WITBERG WIND FARM: ORNITHOLOGICAL COLLISION RISK MODELLING UPDATE REPORT MARCH 2019

Report to Witberg Wind Power (Pty) Ltd

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SECTION 1 - INTRODUCTION

1. The purpose of this report is to update the collision risk modelling for the proposed Witberg wind farm that was reported in the Shoney Renewables Consulting (2013) report. An updated 25-turbine layout is now being considered, with a larger (136m) rotor diameter and various hub height alternatives. The layout revision included moving turbines to ensure that there are none located within 1.5km of any Verreaux's Eagle nest (as recommended by Dr Rob Simmons[1]). This report provides a comparison of the predicted collision risk to key bird species for this new layout with the authorized 27-turbine scheme reported previously.

2. The specific scope of work included:
   - An update of the collision risk modelling using a 136m diameter rotor, for hub heights from 92-120m and an updated 25-turbine layout;
   - A re-assessment of the likely impacts of the updated Witberg wind farm scheme on birds.

3. The same baseline survey data have been used in this assessment update as previously and as described in the 2013 report. The same modelling approach has also been used as previously, following the method of Band et al. (2007).

4. Five wind farm layouts were modelled previously up to and including the current authorized 27-turbine layout (layout E below). These were as follows:
   - A. The initial 70 WTG layout using Turbine Type B (Vestas V100 2MW);
   - B. The 40 WTG layout using Turbine Type C (Vestas V90 3MW) that was originally authorized by the DEA.
   - C. The 27 WTG layout using Turbine Type A (Acciona AW116 3MW);
   - D. The 27 WTG layout but with two turbines (located within an area of higher eagle use) removed, using the same Type A Acciona turbine;
   - E. An updated 'reduced eagle collision risk' 27 WTG layout with 5 turbines moved from an area of higher eagle activity to a lower activity area, using the same Type A Acciona turbine (92m hub height, 116m rotor diameter). This layout is the one referred to in this report as the 'previous 27-turbine layout'. This is Layout Alternative 7, currently authorised by the Department of Environmental Affairs.

5. Layouts A to D were subsequently abandoned by the applicant as the collision risk either remained unchanged, increased or for technical reasons the layouts were no longer supported. Layout 'E' is currently authorized and this therefore forms the base scenario for the comparisons of collision risk made in this report.

6. A revised 25-turbine layout is now being considered (see Figure 1, below) with a larger rotor diameter (up to 136m). Three different hub height options were therefore considered as follows:
   - Scenario 1: 136m rotor diameter, 92m hub height;
   - Scenario 2: 136m rotor diameter, 105m hub height;
   - Scenario 3: 136m rotor diameter, 120m hub height.

7. The proposed wind turbine co-ordinates for the revised 25-turbine scheme are given in Appendix 1.

[1] 2015, Birds Unlimited. Witberg Wind Farm Juvenile Verreaux's Eagle Monitoring. Final Report.

8. Two key species, Verreaux's Eagle and Booted Eagle have been modelled for each of the three scenarios. The collision risks for Martial Eagle and Black Harrier were not modelled as the collision risk associated with both the authorized and the revised layouts would be zero (no flights of either species were recorded flying through the collision risk zone of either layout). No other key species were recorded flying through the collision risk zone at rotor height during the baseline surveys.

9. The collision modelling requires a range of input data on the wind turbine specifications, which were provided by Witberg Wind Power (WWP) and the turbine manufacturer. They are summarised in Table 1. As previously, where any uncertainties exist as to any specifications of the turbines a worst-case approach has been adopted to deliver a precautionary but robust analysis.

Table 1. Wind turbine data used in the January 2019 collision risk modelling

Specification	**Value used in previous collision risk modelling (authorised 27-turbine scheme)**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Hub height	92m	92m	105m	120m
Rotor diameter	116m	136m	136m	136m
Height to blade tip	150m	160m	173m	188m
Minimum height of blade above ground	34m	24m	37m	52m
Rotational speed (variable – mean value)	11.9 (eastern turbine block), 11.68 (western turbine block)	9.8 (mean overall)	9.8 (mean overall)	9.8 (mean overall)
Blade maximum chord	3.28m	4.1m	4.1m	4.1m
Blade pitch (variable – mean value calculated from local wind speed data measured by WWP)	4.13° (eastern turbine block), 3.34° (western turbine block)	4.13° (eastern turbine block), 3.34° (western turbine block)	4.13° (eastern turbine block), 3.34° (western turbine block)	4.13° (eastern turbine block), 3.34° (western turbine block)
Turbine operation time (when not constrained by high/low wind speed or maintenance activity)	92% (eastern turbine block), 90% (western turbine block)	92% (eastern turbine block), 90% (western turbine block)	92% (eastern turbine block), 90% (western turbine block)	92% (eastern turbine block), 90% (western turbine block)

Limitations of the Assessment

10. Inevitably with any ornithological survey it cannot be guaranteed to detect all target species/individuals and surveys cannot be fully representative of all conditions (e.g. severely reduced visibility, including in fog/mist and at night). It was assumed in the assessment that the surveys were representative of flight activity throughout daylight hours (there was no *a priori* ecological reason to suppose that it would be any higher), and no suggestion that the site was likely to be important for any nocturnal species that could be vulnerable to the development.

11. The baseline data remain sufficient to inform this assessment, despite the fact that they were collected some 6-7 years ago, as there have not been any material changes to the habitat at the

site that would be likely to increase the avifaunal activity. The area did experience an extensive fire in February 2015, resulting in damage to much of the grazing veld in the area and natural vegetation, but the most likely outcome of that would have been reduced food availability for birds such as eagles in the vicinity of the wind farm.

12. A review of the baseline data reported previously (Shoney Renewables Consulting 2013) identified a number of issues, with no length of time recorded for each flight line during the vantage point surveys, viewing distance during the surveys exceeded the 2km maximum usually used in the UK, flight heights were only recorded to wide bands, 360-degree viewing may have reduced detectability overall and only low numbers of juvenile Verreaux's Eagle flights were observed. These have all been addressed in the assessment by using a precautionary approach, as set out in Shoney Renewables (2013).

13. The collision risk analysis provided a quantitative assessment of the bird collision risk, but, as with any modelling, the quality of the predictions is dependent on the quality of the input data. A precautionary approach was adopted throughout this analysis where there were any uncertainties, to produce a precautionary predicted risk that would be unlikely to be exceeded.

14. In conclusion, no limitations are considered likely to have materially affected the conclusions of this assessment.

SECTION 2 - KEY SPECIES BASELINE UPDATE

15. There were three key differences in relation to the collision risk modelling, (a) a revised site layout and hence updated collision risk zone, (b) updated minimum heights of blades above the ground resulting in a difference in proportion of flights at rotor height, and (c) a larger rotor swept area resulting in an increased collision risk volume but with reduced rotational speed.

16. The revised 25-turbine layout and its collision risk zone (i.e. the wind farm plus a 200m buffer) are shown in Figure 1, together with the collision risk zone of the authorised 27-turbine layout for comparison. The Vantage Points (VPs) monitored during the monitoring campaigns are also indicated on the Figure. The coordinates are as follows:

- VP – West (the most western VP): 33°17'27.29"S; 20°23'48.73"E
- VP – Mid (the VP in the middle of the project site): 33°16'53.85"S; 20°26'38.27"E
- VP – East (the most eastern VP): 33°16'49.27"S; 20°30'16.11"E

Key Species Flight Activity within the revised site collision risk zone

17. The flight activity of Verreaux's Eagle and Booted Eagle within the collision risk zones of the authorized and the revised layouts are summarised in Table 2 and Table 3 respectively. These Tables show the occupancy rate (% of time when present within the zone) for each of these species, in each of the three main zones of the wind farm, for each layout.

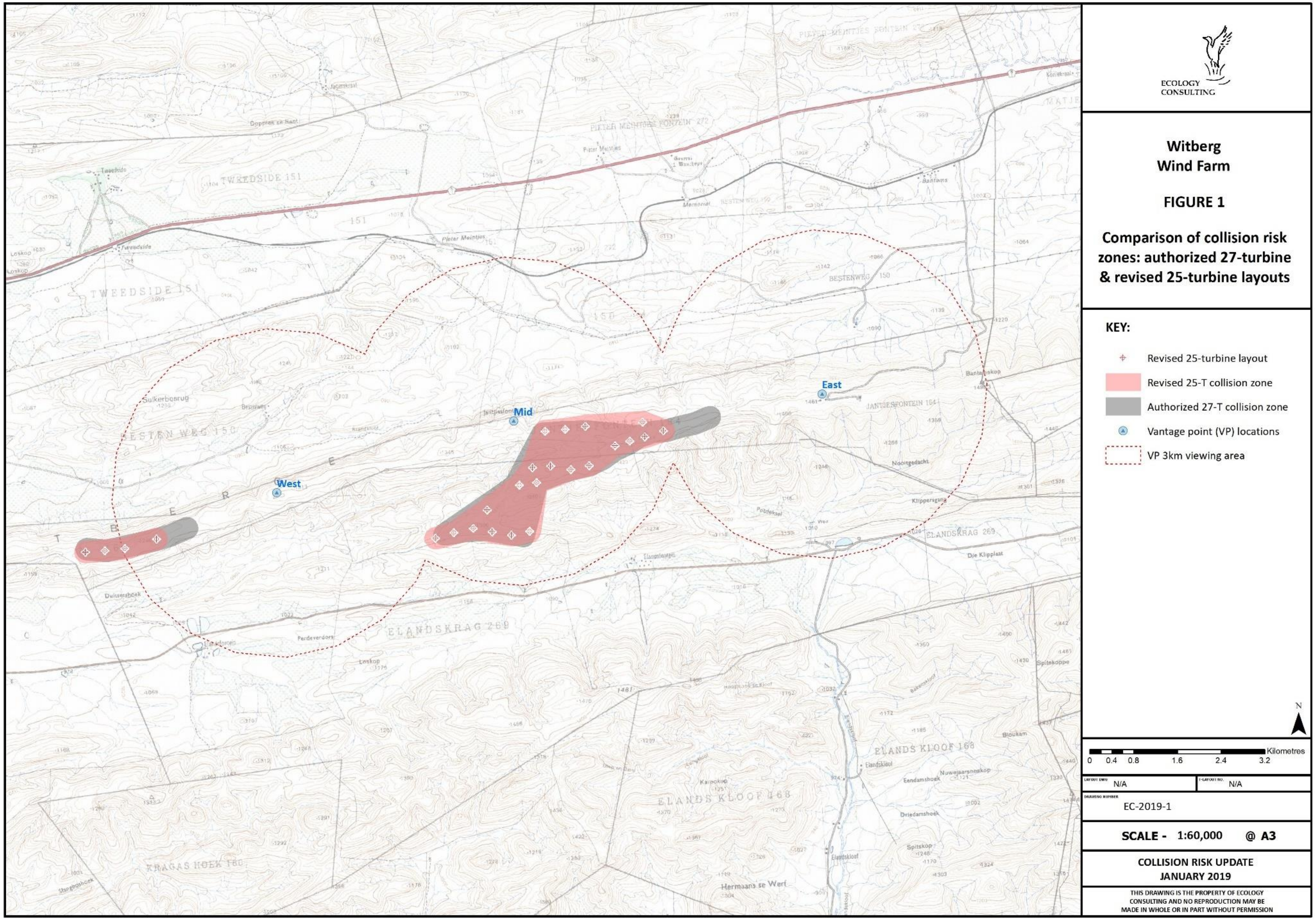
Table 2. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: authorized 27-turbine layout

Species	**Wind farm/VP zone**	**Occupancy rate of collision risk zone (% observation time present)**					
		Jan	**Apr**	**Jun**	**Aug**	**Nov**	**OVERALL MEAN**
Verreaux's Eagle	East	0%	0.127%	0%	0%	0%	0.025%
	Mid	0%	1.851%	0.280%	0%	0.295%	0.485%
	West	0%	0%	1.628%	0%	0.017%	0.329%
Booted Eagle	East	0%	0.004%	0%	0%	0%	0.001%
	Mid	0%	0%	0.039%	0%	0.255%	0.059%
	West	0%	0%	0%	0%	0%	0%

Table 3. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: revised 25-turbine layout

Species	**Wind farm/VP zone**	**Occupancy rate of collision risk zone (% observation time present)**					
		Jan	**Apr**	**Jun**	**Aug**	**Nov**	**OVERALL MEAN**
Verreaux's Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0.771%	0.270%	0%	0.040%	0.216%
	West	0%	0%	0.200%	0%	0%	0.040%
Booted Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0%	0.030%	0%	0.295%	0.065%
	West	0%	0%	0%	0%	0%	0%

18. Flight lines in relation to the revised 25-turbine collision risk zone are shown in Figure 2, below for Verreaux's Eagle, Figure 3, below for Booted Eagle, and Figure 4, below for Martial Eagle and Black Harrier.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Wind Farm
FIGURE 1
Comparison of collision risk zones: authorized 27-turbine & revised 25-turbine layouts
KEY:
Revised 25-turbine layout
Revised 25-T collision zone
Authorized 27-T collision zone
Vantage point (VP) locations
VP 3km viewing area
Mid
West
East
0 0.4 0.8 1.6 2.4 3.2
Kilometres
N
N/A
N/A
EC-2019-1
SCALE - 1:60,000 @ A3
COLLISION RISK UPDATE
JANUARY 2019
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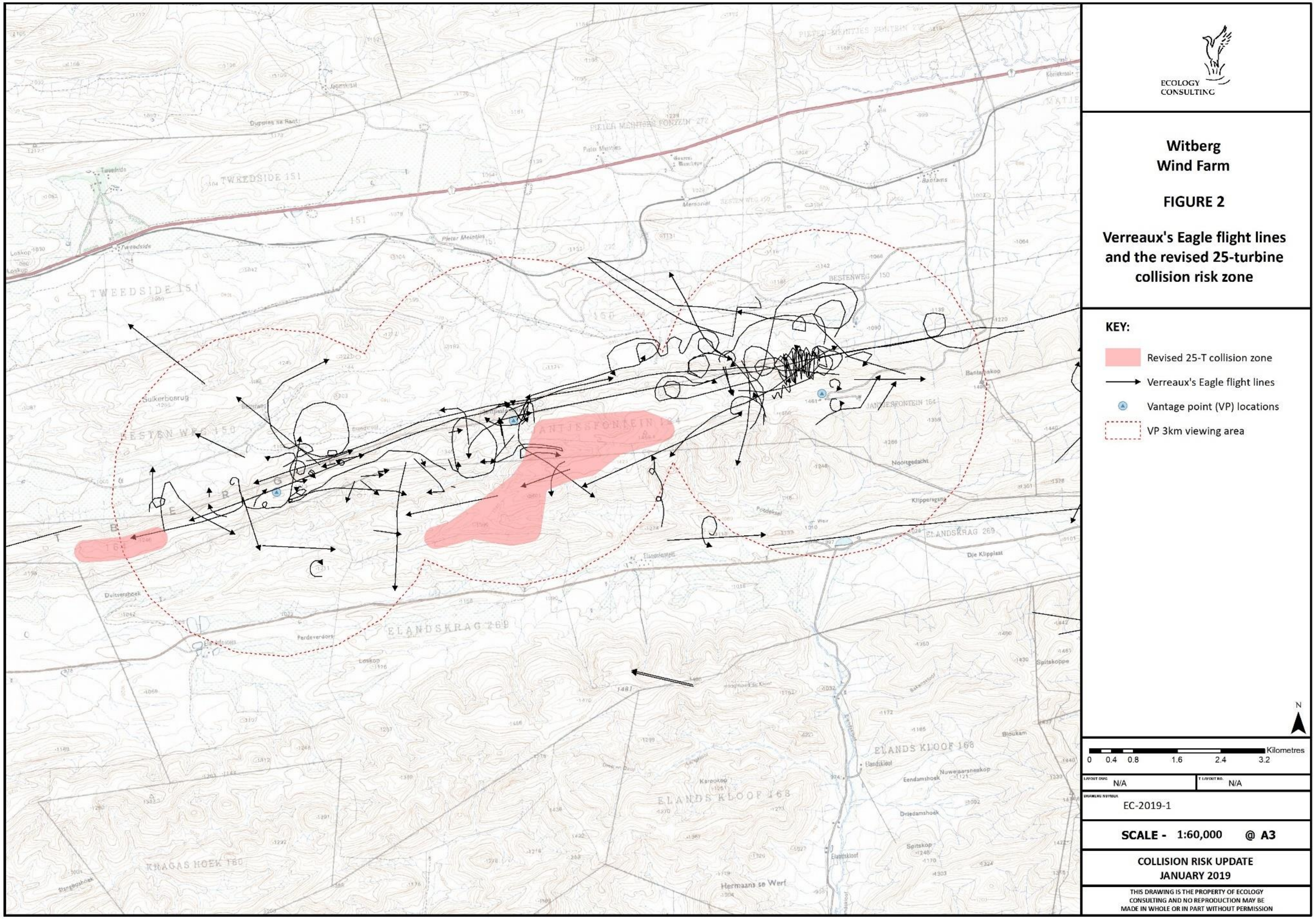
TWEEDSIDE 151
BESTEN WEG 150
ELANDSKRAG 269
ELANDS KLOOF 168
KRAGAS HOEK 160
JANTJIESFONTEIN 154
PIETER MEINTJES FONTEIN 272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Witberg Wind Farm
FIGURE 2
Verreaux's Eagle flight lines and the revised 25-turbine collision risk zone
KEY:
Revised 25-T collision zone
Verreaux's Eagle flight lines
Vantage point (VP) locations
VP 3km viewing area
N
0 0.4 0.8 1.6 2.4 3.2 Kilometres
N/A
N/A
EC-2019-1
SCALE - 1:60,000 @ A3
COLLISION RISK UPDATE JANUARY 2019
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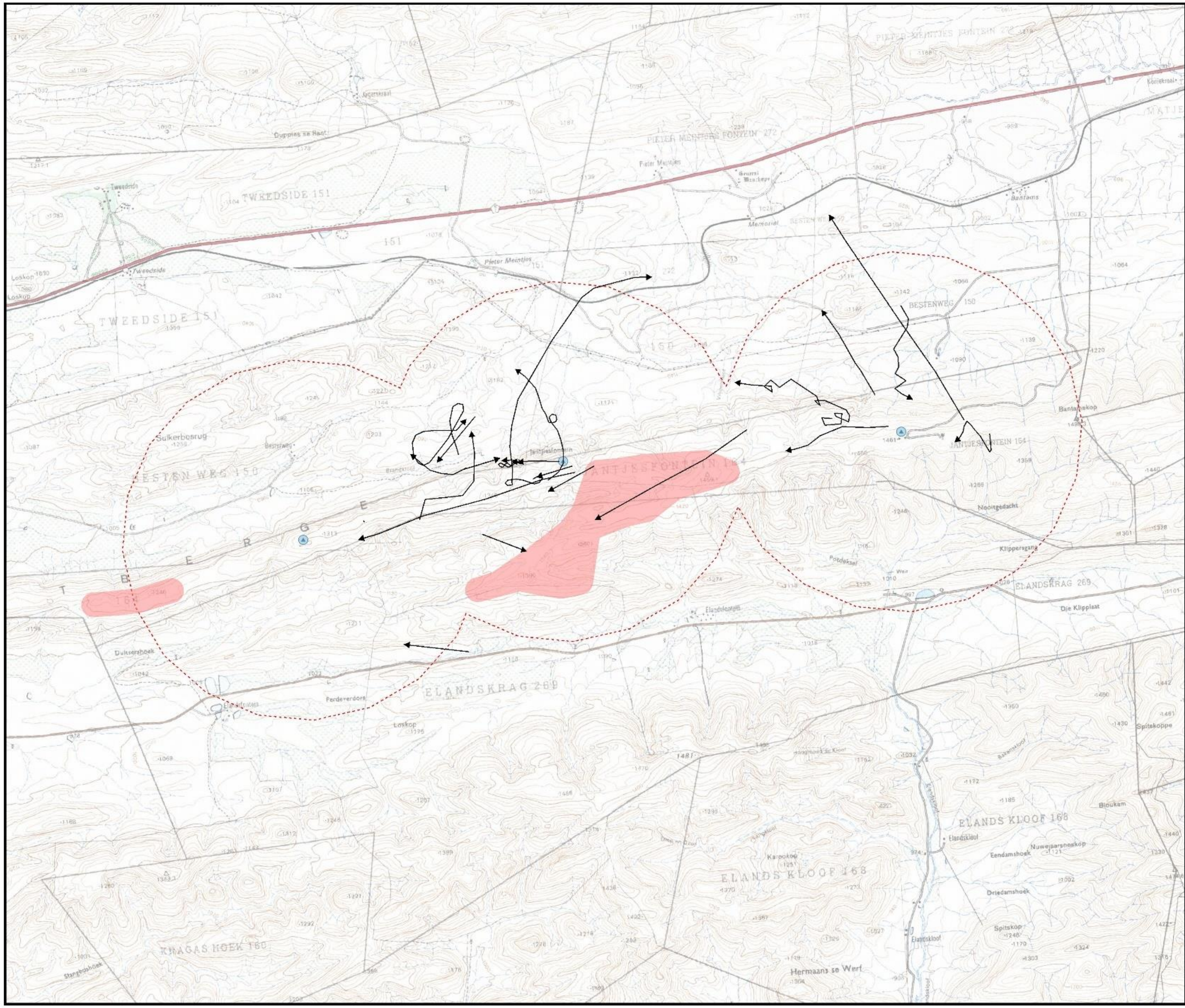

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FIGURE 3

Booted Eagle flight lines and the revised 25-turbine collision risk zone

KEY:

- Revised 25-T collision zone
- Booted Eagle flight lines
- Vantage point (VP) locations
- VP 3km viewing area

N

0 0.4 0.8 1.6 2.4 3.2 Kilometres

LAYOUT DWG N/A	T LAYOUT NO. N/A

DRAWING NUMBER: EC-2019-1

SCALE - 1:60,000 @ A3

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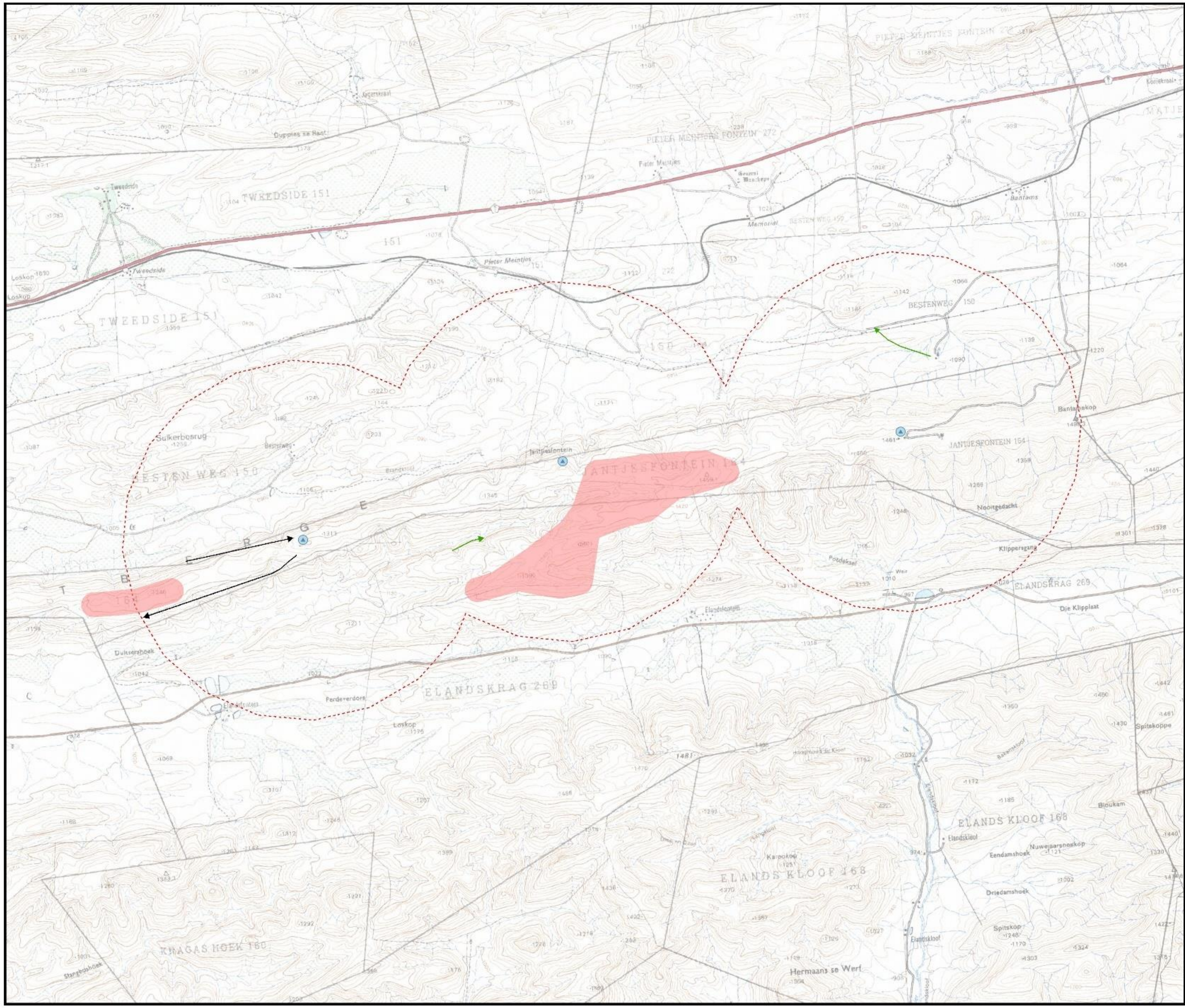

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FIGURE 4

Martial Eagle and Black Harrier flight lines and the revised 25-turbine collision risk zone

KEY:

- Revised 25-T collision zone
- Black Harrier flight lines
- Martial Eagle flight lines
- Vantage point (VP) locations
- VP 3km viewing area

N

Kilometres: 0 0.4 0.8 1.6 2.4 3.2

N/A | N/A

EC-2019-1

SCALE - 1:60,000 @ A3

COLLISION RISK UPDATE JANUARY 2019

Key Species Flight Heights

19. Flight heights were recorded to wide zone bands during the baseline surveys, which did not perfectly match up to the proposed turbine/rotor heights. The proportion of flights at rotor height for each of the different rotor heights for the revised turbine layout was estimated, as previously, assuming that flight activity was uniform within each band, so, for example, 6/40 (15%) of flights in the 'Low' category were assumed to be at rotor height for the Scenario 1 turbine (as per Band et al. 2007). The calculated percentage of flights at rotor height for each key species for each of the three hub height scenarios are shown in Table 4. The percentage at rotor height for the authorized 27-turbine layout is also given for comparison.

Table 4. Key species percentage of flights at rotor height (i.e. rotor swept area) for each scenario used in the January 2019 collision risk modelling

Species	**Value used in previous collision risk modelling (authorized 27-turbine scheme)**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Verreaux's Eagle	68%	78%	69%	61%
Booted Eagle	57%	64%	62%	59%

SECTION 3 – COLLISION MODELLING UPDATE

Collision Risk Modelling Methodology

20. The collision risk modelling (CRM) was undertaken following the method of Band et al. (2007), as extensively used in the UK, and as used for the previous Witberg collision risk modelling (Shoney Renewables Consulting 2013). Details of the original SNH guidance on this model (Band 2000) are available from the SNH web site at <www.snh.gov.uk/docs/C205425.pdf>. The model runs 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 rotor blades) in order to estimate the theoretical numbers at risk of collision if they take no avoiding action.

21. The second stage then incorporates the probability that the birds, rather than flying blindly into the turbines, will actually take a degree of avoiding action, as has been shown to occur in all studies of birds at existing wind farms (Urquhart 2010). The results of any collision risk modelling using the Band et al. (2007) approach is highly sensitive to the avoidance rate used (Chamberlain et al. 2006). Application of an appropriate rate is therefore of fundamental importance in undertaking such modelling. However, there are very few studies at existing wind farm where avoidance rates have been fully determined, comparing pre-construction flight activity with the actual numbers of collisions post-construction (Urquhart 2010). The approach generally used to address this is to apply a precautionary rate based on the available data, such that any collision prediction is unlikely to be exceeded (i.e. represents a reasonable worst case). Where data on actual avoidance rates of particular species/groups have been established, then this has usually enabled a higher rate to be safely applied. For example, SNH currently recommends using a value of 99.8% as an avoidance rate for geese (Douse 2013), 99% for several birds of prey (including golden eagle and hen harrier), and 98% for most other species (Urquhart 2010).

22. There is a lack of specific avoidance rate data from South Africa and on the species of concern at Witberg. It was agreed for the previous collision risk modelling that as collision avoidance rates are not yet known for the species of concern, suitable overseas species should be used as proxies. They have been selected following SNH guidance and with reference to the bird-wind farm literature. A precautionary 98% avoidance rate has been adopted as the default value (Urquhart 2010) but the work has also explored whether particular species exhibit similar behaviour to more vulnerable species such as white-tailed sea eagle and kestrel, or such behaviour that would reduce risk (and hence allow higher rates to be used as is recommended by SNH for golden eagle and hen harrier for example). The collision risk modelling results have been presented for each layout for a range of avoidance rates to inform the assessment but the most appropriate rate to apply in each specific case is also indicated. Most weight has been given to the precautionary SNH position of applying a 98% avoidance rate, though Verreaux's Eagle in particular shares an ecological similarity with golden eagle (albeit at a generally higher breeding density), for which SNH recommends a 99% avoidance rate, so applying that rate could be justified (particularly in relation to adult birds). The Golden Eagle is recognised as the Verreaux's Eagle's closest relative (Wink and Sauer-Gürth 2000). However, a more precautionary approach has been adopted in this assessment. The collision risk to juvenile Verreaux's Eagle has been assessed separately, and, given experience of higher juvenile mortality of eagles at the Smøla wind farm in particular, a lower avoidance rate (95%) has been

considered for these birds. Given that the Witberg eagles occur at a much lower density (3.7/100km^2) than the white-tailed eagles at Smøla, where a density of 73/100km^2 has been recorded with 13 pairs of white-tailed eagle nesting in the wind farm which extends over 17.3km^2, Bevanger et al. 2009) and that the eagle core ranges have been buffered, it is not considered appropriate to apply as low an avoidance rate as 95% to the adult Verreaux's Eagle at Witberg.

23. The main collision risk zones for the layouts were defined, as per Band et al (2007) and SNH guidance (Whitfield et al. 2010) as a 200m zone around the proposed wind turbine locations. These zones were divided into three parts for the purposes of the collision modelling (Figure 1, above), relating to the three vantage points used for surveying the WEF (east, middle and west), and the collision modelling undertaken for each separately. The two westernmost turbines of both the authorized and the revised layouts fell outside the main VP survey area, so the flight densities within part of the collision zone were assumed to be the same as for the main part of the western block that was visible to a sufficient distance. The eastern zone has been retained in the analysis for comparison with the authorized layout, though for the revised layout no turbines would be located in that area.

Collison Risk Modelling Results

24. Tables 5a-c summarise the results of the collision risk analyses for each of the two key species for the revised 25-turbine layout for each wind turbine scenario. Previous results for the authorized turbine layout are given in Table 5d for comparison. There were no records of Martial Eagle or Black Harrier flying through the collision risk zone of either layout, so the modelled collision risk would be zero for both of these species for this layout in all cases. Details of the modelling are given in Appendix 2.

25. These Tables give the number of collisions predicted per year based on a range of avoidance rates (95% - 99%). Verreaux's Eagle is a large non-colonial eagle, and the area in proximity to its nest sites has been avoided in the site layout design process (so 'riskier' display flights and early juvenile flights would be less likely to occur in the wind farm). As a result, 99% should be a suitable precautionary avoidance rate to apply (as is used in the UK for Golden Eagle, an ecologically similar species), though as set out in the methodology section above, a more precautionary 98% avoidance rate has been adopted for the purpose of this assessment.

26. Booted Eagle is more ecologically similar to buzzard species, so on the basis of the information currently available, the possibility of lower avoidance cannot be excluded, so the Scottish Natural Heritage (SNH)[2] default 98% value has been applied.

[2] *Urquhart, B. 2010. Use of Avoidance Rates in the SNH Wind Farm Collision Risk Model. SNH Guidance Note.*

Table 5a. Collision risk modelling predictions for the proposed Witberg wind farm ***revised 25-turbine layout*** *Scenario 1 (136m rotor diameter turbine* ***at 92m hub height****), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	**Precautionary predicted number of collisions per year**											
	East zone[3]			**Mid zone**			**West zone**			**TOTAL**		
Avoidance rate:	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0	**0**	0	0.55	**0.22**	0.11	0.27	**0.11**	0.05	0.83	**0.33**	0.17
Booted Eagle	0	**0**	0	0.10	**0.04**	0.02	0	**0**	0	0.10	**0.04**	0.02

Table 5b. Collision risk modelling predictions for the proposed Witberg wind farm ***revised 25-turbine layout*** *Scenario 2 (136m rotor diameter turbine* ***at 105m hub height****), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	**Precautionary predicted number of collisions per year**											
	East zone			**Mid zone**			**West zone**			**TOTAL**		
Avoidance rate:	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0	**0**	0	0.49	**0.20**	0.10	0.24	**0.10**	0.05	0.73	**0.29**	0.15
Booted Eagle	0	**0**	0	0.10	**0.04**	0.02	0	**0**	0	0.10	**0.04**	0.02

Table 5c. Collision risk modelling predictions for the proposed Witberg wind farm ***revised 25-turbine layout*** *Scenario 3 (136m rotor diameter turbine* ***at 120m hub height****), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	**Precautionary predicted number of collisions per year**											
	East zone			**Mid zone**			**West zone**			**TOTAL**		
Avoidance rate:	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0	**0**	0	0.43	**0.17**	0.09	0.21	**0.09**	0.04	0.65	**0.26**	0.13
Booted Eagle	0	**0**	0	0.09	**0.04**	0.02	0	**0**	0	0.09	**0.04**	0.02

[3] *See Figure 1 depicting the east, mid and west zones*

Table 5d. Collision risk modelling predictions for the proposed Witberg wind farm ***authorized 27-turbine layout*** *Scenario 4 (116m rotor diameter turbine at 92m hub height), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate:	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0.10	**0.04**	0.02	1.06	**0.42**	0.21	0.99	**0.39**	0.20	2.14	**0.86**	0.43
Booted Eagle	0	**0**	0	0.08	**0.03**	0.02	0	**0**	0	0.08	**0.03**	0.02

Juvenile Verreaux's Eagle collision risk assessment

27. As the baseline surveys did not include any period of juvenile flights for the Verreaux's Eagle, a theoretical approach has been adopted to inform the assessment further (as for the previous collision risk modelling). This was carried out as follows:
    - Breeding success is about 0.5 young/pair/year (L. Rodrigues[4]]), so with up to 3 pairs with territories overlapping the wind farm this would give an average number of 1.5 juveniles at risk;
    - The period of key risk of the wind farm to juvenile birds would be about 2 months each year. Collision risk in the first 1-2 months after fledging would not be an issue as flights then are largely restricted to the proximity of the nest and would be outside the collision risk zone (given the 1.5km buffer applied to each nest site).
    - An estimate then needs to be made of the juvenile flight activity (which has not been measured in the field) in relation to that of the adults (for which we do have field data). A precautionary approach has been adopted, assuming that juvenile flight activity over this period was double that of the adults, though further consideration has also been given to how this might change if the juvenile flight activity were higher.
28. The results of the collision risk assessment for juvenile Verreaux's Eagles are summarised in Table 6. As for the assessment presented above, the results have been given for a range of avoidance rates. As previously, this would suggest that even adopting a highly precautionary 95% avoidance rate for the juveniles, the collision risk would be low, all of the three scenarios resulting in a lower collision risk in comparison with the previous 116m rotor diameter at 92m hub height for the authorized 27-turbine layout.

[4] verreaux.wordpress.com/

Table 6. Collision risk predictions for juvenile Verreaux's Eagle at Witberg.

Layout	**Precautionary predicted number of collisions per year**		
Avoidance rate:	**95%**	**98%**	**99%**
Scenario 1: 136m rotor diameter, 92m hub height	0.08	0.03	0.02
Scenario 2: 136m rotor diameter, 105m hub height	0.07	0.03	0.01
Scenario 3: 136m rotor diameter, 120m hub height	0.06	0.02	0.01
Authorized 27-turbine layout	0.21	0.08	0.04

SECTION 4 – COLLISION RISK MODELLING INTERPRETATION

Assessment Methodology

29. The same assessment methodology has been used in this report as used previously in the Shoney Renewables Consulting (2013) report, but is repeated here for completeness.

30. Whilst the Band collision model produces a quantitative estimate of the numbers of birds that might collide with the wind turbines, those numbers need to be put into the context of the existing mortality to enable their significance to be assessed. The same level of additional mortality on a population that has a low level of background mortality could potentially have a much more important effect than on a population with a higher level of existing mortality. The collision mortality needs to be assessed in the context of each species population dynamics. In the UK a 1% increase over the baseline mortality is now frequently being used as an initial filter threshold above which there may be a concern with the predicted collision mortality (and hence requiring further investigation). Collision risks below this level are usually considered not to be significant.

31. A methodology to undertake this assessment in a transparent objective way has been produced in the UK and is now widely used in the wind industry, both onshore and offshore (Maclean et al. 2009). This draws on the methodology developed by SNH and the British Wind Energy Association [BWEA] (Percival et al. 1999) and updated by Percival (2007), and with SNH (2006) guidance on assessing the impacts from onshore wind farms on birds in the wider countryside. The assessment first identifies the sensitivity (conservation importance; as defined in Table 7) of the receptors present in the study area, then determines the magnitude of the possible effect on those receptors (as described in Table 8).

Table 7. Sensitivity (conservation importance) of bird species.

Sensitivity	Definitions
VERY HIGH	Cited interest of an internationally or nationally important statutory protected sites. Cited means mentioned in the citation text for those protected sites as a species for which the site is designated.
HIGH	Other species that contribute to the integrity of an internationally or nationally important statutory protected sites species for which the site is designated. A local population of more than 1% of the national population of a species. Any ecologically sensitive species, e.g. large birds of prey or rare birds (usually taken as <300 breeding pairs in the UK). Species recognised as requiring special conservation measures or otherwise specially protected (in a UK context this includes EU Birds Directive Annex 1, EU Habitats Directive priority habitat/species and/or W&C Act Schedule 1 species. *Note: all of the raptor species assessed fall into this category*
MEDIUM	Regionally important population of a species, either because of population size or distributional context. Biodiversity Action Plan priority species (if not covered above).
LOW	Any other species of conservation interest.

Table 8. Definition of terms relating to the magnitude of ornithological effects

Magnitude	Definition
VERY HIGH	Total loss or very major alteration to key elements/ features of the baseline conditions such that post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether. Guide: >80% of population/habitat lost
HIGH	Major alteration to key elements/ features of the baseline (pre-development) conditions such that post development character/composition/attributes will be fundamentally changed. Guide: 20-80% of population/habitat lost
MEDIUM	Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/ composition/ attributes of baseline will be partially changed. Guide: 5-20% of population/habitat lost
LOW	Minor shift away from baseline conditions. Change arising from the loss/ alteration will be discernible but underlying character/ composition/ attributes of baseline condition will be similar to pre-development circumstances/patterns. Guide: 1-5% of population/habitat lost
NEGLIGIBLE	Very slight change from baseline condition. Change barely distinguishable, approximating to the "no change" situation. Guide: <1% of population/habitat lost

32. The combined assessment of the magnitude of an effect and the sensitivity of the receptor has been used to determine whether or not an adverse effect is significant. These two criteria have been cross-tabulated to assess the overall significance of that effect (Table 9).

Table 9. Matrix of magnitude of effect and sensitivity used to test the significance of effects. The significance category of each combination is shown in each cell. Shaded cells indicate potentially significant effects.

		SENSITIVITY			
		Very high	High	Medium	Low
MAGNITUDE	Very high	Very high	Very high	High	Medium
	High	Very high	Very high	Medium	Low
	Medium	Very high	High	Low	Very low
	Low	Medium	Low	Low	Very low
	Negligible	Low	Very low	Very low	Very low

33. The interpretation of these significance categories is as follows (though careful use of professional judgment should also be a key component of this assessment process):

- **Very low** and **low** are not normally of concern, though normal design care should be exercised to minimise adverse effects;
- **Very high** and **high** represent adverse effects on bird populations which are regarded as significant for the purposes of EIA;
- **Medium** represents a potentially significant adverse effect on which professional judgment has to be made. In the event that mitigation was not possible, it is likely to be significant, but if mitigation is possible, it may well be taken below the significance threshold.

Wind farm mortality and background mortality at Witberg

34. The predicted wind farm collision mortality has been assessed in the context of the background mortality, as previously, using the same baseline population data as in the previous reports. The predicted collision mortality has been set against the regional background mortality for each of the key species at risk of collision. The population data used in this analysis are summarised in Table 10. The region has been taken, through discussions with Rob Simmons, as the Karoo biome (Mucina and Rutherford 2006, and with reference to the WWF Karoo eco-region).

Table 10. Background population data for Verreaux's Eagle, Booted Eagle and Martial Eagle. Source: Roberts VII (Hockey et al. 2005) and Gargett (1990).

Species	Regional population	Adult mortality rate	Immature mortality rate	Annual productivity (chicks/pair /year)	Age at first breeding	Baseline mortality
Verreaux's Eagle	940 pairs	5%	20%	0.5	5	94 (adult)
Booted Eagle	700 pairs	10%	20%	1.0	3	500

35. Rob Simmons has provided a minimum population estimate for the Karoo Verreaux's Eagle, and identified, through consultation with Rob Davies, a conservative estimate of 600 pairs for the Karoo escarpment (Roggeveld, Nuweveld, Sneeuberge and Winterberge) plus a further 100 pairs for the smaller inselbergs outside of the main mountain ranges. These numbers were derived primarily from information collected by Rob Davies for his PhD work (together with other published population density estimates; Simmons in Hockey et al. 2005) and since then the population is thought to have declined by about 15% on the basis of recent field surveys carried out by Rob Davies. This would therefore give a current population estimate for the escarpment plus the inselbergs of about 600 pairs. The area on which this estimate is based does not include approximately 24,000km^2 of other Karoo mountain ranges that would provide suitable habitat Verreaux's Eagle habitat. Using a very conservative nesting density of 1 pair per 60km^2 (the lowest recorded according to Davies 1994, densities at the Karoo National Park and around the Witberg site are considerably higher than this) over this entire area, this gives a further 400 pairs over this area. That too should be scaled down from the 1994 density by 15%, giving an estimated 340 additional pairs, and hence a more realistic total of about 940 pairs for the Karoo.

36. Table 11 shows the predicted collision risks for each of the two key species that were recorded flying through the collision risk zone, for each of the three wind turbine scenarios. This Table also gives the context of their background mortality and the percentage increase over the

baseline that each risk represents, for each scenario and for the previous authorized 27-turbine layout. For Verreaux's Eagle, the assessment summarised in this Table assesses the collision risk against the adult population, as the large majority of records from the site relate to adult birds. Juveniles are assessed separately below.

37. Collision risks for the revised 25-turbine layout were lower than for Verreaux's Eagle but slightly higher for Booted Eagle those presented previously in the 2013 report for the authorized 27-turbine layout, with the higher hub height scenarios giving a reduced risk.

38. For Booted Eagle, the predicted collision risk of all three scenarios was very small both numerically and in a population context (though was marginally higher for the revised 25-turbine layout than the previous 27-turbine one). It represented considerably less than a 1% increase over the existing baseline mortality of the regional population (and was therefore classed as being of negligible magnitude). With such a negligible magnitude risk, there would not be likely to be any regionally significant population impact for this species for any of the scenarios assessed.

39. For Verreaux's Eagle, the authorized 27-turbine layout using a 116m rotor diameter turbine and 92m hub height, had a collision risk of 0.86 adult Verreaux's Eagle per year. It was concluded in the previous report that this would be a negligible magnitude effect, less than a 1% increase over the baseline mortality, which would be of very low significance and not a significant impact.

40. The three scenarios being currently investigated produced predictions of 0.33, 0.29 and 0.26 Verreaux's Eagle collisions per year, equivalent to increases over the baseline mortality of 0.35%, 0.31% and 0.28% respectively. All three were lower risk for this species than the authorized 27-turbine layout, with lower risks for the higher hub height scenarios. All of the risks would be negligible magnitude, and not significant, giving no material change to the conclusion reached previously.

41. As noted in the Shoney Renewables Consulting (2013) report, it should also be noted that this is the result of a precautionary assessment, not the most likely outcome. The analysis has adopted a precautionary approach throughout, including:

- Use of a precautionary 98% avoidance rate rather than the more evidence-based 99% for the closely related Golden Eagle (and use of an even more precautionary 95% avoidance rate for juvenile eagles);
- Use of a conservative regional population estimate against which to assess the predicted wind farm mortality;
- Assessment of mortality has been made against only the existing adult mortality rather than the usual assessment against all of the predicted mortality;
- Flight activity through the wind farm will continue at the same rate after construction. Given that mitigation measures will be implemented to improve the food resource within nest buffers away from the wind farm and the observed behaviour of Golden Eagles (which are similar in their behaviour to the Verreaux's Eagles), some reduction in flight activity is more likely.

Table 11. Collision risk for Verreaux's Eagle and Booted Eagle for each of the three wind turbine scenarios, and the increases that these represent over baseline mortality, and comparison with the authorized 27-turbine layout shown in italics.

Species	Scenario	Rotor diameter (m)	Hub height (m)	Predicted collision risk (98% avoidance rate)	% increase over baseline mortality	Magnitude of effect	Likely significant effect?
Verreaux's Eagle	Revised 25-turbine layout: scenario 1	136	92	0.33	0.35%	Negligible	No
	Revised 25-turbine layout: scenario 2	136	105	0.29	0.31%	Negligible	No
	Revised 25-turbine layout: scenario 3	136	120	0.26	0.28%	Negligible	No
	Authorized 27-turbine layout	*116*	*92*	*0.86*	*0.92%*	*Negligible*	*No*
Booted Eagle	Revised 25-turbine layout: scenario 1	136	92	0.040	0.008%	Negligible	No
	Revised 25-turbine layout: scenario 2	136	105	0.039	0.008%	Negligible	No
	Revised 25-turbine layout: scenario 3	136	120	0.037	0.008%	Negligible	No
	Authorized 27-turbine layout	*116*	*92*	*0.031*	*0.006%*	*Negligible*	*No*

Juvenile Verreaux's Eagle collision risk assessment

42. The assessment of the collision risk for juvenile Verreaux's Eagle, expressed in the context of their background mortality and the % increase over the baseline that each risk represents is summarised in Table 12. For all of the layouts and turbine specification scenarios the predicted juvenile mortality, even applying a highly precautionary 95% avoidance rate, would be a negligible magnitude impact, being less than a 1% increase over the regional baseline mortality.

Table 12. Additional collision risk assessment for Verreaux's Eagle juveniles and the increases that these represent over baseline mortality, with previous results for the authorized 27-turbine layout shown in italics.

Scenario	Rotor diameter (m)	Hub height (m)	Predicted collision risk (95% avoidance rate)	% increase over baseline mortality	Magnitude of effect	Likely significant effect?
Revised 25-turbine layout: scenario 1	136	92	0.08	0.03%	Negligible	No
Revised 25-turbine layout: scenario 2	136	105	0.07	0.03%	Negligible	No
Revised 25-turbine layout: scenario 3	136	120	0.06	0.02%	Negligible	No
Authorized 27-turbine layout	*116*	*92*	*0.21*	*0.08%*	*Negligible*	*No*

43. As in the previous collision risk assessments for this site, consideration was also given to the consequences of increasing the juvenile flight activity, assessing the risk on a precautionary theoretical basis rather than using field data. Even if flight activity were increased 10-fold over the observed adult rate, the collision risk would still be a negligible magnitude effect for all of the three scenarios (and would be lower risk than the authorized 27-turbine layout).

Conclusions and Summary

44. There were three key differences in relation to the collision risk modelling for the revised 25-turbine scheme compared with the authorized 27-turbine layout: (a) a revised site layout and hence an updated collision risk zone (and two fewer turbines); (b) updated minimum heights of blades above the ground resulting in a difference proportion of flights at rotor height, for three different hub heights; and (c) a larger rotor swept area resulting in an increased collision risk volume but reduced rotational speed.

45. Overall this assessment update of the collision risk for three turbine scenarios (all with the revised 25-turbine layout) found a reduced collision risk for Verreaux's Eagle in comparison with the authorized 27-turbine layout with a 116m rotor diameter turbine and 92m hub height. For Booted Eagle a small increase in risk was found. Collison risk to both species was lowest for the highest hub height (reflecting a lower proportion of flights at rotor height for that scenario). This did not, however, make any material difference to the conclusions reached. **There would be negligible magnitude collision risks to all of the key species assessed, which would not result in any significant ornithological impacts**. **All three of the new scenarios tested yielded negligible magnitude collision risks across the range of 92m-120m hub height which would not be significant, and the same conclusion would be valid for any hub height between those values. In other words, should Witberg Wind Power in the future consider an alternative turbine with a hub height between 92m and 120m, no additional collision risk assessments would be required as the results included in this report would remain valid.**

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APPENDIX 1. PROPOSED WIND TURBINE CO-ORDINATES FOR THE CURRENT REVISED 25-TURBINE LAYOUT

WG21 coordinate reference system

Turbine ID	x	y
WTG-01	3684448.69	49082.14
WTG-02	3684539.96	49426.33
WTG-03	3684268.91	49454.02
WTG-04	3684597.9	49706.99
WTG-05	3684666.87	49979.88
WTG-06	3685003.36	50470.85
WTG-07	3684282.19	50499.51
WTG-08	3685057.09	50806.05
WTG-09	3684318.81	50867.65
WTG-11	3684968.03	51170.83
WTG-12	3684333.81	51235.57
WTG-13	3685260.82	51439.92
WTG-14	3684982.01	51501.73
WTG-15	3686135.51	51620.3
WTG-16	3685288.05	51758.22
WTG-17	3686188.03	51955.31
WTG-19	3686104.94	52298.66
WTG-20	3685700.93	52366.39
WTG-21	3686022.75	52639.86
WTG-22	3686081.01	52999.25
WTG-23	3686164.27	53335.45
WTG-24	3685886.43	58410.19
WTG-25	3686023.41	58996.26
WTG-26	3686040.61	59362.41
WTG-27	3686047.23	59714.89

Note: turbines WTG 10 and WTG 18 dropped from previous layout but numbering retained for consistency

APPENDIX 2. COLLISION RISK MODELLING RESULTS REVISED 25-TURBINE LAYOUT (136M ROTOR DIAMETER TURBINE)

This Appendix sets out the collision risk modelling that has been undertaken for the proposed Witberg wind farm in January 2019. Firstly, the standard Band model spreadsheets are presented for each of the two species modelled in turn for the 136m rotor diameter turbine. These provide the information used to calculate the risk that individuals of each species would face if they flew through the wind farm rotor swept area. For the first species, for example, Verreaux's Eagle, this gives an overall 7.9% chance of collision.

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Verreaux's Eagle: 136m rotor

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	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	4.13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.88	m	0.025	0.575	6.82	32.58	1.00	0.00125	32.24	1.00	0.00125
Wingspan	2.4	m	0.075	0.575	2.27	10.97	0.45	0.00339	10.63	0.44	0.00328
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.36	7.39	0.30	0.00381	6.98	0.29	0.00359
			0.175	0.860	0.97	6.02	0.25	0.00434	5.51	0.23	0.00397
Bird speed	11.9	m/sec	0.225	0.994	0.76	5.19	0.21	0.00481	4.61	0.19	0.00427
RotorDiam	136	m	0.275	0.947	0.62	4.17	0.17	0.00472	3.61	0.15	0.00409
RotationPeriod	6.12	sec	0.325	0.899	0.52	3.45	0.14	0.00462	2.92	0.12	0.00391
			0.375	0.851	0.45	2.93	0.12	0.00452	2.42	0.10	0.00374
			0.425	0.804	0.40	2.52	0.10	0.00441	2.04	0.08	0.00358
			0.475	0.756	0.36	2.21	0.09	0.00433	1.77	0.07	0.00345
Bird aspect ratioo: β	0.37		0.525	0.708	0.32	2.03	0.08	0.00439	1.61	0.07	0.00348
			0.575	0.660	0.30	1.88	0.08	0.00444	1.49	0.06	0.00352
			0.625	0.613	0.27	1.74	0.07	0.00449	1.38	0.06	0.00356
			0.675	0.565	0.25	1.63	0.07	0.00453	1.30	0.05	0.00360
			0.725	0.517	0.24	1.53	0.06	0.00457	1.22	0.05	0.00366
			0.775	0.470	0.22	1.44	0.06	0.00460	1.16	0.05	0.00371
			0.825	0.422	0.21	1.36	0.06	0.00462	1.11	0.05	0.00378
			0.875	0.374	0.19	1.29	0.05	0.00464	1.07	0.04	0.00385
			0.925	0.327	0.18	1.22	0.05	0.00466	1.03	0.04	0.00392
			0.975	0.279	0.17	1.16	0.05	0.00466	1.00	0.04	0.00400
				Overall p(collision) =			**Upwind**	**8.6%**		**Downwind**	**7.2%**
								Average	**7.9%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Booted Eagle: 136m rotor											
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	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	4.13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.5	m	0.025	0.575	6.59	23.78	1.00	0.00125	23.44	1.00	0.00125
Wingspan	1.23	m	0.075	0.575	2.20	8.04	0.34	0.00257	7.70	0.33	0.00246
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.32	5.61	0.24	0.00299	5.20	0.22	0.00277
			0.175	0.860	0.94	4.72	0.20	0.00352	4.22	0.18	0.00314
Bird speed	11.5	m/sec	0.225	0.994	0.73	4.17	0.18	0.00400	3.59	0.15	0.00344
RotorDiam	136	m	0.275	0.947	0.60	3.34	0.14	0.00391	2.78	0.12	0.00325
RotationPeriod	6.12	sec	0.325	0.899	0.51	2.75	0.12	0.00381	2.22	0.09	0.00308
			0.375	0.851	0.44	2.32	0.10	0.00371	1.82	0.08	0.00291
			0.425	0.804	0.39	2.01	0.09	0.00364	1.54	0.07	0.00278
			0.475	0.756	0.35	1.80	0.08	0.00363	1.35	0.06	0.00273
Bird aspect ratioo: β	0.41		0.525	0.708	0.31	1.62	0.07	0.00362	1.20	0.05	0.00268
			0.575	0.660	0.29	1.47	0.06	0.00360	1.08	0.05	0.00264
			0.625	0.613	0.26	1.34	0.06	0.00357	0.98	0.04	0.00261
			0.675	0.565	0.24	1.23	0.05	0.00354	0.90	0.04	0.00258
			0.725	0.517	0.23	1.13	0.05	0.00350	0.83	0.04	0.00256
			0.775	0.470	0.21	1.05	0.04	0.00346	0.77	0.03	0.00254
			0.825	0.422	0.20	0.97	0.04	0.00341	0.72	0.03	0.00253
			0.875	0.374	0.19	0.90	0.04	0.00335	0.68	0.03	0.00253
			0.925	0.327	0.18	0.83	0.04	0.00329	0.64	0.03	0.00253
			0.975	0.279	0.17	0.78	0.03	0.00322	0.61	0.03	0.00254
				Overall p(collision) =			**Upwind**	**6.8%**		**Downwind**	**5.4%**
								Average	**6.1%**		

The second section of this Appendix provides details of the calculations that have been made of the key species flight activity within the collision risk zone.

The first part of the Table (Section 1) below gives the survey effort (number of hours observation) for each month.

Both of the key species showed variable non-direct flights through the collision risk zone so were modelled using that variant of the Band model (which required the amount of time that each species was presented within the collision risk zone as its bird activity input).

The times each species was observed within the collision risk zone is summarised in Section 2, and the calculated occupancy rate (the % of observation time observed) are given in Section 3 (which feed into the following section of the modelling).

WITBERG COLLISION RISK MODELLING DATA INPUT: BIRD USAGE														
1. Hours observation														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
East	18.8	0	0	26.2	0	21.0	0	15.2	0	0	20.5	0		
Mid	18.8	0	0	6.0	0	13.8	0	8.3	0	0	18.8	0		
West	15.2	0	0	18.8	0	7.3	0	10.0	0	0	18.5	0		
2. Bird occupancy of collision zone (seconds)														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Black Eagle: East	0.0			0.0		0.0		0.0			0.0			
Black Eagle: Mid	0.0			166.6		133.5		0.0			27.1			
Black Eagle: West	0.0			0.0		52.8		0.0			0.0			
Booted Eagle: East	0.0			0.0		0.0		0.0			0.0			
Booted Eagle: Mid	0.0			0.0		14.9		0.0			200.0			
Booted Eagle: West	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: East	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: Mid	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: West	0.0			0.0		0.0		0.0			0.0			
3. Bird occupancy rate of collision zone (% time present)														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		**Mean occupanc**
Black Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Black Eagle: Mid	0.000%			0.771%		0.270%		0.000%			0.040%			**0.216%**
Black Eagle: West	0.000%			0.000%		0.200%		0.000%			0.000%			**0.040%**
Booted Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Booted Eagle: Mid	0.000%			0.000%		0.030%		0.000%			0.295%			**0.065%**
Booted Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: Mid	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**

The last part of the Appendix shows the details of the collision risk modelling for each zone of the wind farm for each of the two key species that were observed within the collision risk zone at rotor height, for each of the four scenarios. The total risk is the sum of the risks for each zone of the wind farm, plus the additional risk from the 2 further turbines on the western edge of the layout that fell outside the main vantage point survey area (estimated from the mean risk per turbine in the western zone that were fully covered by the VP survey).

WITBERG WIND FARM						
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)						
SCENARIO 1: 136M ROTOR DIAMETER, 92M HUB HT						
	Black Eagle			**Booted Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	40	460	33	40	460	33
Hub Ht	92	92	92	92	92	92
Rotor diameter	136	136	136	136	136	136
Upper rotor ht	160	160	160	160	160	160
Lower rotor ht	24	24	24	24	24	24
Percentage of observation time seen flying in collision zone	**0.000%**	**0.216%**	**0.040%**	**0.000%**	**0.065%**	**0.000%**
Proportion of observation time seen flying at rotor height	78%	78%	78%	64%	64%	64%
Adjusted proportion of observation time seen flying at rotor height	0.000%	0.169%	0.031%	0.000%	0.042%	0.000%
Season length	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.000	7.448	1.379	0.000	1.838	0.000
Flight risk volume	5.440E+07	6.256E+08	4.488E+07	5.440E+07	6.256E+08	4.488E+07
No Turbines	**0**	**21**	**2**	**0**	**21**	**2**
Rotor radius	**68**	**68**	**68**	**68**	**68**	**68**
Rotor depth	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**
Swept volume	0	1519205	144686	0	1403282	133646
Bird occupancy of swept volume	0.00	65.11	16.00	0.00	14.84	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**
Rotor transit time	0.418	0.418	0.418	0.400	0.400	0.400
No of rotor transits	0.0	155.6	38.2	0.0	37.1	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%
Band collision rate	7.9%	7.9%	7.9%	6.1%	6.1%	6.1%
Non-avoid collisions	0.0	11.1	2.7	0.0	2.0	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%
Collision prediction	**0.00**	**0.22**	**0.05**	**0**	**0.04**	**0**
Total collisions (inc. additional 2 western turbines)			**0.33**			**0.04**

WITBERG WIND FARM						
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)						
SCENARIO 2: 136M ROTOR DIAMETER, 105M HUB HT						
	Black Eagle			**Booted Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	40	460	33	40	460	33
Hub Ht	105	105	105	105	105	105
Rotor diameter	136	136	136	136	136	136
Upper rotor ht	173	173	173	173	173	173
Lower rotor ht	37	37	37	37	37	37
Percentage of observation time seen flying in collision zone	**0.000%**	**0.216%**	**0.040%**	**0.000%**	**0.065%**	**0.000%**
Proportion of observation time seen flying at rotor height	69%	69%	69%	62%	62%	62%
Adjusted proportion of observation time seen flying at rotor height	0.000%	0.149%	0.028%	0.000%	0.040%	0.000%
Season length	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.000	6.589	1.220	0.000	1.780	0.000
Flight risk volume	5.440E+07	6.256E+08	4.488E+07	5.440E+07	6.256E+08	4.488E+07
No Turbines	**0**	**21**	**2**	**0**	**21**	**2**
Rotor radius	**68**	**68**	**68**	**68**	**68**	**68**
Rotor depth	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**
Swept volume	0	1519205	144686	0	1403282	133646
Bird occupancy of swept volume	0.00	57.60	14.15	0.00	14.38	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**
Rotor transit time	0.418	0.418	0.418	0.400	0.400	0.400
No of rotor transits	0.0	137.6	33.8	0.0	35.9	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%
Band collision rate	7.9%	7.9%	7.9%	6.1%	6.1%	6.1%
Non-avoid collisions	0.0	9.8	2.4	0.0	2.0	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%
Collision prediction	**0.00**	**0.20**	**0.05**	**0**	**0.04**	**0**
Total collisions (inc. additional 2 western turbines)			**0.29**			**0.04**

WITBERG WIND FARM						
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)						
SCENARIO 3: 136M ROTOR DIAMETER, 120M HUB HT						
	Black Eagle			**Booted Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	40	460	33	40	460	33
Hub Ht	120	120	120	120	120	120
Rotor diameter	136	136	136	136	136	136
Upper rotor ht	188	188	188	188	188	188
Lower rotor ht	52	52	52	52	52	52
Percentage of observation time seen flying in collision zone	**0.000%**	**0.216%**	**0.040%**	**0.000%**	**0.065%**	**0.000%**
Proportion of observation time seen flying at rotor height	61%	61%	61%	59%	59%	59%
Adjusted proportion of observation time seen flying at rotor height	0.000%	0.132%	0.024%	0.000%	0.038%	0.000%
Season length	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.000	5.825	1.078	0.000	1.694	0.000
Flight risk volume	5.440E+07	6.256E+08	4.488E+07	5.440E+07	6.256E+08	4.488E+07
No Turbines	**0**	**21**	**2**	**0**	**21**	**2**
Rotor radius	**68**	**68**	**68**	**68**	**68**	**68**
Rotor depth	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**
Swept volume	0	1519205	144686	0	1403282	133646
Bird occupancy of swept volume	0.00	50.92	12.51	0.00	13.68	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**
Rotor transit time	0.418	0.418	0.418	0.400	0.400	0.400
No of rotor transits	0.0	121.7	29.9	0.0	34.2	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%
Band collision rate	7.9%	7.9%	7.9%	6.1%	6.1%	6.1%
Non-avoid collisions	0.0	8.7	2.1	0.0	1.9	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%
Collision prediction	**0.00**	**0.17**	**0.04**	**0**	**0.04**	**0**
Total collisions (inc. additional 2 western turbines)			**0.26**			**0.04**