



Forestry, Ecology & Environment

Collision Risk Modelling

Inchamore Wind Farm Development

Inchamore, Coolea, Co. Cork

Compiled by: Veon Ecology,
David M. McGillicuddy B.Sc. (Hons) in Wildlife Biology.

Prepared for: BioSphere Environmental Services.

Completion Date: 2nd March 2023



Table of Contents

| | |
|--|-----------|
| Table of Figures | 2 |
| Table of Tables | 2 |
| Section 1: INTRODUCTION..... | 4 |
| 1.1 Background..... | 4 |
| 1.2 Proposed Development and Site Description | 6 |
| 1.3 Statement of Authority..... | 7 |
| 1.4 Data Sources..... | 7 |
| 1.5 Target Species | 7 |
| 1.6 Seasonal Definitions | 8 |
| 1.7 Limitations and Constraints..... | 9 |
| Section 2: ASSESSMENT AND METHODOLOGY | 10 |
| 2.1 Determination of Bird Flights Through the Rotor Swept Area..... | 12 |
| 2.2 Probability of Collision of Birds Passing Through the Rotor Swept Area | 13 |
| Section 3: RESULTS..... | 14 |
| Section 4: CONCLUSION | 16 |
| Section 5: REFERENCES | 17 |
| Section 6: APPENDICES..... | 18 |
| Appendix 1. FIGURES AND MAPS | 18 |
| Appendix 2. VANTAGE POINT DATA | 20 |
| Appendix 3. VANTAGE POINT BIRD FLIGHTLINE DATA | 26 |
| Appendix 4. COLLISION RISK ASSESSMENT CALCULATIONS | 34 |
| Appendix 5. WORKED CALCULATIONS..... | 36 |

Table of Figures

| | |
|---|----|
| Figure 6.1: Site location and boundary with the outlined area in blue indicating the area proposed for turbines. | 18 |
| Figure 6.2: Vantage Point locations and viewshed map. | 19 |

Table of Tables

| | |
|---|----|
| Table 1.1: Wind turbine specification and Wind farm Parameters for Inchamore Wind farm development. | 6 |
| Table 1.2: Seasonal divisions of relevant target species. | 8 |
| Table 3.1: Summary of CRM parameters for VPS at Inchamore Wind Farm. | 14 |
| Table 3.2: Avian Biometric Data and Avoidance Rates. | 14 |
| Table 3.3: Bird biometrics and bird-seconds spent by species at Potential Collision Height (20-180m). | 14 |
| Table 3.4: Number of collisions predicted for target species without the application of avoidance rates. | 15 |
| Table 3.5: Number of collisions predicted for target species with the application of avoidance rates. | 15 |
| Table 3.6: Mean number of collisions predicted for target species with avoidance rates. | 15 |
| Table 6.1: Inchamore VP data (VP1-3) survey effort Summer 2017. | 20 |
| Table 6.2: Inchamore VP data (VP1-3) survey effort Winter 2017-2018. | 20 |
| Table 6.3: Inchamore VP data (VP1-3) survey effort Summer 2018. | 20 |
| Table 6.4: Inchamore VP data (VP1-3) survey effort Winter 2018-2019. | 20 |
| Table 6.5: Inchamore VP data (VP1-3) survey effort overview. | 21 |
| Table 6.6: All species seconds spent at Potential Collision Height (20-180m) (VP 1-3). | 21 |
| Table 6.7: VP data (VP1-3) Survey Effort and Viewshed Coverage. | 21 |
| Table 6.8: VP Summer 2017 - Survey Details. | 22 |
| Table 6.9: VP Winter 2017/2018 - Survey Details. | 23 |
| Table 6.10: VP Summer 2018 - Survey Details. | 24 |
| Table 6.11: VP Winter 2018/2019 - Survey Details. | 25 |
| Table 6.12: Summer 2017 Bird Flightline Data. | 26 |
| Table 6.13: Winter 2017/2018 Bird Flightline Data. | 28 |
| Table 6.14: Summer 2018 Bird Flightline Data. | 31 |
| Table 6.15: Winter 2018/2019 Bird Flightline Data. | 32 |
| Table 6.16: Bird-seconds spent by species at Potential Collision Height (20-180m) for each VP. | 34 |
| Table 6.17: Bird biometrics and bird-seconds spent by species at Potential Collision Height (20-180m). | 34 |
| Table 6.18: Probability of collision – Stage 2 Calculations. | 35 |
| Table 6.19: Avian Biometric Data and Avoidance Rates. | 35 |
| Table 6.20: Target species breeding and non-breeding season periods. | 36 |
| Table 6.21: Avian Biometric Data and Avoidance Rates. | 36 |
| Table 6.22: Probability of collision – Stage 2 Calculations. | 36 |
| Table 6.23: Calculation of collision risk for Hen Harrier passing (Gliding) through rotor area. | 37 |
| Table 6.24: Calculation of collision risk for Hen Harrier passing (Flapping) through rotor area. | 38 |
| Table 6.25: Calculation of collision risk for Hen Harrier Non-Breeding Season 2018/2019. | 39 |
| Table 6.26: Number of collisions predicted for Hen Harrier with the application of avoidance rates. | 40 |
| Table 6.27: Mean number of collisions predicted for Hen Harrier with avoidance rates. | 40 |

General Details

Details of Author(s)

Name: David M. McGillicuddy
Address: The Yard, Market Yard, Newcastle West, Co Limerick
Company name: Veon Ltd. Veon Ecology
Tel. no: M: +353 87 348 9778
E-mail: dmccgillicuddy@veon.ie

Details of relevant qualifications/affiliations/years of experience David M. McGillicuddy B.Sc. (Hons) in Wildlife Biology at MTU, QCIEEM
Munster Technological University (MTU)
Over 6 years' experience working as an ecologist & wildlife education officer at TBW Eco Centre. Completed several key projects and produced reports regarding Biodiversity Action Plans (BAP), Climate Action Plans (CAP), Natura Impact Statement (NIS), Ecological Impact Assessment (EclA) & habitat mapping etc.

Describe scope of contribution in preparing this report Desktop Survey, Collision Risk Modelling, Collision Risk Assessment, Finalising report.

| Veon Ltd. Veon Ecology | | | | | | | |
|------------------------|--------------|---------|------------|--------------|------------|----------------|------|
| Revision | Description | Author: | Date | Reviewed By: | Date | Authorised by: | Date |
| 1 | Draft Report | DM | 31/04/2023 | DP | 02/05/2023 | - | - |
| 2 | Final Report | DM | - | - | - | - | - |

Executive Summary

This report presents the outcome of a Collision Risk Assessment for target species at the proposed Inchamore Wind Farm Development (Summer 2017 to Winter 2018/2019) located in Inchamore, Coolea, Co. Cork. The contents of this report, prepared by Veon Ecology are true and have been prepared with due regard to the Chartered Institute of Ecology and Environmental Management's (CIEEM) Code of Professional Conduct.

Section 1: INTRODUCTION

1.1 Background

Veon Ltd. (Veon Ecology) has been appointed by BioSphere Environmental Services, to carry out a Collision Risk Assessment for target bird species at the proposed Inchamore Wind Farm Development in Inchamore, Coolea, Co. Cork. This Assessment uses standardised Collision Risk Modelling (CRM) methods.

This document has been prepared by David M. McGillicuddy of (Veon Ecology) Veon Ltd. to assess the collision risk for birds (i.e. target species) at the proposed Inchamore Wind Farm Site. The collision risk assessment, prepared by David M. McGillicuddy B.Sc. (Hons) in Wildlife Biology at MTU, QCIEEM, is based on vantage point surveys undertaken at the development site from the breeding and wintering seasons of 2017 - 2019 inclusive. The data represents a 24-month survey period, consisting of two breeding seasons and two non-breeding (wintering) seasons, in full compliance with the Scottish Natural Heritage guidelines SNH (2017).

Surveys were undertaken from April 2017 to March 2019, from three fixed Vantage Point (VP) locations, (i.e. VP1 – VP3) (**See Appendix 1**). The locations of these VPs were strategically positioned to provide the maximum viewshed of the survey area from the minimum number of locations. Bird data gathered from VP3 was not included in the Collision Risk Modelling (CRM) calculations as this VP did not contribute any coverage to the proposed locations of the Inchamore turbines.

Collision risk is calculated using a mathematical model to predict the numbers of individual birds, of a particular species (i.e. target species), that may be collide with moving wind turbine rotor blades. The modelling method and calculations used in this collision risk assessment follows Scottish Natural Heritage (SNH) guidance often referred to as the Band Model (Band et al. 2007). The calculations and results attained from the Band model must be interpreted with a degree of caution. The bird occupancy method (SNH, 2000) was used to calculate the number of bird transits through the rotors, and the spreadsheet accompanying the SNH report was used to calculate collision probabilities for birds transiting the rotors occupied space.

This collision risk modelling used data from vantage point (VP) surveys carried out in the summers of 2017 and 2018, and winters of 2017/2018 and 2018/2019. VP surveys were SNH (Scottish Natural Heritage) compliant (SNH, 2017). Eight target species were recorded in flight within the study area during survey work. These include the following species Common Kestrel, Eurasian Sparrowhawk, White-tailed Eagle, European Golden Plover, Hen Harrier, Merlin, Peregrine Falcon and Common Buzzard. Two of the target species (White-tailed Eagle and European Golden Plover) recorded were present during the winter surveys only and two (Peregrine Falcon and Common Buzzard) were present during the summer surveys only, while the remaining four (Common Kestrel, Eurasian Sparrowhawk, Hen Harrier and Merlin) were present throughout the year.

Two stages are involved in the model:

- **Stage 1:** This includes the estimation of the number of birds or flights passing through the wind turbines rotor blades swept air space. Two forms of collision risk modelling are considered when referencing the Band Model. These are referred to as the “Regular Flight Model” and the “Random Flight Model”. Transits are calculated in this assessment using the “Random Flight” model, due to the bird flight distribution and behaviour recorded.
- **Stage 2:** This includes the calculation of the probability of a bird strike occurring with rotor blades. The probability is calculated using a statistical spreadsheet which considers the turbine parameters and avian biometrics. This spreadsheet is publicly available on the SNH website (<https://www.nature.scot/wind-farmimpacts-birds-calculating-probability-collision>).

The results of Stage 1 and Stage 2 modelling gives a theoretical annual collision mortality rate and is based on the assumption that birds (i.e. target species) make no attempt to avoid colliding with the proposed turbines. Thus, an informal third stage is applied to the Stage 1 and Stage 2 results.

The final stage of the assessment provides for a “real life” scenario, i.e. to account for the avoidance measures taken by each bird species, worked out as a percentage applied to the stage 1 and 2 results. Birds usually demonstrate high rates of avoidance (i.e. 95-99%) according to SNH (2018). This final stage as a result is typically the most important feature of collision risk modelling.

The Band Model values are solely speculative and representative of worst-case scenario estimates, only drawing conclusions by assuming likely levels of active avoidance by specific species. As such, results obtained are dependent on the quality of field observation data and accuracy of the avoidance rates used and must therefore be interpreted with a certain degree of caution.

1.2 Proposed Development and Site Description

The proposed Inchamore wind farm development is located at Inchamore, Coolea, Co. Cork, approximately 5km west of Ballyvourney. The proposed development site comprises of c. 167 hectares and lies in close proximity to the Cork-Kerry county border. The receiving environment for the proposed wind turbine locations is representative of upland habitats and includes lands under active management for forestry and agriculture. The proposed development site is located in close proximity to other constructed windfarm developments (Grousemount, Midas & Foilgreana Wind Farm).

The proposed wind farm design on which this CRM is based, is comprised of five WTG turbines (Candidate Models: Siemens Gamesa SG 6.6 – 155, Nordex N149/5.X and Vestas V150). The Collision Risk Assessment (CRA) makes assumptions on the turbine specifications, such as rotor diameter and rotational speed. Because the final choice of turbine is not known at this stage, the worst-case scenario is assumed. The worst-case scenario is a combination of the maximum collision risk area (affected by hub height and rotor blade length), maximum number of turbines proposed and minimum turbine downtime (i.e. non-operational time) using the specifications of the candidate WTG turbines. Turbine specifications for the proposed Inchamore Wind Farm development site used as per this CRM are shown below in **Table 1.1**.

Table 1.1: Wind turbine specification and Wind farm Parameters for Inchamore Wind farm development.

| Wind Farm Components/Turbine Parameters | |
|---|-----------------------------|
| Technical Information and Wind Farm Component | Data used/Scenario Modelled |
| Turbine model | Siemens Gamesa SG 6.6 – 155 |
| Number of turbines | 5 |
| Number of blades per turbine rotor | 3 |
| Rotor blade maximum chord (m) (i.e., depth of blade) | 4.5m |
| Blade Length (m) | 76m |
| Rotor radius (m) | 77.5m |
| Rotor diameter (m) | 155m |
| Circumference of blade tip (m) (Pi x Rotor Diameter) | 486.7m |
| Swept area (m ²) | 18,859.6 |
| Turbine height (m) | 180m |
| Hub height (m) | 102.5m |
| Swept height (m) | 25-180m |
| Maximum height to blade tip (m) | 180m |
| Minimum height to blade tip (m) | 25m |
| Max Tip Speed (m/s) | 0.724256m/s |
| Rotation speed (rpm) | 11.2rpm |
| Rotation period (s) (i.e., seconds per rotation) | 5.3571s |
| Turbine operation time* | 85% |
| Mean pitch angle of the blade during normal operation (degrees)** | 13° |

* The European Wind Energy Association (2016) provides an average operation time of a turbine of between 70% and 85%. In following the precautionary principal approach this CRM uses the 85% figure.

** The pitch angle of the turbine blade is determined by wind speed, which is variable depending on several factors including, location, local topographic, landscape etc. To maintain a constant operating speed the pitch angle of the blade is altered. The pitch angle of the turbine blade is greater in higher wind speeds to “feather” the wind in order to control rotation speed. The figure of 13° used in this assessment is derived from specifications provided by the client which advocates an average pitch of between 6 – 13 degrees along the length of the turbine blade. In following the precautionary principal approach, the greater 13° figure has been adopted as part of this model.

1.3 Statement of Authority

David M. McGillicuddy B.Sc. (Hons) in Wildlife Biology at MTU, QCIEEM is a qualified ecologist with over 6 years of experience working in the field of ecological research, teaching, and assessment. David is proficient in experimental design and data analysis and has managed a range of large-scale, multi-disciplinary ecological projects. These have included research and targeted management work for species of conservation concern, the design and delivery of practical conservation actions with stakeholders, education and interpretation on the interface between people and the environment and the development of co-ordinated, strategic plans for biodiversity.

David is an ecologist with Veon Ltd. and Veon Ecology and is experienced in several key environmental projects and the production of ecological reports regarding Biodiversity Action Plans (BAP), Climate Action Plans (CAP), Natura Impact Statement (NIS), Ecological Impact Assessments (EclA), etc.

1.4 Data Sources

The following data and information were provided for this collision risk assessment:

- Data outlining all observations of flight activity recorded during the VP surveys.
- Mapping of the proposed turbine locations.
- Technical specifications for the proposed candidate WTG turbines.
- GIS mapping of flight lines recorded during the summers of 2017 and 2018 and winters of 2017/2018 and 2018/2019 VP surveys.
- Clarification about survey methodology.
- Mapping of the VP locations.

All of the survey data used in this assessment was provided externally by Wetlands Surveys Ireland. Additional information, including technical details (e.g. turbine specifications) were provided by the client.

1.5 Target Species

The key target species were selected in line with SNH (2017) guidance, thereby enabling VP surveys to focus on the species of greatest importance. In general target species are those species that are afforded a higher level of legislation protection and also includes species which are more likely to be subject to impact from wind farms, e.g., breeding and non-breeding species forming qualifying features for nearby SPAs or species listed on Annex I of the Birds Directive.

The following species recorded flights within the rotor swept height and inside the 2km arc of the selected vantage points during the VP surveys across 2017, 2018 and 2019:

- Common Buzzard (*Buteo buteo*)
- Common Kestrel (*Falco tinnunculus*)
- European Golden Plover (*Pluvialis apricaria*)
- Hen Harrier (*Circus cyaneus*)
- Peregrine Falcon (*Falco peregrinus*)

Other species of conservation concern were recorded in the vantage point surveys but were excluded from consideration in the collision risk analysis due to the following reasons:

Eurasian Sparrowhawk (*Accipiter nisus*) were not recorded flying within the collision risk height band. Thus, for this species, the collision risk can be assumed to be effectively zero excluding them from further consideration in the analysis.

Merlin (*Falco columbarius*) were only recorded flying within the collision risk height band from VP 3. VP 3 has been excluded from the analysis, as the viewshed does not include any of the proposed turbine locations. Since there are no turbines located within this viewshed, the predicted number of collisions is zero.

White-tailed Eagle (*Haliaeetus albicilla*) were recorded within the potential collision risk height bands from VPs 1 and 2. Although White-tailed Eagle was recorded within the collision risk height bands, the total flight time of these recordings does not exceed 70 seconds (No. 2 observations). Therefore, this species has been excluded from the analyses due to the low level of flight activity recorded.

1.6 Seasonal Definitions

For the species modelled (i.e. Common Buzzard, Common Kestrel, European Golden Plover, Hen Harrier and Peregrine Falcon), the CRM was constructed using data from the relevant breeding and non-breeding season periods, as defined by NatureScot in relation to Scotland and British Trust of Ornithology (BTO) which is also broadly applicable to Ireland.

The data used in this CRM was collected over a period of 24 months from April 2017 to March 2019 inclusive, thereby providing data for two breeding season cycles and two winter cycles for the target species. For each target species included in the CRM, collision risk predictions were calculated for both relevant seasonal periods within each 12-month cycle (see **Table 1.2** for the seasonal divisions for each species). The sum of these separate summer and winter CRM results was taken as the predicted annual collision risk rather than using results from a single all-year CRM. This method minimised any potential biases that may arise from seasonal variation in daylength and the number of hours of activity available to each species in each month. This was to increase precision of the CRM and to ensure that any potential underestimation or overestimation for a species risk of collision was minimised as much as possible.

Table 1.2: Seasonal divisions of relevant target species.

| Species Name | Breeding season start | Breeding season end | Non-breeding season start | Non-breeding season end |
|------------------|-----------------------|---------------------|---------------------------|-------------------------|
| Common Buzzard | April | August | September | March |
| Common Kestrel | April | August | September | March |
| Golden Plover | April | August | September | March |
| Hen Harrier | March | August | September | February |
| Peregrine Falcon | March | August | September | February |

The number of hours that birds are potentially active during the day for the breeding and non-breeding season forms part of the CRM model. This is calculated as 15 hours per day for the summer survey period (i.e. the breeding season) and 10 hours per day for the winter survey period (i.e. the non-breeding season). These figures of activity are based on the average calculation of daylight minutes within the season of analysis and are likely to be over-estimated. These figures would be difficult to quantify in simple terms otherwise, although, the use of an over-estimation of species activity time increases the likelihood of a collision as birds are considered to be more active (i.e. increased flights) than if activity hours were reduced. This approach therefore offers an additional precaution in determining collision risk, and therefore a more robust estimation for collision risk assessment.

The hours that a species may potentially be active was calculated to include daylight, one hour before sunrise, and one hour after sunset (dusk) for all species with the exception of golden plover. For this species it was calculated as daylight, one hour before sunrise, one hour after sunset (dusk), and 25% of the night (SHN, 2017). These flight activity hours were calculated from timeanddate.com.

1.7 Limitations and Constraints

There are a number of limitations and constraints associated with pre-planning ecological assessments for potential development sites, as well as constraints and limitations inherent to the collection and analysis of field-based ecological data. The field survey data evaluated as part of this Collision Risk Assessment was received from Wetland Surveys Ireland. The data comprised of the following:

- Bird flight data from timed Vantage Point surveys. This data consisted of flights within the rotor-swept height bands. The vantage point surveys recorded flight heights in five bands: 0-20 m; 20-40 m; 40-80 m; 80-150 m and > 150 m. The 20-40 m; 40-80 m; 80-150 m and > 150 m height bands have been taken to represent the flight activity within the potential collision risk height zone. Flight duration (in seconds) for all bird observations along with data relevant to each flight record (date, weather conditions, timing, VP number (location), etc.) were provided.
- Vantage Point survey effort data (i.e. hours of observations) on a monthly basis during the summer and winter seasons of 2017 - 2019 (April 2017 to March 2019 inclusive) for all VP survey work undertaken.
- Description and metrics for the wind farm as a whole as well as for individual turbine parameters.
- Area viewed from each vantage point.

This CRM relates specifically to the provided vantage point survey data which has not been independently validated by the author of this report. Any variation in the coverage of the vantage points surveyed during fieldwork, flight data, layout of the wind farm/turbine locations as well as the individual turbine specifications would require the outputs from this CRM to be amended.

For field-based surveys, the availability of suitable weather conditions is important with good visibility and little wind or rain. The flight data used as part of this CRM was collected during optimal weather conditions, as determined by Best Practice guidance. As a result, this required the re-arrangement of monthly schedules in some circumstances, with certain VPs being additionally surveyed in one month to compensate for months when no survey work took place. These alterations in survey schedules are indicated within the data provided. It should be noted that these scheduling re-arrangements are still in line with Best Practice guidelines which requires a minimum coverage of two years of data. The requirement in the SNH (2017) guidance is for 36 hours of VP survey effort per season. For a single species, this is equivalent to 72 hours of VP survey effort per year.

There were a small number of flights for which the number of birds, or duration of flight, were not recorded. Where the number of birds was not recorded, it is assumed that the flight referred to a single bird. Where the duration was not recorded, the mean flight duration for that species was used (in the relevant season, if there was sufficient data, or across the entire dataset).

Section 2: ASSESSMENT AND METHODOLOGY

In regard to the Band Model, two forms of collision risk modelling are typically considered. These are generally referred to as the “Regular Flight Model” and the “Random Flight Model”. The “Regular Flight Model” is generally applied to flightlines which comprise of a more regular pattern such as a commuting corridor between feeding grounds, migratory routes and roosting sites. As a result, the “Regular Flight Model” is typically more relevant for aquatic bird species, particularly swans and geese. The alternative “Random Flight Model” is more relevant for species and scenarios whereby no apparent flight routes or patterns can be associated with a species within the survey area. Thus, Random flights is most prevalent when investigating hunting or foraging flight behaviour.

Collision Risk Modelling (CRM) adopts a mathematical approach to determining the probability of a bird species colliding with wind turbine rotors at a pre-defined site and is described in detail by Band *et al.* (2007) and Scottish Natural Heritage (SNH, 2000), with additional supporting information provided by Scottish Natural Heritage (SNH, 2018).

This report is based upon field data collected at the Inchamore wind farm development, located at Inchamore, Coolea, Co. Cork, approximately 5km west of Ballyvourney. The proposed development site comprises of c. 167 hectares and lies in close proximity to the County Cork/Kerry border. The receiving environment for proposed wind turbine locations is representative of upland habitats and includes lands under active management for forestry and agriculture. The resulting output from the model indicates the number of birds likely to collide with rotors of all 5 turbines within the proposed wind farm development per year of operation of the overall wind farm as a whole. The inverse of this (i.e. the number of years over which a single fatality would be likely) is additionally calculated.

The “**Random Flight Model**” examines the predicted number of transits through the windfarm site with regard to all flights recorded within the viewshed (i.e. a 2km arc of the vantage point) as randomly occurring. The random flight model therefore assumes that any observed flight could occur both within and outside of the wind farm site with equal likelihood. The viewshed of a given VP should extend to a distance no greater than 2km and include an arc of no greater than 180 degrees, as per the SNH (2017) guidelines. Any flights recorded within the rotor swept height and inside the 2km arc of the vantage point are included in the model.

The Random Flight Model has a number of limitations and assumptions.

- Both habitat and bird activity will remain the same over time and be unchanged during the operational stage of the proposed windfarm development.
- Bird activity is not spatially explicit, i.e. bird activity is equal throughout the viewshed area and this is equal to activity in the proposed windfarm development area.
- All flight activity used in the model occurred within the viewshed area calculated at the lowest swept rotor height. (e.g. if the lowest swept height of the turbine blade is 20m, the viewshed coverage displaying the visibility of the area within the 2km arc at a height of 20m above ground level is used). All flights are assumed to have occurred within this visible area, although many are likely to have been above this. The calculation for survey area visible (AVP) from each VP in the model is therefore highly precautionary as it is likely to have been a larger area of coverage for much of the flight activity.

The “**Regular Flight Model**” examines the predicted number of transits through a cross-sectional area of the windfarm which represents the width of the commuting corridor. A “risk window” comprises of a 2-dimensional line which represents the width of the windfarm in addition to a 500m buffer for each of the turbines, multiplied by the rotor diameter. All flights which pass through the identified risk window, within the swept height of the turbines, are included in the collision risk modelling. Any regular flights more than 500m from the turbine layout can be excluded from analysis.

The Regular Flight Model has a number of limitations and assumptions.

- Firstly, that the turbine rotor swept area is 2-dimensional, i.e. there is a single row of turbines in the windfarm. This represents all turbines within the commuting corridor accounted for by a single straight-line.
- It is assumed that bird activity is spatially explicit.
- Birds in an observed flight only cross the turbine area once and do not pass through the cross-section a second time (or multiple times).

Further details regarding both the Random and Regular Flight Model calculations are available on the SNH website. <https://www.nature.scot/wind-farm-impacts-birds-calculating-theoreticalcollision-risk-assuming-no-avoiding-action>.

The data used as part of the model, such as the number, size, dimensions and likely functioning of the proposed turbines for the Inchamore Wind Farm Development Site (See **Table 1.1**) forms part of the calculations, along with the available bird biometric data (See **Table 1.2**). These values are modelled with the standardised field data collected using Best Practice methods on surveying birds flight activity within the proposed Inchamore Wind Farm Development Site.

The data is collectively modelled to predict the number of bird flights through the rotors of all turbines within the site on an annual basis (CRM Stage 1) as well as the probability that a bird flying through the turbine will collide with the rotors (CRM Stage 2). The product of the numerical output from these two stages of assessment then predicts the number of birds likely to collide with the rotors of the turbines if no avoiding action is taken. This value is then corrected using the available avoidance rates (CRM Stage 3), to give a final indication of collision risk (number of bird colliding with the turbine rotors per annum).

The steps used to derive the collision risk for birds observed at the proposed development according to the Band Model are summarised below:

- Stage 1 (Band model): this model uses observations of birds flying through the study area during vantage point surveys to calculate the number of birds estimated to fly through the proposed turbines blade swept areas.
- Stage 2 (Band model): this model calculates the collision risk for an individual bird flying through a rotating turbine blade. The collision risk depends on the flight behaviour and biometrics.
- The result of the number of birds calculated to fly through the turbines annually is then multiplied by the collision risk probability. This calculation gives the worst-case scenario and assumes that birds flying through the site make no attempt to avoid turbines.
- Stage 3: An avoidance factor is applied to the result of the collision risk model to account for avoidance of the turbine rotors by bird species. Avoidance rates are available from SNH online bird collision risk guidance (SNH 2018). This avoidance rate corrects for the ability of the birds to detect and move around the turbines. This final output after all steps of modelling is a real-world estimation of the number of collisions that may occur at the proposed wind farm based on observed bird activity during the survey periods.

Several assumptions were made in the calculation of collision risk for the proposed Inchamore Wind Farm Development. These assumptions are tailored specifically to Inchamore Wind Farm Development and are as follows:

- Birds in flight within the study area at heights greater than 20m above ground level are assumed to be in danger of collision with the rotating turbine blades.
- No preference was taken for birds using gliding or flapping flight through the study area for target species as they exhibit both behaviours. In the calculation of the percentage risk of collision for a bird flying through a rotating turbine, the mean of the worst-case scenario (i.e. a bird flying upwind through a turbine using flapping flight whilst the turbine is at its fastest rotation speed) and the best-case scenario (i.e. a bird flying downwind through a rotating turbine using a gliding flight whilst the turbine at its slowest rotation speed) has been used for birds which exhibit both flapping and gliding flight. However, for Golden Plover (*Pluvialis apricaria*) only the mean calculations for flapping flights were used.

The Collision Risk Assessment (CRA) also makes assumptions on the turbine specifications, such as rotor diameter and rotational speed. Because the final choice of turbine will not be known until a later stage in the planning process, the worst-case scenario is assumed. The worst-case scenario is a combination of the maximum collision risk area (i.e. swept area determined by hub height and rotor blade length), maximum number of turbines proposed and turbine operational time. The turbine and wind farm characteristics for the purposes of this assessment at the proposed Inchamore Wind Farm Development Site are presented in **Table 1.1**.

2.1 Determination of Bird Flights Through the Rotor Swept Area

Stage 1 of the CRM determines the number of transits through the rotors for a given period or season. For the calculations below, this is expressed as the number of birds flying through the rotors per season (Breeding and Non-breeding).

Flight data was recorded at fixed vantage point locations from April 2017 to March 2019 inclusive and the data was provided to Veon Ecology to undertake the Collision Risk modelling for the relevant target species. A potential collision risk height (PCH) of between 20m and 180m above ground was established based on the proposed turbines having a maximum blade tip height of 180m, and a rotor diameter of 155m. This ensured that the PCH was within the rotor sweep of the turbine but also, slightly overestimates the risk of collision as it greater than the actual turbine swept area. The flight height of species was classified into height bands (HB) as follows: HB1 = 0-20m, HB2 = 20-40m, HB3 = 40-80m, HB4 = 80-150m, HB5 = 150m+. Behavioural observations were also recorded with the minimum requirement of 36 hours per VP per season (breeding and non-breeding) and 72 hours of VP survey effort per year achieved.

The VP Arc for each VP is a 180° arc with a radius of 2km from the vantage point location, which represents the theoretical maximum coverage area. The viewshed represents the actual area visible to the surveyor at a specified height above ground level from the vantage point location within each VP Arc. GIS computer software was used to generate the viewsheds for each VP. Flight data from the viewshed mapping for each VP was used to inform this CRM.

In the case of birds observed during surveys for the proposed Inchamore Wind Farm Development, flights recorded from surveys were classified for the purpose of the analysis as “randomly” distributed flights which could occur anywhere within the given viewsheds. The “Random Flight Model” is used in cases of irregular flight activity such as that displayed by raptors occupying a recognized territory, or by waders. This model requires calculation of the proportion of time birds were observed flying per unit of survey area. Therefore the “Random Flight Model” was applied for each target species to calculate the predicted number of transits through the proposed wind farm site.

The proportion of flight time between 20 and 180m for a bird species for each of the VPs was calculated. If multiple birds were observed in one flight, the seconds spent at PCH were calculated by multiplying the number of birds observed per flight by the duration of the flight at PCH (in line with SNH, 2000).

The hours that a species may potentially be active in either a breeding or non-breeding season was calculated to include daylight, one hour before sunrise, and one hour after sunset (dusk) for all species with the exception of Golden Plover. For this species it was calculated as daylight, one hour before sunrise, one hour after sunset (dusk), and 25% of the night (SHN, 2017). These flight activity hours were calculated from timeanddate.com.

Flight activity was used to calculate the number of bird passes through the rotor for each VP in turn and per turbine within each viewshed before being calculated for the entire wind farm. The Stage 1 calculation was carried out for each season (i.e. breeding and wintering) for each species.

2.2 Probability of Collision of Birds Passing Through the Rotor Swept Area

The probability of a birds flying through the rotors and colliding with the turbine blades is determined in Stage 2 of the CRM. The probability of a collision depends on the species biometrics including size (both length and wingspan) and average flight speed. In order to simplify the calculations for this CRM, all birds are assumed to be of simple cruciform shape, with the wings half-way down the length of the body. Characteristics of the turbine and rotor blades are also required as part of the calculations, including the pitch and width of the turbine rotor blades and the rotation speed of the proposed turbines. For Stage 2 of the CRM, the turbine rotor blades are assumed to have no thickness, although the blade depth is considered in Stage 1 of the model.

The risk of a bird colliding with the turbine rotor blades changes depending upon whether the bird passes through the rotor swept area towards the tip of the blade (where the blades are only present for a small proportion of the time, having a short chord width and a faster rotational time) or next to the turbine hub (where the blades have a wider chord width, occupy a larger volume of airspace and are travelling at slower speeds). Towards the blade tips, it is the length of the bird that offers greater contribution to the determination of the risk of collision. Closer to the turbine hub, the wingspan of the bird compared to the physical distance between the blades is the controlling factor. The bird is assumed to enter the rotor swept area at random anywhere along the disc.

The calculations determine the collision risk at several locations along the length of the rotor blade (in intervals of $0.05R$, where R is the radius of the rotor swept area) using numerical integration of various elements in relation to the rotors (notably angular velocity of the blade and chord width) and the bird (such as the point at which the bird enters the rotor along the radius and the flight speed of the bird). These are calculated for both downwind and up-wind flights and averaged to give a probability of collision per season, assuming no avoiding action is taken.

The calculations are performed in the SNH collision risk model, where the relevant data on the turbines and bird biometrics are entered into the model, and the model estimates the probability of a collision when a bird flies through the rotor area. This calculation is based solely upon the behaviour and biometrics of the bird and the specifications of the turbines proposed at the Inchamore site.

For the Inchamore Wind Farm development site, the average probability of each species passing through the wind farm and colliding with the rotors if it takes no avoiding action is presented in **Table 3.4**.

Section 3: RESULTS

The Collision risks were calculated using flight data recorded during vantage point watches at three fixed vantage point locations (VP1-VP3) within the study area between April 2017 and March 2019. The target species recorded within the potential collision risk zone included Common Buzzard (*Buteo buteo*), Common Kestrel (*Falco tinnunculus*), European Golden Plover (*Pluvialis apricaria*), Hen Harrier (*Circus cyaneus*) and Peregrine Falcon (*Falco peregrinus*).

The calculation parameters are outlined in **Tables 3.1, 3.2** and **Table 3.3**. A worked example of the calculation of collision risk for Hen Harrier is available in Appendix 4. **Table 3.1** below presents the details on the viewshed area for each VP.

Table 3.1: Summary of CRM parameters for VPS at Inchamore Wind Farm.

| Vantage Point | VP Arc (ha) | Viewshed area within VP Arc (ha) | Viewshed Coverage (%) | Turbine Buffer Area Within Viewshed (ha) | No. of Turbines Within Viewshed | Total Survey Effort (hrs) |
|---------------|-------------|----------------------------------|-----------------------|--|---------------------------------|---------------------------|
| VP 1 | 628 | 400 | 63.69 | 274.18 | 4 | 147.75 |
| VP 2 | 628 | 376 | 59.87 | 128.98 | 2 | 153.5 |
| VP 3 | 628 | 306 | 48.73 | 58.5 | 0 | 139.13 |

Species-specific morphometric measurements, flight speeds and avoidance rates are shown in **Table 3.2**. The amount of time a species was observed flying at heights of between 20 - 180 metres, i.e. within the Potential Collision Height (PCH), is presented in **Table 3.3** below. Birds in flight within the study area at heights between 20m and 180m are assumed to be in danger of collision with the rotating turbine blades. This is a precautionary approach as the lower extent of the swept area of the turbine blades will be greater than 20m.

Table 3.2: Avian Biometric Data and Avoidance Rates.

| Avian Biometric Data and Avoidance Rates | | | | |
|---|------------|--------------|-------------------------|---------------------|
| Species Name | Length (m) | Wingspan (m) | Mean flight speed (m/s) | Avoidance rates (%) |
| Common Buzzard (<i>Buteo buteo</i>) | 0.54 | 1.2 | 13.3 | 98 |
| Common Kestrel (<i>Falco tinnunculus</i>) | 0.34 | 0.76 | 10.1 | 95 |
| European Golden Plover (<i>Pluvialis apricaria</i>) | 0.275 | 0.715 | 17.9 | 98 |
| Hen Harrier (<i>Circus cyaneus</i>) | 0.48 | 1.1 | 12 | 99 |
| Peregrine Falcon (<i>Falco peregrinus</i>) | 0.42 | 1.02 | 12.1 | 98 |

Table 3.3: Bird biometrics and bird-seconds spent by species at Potential Collision Height (20-180m).

| Seconds spent at PCH (2017-2019) | | | | | | | |
|----------------------------------|------------------------------------|--------|--------|-----------|--------|-------|----------------------------------|
| Species Name (BTO Code) | Seconds in flight at PCH (20-180m) | | | | | | Total secs at PCH over 24 Months |
| | 2017/2018 | | | 2018/2019 | | | |
| | Summer | Winter | Total | Summer | Winter | Total | |
| Buzzard (BZ) | 0 | 0 | 0 | 93 | 0 | 93 | 93 |
| Kestrel (K.) | 60 | 0 | 60 | 2,360 | 504 | 2,864 | 2,924 |
| Golden Plover (GP) | 0 | 61,363 | 61,363 | 0 | 7,725 | 7,725 | 69,088 |
| Hen Harrier (HH) | 0 | 6 | 6 | 156 | 25 | 181 | 187 |
| Peregrine (PE) | 0 | 0 | 0 | 530 | 0 | 530 | 530 |

Table 3.4: Number of collisions predicted for target species without the application of avoidance rates.

| Species | Year | Predicted collisions per season without avoidance rates applied | | |
|------------------------|---------|---|---------|---------|
| | | Breeding | Winter | Total |
| Common Buzzard | 2017/18 | 0.000 | 0.000 | 0.000 |
| | 2018/19 | 1.24 | 0.000 | 1.24 |
| Common Kestrel | 2017/18 | 0.82 | 0.000 | 0.82 |
| | 2018/19 | 23.67 | 17.22 | 40.89 |
| European Golden Plover | 2017/18 | 0.000 | 4164.86 | 4164.86 |
| | 2018/19 | 0.000 | 423.49 | 423.49 |
| Hen Harrier | 2017/18 | 0.000 | 0.06 | 0.06 |
| | 2018/19 | 0.000 | 0.25 | 0.25 |
| Peregrine | 2017/18 | 0.000 | 0.000 | 0.000 |
| | 2018/19 | 6.15 | 0.000 | 6.15 |

Table 3.5: Number of collisions predicted for target species with the application of avoidance rates.

| Species | Year | Predicted collisions per season with avoidance rates applied | | | Predicted collisions over 30-year lifetime of the windfarm | | |
|------------------------|---------|--|--------|--------|--|----------|----------|
| | | Breeding | Winter | Total | Breeding | Winter | Total |
| Common Buzzard | 2017/18 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 2018/19 | 0.012 | 0.000 | 0.012 | 0.372 | 0.000 | 0.372 |
| Common Kestrel | 2017/18 | 0.008 | 0.000 | 0.008 | 0.247 | 0.000 | 0.247 |
| | 2018/19 | 0.237 | 0.172 | 0.409 | 7.100 | 5.166 | 12.266 |
| European Golden Plover | 2017/18 | 0.000 | 41.649 | 41.649 | 0.000 | 1249.459 | 1249.459 |
| | 2018/19 | 0.000 | 4.235 | 4.235 | 0.000 | 127.046 | 127.046 |
| Hen Harrier | 2017/18 | 0.000 | 0.001 | 0.001 | 0.000 | 0.017 | 0.017 |
| | 2018/19 | 0.000 | 0.002 | 0.002 | 0.000 | 0.075 | 0.075 |
| Peregrine | 2017/18 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 2018/19 | 0.062 | 0.000 | 0.062 | 1.846 | 0.000 | 1.846 |

Table 3.6: Mean number of collisions predicted for target species with avoidance rates.

| Target Species Biometrics | | | |
|---------------------------|---|---|--------------------------------------|
| Species Name | Mean no. of predicted collisions per year | Mean no. of predicted collisions per 30 years | Equivalent to 1 bird every x (years) |
| Buzzard (BZ) | 0.006 | 0.019 | 166.6 |
| Kestrel (K.) | 0.209 | 6.257 | 4.8 |
| Golden Plover (GP) | 22.942 | 688.253 | 0.04 |
| Hen Harrier (HH) | 0.002 | 0.046 | 500 |
| Peregrine (PE) | 0.031 | 0.923 | 32.6 |

Section 4: CONCLUSION

This CRM has been completed for the proposed Inchamore Wind Farm development. The VP survey data used for this CRM was collected over two summer surveys (breeding seasons) and two winter surveys (non-breeding seasons), which meets the requirements of current SNH guidelines.

There are a number of potential sources of uncertainty/error that apply to all CRM analyses. The main potential source of error is the accuracy of the surveys and flight activity data, which will affect the accuracy of the predicted transit rate, and the simplification involved in the calculations of collision probabilities.

The Band method used for this collision risk model is developed using several assumptions, particularly regarding bird characteristics and behaviour, and relies on the accuracy of the available information regarding species avoidance rates, turbine specifications, and survey data. As a result of these limitations and assumptions in relation to the CRM, the predicted collision risk should be considered only an indication of the potential collision risk significance for each target species.

The output of the first two stages of the model presents the number of predicted bird collisions with the proposed wind turbines per annum. This is the result of the number of bird transits through the rotor occupied space per season and the probability of a bird passing through the rotor swept area colliding with the turbine blades.

In the present assessment, the predicted collision risks are very low for all the target species, with only Golden Plover and Kestrel, being predicted to have any collisions within the nominal 30 year. Thus, the only species that are likely to have significant levels of collisions are Common Kestrel (*Falco tinnunculus*) and European Golden Plover (*Pluvialis apricaria*). It is clear from the VP surveys that there is a considerable amount of Golden Plover activity in the area during the non-breeding seasons with much of it seemingly at the Potential Collision Height (i.e. 20-180m). However, as discussed above, collision risk modelling is dependent on many assumptions and can be prone to biases.

The Kestrel, a year-round resident of the area, has a prediction of over six collisions every 30 years. However, this value is also liable to be rather tenuous as a large percentage of recorded kestrel flight activity likely involved hovering birds which suggests that the mean kestrel flight speed used in this CRM (i.e. 10.1 m/s) will not be a true indication of the mean flight speed of the kestrels observed during the surveys. Kestrels fly relatively quickly between hovering spots which may lead to an underestimation of their speed resulting in a greater predicted risk of collision than would likely occur in “real-life” scenarios.

It is most notably the flocking species of Golden Plover which are at the greatest potential risk of impact. With more than 688 collisions predicted every 30 years, Golden Plover is by far the species with the highest predicted collision risk output (See **Table 3.6**). Further assessment of the potential collision risk of Golden Plover at Inchamore is advised due to the potential high level of collisions indicated by this CRM. However, as the Golden Plover recorded are part of a wintering population, a single all-year CRM is likely to overestimate the collision risk of the species. The main activity area for Golden Plover lies within the viewsheds for VP 1 and 2, however, the entire turbine envelope does not occur within these viewsheds. The mean flock size recorded across the 2017/18 and 2018/19 winter seasons was of c. 25 individuals (a total of 21 observations comprising 533 individuals in total, with the peak flock size of 70 birds recorded in January 2018). It should be noted that the amount of time at collision risk height has been derived as a product of flight duration and the number of individuals in the flock. Furthermore, given the apparent random nature of golden plover flights, all of those observed within each viewshed (1 and 2) at collision risk height have been included in the CRM, including flights “out” of the collision-risk area. As such, the results of the CRM are likely to over-estimate the theoretical collision risk for Golden Plover.

In conclusion and with regard to the limitations and assumptions presented by collision risk modelling, the resulting predicted collisions should only be considered an indication and not a definitive result. Thus, the outputs of the collision risk modelling should be used solely as a comparative tool rather than an accurate indicator of bird mortality risk. Therefore, it is advised to interpret the results of CRM analyses as indicating only the order of magnitude of the predicted collision risk for given target species.

Section 5: REFERENCES

- Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G. & Hellgren, O. (2007). Flight speeds among bird species: allometric and phylogenetic effects.
- Band, W., Madders, M. and Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at wind farms. In: Birds and wind power: risk assessment and mitigation. M. DeLucas, G.F.E. Janss and M. Ferrer, Eds.: 259-275.
- Chamberlain, D.E., Rehfisch, M.R., Fox, A.D., Desholm, M., Anthony, S.J. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models.
- Cramp, S. (1993) Handbook of the Birds of the Western Palaearctic. Oxford University Press, Oxford.
- Drewitt, A. & Langston, R. (2006). Assessing the impacts of wind farms on birds.
- European Wind Energy Association. 2020. Wind energy's frequently asked questions (FAQ). EWEA, Brussels.
- IWEA (Irish Wind Energy Association). 2012. Best Practice Guidelines for the Irish Wind Energy Industry. IWEA, Co. Kildare.
- Madders, M. & Whitfield, P.D. (2006). Upland Raptors and the Assessment of Wind Farm Impacts.
- Robinson, R.A. 2005. BirdFacts: profiles of birds occurring in Britain & Ireland. BTO, Thetford (Available at <http://www.bto.org/birdfacts>).
- Ruddock, M., Mee, A., Lusby, J., Nagle, A., O'Neill, S. & O'Toole, L. (2016). The 2015 National Survey of Breeding Hen Harrier in Ireland. Irish Wildlife Manuals 93. National Parks and Wildlife Service, Department of the Arts, Heritage and the Gaeltacht, Ireland.
- Scottish Natural Heritage (2000). Windfarms and Birds - Calculating a theoretical collision risk assuming no avoiding action. SNH Guidance Note. Available at <http://www.snh.gov.uk/docs/C205425.pdf>
- Scottish Natural Heritage (2017). Recommended Bird Survey Methods to Inform Impact Assessment on Onshore Wind Farms. Version 2.
- Scottish Natural Heritage (2018). Use of avoidance rates in the SNH wind farm Collision Risk Model. Available at: <https://www.nature.scot/wind-farm-impacts-birds-use-avoidance-rates-snh-wind-farmcollision-risk-model>.
- timeanddate.com Sunrise, Sunset, and Daylength. Available at: <https://www.timeanddate.com>
- Wilson, M. W., Irwin, S., Norriss, D. W., Newton, S. F., Collins, K., Kelly, T. C. & O'Halloran, J. 2009. The importance of pre-thicket conifer plantations for nesting Hen Harriers *Circus cyaneus* in Ireland.
- Wilson, M. W., Irwin, S., O'Donoghue, B., Kelly, T. C. & O'Halloran, J. 2010. The use of forested landscapes by Hen Harriers in Ireland. COFORD Connects. Environment No. 10.

Section 6: APPENDICES
 Appendix 1. FIGURES AND MAPS

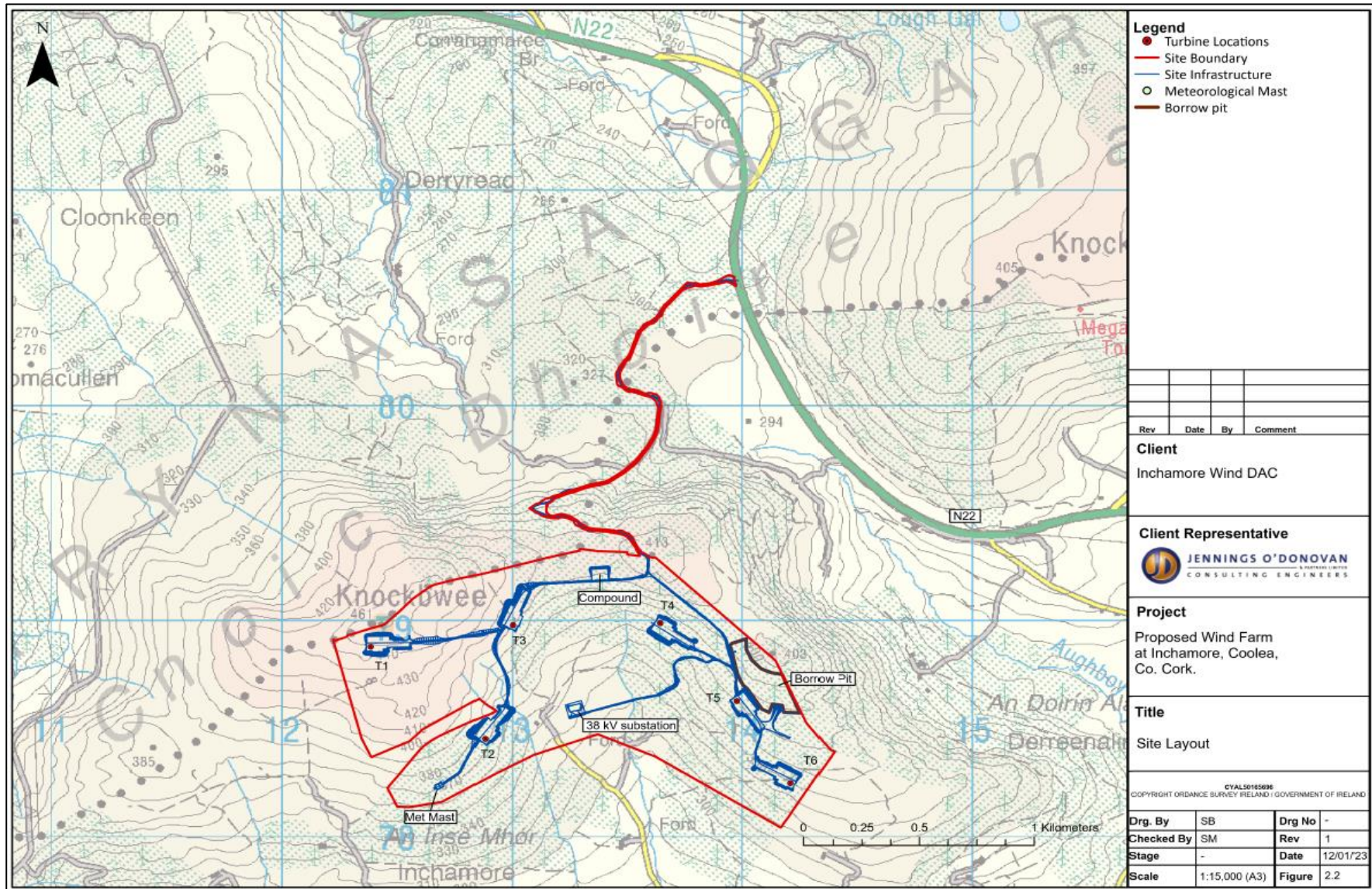


Figure 6.1: Site location and boundary with the outlined area in blue indicating the area proposed for turbines.

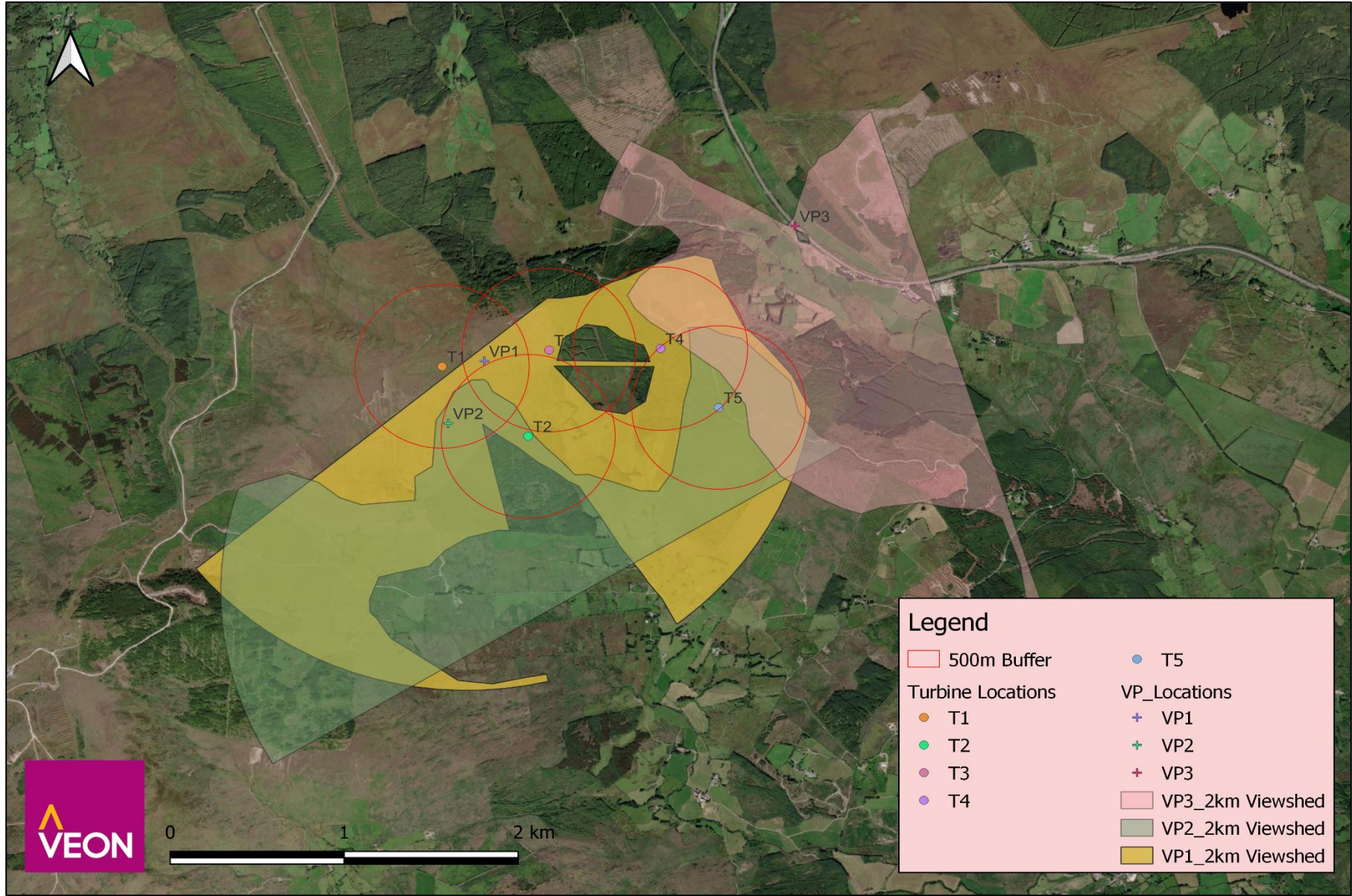


Figure 6.2: Vantage Point locations and viewshed map.

Appendix 2. VANTAGE POINT DATA

VANTAGE POINT SURVEY EFFORT (HOURS) FOR SUMMER 2017

Table 6.1: Inchamore VP data (VP1-3) survey effort Summer 2017.

| Survey Effort Data (Summer 2017 April-September) | | | | | | | |
|--|-----------|-------------|-----------|-----------|-----------|-----------|--------------|
| Vantage Point | April | May | June | July | August | September | Total Hours |
| VP 1 | 6 | 5.5 | 0 | 12 | 6 | 6 | 35.5 |
| VP 2 | 6 | 6 | 6 | 3 | 6 | 6 | 33 |
| VP 3 | 6 | 6 | 6 | 0 | 12 | 6 | 36 |
| Total | 18 | 17.5 | 12 | 15 | 24 | 18 | 104.5 |

VANTAGE POINT SURVEY EFFORT (HOURS) FOR WINTER 2017-2018

Table 6.2: Inchamore VP data (VP1-3) survey effort Winter 2017-2018.

| Survey Effort Data (Winter 2017-2018 October-March) | | | | | | | |
|---|-----------|-----------|-----------|-------------|-----------|----------|-------------|
| Vantage Point | October | November | December | January | February | March | Total Hours |
| VP 1 | 0 | 12 | 12 | 0 | 0 | 12 | 36 |
| VP 2 | 6 | 6 | 6 | 9 | 6 | 6 | 39 |
| VP 3 | 6 | 6 | 6 | 6.5 | 6 | 0 | 30.5 |
| Total | 12 | 24 | 24 | 15.5 | 12 | 6 | 93.5 |

VANTAGE POINT SURVEY EFFORT (HOURS) FOR SUMMER 2018

Table 6.3: Inchamore VP data (VP1-3) survey effort Summer 2018.

| Survey Effort Data (Summer 2018 April-September) | | | | | | | |
|--|-----------|-----------|-----------|-------------|-----------|-----------|--------------|
| Vantage Point | April | May | June | July | August | September | Total Hours |
| VP 1 | 7 | 6 | 6 | 12 | 6 | 6 | 43 |
| VP 2 | 6 | 3 | 0 | 18 | 9 | 9 | 45 |
| VP 3 | 6 | 6 | 6 | 12.3 | 6 | 0 | 36.3 |
| Total | 19 | 15 | 12 | 42.3 | 21 | 15 | 124.3 |

VANTAGE POINT SURVEY EFFORT (HOURS) FOR WINTER 2018-2019

Table 6.4: Inchamore VP data (VP1-3) survey effort Winter 2018-2019.

| Survey Effort Data (Winter 2018-2019 October-March) | | | | | | | |
|---|-----------|--------------|--------------|-----------|-------------|-----------|---------------|
| Vantage Point | October | November | December | January | February | March | Total Hours |
| VP 1 | 3 | 6.25 | 6 | 6 | 1 | 11 | 33.25 |
| VP 2 | 6 | 6 | 6 | 6 | 5.5 | 7 | 36.5 |
| VP 3 | 6 | 6 | 6.33 | 6 | 6 | 6 | 36.33 |
| Total | 15 | 18.25 | 18.33 | 18 | 12.5 | 24 | 106.08 |

Table 6.5: Inchamore VP data (VP1-3) survey effort overview.

| Vantage point survey effort (VP 1-3) | | | |
|--------------------------------------|-----------------|--------------|--------------------------|
| Survey Dataset | Months | Effort/Month | Total hours per VP |
| Summer 2017 | April-September | Variable | 33-36 (Mean 34.83) |
| Winter 2017 - 2018 | October-March | Variable | 30.5-39 (Mean 34.75) |
| Summer 2018 | April-September | Variable | 36.3-45 (Mean 41.43) |
| Winter 2018 - 2019 | October-March | Variable | 33.25-36.5 (Mean 34.875) |

Table 6.6: All species seconds spent at Potential Collision Height (20-180m) (VP 1-3).

| Seconds spent at PCH (2017-2019) | | | | | | | |
|---|------------------------------------|--------|--------|-----------|--------|-------|----------------------------------|
| Species Name | Seconds in flight at PCH (20-180m) | | | | | | Total secs at PCH over 24 Months |
| | 2017/2018 | | | 2018/2019 | | | |
| | Summer | Winter | Total | Summer | Winter | Total | |
| Common Buzzard (<i>Buteo buteo</i>) | 0 | 0 | 0 | 103 | 0 | 103 | 103 |
| Common Kestrel (<i>Falco tinnunculus</i>) | 84 | 0 | 84 | 2,589 | 509 | 3,098 | 3,182 |
| Eurasian Sparrowhawk (<i>Accipiter nisus</i>) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| European Golden Plover (<i>Pluvialis apricaria</i>) | 0 | 61,363 | 61,363 | 0 | 7,725 | 7,725 | 69,088 |
| White-tailed Eagle (<i>Haliaeetus albicilla</i>) | 20 | 4 | 24 | 0 | 45 | 45 | 69 |
| Hen Harrier (<i>Circus cyaneus</i>) | 0 | 6 | 6 | 156 | 30 | 186 | 192 |
| Merlin (<i>Falco columbarius</i>) | 0 | 37 | 37 | 20 | 0 | 20 | 57 |
| Peregrine Falcon (<i>Falco peregrinus</i>) | 0 | 0 | 0 | 530 | 0 | 530 | 530 |

Table 6.7: VP data (VP1-3) Survey Effort and Viewshed Coverage.

| Vantage Point | VP Arc (ha) | Viewshed area within VP Arc (ha) | Viewshed Coverage (%) | Turbine Buffer Area Within Viewshed (ha) | No. of Turbines Within Viewshed | Total Survey Effort (hrs) |
|---------------|-------------|----------------------------------|-----------------------|--|---------------------------------|---------------------------|
| VP 1 | 628 | 400 | 63.69 | 274.18 | 4 | 147.75 |
| VP 2 | 628 | 376 | 59.87 | 128.98 | 2 | 153.5 |
| VP 3 | 628 | 306 | 48.73 | 58.5 | 0 | 139.13 |

Summer Season 2017

Table 6.8: VP Summer 2017 - Survey Details.

| Date | VP no. | Start Time | Duration (Hrs) | Precipitation | Cloud (okta) | Wind | Visibility |
|------------|--------|------------|----------------|--|--------------|---------------------|--|
| 25/04/2017 | 1 | 10.15 | 3 | Dry | 4/8 | F 5-6 NW | Excellent-Good (some heat shimmer) |
| 25/04/2017 | 1 | 13.45 | 3 | some snow & hail showers | 7/8 | NW F6-7 | V. good-good-excellent (some heat shimmer) |
| 18/05/2017 | 1 | 10.4 | 3 | Light rain at start, mainly dry & clear | 5/8-7/8 | F4-5 W | Moderate - excellent |
| 26/05/2017 | 1 | 15.08 | 0.5 | Dry | 8/8 | F6-7 SE | Moderate |
| 29/05/2017 | 1 | 15.12 | 2 | Dry | 8/8 | F3-4 SSW | V. good |
| 03/07/2017 | 1 | 10.26 | 3 | Misty drizzle | 7/8 | F3-4 SW | Excellent-poor |
| 03/07/2017 | 1 | 13.36 | 3 | Misty drizzle | 8/8 | F3-5 SW | Moderate |
| 31/07/2017 | 1 | 10.35 | 3 | Occasional showers; mainly dry | 7/8-6/8 | F6-7 WSW | Good-excellent |
| 31/07/2017 | 1 | 13.35 | 3 | Occasional showers | 6/8-8/8 | F6-7 WSW | Excellent- moderate |
| 29/08/2017 | 1 | 10.3 | 3 | dry | 8/8 | F2-3 W | Good-moderate |
| 29/08/2017 | 1 | 13.3 | 3 | Occasional short showers | 7/8-5/8 | F3-4 W | Excellent |
| 08/09/2017 | 1 | 10.35 | 3 | Occasional short showers | 7/8-5/8-8/8 | F3-5 W | V.good- moderate |
| 08/09/2017 | 1 | 13.45 | 3 | Occ. Brief heavy showers | 7/8-6/8 | F3-5 W | V.good- poor |
| 21/04/2017 | 2 | 10 | 3 | Dry | 1/8-5/8 | F4-5 NW | Ex. -V.good; some heat shimmer |
| 21/04/2017 | 2 | 13.3 | 3 | Dry | 3/8-5/8 | F3-5 NW | V.good; some heat shimmer |
| 18/05/2017 | 2 | 13.5 | 3 | Intermittent showers + dry spells | 6/8 | F3 -4 NW | Ex./mod/poor |
| 26/05/2017 | 2 | 11.57 | 3 | Dry | 8/8-7/8 | F6-7 ESE | Mod-Good; slight haze |
| 28/06/2017 | 2 | 9.45 | 3 | Dry | 5/8 | F2-3 NW | Excellent |
| 28/06/2017 | 2 | 13.05 | 3 | Dry | 7/8-5/8 | F2-5 SW | Excellent |
| 31/07/2017 | 2 | 10.35 | 3 | Showers | 7/8 | F5 SW | Good |
| 30/08/2017 | 2 | 9.5 | 3 | Light drizzle at end of watch | 7/8-5/8 | F1-4 (variable) NW | V.good |
| 30/08/2017 | 2 | 12.5 | 3 | Intermittent misty showers | 8/8-5/8 | F2-4 WNW | Mod-V.good |
| 11/09/2017 | 2 | 11.4 | 3 | Frequent showers | 6/8-8/8 | F6 W | Good-poor |
| 11/09/2017 | 2 | 14.4 | 3 | Frequent showers | 6/8 | F4-5 W | Mod-poor |
| 20/04/2017 | 3 | 11.3 | 3 | Dry | 5/8-6/8 | F2-3 Var. | Excellent |
| 20/04/2017 | 3 | 15 | 3 | Dry | 7/8 | F3-4 NW | Excellent |
| 15/05/2017 | 3 | 10.04 | 3 | Regular misty drizzle/ light showers & dry spells | 8/8 | F4-5 ENE | Moderate/poor |
| 15/05/2017 | 3 | 13.34 | 3 | Occasional showers, misty drizzle & dry clear spells | 8/8 | F4-5 ENE | Moderate/poor |
| 16/06/2017 | 3 | 11.51 | 3 | Dry | 3/8 | F5 NW | Excellent |
| 16/06/2017 | 3 | 15.15 | 3 | Dry | 3/8-5/8 | Var; F0-F5 NW | Excellent |
| 04/08/2017 | 3 | 10.15 | 3 | Medium 20 min shower in last hr of survey | 7/8 | F1-3 NW/N | V.good |
| 04/08/2017 | 3 | 13.45 | 3 | Light spitting on & off for 1st 30 min | 8/8-7/8 | F1-2 N/NW | V.good |
| 18/08/2017 | 3 | 9.25 | 3 | Occ. Showers | 7/8-5/8 | F4-5 WSW | Good-V.good |
| 18/08/2017 | 3 | 12.55 | 3 | showers & dry clear spells | 8/8 | F3-5 (var./gusty) W | V-good-mod |
| 05/09/2017 | 3 | 9.3 | 3 | Dry | 6/8-2/8 | F3-4 W | V.good |
| 05/09/2017 | 3 | 12.3 | 3 | Dry | 3/8 | F4-5W | Excellent |

Winter Season 2017/2018

Table 6.9: VP Winter 2017/2018 - Survey Details.

| Date | VP | Time | Duration (hours) | Precipitation | Cloud (okta) | Wind | Visibility |
|------------|----|-------|------------------|-----------------------------|--------------|-----------|--------------------|
| 22/12/2017 | 1 | 10:15 | 3 | Some misty drizzle | 8/8-7/8 | F2-4 SW | V.good-Mod |
| 22/12/2017 | 1 | 13:15 | 3 | Dry | 8/8 | F3-4 SW | V.good |
| 23/11/2017 | 1 | 10:30 | 3 | Dry | 4/8 | F4-5 NW | V.good |
| 23/11/2017 | 1 | 13:30 | 3 | Dry | 8/8 | F3-4 NW | V.good |
| 30/11/2017 | 1 | 10:30 | 6 | N/A | 6/8 | F4 NNW-S | Good |
| 15/12/2017 | 1 | 10:00 | 3 | Dry | 1/8-4/8 | F5-6 NW | Good-Ex |
| 15/12/2017 | 1 | 13:00 | 3 | Dry | 4/8 | F5-6 NW | Excellent |
| 08/04/2018 | 1 | 12:15 | 6 | N/A | Fog 4/8 | F3 | Good/ Fog |
| 29/04/2018 | 1 | 07:45 | 6 | N/A | 3/8 | F4 | Good |
| 31/12/2017 | 2 | 13:40 | 3 | Frequent Showers | 8/8 | F3-4 SW | Fair-Good |
| 27/10/2017 | 2 | 09:30 | 6 | | 8/8 | F1 SW | Poor-Good |
| 15/11/2017 | 2 | 11:4 | 3 | Occ. Misty showers; 90% dry | 8/8-7/8 | F3 WSW | Mod-V.good |
| 15/11/2017 | 2 | 14:4 | 2 | Some misty showers | 8/8 | F3-4 WSW | V.good-poor |
| 23/11/2017 | 2 | 09:35 | 1 | Dry | 4/8 | F5-6 NW | Good |
| 31/12/2017 | 2 | 13:40 | 3 | frequent squalls | 8/8 | SW F3-4 | Fair-Good |
| 01/01/2018 | 2 | 09:30 | 3 | Heavy showers at first | 8/8 | W-NW F5-6 | Good |
| 19/01/2018 | 2 | 12:30 | 3 | Heavy snow showers | 7/8 | F4 W | Moderate |
| 26/01/2018 | 2 | 09:00 | 3 | Occ. showers | 6/8 | F3 | Good |
| 09/02/2018 | 2 | 11:05 | 3 | 1 brief snow shower | 5/8 | F2 NW | V.good-poor-v.good |
| 09/02/2018 | 2 | 14:05 | 3 | Dry | 8/8 | F3 NW | V.Good |
| 23/03/2018 | 2 | 12:20 | 3 | Light showers | 8/8 | F3 SE | Moderate/Occ. Poor |
| 23/03/2018 | 2 | 15:30 | 3 | Steady light rain | 8/8 | F3 ESE | Mod |
| 25/10/2017 | 3 | 10:00 | 3 | Light spitting for 15 min | 8/8 | F0 | V.Good |
| 25/10/2017 | 3 | 13:30 | 3 | Dry | 8/8 | F0 | V.Good |
| 15/11/2017 | 3 | 11:00 | 3 | Drizzle | 8/8 | F2 ENE | - |
| 15/11/2017 | 3 | 14:30 | 3 | None | 7/8 | F3 S | Excellent |
| 01/12/2017 | 3 | 9:45 | 3 | Dry | 1/8-3/8 | F0-1 NW | V.good |
| 01/12/2017 | 3 | 12:45 | 3 | Dry | 2/8 | F0-1 NW | V.good |
| 04/01/2018 | 3 | 10:30 | 3 | Occ. Light showers | 7/8 | F4-5 W | Good |
| 04/01/2018 | 3 | 13:30 | 3.5 | Occ. Light showers | 7/8 | F3-4 W | Good |
| 08/02/2018 | 3 | 08:30 | 3 | Drizzle | 8/8 | F1 | Poor-mod |
| 08/02/2018 | 3 | 12:00 | 3 | Dry | 7/8 | F2 | Mod-good |
| 09/04/2018 | 3 | 09:50 | 3 | Dry | 6/8-8/8 | F2 SE | Excellent |
| 09/04/2018 | 3 | 12:50 | 3 | Dry | 8/8 | F2/3 SE | Excellent |
| 31/12/2017 | 4 | 09:30 | 4 | Frequent Heavy | 8/8 | SW F3-4 | Poor to Good |

Summer Season 2018

Table 6.10: VP Summer 2018 - Survey Details.

| Date | VP | Time | Duration (hours) | Cloud (okta) | Precipitation | Wind | Visibility |
|------------|----|-------|------------------|----------------------------|--|------------------|--|
| 29/04/2018 | 1 | 07:45 | 07:00 | 3/8 | N/A | 4 | Good |
| 11/05/2018 | 1 | 09:30 | 06:00 | 8/8-3/8 | N/A | SW | Moderate/ low cloud at first - cleared at 13:00 |
| 19/06/2018 | 1 | 13:00 | 06:00 | 8/8 | N/A | SW 3 | Moderate, low cloud |
| 03/07/2018 | 1 | 11:00 | 06:00 | 2/8 | N/A | E 2 | Good |
| 18/07/2018 | 1 | 14:00 | 06:00 | 7/8 | N/A | SSW 1 | Good |
| 07/08/2018 | 1 | 11:00 | 06:00 | 6/8 | N/A | WSW 2 | Good |
| 26/09/2018 | 1 | 12:30 | 06:00 | 8/8 at 12:30, 2/8 at 15:00 | Nil | SW 1-2 | Good |
| 19/04/2018 | 2 | 10:35 | 03:00 | 8/8-4/8 | Dry | F2-3 SW | Excellent |
| 19/04/2018 | 2 | 13:35 | 03:00 | 4/8 | Dry | F2 SW | Excellent |
| 25/05/2018 | 2 | 10:30 | 03:00 | 3/8 | Dry | F2-4N | Excellent |
| 08/07/2018 | 2 | 10:00 | 06:00 | 4/8 | Nil | WNW | Good |
| 17/07/2018 | 2 | 13:00 | 06:00 | - | Nil | SSW1 | Good |
| 23/07/2018 | 2 | 12:45 | 03:00 | 8/8 | light | F2-3 W | Ok-Poor-Fair |
| 23/07/2018 | 2 | 09:15 | 03:00 | 8/8 | V. light | F2-3 W/SW | Good-Poor-OK, very misty at times |
| 16/08/2018 | 2 | 14:00 | 06:00 | 5/8 | Nil | W2-3 | Good |
| 17/08/2018 | 2 | 09:00 | 03:00 | 8/8 | Light showers | F3-4W 5 at times | OK-light mist at times |
| 27/09/2018 | 2 | 11:00 | 04:30 | 1/8 | Nil | WNW 2-3 | Mod-good |
| 27/09/2018 | 2 | 11:00 | 04:30 | 1/8 | Nil | WNW 2-3 | Mod-good |
| 09/04/2018 | 3 | 09:50 | 03:00 | 6/8-8/8 | Dry | F2 SE | Excellent |
| 09/04/2018 | 3 | 12:50 | 03:00 | 8/8 | Dry | F2/3 SE | Excellent |
| 22/05/2018 | 3 | 10:55 | 03:00 | 2/8 | Dry | F1 NW | Excellent |
| 22/05/2018 | 3 | 13:55 | 03:00 | 1/8 | Dry | F1 NW | Excellent |
| 05/06/2018 | 3 | 12:05 | 03:00 | 5/8 | Dry | F2 SE | Excellent |
| 05/06/2018 | 3 | 15:05 | 03:00 | 4/8 | Dry | F2 SE | V. good (slight haze) |
| 20/07/2018 | 3 | 09:55 | 03:00 | 8/8 | Occ. Light misty drizzle | F0-1 W | V. Good |
| 20/07/2018 | 3 | 12:55 | 03:00 | 7/8 | Dry | F2 WNW | Excellent |
| 31/07/2018 | 3 | 08:11 | 03:19 | 8/8-7/8 | Light-medium-clear with showers at times | F2-3 W at times | Ok-Good with poor-ok during intermittent showers |
| 31/07/2018 | 3 | 12:00 | 03:00 | 8/8-7/8 | Light-medium-clear with showers at times | F2-3 W at times | Ok-Good with poor-ok during intermittent showers |
| 16/08/2018 | 3 | 09:10 | 03:00 | 6/8-7/8 | Changeable, bright to light showers | F0-1 NW - 3-4NW | Good-Ok |
| 16/08/2018 | 3 | 12:40 | 03:00 | 6/8-7/8 | Changeable, bright to light showers | F0-1 NW - 3-4NW | Good-Ok |

Winter Season 2018/2019

Table 6.11: VP Winter 2018/2019 - Survey Details.

| Date | VP | Time | Duration (hours) | Cloud (okta) | Precipitation | Wind | Visibility |
|------------|----|-------|------------------|----------------------------|----------------------------------|--------------------|---|
| 26/09/2018 | 1 | 12:30 | 06:00 | 8/8 at 12:30, 2/8 at 15:00 | Nil | SW 1-2 | Good |
| 18/10/2018 | 1 | 08:50 | 03:00 | 1/8 | Dry | F0, building to F1 | V. good |
| 30/11/2018 | 1 | 10:00 | 06:15 | 6/8 -8/8 | Showers | F5-6 Strong | Full - poor |
| 20/12/2018 | 1 | 09:30 | 03:00 | 8/8-6/8 | Intermediate misty showers | F3-4 | V. good |
| 20/12/2018 | 1 | 12:30 | 03:00 | 8/8 | Dry | F3-4 | V. good |
| 17/01/2019 | 1 | 09:30 | 03:00 | 3/8 | None | F1-2 NE | Good-v. good |
| 17/01/2019 | 1 | 12:30 | 03:00 | 3/8-7/8 | None | F1 NE | V. good |
| 15/02/2019 | 1 | 10:10 | 01:00 | 8/8 | Light throughout | F3-4 S | OK |
| 04/03/2019 | 1 | 11:50 | 02:30 | 8/8 | N/A | F3-4W | Good |
| 04/03/2019 | 1 | 14:50 | 02:30 | 8/8 | Heavy sleet with snow | F2-3 W | OK-Good |
| 29/03/2019 | 1 | 09:25 | 06:00 | 6/8-1/8 | N/A | F2 | Excellent |
| 17/10/2018 | 2 | 10:20 | 03:00 | 4/8-8/8 | Misty rain - none | F3-4W | OK, low lying mis, cleared at start of VP |
| 17/10/2018 | 2 | 13:50 | 03:00 | 4/8-8/8 | Misty rain - none | F3-4W | OK, low lying mis, cleared at start of VP |
| 16/11/2018 | 2 | 09:10 | 03:00 | 8/8 low lying fog in areas | Light rain throughout | F2-4 | Fair to OK to Poor at times |
| 21/11/2018 | 2 | 11:30 | 03:00 | 8/8 | Dry | F0-1 | Mod-v. good |
| 18/12/2018 | 2 | 10:10 | 06:00 | 8/8-6/8-2/8 (at times) | Light rain showers passing over | F3S | Excellent to OK at times |
| 16/01/2019 | 2 | 09:30 | 03:00 | 2/8-4/8 | Some brief showers | F2-3W | V. good |
| 16/01/2019 | 2 | 12:30 | 03:00 | 5/8-7/8 | Some brief heavy showers | F3W | V. good-good |
| 12/02/2019 | 2 | 10:00 | 03:00 | 8/8 | Misty drizzle clearing | F2-3 | Moderate-good |
| 14/02/2019 | 2 | 10:15 | 02:30 | 8/8 | N/A | F4S | Good-poor |
| 04/03/2019 | 2 | 14:20 | 00:30 | 8/8 | Light | F0-2 W | Good |
| 25/03/2019 | 2 | 09:25 | 06:30 | 1/8 | N/A | F1 | Excellent |
| 11/10/2018 | 3 | 10:30 | 03:00 | 6/8-8/8-4/8 | Mainly dry, 1 light misty shower | F1 | Excellent-v. good |
| 11/10/2018 | 3 | 13:30 | 03:00 | 3/8 | Dry | F1-2 | Excellent |
| 15/11/2018 | 3 | 09:30 | 03:00 | 8/8 | Light at start | F0-4 S-SE-SE-W | Ok-Fair |
| 15/11/2018 | 3 | 13:00 | 03:00 | 8/8 | Light at start | F0-4 S-SE-SE-W | Ok-Fair |
| 10/12/2018 | 3 | 08:25 | 06:20 | 8/8-7/8 | Light from 09:00 onwards | F0-F1 calm | OK. Some morning haze light, poor vis 10:30-11:45 with changeable, then good thereafter |
| 08/01/2019 | 3 | 09:30 | 03:00 | 7/8 | None | F2 NW | Good |
| 08/01/2019 | 3 | 13:00 | 03:00 | 8/8-7/8 | None | F2 NW | Good- v. good |
| 12/02/2019 | 3 | 09:30 | 03:00 | 8/8 | Some light drizzle | F1-3 SW | Good |
| 12/02/2019 | 3 | 12:30 | 03:00 | 7/8 | None-some drizzle | F2-3SW | V. good |
| 05/03/2019 | 3 | 07:25 | 03:00 | 8/8-5/8 | Light showers constantly | F0-2 at times | Excellent |
| 05/03/2019 | 3 | 10:55 | 03:00 | 8/8 | Light showers constantly | F0-2 at times | Excellent |

Appendix 3. VANTAGE POINT BIRD FLIGHTLINE DATA

Table 6.12: Summer 2017 Bird Flightline Data.

| VP | Date | Start Time | End Time | Species | Flight line no. | Species quantity | Start Time | Inside / outside Buffer | Total Duration (s) | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Bird Notes |
|----|------------|------------|----------|---------------------|-----------------|------------------|------------|-------------------------|--------------------|----------|-----------|-----------|------------|----------|--|
| 2 | 31/07/2017 | 10.35 | 16.35 | Kestrel_K. | 9 | 1 | 13.02 | OUT | 1800 | 1800 | | | | | Moving along short intervals surveying field while hovering |
| 2 | 31/07/2017 | 10.35 | 16.35 | Kestrel_K. | 9 | 1 | 13.32 | IN | 300 | 300 | | | | | Crossed into viewshed & out of viewshed |
| 2 | 31/07/2017 | 10.35 | 16.35 | Kestrel_K. | 8 | 2 | 13.44 | IN | 30 | | 30 | | | | Pair travelling across viewshed, not hovering |
| 2 | 31/07/2017 | 10.35 | 16.35 | Kestrel_K. | 7 | 1 | 14.26 | IN | 45 | 45 | | | | | Travelling & stopped twice to hover briefly |
| 2 | 31/07/2017 | 10.35 | 16.35 | Kestrel_K. | 7 | 1 | 14.26 | OUT | 50 | 50 | | | | | |
| 2 | 31/07/2017 | 10.35 | 16.35 | Kestrel_K. | 6 | 1 | 14.41 | OUT | 70 | 70 | | | | | Travelling, no hovering |
| 2 | 31/07/2017 | 10.35 | 16.35 | Kestrel_K. | 5 | 1 | 14.53 | OUT | 1500 | 1500 | | | | | Circled, then hovered, then moving small distances to hover |
| 3 | 04/08/2017 | 10.15 | 13.15 | Kestrel_K. | 1 | 1 | 11.48 | IN | 55 | 37 | 18 | | | | Flying, hunting, hovering |
| 3 | 04/08/2017 | 10.15 | 13.15 | Kestrel_K. | 1 | 1 | 11.48 | OUT | 55 | 38 | 17 | | | | In/Outside site boundary rather than buffer recorded. |
| 3 | 05/09/2017 | 9.3 | 12.3 | Kestrel_K. | 4 | 1 | 11.24 | IN | 8 | 8 | | | | | Hovering, hunting, flying |
| 3 | 05/09/2017 | 12.3 | 15.3 | Kestrel_K. | 3 | 1 | 13.34 | IN | 22 | 16 | 6 | | | | |
| 3 | 05/09/2017 | 12.3 | 15.3 | Kestrel_K. | 2 | 1 | 13.51 | IN | 11 | 11 | | | | | |
| 2 | 11/09/2017 | 11.4 | 14.4 | Peregrine Falcon_PE | 1 | 1 | 13:36 | IN | 10 | 10 | | | | | |
| 3 | 15/05/2017 | 13.34 | 16.34 | Sparrowhawk_SH | 1 | 1 | 14.28 | IN | 19 | 19 | | | | | Female or juvenile; flying c.1m altitude, hunting along road & field boundaries. Lost sight behind spur. |

| VP | Date | Start Time | End Time | Species | Flight line no. | Species quantity | Start Time | Inside / outside Buffer | Total Duration (s) | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Bird Notes |
|----|------------|------------|----------|----------------|-----------------|------------------|------------|-------------------------|--------------------|----------|-----------|-----------|------------|----------|---|
| 3 | 15/05/2017 | 13.34 | 16.34 | Sparrowhawk_SH | 1 | 1 | 14.28 | OUT | 2 | 2 | | | | | |
| 1 | 29/08/2017 | 10.3 | 13.3 | Sparrowhawk_SH | 3 | 1 | 10.3 | IN | 5 | 5 | | | | | A, B & C = same bird. Flushed on approach to VP, flew downhill behind ridge |
| 1 | 29/08/2017 | 10.3 | 13.3 | Sparrowhawk_SH | 4 | 1 | 10.3 | IN | 3 | 3 | | | | | Approached ridge, flushed again, flew behind 2nd ridge |
| 1 | 29/08/2017 | 10.3 | 13.3 | Sparrowhawk_SH | 5 | 1 | 10.3 | IN | 10 | 10 | | | | | Approached 2nd ridge, flushed, flew across heath into conifer plantation |
| 3 | 05/09/2017 | 9.3 | 12.3 | Sparrowhawk_SH | 2 | 1 | 10.3 | IN | 7 | 7 | | | | | Male; took small passerine from low branch of spruce tree |
| 3 | 05/09/2017 | 9.3 | 12.3 | Sparrowhawk_SH | 2 | 1 | 10.3 | OUT | 3 | 3 | | | | | |

Table 6.13: Winter 2017/2018 Bird Flightline Data.

| VP | Date | Start Time | End Time | Species | Flight line no. | Species quantity | Start Time | Inside / outside Buffer | Total Duration (s) | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Bird Notes |
|----|------------|------------|----------|------------------|-----------------|------------------|-------------|-------------------------|--------------------|----------|-----------|-----------|------------|----------|---|
| 2 | 15/11/2017 | 14.4 | 16.55 | Golden Plover_GP | 11 | | 14.4 | | | | | | | | Heard calling overhead; obscured by cloud; could tell general location & direction of flight from calls |
| 1 | 22/01/2018 | 10.15 | 13.15 | Golden Plover_GP | 20 | 12 | 10.5 | IN | 169 | 17 | 101 | 51 | | | |
| 1 | 23/11/2017 | 10.3 | 13.3 | Golden Plover_GP | 1 | 11 | 10.55 | IN | 15 | 15 | | | | | Lost sight behind rise to west of VP1 |
| 1 | 23/11/2017 | 10.3 | 13.3 | Golden Plover_GP | 2 | 12 | 12.35 | IN | 11 | 11 | | | | | Lost sight behind rise; appeared to be landing |
| 1 | 23/11/2017 | 10.3 | 13.3 | Golden Plover_GP | 3 | c. 35 | 12.56 | IN | 105 | 73 | 32 | | | | c. 25 followed closely by 10. Appeared to land behind rise, same area as above |
| 1 | 23/11/2017 | 10.3 | 13.3 | Golden Plover_GP | 4 | 15 | 13.27 | IN | 18 | 18 | | | | | Probably arrived earlier, + disturbed. Other GO flightpaths (1,4, & 5) considered influx from N + E |
| 1 | 23/11/2017 | 10.3 | 13.3 | Golden Plover_GP | 5 | c.40 | 13.15-13.25 | IN | | | | | | | 4 flocks of c.10 flushed & flew along FP A when area approached to confirm landing |
| 1 | 23/11/2017 | 13.3 | 16.3 | Golden Plover_GP | 6 | c.30 | 13.5 | IN | 18 | 18 | | | | | |
| 1 | 23/11/2017 | 13.3 | 16.3 | Golden Plover_GP | 7 | 16 | 13.54 | IN | 15 | 15 | | | | | |
| 1 | 23/11/2017 | 13.3 | 16.3 | Golden Plover_GP | 8 | 10 | 14 | IN | 4 | 4 | | | | | |
| 2 | 23/11/2017 | 9.35 | 10.2 | Golden Plover_GP | 9 | 4 | 9.48 | IN | 10 | 10 | | | | | |
| 2 | 23/11/2017 | 9.35 | 10.2 | Golden Plover_GP | 10 | 4 | 9.54 | IN | 18 | 18 | | | | | |
| 1 | 15/12/2017 | 13 | 16 | Golden Plover_GP | 13 | 10 | 14.52 | IN | 15 | 15 | | | | | |
| 1 | 15/12/2017 | 13 | 16 | Golden Plover_GP | 14 | 12 | 15.54 | IN | 13 | 13 | | | | | |

| VP | Date | Start Time | End Time | Species | Flight line no. | Species quantity | Start Time | Inside / outside Buffer | Total Duration (s) | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Bird Notes |
|----|------------|------------|----------|------------------|-----------------|------------------|------------|-------------------------|--------------------|----------|-----------|-----------|------------|----------|---|
| 1 | 15/12/2017 | 13 | 16 | Golden Plover_GP | 15 | 12 | 15.55 | IN | 45 | 10 | 35 | | | | Assume same flock as (2) above; appeared to land behind rise west of VP |
| 2 | 19/01/2018 | 12.3 | 15.3 | Golden Plover_GP | 23 | 1 | 14.21 | IN | | | | | 200 | | Calling & travelling |
| 2 | 19/01/2018 | 12.3 | 15.3 | Golden Plover_GP | 23 | 1 | 14.21 | OUT | | | | | 129 | | |
| 1 | 22/01/2018 | 10.15 | 13.15 | Golden Plover_GP | 17 | 1 | 10.12 | IN | 9 | 9 | | | | | Flushed on route to VP, flew off low calling |
| 1 | 22/01/2018 | 10.15 | 13.15 | Golden Plover_GP | 18 | c.40 | 10.3 | IN | 335 | 140 | 160 | 35 | | | |
| 1 | 22/01/2018 | 10.15 | 13.15 | Golden Plover_GP | 18 | c.40 | 10.3 | OUT | 15 | | 15 | | | | |
| 1 | 22/01/2018 | 10.15 | 13.15 | Golden Plover_GP | 19 | c.35 | 10.36 | IN | 42 | 32 | 10 | | | | Presume landed on bog |
| 1 | 22/01/2018 | 10.15 | 13.15 | Golden Plover_GP | 21 | c.70 | 11.55 | IN | 627 | | 43 | 478 | 106 | | Lost in clouds |
| 1 | 22/01/2018 | 10.15 | 13.15 | Golden Plover_GP | 21 | c.70 | 11.55 | OUT | 228 | | | 120 | 108 | | |
| 1 | 22/01/2018 | 13.15 | 16.15 | Golden Plover_GP | 22 | 3 | 15.43 | IN | 15 | | 15 | | | | |
| 2 | 26/01/2018 | 9 | 12 | Golden Plover_GP | 24 | 3 | 9.4 | IN | 132 | | | | 132 | | Calling & travelling |
| 2 | 26/01/2018 | 9 | 12 | Golden Plover_GP | 25 | 1 | 11.18 | IN | 160 | | | | | 160 | Calling & travelling |
| 2 | 26/01/2018 | 9 | 12 | Golden Plover_GP | 25 | 1 | 11.18 | OUT | 20 | | | | | 20 | Calling & travelling |
| 2 | 26/01/2018 | 9 | 12 | Golden Plover_GP | 26 | 1 | 11.5 | IN | 50 | | | | | 50 | Calling & travelling |
| 2 | 23/03/2018 | 12:20 | 15:20 | Golden Plover_GP | 35 | 18 | 12:40 | IN | 270 | 54 | 216 | | | | |
| 1 | 08/04/2018 | 12:15 | 18:15 | Golden Plover_GP | 44 | 16 | 12:12 | IN | 7 | 7 | | | | | Fog <150m visibility |
| 1 | 08/04/2018 | 12:15 | 18:15 | Golden Plover_GP | 45 | 7 | 12:21 | IN | 8 | 8 | | | | | Fog <150m visibility |
| 1 | 08/04/2018 | 12:15 | 18:15 | Golden Plover_GP | 46 | 43 | 16:24 | IN / OUT | 29 | | 29 | | | | |
| 1 | 22/01/2018 | 13.15 | 16.15 | Hen Harrier_HH | 4 | 1 | 15.46 | IN | 13 | 13 | | | | | Male colouring on upper parts, but juvenile underneath & around face |
| 1 | 22/01/2018 | 13.15 | 16.15 | Hen Harrier_HH | 5 | 1 | 15.47 | IN | 45 | 45 | | | | | Same individual as (2) above |
| 2 | 09/02/2018 | 11.05 | 14.05 | Hen Harrier_HH | 7 | 1 | 11.53 | IN | 55 | 49 | 6 | | | | Ringtail; mobbed by RN |

| VP | Date | Start Time | End Time | Species | Flight line no. | Species quantity | Start Time | Inside / outside Buffer | Total Duration (s) | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Bird Notes |
|----|------------|------------|----------|-----------------------|-----------------|------------------|------------|-------------------------|--------------------|----------|-----------|-----------|------------|----------|---|
| 2 | 09/02/2018 | 14.05 | 17.05 | Hen Harrier_HH | 8 | 1 | 14.4 | IN | 7 | 7 | | | | | Male |
| 2 | 09/02/2018 | 14.05 | 17.05 | Hen Harrier_HH | 8 | 1 | 14.40 | OUT | 8 | 8 | | | | | |
| 3 | 04/01/2018 | 10.3 | 13 | Kestrel_K. | 1 | 1 | 11.58 | IN | 7 | 7 | | | | | Seen briefly- lost below hill/WD4 |
| 3 | 15/11/2017 | 11 | 14 | Merlin_ML | 1 | 1 | 11.59 | IN | 20 | | | | 20 | | Flew straight through, flushing approx. 60 SG |
| 3 | 15/11/2017 | 11 | 14 | Merlin_ML | 1 | 1 | 11.59 | OUT | 17 | | | | 17 | | |
| 3 | 01/12/2017 | 12.45 | 15.45 | Sparrowhawk_SH | - | 1 | 15.31 | IN | 4 | 4 | | | | | |
| 3 | 01/12/2017 | 12.45 | 15.45 | Sparrowhawk_SH | - | | | OUT | 16 | 16 | | | | | |
| 1 | 22/01/2018 | 10.15 | 13.15 | White-tailed Eagle_WE | 1 | 1 | 10.53 | OUT | 26 | 6 | 20 | | | | Silhouette only observed, so age not determined |
| 1 | 22/01/2018 | 10.15 | 13.15 | White-tailed Eagle_WE | 1 | 1 | 10.53 | IN | 8 | 2 | 4 | | | | Ground beneath flightpath not visible (hidden behind ridge) so mapping accuracy reduced |

Table 6.14: Summer 2018 Bird Flightline Data.

| VP | Date | Observation No. | Species | Quantity | Start | In/Out | Duration | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Flightline Map | Flightline No. |
|----|------------|-----------------|----------------|----------|-------|--------|----------|----------|-----------|-----------|------------|----------|----------------|----------------|
| 2 | 27/09/2018 | 1 | Buzzard_BZ | 1 | 11:26 | In | 93 | | 93 | | | | 2-8-A-1 | 1 |
| 2 | 27/09/2018 | 1 | Buzzard_BZ | 1 | 11:26 | Out | 10 | | 10 | | | | 2-8-A-1 | 1 |
| 2 | 27/09/2018 | 4 | Hen harrier_HH | 1 | 15:06 | In | 214 | 58 | 156 | | | | 2-8-A-2 | 2 |
| 2 | 27/09/2018 | 4 | Hen harrier_HH | 1 | 15:06 | Out | 5 | | 5 | | | | 2-8-A-2 | 2 |
| 2 | 23/07/2018 | 1 | Kestrel_K. | 2 | 13:16 | Out | 15 | | 5 | 10 | | | - | - |
| 2 | 23/07/2018 | 1 | Kestrel_K. | 2 | 13:16 | In | 600 | 50 | 500 | 50 | | | - | - |
| 2 | 08/07/2018 | 1 | Kestrel_K. | 1 | 13:42 | In | 791 | 312 | 479 | | | | 2-8-A-3 | 1 |
| 2 | 08/07/2018 | 2 | Kestrel_K. | 1 | 15:45 | In | 296 | 98 | 198 | | | | 2-8-A-3 | 2 |
| 2 | 16/08/2018 | 1 | Kestrel_K. | 1 | 18:15 | In | 293 | | | 293 | | | 2-8-A-3 | 4 |
| 2 | 17/07/2018 | 1 | Kestrel_K. | 1 | 15:33 | In | 429 | 184 | 245 | | | | 2-8-A-3 | 3 |
| 3 | 22/05/2018 | 1 | Kestrel_K. | 1 | 13:21 | In | 160 | 16 | 144 | | | | 2-8-A-3 | 7 |
| 3 | 22/05/2018 | 2 | Kestrel_K. | 1 | 13:59 | In | 94 | 14 | 80 | | | | 2-8-A-3 | 8 |
| 3 | 22/05/2018 | 3 | Kestrel_K. | 1 | 14:22 | In | 52 | 47 | 5 | | | | 2-8-A-3 | 9 |
| 2 | 27/09/2018 | 2 | Kestrel_K. | 1 | 12:01 | In | 7 | 7 | | | | | 2-8-A-3 | 5 |
| 2 | 27/09/2018 | 3 | Kestrel_K. | 1 | 12:05 | In | 207 | 162 | 45 | | | | 2-8-A-3 | 6 |
| 1 | 26/09/2018 | 1 | Kestrel_K. | 1 | 13:46 | In | 7 | 7 | | | | | 2-8-A-3 | 10 |
| 1 | 26/09/2018 | 2 | Kestrel_K. | 1 | 14:28 | In | 11 | 11 | | | | | 2-8-A-3 | 11 |
| 1 | 26/09/2018 | 3 | Kestrel_K. | 1 | 14:29 | In | 12 | 12 | | | | | 2-8-A-3 | 12 |
| 3 | 20/07/2018 | 1 | Merlin_ML | 1 | 10:18 | Out | 20 | | 20 | | | | 2-8-A-5 | 1 |
| 2 | 19/04/2018 | 1 | Peregrine_PE | 1 | 16:31 | In | 590 | 60 | 90 | 150 | 290 | | 2-8-A-6 | 1 |
| 2 | 19/04/2018 | 1 | Peregrine_PE | 1 | 16:31 | Out | 10 | | | | 10 | | 2-8-A-6 | 1 |

Table 6.15: Winter 2018/2019 Bird Flightline Data.

| VP | Date | Observation No. | Species | Quantity | Start | In/Out | Duration | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Flightline Map | Flightline No. |
|----|------------|-----------------|------------------|----------|-------|--------|------------|----------|-----------|-----------|------------|----------|----------------|----------------|
| 2 | 18/12/2018 | 1 | Golden Plover_GP | 35 | 10:40 | In | 25 | | | 15 | 10 | | 2-8-B-2 | 10 |
| 2 | 18/12/2018 | 2 | Golden Plover_GP | 10 | 11:21 | In | 120 | | | | 120 | | 2-8-B-2 | 11 |
| 1 | 29/03/2019 | - | Golden Plover_GP | - | 09:26 | In | Heard only | | | | | | - | - |
| 1 | 20/12/2018 | 2 | Golden Plover_GP | 30 | 15:33 | In | 25 | 18 | 7 | | | | 2-8-B-2 | 1 |
| 1 | 15/02/2019 | 1 | Golden Plover_GP | 12 | 10:05 | In | 25 | 5 | 5 | 10 | 5 | | 2-8-B-2 | 2 |
| 1 | 04/03/2019 | 1 | Golden Plover_GP | 28 | 12:03 | In | 300 | 100 | 50 | 50 | | | 2-8-B-2 | 3 |
| 1 | 04/03/2019 | 1 | Golden Plover_GP | 28 | 12:08 | In | 240 | 240 | | | | | 2-8-B-2 | 3 |
| 1 | 04/03/2019 | 2 | Golden Plover_GP | 20 | 12:12 | In | 10 | 10 | | | | | 2-8-B-2 | 4 |
| 1 | 04/03/2019 | 2 | Golden Plover_GP | 20 | 12:12 | In | 1,680 | 1,680 | | | | | 2-8-B-2 | 4 |
| 1 | 04/03/2019 | 1 | Golden Plover_GP | 28 | 12:12 | In | 1,680 | 1680 | | | | | 2-8-B-2 | 5 |
| 1 | 04/03/2019 | 3 | Golden Plover_GP | 20 | 12:40 | In | 5 | 5 | | | | | 2-8-B-2 | 6 |
| 1 | 04/03/2019 | 3 | Golden Plover_GP | 48 | 12:40 | In | 5 | 5 | | | | | 2-8-B-2 | 6 |
| 1 | 04/03/2019 | 4 | Golden Plover_GP | 48 | 13:12 | In | 25 | 20 | 5 | | | | 2-8-B-2 | 7 |
| 1 | 04/03/2019 | 5 | Golden Plover_GP | 48 | 13:13 | In | 35 | 5 | 5 | 5 | 15 | 5 | 2-8-B-2 | 8 |
| 1 | 04/03/2019 | 5 | Golden Plover_GP | 48 | 13:13 | Out | 5 | 5 | | | | | 2-8-B-2 | 8 |
| 1 | 04/03/2019 | 6 | Golden Plover_GP | 48 | 13:29 | In | 20 | 5 | 5 | 10 | | | 2-8-B-2 | 9 |
| 1 | 04/03/2019 | 6 | Golden Plover_GP | 48 | 13:29 | Out | 40 | | | 5 | 5 | 25 | 2-8-B-2 | 9 |
| 2 | 14/02/2019 | - | Golden Plover_GP | - | 12:00 | In | Heard only | | | | | | - | - |
| 2 | 17/10/2018 | 1 | Hen Harrier_HH | 1 | 13:59 | In | 5 | | 20 | | | | | 1 |
| 3 | 11/10/2018 | 1 | Hen Harrier_HH | 1 | 14:15 | In | 20 | | 5 | | | | | 2 |
| 2 | 16/01/2019 | 2 | Hen Harrier_HH | 1 | 10:07 | In | 5 | | 5 | | | | | 3 |
| 1 | 26/09/2018 | 1 | Kestrel_K. | 1 | 13:46 | In | 7 | 7 | | | | | 2-8-A-3 | 10 |
| 1 | 26/09/2018 | 2 | Kestrel_K. | 1 | 14:28 | In | 11 | 11 | | | | | 2-8-A-3 | 11 |
| 1 | 26/09/2018 | 3 | Kestrel_K. | 1 | 14:29 | In | 12 | 12 | | | | | 2-8-A-3 | 12 |
| 1 | 18/10/2018 | 1 | Kestrel_K. | 1 | 14:02 | In | 150 | 50 | 120 | | | | 2-8-B-5 | 1 |
| 1 | 18/10/2018 | 2 | Kestrel_K. | 1 | 14:14 | In | 480 | 96 | 384 | | | | 2-8-B-5 | 2 |
| 3 | 11/10/2018 | 2 | Kestrel_K. | 1 | 15:58 | In | 289 | | 5 | | | | 2-8-B-5 | 3 |
| 3 | 15/11/2018 | 1 | Kestrel_K. | 1 | 12:24 | Out | 5 | | | 25 | | | 2-8-B-5 | 4 |
| 3 | 12/02/2019 | 2 | Kestrel_K. | 1 | 13:13 | In | 25 | 25 | | | | | 2-8-B-5 | 5 |
| 3 | 05/03/2019 | 1 | Kestrel_K. | 1 | 09:49 | In | 5 | 5 | | | | | 2-8-B-5 | 6 |

| VP | Date | Observation No. | Species | Quantity | Start | In/Out | Duration | 0-20 (s) | 20-40 (s) | 40-80 (s) | 80-150 (s) | >150 (s) | Flightline Map | Flightline No. |
|----|------------|-----------------|-----------------------|----------|-------|--------|----------|----------|-----------|-----------|------------|----------|----------------|----------------|
| 2 | 18/12/2018 | 3 | White-tailed Eagle_WE | 1 | 13:32 | In | 45 | 5 | 35 | 5 | | | 2-8-B-9 | 1 |
| 2 | 18/12/2018 | 3 | White-tailed Eagle_WE | 1 | 13:32 | Out | 15 | 10 | 5 | | | | 2-8-B-9 | 1 |

Appendix 4. COLLISION RISK ASSESSMENT CALCULATIONS

Table 6.16: Bird-seconds spent by species at Potential Collision Height (20-180m) for each VP.

| Species (BTO Code) | Year | VP 1 Seconds spent at PCH | | VP 2 Seconds spent at PCH | |
|--------------------|---------|---------------------------|--------|---------------------------|--------|
| | | Summer | Winter | Summer | Winter |
| Buzzard (BZ) | 2017/18 | 0 | 0 | 0 | 0 |
| | 2018/19 | 0 | 0 | 93 | 0 |
| Kestrel (K.) | 2017/18 | 0 | 0 | 60 | 0 |
| | 2018/19 | 0 | 509 | 2,360 | 0 |
| Golden Plover (GP) | 2017/18 | 0 | 56,696 | 0 | 4,694 |
| | 2018/19 | 0 | 4,930 | 0 | 2,075 |
| Hen Harrier (HH) | 2017/18 | 0 | 0 | 0 | 6 |
| | 2018/19 | 0 | 0 | 0 | 25 |
| Peregrine (PE) | 2017/18 | 0 | 0 | 0 | 0 |
| | 2018/19 | 0 | 0 | 530 | 0 |

Table 6.17: Bird biometrics and bird-seconds spent by species at Potential Collision Height (20-180m).

| Seconds spent at PCH (2017-2019) | | | | | | | | | | |
|----------------------------------|------------|--------------|-------------------------|------------------------------------|--------|--------|-----------|--------|-------|----------------------------------|
| Species Name (BTO Code) | Length (m) | Wingspan (m) | Mean flight speed (m/s) | Seconds in flight at PCH (25-180m) | | | | | | Total secs at PCH over 24 Months |
| | | | | 2017/2018 | | | 2018/2019 | | | |
| | | | | Summer | Winter | Total | Summer | Winter | Total | |
| Buzzard (BZ) | 0.54 | 1.2 | 13.3 | 0 | 0 | 0 | 93 | 0 | 93 | 93 |
| Kestrel (K.) | 0.34 | 0.76 | 10.1 | 60 | 0 | 60 | 2,360 | 504 | 2,864 | 2,924 |
| Golden Plover (GP) | 0.275 | 0.715 | 17.9 | 0 | 61,363 | 61,363 | 0 | 7,725 | 7,725 | 69,088 |
| Hen Harrier (HH) | 0.48 | 1.1 | 12 | 0 | 6 | 6 | 156 | 25 | 181 | 187 |
| Peregrine (PE) | 0.42 | 1.02 | 12.1 | 0 | 0 | 0 | 530 | 0 | 530 | 530 |

Table 6.18: Probability of collision – Stage 2 Calculations.

| Key Target Species Stage 2 Calculations | | | | | | | |
|---|---------------|----------|---------|--------------|----------|---------|---|
| Species Name (BTO Code) | Flapping bird | | | Gliding bird | | | Mean probability of Collision Risk (Flapping + Gliding)/2 |
| | Upwind | Downwind | Average | Upwind | Downwind | Average | |
| Buzzard (BZ) | 8.3% | 3.9% | 6.1% | 8.1% | 3.7% | 5.9% | 6% |
| Kestrel (K.) | 8.5% | 3.5% | 6.0% | 8.4% | 3.4% | 5.9% | 5.95% |
| Golden Plover (GP) | 6.2% | 2.7% | 4.5% | N/A | N/A | N/A | 4.5% |
| Hen Harrier (HH) | 8.5% | 3.9% | 6.2% | 8.3% | 3.7% | 6.0% | 6.1% |
| Peregrine (PE) | 8.1% | 3.6% | 5.8% | 8.0% | 3.4% | 5.7% | 5.75% |

No preference was taken for birds using flapping or gliding flight through the study area for species which exhibit both behaviours. In the calculation of the percentage risk of collision for a bird flying through a rotating turbine, the mean of the worst-case scenario (i.e. a bird flying upwind through a turbine using flapping flight whilst the turbine is at its fastest rotation speed) and the best-case scenario (i.e. a bird flying downwind through a rotating turbine using a gliding flight whilst the turbine at its slowest rotation speed) has been used for species which exhibit both flapping and gliding flight. For Golden plover only the mean calculations for flapping flights were used.

Table 6.19: Avian Biometric Data and Avoidance Rates.

| Avian Biometric Data and Avoidance Rates | | | | |
|---|------------|--------------|-------------------------|---------------------|
| Species Name | Length (m) | Wingspan (m) | Mean flight speed (m/s) | Avoidance rates (%) |
| Common Buzzard (<i>Buteo buteo</i>) | 0.54 | 1.2 | 13.3 | 98 |
| Common Kestrel (<i>Falco tinnunculus</i>) | 0.34 | 0.76 | 10.1 | 95 |
| European Golden Plover (<i>Pluvialis apricaria</i>) | 0.275 | 0.715 | 17.9 | 98 |
| Hen Harrier (<i>Circus cyaneus</i>) | 0.48 | 1.1 | 12 | 99 |
| Peregrine Falcon (<i>Falco peregrinus</i>) | 0.42 | 1.02 | 12.1 | 98 |

Appendix 5. WORKED CALCULATIONS

Table 6.20: Target species breeding and non-breeding season periods.

| Key target species breeding and non-breeding season periods | | | | |
|---|-----------------------|---------------------|---------------------------|-------------------------|
| Species Name | Breeding season start | Breeding season end | Non-breeding season start | Non-breeding season end |
| Common Buzzard (<i>Buteo buteo</i>) | April | August | September | March |
| Common Kestrel (<i>Falco tinnunculus</i>) | April | August | September | March |
| Eurasian Sparrowhawk (<i>Accipiter nisus</i>) | April | August | September | March |
| European Golden Plover (<i>Pluvialis apricaria</i>) | April | August | September | March |

Table 6.21: Avian Biometric Data and Avoidance Rates.

| Avian Biometric Data and Avoidance Rates | | | | |
|--|------------|--------------|-------------------------|---------------------|
| Species Name | Length (m) | Wingspan (m) | Mean flight speed (m/s) | Avoidance rates (%) |
| Hen Harrier (<i>Circus cyaneus</i>) | 0.48 | 1.1 | 12 | 99 |

Table 6.22: Probability of collision – Stage 2 Calculations.

| Key Target Species Stage 2 Calculations | | | | | | | |
|---|---------------|----------|---------|--------------|----------|---------|---|
| Species Name (BTO Code) | Flapping bird | | | Gliding bird | | | Mean probability of Collision Risk (Flapping + Gliding)/2 |
| | Upwind | Downwind | Average | Upwind | Downwind | Average | |
| Hen Harrier (HH) | 8.5% | 3.9% | 6.2% | 8.3% | 3.7% | 6.0% | 6.1% |

Table 6.23: Calculation of collision risk for Hen Harrier passing (Gliding) through rotor area.

| K: [1D or [3D] (0 or 1) | 1 | Calculation of alpha and p(collision) as a function of radius | | | | | | | | | |
|---------------------------------|------|---|------------------------|-------|----------|---------|--------------|---------------|--------------|--------------|---------------|
| NoBlades | 3 | Upwind: | | | | | | Downwind: | | | |
| MaxChord | 4.5 | m | r/R | c/C | α | collide | contribution | collide | contribution | | |
| Pitch (degrees) | 13 | | radius | chord | alpha | length | p(collision) | from radius r | length | p(collision) | from radius r |
| BirdLength | 0.48 | m | 0.025 | 0.575 | 5.28 | 17.60 | 0.82 | 0.00103 | 16.44 | 0.77 | 0.00096 |
| Wingspan | 1.1 | m | 0.075 | 0.575 | 1.76 | 6.26 | 0.29 | 0.00219 | 5.09 | 0.24 | 0.00178 |
| F: Flapping (0) or gliding (+1) | 1 | | 0.125 | 0.702 | 1.06 | 4.70 | 0.22 | 0.00274 | 3.28 | 0.15 | 0.00191 |
| | | | 0.175 | 0.860 | 0.75 | 4.25 | 0.20 | 0.00347 | 2.50 | 0.12 | 0.00204 |
| Bird speed | 12 | m/sec | 0.225 | 0.994 | 0.59 | 3.98 | 0.19 | 0.00417 | 1.96 | 0.09 | 0.00206 |
| RotorDiam | 155 | m | 0.275 | 0.947 | 0.48 | 3.29 | 0.15 | 0.00422 | 1.37 | 0.06 | 0.00176 |
| RotationPeriod | 5.36 | sec | 0.325 | 0.899 | 0.41 | 2.99 | 0.14 | 0.00454 | 1.17 | 0.05 | 0.00178 |
| | | | 0.375 | 0.851 | 0.35 | 2.66 | 0.12 | 0.00465 | 0.93 | 0.04 | 0.00163 |
| | | | 0.425 | 0.804 | 0.31 | 2.39 | 0.11 | 0.00473 | 0.76 | 0.04 | 0.00151 |
| | | | 0.475 | 0.756 | 0.28 | 2.17 | 0.10 | 0.00480 | 0.64 | 0.03 | 0.00141 |
| Bird aspect ratio: β | 0.44 | | 0.525 | 0.708 | 0.25 | 1.98 | 0.09 | 0.00484 | 0.54 | 0.03 | 0.00133 |
| | | | 0.575 | 0.660 | 0.23 | 1.81 | 0.08 | 0.00486 | 0.48 | 0.02 | 0.00130 |
| | | | 0.625 | 0.613 | 0.21 | 1.67 | 0.08 | 0.00486 | 0.53 | 0.02 | 0.00155 |
| | | | 0.675 | 0.565 | 0.20 | 1.54 | 0.07 | 0.00484 | 0.57 | 0.03 | 0.00179 |
| | | | 0.725 | 0.517 | 0.18 | 1.42 | 0.07 | 0.00479 | 0.59 | 0.03 | 0.00200 |
| | | | 0.775 | 0.470 | 0.17 | 1.31 | 0.06 | 0.00472 | 0.60 | 0.03 | 0.00218 |
| | | | 0.825 | 0.422 | 0.16 | 1.20 | 0.06 | 0.00463 | 0.61 | 0.03 | 0.00235 |
| | | | 0.875 | 0.374 | 0.15 | 1.11 | 0.05 | 0.00452 | 0.61 | 0.03 | 0.00249 |
| | | | 0.925 | 0.327 | 0.14 | 1.02 | 0.05 | 0.00438 | 0.61 | 0.03 | 0.00261 |
| | | | 0.975 | 0.279 | 0.14 | 0.93 | 0.04 | 0.00422 | 0.60 | 0.03 | 0.00271 |
| | | | Overall p(collision) = | | | | Upwind | 8.3% | Downwind | 3.7% | |
| | | | | | | | Average | 6.0% | | | |

Table 6.24: Calculation of collision risk for Hen Harrier passing (Flapping) through rotor area.

| K: [1D or [3D] (0 or 1) | 1 | Calculation of alpha and p(collision) as a function of radius | | | | | | | | | |
|---------------------------------|------|---|------------------------|-------|----------|---------|--------------|---------------|----------|--------------|---------------|
| NoBlades | 3 | Upwind: | | | | | | Downwind: | | | |
| MaxChord | 4.5 | m | r/R | c/C | α | collide | | contribution | collide | | contribution |
| Pitch (degrees) | 13 | | radius | chord | alpha | length | p(collision) | from radius r | length | p(collision) | from radius r |
| BirdLength | 0.48 | m | 0.025 | 0.575 | 5.28 | 19.71 | 0.92 | 0.00115 | 18.55 | 0.87 | 0.00108 |
| Wingspan | 1.1 | m | 0.075 | 0.575 | 1.76 | 6.96 | 0.32 | 0.00243 | 5.80 | 0.27 | 0.00203 |
| F: Flapping (0) or gliding (+1) | 0 | | 0.125 | 0.702 | 1.06 | 5.12 | 0.24 | 0.00299 | 3.70 | 0.17 | 0.00216 |
| | | | 0.175 | 0.860 | 0.75 | 4.55 | 0.21 | 0.00371 | 2.81 | 0.13 | 0.00229 |
| Bird speed | 12 | m/sec | 0.225 | 0.994 | 0.59 | 4.21 | 0.20 | 0.00442 | 2.20 | 0.10 | 0.00231 |
| RotorDiam | 155 | m | 0.275 | 0.947 | 0.48 | 3.48 | 0.16 | 0.00446 | 1.56 | 0.07 | 0.00201 |
| RotationPeriod | 5.36 | sec | 0.325 | 0.899 | 0.41 | 2.99 | 0.14 | 0.00454 | 1.17 | 0.05 | 0.00178 |
| | | | 0.375 | 0.851 | 0.35 | 2.66 | 0.12 | 0.00465 | 0.93 | 0.04 | 0.00163 |
| | | | 0.425 | 0.804 | 0.31 | 2.39 | 0.11 | 0.00473 | 0.76 | 0.04 | 0.00151 |
| | | | 0.475 | 0.756 | 0.28 | 2.17 | 0.10 | 0.00480 | 0.64 | 0.03 | 0.00141 |
| Bird aspect ratio: β | 0.44 | | 0.525 | 0.708 | 0.25 | 1.98 | 0.09 | 0.00484 | 0.54 | 0.03 | 0.00133 |
| | | | 0.575 | 0.660 | 0.23 | 1.81 | 0.08 | 0.00486 | 0.48 | 0.02 | 0.00130 |
| | | | 0.625 | 0.613 | 0.21 | 1.67 | 0.08 | 0.00486 | 0.53 | 0.02 | 0.00155 |
| | | | 0.675 | 0.565 | 0.20 | 1.54 | 0.07 | 0.00484 | 0.57 | 0.03 | 0.00179 |
| | | | 0.725 | 0.517 | 0.18 | 1.42 | 0.07 | 0.00479 | 0.59 | 0.03 | 0.00200 |
| | | | 0.775 | 0.470 | 0.17 | 1.31 | 0.06 | 0.00472 | 0.60 | 0.03 | 0.00218 |
| | | | 0.825 | 0.422 | 0.16 | 1.20 | 0.06 | 0.00463 | 0.61 | 0.03 | 0.00235 |
| | | | 0.875 | 0.374 | 0.15 | 1.11 | 0.05 | 0.00452 | 0.61 | 0.03 | 0.00249 |
| | | | 0.925 | 0.327 | 0.14 | 1.02 | 0.05 | 0.00438 | 0.61 | 0.03 | 0.00261 |
| | | | 0.975 | 0.279 | 0.14 | 0.93 | 0.04 | 0.00422 | 0.60 | 0.03 | 0.00271 |
| | | | Overall p(collision) = | | | | Upwind | 8.5% | Downwind | 3.9% | |
| | | | | | | | Average | 6.2% | | | |

Table 6.25: Calculation of collision risk for Hen Harrier Non-Breeding Season 2018/2019.

| Hen Harrier, Winter VP Surveys: 2018-2019 | | | | |
|---|----------------------|---------------------------|----------------------|-------------|
| Measurements | Code | Value | | |
| Rotor radius (metres) | R | 77.5 | | |
| Rotor diameter (metres) | RD | 155 | | |
| Max chord width of turbine blades (metres) | d | 4.5 | | |
| Bird length (metres) | l | 0.48 | | |
| Average flight speed (m/s) | s | 12 | | |
| Daily Duration of Activity (hrs) | T ₀₀ | 10 | | |
| Length of Season (days) | T _{ss} | 181 | | |
| Wingspan (m) | | 1.1 | | |
| Mean pitch of blade (degrees) | | 13 | | |
| Rotors per turbine | | 3 | | |
| Rotational period (seconds) | | 5.36 | | |
| Turbine operational time (%) | | 85 | | |
| | | | Vantage Point | |
| | | | VP 1 | VP 2 |
| Total Survey time over 6 months (secs) | T | | 119700 | 131400 |
| Total flight at Rotor Height 20 - 180m (bird-secs) | sPCH | | 0 | 25 |
| No. of turbines in viewshed | x | | 4 | 2 |
| Survey area visible from VP (hectares) | Avp | | 400 | 376 |
| Flight Risk Area, i.e. 500m buffer of turbines within viewshed (hectares) | Afr | | 274.18 | 128.98 |
| Availability of species activity during survey period (hrs) | Sa | | 1810 | 1810 |
| Stage 1 Calculations | | | | |
| Measurements | Code | Calculation | | |
| Proportion of Bird flight-time between 20 - 180m | t | sPCH/T | 0 | 0.000190259 |
| Flight activity in visible area per hectare | F | t/Avp | 0 | 5.06007E-07 |
| Proportion of Bird flight time in Risk Area | Trisk | F*Afr | 0 | 6.52648E-05 |
| Bird occupancy of Risk Area (hrs/season) | n | Trisk*Sa | 0 | 0.118129331 |
| Flight Risk volume (m ³) | Vw | (Afr*RD)*10000 | 424979000 | 199919000 |
| Actual volume of air swept by rotors (m ³) | o | $x*(\pi r^2(d+l))$ | 375683.73 | 187841.865 |
| Bird occupancy of rotor swept area (bird-secs) | b | $3600*(n*(o/Vw))$ | 0 | 0.399575239 |
| Time taken for Bird to pass through rotors (secs) | v | (d+l)/s | 0.415 | 0.415 |
| Number of Bird passes through the rotor during survey period | N | b/v | 0 | 0.9628319 |
| Total transits adjusted for maximum operation of turbines (85%) | Tn | N*0.85 | 0 | 0.818407115 |
| Number of transits per turbine within viewshed | TnT | Tn/x | 0 | 1.636814231 |
| | | | | |
| Average TnT of all VP's (VP 1-2) | ATnT | (TnT1+TnT2+TnT3+.....)/2 | 0.818407115 | |
| Number of transits across windfarm | NT | ATnT*(Total no. turbines) | 4.092035576 | |
| | | | | |
| Stage 2 Calculation | | | | |
| Calculation | Result | | | |
| Collision Probability (%) | (Model) | 6.10% | | |
| Collisions during study period | NT*Collision Probabi | 0.25 | | |
| Collisions during study period with 99% Avoidance Rate | *0.01 | 0.002496142 | | |
| Over 30-year duration of windfarm | *30 | 0.074884251 | | |

Table 6.26: Number of collisions predicted for Hen Harrier with the application of avoidance rates.

| Species | Year | Predicted collisions per season with avoidance rates applied | | | Predicted collisions over 30-year lifetime of the windfarm | | |
|-------------|---------|--|--------|-------|--|--------|-------|
| | | Breeding | Winter | Total | Breeding | Winter | Total |
| Hen Harrier | 2017/18 | 0.000 | 0.001 | 0.001 | 0.000 | 0.017 | 0.017 |
| | 2018/19 | 0.000 | 0.002 | 0.002 | 0.000 | 0.075 | 0.075 |

Table 6.27: Mean number of collisions predicted for Hen Harrier with avoidance rates.

| Target Species Biometrics | | | |
|---------------------------|---|---|--------------------------------------|
| Species Name | Mean no. of predicted collisions per year | Mean no. of predicted collisions per 30 years | Equivalent to 1 bird every x (years) |
| Hen Harrier (HH) | 0.002 | 0.046 | 500 |