in the 2013 and 2015 papers are yet to be finalised and remain at the review stage.

The Southall criteria consist of thresholds formulated using two metrics: the sound exposure level (SEL), and the peak sound pressure level (SPLpeak). Here, the SEL thresholds are considered, since it is much more reliable to model received SEL than received SPLpeak (which varies depending on the temporal structure of the pulse, unlike SEL). Each threshold is further categorised by functional hearing group, which designates groups of marine mammal species with similar hearing abilities. Each functional hearing group has an associated 'M-weighting', which is a frequency-dependent filter designed to approximate the hearing range of the relevant group (Figure 2.2).

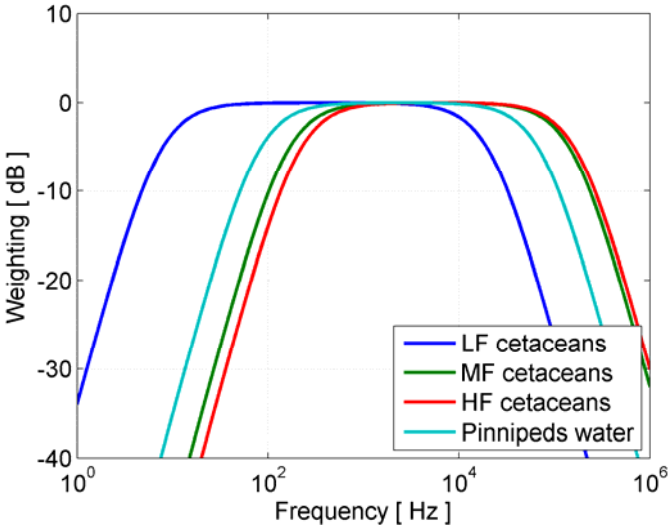

Figure 2.2. Auditory weightings for each of the four functional hearing groups defined by Southall *et al*. (2007): low-, mid-, and high-frequency cetaceans, and pinnipeds. (LF = Low Frequency, MF = Mid-frequency, HF = High Frequency).

The relevant functional hearing groups for the MORL site are mid-frequency cetacean (bottlenose dolphin), high-frequency cetacean (harbour porpoise), and pinniped (harbour seal), which are presented in Figure 2.2. The Southall criteria define sound level thresholds for permanent hearing impairment, known as permanent threshold shift (PTS), which is set at a defined decibel level above estimated thresholds for temporary threshold shift (TTS) (Southall *et al*., 2007; Table 2.1).

Table 2.1. Southall noise exposure criteria for cumulative and single-pulse sound exposure (Southall *et al.*, 2007). All levels quoted are in units of dB re 1 µPa² s.

	TTS	PTS
Mid-frequency cetacean (MF Cet)	183	198
High-frequency cetacean (HF Cet)	183	198
Pinniped in water	171	186

2.3 Modelling of Piling Noise Source Levels

The source level estimate (SLE) for pile driving 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:

$$SL_E = 120 + 10log_{10}\left(\frac{Ec_0\rho}{4\pi}\right) \quad (1)$$

where SL_E is the source level energy for a single strike, E is the converted hammer energy in joules, c_0 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 µPa2 s). This energy is then distributed across the frequency spectrum based on previous measurements of impact piling (Ainslie *et al.*, 2012), as shown in Figure 2.3.

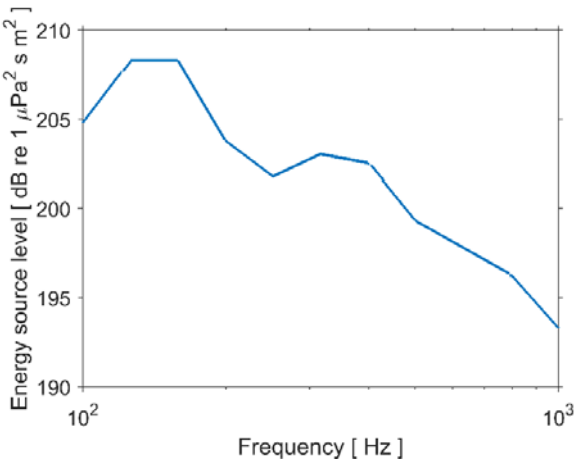

Figure 2.3. Source level spectrum of impact piling, derived from Ainslie *et al.* (2012).

Hammer energy profiles for each of the piling scenarios were produced by MORL's geotechnical consultants, and formed the basis for the source level estimate in each case. Equation 1 was used to compute the source level energies, using an acoustic conversion efficiency coefficient of (0.5%) which estimates that approximately 0.5% of energy is converted into acoustic energy. This energy conversion factor is in keeping with current understanding of how much hammer energy is converted to noise (Dahl and Reinhall, 2013; Zampolli *et al.*, 2013; Dahl *et al.*, 2015). Equation 1 gives the source level energy for a single strike (single-strike SEL), For each of the 5 piling scenarios, the maximal single-pulse SEL as well as the cumulative SEL (the total SEL generated during a specified period) were computed, based on 3 piles being installed within 24-hours.

Five piling scenarios were assessed based on hammer energy profiles for different seabed conditions. This pile drivability assessment indicated that the ground conditions within the development site are heterogeneous with 6 soil profiles being identified. The three most common soil profiles within the development area, 1, 2 and 4, have been modelled (for more information on soil conditions please see Section 3 of the Piling Strategy main document). Soil profile 2 represents the most challenging soil type on site, i.e. the soil profile where higher energies are most likely to be required to drive piles into the seabed. Five piling scenarios were then modelled for the three soil profiles (as shown in Table 2.2). Most probable (MP) hammer energy profiles were modelled for all three soil types and highest expected (HE) for two soil profiles (as one of the soil profiles is relatively uniform and therefore no HE scenario was produced). MP represents the energy profiles most likely to be required for driving piles in each of the soil profiles. HE represents the highest energies that would be required to drive piles into the seabed. A hammer energy of 300 kJ has been agreed as the maximum starting energy for the soft-start, based on the lowest hammer energy that could be produced by the largest hammer which may be used (see Appendix 2 of the Piling Strategy for details). In practice, if a smaller hammer is deployed, then the minimum hammer energies will be lower than those evaluated in this assessment. Table 2.2 details the hammer energies and number of strikes for each piling profile. Note that only Profile 2 required a hammer energy exceeding 1020 kJ.

Table 2.2. Hammer energy profiles assessed. Numbers indicate number of strikes at each hammer energy for a particular profile; gaps indicate no strikes at that particular hammer energy. P2 = profile 2, MP = most probable, HE = highest estimate.

	Pile Scenario				
Hammer Energy	**P1MP**	**P1HE**	**P2MP**	**P2HE**	**P4MP**
300	7850	7500	5900	5060	6160
360			600	660	
420	1400	880			1090
540	1120	970	890	1440	1140
660	1710	640			990
720			820	1290	
840		960			1620
900			920	820	
1020		1270			1590
1200			1080	1440	
1350			2110	1160	
1620			440	930	
1800			730	850	
2250				3000	

2.4 Modelling of Noise Propagation

The propagation of piling noise was modelled using the Cefas noise model, which is based on a parabolic equation solution to the wave equation (RAM; Collins, 1993). Unlike many propagation models, this model takes into account the bathymetry, sediment properties, water column properties, and tidal cycle, leading to more detailed and reliable predictions of sound level. It is also widely used in peer-reviewed scientific studies which have benchmarked it against empirical data, including the work described under Farcas *et al.* (2016) which provides a review of the modelling approach and explores the factors affecting predictions of noise exposure through data collected in the Moray Firth. For these reasons, there can be greater confidence in the modelling predictions in this updated assessment compared to the ES.

The Cefas 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). These transects were then resampled and integrated over frequency (using the appropriate auditory weightings where needed). Finally, the resulting levels were averaged over depth to produce noise maps.

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 was provided by MORL, at 90-m and 1-km resolutions, with the 90-m data being more than adequate for the frequency ranges and spatial scales used in the simulations. Some of the simulations involving locations 5 and 6 involved modelling over a larger area not entirely covered by the 90-m resolution data, and thus required the use of the more extensive 1-km resolution data. In these cases, the results for the lower spatial resolution were benchmarked against the higher resolution results in the areas with dual coverage, and they displayed only very minimal differences.

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. Typical November water properties were used for the acoustic propagation predictions, representing a midpoint between winter and summer sound propagating conditions. It was chosen to model water properties based on a typical November as this represents a mixture of most probable and worst case scenarios which would form a conservative but probable scenario.

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 provided by MORL, by correlating the core sediment information with published acoustic properties of various sediment types (Hamilton, 1980).

3 Results

3.1 Source Levels of Piling Noise

Sound exposure source levels were modelled for each of the five piling scenarios detailed in Section 0. For each scenario, both the cumulative sound exposure and the single-pulse sound exposure from the most energetic hammer strike were calculated (see Table 3.2). Since the hammer energy profile used in the ES was known (see Table 3.1), a direct comparison was made to this profile using the same methodology as for the updated scenarios. However, the method used in the ES to calculate the source level from the hammer energy profile was not explicitly stated, and we infer from the results that a higher acoustic efficiency factor was assumed than in the present study (where we use 0.5%, based on the scientific literature; Dahl *et al*., 2015). This would result in a higher source level estimate than we calculate here. Since the model assumptions for the updated scenarios are based on detailed hammer energy profiles provided by the engineers involved, and the acoustic efficiency factor used is based on the most up-to-date science, there is a higher degree of confidence in these updated source level estimates.

Table 3.1. Assumed hammer energies given in the ES (Appendix 3.6 A, p32) used for comparison to updated assessment.

Hammer energy (kJ)	Number of strikes
170	260
450	2400
890	1000
1080	7000

Table 3.2. Modelled piling noise source levels for cumulative exposure per pile and for the maximum hammer energy strike in each scenario. ES indicates the hammer energy profile which was used in the original ES. Cells where SEL exceeds the ES scenario are highlighted. All sound exposure levels (SEL) are in units of dB re 1 µPa2 s.

	Cumulative SEL per pile		Maximum single-pulse SEL	
Scenario	**SEL at 1 m**	**Difference to ES profile (dB)**	**SEL at 1 m**	**Difference to ES profile (dB)**
ES profile	247.7	0.0	208.2	0.0
Profile 1, MP	244.6	-3.1	206.1	-2.1
Profile 1, HE	245.4	-2.3	208.0	-0.2
Profile 2, MP	247.9	0.2	210.4	2.2
Profile 2, HE	250.2	2.6	211.4	3.2
Profile 4, MP	246.0	-1.6	208.0	-0.2

Compared to the hammer energy profile assumed in ES, only the hammer energy Soil Profile 2 resulted in an increase in cumulative or maximum single-pulse sound exposure at source (Table 3.2). Profile 2 represents the worst-case scenario profile. For the most probable estimate (MP), there is a slight increase of 0.2 dB of cumulative SEL compared to the ES, and an increase of 2.2 dB in the maximal single-pulse SEL compared with the ES. The highest estimate (HE) results were higher at 2.6 and 3.2 dB, respectively, for cumulative SEL and single-pulse SEL.

As stated above, due to the more up-to-date information available to make the current source levels estimates, the source levels predicted for the ES appear higher than those presented here (as greater differences would be expected in the predicted single pulse SELs and cumulative SELs when compared to the ES). The source levels estimates in the ES are likely to exceed those predicted here for all profiles, although these data were not detailed in the ES.

3.2 Received Noise Levels in Moray Firth

Received noise levels generated by the modelled scenarios described in Section 3.1 were mapped throughout the Moray Firth using detailed propagation modelling, see Section 2.4. Figure 3.1 shows the noise map produced for the worst-case scenario cumulative SEL (Profile 2 highest estimate). The levels shown represent the cumulative sound exposure that would be received by a stationary receiver over the course of 24 hours. The noise levels predicted are strongly affected by the bathymetry, and in some places (e.g. to the south of the pile location) show local increases in noise level with increasing distance.

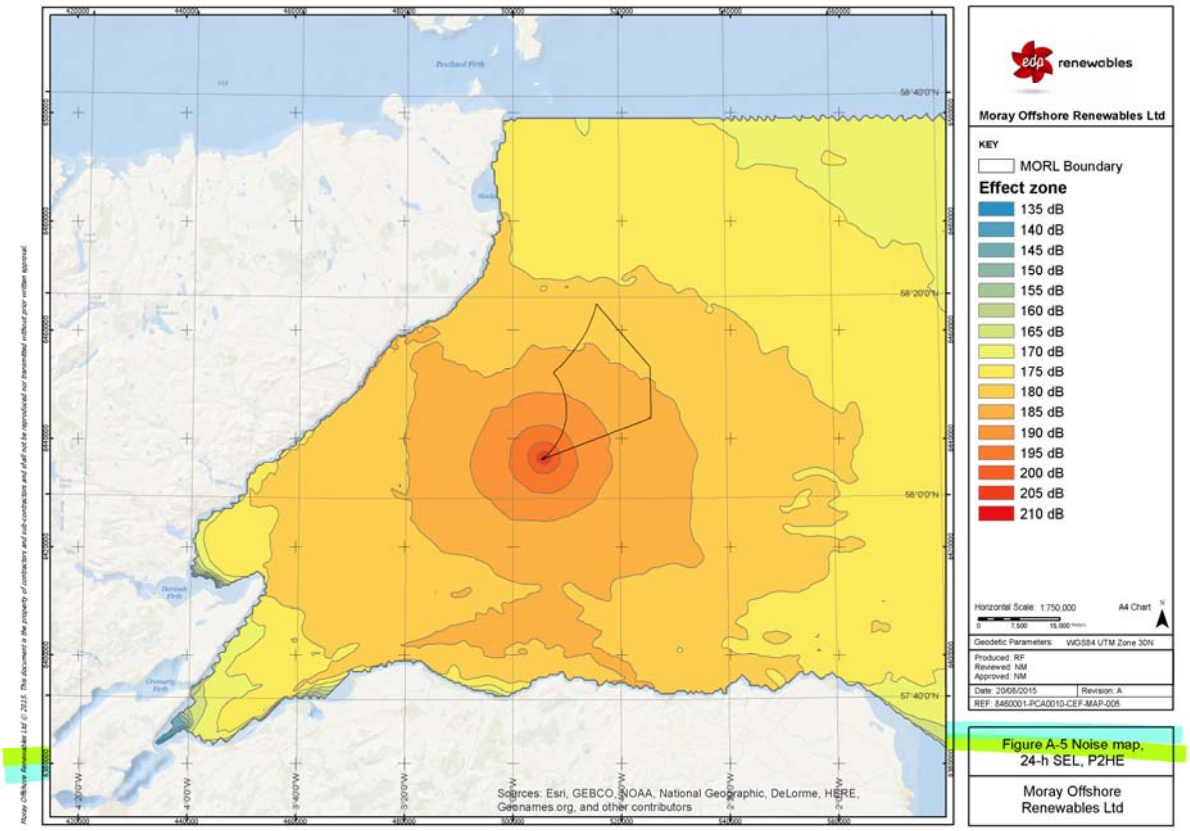

Figure 3.1. Noise map of cumulative SEL over 24 hours for Profile 2 Highest Estimate, based on three piles installed in 24 hours.

The SEL from the maximum hammer energy strike in Profile 2 Highest Estimate (i.e. worst-case) is shown in Figure 3.2. This is the only profile with a hammer energy exceeding 2,000 kJ, at 2,250 kJ, with the next highest energy at 1,800 kJ (for Profile 2 Most Probable). The other four scenarios assessed have lower source levels which are reflected in the noise maps; all of the noise maps produced are provided in Appendix A for reference.

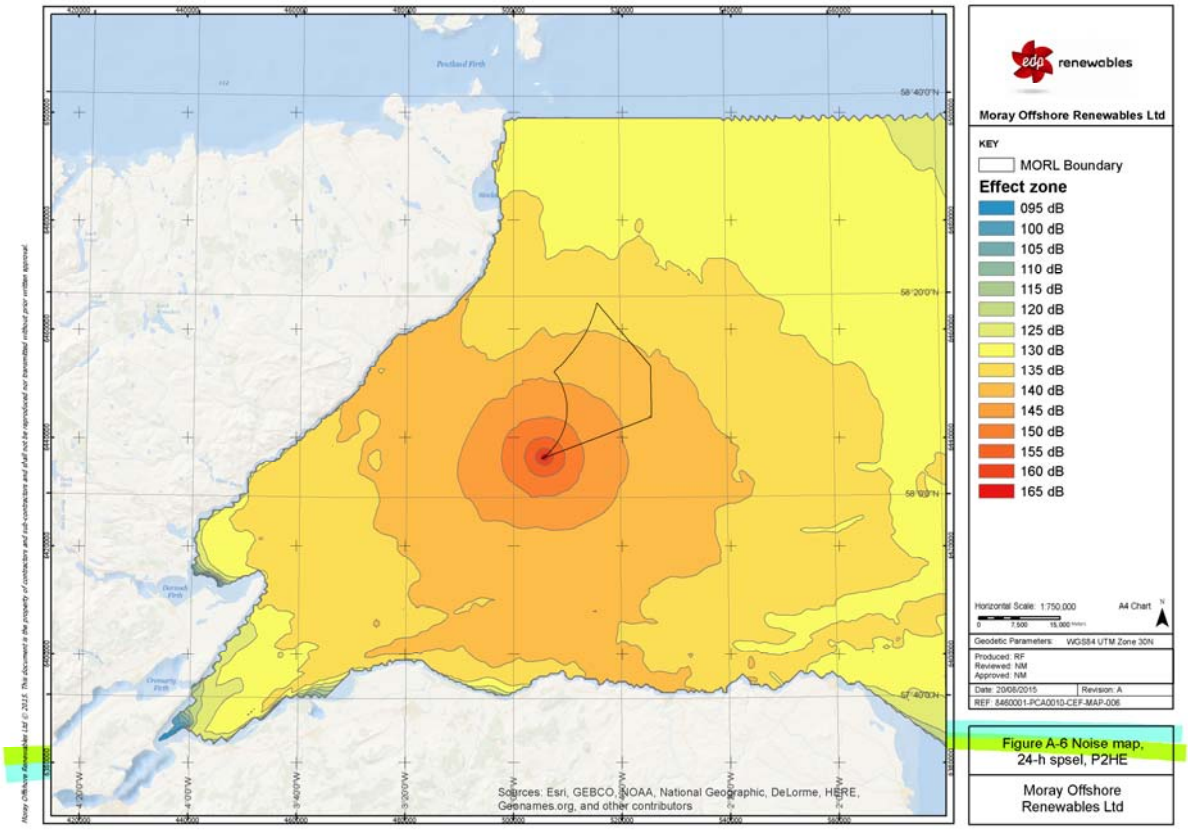

Figure 3.2. Noise map of maximum single-pulse SEL during Profile 2 Highest Estimate (hammer energy is 2,250 kJ).

3.3 Effect Zones for Marine Mammals

Based on the Southall criteria as described in Section 2.2, effect zones were predicted by applying these criteria (including the relevant M-weighting function) to the mapped predictions of noise levels. These effect zones are defined for PTS and TTS for functional hearing groups which encompass harbour porpoises (high-frequency cetaceans), bottlenose dolphins (mid-frequency cetaceans), and harbour seals (pinnipeds).

A direct comparison was made between the predictions made in the ES and the updated predictions and are outlined fully in Appendix 3. The new assessment is more conservative in that it assumes three piles can be driven in a 24-hour period, compared to two in the ES. The new assessment is also more conservative in that TTS is assessed at 183 dB (cetaceans) and 171 dB (pinnipeds) according to the Southall criteria shown in Table 2.1, compared to the lowest M-weighted level assessed in the ES of 186 dB. For reference, we have included the lowest level assessed in the ES in each case (186 dB), which represents a less conservative proxy for TTS than the thresholds used in the present assessment. For PTS assessment, the ES presented equivalent levels for the PTS threshold, where are 198 dB (cetaceans) and 186 dB (pinnipeds) according to the Southall criteria.

Figure 3.3 shows the cumulative exposure predictions for the worst-case scenario, Profile 2 highest estimate, for harbour porpoise. The effect zones shown represent the cumulative noise exposure over a 24-hour period for a stationary animal. This is a more precautionary approach than assuming animals will flee the area, as was assumed for some scenarios in the ES. The updated assessment predicts a markedly smaller effect area for PTS than the ES, with a range from the source of ~1.5 km compared to ~5 km in the ES. The TTS zone is also substantially smaller than the zone predicted for 3 dB greater exposure (186 dB) in the ES. The reason behind the predictions of smaller effect zones despite the greater conservatism in the updated approach is that the source levels predicted are lower than those in the ES, as described in Section 3.1. Since the source model presented in this updated assessment is based on bespoke hammer energy profiles for the site and more recent peer-reviewed literature on the proportion of hammer energy converted into acoustic energy (Dahl *et al.*, 2015), there is greater confidence in this updated assessment.

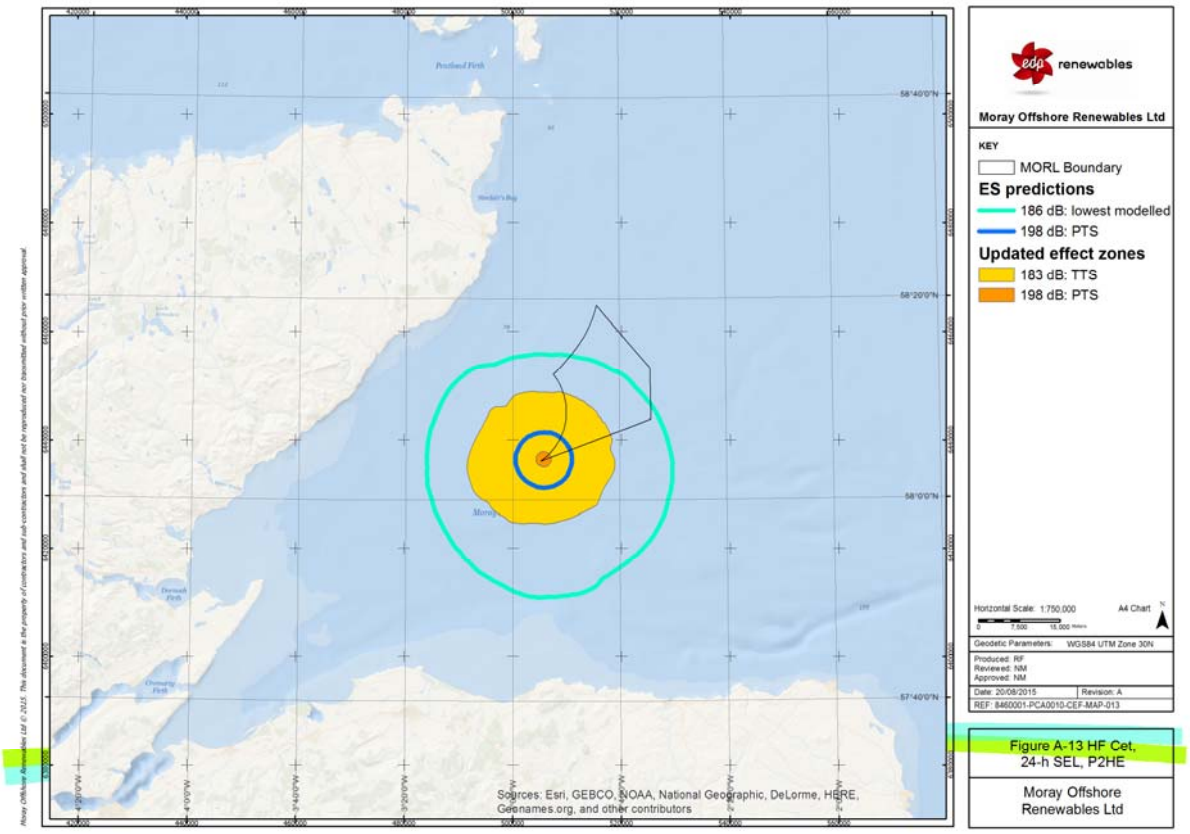

Figure 3.3. Worst-case cumulative effect zone prediction for harbour porpoise.

The corresponding worst-case cumulative SEL predictions for bottlenose dolphins and pinnipeds are shown in Figure 3.4 and Figure 3.5, respectively. Similarly to the predictions for harbour porpoise, the PTS zones predicted are smaller than for the ES in both cases, for the reasons detailed above.

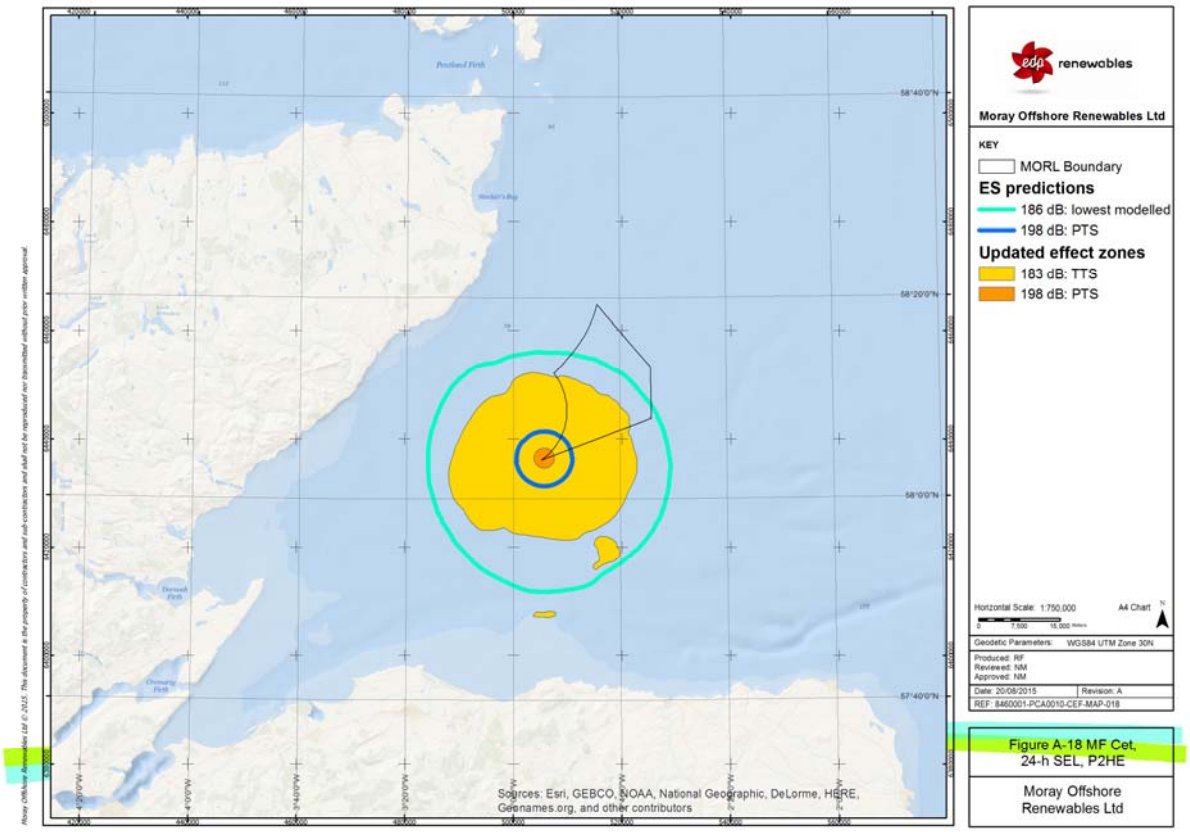

Figure 3.4. Worst-case cumulative effect zone prediction for bottlenose dolphin.

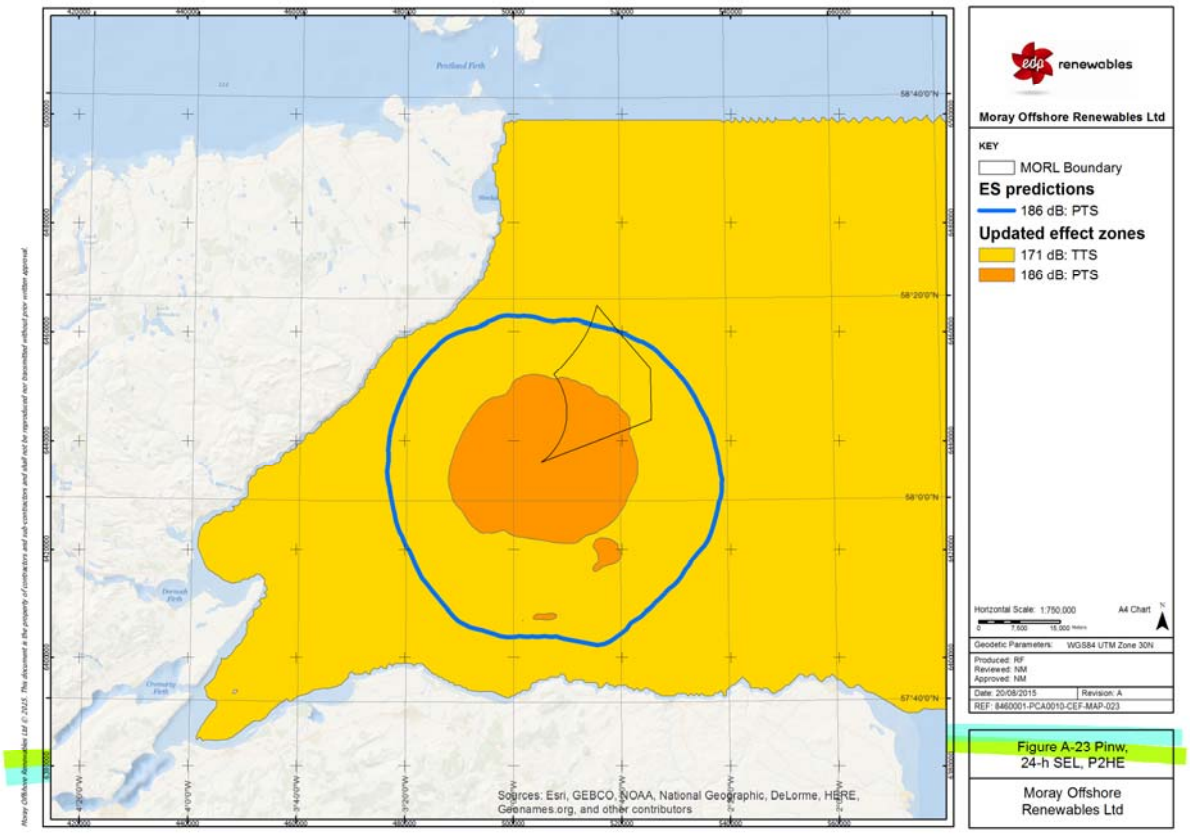

Figure 3.5. Worst-case cumulative effect zone prediction for harbour seals.

In addition to cumulative assessment of PTS and TTS, calculations of instantaneous TTS for single strikes were also made, based on the maximum hammer energy strike in each profile. These predictions were too fine-scale to be included on the effect zone maps. We instead present the ranges at which these effects are predicted based on an assumption of propagation loss corresponding to 15*log(R), which is conservative at the short ranges considered. Table 3.3 shows the worst-case predictions, which were for a 2,250 kJ hammer strike, which was only present in Profile 2's highest estimate.

Table 3.3. Worst-case single-strike effect range predictions for marine mammals.

	TTS	PTS
Harbour porpoise	31.6 m	3.2 m
Bottlenose dolphin	40.0 m	4.0 m
Harbour seals	385 m	38.5 m

4 Conclusions

This noise assessment predicted the noise levels generated by a series of possible piling scenarios at the Project 1 site, using recent data on hammer energy profiles for the site, and scientific literature on the proportion of hammer energy that is converted to acoustic energy which has been published since the original ES was produced. Although the maximum hammer energy for one of the modelled piling profiles was higher than in the ES (2,250 kJ, compared to 1,080 kJ), the noise levels predicted were lower, due to a more realistic source level model being used, informed by recent peer-reviewed studies of impact piling noise (Dahl *et al*., 2015). As a consequence, the effect zones predicted for PTS and TTS in marine mammals were smaller in a like-for-like comparison with the ES predictions. More detailed analysis of the noise results in relation to marine mammals, based on the results of this modelling, are provided in Appendix 3.

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APPENDIX A – Noise Maps for All Piling Scenarios

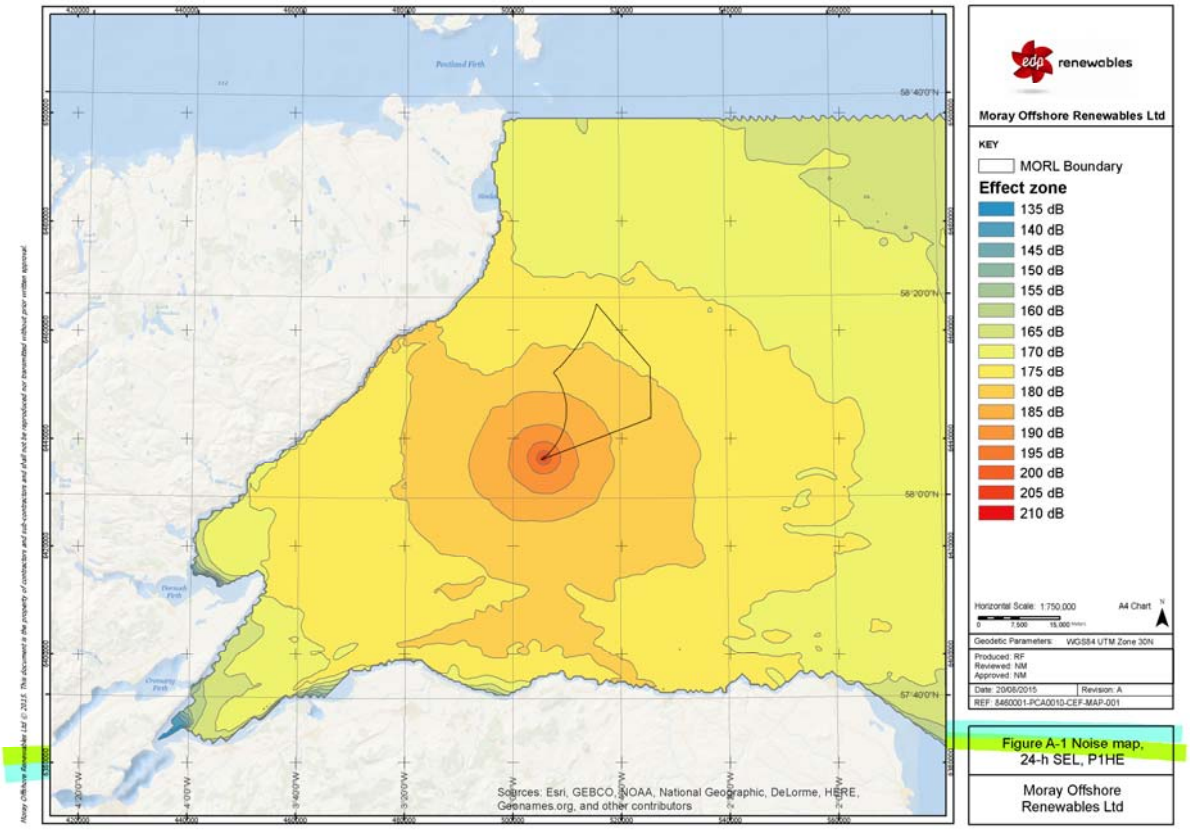

Figure A-1. Noise map of cumulative SEL over 24 hours for Profile 1 HE, based on three piles in 24 hours.

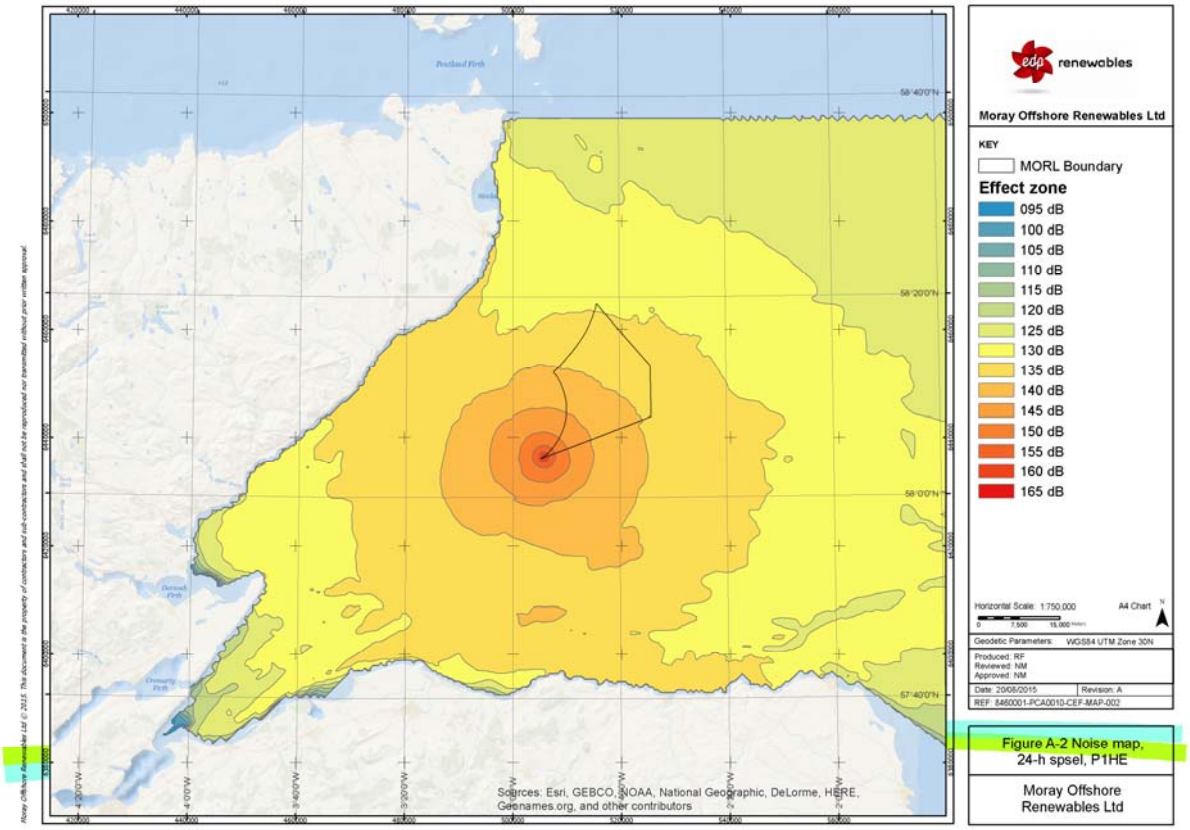

Figure A-2. Noise map of maximum single-pulse SEL during Profile 1 HE (hammer energy is 1,020 kJ).

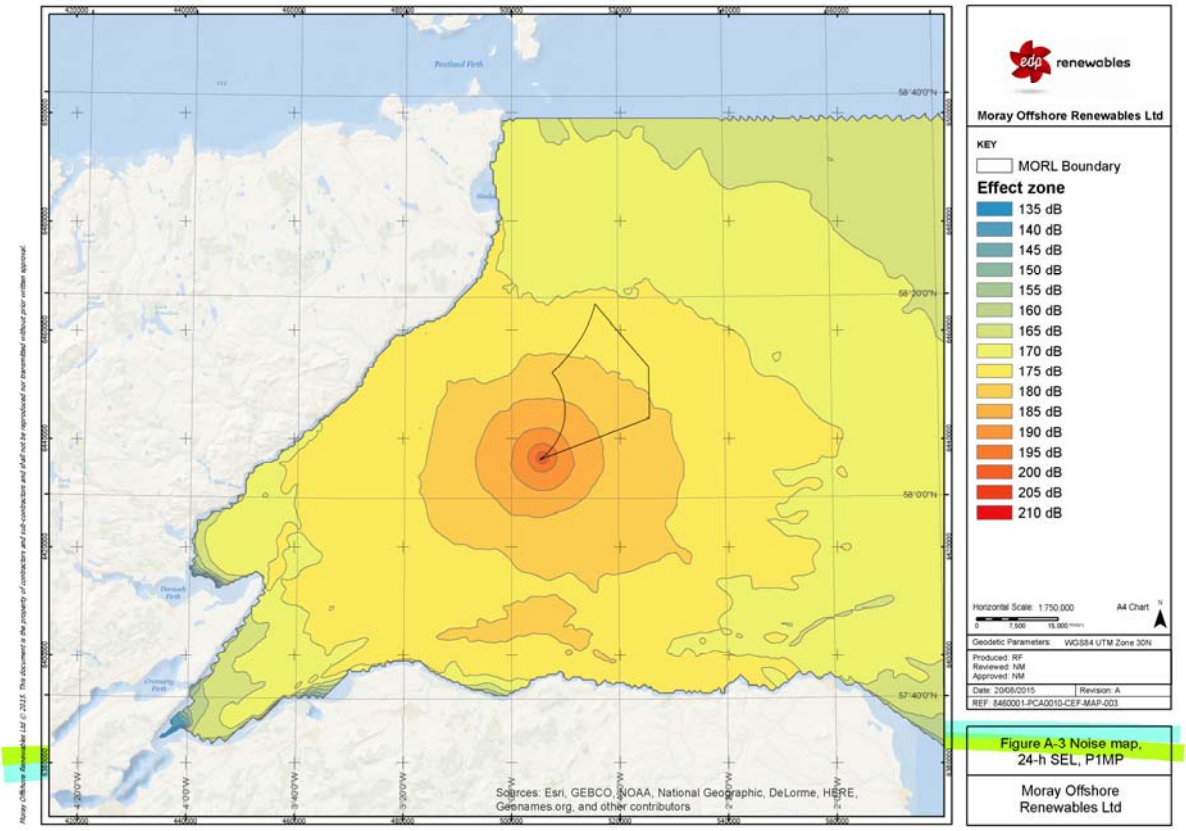

Figure A-3. Noise map of cumulative SEL over 24 hours for Profile 1 MP, based on three piles in 24 hours.

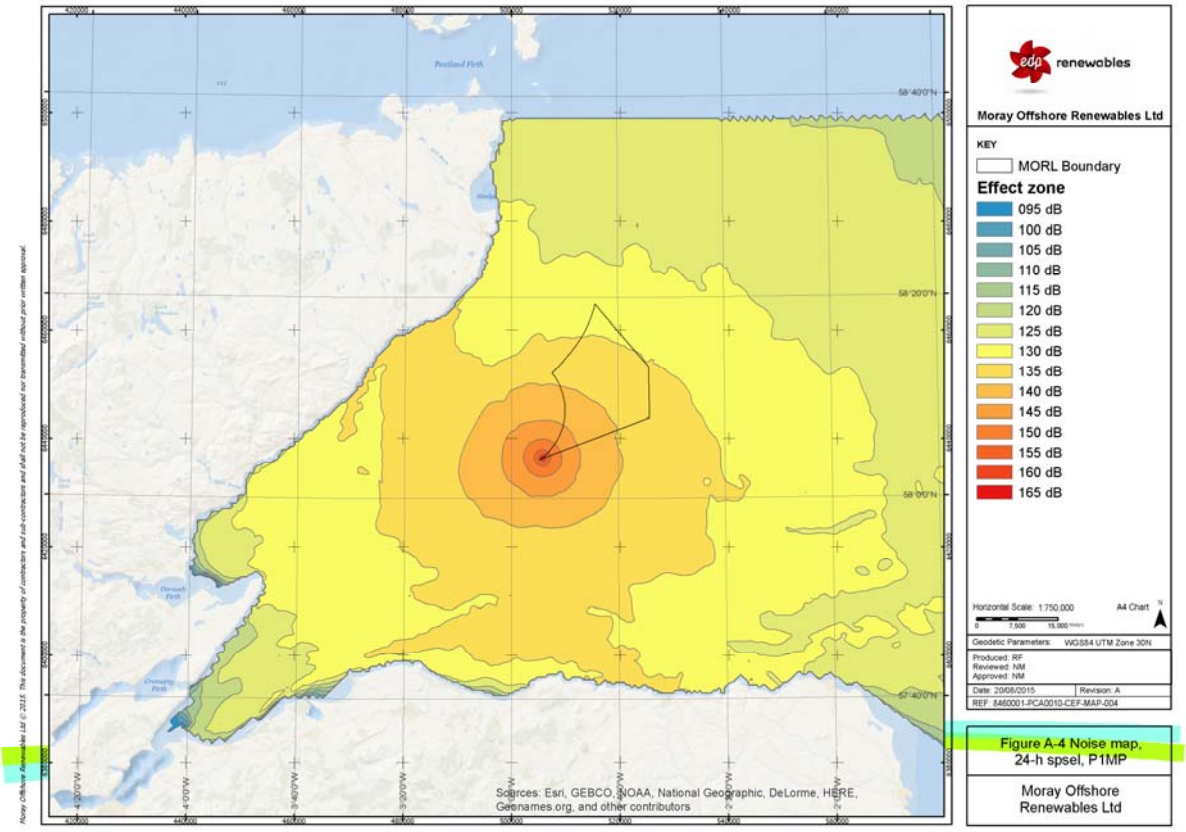

Figure A-4. Noise map of maximum single-pulse SEL during Profile 1 MP (hammer energy is 660 kJ).

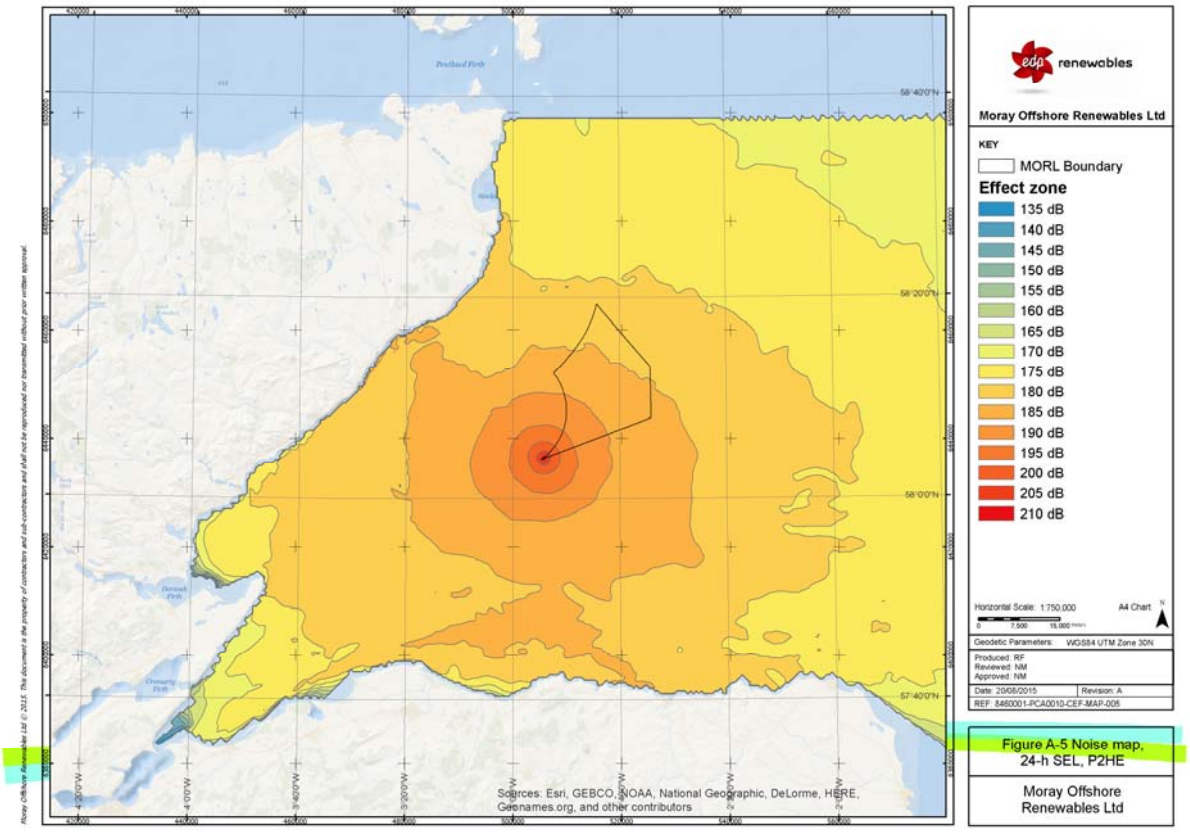

Figure A-5. Noise map of cumulative SEL over 24 hours for Profile 2 HE, based on three piles in 24 hours.

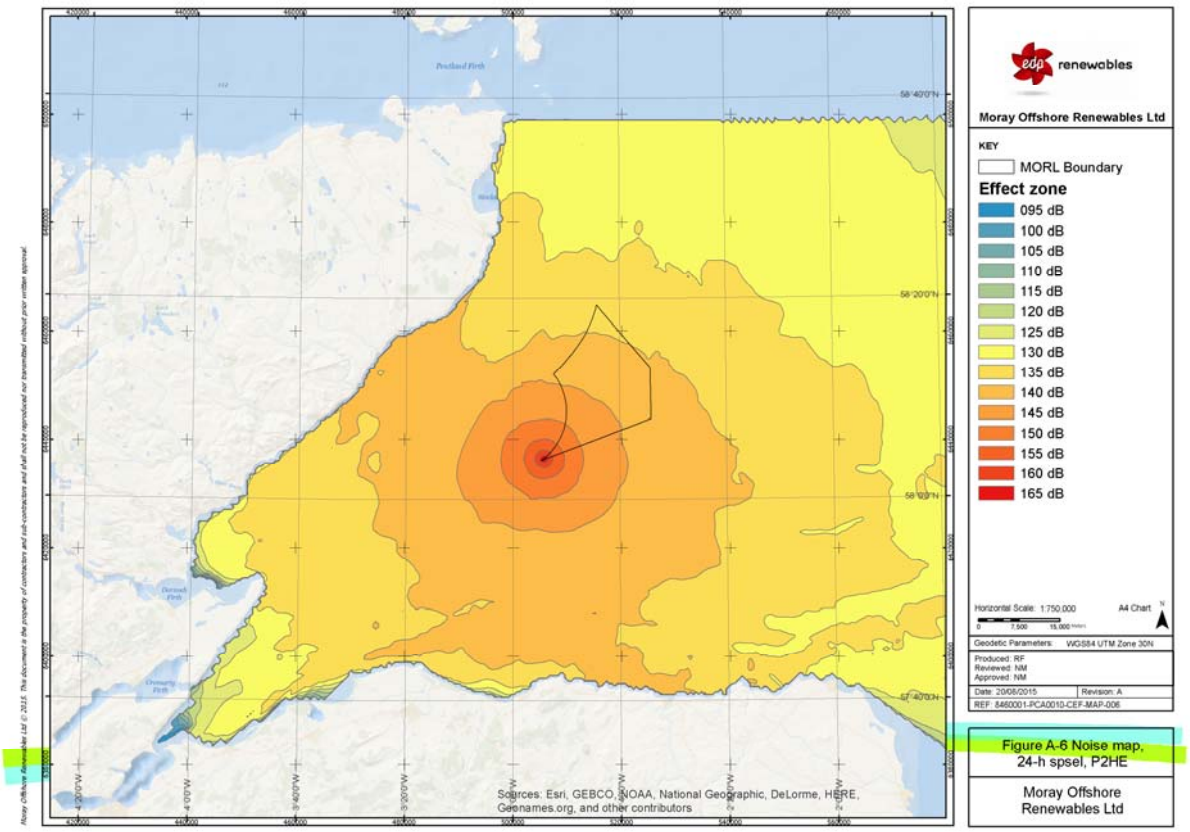

Figure A-6. Noise map of maximum single-pulse SEL during Profile 2 HE (hammer energy is 2,250 kJ).

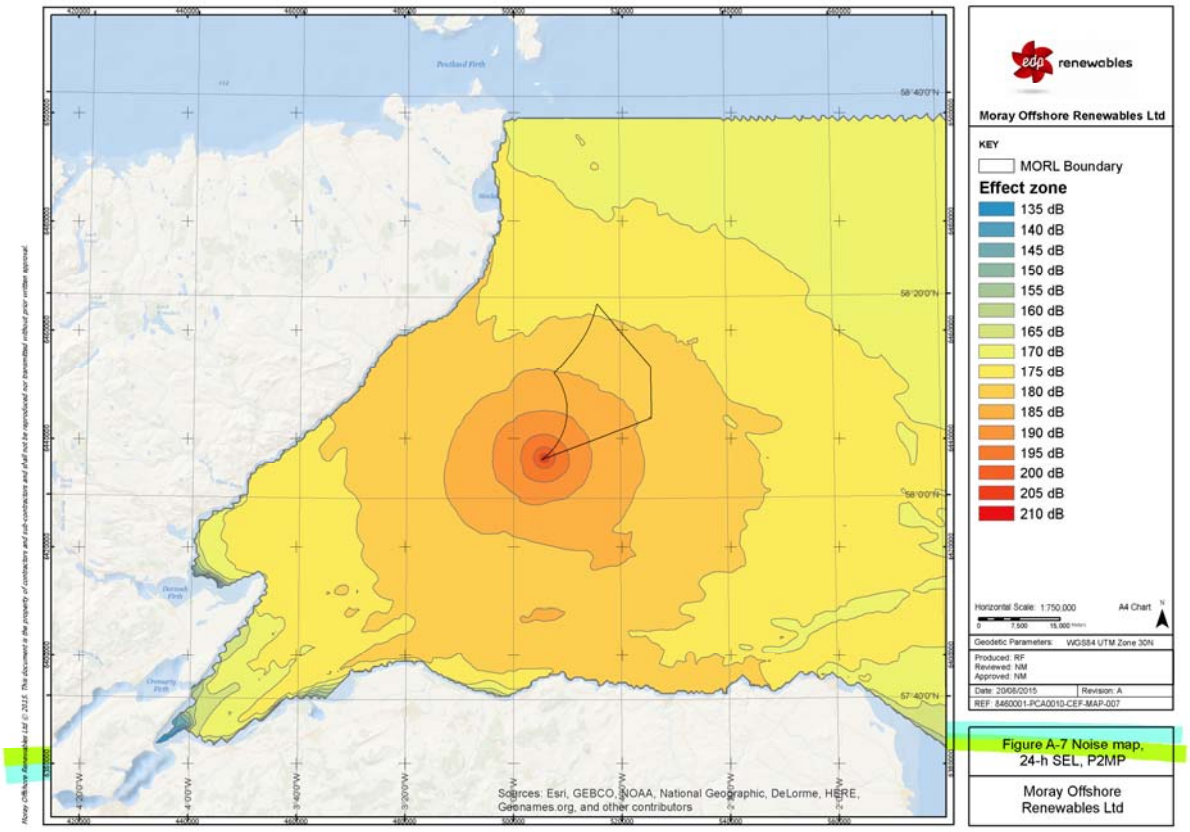

Figure A-7. Noise map of cumulative SEL over 24 hours for Profile 2 MP, based on three piles in 24 hours.

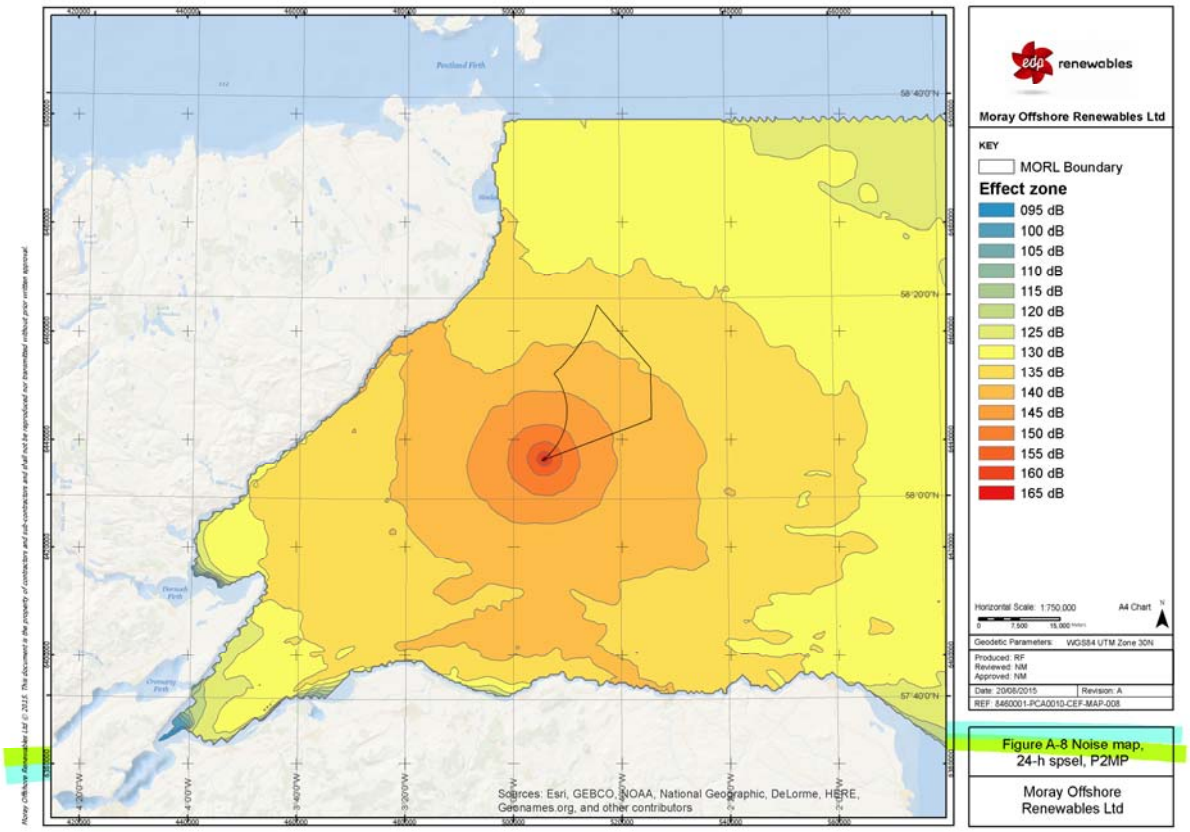

Figure A-8. Noise map of maximum single-pulse SEL during Profile 2 MP (hammer energy is 1,800 kJ).

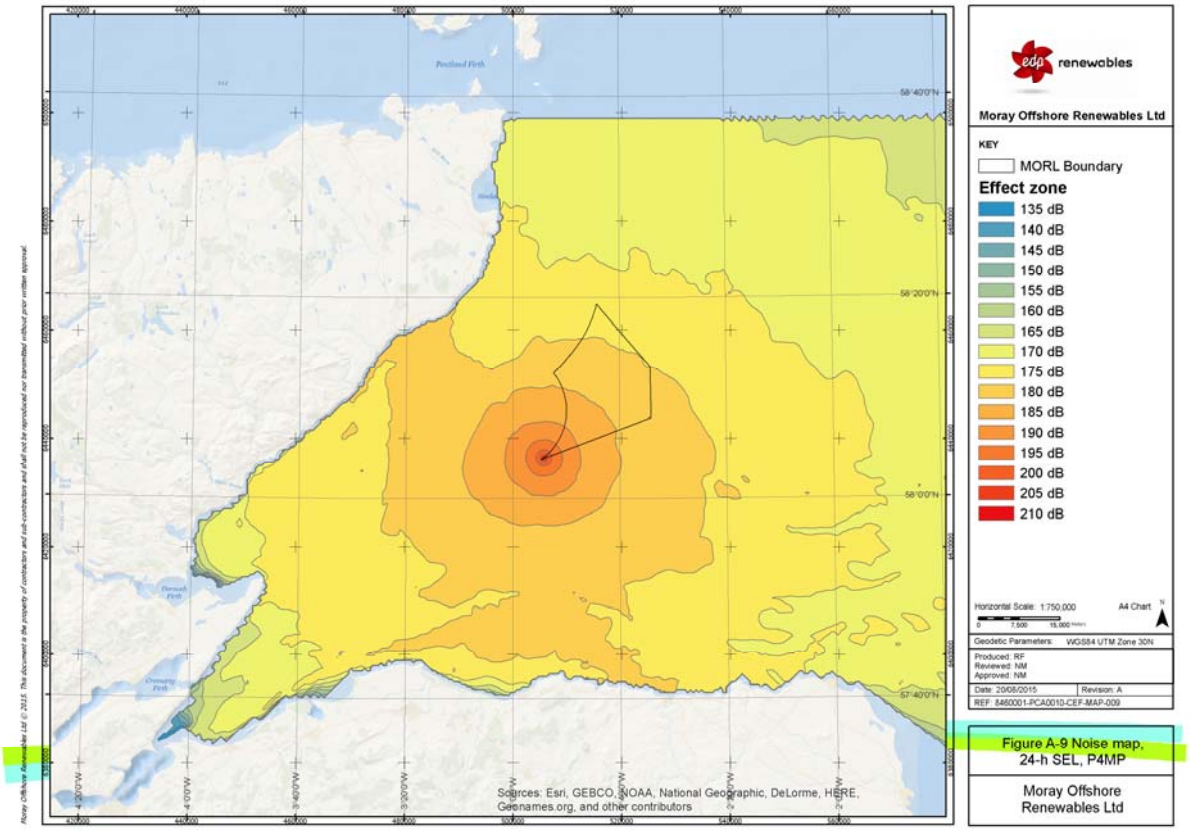

Figure A-9. Noise map of cumulative SEL over 24 hours for Profile 4 MP, based on three piles in 24 hours.

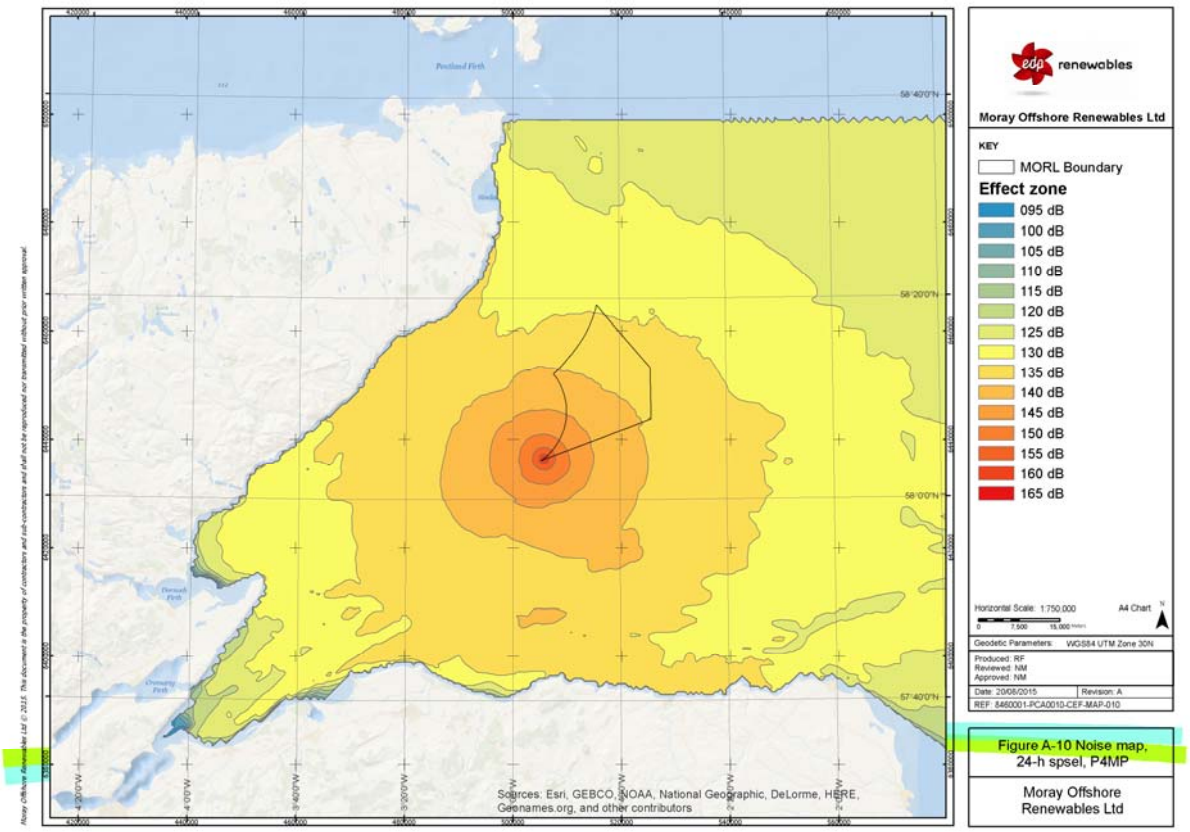

Figure A-10. Noise map of maximum single-pulse SEL during Profile 4 MP (hammer energy is 1,020 kJ).

APPENDIX B – Effect Zones for all Piling Scenarios

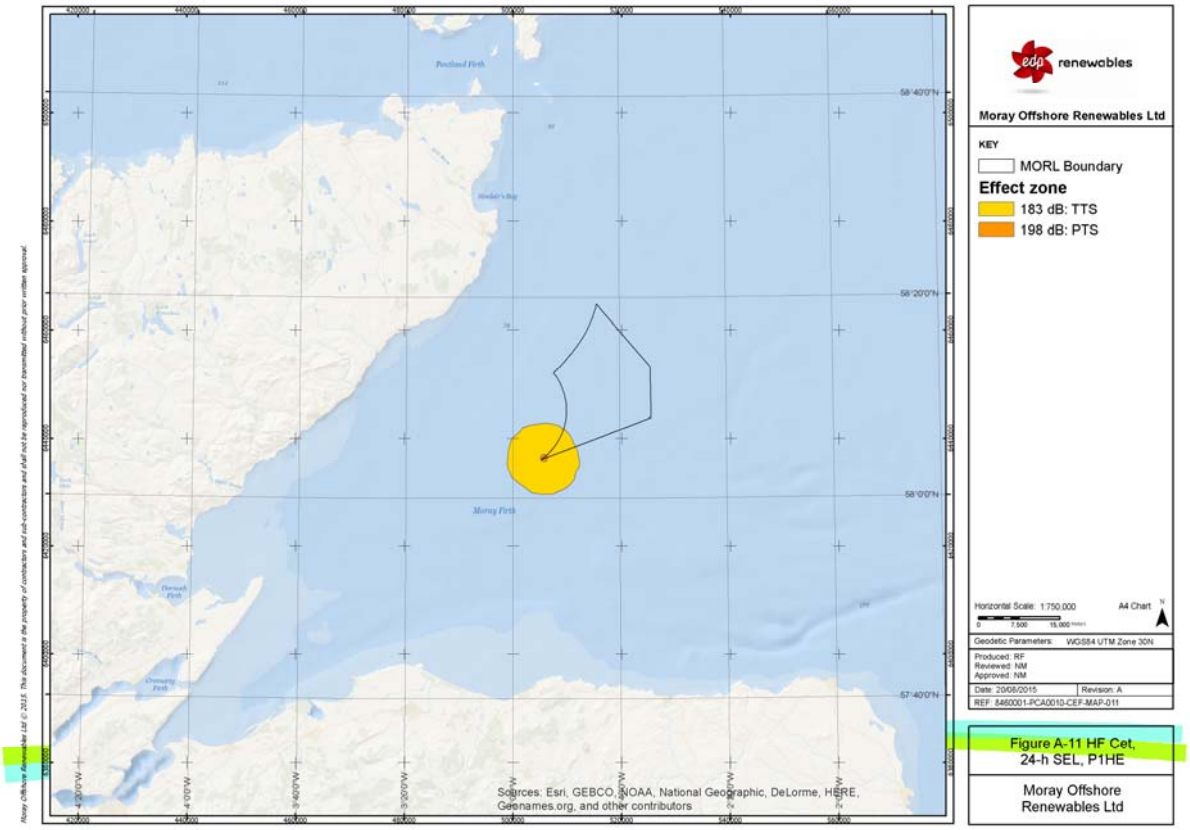

Figure A-11. 24-hour cumulative effect zone prediction for harbour porpoise, Profile 1 HE.

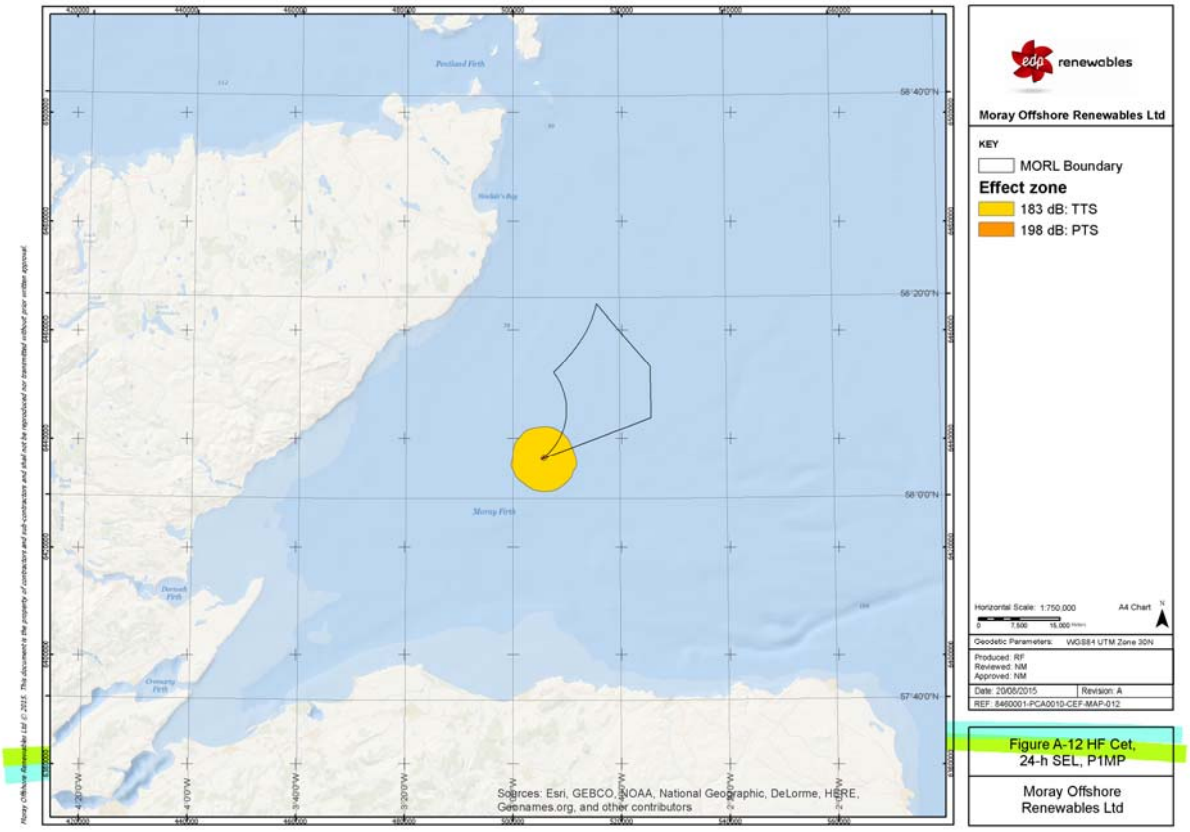

Figure A-12. 24-hour cumulative effect zone prediction for harbour porpoise, Profile 1 MP.

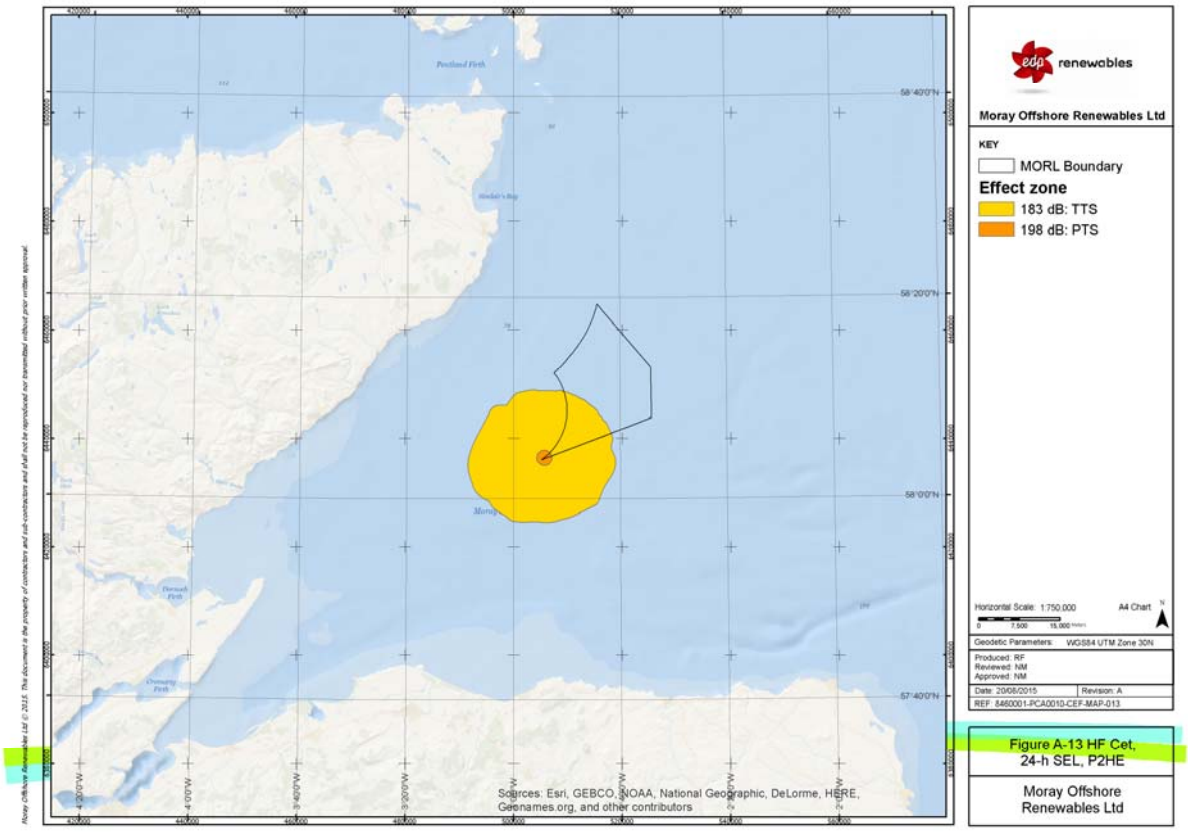

Figure A-13. 24-hour cumulative effect zone prediction for harbour porpoise, Profile 2 HE.

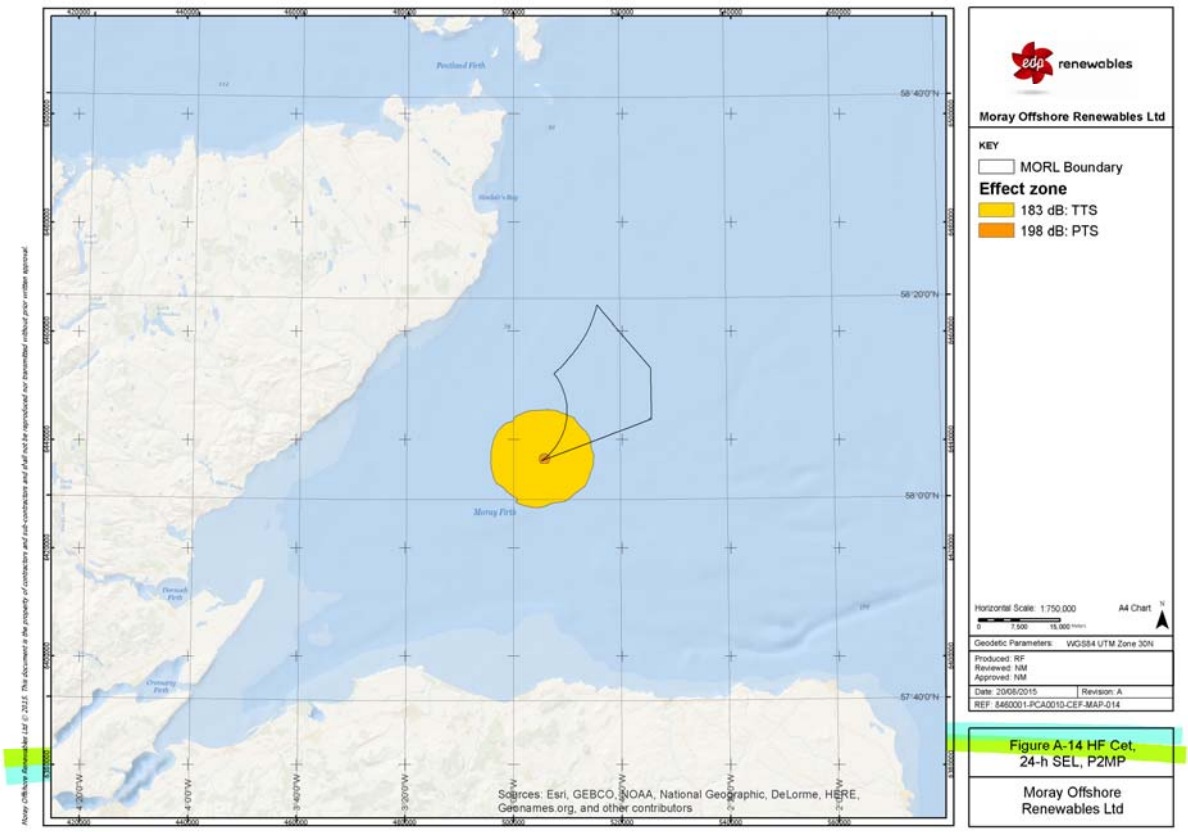

Figure A-14. 24-hour cumulative effect zone prediction for harbour porpoise, Profile 2 MP.

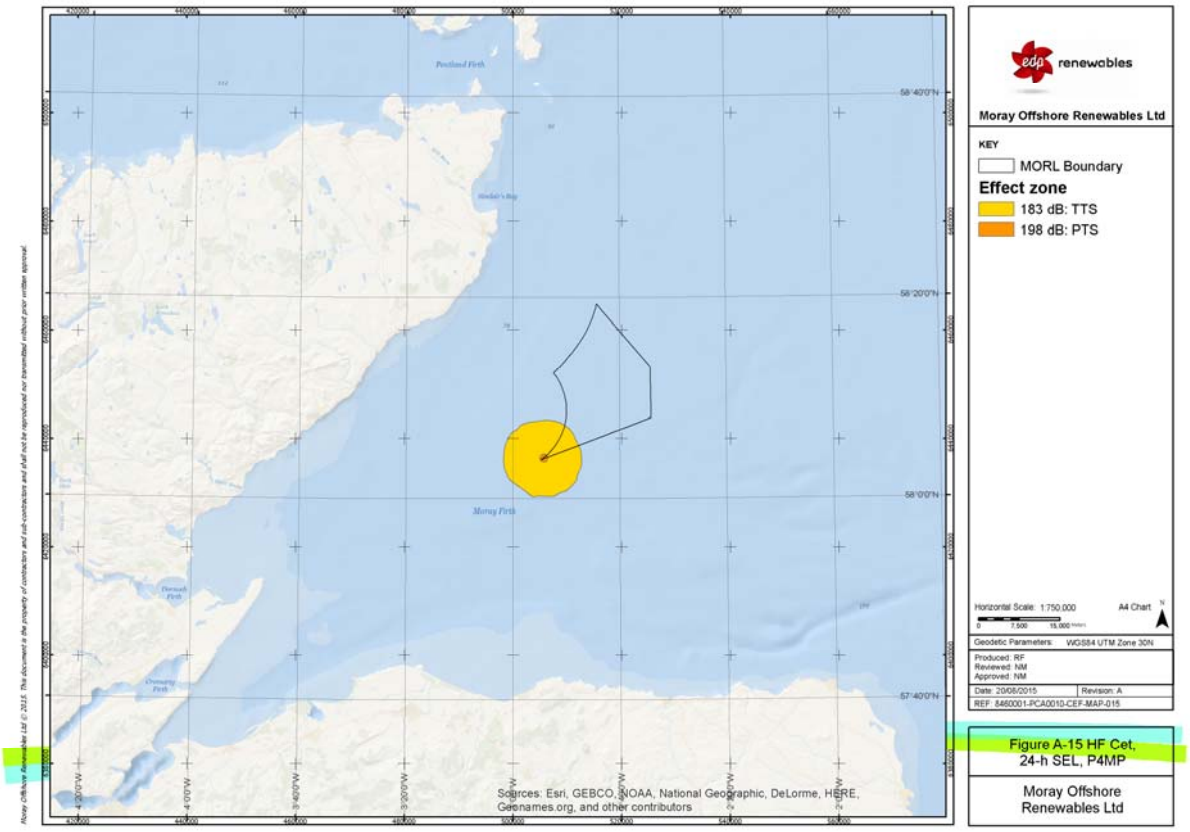

Figure A-15. 24-hour cumulative effect zone prediction for harbour porpoise, Profile 4 MP.

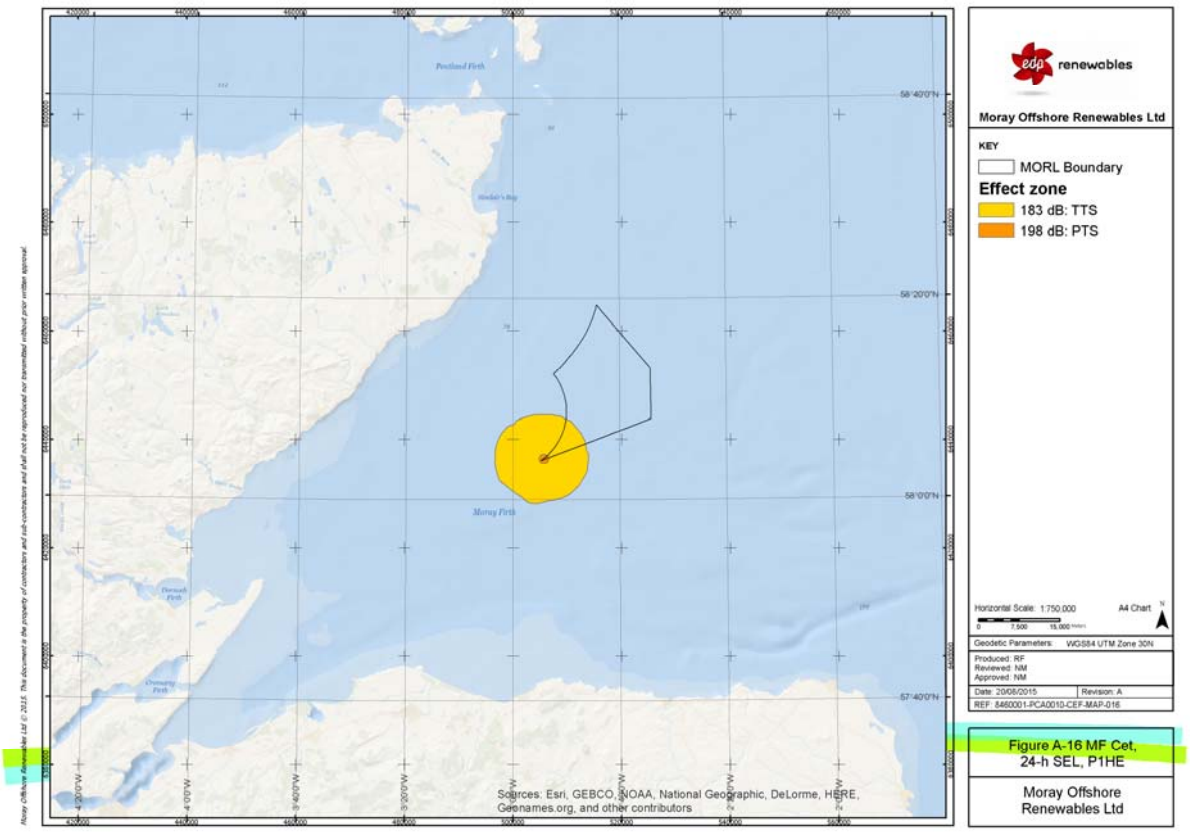

Figure A-16. 24-hour cumulative effect zone prediction for bottlenose dolphin, Profile 1 HE.

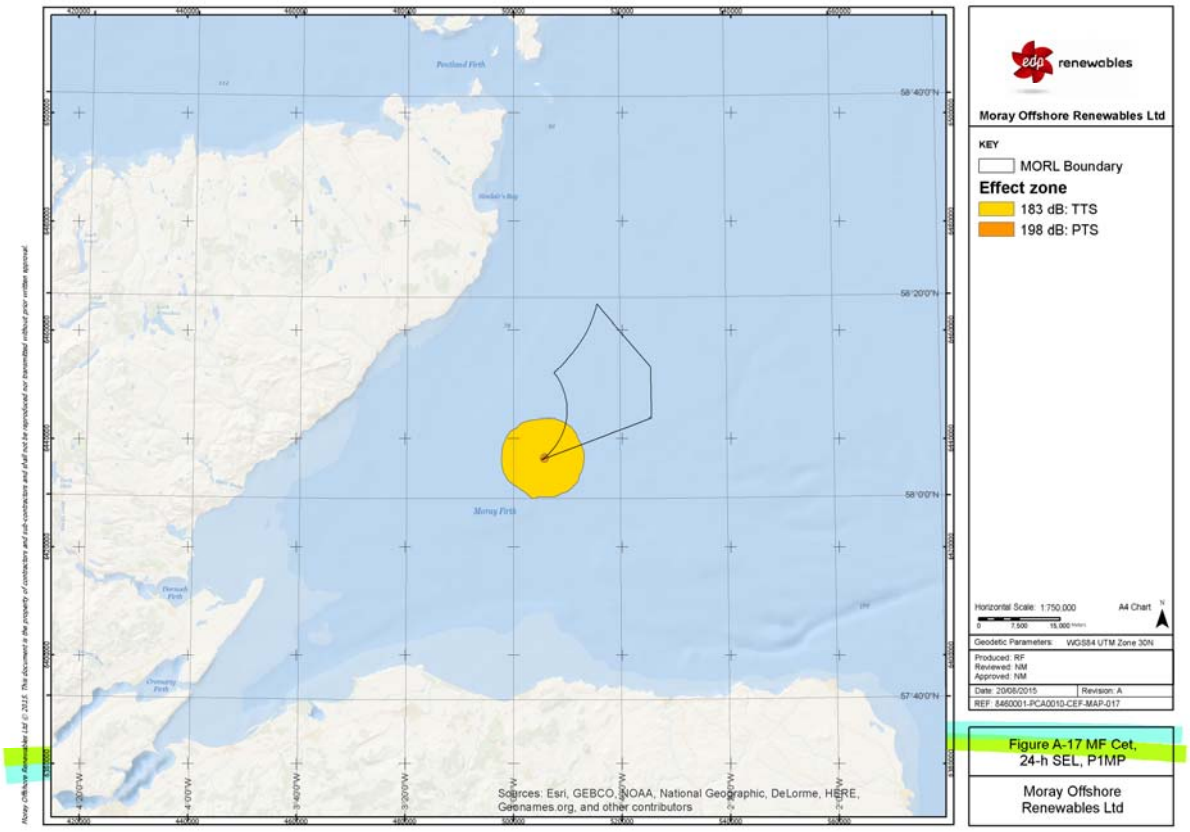

Figure A-17. 24-hour cumulative effect zone prediction for bottlenose dolphin, Profile 1 MP.

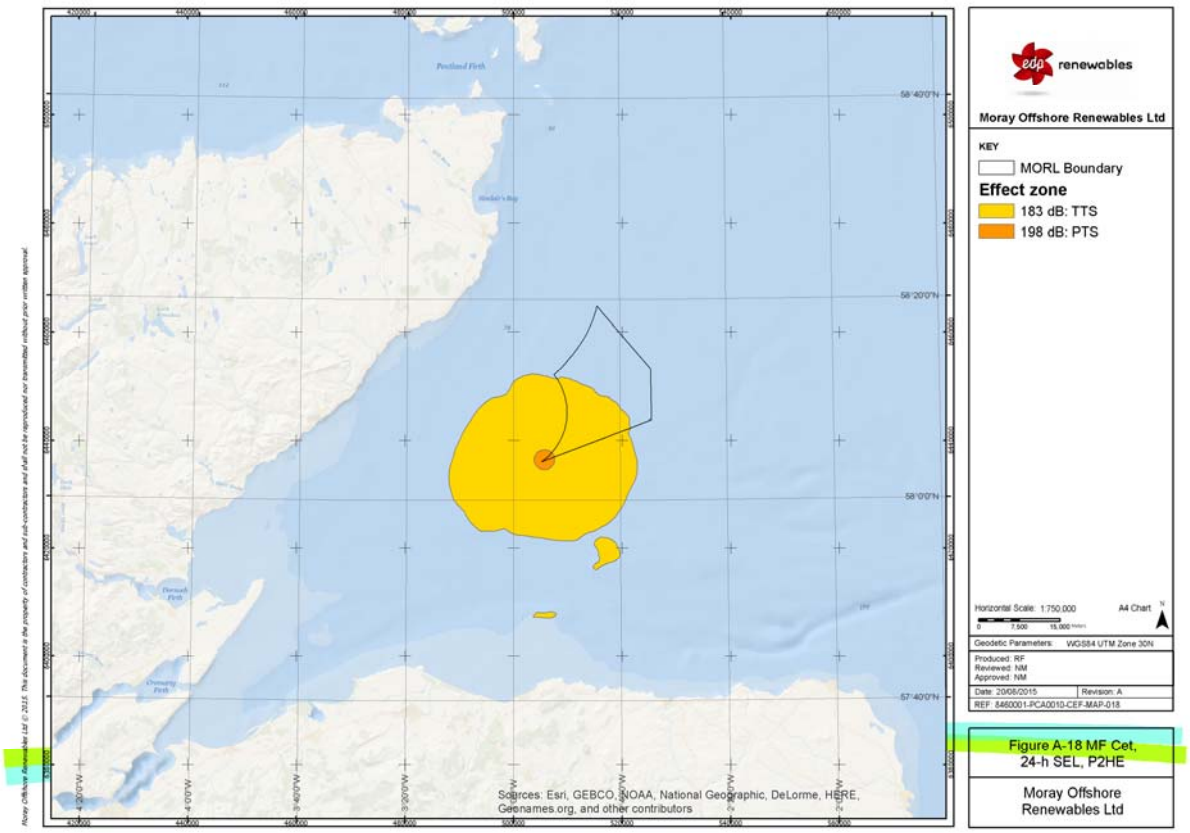

Figure A-18. 24-hour cumulative effect zone prediction for bottlenose dolphin, Profile 2 HE.

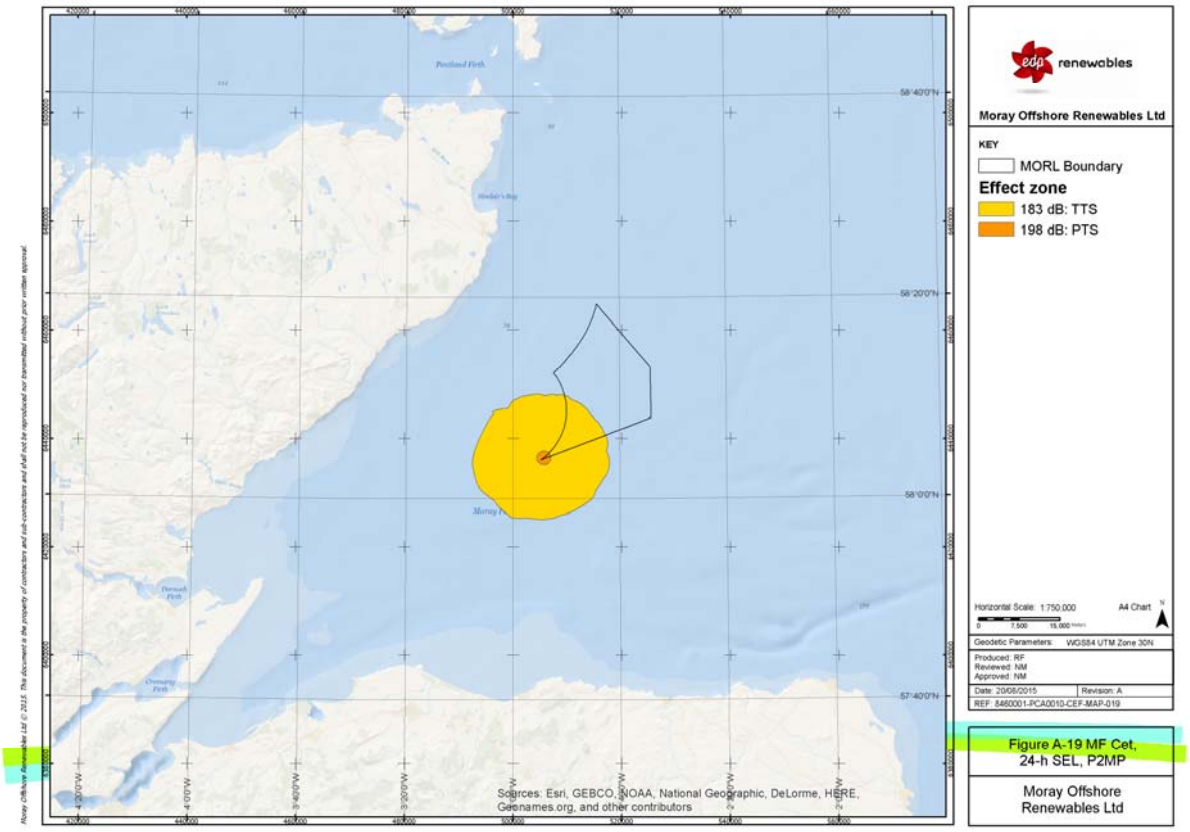

Figure A-19. 24-hour cumulative effect zone prediction for bottlenose dolphin, Profile 2 MP.

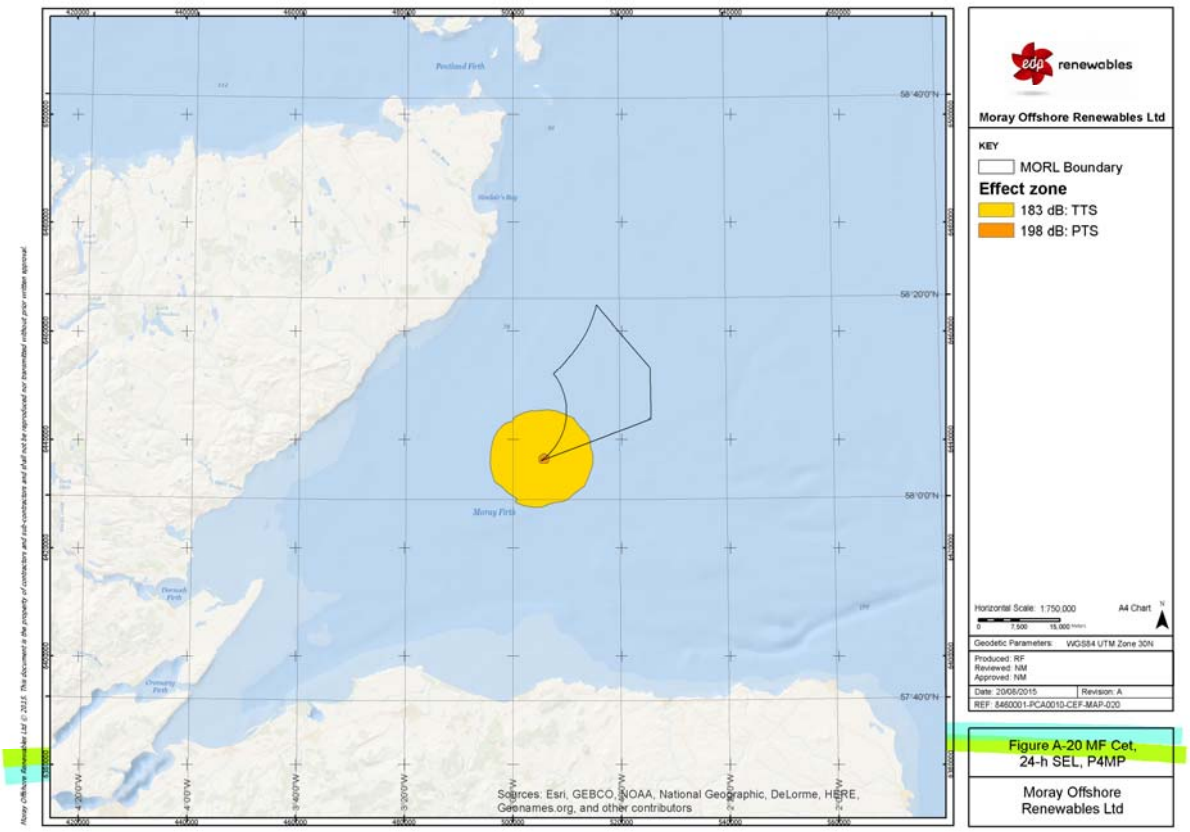

Figure A-20. 24-hour cumulative effect zone prediction for bottlenose dolphin, Profile 4 MP.

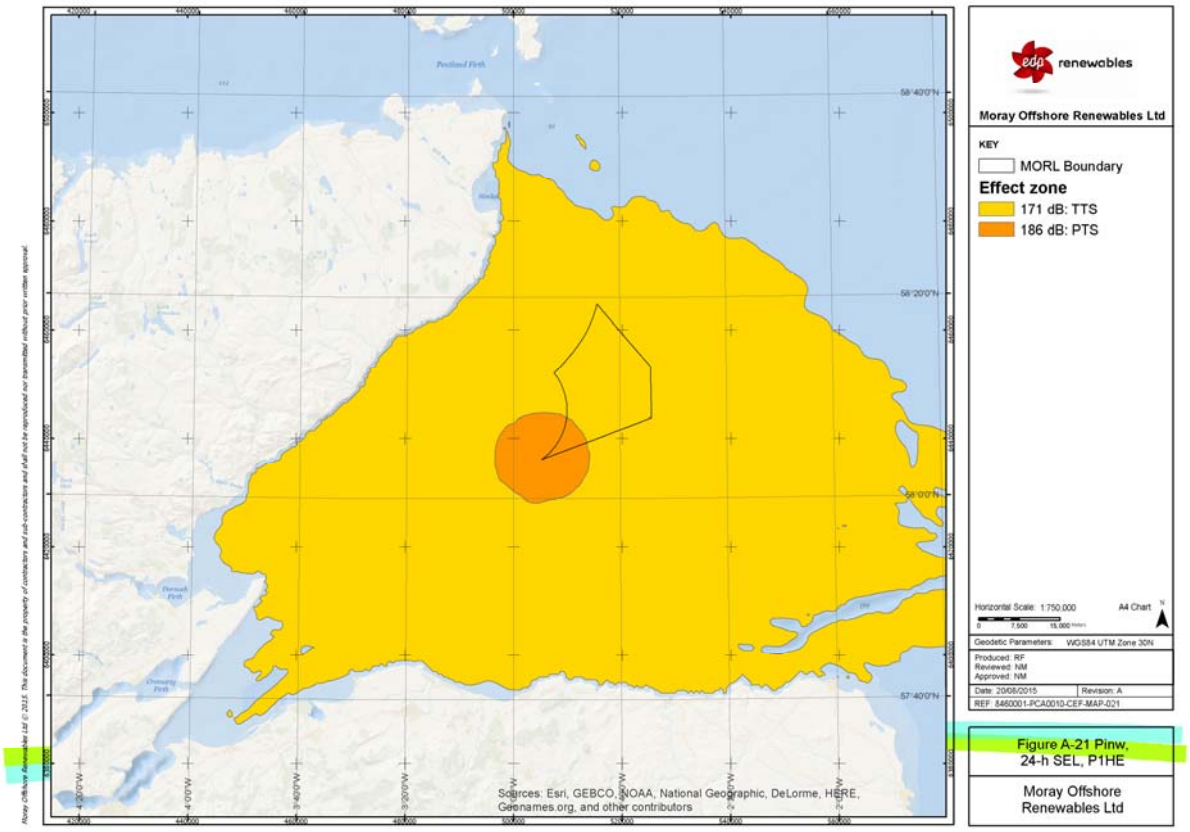

Figure A-21. 24-hour cumulative effect zone prediction for grey and harbour seal, Profile 1 HE.

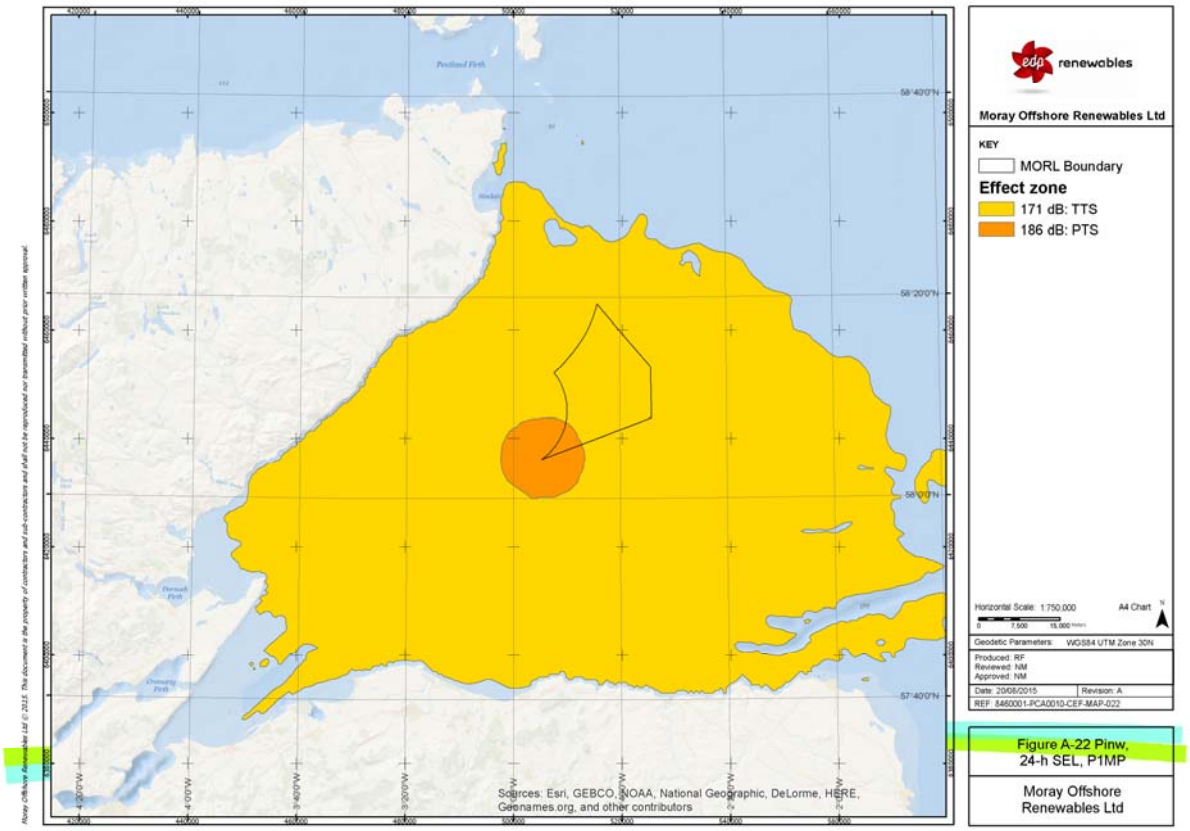

Figure A-22. 24-hour cumulative effect zone prediction for grey and harbour seal, Profile 1 MP.

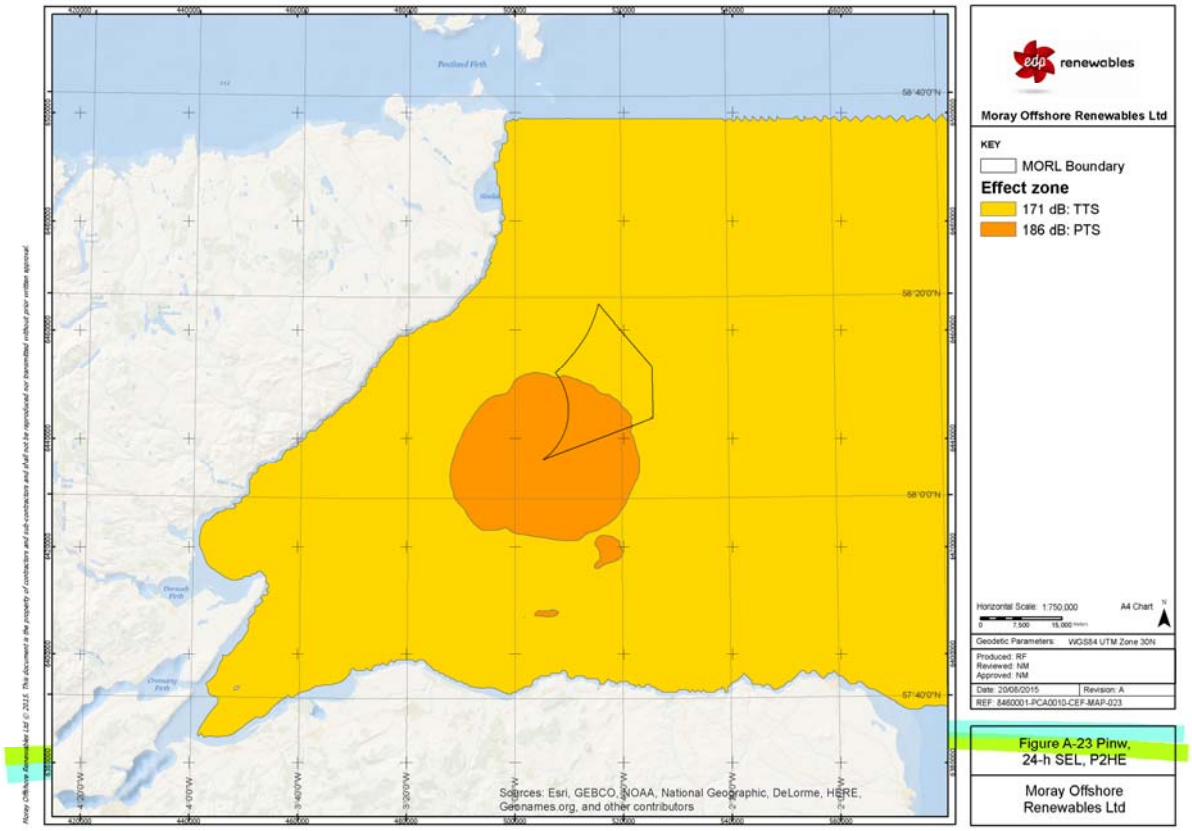

Figure A-23. 24-hour cumulative effect zone prediction for grey and harbour seal, Profile 2 HE.

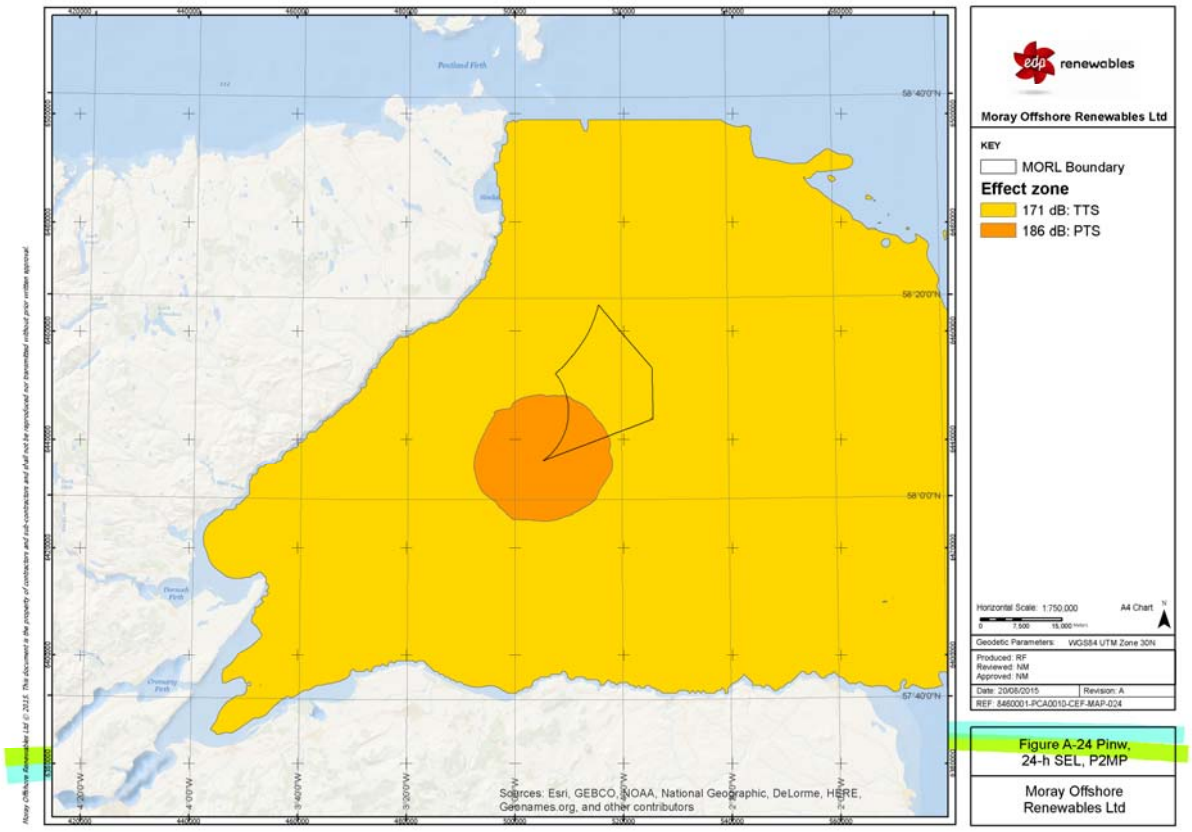

Figure A-24. 24-hour cumulative effect zone prediction for grey and harbour seal, Profile 2 MP.

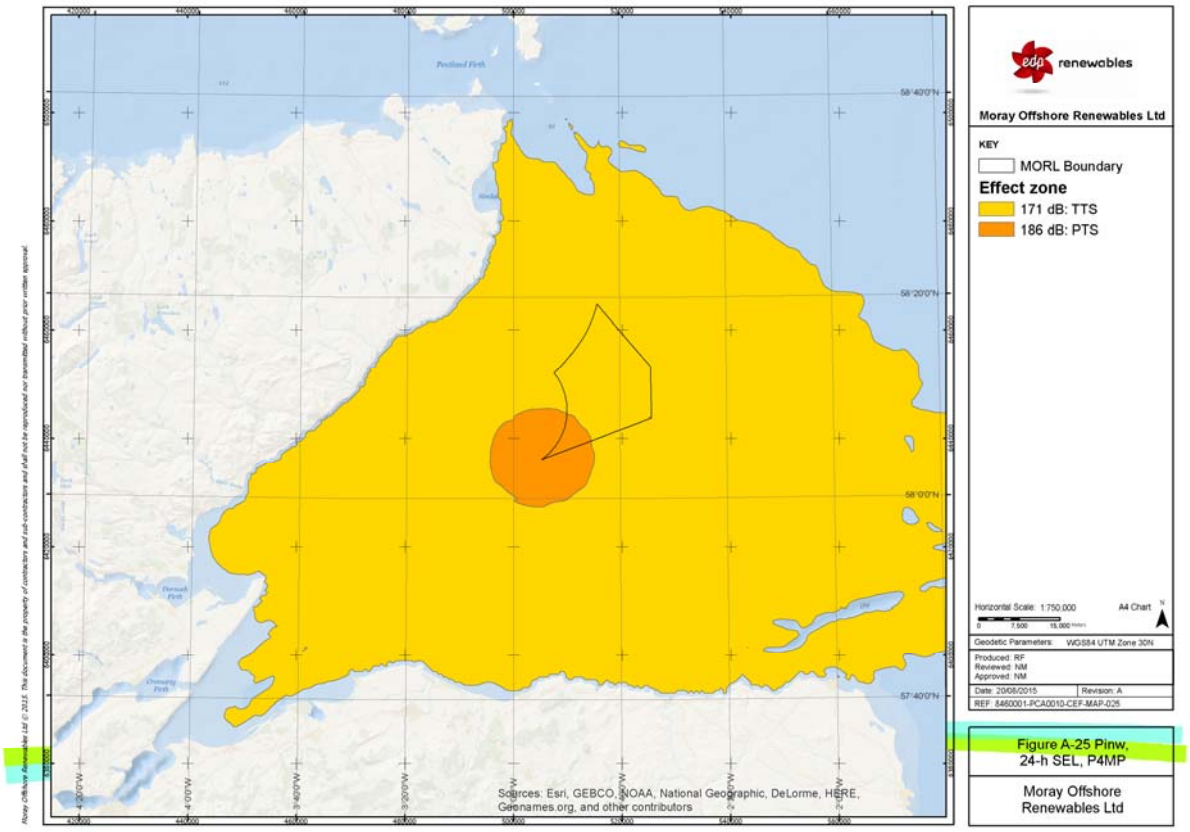

Figure A-25. 24-hour cumulative effect zone prediction for grey and harbour seal, Profile 4 MP.

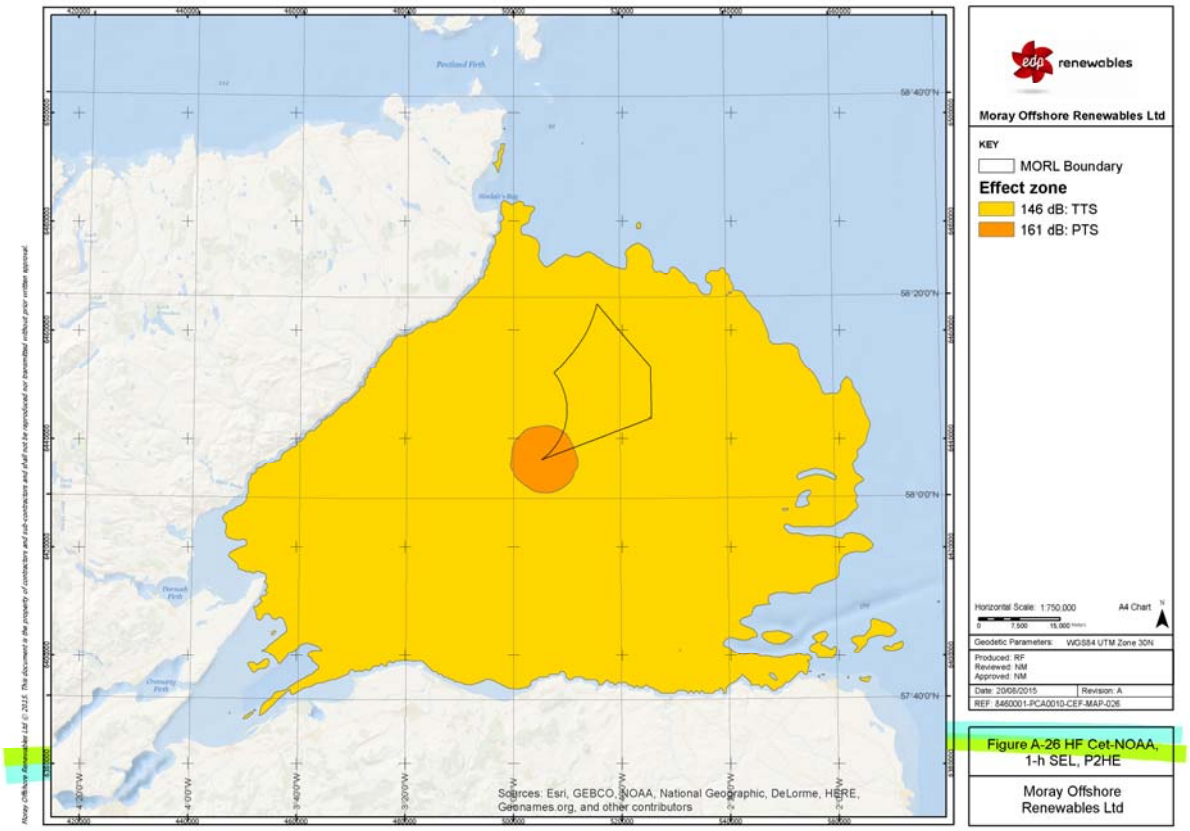

Figure A-26. 24-hour cumulative effect zone prediction for harbour porpoise, Profile 2 HE, 2013 NOAA criteria.

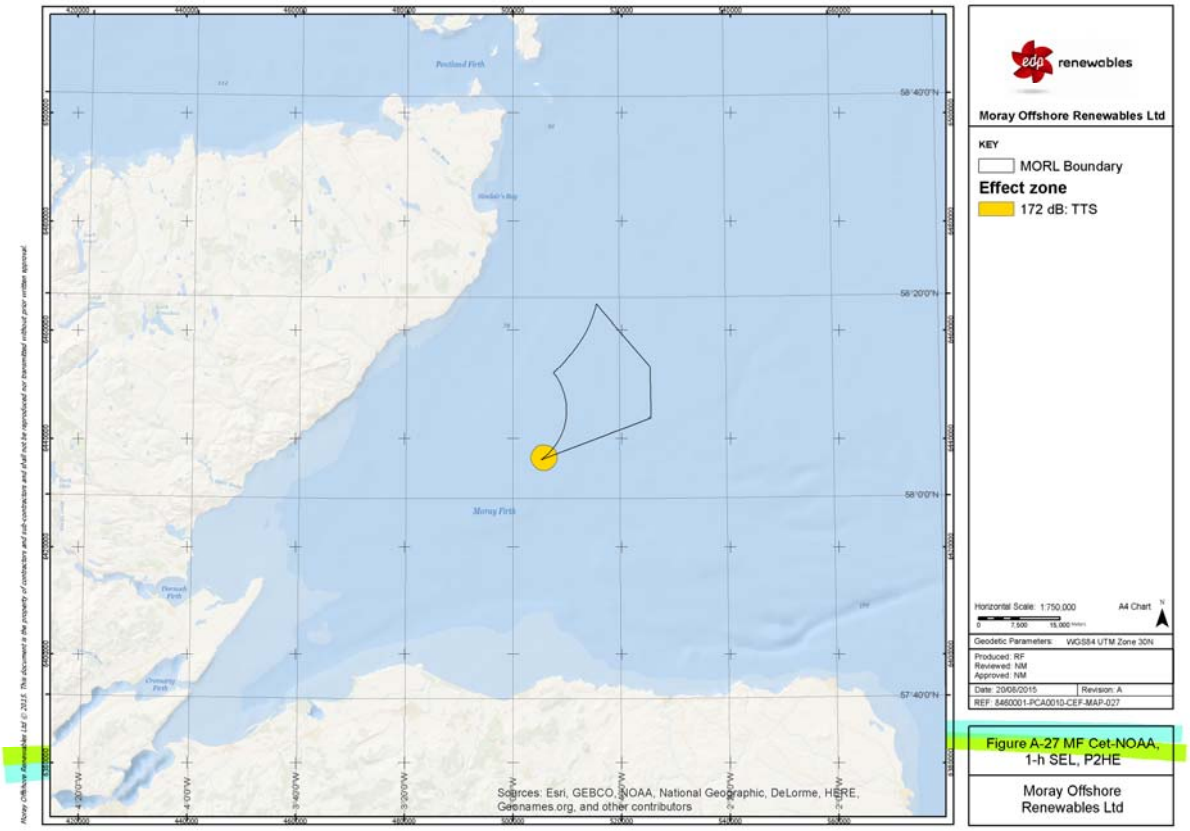

Figure A-27. 24-hour cumulative effect zone prediction for bottlenose dolphin, Profile 2 HE, 2013 NOAA criteria.

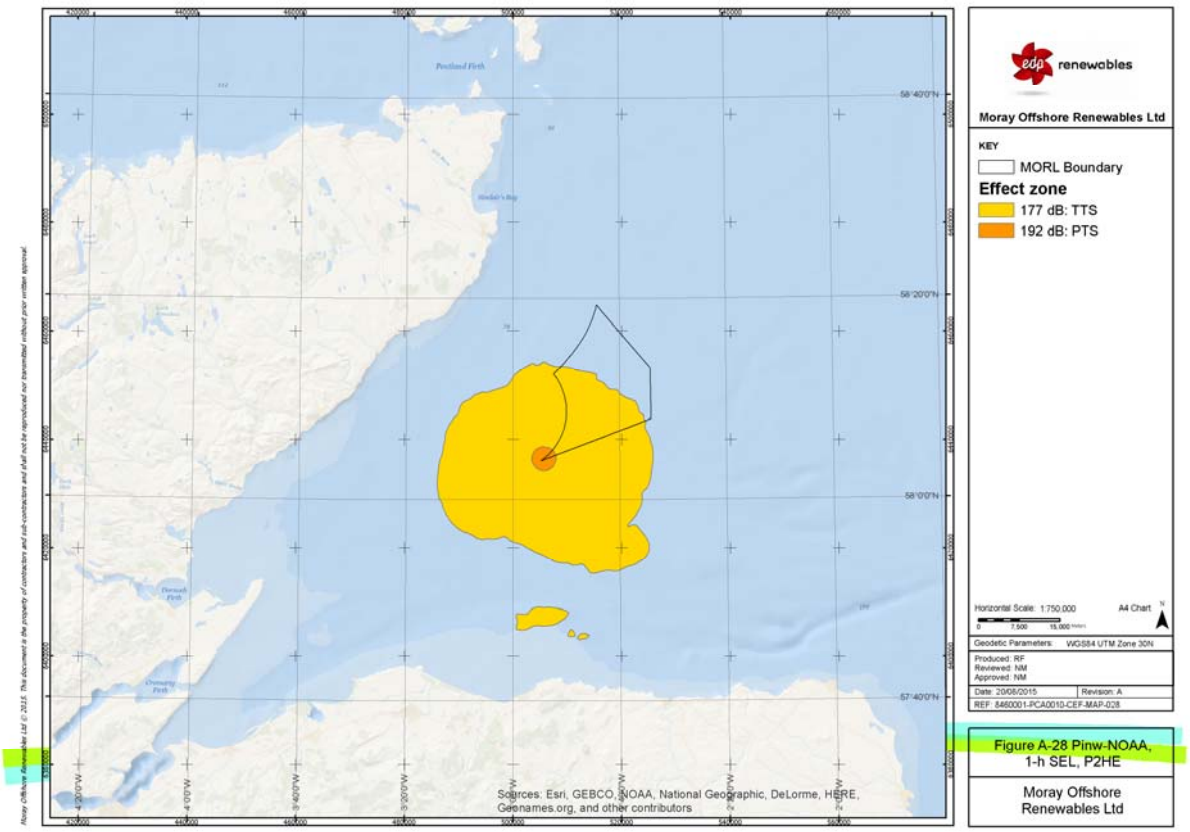

Figure A-28. 24-hour cumulative effect zone prediction for pinnipeds, Profile 2 HE, 2013 NOAA criteria.

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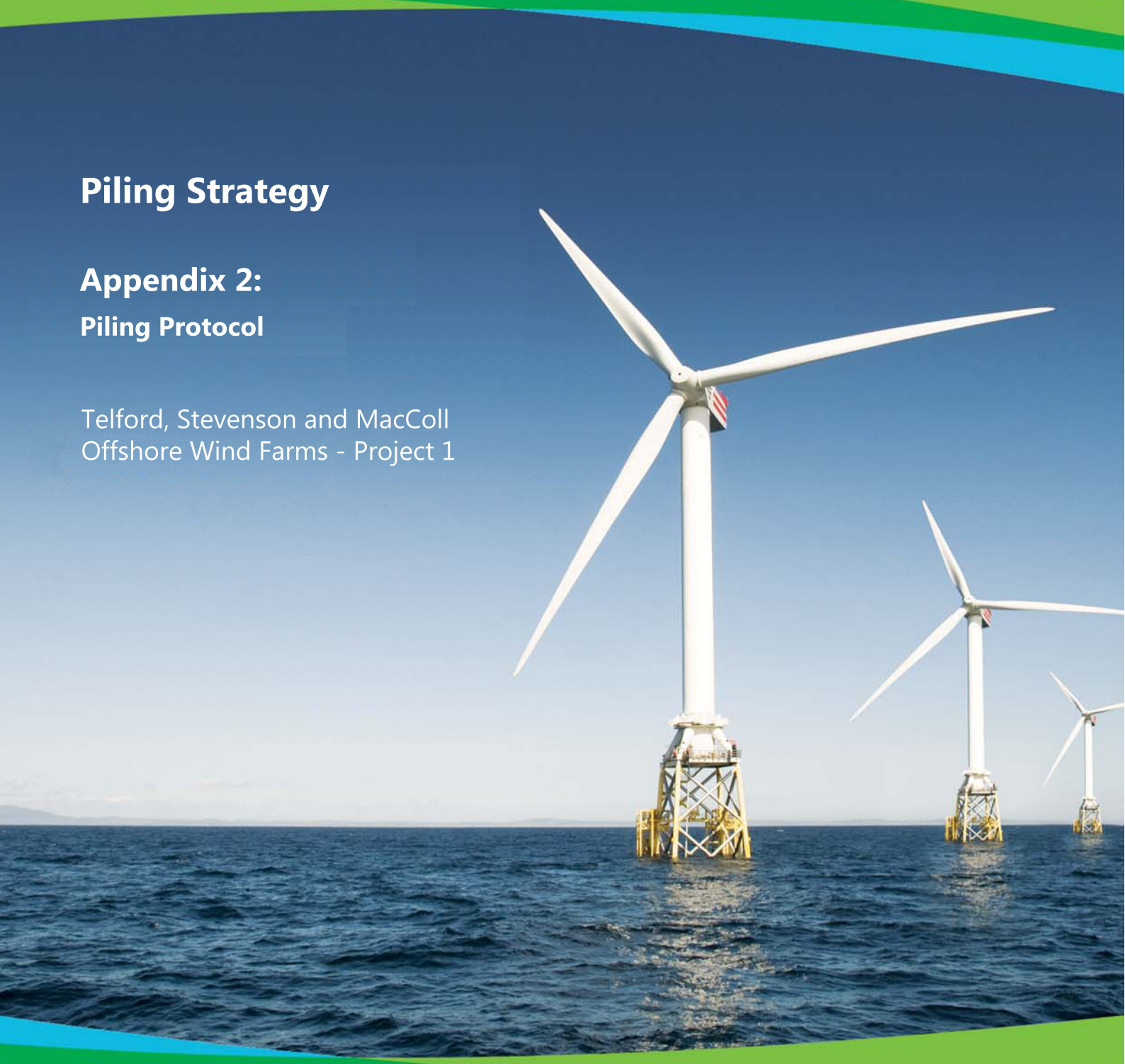
Developing Wind Energy In The Outer Moray Firth

Piling Strategy

Appendix 2:

Piling Protocol

Telford, Stevenson and MacColl
Offshore Wind Farms - Project 1



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Protocol for mitigating the risk of instantaneous death or injury to marine mammals during piling at the BOWL and MORL Wind Farms

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2nd October 2015

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Contents

Background: To date the consents issued to offshore wind farms have focused on the current JNCC guidelines to minimise the instantaneous near-field impacts of piling on marine mammals (JNCC, 2010). Nevertheless these guidelines remain untested and a number of studies have criticised the reliance on these guidelines with calls for more effective mitigation (see Annex 3). Recent studies provide evidence that acoustic deterrent devices (ADDs) can result in aversive responses by both seals and cetaceans over ranges which are at least in the order of magnitude greater than predicted zones for instantaneous death and injury (see Annex 2). This indicates that they could be integrated into piling procedures along with soft start to provide more effective mitigation and improve the protection of marine mammals. This document (including Annexes 1-3) provides the proposals for mitigating the risk of instantaneous death or injury to marine mammals during piling at the BOWL and MORL wind farms.

Aim: This document outlines a procedure for mitigating the risk of instantaneous death or injury to marine mammals during piling at the BOWL and MORL wind farms, with the aim of developing the *Best Available Technique* [1] for balancing the highest level of environmental protection against commercial affordability and practicality.

Specific Objectives: To develop mitigation measures that can be integrated into a predictable and efficient engineering process that:

- minimises the risk of instantaneous death or injury (physical or auditory) for marine mammals during piling operations as a result of single noise pulses at close range;
- allows piling to be initiated in darkness, in poor visibility or after breaks in engineering works;
- can be used safely in an offshore environment in all seasons; and
- minimises the duration of the overall construction period.

Approach:

1. ***Optimise hammer energies to balance environmental risk and engineering requirements.*** Use available geotechnical data to predict the hammer energies required through the piling sequence to minimise the risk of pile refusal. Optimise piling sequence at each site to avoid unnecessary activity at full hammer energy (to minimise impact zones for instantaneous death and injury) and optimise hammer energies throughout the piling process (to minimise cumulative noise exposure).

[1] As defined in 2010 JNCC piling mitigation guidance.

2. ***Identify impact zones***. Estimate the size of impact zones for instantaneous death and injury based upon available geotechnical data, final pile sizes and predicted hammer energies at the start of each piling sequence (see Annex 1).

3. ***Develop site specific protocol for initiating the sequence of piling at each turbine location.*** This should involve the key elements outlined in Figure 1 (see page 5). The piling protocol presents the different steps (a to d) throughout the piling sequence with a justification of how the detail has been determined in each step. In addition, the piling protocol presents an illustration of how far an animal may be deterred (indicative cumulative distance) at each step in order to demonstrate that the protocol is sufficiently conservative to allow marine mammals to avoid the injury zone during piling.

    a. Deploy acoustic deterrent device (ADD) at the piling site for a period of 15 minutes (as agreed with the MFRAG-MM Subgroup at the meeting of the 19/06/2015), to allow marine mammals to be displaced out of the impact zones. Duration of ADD use to be based upon estimates of the size of the impact zone and likely swimming speeds. Herschel et al. (2013) recommend that the duration of mitigation should be tailored to allow all animals to swim twice the distance of the injury zone. Selection of ADD to be based upon available evidence on effective displacement of key receptors for each site (see Annex 2).

    b. Soft start commences with positioning the piling hammer and making 5-6 single blows at a low rate (approximately 1 blow per 10 seconds) using as low an energy as practically possible to check hammer operation and embed the pile into the ground. Although the energy level cannot be specified accurately (as this depends on equipment capabilities) the energy will not exceed 300 kJ (threshold set on the basis of 12%[2] of the maximum hammer size[3] of 2,500 kJ that may be employed during construction).

    c. Soft start continues with an increased blow rate of approximately 1 blow per 2 seconds. The minimum duration of soft start will be 20 minutes, consistent with JNCC guidelines. During this time soft start energy will be as low as possible for as long as possible (following recommendations by Herschel et al.

[2] For each halving of hammer energy there is a 3 dB reduction in sound and the ORJIP report on acoustic deterrent devices (Herschel et al. 2014) suggests that a tenfold reduction in hammer energy may be appropriate for initiating soft start as this represents a potential 10 dB reduction in sound. Whilst it may be possible to achieve this in practice, the thresholds here must be set according to the hammer manufacturers' specifications, which for a 2,500 kJ hammer is given as 12% or 300 kJ. This also represents a considerable reduction in sound of >9dB.

[3] Maximum hammer size is to be distinguished from maximum consented hammer energy.

(2013)), starting at an energy no higher than 300 KJ and not exceeding 500 KJ in the latter part of the soft start.

d. Continue to ramp up hammer energy gradually to the levels required to maintain pile movement at approximately 2.5 cm/blow up to the energy required to drive the pile up to target depth.

4. ***Develop site specific protocol to be used in planned or unplanned breaks in the sequence of piling at each turbine location.*** This should involve the key elements outlined in Figure 2 (see page 6).

   a. In the event of breaks in piling of < 10 minutes no additional mitigation would be required (i.e. the piling may continue from the hammer energy and frequency last used). For breaks in piling > 10 minutes[4] there are two possible outcomes as described in 4b. and 4c. below.

   b. Where duration of break is either unknown, or known to be less than 2.5 hours[5]

      i. deploy ADD for the same pre-determined period (as specified in 3a and as agreed with the MFRAG-MM Subgroup at the meeting of the 19/06/2015) immediately prior to resuming piling,

      ii. initiate piling with approximately 5 - 6 single blows at low energy; and

      iii. continue to ramp up hammer energy to the levels required to maintain pile movement at approximately 2.5 cm/blow.

   c. If the break is greater than 2.5 hours, or if the break occurs during the soft start procedure described under 3 (b. and c.)), re-start procedure as outlined in 3.

5. **Monitoring and Audit.** Establish an agreed monitoring system and an audit trail to demonstrate that:

   a. The ADD is operating according to specifications during all operations.

   b. Hammer energies remain within agreed limits within soft start periods.

   The detailed monitoring and reporting procedures can be integrated within each of the projects' Environmental Management Plans (EMPs) and Project Environmental Monitoring Programmes (PEMPs).

[4] JNCC guidelines state that if there is a pause of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated (Section 2.5 in JNCC, 2010).

[5] Based on the deterrence time (total duration that animals are deterred from a disturbed area) of harbour porpoise estimated for the DEPONS model (van Beest et al. 2015) using the life-history parameters and fine-scale movement behaviour as described in model developed by Nabe-Neilson et al., (2014).

6. **Risk assessment.** Recognising that this protocol represents a change in procedures used for piling mitigation, and the efficacy of this protocol cannot be robustly demonstrated within appropriate timescales, undertake a risk assessment to assess the impact on protected marine mammal populations should key receptors not respond to the chosen ADD as expected. This risk-based approach should be used to place any risk from ineffective mitigation in the context of related impacts from piling noise (i.e. cumulative noise exposure and behavioural disturbance) that have previously been considered in the Environmental Statements (ES) and Habitats Regulations Assessment (HRA). A risk assessment has been undertaken for the BOWL and MORL sites, demonstrating that adoption of these new mitigation procedures should present negligible additional risk to the key receptor population in the Moray Firth (see Annex 3).

Figure 1. Schematic providing an example of a piling mitigation procedure based on the general guidelines outlined in section 3.

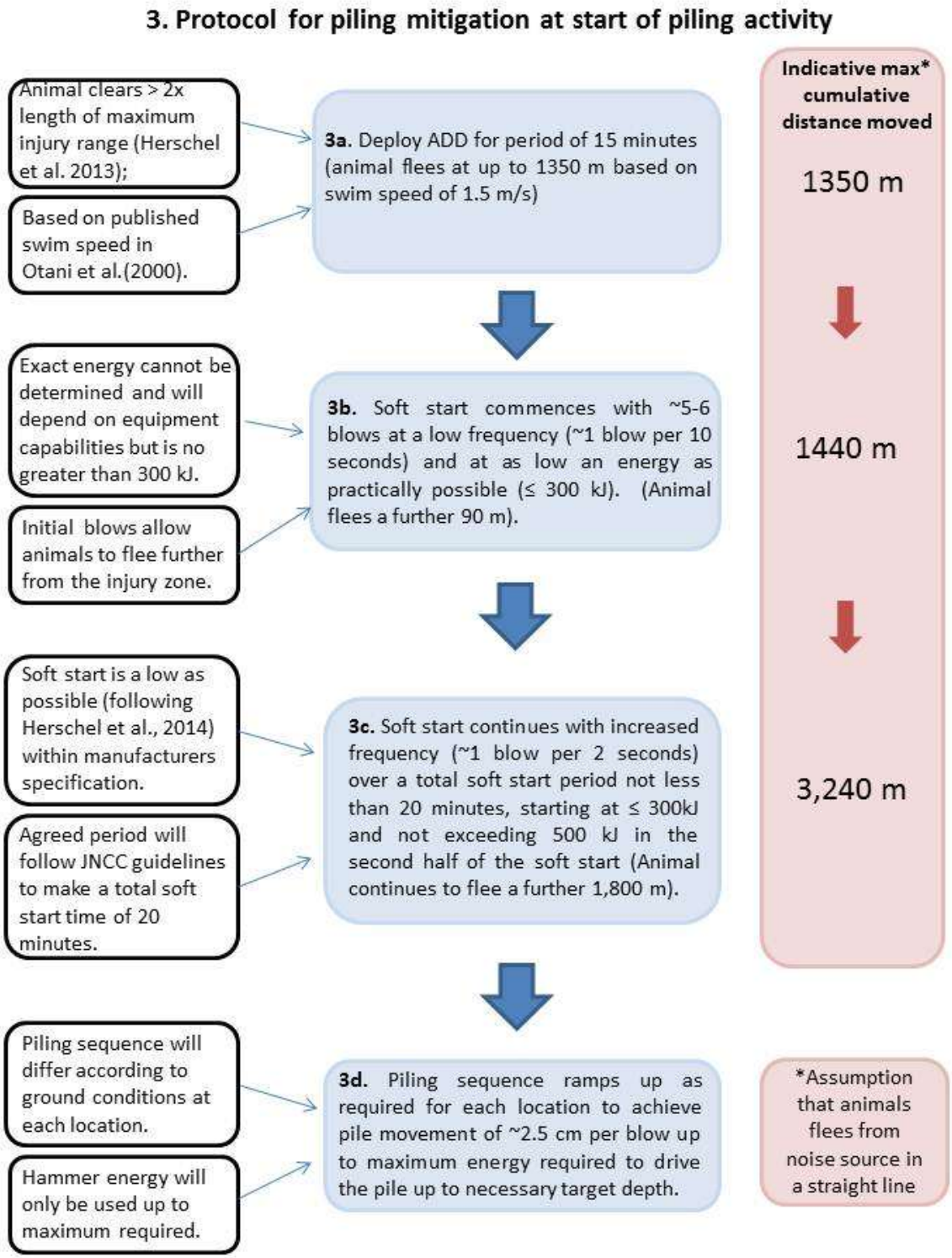
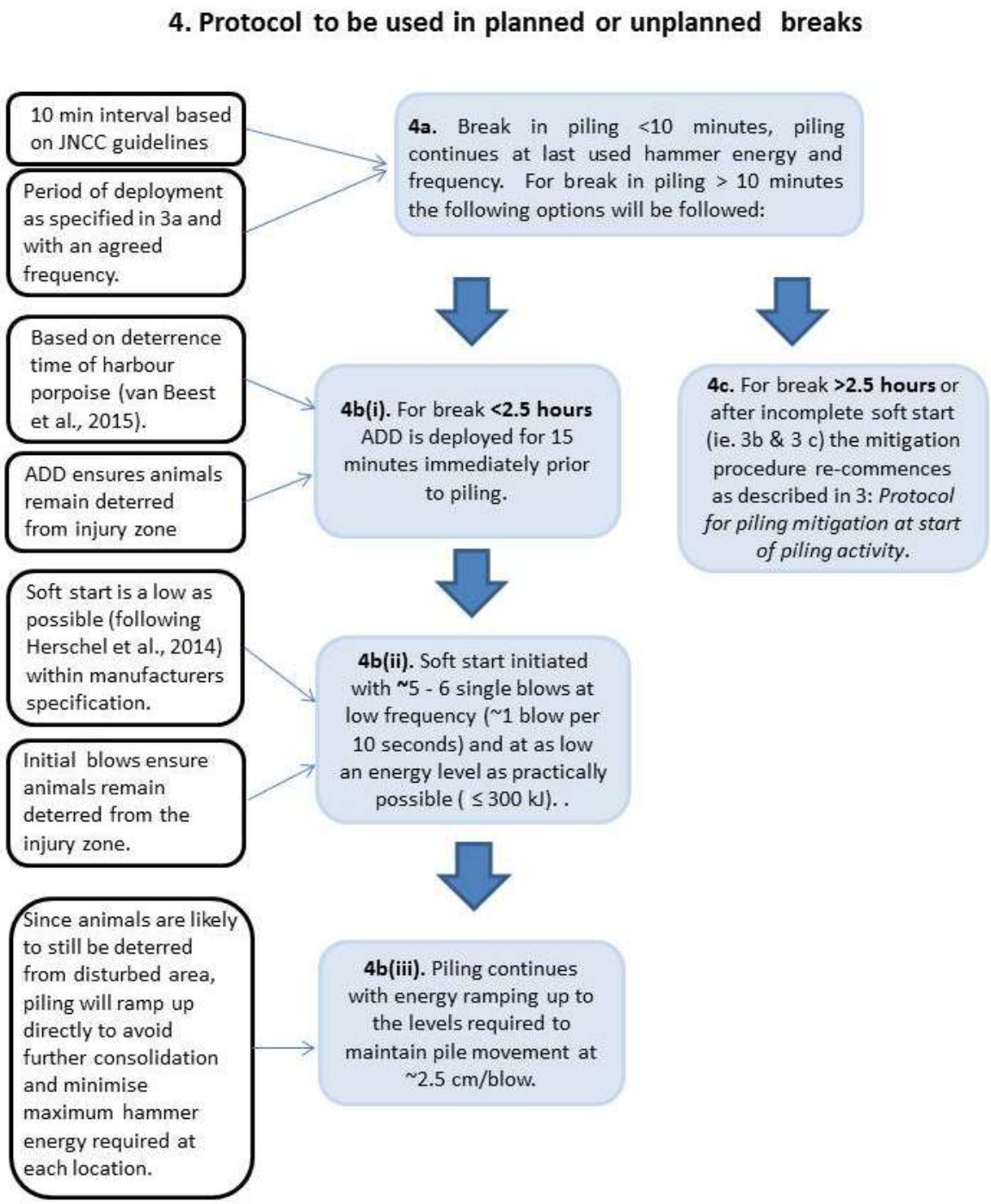


Figure 2. Mitigation protocol to be used in a planned or unplanned break from piling with distinction made between longer breaks and short breaks up to 2.5 hours.



References:

Herschel, A., Stephenson, S., Sparling, C., Sams, C., Monnington, J. (2013). Use of Deterrent Devices and Improvements to Standard Mitigation during Piling. ORJIP Project 4, Phase 1. Xodus Group Ltd. Document L-300100-S00-REPT-002.

Nabe-Nielsen, J., Sibly, R. M., Tougaard, J., Teilmann, J. and Sveegaard, S. (2014) Effects of noise and by-catch on a Danish harbour porpoise population. Ecological Modelling 272: 242-251.

Otani,S., Naito,Y., Kato,A., Kawamura,A. (2000) Diving behaviour and swimming speed of a free-ranging harbor porpoise, *Phocoena Phocoena*. Marine Mammal Science 16: 811-814.

van Beest, F.M, Nabe-Nielsen, J., Carstensen, J., Teilmann, J. & Tougaard, J. 2015: Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS): Status report on model development. Aarhus University, DCE – Danish Centre for Environment and Energy, 43 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 140 (http://dce2.au.dk/pub/SR140.pdf).

Annex 1.

Identification of impact zones

The following criteria should be used to identify the noise levels likely to cause instantaneous death or injury around piling operations using different pile sizes and hammer energies (eg. MORL ES Section 4.2.2 Technical Appendix 3.6A).

Death – may occur where peak-peak levels exceed 240 dB re 1 µPa

Injury (physical or auditory) - may occur where peak-peak levels exceed 220 dB re 1 µPa

In addition instantaneous auditory injury thresholds have been defined based upon Southall et al's (2007) single pulse PTS thresholds, expressed either in terms of a peak pressure level or an M weighted sound exposure level (SEL). More recent studies of harbour porpoise TTS thresholds (Lucke et al. 2009) have led to proposals for a revised single pulse PTS threshold for these high frequency cetaceans (ORJIP Project 4 Phase 1 Report p 139).

Species	Single pulse PTS Thresholds	
	SEL	Unweighted peak pressure
High-Frequency Cetacean (Southall et al. 2007)	M-weighted 198 dB re 1 $\mu Pa^2 s$	200 dB re 1 µPa
Mid-Frequency Cetacean (Southall et al. 2007)	M-weighted 198 dB re 1 $\mu Pa^2 s$	230 dB re 1 µPa
Low-Frequency Cetacean (Southall et al. 2007)	M-weighted 198 dB re 1 $\mu Pa^2 s$	230 dB re 1 µPa
High-Frequency Cetacean (based on Lucke et al. 2009)	Unweighted 179 dB re 1 $\mu Pa^2 s$	200 dB re 1 µPa
Pinniped (Southall et al. 2007)	M-weighted 186 dB re 1 $\mu Pa^2 s$	218 dB re 1 µPa

In the BOWL and MORL ES's the risk of instantaneous death was estimated to occur only at extremely short distances and the risk of instantaneous injury at less than 38 m.

For this assessment, CEFAS conducted additional modelling to provide a conservative estimate of impact ranges for a 300 kJ initial hammer energy. This assumed an energy conversion efficiency of 1%, which is at the upper limit of field observations (Ainslie et al. 2012; Dahl et al. (2015). This 300 kJ strike equates to 205.6 dB of acoustic energy as a single pulse SEL (de Jong & Ainslie 2008). A propagation loss of 15*log(R) was assumed due to cyclindrical spreading in these relatively shallow waters, where R is range from the source,

and an unweighted threshold of 179 dB re 1 µPa^{2}s (Lucke et al. 2009) was used to safeguard the most sensitive of marine mammals, including harbour porpoise. This suggests that the maximum range at which instantaneous injury might occur is <60m.

Estimating the time required for marine mammals to be displaced from injury zones

Following recommendations in the ORJIP Project 4 Phase 1 Report (p 142), ADD should be deployed for long enough for animals to swim twice the radius of the appropriate injury zone. The Piling Mitigation Protocol provides for marine mammals to clear an area an order of magnitude greater than this.

Following the approach taken in the ORJIP Project 4 Phase 1 Report (p141) these calculations should assume a minimum swimming speed of 1.5 m/s (Otani et al. 2000).

References:

Ainslie, M. A., de Jong, C. A., Robinson, S. P., & Lepper, P. A. (2012). What is the source level of pile-driving noise in water? In: The Effects of Noise on Aquatic Life (pp. 445-448). Springer New York.

Dahl, P.H., de Jong, C.A.F. & Popper, A. (2015). The underwater sound field from impact pile driving and its potential effects on marine life. Acoustics Today, 11, 18-25.

De Jong, C. A. F., & Ainslie, M. A. (2008). Underwater radiated noise due to the piling for the Q7 Offshore Wind Park. J Acoust Soc Am 123: 2987.

Herschel, A., Stephenson, S., Sparling, C., Sams, C., Monnington, J. (2013). Use of Deterrent Devices and Improvements to Standard Mitigation during Piling. ORJIP Project 4, Phase 1. Xodus Group Ltd. Document L-300100-S00-REPT-002.

Otani,S., Naito,Y., Kato,A., Kawamura,A. (2000) Diving behaviour and swimming speed of a free-ranging harbor porpoise, *Phocoena Phocoena*. Marine Mammal Science 16: 811-814.

Lucke K, Siebert U, Lepper PA, Blanchet MA (2009) Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. J Acoust Soc Am 125: 4060–4070

Southall B.L., Bowles A.E., Ellison W.T., Finneran J.J., Gentry R.L., Jr C.R.G., Kastak D., Ketten D.R., Miller J.H., Nachtigall P.E., et al. 2007 Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals 33: 411-521.

Annex 2. Deployment of acoustic deterrent devices.

Choice of ADD. Selection of ADD devices should be based upon the available evidence at the time of procurement given the suite of key receptors at a particular site. Based upon the current literature and the ORJIP review of available devices, it is anticipated that this could be a Lofitech Seal Scarer. A review of available literature on the performance of this device can be found on p 149 of the ORJIP Project 4 Phase 1 Report (Herschel et al. 2013).

In summary, marine mammals with both high frequency (harbour porpoise) and low frequency (harbour seal) have been shown to respond to the Lofitech Seal Scarer. Of particular relevance to the Moray Firth developments are the studies of harbour porpoises in the Danish Baltic Sea, where the use of the Lofitech Seal Scarer decreased sighting rates within 1 km to only 1% of baseline (see Figure 4 and Brandt et al. 2013a). Similarly, in the German North Sea waters, deployment of the Lofitech Seal Scarer resulted in significant decrease in harbour porpoise click activity (recorded using C-PODs) at 750 m and at 3,000 m from the source (Brandt et al. 2013b). Notably, at 750 m recovery was found to be gradual with a significant deterrence effect lasting up to 4 to 6 hours after the Lofitech Seal Scarer was turned off, suggesting that effects are likely to last no longer than 6 hours at this distance (Brandt et al. 2013b).

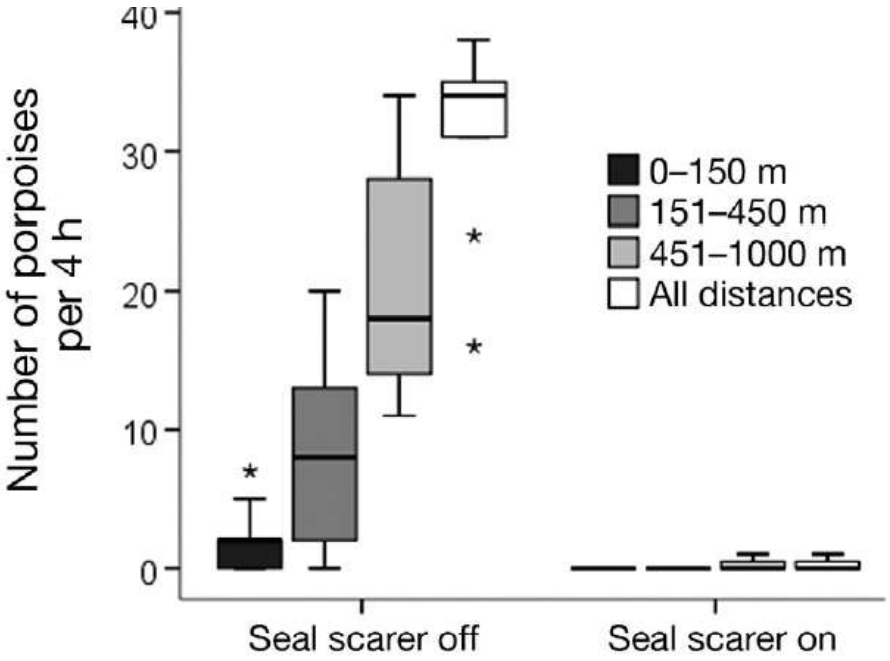


Fig 4 from Brandt et al. (2013) showing variation in sightings rate during observation periods when the Lofitech Seal Scarer was turned on compared to when the Lofitech Seal Scarer was turned off.

Further studies of responses of Moray Firth harbour seals to this device have been conducted both in river systems (Graham et al. 2009) and open water (SMRU Unpublished data). Graham et al's (2009) study showed that use of the device reduced upstream movements of seals by 50%, even though seals are likely to have been strongly motivated to travel upstream to forage on salmonids. Studies conducted for Marine Scotland by SMRU indicate that in open water a behavioural response was observed for all 38 controlled exposure experiments for which a tagged harbour seal was within 1 km of the source, and responses were recorded to a maximum range of > 3km.

Methods for deployment of ADD. A single device should be deployed as close as possible to the piling site, ideally so that the deployment is fully integrated with the engineering process (eg. through remote operation of a device deployed from the piling vessel).

Timing of deployment of ADD. Decisions over the duration of ADD use should seek to balance the key objective of dispersing animals from the injury zone against any risks of habituation to the ADD source, cumulative noise exposure to the ADD source or broader scale disturbance.

Following ORJIP recommendations (Herschel et al. 2013), the duration of deployment at start of piling sequence should be sufficient to allow individuals to travel 2x the distance of the injury zone at a cruising speed of 1.5m/sec.

- Eg. for a 60m injury zone, ADD deployment of just 1.5 minutes would permit animals to swim beyond the required 120 m.

To minimise excessive disturbance and habituation, whilst also ensuring sufficient time for animals to clear the injury zone there should be an agreed duration for each ADD deployment. Following submission of a draft of this Piling Mitigation Protocol, this was discussed with the SNCBs, and the duration for ADD deployment was agreed as 15 minutes.

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Herschel, A., Stephenson, S., Sparling, C., Sams, C., Monnington, J. (2013). Use of Deterrent Devices and Improvements to Standard Mitigation during Piling. ORJIP Project 4, Phase 1. Xodus Group Ltd. Document L-300100-S00-REPT-002.

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

Paul Thompson, 28th September 2015

Overview

There is widespread interest in the use of Acoustic Deterrent Devices (ADDs) as an alternative to Marine Mammal Observers (MMO) and Passive Acoustic Monitoring (PAM) when mitigating the risk of death or injury to marine mammals during offshore piling. However, decisions on the most appropriate mitigation during construction of the Moray Firth developments remain constrained by stakeholder concerns over the relative efficacy of ADDs and the current JNCC guidelines.

To inform decisions about the potential risk of using these alternative piling mitigation measures, an assessment of the potential risk to different marine mammal species in the absence of ***any*** piling mitigation has been developed. To place this risk in the broader population context considered within the original Environmental Statements (ES) and Habitats Regulations Assessments (HRA), the Moray Firth Harbour Seal Assessment Framework has been used to re-assess the long-term population consequences for this key receptor species. In doing so, the effects of post-consent changes in the project design and construction programme have been explored, comparing the original worst case ES scenarios with new worst case scenarios for BOWL and MORL together based on the current design layout. In addition, the potential risk of injury from scenarios in which piling occurred only within the BOWL or the MORL wind farms were developed to support individual EPS Licence applications.

Current JNCC guidelines are assumed to reduce the potential risk of injury or death to negligible levels. The analyses presented here suggest that, in the absence of any piling mitigation, the risk of marine mammals being within sufficiently close range to result in instantaneous death or injury is also negligible even when considering effects from both BOWL and MORL developments together. Thus, the adoption of alternative mitigation measures using ADD should either equal or exceed the level of protection assumed to result from the current JNCC guidelines.

Background

The key impacts of wind farms on marine mammal populations that are likely to result from pile-driving during construction [1] are:

(1) Instantaneous death or injury (physical or auditory) from single noise pulses at close range
(2) Auditory damage from accumulated noise doses
(3) Behavioural disturbance

In the Environmental Statements (ES) for the Moray Firth developments, the distances at which each of these effects might occur were based upon best available scientific evidence from noise propagation modelling and published marine mammal noise exposure criteria [2]. These data indicated that instantaneous death or traumatic injury should occur only at distances of < 40m (see Table 1). In contrast, behavioural disturbance and the impacts of cumulative noise exposure were predicted to occur at much greater distances. For example, piling noise exposure amongst harbour seals could exceed Southall et al.'s (2007) Permanent Threshold Shift (PTS) threshold for auditory damage [2] at distances of > 10-15km.

In 2010, building on related guidelines for seismic surveys [3], guidance was produced by JNCC to mitigate injuries that might result from pile-driving activity. These require the use of Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring (PAM) to minimise the likelihood that a piling sequence is initiated when marine mammals are within a 500m mitigation zone. When assessing the population consequences of piling activity within the Moray Firth developments, it was assumed that close range impacts resulting in instantaneous death or injury would be avoided through adoption of the 2010 JNCC guidelines [4]. Given that cumulative noise exposure may lead to PTS over ranges in excess of 10km, JNCC guidelines clearly provide negligible protection against the effects of any far field auditory damage resulting from cumulative noise exposure, or indeed for behavioural disturbance. The population effects of these other unmitigated residual impacts were assessed in the ES as resulting in no significant long term effects, and the Habitats Regulations Assessment (HRA) concluded that they did not affect the long term conservation status. Efforts have been made to further reduce any of these longer range impacts through post-consent changes in the design layout. Furthermore, post-consent geotechnical investigations are currently underpinning the development of strategies that aim to minimise the cumulative energy required to drive each pile into the seabed. The requirement for mitigation at the start of each piling process is therefore to reduce the risk of instantaneous death or traumatic injury to negligible levels at the start of each of these piling sequences.

The need for alternative mitigation measures

Although a pragmatic first step towards minimising the impacts of noise on marine mammals, the 2010 JNCC guidelines remain untested. Reliance on the guidelines has subsequently received criticism in the scientific literature, with calls for more effective mitigation [5]. In particular, it is recognised that the probability of visually detecting marine mammals at sea is extremely low [6]. Furthermore, the probability of detection by Passive Acoustic Monitoring (PAM) systems is known to be zero for some key receptors such as harbour seals, and is uncertain for all other species [7].

Recognising these issues, there is widespread agreement over the need for more effective measures to mitigate the risk of instantaneous death or injury at close range. Recent studies provide evidence that at least one commercially available Acoustic Deterrent Device (ADD) can result in behavioural responses by both seals and cetaceans over ranges which are at least an order of magnitude greater than predicted zones for instantaneous death and injury [8, 9]. This suggests that ADDs may be a more effective tool than MMOs and PAM where mitigation aims to maximise the likelihood that animals are outside predicted impact zones at the start of piling.

Consequently, ADDs and soft start piling could be integrated into new procedures for offshore piling that should provide more effective mitigation and improve the protection of marine mammals. This approach would also provide greater certainty in engineering timelines, avoiding delays due to the onset of night time, poor weather and MMO detections. This would have three additional benefits:

1) Greater economic certainty for overall construction plans. This would increase the likelihood of individual developments going forward and contributing to the UK's efforts to meet current climate change targets.
2) Greater certainty in timelines for individual piling events. This would improve the optimisation of piling events within predicted weather windows and reduce HSE risks.
3) Overall reduction in the construction period. This would reduce broader scale disturbance from vessel activity. A shorter construction period would likely also have wider environmental benefits by reducing impacts on other receptors and producing less carbon.

Whilst ADDs have been used in conjunction with MMOs under JNCC guidelines in some regions, discussion within the Offshore Renewables Joint Industry Programme (ORJIP) has highlighted that there are strong stakeholder concerns over the adoption of ADDs as an alternative to the temporal restrictions which would result from the use of MMOs and PAM. Most critically, Statutory Nature Conservation Bodies (SNCBs) are currently requesting scientific evidence that ADDs are more effective than current JNCC guidelines before agreeing to their use as an alternative mitigation measure. This raises two key challenges for regulators and the industry:

1) Given there has been no assessment of the efficacy of current JNCC guidelines, it is unclear how proposed studies might demonstrate that ADDs are more effective than this unknown baseline.
2) Given the global experience of previous behavioural response studies, it is unclear whether a viable experiment can be designed to provide the expected level of confidence in the effectiveness of ADDs as an alternative mitigation measure.

BOWL and MORL are currently developing piling strategies that must be economically viable and accepted by key stakeholders. Critically, project milestones dictated by DECC mean that this process must be completed in Q4 2015. In contrast, even if suitable research projects could be designed and commissioned through ORJIP, results would not be available for at least 2 years, well beyond the timescales required for approval of the projects' piling strategies. Decisions on the potential use of ADDs within the BOWL and MORL piling strategies must therefore be made on the existing evidence

base. Currently, however, these decisions are constrained because of SNCB and Regulator concern that the adoption of alternative mitigation measures using ADD may result in unacceptable risks.

Aims

This document develops a framework that aims to allow regulators to assess whether the risk of using ADDs as an alternative form of piling mitigation is acceptable.

Given the challenges outlined above, the proposed approach involves assessing the consequences of a complete failure in the efficacy of ***any*** of the potential mitigation measures.

If it can be demonstrated that there is negligible additional risk to these populations in the absence of any effective mitigation for near-field impacts, then the use of (potentially more effective) alternative mitigation measures using ADDs should either equal or exceed the level of protection assumed to result from the current JNCC guidelines.

Framework overview

The general approach used in this risk assessment was to use site specific density data to estimate the likelihood that randomly distributed individuals may be close enough to a pile to be killed or injured at the start of a single piling sequence. The BOWL Wind Farm layout includes 84 turbines, two offshore transformer modules (OTMs), and two spare locations, each requiring four piles with a maximum diameter of 2.2m. The first phase of the MORL development (Project 1) will not exceed 100 turbines, with a maximum of 4 piles per turbine, and up to 16 piles for each of the up to two Offshore Substation Platforms (OSPs). This information was used to estimate the likelihood of an individual being killed or injured at the start of the resulting maximum number of piling events during the construction period for each scenario. This maximum number was 784 piling events for both projects together, 352 for BOWL only[6] and 432 for MORL Project 1 only scenarios. These calculations were made for all five marine mammal species considered in the ES (Harbour Seal, Grey Seal, Bottlenose Dolphin, Harbour Porpoise & Minke Whale). For harbour seals, the numbers of individuals that might be impacted in the absence of effective mitigation of these close-range impacts were also included in revised scenarios of the Seal Assessment Framework used in the BOWL and MORL ES's. This was then used to compare the long term population consequences of the worst case cumulative construction scenario, with and without mitigation.

Figure 1 provides an overview of the approach used, illustrating where information was drawn from the existing ES's and where new outputs have been generated. More detailed information on the methods used is presented below. As for the Seal Assessment Framework, the approach aimed to be conservative. For example, when generating random distributions of animals, it was assumed that the presence of vessels prior to piling did not disturb any individuals from the immediate vicinity of the piling vessel. Other key assumptions are listed in The Annex.

Potential impact zones were based on ES predictions of the distances at which different species may be killed or physically injured instantaneously from a single loud pulse. The approaches used in the

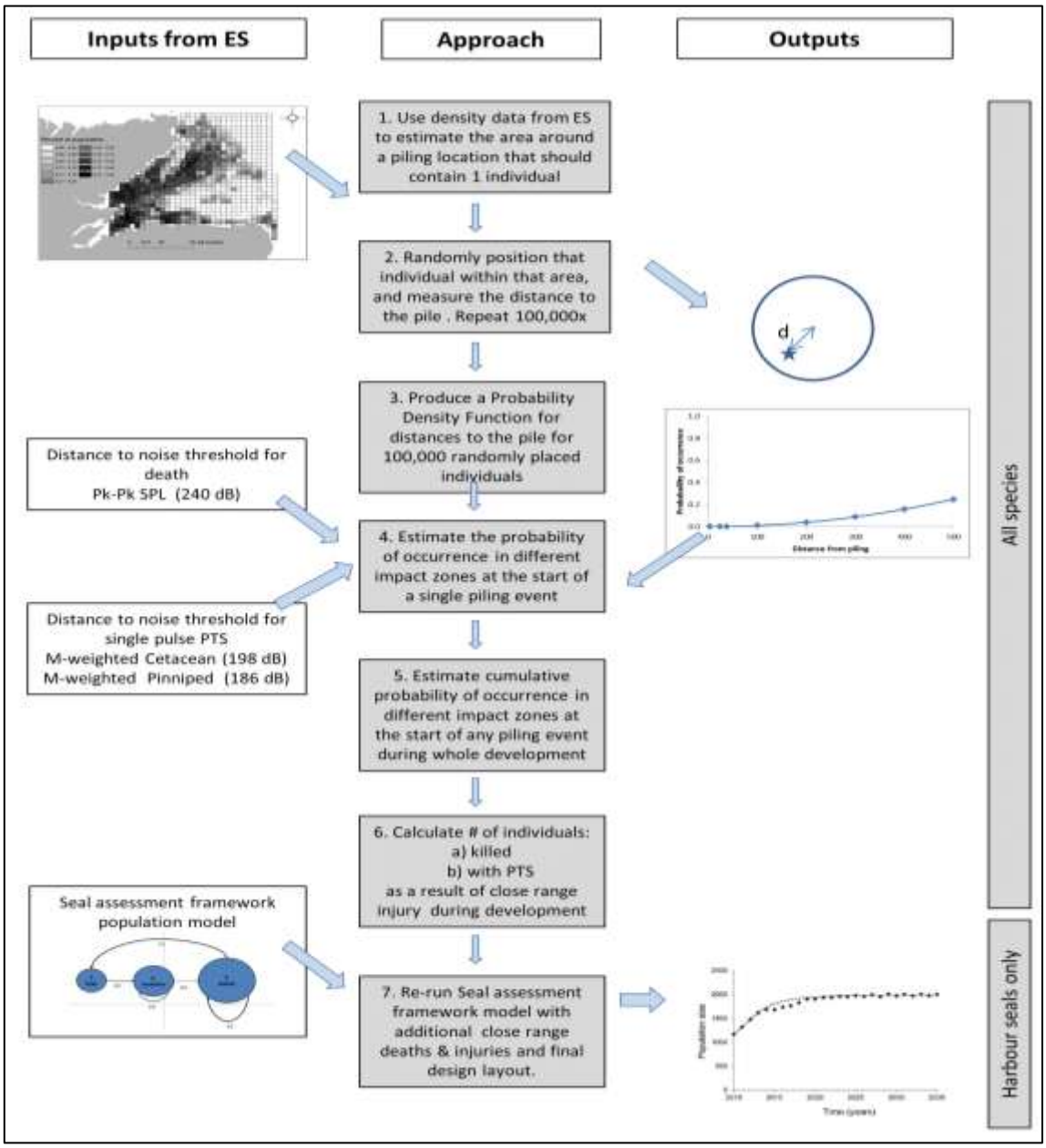
[6] This included 2 spare locations as a worst case scenario

BOWL and MORL ES's varied slightly (Table 1) but, in both cases, risk of death occurred only at extremely short range with risk of instantaneous injury always being <40m. To assess the potential risk of instantaneous injury from a 300 kJ soft start as proposed for the BOWL and MORL Project 1 developments, risk assessments were also used for a more conservative 60m impact zone (see Annex 1 of main document).

Table 1. Distance bands used to estimate close-range impacts of piling

Distance Band	Impact	Species	Criteria	Source
2m	Death	All Marine Mammals	Unweighted pk-pk SPL of 240 dB re. 1µPa (Lethality). Based on a 1200 kJ hammer and a 2.5m pile.	MORL ES Appendix 3.6a, S. 4.2.2.)
4m	Injury	Cetaceans	M weighted single pulse PTS criteria of 198 dB re. 1µPa^2-s. Based on a 360kJ hammer on soft start and a 1.8m pile.	Southall et al (2007) BOWL Supp. noise modelling (unpubl.)
24m	Injury	Pinnipeds	M weighted single pulse PTS criteria of 186 dB re. 1µPa^2-s. Based on a 360kJ hammer on soft start and a 1.8m pile.	Southall et al (2007) BOWL Supp. noise modelling (unpubl.)
38m	Injury	All Marine Mammals	Unweighted pk-pk SPL of 220 dB re. 1µPa (Injury). Based on a 1200 kJ hammer and a 2.5m pile.	MORL ES Appendix 3.6a, S. 4.2.2.)
60m	Injury	All Marine Mammals (based upon harbour porpoise being most sensitive)	Unweighted single pulse PTS criteria of 179 dB re. 1µPa^2-s. Based on a 300kJ hammer energy on soft start.	Annex 1 of main document
500m	N/A	All Marine Mammals	MMO Mitigation Zone	JNCC (2010)

Figure 1. Schematic showing the general approach used to compare the population consequences of variations in the efficacy of mitigation measures used to reduce the impacts of instantaneous death or injury around a piling site.



Methods

Estimating marine mammal occurrence within different impact zones at the start of piling sequences

Predicted distributions were based on the density estimates for each of the marine mammal species that were assessed in the BOWL and MORL ES's. Density estimates for impacts of BOWL and MORL together were based on mean values across all grid cells within the two development zones, whilst

density estimates for BOWL and MORL alone were based on the mean values within each individual development site (Table 2). For each species, density data were used to estimate the area and radius of a circle around each piling site that should include one individual (Table 2).

Individuals were then randomly positioned within these circles and their distance from the pile was measured. This was repeated 100,000 times to estimate the probability of individuals being present within different zones at the start of any individual piling sequence.

If each piling event is assumed to be independent (see the Annex to this Risk-based Framework Assessment), the probability of an individual marine mammal occurring within each impact zone during the first piling strike of any of the 784 piles required for construction of the BOWL and MORL Project 1 wind farms can be calculated from the cumulative binomial probability. This approach can also be used to estimate the maximum number of occasions on which an individual is likely to be present in each zone over the sequence of 784 piling events (here estimated using a 95% probability level). These probabilities were also calculated separately for the individual projects, although to simplify the analysis, the focus was on estimating the probability of occurrence within the 60m injury zone only (as this is the most relevant to the Piling Mitigation Protocol), rather than repeating for all the distance bands.

Table 2. Estimates of density within the Moray Firth development areas, with estimated circle radii that would be expected to contain one individual. Separate estimates were produced for BOWL only, MORL only and impacts for BOWL and MORL Project 1 together based upon local densities within each site

	Mean density (individuals per km^2)	Radius of circle containing one individual (m)
BOWL + MORL		
Harbour Seal	0.31	1020.7
Grey Seal	0.15	1456.0
Harbour Porpoise	0.862	607.7
Bottlenose Dolphin	0.00016	44514.4
Minke Whale	0.022	3803.8
BOWL		
Harbour Seal	0.312	1010.2
Grey Seal	0.119	1638.1
Harbour Porpoise	0.926	586.3
Bottlenose Dolphin	0.00006	70711.8
Minke Whale	0.022	3803.8
MORL		
Harbour Seal	0.304	1023.8
Grey Seal	0.159	1413.1
Harbour Porpoise	0.843	614.5
Bottlenose Dolphin	0.00019	41021.3
Minke Whale	0.022	3803.8

Assessing the population consequences of not mitigating instantaneous death and injury

Assessments of population level impacts were only made for one of the Moray Firth's priority species; harbour seals. This was because the estimated density of bottlenose dolphins in the Outer Moray Firth is so low that the cumulative probability of this second priority species occurring even within a 500m mitigation zone around piling events was <0.1 (see results below).

Population trajectories were compared for different construction scenarios with effective mitigation and without any mitigation to prevent instantaneous death or injury. These comparisons were developed using baseline models from the Moray Firth Seal Assessment Framework. Worst case scenarios used in the BOWL and MORL ES's were first adapted to reflect subsequent changes in the scale of each development (see Table 3), and these were used as baseline construction scenarios assuming that effective mitigation was in place.

These baseline construction scenarios already incorporated impacts of wind farm construction through (1) reductions in survival as a result of PTS from cumulative noise exposure (where 25% of animals that suffer injury from PTS will subsequently die) and (2) declines in reproduction as a result of behavioural displacement (where 100% of animals that suffer behavioural displacement will have reproductive failure in that year) [4]. In addition, baseline construction scenarios include the annual shooting of individuals due to licenced killing by fisheries interests. Any additional impacts from unmitigated instantaneous deaths can therefore be incorporated by supplementing the annual removals from shooting. Any additional impacts from unmitigated instantaneous injury can be incorporated by supplementing the number of individuals with PTS. In addition, an extreme worst case scenario was developed for the unmitigated injuries that assumed 100% mortality as a result of those injuries. In each of these cases, the numbers of individuals were based on the cumulative probability of an individual occurring within the different impact zones (see Table 1) during the initiation of piling at any of the 784 piling events during the entire BOWL and MORL Project 1 construction periods.

Table 3. Comparison of key piling parameters used in the ES worst case scenarios and the current design basis layout for the BOWL and MORL developments.				
Parameter	BOWL		MORL[7]	
	ES Worst case	Design Basis Layout	ES Worst case	Project 1 Indicative Design
Number of turbines	277 x 3.6 MW	84 x 7 MW	339	< 100
Total piling phase for a single vessel	3 years	1.5 years	5 years	2 years

Overall, seven construction scenarios, with different combinations of mitigation and injury severities were compared as outlined in Table 4. These included one of the original ES worst case scenarios, and three variations for each of two different revised construction scenarios. The first revised construction scenario (Revised A) involved a four year construction period, and the second (Revised B) involved a three year construction period. The three variants of each related to whether or not there was mitigation and the mortality rate resulting from PTS (Table 4; Annex to this Risk-based Framework Assessment). To allow comparison with outputs from the ES, the first year of construction was set at 2014 in all cases. Similarly, to facilitate comparison of the effects of any mitigation, models were run using the best fitting curve for behavioural displacement and a carrying capacity of 2000. For further details see relevant ES sections [4]. The primary difference between these scenarios and those used in the ES relates to the numbers of turbines in the final layout, and the consequences that this has on the number of vessels used and the duration of construction. The main comparisons retain the original ES assumption that displacement leads to 100% failure in reproduction. However, the reduction in turbine numbers at both sites means that most piling is likely to occur in the summer months, and emerging data from DECC SEA funded studies in the Wash further indicate that displacement during piling is more limited in both space and time than predicted in the ES. In one additional scenario, we therefore explore the effects of reducing this conservatism in the impacts of displacement to a more probable worst case of a 50% failure in reproduction (see Annex to this Risk-based Framework Assessment).

[7] MORL has received three Section 36 consents for a maximum total capacity of 1,116 MW generated by not more than 186 turbines. MORL is planning to develop the area through a phased approach. The first phase of development (Project 1) is currently being developed pending announcements of a future Contract for Difference (CfD) allocation round. However, MORL anticipates that Project 1 will not exceed 100 turbines with the balance being developed in a subsequent phase(s).

<table>
<tr><th colspan="6">Table 4. Summary of the different indicative construction scenarios modelled to explore the consequences of not mitigating instantaneous death and injury</th></tr>
<tr><th colspan="2">Model Scenario</th><th>Duration</th><th>Construction Scenario (see ES)</th><th>Mitigation</th><th>Mortality rate from instantaneous injury</th></tr>
<tr><td>1</td><td>ES Worst Case Cumulative A</td><td>5 yrs</td><td>2 piling vessels on BOWL for 2 yrs
followed by:
2 piling vessels on MORL for 3 yrs</td><td>Yes</td><td>-</td></tr>
<tr><td>2</td><td rowspan="3">Revised A</td><td>4 yrs</td><td rowspan="3">1 piling vessel on BOWL for 2 yrs
followed by:
1 piling vessel on MORL for 2 yrs</td><td>Yes</td><td>-</td></tr>
<tr><td>3</td><td>4 yrs</td><td>No</td><td>25%</td></tr>
<tr><td>4</td><td>4 yrs</td><td>No</td><td>100%</td></tr>
<tr><td>5</td><td rowspan="3">Revised B</td><td>3 yrs</td><td rowspan="3">1 piling vessel on BOWL for 1 yr followed by
1 piling vessel on BOWL + 1 piling vessel on MORL for 1 yr followed by
1 piling vessel on MORL for 1 yr</td><td>Yes</td><td>-</td></tr>
<tr><td>6</td><td>3 yrs</td><td>No</td><td>25%</td></tr>
<tr><td>7</td><td>3 yrs</td><td>No</td><td>100%</td></tr>
</table>

Results

Estimating marine mammal occurrence within different impact zones at the start of piling sequences for BOWL and MORL Project 1together.

The probability that individuals of any of the five species of marine mammals were within the instantaneous death or injury zones at the beginning of a single piling event was extremely low in all cases (Table 5a). Probabilities are provided for relevant injury zones (death, PTS from instantaneous M weighted single pulse criteria for seals and cetaceans and physical injury) as shown in Table 1. For instantaneous death (within 2m) this was always ≤ 0.0001, and for instantaneous physical injury (within 60m) this was always < 0.05, even using the most conservative case of a harbour porpoise and a 300KJ hammer. In contrast, the probability that individuals may be present within the 500m mitigation zone at the beginning of a single piling event was sometimes much higher, and only extremely low (<0.01), for bottlenose dolphins. In particular, the probability that an individual may be present within the 500m zone at any single point in time was 0.68, for harbour porpoise, and 0.24 for harbour seals (Table 5a).

The cumulative probability for each of the five species being within the instantaneous death zone during the first strike of any of the 784 piling events was also extremely low (<0.01) for all species (see Table 5b). However, cumulative probabilities suggest that, with the exception of bottlenose dolphin, one cannot have 95% confidence that individuals are likely to be absent from the instantaneous injury zones during all the first piling strikes. Conversely it is almost certain (≥99%

probability) that all species except bottlenose dolphin will be present within the 500m mitigation zone during at least one first piling strike of the 784 piling events.

The cumulative probabilities can also be used to place an upper 95% confidence limit on the number of occasions (from the total of 784 piling events) on which individuals might be present in different zones during the first piling strike as shown in Table 5c. Table 5b indicates that there is a cumulative probability of 0.97 that a harbour seal will be present in the 60m single pulse PTS zone at the start of at least one of the 784 piling events. While Table 5c indicates that there is a 95% probability that this will not occur on more than 7 different occasions.

The data in Table 5c can therefore be used to put an upper limit on the number of individuals that may be affected by these instantaneous injuries during the construction period. These values can subsequently be used to assess population consequences, and assess the relative importance of these impacts compared with previously assessed impacts from cumulative noise exposure or behavioural disturbance. Here, this is explored for harbour seals through the Moray Firth Seal Assessment Framework, but data for other species such as harbour porpoise could be compared, for example, with estimates of Potential Biological Removal (PBR) [10, 11].

Similarly, data in Table 5c can be used to provide an indication of the number of times that different species may be present within the 500m mitigation zone (as detailed within JNCC guidelines as discussed above) during the construction period. These data suggest that harbour seals may be present within the mitigation zone during up to 208 (26%) of the first piling strikes, whereas harbour porpoises may be present during up to552 (70%) of these events.

Table 5. Probabilities for each species occurrence in each distance ban. Estimates are based on the BOWL + MORL Project 1 scenario using average densities across the two sites (see Table 2)

a) Probability of an individual being present in each distance band during the first strike of a single pile

	2m	4m	24m	38m	60m	500m
Harbour Seal	0.00001		0.00056	0.00136	0.0045	0.24109
Grey Seal	<0.00001		0.00038	0.00076	0.00218	0.11772
Harbour Porpoise	<0.00001	0.00003		0.00389	0.01293	0.67604
Bottlenose Dolphin	<0.00001	<0.00001		<0.00001	<0.00001	0.0001
Minke Whale	<0.00001	<0.00001		0.00016	0.0004	0.01697

b) Cumulative probability of an individual being present in each zone during at least one of the 784 first piling strikes

	2m	4m	24m	38m	60m	500m
Harbour Seal	<0.01		0.36	0.66	0.97	<1
Grey Seal	<0.01		0.26	0.45	0.82	<1
Harbour Porpoise	<0.01	<0.03		0.95	<1	<1
Bottlenose Dolphin	<0.01	<0.01		<0.01	<0.01	<0.1
Minke Whale	<0.01	<0.01		0.12	0.27	< 1

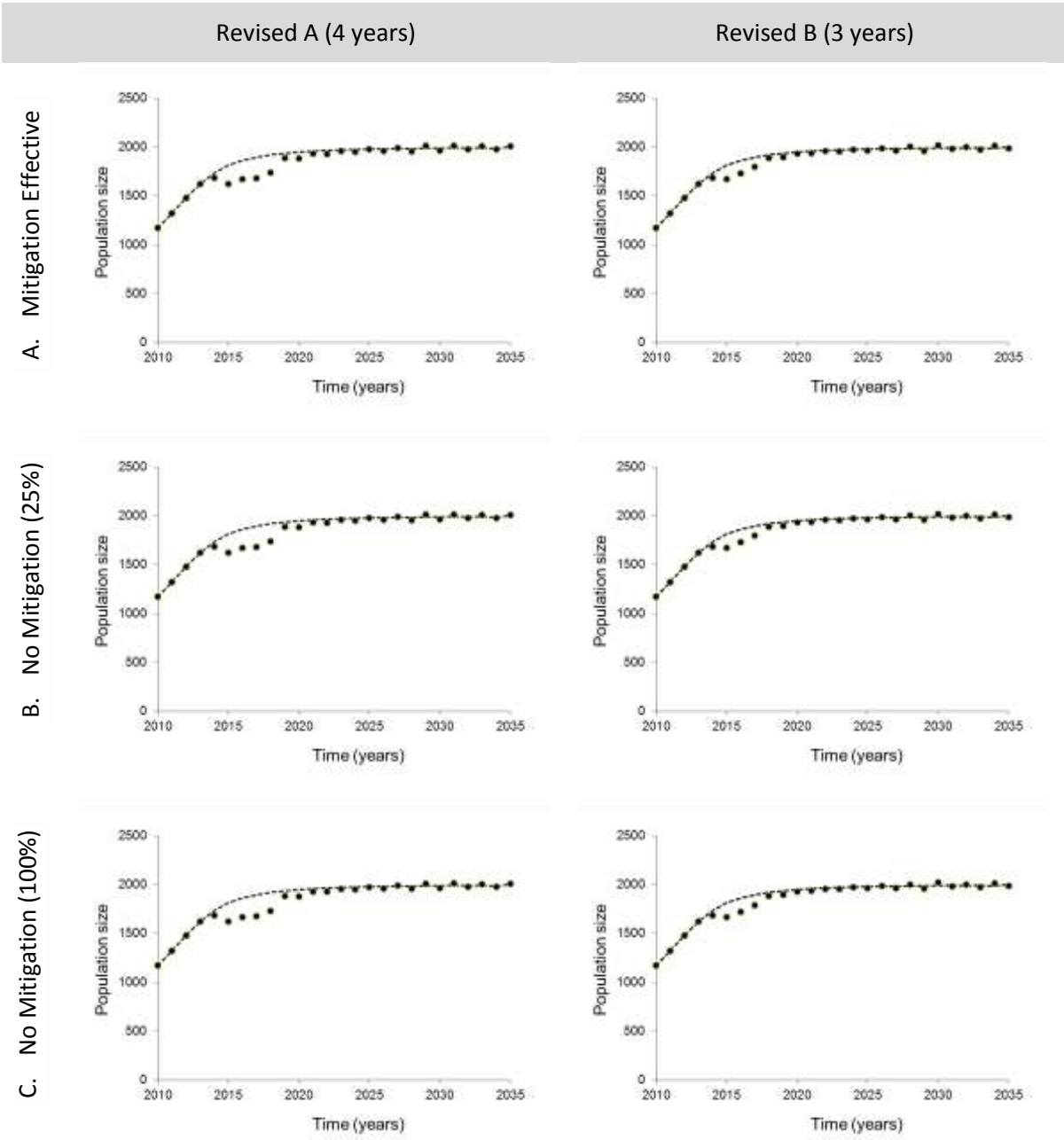
c) Maximum number of first piling strikes in which an individual is likely to be present in each zone (95% Confidence). Data are only presented for those scenarios where the cumulative probability of an individual being present is >0.05 (see Table 5b)

	2m	4m	24m	38m	60m	500m
Harbour Seal	-		2	3	7	208
Grey Seal	-		1	2	4	108
Harbour Porpoise	-	-		6	16	552
Bottlenose Dolphin	-	-		-	-	1
Minke Whale	-	-		1	2	21

Assessing the population consequences of not mitigating instantaneous death and injury for BOWL and MORL Project 1 together

As outlined above, estimates for harbour seals suggest that in the absence of mitigation, there is >99% probability that harbour seals will not be killed during any of the first piling strikes, and a maximum of only seven additional individuals are expected to suffer physical or auditory injury using the larger injury zones (60m) considered in this assessment (Table 1). The impacts of including or not including these additional impacts were explored using the two revised construction scenarios outlined in Table 4, and also by varying the mortality resulting from instantaneous injury between 25% (as used for PTS in the baseline model) and 100% (Figure 2). Inspection of Figure 2 suggests that there is no discernible population level impact from the lack of any mitigation when constructing the BOWL and MORL Project 1 wind farms for either of these construction scenarios, even when all injuries were assumed to result in mortality.

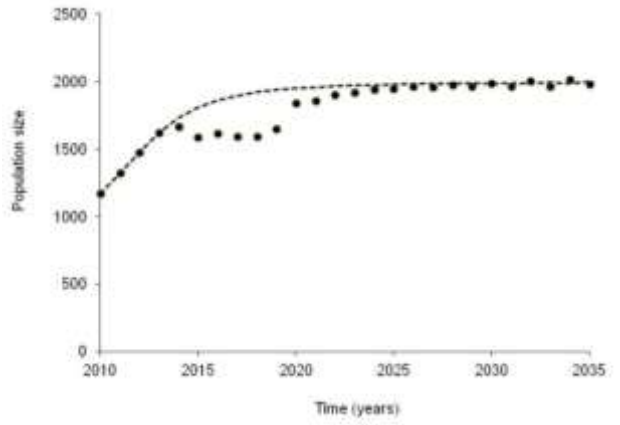
Figure 2. Modelled population trajectories for the two construction scenarios (solid circles) in relation to baseline trends (dashed line) showing patterns with (a) effective mitigation for instantaneous death and injury (b) no mitigation and traumatic injury resulting in 25% mortality and (c) no mitigation and traumatic injury resulting in 100% mortality.



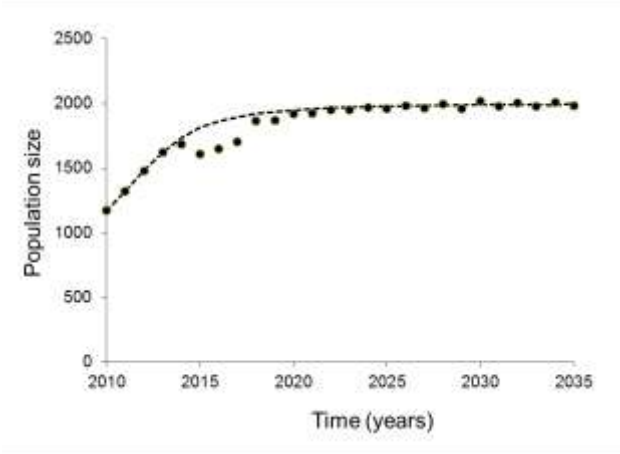
Revised scenario B is presented below in relation to the worst case cumulative assessment from the BOWL and MORL ESs (Figure 3). Assuming 100% reproductive failure and the absence of mitigation for Revised Scenario B, the decrease in population is smaller compared to the worst case scenario assessed in the ESs (Figure 3). Adopting a less conservative assumption for Revised Scenario B, where displacement leads to 50% reproductive failure (a more probable worst case scenario),

illustrates that the decrease in population would be smaller again compared to the worst case cumulative scenario presented in the ES (Figure 3).

Figure 3. Comparison of baseline and construction scenarios for the worst case scenario A (from the ES) and Revised Scenario B with no mitigation and 100% mortality from Figure 2. These can also be compared with a further alternative for Revised Scenario B in which the reduction in reproductive success due to displacement is reduced to 50% instead of 100%.

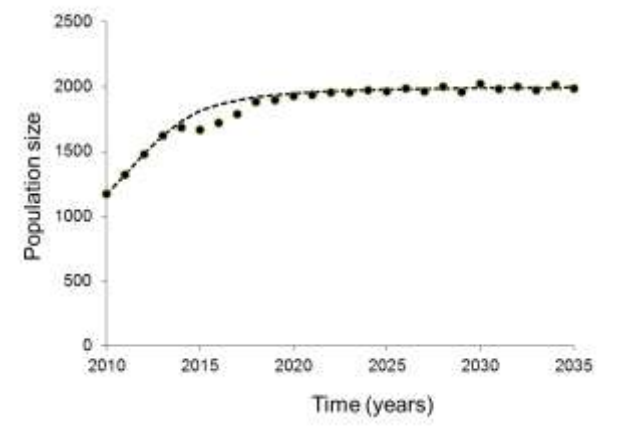


ES Worst Case Cumulative A



Revised Scenario B

100% reproductive failure due to displacement



Revised Scenario B

50% reproductive failure due to displacement

Project specific estimates of marine mammal occurrence within different impact zones at the start of piling sequences

In response to requests from the SNCBs, Table 6 also presents project specific estimates of the risk of different species being present within the 60m instantaneous injury zone, as calculated by Cefas. Here, probabilities are based on the local densities presented in the respective ESs, as summarised in Table 2. The probabilities of occurrence for each species are less than those calculated for the assessment of both projects together (Table 5). On this basis, it can be surmised that there will be no discernible population level impact from the lack of any mitigation when constructing either the BOWL or MORL Project 1 wind farms alone since the construction scenarios for each development alone are considerably less than the scenarios assessed for these two developments together (see Figures 2 and 3). Therefore, even when all injuries are assumed to result in mortality, based on the results of the assessment of both BOWL and MORL Project 1 together, it is considered unlikely that either BOWL or MORL alone would result in a population-level effect.

Table 6. Project specific estimates of the probabilities for each species occurrence within the 60m instantaneous injury zone.

a) Probability of an individual being present within the 60m instantaneous injury zone during the first strike of a single pile

	BOWL	MORL
Harbour Seal	0.00349	0.00339
Grey Seal	0.00141	0.00195
Harbour Porpoise	0.01014	0.00983
Bottlenose Dolphin	<0.00001	0.00001
Minke Whale	0.0002	0.00022

b) Cumulative probability of an individual being present within the 60m instantaneous injury zone at least one of the first piling strikes for BOWL (n=352) and MORL (n=432)

	BOWL	MORL
Harbour Seal	0.71	0.77
Grey Seal	0.39	0.57
Harbour Porpoise	0.97	0.99
Bottlenose Dolphin	<0.01	<0.01
Minke Whale	0.07	0.09

c) Maximum number of first piling strikes in which an individual is likely to be present in each zone (95% Confidence). Data are only presented for those scenarios where the cumulative probability of an individual being present (Table 6b) is >0.05.

	BOWL	MORL
Harbour Seal	3	4
Grey Seal	2	3
Harbour Porpoise	7	8
Bottlenose Dolphin	-	-
Minke Whale	1	1

Conclusions

All stakeholders wish to minimise the likelihood that any marine mammals suffer instantaneous death or injury during offshore piling. Given that these species are expected to move away from loud noise sources, it is accepted that the period of highest risk is likely to be at the beginning of a piling sequence when naïve animals may be close to a piling vessel. Understanding of the noise thresholds that could result in instantaneous death or traumatic injury from a single pulse of this kind is relatively good, and predicted zones in which death or injury may occur (Table 1) are all relatively small for the Moray Firth developments (< 60m). The precautionary nature of the current JNCC guidelines means that MMOs and PAM are required to monitor a much larger 500m mitigation zone around piling activity, with the aim of ensuring that animals are absent from this area before piling can be initiated.

These simulations highlight that, at typical Moray Firth densities, the probability of randomly distributed marine mammals being at risk from instantaneous death or injury at the start of an individual piling event is extremely low (<1%)(see Table 5). In practice, it is likely that the noise coming from vessels during the pile setup would already have displaced individuals out of the immediate danger area, and these values should be even lower. This suggests that, even if mitigation using either JNCC guidelines or ADD failed completely, there are unlikely to be any deaths and a maximum of only 2-16 instantaneous injuries per species during the whole construction programme of the BOWL and MORL Project 1 wind farms. Incorporation of the relevant numbers for seals into the revised scenarios for the Moray Firth Seal Assessment Framework indicate that the absence of mitigation for these near field instantaneous injuries has negligible impact on the resulting population trajectories (Fig. 2).

Notwithstanding these results, it is important to emphasise that they should not be seen as a reason to abandon efforts to mitigate near-field impacts. However, they do provide an evidence base to help balance decisions on the risks of trialling alternative mitigation measures such as ADDs. This framework could also be applied to other developments which have different animal densities or injury zones. Similarly, the approach could be extended for use with other species such as harbour porpoise by considering these injuries as “takes” within a Potential Biological Removal analysis.

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Annex. Summary of key assumptions made within the framework.

1. **The objective of mitigation during the piling process is to minimise the risk of instantaneous death or injury during the initial piling strikes, not to reduce potential impacts from cumulative noise exposure or disturbance**.

2. **Individuals of each species are randomly distributed across the development site at the densities reported within the BOWL and MORL ES's.** This will be a simplification due to spatial variation in habitat quality and, for some species at least, social behaviour. The former should balance out across the sites when considering cumulative probabilities (Table 5b), but assessments could be re-run using minimum and maximum densities to assess how individual probabilities (Table 5b) vary between sites.

3. **Estimates of the cumulative probability of animals occurring in particular impact zones assume that all piling events are independent.** In reality, piling events will be clustered in groups of 4, with longer intervals between events at different turbine sites. Thus, it is more likely that disturbance during the first piling event at each turbine site will reduce the probability of animals being within the injury zone during the next three piling events.

4. **The revised project design for BOWL's construction scenario, as presented in the Piling Strategy, assumes that piling will involve a single vessel working over a maximum 1.5 year period. MORL's development details are still to be finalised, but here it is assumed that MORL Project 1 will also involve a single vessel working over a 2 year period.** Additional piling vessels may be required particularly in case of delays in construction programme, in which case this increase in the intensity of disturbance would result in concurrent reductions in the overall duration of disturbance. Piling at BOWL may be completed within two spring/summer seasons, reducing potential impacts of disturbance on reproductive success.

5. **To model the population consequences of instantaneous death or injury, it was assumed that mortality rates from injury from PTS resulted in either 25% mortality (eg. Fig 2b) or 100% mortality (eg. Fig 2c).** Recent use of Southall et al.'s (2007) M weighted PTS threshold for cumulative noise exposure suggest that ~ 50% of this rapidly increasing harbour seal population may have been at risk of PTS (Hastie et al. 2015). This suggests either that this pinniped PTS threshold is conservative, or that the risk of mortality from PTS is lower than the values used here.

6. **All other assumptions in the population model were the same as those used in the Moray Firth Seal Assessment Framework (Thompson et al. 2013).** The only exception is the final panel in Figure 3, where the impacts of behavioural displacement were reduced to a 50% reduction in reproductive success. This is now likely to represent a more realistic worst case given a) reductions in turbine numbers and the potential to focus piling over the summer season rather than maintain piling intensity throughout the whole annual cycle and b) emerging evidence from DECC SEA funded studies in the Wash that Harbour Seals were not displaced over the whole construction period, and continued to use preferred areas between piling events.

Annex Refs:

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moray offshore renewables ltd

Developing Wind Energy In The Outer Moray Firth

Piling Strategy

Appendix 3:

Marine Mammals Assessment

Telford, Stevenson and MacColl
Offshore Wind Farms - Project 1

edp renewables

APPENDIX 3: Marine Mammals Assessment

Produced by Natural Power Consultants on behalf of Moray Offshore Renewables Ltd	
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List of Abbreviations

BOWL	Beatrice Offshore Wind Ltd
C-POD	Cetacean-POrpoise Detector
ES	Environmental Statement
EDA	Eastern Development Area
GBS	Gravity Based Structure
INSPIRE model	Impulse Noise Sound Propagation and Impact Range Estimator model
MORL	Moray Offshore Renewables Limited
PS	Piling Strategy
PTS	Permanent Threshold Shift
SAFESIMM model	Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna model
SEL	Sound Exposure Level
SNCBs	Statutory Nature Conservation Bodies
WTG	Wind Turbine Generator

Executive Summary

Since the award of Section 36 consents and Marine Licences for Telford, Stevenson and MacColl Wind Farms to build and operate up to 1.116 GW of offshore wind infrastructure in the Moray Firth, Moray Offshore Renewables Limited (MORL) have revised the build out programme for the Eastern Development Area (EDA) in which the turbines are to be located. Rather than develop three separate wind farms, MORL plan to build out the consents as two phases. Project 1 will constitute up to 100 turbines (WTGs) across the Telford, Stevenson and MacColl sites, whilst Project 2 will constitute the remaining turbines of the consents (up to the maximum total of 186 turbines) and is most likely to follow the completion of Phase 1.

The revision in project design has been informed by further geotechnical surveys undertaken to develop the ground model across the site, which in turn has enabled a revised Pile Driveability Assessment. The outcome of the revised Pile Driveability Assessment indicates that there is the requirement for the use of higher blow energies than assessed within the Rochdale Envelope of the MORL Environment Statement (ES) (MORL, 2012) within the latter period of piling for up to 39 % of the turbines across Project 1.

This Appendix accompanies the Piling Strategy that has been developed by MORL to meet the requirements of condition 11 of the Section 36 consents in respect of Project 1 for the three wind farms that make up the EDA. This document:

- Summarises the effects to marine mammals arising from piling noise that were presented within the original MORL ES;
- Provides a review of the conservative assumptions made within the impact assessment presented in the MORL ES, utilising knowledge of the responses of marine mammals to underwater noise that has developed and been presented in peer-reviewed scienctific journals since the ES was submitted;
- Evaluates the potential impacts of Permanent Threshold Shift (PTS) onset and avoidance behaviour in light of recent advances in noise modelling methodology and knowledge of marine mammal behavioural response to loud underwater noises; and
- Considers whether the effects arising from the blow energies profiles resulting from the revised Pile Driveability Assessment are within the predicted effects as assessed in the ES.

It is considered, through review of peer-reviewed scienctific evidience that has become available since the ES was submitted, that the conservatisms inherent within the MORL impact assessment render the magnitude of effects assessed very unlikely to occur in reality. This review is presented within this Appendix, and has enabled a reduction in the conservatism inherent within the Environmental Impact Assessment (EIA). This reduction in conservatism provides confidence that the increase in the blow energies identified within the revised Pile Driveability Assessment will not cause an increase in effect upon the marine mammal species considered and presented within the ES. Thus the potential increase in blow energy from a maximum of 1080 kJ to up to 2250 kJ for up to 39 % of the site is not considered to cause a significant change to the conclusions of the ES for marine mammals or take Project 1 outwith the effects predicted in the ES.

1. Introduction

Moray Offshore Renewables Ltd (MORL) submitted applications for Section 36 consents and associated Marine Licences for three proposed wind farms (Telford, Stevenson and MacColl wind farms) and associated offshore transmission infrastructure in August 2012. These three wind farms are within the Eastern Development Area (EDA) of the Moray Firth Round 3 Zone. The applied capacity of the wind farms was 1.5 GW, split between the three sites, which in combination encompassed between 216 and 339 turbines of between 3.6 and 8 MW in size.

The marine mammal impact assessment that was undertaken for the MORL ES (MORL, 2012) included displacement and Permanent Threshold Shift (PTS) onset effects that had the potential to arise from piling related noise during the construction within the EDA. An initial Pile Driveability Assessment was conducted on the basis of the geophysical and geotechnical surveys undertaken on the site pre-consent. Noise profiles for the worst case blow energies predicted for pin pile installation into the stiffest soil types present across the EDA were used to generate modelled noise fields arising from impact piling. These noise fields were then used to predict the number of animals that could potentially experience displacement and PTS onset through the various construction scenarios considered in the ES. The construction scenarios ranged from a single piling vessel operating within the EDA for up to five years, to up to six piling vessels operating within the EDA for two years.

Section 36 consents for the three wind farms within the EDA were awarded in March 2014 (and the related Marince Licences were granted in September 2014). These consents were for the construction and operation of up to 1.116 GW of offshore wind generation across the three wind farms of Telford, Stevenson and MacColl. Since the award of the Marine Licences and Section 36 consents, MORL has revised their build out programme for the EDA. Rather than develop the 1.116 GW consent in three separate projects (Telford, Stevenson and MacColl), MORL plan to build out the consent as two phases;. Phase 1 (referred to as Project 1) will constitute up to 100 turbines of between 6 and 8 MW across the Telford, Stevenson and MacColl sites, whilst Phase 2 will constitute the remaining turbines of the consent (up to the maximum total of 186 turbines) and is most likely to follow the completion of Phase 1.

Additional detailed geotechnical and geophysical surveys carried out during 2014 have informed the updated ground model for the EDA and enabled further development of the Pile Driveability Assessment. The outcome of the revised Pile Driveability Assessment indicates that there is a potential requirement to use higher blow energies than considered within the Rochdale Envelope in the MORL ES within the latter period of piling for up to 39% of the turbines across Project 1. This document provides a comparison of the blow energies required for installation of the foundation structures for Project 1 against the Rochdale Envelope assessed within the original MORL ES. It concludes that the conservatism inherent within the MORL impact assessment render the magnitude of effects assessed very unlikely[1] to occur in reality. A review of these conservative assumptions provides confidence that the potential increase in blow energies required within the latter period of piling at up to 39 % of the turbine locations (up to approximately 1.5 hours of pile within 6.5 hours of pile driving for Soil Profile 2 as detailed in Section 3.3.2 of main PS) will not cause an increase in effects upon the marine mammal species as considered within the ES.

[1] Definition for the Likelihood of a Defined Outcome Having Occurred or Occurring in the Future, as Defined by the International Panel on Climate Change in Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Threatment of Uncertainties.

2. The assessment criteria presented in the MORL ES and those for Project 1

2.1 Blow energies required for installation of pin piles

2.1.1 Worst case criteria assessed within the MORL in the ES

The full Rochdale Envelope of the MORL project (i.e. the EDA) was presented within the ES as Chapter 2 – Project Details[2]. The Rochdale Envelope assessed within the ES included between 216 and 339 turbines of between 3.6 and 8 MW in generation. Section 6.2 of Technical Appendix 3.6 A – Underwater Noise Technical Report detailed the engineering parameters that were used within the noise modelling undertaken. A summary of the modelling iterations that were undertaken to arrive at the engineering paramaters is provided below, and the final parameters reproduced in Table 2.1. The outputs from the noise modelling were then interpreted by marine mammal specialists to investigate the potential effects upon marine mammal health and behaviour within the relevant assessment chapters of the ES (Offshore Generating Station, Offshore Transmission Infrastructure and Cumulative Assessment chapters).

It was considered that the predicted blow energy required to drive piles to target depth was dependent upon the stiffness of the soil. Technical Appendix 3.6 A described the study that was undertaken into the relative noise produced from pile driving in the three soil types that were considered comprised within the site at the time of the ES production[3]. From the geophysical and geotechnical data available at the time, the soil types predicted to be present across the EDA were categorised into three 'Provinces' within the ES. Province 3 soils were thought to be stiffer than province 2 soils, which in turn were stiffer than province 1 soils. The stiffer the soil, the greater the blow energy required to drive the pile to the required soil depth to secure the wind turbine foundation. However, the length of the piles required in the softer soil were longer than those required in the stiffer soils, potentially resulting in an increased cumulative Sound Exposure Level (SEL) to marine mammals due to an increased piling duration. Modelled SELs from the predicted blow energies and piling durations for the three soil provinces were presented[4] and a conclusion reached that the worst case was represented by the piling predicted for installation of piles into province 3 soils[5]. Predicted SELs were more strongly correlated to the predicted blow energy required to drive the pile, than to the length of the pile.

Section 6.4 of Technical Appendix 3.6 A states '…Whilst recognising that the EIA process should use credible worst case scenarios, it was considered that the complexity arising from modelling a larger number of small turbines compared to a smaller number of large turbines was not warranted. Instead impact assessments from pile driving activity centred around driving the 2.5 m diameter pile into province 3 soils were undertaken, recognising that this represents a conservative impact assessment for the three proposed wind farms… The modelling has been undertaken for two piles being driven in any 24 hr period for the purposes of SELs…'.

The predicted blow energy profile to drive a 2.5 m diameter pin pile to a depth of 26 m in province 3 soils was provided in Table A-5 of Technical Appendix 3.6 A, and is represented below as Table 2.1.

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[2] the chapters and technical appendices making up the MORL ES can be downloaded from http://morayoffshorerenewables.com/Document-Library.aspx?page=1&path=environmental+statement

[3] shown in Figure A-9 of Technical Appendix 3.6 A

[4] Section 6.2, Technical Appendix 3.6 A

[5] Figure A-11, Technical Appendix 3.6 A

Table 2.1 Assumed blow energy profile required to drive a 2.5 m diameter pin pile to a depth of 26 m into province 3 soils

Penetration depth	Hammer efficiency	Impact energy (kJ)	No. of blows	Time
0 to 4 m	15%	170	260	15 mins
3 to 14 m	40%	450	2400	45 mins
14 to 16 m	80%	890	1000	15 mins
16 to 26 m	95%	1080	7000	2 hrs
			Total time	3 hrs 15 mins

2.1.2 Revision of worst case for Project 1

Following receipt of the outputs from the 2014 geotechnical and geophysical surveys of the EDA the soil classification was refined by MORL's geotechnical consultants from the three provinces described in Section 2.1.1 above. Six soil classifications (termed Soil Profiles rather than the province nomenclature of the ES) were identified, and a detailed Pile Driveability Assessment undertaken for each soil profile. The results indicate that piles will be driveable to the target penetration depth using the maximum consented blow energy of 1080 kJ in three of the six soil profiles, and thus the effects from piling in these three soil types (Soil Profiles 1, 3 and 4) will be within the effects assessed in the ES. These three soil profiles make up the majority of the Project 1 area (61 %; see Table 2.2 below).

However, for Soil Profiles 2 and 6 1080 kJ is unlikely to be sufficient to drive the piles to the required depth (higher energies likely to be required for the latter period of pile driving for the most probable and highest expected scenarios), and for Soil Profile 5 there is the potential for the requirement of a greater blow energy during the latter period of installation (for the highest expected scenario as described below) to avoid pile refusal and the attendant delays.

The outcome of the Pile Driveability Assessment for each Soil Profile is provided below in Table 2.2. A conservative worst case scenario (i.e. highest expected) indicates that energies over 1080 kJ may be required for the latter period of piling for up to 39 % of the wind turbine locations (please see Section 3.3.1 of main Piling Strategy document for detailed energy profiles across the six soils).

Table 2.2: Most probable and highest expected blow energies across Project 1

	Consented Rochdale	Soil 1	Soil 2	Soil 3	Soil 4	Soil 5	Soil 6
Percentage of turbines	100	32	17	8	21	8	14
Most probable	Not assessed	660 kJ	1800 kJ	636 kJ	1020 kJ	900 kJ	1140 kJ
Highest expected	1080 kJ	1020 kJ	2250 kJ	996 kJ	1020 kJ	1800 kJ	1800 kJ

In addition to the increase in the modelled blow energy required to drive piles into Soil Profiles 2, 5 and 6, studies also suggest that a longer pile will be required across the site. Whilst the ES

assessed a piling duration required to drive a pile to a depth of 26 m, refinement in the foundation design has resulted in an increase in pile penetration depth of up to 55 m across much of Project 1. This has resulted in increased piling durations for each pile above those assessed in the ES, from 3.25 hours per pile (see Table 2.1) to up to 6.5 hours for the highest expected (HE) blow energy profiles piles being piled into Soil Profile 2. Another change to the Project Envelope that may impact the SELs received by marine mammals present in the Moray Firth is that whilst the ES assessed the impacts arising from SELs resulting from the installation of two piles per 24 hour period, development in construction methodologies has led to confidence that up to three pins could be driven per 24 hour period (see refer to Section 3.4.1 of the main Piling Strategy document for details).

In order to validate that the effects arising from the revised Pile Driveability Assessment are within those assessed in the ES, the following SELs have been modelled and used:

- Installation of piles into Soil Profile 2 (present at 17 % of the likely turbine locations) as installation within these soils will require larger energies than that assessed within the ES;
- SELs calculated for installation into Soil Profile 2 have been taken as a conservative proxy for SELs resulting from installation into Soil Profiles 5 and 6 (present at 22 % of the turbine locations);
- In order to contextualise this additional noise in relation to the 61 % of the turbine locations with blow energy profiles below the consented Rochdale Envelope, SEL modelling has been undertaken for driving piles into Soil Profile 1 (32 % of turbine locations) and Soil Profile 4 (21% of turbine locations); and
- SELs calculated for Soil Profile 1 have been used as a conservative proxy for Soil Profile 3 (present at 8 % of the turbine locations).

These modelled SELs have also included the increased piling duration required for each pile, and the increase from two to three piles installed per day from that assessed in the original ES.

2.2 Temporal scenarios assessed for pin pile installation

2.2.1 Temporal scenarios assessed in the ES

The Project Description (Chapter 2 of the ES) provided information on the estimated temporal element of piling activity. The Rochdale Envelope included piling throughout the year, with a build programme of piling at full intensity during the summer and at half intensity during the winter to allow for weather windows. The foundation installation programme assessed represented the three scenarios detailed in Table 2.3 below.

Table 2.3: MORL construction scenarios (see Technical Appendix 7.3 F of the MORL ES)

Scenario A	One piling vessel to build all three schemes. The vessel would remain within the Moray Firth for up to five years, building each wind farm in succession (build duration 2016-2020). Modelling based on a 2.5 m diameter pile at the closest point within the EDA to the inner Firth as this was deemed the most sensitive location for the majority of marine mammal species assessed.
Scenario B	Two piling vessels to build all three schemes. For this scenario, the build programme was envisaged to take up to three years (build duration 2016-2018). It is likely that the vessel spread at any one time would be relatively small. However, for the purposes of this assessment, the modelled locations have been chosen to reflect the largest vessel spread possible to reflect worst case as this will create the largest cumulative noise footprint.
Scenario C	Six piling vessels to build all three schemes (two vessels within each site) within a two year construction phase (build duration 2016-2017). Whilst six piling vessels are unlikely to require a full two year continuous construction period, there may be some time within this period in which all six vessels would be on site and operational together.

2.2.2 Temporal scenario for Project 1

The base case for pile driving in Project 1 is that a single piling vessel will operate on site for two years. However, if programme delay is encountered, there is the potential for up to three vessels to be operating on site for a short period of time during this two year period, with a maximum of two vessels in an individual site (i.e. Telford, Stevenson or MacColl) at any one time.

2.3 Cumulative scenarios assessed for pin pile installation

2.3.1 Cumulative assessment presented within the ES

A cumulative assessment for the MORL EDA projects (taking into account the potential construction and temporal parameters of the Beatrice Offshore Wind Ltd (BOWL) project) was also presented within the ES. The considered blow energies for installation of the piles within the BOWL project (of up to 2,300 kJ) were presented in Table A-7 of Technical Appendix 3.6 A (and were also provided in Chapter 14 – Biological Environment CIA). Therefore, the potential for displacement and PTS onset arising from the installation of the BOWL foundations already included an assessment for the use of blow energies of up to 2,300 kJ both without the MORL site (within the BOWL ES) and in combination with the MORL site (within the MORL ES).

The BOWL project parameters that informed the cumulative assessment were that the construction phase for up to 277 turbines could last up to three years, with up to two piles being driven within a 24 hr period.

With regards to the construction sequencing of the MORL and BOWL projects, and potential for temporal overlap of the two projects, three scenarios (with indicative dates) were assessed within the cumulative assessment presented in the MORL ES[6]. These scenarios are summarised below:

1. Two vessels piling within the BOWL site for two years (2014 to 2015) immediately followed by two vessels piling within the three proposed EDA wind farms for three years (2016 to 2018).
2. A six year build out phase utilising a single piling vessel for the three proposed EDA wind farms and a single piling vessel for the BOWL site. The model assumes a three year build out programme for BOWL (2014 to 2016) and a five year build out programme for the three proposed EDA wind farms (2016 to 2020) with a year of overlap in which both sites are under construction (2016).
3. Two piling vessels working within each site simultaneously (total of eight vessels) resulting in a two year construction period. This scenario would start in 2016.

2.3.2 Project 1 cumulative effects

As with the original ES the Project 1 construction timescales have not been finalised, but for the purposes of this assessment it is considered that there may be an overlap in the construction periods of the MORL and BOWL wind farms. It is acknowledged that if there is a change in either project programme, then piling could occur on both sites across a timescale from two years to not overlap at all.

[6] Section 14.3.4.8 of Chapter 14 – Biological Environment CIA of the MORL ES.

3. The methodology utilised to assess the impacts from blow energies required for pin pile installation

3.1 Methodology presented in the MORL ES

Utilising the data provided by the preliminary ground model and the Rochdale Envelope information described in Section 2.1.1 above, predicted noise propagation from piling was modelled by Subacoustech Environmental Ltd using their INSPIRE model. Noise propagation outputs for the three construction scenarios (see Table 2.3 above) were modelled.

Death and physical injury resulting from proximity to the pile driving operations were not considered within the MORL ES. It was considered very unlikely that marine mammals would be exposed to noise levels which have the potential to cause death/physical injury as the mitigation protocols developed by the Statutory Nature Coservation Bodies (SNCBs) in order to reduce this risk to negligible levels would be implemented.

For auditory injury (PTS onset) predictions, M-weighted SELs (Southall *et al.*, 2007) were modelled[7]. The number of individuals of each species exposed to sound levels sufficient to induce the onset of PTS was predicted using these SELs within the SAFESIMM programme. SAFESIMM simulates the three dimensional movement of thousands of animals through sound fields based on an understanding of their likely diving and swimming behaviour.

To inform behavioural response predictions, INSPIRE was used to predict received noise levels (dB_{ht} by receptor)[8]. The dB_{ht} contours were generated at 5 dB_{ht} increments between 25 dB_{ht} and 130 dB_{ht}. The dB_{ht} contours were then used to determine the maximum perceived level of noise for each species in each 4 x 4 km grid square across the Moray Firth. The distribution of the different receptor species was estimated using the best available data in habitat association models to provide density estimates per 4 x 4 km grid square across the Moray Firth. Finally, publically available data, primarily the porpoise behavioural studies in response to piling noise at Horns Rev II (Brandt *et al.*, 2011), enabled the generation of a dose-response relationship between received noise levels and the probability of avoidance/ displacement. As described in Technical Appendix 7.3 B of the MORL ES, a precautionary (rather than best) fit was applied to the porpoise displacement data against modelled received levels at the C-POD locations at Horns Rev II. This dose-response relationship for harbour porpoise was then applied to other marine mammal species throughout the impact assessment, and used to estimate the number of individuals of each species in each 4 x 4 km grid square likely to be displaced.

Information on the number of individuals modelled to be displaced or having the potential to experience PTS onset was used in population models to assess the long-term impacts on harbour seal and bottlenose dolphin populations[9]. Assumptions were made about the effects of displacement and potential PTS onset (Table 3.1 below), and effects modelled as a direct impact on survival and reproduction during the years of impact. Models were run for a period of 25 years. This model period was considered appropriate due to the potential for one to two generations of marine mammal species to be affected during the impact period, therefore long term impacts with respect to population change (if any) would be evident during this time. Population level effects of the different construction scenarios were explored and compared to baseline scenarios with no construction.

[7] Details provided in Section 7.3.6, Chapter 7 – Biological Environment OGS IA of the MORL ES.

[8] Details provided in Section 7.3.6, Chapter 7 and Appendix 7.3-B of the MORL ES.

[9] Details provided in Section 7.3.7, Chapter 7 and Appendix 7.3-B of the MORL ES.

3.2 ES Conservative assumptions

In order to achieve a 'probable' degree of confidence (50 to 95% probability as defined by the IEEM guidance (IEEM, 2010)) that the actual impact footprint of the Rochdale Envelope fell within the parameters assessed, conservative assumptions were made throughout the assessment presented in the ES. These conservative assumptions were tabulated in Section 7.3 of the ES (Chapter 7 – Biological Environment OGS) and presented as Table 7.3-11. The information within Table 7.3-11 has been reproduced below in 2.4.

The knowledge of marine mammal behaviour in response to noise that was utilised in the development of the impact assessment methodology presented in the MORL ES has evolved in the years since submission. As a consequence of this increased knowledge, it is considered that the conservatism inherent within the MORL impact assessment renders the potential effects presented in the ES to be highly unlikely to occur in reality.

Table 3.1 below provides a review of the conservative assumptions presented within the ES, and illustrates why the potential effects described in the ES would be unlikely to be realised if Project 1 were to be built out under the Rochdale Envelope described in the MORL ES.

Table 3.1: Review of conservative assumptions made during the MORL impact assessment for marine mammals

Assumption		Conservatism inherent within the ES assessment	Reduction in conservatism considered appropriate as a result of increased knowledge
1	Noise modelling used blow energies required to drive piles into the stiffest of the three soil types present on site throughout assessment	The blow energy required to drive piles into stiffer soil types is greater than that required to drive them into softer soil types. As a consequence, higher noise levels are predicted from pin pile installation in the stiffest soil types. However, the degree of complexity required to model different blow energies in different regions of the sites, over an uncertain build duration, was prohibitive. As a consequence, worst case was used throughout.	It is now understood that the soil stiffness across 39% of the wind turbine locations has the potential to be stiffer than that assumed for the ES, and thus require greater blow energies during the period of pile installation than assessed (see Table 2). The remaining 61% of the turbine locations are predicted not to exceed the blow energies modelled within the ES, and so are within the parameters assessed and consented. Noise impacts from these 61% pile installations would be lower than those described and assessed in the ES.
2	INSPIRE noise propagation modelling is conservative over the 20 to 50 km range	As shown in Technical Appendix 7.3 B – Underwater Noise Assessment Framework of the MORL ES, comparison of INSPIRE model predictions with published measured recordings from the Beatrice Demonstrator (Bailey *et al.*, 2010) indicate that the model predictions for unweighted peak levels provide a relatively good fit of the measured data. Modelled and measured noise levels correlate well at distances up to 20 km from the piling event, but provide a conservative prediction of sound levels across the wider Moray Firth (20 to 50 km).	The Cefas report that accompanies this Piling Strategy (Appendix 1) describes advances in best practice for modelling noise propagation through the water column from piling events, utilising detailed physical and environmental data for the Moray Firth (Appendix 1, section 3.4 and 4.1). The use of these current best practice methodologies has reduced uncertainty within the resulting noise propagation outputs, and thus increases the confidence that they represent likely noise profiles. This confidence enables a reduction in the conservatism inherent within INSPIRE model.
3	Noise modelling locations to represent indicative piling activity have always been chosen to be closest to sensitive receptors or produce the	This approach introduces an inherent conservatism over the duration of the construction phase. For example: a single location closest to the sensitive receptors (bottlenose dolphin and harbour seal) was chosen and effects modelled to occur for five years. This is an over-estimation of effect, as the majority of piling would be more distant than this most sensitive location.	The same, most sensitive piling location has been used to reassess the piling impacts as indicative of worst case.

Assumption		Conservatism inherent within the ES assessment	Reduction in conservatism considered appropriate as a result of increased knowledge
	largest spatial extent of effect	In a similar conservative manner, the two piling locations were chosen to represent the largest possible noise footprint from piling operations. Effects from such scenarios have been modelled to take place for three years. In practice, if two piling vessels were used on site they would operate in relatively close proximity to each other reducing vessel spread and transit time of support vessels, thus producing a significantly reduced noise footprint.	
4	Allocation of perceived noise level to each 4x4 km grid square used for marine mammal displacement modelling always used the highest level predicted for each square	Technical Appendix 7.3 F – Underwater Noise Propagation Modelling of the MORL ES illustrates how the modelled perceived noise levels for each species under individual construction scenarios were allocated. A perceived noise level that equated to the highest dB_{ht} (species) radius that touched the 4x4 km grid square was assigned to each square, rather than allocating a dB_{ht} level that corresponded to the greatest proportion of the square.	SAFESIMM has not been used to predict numbers of animals exposed to sufficient SELs to induce PTS within this assessment (see Section 4.3.3 below). Numbers of animals have been calculated by overlaying the relevant PTS contours modelled by Cefas (Appendix 1) onto the baseline density surface estimates presented within the ES and numbers of animals within these contours summed. Details of the methodology used in this assessment are provided in Section 4.3.1 below. If a grid square was partially covered by a PTS contour, the proportion of the grid square included within the contour was calculated in ArcGIS, and this proportion used to estimate the number of animals exposed using the density surface of the grid square.
5	Degree of displacement from piling associated noise	As described in Technical Appendix 7.3 B of the MORL ES, a precautionary fit was applied to the porpoise displacement data gathered during the foundation piling at Horns Rev II and used to generate a dose response curve for porpoise displacement against perceived noise levels within the Moray Firth. The use of this precautionary fit to generate the dose response curve resulted in a higher level of modelled displacement than the best fit curve to the data, and	During refinement of the framework for assessing impacts of pile-driving noise from offshore wind farms that followed the submission of the MORL ES (Thompson *et al.*, 2013), acceptance was reached to apply the line of best fit to the porpoise displacement data gathered during the foundation piling at Horns Rev II as a dose response curve for porpoise displacement against perceived noise levels (see section 4.3.2 below).

Assumption		Conservatism inherent within the ES assessment	Reduction in conservatism considered appropriate as a result of increased knowledge
		therefore represents a conservative assumption in the modelling that was been undertaken.	
6	Harbour porpoise behaviour was used as a proxy for bottlenose dolphin in the modelled disturbance from piling noise	As described in Technical Appendix 7.3 D – Behavioural Responses to Noise of the MORL ES, analysis of available data indicates higher level responses by harbour porpoises than bottlenose dolphins to similar noise levels. Thus, using harbour porpoise as a proxy for bottlenose dolphin is likely to produce an overestimation of associated effect upon the bottlenose dolphin population.	This conservative approach has been maintained.
7	Modelled avoidance of areas predicted to experience high piling related noise for the full duration of the construction period (i.e. animals modelled to not return in between periods of piling)	At the time of writing the ES no data was available on the period of time that will elapse between the cessation of piling activity and the return of animals displaced from Smith Bank. Animals were therefore modelled to remain excluded for the full duration of the construction period (i.e. a number of years). It was considered likely that animals will return between some piling events, especially during breaks in construction activity (e.g. due to bad weather). Assuming displacement for the entire construction period therefore represented a highly conservative assumption.	Recent work on disturbance from air guns by Thompson *et al.* (2013a) showed that harbour porpoises were typically detected on C-PODs within a few hours of a seismic vessel passing within 5 km whilst firing airguns (median waiting time = 183 minutes). Harbour seals have also been shown to return to foraging sites between piling events in The Wash (Hastie *et al.*, 2015). Thus, it is considered appropriately conservative for displacement to be modelled for the number of days on which piling is likely to take place in a given year, rather than for the full year in which piling takes place. It is considered that the magnitude and duration of displacement presented in the ES are unrealistically high and, therefore, that the consequences of any increase in displacement caused by the use of increased blow energies for the last up to 1.5 hours of potentially 39 % of piling events (see Section 3.3.2 of PS main document for further details on predicted blow energies and energy ramp up) are included within the footprint of the original assessment in the ES.

Assumption		Conservatism inherent within the ES assessment	Reduction in conservatism considered appropriate as a result of increased knowledge
8	Effect of displacement upon reproduction rates of harbour seal and bottlenose dolphins	Population modelling was undertaken to assess the population consequences of effects experienced by individual harbour seals and bottlenose dolphins. Animals modelled as being displaced for the full construction period were assumed to either fail to produce young or for the young produced to not survive. This is considered to be a conservative assumption, at least in part due to the considerations described above (that the animals are displaced for the entire duration of the construction phase, and do not return to favoured feeding grounds in periods of no construction activity such as that induced by bad weather).	This conservative assumption has been maintained.
9	The 186 dB SEL criteria was used for modelling the number of individual seals exposed to noise of sufficient volume and duration to induce PTS onset	Technical Appendix 7.3 E – Noise Exposure Criteria for Pinnipeds of the MORL ES describes how the scientific advisors working with MORL reviewed the available literature for the rationale supporting the 186 dB SEL criteria for seals. They concluded that the evidence did not support the differential sensitivity of seals over cetaceans, and proposed a common criterion (198 dB SEL) for all species assessed. Peer and stakeholder consultation on this approach concluded that whilst there was general agreement that the 186 dB SEL criteria was likely to be overly conservative, there was little evidence to support reducing the criteria to 198 dB SEL. It was generally agreed that the likely criteria for the noise exposure and duration to induce PTS onset would be somewhere between the 198 and 186 dB SEL level (see values provided in Table 7.3-9 of Technical Appendix 7.3 E). As a result of this consultation, the 186 dB SEL criteria was used for seals as a conservative modelling scenario (recognising that there is likely to be an over estimation of numbers of seals modelled to experience the onset of PTS).	This assumption has been maintained.

Assumption		Conservatism inherent within the ES assessment	Reduction in conservatism considered appropriate as a result of increased knowledge
10	SAFESIMM was used to model the number of individual animals which would experience noise levels sufficient to induce PTS onset	As described in Technical Appendix 7.3 B of the MORL ES, SAFESIMM estimates for the number of individual animals experiencing PTS from piling noise were an order of magnitude higher than those calculated using INSPIRE generated SEL radii. Whilst both models use the same impact criteria (dB SEL levels), this difference is likely to be a consequence of the way INSPIRE and SAFESIMM model the fleeing behaviour of animals. In the INSPIRE model, the animal flees at a speed of 1.5 m / s away from the noise source. In the SAFESIMM model, animals make 'directed random walk' movements away from the noise source, and take significantly longer to leave the area affected by noise of sufficient volume to induce PTS. Furthermore, seals in SAFESIMM continue to receive a noise dose regardless of whether they were diving or at the surface, when in reality seals at the surface will have their heads above the water and therefore not receive this dose. The use of SAFESIMM to estimate the number of individuals exposed to sufficient noise to induce PTS therefore represents a conservative element of the impact assessment methodology.	The current assessment presented within this Appendix (Section 4.3.1 below) moves away from the use of SAFESIMM to estimate the number of animals exposed to sufficient SELs to induce PTS. Instead, Cefas have estimated SELs sufficient to induce PTS using Southall noise exposure criteria (see Section 3.1.1 of Appendix 1 for detailed methodology) and numbers of animals within these contours have been estimated as detailed under assumption 4 in this table (also see Section 4.2.1 below).
11	Consequence of PTS is a 25% risk of mortality	The PTS onset criteria proposed by Southall *et al.* (2007) represent an estimate of the noise levels at which a reduction in hearing acuity may start to occur. There are no empirical data on actual levels of PTS in marine mammals, or on whether such hearing impairment may affect their survival. Based upon discussions with scientists and other stakeholders, the 25% mortality risk used in these models is considered highly conservative, but was used due to the degree of uncertainty surrounding the consequences of these criteria.	Hastie *et al.* (2015) used pile driving data and acoustic propagation models, together with seal movement and dive data from 24 tagged harbour seals, to predict auditory damage in each seal exposed to piling noise during construction of wind farms in The Wash. The closest distance of each seal to pile driving varied from 4.7 km to 40.5 km, and predicted maximum cumulative SELs (Mpw) ranged from 170.7 dB to 195.3 dB re 1μPa^2-s for individual seals. Comparison to exposure criteria suggests that half of these seals were exposed to noise levels that exceeded estimated permanent auditory damage thresholds if using Southall noise exposure criteria. However, the population of

Assumption		Conservatism inherent within the ES assessment	Reduction in conservatism considered appropriate as a result of increased knowledge
			harbour seals within the Wash has increased in size despite these predicted construction related impacts. This suggests that although this assumption is maintained, the assumption that exposure to SELs sufficient to induce PTS carries a 25% increase mortality risk in harbour seals is improbably conservative.

3.3 Methodology used to validate whether effects of Project 1 cause a significant change to the conclusions of the ES

3.3.1 *Modelling the number of animals exposed to noise levels sufficient to induce PTS onset*

Cefas provided SEL contours for PTS onset for mid- and high-frequency cetaceans and pinnipeds in water for pin pile installation in Soil Profiles 1and 2 for both 'most probable' and 'highest expected' and for Soil Profile 4 for the 'most probable' blow energy profiles. The location for the propagation modelling was the same location as for the MORL ES (and as described for Scenario A in Section 3.2.1, Table 2.3) and thus represents the worst case on numbers of animals exposed to sufficient SEL to induce PTS onset from a single piling vessel. The methods used to generate these contours are described in PS Appendix 1, Section 3.

Natural Power has overlaid these PTS contours onto the relevant species' estimated density surfaces provided within the MORL ES. These density surfaces are expressed in 4x4 km grid squares across the Moray Firth. The number of animals estimated to be present within the PTS contours was then summed using ArcGIS. If a grid square was partially covered by a PTS contour, the proportion of the grid square included within the contour was calculated in ArcGIS, and this proportion used to estimate the number of animals exposed using the density surface of the grid square. The number of animals within each contour is provided to the same degree of accuracy as in the MORL ES, thus the number of whole animals is provided for seal species and to the nearest hundredth for harbour porpoise and bottlenose dolphin. In order to maintain the conservative nature of the assessment as presented in the ES, numbers for each species have been rounded up in each case (e.g. 0.0008 bottlenose dolphin is rounded to 0.01 and 13.44 harbour seals is rounded to 14).

3.3.2 *Modelling the number of animals with the potential to elicit avoidance behaviour*

Refinement of the framework for assessing impacts of pile-driving noise from offshore wind farms has occurred since the submission of the MORL ES. Further consultation on the use of the best fit (rather than precautionary fit) applied to the porpoise displacement data against modelled received levels at the C-POD locations at Horns Rev II has been undertaken. Acceptance has been reached with stakeholders[10], and through peer review[11], to apply the line of best fit as a dose response curve for porpoise displacement against perceived noise levels, and to continue to apply this dose response to other marine mammals for potential displacement predictions.

The best fit dose response curve to modelled received noise has therefore been utilised in this review of whether the potential effects arising from Project 1 are within those assessed in the ES.

[10] Through the consent process of the Inch Cape Offshore Wind Farm (which was undertaken following the MORL ES submission), that utilised the same assessment framework methodology for marine mammals.

[11] Thompson et al., 2013. Framework for assessing impacts of pile-driving noise from offshore wind farm construction on a harbour seal population. Environmental Impact Assessment Review.

3.3.3 *Additional conservative assumption considered appropriate to include within the consideration of effects for Project 1*

As described in Section 3.1 above, noise propagation modelling outputs from INSPIRE were used as model parameters for SAFESIMM to predict the potential number of animals receiving a sufficient noise dose to induce PTS onset from the piling events assessed within the ES. SAFESIMM models animal movement away from the noise source as a directed random walk (Table 3.1 above), and not a startle and then flee response.

The review of effects considered within this Appendix has not included repeated SAFESIMM modelling. It is felt the conservatism inherent within the assessment presented within the ES, and the complexity of the number of soil profiles present across the EDA, renders SAFESIMM re-runs unnecessary. Instead, whilst acknowledging that this is a highly conservative assumption, Cefas have modelled the PTS onset contours for stationary animals. Natural Power have utilised these contours to predict the number of individuals that may suffer PTS as described in Section 3.3.1 above.

It is considered that, in reality, the flee response to loud underwater noise is likely to be between the directed random walk away from the noise source used by SAFESIMM (Table 3.1) and a 1.5 m/s flee speed until the animal is outside the PTS onset contour model. This consideration takes into account the likely reduced displacement compared to levels modelled for the MORL ES, especially at distance from the piling events for seals given the extent of the 186 dB re 1 μPa^2s PTS criteria used. As a consequence, it is considered that an appropriate (new) conservatism in the modelled SELs used in this assessment would be to assume that animals were stationary i.e. that there was no flee response. This assumption also takes into account the fact that animals are likely to return to favoured foraging grounds between periods of piling activity, thus have a greater potential to be exposed to SELs sufficient to induce PTS onset than if they fled and did not return. It is, however, recognised that assuming animals will not move away from the noise source at all is a highly precautionary assumption in this modelling exercise, and represents a situation which is highly unlikely to occur.

3.4 Comparison of parameters and methodologies used in the MORL ES and the Piling Strategy for Project 1

Table 3.2 below provides a comparison against the Rochdale Envelope parameters and assessment approach used within the original MORL ES to those of Project 1.

Table 3.2: Comparison of parameters used in the MORL ES and the assessment for Project 1

	Rochdale Envelope provided in the ES	Project 1
Project Description		
WTG foundations	Up to 339 WTG foundations – 1356 no. of piles[12].	Up to 100 WTG foundations – 400 no. of piles.
Foundation type	Jackets or GBSs.	Jackets – up to four legged.
Simultaneous piling	Maximum 6 simultaneous piling events across Telford, Stevenson and McColl OWFs.	Most likely scenario is represented by a single piling vessel, but with the potential for up to three vessels if required (e.g. due to programme delays).
Piling duration	Maximum of 183 days over 5 years. 3.25 hours pile driving per pile, and maximum 2 piles per 24 hours.	Piling duration dependent on soil profiles. Modelled worst case of 6.5 hours of piling for Soil Profile 2, with three piles in a 24 hour period. Piling campaign up to two years (average of 5 hours per pile and in the order of 84 days[13] of piling in total).
Piling energies	All assessment based on worst case, which included up to 2 hours of 1080 kJ.	Predicted blow energies dependent on soil profiles – 61 % of WTG predicted to be below 1080 kJ, 39 % of WTG may require (worst case) higher energies (>1080 kJ) for the latter period of piling.
Temporal and spatial piling scenarios	Between 1 and 6 piling vessels operating between 2 and 5 years.	Between 1 and 3 piling vessels operating up to 2 years.

[12] Consented projects: up to 186 WTG (744 piles).

[13] See Section 3.4 of the PS main document for details on piling base case programme.

	Rochdale Envelope provided in the ES	Project 1
Cumulative piling scenario	Either in overlap or following BOWL piling activities .	Either in overlap or following BOWL piling activities.
Methodologies		
Noise modelling	Subacoustech noise modelling followed by SAFESIMM modelling for PTS exposure and dB_{ht} for displacement.	Cefas noise modelling of SEL, followed by contextualisation against ES assessment.
Impact Assessment criteria	Southall criteria and SAFESIMM for PTS, dB_{ht} for displacement.	Southall criteria and stationary animal SEL exposure modelling for PTS exposure. Assessment of conservative assumptions used within the ES, and re-appraisal of potential disturbance and consequences.

4. Validation of Project 1 effects within MORL ES assessments

4.1 Conclusion of the MORL ES

Using the methodology described Section 3.1 and the scenarios provided in Table 2.3, the number of individual animals with the potential to experience PTS onset or avoidance behaviour manifest as displacement were modelled for each piling scenario. These numbers are provided in Table 4.1 below.

Table 4.1: Predicted number of individuals impacted by piling noise in year one of construction

Harbour seal						
	Scenario A (1 vessel)		Scenario B (2 vessels)		Scenario C (6 vessels)	
	Number	%	Number	%	Number	%
PTS: 186 dB	121	10.2	198	16.7	305	25.8
Behavioural displacement: High	731	61.8	823	69.6	853	72.1
Behavioural displacement: Best fit	522	44.1	629	66	667	56.4
Behavioural displacement: Low	42	3.5	66	5.6	92	7.7
Grey seal						
	Scenario A (1 vessel)		Scenario B (2 vessels)		Scenario C (6 vessels)	
	Number	%	Number	%	Number	%
PTS: 186 dB	170	5.4	301	9.5	478	15.1
Behavioural displacement: High	1159	32.2	1656	46	1753	48.7
Behavioural displacement: Best fit	739	20.5	1184	32.9	1285	35.7
Behavioural displacement: Low	45	1.3	94	2.6	123	3.4

Harbour porpoise						
	Scenario A (1 vessel)		Scenario B (2 vessels)		Scenario C (6 vessels)	
	Number	%	Number	%	Number	%
PTS: 198 dB	6.4	0.1	10.2	0.2	21.9	0.4
Behavioural displacement: High	4015	65.6	4056	73.7	5149	84.2
Behavioural displacement: Best fit	2933	47.9	3442	56.3	4208	68.8
Behavioural displacement: Low	263	4.3	367	6	629	10.3
Bottlenose dolphin						
	Scenario A (1 vessel)		Scenario B (2 vessels)		Scenario C (6 vessels)	
	Number	%	Number	%	Number	%
PTS: 198 dB	0.06	<0.1	0.07	<0.1	0.12	0.1
Behavioural displacement: High	31	15.7	33	16.8	36	18.5
Behavioural displacement: Best fit	17	8.9	19	9.7	21	11
Behavioural displacement: Low	0	0.2	1	0.3	1	0.4

For harbour seal and bottlenose dolphin, the numbers of individuals predicted to experience a noise-related effect were used within population models to assess how different construction scenarios might affect long-term population growth in comparison to baseline scenarios with no construction. The numbers provided in the Table 3.2 above, and the consequences of the potential PTS and displacement described in Table 3.1, were used to model the population level effects from the number of years of piling associated to each scenario.

For harbour porpoise and grey seal, the numbers of individuals predicted to experience a noise-related effect were related to regional population sizes to assess the likely magnitude of effects. The conclusions of these impact assessments are provided below.

4.1.1 Bottlenose dolphin

The population modelling undertaken (which assumes displacement from coastal foraging grounds and a similar sensitivity to noise as for harbour porpoises) indicates that there will be no long term effects upon the population size from the modelled construction activity from all three scenarios[14]. The overall effect is considered to be of low magnitude (predicted population size within 10% of that predicted as a baseline if population parameters do not change within the Moray Firth) and so **minor significance**.

4.1.2 Harbour porpoise

Given the wide distribution and relative abundance of harbour porpoise, the long term effects at the population level will be of **minor significance**.

4.1.3 Grey seal

Given the results of the population modelling for harbour seals in the Moray Firth, any effect upon the larger and increasing grey seal population is unlikely to have a significant long-term effect at the population level. Whilst the effects of behavioural displacement on grey seals within the Moray Firth are considered to be of short and medium term major significance, given that most grey seals are not tied to specific breeding or feeding grounds within the Moray Firth it is suggested that the long term effect on this species at the population level will be of **minor significance**.

4.1.4 Harbour seal

The modelling indicates that whilst there will clearly be medium term significant effects to the harbour seal (high magnitude, medium duration), these do not result in long term effects on population. Thus the overall effect is considered to be of low magnitude (predicted population size within 10% of that predicted as a baseline if population parameters do not change within the Moray Firth) and so **minor significance** for harbour seals.

[14] Details provided in Section 7.3.7, Chapter 7 and Appendix 7.3-B of the MORL ES.

4.2 Results for the review of effects for Project 1

4.2.1 Piling Strategy modelling the number of animals exposed to noise levels sufficient to induce PTS onset

The numbers of individuals of each species modelled to be exposed to SELs sufficient to induce PTS onset, using the noise contours provided by Cefas, are provided in Table 4.2 below. These figures are calculated for each soil profile, and would represent the unrealistic scenario of each particular soil profile being present across 100 % of the site. The modelled values from the ES are presented alongside the modelled values for Project 1 development for comparison. For all marine mammal species modelled except harbour seal, the number of animals modelled to be exposed to SELs sufficient to induce PTS onset from the revised blow energy profiles is less than those assessed within the ES.

Current best estimates (based on recent site investigations) indicate that Soil Profile 2 is only present at around 17 % of WTG locations. However, if Soil Profile 2 was present across 100 % of the site and the conditions encountered at every pile location required the highest blow energy (a scenario which we do not consider to be realistic) the number of harbour seals predicted to experience the onset of PTS would be slightly greater (130 animals) than that estimated in the ES (121 animals).

Table 4.2: Number of individuals predicted to experience the onset of PTS during the Project 1 development

Scenario		Bottlenose dolphin (198 dB)	Harbour porpoise (198 dB)	Grey seal (186 dB)	Harbour seal (186 dB)
ES (Scenario A[15], one vessel)		0.06	6.4	170	121
Soil profile 1 (present at 32% of WTG locations)	Highest blow energy	0.00	0.87	49	42
	Most probable blow energy	0.00	0.87	40	34
Soil profile 2 (present at 17% of WTG locations)	Highest blow energy	0.01	4.34	143	130
	Most probable blow energy	0.00	1.91	89	78
Soil profile 4 (present at 21% of WTG locations)	Highest blow energy	No noise impact contour information			
	Most probable blow energy	0.00	1.56	57	49

Table 4.3 below provides the total number of animals modelled to be exposed to SELs sufficient to induce PTS onset from the highest expected (HE) and the most probable (MP) blow energies

[15] One piling vessel in the Moray Firth. Modelling based a piling location at the closest point to the inner Moray Firth. See Section 3.1 above for details.

required for pile installation. The numbers of animals provided in Table 4.3 take into account the proportion of different soil profiles expected to be present across the site and use to proxy soil profiles for Soil Profiles 3, 5 and 6 that were described in Section 2.1.2 above.

It is unrealistic to expect that conditions requiring HE blow energies to install pin piles into each soil profile will be encountered at every location. Therefore, in order to contextualise the number of individuals of each species with the potential to be exposed to SELs sufficient to induce PTS onset from HE profiles with the MP energy profiles, number of individual animals for both scenarios are provided.

Table 4. Error! No text of specified style in document.**3: PTS onset numbers for marine mammal species assuming the highest expected (HE) and most probable (MP) blow energies required for pile installation within Project 1**

Soil profile	% of WTG locations present	Bottlenose dolphin (198 dB)		Harbour porpoise (198 dB)		Grey seal (186 dB)		Harbour seal (186 dB)	
		HE	MP	HE	MP	HE	MP	HE	MP
1	32%	0.00	0.00	0.28	0.28	16	13	14	11
2	17%	0.01	0.00	0.74	0.33	25	16	23	14
3	8% (soil 1 as proxy)	0.00	0.00	0.07	0.07	4	4	4	3
4	21%	0.00	0.00	0.33	0.33	12	12	11	11
5	8% (soil 2 as proxy)	0.01	0.00	0.35	0.16	12	8	11	7
6	14% (soil 2 as proxy)	0.01	0.00	0.61	0.27	20	13	19	11
Total number for Project 1		0.03	0.00	2.38	1.44	89	66	82	57
ES (Scenario A, 1 vessel)		**0.06**		**6.4**		**170**		**121**	

Using this approach to apportion potential effect from piling results to soil profile, the total number of animals exposed to SELs sufficient to induce PTS onset are below those assessed within the MORL ES for all marine mammal species considered.

4.2.2 Project 1 displacement effects

For the animals that have been shown to utilise the Smith Bank as a favoured foraging habitat, the reduction in conservatism described in Section 3.2 results in approximately 25 % to 30 % reduction in the predicted proportion of animals displaced any given scenario for the blow energies assessed within the ES (1080 kJ) (Table 4.1 above). In addition, the up-dated Pile Drivability Assessment indicates that the blow energy required to install 61 % of the pin piles will be below that assessed within the ES. As a consequence, it is considered that the magnitude

of displacement presented in the ES includes the footprint of impact from the increased blow energies required for the latter period of 39 % of the pile driving.

As detailed in Table 3.1, at the time of writing the ES there was no information available as to the speed at which animals would return to Smith Bank following the cessation of piling. Animals were therefore modelled to be displaced throughout the period in which piling was to take place, and the piling duration for each pile was not considered. By maintaining this conservative assumption within this vreview of the effects from Project 1, it is considered that the increase in piling duration for each pile is included.

As a consequence of the above, the displacement of marine mammal species as a result of utilising a higher blow energy for the latter period of pile driving for certain soil profiles is not considered to represent a significant change to the outcome of the assessment presented in the ES and considered for the consent of the 1.116 GW development. Therefore revised estimates of the numbers of animals displaced have not been calculated.

4.2.3 Project 1 spatial and temporal effects

As shown in Table 4.1 above, the numbers of animals impacted from more than one piling vessels operating at one time are a multiple of those impacted from a single piling vessel. As a consequence, it is considered that the potential impact arising from multiple piling vessels on Project 1 will also be within the footprint of effects presented within the MORL ES for Scenarios B (two vessels) and C (six vessels).

4.2.4 Project 1 population levels effects

The potential number of animals to be exposed to sufficient SELs to experience PTS onset and displacement from the realistic worst case described for Project 1 is considered to be below those assessed within the MORL ES for all marine mammal species and scenarios considered. The population level effects from PTS and displacement from the noise resulting from all scenarios presented for Project 1 are therefore considered to be within the effects of the population modelling presented within the MORL ES. Therefore, no additional modelling for the population level effects upon harbour seal and bottlenose dolphin has been undertaken.

4.2.5 Project 1 cumulative effects

As described above in Section 2.3.2, Project 1 is likely to be constructed in a similar timescale to the BOWL project. It is acknowledged that if there is a change in either project programme, then piling could occur on both sites across a timescale from two years to not overlap at all.

The maximum BOWL project blow energy profiles have not changed, and are therefore within those assessed within the ES. The temporal sequence of construction of the two projects is within that described in the MORL ES. Therefore, all of the potential cumulative piling scenarios were considered within the original assessment presented within the MORL ES. As a consequence, in combination with the changes presented for Project 1, there is not considered to be a significant change to the conclusions of the MORL ES with regards to the cumulative impact assessment.

4.2.6 Summary of parameters provided within original ES and presented for Project 1

Table 4.4 below provides a summary of the relevant elements of Project 1 and a consideration of whether each element can be included within the Rochdale Envelope assessed within the MORL ES. If the effects arising from Project 1 are considered to require review within the context of the previous impact assessment undertaken, a summary of the methodology used is provided.

Table 4.4: Summary of the assessment parameters from the original ES and the Piling Strategy for Project 1

Project element	Element description for Project 1	Covered within Rochdale Envelope assessed in MORL ES?	Requiring a review of Project 1 effects?
WTG number	Up to 100 WTG – 400 no. of piles.	Yes (up to 339 WTG – 1356 no. of piles).	No
Foundation type	Jackets or GBSs	Yes (jackets).	No
Simultaneous piling within Project 1	Most likely scenario is represented by a single piling vessel, but with the potential for up to three vessels as a result of construction delays.	Yes. Maximum of 6 simultaneous piling events across Telford, Stevenson and McColl OWFs. Maximum of 2 vessels per site.	No
Piling duration	Max of two years of piling.	Yes, within five year duration assessed is ES.	No
Piling duration	Worst case piling duration of 6.5 hours of piling per pile, and 3 piles in 24 hours.	No. Likely worst case assessed as 3.25 hours of piling, 2 piles in 24 hours	Yes. SELs for species to estimate potential PTS onset numbers and comparison to ES assessment.
Piling energies	Predicted blow energies dependent on soil profiles – 61 % of WTG predicted to be below 1080 kJ, 39 % of WTG may require higher energies (>1080 kJ) for latter period of piling.	No. Worst case assessed as up to 1080 kJ blow energy from 1200 kJ hammer.	Yes. Assessment of conservatism of ES assumptions. Modelling of conservative PTS onset and consideration of likely displacement arising from revised blow energy profiles.
Simultaneous piling within Project 1 and BOWL project	Most likely scenario is represented by a single piling vessel on BOWL for one year, one each on BOWL and MORL for one year followed by a single vessel piling for one year on MORL.	Yes. A variety of possible temporal build out scenarios were assessed with the ES which cover all the temporal potential build out scenarios for BOWL and Project 1.	No

5. Conclusion

The use of higher blow energies during the latter period of piling to install pin piles at up to 39% of the turbine locations of Project 1, over the maximum blow energies assessed within the MORL ES, has the potential to result in larger effects upon marine mammals than those assessed within the ES. This increase in noise exposure was assessed with regards to SELs sufficient to induce PTS onset and elicit avoidance behaviour.

Remodelling of the noise propagation utlising developments in underwater noise modelling methodologies and apportioning potential blow energies to representative numbers of foundations within Project 1 has been undertaken. This has enabled an assessment of the number of animals with the potential to be exposed to SELs to induce PTS onset from the increased blow energies required for Project 1 against those of the Rochdale Envelope of the MORL ES. Table 5.1 below illustrates that these numbers are within the effects assessed within the MORL ES.

Table 5.1: Comparison of potential number of animals to be exposed to PTS onset from Project 1 with those assessed in the MORL ES

	Bottlenose dolphin (198 dB)		Harbour porpoise (198 dB)		Grey seal (186 dB)		Harbour seal (186 dB)	
	HE	MP	HE	MP	HE	MP	HE	MP
Total number for Project 1	0.03	0.00	2.38	1.44	89	66	82	57
ES (Scenario A, 1 vessel)	0.06		6.4		170		121	

Re-appraisal of the conservative assumptions used in the development of the methodology described in the ES through further consultation with stakeholders and peer review has been undertaken since the ES was published. This re-appraisal has provided confidence in the degree of conservatism of the extent of predicted displacement, the consequence to individual marine mammals and the effect of disturbance at the population level. Semi-quantifying this conservatism has enabled the conclusion that the increase in maximum blow energy required for Project 1, against those of the Rochdale Envelope of the MORL ES, will not cause an increase in disturbance or disturbance related consequences from those assessed within the MORL ES.

Consideration of the spatial, temporal and cumulative elements of Project 1 also concludes that the Project is within the Rochdale Envelope described within the MORL ES.

It is considered that the conservatisms inherent within the MORL ES impact assessment render the magnitude of effects assessed very unlikely to occur in reality. A reduction in conservatism using information published in peer review journals since the EIA was undertaken provides confidence that the increase in the blow energies identified within the revised Pile Driveability Assessment will not cause an increase in the predicted effects upon the marine mammal species that was presented in the original ES. Thus the increase in maximum blow energy from a maximum of 1080 kJ to up to 2250 kJ for potentially up to 39 % of the site is not considered to cause a significant change to the conclusions of the ES.

6. References

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Developing Wind Energy In The Outer Moray Firth

Piling Strategy

Appendix 4:

Underwater Noise Modelling – Fish

Telford, Stevenson and MacColl Offshore Wind Farms - Project 1

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APPENDIX 4 Underwater Noise Modelling – Fish Ecology

Produced by Subacoustech on behalf of Moray Offshore Renewables Ltd	
Produced by	Richard Barham
Reviewed by	Tim Mason
Document Status	FINAL
File Name	8460001-PCA0010-MOR-REP-009
Date	15/01/2016

Legal Review

Reviewed by	Company
Patricia Hawthorn	Shepherd and Wedderburn

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Ecological Clerk of Works Approval

Company	Name	Signature
Royal Haskoning DHV	Benjamin King	[redacted]

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Executive Summary

This document presents additional underwater noise modelling undertaken by Subacoustech Environmental in order to assess the effects of impact piling noise at the three consented MORL wind farms on relevant fish species in light of the refined piling strategy. The noise levels have been presented as dB_{ht}(*Species*) levels for salmon, cod and herring in keeping with the previous modelling carried out as part of the Environmental Statement (ES) (MORL, 2012).

The modelling results show that the largest impact ranges are predicted for herring, with maximum impact ranges predicted out to 35.8 km for 90 dB_{ht} and out to 91.0 km for 75 dB_{ht}. Both of these ranges are for the Soil Profile 2, highest estimate (P2HE) piling scenario. Appendix 5 sets out the results of the fish assessment using the outputs of the noise modelling described in this report and provides a comparison with the predicted effects set out in the full MORL Environmental Statement (ES) (2012).

1 Introduction

Underwater noise modelling was undertaken by Subacoustech Environmental for the three consented MORL wind farms as part of the Environmental Statement (ES (MORL, 2012). Since the ES was submitted a greater level of information is now known, in particular, relating to seabed conditions on site, and due to this, some of the construction parameters have been refined since the original modelling was undertaken. This report presents modelling of these refined parameters for salmon, cod and herring in line with the following condition attached to the Section 36 consents for the three consented wind farms:

"*In the event that pile foundations are to be used, the Company must, no later than 6 months prior to the Commencement of the Development, submit a Piling Strategy ("PS"), in writing, to the Scottish Ministers for their written approval. Such approval may only be granted following consultation by the Scottish Ministers with the JNCC, SNH and any such other advisors as may be required at the discretion of the Scottish Ministers. The Development must, at all times, be constructed in accordance with the approved PS (as updated and amended from time to time by the Company). Any updates or amendments made to the PS by the Company must be submitted, in writing, by the Company to the Scottish Ministers for their written approval.*

The PS must include:

a) *Full details of the proposed method and anticipated duration of pile-driving at all locations;*
b) *Details of soft-start piling procedures and anticipated maximum piling energy required at each pile location; and*
c) *Details of mitigation and monitoring to be employed during pile-driving, as agreed by the Scottish Ministers.*

The PS must be in accordance with the ES and reflect any surveys carried out after submission of the Application. 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; Atlantic salmon; cod; and herring.

The PS must, so far as is reasonably practicable, be consistent with the EMP, the PEMP and the CMS.

Reason: To mitigate the underwater noise effects arising from piling activity."

Two piling scenarios have been identified to be modelled:

- P2MP (the most probable scenario in Soil Profile 2); and
- P2HE (the highest estimate scenario in Soil Profile 2).

These piling scenarios relate to two scenarios (Highest Expected (HE) and Most Probable (MP)) for Soil Profile 2. This soil profile has been identified by MORL's geotechnical consultants as the 'stiffest soil' requiring the highest blow energies to drive piles into target depth and therefore represents the worst-case scenario for underwater noise effects. The hammer blow energy is gradually increased during piling operations to maintain a steady rate of pile penetration up to target depth and therefore the highest blow energies will only be required towards the latter period of piling driving (see PS main document for details on pile driving activities).

Both these scenarios assume a pile diameter of 2.5 m with maximum blow energies of 1800 kJ for P2MP and 2250 kJ for P2HE.

In keeping with the previous modelling, the same modelling methodology and locations have been used as in the ES. It was decided to follow the same methodology as used in the ES and by BOWL, the neighbouring development, to ensure consistent and directly comparable results. Consistent with the ES three locations are used: Location 1 (south west of the site) for cod, Location 5 (north) for herring and Location 6 (north west) for salmon. This report presents the modelling results in terms of the species-specific dB_{ht}(*Species*) metric[1] in line with ES. 90 and 75 dB_{ht} impact ranges have been modelled, the effects of these noise levels are summarised as:

- 90 dB_{ht}(*Species*) – Strong avoidance reaction in virtually all individuals;
- 75 dB_{ht}(*Species*) – Some avoidance reaction by the majority of individuals, but habituation or context may limit effect. In the presence of another biological imperative (such as migration to breeding or feeding grounds, or avoiding a predator) individuals may not exhibit any behavioural reaction to the noise source.

The chosen piling locations represent the worst case with regards to proximity to sensitive receptors and, as described above, only the stiffest soil profile was modelled (Soil Profile 2). This therefore represents conservative approach to modelling the predicted effects of underwater noise on fish receptors.

This report presents the results of the updated underwater noise modelling following the refined Piling Strategy. The assessment of effects on fish species is contained within Appendix 5.

[1] Nedwell J R, Turnpenny A W H, Lovell J, Parvin S J, Workman R, Spinks J A L, Howell D (2007). *A validation of the dB_{ht} as a measure of the behavioural and auditory effects of underwater noise.* Subacoustech report no. 534R1231, published by the Department of Business, Enterprise and Regulatory Reform.

2 Modelling Results

Table 2.1 and Table 2.2 present the predicted 90 and 75 dB_{ht}(*Species*) impact ranges at the key locations for both the P2MP and P2HE blow energy scenarios. The largest impact ranges are predicted for herring using the P2HE scenario, with levels of 90 dB_{ht} out to ranges out to 35.8 km and 75 dB_{ht} out to 91.0 km. Slightly smaller impact ranges are predicted for the P2MP scenario, with maximum ranges of 33.5 km and 86.6 km for herring for 90 and 75 dB_{ht} respectively. The percentage increase in impact ranges between P2MP and P2HE are up to approximately 8% for cod, 7% for herring, and 10% for salmon.

The ranges denoted with an asterisk (*) show where the minimum range exists because the contour is limited by the nearest coastline.

Table 2.1: Summary of the predicted dB_{ht} impact ranges using the P2MP (most probable) piling scenario at the Moray Firth Offshore Windfarm

P2MP		90 dBht(Species)	75 dBht(Species)
Location 1 (Cod)	Maximum range	30.3 km	76.0 km
	Minimum range	21.4 km	32.3 km*
	Mean range	25.7 km	52.1 km
Location 5 (Herring)	Maximum range	33.5 km	86.6 km
	Minimum range	22.4 km*	22.4 km*
	Mean range	30.0 km	62.0 km
Location 6 (Salmon)	Maximum range	2.0 km	11.0 km
	Minimum range	2.0 km	10.0 km
	Mean range	2.0 km	10.6 km

Table 2.2: Summary of the predicted dB_{ht} impact ranges using the P2HE (higest estimate) piling scenario at the Moray Firth Offshore Windfarm

P2HE		90 dBht(Species)	75 dBht(Species)
Location 1 (Cod)	Maximum range	32.7 km	79.4 km
	Minimum range	22.9 km	32.3 km*
	Mean range	27.6 km	53.5 km
Location 5 (Herring)	Maximum range	35.8 km	91.0 km
	Minimum range	22.4 km*	22.4 km*
	Mean range	31.8 km	64.0 km
Location 6 (Salmon)	Maximum range	2.3 km	12.1 km
	Minimum range	2.2 km	10.9 km
	Mean range	2.2 km	11.6 km

3 Contour Plots

Figure 3.1 to Figure 3.6 present the predicted impact ranges shown in the preceding tables as contour plots; the noise source on each plot is shown as a small white plus (+).

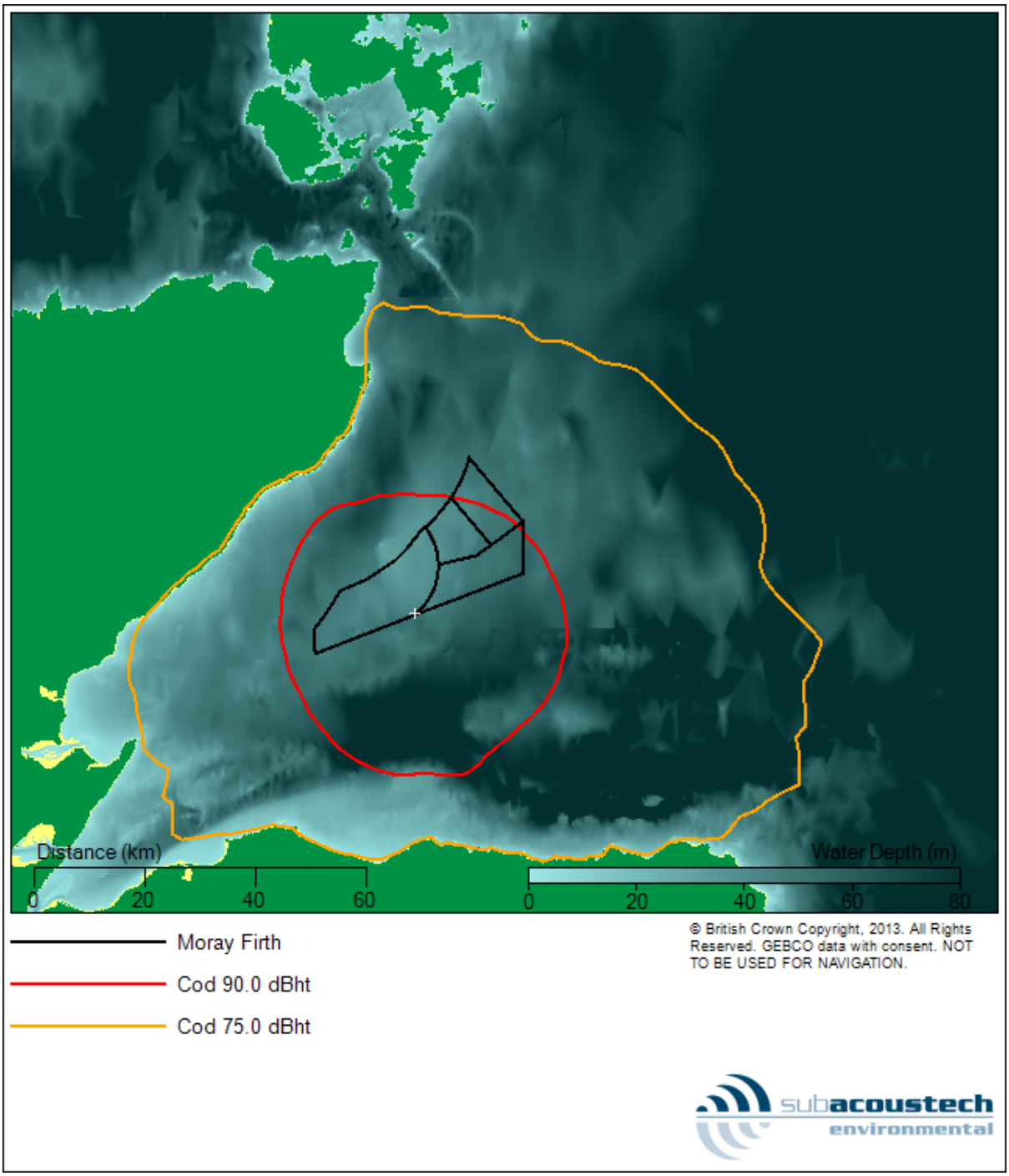

Figure 3.1: Contour plot showing 90 and 75 dB_{ht} ranges for cod at Location 1 using the P2MP scenario

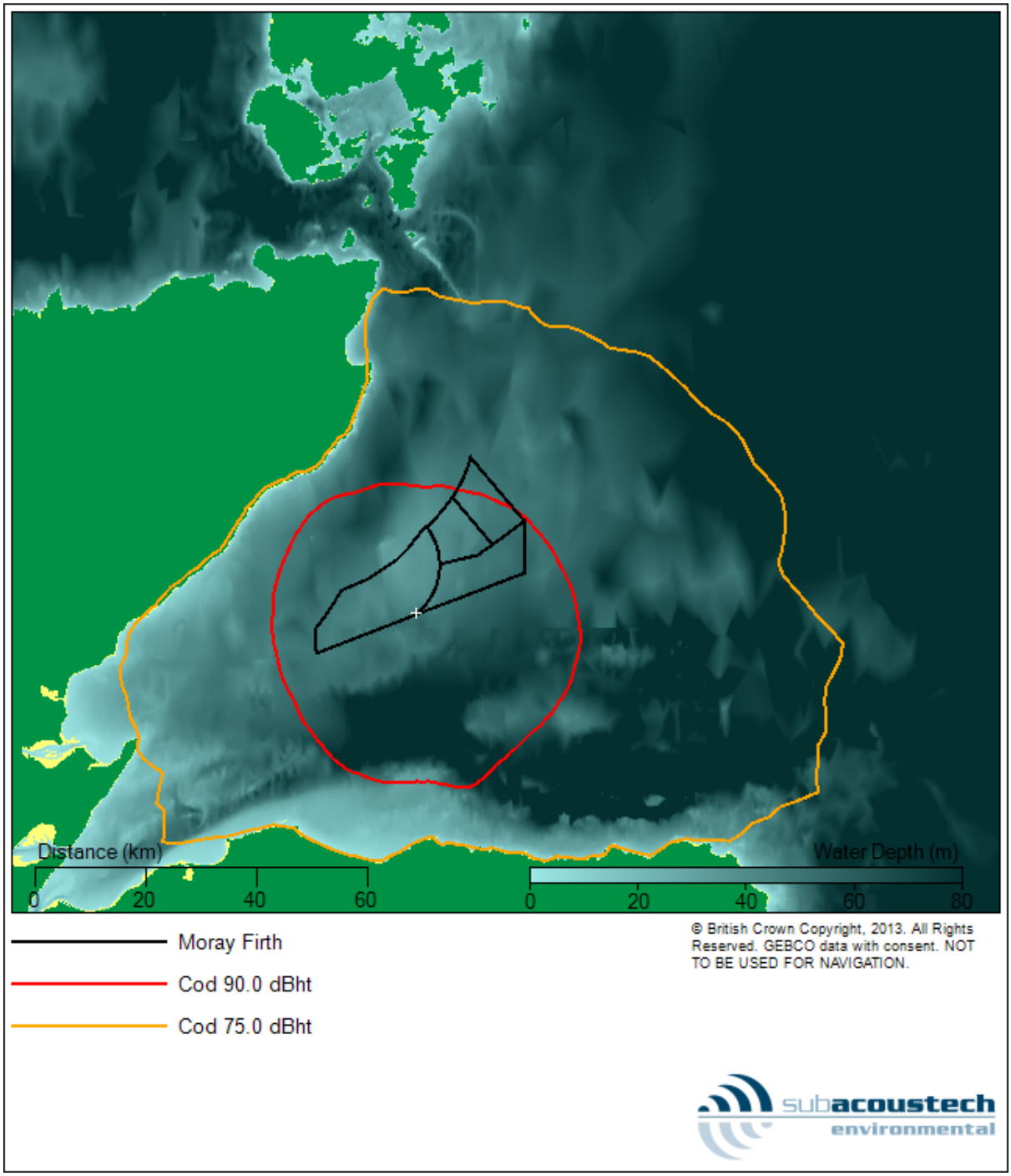

Figure 3.2: Contour plot showing 90 and 75 dB_{ht} ranges for cod at Location 1 using the P2HE scenario

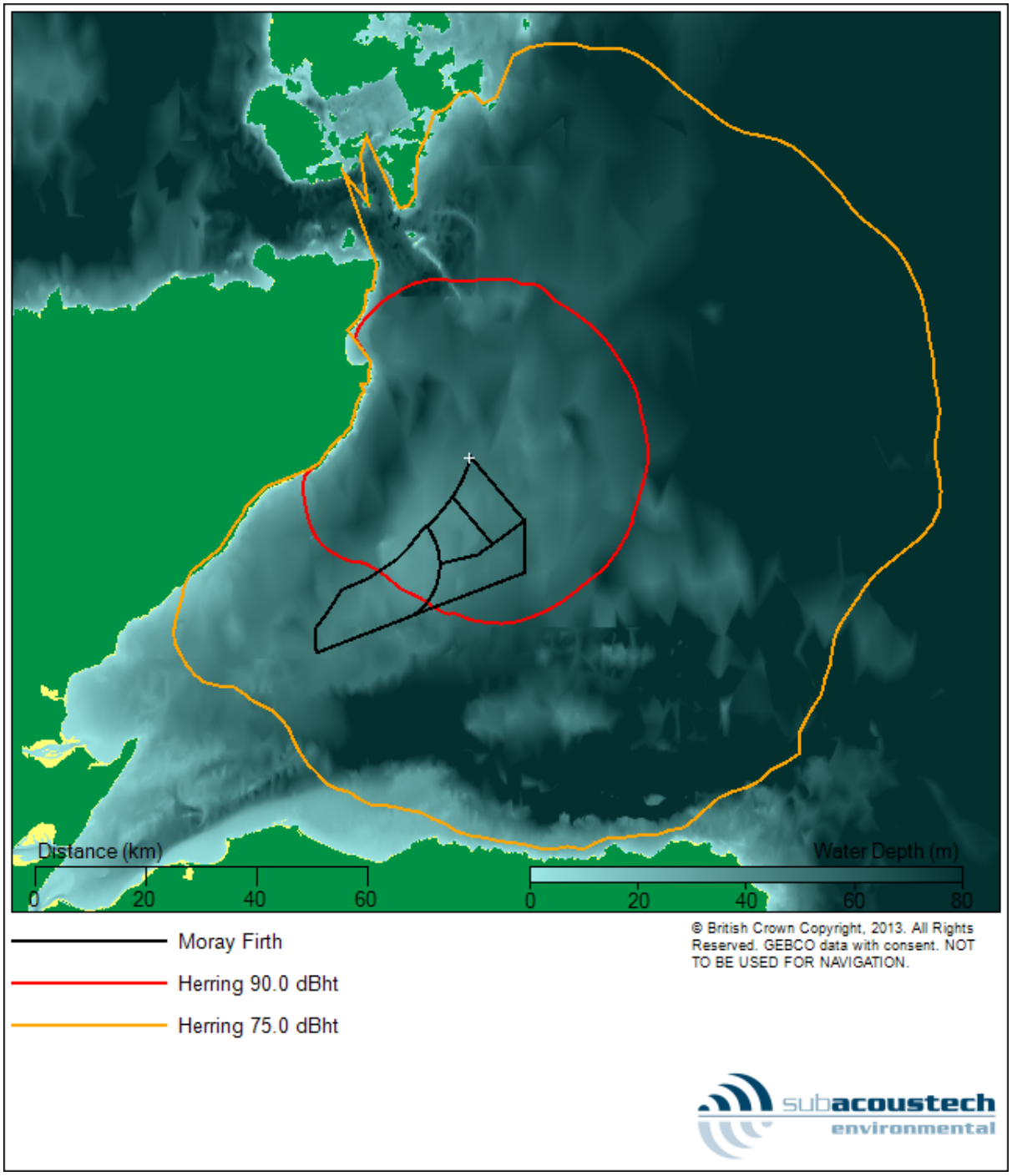

Figure 3.3: Contour plot showing 90 and 75 dB_{ht} ranges for herring at Location 5 using the P2MP scenario

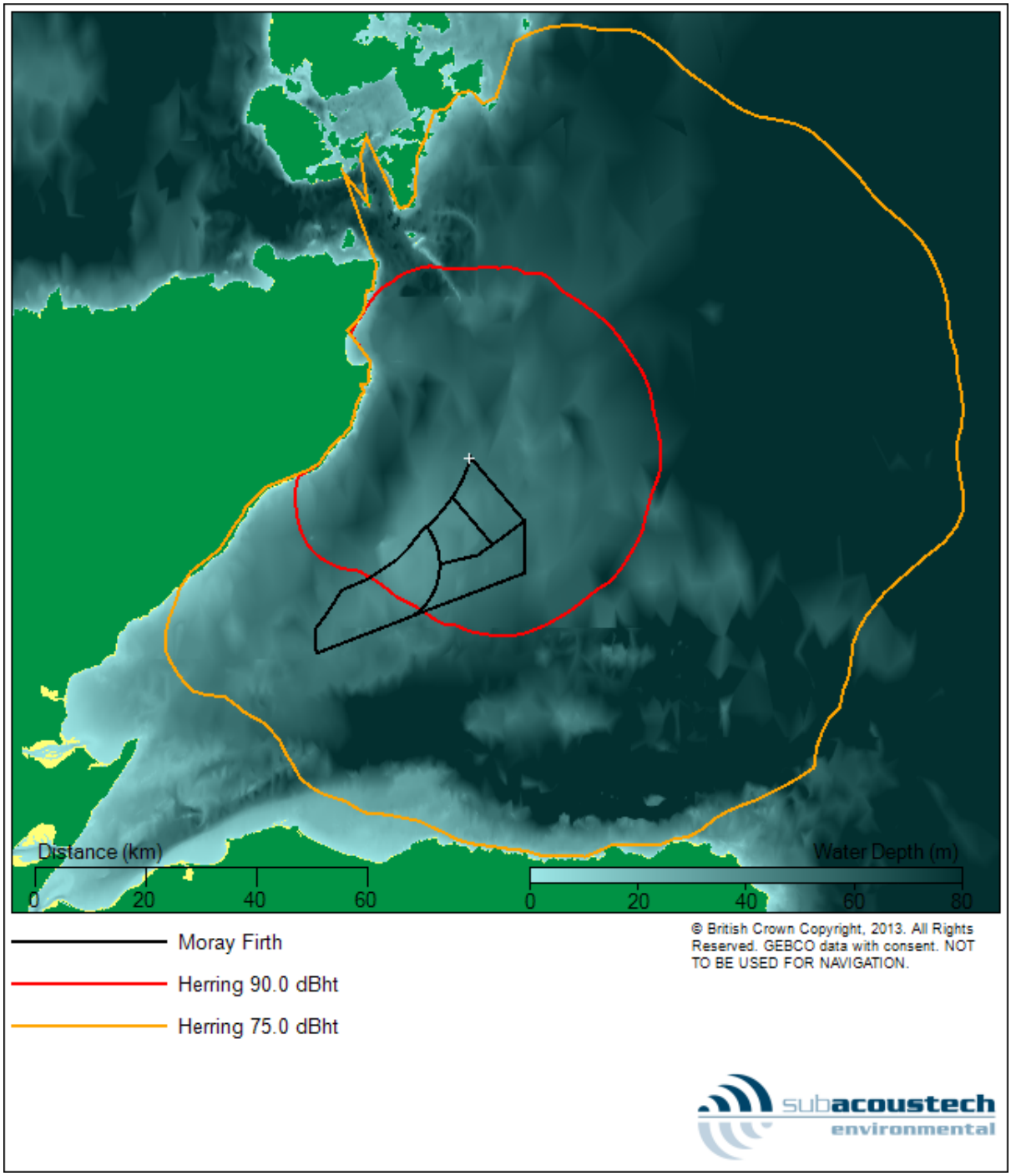

Figure 3.4: Contour plot showing 90 and 75 dB_{ht} ranges for herring at Location 5 using the P2HE scenario

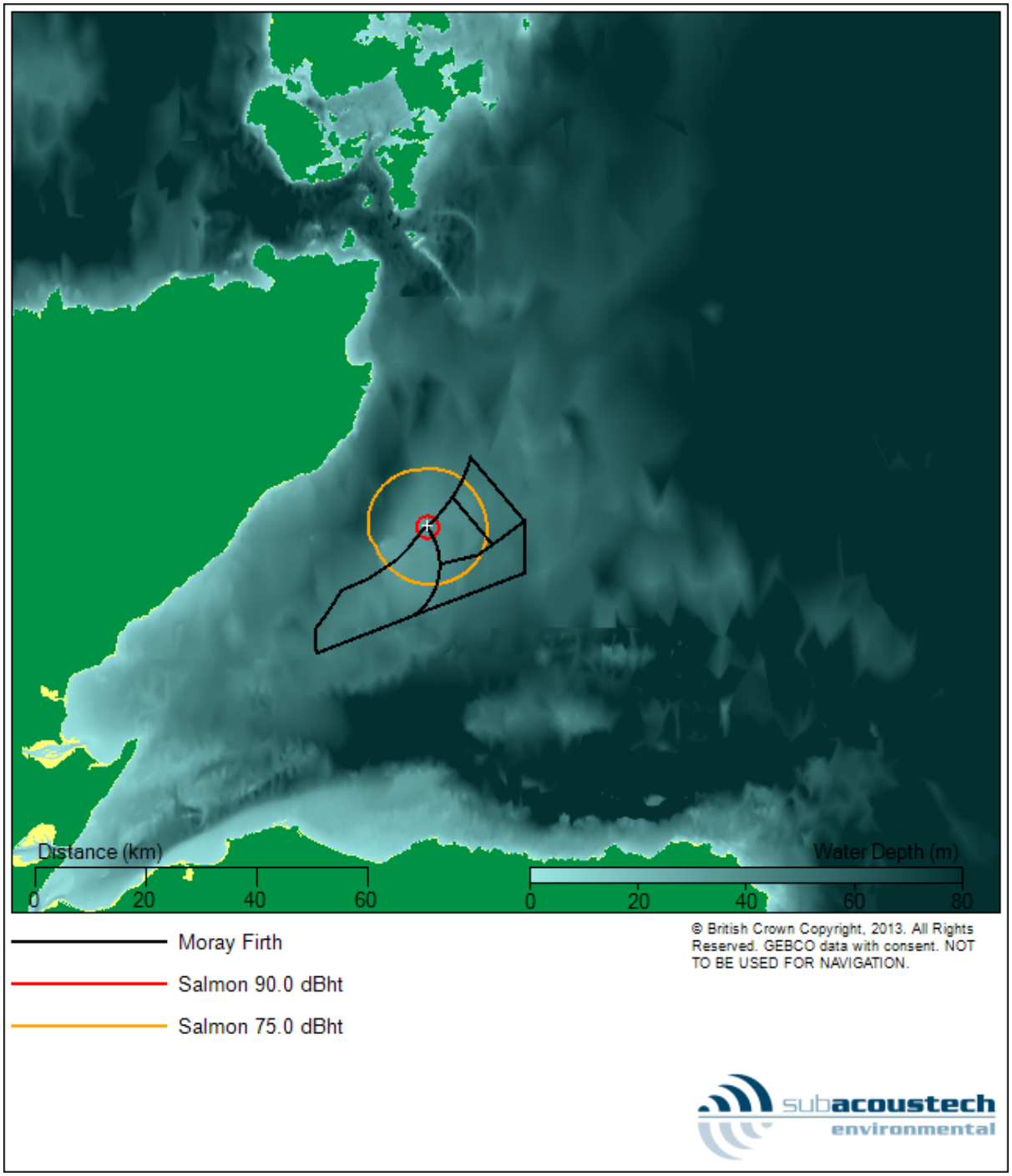

Figure 3.5: Contour plot showing 90 and 75 dB_{ht} ranges for salmon at Location 6 using the P2MP scenario

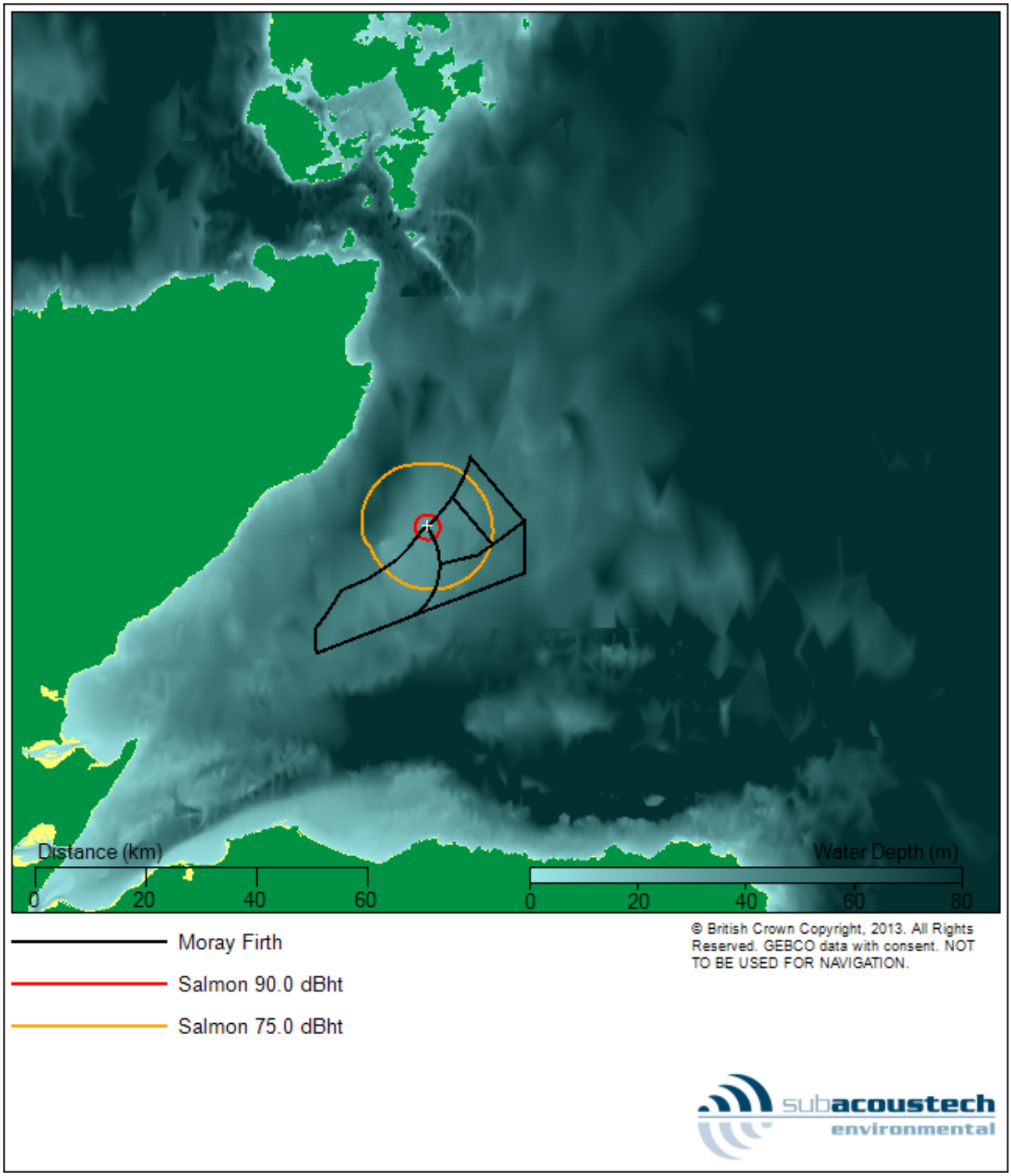

Figure 3.6: Contour plot showing 90 and 75 dB_{ht} ranges for salmon at Location 6 using the P2HE scenario

4 References

MORL (2012). Environmental Statement. Telford, Stevenson and MacColl Offshore Wind Farms and Associated Infrastructure.

Nedwell J R, Turnpenny A W H, Lovell J, Parvin S J, Workman R, Spinks J A L, Howell D (2007). A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech report no. 534R1231, published by the Department of Business, Enterprise and Regulatory Reform.

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Piling Strategy

Appendix 5:

Fish Assessment

Telford, Stevenson and MacColl
Offshore Wind Farms - Project 1

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APPENDIX 5: Fish Assessment

Produced by Brown & May Marine on behalf of Moray Offshore Renewables Ltd Brown & May Marine Ltd.	
Produced by	Jake Laws
Reviewed by	Stephen Appleby
Document Status	FINAL [Version 2]
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Reviewed by	Company
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List of Abbreviations

ASFB	Atlantic Salmon Fisheries Board
BOWL	Beatrice Offshore Wind Ltd
DSFB	District Salmon Fisheries Board
ES	Environmental Statement
EDA	Eastern Development Area
EMF	Electromagnetic Field
MFRAG	Moray Firth Regional Advisory Group
MFSTP	Moray Firth Sea Trout Project
MORL	Moray Offshore Renewables Limited
MS-LOT	Marine Scotland Licensing Operations Team
OfTI	Offshore Transmission Infrastructure
OSP	Offshore Substation Platform
PS	Piling Strategy
SEL	Sound Exposure Level
SSC	Suspended Sediment Concentration
WTG	Wind Turbine Generator

Executive Summary

This document accompanies the Piling Strategy (PS) that has been developed by MORL to meet the requirements of condition 11 of the Section 36 Consents for the Telford, Stevenson and MacColl Wind Farms.

Following submission of the Environmental Statement (ES) in 2012 (MORL ES), and granting of consents to develop up to 1,116 MW in the Eastern Development Area (EDA) (i.e. the area comprising the Telford, Stevenson and MacColl wind farms) MORL have revised their build out programme. It is now anticipated that the consent will be built out under two separate phases. The first phase of development (Project 1) will comprise up to 100 turbines across the Telford, Stevenson and MacColl sites, with the second phase constituting the remainder of the consented capacity (up to a maximum of 186 turbines in total across both phases).

Detailed site investigations (geotechnical surveys) were undertaken within the EDA in 2014. The results of the survey have indicated that, for successful installation, up to 39% of turbines may require higher hammer energies during the latter period of piling than were originally assessed within the MORL ES Rochdale Envelope. Due to the potential requirement for higher hammer energies MORL have commissioned additional modelling in order to validate that the potential noise effects identified in this Appendix are with the overall effects predicted, the order of significance the same or less and the effects are not considered to cause a significant change in the conclusions of the MORL ES for the key fish species identified in the PS consent condition and the MORL ES (i.e. herring, cod and Atlantic salmon).

The updated modelling was undertaken for Soil Profile 2 as it has been identified in the Pile Drivability Assessments as the 'stiffest' soil where the highest energies will be required to drive the pile up to target depth. For herring and cod, 'worst case scenario' piling locations were selected on the basis of the proximity of the given location to defined spawning grounds. For salmon, the worst case was selected on the basis of the closest location to shore (and therefore the natal rivers). For all three of the species under consideration there were small increases in the areas modelled to be within risk of causing displacement/injury.

In the case of herring, the revised modelling resulted in a minor increase in the potential overlap with defined spawning grounds at the 90 dB_{ht} level under both the highest expected (HE) and most probable (MP) piling scenarios (an increase of less than 2% in both cases). Therefore potential increases are small and given that Soil Profile 2 is only predicted to be present at 17% of total piling locations, the likely effects remain within the overall effects predicted in the MORL ES. Nevertheless, MORL is also committed not to pile anywhere outwith the herring mitigation zone, as defined in the S36 consent, during the herring piling restriction period where energies are predicted to be over those assessed in the MORL ES (i.e. over 1080 kJ).

For cod, the increases in the spatial extent of areas of risk for displacement/injury when compared to those predicted in the MORL ES were slightly larger. When considered in the context of the results of the cod spawning survey undertaken in 2013, which suggested relatively low intensity activity in the vicinity of the MORL development which is also detailed in a recent paper by Gonzalez-Irusta and Wright (2015), the magnitude of the effect was not expected to increase. Accordingly, it is considered that there is no significant change to the conclusions of the MORL ES with regard to cod.

For salmon, the new modelling did not result in any increased potential for barrier effects with respect to the natal rivers at either the 90 dB_{ht} or 75 dB_{ht} levels and therefore the likely effects remain within the overall effects predicted within the MORL ES. There are uncertainties regarding the occurrence and movements of salmon in the Moray Firth, including the MORL site. This was highlighted in the MORL ES and remains the case for this assessment. MORL is currently agreeing methods with the relevant stakeholders monitoring within the Moray Firth in accordance with the National Research and Monitoring Strategy for Diadromous Fish together

with requirements under the Project Environmental Monitoring Programme (PEMP) condition for each of the Section 36 consents.

1 Introduction

In 2014 MORL was awarded Section 36 Consents and Marine Licences for a total of 1,116 MW within the Telford, Stevenson and MacColl offshore wind farms located in the Eastern Development Area (EDA). Since the award, MORL has revised its build out programme for the EDA. It is now anticipated that the area will be developed in two separate phases Project 1 is expected to consist of up to 100 turbines across the Telford, Stevenson and MacColl sites, with a subsequent second phase constituting the remainder of the consented capacity (up to a maximum of 186 turbines in total across the EDA). Construction of the second phase will commence at a later date, and this report is in respect of Project 1 only.

Since the award of consents, further geotechnical surveys have been undertaken by MORL in order to further inform detailed engineering design and the Pile Drivability Assessment. The results of this work have indicated that in order to achieve target penetration depth piling at up to 39% of turbines may require higher hammer energies than originally assessed within the Rochdale Envelope of the MORL ES (i.e. larger than 1080 kJ) during the latter period of piling. Additional modelling was therefore undertaken to understand the potential effects on herring (*Clupea harengus*), cod (*Gadus morhua*) and Atlantic salmon (*Salmo salar*) as these were the key fish species identified in the PS consent condition and MORL ES. Due to their likely similar sensitivity to noise, sea trout (*Salmo trutta*) were assessed in the MORL ES alongside salmon. Sea trout were not included within the consent conditions as a key species for the Piling Strategy and for this reason this document focuses on salmon only. However, due to their likely similar sensitivity to noise, it is considered that the assessment presented within this document for salmon also applies to sea trout and as such, the predicted effects remain unchanged from those within the MORL ES.

More specifically, the Pile Drivability Assessment has identified that up to 17% of turbine locations may require hammer energies of up to a maximum of 2250 kJ during the latter period of piling. Therefore, in the case of the three fish species under consideration this has been modelled as the worst case in terms of potential noise related effects. To allow direct comparability, revised modelling has been undertaken using the same method as employed in the MORL ES (the Subacoustech dB_{ht} (Species) metric) but with increased hammer energies (see Appendix 4 for detailed information on revised modelling). To validate that the potential effects are within those predicted in the MORL ES the approach of the assessment undertaken for Project 1 has been to compare the results from the revised modelling with those presented in the MORL ES in order to highlight any changes that could potentially occur as a result of the increased hammer energies. An assessment is carried out to establish whether the potential effects of the PS cause any significant change in the conclusions of the ES in relation to the key fish species.

2 The Project

2.1 Rochdale Envelope considered in the ES

The full Rochdale Envelope of the MORL project was presented within the ES as Chapter 2 – Project Details[1]. The application for the 1.5GW of capacity within the Eastern Development Area (EDA) was split between three sites; Telford, Stevenson and MacColl, which in total encompassed between 216 and 339 turbines of between 3.6 and 8 MW in size.

The consequences of this Rochdale Envelope with regards to the generation of underwater noise associated with the piling activity were explored in detail in the Technical Appendix 3.6 A – Underwater Noise Technical Report. The outputs from the noise modelling undertaken were then used to inform the assessment of potential effects on the ecology of the fish and shellfish species identified within the environmental baseline. The results of the assessment were presented within the MORL ES.

2.1.1 Worst case criteria assessed within the MORL ES

At the time of the application it was envisaged that the first of the three sites to be developed (Telford, Stevenson or MacColl) may be built using smaller turbines, whilst sites constructed later could utilise larger turbines should they become available due to technological advances within the industry. Piles of 2.5 m diameter were selected to represent the worst case scenario throughout the assessment on fish and shellfish species.

In addition to the diameter of the pin pile, the predicted blow energy required to drive piles to the required depth was also dependent upon the composition of the soil. Technical Appendix 3.6 A also detailed the study that was undertaken into the relative noise produced from pile installation in the three soil types that were understood to exist across the site at the time of the ES production (shown in Figure A-9 of the Technical Appendix 3.6 A). Province 3 soils were considered to be the stiffest and therefore requiring the highest blow energy required to drive the pin to the required soil depth to secure the wind turbine foundation.

The blow energy profile predicted to be required to drive a 2.5 m diameter pile to a depth of 26 m in province 3 soils was provided in Table A-5 of the Technical Appendix 3.6 A, and represented below as Table 2.1.

Table 2.1 Assumed blow energy profile required to drive a 2.5 m diameter pin pile to a depth of 26 m into province 3 soils

Penetration depth	Hammer efficiency	Impact Energy (kJ)	No of blows	Time
0 to 4 m	15%	170	260	15 mins
4to 14 m	40%	450	2400	45 mins
14 to 16 m	80%	890	1000	15 mins
16 to 26 m	95%	1080	7000	2 hours

[1] http://www.morayoffshorerenewables.com/Document-Library.aspx

2.1.2 Temporal scenarios assessed in the ES

The Project Description (Chapter 2.2 of the MORL ES) also provided information on the estimated temporal element of piling activity. The Rochdale Envelope included piling throughout the year, with a build programme showing piling at full intensity possible during the summer and at half intensity during the winter to allow for weather windows. As a consequence of these restrictions, the foundation installation programme modelled represented three scenarios (with indicative dates);

1. A five year build programme utilising one installation vessel, installing 2 pin piles in a 24 hr period.
2. A three year build programme utilising two vessels for the majority of the period, also installing 2 pin piles in a 24 hr period.
3. A two year build programme if six vessels are used, each installing two pin piles in a 24 hr period. It was considered at the time of the ES production that each site could be constructed independently of the other two, and as such it was necessary for the impact assessment to include the scenario of construction of all three at the same time (for a limited period only).

2.1.3 Cumulative assessment presented within the ES

A cumulative assessment with the potential construction and temporal parameters of the Beatrice Offshore Wind Ltd (BOWL) project was also presented within the ES. It was assumed that the piling of the 277 turbines of the BOWL project could last up to three years and that the maximum blow energy required would be 2300 kJ (full details of the piling profile for the BOWL project are provided in Table A-7 of the Technical Appendix 3.6 A).

With regards to the construction sequencing of the MORL and the BOWL projects three scenarios were considered with varying piling intensities, whether simultaneous piling would occur and assuming varying piling duration scenarios (full details are provided in 14.3.4.8 of Chapter 14 – Biological Environment CIA).

2.1.4 Conservative Assumptions made during the impact assessment presented within the ES

In order achieve a 'probable' degree of confidence (50 to 95 % probability as defined by the IEEM guidance (IEEM, 2010)) that the impact footprint of the Rochdale Envelope fell within the parameters assessed, it was necessary to make a number of conservative assumptions within the assessment presented in the ES. These conservative assumptions were discussed in Section 7.2 of the ES (Chapter 7 – Biological Environment OGS). To summarise, in order to assess the interest of the worst case scenarios, noise modelling was undertaken at locations closest to the spawning grounds of sensitive fish species (as defined by Coull *et al.*, 1998 and Ellis *et al.*, 2012) such as herring and cod. In the case of salmon, for which there is a paucity of data pertaining to the migration routes of adults and smolts, modelling was undertaken at locations which produced contours that came closest to the coast and or/SAC rivers of origin. By adopting this approach an inherent conservatism was introduced to the assessment of impacts over the construction phase, as in reality the majority of piling would occur further away from the most sensitive 'worst case' locations. In a similar conservative manner, for cumulative impacts the two piling locations were chosen to represent the largest possible noise footprint from piling operations. In light of the uncertainties regarding salmon migration and the use the species could make of the development areas during this life history stage, the assessment approach considered that salmon could be present during piling. This therefore introduced an inherent conservatism over the duration of the construction phase, accounting for uncertainties and gaps in the available scientific data and information.

2.2 Project 1

Project 1 will consist of up to 100 turbines on jacket foundations requiring up to four pin piles as referred to in the Introduction section. The worst case criteria considered is detailed below.

2.2.1 Revision of worst case for Project 1

Since the consent was awarded, MORL has undertaken a further geotechnical campaign across the three consented projects within the EDA. This has enabled MORL to refine the ground model with regards to soil stiffness, and to undertake a detailed Pile Drivability Assessment to inform likely blow energies required to install pin piles across the site. The 2014 site investigations have indicated that the Project 1 ground conditions are very heterogeneous with six soil profiles identified (see PS main document, Section 3.3 for details). The results indicate that in some areas of Project 1 it may be required to use higher energies than those assessed in the MORL ES during the latter period of piling.

Soil Profile 2, which is predicted to be at approximately 17% of the wind turbine locations within Project 1, was identified as the stiffest soil. The Pile Drivability Assessment indicated that 1800 kJ is the most likely (ML) maximum energy required to drive piles into this soil type, with approximately the last hour of driving (within an overall estimated 5.5 hours of pile driving) requiring blow energies above the 1080 kJ assessed within the ES. A conservative worst case scenario (Highest Expected, HE) indicates that a 2250 kJ may be required for this last 1.5 hours (within an overall estimated 6.5 hours of pile driving) (please see Section 3.3 of the PS main document for details on estimated required blow energies across Project 1).

In addition to the increase in the modelled blow energy required to drive piles into Soil Profile 2, studies also suggest that a longer pin pile will be required across the site. This has resulted in increased piling durations (for each pin pile) over those assessed in the ES, from 3.25 hours to up to 6.5 hours. The ES also assessed the effects arising from SELs with the potential to result from the installation of two pin piles per 24 hour period, MORL now considers that up to three piles could be driven within a period of 24 hours.

SELs have therefore been reassessed for installation of pin piles into Soil Profile 2 (present at 17% of the turbine locations) as this represents the worst case scenario for piling.

2.2.2 Temporal scenario for Project 1

The base case for the installation of the piles for Project 1 is that a single piling vessel will operate on site for up to two years. However, if a delay to the programme is encountered, there is the potential for up to three vessels to be operating on site for a short period of time during this two year period, with a maximum of two vessels in each individual site (i.e. Telford, Stevenson and MacColl) at any one time.

2.2.3 Project 1 cumulative effects

As with the original ES the Project 1 timescales have not been finalised, but for the purposes of this assessment it is considered that there may be an overlap in the construction periods of MORL and BOWL wind farms. The base case construction scenario is for there to be an overlap of piling on both projects for the first year of the MORL construction programme. It is acknowledged that if there is a delay in either project programme, then piling could occur on both sites for either two years or not at all.

2.2.4 Appropriate reduction in the Conservative Assumptions made during the impact assessment presented within the ES

The conservative assumptions originally proposed have been maintained as described previously in Section 2.1.4. The principal reduction in conservatism relates to a better understanding of the ground conditions within Project 1 as a result of the site investigations

(geotechnical surveys) undertaken during 2014. Throughout the original MORL ES it was assumed as a worst case scenario assessment that the blow energies required to drive piles into the stiffest of the three soil could be present throughout the site. It is now understood that the stiffest soil is likely to be present at only 17% of the turbine locations of Project 1 (Soil Profile 2). Whilst P2 profile). Whilst hammer energies may be required for up to 2250 kJ (Soil Profile 2 HE scenario) at 17% of the anticipated locations, and in the HE scenario (>1080 kJ) a further 22 % of locations may also require energies over those consented, it is also anticipated that the majority of the WTGs will be located within soil profile types which will require hammer energies below that assessed in the MORL ES. Soil Profile 1 is the most common Soil Profile Type, expected to be at approximately 32% of the wind turbine locations which may only require hammer energies of 660 kJ in the ML scenario (and up to 1020 kJ in the HE scenario) (see Section 3.3.3 of the PS main document for details on hammer energies and drivability across Project 1).

Table 2.2 Summary of assessments provided within original ES and to be presented for Project 1

Project element	Element description	Covered within Rochdale Envelope assessed in ES?	Included in assessment presented for Project 1
WTG Foundation number	Up to 100 WTG – 400 no. of piles	Yes (up to 339 WTG – 1356 no. of piles)	No
Foundation type	Jackets or GBS	Yes (jackets)	No
Simultaneous piling within Project 1	Most likely scenario is represented by a single piling vessel, but with the potential for up to three vessels as a result of construction delays.	Yes. Maximum of 6 simultaneous piling events across Telford, Stevenson and McColl OWFs. Max of 2 vessels per site.	No
Piling duration	Max of 2 years of piling.	Yes, within five year duration assessed is ES.	No
Piling duration	Worst case piling duration of 6.5 hours of piling per pile (HE for Soil Profile 2), and 3 piles in 24 hours.	No. Likely worst case assessed as 3.25 hours of piling, 2 piles in 24 hours.	Yes. SELs for species to estimate potential PTS and comparison to ES assessment
Piling energies	Predicted blow energies dependent on soil profiles – 61 % of WTG predicted to be below 1080 kJ, 39 % of WTG may require higher energies (>1080 kJ) for latter period of piling. Soil Profile 2 (present at approximately 17% of the WTG locations) is the stiffest and may require energies of up to 2250 kJ in HE scenario.	No. Worst case assessed as up to 1080 kJ blow energy from 1200 kJ hammer.	Yes. Assessment of conservatism of ES assessment assumptions and consideration of likely impact ranges from revised blow energy profiles.
Simultaneous piling within Project 1 and BOWL project	Most likely scenario is represented by a single piling vessel on BOWL for one year, one each on BOWL and MORL for one year followed by a single vessel piling for one year on MORL.	Yes. A variety of possible temporal build out scenarios were assessed with the ES which cover all the temporal potential build out scenarios for BOWL and Project 1.	No

3 Methodology used to validate whether effects of Project 1 cause a significant change to the conclusions of the ES

3.1 Impact assessment approach

3.1.1 EIA methodology

The significance criteria used for the assessment of potential effects within the MORL ES were based on the magnitude of the effect and on the sensitivity of the receptor. Both were assigned based on research published within the scientific literature and other relevant data/information sources and the application of professional judgement. Parameters used to define both sensitivity and magnitude followed the 2010 impact assessment guidelines (marine and coastal) published by the Chartered Institute for Ecological and Environmental Management IEEM (CIEEM). This methodology has also been maintained throughout the 2015 assessment. A full description of the methodology can be found in Chapter 7.2 of the 2012 MORL ES.

3.1.2 Noise modelling

In order to assess the likely effect of construction noise on fish for the MORL ES, modelling was undertaken by Subacoustech using the dB_{ht} (*Species*) metric developed by Nedwell *et al.*, (2007). This metric was developed with the intention of defining impact ranges and thresholds of effect that incorporated species specific hearing sensitivities. A full description of the methodology is given within Chapter 7.2 of the 2012 MORL ES. The definition of effects for each dB_{ht} (Species) are given in Table 3.1, below. This methodology has been used throughout the current validation of assessments.

Table 3.1 dB_{ht} (Species) level metric definitions

Level dB_{ht} (Species)	Effect
≥ 75	Mild avoidance reaction by the majority of individuals. At this level individuals will react to the noise, although the effect will probably be transient and limited by habituation.
≥ 90	Strong avoidance reaction by virtually all individuals
> 110	Tolerance limit of sound; unbearably loud
> 130	Possibility of traumatic hearing damage from single event

3.2 Comparison of parameters and methodologies used in the MORL ES and the Piling Strategy for Project 1

Table 3.2 below provides a comparison against the Rochdale Envelope parameters and assessment approach used within the original MORL ES to those of Project 1.

Table 3.2 Comparison of parameters used in the MORL ES and the assessment for Project 1

	Rochdale Envelope provided in the ES	Proposed Development – Project 1
Project Description		
WTG Foundations	Up to 339 WTG Foundations – 1356 no. of piles[2].	Up to 100 WTG Foundations – 400 no. of piles.
Foundation type	Jackets or GBSs.	Jackets – three or four legged.
Simultaneous piling	Max 6 simultaneous piling events across Telford, Stevenson and McColl OWFs.	Most likely scenario is represented by a single piling vessel, but with the potential for up to three vessels if required (e.g. due to programme delays).
Piling duration	Max of 5 years 3.25 hours pile driving per pile, and 2 piles per 24 hours.	Piling duration dependent on soil profiles. Modelled worst case of 6.5 hours of piling for Soil Profile 2, with three piles in a 24 hour period. Piling campaign up to two years (average of five hours per pile and in the order of 84 days[3] of piling in total).
Piling energies	All assessment based on worst case, which included up to 2 hours of 1080 kJ.	Predicted blow energies dependent on soil profiles – 61 % of WTG predicted to be below 1080 kJ; 39 % of WTG may require higher energies (>1080 kJ) for up to 1.5 hours of the latter period of piling.
Methodologies		
Noise modelling	Subacoustech noise modelling dB_{ht} (*Species*) metric.	Subacoustech noise modelling dB_{ht} (*Species*) metric. Subsequent comparison against MORL 2012 ES assessment.
Impact Assessment criteria	Subacoustech noise modelling dB_{ht} (*Species*) metric.	Subacoustech noise modelling dB_{ht} (*Species*) metric. Subsequent comparison against MORL 2012 ES assessment.

[2] Consented projects: up to 186 WTG (744 piles).
[3] See Section 3.4 of the PS main document for details on piling base case programme.

4 Validation of Project 1 effects within the MORL ES assessments

4.1 Summary of Assessments presented in ES [and Appropriate Assessment]

The following provides a summary of the assessments presented in the MORL ES.

4.1.1 Herring

In the MORL ES the impact of piling noise on herring was assessed to be negative, of **moderate significance** and probable.

This result was based on a sensitivity of medium that was assigned in light of increased hearing ability, the requirement for specific spawning substrates and the importance of the species within the wider food web and use of the Moray Firth as a nursery ground. With respect to magnitude of the effect this was considered to be medium due to the overlap of the $90dB_{ht}$ (Species) contour with the spawning grounds of the Orkney- Shetland stock located both inside and outside the Moray Firth.

The application of soft start piling procedures during construction was predicted to ensure that herring would not be exposed to the highest hammer energies. Following the application of this mitigation the residual effect was predicted to be negative, of **minor significance** and probable.

4.1.2 Cod

With respect to potential effects on cod as a result of piling noise, this was assessed to be negative, of **moderate to major significance** and probable within the MORL ES.

The species was assigned a sensitivity of medium to high, in light of the genetic distinction of the Moray Firth population from other North Sea populations and the potential use of the area as a nursery ground. Under the worst case piling scenario the spawning and nursery grounds defined by Coull *et al.*, 1998 and Ellis *et al.*, 2012 were overlapped significantly by the $90dB_{ht}$ (Species) contour. In addition a paucity of research meant that it was not possible to determine the extent and degree of utilisation of the defined spawning grounds. Therefore, the effect of piling noise on cod was conservatively assessed to be of medium magnitude.

The use of soft-start piling during construction was anticipated to prevent cod from being exposed to the highest hammer energies during foundation installation. Following consultation with Marine Scotland and in light of the uncertainties associated with cod spawning in the Moray Firth outlined above, MORL also committed to undertaking two site-specific cod spawning surveys during February and March 2013. The results of this survey are summarised briefly here and presented in full within the cod spawning survey report (Brown and May Marine 2013).

MORL undertook site-specific surveys to determine the intensity and distribution of cod spawning during February and March (peak of cod spawning) 2013 (Brown and May Marine 2013). Cod were recorded in relatively low numbers at 35 of 58 stations sampled throughout the surveys. A maximum of 9 individuals were recorded at any single station. Numbers of spawning cod were also low, totalling 23 individuals over both surveys (12 in trip 1 and 11 in trip 2). The catch rates from these surveys were used by Marine Scotland Science (MSS) to determine whether any stations could be defined as 'spawning areas' MSS (defined as >75 spawning cod/km2). The results of the analysis by MSS indicated that numbers of cod were below the threshold used to define the occurrence of a spawning area at all stations.

The application of soft start piling meant that the residual effect of the effect was reduced to negative, of **minor significance** and probable. Following submission of the MORL ES, the cod surveys undertaken in 2013 and summarised above further validated this assessment.

4.1.3 Salmon

Within the MORL ES the potential effect of piling noise on salmon was assessed to be negative, of **minor to moderate significance** and probable.

Due to the uncertainties relating to the migration routes of smolts and adults it was assumed, as a precautionary measure, that fish may transit the proposed sites as part of their marine migration. In combination with the high conservation status of salmon and the importance of recreational and commercial fisheries, salmon were assigned a receptor sensitivity of medium. With respect to magnitude, this was predicted to be between small to medium as the areas in the immediate vicinity of the rivers (the destination of returning adults and source of origin of smolts) would not be affected. Therefore migration would not be disturbed immediately after leaving or entering the natal river at either the 90 dB_{ht} or 75 dB_{ht} levels. Furthermore, the relatively short range of the 90 dB_{ht} contours meant that there was no potential for any barrier effect (e.g. into or out of natal rivers) to occur.

As for other fish species, the use of soft start piling was expected to prevent salmon from being exposed to the highest hammer energies during piling activity. In addition, MORL has engaged with MS-LOT, MSS the ASFBs and DSFBs, the MFSTP and MFRAG with a view to participating in the monitoring requirements as laid out in the 'Scottish Atlantic Salmon, Sea Trout and European Eel Monitoring Strategy' research program so far as they apply at the local (Moray Firth) level. Following the application of this mitigation the residual effect was assessed to be negative, of **minor significance** and probable.

4.2 Results of the review of effects for Project 1

Throughout the following review the worst case scenario assumed has been Soil Profile P2 (clay overlaying sand). Revised modelling has not been undertaken for any other profile types, which is consistent with the methodology undertaken in the MORL ES. Within Soil Profile 2 the most probable (MP) maximum hammer energy required to reach the minimum target depth would be 1800 kJ in the latter period of pile driving. Under the highest expected (HE) case, hammer energies of up to 2250kJ could be required in the latter period of pile driving. As described previously, this soil type is only expected to be encountered at approximately 17% of piling locations within Project 1 area. Two other soil types (Profile 5 and Profile 6) may also require higher piling energies (1800 kJ is the HE level for both) than previously assessed, though lower than Profile 2. In total, 39% of the turbine locations may require energies higher than previously considered for the latter period of pile driving (for up to approximately 1.5 hours for Soil Profile 2 (HE) (see Section 3.3 of PS main document for more details on pile drivability and likely required maximum blow energies). The majority of the turbine locations (61%) require piling energies lower than that considered in the MORL ES, with approximately half requiring energies as low as 636 kJ.

In keeping with the MORL ES, the following assessment of potential effects is based primarily on the 90 dB_{ht} (*Species*) noise contours. For salmon, in light of its high conservation status and the importance of associated fisheries to the local, regional and national levels in Scotland, 75 dB_{ht} (*Species*) have also been considered within the assessment. A further justification for inclusion is the potential occurrence of barrier effects in relation to inward and outward migration of the natal rivers.

For the purpose of comparison to enable validation that the potential effects for Project 1 are within the effects assessed within the MORL ES, the modelled 90 dB_{ht} noise contours from the MORL ES are shown in conjunction with the results from the new Subacoustech modelling undertaken in 2015. This approach facilitates comparison of any spatial differences between the original and new modelling results at the 90 dB_{ht} level.

4.2.1 Herring

The re-modelled noise results for the Soil Profile 2 under the MP (hammer energies of up to 1800 kJ) and HE (hammer energies of up to 2250 kJ) scenarios for herring at the identified "worst case location" for herring (location 6 within the MORL ES), and the associated spatial comparison with the MORL ES assessment, are presented in Table 4.1 and shown in Figure 1. Data from the international herring larval surveys (average 2000-2013) are also shown in Figure 1. The distribution of early stage larvae determined from these surveys is used to infer the spatial and temporal coverage of herring spawning grounds in active use (Ellis *et al.*, 2012).

Table 4.21 Comparison between spatial areas encompassed by the 90 dB_{ht} from the MORL ES and 2015 noise modelling for herring

2012 ES: 2.5.m pile @ 1200 kJ (location 6: 90dB_{ht})	2012 Spawning area overlap (%)	2015 P2 HE modelling scenario (location 6: 90dB_{ht})	2015 Spawning area overlap (%)
2215.1 km^2	2.07%	MP: (1800 kJ) 2856.8 km^2 (↑ 33%)	2.72%
2215.1 km^2	2.07%	HE: (2250 kJ) 3219.1km^2 (↑ 50%)	3.04%

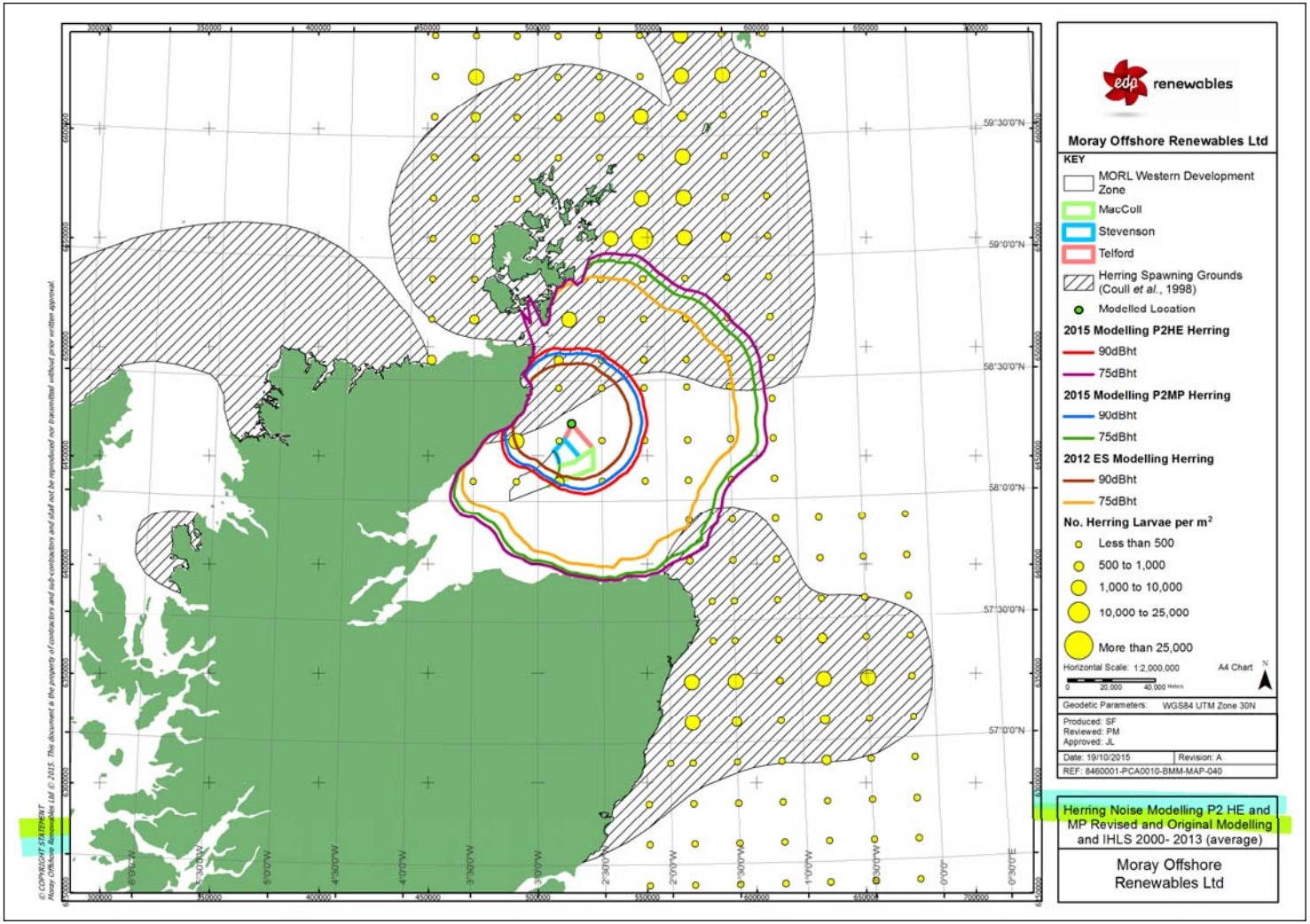

Figure 1 MP (1800KJ) and HE (2250KJ) scenario for Soil Profile 2 piling locations (worst case scenario) and comparison between 2012 ES and 2015 noise modelling results for herring

Throughout the following assessment the sensitivity of herring remains as assessed in the MORL ES (**medium**).

As shown in Table 4.1, there has been an increase in the spatial area affected under the worst case scenario. This applies to both the MP (33% increase) and HE (50% increase) scenarios. However, when considered in the context of the relevant spawning grounds (Figure 1), the associated spatial increases result in an increase of less than 1% for the MP scenario, and less than 2% for the HE scenario.

The P2 profile is only expected to be encountered at approximately 17% of total piling locations and under Project 1 there will be a maximum of 100 WTG foundations installed. This is significantly lower both with respect to the worst case as assessed within the MORL ES (e.g. up to 339 WTG foundations) and the number of turbines consented (186 WTG) The potential temporal disturbance for Project 1 is considerably less compared to that assessed previously. Furthermore, the increase in spawning area potentially affected as a result of the increased hammer energies is less than 2% under both scenarios. As shown in Figure 1, the highest larval densities recorded in the ILHS cruises tend to occur some distance to the north of the MORL development to the east of the Orkney Isles. These areas do not fall within the 90 dB_{ht} contour which may further reduce the potential for noise related effects on the areas where the highest spawning activity is generally held to occur. In light of these considerations the magnitude of the effect under both scenarios (ML and HE) within Soil Profile 2 remains as assessed within the 2012 ES (**medium**). Prior to any mitigation, the assessment therefore remains as previously; negative, of **moderate significance** and probable. Thus the increase in maximum blow energy from a maximum of 1080 kJ to up to 2250 kJ for Project 1 is not considered to cause a material change to the conclusions of the ES and demonstrates that the effects of Project 1 are within the effects predicted for herring in the ES.

4.2.2 Cod

The re-modelled noise results for the P2 (worst case) under the MP and HE scenarios for cod at location 1 and spatial comparison with the MORL ES assessment are presented in Table 4.2 and shown in Figure2.

Table 4.2 Comparison between spatial areas encompassed by the 90 dB_{ht} from the MORL ES and 2015 noise modelling for cod

2012 ES: 2.5.m pile @ 1200 kJ (location 1: 90dB_{ht})	2012 Spawning area overlap (%)	2015 P2 HE modelling scenario (location 1: 90dB_{ht})	2015 Spawning area overlap (%)
1462.3 km^2	47.02%	MP: (1800 kJ) 2089.3 km^2 (↑ 43%)	63.6%
1462.3 km^2	47.02%	HE: (2250 kJ) 2404.9 km^2 (↑ 65%)	69.9%

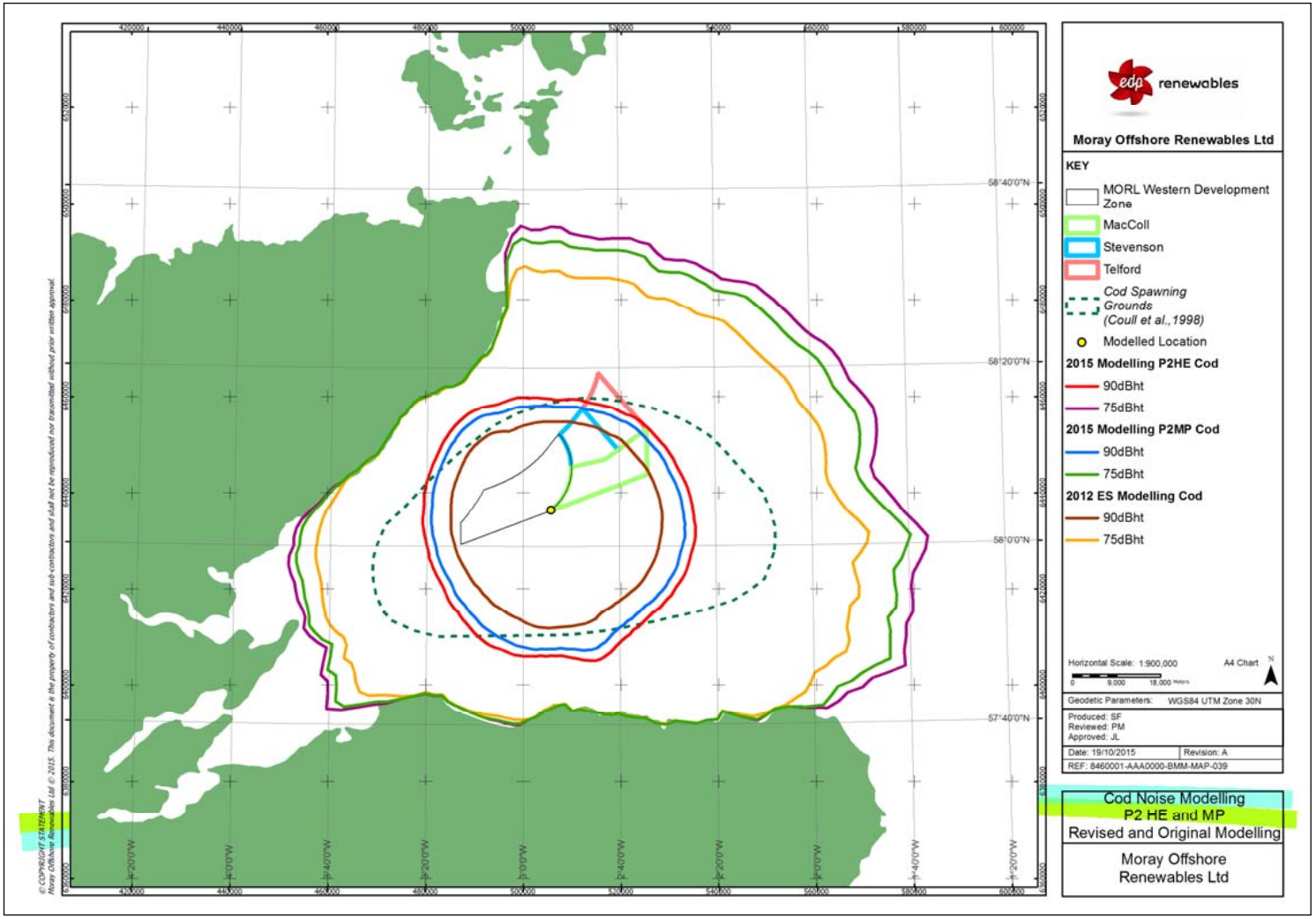

Figure 2 MP (1800KJ) and HE (2250KJ) scenario for Soil Profile 2 piling locations (worst case scenario) and comparison between 2012 ES and 2015 noise modelling results for cod.

There is no reason to expect the sensitivity of cod to have changed from that assigned to the species within the MORL ES (**medium – high**) and so this remains the same throughout the assessment.

The data presented in Table 4.2 shows a small increase in the spatial area affected for both MP and HE scenarios for cod at this location. The associated increase in the overlap of the cod spawning grounds defined within the Moray Firth (after Coull *et al.*, 1998 and Ellis *et al.*, 2012; Figure 2) represents an increase of approximately 16% under the MP scenario and 23% under the HE scenario compared that modelled in the ES (Table 4.2). Whilst there has been an overall increase in the spatial extent of the effect, it is now known that the worst case piling profile would only be expected to be encountered at approximately 17% of locations and that the majority of piling activities will be below that previously assessed. Furthermore, the modelling undertaken is conservative in its assumptions (see section 2.1.4 above).

Recent research regarding cod spawning behaviour in the northwest North Sea (an area including the Moray Firth), the Viking Bank and southern North Sea has provided a number of insights regarding cod behaviour which may be pertinent to the potential effects under consideration. Gonzalez-Irusta and Wright, (2015) used statistical models to predict the spatio-temporal spawning distribution of North Sea cod in response to potential physical constraints and to examine the persistence of spawning ground locations between 2009-2014. Results indicated that in all sea areas considered, the preferred substrate for spawning was coarse sand located in areas where temperatures were around 5 – 7 °C. In addition, it was found that the degree of persistence in relation to spawning grounds was related to inter-annual variability in salinity and temperature. In the northwest North Sea these parameters were more stable compared to the other areas under consideration, suggesting regular use of defined spawning grounds in the northwest North Sea is likely. With specific reference to the Moray Firth, much of this area was classified as 'unfavourable' in terms of spawning habitat type. Based on the modelling undertaken, relatively small areas of 'recurrent' and 'occasional' spawning habitat type were identified on the Smith Bank in the vicinity of the MORL development. The results of the MORL cod spawning survey yielded low numbers of spawning cod in broadly similar areas (see summary under section 4.1.2) which suggests that the MORL site and adjacent areas are not of particular importance as a spawning ground.

There have been some small increases in the area of potential effect under both the MP and HE scenarios at location 1 for cod (see Figure 2). However, in light of the geotechnical survey undertaken to date it is now estimated that only 17% of piling locations could potentially require the use of the highest hammer energies and in the HE scenario (>1080 kJ) a further 22 % of locations may also require energies over those consented during the latter period of piling, it is also anticipated that the majority of the WTGs will be located within Soil Profile types that will require hammer energies below those assessed in the MORL ES (see Section 3.3.3 of the PS main document for details on hammer energies and drivability across Project 1).

Another relevant consideration is that within Project 1 there will be a maximum of 100 WTG foundations. Not only is this considerably lower when compared to the previous Rochdale Envelope (e.g. up to 339 WTG foundations) and the number of turbines that were subsequently granted consent (186 turbines), but in reality it means that only 17 turbines would potentially require installation using the highest hammer energies and another 22 turbines may require energies higher than previously assessed (but lower than the worst case scenario modelled here). Clearly, temporal duration of Project 1 is considerably shorter compared to that assessed previously. In addition, the results of the cod spawning surveys undertaken in 2013 suggest the intensity of spawning in the vicinity of the development is relatively low. The magnitude of the effect remains as **medium** and therefore, the significance of effects remains as assessed within the MORL ES; negative, probable and of **moderate to major significance.** Thus the effects of Project 1 are within the effects predicted for cod in the MORL ES and the increase in maximum blow energy from a maximum of 1080 kJ to up to 2250 kJ for Project 1 is not considered to cause a significant change to the conclusions of the ES.

4.2.3 Salmon

The re-modelled noise results for Soil Profile 2 (worst case) under the MP and HE scenarios for salmon at location 5 and the associated spatial comparison to the MORL ES assessment are presented in Table 4.3 and shown in Figure 3. As adult salmon spawn in the upper reaches of the natal rivers and pre-smolt stages also reside in similar habitats prior to seaward migration, there is no overlap with spawning. In keeping with the conservative approach taken in the MORL ES consideration is also given to the 75 dB_{ht} noise contour with respect to the potential for disturbance to either egress or ingress from or to the relevant natal rivers.

Table 4.22 Comparison between spatial areas encompassed by the 90 dB_{ht} and 75 dB_{ht} contours from the MORL ES and 2015 noise modelling for salmon

2012 ES: 2.5.m pile @ 1200 kJ (location 5: 90dB_{ht})	2012 ES: 2.5.m pile @ 1200 kJ (location 5: 75dB_{ht})	2015 P2 HE modelling scenario (location 5: 90dB_{ht})	2015 P2 HE modelling scenario (location 5: 75dB_{ht})
6.9 km^2	227.2 km^2	MP: (1800 kJ) 12.5 km^2 (↑ 82%)	MP: (1800 kJ) 351.9 km^2 (↑55%)
6.9 km^2	227.2 km^2	HE: (2250 kJ) 15.9 km^2 (↑131 %)	HE: (2300 kJ) 422.8 km^2 (↑86 %)

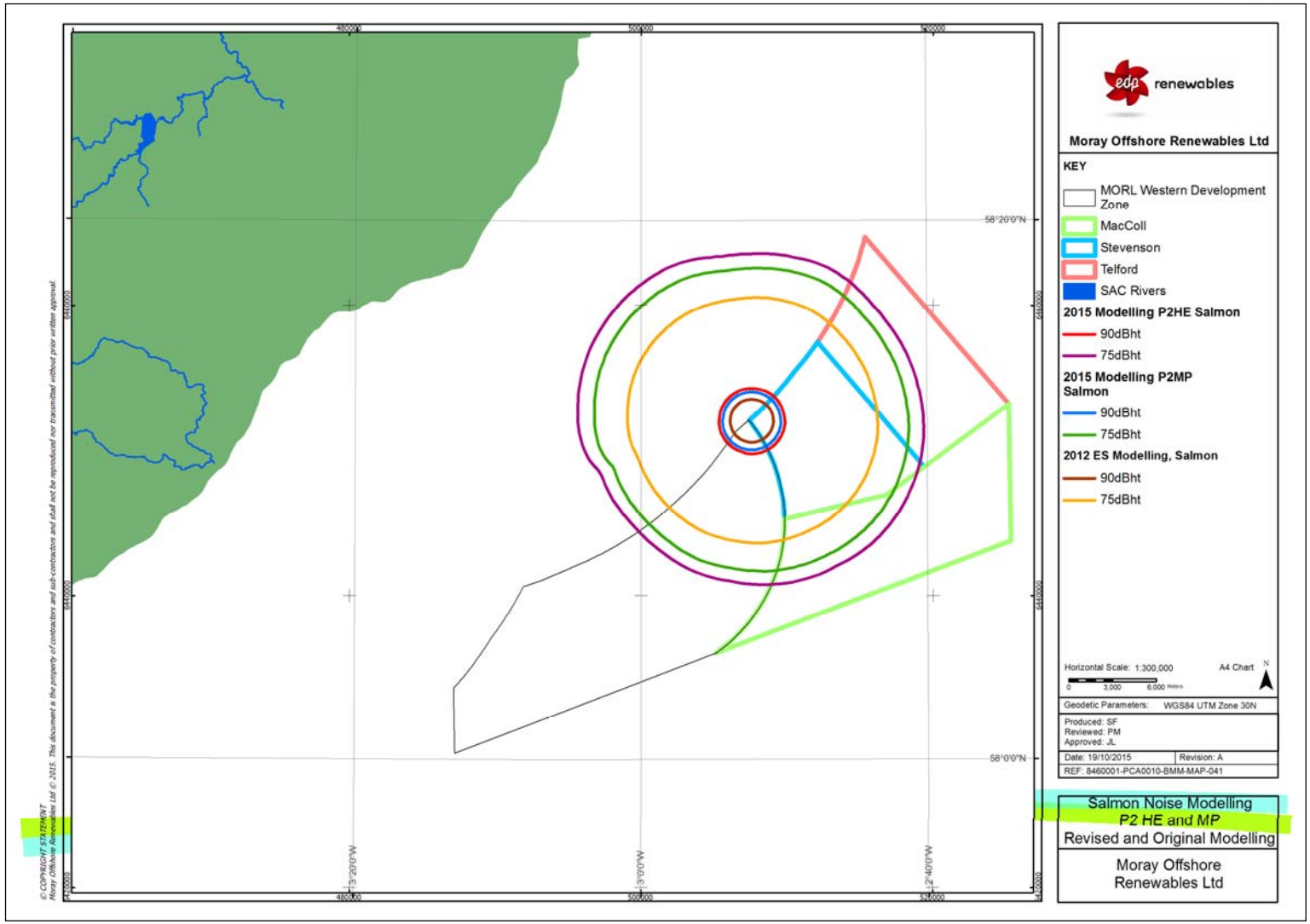

Figure 3 MP (1800KJ hammer) and HE (2300KJ) scenario for Soil Profile 2 piling locations (worst case scenario) and comparison between 2012 ES and 2015 noise modelling results for salmon.

Figure 3 shows the MP (1800 KJ) and HE (2250 KJ) scenarios for Soil Profile 2 piling location (worst case scenario) and comparison with the results of the MORL ES modelling for salmon.

Marine Scotland Science (MSS) is currently undertaking research regarding the potential effects of underwater noise generated during piling on salmon. In addition, further research has been undertaken examining the migratory behaviour of adult salmon which has a potential bearing on their exposure to underwater noise. However, at the time of writing the results from this work were unavailable and cannot therefore be used to inform this assessment.

In the absence of any newly available research the conservative approach taken in the MORL ES is maintained. That is, for the purpose of assessment it is assumed that salmon (smolts and/or adults) could transit the development area during migration.

For the revised assessment of piling noise on Atlantic salmon, receptor sensitivity remains the same as that assigned in the MORL ES (**medium**).

The data presented in Table 4.3, shows that for salmon, should Soil Profile 2 be encountered at location 5, there could be an increase in affected area under both MP and HE scenarios. These appear large in terms of the percentage increase compared to the 2012 MORL ES (MP, 82%; HE, 131%). However, the actual increase in spatial terms under both scenarios is less than 10 km^2. As within the MORL ES, this results in no potential for barrier effects to occur in the vicinity of the natal rivers (Figure 3). Similarly, although there has been an increase in the area potentially encompassed by the $75dB_{ht}$ noise contour (Table 4.3), it can be seen from Figure 3 that this does not result in any significant increase in the potential for barrier effects. Under the previous modelling the closest point of the $75dB_{ht}$ noise contour to land was 13.7 km. Under the newly modelled HE scenario this has decreased to 10.2 km, representing a relatively small difference of 3.5 km. In light of these considerations magnitude remains as previous (**medium**). Prior to the application of any mitigation, the assessment remains as for the MORL ES; negative, probable and of **moderate significance**. Thus the effects of Project 1 are within the effects predicted in the ES and the increase in maximum blow energy from a maximum of 1080 kJ to up to 2250 kJ for Project 1 is not considered to cause a significant change to the conclusions of the ES..

4.3 Project 1 cumulative effects

As described above in Section 2.2.3, Project 1 is likely to be constructed in a similar timescale to the BOWL project. The base case construction scenario is for there to be an overlap of piling on both the BOWL and the MORL projects for the first year of the MORL construction programme. It is acknowledged that if there is a delay in either project programme, then piling on both sites could overlap for either two years or not at all.

The maximum BOWL project blow energy profiles have not changed, and are therefore within those assessed within the MORL ES. The temporal sequence of construction of the two projects is within that described in the MORL ES. Therefore, all of the potential cumulative piling scenarios were considered within the original assessment presented within the MORL ES. As a consequence, in combination with the changes presented for Project 1, it is not considered to be a significant change to the conclusions of the MORL ES with regards to the cumulative impact assessment.

5 Mitigation

5.1 Soft start

A detailed Piling Protocol has been developed with respect to marine mammals in conjunction with BOWL (Appendix 2). This protocol centres on the application of Acoustic Deterrent Devices (ADDs) and soft start piling. The effectiveness of ADDs as a method to deter fish has not been studied and therefore their appropriateness as a mitigation tool for noise related impacts for fish is currently undetermined. The use of soft start piling represents an effective method of preventing sensitive fish species from being exposed to the to the highest hammer energies. The use of soft start piling methods would apply to all species considered within this assessment. The details of planned protocol are provided in Appendix 2. As within the MORL ES the application of soft start piling is expected to result in **residual impacts** of **minor** for all three species under consideration.

5.2 Herring

Based on the outcomes of the new noise modelling presented in Section 4.2.2 it is not expected that there will be any increase in the potential for adverse effects on either adult herring spawning aggregations or early larval stages as a result of piling noise. Therefore, other than the 16 day piling restriction and commitment by MORL not to engage in any piling activity with hammer energies exceeding 1080 kJ outwith the herring mitigation zone (as defined in the S36 conditions) during this period, no further mitigation is proposed at this stage.

5.3 Cod

The data presented within section 4.2.2 shows that there has been a slight increase in the spatial area impacted for the worst case scenario of piling at Soil profile 2 (for the HE and ML scenarios). As described previously, it is not expected that this would result in an increase in magnitude due to the lower number of turbine numbers for Project 1 and because the worst case piling profile (Soil Profile 2) would only be expected to be encountered at approximately 17% of locations, and in the HE scenario (>1080 kJ) that a further 22 % of locations may also require energies over those consented in the HE scenario (>1080 kJ). It is also anticipated that the majority of the WTGs will be located within Soil Profile Types that will require hammer energies below those assessed in the MORL ES (see Section 3.3.3 of the PS main document for details on hammer energies and drivability across Project 1). For these reasons, prior to any mitigation the assessment remains as previously described within the MORL ES.

The new research cited within section 4.2.2 (Gonzalez-Irusta and Wright, 2015) regarding cod spawning behaviour in the northwest North Sea suggests that the use of spawning grounds located within the vicinity of the MORL development is likely to be consistent between years. However, the results of the survey commissioned by MORL in 2013 suggest that spawning intensity may be relatively low in this area. Should further baseline surveys be required, as stipulated within the Section 36 Consents conditions (condition 34 of the Telford and Stevenson Wind Farms and condition 33 of the MacColl Wind Farm), these will be used to further inform the levels of cod spawning activity in the vicinity of the MORL development.

5.4 Salmon

In light of the low potential for any barrier effects to natal rivers as a result of either the 75 dB_{ht} or 90 dB_{ht} noise contours the assessment of potential noise related effects is not expected to exceed that previously assessed within the MORL ES. It is acknowledged that there is still some uncertainty regarding the movements and occurrence of salmon relative to the MORL site.

MORL is currently agreeing methods with the relevant stakeholders for monitoring within the Moray Firth in accordance with the National Research and Monitoring Strategy for Diadromous Fish together with requirements under the Project Environmental Monitoring Programme (PEMP) condition for each of the Section 36 consents.

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moray offshore renewables ltd

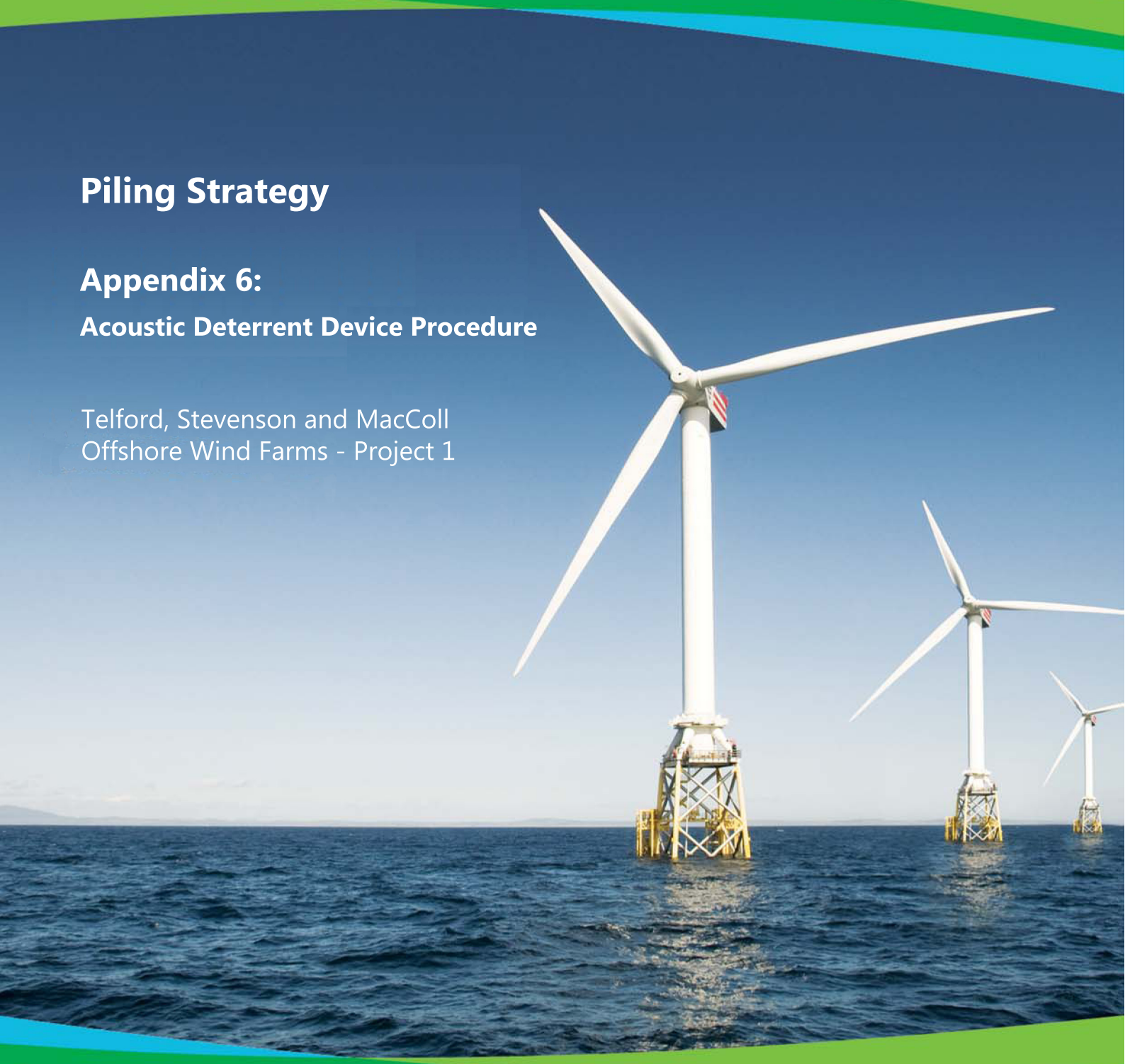
Developing Wind Energy In The Outer Moray Firth

Piling Strategy

Appendix 6:

Acoustic Deterrent Device Procedure

Telford, Stevenson and MacColl
Offshore Wind Farms - Project 1



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APPENDIX 6: Acoustic Deterrent Device Procedure

Produced by Royal Haskoning DHV on behalf of Moray Offshore Renewables Ltd	
Produced by	Benjamin King
Reviewed by	Alistair Davison
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Moray Offshore Renewables Ltd Approvals

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1 Introduction

1.1 Purpose of This Document

As detailed within the Piling Strategy (PS) (see Section 3.5.3 of the main document), Moray Offshore Wind Ltd (MORL) propose to use Acoustic Deterrent Devices (ADDs) as a mitigation tool for reducing the risk of physical injury (death or permanent and temporary hearing loss) to marine mammals within the immediate vicinity of piling operations during wind turbine generator (WTG) foundation installation. The species of particular relevance within the MORL Eastern Development Area (Stevenson, Telford and McCall wind farm sites) are harbour porpoise and harbour seal.

This procedure outlines the general methodology and protocol for the use of ADDs during the installation of WTG foundations. Currently neither the installation contractor nor the ADD operator have been appointed therefore detailed operational procedures are not included at this time. . Detailed operational procedures which shall adhere to the requirements and methods outlined in this document will be provided to Marine Scotland through a method statement (which will be included in the PS) following the completion of detailed engineering with the appointed contractors.

It is noted that a stage of 'phased piling mitigation' including the use of marine mammal observers (MMOs) as per JNCC protocol (JNCC, 2010) will be employed for a period(s) not exceeding 28 days. The details of the phased piling mitigation are included in Appendix 7. The use of ADDs outlined in this procedure would be used outwith the period of Phased Mitigation Protocol outlined in Appendix 7.

1.2 Background

The piling strategies presented by MORL and Beatrice Offshore Wind Ltd (BOWL) have been informed through extensive consultation with Marine Scotland Licensing Operations Team, MS-LOT and relevant stakeholders (Marine Scotland Science (MSS), Scottish Natural Heritage (SNH) Joint Nature Conservation Committee (JNCC) and Whale and Dolphin Conservation (WDC). As discussed within the PS (including within the Piling Protocol in Appendix 2) ADDs have been proposed as the primary mitigation tool, alongside soft-start procedures, to mitigate risk of injury to marine mammals during foundation piling operations.

ADDs are increasingly being used during marine construction projects in conjunction with Marine Mammal Observers (MMOs) and Passive Acoustic Monitors (PAMs) to provide an additional level of mitigation during periods of low visibility. In particular these measures have been deployed to target seal species which are generally not detected using passive acoustic equipment due to their lack of vocalisations.

Discussions on the use of ADDs at the MORL and BOWL sites have focused on the use of ADDs as the primary mitigation technique as this represents an active and potentially more effective way of minimising risk to marine mammals as highlighted in a number of reviews on marine mammal mitigation including within the ORJIP 4 reports (see Herschel *et al.*, 2013). These discussions have been driven by the need to find an effective tool for working in low visibility conditions common in the Moray Firth. The use of ADDs as an effective and appropriate tool is supported by recent studies and evidence which have been outlined in greater detail in Appendix 2. In addition, MORL and BOWL outline their methods for monitoring the effectiveness of ADDs, alongside piling soft-start procedures as the primary mitigation tools for marine mammals within the construction Marine Mammal Monitoring Programme (MMMP) for the MORL and BOWL developments (Thompson, 2016). The MMMP will also be included within each project specific Project Environmental Monitoring Plans (PEMPs).

1.3 ADDs

ADDs come in several different forms but are, in general terms, devices which emit underwater noise within a spectrum audible by marine mammals. Depending on the device

chosen, ADDs can either act as an acoustic beacon to communicate an underwater hazard (such as 'pingers' used in commercial fishing operations) or to actively encourage mammals to leave the area surrounding the ADD through the production of high amplitude noises considered to be unpleasant but not detrimental to marine mammals hearing (otherwise known as 'seal scrammers' due to their use in commercial fish farming operations).

The ADD device typically used for mitigation at offshore wind farm sites is the 'seal scrammer' type which emits a loud, broad spectrum underwater sound to encourage individuals present to vacate the area surrounding the source of sound. This type of ADD usually consists of an electronic base or controller unit which is situated in dry conditions (i.e. on a vessel or platform) and an underwater speaker (transducer) which emits the sound.

Commercially available ADDs tend to emit sounds across a fairly wide range, usually mid-frequency; however, some devices appear to be better suited to deterring certain species.

During offshore wind farm construction ADDs are deployed for a period immediately prior to piling commencing to encourage any individuals present within the area around the pile to leave with the intended result that they move to a distance where they are not at risk of physical injury.

2 The Use of ADDs at MORL Project 1

2.1 Chosen ADD – Lofitech Seal Scarer

At present, it is MORL's intention to use the Lofitech Seal Scarer device as its chosen ADD. Based on the available information and limited practical testing on other devices, at present the Lofitech ADD represents the best available technology for both seal and cetacean mitigation. Should further information become available prior to construction that indicates other suitable devices, MORL would discuss the possibility of using other devices with stakeholders and Marine Scotland.

The Lofitech device is one of a range of similar products available commercially; others include the Airmar dB Plus II and Ace Aquatec Universal Scrammer 3. Of these, the Lofitech has been the most rigorously tested to determine its effectiveness and the device has been shown to significantly reduce predation at fish farms from both grey and harbour seal.

The effectiveness of device has been tested in several studies undertaken in both Kyle Rhea and the Moray Firth, where it was reported that tagged seals reacted to the Lofitech ADD sounds and moved away from the source of sound (SMRU, 2014; Gordon *et al*., 2015). These studies indicated that harbour seals responded to the Lofitech device at a range of approximately 1,000 m (or greater).

Studies into the effectiveness of the Lofitech ADDs in relation to cetaceans have suggested that harbour porpoise (and other toothed whales such as killer whale) display avoidance reactions to the Lofitech ADD (Coram *et al*., 2014). One of the most robust trails undertaken to demonstrate effectiveness of ADDs on cetaceans looked at harbour porpoise reactions to a Lofitech device deployed in two distinct areas and situations.

One study focused on an inshore location in the Danish Baltic, the second an offshore site in the German sea (Brandt *et al.* 2012 a & b; Brant *et al*., 2013). Results of the studies indicated that detection rates were significantly (86 %) lower at 750 m from the source of sound and 96 % lower at 7,500 m, suggesting significant effectiveness at displacing porpoise to a range of at least 7,500 m. Detection rates similar to those seen during control conditions were reported between 9-12 hours after the cessation of the trial.

2.2 Technical Specification of the Lofitech ADD

The Lofitech device consists of an electronic control unit and a transducer. The controller can either be plugged in directly to the mains or be powered by a rechargeable Auto-Marin 12v battery. The transducer is deployed into the water and attached to the controller by waterproof cabling.

The Lofitech device creates a pulsed sound, which is amplified and transmitted to the transducer as random bursts of audio frequency signals. The transducer converts this into an intense burst of sound over a spectrum of randomised frequencies to avoid habituation. Sound frequencies are typically emitted between 10 to 20 kHZ at an output level of 189-191 dB re 1 µPa.

As the effective range of the Lofitech ADD is thought to be 7,500 m or more for cetaceans and 1,000 m for seals, a single deployed unit would displace any individuals from the injury zone (predicted to be up to 60 m as detailed in Annex 1 of the Piling Protocol within Appendix 2 of the PS) as well as the standard 500 m JNCC mitigation zone. Therefore, a single transducer would be deployed from a controller unit located on the pile installation vessel.

3 Communication Channels

During the execution of the piling operations a person responsible for on-board communications during piling operations will be identified. This is likely to be the contractor's Offshore Construction Manager. The ADD operator will be appointed by and will report directly to MORL. It will also be supported by the MORL on-board client representative and the Ecological Clerk of Works (ECoW), although it is not anticipated that the ECoW would be present offshore at all times and therefore would not be responsible for ensuring ADD deployment and soft-start procedures are followed. However, the ECoW will be available to assist the ADD operator or MORL with any concerns that may arise. The ECoW will also review mitigation recording forms to ensure that the protocol is being undertaken in a way which is compliant with the Piling Strategy. MORL would be notified of any concerns that arise and MS-LOT would be notified as appropriate.

The ADD operator would be responsible for liaison with the Offshore Construction Manager to ensure that the ADD is deployed and activated at the correct times and for the appropriate periods of time. It would be the responsibility of the Offshore Construction Manager to ensure that accurate and up to date information is provided to the ADD operator when requested. When there is a break in piling, it would be the ADD operators' responsibility to contact the Offshore Construction Manager to determine, as a far as reasonably possible, the length of the break and the likely need for ADD activation. However, ultimately, it would be the responsibility of the Offshore Construction Manager to ensure that piling does not commence without the required level of ADD activation beforehand.

The ADD operator would have the responsibility for ensuring that the ADD device is deployed for at least fifteen minutes prior to the start of piling, if, for any reason other than those outlined in the agreed protocol, the fifteen minutes have not elapsed prior to piling, it would be the ADD operators' responsibility to communicate to the Offshore Construction Manager that there is a potential compliance breach. The ADD operator would also be responsible for reporting any compliance issues to MORL or MORL's ECoW, along with details of relevant information regarding the circumstances of the breach. MORL would then investigate and notify Marine Scotland of any compliance issues and how they have been resolved.

4 Deployment Method

4.1 Deployment of ADD

The specific method of deployment will depend on the piling installation vessel yet to be selected. Further details regarding the piling vessel will be provided to stakeholders and Marine Scotland as part of the Construction Method Statement (CMS) and the Vessel Management Plan (VMS). The following section outlines a generalised deployment of a Lofitech device from a typical installation vessel.

The ADD will be located on the piling vessel in an area that will allow for deployment as near to the pile location as is practical and safe to do so. For most vessels, the electrical control unit will be permanently located in a secure and safe location and connected to a permanent power source, however, depending on the layout of the vessel, this may not be possible. If permanent connection is not possible, the ADD will be made portable through the use of a battery pack which will allow the device to be moved to a suitable location prior to each piling event, and removed when not in use.

Once the control unit is in the correct position, the transducer will be connected (if not already the case) and tested (see Section 4.2.2) before deployment. The transducer would then be deployed over the side of the vessel.

In order for the transducer to have optimum range in all directions it is necessary to ensure that the depth of the transducer is below that of the hull of the installation vessel. This will vary considerably from vessel to vessel but would not be expected to be more than 10m. In the case of a jack-up vessel being used, this is less of a consideration as the hull will be clear of the water. The water depth across the Project 1 area is between 37 m and 57 m mCD, the optimum position for the transducer is mid-water, therefore at depths between 16 m and 28.5 m depending on the depth of the pile location. To ensure that a mid-water deployment is achieved at each site, the length of ADD transducer cable deployed will need to vary between location depending on the water depth and the tidal current. To ensure that the transducer achieves the required depth, the transducer will be weighted and additional cable would be deployed to compensate for layback[1]. As a rule of thumb, when deploying from a vessel, two to three times the cable length of the required target depth is required depending on the weight of the object being deployed and the strength of the tidal current. For example, to deploy the weighted transducer at a depth 16 m in minor (0.5m/s) current speeds, approximately 40 m of transducer cable would be needed to ensure a 16 m depth. During periods of lower tidal conditions such as during slack tide, less cable would be needed to be deployed as less layback compensation would be required. The ADD operator would need to determine the water depth and approximate tidal conditions prior to deployment at each site based on the information that will be made available by MORL to the ADD operator.

Once the correct length of cable has been deployed, the cable holding the transducer would then be secured to the vessel to ensure that the transducer remains at the correct water depth. The cable would be secured in such a way as to avoid load or bending being applied to small sections of cable in order to reduce the vibration, wear and damage to the cable.

The mitigation protocol outlined in Appendix 2 of the PS stipulates that ADDs must be activated fifteen minutes prior to soft-start commencing. The ADD operator will activate the ADD once the Offshore Construction Manager has indicated that piling will commence in fifteen minutes. Once soft-start procedures have begun, the ADD operator will turn off the ADD. Where safe and practical to do so, the ADD transducer will be left deployed but

[1] Layback is the lateral movement caused to an object as a result of water resistance. When an object is deployed into moving water, the object moves laterally as well as vertically due to water resistance from tidal currents acting on the object.

inactive during piling so that it can be quickly activated again if needed during planned or unplanned breaks (as detailed within Appendix 2). Where breaks are greater than 10 minutes, the ADD will be activated 15 minutes before piling can be recommenced.

During the implementation of the Piling Protocol (Appendix 2) the ADD operator will visually scan the area surrounding the installation vessel for marine mammal presence/ absence. In the event that a marine mammal is observed this will be recorded and mitigation measures and piling operations will continue as set out in the Piling Protocol. The sequencing of activities prior to and during deployment of ADDs in included in the flowchart in Figure 1 below.

4.2 Role of the ADD Operator

The ADD operator would have the following responsibilities;

- Coordination of the deployment and activation of the ADD;
- Maintenance and testing of the ADD; and
- Compliance reporting of ADD deployment and piling activity.

A competent and independent ADD operator will be contracted by MORL to undertake the role (details will be provided to MS-LOT). As piling operations are assumed to be over a 24 hour period sufficient ADD operators will be present on board the piling installation vessel to ensure piling operations can be progressed. It is not possible to provide a total number of ADD operators at this stage as it is likely there would be a number appointed throughout the duration of the piling activities. It is envisaged that there will be at least two contractors on board of the piling vessel performing the role of ADD operator at any one time, so that they can work in shifts (12 hour shifts) in order to allow flexibility in the start of piling operations. ADD operators will be JNCC MMO trained and will have their qualifications and experience reviewed prior to award of contract.

4.2.1 Coordination of Deployment and Activation

Methods of communication would be determined through discussions with the piling contractor, however, it would be anticipated that the ADD operator would communicate with the Offshore Construction Manager using either an internal communication system or using hand-held radios.

Communication between the ADD operator and Offshore Construction Manager would be ongoing so that the ADD operator is aware of when soft-start activities are predicted to begin. Deployment of the ADD transducer would be undertaken no less than 30 minutes prior to the estimated start of piling. The ADD operator would be responsible for notifying the Offshore Construction Manager that the ADD transducer has been deployed and for ensuring that they are aware of any changes to the estimated start time. Once the estimated start time has been confirmed, the ADD operator would ensure that the ADD is activated and working fifteen minutes prior to the start of soft-start procedures (see Section 4.2.2 below for details on ADD testing and maintenance). If there is a delay in the start of piling the Offshore Construction Manager would notify the ADD operator. A decision would then be made on whether to deactivate the ADD based on the anticipated duration of the delay. If the delay is greater than fifteen minutes, the ADD would be temporarily deactivated until fifteen minutes before piling is expected to begin. If the delay to piling commencement is less than fifteen minutes, the ADD would be left active to ensure the ADD is active in the period immediately prior to soft start commencing. Once the ADD has been active for fifteen minutes, the ADD operator would undertake visual checks for marine mammal, record any observations and would notify the Offshore Construction Manager that piling soft start is able to commence. A communications flowchart is provided in Figure 1 below.

Once piling begins the ADD operator will then leave the ADD deployed and deactivated; however, this will be subject to the discretion of the Offshore Construction Manager as there maybe health and safety reasons for not having the ADD transducer continuously deployed (for example, it may interfere with the deployment or operation of a safety vessel or other deployed equipment). If the ADD transducer is retrieved, the ADD operator would inform the Offshore Construction Manager and undertake ongoing liaison with the Offshore Construction Manager to ensure the ADD is re-deployed if required (in the event of breaks in piling). The ADD operator would confirm any intention to deploy or retrieve the ADD transducer with the Offshore Construction Manager prior to undertaking the action.

If there are delays in piling (expected or otherwise) the ADD operator would liaise with the Offshore Construction Manager to determine the anticipated length of the break and the appropriate time to reactivate (or redeploy) the ADD. If the break is greater than ten minutes but less than two and a half hours, the Offshore Construction Manager would notify the ADD operator with sufficient time to allow the ADD device to be activated fifteen minutes prior to piling re-commencing. If the break is greater than two and a half hours, the ADD operator would activate the ADD fifteen minutes before a soft-start procedure (for further details on mitigation procedure in the event of delays in piling please see Appendix 2 Piling Protocol).

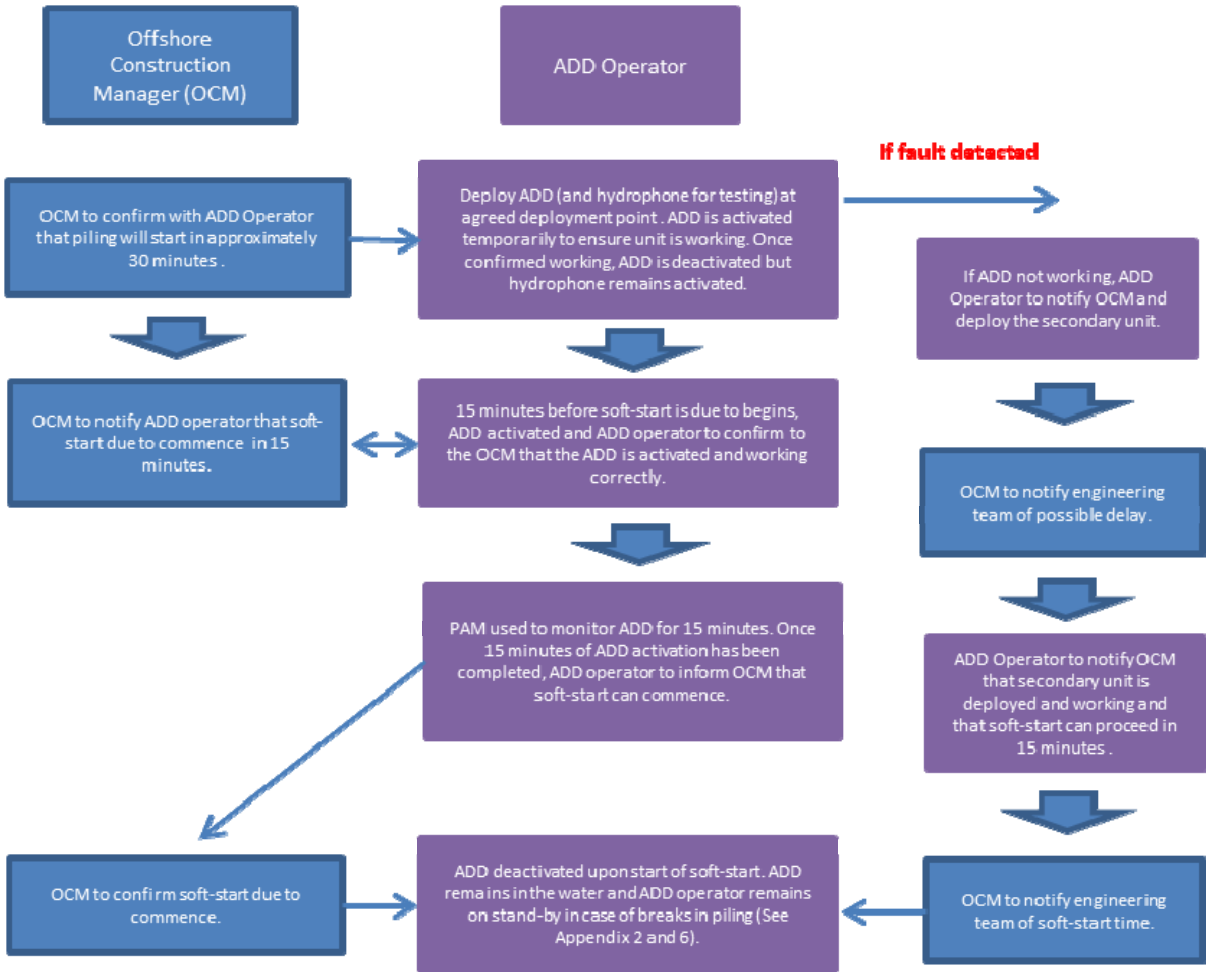

Figure 1 ADD Operator communication flowchart and outline of deployment protocol.

4.2.2 Testing and Maintenance

The ADD operator would be responsible for ensuring the ADD is working correctly prior to the start of piling. The ADD operator would be trained in the deployment and maintenance of

the equipment prior to use and would also be competent to test the ADDs transducer is working correctly. If the ADD is being powered remotely by batteries, the ADD operator will be responsible for ensuring the batteries are charged sufficiently prior to the start of operations.

Prior to each deployment, the ADD would be tested to ensure that the device is working sufficiently. Noise emitted by the transducer is generally audible by the human ear in air and turning the device on before deployment would represent the initial method of testing that the device is working.

Provisionally, MORL intend to test that the ADD is functioning using a deployed hydrophone, attached to a simple audio base-unit and laptop. The hydrophone would be deployed via a cable which would be attached to the transducer of the ADD to ensure both the hydrophone and transducer remain in a similar position in the water column.

The ADD operator would be able to check the ADD is active and working via a real-time audiogram using PAMGuard software. However, it should be noted that using this method may not be the most effective way of ensuring that all frequency bands are being emitted effectively due to the difficulties associated with accurately recording high frequency bandwidths in open water.

In order to ensure the ADD is tested by the most appropriate method, MORL would undertake discussions with the manufacturer to determine whether the deployment of a hydrophone is the most appropriate method of testing. Other potential methods of testing could involve;

- Placing the transducer within a tank and testing using a hydrophone prior to deployment; or
- Electronic frequency testing in dry conditions (it would be possible to get a greater degree of accuracy when testing frequency spectrums in dry conditions).

Selection of the final method for testing ADDs will include considerations of personnel health and safety associated with the deployment of additional equipment.

If there is a problem with the ADD device, the operator would report this immediately to the Offshore Construction Manager to discuss potential actions. These will include the provision and use of stand-by units and/or contacting the manufacturer for support as required.

4.2.3 Compliance Reporting

The ADD operator will be responsible for compliance reporting, a role which has to date generally been undertaken by PAM operators or MMOs to provide evidence that the mitigation protocols have been followed. The extent of reporting will be agreed with stakeholders before the start of the construction phase, however it is anticipated that reporting will include the following elements;

- Details of time and duration that the ADD device was deployed and active, including details of when the device was deployed but not active.
- Timings and durations of piling events, including breaks in piling, durations and compliance with soft-start procedures.
- Relevant observations, such as incidental mammal sightings, weather/wave conditions etc.

Compliance reports would be undertaken for each piling event and submitted to either MORL or the MORL ECoW for submission to regulators in a format agreed by Marine Scotland.

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moray offshore renewables ltd

Developing Wind Energy In The Outer Moray Firth

Piling Strategy

Appendix 7:

Phased Piling Mitigation Strategy

Telford, Stevenson and MacColl
Offshore Wind Farms - Project 1

edp renewables

APPENDIX 7: Phased Piling Mitigation Strategy

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Executive Summary

This document sets out MORL's (Moray Offshore Renewables Limited) proposed phased piling mitigation strategy for marine mammals for the first phase of development of the Telford, Stevenson and MacColl sites (i.e. Project 1) over a period of up to 28 days, as recommended by MS-LOT. This approach is based on the approach approved by MS-LOT for use at the Beatrice Offshore Wind Farm.

The phased strategy comprises of two stages:

- Stage 1 implements mitigation recommended in the JNCC (2010) protocol as outlined in the JNCC 2010 guidelines for minimising the risk of injury to marine mammals from piling noise, requiring the use of marine mammal observers (MMOs) and passive acoustic monitoring (PAM) operators;
- Stage 2 follows the Piling Protocol as set out Appendix 2, using acoustic deterrent devices (ADDs) and soft start with the addition of MMOs and a PAM operator to record a log of visual and acoustic detections of marine mammals during this stage.

Following the phased mitigation period, mitigation will be deployed in accordance with the Piling Protocol will be followed for the remainder of the piling operations.

Monitoring will be undertaken to determine the effectiveness of each mitigation method and data collected over the first two stages of the phase mitigation period will be provided to MS-LOT. Data collected will provide a record of passive acoustic detections and sightings or lack thereof within each stage. Data will be presented to MS-LOT using amended JNCC marine mammal data recording forms, and as a report summarising the observations.

This document sets out the approach to be taken at Stages 1 and 2 of the phased mitigation period, including definition of the injury zone, personnel and equipment, data collected and reporting methods. This document therefore provides information on the phase approach to mitigation as requested by MS-LOT on their letter dated 9 of May 2016.

1 Introduction

1.1 Project Background

MORL submitted a draft Piling Strategy (MORL, 2016) to Marine Scotland Licensing and Operations Team (MS-LOT) on 15th January 2016 following close consultation with the Joint Nature Conservation Committee (JNCC), Scottish Natural Heritage (SNH), Marine Scotland Science (MSS) and Whale and Dolphin Conservation (WDC) during 2015 (see Table 1.1 within Section 1.5 of PS main document). Comments from stakeholders have been received, with a request for further information on the proposed mitigation strategy for marine mammals. This document has been produced and included within the revised PS in order to address comments received from stakeholders (during February and March 2016) and MS-LOT on the 9th May 2016.

This phased mitigation strategy has been based on principles agreed through consultation with stakeholders and is in line with the approach that has been approved for use during BOWL construction activities (BOWL, 2016).

1.2 Phased Approach

This document sets out the procedure for phasing and reporting of piling noise mitigation methods during offshore piling at MORL's first phase of development within the Telford, Stevenson and MacColl sites, i.e. Project 1. Phased mitigation will be undertaken over the period of time not exceeding 28 days as recommended by MS-LOT.

Stage 1 of the phased mitigation period will start by undertaking mitigation in line with the draft JNCC (2010) protocol which will include the use of Marine Mammal Observers (MMOs) and Passive Acoustic Monitors (PAMs) with the additional use of Acoustic Deterrent Devices (ADDs) whenever conditions are not suitable for visual recordings. Stage 2 will be the application of the Piling Protocol (Appendix 2) with the use of ADDs (as outlined in Appendix 6) with the addition of MMOs and PAM operators to record a log of visual and acoustic detections during the application of this mitigation. The agreed Piling Protocol will use ADDs and soft start mitigations alone with regular monitoring to ensure that ADD devices are working correctly.

The phased approach to mitigation during piling works at Project 1 is illustrated in Figure 1.

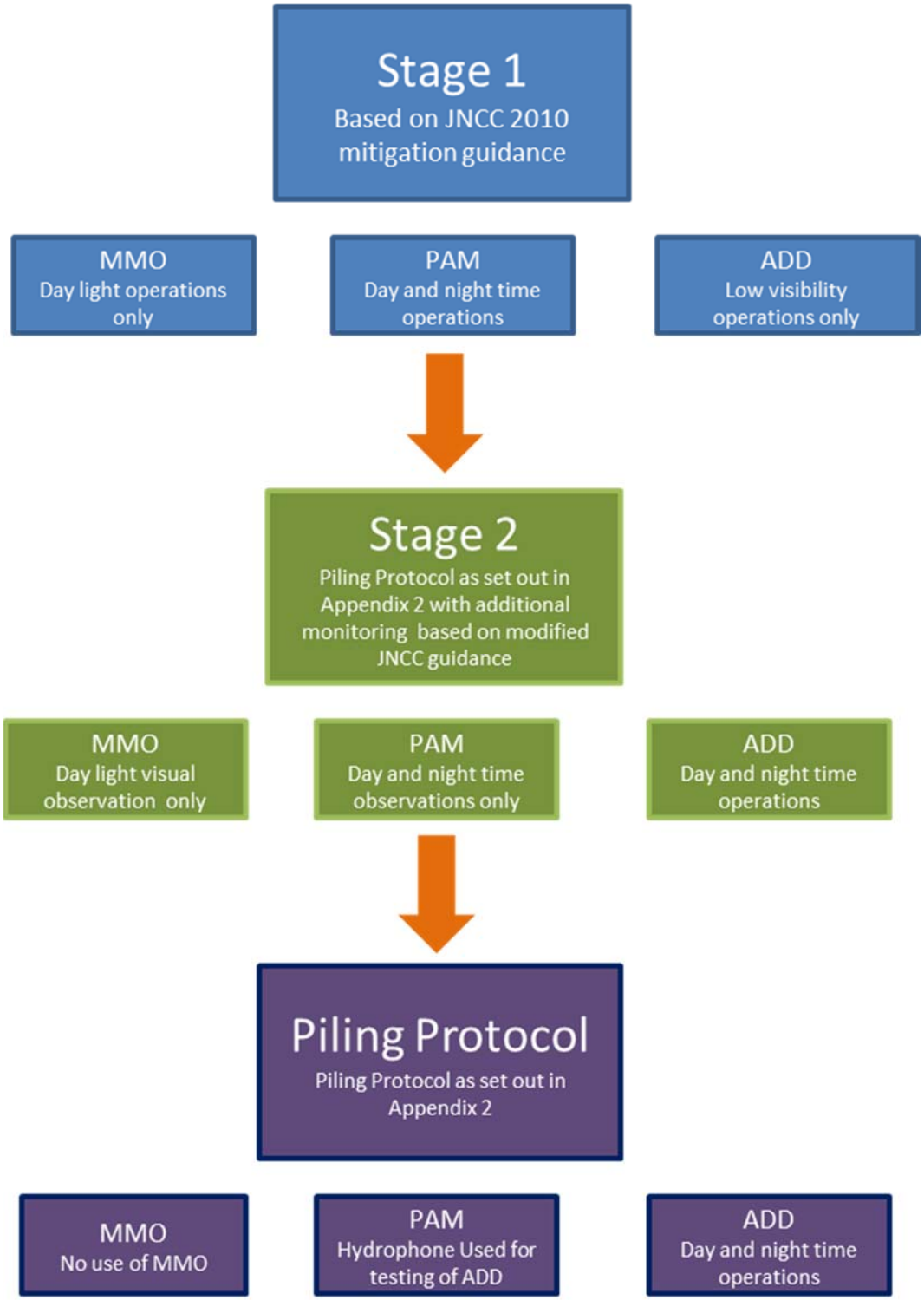


Figure 1: Overview of phased approach to mitigation at Project 1

It may be the case that the initial piling period may not be the most optimum for gathering data and therefore MORL may decide that it is preferable to not implement the Phased Piling Mitigation Strategy at the start of piling operations. If this is proved to be the case, MORL will implement the Piling Protocol described in Appendix 2 at the start of the piling operations and the Phased Piling Mitigation Strategy will be applied whenever the conditions are perceived to be the most suitable (from an operational perspective and marine mammal monitoring) as detailed in Section 1.3 below.

During the implementation of the Piling Protocol (Appendix 2), the ADD operator will visually scan the area surrounding the installation vessel for marine mammal presence / absence prior to deploying the ADD to ensure that the area is free of marine mammals. This will be completed up to twice a day on selected days or periods and only during daylight hours and when weather conditions are suitable for observation. In the event that a marine mammal is observed, the sighting will be recorded and MORL will continue with the mitigation measures and piling operations as set out in the Piling Protocol.

Further detail for each stage of the Phased Piling Mitigation Strategy is presented in the following sections.

1.3 Timing and Scope of the Phased Mitigation Period

1.3.1 Timing

Several considerations may determine the most appropriate timing of implementing the Phased Piling Mitigation Strategy during the piling operations programme, including the following key items:

- Aligning it with the study developed to monitor the behavioural responses of harbour seal and harbour porpoise to ADDs as part of the construction Marine Mammal Monitoring Programme (cMMMP) developed by Professor Paul Thompson (University of Aberdeen), MORL and BOWL. The scope of this monitoring programme has been developed in consultation with the Moray Firth Regional Advisory Group (MFRAG) Marine Mammal Subgroup;
- The likelihood of capturing information across multiple wind turbine or Offshore Substation Platform(s) (OSPs) foundation installations.
- The time of year when marine mammals may be most abundant in the area; and
- The likely weather conditions, in particular visibility, prevalent during this period.

MORL propose that the timing of implementing the Phased Piling Mitigation Strategy is determined at a later date once further details of MORL's piling schedule and turbine locations are confirmed. If available the results of the phased mitigation piling at the BOWL site will also be taken into account in the design of the phased piling mitigation at Project 1.

1.3.2 Scope

The scope of the Phased Piling Mitigation Strategy has been determined through discussions with offshore construction engineers (internal and external to MORL), specialists in practical undertaking of marine mammal mitigation and Professor Thompson, as the lead scientist for the cMMMP. MORL's offshore piling engineers (through discussions with potential piling contractors)

provided information on the likely duration of each step in the foundation installation sequence and the number of wind turbines that could be installed within 28 days.

In order to ensure that sufficient data are collected, MORL would undertake monitoring at a minimum of two wind turbine or substation foundations for each Stage of the Phased Mitigation Procedure (i.e. a minimum of four foundations in total would be monitored in Stages 1 and 2). In summary, the following rules will be applied to the phased mitigation period to ensure sufficient data are collected (and such that monitoring plans for marine mammals are not compromised):

- A minimum of two and maximum of three wind turbine or substation foundations will be included within each Stage;
- The number of locations in each Stage of the phased mitigation period will be equal;
- The mitigation protocol at each Stage will be applied to complete foundations only i.e. mitigation will not cease half way through the pile installation sequence at a single location;
- Stage 1 will end when a maximum of three wind turbine or substation foundations have been completed, or when the 14th day is reached as long as the minimum of two complete foundations have been installed before that day;
- The phased mitigation period will end once an equal number of wind turbine or OSP foundations have been installed in each Stage (and this number is a minimum of two in each Stage), regardless of whether the duration is less than or more than the guideline 28 day period.

2 Stage 1: JNCC Approach to Mitigation

2.1 Overview

Although the draft JNCC (2010) protocol has been widely applied during the construction of offshore wind farms in the UK, there is considerable uncertainty as to the effectiveness of this mitigation in reducing the risk of injury (Herschel *et al.*, 2013). During Stage 1 of the test period for Project 1, data will be gathered by trained MMOs and a PAM operator in line with the draft JNCC (2010) protocol.

2.2 Roles and Responsibilities

2.2.1 MMOs

Two MMOs will be appointed by MORL, and will be responsible for carrying out the pre-piling search, recording the observations on the JNCC marine mammal recording form, and liaising with the Offshore Construction Manager (Section 2.2.3) to advise whether a delay to piling is necessary in the case that any marine mammals are detected during the pre-piling search. The MMO will be in direct contact with the Offshore Construction Manager and PAM/ADD Operator via radio. However for practicality, it is important that there is a single point of contact between the MMO team and the installation team. Communication lines will be established between the MMO/PAM team and the Offshore Construction Manager to ensure a single point of contact is established.

The MMOs will be trained to JNCC standards as Marine Mammal Observers (by a JNCC approved course provider). The MMOs will have an appropriate level of field experience, including where possible, experience of offshore piling operations. MORL will inform MS-LOT and the Statutory Nature conservation Bodies (SNCBs) on the appointment of the MMOs.

2.2.2 PAM/ADD Operators

The PAM/ADD Operator, appointed by MORL, will be responsible for deployment, maintenance and operation of the PAM hydrophone and ADD device, including spares. Two PAM/ADD Operators are required to cover shifts since the piling is scheduled to take place over a 24 hour working period. During each shift the PAM/ADD Operator will be supported by offshore construction vessel personnel, who can be trained *in situ* to assist with the deployment of equipment if required. The PAM/ADD Operator will be required to liaise with the Offshore Construction Manager and MMOs in order to confirm timings for piling operations and start the 30 minute pre-watch period. The PAM/ADD Operator will be in direct contact with the Offshore Construction Manager and MMOs via radio. Any recordings of marine mammals using PAM can be communicated immediately to the Offshore Construction Manager to delay the commencement of soft start. As described above (Section 2.2.1) communication lines will be established within MMO/PAM team to ensure that a singular point of contact is identified. This person would then have responsibility for ensuring that a clear indication of the need to delay piling, or that piling can commence is provided to the offshore installation team via the Offshore Construction Manager.

The PAM/ADD Operators will be suitably trained in passive acoustic monitoring and the use of PAMGuard with training provided by an appropriate organisation. The PAM/ADD Operators will have an appropriate level of field experience, including where possible, experience of offshore piling operations. MORL will inform MS-LOT and the SNCBs on the appointment of the PAM/ADD Operators.

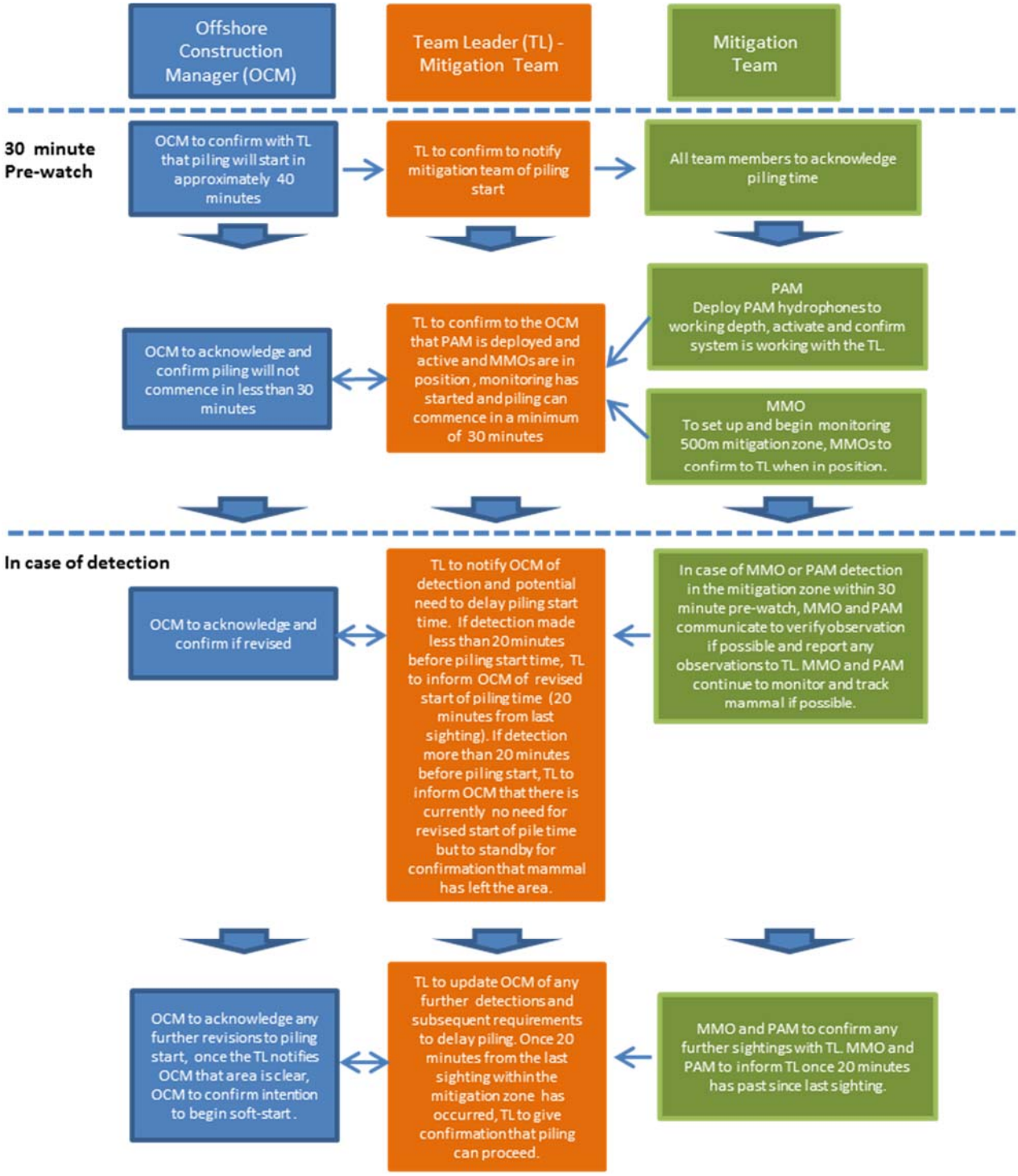
2.2.3 Offshore Construction Manager and Offshore Vessel Personnel

The Offshore Construction Manager, employed by the offshore construction contractor, will be based on piling installation vessel (either a floating heavy lift vessel (HLV) or jack-up platform (JUP) as detailed in Section 3.2.1 of the PS main document). In consultation with the vessel's master, the Offshore Construction Manager will be in charge of all operations on the main deck, including piling operations. The Offshore Construction Manager will be responsible for ensuring that piling operations are undertaken in a controlled, safe and efficient manner in line with the Piling Strategy.

The PAM/ADD Operator will be assisted by offshore construction vessel personnel during the deployment of the PAM and ADD device if required.

2.3 Task Plan

A task plan has been prepared in order to aid communications and outline responsibilities between the Offshore Construction Manager and the marine mammal team (MMOs and PAM/ADD Operator) during Stage 1. This task plan sets out the sequence of events required to apply the JNCC (2010) protocol for mitigation during daylight hours (Figure 2) and during night time/low visibility (Figure 3). Whilst MMOs and PAM/ADD operators will all have the ability to communicate with the Offshore Construction Manager if required, a team leader would be identified to act as the primary point of contact for issuing messages on delay or commencement of piling.


Offshore Construction Manager (OCM)
Team Leader (TL) - Mitigation Team
Mitigation Team
30 minute Pre-watch
OCM to confirm with TL that piling will start in approximately 40 minutes
TL to confirm to notify mitigation team of piling start
All team members to acknowledge piling time
PAM
Deploy PAM hydrophones to working depth, activate and confirm system is working with the TL.
OCM to acknowledge and confirm piling will not commence in less than 30 minutes
TL to confirm to the OCM that PAM is deployed and active and MMOs are in position, monitoring has started and piling can commence in a minimum of 30 minutes
MMO
To set up and begin monitoring 500m mitigation zone, MMOs to confirm to TL when in position.
In case of detection
OCM to acknowledge and confirm if revised
TL to notify OCM of detection and potential need to delay piling start time. If detection made less than 20 minutes before piling start time, TL to inform OCM of revised start of piling time (20 minutes from last sighting). If detection more than 20 minutes before piling start, TL to inform OCM that there is currently no need for revised start of pile time but to standby for confirmation that mammal has left the area.
In case of MMO or PAM detection in the mitigation zone within 30 minute pre-watch, MMO and PAM communicate to verify observation if possible and report any observations to TL. MMO and PAM continue to monitor and track mammal if possible.
OCM to acknowledge any further revisions to piling start, once the TL notifies OCM that area is clear, OCM to confirm intention to begin soft-start.
TL to update OCM of any further detections and subsequent requirements to delay piling. Once 20 minutes from the last sighting within the mitigation zone has occurred, TL to give confirmation that piling can proceed.
MMO and PAM to confirm any further sightings with TL. MMO and PAM to inform TL once 20 minutes has past since last sighting.

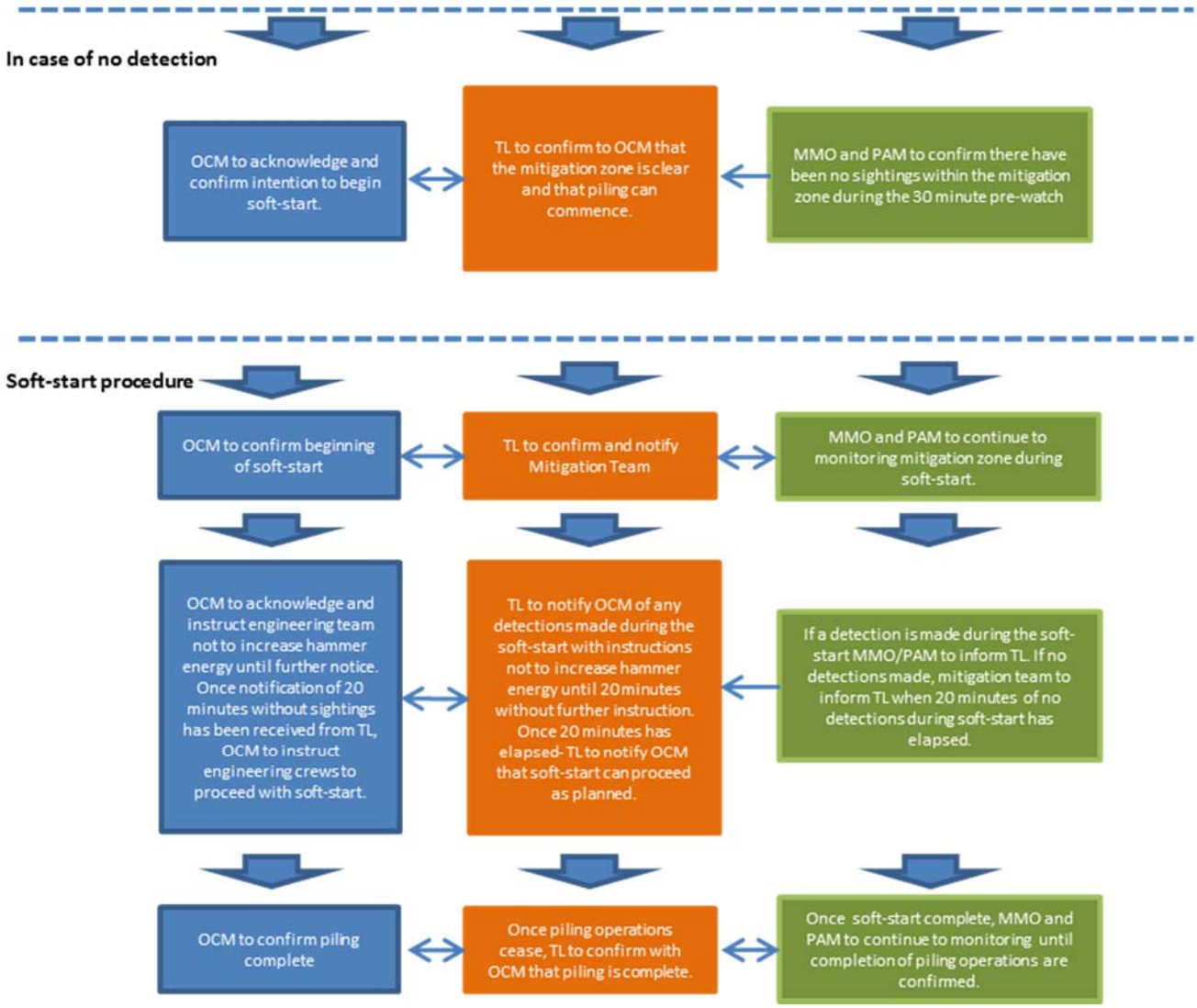


Figure 2: Task plan for applying the JNCC (2010) protocol during daylight hours for Stage 1 of the phased mitigation period.

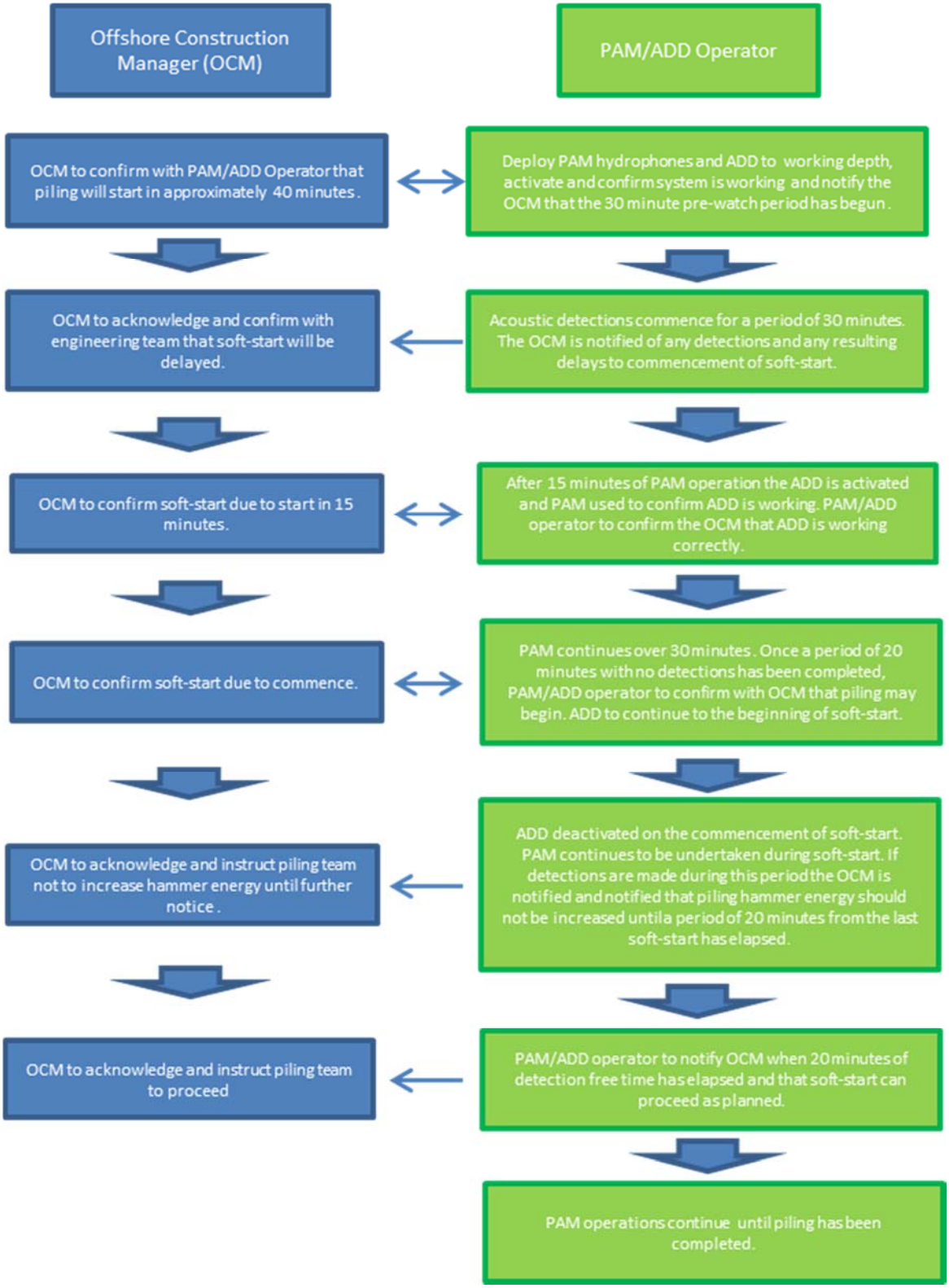


Figure 3: Task plan for applying the JNCC (2010) protocol during night time/low visibility hours for Stage 1 of the phased mitigation period.

2.4 Mitigation Zone

A mitigation zone of 500 m radius will be established around the piling location. This exceeds the instantaneous injury zone for harbour porpoise of 60 m for the initial hammer energy of 300 kJ employed during soft start (see Section 4.2 below, and also detailed in Appendix 2).

2.5 Soft Start

Soft start piling will be undertaken as per the procedure detailed in the Piling Protocol (Appendix 2). This procedure commences with five to six blows (~1 blow per 10 seconds) at as low an energy as possible (≤ 300 kJ). Soft start continues with blows at an increased frequency (~1 blow per 2 seconds) starting at an energy of ≤ 300kJ and not exceeding 500 kJ over a duration of 20 minutes. After the 20 minutes has elapsed the hammer energy will ramp up as required for each location to achieve pile movement of ~2.5cm per blow, with the maximum energy no greater than 2,300 kJ.

2.6 Approach

2.6.1 Daylight hours

During daylight hours mitigation will be achieved through visual observations using two suitably trained, dedicated MMOs located in a suitable place on the installation vessel to allow for a 360° view of the 500 m mitigation zone. Observations, including species present, number of animals, distance and behaviour will be recorded using the JNCC Marine Mammal Recording Forms. The standard JNCC recording forms are designed for use during mobile seismic surveys, and accordingly it is proposed to modify the forms to make them relevant a static windfarm operation to ensure the relevant data is collected. Any changes would be agreed with MS-LOT. Further detail on reporting is provided in Section 6 below. Acoustic detection of cetaceans will be undertaken by a suitably trained, dedicated PAM/ADD Operator who will be located on the deck of the installation vessel in order to manage the computer interface of the PAM system using PAMGuard software (ADDs will only be deployed during night time/low visibility as detailed in Section 2.6.2 below). The PAMGuard software will be used to record the vocalisations of cetaceans and these then saved as a .wav file as a log. These detections will also be logged by the PAM/ADD Operator using the JNCC Recording form. Suitable locations for the deployment of PAM equipment will be confirmed once the appointment of the offshore installation vessel has been finalised.

Visual and acoustic detection will be undertaken over a 30 minute period prior to the start of soft start piling. If a marine mammal is detected within the 500 m mitigation zone during this pre-piling visual and acoustic detection period, the start of soft start piling will be delayed until a period of 20 minutes has elapsed after the last visual or acoustic detection within the mitigation zone. Any animals detected will be observed to ensure that they have left the mitigation zone prior to the start of soft start piling.

If a marine mammal is detected within the 500 m mitigation zone during the soft start, the soft start will continue at the same hammer energy until the marine mammal has left the mitigation zone and no detections are made for a further 20 minutes, after which time piling may continue to ramp up to the maximum rate required to install the pile at a rate of ~2.5 cm per blow.

Following completion of the soft start, the MMOs and PAM/ADD Operator will continue to record detections during piling operations in the event that a break in piling occurs and they are required to communicate to the Offshore Construction Manager whether piling soft start can commence (if no marine mammal is detected) or whether the pre-watch must be repeated (if a marine mammal is present) (see Section 2.7).

2.6.2 Night time/low visibility

During night time or hours of low visibility, mitigation will be undertaken acoustically by the PAM/ADD Operator through the computer interface using PAMGuard software. Acoustic detection will commence 30 minutes prior to the start of soft start piling. The PAMGuard software will be used to record the vocalisations of cetaceans and these then saved as a .wav file as a log. These detections will also be logged by the PAM/ADD Operator using the amended JNCC Recording form. During the acoustic detection period (and regardless of whether a marine mammal is present) the ADD will be activated for a period of 15 minutes (to be consistent with the Piling Protocol) prior to the start of soft start piling. The PAM/ADD Operator will be responsible for managing the computer interface when the ADD is activated to ensure the device is working correctly. Soft start piling will not commence until the ADD has functioned correctly for a period of 15 minutes.

If a cetacean is detected within the mitigation zone during the pre-piling acoustic detection period (either before or after the ADD is deployed), the start of the soft start piling will be delayed until a period of 20 minutes has elapsed after the last acoustic detection. The ADD device will continue to be activated during this period. The PAM/ADD Operator will ensure that no further vocalisations are detected prior to the start of soft start piling.

If a marine mammal is detected within the 500 m mitigation zone during the soft start, the soft start will continue at the same hammer energy until the marine mammal has left the mitigation zone and no detections are made for a further 20 minutes, after which time piling may continue to ramp up to the maximum rate required to install the pile at a rate of ~2.5 cm per blow.

Following completion of the soft start, the PAM/ADD Operator will continue to record detections during piling operations in the event that a break in piling occurs and they are required to communicate to the Offshore Construction Manager whether piling soft start can commence (if no cetacean is detected) or whether the pre-watch must be repeated (if a cetacean is present) (see Section 2.7).

2.7 Planned and Unplanned Breaks

The JNCC (2010) guidelines recommend that where there is a pause in piling for greater than 10 minutes, the pre-piling 30 minute search using MMOs and PAM will be repeated before piling recommences. If, however, the MMO and PAM/ADD Operator have continued to record detections during the piling operation they will be able to confirm the presence or absence of marine mammals and therefore it would be possible to commence the soft start immediately unless a marine mammal has been detected within the last 20 minutes of monitoring.

Since the approach to be employed in Stage 1 will include ongoing detections during piling operations, the MMO/ PAM/ADD Team will continue to communicate with the Offshore Construction Manager during a break in piling to advise whether the soft start can commence immediately. The soft start following a break in piling will be undertaken following the approach described in Section 2.5.

3 Stage 2: Piling Protocol with MMOs and PAM

3.1 Overview

Stage 2 of the phased mitigation period will be the application of the MORL's Piling Protocol (based on the use of ADDs) with the addition of MMOs and PAM. The key differences between Stage 1 and Stage 2 mitigation are summarised in Box 1 below.

Box 1 - Summary and Key Differences from Stage 1 Mitigation

- An ADD will be deployed for 15 minutes into the 30 minute PAM and MMO pre-watch (i.e. 15 minutes prior to soft start piling commences) every time, also during the day/ good visibility.
- In Stage 2, the mitigation zone (with the exception of the 60 m injury zone) will only be monitored. For Stage 2, the 500 m area around the pile will be referred to as the monitoring zone. If during the 30 minute PAM detection and MMO pre-watch (including the 15 minute ADD deployment) a marine mammal is detected within the 500 m monitoring zone, soft start will commence as planned, unless a marine mammal is observed within the 60 m injury zone. In this unlikely event the ADD will continue to be activated and soft start will be delayed until it is assessed by the MMOs and/or PAM/ADD Operator that the marine mammal has vacated this 60 m injury zone.
- If, during soft start a marine mammal is observed or detected within the 500 m mitigation zone, soft-start will continue as planned.
- The PAM/ADD Operator and MMOs will continue to note detections and observations on the animals' behaviour during the soft start procedure.

3.2 Roles and Responsibilities

3.2.1 MMOs

The MMOs, appointed by MORL, will be responsible for carrying out the pre-piling observations and recording the observations on the JNCC marine mammal recording form. In this stage of the phased mitigation period there is no requirement to delay piling if a marine mammal is sighted in the 500 m monitoring zone (unless a marine mammal is observed within the 60 m injury zone – see Sections 3.5 and 3.6 for further information). The MMOs will continue to note observations on an animals' behaviour during the soft start procedure. The MMO will be in direct contact with the Offshore Construction Manager and PAM/ADD Operator via radio.

As previously described for Stage 1, the MMOs will be trained to JNCC standards as MMOs with an appropriate level of field experience, including where possible.

3.2.2 PAM/ADD Operator

The PAM/ADD Operators, appointed by MORL, will be responsible for deployment, maintenance and operation of the PAM hydrophone and ADD device, including spares. Two PAM/ADD Operators are required to cover shifts since the piling is scheduled to take place over a 24 hour working period.

During each shift the PAM/ADD Operator will be supported by installation vessel personnel, who will be able to aid with the deployment of ADD/PAM equipment if required. The PAM/ADD Operator will be required to liaise with the Offshore Construction Manager and MMOs in order to confirm timings for piling operations and start of the 30 minute pre-watch period. During the day the PAM/ADD Operator will be in direct contact with the Offshore Construction Manager and MMOs via radio, although a single point of contact between the MMO/PAM team and Offshore Construction Manager will be established through the use of a mitigation team leader. When operating at night without the use of MMOs, the PAM/ADD operator will communicate directly with the Offshore Construction Manager.

In this stage of the phased mitigation period there is no requirement to delay piling if a cetacean is detected in the 500 m monitoring zone (unless it is considered that the cetacean could be within a distance of approximately 60 m – see sections 3.5 and 3.6 for further information). The PAM/ ADD Operator will continue to note detections of cetaceans in the 500 m monitoring zone during the soft start procedure.

As previously described for Stage 1, the PAM/ADD Operators will be suitably trained in passive acoustic monitoring and ADDs and the use of PAMGuard software with training provided by an appropriate organisation and will have a suitable level of experience.

3.2.3 Offshore Construction Manager and Vessel Personnel

The role of the Offshore Construction Manager, vessel master and other installation vessel personnel during the implementation of Stage 2 of the Phased Piling Mitigation period will be in line with that summarised above in Section 2.2.3.

3.3 Monitoring Zone

A monitoring zone of 500 m radius will be established around the piling location. This exceeds the instantaneous injury zone for harbour porpoise of 60 m for the initial hammer energy of 300 kJ employed during soft start (see Section 4.2).

3.4 Soft Start

Soft start piling will be undertaken following the procedure detailed in the Piling Protocol (Appendix 2). This procedure has been summarised in Section 2.5 of this document.

3.5 Approach

3.5.1 Daylight hours

During daylight hours visual observations will be recorded by two suitably trained, dedicated MMOs located on the bridge of the installation vessel, which will give a 360° view of the 500 m monitoring zone. Observations including species present, number of animals, distance and behaviour will be recorded using the amended JNCC Marine Mammal Recording Forms. Further detail on reporting is provided in Section 6 below. Acoustic detection and deployment of the ADD will be undertaken by a suitably trained, dedicated PAM/ADD Operator who will be stationed in an appropriate location in order to monitor the computer interface of the PAM system. The PAMGuard software will be used to record the vocalisations of cetaceans and these then saved as a .wav file as a log. These detections will also be logged by the PAM/ADD

Operator using the amended JNCC Recording form. Possible locations for the PAM equipment will be determined once a final decision is made on the offshore installation vessel.

Visual and acoustic observations and detections will be undertaken over a 30 minute period prior to the start of soft start piling. Fifteen minutes into this pre-watch period the ADD device will be deployed at an appropriate depth and location (see Appendix 6) by the PAM/ADD Operator and the system activated. The PAM/ADD Operator will monitor the ADD functioning via the computer interface (using the PAMGuard software). Any malfunctions will be reported immediately to the Offshore Construction Manager and the start of piling will be delayed while the back-up device is deployed, tested and verified to be working correctly. Once functioning correctly, the ADD device will be deployed for a period of 15 minutes, as agreed with MS-LOT and the MFRAG-MM Subgroup in the Piling Protocol (see Appendix 2).

If, during the 30 minute MMO pre-watch and 15 minute ADD deployment a marine mammal is detected within the 500 m mitigation zone, soft start will continue as planned unless a marine mammal is observed or acoustically detected within the 60 m injury zone. In the unlikely event that this occurs, the MMOs and/or PAM / ADD Operator will notify the Offshore Construction Manager via hand held radio that soft start should be delayed and the ADD will continue to be activated until it is assessed by the MMOs and/or PAM/ADD Operator that the marine mammal has vacated the 60 m injury zone. The PAM/ADD Operator and MMOs will continue to detect vocalisations and observe the animals' behaviour in the 500 m monitoring zone throughout the pre-watch and also during the soft start procedure.

3.5.2 Night time/low visibility

During night time or hours of low visibility, mitigation will be undertaken acoustically by the PAM/ ADD Operator through the computer interface using PAMGuard software. Acoustic detection will commence 30 minutes prior to the start of soft start piling. The PAMGuard software will be used to record the vocalisations of cetaceans and these then saved as a .wav file as a log. These detections will also be logged by the PAM/ADD Operator using an amended JNCC Recording form. During the acoustic detection period (and regardless of whether a marine mammal is present) the ADD will be activated for a period of 15 minutes (to be consistent with the Piling Protocol) prior to the start of soft start piling. The PAM/ADD Operator will be responsible for managing the computer interface when the ADD is activated to ensure the device is working correctly. Soft start piling will not commence until the ADD has functioned correctly for a period of 15 minutes. Any malfunctions will be reported immediately to the Offshore Construction Manager and the start of piling will be delayed while the back-up device is deployed, tested and verified to be working correctly. Once functioning correctly, the ADD device will be deployed for a period of 15 minutes, as agreed with MS-LOT and MFRAG-MM Subgroup for the Piling Protocol (Appendix 2).

If a cetacean is detected during this period the PAM/ADD Operator notes this as a record but no further action is taken to delay the start of soft start piling, unless it is considered that the cetacean could be within a distance of approximately 60 m[1]. In this case it will be communicated to the Offshore Construction Manager via hand held radio that soft start should be delayed and the ADD will continue to be activated until the cetacean is assessed by the PAM/ADD Operator to be beyond the 60 m injury zone. The PAM/ADD Operator will continue to record acoustic detections during the pre-watch and during the piling soft start.

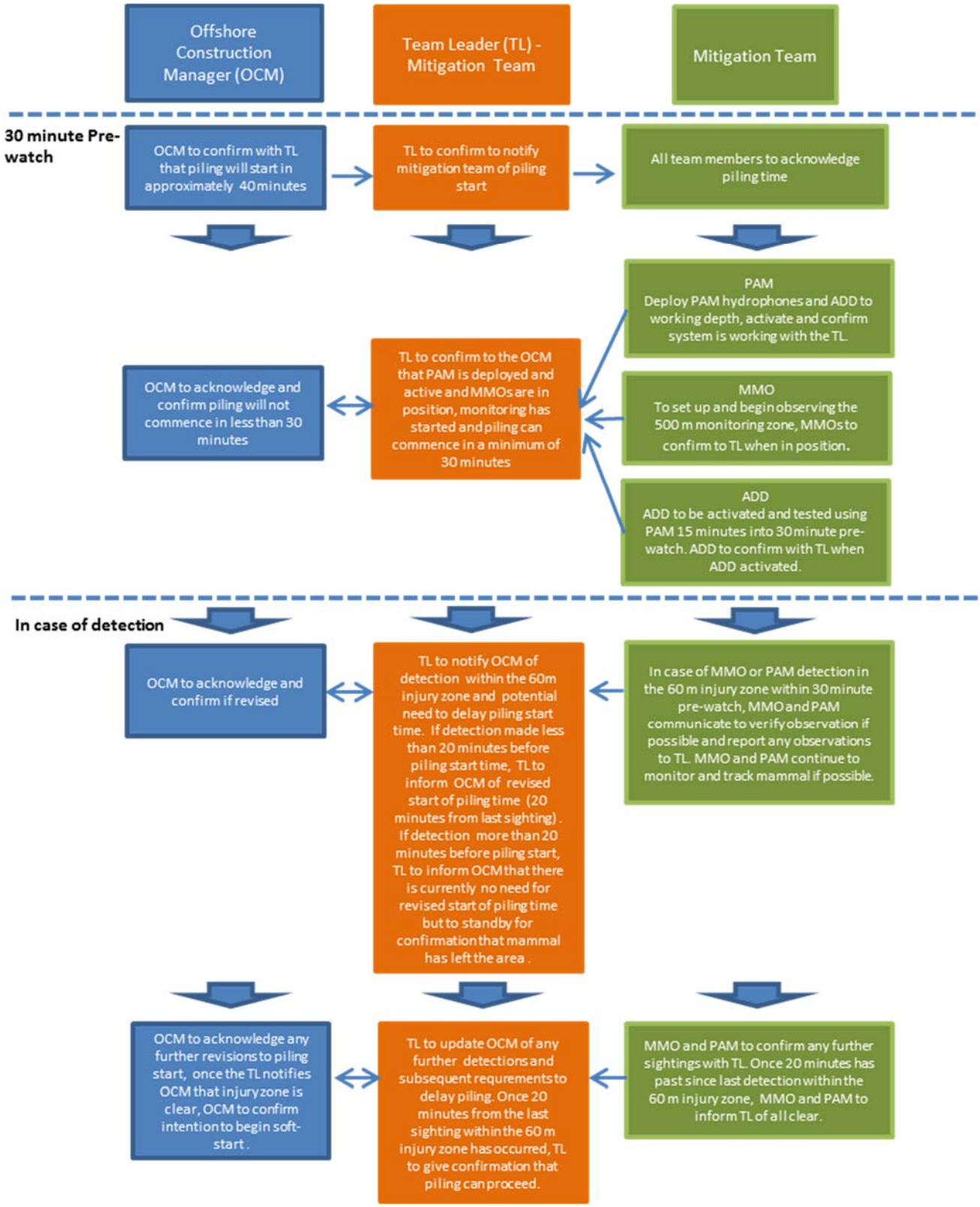
[1] Exact distances cannot be measured during acoustic detections but it will be possible to estimate these by undertaking a ground-truthing exercise during daylight hours to match the strength of the vocalisations displayed on the computer interface with the distances estimated by the MMOs during visual observations.

3.6 Planned and Unplanned Breaks

The procedure for planned and unplanned breaks has been illustrated in Figure 4 and detailed within the Piling Protocol (Appendix 2). If the break during piling exceeds 2.5 hours, the PAM/ADD Operator and MMO will cease observations until such a time that the Offshore Construction Manager can notify them that piling will re-commence in approximately 40 minutes. At this point the approach described above (Section 3.5) will be repeated including the pre-watch observations and detections required as part of Stage 2. If the break is less than 2.5 hours the PAM/ADD Operator will liaise with the Offshore Construction Manager and the ADD will be deployed for 10 minutes prior to piling re-start. In the unlikely event that a marine mammal is observed within the 60 m injury zone, the MMOs and/or PAM/ADD Operator will communicate this to the Offshore Construction Manager via hand held radio. The ADD will continue to be deployed and piling will be delayed until it is assessed by the MMOs and/or PAM/ADD Operator that the marine mammal has vacated the zone. Piling will be initiated with 5 – 6 single blows at low energy after which time the hammer energy will be ramped up to the levels required to maintain pile movement at approximately 2.5 cm/blow (Section 5 of the Piling Protocol (Appendix 2)).

3.7 Task Plan

A task plan has been prepared in order to aid communications between the Offshore Construction Manager and the marine mammal team (MMOs and PAM/ADD Operator) for Stage 2. As previously described for Stage 1 the mitigation team will have a designated team leader who will be responsible for liaison with the Offshore Construction Manager. This task plan sets out the sequence of events required to apply the Piling Protocol with the addition of MMOs and PAM during daylight hours (Figure 4). The task plan for the sequence of events for night time/low visibility piling is the same with the exception of the MMOs, who will not be present during this time.


Offshore Construction Manager (OCM)
Team Leader (TL) - Mitigation Team
Mitigation Team
30 minute Pre-watch
OCM to confirm with TL that piling will start in approximately 40 minutes
TL to confirm to notify mitigation team of piling start
All team members to acknowledge piling time
PAM
Deploy PAM hydrophones and ADD to working depth, activate and confirm system is working with the TL.
OCM to acknowledge and confirm piling will not commence in less than 30 minutes
TL to confirm to the OCM that PAM is deployed and active and MMOs are in position, monitoring has started and piling can commence in a minimum of 30 minutes
MMO
To set up and begin observing the 500 m monitoring zone, MMOs to confirm to TL when in position.
ADD
ADD to be activated and tested using PAM 15 minutes into 30 minute pre-watch. ADD to confirm with TL when ADD activated.
In case of detection
OCM to acknowledge and confirm if revised
TL to notify OCM of detection within the 60m injury zone and potential need to delay piling start time. If detection made less than 20 minutes before piling start time, TL to inform OCM of revised start of piling time (20 minutes from last sighting). If detection more than 20 minutes before piling start, TL to inform OCM that there is currently no need for revised start of piling time but to standby for confirmation that mammal has left the area.
In case of MMO or PAM detection in the 60 m injury zone within 30 minute pre-watch, MMO and PAM communicate to verify observation if possible and report any observations to TL. MMO and PAM continue to monitor and track mammal if possible.
OCM to acknowledge any further revisions to piling start, once the TL notifies OCM that injury zone is clear, OCM to confirm intention to begin soft-start.
TL to update OCM of any further detections and subsequent requrements to delay piling. Once 20 minutes from the last sighting within the 60 m injury zone has occurred, TL to give confirmation that piling can proceed.
MMO and PAM to confirm any further sightings with TL. Once 20 minutes has past since last detection within the 60 m injury zone, MMO and PAM to inform TL of all clear.

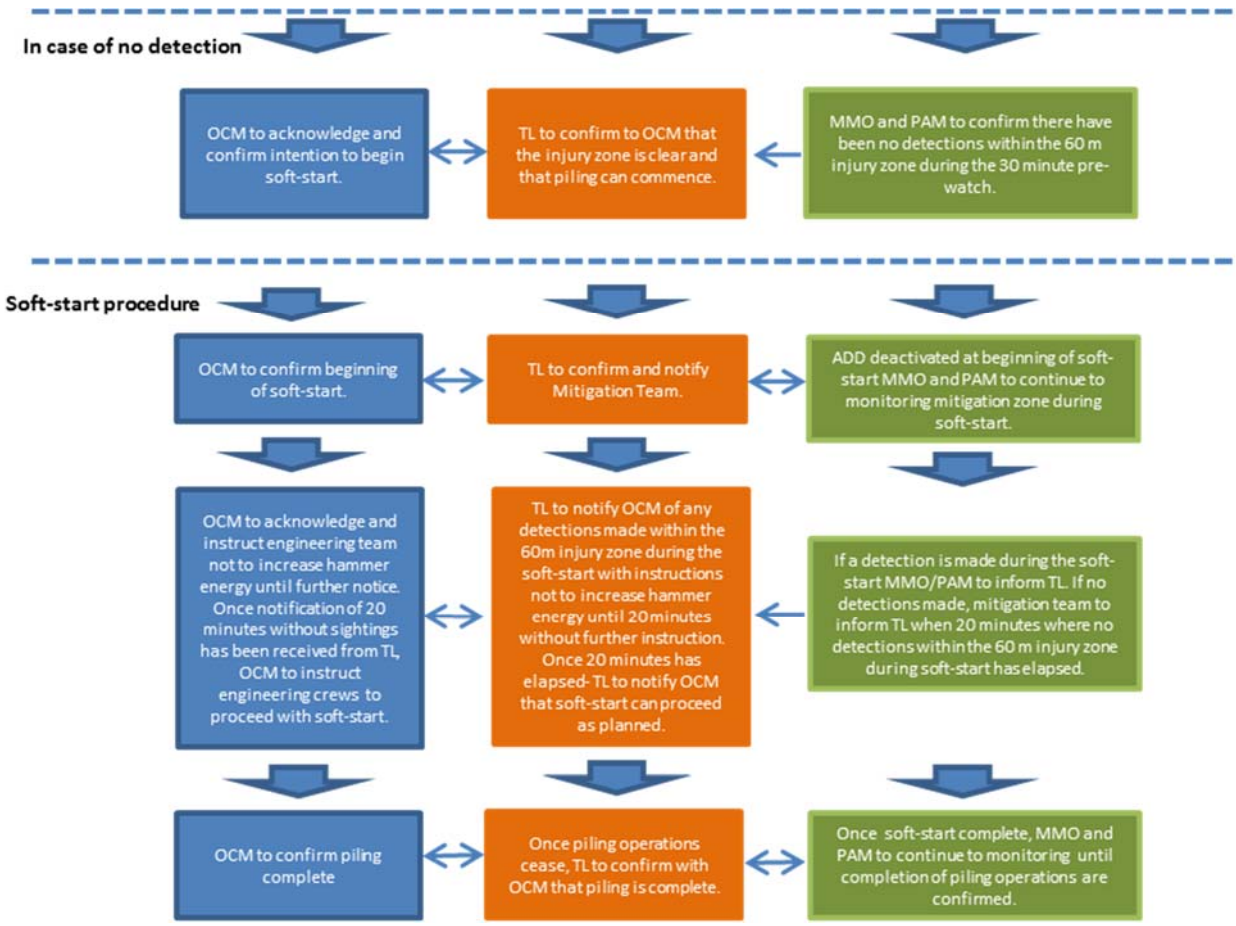


Figure 4: Task plan for applying The Piling Protocol with PAM and MMOs during daylight hours for Stage 2 of the phased mitigation period.

4 Piling Mitigation Protocol

4.1 Overview

Following the completion of the phased mitigation period MORL will implement the Piling Protocol as described in Appendix 2.

4.2 Mitigation Zone

The mitigation zone assessed in the Piling Protocol is 60m, based on the instantaneous injury zone for harbour porpoise at the soft start hammer energy of 300kJ. The injury zone was predicted by the CEFAS noise modelling assessment undertaken for the Piling Protocol (Appendix 2).

4.3 Approach

The Piling Protocol is described in full in Appendix 2. Further detail on the ADD deployment protocol is provided in Appendix 6, including: 1) the technical specification of the Lofitech device and depth of deployment, 2) effectiveness of the Lofitech device, 3) role and training of the ADD Operator, 4) testing the ADD functioning, 5) Communication channels 6) Protocols for planned and unplanned breaks.

4.4 Planned and Unplanned Breaks

The procedure for planned and unplanned breaks of less than 2.5 hours and more than 2.5 hours has been outlined in the Piling Protocol (Appendix 2).

4.5 Soft Start

Soft start piling will be undertaken following the procedure detailed in the Piling Protocol (Appendix 2). This procedure has been summarised in Section 2.5 of this document.

4.6 Task Plan

The task plan showing the sequence of events described in the Protocol is provided below (Figure 5).

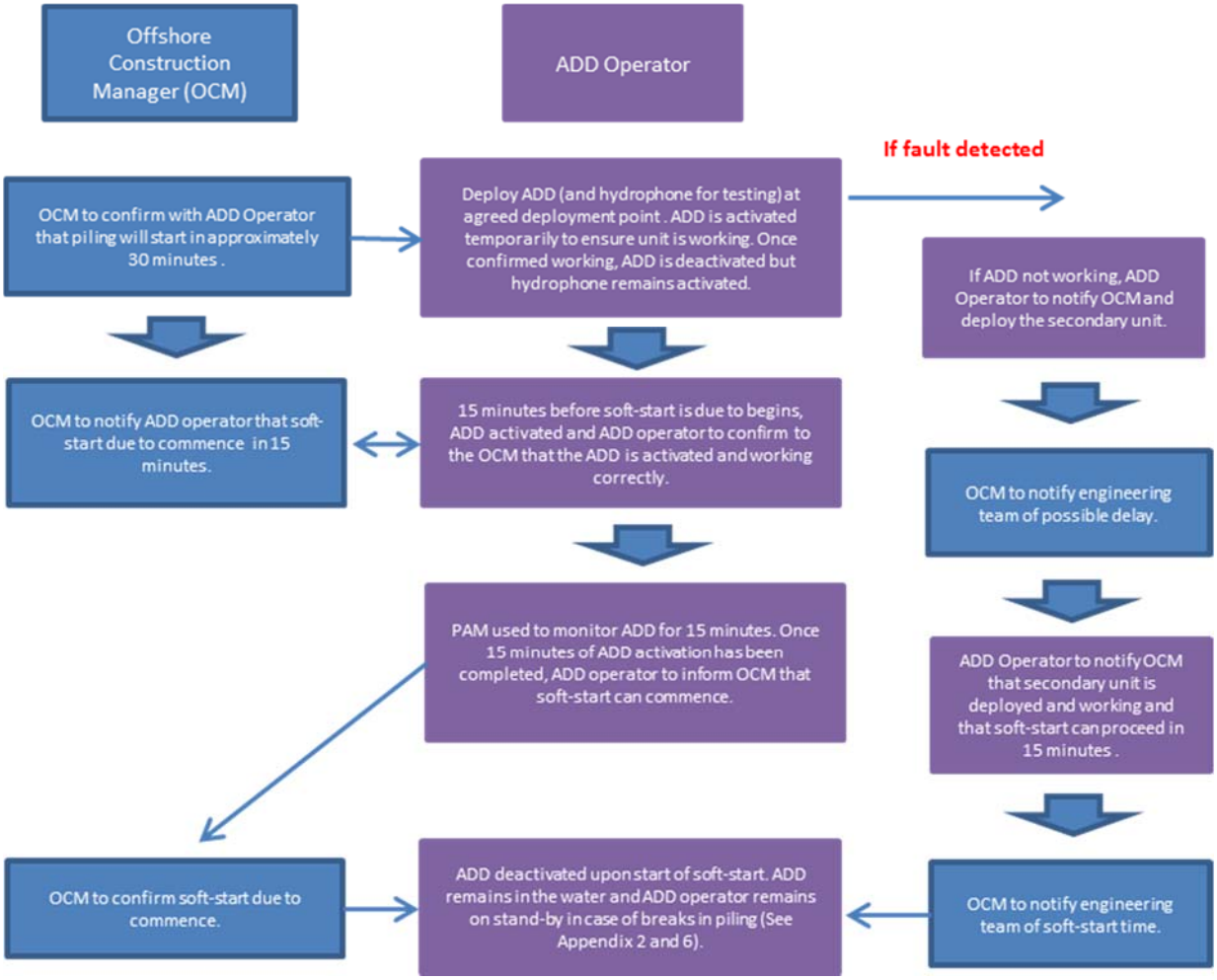


Figure 5: Task plan for undertaking mitigation using ADDs following the procedure described in the Piling Mitigation Protocol.

5 Equipment

5.1 MMOs

MMOs will be equipped with binoculars, a range finding stick and the amended JNCC Marine Mammal Recording Forms.

5.2 PAM

For Stage 1 and Stage 2 operations the PAM equipment will comprise a single hydrophone, calibrated in the laboratory in order to test the sensitivity of the system and ensure repeatability with the construction MMMP. The hydrophone would be connected to a laptop via a base unit. The laptop would be installed with PAMGuard which will be used for live monitoring. Outwith the protocol for phased mitigation, mitigation will be undertaken as outlined in the Piling Protocol (Appendix 2).

5.3 ADD

The device identified in MORL's Piling Strategy for carrying out the Piling Protocol is the Lofitech Seal Scarer (http://www.lofitech.no/en/seal-scarer.html). Further information on this device is included in Appendix 6 (Acoustic Deterrent Device Procedure). A single device with single underwater speaker will be used for mitigation, although a spare ADD device and spare batteries will be carried on board the vessel in the event of equipment failure.

6 Reporting

During the phased piling mitigation period (Stages 1 and 2), MORL propose to report to MS-LOT and MSS on the mitigation described in this Phased Piling Mitigation Strategy on a weekly basis. This reporting will include the following information as set out in the JNCC (2010) guidance;

- Amended JNCC Marine Mammal Reporting Forms completed by the MMOs, including information on any species present, number of animals, distance from installation vessel and behaviour during pre-piling watches (including during soft start piling and ADD deployments during Stage 1 (during periods of bad weather and night time operations) and Stage 2);
- Details of PAM equipment used, recording of detections using PAMGuard supplied as .wav files, log of acoustic detections in amended JNCC Marine Mammal Reporting Form completed by the PAM/ADD Operator, including information on time and location of detection and species or species group;
- Marine Mammal Reporting Forms completed by the MMO and PAM/ADD Operator will be compiled to determine any duplicate detections (this may assist in calibrating the distance of acoustic detections);
- Date and location of the piling operations and details of the piling activity;
- A record of all occasions when piling occurred, including details of the duration of the pre- piling search and soft-start procedures, and any occasions when piling activity was delayed or stopped due to presence of marine mammals;
- Details of the ADD used, and any relevant observations on its efficacy (as set out in the JNCC (2010) protocol); and
- Details of any problems encountered during the piling process including instances of non- compliance with the Piling Protocol and this Phased Piling Mitigation Strategy (as set out in the JNCC (2010) protocol).

Upon completion of the Phased Piling Mitigation Strategy (Stages 1 and 2), MORL will provide any raw observational data that has not been provided as part of the data listed above to MS- LOT, and a report summarising the observations made. Further to this MORL will propose a meeting with MS-LOT and MSS no later than three working days before the end of Stage 2 of the Phased Piling Mitigation Period to review the data collected to date and the summary report. This will however not delay MORL in progressing piling operations in line with MORL's Piling Strategy.

7 References

BOWL (2016). Beatrice Offshore Wind Farm Consent Plan: Phased Piling Mitigation Strategy. February, 2016.

Herschel, A., Stephenson, S., Sparling, C., Sams, C., Monnington, J. (2013). Use of Deterrent Devices and Improvements to Standard Mitigation during Piling. ORJIP Project 4, Phase 1. Xodus Group Ltd. Document L-300100-S00-REPT-002.

JNCC (2010) Statutory Nature Conservation Agency Protocol for Minimising the Risk of Injury to Marine Mammals from Piling Noise. August 2010.

MORL (2016). Moray Offshore Renewables Limited: Piling Strategy. January 2016.

Thompson, P. (2015). A strategic regional Marine Mammal Monitoring Programme for assessing the population consequences of constructing the BOWL and MORL wind farm developments. 20th May 2015.