MORAY EAST
OFFSHORE WINDFARM

Piling Strategy Implementation Report

Moray East Offshore Wind Farm

April 2021

Moray Offshore Windfarm (East) Limited

Produced by Royal HaskoningDHV on behalf of Moray Offshore Windfarm (East) Limited	
Produced by	Gemma Starmore and Anna Sweeney
Reviewed by	Jennifer Learmonth
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Moray East Ecological Clerk of Works	**Moray East**
Alexia Chapman [Royal HaskoningDHV]	Catarina Rei [Offshore Consents Manager]

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List of Abbreviations

ADD	Acoustic Deterrent Device
BOWL	Beatrice Offshore Windfarm Ltd
CMS	Construction Method Statement
CoP	Construction Programme
ECoW	Environmental/Ecological Clerk of Works
EMP	Environmental Management Plan
EPS	European Protected Species
ES	Environmental Statement
HDD	Horizontally Drilled Duct
JNCC	Joint Nature Conservation Committee
kJ	Kilojoule
km	Kilometre
MFRAG	Moray Firth Regional Advisory Group
MFRAG-MM	Moray Firth Regional Advisory Group – Marine Mammals Subgroup
MMOs	Marine Mammal Observers
MS-LOT	Marine Scotland – Licensing Operations Team
OfTI	Offshore Transmission Infrastructure
OSP	Offshore Substation Platform
PAM	Passive Acoustic Monitoring
PEMP	Project Environmental Monitoring Programme
PS	Piling Strategy
PSIR	Piling Strategy Implementation Report
SEL	Sound Exposure Level
TI	Transmission Infrastructure
WTG	Wind Turbine Generator

Definitions

The following definitions have been used throughout this document with respect to the company, the consented wind farms and how these definitions have changed since submission of the Moray East Environmental Statement (ES) in 2012 and the Moray East Modified Transmission Infrastructure (TI) ES in 2014 and the Moray East Offshore Substation Platform (OSP) Environmental Report in 2017:

- **Moray Offshore Windfarm (East) Limited (formerly known as Moray Offshore Renewables Limited)** – the entity submitting this document;
- **Moray East Offshore Wind Farm** - the wind farm currently in development in the Moray East site (also referred as the Wind Farm);
- **The Moray East site** - the area in which the Moray East Offshore Wind Farm is located. Section 36 Consents and associated Marine Licences to construct and operate up to three generating stations on the Moray East site were granted in March 2014. At that time the Moray East site was known as the "Eastern Development Area (EDA)" and was made up of three sites known as the Telford, Stevenson and MacColl offshore wind farm sites. The Section 36 Consents and Marine Licences were subsequently varied in March 2018, with the Marine Licences additionally varied in July 2019, April and October (MacColl)/November (Telford & Stevenson) 2020;
- **Telford, Stevenson and MacColl wind farms** – these names refer to the three consented offshore wind farm sites located within the Moray East site;
- **Moray East ES 2012** – The ES for the Telford, Stevenson and MacColl wind farms and Associated TI, submitted August 2012;
- **Moray East Modified TI ES 2014** – the ES for the TI works in respect to the Telford, Stevenson and MacColl wind farms, submitted June 2014;
- **Moray East OSP Environmental Report 2017** – the environmental report comprising of the "Statement Regarding Implications for the Modified TI ES 2014 and HRA". The report was produced in support of the application submitted in May 2017 for the Moray East OSP Marine Licence;
- **Transmission Infrastructure (TI)** - includes both offshore and onshore electricity TI for the consented Telford, Stevenson and MacColl wind farms. Includes connection to the national electricity transmission system near New Deer in Aberdeenshire encompassing Alternating Current (AC) OSPs, AC OSP interconnector cables, AC export cables offshore to landfall point at Inverboyndie continuing onshore to the AC collector station (onshore substation) and the additional regional Transmission Operator substation near New Deer. A Marine Licence for the offshore TI was granted in September 2014 (Modified Offshore Transmission Infrastructure (OfTI) Licence) and varied in July 2019 and December 2020. A further Marine Licence for two additional distributed OSPs was granted in September 2017 and subsequently varied in July 2019. The onshore TI was granted Planning Permission in Principle in September 2014 by Aberdeenshire Council and a Planning Permission in Principle under Section 42 in June 2015. In June 2018 Aberdeenshire Council granted Approval of Matters Specified in Conditions for both the cable route and substation;
- **Offshore Transmission Infrastructure (OfTI)** – the offshore elements of the TI comprising AC OSPs, OSP interconnector cables and AC export cables offshore to landfall (for the avoidance of doubts some elements of the OfTI will be installed in the Moray East site);
- **The Development** – the Moray East Offshore Wind Farm and OfTI;
- **Design Envelope** – the range of design parameters used to inform the assessment of impacts;

- **OfTI Corridor** – the export cable route corridor, i.e. the OfTI area as assessed in the Moray East Modified TI ES 2014 excluding the Moray East site;
- **Piling Strategy** – a collective term used to refer to two documents developed to comply with condition 11 of the Section 36 Consents and condition 3.2.2.5 of the OfTI Marine Licence and condition 3.2.2.6 of the OSP Marine Licence. The Piling Strategies (PSs) were developed prior to the construction taking place, and set out the proposed method and anticipated durations of piling activities at all locations, updated impact assessments for marine mammals and fish species in line with the final project design, and the details of all mitigation measures to reduce impacts to all marine receptors to be used during the piling activities at the project; and
- **Piling Strategy Implementation Report** – this report, with the aim of confirming that all piling activities and operations were undertaken in line with the PS, including confirming that all impacts were within parameters assessed as part of the ES (and PS), and that all mitigation measures outlined within the PS were undertaken.
- **Moray East Offshore Wind Farm Section 36 Consents and Marine Licences** are comprised of the following:

  Section 36 Consents:

  - Section 36 Consent for the Telford Offshore Wind Farm (as varied on 22 March 2018) – consent under Section 36 of the Electricity Act 1989 for the construction and operation of the Telford Offshore Wind Farm assigned to Moray East on 19 June 2018.
  - Section 36 Consent for the Stevenson Offshore Wind Farm (as varied on 22 March 2018) – consent under Section 36 of the Electricity Act 1989 for the construction and operation of the Stevenson Offshore Wind Farm assigned to Moray East on 19 June 2018.
  - Section 36 Consent for the MacColl Offshore Wind Farm (as varied on 22 March 2018) – consent under Section 36 of the Electricity Act 1989 for the construction and operation of the MacColl Offshore Wind Farm assigned to Moray East on 19 June 2018.

  Marine Licences

  - Marine Licence for the Telford Offshore Wind Farm (as varied) – Licence Number: MS-00009051 – granted under the Marine (Scotland) Act 2010 & the Marine and Coastal Access Act 2009, Part 4 Marine Licensing for marine renewables construction works and deposits of substances or objects in the Scottish Marine Area and the United Kingdom Marine Licensing Area transferred to Moray East on 19 July 2018.
  - Marine Licence for the Stevenson Offshore Wind Farm (as varied) – Licence Number: MS-00008985 – granted under the Marine (Scotland) Act 2010 & the Marine and Coastal Access Act 2009, Part 4 Marine Licensing for marine renewables construction works and deposits of substances or objects in the Scottish Marine Area and the United Kingdom Marine Licensing Area transferred to Moray East on 19 July 2018.
  - Marine Licence for the MacColl Offshore Wind Farm (as varied) – Licence Number: MS-00008972 - granted under the Marine (Scotland) Act 2010 & the Marine and Coastal Access Act 2009, Part 4 Marine Licensing for marine renewables construction works and deposits of substances or objects in the Scottish Marine Area and the United Kingdom Marine Licensing Area transferred to Moray East on 19 July 2018.

- **Offshore Transmission Infrastructure (OfTI) Licences** – are comprised of the following:
  - Marine Licence for the Offshore Transmission infrastructure (as varied) – Licence Number MS-00008919 – granted under the Marine (Scotland) Act 2010 & the Marine and Coastal

Access Act 2009, Part 4 Marine Licensing for marine renewables construction works and deposits of substances or objects in the Scottish Marine Area and the United Kingdom Marine Licensing Area (referred to as the "OfTI Marine Licence").

- Marine Licence for two additional distributed OSPs (as varied) – Licence Number 06347/19/0 – granted under the Marine (Scotland) Act 2010 & the Marine and Coastal Access Act 2009, Part 4 Marine Licensing for marine renewables construction, operation and maintenance works and the deposit of substances or objects in the Scottish Marine Area and the United Kingdom Marine Licensing Area (referred to as the "OSP Marine Licence").

Executive Summary

This Piling Strategy Implementation Report (PSIR) has been prepared by Moray Offshore Windfarm (East) Limited to provide information on the piling activities undertaken during the construction of the Moray East Offshore Windfarm (Moray East), in relation to both the piling parameters and mitigation requirements as set out within the Piling Strategy (PS), which was a requirement under condition 11 of the Section 36 Consents, condition 3.2.2.6 of the Offshore Substation Platform (OSP) Marine Licence, and condition 3.2.2.5 of the Offshore Transmission Infrastructure (OfTI) Marine Licence.

The purpose of this PSIR is to provide information on the piling and mitigation that was undertaken, to ensure that the piling was undertaken in line with the PS. The parameters of piling activity that are the focus of this PSIR, and that have compared to the predictions (and consented parameters) outlined within the PS, include piling durations, hammer energies, and hammer blow counts. Additional information has also been provided on the overall piling programme.

For the overall piling durations, the piling at each WTG was considerably shorter than expected, with the majority of actual durations being less than 20% or between 20% and 40% less than predicted duration. The piling duration per pin-pile was between 70 and 80 minutes at 27.2% of pin-piles, between 60 and 70 minutes at 18.4% of pin-piles and between 80 and 90 minutes at 18.8% of pin-piles, compared to the predicted duration of 390 minutes. Three pin-piles took less than 60 minutes to install, with a minimum piling duration of 47 minutes.

For maximum hammer energies, the actual maximum hammer energies required were lower than the consented maximum hammer energy of 2,250 kJ, in all cases. A total of 13 WTG locations of the total 103 WTG locations had actual maximum hammer energies close to the consented maximum (80% to 100% of predicted), while the majority of the piles (n = 51) recorded actual maximum hammer energies of 40% to 60% of the maximum consented hammer energy. A smaller number of piles (five) recorded much lower hammer energies (between 20% to 40%) than the consented maximum hammer energy. The highest required hammer energy recorded across the three pin-piles, out of all foundation locations, was 2,071 kJ, while the lowest hammer energy required (across the three pin-piles, out of all foundation locations), was 628 kJ, and the average actual hammer energy across all piles was 1,341 kJ.

For total blow counts, again the total counts were considerably lower than expected (predicted number of blows was 16,650), with the majority of the maximum blow counts recorded per WTG being less than 20% of the predicted maximum, and nine WTGs having a maximum count of between 20% and 40% of the expected blows per pin-pile. The highest blow count recorded was 4,773, while the lowest was 1,364. The average blow count per pin-pile was 2,352.

Overall, the analysis and comparisons presented within this PSIR show that, for all piling parameters, the piling undertaken was within consented parameters within the PS.

Mitigation measures undertaken during the piling at Moray East included the use of Acoustic Deterrent Devices (ADDs), as well as a soft-start and ramp-up procedure, the specifics of which was dependent of the length of time elapsed from the previous piling bout. There was also a requirement to undertake a phased piling process, a description of which, including the results and success of the phased piling, is included within this PSIR.

The deployment and activation of ADDs was a core part of the marine mammal underwater noise mitigation. When required ADDs were to be activated for five to ten minutes prior to piling. During the piling installations, ADDs were deployed and activated on a total of 131 occasions, with the majority being activated for a period of five to six minutes (65.2%). Of these 131 activations (where ADDs were required),

on seven occasions the ADDs were activated for more than ten minutes as agreed with MS-LOT. Each of these instances was due to a technical issue or fault with the deployment and activation of the ADDs (see **section 6.2.5** and **Table 6-3** for further information).

In total, 430 piling bouts (identified as piling periods with less than ten minutes between each hammer blow) were undertaken through the piling programme. Of those piling bouts, 132 required full mitigation, including ADD deployment, soft-start, and ramp-up procedures. The remaining 298 piling bouts required piling break mitigation (as commenced within six hours of the previous piling bout), which included soft-start procedures only.

The majority of piling bouts commenced with the required five to six initial soft-start blows, with 97.7% having six initial blows, and 2.1% starting with five blows. On one instance, piling began with only one initial blow (0.2% of piling bouts), outside of the mitigation protocol. However, this was an agreed variation to the mitigation procedure (with MS-LOT) for location J10. See **Section 6.2.7.1** for more information.

The majority of the 430 piling bouts (87.4% of all piling bouts) undertook a soft-start with starting hammer energy of between 100 kJ and 150 kJ, a further 11.2% of soft-starts had a starting hammer energy of less than 100 kJ, and 0.5% had an starting hammer energy between 150 kJ and 200 kJ, in line with the mitigation protocol, as set out in the PS, for a starting hammer energy of less than 300 kJ. The remaining four (0.9%) piling bouts were undertaken with a starting hammer energy that exceeded 300 kJ for WTGs K17 and I20. The incidents were raised with the construction team, reported to MS-LOT, and additional mitigation was undertaken to ensure that no further issues with compliance of the soft-start and ramp-up procedures occurred. See **Section 6.2.7.1** for more information**.**

A total of 132 piling bouts were undertaken that required an additional ramp-up procedure over a period of 20 minutes, as outlined within the PS. For the majority of these piling bouts the ramp-up took 20 or 21 minutes (45.5% and 32.6%, respectively). For a further 17.4% piling bouts the ramp-up was between 22 and 25 minutes, with the ramp-up for 1.5% of the piling bouts taking longer than 25 minutes. A total of four instances (3.0%) took less than the required 20 minutes to ramp-up due to a technical break-down of the hammer at WTGs J10, G06 and J19. Agreement was reached with MS-LOT for piling at these WTGs to continue with no 20 minute ramp-up. See **Section 6.2.7.1** for more information.

The majority of the 132 piling bouts undertook ramp-up procedures with hammer energies of between 400 kJ and 500 kJ (72.0% of all piling bouts requiring ramp-up). A further 12.1% of ramp-ups had hammer energies of 300 kJ to 400 kJ, 12.1% with 200 kJ to 300 kJ, and 1.5% with less than 150 kJ. The remaining 2.3% of piling bouts were undertaken with a ramp-up that exceeded 500 kJ. For all these occasions, they were agreed variations (with MS-LOT) to the mitigation procedure. See **Section 6.2.7.1** for more information.

No marine mammals were recorded during times of active mitigation (pre-watch) or piling activity.

1 Introduction

1.1 Overview of the Moray East Project

Moray East is a joint venture partnership between OceanWinds Offshore, Diamond Generating Europe and China Three Gorges and has been established to develop, finance, construct, operate, maintain and decommission the Moray East Offshore Wind Farm (Moray East).

In March 2014, Section 36 Consents were granted to Moray Offshore Windfarm (East) Limited (Moray East) for the construction and operation of three offshore wind farms (Telford, Stevenson and MacColl) within the Moray East site. Marine Licences for the three offshore wind farms were granted in September 2014 (together the Section 36 Consents and Marine Licences for the Wind Farm are referred to as the Moray East Offshore Wind Farm Consents). The Section 36 Consents were varied in March 2018. The Marine Licenses for Telford, Stevenson and MacColl were subsequently varied in July 2019, and April, October (MacColl) and November (Telford & Stevenson) 2020. A Marine Licence for the Modified Offshore Transmission Infrastructure (OfTI) was granted in September 2014, under the Marine (Scotland) Act 2010 & the Marine and Coastal Access Act 2009, Part 4 Marine Licensing and subsequently varied in July 2019 and December 2020 (Modified OfTI Licence), a Marine Licence for two additional distributed offshore substation platforms (OSPs) was granted in September 2017 and subsequently varied in July 2019 (together these are referred to as the OfTI Marine Licences).

The final design of the Moray East project comprises of 100 Wind Turbine Generators (WTGs), three OSPs, a total inter-array cable network of approximately 156 kilometre (km), two interconnector cables (between the three OSPs), and three subsea export cables to connect to landfall on the Aberdeenshire coast.

Offshore construction of the Wind Farm started in 2019, with piling operations starting on 19 May 2019, and completed on 27 February 2020. Piling was undertaken at a total of 103 locations. The piled foundations, for both WTGs and OSPs, were tripod jacket foundations with pin-piles.

At the time of writing (April 2021) offshore construction is continuing. To date, all piles and jackets have been installed, with a three-legged jacket being placed over the pre-installed piles at each location. The WTGs are currently being installed at each location. The three OSP jackets and their topsides have also been installed. Cable laying and burial activities for the three export cables have been mostly completed with final rock protection works at the OSPs to be completed. Inter-array cable installation is underway with cable lay and burial, cable pull-in, and testing & termination works. The drilling of the Horizontally Drilled Ducts (HDDs) is completed and all three export cables have been pulled into the HDDs for connection with the onshore export cables.

1.2 The Piling Strategy

Under condition 11 of the Section 36 Consents, condition 3.2.2.6 of the OSP Marine Licence, and condition 3.2.2.5 of the OfTI Marine Licence, two Piling Strategies (PS) were developed prior to the construction taking place: one for the WTGs and one for the OSPs. The PSs set out the proposed method and anticipated durations of piling activities at all locations, the details of soft-start piling procedures and maximum hammer energy requirements, as well as detailed information on the mitigation and monitoring that was to be used during the piling activities at the Wind Farm and OfTI. The details within each of PSs, in terms of mitigations and piling parameters were similar and, therefore, the rest of the scope will refer to the two PSs as one document (PS).

The aim of the PS was to detail the underwater noise assessments undertaken for the Wind Farm and OfTI, to outline mitigation that was determined to be required, and to describe how mitigation was incorporated into the PS to minimise the impacts of underwater noise on marine receptors. The PS was designed to sit alongside other consent condition documents including the Construction Programme (CoP), Construction Method Statement (CMS), Project Environmental Monitoring Programme (PEMP), and the Environmental Management Plan (EMP).

The PS was developed with the aim of ensuring potential effects from piling, with respect to the species identified in condition 11 of the Section 36 Consent, condition 3.2.2.5 of the OfTI Marine Licence and condition 3.2.2.6 of the OSP Marine Licence, i.e. bottlenose dolphins *Tursiops truncatus*, harbour seals *Phoca vitulina*, Atlantic salmon *Salmo salar*, cod *Gadus morhua* and herring *Clupea harengus*, were no worse than assessed in the Moray East (2012) Environmental Statement (ES), and were not considered significant. Moray East additionally included harbour porpoise *Phocoena phocoena* within the PS at request from the Moray Firth Regional Advisory Group – Marine Mammals (MFRAG-MM) subgroup and as recognition that harbour porpoise was expected to be the most common European Protected Species (EPS) within the site.

Within the PS, parameters of the piling activities were set out, such as durations of piling and maximum hammer energies, as well as the mitigation required to ensure that marine mammals and some fish species were not significantly impacted by the activities.

1.3 The Piling Strategy Implementation Report

As per condition of the Section 36 Consents and the OfTI Marine Licences, Moray East participate in the Moray Firth Regional Advisory Group (MFRAG), with the purpose of providing detail on any research, monitoring and mitigation programmes for marine mammals (and other receptors). Monitoring reports are required to be provided on compliance with the PS. The purpose of this Piling Strategy Implementation Report (PSIR) is to provide information on the piling and mitigation that was undertaken in line with the details set out within the PS, to confirm that all piling activities were undertaken in line with the PS or to identify any deviations from the PS. The report also outlines additional research that has been undertaken as part of the project.

The aims of this Piling Strategy Implementation Report are as follows:

1. To report on the implementation of the mitigation measures as outlined in the PS.
2. To provide a summary of the piling activities and parameters, and to provide a comparison between what was predicted in the PS and actual piling activities, including:
    a. the maximum and average hammer energies per pile location, with reference to the different hammer energies predicted for each pile location;
    b. the maximum and average piling durations per pile location, with reference to the different durations predicted for each pile location. This will also include the hammer energy of the first pile strike;
    c. the blow counts to complete a pile at each piling location, with reference to the total blow counts predicted for each pile location; and
    d. soft-start and ramp-up procedures undertaken, including durations and maximum and average hammer energies.
3. To provide an overview of the additional research projects being undertaken, using monitoring and piling data collected through the Moray East piling campaign.

In addition to the above, a high-level analysis comparing the piling activities to that predicted within the Moray East ES (2012) has been provided in **Appendix 2**. This includes a high-level review of hammer

energies, piling durations and blow counts. A comparison of piling as undertaken, to the parameters as set out within the Moray East ES (2012) for hammer energies, piling durations and pile blow counts, is for information purposes only, as the details within the PS (and therefore the focus of this report) supersede those within the Moray East ES (2012).

Prior to the writing of this PSIR, the scope of the report was agreed with members of the MFRAG-MM subgroup through the production of a Piling Strategy Implementation Report Scope document that was distributed to MFRAG-MM subgroup members and discussed at a meeting of the MFRAG-MM subgroup on 30 October 2020. Following the review of the scope document and meeting discussion, the proposed scope was accepted by the MFRAG-MM subgroup and therefore this PSIR has been produced to the agreed scope.

2 The Piling Strategy

Within the PS, parameters of the planned piling activities were set out, in addition to the mitigation required to ensure that marine mammals (and relevant fish species) were not significantly impacted by the piling activities. This report outlines what those parameters and mitigation measures were, and outlines how the piling undertaken was in compliance with those conditions.

The piling parameters for Moray East were determined according to the site-specific seabed sediments, referred to as 'soil profiles'. Where relevant, the different parameters under each soil profile has been provided. **Section 3.2** includes information on the number of piles expected under each of the soil profiles. However, it is important to note that due to changes in WTG locations following the soil profile analysis, soil profiles are not available for each pile location, particularly in the east of the site, although the number of piles under each soil profile were expected to be the same as presented in the PS (see **Section 3.2**).

2.1 Piling Parameters within the Piling Strategy

Table 2-1 provides the design envelope of piling parameters for the WTGs and OSPs at Moray East. Any piling event undertaken at Moray East should be within each of these parameters. All comparisons undertaken within this PSIR are against the maximum worst-case values as presented within this table (highlighted in blue).

Where any of the parameters are different is dependent on the soil profile present, these are also shown in **Table 2-1**. More information on how the soil profiles have been included within this analysis (as information only) is included in **Section 3.2**.

Table 2-1: Piling parameters outlined within the Moray East Piling Strategy (values used within the subsequent analysis and comparisons are shown in bold and signified with *)

Piling element	Parameter
Project description	
Number of piles	100 WTGs and three OSPs Tripod piles = 309 piling events in total
Piling programme	May 2019 to April 2020 (12 months total duration)
Number of concurrent piling events	2
Pile parameters	
Maximum pile diameter	2.5 m (expected worst-case)
Maximum number of piles per WTG	3 (expected worst-case)
Aggregate duration of piling per WTG	Up to 16 hours (assuming average expected soil conditions, not worst-case scenario)
Duration of piling in any 24-hour period	Up to 16 hours (or the time it takes to pile one WTG under each soil profile as set out below)
Total cumulative duration of piling	63 days (note this refers to time spent conducting piling and excludes all non-piling time e.g. moving between locations)

Piling element	Parameter						
Pile driving parameters (PS)							
Soil profiles:	**1**	**2**	**3**	**4**	**5**	**6**	**Worst-case**
Maximum hammer energy Kilojoule (kJ)	1,020	2,250	996	1,020	1,800	1,800	**2,250***
Total blow counts per pin-pile (most probable – highest expected)	12,080 – 12,220	13,490 – 16,650	12,080 – 12,220	12,080 – 12,220	13,490 – 16,650	13,490 – 16,650	**13,490 – 16,650***
Duration of active piling in hours per pin-pile (most probable – highest expected)	5 – 5.1	5.5 – 6.5	3.9 – 4.5	5.2*	5.1 – 5.4	5.1 – 5.2	**5.5 – 6.5***
Soft-start blows	**5 – 6 blows at 300 kJ***						
Maximum ramp-up hammer energy	**500 kJ***						

2.2 Mitigation outlined within the Piling Strategy

Table 2-2 shows the mitigation methods, that were outlined within the PS, to be undertaken for piling activities at the WTGs and OSPs at Moray East. **Section 6** of this PSIR provides information on compliance with the required mitigation.

Table 2-2 Mitigation requirements outlined within the Moray East Piling Strategy

Mitigation element	Method
Herring	
Seasonal restrictions	No piling for a maximum of 16 days during August and September[1]
Underwater noise – marine mammals and fish	
Acoustic Deterrent Device (ADD)	Deploy for 5 - 10 minutes prior to piling[2] ADDs to be deployed before the first pile of the three in a jacket if they are installed directly after the preceding pile
Soft-start	Initial 5 – 6 blows with a hammer energy as low as practically possible (300 kJ or less) Ramp up continues with blow energies remaining at less than 500 kJ for 20 minutes
Hammer energies	Minimise hammer energies at levels sufficient for pile, resulting in energy ramp-up throughout the piling operation
Breaks in piling	Less than 10 minutes = piling may continue as before Between 10 minutes and 6 hours = recommence piling with 5 – 6 blows at low energy, and continue to ramp-up energy levels to required level Breaks more than 6 hours, undertake entire mitigation procedure
Phased piling	Not exceeding 28 days, where combination of Marine Mammal Observers (MMOs), Passive Acoustic Monitoring (PAM) and ADDs are used

[1] Note that following approval of the PS, it was agreed with MS-LOT that the seasonal herring restrictions were not required during construction. Further information provided within the **Section 6.1** of the report.
[2] Note that following approval of the PS, it was agreed that ADD deployments could be extended up to 15 minutes. Further information provided in **Section 6.2.5** of the report.

2.3 Monitoring outlined within the Piling Strategy

Table 2-3 shows the monitoring methods, that were outlined within the PS, to be undertaken during piling activities at the WTGs and OSPs at Moray East. **Section 8** of this PSIR provides further information on compliance with these monitoring requirements.

Table 2-3 Monitoring requirements outlined within the Moray East Piling Strategy[3]

Monitoring element	Method
Underwater noise	
Underwater noise monitoring	Seabed mounted noise recorders to monitor and record noise levels during piling. This to be used to validate conclusions of the Sound Exposure Level (SEL) predicted marine mammal injury zone, for both near and far field.
Marine mammals	
Harbour porpoise - ADDs	To validate responses predicted of harbour porpoise to ADDs. Seabed mounted passive acoustic monitoring data loggers placed around a pile site and at distance.
Compliance monitoring	
Underwater noise	Reporting to the Noise Registry.
Marine mammal and fish	Compliance reporting to demonstrate correct use of ADDs and soft-start procedures.

[3] Excluding herring seasonal restrictions which were not required.

3 Methodology of the Piling Strategy Implementation Comparisons and Analysis

3.1 Overview of the Data Used

In order to confirm compliance with the PS through this PSIR, analyses have been undertaken on the piling records, ADD and PAM reports. The data used within the PSIR includes the following information:

- piling logs for each WTG and OSP;
- ADD and PAM reports;
- Ecological Clerk of Works (ECoW) Compliance Reporting;
- piling log summary by piling bout with ADD activation (one bout is defined as piling undertaken with less than a ten minute break in piling): this has been provided by Aberdeen University, and
- soil profiles.

As outlined in **Section 2**, due to a change in location for some of the WTGs, soil profiles were not known for all locations, particularly those in the east of the site.

The piling parameters used for the purposes of the PS were identified according to the site-specific soil profiles. Geotechnical data collected during a ground investigation survey was used to classify each pile location into one of six representative soil profile groups. Where relevant, the different piling parameters for each soil profile have been provided in **Table 2-1**.

Table 3-1 includes the soil profiles and the percentage of pile locations that were expected to be within each soil profile group. This data was then used to inform the PS. This initial ground investigation survey did not cover all parts of the Moray East site, because at the time it was not intended to develop some parts of the site, due to the water depth in some parts of the site being too deep for the type of foundation design being considered at that time. Following evolution of Front End Engineering Design (FEED) studies, and appointment of a preferred foundations and substructures EPCI contactor, it was concluded that some parts of the site that had originally been discounted could be developed.

Table 3-1 Soil profile types and proportion of each expected across the Moray East site

Soil Profile	Soil / sediment type	Proportion of Moray East with this soil profile
Profile 1	Sand / clay	32%
Profile 2	Clay / sand	17%
Profile 3	Clay / sand / clay	8%
Profile 4	Sand	21%
Profile 5	Clay	8%
Profile 6	Sand / clay / sand	14%

This subsequent design change to include development of additional areas of the site resulted in further ground investigation surveys being undertaken, to obtain data for the pile locations not previously surveyed. Data from these surveys was analysed on behalf of Moray East by the piling installation contractor in order to inform their piling method; however, these pile locations were not assigned to one of the soil profile groups identified following the original surveys. Analysis of the geotechnical survey data indicated that the ground conditions at these pile locations were not significantly different from the

conditions at the pile locations which had been assigned a soil profile group. Therefore, the percentage distribution of pile locations between soil profile groups, and the worst-case scenarios presented in the PS for piling duration and hammer energies, was expected to remain applicable to these pile locations.

Although detailed geotechnical data was collected for all pile locations, a soil profile group categorisation is not available for each pile location, particularly those locations in the east of the site. Analysis has been undertaken per soil profile, including all pile locations where a soil profile is available. Where soil profiles are not available for a pile location, pile locations have been categorised according to the hammer energy recorded at that pile, and the number of pile locations that are expected for each profile[4].

3.2 Comparisons

For each of the piling parameters, the categories shown in **Table 3-2** have been applied to show clearly the difference in what was expected based on the PS, and what was actually required during piling.

Table 3-2 Categories used for the comparisons of piling parameters

Comparison to prediction in PS	Category shown in analysis tables
Less than 20% of prediction	Less than 20%
Between 20% and 40% of prediction	20-40%
Between 40% and 60% of prediction	40-60%
Between 60% and 80% of prediction	60-80%
Between 80% and 100% of prediction	80-100%
Over than 100% of prediction	More than 100%

[4] Soil profiles determined the hammer energy; therefore, for locations without the known soil profile, the actual hammer energy that was required can give an indication of the probable soil profile when compared to hammer energy used at locations with known soil profiles, as well as taking into account the number of pile locations expected for the different types of soil profiles,

4 Foundation Installation Methodology

There are a total of 100 WTG foundations and three OSP foundations within the Wind Farm site. The location of these within the Wind Farm site are shown in **Figure 4-1**.

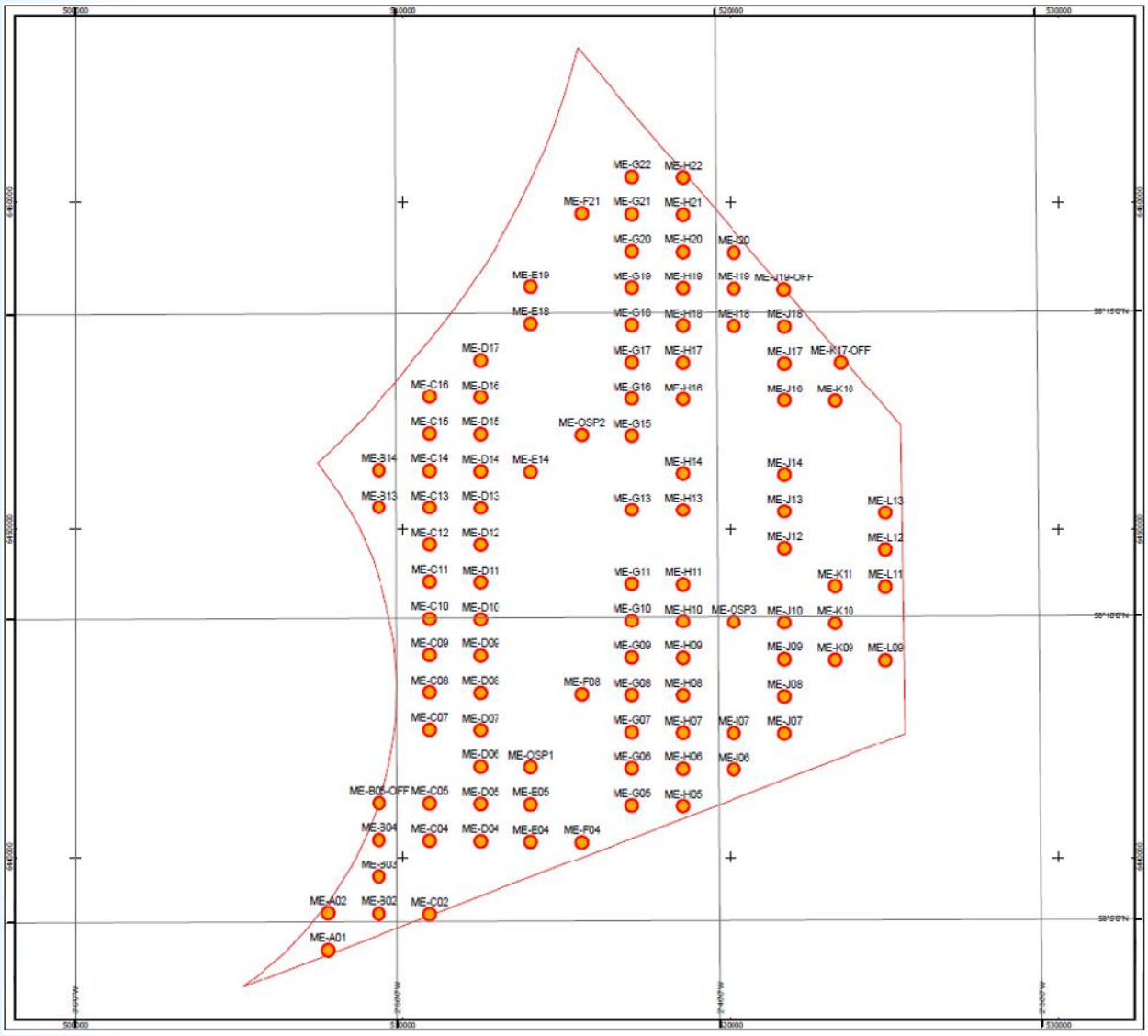


Figure 4-1 Location of WTG and OSP foundations within the Wind Farm Site

4.1 Overview of Piling Activities

The WTG supporting foundation and substructure is a steel lattice 'jacket' structure, comprised of three braced legs each with a grouted connection to pre-driven tubular pin-piles. There are four design variants for the selected jacket type across the Wind Farm to accommodate water depth variation. Pile size (length and/or wall thickness) also varies across the site depending on the particular soil condition at each of the WTG locations.

Piling activities commenced on the 19 May 2019 and were completed on 27 February 2020, therefore taking place over a period of nine months.

A total of three to four vessels were used through the piling operations, and were present at the Wind Farm site throughout the piling period:

- pin-pile support vessel (a platform supply vessel, 88 m in length);
- pin-pile installation vessel (a heavy lift jack-up vessel, 89 m in length); and
- at least one (up to two) guard vessel(s) present during the piling campaign at all times (23-25 m in length).

The general piling operations were undertaken as follows on each location (**Figure 4-2**):

1. the pin-pile installation vessel arrived at the foundation location, and was positioned in readiness for pile installation by jacking up on a pre-determined position.
2. the three pin-piles were stabbed into the seabed with the use of a pile installation template.
3. once in place, the three pin-piles were then driven into the seabed, to the target depth.
4. the pile installation template was then recovered, and the pin-pile installation vessel moved to the next foundation location.

Figure 4-2 Examples of foundation installation process at Moray East

5 Foundation Installation Implementation

The following sections outline the more in-depth analysis that has been completed on specific aspects of the piling activities, including:

1. The piling programme:
    - installation sequence;
    - concurrent piling; and
    - breaks in piling.
2. Piling durations
3. Piling hammer energies
4. Pile blow counts
5. Pile profiles; and
6. Pile refusal and relief drilling.

5.1 Piling Programme

The piling duration was predicted to be approximately 12 months within the PS; however, piling was completed within a period of nine months (284 days). Piling was undertaken on 132 days (46.5%) of the 284 days. The total number of active pile-driving hours (where the hammer was operating) was 416.3 (less than 17.35 days, 13.1% of the 132 active piling days). Days on which no piling was undertaken were typically due to time spent transiting between locations, weather or technical downtime, or the piling vessel being resupplied.

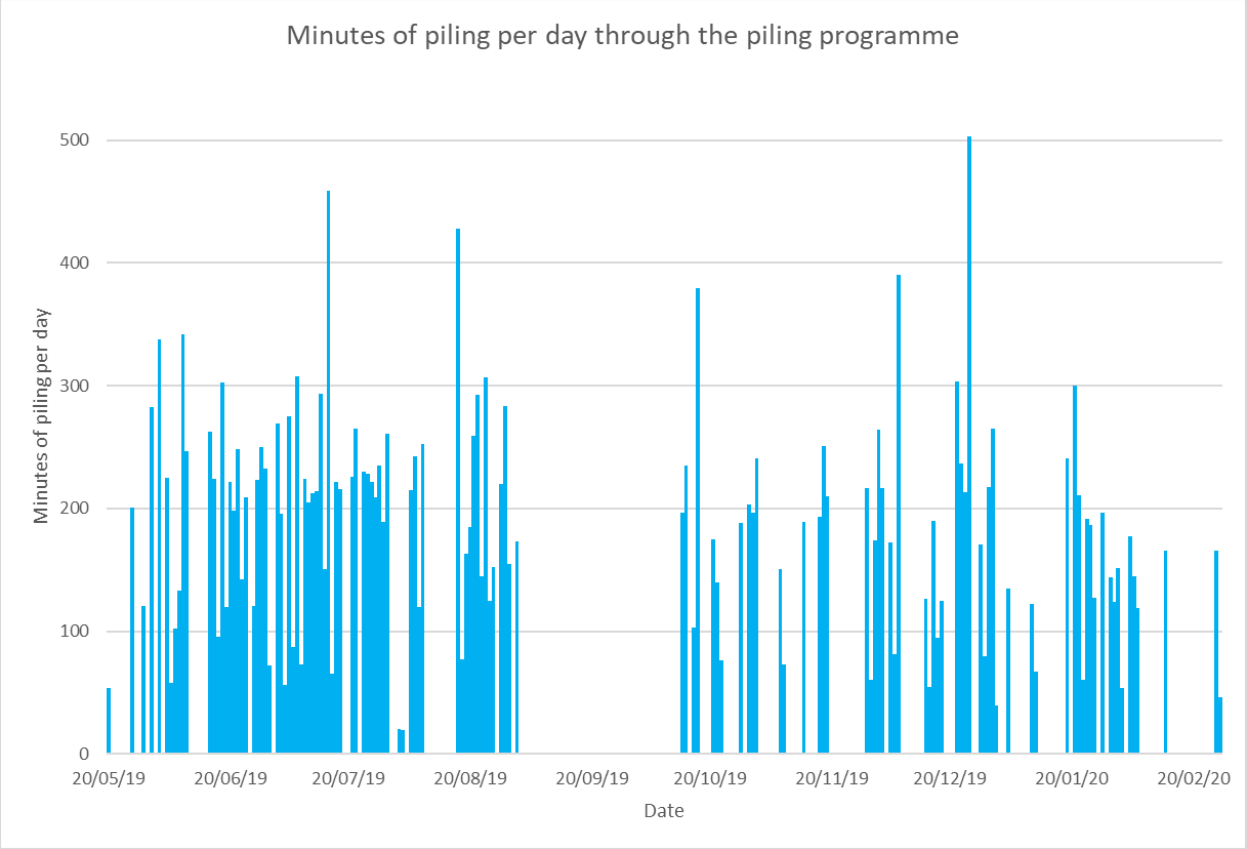
On the 132 active piling days, the average active piling time was 189.2 minutes, with the maximum piling time on any one day of 503.3 minutes, and the minimum active piling time on any day was 19.6 minutes. The most typical active piling time (median for the active piling days) was 196.3 minutes. **Graph 5-1** shows the number of minutes of piling per day, throughout the 284 day piling period. This shows a number of small gaps in piling, intersected with smaller piling periods, with a large gap in the piling period through September and the first half of October 2019. This gap was initially due to a technical fault with the hammer, followed by delays on pile supply from one of the manufacturers and resulted in the suspension of piling while the issues were resolved.

On each day of active piling (132 days), an average of 1.1 WTGs were piled, with the majority of days (n=117; 88.6%) having only one WTG location piled, and 11.5% (n=15) of days having two WTGs being piled in a day (**Graph 5-2**).

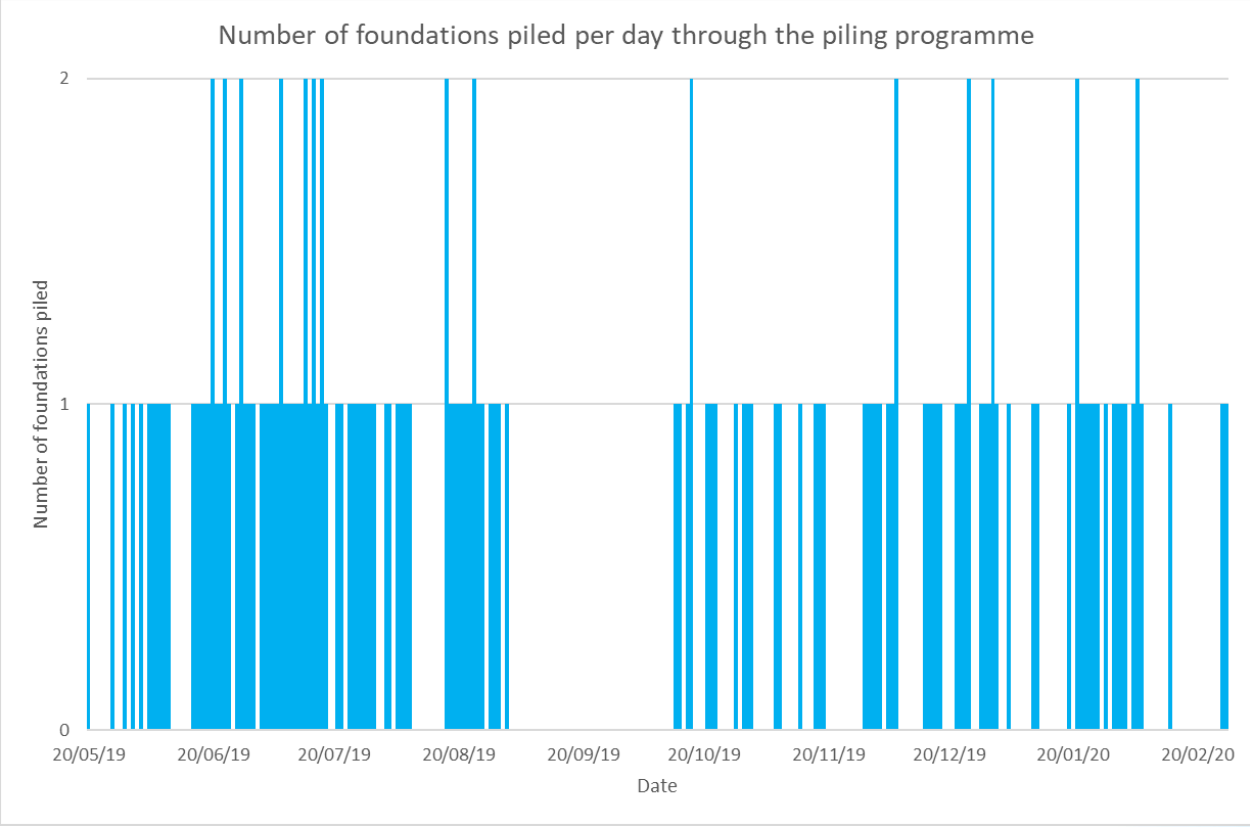
Throughout the piling period, an average of 2.8 pin-piles were piled each day of active piling (**Graph 5-3**), with an average of 3.3 piling bouts per active piling day (**Graph 5-4**). The maximum number of pin-piles piled in one day, and the maximum number of separate piling bouts, was six; however, more commonly (median of active piling days) three pin-piles were piled each day, and there were three separate piling bouts.

5.1.1 Concurrent Piling

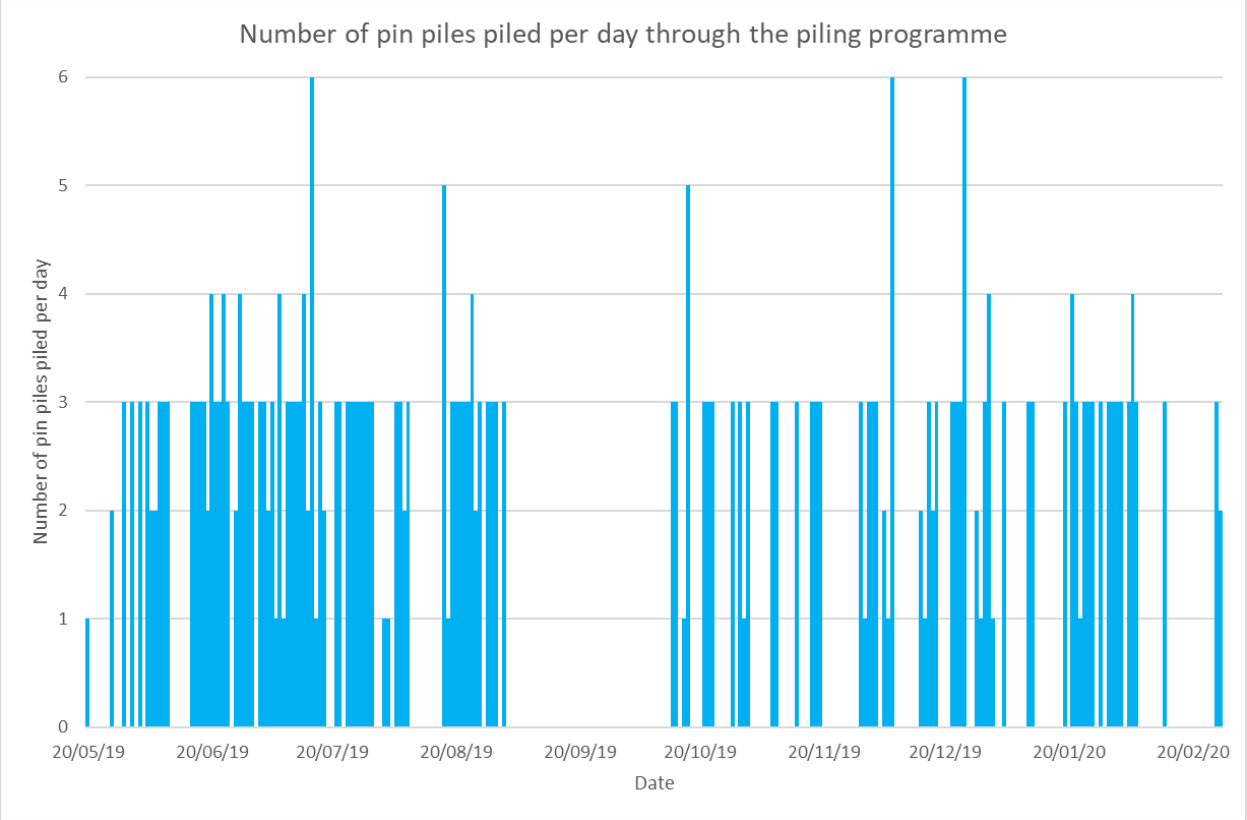
The PS stated that up to two pin-piles could be installed at one time. However, no concurrent piling was undertaken throughout the piling programme.



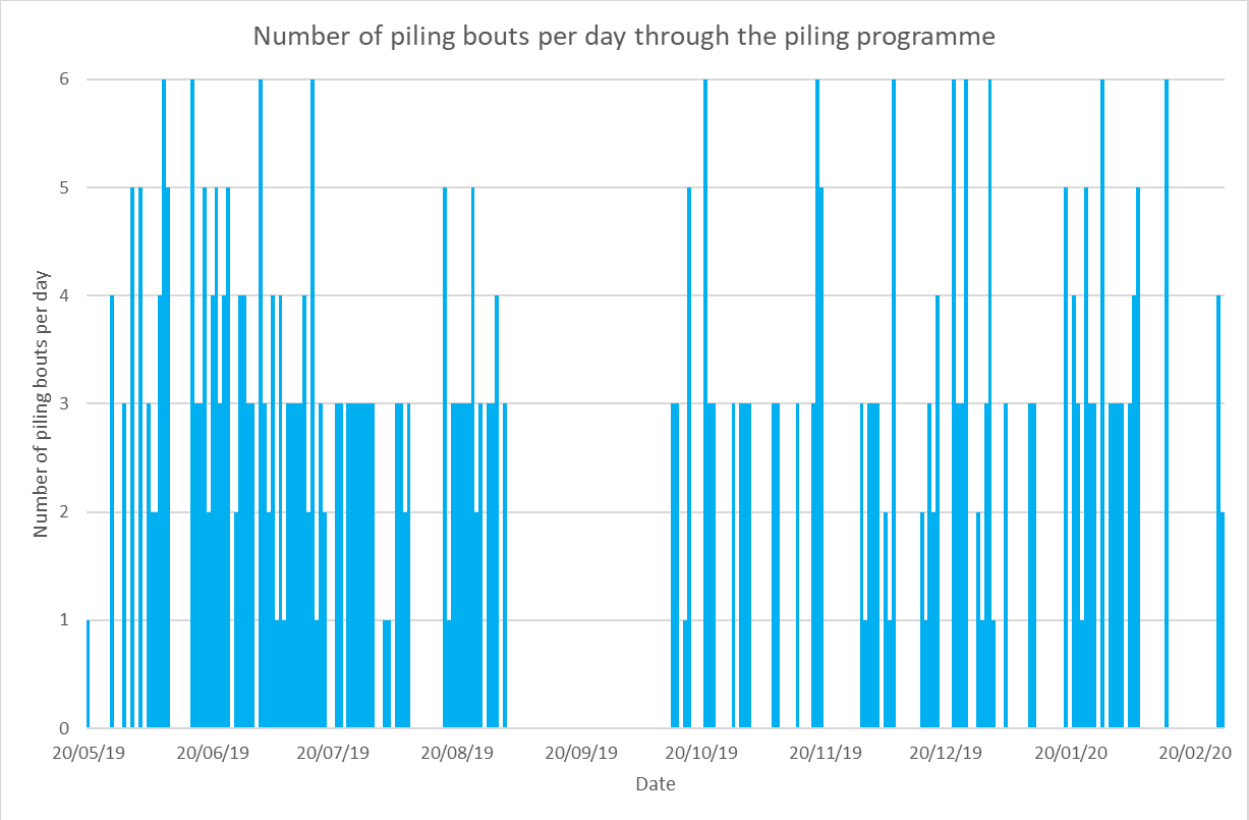
Graph 5-1 Piling time (in minutes) per day throughout the piling programme



Graph 5-2 Number of foundation locations piled per day throughout the piling programme



Graph 5-3 Number of pin-piles piled per day throughout the piling programme



Graph 5-4 Number of piling bouts per day throughout the piling programme

5.2 Piling Durations

The overall timing of construction activities for the WTG foundation installation can vary significantly depending on a number of factors and the overall time taken for driving each pin-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 provided in the PS estimated the duration of the continuous pile driving required for a pin-pile in each of six soil profiles. **Table 2-1** gives the typical estimated driving durations for a typical pin-pile in each of the characteristic soil profiles outlined in the PS.

For operational reasons, the pile driving duration (for each pin-pile) may not be continuous as, depending on operational requirements, driving may be suspended on a single pin-pile prior to achieving target depth (to undertake relief drilling, commence piling an adjacent pin-pile, add a pile follower or other intervention) before returning to finish driving to depth.

Table 5-1 shows a comparison of the predicted piling durations (predicted maximum of up to 16 hours per WTG location, or up to 6.5 hours per pin-pile) to the piling durations recorded during the foundation installation. The comparison shows that the piling durations per pin-pile were considerably shorter than expected, with the majority of the durations being less than 20% (e.g. less than 78 minutes) or between 20% and 40% (e.g. 78 – 156 minutes) of the predicted maximum piling time of 6.5 hours (390 minutes) per pin-pile. One pin-pile took 2.7 hours; 41.5% of the predicted maximum worst-case piling time.

Graph 5-5 shows that the typical piling duration per pin-pile was between 70 and 80 minutes (27.2% of pin-piles), with between 60 and 70 minutes required for 18.4% of pin-piles and between 80 and 90 minutes required for 18.8% of pin-piles. Three pin-piles took less than 60 minutes to install, with a minimum piling duration of 47 minutes for one pin-pile.

Table 5-1 A comparison of the predicted and actual piling durations (colours in line with categorisations as shown in Table 3-2; less than 20% of predicted, 20-40% of predicted, 40-60% of predicted, 60-80% of predicted, 80-100% of predicted, and more than 100% of predicted active piling durations)

Turbine	Durations of piling (in minutes)						Comparison to predicted soil profile [5]				Comparison to maximum durations estimated
	Pin-pile			Longest duration of the three pin-piles	Total duration for all three pin-piles	Average duration for the three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum durations for soil profile	Difference to predicted maximum duration	Difference to predicted most probable duration for average at WTG	Difference to predicted maximum duration (of 6.5 hours, 390 mins)
	Aft	Fore	MP								
A01	57	63	64	64	185	62	1	306	21.0%	20.5%	16.5%
A02	58	65	73	73	197	66	1*	306	23.9%	21.9%	18.8%
B02	73	97	94	97	264	88	2	390	25.0%	26.7%	25.0%
B03	68	68	74	74	210	70	2	390	18.9%	21.2%	18.9%
B04	56	54	64	64	173	58	6	312	20.4%	18.9%	16.3%
B05	73	80	82	82	235	78	2	390	20.9%	23.7%	20.9%
B13	75	76	90	90	241	80	1	306	29.5%	26.8%	23.1%
B14	75	72	77	77	224	75	5	324	23.9%	24.4%	19.9%
C02	69	63	92	92	223	74	6	312	29.4%	24.3%	23.5%
C04	57	60	58	60	175	58	2	390	15.3%	17.7%	15.3%
C05	47	51	56	56	155	52	6	312	18.1%	16.9%	14.5%
C07	78	70	103	103	252	84	6	312	33.2%	27.4%	26.5%
C08	64	68	79	79	211	70	4	312	25.2%	22.5%	20.2%
C09	71	82	78	82	231	77	4	312	26.2%	24.7%	20.9%
C10	55	59	75	75	188	63	2	390	19.2%	19.0%	19.2%

[5] *Based on known profiles for each location, and defined according to the expected number in each profile for unknown locations (see Section 3.2 for further details on how profiles were assigned to locations not originally classified into a soil profile)*

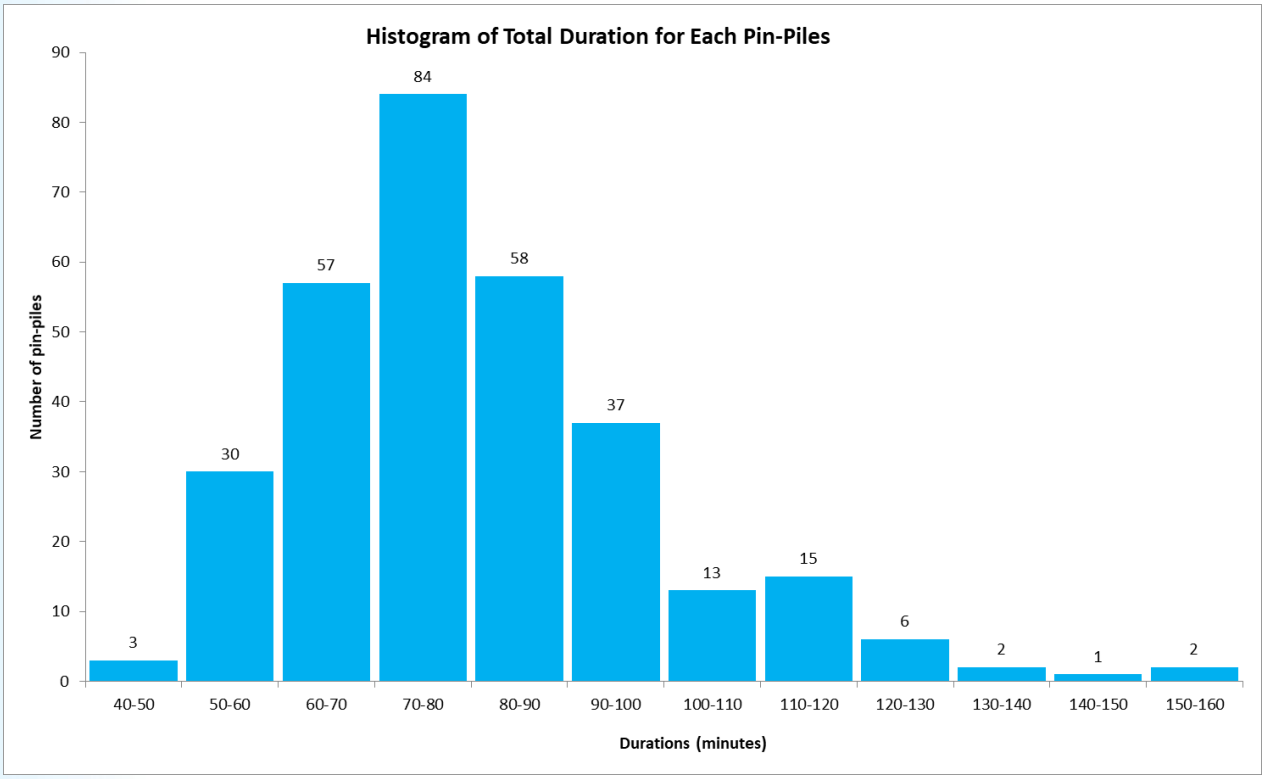
Turbine	Durations of piling (in minutes)						Comparison to predicted soil profile [5]				Comparison to maximum durations estimated
	Pin-pile			Longest duration of the three pin-piles	Total duration for all three pin-piles	Average duration for the three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum durations for soil profile	Difference to predicted maximum duration	Difference to predicted most probable duration for average at WTG	Difference to predicted maximum duration (of 6.5 hours, 390 mins)
	Aft	Fore	MP								
C11	64	60	79	79	203	68	2	390	20.3%	20.5%	20.3%
C12	71	63	62	71	197	66	3	270	26.5%	28.0%	18.3%
C13	86	87	119	119	292	97	1	306	39.0%	32.5%	30.6%
C14	73	73	74	74	220	73	6	312	23.8%	24.0%	19.1%
C15	73	66	65	73	205	68	1	306	24.0%	22.8%	18.8%
C16	66	75	73	75	215	72	5	324	23.3%	23.4%	19.3%
D04	96	95	123	123	314	105	2	390	31.6%	31.7%	31.6%
D05	62	65	63	65	190	63	2	390	16.7%	19.2%	16.7%
D06	55	52	74	74	181	60	2	390	19.0%	18.3%	19.0%
D07	81	77	91	91	248	83	6	312	29.0%	27.0%	23.2%
D08	69	70	72	72	212	71	4	312	23.2%	22.6%	18.5%
D09	60	52	67	67	179	60	4	312	21.3%	19.1%	17.1%
D10	65	73	78	78	216	72	4	312	25.0%	23.1%	20.0%
D11	76	72	104	104	252	84	4	312	33.2%	27.0%	26.6%
D12	80	74	115	115	268	89	2	390	29.4%	27.1%	29.4%
D13	81	83	89	89	254	85	1	306	29.2%	28.2%	22.9%
D14	64	65	76	76	205	68	4	312	24.3%	21.9%	19.4%
D15	62	62	66	66	189	63	3	270	24.3%	26.9%	16.8%
D16	67	67	79	79	213	71	1	306	25.8%	23.6%	20.3%

Turbine	Durations of piling (in minutes)						Comparison to predicted soil profile [5]				Comparison to maximum durations estimated
	Pin-pile			Longest duration of the three pin-piles	Total duration for all three pin-piles	Average duration for the three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum durations for soil profile	Difference to predicted maximum duration	Difference to predicted most probable duration for average at WTG	Difference to predicted maximum duration (of 6.5 hours, 390 mins)
	Aft	Fore	MP								
D17	64	74	71	74	209	70	1	306	24.2%	23.3%	19.0%
E04	60	59	74	74	193	64	2	390	18.9%	19.5%	18.9%
E05	77	86	89	89	251	84	2	390	22.7%	25.3%	22.7%
E14	82	78	87	87	247	82	1	306	28.4%	27.5%	22.3%
E18	74	76	84	84	235	78	1	306	27.6%	26.1%	21.6%
E19	73	86	95	95	254	85	1	306	31.1%	28.2%	24.4%
F04	66	55	75	75	197	66	4*	312	24.1%	21.0%	19.3%
F08	99	89	95	99	284	95	2	390	25.5%	28.6%	25.5%
F21	68	68	69	69	205	68	4	312	22.1%	21.9%	17.7%
G05	79	78	77	79	234	78	1*	306	25.7%	26.0%	20.2%
G06	62	63	64	64	189	63	4*	312	20.6%	20.2%	16.4%
G07	121	105	146	146	372	124	4	312	46.8%	39.8%	37.4%
G08	78	78	81	81	237	79	4	312	25.9%	25.3%	20.7%
G09	110	136	116	136	362	121	5	324	42.0%	39.5%	34.9%
G10	77	79	111	111	267	89	3	270	41.0%	38.0%	28.4%
G11	73	70	86	86	229	76	3	270	32.0%	32.7%	22.1%
G13	90	95	90	95	275	92	5	324	29.4%	30.0%	24.5%
G15	86	88	102	102	275	92	1	306	33.3%	30.6%	26.1%
G16	86	92	106	106	284	95	1	306	34.6%	31.5%	27.2%

Turbine	Durations of piling (in minutes)						Comparison to predicted soil profile [5]				Comparison to maximum durations estimated
	Pin-pile			Longest duration of the three pin-piles	Total duration for all three pin-piles	Average duration for the three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum durations for soil profile	Difference to predicted maximum duration	Difference to predicted most probable duration for average at WTG	Difference to predicted maximum duration (of 6.5 hours, 390 mins)
	Aft	Fore	MP								
G17	99	100	120	120	319	106	5	324	37.2%	34.8%	30.9%
G18	83	84	95	95	262	87	6	312	30.6%	28.6%	24.5%
G19	82	75	90	90	247	82	3	270	33.4%	35.2%	23.1%
G20	55	57	54	57	166	55	1	306	18.8%	18.4%	14.7%
G21	90	86	89	90	265	88	4	312	28.9%	28.3%	23.1%
G22	60	59	65	65	184	61	4	312	20.9%	19.6%	16.7%
H05	73	69	74	74	217	72	3*	270	27.4%	30.9%	18.9%
H06	84	73	84	84	240	80	4*	312	26.9%	25.7%	21.5%
H07	72	69	72	72	213	71	1*	306	23.7%	23.7%	18.6%
H08	67	65	88	88	220	73	6	312	28.2%	23.9%	22.6%
H09	59	71	85	85	215	72	5	324	26.2%	23.4%	21.7%
H10	68	77	65	77	210	70	5	324	23.7%	22.9%	19.7%
H11	93	94	117	117	304	101	5	324	36.2%	33.1%	30.1%
H13	86	76	90	90	252	84	1*	306	29.3%	28.0%	23.0%
H14	114	110	95	114	319	106	1	306	37.2%	35.4%	29.2%
H16	104	86	125	125	316	105	6	312	40.2%	34.4%	32.2%
H17	93	111	98	111	302	101	4	312	35.7%	32.3%	28.6%
H18	83	81	89	89	252	84	4	312	28.5%	26.9%	22.8%
H19	128	101	112	128	342	114	2	390	32.9%	34.5%	32.9%

Turbine	Durations of piling (in minutes)						Comparison to predicted soil profile [5]				Comparison to maximum durations estimated
	Pin-pile			Longest duration of the three pin-piles	Total duration for all three pin-piles	Average duration for the three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum durations for soil profile	Difference to predicted maximum duration	Difference to predicted most probable duration for average at WTG	Difference to predicted maximum duration (of 6.5 hours, 390 mins)
	Aft	Fore	MP								
H20	77	72	82	82	230	77	1	306	26.7%	25.6%	20.9%
H21	68	71	87	87	226	75	1	306	28.4%	25.1%	22.3%
H22	105	111	103	111	319	106	6*	312	35.4%	34.8%	28.3%
I06	61	59	96	96	216	72	1*	306	31.4%	24.0%	24.7%
I07	88	85	91	91	263	88	6*	312	29.1%	28.6%	23.3%
I18	79	68	92	92	238	79	4	312	29.4%	25.5%	23.5%
I19	87	99	97	99	283	94	2	390	25.3%	28.6%	25.3%
I20	80	84	72	84	236	79	5	324	26.1%	25.7%	21.6%
J07	64	61	76	76	200	67	1*	306	24.7%	22.3%	19.4%
J08	74	80	77	80	231	77	1*	306	26.2%	25.7%	20.6%
J09	86	80	112	112	278	93	4*	312	35.9%	29.7%	28.7%
J10	111	92	97	111	301	100	6*	312	35.5%	32.7%	28.4%
J12	50	54	59	59	163	54	1*	306	19.4%	18.1%	15.2%
J13	89	88	93	93	269	90	3*	270	34.3%	38.4%	23.8%
J14	100	95	110	110	305	102	1*	306	36.1%	33.9%	28.3%
J16	80	93	98	98	271	90	1*	306	32.0%	30.1%	25.1%
J17	100	131	107	131	337	112	6*	312	42.0%	36.7%	33.6%
J18	93	89	86	93	268	89	4*	312	29.9%	28.7%	23.9%
J19	68	73	71	73	212	71	2*	390	18.8%	21.4%	18.8%

Turbine	Durations of piling (in minutes)						Comparison to predicted soil profile [5]				Comparison to maximum durations estimated
	Pin-pile			Longest duration of the three pin-piles	Total duration for all three pin-piles	Average duration for the three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum durations for soil profile	Difference to predicted maximum duration	Difference to predicted most probable duration for average at WTG	Difference to predicted maximum duration (of 6.5 hours, 390 mins)
	Aft	Fore	MP								
K09	82	80	89	89	251	84	4*	312	28.6%	26.8%	22.9%
K10	75	73	87	87	235	78	1*	306	28.3%	26.1%	22.2%
K11	57	62	70	70	189	63	3*	270	26.1%	26.9%	18.1%
K16	85	86	111	111	282	94	1*	306	36.3%	31.4%	28.5%
K17	117	96	162	162	375	125	1*	306	52.9%	41.7%	41.5%
L09	72	59	78	78	209	70	1*	306	25.4%	23.2%	19.9%
L11	78	66	78	78	222	74	1*	306	25.6%	24.7%	20.1%
L12	72	68	88	88	228	76	1*	306	28.9%	25.4%	22.6%
L13	68	70	79	79	217	72	6*	312	25.3%	23.6%	20.3%
OSP1	130	152	155	155	438	146	2	390	39.9%	44.2%	39.9%
OSP2	54	50	60	60	164	55	1	306	19.5%	18.2%	15.3%
OSP3	84	85	91	91	259	86	4	312	29.1%	27.7%	23.3%



Graph 5-5 Histogram for total piling durations for each pin-pile

5.3 Pile Hammer Energies

As shown in **Table 5-2**, different hammer energy requirements were predicted to be required across the Wind Farm site, dependant on the soil profile of the WTG location, within the maximum consented hammer energy of 2,250 kJ.

For the worst case analysis (i.e. highest expected scenario) as evaluated in the PS, piles driven at three of the six soil profiles (profiles 1, 3 and 4) were expected to reach the target depth using less than 1,080 kJ; however, piles driven in profiles 2, 5, and 6 were predicted to potentially encounter early refusal at this blow energy level and would, therefore, require a hammer energy of up to 2,250 kJ. For all pile driving locations, the pile would only be driven using the upper end of the hammer energy predicted for a short period (if at all) in the latter period of pile driving, resulting in the maximum hammer energy of 2,250 kJ being used as little as possible.

Table 5-2 shows the predicted hammer energies required dependent on soil profile present, as well as the expected number of foundations within each category. These expected number of foundations within each soil profile and the maximum hammer energy predicted to be required at each location, were used to estimate the soil profile of all foundations installed where they were not previously known.

Table 5-2 Estimated number of piles under each soil profile, and their most probable and maximum hammer energies

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6
Estimated % of WTG	32%	17%	8%	21%	8%	14%
Number of WTGs (based on estimated %)	33	18	8	22	8	14

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6
Most probable (kJ)	660	1800	636	1020	900	1140
Highest expected (kJ)	1020	2250	996	1020	1800	1800

However, once construction began at the Wind Farm site, it was found that the seabed characteristics at some locations varied from what was initially expected, with some locations having a softer than expected soil profile, and some locations having harder than expected soil profiles. Subsequently, this led to some changes in the predicted hammer energy (as well as blow count) requirements.

Table 5-3 provides an indication of soil profiles, based on the actual hammer energies recorded during piling. When comparing this to the predicted number of foundations within each soil profile, significantly more foundations were expected to be in soil profiles 5 and 6, and significantly less in soil profiles 1 and 4, then was predicted during the PS. For this reason, a number of locations exhibited a higher hammer energy requirement than was initially predicted in the PS.

Table 5-3 Number of piles within the hammer energy defined for each profile (or set of profiles) based on the highest expected hammer energy

	Max energy up to 996 kJ (Profile 3)	Max energy up to 1,020 kJ (Profiles 1 and 4)	Max energy up to 1,800 kJ (Profiles 5 and 6)	Max energy up to 2,250 kJ (Profile 2)
Number of WTGs	15	3	72	13
% of WTG	15%	3%	70%	13%
Difference from predicted (%)	7%	-50%	48%	-4%

Table 5-4 shows a comparison of the predicted maximum hammer energies (with a maximum consented hammer energy of 2,250 kJ) to the actual maximum hammer energies required at each pin-pile location during the foundation installation. The comparison uses the maximum pin-pile hammer energy at each WTG, and shows that the maximum hammer energies required were lower than the consented maximum in all cases. A total of 13 pin-piles had maximum hammer energies of more than 80% of the maximum hammer energy (i.e. more than 1,800 kJ), a number of pin-piles had hammer energies of between 60% and 80% of the maximum consented hammer energy (n= 34; 1,350 – 1,800 kJ), while the majority of the pin-piles (n=51) required maximum hammer energies of 40% to 60% of the maximum consented hammer energy (900 – 1,350 kJ). A smaller number of pin-piles (five) required much lower maximum hammer energies of between 20% and 40%) of the consented maximum hammer energy (0 – 900 kJ).

The highest maximum hammer energy required was 2,071 kJ, while the lowest maximum hammer energy required was 628 kJ, and the average maximum hammer energy across all pin-piles was 1,341 kJ.

Although, a number of pin-piles (at 55 foundations) required a maximum hammer energy higher than was initially predicted to be required, based on the soil profile analysis presented at the PS stage, all were less than the maximum consented hammer energy of 2,250 kJ.

Table 5-4 A comparison of the predicted and actual maximum hammer energies (colours in line with categorisations as shown in Table 3-2; less than 20% of predicted, 20-40% of predicted, 40-60% of predicted, 60-80% of predicted, 80-100% of predicted, and more than 100% of predicted maximum hammer energies)

Turbine	Hammer energy (kJ)					Comparison to predicted soil profile[6]				Comparison to maximum hammer energy consented
	Pin-pile			Maximum at WTG	Average of three pin-piles at WTG	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum hammer energy (kJ) for soil profile	Difference to predicted maximum kJ	Difference to predicted most probable kJ for average at WTG	Difference to predicted maximum kJ (of 2,250 kJ)
	Aft	Fore	MP							
A01	810	1014	1010	1014	945	1	1020	99.4%	143.1%	45.1%
A02	1307	1212	1303	1307	1274	1*	1020	128.1%	193.0%	58.1%
B02	1220	1309	1045	1309	1191	2	2250	58.2%	66.2%	58.2%
B03	930	918	1065	1065	971	2	2250	47.3%	53.9%	47.3%
B04	1032	1025	1014	1032	1024	6	1800	57.3%	89.8%	45.9%
B05	1408	1121	1402	1408	1310	2	2250	62.6%	72.8%	62.6%
B13	1311	1522	1520	1522	1451	1	1020	149.2%	219.8%	67.6%
B14	1409	1220	1407	1409	1345	5	1800	78.3%	149.5%	62.6%
C02	1140	1211	1126	1211	1159	6	1800	67.3%	101.7%	53.8%
C04	813	815	826	826	818	2	2250	36.7%	45.4%	36.7%
C05	850	823	917	917	863	6	1800	50.9%	75.7%	40.8%
C07	1124	1097	1201	1201	1141	6	1800	66.7%	100.1%	53.4%
C08	1116	1125	1218	1218	1153	4	1020	119.4%	113.0%	54.1%
C09	1141	1103	1291	1291	1178	4	1020	126.6%	115.5%	57.4%
C10	911	973	881	973	922	2	2250	43.2%	51.2%	43.2%
C11	1526	1327	1415	1526	1423	2	2250	67.8%	79.0%	67.8%

[6] *Based on known profiles for each location, and defined according to the expected number in each profile for unknown locations (see Section 3.2 for further details on how profiles were assigned to locations not originally classified into a soil profile)*

Turbine	Hammer energy (kJ)					Comparison to predicted soil profile[6]				Comparison to maximum hammer energy consented
	Pin-pile			Maximum at WTG	Average of three pin-piles at WTG	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum hammer energy (kJ) for soil profile	Difference to predicted maximum kJ	Difference to predicted most probable kJ for average at WTG	Difference to predicted maximum kJ (of 2,250 kJ)
	Aft	Fore	MP							
C12	994	800	1027	1027	940	3	996	103.1%	147.9%	45.6%
C13	1466	1441	1810	1810	1572	1	1020	177.5%	238.2%	80.4%
C14	1419	1216	1008	1419	1214	6	1800	78.8%	106.5%	63.1%
C15	829	1103	1123	1123	1018	1	1020	110.1%	154.3%	49.9%
C16	1119	1201	1015	1201	1112	5	1800	66.7%	123.5%	53.4%
D04	1844	1838	1833	1844	1838	2	2250	82.0%	102.1%	82.0%
D05	912	1154	1106	1154	1057	2	2250	51.3%	58.7%	51.3%
D06	628	527	531	628	562	2	2250	27.9%	31.2%	27.9%
D07	1299	1005	1005	1299	1103	6	1800	72.2%	96.8%	57.7%
D08	1371	1472	1408	1472	1417	4	1020	144.3%	138.9%	65.4%
D09	926	923	942	942	930	4	1020	92.4%	91.2%	41.9%
D10	913	1224	928	1224	1022	4	1020	120.0%	100.2%	54.4%
D11	1685	1524	1633	1685	1614	4	1020	165.2%	158.2%	74.9%
D12	1695	1805	1839	1839	1780	2	2250	81.7%	98.9%	81.7%
D13	1123	1068	1165	1165	1119	1	1020	114.2%	169.5%	51.8%
D14	1216	1135	1513	1513	1288	4	1020	148.3%	126.3%	67.2%
D15	919	1061	911	1061	964	3	996	106.5%	151.5%	47.2%
D16	1033	938	1030	1033	1000	1	1020	101.3%	151.6%	45.9%
D17	1119	1207	1217	1217	1181	1	1020	119.3%	178.9%	54.1%
E04	890	973	907	973	923	2	2250	43.2%	51.3%	43.2%

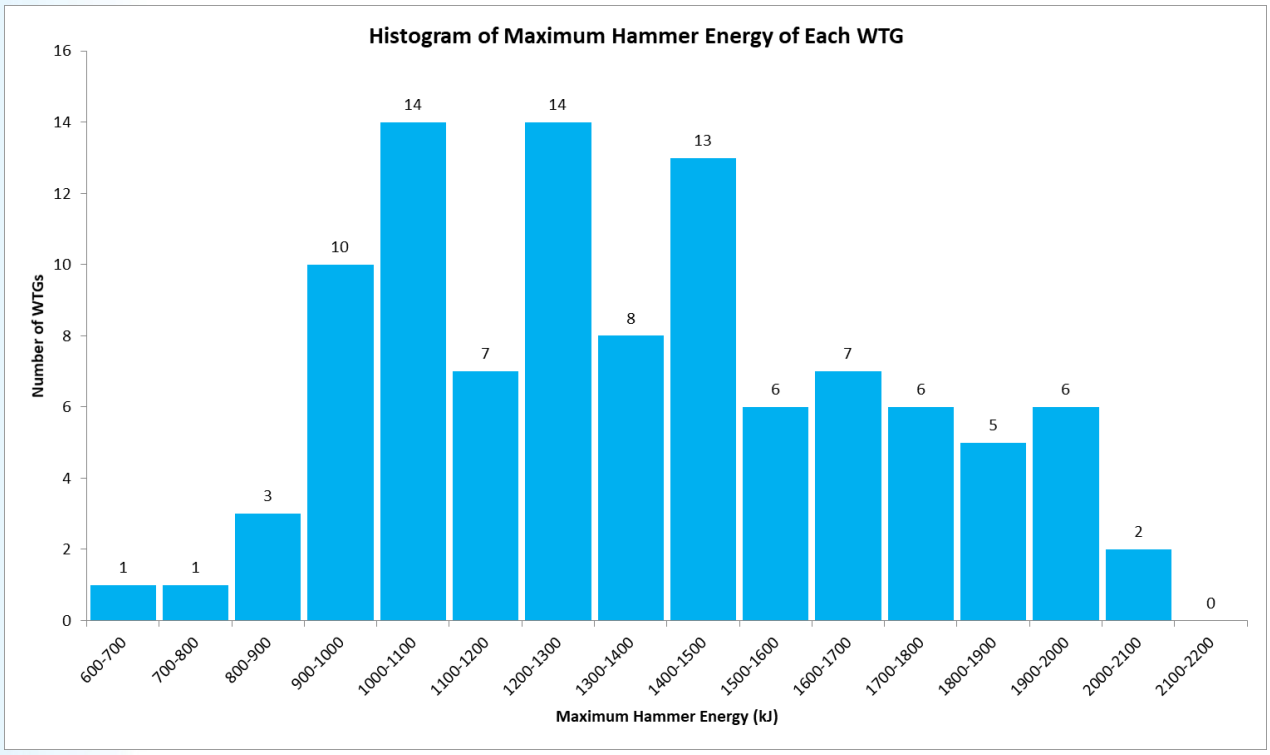
Turbine	Hammer energy (kJ)					Comparison to predicted soil profile[6]				Comparison to maximum hammer energy consented
	Pin-pile			Maximum at WTG	Average of three pin-piles at WTG	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum hammer energy (kJ) for soil profile	Difference to predicted maximum kJ	Difference to predicted most probable kJ for average at WTG	Difference to predicted maximum kJ (of 2,250 kJ)
	Aft	Fore	MP							
E05	985	621	934	985	847	2	2250	43.8%	47.0%	43.8%
E14	1402	1325	1317	1402	1348	1	1020	137.5%	204.2%	62.3%
E18	1218	1434	1426	1434	1359	1	1020	140.6%	206.0%	63.7%
E19	1106	1216	1508	1508	1277	1	1020	147.8%	193.4%	67.0%
F04	1436	1122	1620	1620	1393	4*	1020	158.8%	136.5%	72.0%
F08	1606	1634	1660	1660	1633	2	2250	73.8%	90.7%	73.8%
F21	1407	1523	1409	1523	1446	4	1020	149.3%	141.8%	67.7%
G05	1044	942	1015	1044	1000	1*	1020	102.4%	151.6%	46.4%
G06	1428	1348	1115	1428	1297	4*	1020	140.0%	127.2%	63.5%
G07	2015	2045	1951	2045	2004	4	1020	200.5%	196.4%	90.9%
G08	1825	1631	1823	1825	1760	4	1020	178.9%	172.5%	81.1%
G09	2025	2071	1933	2071	2010	5	1800	115.1%	223.3%	92.0%
G10	1727	1562	1901	1901	1730	3	996	190.9%	272.0%	84.5%
G11	1625	1835	1913	1913	1791	3	996	192.1%	281.6%	85.0%
G13	1013	1065	1008	1065	1029	5	1800	59.2%	114.3%	47.3%
G15	908	1027	1309	1309	1081	1	1020	128.3%	163.8%	58.2%
G16	909	811	721	909	814	1	1020	89.1%	123.3%	40.4%
G17	1548	1524	1619	1619	1564	5	1800	89.9%	173.7%	72.0%
G18	1111	1199	1105	1199	1138	6	1800	66.6%	99.9%	53.3%
G19	1025	922	1201	1201	1049	3	996	120.6%	165.0%	53.4%

Turbine	Hammer energy (kJ)					Comparison to predicted soil profile[6]				Comparison to maximum hammer energy consented
	Pin-pile			Maximum at WTG	Average of three pin-piles at WTG	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum hammer energy (kJ) for soil profile	Difference to predicted maximum kJ	Difference to predicted most probable kJ for average at WTG	Difference to predicted maximum kJ (of 2,250 kJ)
	Aft	Fore	MP							
G20	1227	1228	1148	1228	1201	1	1020	120.4%	182.0%	54.6%
G21	1429	1402	1317	1429	1383	4	1020	140.1%	135.6%	63.5%
G22	1208	1215	1206	1215	1210	4	1020	119.1%	118.6%	54.0%
H05	774	821	761	821	785	3*	996	82.4%	123.5%	36.5%
H06	1626	1454	1439	1626	1506	4*	1020	159.4%	147.7%	72.3%
H07	1021	1026	1014	1026	1020	1*	1020	100.6%	154.6%	45.6%
H08	1427	1441	1324	1441	1397	6	1800	80.1%	122.6%	64.0%
H09	1124	1031	1026	1124	1060	5	1800	62.4%	117.8%	50.0%
H10	1544	1760	1621	1760	1642	5	1800	97.8%	182.4%	78.2%
H11	1919	1840	1832	1919	1864	5	1800	106.6%	207.1%	85.3%
H13	993	915	901	993	936	1*	1020	97.4%	141.9%	44.1%
H14	1006	1002	1011	1011	1006	1	1020	99.1%	152.5%	44.9%
H16	722	710	1311	1311	914	6	1800	72.8%	80.2%	58.3%
H17	1524	1424	1194	1524	1381	4	1020	149.4%	135.4%	67.7%
H18	1317	1226	1371	1371	1305	4	1020	134.4%	127.9%	60.9%
H19	1784	1710	1619	1784	1704	2	2250	79.3%	94.7%	79.3%
H20	917	1012	923	1012	951	1	1020	99.2%	144.0%	45.0%
H21	1411	1101	1032	1411	1181	1	1020	138.3%	179.0%	62.7%
H22	1438	1748	1210	1748	1465	6*	1800	97.1%	128.5%	77.7%
I06	1304	1325	1109	1325	1246	1*	1020	129.9%	188.8%	58.9%

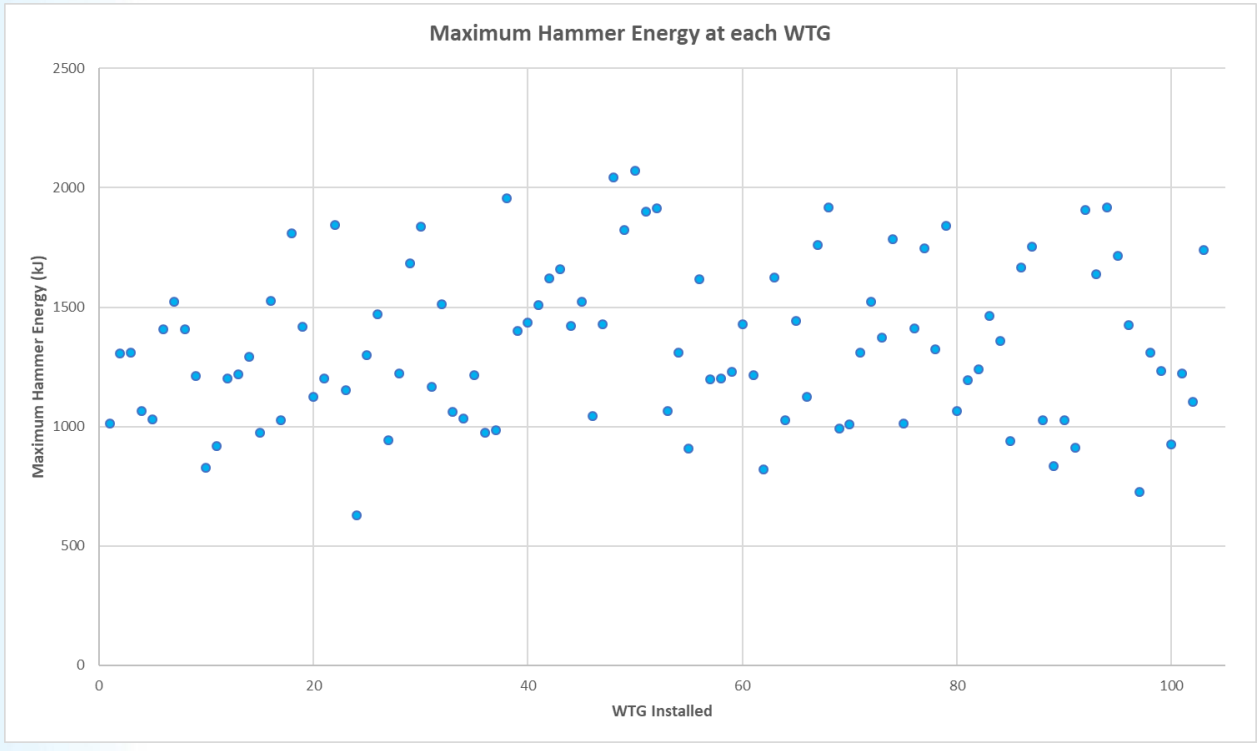
Turbine	Hammer energy (kJ)					Comparison to predicted soil profile[6]				Comparison to maximum hammer energy consented
	Pin-pile			Maximum at WTG	Average of three pin-piles at WTG	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum hammer energy (kJ) for soil profile	Difference to predicted maximum kJ	Difference to predicted most probable kJ for average at WTG	Difference to predicted maximum kJ (of 2,250 kJ)
	Aft	Fore	MP							
I07	1841	1647	1838	1841	1775	6*	1800	102.3%	155.7%	81.8%
I18	834	1125	1194	1194	1051	4	1020	117.1%	103.0%	53.1%
I19	1220	1241	1221	1241	1227	2	2250	55.2%	68.2%	55.2%
I20	1205	1463	1301	1463	1323	5	1800	81.3%	147.0%	65.0%
J07	1295	1269	1360	1360	1308	1*	1020	133.3%	198.2%	60.4%
J08	900	939	817	939	885	1*	1020	92.1%	134.1%	41.7%
J09	1665	1647	1652	1665	1655	4*	1020	163.2%	162.2%	74.0%
J10	1754	988	824	1754	1189	6*	1800	97.4%	104.3%	78.0%
J12	1028	935	926	1028	963	1*	1020	100.8%	145.9%	45.7%
J13	807	836	800	836	814	3*	996	83.9%	128.0%	37.2%
J14	830	1027	995	1027	951	1*	1020	100.7%	144.0%	45.6%
J16	816	913	910	913	880	1*	1020	89.5%	133.3%	40.6%
J17	1821	1909	1613	1909	1781	6*	1800	106.1%	156.2%	84.8%
J18	1638	1529	1410	1638	1526	4*	1020	160.6%	149.6%	72.8%
J19	1919	1917	1791	1919	1876	2*	2250	85.3%	104.2%	85.3%
K09	1404	1715	1401	1715	1507	4*	1020	168.1%	147.7%	76.2%
K10	1310	1426	1345	1426	1360	1*	1020	139.8%	206.1%	63.4%
K11	728	728	710	728	722	3*	996	73.1%	113.5%	32.4%
K16	1237	1310	1198	1310	1248	1*	1020	128.4%	189.1%	58.2%
K17	1217	1226	1234	1234	1226	1*	1020	121.0%	185.7%	54.8%

Turbine	Hammer energy (kJ)					Comparison to predicted soil profile[6]				Comparison to maximum hammer energy consented
	Pin-pile			Maximum at WTG	Average of three pin-piles at WTG	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum hammer energy (kJ) for soil profile	Difference to predicted maximum kJ	Difference to predicted most probable kJ for average at WTG	Difference to predicted maximum kJ (of 2,250 kJ)
	Aft	Fore	MP							
L09	925	925	717	925	856	1*	1020	90.7%	129.6%	41.1%
L11	1222	1203	1022	1222	1149	1*	1020	119.8%	174.1%	54.3%
L12	1102	924	1016	1102	1014	1*	1020	108.0%	153.6%	49.0%
L13	1739	1648	1626	1739	1671	6*	1800	96.6%	146.6%	77.3%
OSP1	1955	1954	1954	1955	1954	2	2250	86.9%	108.6%	86.9%
OSP2	1420	1354	1103	1420	1292	1	1020	139.2%	195.8%	63.1%
OSP3	1025	1066	1017	1066	1036	4	1020	104.5%	101.6%	47.4%

Graph 5-6 shows that the typical maximum hammer energy required was between 1,000-1,100 kJ and 1,200-1,300 kJ for 13.6% of WTG locations, and between 1,400-1,500 kJ for12.6% of WTG locations. A total of five of the WTG locations required hammer energies of less than 900 kJ and two of more than 2,000 kJ. **Graph 5-7** again shows that the most commonly required hammer energies per foundation were between 1,000 kJ and 2,000 kJ.



Graph 5-6 Histogram to show the maximum hammer energies recorded at each WTG



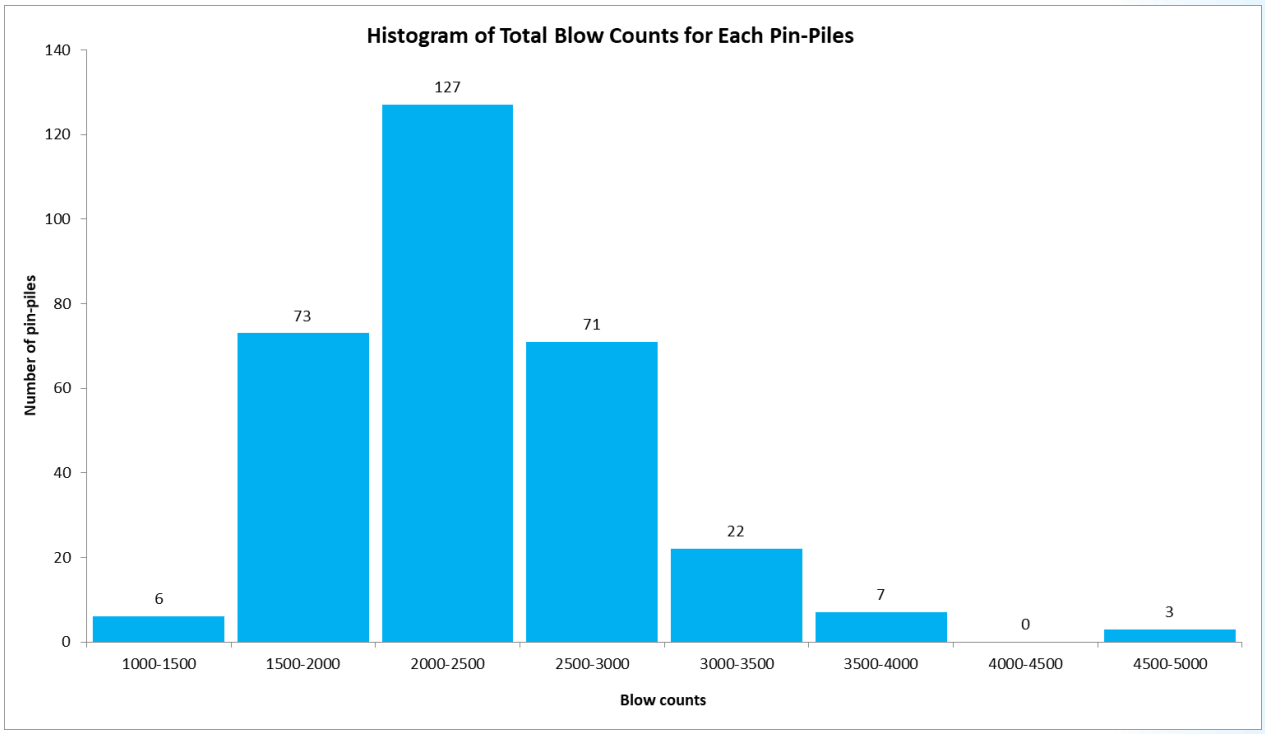
Graph 5-7 Scatter graph to show the maximum hammer energies at each WTG installed

5.4 Pile Blow Counts

Table 5-5 shows a comparison of the predicted pile blow counts per pin-pile (of up to 16,650 per pin-pile) to the blow counts required during the foundation installation. The comparison shows that the pile blow counts were considerably less than expected, with the majority of the maximum blow counts required per foundation being less than 20% of the predicted maximum, and nine foundations having a recorded maximum blow count of between 20% and 40% of the expected blow count per pin-pile. The highest blow count recorded was 4,773, while the lowest was 1,364. The average blow count per pin-pile was 2,352.

When comparing against the predicted pile blow counts predicted from the location specific soil profile, the highest comparison was again that the maximum blow count recorded at foundation locations were predominantly less than 20% of the maximum predicted, with a smaller number (n=30) having blow counts of between 20% and 40% of the predicted blow count (based on the soil profiles).

Graph 5-8 shows that the most common blow count per pin-pile was between 2,000 and 2,500 for 41.1% of pin-piles, with between 1,500 and 2,000 blows for 23.6% of pin-piles, and between 2,500 and 3,000 blows for 23.0% of pin-piles. Three pin-piles required 4,500 to 5,000 blows and six pin-piles between 1,000 and 1,500 blows to install.



Graph 5-8 Histogram of the total blow counts for all pin-piles

Table 5-5 A comparison of the predicted and actual blow counts (colours in line with categorisations as shown in Table 3-2; less than 20% of predicted, 20-40% of predicted, 40-60% of predicted, 60-80% of predicted, 80-100% of predicted, and more than 100% of predicted blow counts)

Turbine	Blow counts						Comparison to predicted soil profile[7]				Comparison to maximum blow count predicted
	Pin-pile			Highest at WTG	Total for all three pin-piles at WTG	Average of three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum blow count for soil profile	Difference to predicted maximum blow count	Difference to predicted most probable for average at WTG	Difference to predicted maximum (of 16,650)
	Aft	Fore	MP								
A01	1543	1565	1364	1565	4472	1491	1	16650	9.4%	11.1%	9.4%
A02	1764	1889	2016	2016	5669	1890	1*	16650	12.1%	14.0%	12.1%
B02	2299	2926	2762	2926	7987	2662	2	16650	17.6%	19.7%	17.6%
B03	1941	1958	2020	2020	5919	1973	2	16650	12.1%	14.6%	12.1%
B04	1543	1493	1630	1630	4666	1555	6	12220	13.3%	12.9%	9.8%
B05	2154	2194	2147	2194	6495	2165	2	16650	13.2%	16.0%	13.2%
B13	2276	2313	2552	2552	7141	2380	1	16650	15.3%	17.6%	15.3%
B14	2196	2258	2166	2258	6620	2207	5	16650	13.6%	16.4%	13.6%
C02	2231	2162	2732	2732	7125	2375	6	12220	22.4%	19.7%	16.4%
C04	1392	1364	1393	1393	4149	1383	2	16650	8.4%	10.3%	8.4%
C05	1388	1523	1620	1620	4531	1510	6	12220	13.3%	12.5%	9.7%
C07	2341	2207	2546	2546	7094	2365	6	12220	20.8%	19.6%	15.3%
C08	2209	2266	2261	2266	6736	2245	4	12220	18.5%	18.6%	13.6%
C09	2325	2463	2255	2463	7043	2348	4	12220	20.2%	19.4%	14.8%
C10	1639	1791	2233	2233	5663	1888	2	16650	13.4%	14.0%	13.4%

[7] *Based on known profiles for each location, and defined according to the expected number in each profile for unknown locations (see Section 3.2 for further details on how profiles were assigned to locations not originally classified into a soil profile)*

Turbine	Blow counts						Comparison to predicted soil profile[7]				Comparison to maximum blow count predicted
	Pin-pile			Highest at WTG	Total for all three pin-piles at WTG	Average of three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum blow count for soil profile	Difference to predicted maximum blow count	Difference to predicted most probable for average at WTG	Difference to predicted maximum (of 16,650)
	Aft	Fore	MP								
C11	1994	1826	2217	2217	6037	2012	2	16650	13.3%	14.9%	13.3%
C12	2146	1876	1764	2146	5786	1929	3	12220	17.6%	16.0%	12.9%
C13	3017	2992	3365	3365	9374	3125	1	16650	20.2%	23.2%	20.2%
C14	2281	2223	1979	2281	6483	2161	6	12220	18.7%	17.9%	13.7%
C15	2160	1846	1817	2160	5823	1941	1	16650	13.0%	14.4%	13.0%
C16	2018	2027	2088	2088	6133	2044	5	16650	12.5%	15.2%	12.5%
D04	3182	3127	3631	3631	9940	3313	2	16650	21.8%	24.6%	21.8%
D05	1890	1921	1792	1921	5603	1868	2	16650	11.5%	13.8%	11.5%
D06	1718	1508	1835	1835	5061	1687	2	16650	11.0%	12.5%	11.0%
D07	2797	2703	2844	2844	8344	2781	6	12220	23.3%	23.0%	17.1%
D08	2191	2198	2185	2198	6574	2191	4	12220	18.0%	18.1%	13.2%
D09	1897	1699	1916	1916	5512	1837	4	12220	15.7%	15.2%	11.5%
D10	2009	2227	2226	2227	6462	2154	4	12220	18.2%	17.8%	13.4%
D11	2548	2378	3080	3080	8006	2669	4	12220	25.2%	22.1%	18.5%
D12	2411	2281	3027	3027	7719	2573	2	16650	18.2%	19.1%	18.2%
D13	2683	2617	2631	2683	7931	2644	1	16650	16.1%	19.6%	16.1%
D14	2203	2163	2441	2441	6807	2269	4	12220	20.0%	18.8%	14.7%
D15	1786	1831	1898	1898	5515	1838	3	12220	15.5%	15.2%	11.4%
D16	2065	2149	2260	2260	6474	2158	1	16650	13.6%	16.0%	13.6%

Turbine	Blow counts						Comparison to predicted soil profile[7]				Comparison to maximum blow count predicted
	Pin-pile			Highest at WTG	Total for all three pin-piles at WTG	Average of three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum blow count for soil profile	Difference to predicted maximum blow count	Difference to predicted most probable for average at WTG	Difference to predicted maximum (of 16,650)
	Aft	Fore	MP								
D17	1897	1894	1781	1897	5572	1857	1	16650	11.4%	13.8%	11.4%
E04	1713	1667	1742	1742	5122	1707	2	16650	10.5%	12.7%	10.5%
E05	2018	2292	2379	2379	6689	2230	2	16650	14.3%	16.5%	14.3%
E14	2280	2163	2347	2347	6790	2263	1	16650	14.1%	16.8%	14.1%
E18	2338	2183	2342	2342	6863	2288	1	16650	14.1%	17.0%	14.1%
E19	2423	2674	2675	2675	7772	2591	1	16650	16.1%	19.2%	16.1%
F04	1982	1700	1942	1982	5624	1875	4*	12220	16.2%	15.5%	11.9%
F08	2666	2603	2676	2676	7945	2648	2	16650	16.1%	19.6%	16.1%
F21	1875	1818	1872	1875	5565	1855	4	12220	15.3%	15.4%	11.3%
G05	2250	2058	2227	2250	6535	2178	1*	16650	13.5%	16.1%	13.5%
G06	1909	1959	1924	1959	5792	1931	4*	12220	16.0%	16.0%	11.8%
G07	3564	2781	3571	3571	9916	3305	4	12220	29.2%	27.4%	21.4%
G08	2465	2386	2374	2465	7225	2408	4	12220	20.2%	19.9%	14.8%
G09	3098	3830	3052	3830	9980	3327	5	16650	23.0%	24.7%	23.0%
G10	2299	2396	3246	3246	7941	2647	3	12220	26.6%	21.9%	19.5%
G11	2250	2075	2436	2436	6761	2254	3	12220	19.9%	18.7%	14.6%
G13	2428	2651	2622	2651	7701	2567	5	16650	15.9%	19.0%	15.9%
G15	2239	2285	2486	2486	7010	2337	1	16650	14.9%	17.3%	14.9%
G16	2587	2805	2927	2927	8319	2773	1	16650	17.6%	20.6%	17.6%

Turbine	Blow counts						Comparison to predicted soil profile[7]				Comparison to maximum blow count predicted
	Pin-pile			Highest at WTG	Total for all three pin-piles at WTG	Average of three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum blow count for soil profile	Difference to predicted maximum blow count	Difference to predicted most probable for average at WTG	Difference to predicted maximum (of 16,650)
	Aft	Fore	MP								
G17	3005	3314	3685	3685	10004	3335	5	16650	22.1%	24.7%	22.1%
G18	2469	2563	2862	2862	7894	2631	6	12220	23.4%	21.8%	17.2%
G19	2435	2165	2422	2435	7022	2341	3	12220	19.9%	19.4%	14.6%
G20	1781	1886	1634	1886	5301	1767	1	16650	11.3%	13.1%	11.3%
G21	2716	2596	2527	2716	7839	2613	4	12220	22.2%	21.6%	16.3%
G22	1694	1705	1717	1717	5116	1705	4	12220	14.1%	14.1%	10.3%
H05	1939	2043	1887	2043	5869	1956	3*	12220	16.7%	16.2%	12.3%
H06	2547	2368	2477	2547	7392	2464	4*	12220	20.8%	20.4%	15.3%
H07	2224	1969	2110	2224	6303	2101	1*	16650	13.4%	15.6%	13.4%
H08	2152	1861	2295	2295	6308	2103	6	12220	18.8%	17.4%	13.8%
H09	2004	2104	2309	2309	6417	2139	5	16650	13.9%	15.9%	13.9%
H10	2024	2249	1950	2249	6223	2074	5	16650	13.5%	15.4%	13.5%
H11	2802	2783	3245	3245	8830	2943	5	16650	19.5%	21.8%	19.5%
H13	2008	1703	1853	2008	5564	1855	1*	16650	12.1%	13.7%	12.1%
H14	2584	2215	1888	2584	6687	2229	1	16650	15.5%	16.5%	15.5%
H16	3320	2712	3592	3592	9624	3208	6	12220	29.4%	26.6%	21.6%
H17	2645	3012	2810	3012	8467	2822	4	12220	24.6%	23.4%	18.1%
H18	2618	2584	2516	2618	7718	2573	4	12220	21.4%	21.3%	15.7%
H19	3140	2816	2835	3140	8791	2930	2	16650	18.9%	21.7%	18.9%

Turbine	Blow counts						Comparison to predicted soil profile[7]				Comparison to maximum blow count predicted
	Pin-pile			Highest at WTG	Total for all three pin-piles at WTG	Average of three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum blow count for soil profile	Difference to predicted maximum blow count	Difference to predicted most probable for average at WTG	Difference to predicted maximum (of 16,650)
	Aft	Fore	MP								
H20	2349	2219	2347	2349	6915	2305	1	16650	14.1%	17.1%	14.1%
H21	2056	2081	2418	2418	6555	2185	1	16650	14.5%	16.2%	14.5%
H22	2959	2786	2683	2959	8428	2809	6*	12220	24.2%	23.3%	17.8%
I06	1929	1827	2884	2884	6640	2213	1*	16650	17.3%	16.4%	17.3%
I07	2806	2747	2695	2806	8248	2749	6*	12220	23.0%	22.8%	16.9%
I18	2842	1932	2473	2842	7247	2416	4	12220	23.3%	20.0%	17.1%
I19	2366	2610	2243	2610	7219	2406	2	16650	15.7%	17.8%	15.7%
I20	2533	2592	2486	2592	7611	2537	5	16650	15.6%	18.8%	15.6%
J07	1809	1653	2117	2117	5579	1860	1*	16650	12.7%	13.8%	12.7%
J08	2338	2106	2029	2338	6473	2158	1*	16650	14.0%	16.0%	14.0%
J09	2706	2613	3393	3393	8712	2904	4*	12220	27.8%	24.0%	20.4%
J10	2954	2852	3031	3031	8837	2946	6*	12220	24.8%	24.4%	18.2%
J12	1836	1908	1960	1960	5704	1901	1*	16650	11.8%	14.1%	11.8%
J13	2375	2401	2304	2401	7080	2360	3*	12220	19.6%	19.5%	14.4%
J14	2998	2788	3138	3138	8924	2975	1*	16650	18.8%	22.1%	18.8%
J16	2466	2507	2464	2507	7437	2479	1*	16650	15.1%	18.4%	15.1%
J17	2858	3339	2686	3339	8883	2961	6*	12220	27.3%	24.5%	20.1%
J18	2603	2738	2652	2738	7993	2664	4*	12220	22.4%	22.1%	16.4%
J19	2099	2241	2282	2282	6622	2207	2*	16650	13.7%	16.4%	13.7%

Turbine	Blow counts						Comparison to predicted soil profile[7]				Comparison to maximum blow count predicted
	Pin-pile			Highest at WTG	Total for all three pin-piles at WTG	Average of three pin-piles	Predicted soil profile [estimated soil profiles are symbolised by *]	Predicted maximum blow count for soil profile	Difference to predicted maximum blow count	Difference to predicted most probable for average at WTG	Difference to predicted maximum (of 16,650)
	Aft	Fore	MP								
K09	2411	2515	2647	2647	7573	2524	4*	12220	21.7%	20.9%	15.9%
K10	2325	2307	2506	2506	7138	2379	1*	16650	15.1%	17.6%	15.1%
K11	1791	2003	2050	2050	5844	1948	3*	12220	16.8%	16.1%	12.3%
K16	2416	2705	2665	2705	7786	2595	1*	16650	16.2%	19.2%	16.2%
K17	2895	2519	3546	3546	8960	2987	1*	16650	21.3%	22.1%	21.3%
L09	2233	1898	2212	2233	6343	2114	1*	16650	13.4%	15.7%	13.4%
L11	2242	2085	2341	2341	6668	2223	1*	16650	14.1%	16.5%	14.1%
L12	2220	2212	2429	2429	6861	2287	1*	16650	14.6%	17.0%	14.6%
L13	2013	1979	2125	2125	6117	2039	6*	12220	17.4%	16.9%	12.8%
OSP1	4534	4758	4773	4773	14065	4688	2	16650	28.7%	34.8%	28.7%
OSP2	1845	1599	2009	2009	5453	1818	1	16650	12.1%	13.5%	12.1%
OSP3	3127	3278	3158	3278	9563	3188	4	12220	26.8%	26.4%	19.7%

5.5 Piling Energy Profiles

A piling energy profile refers to the incremental increase in hammer energy over time, as each pile is installed. A piling energy profile was derived for each pin-pile installation, resulting in a total of 309 profiles. Three of these are included below, with one example showing relatively higher hammer energies and durations (**Figure 5-1**), one example showing relatively lower hammer energies and durations (**Figure 5-2**), and one example to show the typical average hammer energies and durations of installed piles at Moray East (**Figure 5-3**).

As shown in the piling energy profiles below, there is an evident sharp decrease in hammer energy. This decline is due to the piles being driven to mid-depth, and the hammer moving onto a new pile to pile all three pin-piles at each location to mid-depth, before the pile was then subsequently driven to full depth.

The piling energy profiles also show a clear soft-start implementation at the start, followed by a ramp-up period, before reaching the maximum hammer energy required for each location.

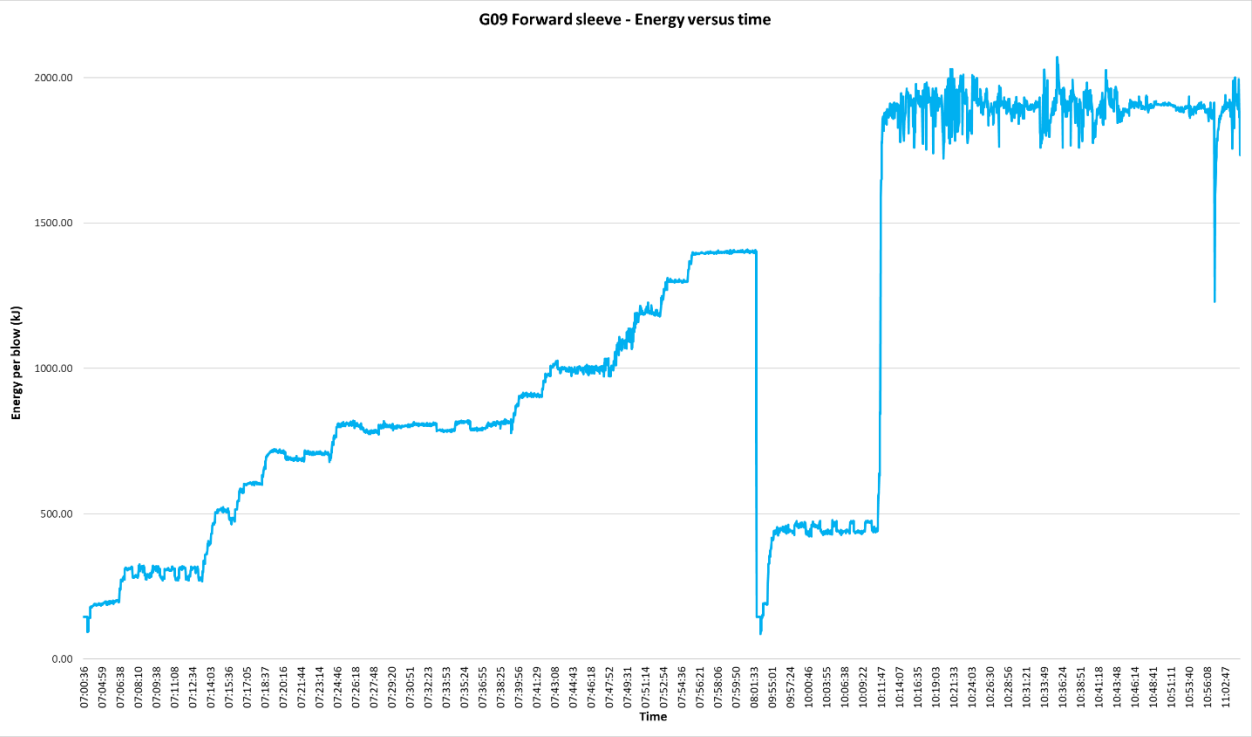


Figure 5-1 Example pile energy profile for relatively high hammer energies and durations (example shown is for foundation G09; Fore pile)

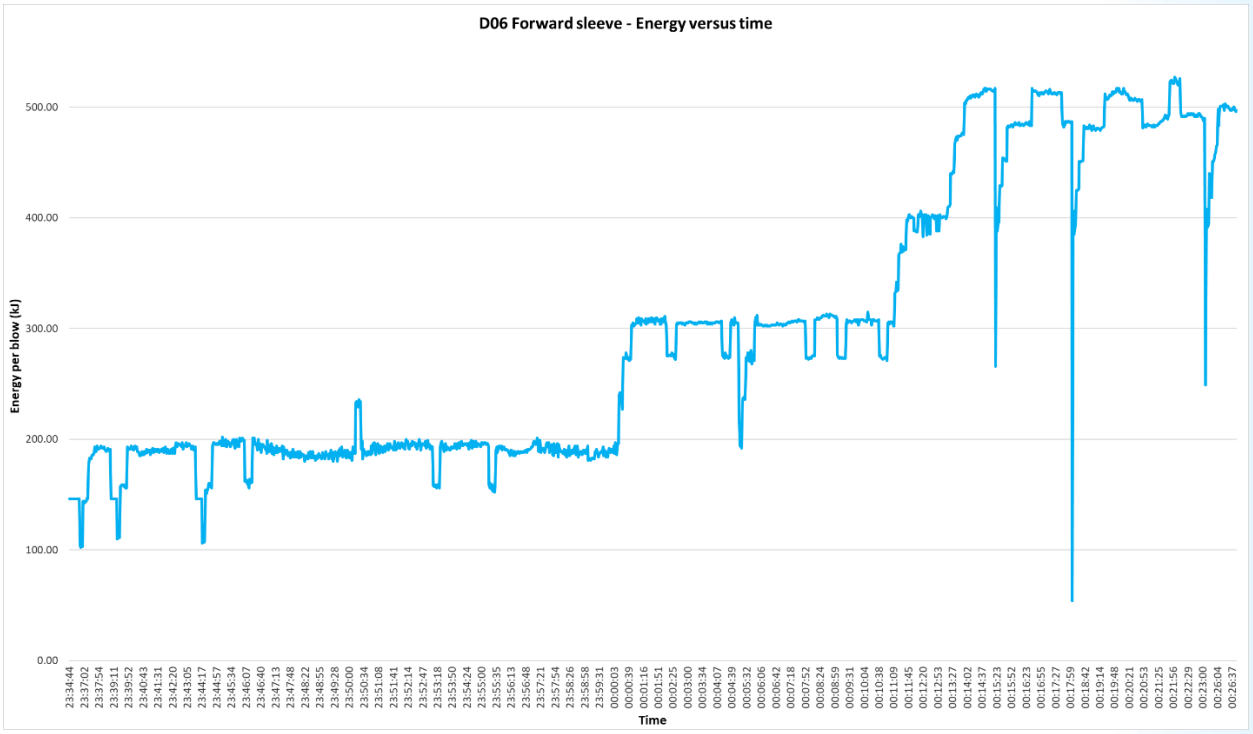


Figure 5-2 Example pile energy profile for relatively low hammer energies and durations (example shown is for foundation D06; Fore pile)

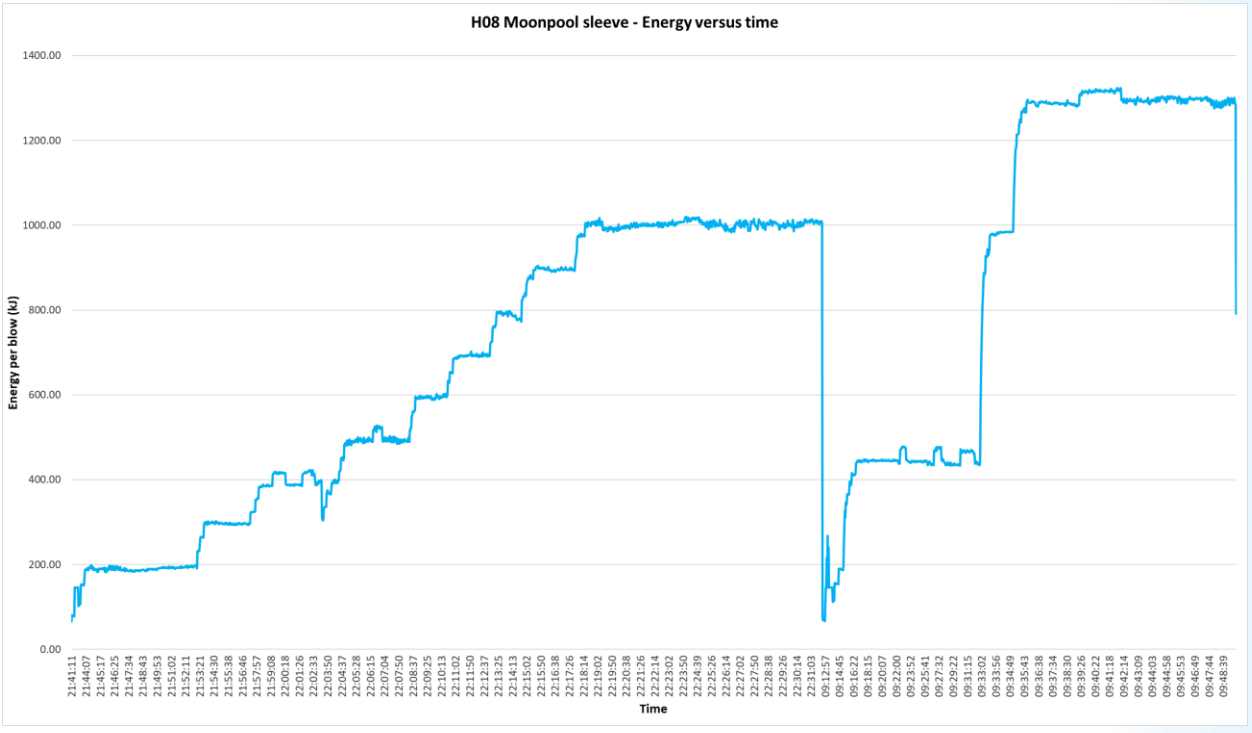


Figure 5-3 Example pile energy profile for typical average hammer energies and durations (example shown is for foundation H08; MP pile)

5.6 Pile Refusal and Relief Drilling

Within the PS, it was stated that a number of pile locations were at risk of pile refusal due to the characteristics of the seabed (in total, 15 of the foundation locations were identified to be at either medium or high risk of refusal).

During the piling programme, those locations that were identified to be at risk of pile refusal were installed using the larger hammer, with the pile driving hammer energy used being determined by the known seabed conditions and observed movements of the pile at each location (i.e. the hammer energy was optimised to ensure that the pile was moving at all times, regardless of the whether there was an elevated risk of refusal).

During piling, no pile refusal occurred, with the optimisation of hammer energies providing the required mitigation against this risk.

5.7 Overall Summary

Table 5-6 below shows an overall summary of the piling undertaken at Moray East, in comparison to what was predicted within the PS. For all piling parameters, the piling undertaken was within consented parameters.

Table 5-6 Overall summary of the piling undertaken Moray East, in comparison to predicted values

Parameter	Consented maximum	Maximum recorded	Minimum recorded	Average	Within consented parameter
Piling programme					
Overall piling period	12 months	9 months	-	-	**Yes**
Maximum active piling time per day	16 hours (960 minutes)	8.4 hours (503.3 minutes)	0.33 hours (19.6 minutes)	3.2 hours (189.2 minutes)	**Yes**
Total cumulative duration of piling	63 days (1512 hours)	17.5 days (416.3 hours)	-	-	**Yes**
Number of concurrent piling events	2	1	1	1	**Yes**
Piling durations					
Maximum duration per pin-pile	6.5 hours (390 minutes)	2.7 hours (162 minutes)	0.8 hours (47 minutes)	1.4 hours (81 minutes)	**Yes**
Maximum duration per foundation (three pin-piles)	16 hours (960 minutes)	7.3 hours (438 minutes)	2.7 hours (155 minutes)	4.0 hours (242 minutes)	**Yes**
Piling hammer energies					
Maximum hammer energy	2250 kJ	2071 kJ	628 kJ	1341 kJ	**Yes**

Parameter	Consented maximum	Maximum recorded	Minimum recorded	Average	Within consented parameter
Piling blow counts					
Number of hammer blows per pin-pile	16650	4733	1364	2352	**Yes**

6 Implementation of Piling Mitigation Protocol

Table 2-2 outlines the mitigation required at Moray East, with regards to the piling activities, as described within the PS, and includes the use of ADDs, a soft-start and ramp-up of piling protocol, the minimisation of hammer energies wherever possible, and a phased piling protocol.

6.1 Herring Seasonal Restrictions

There is concern about the potential adverse effects of underwater noise generated by pile-driving during the construction of offshore wind farms. Loud impulsive noises, such as pile-driving sound, can cause fatal injuries in fish and has the potential to disrupt the Orkney-Shetland herring spawning grounds.

Section 36 Consent condition 33 placed seasonal restrictions on piling within a mitigation zone within the Telford and Stevenson Wind Farms. During these periods there is a piling restriction not exceeding 16 days within the months of August and September. It was agreed in the PS that soft-start would also be employed (see **Section 2.2**) and in addition Moray East would not undertake any piling using hammer energies over 1,080 kJ during this period in any of the wind farm sites outwith the herring mitigation zone.

Herring surveys were carried out by Beatrice Offshore Windfarm Ltd (BOWL) during 2014 and 2015 (BOWL, 2016). Moray East carried out a desktop review of herring larvae (Moray East, 2018) and a herring larvae survey during August and September 2018 (Moray East, 2019). 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 Moray East ES (2012) assessments and beyond the area of potential impact from piling noise at the Wind Farm.

The Herring Spawning and Piling Noise Review (Moray East, 2018) submitted to Marine Scotland – Licensing Operations Team (MS-LOT) by Moray East concluded that the planned piling activities would not adversely impact the Orkney-Shetland herring sub-stock and that the seasonal piling restriction of up to 16 days within August and September would not be required. After consultation with Marine Scotland Science (MSS), MS-LOT confirmed on 12 September 2019 that no restrictions would be required in regard to the herring spawning season.

6.2 Underwater Noise Mitigation

Appendix 1 includes a summary of all piling bouts and the mitigation required for each piling bout based on the break from the previous piling bout (i.e. whether it was between ten minutes and six hours, or longer than six hours). The following sections provide a summary of each stage of the mitigation protocols.

6.2.1 Phased Piling Protocol

6.2.1.1 Requirements of the phased piling protocol

The PS set out the procedure for phasing and reporting of piling noise mitigation methods during offshore piling at the Moray East Offshore Wind Farm. Phased piling mitigation was planned to be undertaken over a period not exceeding 28 days as recommended by MS-LOT. A soft-start procedure as outlined in **Table** 2-2 was required prior to each pile regardless of the phase of the protocol.

Stage 1 of the phased piling mitigation period would implement mitigation in line with the Joint Nature Conservation Committee (JNCC) (2010) guidelines, which includes the use of MMOs and PAM operators monitoring a 500 m mitigation zone for 30 minutes with the additional use of ADDs whenever conditions

are not suitable for visual recordings. Stage 1 would last until a maximum of three WTG or OSP foundations were completed, or when day 14 was reached, provided that a minimum of two complete foundations had been installed during that period.

Stage 2 was the application of the Piling Mitigation Protocol using ADDs and soft start (**Table 2-2**) with the addition of the MMOs and PAM operator to record a log of visual and acoustic detections during this stage. Stage 2 was planned to end when an equal number of WTG or OSP foundations had been installed as in Stage 1, with a minimum of two in each stage, regardless of if the phased piling had reached or exceeded the 28 day guidelines. The piling mitigation protocol was then to continue until foundation installation was complete.

Following completion of the phased piling mitigation (i.e. at least two foundations in each stage), the agreed Piling Protocol would then use ADDs and soft-start mitigation (**Table 2-2**) with regular monitoring to ensure that ADD devices were working correctly.

6.2.1.2 Summary of the phased piling stages undertaken

Stage 1 occurred between 5 and 8 July 2019 and stage 2 occurred between 9 and 11 July 2019. During this time, mitigation as outlined above was carried out for six foundations (18 pin-piles). The mitigation carried out for each pin-pile is outlined in **Table 6-1**, and monitoring effort in **Sections 6.2.2** and **6.2.3**; due to the timing of the piling events with regard to daylight hours, visual observations were only conducted prior to six of the pin-pile installations. There was only one occasion when visual and acoustic mitigation were both used as the primary measures prior to a turbine installation throughout the phased piling mitigation protocol, limiting the ability to draw any conclusions between the different protocols.

Table 6-1 below shows the mitigation undertaken throughout the Phased piling periods, rather than just for the mitigation required for the onset of piling. The table identifies which mitigation measures were associated with the onset of piling requirements, and which were undertaken at other periods during pile installation (for example, to cover any breaks in piling).

Table 6-1 Summary of mitigation carried out per pin-pile during stages 1 and 2 of phased piling (where a pre-piling search was required under stage 1, this was required to be undertaken by an MMO, unless piling commenced in low visibility, in which case an ADD was required to be deployed)

Turbine	Pile	Time and Date	Pre-piling search required	Mitigation measures	Was an ADD used
Stage 1					
G13	FORE	02:53 05/07/2019	Yes	PAM, ADD and Soft start	Yes
	AFT	04:13 05/07/2019	No	MMO and PAM	No
	MP	07:00 05/07/2019	No	MMO and PAM	No
	FORE	10:06 05/07/2019	No	MMO and PAM	No
E14	MP	22:25 06/07/2019	Yes	PAM, ADD and Soft start	Yes
	FORE	00:34 07/07/2019	No	PAM	No
	AFT	02:43 07/07/2019	No	PAM	No
C14	MP	21:08 07/07/2019	Yes	MMO, PAM and Soft start	No
	FORE	22:52 07/07/2019	No	PAM	No
	AFT	00:58 08/07/2019	No	PAM	No

Turbine	Pile	Time and Date	Pre-piling search required	Mitigation measures	Was an ADD used
Stage 2					
B14	MP	03:24 09/07/2019	Yes	PAM, ADD and Soft start	Yes
	FORE	05:11 09/07/2019	No	MMO and PAM	No
	AFT	07:04 09/07/2019	No	MMO and PAM	No
C15	MP	00:48 10/07/2019	Yes	PAM, ADD and Soft start	Yes
	FORE	02:17 10/07/2019	No	PAM	No
	AFT	04:47 10/07/2019	No	PAM	No
D16	MP	07:27 11/07/2019	Yes	PAM, ADD and Soft start	Yes
	FORE	09:20 11/07/2019	No	PAM	No
	AFT	11:12 11/07/2019	No	PAM	No

6.2.2 Marine Mammal Observers

During the piling operations undertaken at the Wind Farm between 19 May 2019 and 27 February 2020, visual observations were undertaken for a total of 289 hours and 29 minutes, with 14 hours and 39 minutes of observations taking place during ADD use and piling operations.

Phased piling was undertaken between 5 and 11 July 2019 with Stage 1 occurring between 5 and 8 July 2019 and Stage 2 occurring between 9 and 11 July 2019. During the phased piling, there was a total of 19 hours and 11 minutes of visual observation undertaken by MMOs prior to piling during daylight hours, at three separate pile locations.

All visual observations were done in good viewing conditions with sea states of Beaufort scale 4 or less. Of the time spent on visual observations, 12 hours and three minutes were undertaken during periods prior to or during breaks in piling with no underwater noise. There were visual observations undertaken for 23 minutes during soft-starts and for 6 hours and 45 minutes during piling operations.

6.2.3 Passive Acoustic Monitoring

PAM was used throughout all of the piling operations undertaken at Moray East, either for mitigation or monitoring the ADD use. A total of 105 hours and four minutes of PAM were undertaken, of which 82 hours and eight minutes of monitoring were during ADD use and piling operations, and 22 hours and 56 minutes were prior to any underwater noise.

During the staged phases of piling, 16 hours and 43 minutes were undertaken during periods prior to or during breaks in piling with no underwater noise. PAM was undertaken for 45 minutes of ADD activation, two hours and nine minutes during soft-starts, and for 20 hours and 46 minutes during piling operations, across the two stages.

6.2.4 Sightings and Detections

During the foundation installations taking place at the Wind Farm, between 20 May 2019 and 27 February 2020, there were four visual sightings, and no acoustic detections. The sightings all occurred outside of piling activities, ADD activation and mitigation watches.

A summary of the sightings during the project is given in **Table 6-2**.

Table 6-2 Summary of the sightings during the Moray East foundation installation period but outside of piling activities and ADD activation

Time and Date	Species	No of Animals	Operation activity	Closest distance to the vessel	Entered mitigation zone
04:25 10/06/2019	Minke whale	1	Not Activated	5 m	Yes
08:15 10/06/2019	Minke whale	1	Not Activated	700 m	No
18:50 10/06/2019	Minke whale	1	Not Activated	800 m	No
04:40 07/08/2019	UnID Seal	1	Not Activated	80 m	Yes

6.2.4.1 Delay Procedures

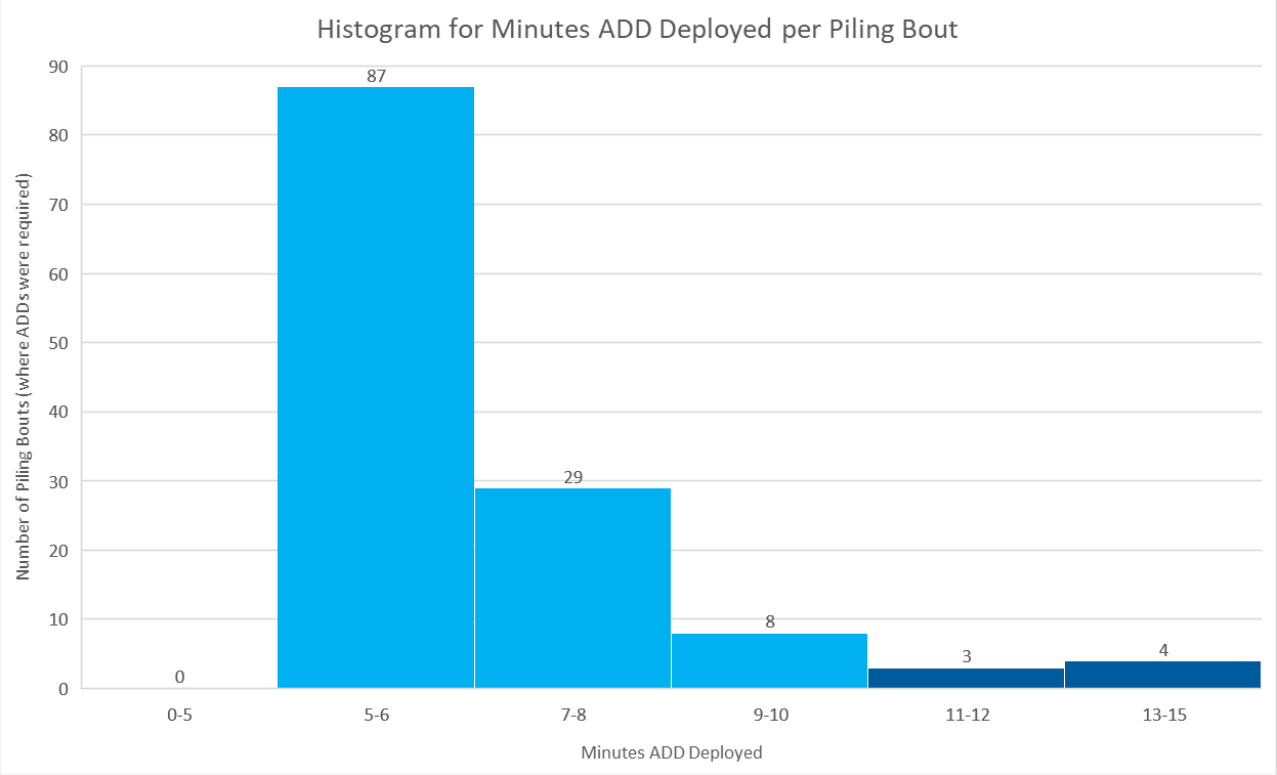
As all the sightings recorded occurred outside mitigation periods, there was no requirement to delay operations during the works.

6.2.5 ADD Activation

The deployment and activation of ADDs was a core part of the marine mammal (and fish) underwater noise mitigation methods. As outlined in the PS and **Section 2.2**, ADDs were activated at the piling site for a period of five to ten minutes prior to piling, to allow marine mammals to be displaced out of the impact zones. ADD activation was determined by the size of the injury zone at each pile (based on predicted hammer energies) and the animal's swimming speed. The 20 minute soft-start commenced after the ADD activation had been completed.

As shown in **Appendix 1**, during the piling installations at Moray East, the ADDs were required to be activated on a total of 131 occasions (and one occasion where ADDs would normally be activated under standard mitigation, however it was during the phased piling mitigation period, and therefore not required). The ADDs were deployed for each of the piling bouts where it was required and were active for a total of 880 minutes (14.7 hours).

Graph 6-1 shows a histogram of the time the ADDs were activated for all piling bouts where ADDs were required. Almost all of the ADD activations were for five to six minutes (65.2%). Of the 131 activations (where ADDs were required), seven were greater than the initially recommended protocol of five to ten minutes (as described within the PS, and shown in dark blue on **Graph 6-1** below), with a required activation time of more than ten minutes. These deployments were in line with an increased ADD deployed of up to 15 minutes as approved by MS-LOT in June 2019 in the case of a delay to the onset of soft-start (following agreement with SNH and MSS). Further details on the reasons for these extended activations are provided in **Table 6-3**. ADD activation time did not exceed 15 minutes on any occasion.



Graph 6-1 Histogram for the number of minutes of ADD activation per ADD deployment (deployments with ADD activation outside of 5 – 10 minutes as specified within the mitigation protocol are shown in red)

Table 6-3 Summary of ADD activation outside the original PS protocol, but within additional agreement with MS-LOT to be used in the case of any delay to the onset of soft-start

Pile	Date	Time ADD active (minutes)	Reason given
A01	20-Aug-19	14	Technical problem with the power pack.
E06	23-Aug-19	11	Technical delay – airline entangled on hammer.
J08	24-Aug-19	15	Technical problem of pile stability because of soft material.
A02	13-Oct-19	12	Technical delay due to hammer power pack malfunction.
B05	14-Oct-19	14	Technical delay due to hammer hose reel issue.
C02	07-Nov-19	15	ADD operations had to be extended to 15 minutes due to technical fault with start of soft-start, which was a further 1 minute after the end of ADD activation
D09	07-Dec-19	11	Technical/physical delay to pile due to sinking in soft material.

6.2.6 Soft-Start and Ramp-Up Procedures

This section provides an analysis of the soft-start and ramp-up procedures, including breaks during piling and the mitigation that was undertaken following those breaks (i.e. whether full mitigation was

undertaken after a break in piling for more than six hours, and whether piling break mitigation (of soft-start only) was undertaken for breaks in piling between ten minutes and six hours).

The piling log summary by piling bout with ADD activation data sheet was used (as it is in split into bouts of piling with breaks of more than ten minutes), and the data cross-referenced against the ADD and PAM reports, to determine where the breaks in piling occurred, and then what mitigation was subsequently required, and undertaken.

Appendix 1 outlines details of each piling bout, including the interval from the previous piling bout. From that information, the required soft-start and ramp-up procedures are noted:

- Full mitigation
    - for piling intervals (time from previous piling) of more than six hours
        - Soft-start of approximately five to six blows, with a hammer energy of less than 300 kJ
        - followed by ramp-up over a 20 minute period, with hammer energies of less than 500 kJ
            - Ramp-up end times are taken from the PAM and ADD reporting.
- Piling break mitigation
    - for piling intervals of between ten minutes and six hours
        - Soft-start of approximately five to six blows, with a hammer energy of less than 300 kJ

In total, 430 piling bouts were undertaken through the piling programme. Of these 430 piling bouts, 132 required full mitigation[8], including ADD deployment, soft-start, and ramp-up procedures. The remaining 298 piling bouts required piling break mitigation, which included soft-start procedures only. The following sections provide a summary of both full and piling break mitigation. **Appendix 1** includes details on each piling bout mitigation undertaken, including ADD deployment time (where required), the number and hammer energy of soft-start blows, and the duration and hammer energy of ramp-ups (where they were required).

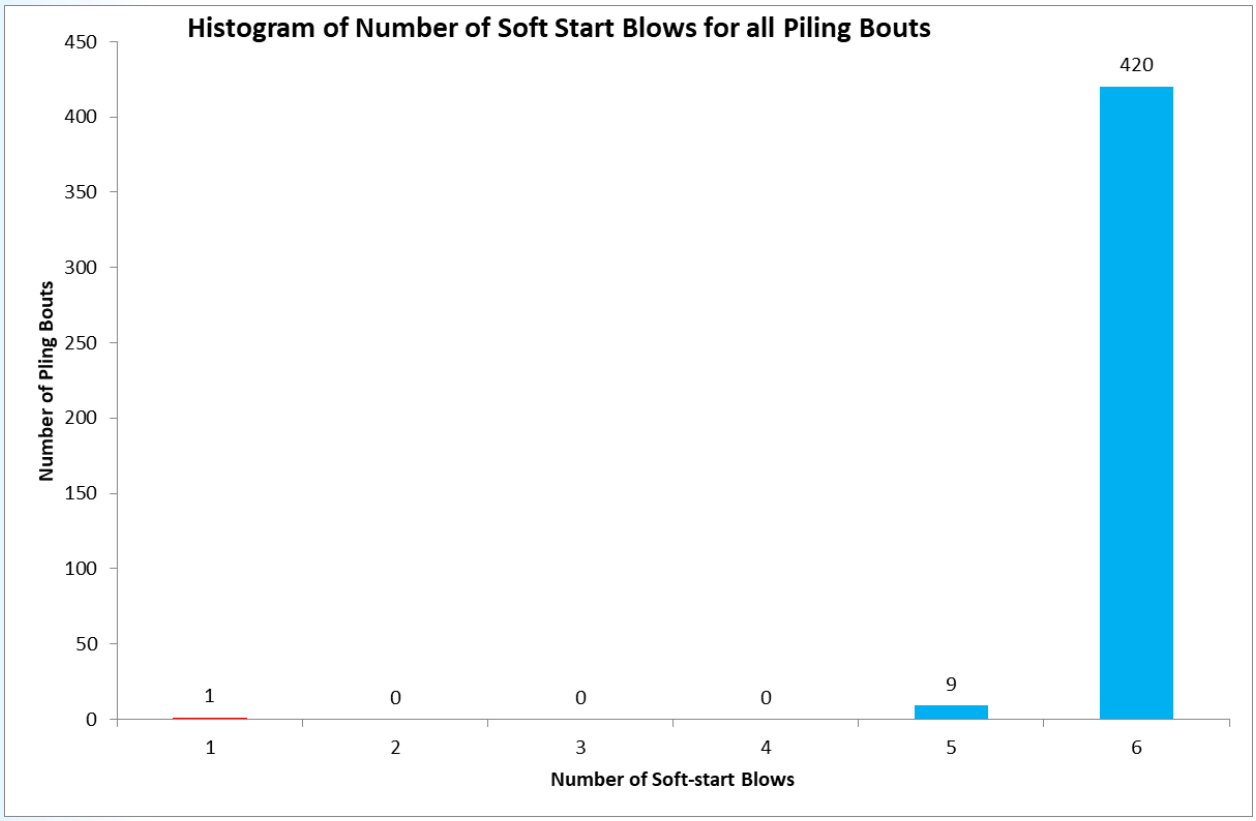
6.2.6.1 Soft-Start

As outlined above, a total of 430 piling bouts were undertaken, all of which required soft-start regardless of the interval from previous piling. **Graph 6-2** shows that the majority of piling bouts commenced with the required five to six initial blows, with 97.7% having six initial blows, and 2.1% starting with five blows. On one instance, piling began with only one initial blow (0.2% of piling bouts), however, this was an agreed variation to the mitigation procedure for location J10. See **Section 6.2.7.1** for more information.

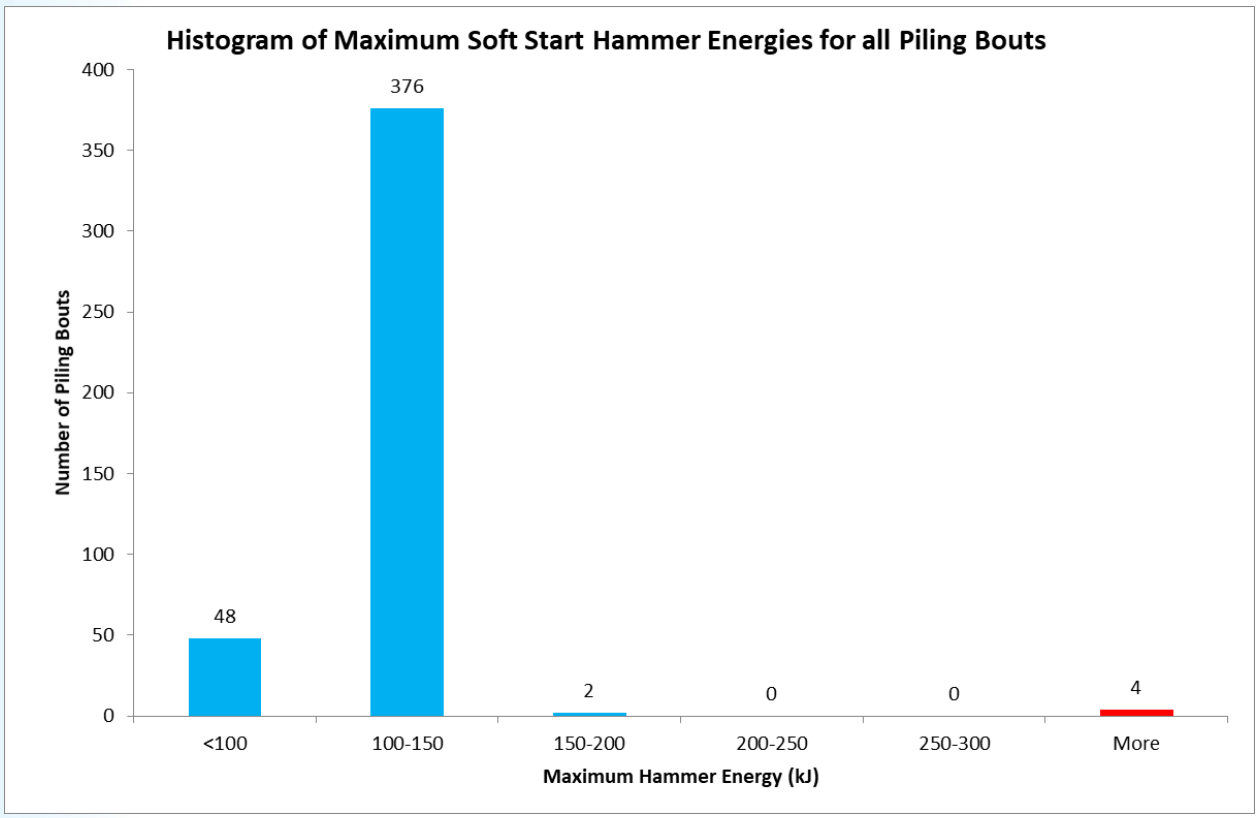
Graph 6-3 shows the soft-start hammer energies for all piling bouts. The majority of the 430 piling bouts undertook a soft-start with hammer energies of between 100 kJ and 150 kJ (87.4% of all piling bouts), 11.2% of soft-starts had a hammer energy of less than 100 kJ, and 0.5% an energy of 150 kJ to 200 kJ, in line with the mitigation protocol, as set out in the PS, of less than 300 kJ. The remaining 0.9% (n=4) of piling bouts were required to be undertaken with a soft-start that exceeded the recommended 300 kJ.

See **Section 6.2.7** and **Table 6-4** for more information on the mitigation variations for the number of soft-start blows, and for more information on the soft-starts with hammer energies exceeding 300 kJ. All other soft-starts were undertaken in line soft-start requirements as set out within the PS.

[8] Including one occasion during the phased piling mitigation period; therefore, ADD was not required.



Graph 6-2 Histogram of the number of soft-start blows per piling bout for all piling bouts (piling bouts with more or less than the specified number of soft-start blows of approximately 5 – 6 are shown in red)



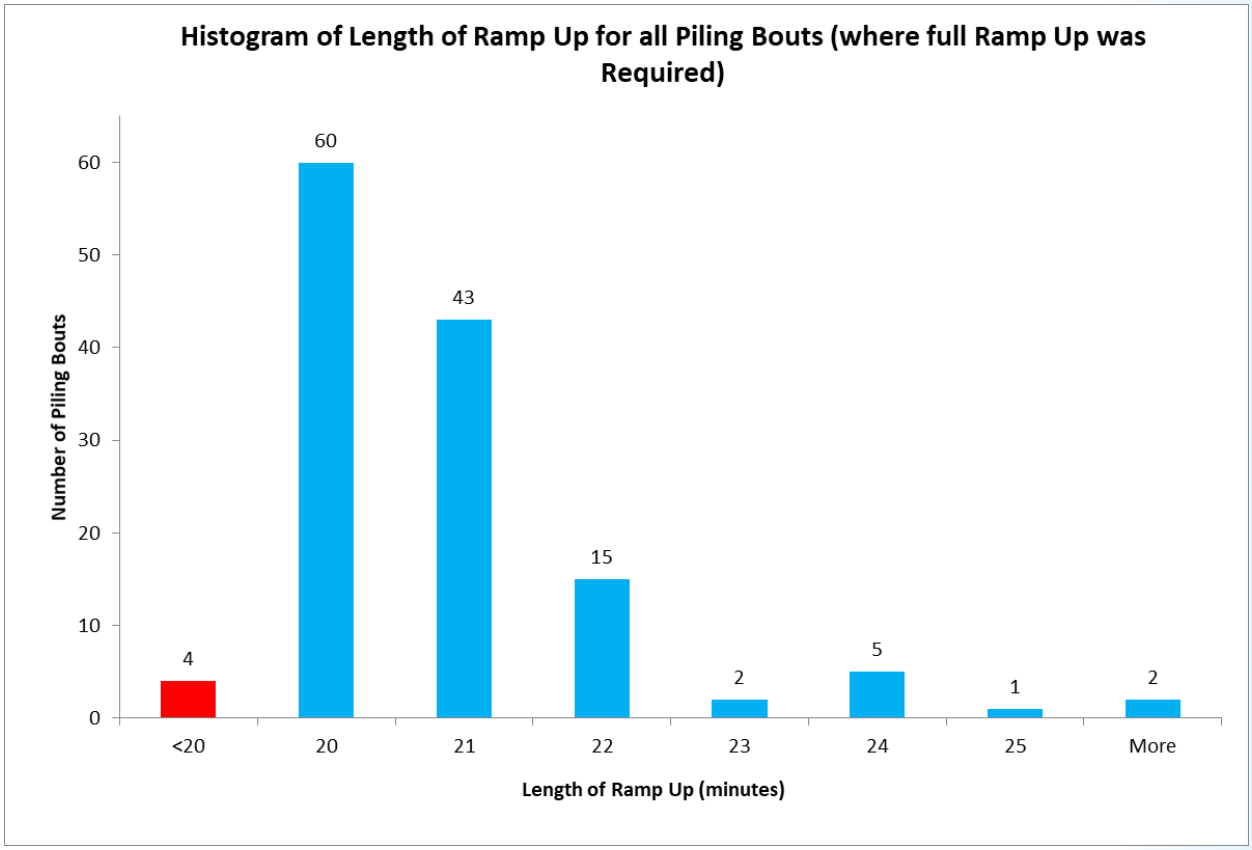
Graph 6-3 Histogram of the maximum soft-start hammer energies for all piling bouts (piling bouts with more than the specified 300 kJ maximum hammer energy during soft-start are shown in red)

6.2.6.2 Ramp-Up

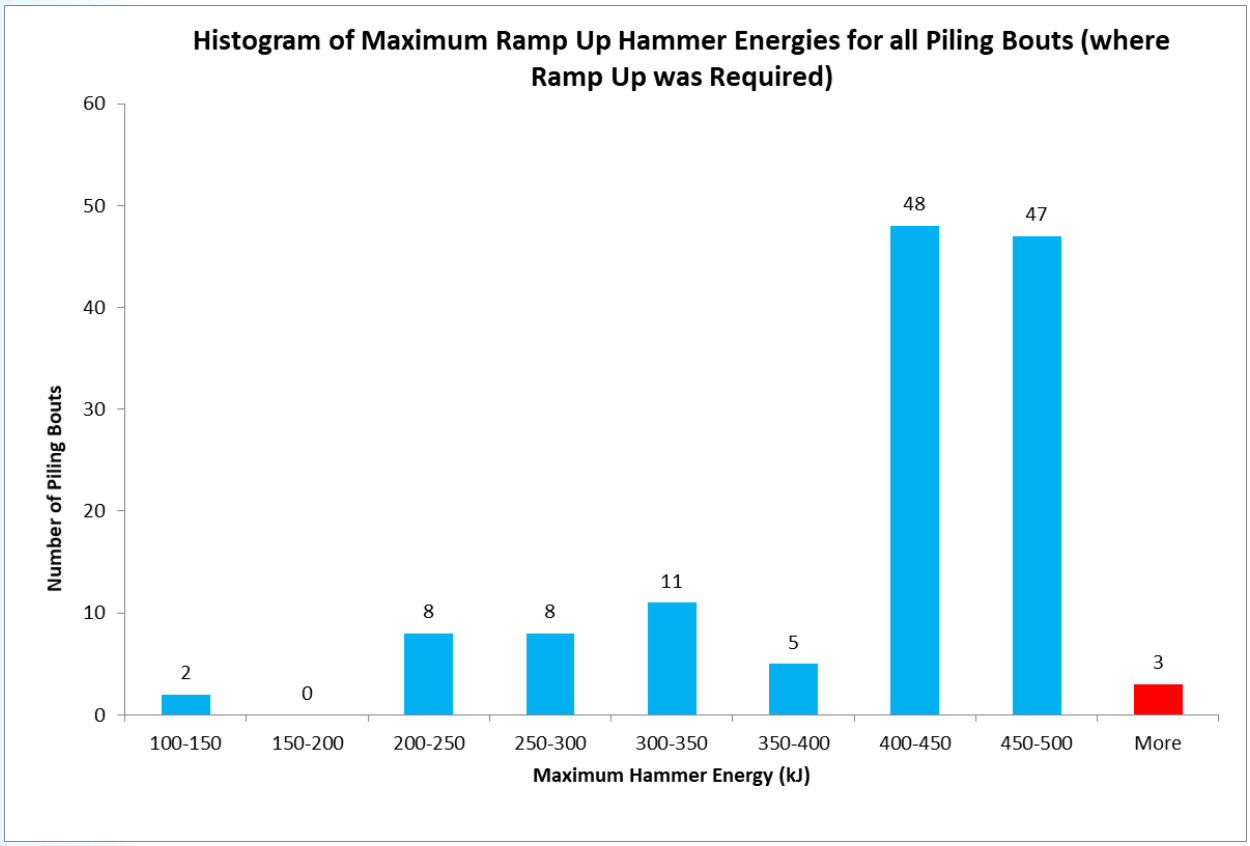
As outlined above, a total of 132 piling bouts were undertaken that required the full mitigation and, therefore, ramp-up procedure, as outlined within the PS. **Graph 6-4** shows that the majority of piling bouts, that required ramp-up, the procedure took 20 or 21 minutes (45.5% and 32.6%, respectively). A further 17.4% of piling bouts required a ramp-up procedure of between 22 and 25 minutes, with 1.5% of the ramp-up procedures taking more than 25 minutes. A total of four instances (3.0%) took less than the required 20 minutes to ramp-up. For locations J10 and J19 these were agreed variations to the mitigation procedure. See **Section 6.2.7.1** for more information.

Graph 6-5 shows the ramp-up hammer energies for all piling bouts, where ramp-up was required. The majority of the 132 piling bouts undertook ramp-up with hammer energies of between 400 kJ and 500 kJ (72.0% of all piling bouts requiring ramp-up). A further 12.1% of ramp-ups had a hammer energies of 300 kJ to 400 kJ, 12.1% of 200 kJ to 300 kJ, and 1.5% of less than 150 kJ. The remaining 2.3% of piling bouts were undertaken with a ramp-up that exceeded 500 kJ. For all these occasions, they were agreed variations to the mitigation procedure. See **Section 6.2.7.1** for more information.

See **Section 6.2.7** and **Table 6-4** for more information on the mitigation variation for the duration of ramp-up and exceedance of the 500 kJ. All other ramp-ups were undertaken in line with the requirements as set out within the PS.



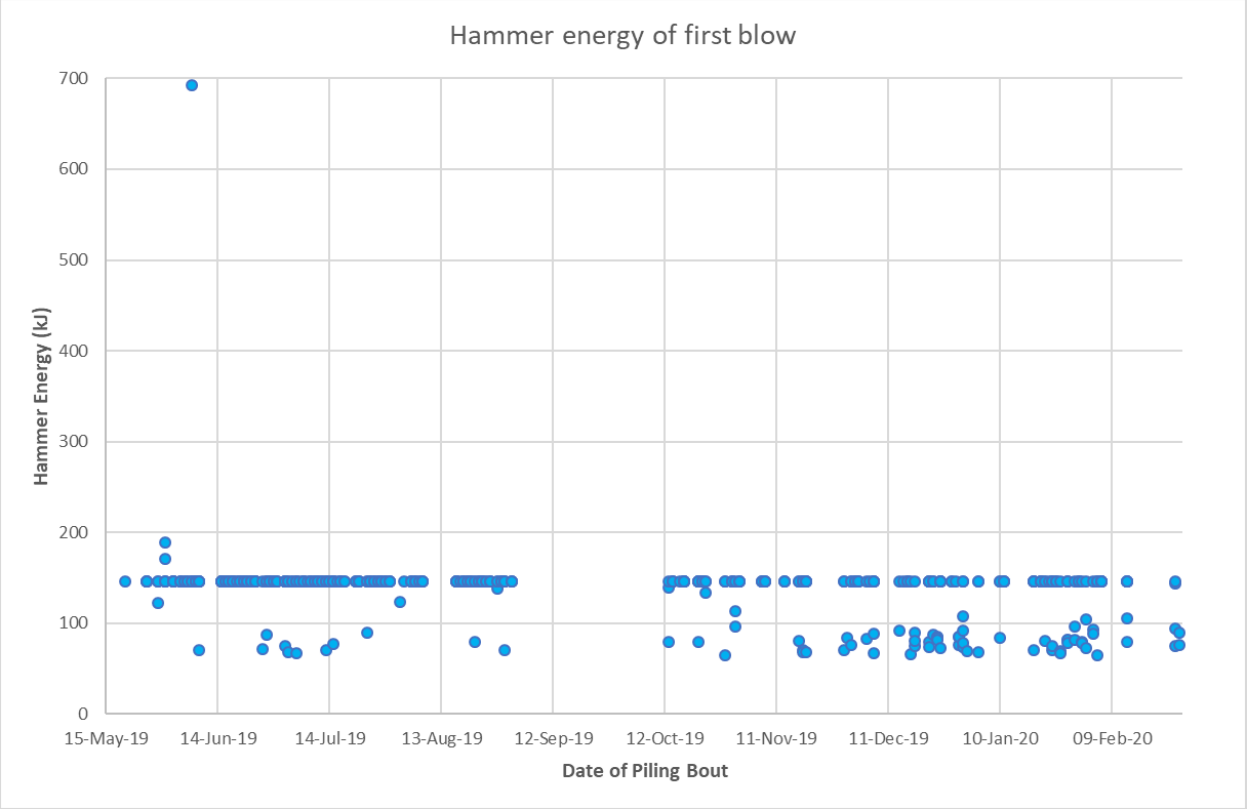
Graph 6-4 Histogram of the ramp-up time for all piling bouts where ramp-up was required (piling bouts with less than the specified 20 minute ramp-up time are shown in red)



Graph 6-5 Histogram of the maximum ramp-up hammer energies for all piling bouts where ramp-up was required (piling bouts with more than the specified 500kJ maximum hammer energy during ramp-up are shown in red)

6.2.6.3 Starting Hammer Energy for First Blow

Graph 6-6 shows the starting hammer energy of each of the 430 piling bouts. The majority of piling bouts commenced with a starting hammer energy of 146 kJ, (349 bouts; 81.2%), with a further 18.1% commencing with a starting hammer energy of less than 146 kJ. One initial hammer blow had a starting energy of 693 kJ; considerably higher than for all other piling bouts. This was for foundation I20; see **Section 6.3.1.1** for more information on the requirements for high starting hammer energy at this location.



Graph 6-6 Scatter graph to show the hammer energy of first hammer strike, for all piling bouts

6.2.7 Variations in the piling protocol

During the piling operations at Moray East, the hammer was activated on 430 occasions to initiate piling at a new location, or after a break greater than ten minutes. As summarised in **Section 2.2** there were two parts to the soft-start:

- Initial five to six blows with a hammer energy as low as practically possible (300 kJ or less); and
- Ramp-up with blow energies remaining at less than 500 kJ for 20 minutes.

There were ten occasions when the mitigation requirements were not met during the soft-start or ramp-up phase, and these have been summarised in **Table 6-4**. Further information on each of these occasions is provided in the following sections.

Table 6-4 Variations to the soft-start and ramp-up mitigation procedures (highlighted in red where outside of recommended mitigation protocols)

Pile	Time and Date	Mitigation required	No. soft-start blows	Maximum soft-start hammer energy (kJ)	Duration of ramp-up (minutes)	Maximum ramp-up hammer energy (kJ)	Comments
K17	08:43 26/05/2019	Piling break	6	407	N/A	N/A	Non-compliance with soft-start protocol, with the 300 kJ maximum hammer energy exceeded. Reported to MS-LOT, and corrective measures put in place to ensure this did not happen again. See Section **6.2.7.1** for more information.
K17	12:13 26/05/2019	Piling break	6	978	N/A	N/A	
I20	03:17 07/06/2019	Piling break	5	533	N/A	N/A	
I20	04:52 07/06/2019	Full mitigation	6	693	N/A	N/A	
J18	21:34 19/06/2019	Full mitigation	6	146	21	508	Non-compliance with ramp-up protocol, with the 500 kJ maximum hammer energy exceeded. Reported to MS-LOT, and corrective measures put in place to ensure this did not happen again. See **Section 6.2.7.1** for more information.
K10	18:26 28/07/2019	Full mitigation	6	146	22	512	Non-compliance with ramp-up protocol, with the 500 kJ maximum hammer energy exceeded. Reported to MS-LOT, and corrective measures put in place to ensure this did not happen again. See **Section 6.2.7.1** for more information.
J10	15:48 02/08/2019	Piling break	6	146	2	842	Hammer break down once pile was near required depth. Further piling with no pile movement was likely if full mitigation was followed, due to hardness of soil, and compaction of soil while pile was static. Agreement was reached with MS-LOT that piling could resume without full soft-start and ramp-up, in order to lower risk of further hammer breakdown. See **Section 6.2.7.1** for more information.
J10	20:59 02/08/2019	Piling break	1	146	2	1151	
G06	19:33 11/01/2020	Full mitigation	6	146	1	146	Hammer break down once pile was near required depth. Further piling with no pile movement was likely if full mitigation was followed, due to hardness of soil, and compaction of soil while pile was static. Agreement was reached with MS-LOT that piling could resume without full

Pile	Time and Date	Mitigation required	No. soft-start blows	Maximum soft-start hammer energy (kJ)	Duration of ramp-up (minutes)	Maximum ramp-up hammer energy (kJ)	Comments
							soft-start and ramp-up, in order to lower risk of further hammer breakdown. See **Section 6.2.7.1** for more information.
J19	23:55 26/02/2020	Full mitigation	6	144	0	144	Variation of procedure for this location agreed with MS-LOT. J19 considered to be the location with the highest risk of pile refusal, and the hardness of the soil posed a Health and Safety risk in relation to breakdown of the hammer. See **Section 6.2.7.1** below for more information.

6.2.7.1 Location Specific Variations

Foundations K17, I20 & J18

During soft-starts at K17 and I20, the maximum energy levels were exceeded, and during ramp-up at J18, the maximum hammer energy was exceeded.

The incidents were raised with the construction team, the following additional mitigation was undertaken to ensure that no further issues with compliance of the soft-start and ramp-up procedures occurred:

- extra vigilance to be shown after breaks in piling;
- Toolbox talks and additional briefings to be undertaken to raise awareness;
- communications to be increased throughout piling operations –piling team reminded to ask questions as necessary;
- Client Representative reiterated (both initially and as a follow-up) piling break procedures to the piling team;
- Client Representative re-iterated the soft-start procedure to Hammer Control Operatives;
- Hammer Control Operatives instructed to set the hammer energy at a level that cannot accidentally exceed 500 kJ during the 20 minute period specified during the soft-start procedure; and
- ECoW prepared and presented a refresher toolbox talk on compliance with the PS to relevant personnel within the piling team.

Foundation K10

During the 20 minute ramp-up, at approximately 18 minutes after the initial blow, there were a total of ten blows at 512 kJ (therefore slightly greater than 500 kJ). Piling energy then dropped below 500 kJ for the remainder of the ramp-up period.

The incidents were raised with the construction team, the following mitigation was undertaken to ensure that no further issues with compliance of the ramp-up procedure occurred:

- extra vigilance to be shown after breaks in piling;
- communications to be increased throughout piling operations:
- piling team to be reminded to ask questions as necessary;
- suggest one person leads communications with the Hammer Control Operatives, to ensure no confusion
- Hammer Control Operatives should acknowledge / repeat instruction to ensure it has been heard correctly and confirm before hammer energy is increased; and
- Toolbox talks to be undertaken to raise awareness of the communication procedure.

Foundation J10

The hammer broke down when one of the piles was already near target depth and Moray East were advised that undertaking a full 20 minute at energies below 500 kJ would not be possible, due to the risk of further damage to the hammer. In addition, as the pile was near target depth (but static) for an extended duration, the soil around the pile became compacted and higher energies were required to ensure the pile moved when piling recommenced.

Moray East liaised with MS-LOT and it was agreed on 2 August 2019 that the following procedure would be undertaken to reduce risks to marine mammals as far as possible:

1) deploy and activate the ADD five to ten minutes before the start of piling;
2) undertake five to six blows at low energy; and
3) continue ramping up with energy sufficient to get the pile moving (in line with the principles detailed in the PS); however, noting that ramp-up will be quicker than that detailed in the soft-start procedure.

Piling at this location recommenced, after the ADD was deployed and activated for five to ten minutes prior to piling activities resuming, with six blows at low energy (between 124 kJ and 126 kJ), followed by a ramp-up with energy sufficient to get the pile moving.

When piling recommenced on 3 August 2019, only one blow at lower energy was achieved (146 kJ) before ramp-up to the energy required to get the pile moving (1,151 kJ). The energy required to get the pile moving was high due to the fact the pile had been static and the soil around the pile had compacted, resulting in a higher energy being required to get the pile moving.

Moray East notified MS-LOT and noted that although this is a slight deviation to the approach discussed and agreed (as above), the justification and technical restrictions relating to the hammer are the same.

MS-LOT confirmed that due to technical restrictions, the variation to mitigation procedures was again agreed.

Foundation G06

The winch broke down during the lowering of the pile template onto the seabed, causing a delay in the commencement of piling. With only a 13.8 hour weather window for installation, full installation of foundation piles at the location was not possible within the weather window available.

The piles were driven to mid-depth before the weather window closed down; the next available weather window was not due for over 24 hours. Moray East was advised that undertaking the full 20 minute soft-start at energies below 500 kJ would not be possible, due to the risk of damage to the hammer as soil around the pile becomes compacted while left in-situ, with higher energies required to get the pile moving again. This situation was exacerbated by the harder soil conditions present at this location (higher proportion of clay present). Piling with no movement leads to a high risk of hammer breakdown.

Moray East liaised with MS-LOT and it was agreed on 10 January 2020 that the following procedure would be undertaken to reduce risks to marine mammals as far as possible:

1) deploy and activate the ADD five to ten minutes before the start of piling;
2) undertake five to six blows at low energy; and
3) continue ramping up with energy sufficient to get the pile moving (in line with the principles detailed in the PS); however, noting that ramp up will be quicker than that detailed in the soft-start procedure.

The ADD was deployed and activated for five minutes before piling activities resumed. When piling resumed, there were six blows at low energy (between 75 kJ and 1,746 kJ) before ramping up with energy sufficient to get the pile moving.

Foundation J19

Prior to the installation of piles at J19, Moray East sought approval from MS-LOT to deviate from the PS. This was due to the soil conditions at location J19 being harder than expected which could cause an increase in hammer failure once piles have been driven to half-depth.

Due to the harder soil conditions, the intermediate depth soil plug removal was taking longer than previous locations. This meant, once piling recommenced, there was a gap of no piling for greater than six hours; therefore, requiring a full soft-start to be undertaken. However, due to the length of time that the piles sat at mid-depth, the sediment surrounding the piles 'settled'. Attempting a soft-start with such soil conditions greatly increase the possibility of hammer failure.

MS-LOT provided the approval necessary to deviate from the soft-start procedure in the PS for locations G20 and J19 (this was only needed at J19) on 7 February 2020. Mitigation proposed by Moray East was accepted by MS-LOT and consisted of the following:

1) PAM watch is carried as instructed within the piling strategy;
2) deploy and activate the ADD five to ten minutes before the start of piling; and.
3) piling would commence with five to six low energy blows followed immediately with an increase to the energy required to restart pile movement.

An additional mitigation was to activate the ADD at hour six after cessation of piling, should soil plug removal not be completed within the six-hour window, in order to deter any marine mammals that have travelled back into the area during soil plug removal.

The ADD was deployed and activated for five minutes at hour six. The ADD was then deployed for six minutes before piling activities resumed. When piling resumed, there were six blows at low energy (between 84 kJ and 90 kJ) before increasing to maximum energy (1,390 kJ).

6.3 Noise Registry Reporting

Information on the piling activities undertaken at the Wind Farm were submitted to JNCC Marine Noise Registry, in line with Condition 3.2.1.5 of the Wind Farm Marine Licences, and Condition 3.2.2.17 of the OSP Marine Licence.

7 Lessons Learned

It is important to consider lessons learned, from the implementation of piling protocols and reporting procedures, in order to ensure that future projects can develop mitigation protocols that are easily understood and communicated, that any common issues with deployment of PAM and ADD equipment is considered when developing mitigation protocols, and to ensure that reporting protocols are efficient.

The key lessons that can be taken from these piling works are those of communication and reporting of data. With regards to the reporting carried out by the PAM / ADD operator, issues and inconsistencies in the reporting regularly included the following issues:

- discrepancies between the weekly ADD and PAM reports, and the Marine Mammal recording forms (which are filled in throughout the piling operations);
- out of date and/or multiple recording sheets used on a regular basis, with no clear filing or naming system;
- weekly ADD and PAM reports and recording forms consistently had missing information, such as missing ADD testing times, start times of piling, etc; and
- confusion over what constituted the start of piling – whether the start of piling is recorded as the first blow, or the first blow following the soft-start and ramp-up procedures.

These issues all come down to communication and reporting, or lack of information / training, and should be considered when developing mitigation and reporting protocols. In addition to the above, questions were raised on what to do in certain complex situations, should they occur through piling, such as for delay procedures. These were fully discussed between Moray East and the ADD operators on a regular basis; however, it would be beneficial for an increased level of information to be provided within the mitigation and reporting protocols prior to the mitigation commencing.

7.1 Future Recommendations

One option to reduce these issues in the future could be to develop more detailed method statements prior to piling commencing, that can be provided to MMOs / ADD / PAM Operatives, which includes details on the correct communication procedures, step by step guides as to how the mitigation should be undertaken, with some example scenarios to explain what to do in more complex situations. This should also include clear guidelines on what certain terms mean, such as the commencement of piling being the first strike.

A commitment to undertake this process could be included in Marine Mammal Mitigation Plans, to ensure the best, and most detailed information, is available to personnel undertaking mitigation methods prior to the commencement of the activity. Alongside this, a commitment could also be made to undertake a training session, to go through this developed method statement, and to provide an opportunity to provide detail on how the reporting should be undertaken. Members of the piling team could also be involved in this process to ensure that the requirements with regards to timings and hammer energies are well understood and implemented within the piling activities.

Providing a commitment to undertake this process would allow developers greater certainty that their mitigation plans are being followed exactly as they were intended, and to provide assurances that both the reporting and communications aspect of the mitigation methods are well understood by the

personnel undertaking the mitigation methods. This would reduce the chance for any communications and reporting issues to occur through the piling programme.

8 Marine Mammal Monitoring

In line with the monitoring requirements of the PS, and as agreed through the MFRAG, a series of reporting and analyses is to be undertaken, using data collected during the piling programme at Moray East. These reports and analyses are to be compiled by the University of Aberdeen, with the following outputs and indicative delivery dates:

1. Broad-scale responses of harbour porpoises to pile-driving and vessel activities during offshore windfarm construction
    - Indicative delivery date of Q2 2021
2. How do vessel characteristics and activities affect underwater soundscapes and porpoise responses prior to pile-driving at offshore windfarm sites?
    - Indicative delivery date of Q3 2021
3. Comparison of piling noise levels at Beatrice and Moray East offshore windfarms
    - Indicative delivery date of Q2 2021
4. Assessing the far-field effect of offshore developments on coastal bottlenose dolphins
    - Indicative delivery date of Q1 2021
5. Evasive responses of small cetaceans to anthropogenic disturbance – insights from a novel passive acoustic monitoring system
    - Indicative delivery date of Q4 2021
6. Temporal variation in abundance and vital rates of Moray Firth harbour seals and bottlenose dolphins
    - Indicative delivery date of Q1 2022

9 Conclusions

This PSIR demonstrates that the foundation installation at Moray East was carried out in accordance with the procedures and protocols described in the PS, with the exception of some variations to the piling mitigation, due to issues with both the hammer and soil characteristics. It provides detailed information on the implementation of the PS, outlining how the project undertook piling within the consented parameters (including piling programme, durations, hammer energies and blow counts), and how mitigation methods were implemented throughout the piling programme (including ADD deployments, soft-starts and ramp-ups), as well as highlighting instances where variations were necessary to the required mitigation procedures.

The piling programme for Moray East was shorter than predicted, with the piling being completed within nine months (compared to predicted 12 months), with the total duration of active piling also being significantly less than predicted (a total of 17.5 days of active piling, compared to 63 days predicted within the PS). In addition, no concurrent piling was undertaken.

The total piling durations for each foundation were below what was predicted within the PS; with an average duration of 1.4 hours compared to 6.5 hours predicted per pin-pile, and an average duration of 4.0 hours compared to 16 hours predicted per foundation. The maximum duration recorded for a pin-pile was 2.7 hours, and the maximum recorded for a foundation was 7.3 hours.

Analyses of the piling undertaken at Moray East shows that the maximum hammer energy recorded for all piling undertaken was 2,071 kJ, below the consented maximum of 2,250 kJ, and the average maximum hammer energy was 1,341 kJ, considerably lower than the consented maximum. The number of hammer blows was also significantly lower than predicted, with a maximum blow count of 4,733 required for a pin-pile, compared to a predicted 16,650 blows per pin-pile.

Mitigation methods were undertaken in line with the mitigation requirements for ADDs, soft-starts and ramp-ups, for both piling with an interval more than six hours (where full mitigation methods were required) and for piling with interval of less than six hours, with the exception of ten instances. For those instances where piling was undertaken outside of the mitigation protocols, most were agreed with MS-LOT prior to the piling being undertaken, therefore they were undertaken in line with agreed variations to the piling protocol.

No marine mammals were recorded during times of active mitigation (pre-watch) or piling activity.

10 References

BOWL (2016). Pre-construction Baseline Herring Larval Surveys. Summary Technical Report, February 2016. Available at: http://www.gov.scot/Resource/0049/00499204.pdf.

JNCC (2010) Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise. August 2010

Moray East (Moray Offshore Windfarm (East) Limited) (2018). Herring Larvae Annual Review; January 2018. Report produced by Brown & May Marine Ltd. Report reference: 8460001-PCA0010-BAM-REP-001

Moray East (Moray Offshore Windfarm (East) Limited)) (2019). Herring Larval Survey; May 2019, Fish Ecology. Report produced by Brown & May Marine Ltd.

Moray East (Moray Offshore Windfarm (East) Limited) 2020 Moray East Piling Strategy Implementation Report – Scope, document reference 8460001-PCA0010-MWE-REP-010, dated 19 October 2020.

Appendix 1: Mitigation Requirements for each Piling Bout

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
20-May-19	K17	03:30:23	0:00:00	Full mitigation	ADD	6	5	146	146	24	497	Yes
26-May-19	K17	07:02:32	146:38:06	Full mitigation	ADD	7	6	146	146	25	470	Yes
26-May-19	K17	08:43:04	0:55:10	Piling break	N/A	N/A	6	146	407	N/A	N/A	No
26-May-19	K17	10:28:04	1:19:57	Piling break	N/A	N/A	5	146	146	N/A	N/A	Yes
26-May-19	K17	12:13:34	0:17:42	Piling break	N/A	N/A	6	146	978	N/A	N/A	No
29-May-19	K17	18:40:40	77:44:34	Full mitigation	ADD	7	6	146	146	22	391	Yes
29-May-19	K17	21:48:15	2:36:07	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-May-19	K17	23:45:53	1:10:44	Piling break	N/A	N/A	6	122	127	N/A	N/A	Yes
31-May-19	K16	12:47:56	36:19:45	Full mitigation	ADD	6	6	146	146	22	430	Yes
31-May-19	K16	14:56:13	1:09:24	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
31-May-19	K16	16:58:16	1:05:03	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
31-May-19	K16	20:04:14	1:15:00	Piling break	N/A	N/A	6	171	199	N/A	N/A	Yes
31-May-19	K16	21:24:30	0:52:12	Piling break	N/A	N/A	6	189	194	N/A	N/A	Yes
02-Jun-19	J17	07:06:02	33:14:06	Full mitigation	ADD	6	6	146	146	23	261	Yes
02-Jun-19	J17	09:21:49	0:54:50	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jun-19	J17	11:26:14	0:52:58	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jun-19	J17	14:10:22	0:57:36	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jun-19	J17	15:42:37	0:42:01	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
04-Jun-19	I19	18:18:39	50:07:55	Full mitigation	ADD	6	6	146	146	22	476	Yes
04-Jun-19	I19	20:21:39	0:55:28	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
04-Jun-19	I19	22:15:26	0:53:30	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Jun-19	I19	00:48:59	0:56:35	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Jun-19	I19	01:55:24	0:39:30	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Jun-19	I20	21:55:25	43:28:53	Full mitigation	ADD	6	6	146	146	24	325	Yes
06-Jun-19	I20	23:33:50	0:42:22	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
07-Jun-19	I20	01:13:54	0:53:43	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
07-Jun-19	I20	03:17:38	0:52:12	Piling break	N/A	N/A	5	146	533	N/A	N/A	No
07-Jun-19	I20	04:24:27	0:38:27	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
07-Jun-19	I20	04:52:25	0:14:12	Piling break	N/A	N/A	6	693	693	N/A	N/A	No
08-Jun-19	H19	00:54:15	19:42:05	Full mitigation	ADD	5	6	146	146	29	453	Yes
08-Jun-19	H19	02:50:10	0:47:17	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Jun-19	H19	04:47:50	0:48:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Jun-19	H19	07:47:58	1:08:07	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Jun-19	H19	08:27:22	0:13:08	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Jun-19	H19	09:21:22	0:47:47	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
09-Jun-19	G19	10:58:48	24:37:51	Full mitigation	ADD	6	6	146	146	20	419	Yes
09-Jun-19	G19	12:46:13	0:57:02	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
09-Jun-19	G19	14:30:34	0:50:19	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
09-Jun-19	G19	16:59:04	0:58:16	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
09-Jun-19	G19	17:55:22	0:31:50	Piling break	N/A	N/A	6	71	71	N/A	N/A	Yes
15-Jun-19	G18	04:18:05	129:55:04	Full mitigation	ADD	6	6	146	146	21	425	Yes
15-Jun-19	G18	05:59:34	0:40:33	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
15-Jun-19	G18	07:46:00	0:46:01	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
15-Jun-19	G18	17:53:17	9:06:44	Full mitigation	ADD	7	5	146	146	20	426	Yes
15-Jun-19	G18	19:25:57	0:57:47	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
15-Jun-19	G18	20:21:02	0:31:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
16-Jun-19	G17	19:15:52	22:32:31	Full mitigation	ADD	6	6	146	146	20	409	Yes
16-Jun-19	G17	21:09:27	0:39:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
16-Jun-19	G17	23:10:12	0:46:44	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Jun-19	G17	11:32:49	11:06:36	Full mitigation	ADD	6	6	146	146	21	481	Yes
17-Jun-19	G17	13:10:21	0:53:09	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Jun-19	G17	14:06:25	0:29:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Jun-19	H17	10:03:27	19:32:33	Full mitigation	ADD	7	6	146	146	21	419	Yes
18-Jun-19	H17	14:13:16	2:49:44	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Jun-19	H17	16:18:59	1:00:19	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Jun-19	H17	18:49:09	0:52:20	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Jun-19	H17	19:53:38	0:33:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Jun-19	J18	21:34:24	25:12:57	Full mitigation	ADD	6	6	146	146	21	508	No
19-Jun-19	J18	23:11:08	0:38:31	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
20-Jun-19	J18	01:08:26	0:55:57	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
20-Jun-19	J18	03:27:33	0:52:47	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
20-Jun-19	J18	04:33:24	0:35:14	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
20-Jun-19	J16	22:53:48	17:48:31	Full mitigation	ADD	6	6	146	146	20	221	Yes
21-Jun-19	J16	00:39:40	0:33:01	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
21-Jun-19	J16	02:20:48	0:41:08	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Jun-19	J16	10:15:04	6:48:52	Full mitigation	ADD	6	6	146	146	20	463	Yes
21-Jun-19	J16	11:41:50	0:54:15	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Jun-19	J16	12:35:36	0:33:50	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Jun-19	H16	14:52:35	25:56:54	Full mitigation	ADD	6	6	146	146	20	228	Yes
22-Jun-19	H16	16:54:57	0:52:35	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Jun-19	H16	19:08:40	0:46:20	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Jun-19	H16	04:29:19	7:49:33	Full mitigation	ADD	6	6	146	146	22	481	Yes
23-Jun-19	H16	06:05:40	1:02:02	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Jun-19	H16	07:03:36	0:41:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Jun-19	G16	22:19:48	14:59:08	Full mitigation	ADD	7	6	146	146	21	268	Yes
24-Jun-19	G16	00:26:13	0:51:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Jun-19	G16	02:19:14	0:45:24	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Jun-19	G16	12:47:06	9:12:48	Full mitigation	ADD	5	6	146	146	22	478	Yes
24-Jun-19	G16	14:08:16	0:50:17	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Jun-19	G16	14:57:23	0:31:46	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Jun-19	G15	21:11:41	53:56:11	Full mitigation	ADD	6	6	72	146	21	269	Yes
26-Jun-19	G15	23:13:52	1:00:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
27-Jun-19	G15	00:51:33	0:38:59	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
27-Jun-19	G15	03:48:03	1:14:44	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
27-Jun-19	G15	05:10:35	0:57:00	Piling break	N/A	N/A	6	87	87	N/A	N/A	Yes
27-Jun-19	H14	23:47:28	18:09:26	Full mitigation	ADD	6	6	146	146	21	237	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
28-Jun-19	H14	01:27:01	0:31:17	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Jun-19	H14	03:21:54	0:38:58	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Jun-19	H14	05:47:55	0:50:56	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Jun-19	H14	07:08:56	0:39:36	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Jun-19	J14	19:11:07	35:24:19	Full mitigation	ADD	6	6	146	146	21	385	Yes
29-Jun-19	J14	21:01:32	0:36:37	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Jun-19	J14	23:05:22	0:43:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Jun-19	J14	07:26:43	7:02:47	Full mitigation	ADD	7	6	146	146	21	495	Yes
30-Jun-19	J14	09:02:07	1:03:36	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Jun-19	J14	09:56:35	0:33:43	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jul-19	J13	00:16:13	37:59:43	Full mitigation	ADD	5	6	75	146	21	272	Yes
02-Jul-19	J13	01:44:43	0:28:48	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jul-19	J13	03:22:23	0:37:22	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jul-19	J13	05:46:38	0:51:34	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jul-19	J13	06:17:35	0:11:23	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Jul-19	J13	07:05:09	0:39:12	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
03-Jul-19	H13	20:04:11	36:30:16	Full mitigation	ADD	6	6	68	146	20	222	Yes
03-Jul-19	H13	21:20:08	0:29:07	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
03-Jul-19	H13	23:03:42	0:44:14	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
04-Jul-19	H13	01:34:50	1:01:21	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
04-Jul-19	H13	02:33:39	0:29:44	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Jul-19	G13	02:33:00	23:32:30	Phased piling – Stage 1	ADD	7	6	67	146	21	392	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
05-Jul-19	G13	04:13:40	0:34:24	Phased piling – Stage 1	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Jul-19	G13	06:59:37	1:15:46	Phased piling – Stage 1	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Jul-19	G13	10:07:18	1:37:51	Phased piling – Stage 1	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Jul-19	E14	22:05:01	35:28:35	Phased piling – Stage 1	ADD	8	6	146	146	21	425	Yes
07-Jul-19	E14	00:35:14	1:03:17	Phased piling – Stage 1	N/A	N/A	6	146	146	N/A	N/A	Yes
07-Jul-19	E14	02:43:34	0:50:28	Phased piling – Stage 1	N/A	N/A	6	146	148	N/A	N/A	Yes
07-Jul-19	C14	20:47:35	16:41:39	Phased piling – Stage 1	N/A	N/A	6	146	146	21	416	Yes
07-Jul-19	C14	22:52:52	0:50:56	Phased piling – Stage 1	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Jul-19	C14	00:58:58	0:53:27	Phased piling – Stage 1	N/A	N/A	6	146	146	N/A	N/A	Yes
09-Jul-19	B14	03:04:01	24:51:45	Phased piling – Stage 2	ADD	8	6	146	146	21	461	Yes
09-Jul-19	B14	05:11:41	0:50:13	Phased piling – Stage 2	N/A	N/A	6	146	146	N/A	N/A	Yes
09-Jul-19	B14	07:05:16	0:41:58	Phased piling – Stage 2	N/A	N/A	6	146	146	N/A	N/A	Yes
10-Jul-19	C15	00:27:37	16:07:18	Phased piling – Stage 2	ADD	9	6	146	146	21	427	Yes
10-Jul-19	C15	02:26:30	0:53:36	Phased piling – Stage 2	N/A	N/A	6	146	146	N/A	N/A	Yes
10-Jul-19	C15	04:48:16	1:15:19	Phased piling – Stage 2	N/A	N/A	6	146	146	N/A	N/A	Yes
11-Jul-19	D16	07:04:15	25:02:33	Phased piling – Stage 2	ADD	8	6	146	146	24	325	Yes
11-Jul-19	D16	09:21:04	0:57:43	Phased piling – Stage 2	N/A	N/A	6	146	146	N/A	N/A	Yes
11-Jul-19	D16	11:13:11	0:45:14	Phased piling – Stage 2	N/A	N/A	6	146	146	N/A	N/A	Yes
12-Jul-19	C16	02:15:06	13:55:08	Full mitigation	ADD	7	6	146	146	21	425	Yes
12-Jul-19	C16	04:20:35	0:52:35	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
12-Jul-19	C16	06:22:52	0:46:57	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Jul-19	D17	02:00:04	18:30:56	Full mitigation	ADD	8	6	70	146	21	459	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
13-Jul-19	D17	03:50:53	0:39:55	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Jul-19	D17	05:41:26	0:36:37	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Jul-19	E18	23:06:54	16:21:01	Full mitigation	ADD	10	6	146	146	21	404	Yes
14-Jul-19	E18	01:23:28	0:52:13	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
14-Jul-19	E18	04:48:29	2:08:53	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
15-Jul-19	E19	00:52:24	18:49:34	Full mitigation	ADD	6	6	146	146	21	428	Yes
15-Jul-19	E19	04:37:21	2:09:46	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
15-Jul-19	E19	06:28:57	0:26:00	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
15-Jul-19	F21	20:14:40	12:32:20	Full mitigation	ADD	6	6	146	146	21	487	Yes
15-Jul-19	F21	22:10:46	0:47:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
15-Jul-19	F21	23:55:50	0:36:52	Piling break	N/A	N/A	6	77	77	N/A	N/A	Yes
16-Jul-19	G22	23:07:09	22:03:39	Full mitigation	ADD	5	6	146	146	21	402	Yes
17-Jul-19	G22	01:17:15	1:04:47	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Jul-19	G22	02:54:20	0:38:15	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Jul-19	H22	23:52:07	19:58:16	Full mitigation	ADD	8	6	146	146	21	490	Yes
18-Jul-19	H22	02:22:11	0:46:39	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Jul-19	H22	04:50:10	0:37:27	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Jul-19	H21	04:27:17	69:51:43	Full mitigation	ADD	6	6	146	146	24	415	Yes
21-Jul-19	H21	06:39:03	0:44:57	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Jul-19	H21	08:42:18	0:52:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Jul-19	G21	16:04:56	30:14:46	Full mitigation	ADD	8	6	146	146	21	462	Yes
22-Jul-19	G21	18:36:32	1:02:58	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
22-Jul-19	G21	20:35:05	0:32:19	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Jul-19	H20	00:39:23	26:34:08	Full mitigation	ADD	5	6	146	146	22	417	Yes
24-Jul-19	H20	02:45:48	0:44:47	Piling break	N/A	N/A	6	90	146	N/A	N/A	Yes
24-Jul-19	H20	04:20:03	0:22:36	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
25-Jul-19	L12	00:03:01	18:26:15	Full mitigation	ADD	6	6	146	146	24	422	Yes
25-Jul-19	L12	02:07:09	0:35:48	Piling break	N/A	NA	6	146	146	N/A	N/A	Yes
25-Jul-19	L12	03:37:44	0:22:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Jul-19	L11	15:54:48	35:05:34	Full mitigation	ADD	6	6	146	146	21	473	Yes
26-Jul-19	L11	17:53:24	0:40:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Jul-19	L11	19:23:37	0:24:25	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
27-Jul-19	L09	14:16:12	17:34:53	Full mitigation	ADD	7	6	146	146	22	426	Yes
27-Jul-19	L09	16:27:08	0:53:18	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
27-Jul-19	L09	17:49:26	0:23:17	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Jul-19	K10	18:26:39	23:24:44	Full mitigation	ADD	7	6	146	146	22	512	No
28-Jul-19	K10	21:04:29	1:11:05	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Jul-19	K10	22:49:30	0:32:18	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Jul-19	K11	15:19:38	15:15:02	Full mitigation	ADD	10	6	146	146	21	413	Yes
29-Jul-19	K11	17:11:15	0:41:09	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Jul-19	K11	18:54:56	0:41:39	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Jul-19	J10	12:33:27	16:42:00	Full mitigation	ADD	6	6	146	146	22	412	Yes
30-Jul-19	J10	14:46:51	0:35:56	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Jul-19	J10	16:41:48	0:22:44	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
02-Aug-19	J10	15:48:10	69:55:06	Full mitigation	ADD	5	6	124	146	2	842	No
03-Aug-19	J10	20:59:02	28:50:49	Full mitigation	ADD	5	1	146	146	2	1151	No
05-Aug-19	H09	03:36:08	30:17:32	Full mitigation	ADD	5	6	146	146	22	418	Yes
05-Aug-19	H09	11:43:30	6:42:37	Full mitigation	ADD	6	6	146	146	21	416	Yes
05-Aug-19	H09	13:46:26	0:51:59	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Aug-19	G09	03:26:00	12:40:07	Full mitigation	ADD	6	6	146	146	22	421	Yes
06-Aug-19	G09	06:00:36	0:38:37	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Aug-19	G09	14:01:31	6:59:46	Full mitigation	ADD	6	6	146	146	22	450	Yes
07-Aug-19	G09	08:49:49	17:43:11	Full mitigation	ADD	6	6	146	146	21	479	Yes
07-Aug-19	G09	10:20:34	0:15:43	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Aug-19	H18	05:30:55	18:25:16	Full mitigation	ADD	10	6	146	146	22	419	Yes
08-Aug-19	H18	07:39:17	0:39:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Aug-19	H18	09:33:48	0:33:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Aug-19	I18	00:39:57	205:43:33	Full mitigation	ADD	9	6	146	146	20	415	Yes
17-Aug-19	I18	02:58:25	0:46:41	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Aug-19	I18	04:30:55	0:25:00	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Aug-19	G10	21:03:14	15:13:23	Full mitigation	ADD	6	6	146	146	20	479	Yes
17-Aug-19	G10	23:28:37	0:34:34	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Aug-19	G10	01:22:03	0:34:38	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Aug-19	F15	02:52:12	24:13:05	Full mitigation	ADD	8	6	146	146	20	453	Yes
19-Aug-19	F15	04:32:15	0:40:15	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Aug-19	F15	05:53:01	0:31:01	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
20-Aug-19	A01	03:19:12	20:32:12	Full mitigation	ADD	14	6	146	146	20	207	Yes
20-Aug-19	A01	04:58:20	0:34:47	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
20-Aug-19	A01	06:27:22	0:25:51	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Aug-19	I10	05:54:02	22:29:16	Full mitigation	ADD	9	6	146	146	20	327	Yes
21-Aug-19	I10	08:36:32	1:11:44	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Aug-19	I10	10:59:49	0:58:39	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Aug-19	E06	05:27:17	17:03:42	Full mitigation	ADD	6	6	146	146	20	424	Yes
22-Aug-19	E06	07:33:56	0:21:58	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Aug-19	E06	12:48:41	3:40:51	Piling break	N/A	N/A	6	80	146	N/A	N/A	Yes
23-Aug-19	E06	02:37:30	12:14:39	Full mitigation	ADD	11	6	146	146	20	235	Yes
23-Aug-19	E06	04:15:17	0:36:28	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Aug-19	E06	05:27:16	0:24:14	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Aug-19	J08	02:45:22	20:42:21	Full mitigation	ADD	15	6	146	146	28	472	Yes
24-Aug-19	J08	04:39:10	0:36:59	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Aug-19	J08	08:44:22	3:15:19	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Aug-19	J08	09:43:48	0:29:02	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Aug-19	J07	22:38:23	11:40:13	Full mitigation	ADD	6	6	146	146	20	470	Yes
25-Aug-19	J07	00:31:49	0:37:51	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
25-Aug-19	J07	02:22:25	0:50:05	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Aug-19	G07	07:04:57	27:38:20	Full mitigation	ADD	5	6	146	146	20	457	Yes
26-Aug-19	G07	08:37:33	0:31:41	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Aug-19	G07	09:40:33	0:27:25	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
28-Aug-19	G07	13:09:15	50:32:48	Full mitigation	ADD	6	6	138	138	20	281	Yes
28-Aug-19	G07	15:23:02	0:48:46	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Aug-19	G07	17:04:26	0:32:05	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Aug-19	F08	09:13:53	15:03:53	Full mitigation	ADD	6	6	146	146	20	466	Yes
29-Aug-19	F08	11:17:30	0:34:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Aug-19	F08	17:38:32	4:41:43	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Aug-19	C05	11:44:54	16:31:02	Full mitigation	ADD	6	6	146	146	20	406	Yes
30-Aug-19	C05	12:58:53	0:37:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Aug-19	C05	14:19:22	0:29:01	Piling break	N/A	N/A	6	70	82	N/A	N/A	Yes
30-Aug-19	C05	15:44:33	0:38:09	Piling break	N/A	N/A	5	146	146	N/A	N/A	Yes
01-Sep-19	B04	10:22:01	42:17:50	Full mitigation	ADD	5	6	146	146	20	420	Yes
01-Sep-19	B04	12:03:31	0:37:48	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
01-Sep-19	B04	13:27:05	0:27:43	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Oct-19	A02	12:13:01	1005:52:18	Full mitigation	ADD	12	6	139	139	20	264	Yes
13-Oct-19	A02	14:11:27	0:45:15	Piling break	N/A	N/A	6	79	81	N/A	N/A	Yes
13-Oct-19	A02	15:45:44	0:28:55	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
14-Oct-19	B05	08:26:23	15:42:16	Full mitigation	ADD	14	6	146	146	20	451	Yes
14-Oct-19	B05	10:35:39	0:47:44	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
14-Oct-19	B05	12:23:25	0:27:50	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
16-Oct-19	C07	23:40:24	58:03:51	Full mitigation	ADD	10	6	146	146	20	264	Yes
17-Oct-19	C07	01:57:35	0:33:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Oct-19	C07	03:32:02	0:24:06	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
17-Oct-19	C09	15:02:57	10:13:11	Full mitigation	ADD	8	6	146	146	20	428	Yes
17-Oct-19	C09	17:01:27	0:40:15	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Oct-19	C09	18:58:01	0:34:58	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Oct-19	C04	05:19:47	81:10:33	Full mitigation	ADD	8	6	146	146	21	313	Yes
21-Oct-19	C04	06:32:58	0:47:02	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Oct-19	C04	07:29:09	0:30:58	Piling break	N/A	N/A	6	80	88	N/A	N/A	Yes
21-Oct-19	C04	11:02:54	3:06:48	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Oct-19	C04	12:05:53	0:31:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Oct-19	C04	13:06:47	0:26:30	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Oct-19	I06	18:44:39	29:07:30	Full mitigation	ADD	8	6	146	146	20	325	Yes
22-Oct-19	I06	20:23:05	0:39:54	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Oct-19	I06	21:38:28	0:36:28	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Oct-19	I06	04:57:00	6:36:06	Full mitigation	ADD	7	6	146	146	20	479	Yes
23-Oct-19	I06	06:09:59	0:35:20	Piling break	N/A	N/A	6	134	135	N/A	N/A	Yes
23-Oct-19	I06	06:55:09	0:24:51	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Oct-19	C10	04:13:05	116:59:49	Full mitigation	ADD	8	6	146	146	20	422	Yes
28-Oct-19	C10	06:09:37	0:41:47	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Oct-19	C10	08:16:01	1:07:37	Piling break	N/A	N/A	6	65	97	N/A	N/A	Yes
30-Oct-19	C11	03:09:02	41:58:08	Full mitigation	ADD	6	6	146	146	20	419	Yes
30-Oct-19	C11	05:02:37	0:34:33	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Oct-19	C11	06:28:24	0:25:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
31-Oct-19	C12	10:23:45	26:51:26	Full mitigation	ADD	6	6	113	113	20	423	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
31-Oct-19	C12	11:56:31	0:31:09	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
31-Oct-19	C12	13:21:10	0:21:11	Piling break	N/A	N/A	6	96	99	N/A	N/A	Yes
01-Nov-19	B13	03:42:42	13:10:03	Full mitigation	ADD	6	6	146	146	23	422	Yes
01-Nov-19	B13	05:47:18	0:34:24	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
01-Nov-19	B13	07:22:55	0:20:03	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
07-Nov-19	C02	08:17:17	143:39:18	Full mitigation	ADD	15	6	146	146	21	443	Yes
07-Nov-19	C02	09:45:46	0:33:42	Piling break	N/A	NA	6	146	146	N/A	N/A	Yes
07-Nov-19	C02	10:52:30	0:21:19	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Nov-19	C02	07:20:35	19:37:58	Full mitigation	ADD	6	6	146	146	21	421	Yes
08-Nov-19	C02	08:29:18	0:31:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
08-Nov-19	C02	09:06:05	0:19:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Nov-19	D15	16:47:12	127:22:32	Full mitigation	ADD	6	6	146	146	22	327	Yes
13-Nov-19	D15	18:26:05	0:33:22	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Nov-19	D15	19:49:54	0:21:57	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Nov-19	E04	09:39:37	84:48:03	Full mitigation	ADD	8	6	81	81	21	326	Yes
17-Nov-19	E04	11:57:10	1:03:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Nov-19	E04	13:22:40	0:26:29	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Nov-19	E05	08:40:26	18:17:30	Full mitigation	ADD	7	6	71	146	21	237	Yes
18-Nov-19	E05	10:21:50	0:38:55	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Nov-19	E05	11:50:02	0:22:57	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Nov-19	E05	17:06:58	4:22:24	Piling break	N/A	N/A	6	68	146	N/A	N/A	Yes
18-Nov-19	E05	18:04:14	0:31:07	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
18-Nov-19	E05	18:43:38	0:19:08	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Nov-19	B03	17:55:36	22:49:55	Full mitigation	ADD	7	6	146	146	21	324	Yes
19-Nov-19	B03	19:44:51	0:35:41	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Nov-19	B03	20:11:19	0:17:35	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Nov-19	B03	22:21:19	2:09:36	Piling break	N/A	N/A	6	68	146	N/A	N/A	Yes
19-Nov-19	B03	23:44:37	0:24:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Nov-19	H05	19:55:12	235:02:33	Full mitigation	ADD	5	5	70	146	22	296	Yes
29-Nov-19	H05	21:42:19	0:33:14	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Nov-19	H05	23:16:21	0:24:45	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Nov-19	G05	21:45:20	21:15:34	Full mitigation	ADD	6	6	84	86	20	387	Yes
01-Dec-19	G05	12:37:03	13:51:35	Full mitigation	ADD	6	5	146	146	20	328	Yes
01-Dec-19	G05	14:25:00	0:29:43	Piling break	N/A	N/A	6	76	86	N/A	N/A	Yes
01-Dec-19	G05	16:21:34	0:37:53	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Dec-19	B02	11:31:37	18:52:52	Full mitigation	ADD	6	6	146	146	20	420	Yes
02-Dec-19	B02	13:38:20	0:32:54	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Dec-19	B02	15:37:11	0:21:24	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
03-Dec-19	D10	18:27:17	25:37:03	Full mitigation	ADD	5	6	146	146	21	426	Yes
03-Dec-19	D10	20:14:59	0:29:43	Piling break	N/A	N/A	5	146	146	N/A	N/A	Yes
03-Dec-19	D10	21:51:58	0:23:31	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Dec-19	D13	21:22:50	46:25:51	Full mitigation	ADD	7	6	83	83	21	419	Yes
05-Dec-19	D13	23:28:05	0:35:56	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Dec-19	D13	01:16:22	0:24:51	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
07-Dec-19	D09	02:13:32	23:36:02	Full mitigation	ADD	11	6	89	89	21	451	Yes
07-Dec-19	D09	03:53:34	0:33:29	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
07-Dec-19	D09	05:06:50	0:20:55	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
07-Dec-19	D08	16:59:35	10:52:53	Full mitigation	ADD	5	6	146	146	20	457	Yes
07-Dec-19	D08	18:58:51	0:46:58	Piling break	N/A	N/A	6	67	146	N/A	N/A	Yes
07-Dec-19	D08	20:28:35	0:19:43	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
14-Dec-19	D06	21:49:04	168:11:00	Full mitigation	ADD	6	6	92	92	21	224	Yes
14-Dec-19	D06	23:34:44	0:31:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
15-Dec-19	D06	00:50:51	0:24:03	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
16-Dec-19	D05	18:26:58	40:41:33	Full mitigation	ADD	6	6	146	146	20	307	Yes
16-Dec-19	D05	20:05:41	0:35:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
16-Dec-19	D05	21:35:27	0:24:28	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
17-Dec-19	H08	21:41:11	23:04:12	Full mitigation	ADD	6	6	66	81	20	419	Yes
17-Dec-19	H08	23:06:54	0:35:13	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Dec-19	H08	00:09:40	0:18:15	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
18-Dec-19	H08	09:12:00	8:15:54	Full mitigation	ADD	6	6	75	75	20	478	Yes
18-Dec-19	H08	10:23:16	0:33:46	Piling break	N/A	N/A	6	90	91	N/A	N/A	Yes
18-Dec-19	H08	11:18:29	0:34:58	Piling break	N/A	N/A	6	81	89	N/A	N/A	Yes
22-Dec-19	H11	05:22:13	89:43:14	Full mitigation	ADD	6	6	80	82	20	474	Yes
22-Dec-19	H11	07:00:33	0:32:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Dec-19	H11	08:49:58	0:48:28	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Dec-19	H11	17:39:54	7:49:33	Full mitigation	ADD	6	6	74	78	20	467	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
22-Dec-19	H11	19:10:42	0:39:03	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Dec-19	H11	20:03:06	0:19:38	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Dec-19	G08	15:34:22	18:59:07	Full mitigation	ADD	6	6	87	87	21	478	Yes
23-Dec-19	G08	17:35:12	0:40:05	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Dec-19	G08	19:18:22	0:24:46	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Dec-19	H07	07:30:20	10:54:23	Full mitigation	ADD	6	6	85	95	21	478	Yes
24-Dec-19	H07	09:16:33	0:33:50	Piling break	N/A	N/A	6	84	95	N/A	N/A	Yes
24-Dec-19	H07	10:47:28	0:22:21	Piling break	N/A	N/A	6	82	87	N/A	N/A	Yes
25-Dec-19	H06	03:33:28	15:33:54	Full mitigation	ADD	5	6	146	146	20	420	Yes
25-Dec-19	H06	05:31:17	0:33:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
25-Dec-19	H06	07:08:07	0:24:00	Piling break	N/A	N/A	6	73	80	N/A	N/A	Yes
25-Dec-19	I07	19:08:38	10:36:52	Full mitigation	ADD	5	5	146	146	20	416	Yes
25-Dec-19	I07	21:09:40	0:30:19	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
25-Dec-19	I07	22:56:41	0:22:27	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Dec-19	K09	19:43:31	67:19:16	Full mitigation	ADD	5	6	146	146	20	425	Yes
28-Dec-19	K09	21:44:39	0:31:52	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
29-Dec-19	K09	14:34:31	15:28:15	Full mitigation	ADD	6	6	146	146	20	477	Yes
30-Dec-19	L13	05:05:56	13:11:20	Full mitigation	ADD	7	6	85	85	20	402	Yes
30-Dec-19	L13	07:07:40	0:42:40	Piling break	N/A	N/A	6	76	86	N/A	N/A	Yes
30-Dec-19	L13	08:42:53	0:25:19	Piling break	N/A	N/A	6	85	85	N/A	N/A	Yes
31-Dec-19	H10	07:40:37	21:49:36	Full mitigation	ADD	6	6	92	98	20	468	Yes
31-Dec-19	H10	08:54:52	0:20:24	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
31-Dec-19	H10	10:12:10	0:30:50	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
31-Dec-19	H10	11:48:16	0:30:44	Piling break	N/A	N/A	6	108	115	N/A	N/A	Yes
31-Dec-19	H10	12:31:23	0:20:19	Piling break	N/A	N/A	6	74	146	N/A	N/A	Yes
31-Dec-19	G11	23:57:05	11:03:53	Full mitigation	ADD	5	6	78	85	20	424	Yes
01-Jan-20	G11	01:38:59	0:47:33	Piling break	N/A	N/A	6	69	146	N/A	N/A	Yes
04-Jan-20	G11	20:57:37	90:38:46	Full mitigation	ADD	5	6	68	84	20	449	Yes
04-Jan-20	G11	22:29:24	0:18:42	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
04-Jan-20	G11	23:30:35	0:31:03	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
10-Jan-20	G06	09:13:26	129:10:55	Full mitigation	ADD	9	6	84	84	20	454	Yes
10-Jan-20	G06	10:30:13	0:32:49	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
10-Jan-20	G06	11:30:29	0:21:16	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
11-Jan-20	G06	19:33:28	31:23:52	Full mitigation	ADD	5	6	146	146	1	146	No
11-Jan-20	G06	20:36:08	0:42:30	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
11-Jan-20	G06	21:18:21	0:18:22	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Jan-20	C13	00:30:35	170:49:04	Full mitigation	ADD	6	6	146	146	20	336	Yes
19-Jan-20	C13	02:04:10	0:25:48	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Jan-20	C13	03:23:36	0:16:58	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
19-Jan-20	C13	09:29:29	5:03:05	Piling break	N/A	N/A	6	70	77	N/A	N/A	Yes
19-Jan-20	C13	10:10:18	0:16:35	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
21-Jan-20	C13	01:03:56	38:30:07	Full mitigation	ADD	5	6	146	146	20	468	Yes
21-Jan-20	D07	19:54:30	17:59:02	Full mitigation	ADD	6	6	146	146	20	355	Yes
21-Jan-20	D07	21:52:19	0:27:11	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
21-Jan-20	D07	23:27:11	0:17:53	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Jan-20	C08	17:29:27	16:41:37	Full mitigation	ADD	6	6	81	146	20	423	Yes
22-Jan-20	C08	19:17:44	0:29:34	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
22-Jan-20	C08	20:45:31	0:20:04	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
23-Jan-20	D11	23:59:13	26:09:17	Full mitigation	ADD	6	6	146	146	20	456	Yes
24-Jan-20	D11	01:37:02	0:37:10	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Jan-20	D11	02:43:50	0:17:26	Piling break	N/A	N/A	6	70	146	N/A	N/A	Yes
24-Jan-20	D11	15:28:31	11:52:13	Full mitigation	ADD	7	6	146	146	20	424	Yes
24-Jan-20	D11	16:43:06	0:31:35	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
24-Jan-20	D11	17:23:16	0:17:08	Piling break	N/A	N/A	6	75	146	N/A	N/A	Yes
25-Jan-20	D04	18:50:19	25:03:07	Full mitigation	ADD	7	6	146	146	20	471	Yes
25-Jan-20	D04	20:28:29	0:33:05	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
25-Jan-20	D04	21:47:03	0:18:51	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Jan-20	D04	06:40:14	7:51:15	Full mitigation	ADD	6	6	69	83	20	456	Yes
26-Jan-20	D04	08:11:53	0:33:25	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Jan-20	D04	09:18:42	0:31:31	Piling break	N/A	N/A	6	67	146	N/A	N/A	Yes
28-Jan-20	F04	06:32:59	44:40:36	Full mitigation	ADD	6	6	82	82	21	426	Yes
28-Jan-20	F04	07:56:32	0:32:40	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Jan-20	F04	08:55:51	0:21:20	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
28-Jan-20	F04	13:49:50	4:06:25	Piling break	N/A	N/A	6	82	86	N/A	N/A	Yes
28-Jan-20	F04	14:45:22	0:31:14	Piling break	N/A	N/A	6	78	146	N/A	N/A	Yes
28-Jan-20	F04	15:22:06	0:19:26	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
30-Jan-20	D12	01:00:49	33:20:00	Full mitigation	ADD	6	6	97	98	21	428	Yes
30-Jan-20	D12	02:24:20	0:31:28	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
30-Jan-20	D12	03:24:01	1:31:09	Piling break	N/A	N/A	6	82	93	N/A	N/A	Yes
31-Jan-20	D12	10:11:06	29:57:57	Full mitigation	ADD	5	6	146	146	20	462	Yes
31-Jan-20	D12	11:42:43	0:28:57	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
31-Jan-20	D12	12:29:19	1:15:33	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
01-Feb-20	D14	18:54:43	29:54:53	Full mitigation	ADD	6	6	80	85	20	457	Yes
01-Feb-20	D14	20:18:50	0:27:45	Piling break	N/A	N/A	6	78	84	N/A	N/A	Yes
01-Feb-20	D14	21:35:03	0:27:25	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
02-Feb-20	D14	02:04:58	3:43:45	Piling break	N/A	N/A	6	73	73	N/A	N/A	Yes
02-Feb-20	D14	02:51:38	0:27:15	Piling break	N/A	N/A	6	104	113	N/A	N/A	Yes
02-Feb-20	D14	03:25:04	0:17:34	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
04-Feb-20	J09	19:27:26	63:44:06	Full mitigation	ADD	6	6	93	99	20	476	Yes
04-Feb-20	J09	21:03:08	0:30:13	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
04-Feb-20	J09	22:19:44	0:23:06	Piling break	N/A	N/A	6	89	93	N/A	N/A	Yes
05-Feb-20	J09	08:11:27	8:52:57	Full mitigation	ADD	5	6	146	146	20	493	Yes
05-Feb-20	J09	09:30:56	0:32:52	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Feb-20	J09	10:19:05	0:21:46	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
05-Feb-20	J12	23:21:52	12:35:39	Full mitigation	ADD	5	6	65	75	21	456	Yes
06-Feb-20	J12	00:36:23	0:30:05	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Feb-20	J12	01:38:50	0:21:56	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Feb-20	J12	07:27:35	5:13:20	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes

Date	Pile	Start time of piling	Time from previous piling bout (hh:mm:ss)	Mitigation required	ADD deployed	ADD duration	Soft start blows	Hammer energy of first blow	Soft start maximum energy	Ramp up duration	Ramp up maximum energy	Mitigation followed
06-Feb-20	J12	08:10:58	0:28:33	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
06-Feb-20	J12	08:43:28	0:18:34	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Feb-20	G20	00:42:50	159:45:14	Full mitigation	ADD	5	6	106	106	21	468	Yes
13-Feb-20	G20	01:48:10	0:30:02	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Feb-20	G20	02:47:07	0:18:31	Piling break	N/A	N/A	6	80	146	N/A	N/A	Yes
13-Feb-20	G20	07:25:03	4:00:24	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Feb-20	G20	08:12:13	0:28:58	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
13-Feb-20	G20	08:47:26	0:18:13	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Feb-20	J19	08:55:18	311:50:24	Full mitigation	ADD	5	6	94	98	20	486	Yes
26-Feb-20	J19	10:36:55	0:49:08	Piling break	N/A	N/A	6	75	90	N/A	N/A	Yes
26-Feb-20	J19	12:25:35	0:59:32	Piling break	N/A	N/A	6	146	146	N/A	N/A	Yes
26-Feb-20	J19	23:55:02	10:43:49	Full mitigation	ADD	6	6	144	144	0	144	No
27-Feb-20	J19	00:42:08	0:29:01	Piling break	N/A	N/A	6	90	90	N/A	N/A	Yes
27-Feb-20	J19	01:23:53	0:17:41	Piling break	N/A	N/A	6	76	79	N/A	N/A	Yes

Appendix 2: Comparison to Environmental Statement

The following section of the PSIR provides a high level summary to compare the piling as predicted within the Moray East ES (2012) and the piling that was undertaken. It should be noted that the piling parameters set out as the worst-case within the Moray East ES (2012) was superseded by the parameters as set out within the PS, and the consented project parameters are therefore those that were presented within the PS.

As noted in the PSIR, the piling parameters changed (including the maximum hammer energy required, the durations of piling, and the total blow counts) as a result of further information becoming available on both the project design, and the seabed conditions at the site.

The following comparisons are, therefore, shown for information purposes only, and the comparisons provided within the main sections of the PSIR should be taken as the comparison to consented and predicted piling parameters.

Purpose of the Comparisons to the Moray East ES (2012)

Taking into account the above, the following comparisons of piling activities to the Moray East ES (2012) as an illustrative exercise in comparing changes in predicted piling requirements over the course of an offshore wind farm project, from what was predicted at an early stage of the project, to what was predicted when further information on both pile design and seabed conditions was known (as presented within the PS, and the consented parameters), and the piling activities that were eventually undertaken.

Piling Parameters set out within the Moray East ES (2012) and PS

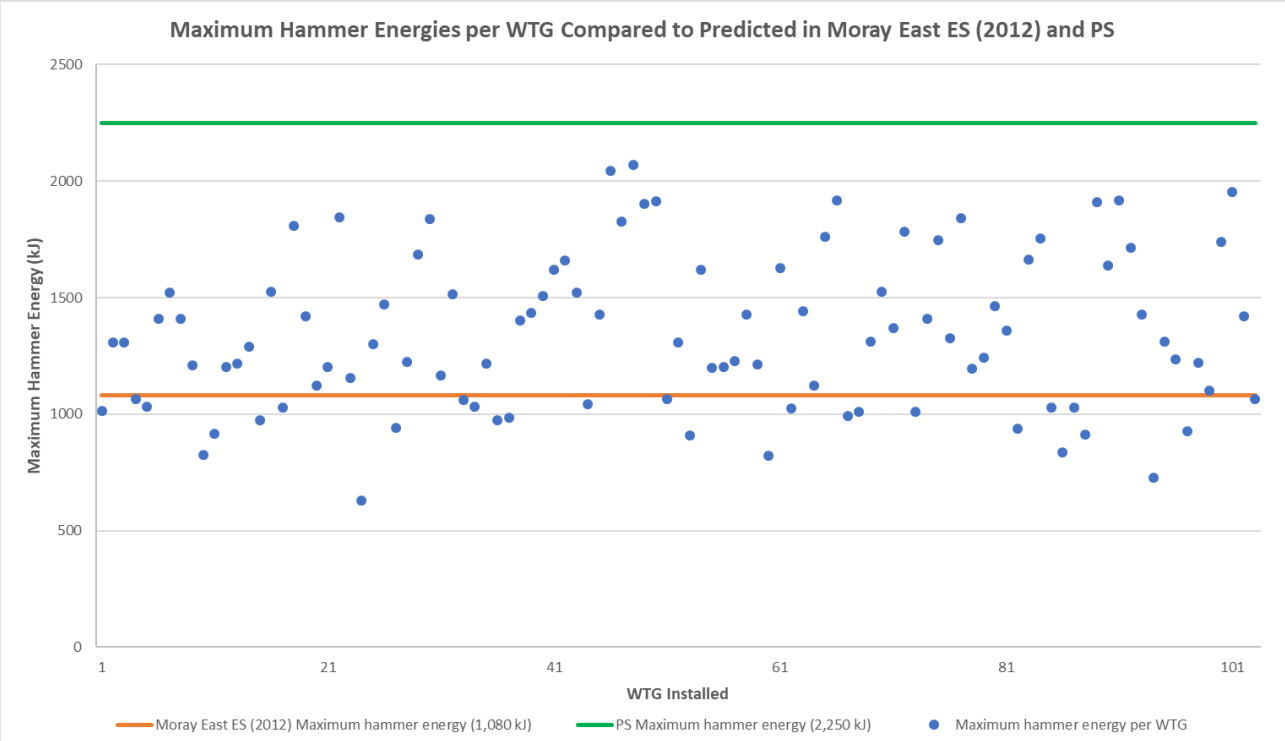
The following table provides a high level summary of the piling parameters predicted to be required in the Moray East ES (2012), and those that were predicted (and therefore the final consented parameters) within the PS. In all cases, the parameters were predicted to be higher within the PS than in the Moray East ES (2012).

Piling element	Pile driving parameters (Moray East ES (2012)) Parameter	Pile driving parameters (PS) (worst-case)
Maximum hammer energy (kJ)	1,080 kJ	2,250 kJ
Total blow counts (most probable – highest expected)	10,660	16,650
Duration of active piling per pile in hours (most probable – highest expected)	3.25 hours (195 minutes) per pin-pile 585 minutes per WTG	6.5 hours (390 minutes) per pin-pile 1,170 minutes per WTG

Comparison of Hammer Energies

The following graph show a high level comparison of predicted hammer energies in the Moray East ES (2012) (of 1,080 kJ as shown by the orange line on the graph below), the predicted hammer energy in the PS (of 2,250 kJ as shown by the green line below), and the maximum hammer energies recorded at each WTG (shown by the blue dots on the graph below).

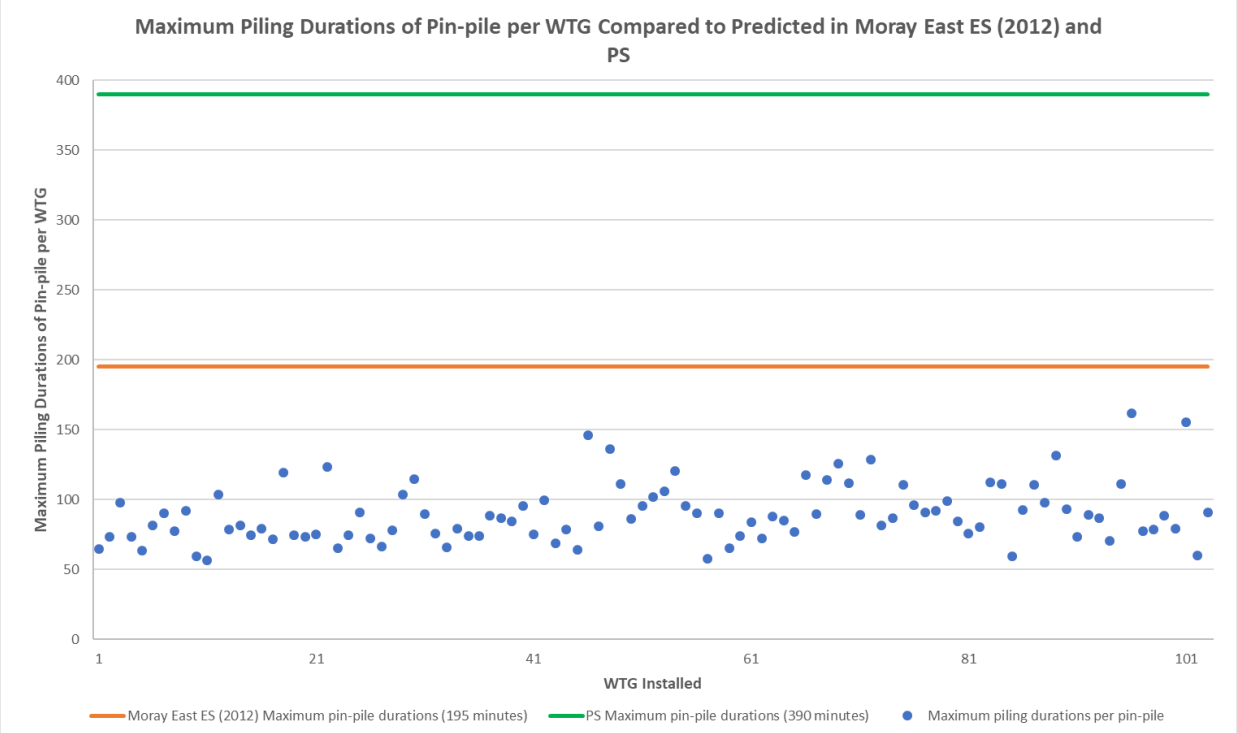
As shown by the graph, the majority of WTGs required hammer energies exceeding those that were predicted in the Moray East ES (2012) (74 WTGs recorded hammer energies above the ES limit), however, no hammer energies exceeded the consented hammer energy of 2,250 kJ at PS.

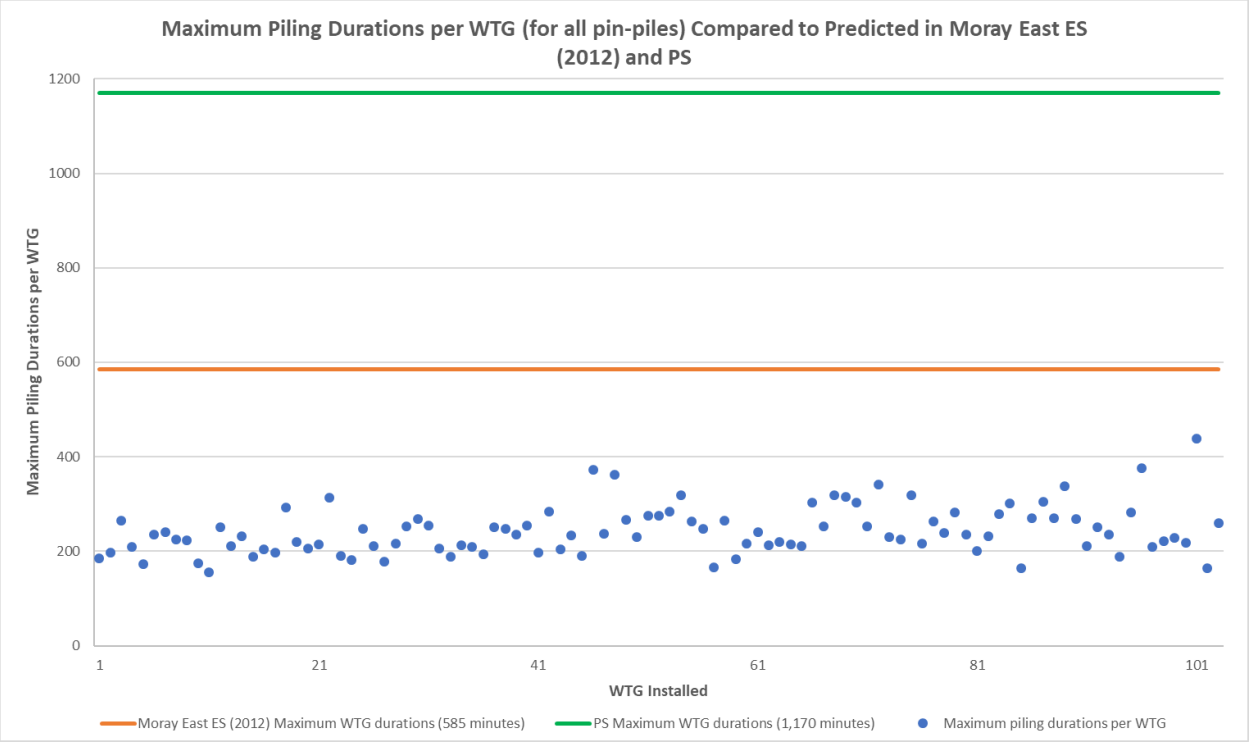


Comparison of Piling Durations

The following graph show a high level comparison of predicted piling durations per pin-pile, and per WTG in the Moray East ES (2012) (of 195 minutes per pin-pile, and 585 minutes per WTG) as shown by the orange lines on the graphs below), the predicted durations, per pin-pile and per WTG, in the PS (of 390 minutes per pin-pile, and 1,170 per WTG, as shown by the green lines below), and the maximum duration recorded between pin-piles at each WTG, and the total durations per WTG for all three pin-piles (shown by the blue dots on the graphs below).

As shown by the graph, all pin-piles and WTGs recorded durations below those that were predicted in the Moray East ES (2012) and within the PS.

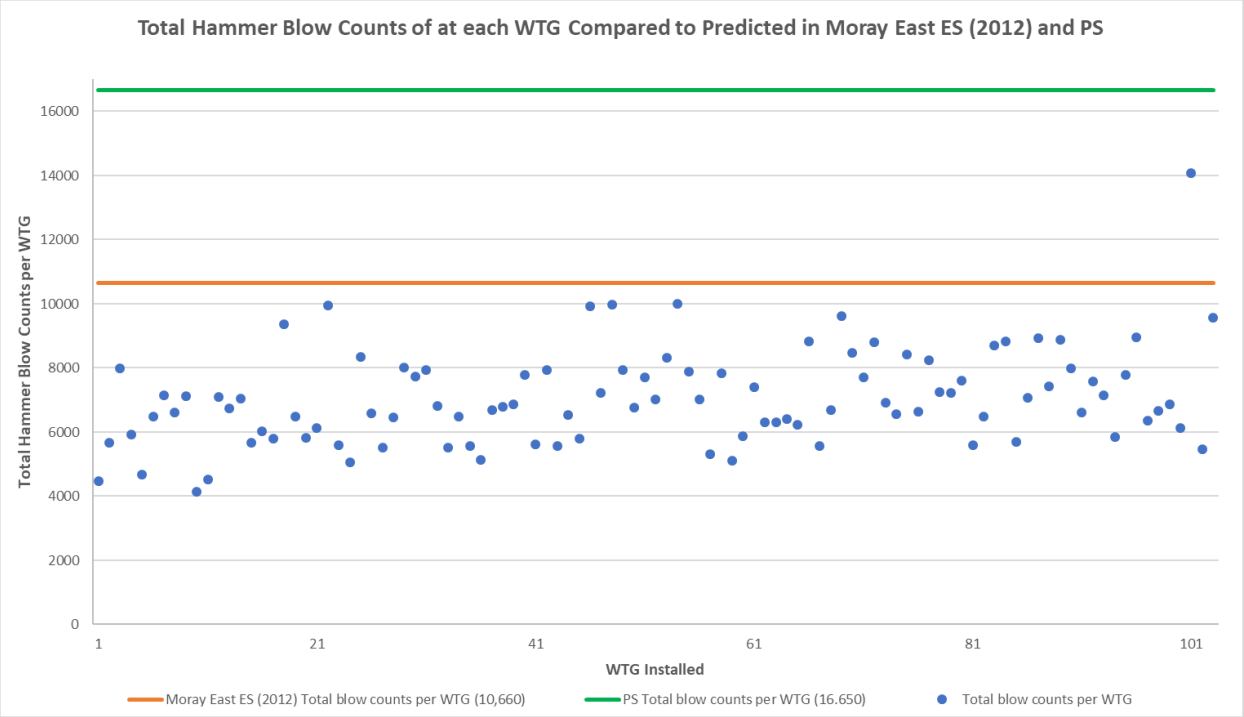




Blow Counts

The following graph show a high level comparison of predicted blow counts in the Moray East ES (2012) (of 10,660 as shown by the orange line on the graph below), the predicted blow counts in the PS (of 16,650 as shown by the green line below), and the total blow counts for each WTG (shown by the blue dots on the graph below).

As shown by the graph, all but one WTG required blow counts below the prediction in the ES, and were below the blow count prediction in the PS.



MORAY EAST
OFFSHORE WINDFARM

Contact

Moray Offshore Windfarm (East) Limited
5th Floor, Atria 1, 144 Morrison Street,
Edinburgh, EH3 8EX
Tel: +44 (0)131 556 7602