Appendix 7.6 – Collision Risk Assessment

Derrinlough Wind Farm

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1. INTRODUCTION

This document has been prepared by McCarthy Keville O'Sullivan Ltd. to assess the collision risk for birds at the proposed Derrinlough Wind Farm Site, Co. Offaly. The collision risk assessment, prepared by Mr David Naughton (BSc), is based on vantage point watch surveys undertaken at the development site from October 2017 up to and including September 2019. This represents a 24-month survey period, consisting of two breeding seasons and two non-breeding seasons, in full compliance with SNH (2017)[1]. Surveys were undertaken from ten fixed Vantage Point (VP) Locations, (i.e. VP1 – VP10) between October 2017 and September 2019.

Bird data gathered from VP1 and VP9 was not included in Collision Risk Modelling (CRM) calculations as these VPs did not contribute any coverage of the proposed turbine locations or 500m of same. Areas of sensitive habitat, including the Drinagh and Clooneen wetlands were constrained out of the design process for turbine locations due to the sensitivity of these areas from an ornithological and habitats perspective. However, these areas were continuously surveyed, through surveys at VP1 and VP9, in order to develop an understanding of bird activity levels in these areas, more than 500m from the proposed turbines.

Collision risk is calculated using a mathematical model to predict the numbers of individual birds, of a particular species, that may be killed by collision with moving wind turbine rotor blades. The modelling method used in this collision risk calculation follows Scottish Natural Heritage (SNH) guidance which is sometimes referred to as the Band Model (Band et al. 2007). The Band model has been the subject of academic assessment (e.g. Chamberlain et al., (2005 & 2006), Madders & Whitfield (2006), Drewitt & Langston (2006), Fernley, Lowther & Whitfield (2006)) and its results must be interpreted with a degree of caution.

Two stages are involved in the model:

> Stage 1: Estimation of the number of birds or flights passing through the air space swept by the rotor blades of the wind turbines. Transits are calculated using either the "**Regular or Random Flight**" model, depending on flight distribution and behaviour.
> Stage 2: Calculation of the probability of a bird strike occurring. Calculated using a statistical spreadsheet which considers avian biometrics and turbine parameters. This spreadsheet is publicly available on the SNH website. https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision

The product of Stage 1 and Stage 2 gives a theoretical annual collision mortality rate and is based on the assumption that birds make no attempt to avoid colliding with turbines.

An informal third stage is then applied to the generated outcome of Stage 1 and Stage 2. This third stage is to account for a "real life" scenario, i.e. to account for the avoidance measures taken by each bird species, worked out as percentage applied to the product of stage 1 and 2. This third "informal" stage is often the most important factor of collision risk modelling. For several years, SNH advocated a highly precautionary approach, recommending a value of 95% as an avoidance rate (Band et al., (2007)). However, based on empirical evidence and continuous studies and literature, precautionary rates have now been increased to 98-99% or higher in most cases and are regularly evolving with further examination of bird behaviour and mortality rates at windfarm sites. The most recently recommended species' avoidance rates can be found on the SNH website at https://www.nature.scot/wind-farm-impacts-birds-guidance-avoidance-rates-guidance.

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[1] *SNH (2017). Recommended bird survey methods to inform impact assessment of onshore wind farms. Scottish Natural Heritage.*

2. **METHODOLOGY**

Two forms of collision risk modelling are considered when referencing the Band Model. These are often referred to as the **"Regular Flight Model"** and the **"Random Flight Model"**. The "Regular Flight Model" is generally applied to a suite of flightlines which form a regular pattern such as a commuting corridor between roosting and feeding grounds or migratory routes. As such the "Regular Flight Model" is typically relevant for waterbird species, particularly geese and swans. The "Random Flight Model" is relevant for scenarios whereby no discernible patterns or flight routes can be associated with a species within the study area. Random flights can occur for any species but is most prevalent when examining foraging or hunting flight behaviour.

> **"Random Flight Model"** examines the predicted number of transits through the windfarm by regarding all flights within the viewshed (i.e. a 2km arc of the vantage point) as randomly occurring. This model therefore assumes that any observed flight could just as easily occur within the windfarm site as outside it. Any flights recorded as flying within the rotor swept height inside the 2km arc of the vantage point is to be included in the model.
> This model has a number of key assumptions and limitations;

> 1. *Bird activity is not spatially explicit, i.e. activity is equal throughout the viewshed area and this is equal to activity in the windfarm area.*
> 2. *Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the windfarm.*
> 3. *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 30m, the viewshed coverage displaying the visibility of the area within the 2km arc at a height of 30m 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 AVP calculation in the model is therefore highly precautionary as it likely to have been a larger area of coverage for much of the flight activity.*

> **"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 2-dimesional line represents a "risk window" which is the width of the windfarm plus a 500m buffer of the turbines, multiplied by the rotor diameter. All commuting flights which pass through this risk window, within the swept height of the turbines, are included in collision risk modelling. Any regular flights more than 500m from the turbine layout can be excluded from analysis.
> This model has a number of key assumptions and limitations;

> 1. *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.*
> 2. *It is assumed that bird activity is spatially explicit.*
> 3. *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).*

More detail on both the Random and Regular Flight Model calculations are publicly available and can be found on the SNH website. https://www.nature.scot/wind-farm-impacts-birds-calculating-theoretical-collision-risk-assuming-no-avoiding-action.

In the case of all species observed during surveys for the proposed Derrinlough wind farm, flights recorded from surveys were classified for the purpose of the analysis as randomly distributed flights which could occur anywhere within the given viewsheds, unless there was an ecological justification that the flights were not random. Therefore the "Random Flight Model" was applied to these species to calculate the predicted number of transits through the windfarm site.

However, some flight activity was not included in the analysis as it was associated with distinct landscape features away from proposed turbine locations. The flight activity of water birds (e.g. golden plover, whooper swan, lapwing, black-headed gull, etc.) around the Drinagh wetlands more than 500m to the east of the nearest turbine is considered to be directly associated with the optimal foraging habitat found in this area. The flight activity of water birds in this portion of the site is not considered to be random but rather directly related to the preference of water birds for wetland sites for foraging, breeding and roosting. Similar habitat is not found within 500m of proposed turbine locations. It was considered that flight activity of waders and waterfowl within the Drinagh wetlands is not random and therefore should be excluded from the CRM calculations. All remaining flight activity within the proposed development site, either within 500m of turbines or not has been assumed as randomly occurring due to the similar nature of habitats in these areas and lack of defined flight patterns.

The steps used to derive the collision mortality risk for each species observed at the proposed development according to the Band Model are outlined below:

1. Stage 1 (Band): the 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.

2. Stage 2 (Band): the model calculates the collision risk for an individual bird flying through a rotating turbine blade. The collision risk depends on the species biometrics and flight behaviour. Bird biometrics are available from the British Trust of Ornithology (BTO) online bird collision risk guidance, while flight speeds have been referenced from Alerstam et al. (2007).

3. The product of the number of birds calculated to fly through the turbines in a year multiplied by the collision risk (i.e. that a bird doing so will collide with the moving blades) gives the worst-case scenario for collision mortality. The worst-case scenario assumes that birds flying towards the turbines make no attempt to avoid them.

4. An avoidance factor is applied to the results to account for avoidance of the turbines by birds in flight. This corrects for the ability of the birds to detect and manoeuvre around the turbines. Avoidance rates are available from SNH online bird collision risk guidance (SNH 2018).

5. This final output after all steps to the model is a real-world estimation of the number of collisions that may occur at the wind farm based on observed bird activity during the survey period.

The Band Method makes a number of assumptions on the biometrics of birds and the turbine design. These are:

> Birds are assumed to be of a simple cruciform shape.
> Turbine blades are assumed to have length, depth and pitch angle, but no thickness.
> Birds fly through turbines in straight lines.
> Bird flight is not affected by the slipstream of the turbine blade.
> Because the model assumes that no action is taken by a bird to avoid collision, it is recognised that the collision risk figures derived are purely theoretical and represent worst case estimates.

Several assumptions were made in the calculation of collision risk for the proposed Derrinlough Windfarm. These assumptions are tailored specifically to Derrinlough and are as follows:

> Birds in flight within the study area at heights greater than 25m above ground level are assumed to be in danger of collision with the rotating turbine blades.

> Avoidance factors of individual species are those currently recommended by SNH (2018). An avoidance factor is applied to the results to account for avoidance of the turbines by birds in flight. This corrects for the ability of the birds to detect and manoeuvre around the turbines.

> 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 species such as whooper swan, lapwing and golden plover; 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 competitive tendering process is complete, 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 Derrinlough Windfarm Site are presented in Table 1.

Table 1 Windfarm Parameters at Derrinlough Wind Farm

Wind Farm Component	Scenario Modelled
Assumed turbine model	GE 3.6-137 Turbine
Number of turbines	21
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	150
Rotor radius (m)	75
Hub height (m)	110
Swept height (m)	35 - 185
*Mean pitch of blade (degrees)	25
Maximum chord (m) (i.e. depth of blade)	4.0
Max Tip Speed (m/s)	82
Circumference of Blade Tip (Pi*Rotor Diameter)	471.2
Rotational period (s) [430.4/82]	5.75
**Turbine operational time (%)	85%

**This operational period of 85% is referenced from a report by the British Wind Energy Association (BWEA) (2007) which identifies the standard operational period of the wind turbines in the UK to be roughly 85%.

*Pitch of Blade used in the Analysis

It is acknowledged that pitch angle is determined by wind speeds which is something that is variable across seasons, and a range of geographical areas. Wind speed versus the desired turbine rpm determines blade pitch. There is a specific pitch angle for any given wind speed to optimise output power. Typically speaking, the higher the wind speeds are, the higher the angle of the pitch.

This figure of 25 degrees is from Band (2012) where it is quoted that a standard figure for pitch for most large modern turbines would be between 25 – 30 degrees. This figure is considered highly precautionary however as the paper examines collision risk modelling for offshore windfarms, where windspeeds would be expected to be much higher than an onshore windfarm site in County Offaly.

3. # RESULTS

Collison estimates were calculated using flight data recorded during vantage point watches at eight vantage point locations (VP2, VP3, VP4, VP5, VP6, VP7, VP8 and VP10) within the study area between October 2017 and September 2019. The target species recorded within the potential collision risk zone included whooper swan, golden plover, hen harrier, little egret, peregrine, lapwing, black-headed gull, curlew, buzzard, sparrowhawk, kestrel and snipe. It is acknowledged that the predicted number of transits, and hence predicted rate of collision for snipe may be underestimated, as flight activity for this species is largely crepuscular in nature (during twilight) while the VP survey sample predominantly consists of hours during daylight period when visibility is not an issue (Table 1.4, SNH (2017)).

The calculation parameters are outlined in Tables 2 – 8. A fully worked example of the calculation of collision risk for wintering lapwing populations is available in Appendix 1.

Table 2 Derrinlough Windfarm VP Survey Effort and Viewshed Coverage

Vantage Point	Visible Area at 25m (hectares)	Risk Area (hectares)	Turbines visible from VP	Total Survey Effort (hrs)
VP2	628	326.4	6	145.75
VP3	628	139.7	2	145.5
VP4	628	288.8	3	149
VP5	568	109.9	2	150
VP6	489.5	145.1	3	148.75
VP7	605	64.87	1	144.5
VP8	628	46.1	1	143
VP10	628	453.5	8	144

Table 3 Bird Biometrics (Taken from BTO BirdFacts & Alerstam et al. (2007)) and duration at PCH during VP Surveys

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (>25m)
Whooper Swan (Winter)	1.52	2.30	17.3	8,190
Golden Plover (Winter)	0.28	0.72	17.9	275,725
Hen Harrier (Winter)	0.48	1.10	9.1	180
Little Egret	0.60	0.92	10.2	270
Peregrine (Winter)	0.42	1.02	12.1	1,347
Lapwing (Breeding)	0.30	0.84	11.9	2,908
Lapwing (Winter)	0.30	0.84	11.9	66,757

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (>25m)
Black-headed Gull (Breeding)	0.36	1.05	11.9	32,946
Curlew	0.55	0.90	16.3	2,483
Buzzard	0.54	1.20	13.3	68,540
Sparrowhawk	0.33	0.62	10.0	3,456
Kestrel	0.34	0.76	10.1	13,269
Snipe	0.26	0.46	17.1	1,004

Seconds in flight at PCH is calculated by multiplying the number of birds observed per flight by the duration of the flight spent within the height bands 25-175m and >175m.

Table 4 Random CRM - Number of Transits per Turbine within the Viewshed of each VP

Species	VP2	VP3	VP4	VP5	VP6	VP7	VP8	VP10
*Whooper Swan (Winter)	12.52		20.56		61.74			80.62
*Golden Plover (Winter)	1,823.18	1,291.25		562.05	781.82	1,270.35		210.63
Hen Harrier (Winter)				0.45				1.48
Little Egret			1.71		1.76			
Peregrine (Winter)		10.4	2.9	2.97	1.04			1.69
*Lapwing (Breeding)		2.23	27.76		20.95			7.65
*Lapwing (Winter)	62.9		0.53	60.03	440.94			471.01
Black-headed Gull (Breeding)	0.58		112.84		32.43	64.84	10.47	331.63
*Curlew							55.07	
Buzzard	200.12	175.55	35.17	105.27	157.97	162.28	89.55	89.66
Sparrowhawk	9.28	11.2	4.58	2.15	5.48	2.2	2.79	3.16
Kestrel	5.61	5.54	14.55	8.52	23.74	31.12	26.55	45.16
*Snipe			13.49			9.56		

*Assumed to be active 25% of the night as well as daylight hours as per SNH guidance accounting for Swan/Goose and Wader activity. This is calculated as a portion of the length of night for the survey period provided by www.timeanddate.com and is added to available hours for activity of the species per year.

Table 5 Number of Transits across site per year (Averages calculated from Table 4 Above and adjusted for all 21 turbines)

Species	Average Transits	Transits Across Entire Site (All 21 Turbines) (Average Transits*21)
Whooper Swan (Winter)	21.93	460.52
Golden Plover (Winter)	742.41	15,590.61

Species	Average Transits	Transits Across Entire Site (All 21 Turbines) (Average Transits*21)
Hen Harrier (Winter)	0.24	5.06
Little Egret	0.43	9.09
Peregrine (Winter)	2.37	49.87
Lapwing (Breeding)	7.32	153.79
Lapwing (Winter)	129.43	2,717.96
Black-headed Gull (Breeding)	69.10	1,451.05
Curlew	6.88	144.55
Buzzard	136.41	2,864.69
Sparrowhawk	5.10	107.18
Kestrel	20.10	422.08
Snipe	2.88	60.50

Table 6 Collision Risk Workings (Both Flapping and Gliding Flights took the average Collision Risk Percentage between upwind and downwind)

Species	Flapping Flight	Gliding Flight	Collision Risk [(Flapping + Gliding)/2]
Whooper Swan (Winter)	8.5%	N/A	8.5%
Golden Plover (Winter)	4.6%	N/A	4.6%
Hen Harrier (Winter)	8.6%	8.5%	8.5%
Little Egret	8.3%	8.3%	8.3%
Peregrine (Winter)	6.5%	N/A	6.5%
Lapwing (Breeding & Wintering)	6.1%	N/A	6.1%
Black-headed Gull (Breeding)	6.4%	6.2%	6.3%
Curlew	5.6%	5.5%	5.5%
Buzzard	6.6%	6.4%	6.5%
Sparrowhawk	7.1%	N/A	7.1%
Kestrel	7.1%	N/A	7.1%
Snipe	4.5%	N/A	4.5%

*Table 7 Collision Probability assuming no Avoidance (Transits*Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Whooper Swan (Winter)	8.5%	460.52	39.28
Golden Plover (Winter)	4.6%	15,590.61	709.53
Hen Harrier (Winter)	8.5%	5.06	0.43
Little Egret	8.3%	9.09	0.75
Peregrine (Winter)	6.5%	49.87	3.26
Lapwing (Breeding)	6.1%	153.79	9.36
Lapwing (Winter)	6.1%	2,717.96	165.34
Lapwing (Combined/All Year)	6.1%	2,871.76	174.69
Black-headed Gull (Breeding)	6.3%	1,451.05	91.61
Curlew	5.5%	144.55	8.00
Buzzard	6.5%	2,864.69	185.64
Sparrowhawk	7.1%	107.18	7.56
Kestrel	7.1%	422.08	29.91
Snipe	4.5%	60.50	2.71

Table 8 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Whooper Swan	39.28	99.5%	0.196	5.89	Winter/Passage (Oct-Mar)
Golden Plover	709.53	98%	14.191	425.72	Winter/Passage (Oct-Mar)
Hen Harrier	0.43	99%	0.004	0.13	Winter/Passage (Oct-Mar)
Little Egret	0.75	98%	0.015	0.45	All year
Peregrine	3.26	98%	0.065	1.95	All year
Lapwing	9.36	98%	0.187	5.61	Breeding (Apr – Aug)
Lapwing	165.34	98%	3.307	99.20	Winter/Passage (Sep-Mar)
Lapwing	174.69	98%	3.494	104.81	All year (Combined)
Black-headed Gull	91.61	98%	1.832	54.97	Breeding (Apr – Sep)
Curlew	8.00	98%	0.160	4.80	All year
Buzzard	185.64	98%	3.713	111.38	All year
Sparrowhawk	7.56	98%	0.151	4.54	All year
Kestrel	29.91	95%	1.496	44.87	All year
Snipe	2.71	98%	0.054	1.62	All year

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https://www.timeanddate.com/sun/

APPENDIX 1

WORKED EXAMPLE OF COLLISION RISK CALCULATION (RANDOM FLIGHT MODEL) – LAPWING (WINTER)

Stage 1 (Transits through rotors per year) [Using figures from VP2 Column]

Table 9 Standard Measurements (Specific to Lapwing, Windfarm Site, Turbines modelled & VP2)

Description	Value	Units
Survey area visible from VP (Hectares) [At 25m]	Avp	628
Survey Time at VP2 September – March (secs) (Winter Months)	s	308,700
Bird observation time at >25m (secs)	PCH	4,488
Rotor Radius (metres)	r	75
Rotor Diameter (metres)	D	150
Max chord width of turbine blade (metres)	d	4.0
No. of turbines in viewshed of VP2	x	6
Bird length in metres (lapwing) [Taken from BTO online]	l	0.30
Ave. Flight speed of lapwing (m/s) [Allerstam et al. 2007]	v	11.9
500m buffer of turbines within viewshed, i.e. Area of Risk (Hectares)	Arisk	326.4
Availability of species activity during survey period (hours) [Daylight hours]	Ba	6,333.83

Table 10 CRM Stage 1 Calculations using Standard Measurements in Table 1

Description	Value	Formula	Units
Proportion of time in flight >25m	t1	PCH/s	0.014538387
Flight activity per visible unit of area	F	t1/Avp	2.32E-05
Proportion of time in risk area	Trisk	F*Arisk	7.556E-03
Bird occupancy of risk area	n	Trisk*Ba	47.86004778
Risk volume (Area of risk*Rotor Diameter)	Vw	(Arisk*D)*10,000	489600000
Actual volume of air swept by rotors	o	X*(Pi*r2(d+l))	455923.6339
Bird occupancy of rotor swept area (seconds)	b	3600*(n*(o/Vw))	160.4450507
Time taken for bird to pass through rotors (seconds)	t2	(d+Bl)/v	0.361344538
Number of bird passes through the rotor in the survey period	N	b/t2	444.0223497

Description	Value	Formula	Units
Total transits adjusted for max annual Turbine Operation Time (85% in this case)	Tn	N*0.85	377.42
Number of transits per turbine within viewshed of VP2	TnT1	Tn/x	62.90

Table 11 CRM Stage 1 Calculations – Number of transits through windfarm

Description	Value	Formula	Units
Number of transits per turbine with viewshed of VP2	**TnT1**	**Tn/x**	**62.90**
Number of transits per turbine with viewshed of VP3	TnT2	Tn/x	0
Number of transits per turbine with viewshed of VP4	TnT3	Tn/x	0.53
Number of transits per turbine with viewshed of VP5	TnT4	Tn/x	60.03
Number of transits per turbine with viewshed of VP6	TnT5	Tn/x	440.94
Number of transits per turbine with viewshed of VP7	TnT6	Tn/x	0
Number of transits per turbine with viewshed of VP8	TnT7	Tn/x	0
Number of transits per turbine with viewshed of VP10	TnT8	Tn/x	471.01
Average transits per turbine for all VPs	ATnT	(TnT1+TnT2........+TnT8)/8	129.43
Predicted number of transits through windfarm site (All 21 turbines)	T	ATnT*21	2,717.96

Transits through rotors for the species in a one-year period across the site

2,717.96

Stage 2 (Collision Probability)

Calculation of the probability of the birds colliding with the turbine rotors:

The probability of a bird colliding with the turbine blades when making a transit through a rotor depends on a number of estimated factors. These factors include the avoidance factor 98% – the ability of birds to take evasive action when coming close to wind turbine blades.

In the calculations, the length of a lapwing was taken to be 0.30 metres and the wingspan 0.84 metres. The flight velocity of the bird is assumed to be 11.9 metres per second. The maximum chord of the blades is taken to be 4.0 metres, variable pitch is assumed to be 25 degrees and the average rotation cycle is taken to be 5.25 seconds per rotation, depending on wind conditions. A probability, $\rho\,(r, \varphi)$, of collision for a bird at radius r from the hub and at a position along a radial line that is at angle φ from the vertical is calculated. This probability is then integrated over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the disc. Scottish Natural Heritage (SNH) have made available a spreadsheet to aid the calculation of these probabilities as referenced previously. For a full explanation of the calculation methods see Band et al. (2007). The results of these calculations for all species are shown in Table 8 above.

Collision Probability*

6.1%

*This is calculated using the SNH collision risk probability model at https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision

Collisions per year

The annual theoretical collision rate assuming no avoidance = Transits (T)*Collision probability

165.34

The annual theoretical collision rate assuming 98% avoidance (165.34*0.02)

3.31

Theoretical collision rate assuming 98% avoidance across the 30-year duration of the windfarm (3.31*30)

99.20