MORAY OFFSHORE WINDFARM (WEST) LIMITED

Moray West Pre-Construction Digital Aerial Survey Method Statement

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1 Moray West Pre-Construction Digital Aerial Surveys

This document sets out the proposed approach and method that will be used to complete the Moray West pre-construction digital aerial surveys. The main purpose of the pre-construction digital aerial surveys is to acquire information on the distribution and abundance of seabirds within and around the Moray West Offshore Wind Farm Site. These surveys are required in accordance with Condition 25 of the Moray West Section 36 Consent: Project Environmental Monitoring Programme (PEMP) and will be undertaken by APEM Ltd (APEM).

Information collected during the surveys will include: date of survey and time; seabird species, age and gender where relevant; behaviour; abundance estimates; flight height and associated confidence limits (CLs); flight directions; weather conditions and any anthropogenic features. The key species that are the focus of the outlined aerial surveys are great black-backed gulls (*Larus marinus*), kittiwakes (*Rissa tridactyla*), herring gulls (*Larus argentatus*), guillemots (*Uria aalge*), razorbills (*Alca torda*), puffins (*Fratercula arctica*), gannets (*Morus bassanus*) and fulmar (*Fulmarus glacialis*). Observations of marine mammals and other large marine megafauna will also be recorded during the surveys.

The Moray West site is located on the Smith Bank in the Outer Moray Firth, approximately 22.5km from the Caithness coastline (Figure 3.1). The Moray West Site covers an area of approximately 225km^2. The proposed site is adjacent to and to the southwest of the Moray East Offshore Wind Farm, which will be in construction during the pre-construction surveys of the Moray West Wind Farm area, and the Beatrice Offshore Wind Farm which will be in operation.

2 Context

2.1 Existing ornithological data within the Moray Firth

Extensive ornithological data are available for the Moray Firth region, including data from baseline digital aerial surveys of the Moray West Offshore Wind Farm (2016-2017) and baseline characterisation and pre-construction digital aerial surveys of the Beatrice and Moray East Offshore Wind Farms. This survey data is supplemented by extensive data from literature. A full description of these key existing ornithological data is provided in the Moray West EIA Report – Volume 2 Chapter 10 and Volume 4 Technical Appendix 10.1 - Annex 10.1A.

Further data is currently being collected as part of the Beatrice post-construction aerial surveys.

2.2 Summary of key conclusions from the Moray West EIA – Ornithological Impact Assessment

Key conclusions from the Moray West Ornithological Impact Assessment as presented in the Moray West EIA Report Volume 2 Chapter 10 are summarised below:

- Based on advice received during EIA Scoping from NatureScot (formally Scottish Nature Heritage (SNH)) and Marine Scotland Science (MSS) the key species requiring assessment were identified as guillemot, fulmar, gannet, puffin, razorbill, kittiwake, herring gull and great back-backed gull. For most species present in the Project study area (Moray West Offshore Wind Farm Site and the Offshore Export Cable Corridor), sensitivity to disturbance during construction was assessed as negligible to low except for guillemot, razorbill and puffin which have medium sensitivity. Overall, it was concluded that effect significance would be negligible to minor adverse for all species and therefore not significant in EIA terms.
- Effects due to changes to prey availability during construction and operation were assessed as being of negligible to minor significance for all species.
- Although species with high sensitivity to pollution effects (red-throated divers, great Northern divers and shag) are present in the project study area, the risk of pollution incident occurring is considered to be negligible. The potential significance of effects of pollution during construction and operation on all species were assessed as negligible and therefore not significant in EIA terms.
- Potential **displacement and barrier effects during operation** were assessed for puffins, razorbills, guillemots and kittiwakes based on advice from the JNCC Joint SNCB Interim Displacement Advice Note 2017[1] and scoping advice provided by MSLOT to the Forth and Tay developers (e.g. Scoping Opinion for Seagreen Offshore Wind Farm, 2017). These effects were assessed to be of minor adverse significance for all species and therefore not significant in EIA terms. This includes

[1] JNCC, Natural Resources Wales, Department of Agriculture, Environment and Rural Affairs/Northern Ireland Environment Agency, Natural England and Scottish Natural Heritage, (2017). *Joint SNCB Interim Displacement Advice Note*. [Online]. Available at: http://jncc.defra.gov.uk/pdf/Joint_SNCB_Interim_Displacement_AdviceNote_2017.pdf (Accessed May 2017).

consideration of additional information provided in the Moray West Addendum Document 2018 relating to assessment of displacement impacts.

- Having adjusted the minimum blade tip clearance from 22 m to 35 m it was concluded that for all four species identified as being at risk from collisions (kittiwake, herring gull, gannet and great black-backed gull), based on the predicted number of birds at risk of collision (collision mortality) during the breeding and non-breeding season, impact magnitude would be low. Overall effect significance was assessed as minor adverse and therefore not significant in EIA terms. Even when seasonal variations were considered (Moray West Addendum Document 2018), effects of collision risk remained minor.

Table 2.1 Summary of the selected "aerial density" estimates for applications to the collision risk model

Month	Kittiwake	Gannet	Herring gull	Great black-backed gull
April	0.21	0.00	0.00	0.00
May	2.49	0.27	0.00	0.00
June	11.14	0.66	0.99	0.07
July	19.67	0.10	0.20	0.07
August	2.38	0.21	0.14	0.29
September	2.21	1.49	0.00	0.52
October	1.61	0.28	0.00	0.15
November	3.49	0.40	0.00	0.00
December	2.15	0.05	0.00	0.00
January	0.36	0.00	0.05	0.00
February	0.67	0.00	0.10	0.00
March	1.48	0.20	0.00	0.00

- Attraction to lit structures and associated disorientation was deemed low, due to the reduced activity of key species (kittiwake, gannet and guillemot) at night and minimal spatial extent reducing risk for gulls. Effect significance was assessed as negligible to minor adverse and therefore effects are not significant in EIA terms.

Potential cumulative effects (displacement during construction and operation) and collision risk were also assessed as being at most minor adverse and therefore not significant in EIA terms for all key species (guillemot, fulmar, gannet, puffin, razorbill, kittiwake, herring gull and great back-backed gull).

2.3 Summary of conclusions regarding gannet from the Moray West HRA

Gannet were recorded in 11 of the aerial surveys undertaken across the Moray West Site plus 4 km buffer with a peak in abundance in September corresponding with the post-fledging period. The population estimates of gannet in the Moray West Site plus 4 km buffer in the breeding season (April to September) exceed the 1% threshold of the regional population (1,681 individuals) in September only when an estimated 2,827 birds were present. For the Moray West Site analysed through MRSea, 336 gannet were estimated to be present in September. Outside of September, breeding season populations of gannet were comparatively low with next highest estimate being of 238 birds in June 2016. The 1% values of the national and international populations for gannet were not surpassed in any month. In aerial surveys undertaken in the post-breeding season as defined for gannet (October to November) a peak population of 439 birds was estimated during October 2016. This population does not exceed the 1% threshold of the post-breeding BDMPS population for gannet (4,562 individuals). Similarly, during surveys undertaken in the pre-breeding season (December to March) the peak population of 144 birds that occurred in February was also not of regional importance (1% of 2,484 individuals).

2.4 Summary of conclusions from the Moray West HRA

In determining the Moray West Offshore Wind Farm Consent Application, Scottish Ministers were required to carry out an Appropriate Assessment of the project in accordance with The Conservation (Natural Habitats &c.) Regulations 1994 (as amended) (the Habitats Regulations) and The Conservation of Offshore Marine Habitats and Species Regulations 2017 (the Offshore Habitats Regulations). Both of these regulation transpose requirements of European Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive).

In accordance with the Habitats Directive, Scottish Ministers were able to conclude that, with respect to European Site with ornithological interests, that there would be no adverse effects on the Buchan Ness to Collieston Coast SPA, East Caithness Cliffs SPA, North Caithness Cliffs SPA, Troup, Pennan and Lion's Head SPA and the Moray Firth proposed SPA ("pSPA") from the development either in isolation or in-combination with other plans or projects, providing that the conditions set out in Section 4 of the Appropriate Assessment are complied with.

These conclusions were based on information presented in the following documents:

- Moray West Report to Inform an Appropriate Assessment (RIAA) July 2017;
- Moray West Application Addendum Document November 2017; and
- Moray West Great Black Backed Gull Report March 2018.

Key species considered for each of the SPAs listed above are listed in Table 2.2 below:

Table 2.2 Summary of European Sites (SPAs) with ornithological interests assessed in the Moray West AA		
SPA	**Qualifying Features**	**Comments**
Buchan Ness to Collieston Coast SPA	Kittiwake, herring gull, guillemot, fulmar	Population viability analysis (PVAs) not required for this site for any species.
East Caithness Cliffs SPA	Kittiwake, great black-backed gull, guillemot, razorbill, herring gull, fulmar	PVAs completed for all species except fulmar (not required)
North Caithness Cliffs SPA	Kittiwake, guillemot, razorbill, puffin, fulmar	PVAs completed for all species except fulmar (not required)
Troup, Pennan and Lion's Head SPA	Herring gull, kittiwake, guillemot, razorbill, fulmar	PVAs not required
Moray Firth proposed SPA ("pSPA")	Common scoter, eider, goldeneye, great northern, diver, long-tailed duck, red-breasted merganser, red-throated diver, scaup, shag, Slavonian grebe and velvet scoter	PVAs not required. Potential effects relating to temporary construction / cable installation activities only.

2.5 Key species, SPAs and potential impacts requiring monitoring in relation to Moray West project

Based on the results from the Moray West EIA and Appropriate Assessment (AA) it is proposed that the ornithological monitoring required under the Project Environmental Monitoring Programme (PEMP), which includes the digital aerial surveys included in this Method Statement, focuses on the key species and impacts listed in Table 2.3 below.

Table 2.3 Key species, SPAs and potential impacts requiring monitoring			
	Species [Note 1]	**Sites (SPA)**	**Impact to be monitored**
Primary	Kittiwake	East Caithness Cliffs SPA North Caithness Cliffs SPA	Collision risk Displacement
	Great black-backed gull	East Caithness Cliffs SPA	Collision Risk
Secondary	Herring gull	East Caithness Cliffs SPA Troup, Pennan and Lion's Head SPA	Collision Risk
	Guillemot	East Caithness Cliffs SPA North Caithness Cliffs SPA	Displacement
	Razorbill	East Caithness Cliffs SPA North Caithness Cliffs SPA Troup, Pennan and Lion's Head SPA	Displacement
Tertiary	Puffin	North Caithness Cliffs SPA	Displacement
	Gannet	Gamrie and Pennan Coast SSSI	Collision Risk Displacement
	Fulmar	East Caithness Cliffs SPA North Caithness Cliffs SPA Troup, Pennan and Lion's Heads SPA	Displacement
	Note 1: As part of the aerial surveys, all species (in additional to those listed above) observed within the Moray West Site and surrounding buffer area will be reported as part of the pre-construction surveys. The species listed above have been identified specifically to inform the design of the surveys to ensure data coverage enables change to be detected pre and post construction.		

3 Survey Methodology

3.1 Aims and objectives of the surveys

The main aims of the pre-construction digital aerial surveys are to:

- Collect pre-construction data on seabird distributions, and estimations of species abundance, from which potential changes occurring post-construction can be detected through post construction surveys in order to determine the extent to which (if any) displacement of key species (guillemot, razorbill, kittiwake, puffin, gannet and fulmar) has occurred;
- Collect data on flight direction of key species (guillemot, razorbill, kittiwake, great black-backed gull, herring gull, puffin, gannet and fulmar) to further inform understanding on the extent of connectivity with key SPA breeding colonies (East Caithness Cliffs SPA, North Caithness Cliffs SPA, Troup, Pennan and Lion's Heads SPA and Gamrie and Pennan Coast SSSI); and
- Where possible, obtain flight height data for key species (kittiwake, great black-backed gull, herring gull and gannet) to assess flight heights in relation to the wind farm and/or turbines.

3.2 Outline of survey programme

It is proposed that the pre-construction digital aerial surveys will commence in March 2021 and will cover two breeding seasons (March-October) over two consecutive years (Table 3.1). The timings of the surveys are presented in Table 3.1 below.

Table 3.1 Proposed Survey Timeline		
Survey Year	**Survey Number**	**Survey Month**
Year 1 (2021)	1	March 2021
	2	April 2021
	3	May 2021
	4	June 2021
	5	July 2021
	6	August 2021
	7	September 2021
	8	October 2021
Year 2 (2022)	9	March 2022
	10	April 2022
	11	May 2022
	12	June 2022
	13	July 2022
	14	August 2022
	15	September 2022
	16	October 2022

3.3 Survey Design

Based on the conclusions of the EIA and HRA, the key species identified as being subject to potential adverse effects during construction and operation, and aims of the pre-construction digital aerial surveys, Moray West have proposed the following survey design.

APEM will carry out a transect-based survey design with an additional uneven buffer area surrounding the Moray West Offshore Wind Farm Site (Figure 3.1). It is noted that Moray West was advised by the Moray Firth Regional Advisory Group (MFRAG) – Ornithology Sub-Group that it would be preferable to adopt a reduced buffer area within existing wind farms (Beatrice and Moray East) but increase the survey area into un-surveyed regions surrounding the site.

Moray West acknowledges that a 10 km buffer was adopted for the Moray East pre-construction surveys and that larger buffer zones e.g. 12 km have also been adopted for the Forth and Tay projects. However,

it is understood that the larger buffer zones being applied to Forth and Tay projects have been developed as part of a collaborative approach to collecting data on a number of species, including gannet, at a more regional scale.

Moray West does however, acknowledge the importance of collecting pre-construction monitoring data and as such, has proposed to explore options for incorporating the use of lidar into the surveys to measure flight heights. Further detail on this is provided in Section 5.

Moray West's proposed survey design consists of transect flight lines spaced 2.53 km apart. This spacing with the imaging equipment employed by APEM delivers the 15% area coverage necessary to provide sufficient data to meet the recommendations of the previous power analysis. The areas covered for the survey are illustrated in Figure 3.1.

The proposed transect based survey design is based on the power analysis completed by Moray East Offshore Wind Farm (East) Limited (Moray East) in 2018 for the Moray East Offshore Wind Farm pre-construction digital aerial surveys using puffin as an example species[2]. A power analysis is used to quantify the chance that a genuine impact effect is able to be detected using the proposed survey design, by calculating the probability of detecting a change, given that a change has occurred. According to this power analysis the survey design delivers a large enough number of samples to allow 30% or more population displacement, from the wind farm area to the buffer, to be detected with 80% or more power. The survey design is also capable of detecting a 50% decline in seabird population density within the study area. The model used to achieve this level of power has a precision estimate level (in the form of a coefficient of variation (CV)) of 0.6, demonstrating a good model fit, and with a probability of greater than 95%, demonstrating statistical significance. Although power analyses are site specific to take account of the environment and species abundance within the area, due to the close proximity of the Moray East Site to the Moray West Site, this same power analysis is likely to be suitable. The Moray West and Moray East sites, are located adjacent to each other, and therefore there was significant overlap of the area assessed during the power analysis with the current Moray West site. As environmental conditions are very similar and the survey design has been maintained, the results to assess the power of the design are likely to be applicable across both areas.

[2] Power analysis for pre-construction aerial surveys (2018) https://www2.gov.scot/Resource/0053/00536269.pdf

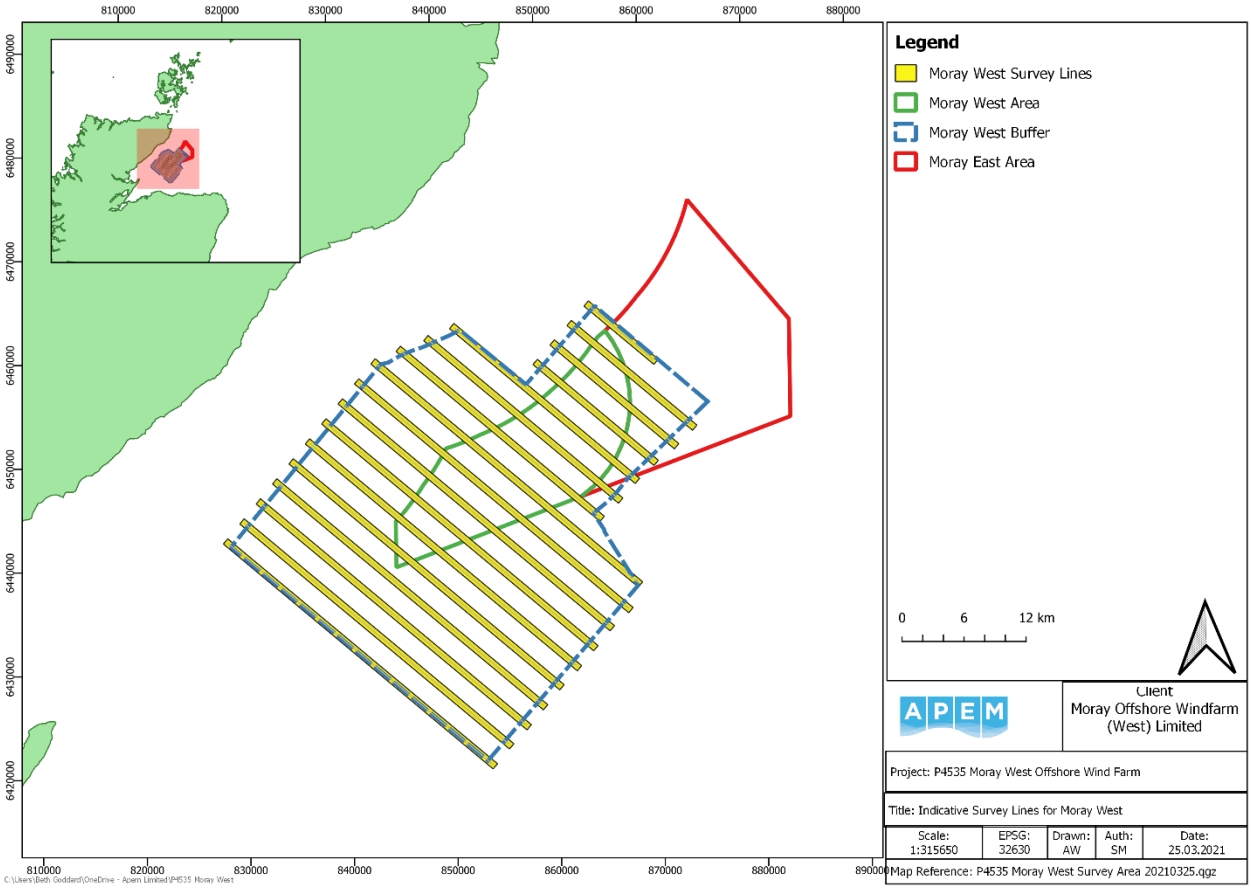

Figure 3.1 Moray West survey area with buffer area and indicative survey transects

To ensure an assessment of distance to turbines can be incorporated robustly into statistical analyses, following data collection, it is recommended that data are collected at a range of distances from the turbine locations to take into account effects of proximity to turbines. Figures 3.2 and 3.3 demonstrate the variability in distances between proposed turbine locations and transect lines, supporting an appropriate survey design. Distances range between 72 m and 1.3 km. These distributions can be re-checked, and if necessary, adjusted by small changes to transect lines, following construction, when the exact locations of installed turbines are known.

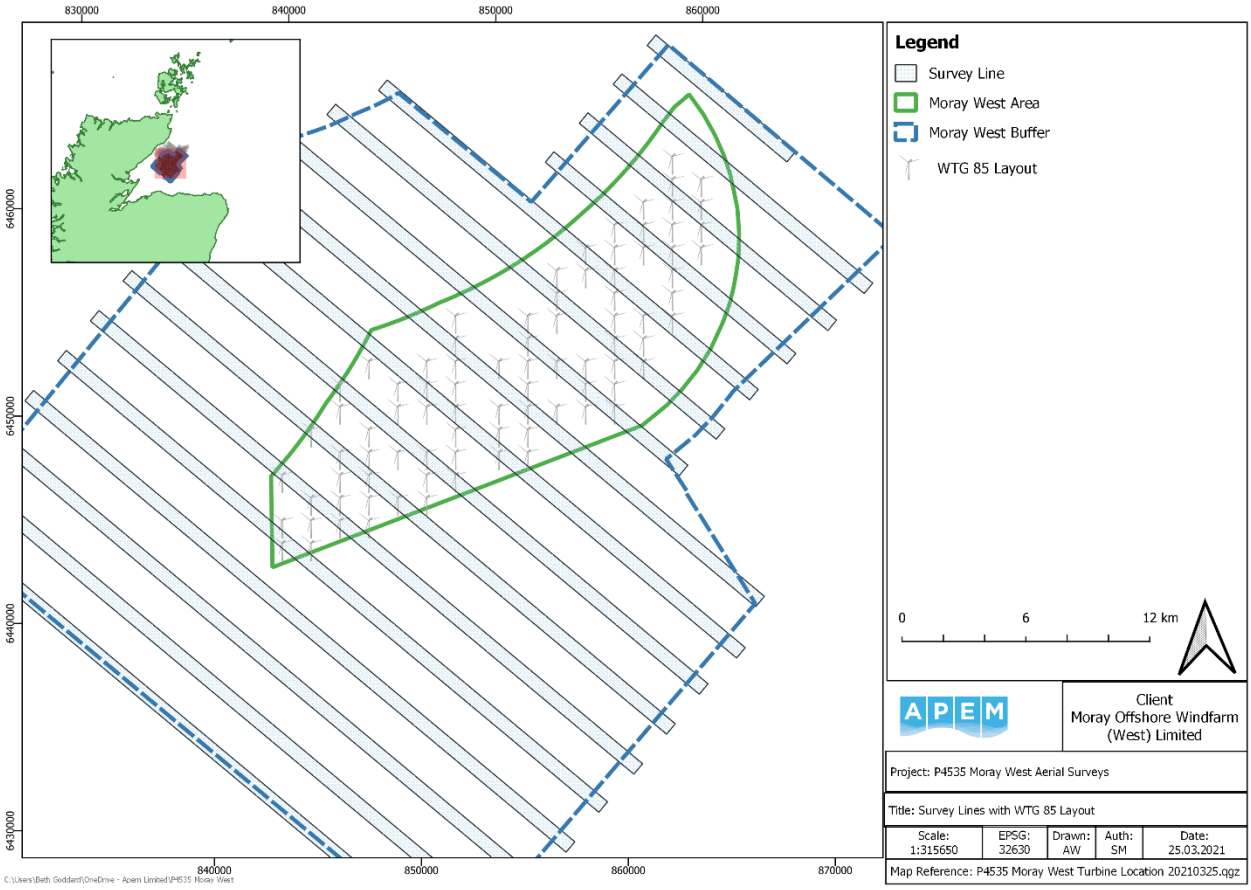

Figure 3.2 Moray West survey area with 4km buffer with indicative survey transects and proposed turbine locations

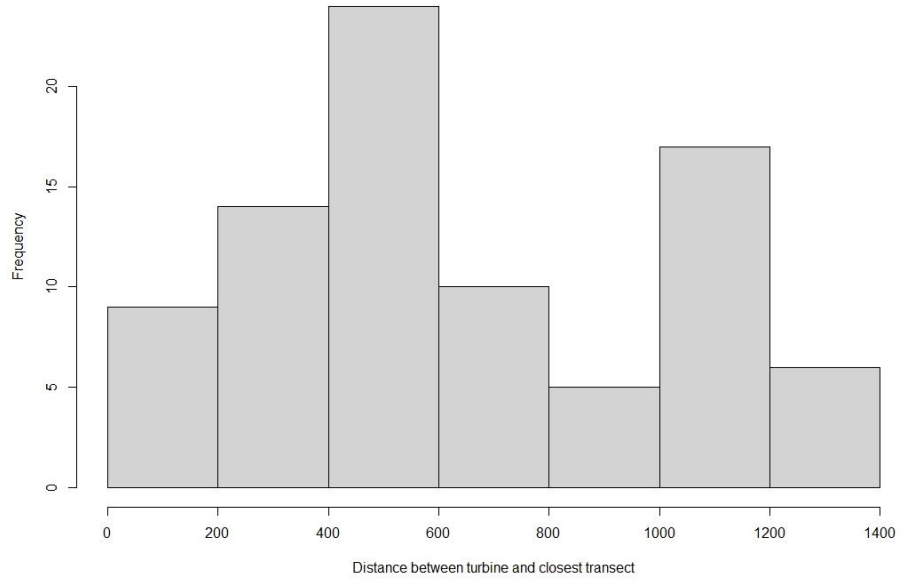

Figure 3.3 Histogram showing the variability of distances from proposed turbine locations and flight transects

3.4 The survey methodology and data collection

The surveys would be undertaken in weather conditions that do not limit the ability to identify marine fauna at or near the water surface. These conditions are listed below and are those that have been acceptable to the UK statutory nature conservation advisers:

- Cloud base: > 1,700 ft
- Visibility: > 5 km
- Wind speed: < 30 knots
- Sea state: 4 or less (Beaufort 5 or 6)
- No icing conditions

Data will be collated and provided in the form of ArcGIS Shapefiles and corresponding MS Excel spreadsheets, where applicable. The data relevant to birds recorded as part of our aerial digital still imagery are as follows:

- Date and time of each bird recorded on survey;
- Corresponding GPS coordinate for each bird recorded (for instance the Easting and Northing of the location is provided as standard, but other formats are readily available on request). Our

aircraft's internal GPS and IMU (Inertial Measurement Unit) systems record to an accuracy of +/- 3 to 5 m as standard;

- Unique identifying numbers for each bird recorded, with reference to the survey line (transect line), the image number and individual camera that captured that image provided in the data as standard;
- APEM's bird species identification process allows for both internal and external Quality Assurance and delivers high levels of species identification;
- All individual birds recorded are provided with details of their age, gender and moult status where possible;
- Additional behavioural information observed for each bird is recorded to provide data on whether a bird is sitting, flying or diving. Further information on whether an individual is part of a group, carrying food or nursing a juvenile are also recorded;
- The height at which individual birds are flying with associated +/- error and confidence are provided for birds that can be measured accurately;
- The orientation of birds in flight is routinely collected and provided in APEM's standard data sets from our aerial digital surveys. This would be provided in compass degrees to the True North); and
- The sea state whilst on survey is assessed and recorded on a regular basis throughout an aerial digital survey. APEM's camera technicians and pilots are well trained in identifying the sea state according to the level of swell and wave crests visible from the air, which may vary over the course of a survey. Additional information relating to water turbidity and the percentage of glare are also recorded throughout.

The data relevant to marine mammals and other large marine megafauna recorded as part of our aerial digital still imagery are as follows;

- Date and time of each individual recorded on survey;
- Corresponding GPS coordinate for each individual recorded (for instance the Easting and Northing of the location is provided as standard, but other formats are readily available on request). Our aircraft's internal GPS and IMU systems record to an accuracy of +/- 3 to 5 m as standard;
- Unique identifying numbers for each individual recorded, with reference to the survey line (transect line), the image number and individual camera that captured that image provided in the data as standard;
- APEM's marine mammal species identification process allows for both internal and external Quality Assurance and delivers high levels of species identification; and
- Additional behavioural information observed for each individual is recorded to provide data on whether an individual is submerged or surfacing.

All spatial data will be geo-referenced to WGS 84 UTM 30N projection as a matter of course. Information derived from the imagery is held in the industry standard ESRI shapefile format, compatible with ArcGIS. The spatial datasets contain information on all the digitised records.

APEM routinely collects and records additional data relating to each survey flight, which is collated and provided in the form of ArcGIS Shapefiles and corresponding MS Excel spreadsheets, where applicable, as follows:

- The timings for all data collected are recorded as standard by APEM during our aerial digital surveys. This includes the time at which individual images are collected, start times and end times of each transect line and the start and end time of the overall survey;
- APEM's data collection and collation follows standard practice for offshore aerial digital survey data requirements and is available as GPS tracks for each flight line in ArcGIS shapefiles;
- Weather conditions are regularly checked and recorded for each transect throughout our surveys. These include visibility, cloud cover, sun angle, wind speed, wind direction, air temperature, air pressure and precipitation;
- Additional data on shipping observations are recorded within 1.6 km either side of the transect line; and
- Transect orientation is recorded for each survey in compass degrees.

All images acquired on survey would be securely saved and backed-up on mirrored disks during flight and multiple servers at APEM in order to ensure data security.

3.5 Image acquisition

Image acquisition would be with a bespoke camera and sensor system, the Shearwater IV, set up to acquire and save a series of digital still images based on the latest (2019) technology. This state-of-the-art system provides Ultra High Resolution digital still imagery.

The images will be captured at a 1.5 cm ground surface distance (GSD) resolution. At this resolution it is possible to identify the large majority of seabirds and marine megafauna to species level while delivering high coverage and causing no or minimal disturbance. APEM's transect method collects multiple images of this sized footprint along the transect corridors planned for each survey, providing an accurate footprint that allows very accurate abundance and density estimates to be modelled.

3.6 Coping with glare

On days with little cloud we would avoid surveying for some two hours around midday to minimise the risk of collecting images with glare (strong reflected light off the sea) that makes finding and subsequently identifying the birds and marine megafauna recorded in the images more difficult. Our on-board camera technician continuously monitors the images collected and if they cease to be of a sufficient quality image acquisition ceases until suitable conditions return.

3.7 Quality assurance

All of APEM's senior image analysts have at least two years of full-time experience at identifying birds to species level. Images are viewed by at least two members of staff as part of our comprehensive internal

Quality Assurance process. Where identification to species is not possible individuals will be assigned to taxonomic groups such as:

- 'black-backed gull sp.' (lesser black-backed or great black-backed gull);
- 'grey gull sp.' (common, herring, black-headed or little gull); and
- 'gull sp.'

3.8 Other considerations

As noted in the Introduction and illustrated in Figure 3.4 below, the Moray West Site lies immediately adjacent to the Moray East Offshore Wind Farm and the Beatrice Offshore Wind Farm. The Beatrice Offshore Wind Farm is now fully operation. With respect to the Moray East Offshore Wind Farm, it is expected that there will be a large amount of activity on the Moray East Site during the first of the survey seasons (March – October 2021) as this will coincide with the installation of the turbines and inter-array cables. It is also expected that first turbine generation will commence in April 2021 therefore, in addition to the ongoing installation activities there will also be operational turbines on the site. These activities will be recorded as part of the survey reporting.

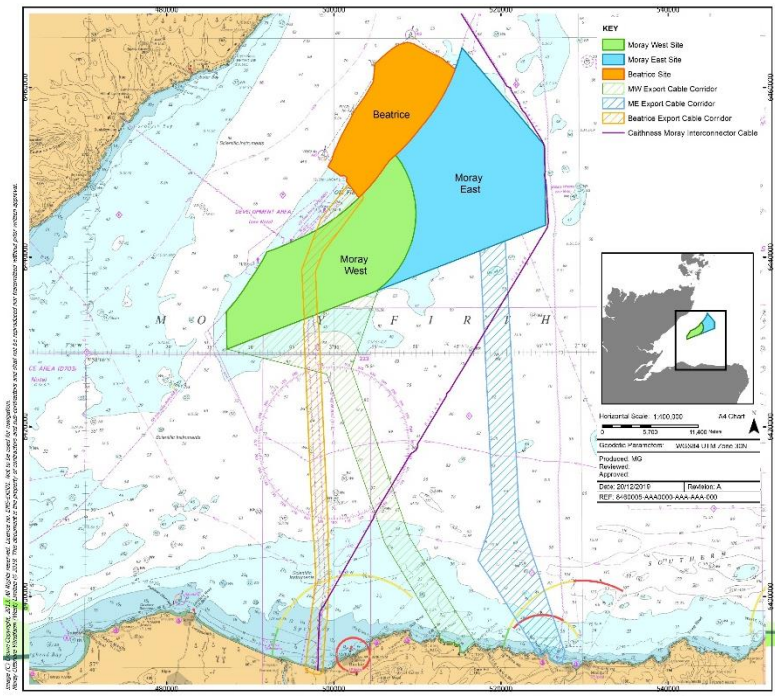

Figure 3.4 Adjacent Project Sites (Moray East and Beatrice)

3.9 Contingency planning

Project specific dynamic risk assessments will be developed and continue through the lifetime of a project. This ensures that risks which could impact project deliverables or APEM staff safety are continually identified and reviewed, enabling mitigations to be developed swiftly. Most notably this is seen during the global COVID-19 pandemic. Risk assessments are currently continually reviewed and updated in line with government guidance. APEM are taking an active approach to reviewing all H&S advice in relation to COVID-19 and are following UK Government advice and devolved administration specific variations closely. APEM has and will continue to provide updates to its staff as advice and revisions are made. Currently APEM is also actively seeking and receiving COVID-19 updates from various sources to maintain staff/client safety and business continuity. These include but are not limited to:

- UK government legislation, guidelines and automated updates
- NHS guidelines
- WHO information and guidelines.

Specifically, APEM is taking the following approach to site-based work during the Covid-19 pandemic, based on current advice provided by the UK Government (COVID-19: guidance for employees, employers and businesses - GOV.UK) (Construction and other outdoor work - Working safely during coronavirus (COVID-19) - Guidance - GOV.UK) and advice provided to the Chartered Institute of Ecology and Environmental Management by DEFRA https://cieem.net/wp-content/uploads/2020/04/Defra-letter-to-CIEEM-TO2020_08658-9-April-2020.pdf

COVID-19 legislation and guidelines have been incorporated into APEM's risk assessments across all business and project activities. The mitigation measures identified within the risk assessments allow us to identify in practical terms how project work will be impacted or if amendments are required to maintain the H&S of our staff and clients, and legal compliance. Although APEM's ability to provide an exceptional quality service is not hindered by these COVID-19 mitigation measures, the project team are regularly checking and updating risk assessments to ensure projects are undertaken as safely and efficiently as possible. APEM will also adhere to any additional restrictions put in place by clients, and are aware this may be subject to change as the situation develops. All project work is being assessed on a case by case basis and the necessary mitigation put in place to ensure the safety of APEM employees, our clients and the public and ensure APEM do not do anything that could increase the spread of COVID-19.

As is standard, APEM designate a forward operating airbase and alternative airbases for each survey in case of emergency. During the COVID-19 pandemic, APEM has been able to continue with access to local airbases and continued surveys during even the toughest lock down measures. As such, we plan to continue with this approach to provide contingency in our operations away from base.

4 Data Analysis and Reporting

4.1 Methodology for estimating bird flight heights

Using a set of rules developed in-house, based upon trigonometry and more complex mathematics, we can estimate the flight height of birds with a range of error and confidence intervals, dependent upon image quality, size of the bird species and the size of the bird relative to the image. From the basic premise that the higher the bird is flying the greater the proportion of its reference length will be in the image, its flight height can be calculated.

The position of a bird's head and tail in an image as well as species is recorded by an analyst. All inputs have an individual error associated with them (derived from internal trials), and for the calculation each input is bootstrapped to 10,000 samples. Using accurate GPS, IMU, aircraft and camera system data these two positions in the image are translated to real-world coordinates, using principles of geometry, map projection and vector manipulation. This step accounts for changes in surface GSD, orientation of the aircraft and camera system, and other spatial factors. The distance between these two points is compared to a normal distribution of reference lengths measured physically for that species. From this we calculate the height of the bird above the surface, the orientation, and the real world position above the surface. The output is a normal distribution of 10,000 results, from which a mean and standard deviation are derived, for the bird's flight height, orientation, and position. All results are to 99.7% confidence intervals.

It must be noted that we are unable to accurately estimate flight heights for birds that are diving or turning sharply, as these individuals are not fully stretched out and therefore their measured lengths are not comparable to the reference length of the relevant species.

Following various trials to better understand the accuracy and precision of bird flight heights generated from high resolution aerial digital imagery, APEM has developed a robust approach to generating confidence intervals for bird flight heights. These new estimates allow for variation in the size of individual birds, aircraft flight height measured by GPS, aircraft pitch, roll and yaw and analyst measurements. The whole approach that has been developed by an Imperial College mathematician is based on statistical randomisation procedures and vectorial maths (to allow for, amongst other factors, the aircraft's movements in three-dimensions). Much of the standard deviation in each flight height estimate is due to the variation in the body lengths of each species of seabird of interest to this project. A full description can be provided upon request.

4.2 Reporting

Monthly reports summarising the results of each aerial digital survey undertaken will be provided to Moray West. Each monthly report provides the raw counts of all birds and marine megafauna recorded, their distribution on a simple GIS map and a description of the survey conditions encountered including environmental conditions such as weather and sea state.

5 Exploration of the Use of LiDAR

APEM has used an innovative new technique to measure flight heights[3]. This involved capturing LiDAR (light detecting and ranging) data matched with ultra-high resolution digital still imagery. Using pulses of light from lasers to measure the distance of objects from the sensor the height of birds above the ground can be determined within 5 cm accuracy. Although the innovative survey took place over land, the same technique can also be used to measure the flight heights of birds at sea.

LiDAR has been successfully trialled in the industry to measure seabird flight heights (Cook et al 2018)[4], and Moray West Offshore Wind Farm could be used as a test site for any future work to investigate the relatively novel application of this technology.

It is unlikely that LiDAR surveys will replace 'standard' digital methods (still or video) in the near future as the technology is very expensive to implement, which needs to be weighed up against the benefits. It would be more appropriate on balance to supplement or replace a number of the 'standard' surveys with LiDAR surveys to target any known key species for the purposes of obtaining flight heights for future use in collision risk modelling. Therefore, should the use of LiDAR wish to be explored, APEM would propose carrying out two LiDAR surveys during the breeding season each year, in addition to the standard aerial digital surveys and proposed flight height calculations.

[3] Inside Ecology Ltd. (2018) New Technique measures bird flight heights. Available from: https://insideecology.com/2018/02/27/new-technique-measures-bird-flight-heights/ [Accessed on: 03/11/2018].
[4] Cooke et al (2018) https://data.marine.gov.scot/sites/default/files/SMFS%200914_1.pdf