GLENBURNIE WIND FARM
AEI TECHNICAL APPENDIX 9.1: COLLISION RISK MODELLING CALCULATIONS

March 2025

AEI TECHNICAL APPENDIX 9.5: GLENBURNIE WIND FARM COLLISION RISK MODELLING CALCULATIONS

INTRODUCTION

This AEI Technical Appendix sets out the collision risk modelling that has been undertaken to support the ornithological assessment of the proposed Glenburnie Wind Farm (the revised proposed development) for the AEI. The collision risk modelling was carried out for all the key target species recorded flying through the collision risk zone at rotor height (as per SNH guidance 2018). Rotor height would be 50-200 m above ground level.

The 12-turbine revised proposed development has been reduced from 19 turbines as assessed in the EIA Report October 2023. The locations of the 12 remaining wind turbines has not changed, however the seven southernmost turbines have been deleted from the proposed layout. There will be no change to the wind turbine specifications. The proposed wind turbine locations and the collision risk zones are shown in **Figure 9.1.1**.

The modelling included the same species as for the EIA Report October 2023, i.e. five target raptor species (goshawk, red kite, golden eagle, marsh harrier and peregrine) and three breeding waders (curlew, lapwing and golden plover). The collision risk for each of these species was modelled using the non-direct flight model. In addition, wintering/migrating whooper swans, greylag geese, pink-footed geese and herring gulls were observed flying through the collision risk zone and were also modelled to determine their collision risk. As their flights were largely direct ones through the site, the direct flight model was applied. No other key species was recorded flying through the collision risk zone at rotor height.

The collision risk model used in this assessment (Band *et al.* 2007) was run as a two-stage process. Firstly, the risk is calculated making the assumption that flight patterns are unaffected by the presence of the wind turbines, i.e. that no avoidance action is taken. This is essentially a mechanistic calculation, with the collision risk calculated as the product of (i) the probability of a bird flying through the rotor swept area, and (ii) the probability of a bird colliding if it does so. This probability is then multiplied by the estimated numbers of bird movements through the wind farm rotors at the risk height (i.e. the height of the rotating wind turbine blades) in order to estimate the theoretical numbers at risk of collision if they take no avoiding action.

The second stage then incorporates the probability that the birds, rather than flying blindly into the wind turbines, will actually take a degree of avoiding action, as has been shown to occur in all studies of birds at existing wind farms. NatureScot has recommended a precautionary approach, using a value of 98% as a general default avoidance rate, 99% for some larger raptors (including red kite and hen harrier) and 99.8% for geese (SNH 2017). This precautionary approach is useful as an initial filter to identify sites where collision risk is clearly not an issue, but does not necessarily provide a realistic estimate of actual likely collision rates when compared with data from existing wind farms. The magnitude of the impact was determined as a percentage increase in the existing baseline mortality (to put the potential wind farm mortality into the ecological context of the birds' population dynamics), though professional judgement was also applied in the assessment of any non-negligible magnitude collision risks predicted.

Body sizes and baseline mortality rates were taken from Robinson (2005) and flight speeds from Alerstam *et al.* (2007).

BAND MODEL SPREADSHEETS (STAGE 1)

Firstly, the standard Band model spreadsheets (Band *et al*. 2007) are presented for each species modelled in turn. These provide the information used to calculate the risk that individuals of each

species would face if they flew through the revised proposed development rotor swept area. For the first species, for example, whooper swan, this gives an overall 6.7% chance of collision. This is unchanged from the EIA Report October 2023, as the individual wind turbine specifications would be the same.

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Whooper Swan											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	1.52	m	0.025	0.575	9.72	47.31	1.00	0.00125	45.97	1.00	0.00125
Wingspan	2.3	m	0.075	0.575	3.24	16.22	0.37	0.00281	14.88	0.34	0.00258
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.94	11.21	0.26	0.00324	9.58	0.22	0.00277
			0.175	0.860	1.39	9.38	0.22	0.00380	7.38	0.17	0.00299
Bird speed	17.3	m/sec	0.225	0.994	1.08	8.31	0.19	0.00432	5.99	0.14	0.00312
RotorDiam	170	m	0.275	0.947	0.88	6.77	0.16	0.00430	4.56	0.11	0.00290
RotationPeriod	7.50	sec	0.325	0.899	0.75	5.69	0.13	0.00427	3.59	0.08	0.00270
			0.375	0.851	0.65	4.91	0.11	0.00426	2.93	0.07	0.00254
			0.425	0.804	0.57	4.45	0.10	0.00438	2.58	0.06	0.00254
			0.475	0.756	0.51	4.08	0.09	0.00448	2.32	0.05	0.00255
Bird aspect ratio: b	0.66		0.525	0.708	0.46	3.77	0.09	0.00458	2.12	0.05	0.00257
			0.575	0.660	0.42	3.50	0.08	0.00466	1.96	0.05	0.00261
			0.625	0.613	0.39	3.27	0.08	0.00472	1.84	0.04	0.00266
			0.675	0.565	0.36	3.06	0.07	0.00478	1.75	0.04	0.00272
			0.725	0.517	0.34	2.88	0.07	0.00482	1.67	0.04	0.00280
			0.775	0.470	0.31	2.71	0.06	0.00485	1.61	0.04	0.00289
			0.825	0.422	0.29	2.55	0.06	0.00487	1.57	0.04	0.00299
			0.875	0.374	0.28	2.41	0.06	0.00487	1.54	0.04	0.00311
			0.925	0.327	0.26	2.27	0.05	0.00486	1.53	0.04	0.00327
			0.975	0.279	0.25	2.15	0.05	0.00484	1.54	0.04	0.00348
				Overall p(collision) =			**Upwind**	**8.5%**		**Downwind**	**5.5%**
								Average	**7.0%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Greylag Goose											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.82	m	0.025	0.575	9.61	40.43	0.95	0.00118	39.09	0.91	0.00114
Wingspan	1.64	m	0.075	0.575	3.20	13.92	0.33	0.00244	12.58	0.29	0.00221
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.92	9.83	0.23	0.00287	8.19	0.19	0.00240
			0.175	0.860	1.37	8.38	0.20	0.00343	6.38	0.15	0.00261
Bird speed	17.1	m/sec	0.225	0.994	1.07	7.52	0.18	0.00396	5.21	0.12	0.00274
RotorDiam	170	m	0.275	0.947	0.87	6.13	0.14	0.00394	3.92	0.09	0.00252
RotationPeriod	7.50	sec	0.325	0.899	0.74	5.15	0.12	0.00391	3.05	0.07	0.00232
			0.375	0.851	0.64	4.41	0.10	0.00387	2.43	0.06	0.00213
			0.425	0.804	0.57	3.84	0.09	0.00381	1.96	0.05	0.00195
			0.475	0.756	0.51	3.37	0.08	0.00374	1.61	0.04	0.00179
Bird aspect ratio: b	0.50		0.525	0.708	0.46	3.05	0.07	0.00375	1.40	0.03	0.00172
			0.575	0.660	0.42	2.79	0.07	0.00375	1.25	0.03	0.00168
			0.625	0.613	0.38	2.56	0.06	0.00374	1.13	0.03	0.00165
			0.675	0.565	0.36	2.35	0.06	0.00371	1.04	0.02	0.00164
			0.725	0.517	0.33	2.17	0.05	0.00368	0.96	0.02	0.00163
			0.775	0.470	0.31	2.00	0.05	0.00362	0.91	0.02	0.00164
			0.825	0.422	0.29	1.85	0.04	0.00356	0.86	0.02	0.00166
			0.875	0.374	0.27	1.70	0.04	0.00348	0.83	0.02	0.00170
			0.925	0.327	0.26	1.57	0.04	0.00339	0.83	0.02	0.00180
			0.975	0.279	0.25	1.44	0.03	0.00329	0.85	0.02	0.00193
				Overall p(collision) =			**Upwind**	**6.9%**		**Downwind**	**3.9%**
								Average	**5.4%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Pink-footed Goose											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.68	m	0.025	0.575	9.72	39.73	0.92	0.00115	38.39	0.89	0.00111
Wingspan	1.52	m	0.075	0.575	3.24	13.69	0.32	0.00237	12.35	0.29	0.00214
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.94	9.70	0.22	0.00280	8.06	0.19	0.00233
			0.175	0.860	1.39	8.30	0.19	0.00336	6.30	0.15	0.00255
Bird speed	17.3	m/sec	0.225	0.994	1.08	7.47	0.17	0.00388	5.15	0.12	0.00268
RotorDiam	170	m	0.275	0.947	0.88	6.08	0.14	0.00387	3.88	0.09	0.00246
RotationPeriod	7.50	sec	0.325	0.899	0.75	5.10	0.12	0.00384	3.01	0.07	0.00226
			0.375	0.851	0.65	4.37	0.10	0.00379	2.39	0.06	0.00207
			0.425	0.804	0.57	3.80	0.09	0.00374	1.93	0.04	0.00190
			0.475	0.756	0.51	3.34	0.08	0.00367	1.58	0.04	0.00173
Bird aspect ratio: b	0.45		0.525	0.708	0.46	2.95	0.07	0.00358	1.30	0.03	0.00158
			0.575	0.660	0.42	2.66	0.06	0.00354	1.12	0.03	0.00149
			0.625	0.613	0.39	2.43	0.06	0.00351	1.00	0.02	0.00145
			0.675	0.565	0.36	2.22	0.05	0.00347	0.91	0.02	0.00141
			0.725	0.517	0.34	2.04	0.05	0.00341	0.83	0.02	0.00139
			0.775	0.470	0.31	1.87	0.04	0.00335	0.77	0.02	0.00139
			0.825	0.422	0.29	1.71	0.04	0.00326	0.73	0.02	0.00139
			0.875	0.374	0.28	1.57	0.04	0.00317	0.70	0.02	0.00141
			0.925	0.327	0.26	1.43	0.03	0.00307	0.69	0.02	0.00147
			0.975	0.279	0.25	1.31	0.03	0.00295	0.70	0.02	0.00158
				Overall p(collision) =			**Upwind**	**6.6%**		**Downwind**	**3.6%**
								Average	**5.1%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Red Kite											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.63	m	0.025	0.575	6.74	29.99	1.00	0.00125	28.65	0.95	0.00119
Wingspan	1.85	m	0.075	0.575	2.25	10.44	0.35	0.00261	9.10	0.30	0.00228
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.35	7.42	0.25	0.00309	5.79	0.19	0.00241
			0.175	0.860	0.96	6.38	0.21	0.00372	4.38	0.15	0.00255
Bird speed	12	m/sec	0.225	0.994	0.75	5.78	0.19	0.00434	3.46	0.12	0.00260
RotorDiam	170	m	0.275	0.947	0.61	4.76	0.16	0.00436	2.55	0.09	0.00234
RotationPeriod	7.50	sec	0.325	0.899	0.52	4.03	0.13	0.00437	1.94	0.06	0.00210
			0.375	0.851	0.45	3.49	0.12	0.00436	1.50	0.05	0.00188
			0.425	0.804	0.40	3.05	0.10	0.00433	1.18	0.04	0.00168
			0.475	0.756	0.35	2.70	0.09	0.00428	0.94	0.03	0.00149
Bird aspect ratio: b	0.34		0.525	0.708	0.32	2.44	0.08	0.00427	0.79	0.03	0.00139
			0.575	0.660	0.29	2.24	0.07	0.00429	0.70	0.02	0.00135
			0.625	0.613	0.27	2.06	0.07	0.00430	0.63	0.02	0.00132
			0.675	0.565	0.25	1.90	0.06	0.00428	0.67	0.02	0.00152
			0.725	0.517	0.23	1.76	0.06	0.00424	0.71	0.02	0.00172
			0.775	0.470	0.22	1.62	0.05	0.00419	0.73	0.02	0.00189
			0.825	0.422	0.20	1.50	0.05	0.00411	0.75	0.02	0.00205
			0.875	0.374	0.19	1.38	0.05	0.00402	0.75	0.03	0.00220
			0.925	0.327	0.18	1.27	0.04	0.00391	0.75	0.03	0.00232
			0.975	0.279	0.17	1.16	0.04	0.00378	0.75	0.02	0.00242
				Overall p(collision) =			**Upwind**	**7.8%**		**Downwind**	**3.9%**
								Average	**5.8%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Goshawk											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.55	m	0.025	0.575	6.35	26.06	0.92	0.00115	24.72	0.87	0.00109
Wingspan	1.5	m	0.075	0.575	2.12	9.13	0.32	0.00242	7.79	0.28	0.00207
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.27	6.59	0.23	0.00292	4.96	0.18	0.00219
			0.175	0.860	0.91	5.75	0.20	0.00356	3.75	0.13	0.00232
Bird speed	11.3	m/sec	0.225	0.994	0.71	5.26	0.19	0.00419	2.95	0.10	0.00235
RotorDiam	170	m	0.275	0.947	0.58	4.34	0.15	0.00423	2.14	0.08	0.00208
RotationPeriod	7.50	sec	0.325	0.899	0.49	3.69	0.13	0.00424	1.59	0.06	0.00183
			0.375	0.851	0.42	3.19	0.11	0.00424	1.21	0.04	0.00160
			0.425	0.804	0.37	2.80	0.10	0.00421	0.93	0.03	0.00140
			0.475	0.756	0.33	2.53	0.09	0.00425	0.77	0.03	0.00129
Bird aspect ratio: b	0.37		0.525	0.708	0.30	2.31	0.08	0.00428	0.66	0.02	0.00122
			0.575	0.660	0.28	2.11	0.07	0.00430	0.57	0.02	0.00117
			0.625	0.613	0.25	1.94	0.07	0.00429	0.59	0.02	0.00130
			0.675	0.565	0.24	1.79	0.06	0.00427	0.63	0.02	0.00151
			0.725	0.517	0.22	1.64	0.06	0.00422	0.66	0.02	0.00169
			0.775	0.470	0.20	1.51	0.05	0.00416	0.68	0.02	0.00186
			0.825	0.422	0.19	1.39	0.05	0.00407	0.69	0.02	0.00201
			0.875	0.374	0.18	1.28	0.05	0.00397	0.69	0.02	0.00214
			0.925	0.327	0.17	1.17	0.04	0.00384	0.69	0.02	0.00225
			0.975	0.279	0.16	1.07	0.04	0.00370	0.68	0.02	0.00234
				Overall p(collision) =			**Upwind**	**7.7%**		**Downwind**	**3.6%**
								Average	**5.6%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Golden Eagle											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.87	m	0.025	0.575	6.68	31.28	1.00	0.00125	29.94	1.00	0.00125
Wingspan	2.08	m	0.075	0.575	2.23	10.87	0.37	0.00274	9.53	0.32	0.00240
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.34	7.67	0.26	0.00322	6.04	0.20	0.00254
			0.175	0.860	0.95	6.56	0.22	0.00386	4.55	0.15	0.00268
Bird speed	11.9	m/sec	0.225	0.994	0.74	5.91	0.20	0.00447	3.60	0.12	0.00272
RotorDiam	170	m	0.275	0.947	0.61	4.87	0.16	0.00450	2.66	0.09	0.00246
RotationPeriod	7.50	sec	0.325	0.899	0.51	4.13	0.14	0.00451	2.03	0.07	0.00222
			0.375	0.851	0.45	3.57	0.12	0.00450	1.58	0.05	0.00200
			0.425	0.804	0.39	3.18	0.11	0.00454	1.31	0.04	0.00187
			0.475	0.756	0.35	2.91	0.10	0.00464	1.15	0.04	0.00183
Bird aspect ratio: b	0.42		0.525	0.708	0.32	2.67	0.09	0.00472	1.03	0.03	0.00181
			0.575	0.660	0.29	2.47	0.08	0.00478	0.94	0.03	0.00181
			0.625	0.613	0.27	2.30	0.08	0.00482	0.87	0.03	0.00183
			0.675	0.565	0.25	2.14	0.07	0.00485	0.92	0.03	0.00209
			0.725	0.517	0.23	1.99	0.07	0.00485	0.95	0.03	0.00233
			0.775	0.470	0.22	1.86	0.06	0.00484	0.98	0.03	0.00254
			0.825	0.422	0.20	1.73	0.06	0.00481	0.99	0.03	0.00275
			0.875	0.374	0.19	1.62	0.05	0.00475	1.00	0.03	0.00293
			0.925	0.327	0.18	1.51	0.05	0.00468	0.99	0.03	0.00309
			0.975	0.279	0.17	1.40	0.05	0.00460	0.99	0.03	0.00323
				Overall p(collision) =			**Upwind**	**8.6%**		**Downwind**	**4.6%**
								Average	**6.6%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Marsh Harrier											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.48	m	0.025	0.575	6.29	24.38	0.87	0.00109	23.04	0.82	0.00103
Wingspan	1.27	m	0.075	0.575	2.10	8.57	0.31	0.00230	7.23	0.26	0.00194
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.26	6.25	0.22	0.00279	4.62	0.16	0.00206
			0.175	0.860	0.90	5.50	0.20	0.00344	3.50	0.12	0.00219
Bird speed	11.2	m/sec	0.225	0.994	0.70	5.07	0.18	0.00407	2.75	0.10	0.00221
RotorDiam	170	m	0.275	0.947	0.57	4.18	0.15	0.00411	1.98	0.07	0.00194
RotationPeriod	7.50	sec	0.325	0.899	0.48	3.55	0.13	0.00412	1.46	0.05	0.00169
			0.375	0.851	0.42	3.08	0.11	0.00412	1.09	0.04	0.00146
			0.425	0.804	0.37	2.71	0.10	0.00411	0.84	0.03	0.00127
			0.475	0.756	0.33	2.45	0.09	0.00415	0.69	0.02	0.00117
Bird aspect ratio: b	0.38		0.525	0.708	0.30	2.23	0.08	0.00418	0.58	0.02	0.00108
			0.575	0.660	0.27	2.03	0.07	0.00418	0.50	0.02	0.00102
			0.625	0.613	0.25	1.86	0.07	0.00416	0.52	0.02	0.00117
			0.675	0.565	0.23	1.71	0.06	0.00412	0.57	0.02	0.00136
			0.725	0.517	0.22	1.57	0.06	0.00407	0.59	0.02	0.00154
			0.775	0.470	0.20	1.44	0.05	0.00399	0.61	0.02	0.00170
			0.825	0.422	0.19	1.32	0.05	0.00389	0.62	0.02	0.00183
			0.875	0.374	0.18	1.21	0.04	0.00378	0.62	0.02	0.00195
			0.925	0.327	0.17	1.10	0.04	0.00364	0.62	0.02	0.00204
			0.975	0.279	0.16	1.00	0.04	0.00348	0.61	0.02	0.00212
				Overall p(collision) =			**Upwind**	**7.4%**		**Downwind**	**3.3%**
								Average	**5.3%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Peregrine											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.42	m	0.025	0.575	6.80	24.59	0.81	0.00102	23.25	0.77	0.00096
Wingspan	1.02	m	0.075	0.575	2.27	8.64	0.29	0.00214	7.30	0.24	0.00181
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.36	6.35	0.21	0.00262	4.71	0.16	0.00195
			0.175	0.860	0.97	5.62	0.19	0.00325	3.62	0.12	0.00209
Bird speed	12.1	m/sec	0.225	0.994	0.76	5.19	0.17	0.00386	2.88	0.10	0.00214
RotorDiam	170	m	0.275	0.947	0.62	4.28	0.14	0.00389	2.07	0.07	0.00188
RotationPeriod	7.50	sec	0.325	0.899	0.52	3.62	0.12	0.00389	1.53	0.05	0.00164
			0.375	0.851	0.45	3.13	0.10	0.00388	1.15	0.04	0.00142
			0.425	0.804	0.40	2.75	0.09	0.00387	0.88	0.03	0.00124
			0.475	0.756	0.36	2.48	0.08	0.00389	0.71	0.02	0.00112
Bird aspect ratio: b	0.41		0.525	0.708	0.32	2.24	0.07	0.00389	0.59	0.02	0.00103
			0.575	0.660	0.30	2.04	0.07	0.00387	0.50	0.02	0.00095
			0.625	0.613	0.27	1.86	0.06	0.00384	0.43	0.01	0.00089
			0.675	0.565	0.25	1.70	0.06	0.00379	0.46	0.02	0.00103
			0.725	0.517	0.23	1.55	0.05	0.00371	0.50	0.02	0.00119
			0.775	0.470	0.22	1.41	0.05	0.00362	0.52	0.02	0.00133
			0.825	0.422	0.21	1.29	0.04	0.00352	0.53	0.02	0.00146
			0.875	0.374	0.19	1.17	0.04	0.00339	0.54	0.02	0.00156
			0.925	0.327	0.18	1.06	0.04	0.00324	0.54	0.02	0.00165
			0.975	0.279	0.17	0.96	0.03	0.00308	0.53	0.02	0.00172
				Overall p(collision) =			**Upwind**	**6.8%**		**Downwind**	**2.9%**
								Average	**4.9%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Golden Plover											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	7.70	25.44	0.74	0.00093	24.11	0.70	0.00088
Wingspan	0.72	m	0.075	0.575	2.57	8.93	0.26	0.00196	7.59	0.22	0.00166
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.54	6.62	0.19	0.00242	4.98	0.15	0.00182
			0.175	0.860	1.10	5.90	0.17	0.00302	3.90	0.11	0.00199
Bird speed	13.7	m/sec	0.225	0.994	0.86	5.47	0.16	0.00359	3.15	0.09	0.00207
RotorDiam	170	m	0.275	0.947	0.70	4.48	0.13	0.00360	2.28	0.07	0.00183
RotationPeriod	7.50	sec	0.325	0.899	0.59	3.79	0.11	0.00359	1.69	0.05	0.00161
			0.375	0.851	0.51	3.26	0.10	0.00357	1.28	0.04	0.00140
			0.425	0.804	0.45	2.84	0.08	0.00353	0.97	0.03	0.00121
			0.475	0.756	0.41	2.50	0.07	0.00347	0.74	0.02	0.00103
Bird aspect ratio: b	0.39		0.525	0.708	0.37	2.23	0.07	0.00342	0.58	0.02	0.00089
			0.575	0.660	0.33	2.01	0.06	0.00337	0.47	0.01	0.00079
			0.625	0.613	0.31	1.81	0.05	0.00331	0.39	0.01	0.00070
			0.675	0.565	0.29	1.64	0.05	0.00323	0.32	0.01	0.00063
			0.725	0.517	0.27	1.48	0.04	0.00313	0.29	0.01	0.00060
			0.775	0.470	0.25	1.33	0.04	0.00302	0.32	0.01	0.00072
			0.825	0.422	0.23	1.20	0.04	0.00289	0.34	0.01	0.00083
			0.875	0.374	0.22	1.07	0.03	0.00274	0.36	0.01	0.00092
			0.925	0.327	0.21	0.96	0.03	0.00258	0.37	0.01	0.00099
			0.975	0.279	0.20	0.84	0.02	0.00240	0.37	0.01	0.00104
				Overall p(collision) =			**Upwind**	**6.0%**		**Downwind**	**2.4%**
								Average	**4.2%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Lapwing											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.3	m	0.025	0.575	6.68	22.99	0.77	0.00097	21.65	0.73	0.00091
Wingspan	0.84	m	0.075	0.575	2.23	8.11	0.27	0.00204	6.77	0.23	0.00171
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.34	6.02	0.20	0.00253	4.38	0.15	0.00184
			0.175	0.860	0.95	5.37	0.18	0.00316	3.37	0.11	0.00198
Bird speed	11.9	m/sec	0.225	0.994	0.74	4.99	0.17	0.00378	2.68	0.09	0.00202
RotorDiam	170	m	0.275	0.947	0.61	4.11	0.14	0.00380	1.91	0.06	0.00176
RotationPeriod	7.50	sec	0.325	0.899	0.51	3.49	0.12	0.00381	1.39	0.05	0.00152
			0.375	0.851	0.45	3.01	0.10	0.00380	1.03	0.03	0.00130
			0.425	0.804	0.39	2.64	0.09	0.00377	0.77	0.03	0.00110
			0.475	0.756	0.35	2.34	0.08	0.00373	0.58	0.02	0.00092
Bird aspect ratio: b	0.36		0.525	0.708	0.32	2.10	0.07	0.00371	0.46	0.02	0.00080
			0.575	0.660	0.29	1.90	0.06	0.00368	0.37	0.01	0.00071
			0.625	0.613	0.27	1.73	0.06	0.00363	0.30	0.01	0.00063
			0.675	0.565	0.25	1.57	0.05	0.00355	0.35	0.01	0.00079
			0.725	0.517	0.23	1.42	0.05	0.00346	0.38	0.01	0.00094
			0.775	0.470	0.22	1.29	0.04	0.00335	0.41	0.01	0.00106
			0.825	0.422	0.20	1.16	0.04	0.00322	0.42	0.01	0.00116
			0.875	0.374	0.19	1.05	0.04	0.00308	0.43	0.01	0.00125
			0.925	0.327	0.18	0.94	0.03	0.00291	0.42	0.01	0.00132
			0.975	0.279	0.17	0.83	0.03	0.00273	0.42	0.01	0.00137
				Overall p(collision) =			**Upwind**	**6.5%**		**Downwind**	**2.5%**
								Average	**4.5%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Curlew											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.55	m	0.025	0.575	9.16	31.79	0.78	0.00098	30.45	0.75	0.00093
Wingspan	0.9	m	0.075	0.575	3.05	11.04	0.27	0.00203	9.71	0.24	0.00179
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.83	8.05	0.20	0.00247	6.41	0.16	0.00197
			0.175	0.860	1.31	7.07	0.17	0.00304	5.07	0.12	0.00218
Bird speed	16.3	m/sec	0.225	0.994	1.02	6.47	0.16	0.00357	4.15	0.10	0.00229
RotorDiam	170	m	0.275	0.947	0.83	5.28	0.13	0.00356	3.07	0.08	0.00207
RotationPeriod	7.50	sec	0.325	0.899	0.70	4.43	0.11	0.00354	2.34	0.06	0.00187
			0.375	0.851	0.61	3.80	0.09	0.00350	1.82	0.04	0.00167
			0.425	0.804	0.54	3.37	0.08	0.00351	1.50	0.04	0.00156
			0.475	0.756	0.48	3.01	0.07	0.00351	1.25	0.03	0.00146
Bird aspect ratio: b	0.61		0.525	0.708	0.44	2.72	0.07	0.00350	1.07	0.03	0.00138
			0.575	0.660	0.40	2.46	0.06	0.00347	0.92	0.02	0.00130
			0.625	0.613	0.37	2.24	0.05	0.00343	0.81	0.02	0.00125
			0.675	0.565	0.34	2.04	0.05	0.00338	0.72	0.02	0.00120
			0.725	0.517	0.32	1.86	0.05	0.00331	0.66	0.02	0.00117
			0.775	0.470	0.30	1.70	0.04	0.00323	0.61	0.01	0.00115
			0.825	0.422	0.28	1.55	0.04	0.00314	0.57	0.01	0.00115
			0.875	0.374	0.26	1.41	0.03	0.00303	0.56	0.01	0.00120
			0.925	0.327	0.25	1.28	0.03	0.00291	0.58	0.01	0.00131
			0.975	0.279	0.23	1.16	0.03	0.00277	0.59	0.01	0.00141
				Overall p(collision) =			**Upwind**	**6.2%**		**Downwind**	**3.0%**
								Average	**4.6%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Herring Gull											
Only enter input parameters in blue											
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	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.6	m	0.025	0.575	7.19	28.99	0.91	0.00113	27.65	0.86	0.00108
Wingspan	1.44	m	0.075	0.575	2.40	10.11	0.32	0.00237	8.77	0.27	0.00206
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.44	7.27	0.23	0.00284	5.64	0.18	0.00220
			0.175	0.860	1.03	6.32	0.20	0.00346	4.32	0.13	0.00236
Bird speed	12.8	m/sec	0.225	0.994	0.80	5.76	0.18	0.00405	3.45	0.11	0.00242
RotorDiam	170	m	0.275	0.947	0.65	4.73	0.15	0.00407	2.53	0.08	0.00217
RotationPeriod	7.50	sec	0.325	0.899	0.55	4.00	0.13	0.00407	1.91	0.06	0.00194
			0.375	0.851	0.48	3.46	0.11	0.00405	1.47	0.05	0.00173
			0.425	0.804	0.42	3.02	0.09	0.00401	1.15	0.04	0.00153
			0.475	0.756	0.38	2.72	0.09	0.00404	0.96	0.03	0.00143
Bird aspect ratio: b	0.42		0.525	0.708	0.34	2.48	0.08	0.00407	0.83	0.03	0.00136
			0.575	0.660	0.31	2.27	0.07	0.00407	0.73	0.02	0.00131
			0.625	0.613	0.29	2.08	0.06	0.00406	0.65	0.02	0.00127
			0.675	0.565	0.27	1.91	0.06	0.00403	0.60	0.02	0.00127
			0.725	0.517	0.25	1.76	0.06	0.00399	0.65	0.02	0.00146
			0.775	0.470	0.23	1.62	0.05	0.00392	0.67	0.02	0.00163
			0.825	0.422	0.22	1.49	0.05	0.00384	0.69	0.02	0.00178
			0.875	0.374	0.21	1.37	0.04	0.00375	0.70	0.02	0.00192
			0.925	0.327	0.19	1.26	0.04	0.00363	0.70	0.02	0.00204
			0.975	0.279	0.18	1.15	0.04	0.00350	0.70	0.02	0.00214
				Overall p(collision) =			**Upwind**	**7.3%**		**Downwind**	**3.5%**
								Average	**5.4%**		

KEY SPECIES FLIGHT ACTIVITY AND COLLISON RISK: DIRECT FLIGHT MODEL (STAGE 2)

The second section of this AEI Technical Appendix provides example calculations that have been made of the key species flight activity within the collision risk zone, which has been updated to reflect the reduction from 19 to 12 wind turbines. The remaining wind turbines will be in the same locations as for the assessment presented in the EIA Report October 2023.

The model was run separately for each of five zones across the collision risk area that were visible from each of the three Vantage Points (VPs) (three areas were visible from only a single VP, and two where there was overlap between two VPs). Bird flight activity within each of these zones was calculated separately.

For the direct flight variant of the Band model (used for whooper swan, greylag goose, pink-footed goose and herring gull), flight activity was calculated as the total number of flights through each of the five collision zones (delineated according to which VPs the zone was visible), estimated from the VP data (clipping mapped flights in QGIS to those zones and calculating the numbers of flights per hour at rotor height over each season). An example calculation is given below in **Table 9.1.1: Collision risk calculations for pink-footed goose for the 2021-22 and 2022-23 winters using the direct flight Band model.** The total risk for the whole wind farm was calculated as the sum of the risks for each of the five zones (A-E), and the last row gives the mean risk over the two winters.

Table 9.1.1: Collision risk calculations for pink-footed goose for the 2021-22 and 2022-23 winters using the direct flight Band model.

GLENBURNIE WIND FARM **BAND ET AL 2007 COLLISION MODEL (DIRECT FLIGHTS)**										
	Pink-footed Goose	*Winter only*								
	2021-22					**2022-23**				
	Zone A	**Zone B**	**Zone C**	**Zone D**	**Zone E**	**Zone A**	**Zone B**	**Zone C**	**Zone D**	**Zone E**
Collision risk height	170	170	170	170	170	170	170	170	170	170
Risk corridor Width	1,850	1,300	2,100	1,200	2,650	1,850	1,300	2,100	1,200	2,650
Risk corridor Area	314,500	221,000	357,000	204,000	450,500	314,500	221,000	357,000	204,000	450,500
Annual number of flights through collision zone at rotor ht	1,217	0	9,603	4,215	0	18,950	6,379	12,758	23,130	0
No turbines	6	1	5	1	6	6	1	5	1	6
Rotor diameter	170	170	170	170	170	170	170	170	170	170
Rotor swept area	22698	22698	22698	22698	22698	22698	22698	22698	22698	22698
Allowance for overlap	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Proportion of risk window occupied by rotors	22%	5%	16%	6%	15%	22%	5%	16%	6%	15%
Annual no bird rotor passes	263	0	1526	234	0	4103	328	2028	1287	0
Band individual collision risk	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%
Turbine downtime	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Non-avoidance collisions	11	0	66	10	0	177	14	88	56	0
Avoidance rate	99.80%	99.80%	99.80%	99.80%	99.80%	99.80%	99.80%	99.80%	99.80%	99.80%
Predicted collisions per year	**0.023**	**0.000**	**0.132**	**0.020**	**0.000**	**0.354**	**0.028**	**0.175**	**0.111**	**0.000**
Total annual collision risk					***0.17***					***0.67***
									Mean:	*0.42*

KEY SPECIES FLIGHT ACTIVITY AND COLLISON RISK: NON-DIRECT FLIGHT MODEL (STAGE 2)

As an example, for the variable non-direct flight modelling, the collision risk calculations for golden eagle for each of the winter and breeding baseline periods (breeding 2021 and 2022, winter 2021-22 and 2022-23) is shown in **Table 9.1.2: Collision risk calculations for golden eagle for using the non-direct random flight Band model**. This requires an estimate of the amount of time that each species was present within the collision risk zone for its bird activity input, calculated from the amount of time observed in each zone during the VP surveys (as the percentage occupancy rate of each zone, i.e. the percentage of observation time that each species was observed flying at rotor height within the zone). This occupancy of the collision risk zone was determined from the flight tracks and divided by the observation time for each month to give the monthly occupancy rate (percentage of time present in the collision zone). The overall occupancy was then calculated for each of the four survey periods (breeding 2021 and 2022, winter 2021-22 and 2022-23). The survey results for these periods are given in EIA Report October 2023 Technical Appendices 9.1, 9.2, 9.3 and 9.4 respectively.

As for the direct flight model, the total risk for the whole wind farm was calculated as the sum of the risks for each of the five zones (as shown in Figure 9.1.1).

Table 9.1.2. Collision risk calculations for golden eagle using the non-direct random flight Band model.

GLENBURNIE WIND FARM BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)																				
	Golden Eagle	*All year*																		
	2021-22					2022-23					2021					2022				
	Zone A	Zone B	Zone C	Zone D	Zone E	Zone A	Zone B	Zone C	Zone D	Zone E	Zone A	Zone B	Zone C	Zone D	Zone E	Zone A	Zone B	Zone C	Zone D	Zone E
Collision Zone Area (ha)	291	254	317	42	56	291	254	317	42	56	291	254	317	42	56	291	254	317	42	56
Hub Ht	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5	127.5
Rotor diameter	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
Upper rotor ht	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220
Lower rotor ht	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Percentage of observation time seen flying in collision zone at rotor ht	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.01%**	**0.01%**	**0.07%**	**0.03%**	**0.00%**	**0.000%**	**0.006%**	**0.000%**	**0.000%**	**0.084%**	**0.026%**	**0.100%**	**0.006%**	**0.000%**
Season length	212	212	212	212	212	212	212	212	212	212	153	153	153	153	153	153	153	153	153	153
Activity per day	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Total flight activity in collision zone at rotor ht	0.000	0.000	0.000	0.000	0.000	0.000	0.109	0.177	1.454	0.571	0.058	0.010	0.144	0.000	0.000	2.055	0.640	2.445	0.155	0.000
Flight risk volume	4.947E+08	4.314E+08	5.392E+08	7.099E+07	9.436E+07	4.947E+08	4.314E+08	5.392E+08	7.099E+07	9.436E+07	4.947E+08	4.314E+08	5.392E+08	7.099E+07	9.436E+07	4.947E+08	4.314E+08	5.392E+08	7.099E+07	9.436E+07
No Turbines	**6**	**1**	**5**	**1**	**6**	**6**	**1**	**5**	**1**	**6**	**6**	**1**	**5**	**1**	**6**	**6**	**1**	**5**	**1**	**6**
Rotor radius	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**
Rotor depth	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**
Bird length	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**
Swept volume	731330	121888	609441	121888	731330	731330	121888	609441	121888	731330	731330	121888	609441	121888	731330	731330	121888	609441	121888	731330
Bird occupancy of swept volume	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.72	8.99	15.92	0.31	0.01	0.59	0.00	0.00	10.94	0.65	9.95	0.96	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**	**11.9**
Rotor transit time	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451
No of rotor transits	0	0	0	0	0	0	0	2	20	35	1	0	1	0	0	24	1	22	2	0
Turbine downtime	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Band collision rate	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%
Non-avoid collisions	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	2.0	0.0	0.0	0.1	0.0	0.0	1.4	0.1	1.2	0.1	0.0
Avoidance rate	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%	99.0%
Collision prediction	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.011**	**0.020**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.014**	**0.001**	**0.012**	**0.001**	**0.000**
OVERALL TOTAL					**0.000**					**0.032**					**0.001**					**0.028**

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