EDF RENEWABLES

Neart na Gaoithe Offshore Wind Farm

Piling Strategy

Revision 4.0

March 2021

DOCUMENT REFERENCE: NNG-NNG-ECF-PLN-0011

Neart na Gaoithe Offshore Wind Farm

Piling Strategy

Pursuant to Section 36 Consent Condition 11, Marine Licence (Generating Station) Condition 3.2.2.10 and the Marine Licence (Offshore Transmission Works) Condition 3.2.2.9

For the approval of the Scottish Ministers

Document Control

SIGN OFF		
Name (Role)	**Signature**	**Date**
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Plan Overview

Purpose and Objectives of the Plan

This Piling Strategy (PS) document has been prepared to address the specific requirements of the relevant conditions attached to the Section 36 (S36) consent and Marine Licences (collectively referred to as the Offshore consents) issued to Neart na Gaoithe Offshore Wind Limited (NnGOWL).

The overall objective of the PS is to provide detailed description of the pile installation procedures and associated mitigating during the construction of the Neart na Gaoithe Offshore Wind Farm and Offshore Transmission Works (OfTW) (collectively referred to as the Project).

All NnGOWL personnel and Contractors involved in the Project must comply with the procedures and mitigation measures presented in this PS.

Scope of the Plan

In line with the requirements of the consents conditions, and in line with industry standards and good practice, the PS provides details of the following:

- Proposed methods and expected durations of the pile installation;
- Anticipated maximum hammer energy required;
- Soft-start procedures; and
- Mitigation during the pile driving operations.

Structure of the Plan

The PS is structured as follows:

Sections 1 to 3 set out the scope and objectives of the PS, statements of compliance and provide an overview of the Project.

Section 4 summarises the design constraints, details the installation methodology and key steps of pile installation.

Section 5 confirms the key parameters including pile dimensions, hammer energies and durations.

Section 6 sets out key mitigation measures to minimise the risk of injury to the sensitive species.

Section 7 confirms that the details set out in this PS are in accordance with those assessed in the EIA.

Plan Audience

The PS document is intended to be referred to by personnel involved in the construction of the Project, including NnGOWL personnel and Contractors.

Compliance with this PS will be monitored by the NnGOWL Consents team the NnGOWL's Environmental Clerk of Works (ECoW) and the Marine Scotland Licensing and Operations Team (MS-LOT).

Plan Locations

Copies of this PS are to be held in the following locations:

- NnGOWL Project Office;
- At the premises of the pile installation Contractor acting on behalf of NnGOWL;
- NnGOWL Marine Coordination Centre; and
- With NnGOWL's ECoW.

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Acronyms and Abbreviations

TERM	DESCRIPTION
AC	Alternating Current
ADD	Acoustic Deterrent Device
AGDS	Acoustic Ground Discrimination System
CPT	Cone Penetration Test
Db	Decibel
DBHT	Decibel Values Above Hearing Threshold
DP	Dynamic Positioning
ECOMMAS	East Coast Marine Mammal Acoustic Study
ECOw	Environmental Clerk of Works
GPS	Global Positioning System
HLV	Heavy Lift Vessel
ILT	Internal Lifting Tool
JNCC	Joint Nature Conservation Committee
KHZ	Kilohertz
KV	Kilovolt
MMO	Marine Mammal Observer
MS-LOT	Marine Scotland Licensing and Operations Team
MW	Megawatt
OCV	Offshore Construction Vessel
OSP	Offshore Substation Platforms
PAM	Passive Acoustic Monitoring
PTS	Permanent Threshold Shift
RMS	Root Mean Square
ROV	Remote Operated Vehicle

TERM	DESCRIPTION
RTC	River Tweed Commission
SEL	Sound Exposure Level
SNH	Scottish Natural Heritage
SPL	Sound Pressure Level
SSCV	Semi-Submersible Crane Vessel
SSS	Side-Scan Sonar
SST	Subsea Template
SSVBM	Subsea Vertical Boring Machine
TTS	Temporary Threshold Shift
µPa	Micropascal
WDC	Whale and Dolphin Conservation

Defined Terms

TERM	DESCRIPTION
Addendum	The Addendum of Additional Information submitted to the Scottish Ministers by NnGOWL on 26 July 2018.
Application	The Environmental Impact Assessment Report, Habitats Regulations Appraisal Report and supporting documents submitted to the Scottish Ministers by NnGOWL on 16 March 2018; the Addendum of Additional Information submitted to the Scottish Ministers by NnGOWL on 26 July 2018 and the Section 36 Consent Variation Report dated 08 January 2019.
Company	Neart na Gaoithe Offshore Wind Limited (NnGOWL) (Company Number SC356223).
Consent Conditions	The terms that are imposed on the Company under the Offshore Consents that must be complied with.
Consent Plans	The plans, programmes or strategies required to be approved by the Scottish Ministers (in consultation with appropriate stakeholders) in order to discharge the Consent Conditions.
Contractors	Any Contractor/Supplier (individual or firm) working on the Project.
EIA Report	The Environmental Impact Assessment Report, dated March 2018, submitted to the Scottish Ministers by NnGOWL as part of the Application.
Inter-array Cables	The offshore cables connecting the wind turbines to one another and to the OSPs.

TERM	DESCRIPTION
Interconnector Cables	The offshore cables connecting the OSPs to one another.
Marine Licences	The written consents granted by the Scottish Ministers under the Marine (Scotland) Act 2010, for construction works and deposits of substances or objects in the Scottish Marine Area in relation to the Wind Farm (Licence Number 06677/19/0) and the OfTW (Licence Number 06678/19/1), dated 4 June 2019 and 5 June 2019 respectively.
Offshore Consents	The Section 36 Consent and the Marine Licences.
Offshore Export Cable Corridor	The area within which the offshore export cables are to be located.
Offshore Export Cables	The offshore export cables connecting the OSPs to the landfall site.
OfTW	The Offshore Transmission Works comprising the OSPs, offshore interconnector cables and offshore export cables required to connect the Wind Farm to the Onshore Transmission Works at the landfall.
OfTW Area	The area outlined in red and blue in Figure 1 attached to Part 4 of the OfTW Marine Licence.
OnTW	The onshore transmission works from landfall and above Mean High Water Springs, consisting of onshore export cables and the onshore substation.
Project	The Wind Farm and the OfTW.
Section 36 Consent	The written consent granted on 3 December 2018 by the Scottish Ministers under Section 36 of The Electricity Act 1989 to construct and operate the Wind Farm, as varied by the Scottish Ministers under section 36C of the Electricity Act 1989 on 4 June 2019.
Section 36 Consent Variation Report	The Section 36 Consent Variation Report submitted to the Scottish Ministers by NnGOWL as part of the Application as defined above on 08 January 2019.
Subcontractors	Any Contractor/Supplier (individual or firm) providing services to the Project, hired by the Contractors (not NnGOWL).
Wind Farm	The offshore array as assessed in the Application including wind turbines, their foundations and inter-array cabling.
Wind Farm Area	The area outlined in black in Figure 1 attached to the Section 36 Consent Annex 1, and the area outlined in red in Figure 1 attached to Part 4 of the Wind Farm Marine Licence.

Consent Plans

CONSENT PLAN	ABBREVIATION	DOCUMENT REFERENCE NUMBER
Decommissioning Programme	DP	NNG-NNG-ECF-PLN-0016
Construction Programme and Construction Method Statement	CoP and CMS	NNG-NNG-ECF-PLN-0002
Piling Strategy	PS	NNG-NNG-ECF-PLN-0011
Development Specification and Layout Plan	DSLP	NNG-NNG-ECF-PLN-0003
Design Statement	DS	NNG-NNG-ECF-PLN-0004
Environmental Management Plan	EMP	NNG-NNG-ECF-PLN-0006
Operation and Maintenance Programme	OMP	NNG-NNG-ECF-PLN-0012
Navigational Safety Plan and Vessel Management Plan	NSVMP	NNG-NNG-ECF-PLN-0010
Emergency Response Cooperation Plan	ERCoP	NNG-NNG-ECF-PLN-0015
Cable Plan	CaP	NNG-NNG-ECF-PLN-0007
Lighting and Marking Plan	LMP	NNG-NNG-ECF-PLN-0009
Project Environmental Monitoring Programme	PEMP	NNG-NNG-ECF-PLN-0013
Fisheries Management and Mitigation Strategy	FMMS	NNG-NNG-ECF-PLN-0008
Written Scheme of Investigation and Protocol for Archaeological Discovery	WSI&PAD	NNG-NNG-ECF-PLN-0005
Construction Traffic Management Plan	CTMP	NNG-NNG-ECF-PLN-0014

1 Introduction

1.1 Background

1. The Neart na Gaoithe Offshore Wind Farm (Revised Design) received consent under Section 36 of the Electricity Act 1989 from the Scottish Ministers on 03 December 2018 and was granted two Marine Licences by the Scottish Ministers, for the Wind Farm and the associated Offshore Transmission Works (OfTW), on 03 December 2018. The S36 consent and Wind Farm Marine Licence were revised by issue of a variation to the S36 Consent and Marine Licence 06677/19/0 on 4 June 2019, and the OfTW Marine Licence by the issue of Marine Licence 06678/19/1 on the 5 June 2019 and most recently by the issue of Marine Licence MS-00008954 on the 12 October 2020. The revised S36 Consent and associated Marine Licences are collectively referred to as 'the Offshore Consents'.
2. The Project is being developed by Neart na Gaoithe Offshore Wind Limited (NnGOWL).

1.2 Objectives of the Plan

3. The S36 Consent and Marine Licences contain a variety of conditions that must be discharged through approval by the Scottish Ministers prior to the commencement of any offshore construction works. One such requirement is the approval of a Piling Strategy (PS) setting out the key pile installation parameters and an associated mitigation strategy. The relevant conditions setting out the requirement for a PS and which are to be discharged by this PS, are presented in full in Table 1-1. This PS is intended to allow the complete discharge of these conditions.

Table 1-1 : PS consent conditions to be discharged by this Consent Plan

OFFSHORE CONSENTS REFERENCE	CONDITION TEXT	WHERE ADDRESSED
Section 36 Consent Condition 11	The Company must, no later than six months prior to the Commencement of the Project, submit a Piling Strategy ("PS"), in writing, to the Scottish Ministers for their written approval.	This document sets out the PS for approval by the Scottish Ministers
	Such approval may only be granted following consultation by the Scottish Ministers with Scottish Natural Heritage (SNH), River Tweed Commission ("RTC"), Whale and Dolphin Conservation ("WDC"), Scottish Borders Council and any such other advisors or organisations as may be required at the discretion of the Scottish Ministers.	Consultation to be undertaken by the Scottish Ministers
	The PS must include, but not be limited to: a. Details of expected noise levels from pile-drilling/driving in order to inform point d. below;	Section 6.2
	b. Full details of the proposed method and anticipated duration of piling to be carried out at all locations;	Section 4 and Section 5
	c. Details of soft-start piling procedures and anticipated maximum piling energy required at each pile location; and	Section 6.3.4 and 5.3 respectively
	d. Details of any mitigation such as Passive Acoustic Monitoring ("PAM"), Marine Mammal Observers ("MMO"), use of Acoustic	Section 6

OFFSHORE CONSENTS REFERENCE	CONDITION TEXT	WHERE ADDRESSED
	Deterrent Devices ("ADD") and monitoring to be employed during pile-driving, as agreed by the Scottish Ministers.	
	The PS must be in accordance with the Application and must also reflect any monitoring or data collection carried out after submission of the Application.	Section 7
	The PS must demonstrate how the exposure to and/or the effects of underwater noise have been mitigated in respect to harbour porpoise, minke whale, bottlenose dolphin, harbour seal, grey seal, Atlantic salmon and sea trout.	Section 6
	The PS must, so far as is reasonably practicable, be consistent with the Environmental Management Plan ("EMP"), the Project Environmental Monitoring Programme ("PEMP") and the Construction Method Statement ("CMS").	Section 1.3
Wind Farm Marine Licence Condition 3.2.2.10 and OfTW Marine Licence Condition 3.2.2.9	The Licensee must, no later than six months prior to the Commencement of the Works, submit a PS, in writing, to the Licensing Authority for their written approval.	This document sets out the PS for approval by the Scottish Ministers
	Such approval may only be granted following consultation by the Licensing Authority with SNH, RTC, WDC, Scottish Borders Council and any such other advisors or organisations as may be required at the discretion of the Licensing Authority. Commencement of the Works may not take place until such approval is granted.	Consultation to be undertaken by the Scottish Ministers
	The PS must include, but not be limited to: a. Details of expected noise levels from pile-drilling/driving in order to inform point d below;	Section 6.2
	b. Full details of the proposed method and anticipated duration of piling to be carried out at all locations;	Section 4 and Section 5
	c. Details of soft-start piling procedures and anticipated maximum piling energy required at each pile location; and	Section 6.3.4 and 5.3 respectively
	d. Details of any mitigation such as Passive Acoustic Monitoring, MMO, use of Acoustic Deterrent Devices and monitoring to be employed during pile-driving, as agreed by the Licensing Authority.	Section 6
	The PS must be in accordance with the Application and must also reflect any monitoring or data collection carried out after submission of the Application.	Section 7
	The PS must demonstrate how the exposure to and/or the effects of underwater noise have been mitigated in respect to harbour porpoise, minke whale, bottlenose dolphin, harbour seal, grey seal, Atlantic salmon and sea trout.	Section 6

OFFSHORE CONSENTS REFERENCE	CONDITION TEXT	WHERE ADDRESSED
	The PS must, so far as is reasonably practicable, be consistent with the EMP, the PEMP and the CMS.	Section 1.3

1.3 Linkages with other Consent Plans

4. This PS forms part of a suite of approved documents that provide the framework for managing and mitigating the environmental effects of construction. Condition 11 of the S36 consent, Condition 3.2.2.10 of the Wind Farm Marine Licence and Condition 3.2.2.9 of the OfTW Marine Licences (see Table 1-1 above) require this PS to be, as far as reasonably practicable, consistent with the following consent plans:

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

5. Linkages between the Consent Plans are detailed in Table 1-2.

Table 1-2: PS linkages with other Consent Plans (and consent conditions)

OFFSHORE CONSENT REFERENCE	CONSENT PLAN	LINKAGES WITH PS
Section 36 Consent, Condition 14 **Wind Farm Marine Licence, Condition 3.2.2.11** **OfTW Marine Licence Condition 3.2.2.10**	**Environmental Management Plan (EMP)**	The EMP sets out the environmental management framework for the construction and operation of the Project. This will provide the overarching environmental management framework setting out procedures to be applied during these phases. In addition to the mitigation detailed within this PS, the relevant parts of the EMP will be adhered to during the construction of the Project.
Section 36 Consent, Condition 23 **OfTW Marine Licence, Condition 3.2.2.14**	**Project Environmental Monitoring Programme (PEMP)**	A PEMP details the intended pre-construction, construction (if appropriate) and post-construction monitoring of marine mammals.
Section 36 Consent, Condition 10 **Wind Farm Marine Licence, Condition 3.2.2.8** **OfTW Marine Licence, Condition 3.2.2.7**	**Construction Method Statement (CMS)**	The CMS describes the construction of the Project. This sets out the construction procedures and good working practices for installing the Project and provides an overview of pile installation; further detail on installation methods is provided in this PS.

1.4 PS Document Structure

6. This document seeks to satisfy the consent conditions set out in Table 1-1. This PS describes how pile installation will be phased throughout construction and how species listed in the consent conditions have been taken into account.

7. The structure of this PS is summarised in Table 1-3 below.

Table 1-3: PS document structure

SECTION	TITLE	SUMMARY OF CONTENT
1	Introduction	Background to consent requirements and overview of the PS scope and structure; Identifies those other Consent Plans relevant to the environmental management process and the linkage between those plans and the PS; and Sets out the procedures for any required updating or amending the approved PS and subsequent further approval by the Scottish Ministers.
2	NnGOWL Statements of Compliance	Sets out the NnGOWL statements of compliance in relation to the PS.
3	Project Overview	Provides an overview of the Project.
4	Approach to Pile Installation	Provides detail on the design constraints considered in finalising the pile design and installation methodology and sets out key steps during the pile installation for the Project.
5	Key Piling Parameters	Confirms the key piling parameters including pile dimensions, hammer energies and durations.
6	Mitigation Strategy	Sets out key mitigation and management measures to minimise the risk of injury to the sensitive species.
7	Compliance with the Application	Confirms that the details set out in this PS are in accordance with those assessed in the EIA Report.

2 NnGOWL Statements of Compliance

8. NnGOWL (including NnGOWL's relevant contractors/subcontractors) in undertaking the construction of the Project, will comply with this PS as approved by the Scottish Ministers.

9. Where updates or amendments are required to this PS, NnGOWL will ensure the Scottish Ministers are informed as soon as reasonably practicable and where necessary the PS will be resubmitted for approval.

10. NnGOWL will comply with the limits defined by the Application and supporting documentation (referred to in Annex 1 of the S36 Consent and Part 2 of the OfTW Marine Licence in so far as they apply to this PS (unless otherwise approved in advance by the Scottish Ministers).

3 Project Overview

11. The Wind Farm Area is located to the northeast of the Firth of Forth, 15.5 km directly east of Fife Ness on the east coast of Scotland (see Figure 3-1). The Wind Farm Area covers approximately 105 km^2. Offshore Export Cables will be located within the 300 m wide Offshore Export Cable Corridor, running in an approximately southwest direction from the Wind Farm Area, making landfall at Thorntonloch beach to the south of Torness Power Station in East Lothian. Figure 3-1 shows the Wind Farm Area and Offshore Export Cable Corridor.

12. The Offshore Consents allow for the construction and operation of the following main components, which together comprise the Project:

- 54 wind turbines generating a maximum total output of around 450 Megawatts (MW);
- 54 jacket substructures installed on pre-piled foundations, to support the wind turbines;
- Two alternating current (AC) substation platforms, referred to as Offshore Substation Platforms (OSPs), to collect the generated electricity and transform the electricity from 66 kilovolts (kV) to 220 kV for transmission to shore;
- Two jacket substructures installed on piled foundations, to support the OSPs;
- A network of inter-array subsea cables, buried and/or mechanically protected, to connect strings of turbines together and to connect the turbines to the OSPs;
- One interconnector cable connecting the OSPs to each other;
- Two buried and/or mechanically protected subsea export cables to transmit the electricity from the OSPs to the landfall at Thorntonloch and connecting to the onshore buried export cables for transmission to the onshore substation and connection to the National Grid network; and
- Minor ancillary works such as the deployment of metocean buoys and permanent navigational marks.

13. Offshore construction commenced in August 2020. Details of the construction programme are provided in the Construction Programme and Construction Method Statement (CoP and CMS).

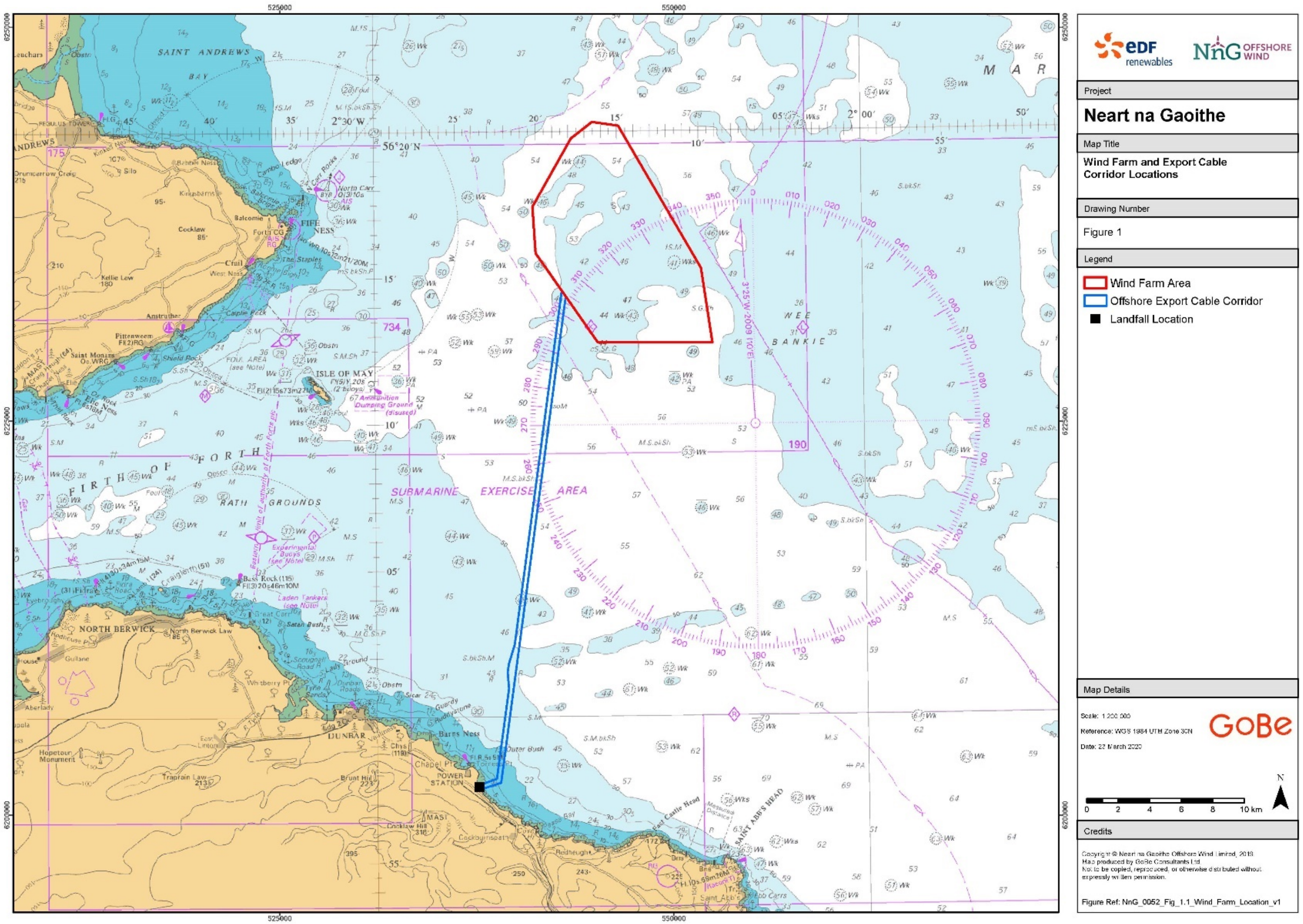

Figure 3-1: Wind Farm Area and Offshore Export Cable Corridor locations

4 Approach to Pile Installation

4.1 Introduction

14. This chapter summarises the pile installation methods for the turbine and OSP jackets. It also summarises the information which has informed these methods.

15. Further details on the construction processes associated with jacket and turbine installation and the inter-array, interconnector and export cables are set out in the CoP and CMS and the CaP.

4.2 Pile Design and Installation Considerations

16. NnGOWL has undertaken a number of geophysical and geotechnical surveys to determine seabed conditions. The survey data has been reviewed by NnGOWL engineers and contractors in order to identify the most suitable means of pile installation for the Project. Table 4-1 summarises the surveys which have been used to develop the pile installation methodology and inform this PS.

Table 4-1: Details the type of surveys conducted in relation to the PS

DATA SOURCE	COVERAGE	DATA USE	DATE
Geophysical surveys	Within and around the Wind Farm Area and Offshore Export Cable Corridor	Side Scan Sonar (SSS), Acoustic Ground Discrimination System (AGDS) and swath bathymetry. Data used to inform site development (e.g. identification of a likely layout) and Environmental Impact Assessment.	2009
Geotechnical surveys	Within and around the Wind Farm Area	Cone Penetration Tests (CPTs), vibrocores and borehole sampling. Data used to inform site development and Environmental Impact Assessment.	2010
Sub-tidal benthic survey	Within and around the Offshore Wind Farm Area and Export Cable Route Corridor.	Sub tidal sampling comprising of 0.1 m^2 Hamon grab for quantitative faunal and sediment analysis, seabed digital images collected using drop down video, 2 m epibenthic beam trawls and 0.04 m^2 Shipek grab for contaminant analysis. Data used to inform Environmental Impact Assessment.	2009
Intertidal biotope mapping survey	500 m cable corridor at the landfall location at Thorntonloch	Intertidal Global Positioning System (GPS) biotope mapping survey, core sampling and dig over survey to identify habitat distribution. Data used to inform Environmental Impact Assessment.	2009
Habitat mapping	Within and around the Offshore Wind Farm Area, Export Cable Route Corridor and landfall location.	Interpretation of sub-tidal and intertidal benthic datasets for biotope classification and mapping. Data used to inform Environmental Impact Assessment.	2009
Preliminary assessment of coarse sediment benthic habitats	Within and around the Offshore Wind Farm area.	Data interpretation to determine potential presence of geogenic stony reef. Data used to inform Environmental Impact Assessment.	2011
Geotechnical surveys	Offshore Wind Farm Area and Offshore Export Cable Corridor	CPTs within the Wind Farm Area and CPTs and vibrocores along the offshore export cable corridor.	2012

DATA SOURCE	COVERAGE	DATA USE	DATE
		Data used to inform site development.	
Geotechnical Survey	Offshore Wind Farm Area	Boreholes to inform site development, pile installation and design.	2014
Geophysical Survey	Offshore Wind Farm Area focusing on lines orientated along rows of turbines following a north west to south east orientation.	Multibeam echosounder and SSS. Data used to inform site development, pile installation and design.	2015
Geotechnical Survey	Offshore Wind Farm Area	Boreholes and CPTs. Data used to inform detailed pile design and installation (e.g. pile drivability assessment).	2018
Geophysical Survey	Offshore Wind Farm Area focused on intended works/infrastructure locations, and the Export Cable Corridor.	Multibeam echosounder, SSS, magnetometer and sparker. Data used to inform pile design and installation and identify seabed preparation requirements and micro-siting tolerances. Data also analysed to refine Archaeological Exclusion Zones.	2019
Geotechnical Survey	Offshore Wind Farm Area	Boreholes. Data used to inform detailed pile design and installation (e.g. pile drivability assessment).	2020

17. Further geophysical and geotechnical surveys are currently being undertaken to confirm the seabed conditions. Any additional constraints identified following review of this additional survey data that results in a significant change to the pile installation methods, will be addressed through an update to this PS.

4.3 Overview of Pile Installation Methods

18. A review of the geophysical and geotechnical data has identified a layer of sedimentary deposits of varying depths overlying bedrock. A detailed analysis of the data has confirmed that the following methods of pile installation will be used:

- Drill-only, whereby casings and piles will be fully installed using a drilled method; and
- Drive-drill-drive, whereby the casings will be installed using driving and drilling. Piles will be installed using a drill-only method.

19. The drill-only method will be used across the majority of locations; it is currently anticipated that the drive-drill-drive method will be required at a single location. Pile and casing installation using solely driven methods will not be undertaken. This approach represents a significant reduction in the amount of driving than was assessed in the EIA (see Section 7 for further comparison with the Application).

4.3.1 Drill-only Method

20. This method involves use of a drilling tool (a Subsea Vertical Boring Machine (SSVBM)) that can move vertically beneath the seabed through a variety of ground conditions to create an empty ‘socket’ into which the pile casing and then the pile can be installed (see Section 4.5 for more detail on the casing and pile). Drilled casing and pile installation techniques have to date typically been used in combination with driven techniques (e.g. in the drive-drill-drive method as described below).

4.3.2 Drive-drill-drive Method

21. This method involves application of successive driving (using a hydraulic hammer) and drilling (using the SSVBM) phases to ensure the sacrificial casing is installed to target depth, and then drilling is undertaken to deepen the socket to pile target depth.

4.3.3 Rationale for Use of Alternative Methods

22. The drive-drill-drive installation method is required at a single location for the following reasons. Firstly, ground conditions mean that the pushing force required to jack the casing into the seabed is greater than the jacking capacity of the SST and SSVBM, which are limited to the weight of the SST. Secondly, the length of casings are required to be beyond the installation capability of the SSVBM and SST.

4.4 Components to be Installed

23. The pile foundations will comprise two main elements: a steel tubular casing which will be installed first and then the steel pile which will be installed through the casing and rock socket. The dimensions of these are summarised in Table 4-2.

Table 4-2: Summary of foundation components to be deposited or installed

COMPONENT	NUMBER	KEY DIMENSIONS
Turbine and OSP foundation casings	56 x 3	Outer diameter: up to 3.5m Average Length: 11.5m
Turbine and OSP foundation piles	56 x 3	Pile Outer Diameter: Up to 3.2 m Pile Length: up to 60 m

4.5 Pile Installation Method

24. This section summarises intended operations, from vessel set up through to the pile installation and finishing with jacket substructure installation (Figure 4-1). Further detail on each of the stages in the process (Stage 1 – 6) is provided in the subsequent sections. Durations are set out separately under Section 5.4.

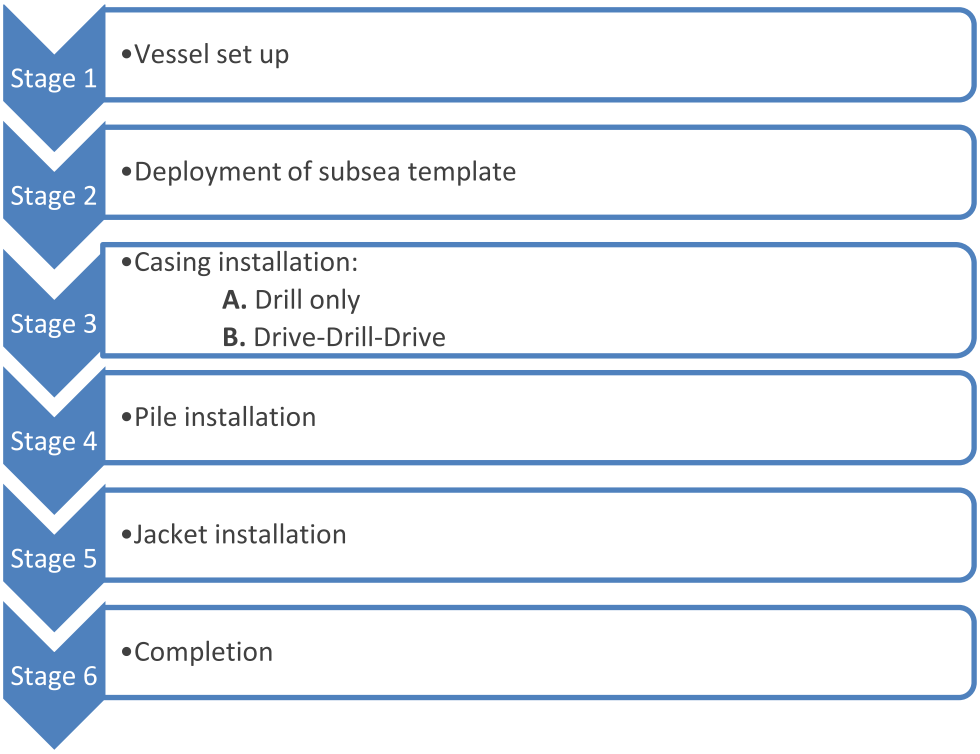

Figure 4-1: Pile foundation (and jacket substructure) installation sequence.

25. Stages 1 – 2 and 4 –6 will be the same for the drill-only and drive-drill-drive installation methods of the pile installation methods being used. Stage 3A sets out the casing installation scenario using a drill-only method. Stage 3B outlines the alternative solution using a drive-drill-drive technique. An indicative number of locations at which each method will be employed is set out in Table 4-3 below; the number of drive-drill-drive locations is not expected to be exceeded.

Table 4-3: Number of locations using each pile installation method

METHOD	NUMBER OF PILE LOCATIONS
Drill-only	55 x 3
Drive-drill-drive	1 x 3

4.5.1 Stage 1 - Vessel Set Up

26. A Semi-Submersible Crane Vessel (SSCV) will be mobilised to the Wind Farm Area with all installation equipment on board. Dynamic positioning (DP) will be used to ensure the SSCV is in the correct position.

27. The piles will be delivered to the SSCV using a Heavy Lift Vessel (HLV). The HLV will also assist with post-installation surveys.

28. The installation vessel will require several support vessels.

29. The SSCV arrives at the proposed turbine location and is positioned in readiness for the foundation pile installation works. Note that seabed surveys may be performed prior to vessel set-up to ensure the

seabed is clear of debris that could be hazardous to pile installation operations. Survey work may be carried out from the SSCV or from the HLV or another support vessel.

30. The SSCV activates its DP system which will be used to maintain position during installation of the piles.

4.5.2 Stage 2 – Deployment of the Subsea Template (SST)

31. Casing installation will be guided by a SST placed on the seabed by the SSCV crane and then self-levelled to accommodate seabed slopes, an illustration of which is shown in Figure 4-2. The SST will be used to temporarily stabilise and handle the pile casings.

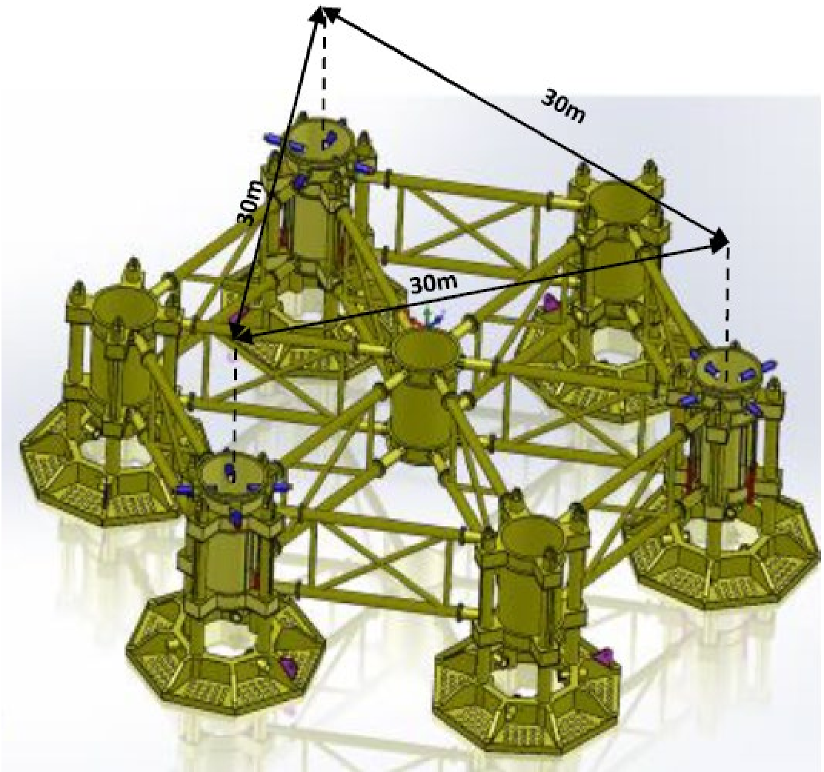

Figure 4-2: Illustration of SST

4.5.3 Stage 3A – Casing (Drill-only Method)

32. Steel 'casings' (steel tubulars) will be used to prevent loose soil and fractured rock layers from collapsing into the rock socket.

33. Once the SST is in position, the SSCV crane will lift a casing and place this onto the drill string that will be used to drill the pile socket. The casing and drill string will then be lowered through a sleeve of the SST and into the seabed sediment (Figure 4-3). The casing will penetrate the seabed sediment under its own weight and be further installed into the seabed using a rack and pinion system (i.e. a circular gear that when actuated travels vertically along a toothed upright) integrated with the drill and SST. The drill has an under-reaming capability and is used to enlarge the socket below the casing and in harder ground conditions, enabling further penetration of the casing into the seabed to the desired depth.

34. The SST will be fitted with guide that can be controlled by a rack and pinion system to control the verticality of the casing. Once the casing is at target depth and stable, the drill tool progresses to drill the pile socket to the target depth. Drill spoil will be released into the water column at the top of the drill tool. Once the target socket depth is achieved the drill is recovered and this process is then repeated for the remaining sockets required at that location.

35. At this stage it is anticipated that the installed casings will be left in situ for a period of approximately twelve months before piles are installed. A post-installation survey will take place to ensure that the casing has reached the required depth, and that the socket profile is as per the design. A Sonar Calliper Tool (SCT) will survey each socket. This tool uses sonar (operating at a frequency of 2MHz; beyond the range at which all marine mammals can detect sound) to create a 3D profile of the socket, and the survey of each socket would take approximately one hour.

36. When the SSCV has installed all casings loaded out at first mobilisation, a Platform Supply Vessel (PSV) will deliver additional casings to the Wind Farm Area. Both vessels will maintain positioning using DP and the casings will be loaded onto the SSCV by crane.

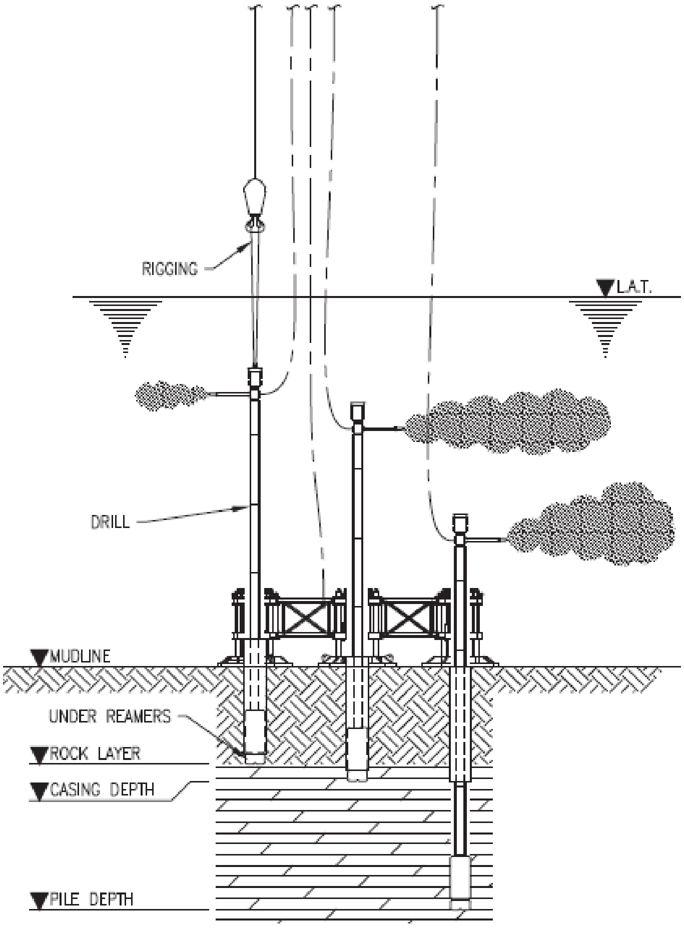

Figure 4-3: Illustration of drilling operations

4.5.4 Stage 3B – Casing Installation (Drive-Drill-Drive Method)

37. Where installation is by drive-drill-drive, the casing will be placed into the SST using an ILT and will penetrate the seabed under its own weight. A follower (a member between the hammer and the casing to transmit blows to the casing when the top of it is below the reach of the hammer) and hydraulic hammer will then be lifted onto the casing and will drive the casing to a pre-defined depth within the overburden layer (specific to each location). The follower and hammer will then be recovered and the drill will be deployed to remove the soil heave and if required perform under-reaming ahead of the casing. The drill is then recovered and the follower and hammer are deployed again to drive the casing further into the ground. This cycle is repeated until the casing reaches the target penetration. The number of cycles are case specific but it is anticipated that most locations will require one cycle.

38. The hammer is then recovered and the drill is inserted through the casing. Drilling is undertaken to remove the remaining soil plug within the casing and it continues into the bedrock until target pile penetration depth is reached.

39. At this point, the method of pile installation within the casing is as described in Section 4.5.5 below, with the pile upended and placed into the casing, and grouting undertaken.

40. Piling mitigation as detailed in Section 6.3 will be implemented throughout all casing driving operations.

4.5.5 Stage 4 – Pile Installation

41. An Offshore Construction Vessel (OCV) and a Heavy Lift Vessel (HLV) will be mobilised for the pile installation campaign. These two additional vessels will be undertaking piling works in sequence to the SSCV, which is working on the casing installation campaign.

42. In preparation for pile installation, a seabed and pre-pile survey will be completed. A visual seabed survey will be conducted by an ROV to ensure that the seabed is clear and there are no obstructions. Once it is confirmed that there are no obstructions, a pre-pile installation SCT socket survey will be completed, to assist in verifying the quantity of collapsed material, if any, within the drilled socket. This survey will verify that the socket integrity remains intact since the casing installation campaign and confirm whether the socket requires dredging.

43. If the socket survey detects loose material in the rock socket, and should the particles be less than approximately 150mm in diameter, a dredging tool will be used to extract the material. For larger diameters, a grab tool will be used. Any extracted material will be placed on the adjacent seabed. If the pre-installation surveys determine that casing cleaning is required, this will be undertaken using a specialised Cleaning Tool (CT). This high-pressure water jetting tool, assisted by the ROV, will remove marine growth on the inner surface of the casing.

44. To assist with the pile installation campaign, clump weights and shrouds will be temporarily installed on or around the pile until grouting is complete (Figure 4-4). The clump weight is a weight deployed on top of the pile to resist any pile uplift during grouting. The shroud cover is a steel structure placed over and around a pile location to prevent environmental pressure (e.g. from currents) during grouting. Clump weights might not be required at every location but the shrouds are likely to be required for each pile installation. Pile centralisation units (PCUs) per pile location will also be required to be deployed (Figure 4-5). These centralise the pile within the socket to ensure the correct spacing is achieved between all 3 No. piles and will be removed once grouting is complete.

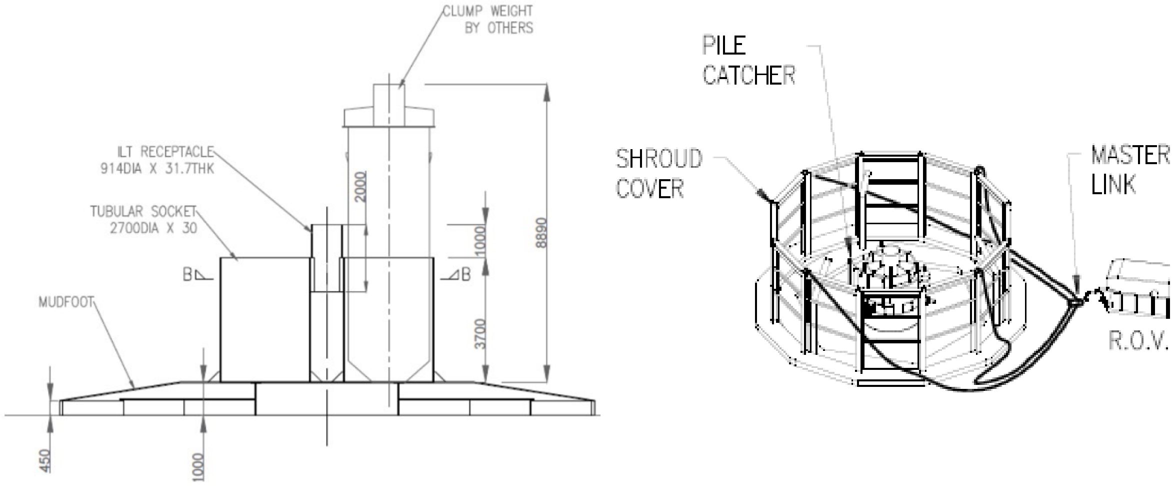

Figure 4-4 Clump Weight and Clump Weight Storage Frame (left); Shroud Cover (right)

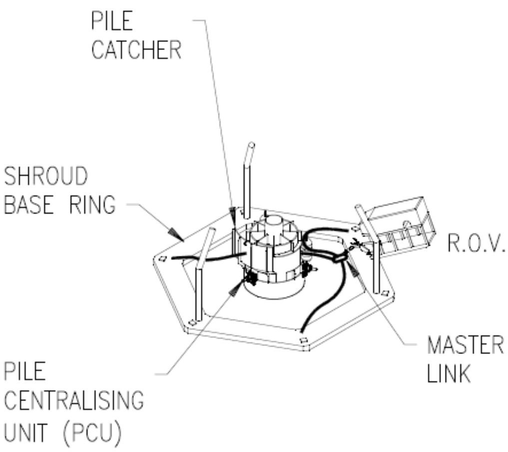

Figure 4-5 Illustration of Pile Centralisation Unit

45. The clump weights will be stored within a clump weight storage frame (CWSF), and the shrouds will be wet stored adjacent to the socket locations (Figure 4-6). The items will be positioned by the OCV, prior to arrival to the location by the pile installation HLV, to optimise the timing, avoid vessel to vessel transfers and deck space limitations.

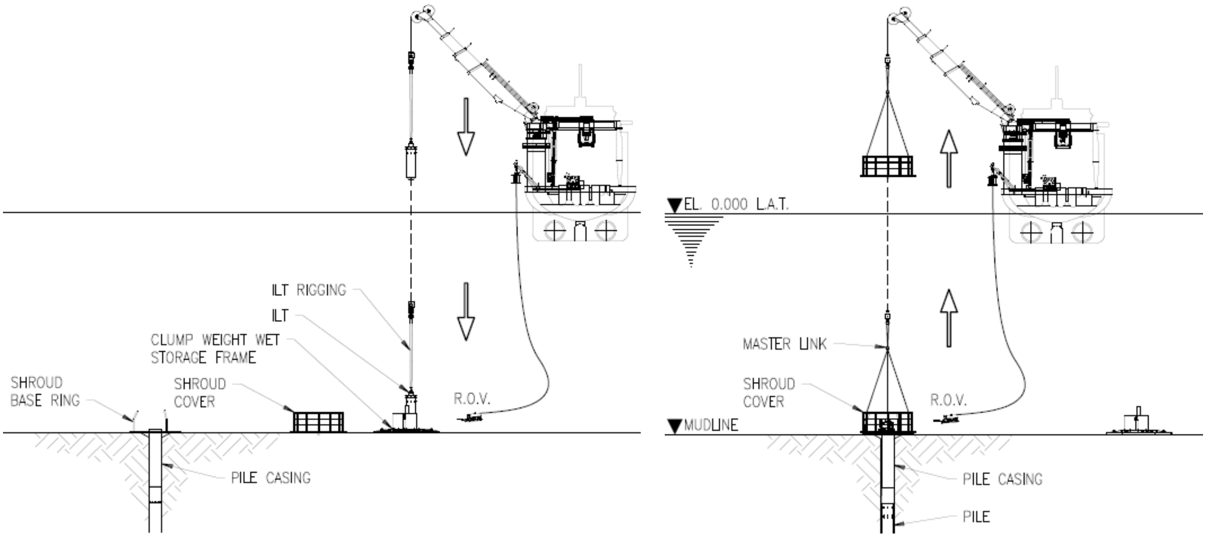

Figure 4-6 Clump weight placed in CWSF (left); Shroud cover being lifted from pile location once grout curing period complete (right)

46. For each location requiring temporary clump weight installation, three clump weights (one for each pile location) will be wet stored in the CWSF. It is expected that the CWSF will be wet stored on the seabed for approximately 10 days, weather dependent on enabling operations. There will be three sets of clump weights which will be transferred between locations, as required.

47. The subsea basket and shroud cover will be wet stored separately, at each location, in close proximity to the pile socket. Three shroud bases (one for each pile location) and nine PCUs (three for each pile location) will be wet stored at each location. It is expected that the shrouds and subsea baskets will be deployed on the seabed for approximately 10 days.

48. Once on location, the HLV will commence pile installation. The pile installation commences with the pile upended onboard the HLV by one Internal Lifting Tools (ILTs) and one upending bucket then lowered into the casing until it reaches the socket depth. Alternatively, the piles may be upended directly from a supply vessel (PSV).

49. The HLV will then collect the clump weights using an ILT, where required, directly from the seabed and deploy on to the pile. These are installed prior to grouting to counteract pile buoyancy during grouting. The three PCUs will be removed from the seabed basket and will be installed by the ROV between the casing and the pile (Figure 4-5), to ensure pile centralising within the socket.

50. Once all three piles for the location have been secured, a survey will be completed prior to grouting to confirm final positions. The shroud cover will then be lifted from the wet-stored location and be installed on each pile, to reduce loading during the grout curing.

51. Grouting operations will commence by pumping grout, from onboard vessel silos through a grout tool into the internal grout system. Pre-fitted grout sensors will monitor the grout levels to determine when the grout reaches the required level.

52. Once a sufficient grout curing period has been completed, for a minimum of 24 hours, the clump weights, PCUs and shrouds will be collected by the OCV and relocated to the next location.

53. When all piles loaded out at first mobilisation have been installed, a PSV will deliver additional piles and grout silos to the Wind Farm Area. Both vessels will maintain positioning using DP and the piles and grout silos will be loaded onto the HLV. Alternatively, the PSV may be moored to the HLV and piles upended directly from the PSV and installed into the sockets.

4.5.6 Stage 5 - Jacket Installation

54. Once piling is complete at all locations, the SSCV will prepare for the installation of the jacket substructures onto the pre-installed piles. For jacket installation the SSCV may be supported by two OCVs. Further details on the jacket substructure installation process are set out in the CoP and CMS.

4.5.7 Stage 6 – Completion and Post-Construction Inspection

55. Personnel on the jacket will install aids to navigation in accordance with the NnGOWL Lighting and Marking Plan (LMP) and to cover the installation flange. A post installation Remote Operated Vehicle (ROV) survey will also be conducted from the OCV to confirm that the pile connections are all intact.

4.6 Foundation Installation Programme

56. Details on the timing of the overall construction programme are provided in the CoP and CMS.

57. It is anticipated that casing installation will take place first. To match the supply of piles and jackets, the installation campaign for the piles will be split into multiple smaller campaigns to prioritise installation of jackets when they become available. It is currently envisaged that pile installation will be split into three campaigns.

5 Key Piling Parameters

5.1 Introduction

58. The section below sets out the anticipated maximum piling energy (Section 5.3) and durations (Section 5.4). Soft-start procedures are summarised in Section 5.5.

5.2 Pile Foundation Parameters

59. Table 5-1 sets out the key pile dimensions associated with each turbine and OSP foundation.

Table 5-1: Details of piling parameters

DESIGN FEATURE	PARAMETER
Maximum number of pin piles per jacket structure	3
Maximum casing diameter (m)	Up to 3.5
Maximum pile diameter (m)	Up to 3.2
Maximum embedded length of pile (m)	50
Maximum distance between piles within a jacket foundation (m)	30

5.3 Maximum Hammer Energies

60. The maximum hammer energy permitted under the Offshore Consents is 1635 kJ as set out in the Application. Analysis of geotechnical data as detailed under Section 4.2 has determined a maximum hammer energy of 1635 kJ will be sufficient to drive the pile casings to the required depth at all of the locations where the drive-drill-drive method will be employed. Hammer energies will be optimised at each location to minimise hammer energies as far as possible.

5.4 Duration of Pile Installation

61. Analysis of geotechnical data has been undertaken to determine maximum installation durations. Table 5-2 sets out durations for each of the pile installation methods.

Table 5-2: Approximate installation durations of pile and casing installation

PILING ACTIVITY	DRILL-ONLY METHOD	DRIVE-DRILL-DRIVE METHOD
Number of foundation locations	55	1
Installation of three pin piles (hours) (i.e. a single foundation location)	140	220
Duration of impact pile installation per foundation with three pin piles	Not applicable	Up to 12 hours split over 6 discrete events (i.e. two rounds of 'driving' at each of the three pin pile locations)
Cumulative duration of impact piling (hours)	Not applicable	12

5.5 Soft-start and Ramp-up

62. At commencement of each drive (including recommencement following stoppage or interruption), the hammer energy will be limited to 360 kJ and will be operated in single blow mode in order to deter the presence of any marine mammals in the vicinity. The hammer energy will be maintained, at no more than 360 kJ for 30 minutes at a reduced blow rate.

63. Thereafter, the hammer energy will be increased incrementally to an optimised hammer energy for that pile location.

6 Mitigation Strategy

6.1 Introduction

64. This section sets out NnGOWL's proposed approach to mitigating the effects of noise from pile installation taking account of the likely sound levels associated with both the drill-only and drive-drill-drive installation methods.

6.2 Expected Noise Levels

65. To inform and provide context to the mitigation strategy, this section sets out predicted noise levels arising from drill-only and drive-drill-drive methods and considers their effects on the species listed in the Offshore Consents, namely: harbour porpoise, bottlenose dolphin, minke whale, harbour seal, grey seal, Atlantic salmon and sea trout.

6.2.1 Drill-only Method

66. To determine the requirement for mitigation associated with the drill only installation method, a desk-based study of noise levels associated with offshore drilling operations has been undertaken. Reported noise levels were subsequently compared with levels likely to cause an effect to sensitive marine species including marine mammals and fish (see Sections 6.2.3 and 6.2.4).

67. Sound generated during drilling will be transmitted into the water column through two mechanisms: either by sound transmitted from the drill-bit sediment interface and into surrounding seabed layers, or through vibrations which travel up the drill shaft and into the water column (Kongsberg, 2015).

68. Underwater noise associated with pile drilling have been measured in several studies and these are summarised in Table 6-1. These published studies identify the measurements of sound levels for drilling activity as varying between 100 to 162 dB re 1 µPa (rms) at ranges of between 1 m and 179 m from the drilling operation.

Table 6-1: Summary of reports documenting foundation drilling operations

SOURCE TYPE	ACTIVITY	REPORTED NOISE MEASUREMENT	MEASUREMENT BANDWIDTH (KHZ)	NOISE CHARACTERISTICS	REFERENCE
Drill Ship – converted freighter	Logging	125 dB (rms) re 1 µPa @ 170 m	0.02-1	Continuous tones up to 1850 Hz	Greene, 1987
	Drilling	134 dB (rms) re 1 µPa @ 200 m	0.02-1	Continuous strong tones at 277 Hz	
Drill Ship '*West Navion*' 250 m long	Drilling	195 dB (rms) re 1 µPa @ 1 m	0.001-139	Continuous low frequency 100-400 Hz band	Nedwell and Edwards, 2004
	Active not drilling	117 dB (rms) re 1 µPa @ 125 m	0.01-10	Continuous low frequency	McCauley, 1998

SOURCE TYPE	ACTIVITY	REPORTED NOISE MEASUREMENT	MEASUREMENT BANDWIDTH (KHZ)	NOISE CHARACTERISTICS	REFERENCE
Semi-Submersible	Drilling	115 dB (rms) re 1 µPa @ 405 m	0.01-10	Tones produced from drill string in low frequency bands <70 Hz	
Platform	Drilling, production and water injection	162 dB (rms) re 1 µPa @ 1 m	0.01-10	Broadband noise	Hannay et al. 2004
	Drilling	148 dB (rms) re 1 µPa @ 1 m	Not available	Not available	Bach et al. 2013
Jack up platform	Pile drilling at Strangford Lough Tidal device to 7.4 m	139 dB re 1 µPa (rms) at 28 m; Source Level of 162 dB re 1 µPa at 1 m	7 Hz to 80 kHz	Frequency components of 20 Hz to 100 Hz	Nedwell and Brooker, 2008
Jack up platform	Drilling of anemometry hub foundation	100 dB re 1 µPa (rms)	Not reported	Highest sound levels between 100hz – 600 hz	Broudic et al, 2014
Large diameter drill rig	Installation of Oyster 800 Array wave energy devices, Orkney	153.8 ± 12.1 dB re 1 Pa at 1m	Not available	Not available	Kongsberg, 2011 (Cited from Xodus, 2015)

69. Although underwater sound levels increase during periods of drilling in comparison to non-drilling periods, the sound levels during these periods are still relatively low (and certainly when compared to conventional piling operations for example) (Genesis, 2011).

70. Southall et al. (2007) found sound levels from all types of drilling platforms were all below the threshold levels for TTS in cetaceans and pinnipeds. From the available information on noise measurements, drillships are considered to produce the highest sound levels in comparison to semi-submersibles and fixed platforms, with a maximum SPL of 195 dB re 1 µPa @ 1 m (rms). Semi-submersibles, equivalent to the sub-surface drilling methods that will be used during pile drilling for the Project, and fixed drilling platforms produce relatively low sound levels and are predominantly low frequency (Table 6-1) (Genesis, 2011).

71. The study by Nedwell and Brooker (2008), which reported on pile drilling operations during the installation of a tidal stream device at Strangford Lough, indicated that the levels of underwater noise recorded were comparable with small vessel noise and at 800 m from the source the underwater noise was recorded at the same level or below ambient noise levels (Table 6-2).

Table 6-2: Summary of behavioural avoidance ranges of decibel values above Hearing Threshold (dBht) from foundation drilling operations of the SeaGen tidal turbine, (taken from Nedwell and Brooker, 2008)

SPECIES	75 DBHT MILD AVOIDANCE RANGE	50 DBHT LOW LIKELIHOOD OF DISTURBANCE RANGE	RANGE TO PERCEIVED BACKGROUND LEVELS
Cod	2.5 m	75 m	750 m
Dab	1 m	16 m	600 m
Herring	3 m	115 m	550 m
Trout	<1 m	<1 m	-
Harbour seal	1.5 m	85 m	100 m

6.2.2 Drive-drill-drive Method

72. The sound levels reported for drilling activity will be considerably lower than those recorded during conventional pile driving operations. The literature records source levels for pile driving in the range of approximately 210 – 250 dB re 1 µPa-m from the source of pile-driving (Bailey et al., 2010; McHugh, 2005; Thomsen et al., 2006; Tougaard et al., 2009) at a frequency of predominantly <1 kilo Hertz (kHz) and can extend to at least 100 kHz (Tougaard et al., 2009).

73. The worst-case scenario considered in the Application (which was set out for a drive only scenario rather than a drive-drill-drive scenario) identified that a maximum hammer energy of 1635 kJ would generate a source peak sound pressure level (SPL) of 242.5 dB re 1 µPa-m and a sound exposure levels (SEL) of 219.4 dB re 1 µPa^{2}s-m. Following submission of the Application additional noise modelling has been undertaken to explore the implications of using increased hammer energies of between 1,850 kJ and 2,500 kJ and a peak SPL of between 245.1 and 246.4 dB re 1 µPa-m and SEL of between 219.1 and 220.4 dB re 1 µPa^{2}s-m.

74. SPLs are dependent on the length and diameter of the pile and the hammer energy required for that pile. It is noted that it was assumed that the maximum hammer energy would only be used for a small proportion of the overall piling period with the majority of piling completed at lower hammer energies (see Table 6-3). In addition, the noise propagation model undertaken to support the Application considered a pile diameter of 3.5 m, whereas the pile casing diameter that will be piled as part of the drive-drill-drive process will have an outer diameter of 3.1 m.

Table 6-3: Modelled pile-driving sequence (NnGOWL, 2018; Genesis, 2018)

MODELLING SCENARIO	TOTAL NUMBER OF PILES PER FOUNDATION	PILE-DRIVING SEQUENCE	
		HAMMER ENERGY (KJ)	DURATION (MINS)
Application	4[1]	360	30
		1,026	85
		1,635	180
Revised	3	500	30
		1,425	85
		1,850	180

75. For drive-drill-drive operations there is no evidence available on the noise levels produced by comparison to standard pile driving operations. However, it is expected that the noise will be lower as a result of the drill operations reducing the resistance to piling resulting in the need for relatively low hammer energies for at least a proportion of the time.

6.2.3 Marine Mammals

76. It is noted that majority of piles will be installed using the drill only method; as noted above noise levels from drilling will give rise to a substantially reduced source noise level when compared to pile driving which will result in a significant reduction in the potential for PTS and TTS impacts compared with the Application worst case design scenario. Indeed, based on the review of studies investigating noise levels associated with underwater drilling it is considered that noise levels would be below those at which the onset of PTS or TTS are predicted to occur for all species. Whilst drilling is likely to be audible to marine mammals, disturbance effects are likely to be restricted in spatial extent and broadly comparable to vessel traffic and other construction activities.

77. The pile-driving noise modelling used to inform the Application and the subsequent modelling applied PTS thresholds published by the National Oceanic and Atmospheric Administration (NOAA) (NMFS, 2016) to predict PTS impact ranges (see Table 6-5). The modelling undertaken following the Application differs from that in the EIA Report as it is based on a marginally higher hammer energy and the installation of three piles over a period of 24 hrs as opposed to four. Furthermore, the modelling presumed the total duration of piling would be 14.75 hrs at each turbine location with just less than 5 hours of driving required for each individual pile. Under the drive-drill-drive scenario, the total driving duration at each location will be of up to 12 hours with up to 4 hours of impact driving required for each casing. Further the 4 hour impact driving duration required for each casing will be split with a break in driving of approximately 14 hours occurring whilst drilling into the underlying rock is completed. Driving of the casing will then recommence until the target depth is reached.

[1] The consented design envelope considered a 6 leg jacket solution; however, modelling was undertaken for a four leg jacket due to the greater overall impact driving durations associated with the longer piled foundations. The four leg jacket was considered the worst case scenario.

78. The revised modelling is also based on a depth-averaged received SEL as opposed to a maximum received SEL. This results in a more realistic behavioural response by marine mammals as they move away from the noise source.

79. Current guidance advises that when assessing potential impacts from impulsive underwater noise both unweighted zero-to-peak SPL and weighted cumulative SEL metrics should be considered (e.g. Southall et al. 2019). Consequently, the predicted distances at which the onset of PTS are predicted to arise based on unweighted zero-peak SPL are presented in Table 6-4 and weighted cumulative SEL in Table 6-5.

Table 6-4: Predicted PTS (un-weighted SPL) impact ranges resulting from pile driving on marine mammals based on the revised noise modelling (Genesis 2018)

SPECIES OR GROUP	PTS CRITERIA (NMFS, 2016)	DISTANCE TO THRESHOLD EXCEEDANCE (M)		
		MINIMUM	MEAN	MAXIMUM
Harbour porpoise	Unweighted SPL $_{(0-p)}$ 202 dB re 1 µPa	311	319	354
Bottlenose dolphin	Unweighted SPL $_{(0-p)}$ 230 dB re 1 µPa	4	4	4
Minke whale	Unweighted SPL $_{(0-p)}$ 219 dB re 1 µPa	19	19	19
Pinnipeds (harbour and grey seals)	Unweighted SPL $_{(0-p)}$ 218 dB re 1 µPa	21	21	21

Table 6-5: Predicted PTS impact ranges resulting from pile driving on marine mammals based on the consented design envelope (NnGOWL, 2018)

SPECIES OR GROUP	PTS CRITERIA (NMFS, 2016)	DISTANCE TO THRESHOLD EXCEEDANCE (M)		
		MINIMUM	MEAN	MAXIMUM
Harbour porpoise	Weighted cumulative SEL 155 dB re 1 µPa	333	347	357
Bottlenose dolphin	Weighted cumulative SEL 185 dB re 1 µPa	0	0	0
Minke whale	Weighted cumulative SEL 183 dB re 1 µPa	2,229	2,900	3,375
Pinnipeds (harbour and grey seals)	Weighted cumulative SEL 185 dB re 1 µPa	3	3	4

80. The use of drilling is considered likely to reduce the blow energies required to embed the pile casing and the overall piling duration will be reduced from that assumed for the Application. It is therefore

considered likely that the PTS ranges predicted for the Application and the revised modelling will be an over-estimate of the ranges likely to occur under the drive-drill-drive scenario.

6.2.4 Atlantic Salmon and Sea Trout

81. The noise modelling undertaken for the EIA also considered noise impacts on fish species. Using criteria published in Popper et al (2014) the EIA Report predicted cumulative SEL thresholds based on the piling sequence set out in Table 6-3. Atlantic salmon and sea trout as hearing generalists fall into the category for 'fishes with a swim bladder where the organ does not appear to play a role in hearing' as defined in Popper et al (2014). Table 6-6 presents the predicted distance for Atlantic salmon and sea trout. The noise modelling indicates that noise levels that would cause mortality will not be exceeded during piling. Noise levels that have the potential to result in permanent injury are only predicted within close proximity to the pile location, whilst potential temporary impacts on hearing sensitivity (taken as a proxy for behavioural disturbance) may occur out to greater distances.

82. No specific mitigation is proposed for diadromous fish, however, the soft start procedure which forms part of the piling mitigation outlined in Section 6.3 may initiate a response for individuals that are likely to be present within 6 m of the piling location. Due to the small impact range for potential injury it is not necessary to incorporate specific mitigation in respect of salmonids, however, the proposed mitigation measures has the potential to initiate a behavioural response that could result in individuals moving away from the noise source.

Table 6-6: Predicted distances where thresholds for fish mortality and injury are exceeded during pile driving based on the consented design envelope (NnGOWL, 2018)

IMPACT CRITERIA	DISTANCE TO THRESHOLD EXCEEDANCE (M)		
	MINIMUM	MEAN	MAXIMUM
Mortality / Mortal Injury (Unweighted cumulative SEL of 219 dB re 1 µPa)	Threshold not exceeded		
Recoverable Injury (Unweighted cumulative SEL of 203 dB re 1 µPa)	6	6	6

83. For drill only operations, the impact ranges are considered likely to be substantially reduced and occur only in relatively close proximity to the drilling operations; for the drill only installation therefore the disturbance of fish species will be substantially reduced from the worst case described in the Application.

6.3 Piling Mitigation Protocol

84. Drilling activities during pile installation are considered unlikely to produce noise levels that could result in PTS or TTS to sensitive marine mammal or fish receptors as detailed in Section 6.2. Therefore, no specific mitigation is proposed in relation to drilling operations.

85. For pile driving, a mitigation zone is identified which ensures that no animals are within a range which may cause injury or fatality when piling starts. For each marine mammal species, the appropriate mitigation zone is determined as the impact range associated with either the unweighted SPL or the cumulative SEL, whichever is greater, for PTS.

86. During pile driving it is proposed that the following steps are implemented to minimise the risk of injury to marine mammals or fish species within PTS range:

- Optimise hammer energies;
- Deployment of Acoustic Deterrent Devices (ADDs); and
- Soft-start driving.

6.3.1 Instantaneous PTS Ranges

87. Based on the worst case prediction provided by the noise modelling (summarised in Table 6-4), the maximum range at which instantaneous PTS may occur to marine mammal species in the vicinity of the Wind Farm Area was predicted to be 19 m for minke whale, 354m for harbour porpoise and 4 m for bottlenose dolphin and 21 m for seals. For fish the range at which recoverable injury was predicted to occur was no further than 6 m (Table 6-6).Whilst it is considered likely that these PTS ranges are precautionary given the lower hammer energy to be used and the reduced piling durations the piling mitigation has been developed to minimise the risk of marine mammals being exposed to PTS at these ranges.

6.3.2 Optimised Hammer Energies

88. The minimum practical hammer energy will be used for each pile to minimise the underwater noise.

6.3.3 Acoustic Deterrent Devices

89. It is proposed that ADDs are used to displace marine mammals prior to the commencement of pile driving. The aim of the ADD will be to remove animals from an area where there is potential for injury or fatality to be caused by pile driving noise. The mitigation zones also take into consideration the range at which the ADD has been shown to have an effect.

90. ADDs produce relatively high levels of sound in the water column with the aim of causing an avoidance behaviour in marine mammals and discouraging them from a particular area. The extent and duration of any displacement varies across devices and the behaviour of the individual species, with ADDs having less of an effect where marine mammals may be attracted to a site, e.g. seals and fish farms (Coram *et al.* 2014). However, in areas where there is less of an attraction, the use of ADDs have been found to be effective at temporarily displacing marine mammals from an area (Table 6-7).

91. Published studies have been undertaken on the effectiveness of using an ADD to displace harbour porpoise (Brandt *et al.* 2012, 2013, Dähne *et al.* 2017). The studies have reported differing levels of effectiveness with one recording a harbour porpoise within 798 m of an active ADD and another showing that all harbour porpoise avoided the area within 1.9 km and for half the time between 2.1 and 2.4 km (Brandt *et al.* 2012, 2013). Both these studies reported a strong avoidance behaviour by harbour porpoise to the ADDs with one study recording a 96% reduction in the number of detections out to 7.5 km (Brandt *et al*. 2013, Coram *et al*. 2014). The studies concluded that there appeared to be effective deterrence at levels of 132 dB re 1 µPa (rms SPL) and no clear avoidance at levels below 119 dB re 1 µPa (rms SPL) (Brandt *et al*. 2012). Avoidance from the area lasted approximately six hours.

92. A study undertaken looking at the effects of pile-driving at the DanTysk wind farm in the German Bight reported a significant reduction in the number of harbour porpoise detected out to at least 12 km from the ADD with near total avoidance of the area within 3 km by (Dähne *et al.* 2017).

93. There are limited studies undertaken on the effectiveness of ADDs on dolphins (Sparling *et al*. 2015). However, they are recognised to be less sensitive to noise than other cetaceans and the deterrent radius from an ADD is likely to be smaller than that for other cetaceans. However, the area within which the onset of PTS is predicted to occur extends less than 1 km from the source and therefore an ADD is predicted to be an effective deterrence for dolphins.

94. Studies undertaken for minke whale indicate that the use of an ADD caused a change to a direct swimming direction away from the sound source and significant increase in the net speed of minke whales, minke whales were reported to respond within 4 km of the ADD (McGarry *et al*. 2017).

95. Studies undertaken on harbour seals indicate a strong response to ADDs out to 1 km with weaker responses beyond that range out to 3.1 km (Gordon *et al.* 2015).

Table 6-7: Predicted range of effective deterrence by Acoustic Deterrent Devices.

SPECIES OR GROUP	DETERRENT RANGE	SOURCE
Harbour porpoise	Up to 7.5 km	Brandt *et al.* (2013)
Bottlenose dolphin	Unknown	Sparling *et al.* (2015)
Minke whale	Up to 4 km	McGarry *et al.* (2017)
Pinnipeds (harbour and grey seals)	>1,000 m	Gordon *et al.* (2015)

96. An ADD device will be selected based on sound levels and frequencies which are appropriate to the hearing capabilities of the key marine mammal species present within the vicinity of the Wind Farm Area to stimulate a disturbance response and cause the animals to leave the mitigation impact zones.

97. The duration of ADD use is aimed at balancing the key objective of dispersing animals from the mitigation zone against risks of habituation to the ADD source or significantly increasing disturbance effects. The ADDs will be deployed from the piling vessel for a period of 5 – 10 minutes prior to pile driving, to allow marine mammals to be displaced from the mitigation zone. The mitigation zone is determined by the length of time that it takes for a fleeing marine mammal to vacate the maximum distance at which the onset of auditory injury could occur when pile driving at maximum hammer energy using instantaneous PTS ranges as advised by SNH (See Section 6.3.1 and Table 6-4).In this case, the maximum predicted distance is 354 m for harbour porpoise which, if swimming at a speed of 1.5 m/s (Williams 2009) will take just under 4 minutes to swim beyond the range at which the onset of PTS is predicted to occur. For all other marine mammals, the time it will take to swim beyond the range of PTS is lower than this. Deployment of the ADD for 5 – 10 minutes is sufficient to displace harbour porpoise, and all other marine mammals, from the mitigation zone prior to piling at full power.

98. The ADD operator will be in direct communications with the offshore construction manager responsible for managing offshore piling operations. Communications will be maintained throughout ADD deployment and commencement of piling to ensure ADD has been effectively deployed for the required duration.

6.3.4 Soft Start

99. The 30 minute soft start mitigation (see Section 5.5) would commence after the ADD deployment has been completed. The soft-start would commence with a low blow rate of 20 or less strikes per minute and as low a hammer energy as is practicable but not exceeding 360 kJ.

100. Following completion of the soft-start the hammer energy and blow rate will be incrementally ramped up until the optimum blow rate is achieved. At no time will the hammer energy exceed 1,635 kJ.

6.3.5 Protocol for Planned and Unplanned Breaks

101. At the location where the drive-drill-drive method will be used there will be a planned break in impact driving of approximately 14 hours during installation of each pile casing during which drilling will be completed. Prior to recommencement of impact driving the ADD will be deployed and a soft start completed in accordance with the piling mitigation set out above.

102. For unplanned breaks in impact driving mitigation will be 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. pile driving may continue from the hammer energy and frequency last used).

103. For breaks in piling of greater than 10 minutes the following procedures are proposed:

- Where duration of break is predicted to be less than six hours:
    - 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 optimised rate
- If the break is predicted to be greater than six hours the ADD will be switched on 5 – 10 minutes before piling activities are planned to commence, with a full 30 minute soft-start followed by a ramp-up in hammer energy will be undertaken.

6.4 Compliance Monitoring

104. The ADD Operators will be required to maintain a record of ADD deployment durations through piling. These will be submitted regularly to the project Environmental Clerk of Works (ECoW). In addition, Contractors are required to submit piling reports and pile driving profiles to confirm the use of soft-starts and appropriate ramp-up procedures to the ECoW. Both records will be submitted periodically to the ECoW and incorporated into regular compliance reporting as required.

105. Any instances of non-compliance will be raised with the ECoW and the Consents Manager immediately and remedial actions implemented. Any instances of non-compliance will be reported to MS-LOT as soon as reasonably practicable after the incident.

7 Compliance with the Application

7.1 Introduction

106. In addition to the conditions presented in Table 1-1, Condition 7 of the S36 Consent states that:

> *the Development must be constructed and operated in accordance with the Application (as supplemented by the additional environmental information ("EIA Addendum"), submitted by the Company on 26 July 2018) and any other documentation lodged in support of the Application*

107. Condition 3.1.1 of both the Wind Farm and OfTW ML also state that:

> *The Licensee must at all times construct, operate and maintain the Works in accordance with this licence, the Application and the plans and programmes approved by the Licensing Authority.*

108. Section 7.2 sets out information from the Application where it relates to pile installation and how it compares with the parameters set out in this PS.

7.2 Compliance with Piling Parameters assessed in the EIA

109. Since the Offshore Consents were awarded, the design of the Project and the approach to installation has been refined to that described in this PS (and in other relevant consent plans).

110. Table 7-1 summaries the foundation options and assumed installation methods presented within the Applications. It also summarises the selected options and confirmed installation methods described in this PS.

Table 7-1: Summary of reduction to key engineering parameters relevant to this PS

PILE PARAMETER / DESIGN SCENARIO	APPLICATION PROJECT DESCRIPTION	PILING STRATEGY	ACTUAL REDUCTION	PERCENTAGE OF REDUCTION
Number of Turbine and OSP Foundations	56	56	0	0%
Number of piles per foundation	Maximum of 6 pin piles per jacket	3 pin piles per jacket	3	50%
Total number of piles	336	168	168	50%
Installation technique	0 – 10% Drive only method	0% Drive only method	n/a	100% for Drive only
	90 – 100% Drill only or Drive – Drill – Drive method. Note, worst case scenario considered to be 90 – 100% installed using Drive-Drill-Drive scenario	Approximately 98% using Drill only; Approximately 2% Drive – Drill – Drive method	n/a 55 locations	n/a 98% reduction in impact driving when considering impact driving at 100% of locations.

PILE PARAMETER / DESIGN SCENARIO	APPLICATION PROJECT DESCRIPTION	PILING STRATEGY	ACTUAL REDUCTION	PERCENTAGE OF REDUCTION
Pile diameter	3.5 m pile diameter	3.5.m diameter casing diameter and up to 3.2 m pile diameter.	0 m (casing)	0%
Anticipated maximum hammer energy (Driven only and Drill – Drive – Drill)	1635 kJ	1635 kJ	0 kJ	0%
Anticipated maximum impact piling duration (per foundation)	Drill – only scenario Approximately 20 hours of impact driving per foundation for four piles	Drive-drill-drive scenario Approximately 12 hours of piling at the Drill-Drive-Drill location for three piles, split over 6 distinct impact driving events	8 hours	40 %
Anticipated total duration of impact driving activities during pile installation	Approximately 9 months	Impact piling at one location completed over 220 hour period	Approximately 8.5 months	Approximately 94%

111. The refined Project design when compared to the Application design envelope results in the complete removal of a Drive only pile installation solution. There is also a considerable reduction in the pile driving duration due to the predominant use of a drill-only solution at the majority of foundation locations. The EIA Report described the potential use of an element of driving at all foundation locations whereas pile driving will now only be used at one location as part of the drive-drill-drive solution.

112. This refinement in the project design, total number of piled foundations and overall pile duration results in a notable decrease in potential temporal and spatial disturbance to sensitive marine species resulting from construction noise when compared to the consented design envelope set out at the point of application.

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