Avian Baseline Monitoring Programme for the Witberg Renewable Energy Facility

# Pre-construction Monitoring Report

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# List of acronyms and abbreviations

| | |
|---|---|
| AIA | Avifaunal Impact Assessment |
| BAWESG | Birds and Wind Energy Study Group |
| EIA | Environmental Impact Assessment |
| EWT | Endangered Wildlife Trust |
| masl | Metres above sea level |
| SD | Standard deviation |
| SE | Standard error |
| WEF | Wind energy facility |
| NEMA | National Environmental Management Act |
| NSBA | National Spatial Biodiversity Assessment |
| NBSAP | National Biodiversity Strategic Action Plan |

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# 1 INTRODUCTION

G7 Renewable Energies ("G7")[1] has proposed the development of a Wind Energy Facility on a ridge of the Witteberg mountains, directly south of the N1 highway, 4km west of Matjiesfontein and approximately 40km east of Touwsrivier in the Western Cape Province. The proposed Wind Energy Facility (WEF) would be spread over distance of about 13km along the main "Witberg ridge".

The proposed project has an operational lifespan of 20 – 25 years (S. Hirschman, G7, pers. comm.). A potential replacement of turbines - including change of turbine hub height, rotor diameter, turbine position, foundations substations, roads etc. – thereafter, may require a new environmental impact assessment (EIA).

An Avian Impact Assessment (AIA) was carried out for the study area by Avisense (2010) as part of the overall Environmental Impact Assessment (EIA) for the proposed development. Recommendations of the AIA report included that pre- and post-construction monitoring of birds should be carried out at the site, following the guidelines published by the Birds and Wind Energy Specialist Group (BAWESG) of the Endangered Wildlife Trust (Jenkins et al. 2011), and that the outcome of the monitoring studies should be used to update the recommendations in the AIA for the mitigation of potential negative impacts of the WEF on avifauna. Anchor Environmental Consultants was contracted by G7 to undertake the pre-construction avifaunal monitoring for the proposed WEF site.

The primary aims of the baseline monitoring as taken from the best practise guidelines for avian monitoring at proposed wind energy development sites (Jenkins *et al*. 2011) include:

- Determining the densities of birds regularly present or resident within the impact area of the WEF (and a control site) before the construction phase.
- Documenting the patterns and movements of birds in the vicinity of the proposed WEF before its construction.
- Monitoring the patterns and movements of birds in the WEF vicinity in relation to weather conditions, time of day and season for at least a year.
- Establishing a pre-impact baseline for bird numbers, distributions and movements.
- Informing final design, construction and management strategy of development with a view to mitigating potential impacts.

Five pre-construction monitoring trips have been undertaken to survey the avifauna in the vicinity of the proposed WEF. More than 200 hours have been spent recording the bird activity of the area and a valuable data set has been collated. This report provides

[1] The development will be undertaken by Witberg Wind Power (Pty) Ltd, which has been established subsequently.

the overall results of all the bird monitoring undertaken and updates the recommendations made in the AIA. These updated recommendations are required by the Environmental Management Plan that has been prepared for the site, as well as in terms of the Environmental Authorisation that has been granted by the national Department of Environmental Affairs for the listed activities that comprise the proposed development.

# 2 STUDY AREA

The proposed Witberg WEF will be located on a number of immovable properties immediately south of the N1 highway 4km west of Matjiesfontein in the Western Cape Province. The farms include Jantjesfontein, Besten Weg, Tweedside, and Elandskrag (Avisense 2011). Up to 40 wind turbines were initially included in the proposed layout at the start of the monitoring study (Figure 1). By the end of this study this number had been reduced to 26 turbines (see Discussion). The WEF site is centred on 13km of the main Witberg ridgeline, which runs east-west between Laingsburg and Matjiesfontein. The terrain is rocky and mountainous along the ridge (Avisense 2011).

The proposed WEF is located at the interface of the Fynbos and Succulent Karoo biomes (Avisense 2011). The natural vegetation is dominated by Matjiesfontein Shale Renosterveld in the valleys and Matjiesfontein Quartzite Fynbos on the ridges (Avisense 2011). The vegetation and habitats in the study area are described in detail in the AIA (Avisense 2011). The lowlands are mainly used for stock farming (cattle and sheep) as well as for cereal crops. The ridge itself is relatively pristine, except for the road access to the top from the north-east, and the large communications tower situated on the crest (Avisense 2011).

The prevailing winds are from the north-west in winter and the south-east and north-east in summer, with the north-west winds being the dominant wind in terms of strength.


**Figure 1: Site map of the Witberg Wind Farm in the Western Cape Province. The authorised turbine layout is shown in red with alternatives in white.**

# 3 MONITORING METHODS

## 3.1 INTRODUCTION

Monitoring data needs to be collected from both the impact zone of the proposed Witberg WEF as well as a control site. By doing so, data can be compared between the two sites from pre- and post- construction and actual impacts associated with the WEF can be accurately quantified (Jenkins *et al*. 2011). Suitable control sites should match the habitats, land-use and topography of the proposed WEF site, host a similar mix of bird species to those found in the WEF, be at least half the size of the WEF, be situated as close as possible to the WEF but simultaneously far enough to ensure that the resident bird species are not directly affected by the wind farm activities or operations (Jenkins *et al.* 2011). This study attempted to meet these conditions as far as was practically possible within time and other constraints such as land accessibility. The control site was considered to be very satisfactory.

Monitoring of the proposed WEF site and of the control site was conducted during five sampling trips over a twelve-month period, to be representative of the full environmental conditions likely to occur at these specific sites (Jenkins *et al.* 2011). At least two off-road vehicles and four observers were used on each trip of four to five days. The activities carried out during monitoring are detailed below. The study team included two professional ornithologists and the remaining observers were ecologists and professional birdwatchers.

Prior to the monitoring study, data provided by Avisense (2011) in the AIA included the extraction of all bird atlas records for the study area, as well as a bird list compiled from three days in the study area and its immediate surrounds. In addition, the cliffs of the study area were searched for raptor nesting sites and the locations of those nests were mapped. This study builds on the findings of the AIA, and where appropriate, the results of the AIA are included and/or compared with the results of the monitoring trips.

## 3.2 PRESENCE AND ABUNDANCE OF BIRDS

All species present on and around the site were noted on each visit. Densities of birds were measured using 1 km-long walked transects. Six transects were established along the ridge at the WEF site, and three were sited along the ridge at the control site (Figure 2, Table 1). All transects were in the same vegetation type and within a narrow altitudinal band between 1200 and 1500 metres above sea level (masl). The density sampling was carried out in the early to mid-morning, recording species, number and distance from the transect line or central point of all birds seen.

Since the above method is more suited to smaller passerine species, populations of large terrestrial birds and raptors, with emphasis on the priority species listed in the AIA, were also estimated on the basis of observations made during the course of the field visits, particularly in the course of travelling the length of the site *en route* to vantage points.


**FIGURE 2. GOOGLE EARTH IMAGE OF THE STUDY AREA SHOWING TURBINE LAYOUT (GREEN), AND POSITION OF VANTAGE POINTS AND TRANSECTS ON THE WEF SITE AND THE CONTROL SITE TO THE EAST. SCALE: ROUGHLY 24 KM FROM MOST WESTERLY TURBINE TO OUTER LIMIT OF TRANSECTS ON CONTROL SITE.**

**TABLE 1. GPS CO-ORDINATES OF VANTAGE POINTS AND TRANSECTS ON THE WEF AND CONTROL SITES**

| **WEF site** | Lat | Long | **Control site** | Lat | Long |
|---|---|---|---|---|---|
| Vantage E | 33°16'49.27"S | 20°30'16.11"E | Vantage | 33°16'57.86"S | 20°36'16.88"E |
| Vantage Mid | 33°16'53.85"S | 20°26'38.27"E | | | |
| Vantage W | 33°17'27.29"S | 20°23'48.73"E | | | |
| **Transects** | | | **Transects** | | |
| T1 start | 33°16'47.55"S | 20°31'23.09"E | T1 start | 33°17'5.61"S | 20°35'27.39"E |
| T1 end | 33°16'53.22"S | 20°30'45.02"E | T1 end | 33°17'8.45"S | 20°34'48.76"E |
| T2 start | 33°16'48.88"S | 20°30'12.52"E | T2 start | 33°17'5.96"S | 20°35'32.61"E |
| T2 end | 33°16'50.28"S | 20°29'34.29"E | T2 end | 33°16'57.43"S | 20°36'10.23"E |
| T3 start | 33°17'01.01"S | 20°27'38.47"E | T3 start | 33°17'0.23"S | 20°36'17.93"E |
| T3 end | 33°16'56.93"S | 20°27'00.21"E | T3 end | 33°17'3.98"S | 20°36'56.48"E |
| T4 start | 33°17'04.18"S | 20°26'55.03"E | | | |
| T4 end | 33°17'07.17"S | 20°26'16.77"E | | | |
| T5 start | 33°16'54.05"S | 20°29'15.09"E | | | |
| T5 end | 33°17'1.76"S | 20°28'37.28"E | | | |
| T6 start | 33°17'5.64"S | 20°28'8.49"E | | | |
| T6 end | 33°17'11.16"S | 20°27'30.46"E | | | |

## 3.3 Breeding activity of key raptor species

Areas deemed suitable for nesting of key raptor species, particularly the raptor nesting sites identified in the area during the AIA study, were checked for activity during the breeding period.

## 3.4 Movements of priority species

Movements of priority species plus any other large bird species over and around the WEF site and control site were recorded from suitable vantage points at the sites. Bird movements were simultaneously monitored by four observers stationed at three vantage points at the WEF site and one at the control site, located about 7.5 km to the east of the WEF site (Figure 2). GPS positions of the vantage points are provided in Table 1.

The vantage points are higher than the surrounding landscape and were strategically chosen to achieve maximum coverage of the study area. There was little overlap between the view sheds of each vantage point. Observers were stationed at the vantage points over a three day period, and observations were made for blocks of time within the day (typically midday to sunset). Observations involved continuous slow scanning of a 360° area, alternately with telescopes and binoculars. Once a large bird was spotted, it was followed till out of sight and its flight path recorded on a 1: 50 000 topographic map in addition to height and behavioural data. For each sighting, the following information was recorded as far as possible:

- Time
- Updated weather conditions
- Species and number
- Mode of flight (gliding, flapping, soaring)
- Flight activity (commuting, hunting)
- Vertical zoning relative to the proposed turbines (low/below turbines, medium/within turbine zone, high/above turbines)
- Horizontal distance and bearing from the observer at start and end of observation.
- Direction of flight, or flight path plotted on map.

These data were then mapped digitally in ArcView and passage rates calculated.

# 4 RESULTS

## 4.1 Species richness and endemism

A total of 220 bird species have been recorded in the bird atlassing squares of the South African Bird Atlas Project (round two) that overlap and immediately surround the original study area. These include 13 South African red-listed species, 69 endemics or near endemics, and three red-listed endemics (Avisense 2011).

Within the study area itself, a total of 49 species were recorded during the initial site visit undertaken as part of the AIA (Avisense 2011). During the pre-construction monitoring study, efforts were concentrated on the ridge. A total of 47 – 57 species was seen on each trip, and the overall list of bird species was expanded to a total of 108 species. A complete list of birds recorded, their scientific names, conservation status, endemicity and local status is provided in Appendix 1. The species-effort curve suggests that the number of species recorded is close to the maximum number of bird species that can be expected to be recorded on the site (Figure 3).

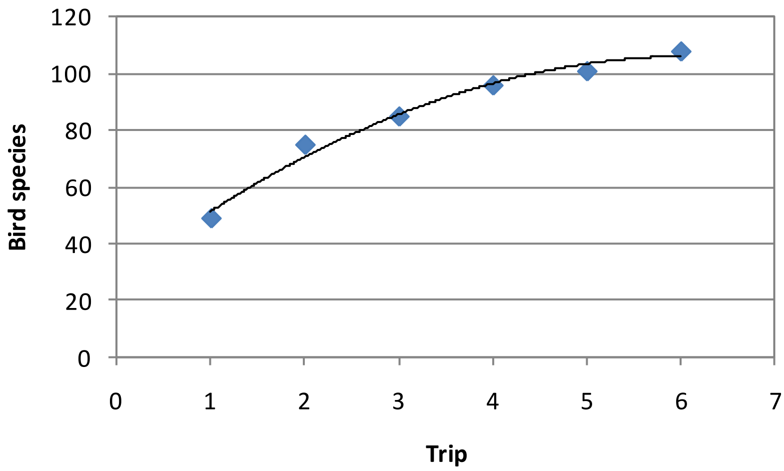


Figure 3. Cumulative total number of species seen after each 3-4 day trip, starting with the AIA field work.

The avifauna recorded at the site has an extremely high level of endemism. The birds recorded in the area included 31 endemic and 13 near-endemic species whose distributions are confined or largely confined to southern Africa (Table 2), four of which are also Priority Species (discussed in more detail below). Most of these were present on ridges of the WEF site, but a few (e.g. Blue Crane) were only seen in the valleys.

Several endemic resident species were present on the WEF site year-round, and seen on most or all visits. These included species that are uncommon or rare in South Africa, due to having very narrow habitat requirements, such as Cape Rockjumpers, Ground Woodpecker (Figure 4), African Rock Pipit and Cape Sugarbird. The birds found year–round on the site are likely to breed there. Only one, the Lark-like Bunting, was a seasonal non-breeding visitor, seen only in summer.

TABLE 2. SPECIES ENDEMIC TO SOUTHERN AFRICA THAT WERE RECORDED AT THE WEF SITE. E = ENDEMIC, N = NEAR-ENDEMIC. PRIORITY ENDEMIC SPECIES ARE INDICATED WITH AN ASTERISK.

| Species | | Local status | Species | | Local status |
|---|---|---|---|---|---|
| Cape Spurfowl | E | Common resident | Pied Starling | E | Common resident |
| Grey-winged Francolin | E | Uncommon resident | Orange-breasted Sunbird | E | Common resident |
| South African Shelduck | E | Common resident | Southern Double-collared Sunbird | E | Common resident |
| Ground Woodpecker | E | Uncommon resident | Cape Sugarbird | E | Uncommon resident |
| White-backed Mousebird | E | Common migrant | Cape Weaver | E | Common resident |
| Blue Crane (V)* | E | Uncommon resident | African Rock Pipit* | E | Uncommon resident |
| Black Harrier (NT)* | E | Uncommon resident | Cape Canary | E | Common resident |
| Jackal Buzzard | E | Common resident | Black-headed Canary | E | Uncommon resident |
| Cape Rock-jumper* | E | Rare resident | Cape Siskin | E | Uncommon resident |
| Cape Bulbul | E | Common resident | Southern Pale Chanting Goshawk | N | Uncommon resident |
| Layard's Tit-Babbler | E | Uncommon resident | Bokmakierie | N | Common resident |
| Karoo Prinia | E | Common resident | Pririt Batis | N | Uncommon resident |
| Rufous-eared Warbler | E | Common resident | Chestnut-vented Tit-Babbler | N | Uncommon resident |
| Cape Clapper Lark | E | Uncommon resident | Grey-backed Cisticola | N | Common resident |
| Karoo Lark | E | Uncommon resident | Mountain Wheatear | N | Common resident |
| Karoo Long-billed Lark | E | Uncommon resident | Cape Sparrow | N | Common resident |
| Large-billed Lark | E | Common resident | Yellow Canary | N | Common resident |
| Cape Rock Thrush | E | Common resident | White-throated Canary | N | Common resident |
| Sentinel Rock Thrush | E | Uncommon resident | Lark-like Bunting | N | Common visitor |
| Karoo Scrub-Robin | E | Common resident | Cape Bunting | N | Common resident |
| Ant-eating Chat | E | Common resident | Protea Seedeater | E | Uncommon resident |
| Karoo Chat | N | Common resident | | | |
| Pale-winged Starling | N | Common resident | | | |

FIGURE 4. GROUND WOODPECKERS SEEN AROUND THE EAST VANTAGE POINT.

## 4.2 Densities of small birds

Small passerine densities were determined from the 1km transects at both the proposed WEF and Control sites. Average ± SD species diversity per sampling period was relatively low ranging from 3.7 ± 2.1 to 10.0 ± 4.8 species per kilometre at the proposed WEF. Overall average ± SE species diversity was 7.1 ± 1.1 for the five independent sampling periods (Table 3).

Table 3. Numbers of passerine species and bird abundance per kilometre for the Witberg WEF and Control sites based on four independent surveys

| Survey Period | Proposed WEF Site | | Control Site | |
|---|---|---|---|---|
| | Species/km ± SD | Frequency/km ± SD | Species/km ± SD | Frequency/km ± SD |
| 18-21 Jun 2011 | 3.7 ± 2.1 | 9.3 ± 6.3 | 4.7 ± 1.5 | 14.7 ± 6.0 |
| 28-30 Aug 2011 | 5.5 ± 3.9 | 12.8 ± 14.8 | 5.0 ± 1.7 | 13.7 ± 3.5 |
| 1-4 Nov 2011 | 7.5 ± 2.0 | 19.2 ± 10.0 | 7.0 ± 4.0 | 13.0 ± 7.9 |
| 8-10 Jan 2012 | 10.0 ± 4.8 | 131.0 ± 109.1 | 6.7 ± 4.6 | 39.7 ± 56.6 |
| 19-20 Apr 2012 | 8.8 ± 3.7 | 23.7 ± 7.8 | 5.0 ± 2.6 | 24.0 ± 20.3 |
| **Summary** | | | | |
| **Min** | 3.7 ± 2.1 | 9.3 ± 6.3 | 4.7 ± 1.5 | 13.0 ± 7.9 |
| **Max** | 10 ± 4.8 | 131 ± 109.1 | 7.0 ± 4.0 | 39.7 ± 56.6 |
| **Median** | 7.5 | 19.2 | 5.0 | 14.7 |
| **Average ± SE** | 7.1 ± 1.1 | 39.2 ± 23.1 | 5.7 ± 0.5 | 21.0 ± 5.1 |

A similar average ± SE species diversity of 5.7 ± 0.5 was recorded at the adjacent Control Site. In terms of passerine abundances, these varied considerably between the five periods sampled, and were influenced by weather conditions (low numbers recorded in very windy conditions). Average abundance ± SD per period ranged from 9.3 ± 6.3 to 131 ± 109.1 at the proposed WEF with a median value of 19.2. A similar median abundance of 14.7 was recorded at the Control Site. These data can be analysed more rigorously when used for comparative analysis with the post-construction data.

## 4.3 Priority species

Eight out of 12 Priority Bird species from the region were recorded in the immediate vicinity of the proposed WEF (Table 4), and a ninth (Blue Crane), was recorded in the cultivated lands below. Those not recorded were Ludwig’s Bustard, Black Stork and Peregrine Falcon. The most consistently-present species were the Verreaux’s Eagle and Cape Rock-Jumper as they were seen every day on all visits. Booted Eagle and African Rock Pipit were also regularly seen. It is highly likely that all of the eight species occurring on the ridge were breeding in the vicinity of the WEF site, and this was confirmed for the eagle species. Some pertinent facts about the priority species found on the ridge are given below (based on Hockey et al. 2005). Red data status is taken from the Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland (Barnes 2000).

**TABLE 4. PRIORITY SPECIES SEEN DURING THE AIA AND MONITORING VISITS TO THE WITBERG WEF.**

| Species | Oct 2010 | Jun 2011 | Aug 2011 | Nov 2011 | Jan 2012 | Apr 2012 |
|---|---|---|---|---|---|---|
| African Rock Pipit | x | | x | x | x | x |
| Blue Crane | x | x | | | | |
| Cape Rock-Jumper | x | x | x | x | x | x |
| Cape Eagle-Owl | | | x | | | |
| Black Harrier | x | | | x | | |
| Verreaux's Eagle | x | x | x | x | x | x |
| Booted Eagle | x | x | x | x | | x |
| Martial Eagle | x | x | x | | | |
| Lanner Falcon | | x | | | | |

**African Rock Pipit** (range-restricted endemic) occurs along the southern Cape fold mountains and highlands of the southern Nama Karoo and Drakensberg, and has a total breeding population of about 5-10 000 birds, entirely within South Africa and Lesotho. It is territorial and spends most of the time on the ground moving among vegetation and rocks. This species was fairly common on the WEF site.

**Cape Rock Jumper** (range-restricted endemic) has a very limited distribution range largely within the fynbos biome, but is not threatened because most of its habitat is still largely intact. If forages on the ground among bushes and rocks. Pairs or small groups maintain territories year round. There were several groups present on the WEF site.

**Cape Eagle Owl** occurs throughout much of southern and eastern Africa, but is generally uncommon, and should be considered for Red-listing (Avisense 2011). It tends to be associated with rocky outcrops and cliffs, and feeds mainly on small mammals. Its movements are unknown, but may be nomadic. This species was not found during the day, but was recorded on the single occasion that the study area was visited at night.

**Black Harrier** (Near Threatened) is restricted to South Africa and Namibia, and is uncommon, with a total of only 500 -1000 breeding pairs. It is territorial, nesting on or near the ground. It feeds aerially, being particularly active on windy days. Its main concentrations are associated with coastal lowlands and mountains and high altitude grasslands. Black Harrier was seen several times on the WEF site, as well as in the valleys below, where some breeding behaviour was also observed.

**Verreaux's Eagle** (important apex predator) occurs throughout Africa and into the Middle East, and is fairly common in South Africa. Within southern Africa, the density of Verreaux's Eagles is highest in a band from the south-western Cape to KwaZulu-Natal, incorporating the study area. There are an estimated 400 – 2000 pairs in the old Cape Province (Northern Cape, the Eastern Cape and the western edge of the North West Province; Boshoff & Vernon 1980, Hockey et al. 2005). Of these there are probably a maximum of 800 pairs in the Western Cape (L. Rodriguez, pers. comm.). Densities of 1 pair per 24km$^2$ have been recorded in the Karoo (Davies 1994, Hockey et al. 2005).

Verreaux's Eagles are found in mountainous and rocky areas with cliffs, and because of this their populations have remained relatively secure in the past. Verreaux's Eagles are monogamous and defend territories year round, the pairs staying together most of the day. Most territories contain multiple nest sites (up to 5), although one nest might be favoured for several years in a row. Verreaux's Eagles tend to hunt by soaring along ridges and their diet is dominated by mammals, particularly hyrax. They tend to rest during the middle of the day. Verreaux's Eagles were present in high densities in the study area, where they nested on cliffs just below the ridge top, and hunted mainly along the ridges and slopes.

**Booted Eagle** (important apex predator) is found throughout much of Africa and Eurasia, but their world population is less than 100 000 birds. Within southern Africa, they are most common in the south and south west part, which includes the study area. An estimated 700 breeding pairs occur in the 'Cape' area, breeding mainly in mountainous areas, where they nest on cliffs. The Palaearctic breeders migrate to southern Africa spending November to March here. The population resident in southern Africa move into the south-western areas to breed during July-August, remaining until March. This population is a separate subspecies to the Palearctic migrants, but they are not considered threatened. In southern Africa, Booted Eagles are monogamous, and while they are territorial, they are often known to have nest sites in close proximity to their neighbours (e.g. less than 300m), as was the case in the study area. Booted Eagles are agile aerial foragers, and their diet is dominated by birds. At least two pairs of Booted Eagles nested on the cliffs at the WEF site and foraged over the ridges.

**Martial Eagle** (Vulnerable) is widespread throughout Africa, but occurs only sparsely within southern Africa, and is more common in flat country than in mountainous areas. In the study area, their nests are on pylons at the base of the Witberg mountains (north of the proposed turbine ridge), but they forage over the ridges as well as over the lower hills and valleys in the surrounding areas. Martial Eagles tend to be resident, with a monogamous pair defending a territory for several seasons. Although the majority of pairs have one nest site (typically on a pylon or tree fork), multiple nest sites (up to 4) are not uncommon. They defend large territories of at least 280 km$^2$ in the Nama Karoo

(Simmons 2005). While hunting, they often soar at high altitudes, and their diet is dominated by small mammals. Martial Eagles foraged over the WEF site and were frequently seen in the surrounding hill areas as well.

**Lanner Falcon** (Near-Threatened) occurs through much of Africa and Eurasia, and is fairly common. It favours sites where there are cliffs available for nesting and roosting. It feeds from a perch or on the wing, catching mainly birds. It is a partial and facultative migrant in South Africa. This species was only seen on one occasion at the WEF site, in an aggressive interaction with Verreaux's Eagles near their nest site. It was not seen foraging over the WEF site.

## 4.4 Breeding activity of eagles

In the AIA, Avisense (2011) recorded four Verreaux's Eagle nests and two Martial Eagle nests within 5km of the turbine layout. After the AIA was carried out, the proposed turbine layout was revised to avoid the Martial Eagle nests (based on a 2.5km buffer suggested by Avisense 2011). This was done prior to the Environmental Authorisation being granted.

During the pre-construction monitoring additional Verreaux's Eagle nests were found within this area, bringing the total of Verreaux's Eagle nests to seven, as well as two Booted Eagle nests (see Figure 5). Four Verreaux's Eagle nests (M1, M2, E2, E3) and two Booted Eagle nests are in very close proximity to the current proposed line of turbines along the main ridge (Figure 8). The most recent nest (M2) was discovered during the April 2012 trip and is located approximately 2.5km south of the WEF (see Figure 6 and Figure 7). Although eagles can have multiple nest sites, sightings of pairs interacting suggested that each nest on the northern ridge belonged to a different eagle pair. The two nests to the south of the ridge (M2 and E2) were found in two different seasons and could have belonged to the same pair of birds, but this is unlikely. All of the eagle pairs close to the WEF were observed to be engaged in one or more breeding activities during the course of the monitoring period, including mating, displaying, attendance of nests and feeding chicks. The WEF ridge was also frequented by several other raptor species likely to breed, including Jackal Buzzard [endemic], Cape Eagle Owl [endemic subspecies] and Rock Kestrel.

**FIGURE 5. PRIME NESTING HABITAT FOR MANY SPECIES OF RAPTORS, INCLUDING PRIORITY SPECIES, IS FOUND ALONG THE WITBERG RANGE. THE TOP PHOTOGRAPH SHOWS A VERREAUX'S EAGLE AT THE NEST.**

Several more pairs of Verreaux's Eagles were also sighted in the areas further from the turbines, suggesting that their nesting density is high throughout the Witteberge range. This is a cause for concern regarding the development of Wind Energy Facilities in the area.


**FIGURE 6. VERREAUX'S EAGLE NEST M2. THE GOOGLE EARTH IMAGE SHOWS THE POSITION OF THE NEXT IN RELATION TO THE ROW OF TURBINES ON THE RIDGE.**

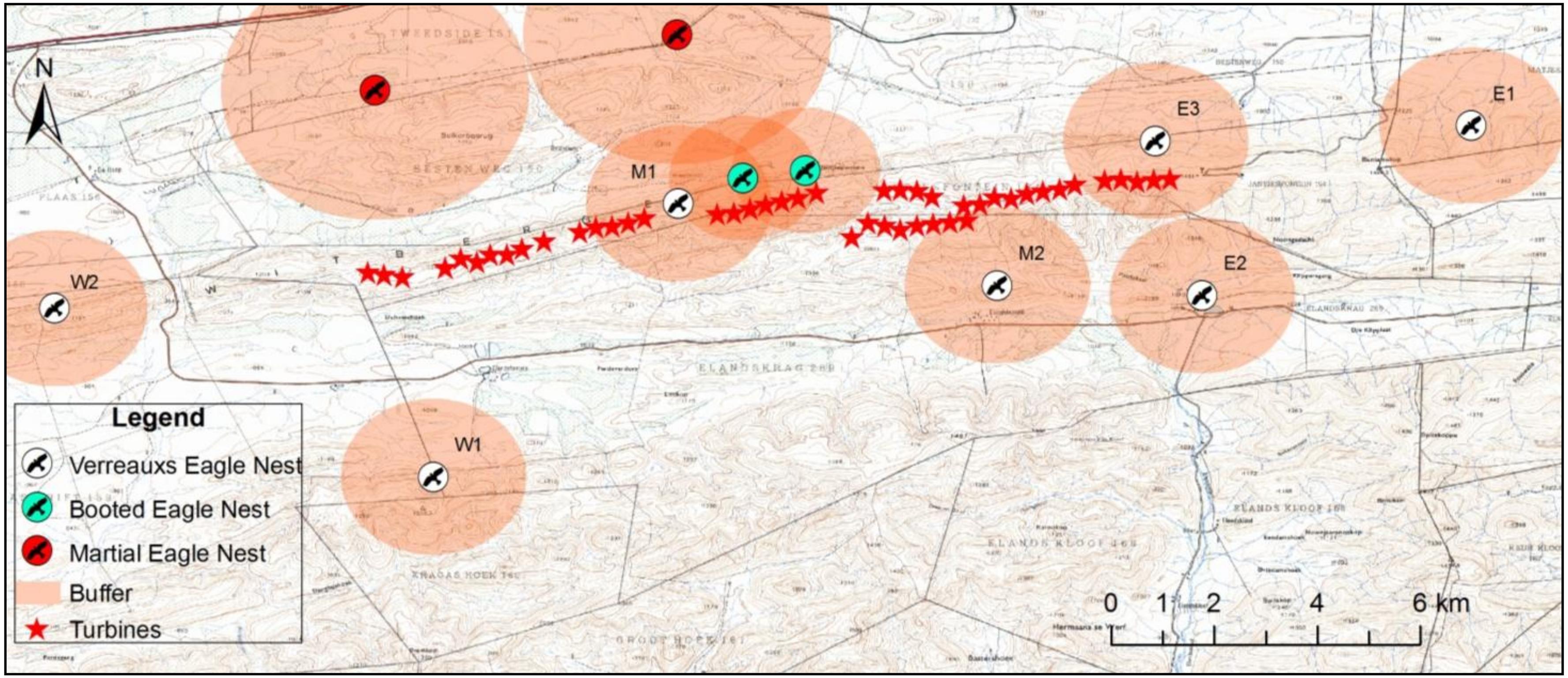


**FIGURE 7. POSITION OF RAPTOR NESTS SHOWING BUFFER AREAS OF 2.5KM DIAMETER FOR MARTIAL EAGLE, 1.5KM FOR VERREAUX'S EAGLE AND 1.2KM FOR BOOTED EAGLE. PROPOSED TURBINE POSITIONS (AS AT START OF MONITORING STUDY) ARE INDICATED BY RED STARS**

## 4.5 Flight activity of large birds

During the observations from vantage points, movements of all large birds were recorded, including crows and ravens and smaller raptors such as kestrels. In fact most of the movements recorded were undertaken by raptors (mainly eagles). No flights by cranes, bustards, storks or waterbirds were seen, and crows and ravens were uncommonly seen. Commuting flights by smaller birds such as doves were also fairly uncommon. Raptor flight paths recorded during more than 200 hrs of observations are shown in relation to the turbines of the proposed Witberg WEF (Figure 8). Flight paths observed from the Control Site vantage point are shown in Figure 9.

During the five 3-day periods flights paths were recorded, passage rates at the proposed WEF ranged from 1.2 to 6.9 large birds per hour with an average ± SD of 2.4 ± 2.5 (Table 5**Error! Reference source not found.**). The passage rates of the Priority Species alone were 1.4 ± 1.3 birds per hour with the lowest passage rate of 0.5 birds per hour being recorded in January 2012. At the Control Site similar rates to the proposed WEF were recorded with 1.2 ± 0.7 Priority Species being recorded per hour on average and never less than 0.4 Priority Species per hour. These rates are very high and a cause for concern. The data collected on passage rates are designed for comparison with similar data to be collected during the post-construction monitoring.

**Table 5. Hours surveyed, number of species and passage rates recorded during four periods of observation at the Witberg WEF and Control Sites.**

| Survey Period | WEF Site | | | | Control Site | | | |
|---|---|---|---|---|---|---|---|---|
| | Hours surveyed | Species | Passage rate (large birds/hr) | Passage rate (priority species/hr) | Hours surveyed | Species | Passage rate (large birds/hr) | Passage rate (priority species/hr) |
| Jun 2011 | 18.1 | 8 | 6.9 | 3.7 | 14.5 | 5 | 5.2 | 2.3 |
| Aug 2011 | 33.5 | 7 | 1.2 | 0.7 | 19.3 | 5 | 2.6 | 1.2 |
| Nov 2011 | 57.9 | 9 | 1.2 | 0.8 | 18.6 | 5 | 0.8 | 0.4 |
| Jan 2012 | 52.8 | 4 | 1.2 | 0.5 | 13.2 | 5 | 2.0 | 0.6 |
| Apr 2012 | 50.9 | 6 | 1.6 | 1.1 | 16.8 | 4 | 4.9 | 1.3 |
| **Min** | 18.1 | 4 | 1.2 | 0.5 | 13.2 | 5 | 0.8 | 0.4 |
| **Max** | 57.9 | 9 | 6.9 | 3.7 | 19.3 | 5 | 5.2 | 2.3 |
| **Average ± SD** | 42.6 ± 16.5 | 6.8 ± 1.9 | 2.4 ± 2.5 | 1.4 ± 1.3 | 16.5 ± 2.6 | 4.8 ± 0.4 | 3.1 ± 1.9 | 1.2 ± 0.7 |
| **Total** | 213.2 | 13 | | | 82.4 | 8 | | |

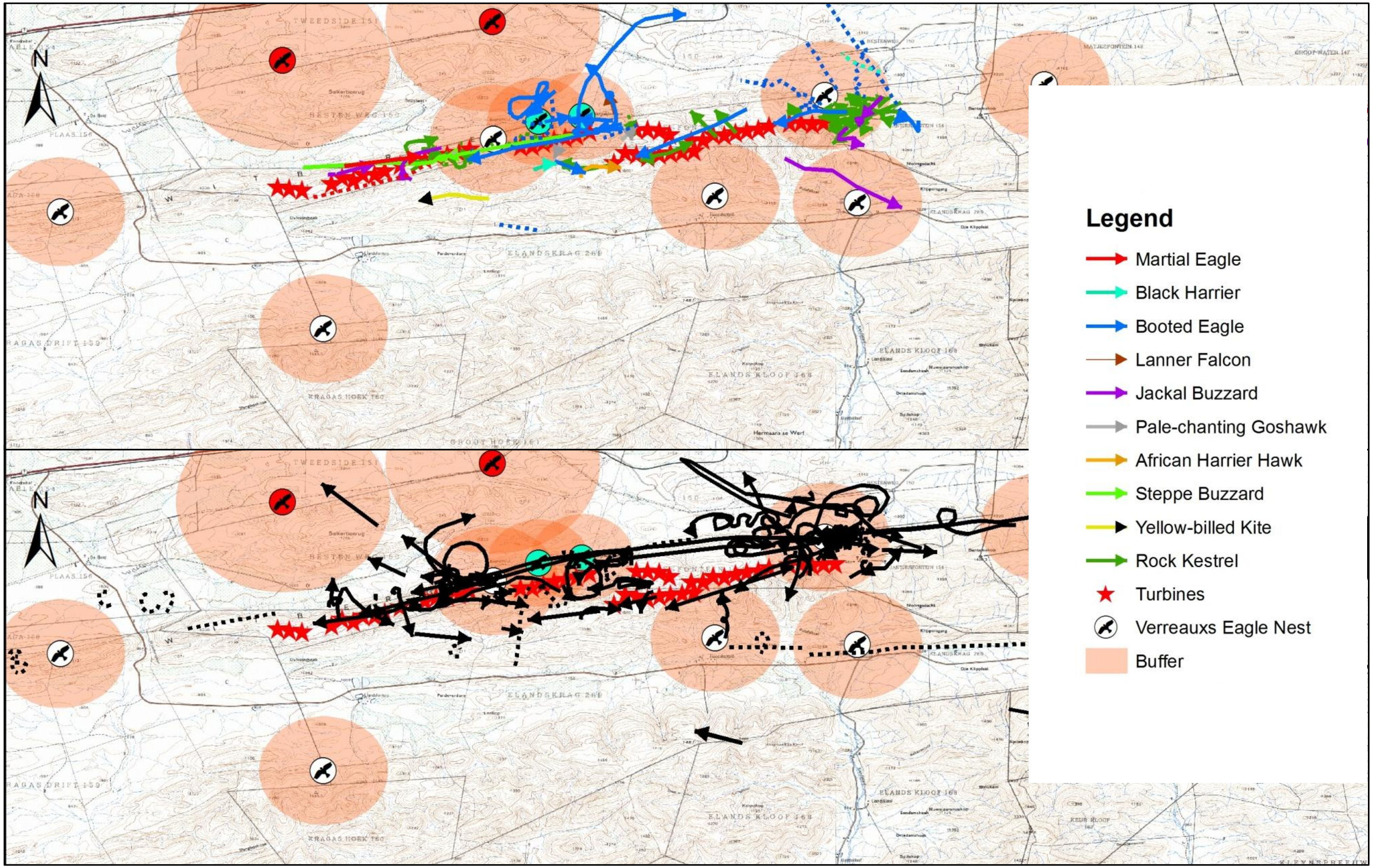


**Figure 8. Raptor flight paths recorded at the WEF site during the study. Proposed turbine positions (as at start of monitoring study) are indicated by red stars. Verreaux's Eagle flight paths are shown separately from other species on the lower map.**

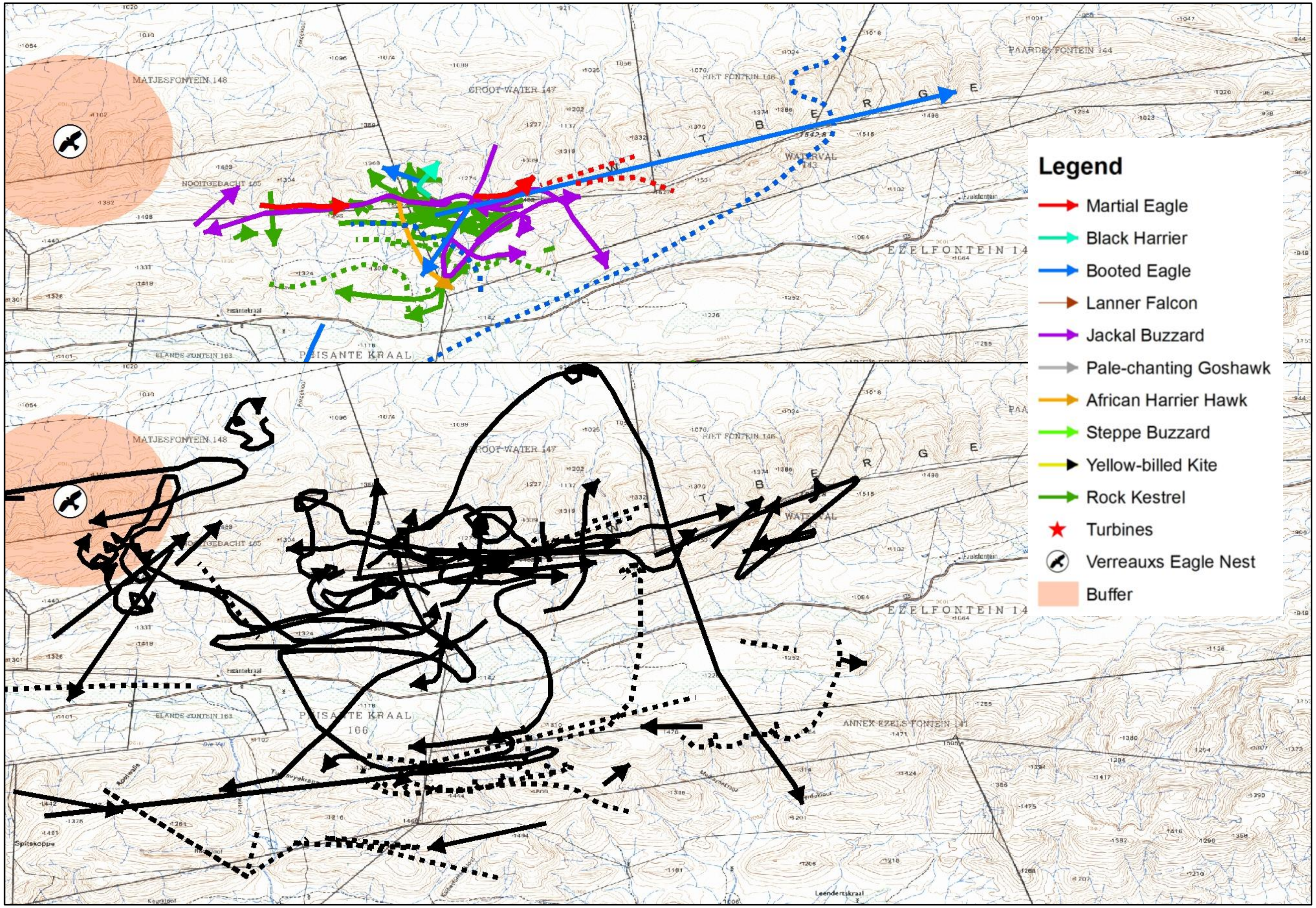


**Figure 9. Raptor flight paths recorded from the control site vantage point during the study. Verreaux's Eagle flight paths are shown separately from other species on the lower map.**

Of the eagles, flight activity was mainly by Verreaux's Eagle, and most flight activity occurred along the sides and tops of the ridges (Figure 8). This was generally soaring flight, but typically fast, covering long distances in a short period. There were also many instances of birds traversing the ridge, usually commuting at high speed, and heading over the adjacent valleys. Aerial activity of Verreaux's Eagles was highest during the breeding season, especially the laying period, when several interactions between neighbouring pairs were observed. Vertical zones utilised by eagles at the WEF were mainly at medium heights (40-120m; 45%) followed closely by low (<40m; 34%) and high zones (120<150m; 18%). In other words, the birds fly mostly in the vertical zone corresponding to the turbine blade zone, which puts them at a significant risk of collision. A similar pattern was observed at the Control Site..

Booted Eagles were active in the area all year. Although they were not recorded specifically from the WEF in January, they were recorded at the control site. Booted Eagles also appeared to hunt over the lower slopes and valleys as well as on the ridge. They utilised all vertical zones, but were recorded to fly within the medium vertical zone (40-120m) most frequently on 33% of occasions putting them at high risk of collision (Table 6).

Martial Eagle activity on the ridge was not as common as other eagle species. They were seen during the winter months on the first field trip in June and again in August. This species is very wide-ranging and would have been hunting over the valleys and other ridges and hills in the area as well. Flight zones utilised varied considerably and there was no evidence of a preference a particular height to fly at (Table 6).

Other commonly observed raptor species worthy of mention include the Rock Kestrel and Jackal Buzzard. Rock Kestrel were often seen gliding along the ridge which they regularly traversed, and during times of north-easterly winds were found to hover facing into the wind on the north facing slopes at the proposed WEF. They utilised the low (58%) and medium (29%) flight zones at the proposed WEF extensively and are therefore at high risk of collision.

Jackal Buzzards also utilised the low and medium flight zones more extensively than other zones at both the proposed WEF and the Control Site (Table 6). They were seen making use of the ridge at the proposed WEF, either flying along it or crossing it over saddles. In addition they were seen to hunt over undulating hills adjacent to the ridge at moderately lower altitudes.

The Cape Eagle owl was not recorded via a flight-path record but rather from a call on the proposed WEF ridge. Two unconfirmed sightings were also made at and near the Control Site. The habitat at Witberg is ideal for Cape Eagle owl, which favours rocky outcrops, cliffs and gorges with scrub in the vicinity (Martin & Pepler 1977). The Cape Eagle Owl is known to roost in rock or shrub during the day and then move to a prominent perch at dusk (Kemp, A.C, *unpublished data*). In the Karoo, the owl mainly feeds on small prey such as rodents and other birds (Steyn & Myburgh 1983). Due to its rather sedentary habits of swooping on prey from perches, it is not likely to prominently fly higher than 40m above the ridge. The Cape Eagle Owl is therefore not likely to be at major risk of collision. It is more likely however to be affected by the construction of the WEF due to disturbance (noise and light) and habit destruction imposed by the WEF footprint.

Generally, raptors appeared on slopes facing the prevailing wind, probably due to the updrafts experienced here and the turbulence on the leeward slopes. The ridges above the north-facing slopes had a higher level of activity than the south side of the ridges. Raptors were found to generally fly along and periodically across the WEF ridge or hover above the faces of the north-facing slopes during north-easterly winds.

More than two-thirds (73%) of raptor flight paths recorded at the proposed WEF were within low to medium vertical zones, with the latter being in the range of the turbine blades (i.e. 40-120m; Table 6). At the WEF site most raptors utilised the low vertical zone (37%) closely followed by the medium vertical zone (36%) and high vertical zone (16%; Table 6). A similar trend was observed at the Control Site.

At the study area, the cloud ceiling is frequently low and can envelope the top of the mountains. During these conditions we noticed that the raptors tended to fly below the cloud ceiling, at much lower altitudes than on other days.  In very low cloud they remained perched, and during calm conditions there was less activity. Verreaux's Eagles are known for their ability to forage in very strong winds, and this was observed to a degree.

Table 6. Proportion (%) of vertical height zones utilised by raptors at the proposed WEF, Control and combined sites. L = Low Vertical Zone (i.e. <40m); M = Medium Vertical Zone (40-120m); H = High Vertical Zone (120-150m); VH = Very High Vertical Zone (>150m). Values in brackets after the species name give the number of flight paths used to calculate the percentages for the proposed WEF Site followed by the control site.

| **Species** | **Proposed WEF Site** | | | | **Control Site** | | | | **Combined Sites** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **L** | **M** | **H** | **VH** | **L** | **M** | **H** | **VH** | **L** | **M** | **H** | **VH** |
| African Harrier Hawk (2,2) | 50 | 50 | 0 | 0 | 50 | 50 | 0 | 0 | 50 | 50 | 0 | 0 |
| Black Harrier (2,2) | 50 | 0 | 50 | 0 | 50 | 50 | 0 | 0 | 50 | 25 | 25 | 0 |
| Booted Eagle (33,6) | 18 | 33 | 21 | 27 | 33 | 33 | 0 | 33 | 21 | 33 | 18 | 28 |
| Greater Kestrel (0,1) | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| Jackal Buzzard (7,8) | 43 | 43 | 14 | 0 | 13 | 75 | 13 | 0 | 27 | 60 | 13 | 0 |
| Lanner Falcon (1,0) | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Martial Eagle (2,5) | 0 | 50 | 0 | 50 | 60 | 0 | 0 | 40 | 43 | 14 | 0 | 43 |
| Pale-chanting Goshawk (3,0) | 67 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 67 | 33 | 0 | 0 |
| Rock Kestrel (48,37) | 58 | 29 | 10 | 2 | 46 | 32 | 11 | 5 | 54 | 31 | 11 | 4 |
| Steppe Buzzard (2,0) | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 0 | 0 |
| Yellow-billed Kite (1,0) | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| Verreaux's Eagle (77,90) | 34 | 45 | 18 | 13 | 27 | 50 | 13 | 10 | 37 | 57 | 19 | 14 |
| **Combined Species per Site** | 37 | 36 | 16 | 11 | 36 | 41 | 12 | 11 | | | | |
| **Combined Species & Sites** | | | | | | | | | 37 | 38 | 14 | 11 |

# 5 IMPACTS AND RECOMMENDATIONS

## 5.1 IMPACTS

The AIA described the WEF as being medium-sized with a moderate to high degree of avian sensitivity with respect to birds (Avisense 2011). The AIA states that there are no regionally- or nationally-critical populations of impact-susceptible species within or near to the development area, and the proposed WEF site does not impinge on any known major avian fly-ways or migration routes (Avisense 2011). However, the AIA also recognised that the WEF would seriously impinge on the Witberg ridge, which is an important landscape feature, and may have a significant negative effect on the avifauna of this ridge (including breeding pairs of large eagles and concentrations of localised endemic species) in both the construction and operational phases of the development (Avisense 2011). The AIA concluded that the proposed WEF "could have a significant, long-term impact on the avifauna of the area" as a result of disturbance, displacement and/or collision mortality, mainly affecting raptors, endemic passerines, large terrestrial birds commuting over the area, and flocks of waterbirds moving over the area. The AIA listed the expected impacts as likely to include:

1. "Disturbance and displacement of **resident/breeding raptors** (especially Verreaux's Eagle, Martial Eagle, Booted Eagle, Black Harrier, Cape Eagle Owl) from nesting and/or foraging areas by construction and/or operation of the facility, and /or mortality of these species in collisions with the turbine blades or associated new power lines while slope-soaring along the high-lying ridges or hunting in the valleys, or by electrocution when perched on power infrastructure.
2. Disturbance and displacement of **resident/breeding Fynbos/montane endemics** on the high-lying ridges central to the study area by construction and/or operation of the facility.
3. Disturbance and displacement of **resident/breeding large terrestrial birds** (especially Blue Crane and possibly Ludwig's Bustard) from nesting and/or foraging areas by construction and/or operation of the facility, and /or mortality of these species in collisions with the turbine blades or associated new power lines while commuting between resource areas (croplands, nest sites, roost sites/wetlands).
4. Disturbance and displacement of **resident/breeding wetland birds** from nesting and/or foraging areas by construction and/or operation of the facility, and /or mortality of these species in collisions with the turbine blades or associated new power lines while commuting between resource areas (croplands, wetlands)." (Avisense 2011).

The pre-construction monitoring study confirmed that the proposed development site is rich in birdlife, and has an extremely high level of activity by priority species, including species that are range restricted and of particular conservation concern in southern Africa. The focus of the pre-construction monitoring study was slightly narrower than that of the AIA, because of the change in turbine layout, which was reduced to being on the main Witberg ridge. The potential impacts listed above remain accurate, although this study has shown that the first two appear to be more serious than originally thought, while the last two impacts are somewhat diminished, due to the absence of large terrestrial birds such as cranes and bustards, and the absence of waterbirds commuting over the ridge.

The monitoring study confirms that a high density of raptors is resident in the area, but also found that there are at least five eagle nests close to the proposed line of turbines, a situation more serious than originally thought. Mating behaviour and breeding was observed in all three pairs of Verreaux's Eagles and both pairs of Booted Eagles in closest proximity to the turbine line.

High levels of activity and passage rates were recorded throughout the area that could be monitored from the vantage points. Many of the eagles observed ranged long distances from their home bases during the course of a day, much further than the range of the buffer zones mapped in the AIA report (1.5km for Verreaux's Eagle). Flights of up to 9km long were recorded.

Birds of prey worked the ridges throughout the study area, usually soaring along the ridges at medium altitude (within the turbine blade zone), but also commuting at higher altitudes both along and across the ridge and occasionally spending time foraging over the valleys. High rates of passage occurred over the whole ridge, but particularly on the northern edge of the ridge, probably because of the direction of prevailing winds. Both Verreaux's Eagle and Booted Eagle also alighted on the WEF ridge, and mating also occurred on the ridge (as opposed to the cliffs below). Booted, Verreaux's and Martial Eagles and several other raptor species were observed to move through the turbine blade zone.

The high density and passage rates of raptors within the proposed development footprint suggests that there is a high likelihood of impacts of the proposed WEF on these species in the form of the loss of habitat, obstruction of foraging paths, and collision with turbines. Furthermore, the danger exists that the mortality caused will create a vacuum in these strongly territorial species. This could bring in other adult eagles to take their place and create a "sink" effect into which other adult eagles seeking vacant nesting sites will be drawn. This can happen in a matter of hours or days of a nest site being vacated (R. Simmons, pers. obs.). This could lead to further mortality, affecting the population over a much broader area. It is also possible that the area may be abandoned by some species. In the case of the endemic passerine species of concern, such as Cape Rock Jumper, their numbers are likely to be reduced as a result of loss of habitat, and they may be further deterred by human activity, vibration and noise disturbance during the operational phase. Although little is known about the impacts of wind turbines on birds in South Africa, studies from elsewhere in the world have shown that these impacts can be major (Drewitt & Langston 2006).

## 5.2 Mitigation

Recommendations in the AIA regarding mitigation measures to be undertaken, are as follows, in brief (for details, see Avisense 2011):

1. 'No-go' areas to minimise disturbance during construction;
2. Minimising construction footprint and noise disturbance during construction;
3. Minimizing disturbance during operation;
4. Excluding development from near large eagle nest sites and a locally important wetland (1.5km from Verreaux's Eagle nests, 2.5km from Martial Eagle nests and 1.5km from the large waterbody near the site;
5. Painting one blade of each turbine black[2];
6. Ensuring that lighting is kept to a minimum, is coloured (red or green) and intermittent;
7. Ensuring that all new power infrastructure is bird-friendly;
8. Minimising the length of any new power lines installed;
9. Routing power lines underground as far as possible; and
10. Monitoring, including radar tracking systems.

These recommendations were based on a comprehensive review of the literature as well as specialist opinion. It is also stated in both the AIA and the EMP that these recommendations should be updated following the pre-construction monitoring study.

The developer has queried whether mitigation could be achieved by relocating the affected breeding eagle pairs away from the site. Unfortunately, this is not a feasible option. Practiced in the past to deal with 'problem' Verreaux's Eagles, this has resulted in the birds either returning to their capture site or dying (Simmons 2005).

Another desirable form of mitigation would be to stop the movement of the rotors during parts of the day when activity is highest, particularly during the months of peak activity by eagles. However, the developer has stated this is not a feasible option given the available technology.

The most controversial of the above recommendations (from the developer's perspective) was the exclusion of development from within a radius of eagle nests and wetlands. The buffer areas around the eagle nests were decided on the basis of

[2] Not allowed by Civil Aviation, we suggest UV paint seen well by birds but not humans

estimated territory radius and the assumption that the core activity areas would be contained within about half of the full extent (citing Walker *et al.* 2005, Martínez *et al.* 2010, Boshoff 1993, Machange *et al.* 2005). Observations suggested that this was not the case for the Verreaux's Eagle pairs nesting close to the proposed turbine layout. These birds moved great distances along the ridges, and were frequently seen several kilometres from the nest. Interactions between neighbouring pairs were also not uncommon[3], suggesting that the area was quite fully utilised, as opposed to being largely restricted to core areas around the nest. It is thus doubtful that a 1.5km radius would provide sufficient protection for Verreaux's Eagle. There are four eagle nests which are within a few hundred metres of the original turbine layout. If buffer areas are applied for each of these, then three of the buffer areas would be overlapping, thus fortunately extending the effective buffered zone for each. A further concern is that having a limited buffer around a current nest site does not adequately deal with the fact that the birds may have multiple nesting sites.

Based on flight activity patterns, even if buffer zones are implemented there would be a high probability of residual impacts in the remaining turbine layout, particularly along the ridge to the west of the M1 nest site (Figure 8). It is unknown to what extent the eagles would be able to avoid collision with the remaining turbines, or to what extent their foraging requirements could be met in other parts of their territories. Studies from elsewhere show that eagles can suffer heavy mortality with similar turbines (e.g. White-tailed Eagles on the island of Smola in Norway). In addition, the habitat in the vicinity of the proposed WEF is ideal breeding habitat for many raptor species as there is an abundance of rocky ridges and cliffs. It is therefore likely that other raptors recorded in the area which nest in such habitat are also breeding in the vicinity, in particular Rock Kestrel, Jackal Buzzard, Cape Eagle Owl and Lanner Falcons.

The bottom line is that it is unlikely that the buffer areas proposed in the AIA would adequately mitigate the potentially high impacts of the proposed development. Unfortunately the effectiveness of such buffers has simply not been tested in this situation. Thus we would suggest that, in addition to buffer zones around the eagle nests, development is avoided in areas where a high level of raptor activity was recorded during the monitoring study, notably along the northern edge of the ridge on the western half of the proposed layout (Figure 8), and that the developer offsets the residual impacts of the development through conservation action elsewhere. The latter is discussed in more detail below.

## 5.3 Biodiversity offset

As long as there is any development of turbines along the Witberg ridge, there are likely to be residual impacts, as the turbines would fall within the foraging range of several

[3] On more than one occasion, as many as five adult Verreaux's Eagles were seen interacting above the ridge.

important species. Thus the only other option available, short of stopping the development in its entirety, is to create a biodiversity offset that more than makes up for the residual loss of biodiversity that is likely to occur at the WEF site. Since the development has already been authorised, this will be a necessary option. The notion of biodiversity offsets has become popular during recent years, and offsets have been implemented around the globe. In the Western Cape, guidelines have been developed for the establishment of biodiversity offsets (Brownlie *et al.* 2007), although these have not yet been finalised. Biodiversity offsets are also being considered in the context of WEF developments elsewhere in the world (e.g. New Zealand).

In South Africa, biodiversity offsets are supported by a number of laws, policies and plans. The Constitution of the Republic of South Africa (Act 108 of 1996), the NEMA (National Environmental Management Act (Act No. 107 of 1998) and the National Environmental Management Biodiversity Act (Act No. 10 of 2004) provide the groundwork, mandating the protection of the natural environment, while offsets are more directly provided for by the Western Cape Spatial Development Framework and the National Biodiversity Strategy Action Plan (NBSAP), which highlights the need for biodiversity offsets.

The draft Western Cape guidelines suggest that biodiversity offsets must be identified in the decision-making process for a proposed development. Furthermore, they state that the purpose of biodiversity offsets is to ensure compensation for residual impacts on biodiversity and ecosystem services that are not so great as to constitute a fatal flaw, nor so small as to be of low significance, ensuring that ecological integrity is maintained and development is sustainable. The guidelines highlight that biodiversity offsets are a 'last resort', to be implemented only once all other mitigatory options have been employed, in order to offset whatever 'residual impacts' remain. Only residual impacts on biodiversity which are of medium to high significance should be explored, as impacts which are greater cannot be compensated for through offsets, and impacts which are lesser do not warrant offsets. In the case of the Witberg WEF, residual impacts on birds are likely to fall within this middle range.

The significance of residual impacts is influenced heavily by the characteristics of the environment they fall within. Of the four characteristics identified in the guidelines, the area under consideration could potentially be classified as "a threatened ecosystem, habitat containing threatened species, special habitats or an ecological corridor". The guidelines at this stage are very much geared towards the assessments that have been done for the National Spatial Biodiversity Assessments, which are focused on vegetation types, wetland types and marine ecozones. None of these analyses suit the perspective of this situation, and thus a suitable logic for this kind of case will need to be devised.

The draft provincial guidelines suggest that offsets should be located within a core biodiversity area, or priority area identified in bioregional or biodiversity plans.

Furthermore, it should be stressed that in order for the offsets to fulfil the role of continued protection of the species threatened by the development, they would need to conserve a similar habitat to that which is being developed, i.e. like for like. The ecosystem component under consideration in the present instance is relatively high altitude (1200 - 1500m) rocky fynbos ridges with cliffs within the Nama Karoo biome, and can be considered as a special habitat (having high densities of eagles and other birds of prey) as well as habitat containing threatened and endemic species. The main direct threats to this habitat and associated fauna are overgrazing, off-road vehicle trails and the development of wind energy facilities, with the latter two only having come to the fore as a significant threat in the last few years. As such, the habitat in question may also become a threatened ecosystem.

In Figure 10, the Witteberge range more or less corresponds with the area above 950m in north of the Anysberg, which traverses the southern part of the Anysberg Nature Reserve. The area shown to be above 1200m, within which the proposed development is sited, clearly shows that the main ridge stands out as a 34km-long unbroken ridge within the Witteberge range which accounts for almost half of this habitat in the Witteberge. South of this ridge, the area above 1200m is a bit more fragmented but is still prime habitat. These areas, both on the main ridge and to the south, provide opportunities for offsetting the potential residual impacts of the development.

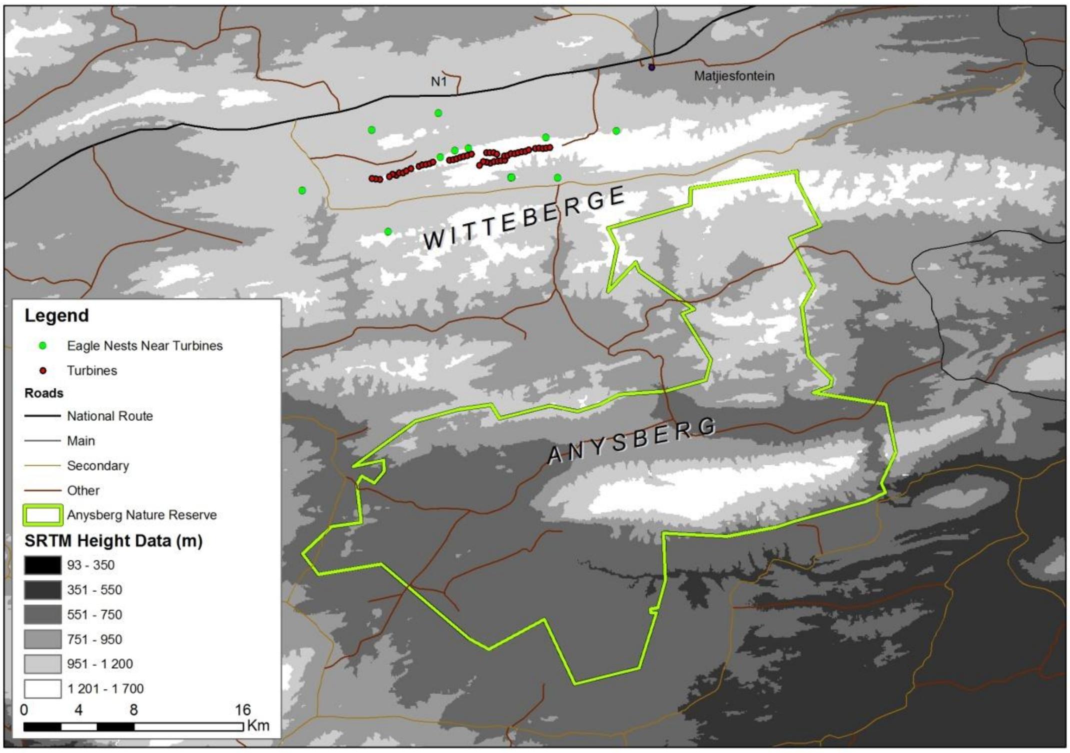


**Figure 10. Map of the Witteberge and the Anysberg (to the south), showing the layout of the proposed wind energy facility on the main Witberg ridge, the location of eagle nests near the turbines, and the boundaries of the Anysberg Nature reserve. Location of roads are also shown for reference.**

In terrestrial systems, conservation status has only been evaluated for vegetation types, no such analysis has been done in terms of holistic analysis of ecosystems which includes avifauna. Some of the study area falls within the boundaries of the Gouritz Initiative, but even the detailed conservation assessment in this case was based only on vegetation parameters (Lombard & Wolf 2004). At this stage, if an offset were deemed feasible, the size and location of the area required would have to be based on expert opinion and where possible, analysis, in order to meet agreed criteria.

Guidelines further state that when a biodiversity offset option is pursued, an additional specialist study must be conducted. An offset report must be prepared which details the information gathering and matters relating to offset design and management mechanisms – including an offset management plan and a means through which to guarantee the long term security of the offset.

While there is no precedent for offsets in the context of wind energy developments in South Africa, and this process is still fairly new on a global scale, this would provide an interesting test case for South Africa, would allow detailed study of the impacts of turbines in this kind of habitat, and would potentially render the development biodiversity-friendly on balance.

## 5.4 Recommendations

In view of the above, and in addition to the recommendations made by Avisense (2011), it is our recommendation that the development is not allowed to proceed unless (a) **buffers** are established around all known eagle nests in the vicinity of the development, with a diameter of 2.5km for Martial Eagle, 1.5km for Verreaux's Eagle and 1.2km for Booted Eagle, as well as any other nests of priority species that may yet come to light, (b) outside of these buffers, the layout of turbines should **avoid the areas of high raptor flight activity** along the northern edge of the ridge as far as possible, and (c) a suitable **offset** area is purchased that mitigates the residual impacts of the development.

Given the indications of what is possible regarding recommendation (b), the development will still carry significant risk to the priority species in the study area. We thus recommend that an offset study is conducted which investigates how the developer can contribute to securing equivalent populations elsewhere, following international best practice and involving adequate stakeholder participation.

At the minimum, the offset should remove the risk of habitat loss or degradation (e.g. due to developments and grazing) from a land area that would be able to support populations of the priority bird species as found on the WEF site. Verreaux's Eagle can be used as an 'umbrella species' in this regard in that meeting their range requirements will likely take care of the other species. Given that there are four pairs of Verreaux's

Eagle at high risk, and working with the offset principle that the conservation area should be scaled up, this probably requires securing a land area of about 20 - 30 000 ha of similar habitat. The area and spatial possibilities would have to be investigated in a more thorough analysis which takes eagle densities, land use and threats into account. Securing conservation areas might take the form of acquiring land to be added to the existing Anysberg Nature Reserve, which is desirable under the National Protected Areas Expansion Plan, or paying farmers to incorporate title deed restrictions on appropriate parcels of land. The fact that some land parcels in the area are already being managed as private nature reserves could be advantageous, as consolidation of these areas would also be possible.

In response to these recommendations, the developer has proposed a new layout of 26 turbines which was devised using optimisation software within the constraint of the developable footprint (Figure 11). This layout was constrained by the eagle buffer zones (apart from M2 – discussed below) as well as a 50m buffer of the northern ridge east of the 60m western mast. Turbine positions are given in Table 7. Details of the changes to the layout are shown in Appendix 2.

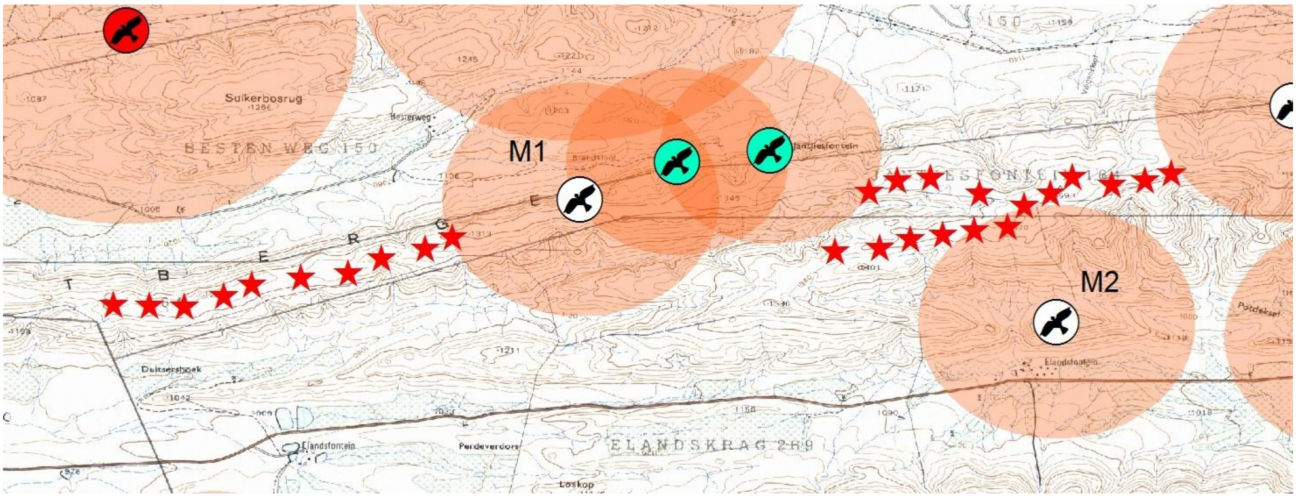


**Figure 11. Turbine layout proposed by G7 as at April 2012.**

The proposed layout has the caveat that 20m shifts must be allowed for each turbine subject to micrositing, and for turbines west of the western mast, shifts of turbines of up to 100m are possible.

The layout in Figure 11 was devised before the use of nest site M2 was discovered, and falls within the edge of the 1500m buffer zone for this nest, however, moving the turbine that falls just inside the buffer zone would probably not appreciably lower the risk of collision for that pair. This layout and associated caveats will be acceptable on condition that it is established in conjunction with an offset arrangement that significantly improves the conservation status of 20 – 30 000 ha of similar habitat in the Witteberg Range, preferably adjacent to the Anysberg Nature Reserve.

**Table 7. Positions of the turbines shown in Figure 11.**

| Turbine ID | Eastings (m) | Northings (m) | Turbine ID | Eastings (m) | Northings (m) |
|---|---|---|---|---|---|
| 1 | 451852 | 6317234 | 14 | 450512 | 6316950 |
| 2 | 451538 | 6317109 | 15 | 450224 | 6316794 |
| 3 | 451175 | 6317069 | 16 | 448983 | 6316339 |
| 4 | 450742 | 6317176 | 17 | 440320 | 6315449 |
| 5 | 449683 | 6316472 | 18 | 440703 | 6315441 |
| 6 | 449200 | 6317149 | 19 | 441085 | 6315441 |
| 7 | 449340 | 6316398 | 20 | 441519 | 6315571 |
| 8 | 448835 | 6317118 | 21 | 442357 | 6315819 |
| 9 | 448170 | 6316171 | 22 | 442867 | 6315880 |
| 10 | 444001 | 6316350 | 23 | 443138 | 6316061 |
| 11 | 450039 | 6316524 | 24 | 441818 | 6315726 |
| 12 | 448650 | 6316241 | 25 | 448532 | 6316965 |
| 13 | 449739 | 6316944 | 26 | 443704 | 6316204 |

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# 8 APPENDIX 1. BIRD SPECIES RECORDED AT THE SITE

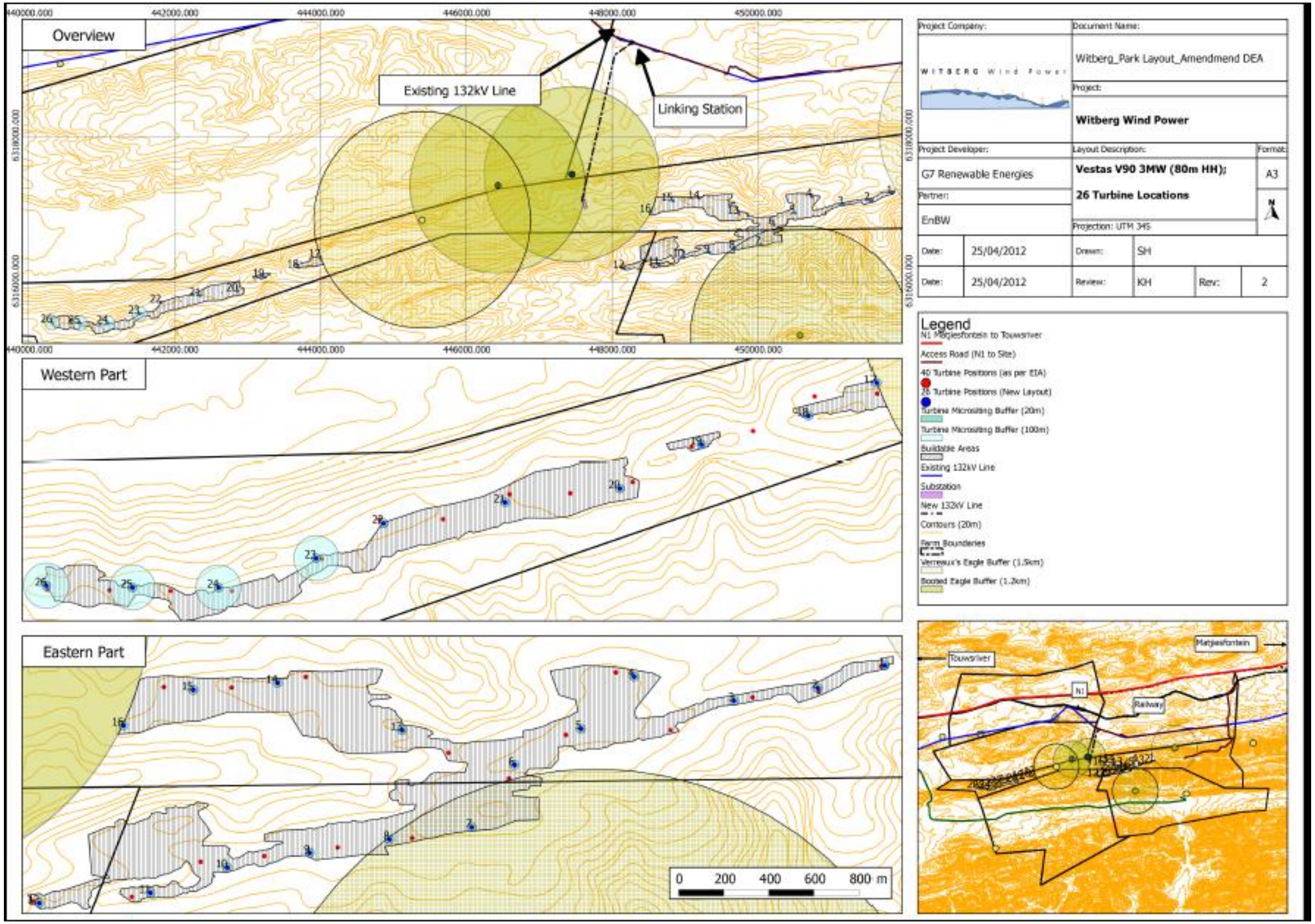
South African Red Data status: V = vulnerable, NT = near-threatened; E = endemism: E = endemic, N= near endemic; Local status: C = common, UnC= uncommon, R = Rare; R = resident, M = migrant, V = visitor; Risk: H = high, M = moderate

| | | | | | | Recorded | | | | | | Risk | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Name** | **Scientific name** | **Red data status** | **Endemism** | **Local status** | **Oct-10** | **Jun-11** | **Aug-11** | **Nov-11** | **Jan-12** | **Apr 12** | **Overall** | **Clision** | **Electrocution** | **Hab loss** |
| Cape Spurfowl | *Pternistis capensis* | - | E | CR | | 1 | 1 | 1 | | | 1 | M | - | H |
| Grey-winged Francolin | *Scleroptila africanus* | - | E | | | | | | 1 | 1 | 1 | M | - | H |
| Helmeted Guineafowl | *Numida meleagris* | - | - | CR | | 1 | | | | | 1 | M | - | H |
| Egyptian Goose | *Alopochen aegyptiaca* | - | - | CR | 1 | 1 | 1 | 1 | 1 | | 1 | H | H | - |
| South African Shelduck | *Tadorna cana* | - | E | CR | 1 | 1 | 1 | | 1 | 1 | 1 | H | - | - |
| Spur-winged Goose | *Plectropterus gambensis* | - | - | CR | | 1 | | | 1 | | 1 | H | M | - |
| African Black Duck | *Anas sparsa* | - | - | UnCR | | 1 | | | | | 1 | M | - | - |
| Yellow-billed Duck | *Anas undulata* | - | - | CR | 1 | 1 | | | 1 | | 1 | M | - | - |
| Ground Woodpecker | *Geocalaptes olivaceus* | - | E | UnCR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| White-backed Mousebird | *Colius colius* | - | E | CM | 1 | | | | | | 1 | - | - | M |
| Alpine Swift | *Tachymarptis melba* | - | - | CR | | | | 1 | 1 | 1 | 1 | M | - | - |
| Common Swift | *Apus apus* | - | - | UnCM | | | | | 1 | 1 | 1 | M | - | - |
| African Black Swift | *Apus barbatus* | - | - | CR | | | 1 | | 1 | | 1 | M | - | - |
| Little Swift | *Apus affinis* | - | - | CR | | | | 1 | 1 | | 1 | M - | - | - |
| White-rumped Swift | *Apus caffer* | - | - | CV | 1 | | 1 | 1 | 1 | 1 | 1 | M | - | - |
| Cape Eagle-Owl | *Bubo capensis* | - | - | UnCR | | | 1 | | | | 1 | - | H | M |
| Spotted Eagle-Owl | *Bubo africanus* | - | - | CR | | | 1 | | 1 | | 1 | - | H | M |
| Rock Dove | *Columba livia* | - | - | CV | | 1 | 1 | 1 | | | 1 | - | - | M |
| Speckled Pigeon | *Columba guinea* | - | - | CR | 1 | 1 | 1 | | 1 | 1 | 1 | - | - | M |
| Cape Turtle-Dove | *Streptopelia capicola* | - | - | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Namaqua Dove | *Oena capensis* | - | - | CR | | | | 1 | 1 | | 1 | - | - | M |
| Blue Crane | *Anthropoides paradiseus* | V | E | UnCR | 1 | 1 | | | | | 1 | H | - | M |
| Red-knobbed Coot | *Fulica cristata* | - | - | CR | | 1 | | | | | 1 | M - | - | - |
| Pied Avocet | *Recurvirostra avosetta* | - | - | CR | 1 | | | | | | 1 | M | - | - |
| Blacksmith Lapwing | *Vanellus armatus* | - | - | CR | | 1 | | | | | 1 | M | - | - |
| Yellow-billed Kite | *Milvus migrans* | - | - | UnCM | | | | 1 | | | 1 | - | - | - |
| African Fish-Eagle | *Haliaeetus vocifer* | - | - | UnCR | 1 | | | | | | 1 | - | H | - |
| Black Harrier | *Circus maurus* | NT | E | UnCR | 1 | 1 | | 1 | 1 | | 1 | M | - | M |
| African Harrier-Hawk | *Polyboroides typus* | - | - | UnCV | | | | 1 | 1 | | 1 | - | - | M |
| Southern Pale Chanting Goshawk | *Melierax canorus* | - | N | UnCR | 1 | 1 | | 1 | 1 | 1 | 1 | - | M | M |
| Gabar Goshawk | *Melierax gabar* | - | - | UnCR | | 1 | | | | | 1 | - | - | M |
| Steppe Buzzard | *Buteo vulpinus* | - | - | CM | | | | 1 | | | 1 | - | M | M |
| Jackal Buzzard | *Buteo rufofuscus* | - | E | CR | | 1 | 1 | 1 | 1 | 1 | 1 | - | M | M |
| Verreaux's Eagle | *Aquila verreauxii* | - | - | UnCR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | M | H | M |
| Booted Eagle | *Aquila pennatus* | - | - | UnCR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Martial Eagle | *Polemaetus bellicosus* | V | - | UnCR | 1 | 1 | | | | | 1 | M | H | M |
| Rock Kestrel | *Falco rupicolus* | - | - | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Greater Kestrel | *Falco rupicoloides* | - | - | UnCV | | 1 | | | | | 1 | - | - | M |
| Lanner Falcon | *Falco biarmicus* | NT | - | UnCV | | 1 | | | | | 1 | H | M | - |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Grebe | *Tachybaptus ruficollis* | - | - | CR | | 1 | | | | | 1 | - | - | - |
| Reed Cormorant | *Phalacrocorax africanus* | - | - | CV | 1 | 1 | | | | | 1 | - | - | - |
| Grey Heron | *Ardea cinerea* | - | - | CV | 1 | | | | | | 1 | M | M | - |
| Hadeda Ibis | *Bostrychia hagedash* | - | - | CR | 1 | 1 | | | | | 1 | M | - | - |
| African Spoonbill | *Platalea alba* | - | - | CV | 1 | | | | | | 1 | M | - | - |
| Bokmakierie | *Telophorus zeylonus* | - | N | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Pririt Batis | *Batis pririt* | - | N | UnCR | | | 1 | | | | 1 | - | - | M |
| Cape Crow | *Corvus capensis* | - | - | CR | | 1 | | | | | 1 | - | - | M |
| Pied Crow | *Corvus albus* | - | - | CR | 1 | 1 | 1 | 1 | | | 1 | - | - | M |
| White-necked Raven | *Corvus albicollis* | - | - | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Common Fiscal | *Lanius collaris* | - | - | CR | | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Cape Rock-jumper | *Chaetops frenatus* | - | E | RR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Brown-throated Martin | *Riparia paludicola* | - | - | CR | | | | 1 | 1 | | 1 | - | - | M |
| Barn Swallow | *Hirundo rustica* | - | - | CM | 1 | | | | 1 | | 1 | - | - | M |
| White-throated Swallow | *Hirundo albigularis* | - | - | CR | | | | | 1 | | 1 | - | - | M |
| Greater Striped Swallow | *Hirundo cucullata* | - | - | CM | 1 | | | 1 | 1 | 1 | 1 | - | - | M |
| Rock Martin | *Hirundo fuligula* | - | - | CR | 1 | | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Cape Bulbul | *Pycnonotus capensis* | - | E | CR | 1 | 1 | 1 | | | 1 | 1 | - | - | M |
| Layard's Tit-Babbler | *Parisoma layardi* | - | E | UnCR | | 1 | | 1 | | | 1 | - | - | M |
| Chestnut-vented Tit-Babbler | *Parisoma subcaeruleum* | - | N | UnCR | | | | 1 | | | 1 | - | - | M |
| Grey-backed Cisticola | *Cisticola subruficapilla* | - | N | CR | | | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Karoo Prinia | *Prinia maculosa* | - | E | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Rufous-eared Warbler | *Malcorus pectoralis* | - | E | CR | | 1 | 1 | | | | 1 | - | - | M |
| Cape Clapper Lark | *Mirafra apiata* | - | E | UnCR | | | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Karoo Lark | *Calendulauda albescens* | - | E | UnCR | | | 1 | | 1 | 1 | 1 | - | - | M |
| Karoo Long-billed Lark | *Certhilauda subcoronata* | - | E | UnCR | 1 | | 1 | 1 | | | 1 | - | - | M |
| Red-capped Lark | *Calandrella cinerea* | - | - | CR | | | | 1 | | | 1 | - | - | M |
| Large-billed Lark | *Galerida magnirostris* | - | E | CR | 1 | | 1 | 1 | | | 1 | - | - | M |
| Cape Rock Thrush | *Monticola rupestris* | - | E | CR | | 1 | | 1 | | | 1 | - | - | M |
| Sentinel Rock Thrush | *Monticola explorator* | - | E | UnCR | 1 | | | | | | 1 | - | - | M |
| Karoo Scrub-Robin | *Cercotrichas coryphoeus* | - | E | CR | 1 | | 1 | 1 | | 1 | 1 | - | - | M |
| African Stonechat | *Saxicola torquatus* | - | - | CR | | 1 | 1 | | | | 1 | - | - | M |
| Mountain Wheatear | *Oenanthe monticola* | - | N | CR | 1 | | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Familiar Chat | *Cercomela familiaris* | - | - | CR | 1 | 1 | 1 | 1 | 1 | | 1 | - | - | M |
| Ant-eating Chat | *Myrmecocichla formicivora* | - | E | CR | | 1 | | | | | 1 | - | - | M |
| Red-winged Starling | *Onychognathus morio* | - | - | CR | 1 | 1 | | 1 | 1 | 1 | 1 | - | - | M |
| Pied Starling | *Spreo bicolor* | - | E | CR | 1 | 1 | 1 | 1 | 1 | | 1 | - | - | M |
| Orange-breasted Sunbird | *Anthobaphes violacea* | - | E | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Malachite Sunbird | *Nectarinia famosa* | - | - | CR | | 1 | 1 | 1 | | 1 | 1 | - | - | M |
| Southern Double-collared Sunbird | *Cinnyris chalybeus* | - | E | CR | 1 | 1 | 1 | 1 | | 1 | 1 | - | - | M |
| Cape Sugarbird | *Promerops cafer* | - | E | UnCR | | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Cape Weaver | *Ploceus capensis* | - | E | CR | | 1 | | | | | 1 | - | - | M |
| Southern Masked-Weaver | *Ploceus velatus* | - | - | CR | 1 | | | 1 | | | 1 | - | - | M |
| Southern Red Bishop | *Euplectes orix* | - | - | CR | | | | 1 | | | 1 | - | - | M |
| Yellow Bishop | *Euplectes capensis* | - | - | CR | | | 1 | 1 | | 1 | 1 | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common Waxbill | *Estrilda astrild* | - | - | CR | 1 | | | 1 | | | 1 | - | - | M |
| House Sparrow | *Passer domesticus* | - | - | CR | | 1 | | | | | 1 | - | - | M |
| Cape Sparrow | *Passer melanurus* | - | N | CR | 1 | 1 | 1 | 1 | | | 1 | - | - | M |
| Cape Wagtail | *Motacilla capensis* | - | - | CR | | 1 | 1 | 1 | | | 1 | - | - | M |
| African Rock Pipit | *Anthus cinnamomeus* | - | E | UnCR | 1 | | 1 | 1 | 1 | 1 | 1 | - | - | M |
| African Pipit | *Anthus cinnamomeus* | - | - | CR | | | 1 | | | | 1 | - | - | M |
| Long-billed Pipit | *Anthus similis* | - | - | UnCR | 1 | | 1 | | | | 1 | - | - | M |
| Cape Canary | *Serinus canicollis* | - | E | CR | | 1 | | 1 | | | 1 | - | - | M |
| Black-headed Canary | *Serinus alario* | - | E | UnCR | | | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Yellow Canary | *Crithagra flaviventris* | - | N | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Brimstone Canary | *Crithagra sulphuratus* | - | - | UnCR | | 1 | | | | | 1 | - | - | M |
| White-throated Canary | *Crithagra albogularis* | - | N | CR | 1 | 1 | 1 | 1 | | | 1 | - | - | M |
| Cape Siskin | *Crithagra totta* | - | E | UnCR | | | | 1 | | 1 | 1 | - | - | M |
| Lark-like Bunting | *Emberiza impetuani* | - | N | CV | | | | | 1 | 1 | 1 | - | - | M |
| Cape Bunting | *Emberiza capensis* | - | N | CR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | M |
| Protea seedeater | *Crithagra leucoptera* | - | E | UnCR | | | | | | 1 | 1 | | | H |
| Pale-winged Starling | *Onychognathus nabouroup* | - | E | CR | | | | | | 1 | 1 | | | M |

# 9 APPENDIX 2. DETAILS OF THE LAYOUT CHANGES PROPOSED BY DEVELOPER



# WITBERG WIND FARM JUVENILE VERREAUX'S EAGLE MONITORING

# FINAL REPORT

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## Juvenile Verreaux's Eagle monitoring at the Witberg wind farm site

### Background

The wind farm site at the Witberg, near Matjiesfontein, in the western Karoo was proposed by G7 Renewable Energies, and was originally planned with 70 turbines. Following the EIA and pre-construction monitoring of the possible bird impacts (Avisense 2010, Turpie et al. 2012) it was revealed that the area held three breeding pairs of Verreaux's Eagles *Aquila verreauxii* on the ridges, and a breeding Martial Eagle *Polemaetus bellicosus* pair below the ridge. Buffers of 1.5 km and 2.5 km around the Verreaux's and Martial Eagle nests respectively were suggested (following the recommendations of Avisense 2010) and reduced the number, and altered the placement of, the turbines. Birdlife South Africa, as an interested and affected party, objected to the Environmental Authorization and called for Collision-Risk modelling to quantitatively assess the impact to the Verreaux's Eagles there, considering it was too risky to have turbines so close to active nests. That was followed by collision-risk modelling of adult eagles by Shoney Renewables (Percival 2013), based on flight paths collected during the Turpie et al. report (2012).
Turbine numbers were reduced to 27 as a result of that report and further consultation, and some turbines moved to other locations. However, no juvenile eagles were present in the environment during these exercises, so it was recommended that further study be undertaken to determine flight paths and patterns of juvenile eagles to assess the risks to them.
The importance of the Verreaux's Eagle lies in its Vulnerable red data status (Taylor et al. 2015) and high collision-risk ranking at No. 2 (BAWESG 2014).

The present report on juvenile Verreaux's Eagles (*Aquila verreauxii*) satisfies the requirements of the Environmental Authorization by providing results from the monitoring of the juvenile eagles present within the wind farm proposed at the Witberg site. Specifically we were tasked by G7 Renewables/EDPR with recording the flight paths of juvenile Verreaux's eagles to determine the risk they are exposed to by the presently accepted layout of the 27 turbines (Figure 1).

We undertook four site visits from winter (July 2014) to summer (January 2015) to track the progress of all breeding eagles at the proposed Witberg wind energy facility (S33$^{o}$ 17 E20$^{o}$ 26). This final report collates our findings from all visits, and provides (i) maps for all flights undertaken by all juvenile and adult birds; (ii) a summary of all nests, including those interfered with; and (iii) recommends mitigation measures to avoid risks to this highly collision-prone species.

## Protocol and Methods

### Timing of site visits

- **Winter** – egg-laying – 3 full field days (27-30 June 2014) at the start of eagle breeding, to determine nest activity and collect adult flight data (22.5h observation);
- **Spring** – small young – 3 days (3-5 October 2014) spent observing the young on the nest and visiting other eagle sites to determine activity, or not (28.7h observation);
- **Summer** – 4 days observing first flights of fledged youngster (15-18 December 2015) from Bantam nest (46.0h observation);
- **Summer** – 5 days observing extended flights (21-26 January 2015) of the fledged youngster from Bantam nest (62.8h observation).

Our previous, extensive, knowledge of the site allowed us to quickly re-locate the three known Verreaux's Eagles nest sites and the two known Martial nests on pylons in the proposed wind energy facility (WEF). On these visits we wished to ascertain all flight paths around the active Verreaux's nest (Bantam Nest No. 1). The Martial Eagle nests were inactive and are not treated further here.
We spent a total of 160 hours observing at the Verreaux's Eagle nests (the majority at the active Bantam Nest No.1) and recorded all flight activity of the pair at the nest. Laminated Google Earth images are taken into the field and flight paths (and heights) are recorded on them as we see the birds. Heights were estimated using the existing Sentec tower and graded into *Below* blade-swept area (0-20m and 20-40m), *Within* the blade-swept area (40-130m) or *Above* this high risk area (130+m).
We observed for 10h at the other two known Verreaux's Eagle nest sites to determine if they had become active (eggs laid, or not).

### Bantam Nest No.1

This new alternate nest was found on 30 June 2014 in our first recce trip and was 1.03km west of the previously known nest No. 1 (Turpie et al. 2012). This nest successfully fledged a youngster in early December and all observations of juvenile birds refer to this nest.

**Photo 1:** The female Verreaux's Eagle returning to her alternate nest in June 2014 with eggs already present

**Besterweg Nest No.2**

None of the three alternative nests at this site were active in 2014/2015 (photo 2). The nest positions are shown in Figure 1.

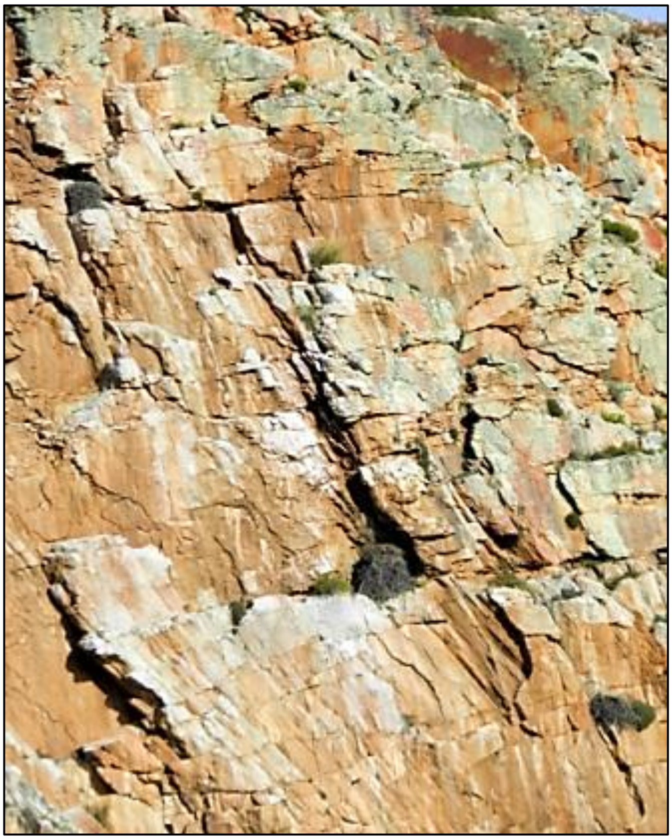

**Photo 2:** Three Verreaux's Eagle nests at Besterweg Nest No. 2 site. The middle nest had some signs of green lining in July 2014, but no birds were in attendance and no subsequent activity was observed when checked again in January 2015.

**Elandsfontein Nest No.3**

This nest area is 4 km west south west of the Sentec tower, and was active in November 2002 (pers. obs. and L Rodrigues photographed a juvenile bird there). In 2014-2015 we could find no nest structures on the cliff that previously held nests. We also rarely saw a pair of eagles that had been previously regularly seen, in this area. This was puzzling because Verreaux's Eagles are territorial year round and do not leave their nest area. More important their large cliff nests stay intact for decades (Steyn 1982). Therefore, we scoured the base of the cliff for signs of the nests.
Our search revealed that a nest had been pulled down, based on the number of hyrax skulls and sticks below the previous site. Nearby were carbon and smoke marks on the base of the rock suggesting a localised fire had been lit there in the last 12 months (but nowhere else).
This helps confirm the suspicions of L Rodrigues that an eagle nest (or nests) are being removed from the cliff site. We assume that this is by the Elandsfontein farmer or his labourers. This is an illegal activity and action should be enforced by Cape Nature and the developers (e.g. turbines will

not be erected on Elandsfontein until guarantees are secured that no eagle nests or adult birds will be interfered with).

As a threatened red data species (Taylor et al. 2015) it is illegal and unethical to interfere, in any way, with Verreaux's Eagles.

**Photo 3: E**landsfontein nest cliff showing the area (circled) where an eagle nest was removed from the cliff.

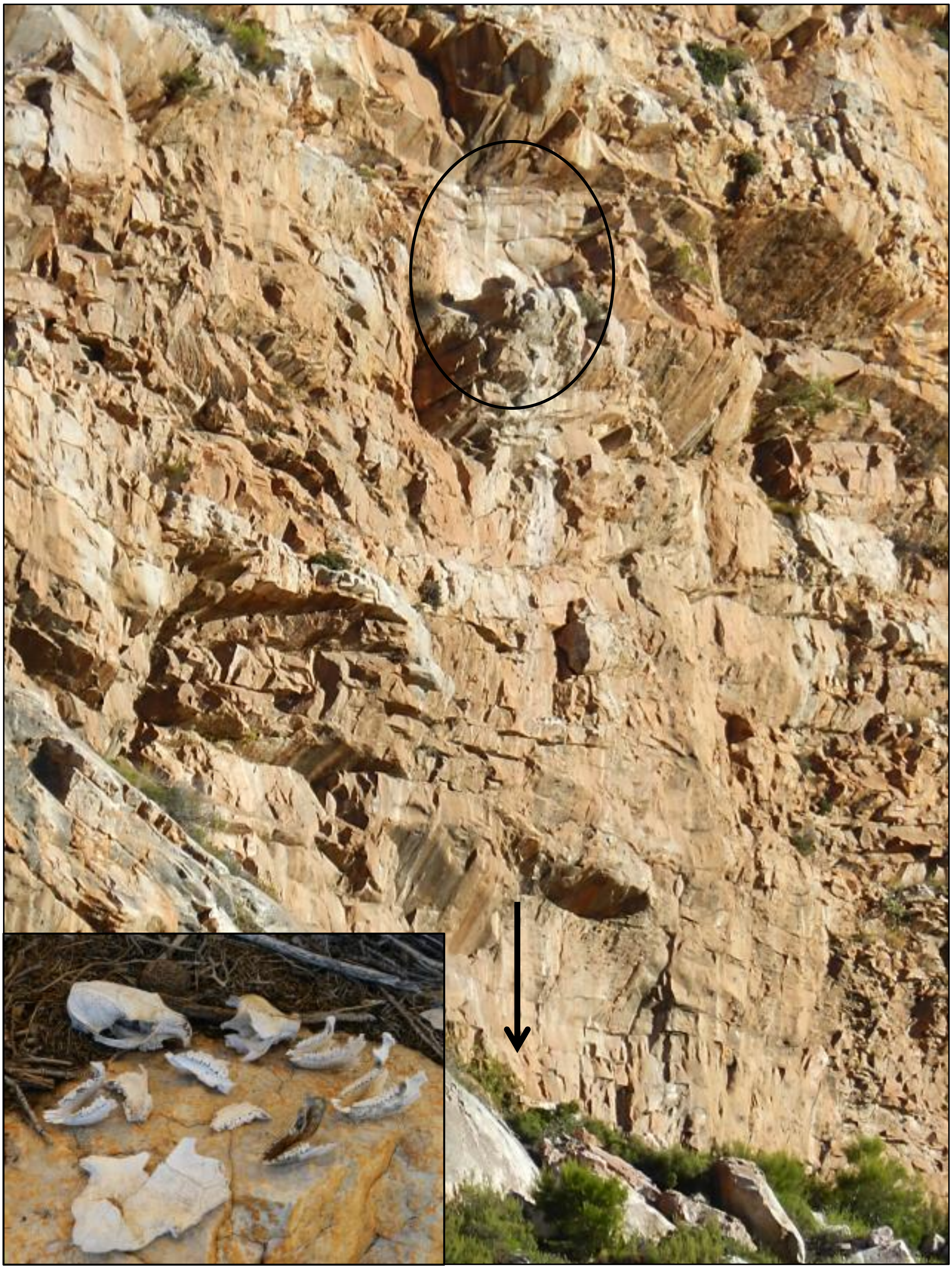

**Photo 4:** Nest site 3 – the **arrow** indicates where nest remains and 11 hyrax skulls (inset) and some tortoise shells were located indicating a Verreaux's Eagle nest once occurred above this site. The **circle** indicates where "white-wash" (eagle faeces) is apparent on the rock face, and an appropriate ledge for a nest occurs. This indicates that an eagle nest has been removed from this site.

## Flight activity of the adults and juvenile at Bantam Nest No.1

All **juvenile** eagle flights recorded in 160h of observation were, as expected, centred around the Bantam nest itself. All other flights were directed to the east of the nest – along the rock face underneath the level of the nest itself – and thus away from the turbines. Significantly, there were no flights recorded by the juvenile near, or even towards, the nearest proposed turbine (No. 27). All recorded flights are shown in Figure 3.

Most flights of the **adult Verreaux's Eagles** were also centred around the nest or just above it. Their longer flights were directed either (i) in a north-north-easterly direction, away from the ridge, and at heights around 80-100 m, (ii) east along the lower ridge to and past the alternate nest (1 km east), presumably hunting, and (iii) north-west over the valley, also to hunt.
These were flights made despite the prevailing winds being predominantly from the south-east: this was unexpected because large eagles typically use the updraft created by the winds to forage, and thus use the slopes on the north-side of the nest. Because at least two of three prey item seen came in from the north-east this suggests that the adults' favoured foraging areas were away from the turbines and the nest No. 1 is at the western corner of the territory (Figure 2).

## Passage Rates

The overall rate of passage (the number of times birds were seen in flight per hour of observation) declined steadily across seasons. In October 2014, passage rates were 1.36 eagles/hour, in December 2014, the rate was 0.98 eagles/hour and in January 2015 only 0.51 eagles/hour were recorded. This is despite the juvenile eagle taking more flights in January than earlier in the year. The reason for this is not known but the energy demands of young nestlings, including eaglets, often reaches a peak about two thirds of the way through the nestling period. This coincided with the October 2014 visit, and is also a time when the adult female no longer needs to brood the youngster, but stays in the vicinity of the nest to protect it.


**Fig 1:** The currently proposed (27) turbine layout (yellow pins) at the Witberg WEF site in relation to the active and inactive Verreaux's Eagles' nests on site, January 2015.


**Fig 2**: Overview of all flight paths of all Verreaux's Eagles from visits in October and December 2014, and January 2015. The adult flights (orange & yellow), fledgling flights (red) and a sub-adult bird (maroon) are shown in relation to turbine layout (yellow pins). One flight to the south (yellow line) was by Pair 3 towards their inactive nest. The blue lines indicate an intruding Verreaux's Eagle that was escorted out of the territory by an adult bird. A Martial Eagle (white line) was briefly seen above turbine 17.


**Figure 3:** All flights of the **juvenile** Verreaux's Eagle from December 2014 and January 2015 at Nest No.1. The red lines represent the juvenile eagle and the maroon lines are those of a sub-adult (3-4 year old bird) escorted by one of the adults from the territory. Note that the juvenile bird spent no time near the turbines (yellow pins).

## Eagle flying heights

By estimating the height at which all eagles flew every 15 seconds we can determine how frequently these birds flew in the danger zone i.e. the zone of the blade-swept area (40-130 m).

The results (Table 1) indicate that the proportion of time the **juvenile eagle** flew in the danger zone increased as it became more proficient. In October 2014 it spent no time at 30-140m, in December 2014 it spent 18% of its time in the danger zone, and in January 2015 it spent 43% of its time at this height. For all months it spent 31% of its flying time at the high-risk height.

Over the three site visits the **adult eagles** (often flying together) were recorded 554 times. For 29% of that period they flew within the high-risk height zone (Table 1). The next most often used category was the lowest height (1-20 m) and they spent 28% of the time at that height. Thus, while no flights took place over the proposed turbines, the juvenile and adult eagles could be at risk 31% and 29% of the time, respectively (Table 1).

**Table 1:** Recordings of the height at which the **juvenile** and adult Black (Verreaux's) eagles were flying in the Witberg study in October 2014, December 2014 and January 2015. Most data from Bantam Nest No.1.

| | **Ht Categories** | **Number of Observation** | | | **% of all Observations** | | | **% Observations** |
|---|---|---|---|---|---|---|---|---|
| **Adults only** | | **Oct** | **Dec** | **Jan** | **Oct** | **Dec** | **Jan** | **All months** |
| | 1 (1-20m) | 67 | 48 | 41 | 36% | 18.8% | 37% | **28%** |
| | 2 (20-40 m) | 44 | 21 | 24 | 24% | 8.2% | 21% | **16%** |
| **High risk** | **3 (40-130 m)** | **45** | **81** | **36** | **24%** | **31.8%** | **32%** | **29%** |
| | 4 (130-160 m) | 17 | 56 | 11 | 9% | 22.0% | 10% | **15%** |
| | 5 (>160m) | 14 | 49 | 0 | 7% | 19.2% | 0% | **11%** |
| **Totals** | | **187** | **255** | **112** | | | | **of 554 obs** |
| **Fledgling** | 1 (1-20m) | 4 | 14 | 24 | 100% | 35% | 45% | **43%** |
| | 2 (20-40 m) | 0 | 19 | 4 | 0% | 48% | 8% | **24%** |
| **High risk** | **3 (40-130 m)** | **0** | **7** | **23** | **0%** | **18%** | **43%** | **31%** |
| | 4 (130-160 m) | 0 | 0 | 2 | 0% | 0% | 4% | **2%** |
| | 5 (>160m) | 0 | 0 | 0 | 0 | 0% | 0% | **0%** |
| **Totals** | | **4** | **40** | **53** | | | | **of 97 obs** |

## Reasons for the lack of flights over the ridge line and proposed turbines

The result that almost no eagle flights took place over the ridge (and turbines) south of the Bantam Nest No.1 is unusual, given that Verreaux's Eagles are montane species and should use most parts of their territory. It seems that there are two likely explanations for this: (i) eagles hunt where their prey base (the Rock Hyrax *Procavia capensis*) is most vulnerable, along rocky ridges, and (ii) they use updrafts from steeper slopes to assist in their foraging and soaring (Gargett 1990, Davies and Ferguson 1994, Simmons 2005).

Our observation from many days spent walking and driving the ridge tops indicates that the areas where the turbines are to be situated do not support any hyrax, but only a few Klipspringer and a few game birds such as Grey-winged Francolin. The ridge tops are also topographically not conducive to slope-soaring because of their rounded nature and shallow slopes. Both reasons may explain the almost complete absence of birds from the areas around the proposed turbine sites.

## Summary of findings

In four site visits (July 2014-January 2015) to the Witberg WEF site to determine the risk to Verreaux's Eagles of the proposed wind farm we found:

- The Verreaux's Eagle Nest No.1 (at Bantam) successfully fledged their nestling in December 2014;
- Neither of the other two nests (Besterweg Nest No.2 and Elandsfontein Nest No.3) were active, but a pair of Eagles was seen over the Elandsfontein nest;
- The Elandsfontein nest cliff had no nest structures and there was evidence that the nest had been taken down and possibly burnt. This is illegal.
- The adult pair of eagles at the active Bantam Nest No.1 spent all of their flight time around the nest or heading north-east and north-west to soar and forage; only one trip was recorded near the turbines (250m from turbine 27) in 160h of observation from Vantage Points above and below the nest;
- As the juvenile matured it became a more proficient flier and spent longer at greater heights. It spent 31% of its time within the danger zone (30-140m) but did not venture closer than 660m from any proposed turbines;
- The adults spent a similar amount of time (29% of 554 observations) within the high-risk zone of 40-130m. None of their flights took place closer than 250m from the nearest proposed turbines.

- These results and observations suggest that there is little risk from the turbines as presently laid out to either the adults or juvenile eagles at Bantam Nest No.1.

**Recommendations**

We recommend that the development of the wind farm at the Witberg site be allowed to proceed with the following provisos:

(i) A binding agreement be reached with the Elandsfontein landowner that he, and his staff, do not interfere with, obstruct or remove nests from any eagle breeding site on his farm. Failure to do so would prevent the construction or further operation of the turbines on his property;

(ii) During-construction monitoring of all eagle breeding sites be implemented to ensure that minimum interference occurs; this would require unrestricted access to all properties to monitor the eagles by registered specialists;

(iii) Post-construction monitoring of the site proceeds as stipulated in previous authorizations by recognised specialists;

(iv) As one of the first montane areas in South Africa to be developed for wind farms a longer-term monitoring programme should be implemented to determine the effects that wind turbines have on eagle breeding success and site occupancy. That should then be compared with eagle data being collected elsewhere in the Karoo.

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**Dr Rob Simmons / Marlei Martins**
**Birds Unlimited Environmental Consultants**
14 February 2015

# Amendment Report

# WITBERG WIND ENERGY FACILITY

**Prepared for:**

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# 1 EXECUTIVE SUMMARY

This study contains an appraisal of the amendments made for the proposed Witberg Wind Energy Facility and their likely impacts on the avian community, particularly the eagles. The avian component was previously reported on in 2012, following six site visits (Anchor Environmental 2012) and the use of the area specifically by juvenile Verreaux's Eagles, in 2014 over four site visits (Simmons and Martins 2015), including Collision-Risk Modelling (CRM: Percival 2013). The original 70 turbines of 80-m hub height (HH) proposed by the developer, Witberg Wind Power (Pty) Ltd, in 2012, was reduced on appeal to the minister to 27 turbines of 92-m HH following the CRM and public comment. The following changes are requested and their impacts on the avifauna assessed: (i) a decrease in the number of turbines to 25; (ii) a 30% increase in hub height of the turbines from 92-m to 120-m; and (iii) a 17% increase in rotor diameter from 116-m to 136-m. This may influence species there, both positively and negatively.

Literature surveys suggest that the effect of the changes proposed on the authorised project are expected to be mainly negative because of the statistically significant increase in collisions for higher turbines (Loss et al. 2013, Simmons et al. MS). However, the Collision-Risk model (CRM) based on site-specific avifaunal data suggested lower eagle fatalities (Percival 2018, 2019). This may affect a suite of collision-prone birds highlighted by Turpie et al. (2012) and Simmons and Martins (2015), particularly the Verreaux's Eagles that breed in the area. Thus, impacts with the blades of the wind turbines, and the associated power line network, are the biggest potential risks with turbines placed on the upland ridges or near foraging areas. Theoretically, if the rotor blade length is doubled, a four-fold greater risk area is created if the turbines are placed in areas used by the species of concern. If hub height is also increased then birds flying higher could be impacted. A meta-analysis from North America reported a strongly significant effect of increased hub height on proportionately more avian fatalities, in a large sample of wind farms with turbines up to 80-m hub height. Our statistical modelling using data from North America and including South African turbines (not Witberg wind farm data) with hub heights up to 92-m found that avian fatalities are forecast to double for turbines increasing from 92-m to 120-m hub height. However, to consider site specific data, a CRM was prepared by Dr S. Percival using the Band et al (2007) method. To implement the precautionary principle and since the CRM estimated 0.28 Verreaux's Eagle adult and juvenile fatalities annually (Percival 2018, 2019) with taller turbines, we conclude that by combining the two models we estimate that, on average, 0.56 Verreaux's Eagles *Aquila verreauxii* and 0.08 Booted Eagle *Aquila hieraetus* fatalities will occur per year. Further mitigations are required if the level of eagle fatalities exceeds 1.0 Verreaux's Eagle per year to reach acceptable levels. Potential mitigations recommended for risky turbines include black-blade painting and shut-down-on-demand.

Birdlife South Africa (BLSA) guidelines (Ralston-Paton 2017) dictate that turbines within 3.0-km of Verreaux's Eagle nests can only be justified with detailed avifaunal surveys. Our surveys show almost no use of the area around eagle nest 1 by the adult or juvenile eagles (7 flights in 333 hours of detailed monitoring in 2.5 years), suggesting very low risk to the birds there. However, BLSA do not allow turbines within 1.5 km of any eagle nests, and this has been complied with in the latest amended 25-turbine layout provided in August 2018.

The impact zone of the originally proposed facility lies in montane areas of the Karoo biome, an area that holds a suite of southern African endemic birds and some Red Data species (e.g. eagles, harriers and cranes). Previous surveys indicated that 11 collision-prone species (CPS) occur in the area of which five are Red Data species. The passage rate of the Verreaux's Eagles along the whole Witberg Ridge was high at 0.84 birds/hour. However, within the present 1.5-km buffers around each eagle nest a very low Passage Rate of 0.021 eagles/hour was recorded within the 3-km buffer.

In a follow-up site visit in February 2019, we ascertained that despite an extensive wild fire and a 2-year drought negatively influencing the habitat, the presence of eagles and their nests remained un-affected in either their number or position. Passage Rates had decreased to 0.21 eagles per hour.

Detailed construction and post-construction monitoring, is required to determine the effectiveness of the suggested mitigations. Operational-phase monitoring is essential to determine the actual impacts on birds and, therefore, the required mitigation measures and thresholds. Such an approach requires a flexible Adaptive Management Plan to be implemented during operation. This plan must allow for: (i) changes to be implemented within a time-frame of 3-4 weeks; (ii) the wind farm has agreed to follow the mitigation measures as suggested by the Minister of Environment; and (iii) in accordance with the Adaptive Management Plan and the Environmental Authorisation, appropriate mitigation measures, such as black-blade painting or curtailment during specific environmental conditions or during high risk periods will be implemented. If the data show that more than one Red Data species is killed per year on the wind farm, then additional appropriate technology needs to be implemented at that turbine, as set out in the original EA. If these recommendations, and those of BLSA are followed, we see no reason why the Witberg wind farm cannot be developed.

## 1.1 Consultant's Declaration of Independence

Dr Rob Simmons of Birds & Bats Unlimited is an independent consultant to Witberg Wind Power (Pty) Ltd. He has no business, financial, personal or other interest in the activity, application or appeal in respect of which he was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of this specialist performing such work.

## 1.2 Qualifications of Specialist Consultants

Dr Rob Simmons, of Birds & Bats Unlimited Environmental Consultants (http://www.birds-and-bats-unlimited.com/) was approached to undertake the specialist avifaunal addendum to the Avian Impact Assessments to determine the implications of changes in the number, size and blade swept areas of the wind turbines proposed at the Witberg Wind energy facility, Western Cape. Dr Simmons is an ecologist and ornithologist, with 30 years' experience in avian research and impact assessment work. He has published over 100 peer-reviewed papers and two books, (see http://www.fitzpatrick.uct.ac.za/fitz/staff/research/simmons for details). He was the State Ornithologist for Namibia's Ministry of Environment for 14-years and has undertaken more than 50 avian impact assessments in Angola, Namibia, South Africa and Lesotho. He also undertakes long-term research on threatened species (raptors, flamingos and terns) and their predators (cats) at the FitzPatrick Institute, UCT. He supervises PhD students studying the ecology of threatened raptors (harriers and vultures) and statistical approaches to recording avian impacts at wind farms.

Marlei Martins, co-director of Birds & Bats Unlimited, has eight years' consultancy experience in avian wind and solar farm impacts as well as environmental issues, and has been employed by several consultancy companies throughout South Africa because of her expertise in this field. She has published papers on her observations including a new species of raptor to South Africa (http://www.birds-and-bats-unlimited.com/).

# 2 TERMS OF REFERENCE

The Terms of Reference for the avian impact assessment are to:

Compile an addendum to the 2012 and 2015 specialist avian reports addressing the following:

- The implications of the proposed amendments in terms of the potential impact(s);
- A re-assessment of the significance (before and after mitigation) of the identified impact(s) in light of the proposed amendments (as required in terms of the 2014 EIA Regulations) for the construction and operational phases, including consideration of the following:
  - Cumulative impacts;
  - The nature, significance and consequence of the impact;
  - The extent and duration of the impact;
  - The probability of the impact occurring;
  - The degree to which the impact can be reversed;
  - The degree to which the impact may cause irreplaceable loss of resources;
  - The degree to which the impact can be avoided, managed or mitigated.

This addendum to the 2013 and 2015 reports should include an impact summary table outlining the findings of the re-assessment in terms of the above-mentioned assessment criteria.

- A statement as to whether the proposed amendments will result in a change to the significance of the impact assessed in the original EIA for the proposed project (and if so, how the significance would change);
- A detailed description of measures to ensure avoidance, management and mitigation of impacts associated with the proposed changes;
- An outline of the potential advantages and disadvantages of the proposed amendments in terms of potential impacts ;
- Provide confirmation as to whether the proposed amendments will require any changes or additions to the mitigation measures recommended in our original specialist report. If so, provide a detailed description of the recommended measures to ensure avoidance, management and mitigation of impacts associated with the proposed amendments.
- The re-assessment must take into account the findings of the 12 months pre-construction monitoring.

## 2.1 Study Area

The proposed wind farm lies 10-km west of Matjiesfontein in the Witteberg mountains at S33$^{o}$ 17' E20$^{o}$ 26'. The ridge along which the wind farm is proposed is ~25 km long. The substrate is rocky, and the topography of the WEF is highly undulating varying from 1179-m asl to the highest point at 1452-m asl. Two wind masts, and a Sentec communication tower are the only man-made structures currently on the WEF site (pers. obs.). The study area is dominated by high wind-swept ridges and the natural vegetation is dominated by Matjiesfontein Shale Renosterveld in the valleys, and Matjiesfontein Quartzite Fynbos on the ridges (Mucina and Rutherford 2006 pp 132, 179). It lies in the Nama-Karoo biome, with habitat elements of Fynbos (e.g. proteas) and Succulent Karoo on the higher slopes.

The proposed Witberg wind farm site is situated on the farms Jantjesfontein (Farm RE/164), Besten Weg (Farm 1/150 and Farm RE/150), Tweedside (Farm RE/151), Elandskrag/Elandsfontein (Farm RE/269 and Farm 1/269).

## 2.2 Background

The wind farm site at the Witberg, near Laingsburg in the western Karoo was proposed by Witberg Wind Power (Pty) Ltd. It was originally planned with 70 turbines. Following the EIA and pre-construction monitoring of the possible bird impacts (Avisense 2010, Anchor Environmental 2012) it was revealed that the area held three breeding pairs of Verreaux's Eagles *Aquila verreauxii* on the ridges, and a possible breeding Martial Eagle *Polemaetus bellicosus* pair north of the ridge. Buffers of 1.5-km and 2.5-km around the Verreaux's and Martial Eagle nests respectively were suggested (following the recommendations of Avisense 2010) which reduced the number of, and altered the placement of, turbines. Birdlife South Africa, and others, as interested and affected parties (I&APs), objected to the Environmental Authorization and called for Collision-Risk Modelling (CRM) to quantitatively assess the impact to the Verreaux's Eagles there, considering it too risky to have turbines so close to active nests. That was duly undertaken by Shoney Renewables (Percival 2013), based on flight paths collected by Anchor Environmental (2012). That CRM has since been updated twice (Percival 2018, 2019).

Turbine numbers were reduced to 27 as a result of that report and further consultation, and some were moved to other locations. However, the I&AP also pointed out that no juvenile eagles were present in the environment during these exercises, so it was further recommended that additional studies be undertaken to determine flight paths and patterns of juvenile eagles to assess the risks to them. Birds & Bats Unlimited undertook those assessments (2014) and found no activity of the juvenile eagle (or the adults) over the ridges ear-marked for possible turbine positions (Simmons and Martins 2015) for the proposed Witberg wind energy facility. While this may seem unusual so close to active eagle nests, we suspect that there are too few cliffs to allow for either slope soaring by the eagles (the hills here have a rounded topography) or for their main prey (Rock Hyrax) to exist. We, thus, suggested it was safe to construct turbines within 750-m of the nest No. 1 where the eastern-most turbine on the farm was proposed.

Subsequently, in 2018, new technology introduced taller turbines that generate more power than approved in the original Environmental Authorisation.

Specifically, the proposed amendments to the authorised wind farm include the following:

- Hub height increased (30%) from 92-m to up to 120-m;
- Rotor diameter increased (17%) from 116-m up to 136-m (blades increased from 58m to 78m);
- Increased power output up to 5.0MW per turbine;
- A decrease in the number of authorised turbines from 27 to 25;
- Re-micro-siting of the remaining turbines;
- Amendment of the layout including reduction of wind turbines and relocation to avoid sensitive areas, including the relocation of infrastructure to avoid sensitive areas (i.e. substation, powerline and construction camps);
- Extension of validity period by an additional two years.

The overall generation capacity has not changed and remains at 120MW. The layout, as defined in 2015, has changed slightly as depicted in Figure 1.

## 2.3 Methods

All the methods employed in the original EIA study (Turpie et al. 2012) and the follow up focussed study on the active nests (Simmons and Martins 2015) are detailed in those reports. Briefly, six equally-spaced visits were undertaken in 2011-2012 covering 213 hours, followed by another 4 visits (and 160 hours) in 2014-2015. This covered 2.5 years of monitoring, satisfying BLSA's 2-year monitoring requirements for Verreaux's Eagles (Ralston 2017). It is also close to the number of hours recommended per vantage point (72 h per year) given that there were 3 VPs on the Witberg ridge and a total of 373 hours of VP observations in the WEF over 2 years. A further 28 hours in 2019 (below) gives a total of 401 hours or 66.8 hours per VP per year - not far short of the 72 hours suggested by BLSA, before the guidelines were published. Thus, our methods during the monitoring undertaken largely comply with what is now recommended for Verreaux's Eagles (Ralston 2017), allowing us to reach robust conclusions across all seasons and multiple years.

Among the comments received during the public participation conducted in November-December 2018, was that the receiving environment may have changed since the last visit in 2015, and our results may thus be "out of date". We, therefore, undertook a 3-day site visit from 9-11 February 2019 to :

(i) survey all four large eagle nests (Verreaux's and Martial) known on the site,

(ii) undertake vantage point surveys along the top ridge for flying eagles,

iii) photograph all the known eagle nests,

iv) survey by foot different sections of the veld to determine differences from 2015,

(v) meet with the two land-owners (L. Hart and J. du Plessis) to discuss local conditions.

### 2.3.1 Limitations

The limitations of the original reports (Turpie et al. 2012, Simmons and Martins 2015) were covered therein. For the updates in 2019 the observations were designed to assess the receiving environment and the status of the eagle nests, so they are not the typical 12h VP observations for raptors or 18 h for the Verreaux's Eagles. The number of hours spent observing amounted to 28 h of surveys.

We also note that the 2011-2012 and 2014-2015 observations were undertaken when rainfall was average or close to average, thus we can expect typical eagles breeding patterns. Rainfall after 2015 was classed as drought conditions (http://www.weathersa.co.za/climate/historical-rain-maps) potentially hindering eagle breeding. A fire swept the area of the WEF in 2016 and would have reduced the primary productivity. Since our follow-up surveys were undertaken 3 years later, however, the land had a chance to recover, even with minimal rains.

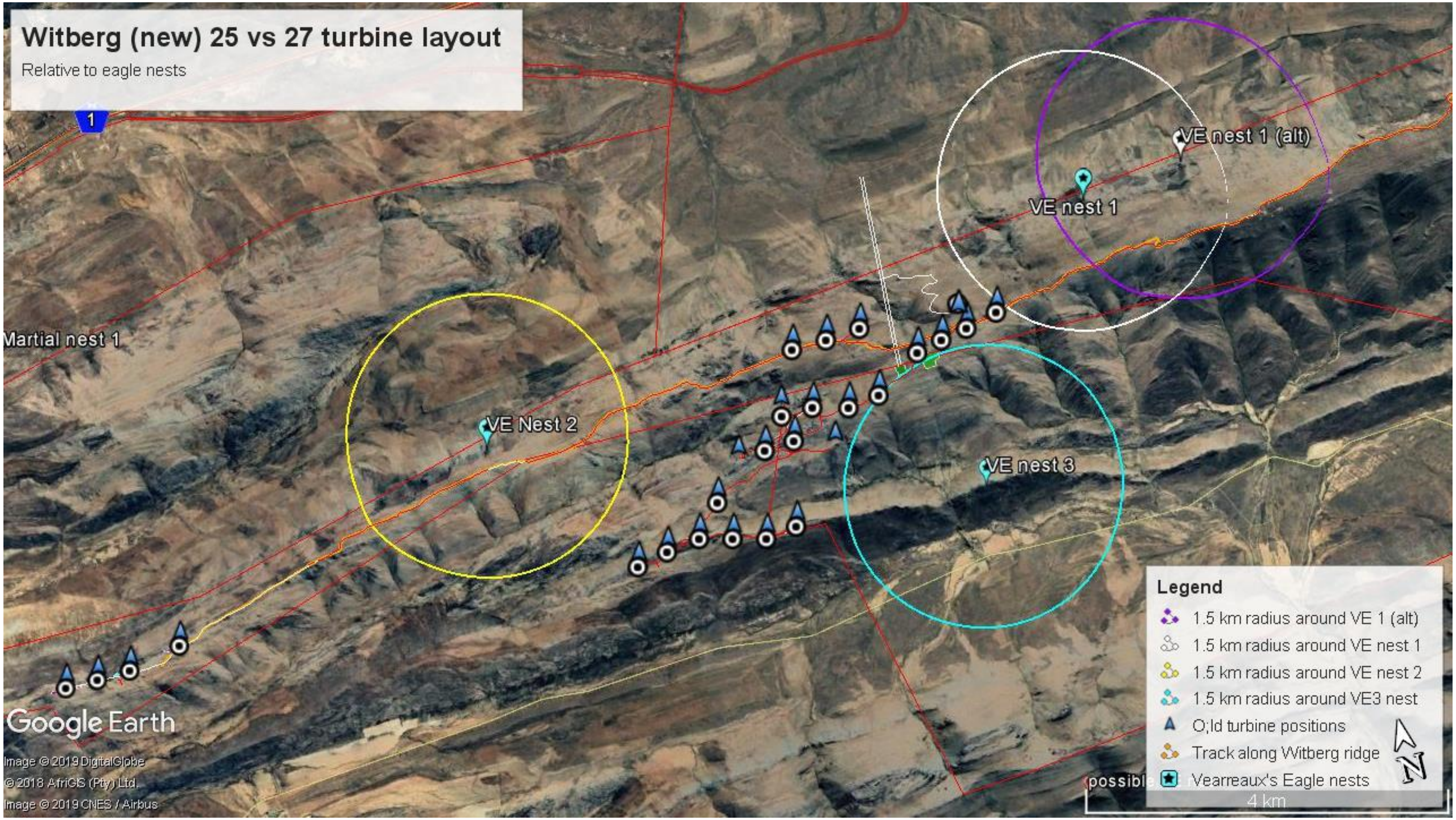


**Figure 1**: Turbine layout design compared: The authorised turbine design with 27 turbines (= blue arrows), relative to the new (August 2018) turbine layout of 25 turbines (= white circles) as supplied by Witberg Wind Power. All 25 turbines (and substation and lay-down areas in green) lie outside the 1.5-km radius circle shown around all known Verreaux's Eagle (VE) nests. Almost no eagle flights were recorded, even within 3-km of the nests, during all 333-h of monitoring, including the fledging period at VE nest 1.

# 3 SUMMARY OF FINDINGS OF THE ORIGINAL EIA REPORT

The original Witberg EIA avian pre-construction report assessed the possible impacts to birds (Turpie et al. 2012), updating the first Scoping Report by Avisense (2010). Twelve priority collision-prone species were recorded on, or around, the Witberg ridge including five Red Data species (Table 1). These species may be impacted by turbine placements – either by direct impact or disturbance and displacement. The collision-prone species included: 11 raptors (four Red Data), and one crane (Red Data) (Table 1). Of the Red Data species, the Blue Crane had a very low likelihood of occurrence on the site (Table 1), and were, therefore, deemed unlikely to be negatively affected by the turbines. Too few data were available for the other priority species to be gauged.

**Table 1:** Twelve priority collision-prone species and five Red Data species (Taylor et al. 2015) identified in previous avian EIA reports for Witberg (Avisense 2010, Turpie et al. 2012). Flight height is taken from field measures in the Turpie et al. (2012) and Simmons and Martins (2015). Passage Rates (bird flights per hour) were available only for Verreaux's Eagles from Simmons and Martins (2015). Reporting Rate taken from SABAP2 sourced on 3 July 2018 for three pentads along the Witberg Ridge (n = 7 full protocol cards).

| | | | | Susceptibility: | |
|---|---|---|---|---|---|
| **Common Name and *Scientific Name*** | **Red-list status** | **Reporting Rate*** | **Passage Rate ** (mean ± 1SD)** | **Collision Rank ***** | **Flight height******* |
| **Verreaux's Eagle** *Aquila verreauxii* | **Vulnerable** | **50%** | **0.84 ± 0.4** | **2** | **76%** |
| **Martial Eagle** *Polemaetus bellicosus* | **Endangered** | **3.5%** | | **5** | **14%** |
| **Black Harrier** *Circus maurus* | **Endangered** | **10%** | | **6** | **50%** |
| **Blue Crane** *Anthropoides paradiseus* | **Near Threatened** | **0.0%** | | **11** | **n.d.** |
| **Lanner Falcon** *Falco biarmicus* | **Vulnerable** | **14.3%** | | **22** | **100%** |
| Cape Eagle Owl *Bubo capensis* | - | **0.0%** | | **41** | **n.d.** |
| Jackal Buzzard *Buteo rufofuscus* | - | **60.0%** | | **42** | **73%** |
| Booted Eagle *Aquila pennatus* | - | **30%** | | **55** | **51%** |
| Yellow-billed Kite *Milvus parasiticus* | - | **n.d.** | | **60** | **0%** |
| Steppe Buzzard *Buteo buteo vulpinus* | - | **n.d.** | | **67** | **50%** |
| Pale Chanting Goshawk *Melierax canorus* | - | **40%** | | **73** | **33%** |
| African Harrier Hawk *Polyboroides typus* | - | **10%** | | **85** | **50%** |

* Reporting Rate is a measure of the frequency of occurrence (as reported by Avisense 2010 from 57 bird atlas cards, updated in June 2018 for this report from SABAP2).

** Passage Rate (number of birds/h) is a measure of the number of flights per hour of the priority species

*** Collision rank is taken from BLSA assessment (Ralston-Paton et al. 2017). Smaller numbers denote higher collision-risk.

**** Flight height is an estimate of the proportion of time spent at rotor-swept heights (adapted from Turpie et al 2012). Tip Height categories "Medium" [40-120] and "High" [120-150m] in Turpie et al (2012) were combined to mimic the blade swept areas that are proposed in the Amendments of 58-m to 198-m to provide an estimate only.

The threatened species that remain vulnerable to impacts include:

- **Verreaux's Eagle** *Aquila verreauxii* – a *Vulnerable* red data species (Taylor et al. 2015) and No. 2 in the priority list of collision-prone species (Ralston et al. 2017). This species, with a reporting rate of 50% on atlas cards has a 100% chance of occurring on site as it breeds there (Simmons and Martins 2015, Photo 1). Three nests are known on site and at least one is active every year. In 2019, the VE1 nest had been active as judged by "whitewash" around the nest, and VE2 nest was not active, and no eagles were present. The VE3 nest, that was removed on Elandsfontein, had not been re-built but a pair were observed perched above it and actively hunting along this east-west ridge. They may have relocated 3.5 km south in the Witberg Nature Reserve.
- **Martial Eagle** *Polemaetus bellicosus* – an *Endangered* species (Taylor et al. 2015) and No. 5 in the list of collision-prone species. This species had a 3-4% chance of occurring on site and has bred on the pylons below the ridge on the karoo plains (Avisense 2010). An adult bird was present on the same transmission line in February 2019, but neither nest appeared to be used. A 3-km buffer around either nest does not impact on the present placement of the 25 turbines planned**;**
- **Black Harrier** *Circus maurus* – an *Endangered* species (Taylor et al 2015, IUCN 2018) and No. 6 in the list of collision-prone species. This species has a 10% chance of occurring on the Witberg Ridge and may breed in the area (Simmons and Martins 2015).
- **Lanner Falcon** *Falco biarmicus* – a *Vulnerable* species (Taylor et al. 2015) and No. 22 in the list of collision-prone species. This species had a 13-14% chance of occurring on site (Avisense 2010).

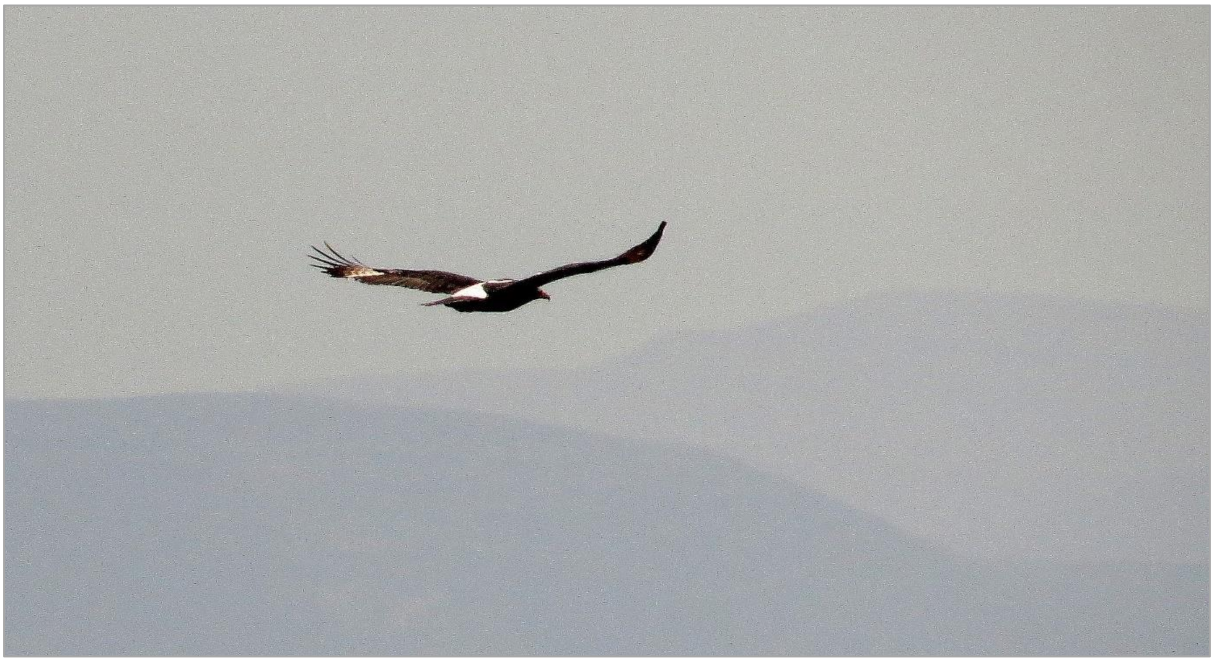

**Photo 1:** Verreaux's Eagles were seen daily in the study site and three nests were known in 2014, but only one was ever active during our site visits, despite three pairs being present (Turpie et al. 2012, Simmons and Martins 2015). One nest had been illegally removed from the Elandsfontein farm, probably by the farmer between site visits, and we recommended that an undertaking is put into place with farmers do not interfere with the eagles in any way. A pair were seen here in February 2019. This undertaking must form part of the environmental authorisation (Simmons and Martins 2015).

These are the priority species threatened by the proposed wind farm facility at Witberg and require special attention. Two additional species that are not threatened species in South Africa (Taylor et al. 2015), but are vulnerable to collision with wind farms are:

- **Booted Eagle** *Aquila pennatus* – ranked 55th in the Top 100 collision-prone birds (Ralston-Paton et al. 2017). This species was recorded on 30% of all SABAP2 cards and is known to breed within the wind farm site. It is designated Red Data status in Namibia (Simmons et al. 2015);
- **Jackal Buzzard** *Buteo rufofuscus* – ranked 42nd in the Top 100 collision-prone birds (Ralston-Paton et al. 2017). This species was recorded on 60% of all SABAP2 cards and, therefore, has a high chance of occurring.

Thus, of the 12 collision-prone species at the proposed Witberg wind farm, the six species above require an assessment of impacts. Some, such as the Martial Eagle, however, have too few flights to allow us to determine their risk of collision, and this species rarely occurs over the ridges.

The biggest potential avian impact issues on the Witberg site relate to the three Verreaux's Eagle nests (Figure 1). Birdlife South Africa (BLSA) guidelines stipulate:

> "**A buffer of 3 km is recommended around all nests** (including alternate nests). This is intended to reduce the risk of collisions and disturbance. This is a precautionary buffer and may be reduced (or increased) based on the results of rigorous avifaunal surveys, but nest buffers should never be less than 1.5 km (Ralston-Paton 2017)."

Because the exact positions are important for avoidance and planning purposes, we give the exact GPS locations in Table 2.

**Table 2**: all known positions of Verreaux's Eagle nest on the Witberg Ridge 2011-2014.

| Nest site | Latitude | Longitude | Notes |
|---|---|---|---|
| **VE nest 1** (new in 2014) | S 33°16'35.18" | E 20°29'9.15" | Bantam nest |
| **VE nest 1 alt** | S 33°16'30.89" | E 20°29'48.39" | Bantam nest alternative 1.03-km east of new nest (found Aug 2011 by Lucia Rodrigues) |
| **VE nest 2** | S 33°17'9.45" | E 20°24'48.93" | Besterweg nest (3 nest sites, one above the other) |
| **VE nest 3** (southern-most nest) | S 33°18'2.23" | E 20°28'3.56" | Elandsfontein or Elandskrag (nest illegally removed) |

The 1.5-km buffer referred to (Ralston-Paton 2017) is shown in Figure 2. This also has ecological significance because Percival (2013) shows that Witberg Verreaux's Eagle flight densities drop off at 1.5-km, meaning most flights are expected inside this buffer.

Note also, that the fact that VE nest 3 was illegally removed (Simmons and Martins 2015) does not mean the nest site no longer exists. The pair, possibly also persecuted, will be replaced by another pair which will very likely build a nest in a similar position. Thus, their absence in 2014 does not mean a 1.5-km buffer is not required. The post-construction monitoring must take careful cognisance of this area, and report any further attempts to disrupt the breeding of this site. We would recommend a concealed trail camera is erected to record all eagle (and human) activity at this site.

The summer 2019 site visit covering 3 days (9-11 February) revealed the following:

(a) the habitat has been negatively affected by a combination of a large fire in February 2016 and two years of drought; both farmers (L Hart and J du Plessis pers. comm.) said that the drought was one of the worst in their memory;
(b) fewer smaller bird species were recorded on both the Witberg Ridge (4 spp) and the surrounding plains (13 spp);
(c) nevertheless, eagles were present: An adult Martial Eagle was present on the transmission line pylons 3.5 km north of the proposed WEF and at least one of the two Verreaux's Eagle (VE) nests on the north-facing ridge had been active this year (VE nest 1 and VE nest 1 alt., east) as judged by fresh "white-wash" (faeces). Both were photographed (Photos 2 and 3).
(d) The VE nest 3 on Elandsfontein was still absent – no nests have been re-built on this southern-most cliff-face: however
(e) The pair of eagles were recorded perched above the nest site and hunting along the southern ridge that runs east-west from Mr. du Plessis' farm house. This pair may have relocated their nest to the Witberg Nature Reserve 3.5 km south east of the Witberg nest.

We conclude that despite the baseline habitat being negatively affected by the 2016 fire (covering 6600 ha) and 2-years of drought, the raptor component has not changed from the time of the original EA and, thus, the extension of the validity of the EA is well founded.

**Photo 2:** A Verreaux's Eagle pair (above) were seen perched above the Elandsfontein nest area in February 2019, but their nest has not been re-built on the cliff face here. By contrast, the Verreaux's nest VE1 at the east end of the ridge had clearly been used during the year as evidenced by large amount of white-wash around the nest (right).

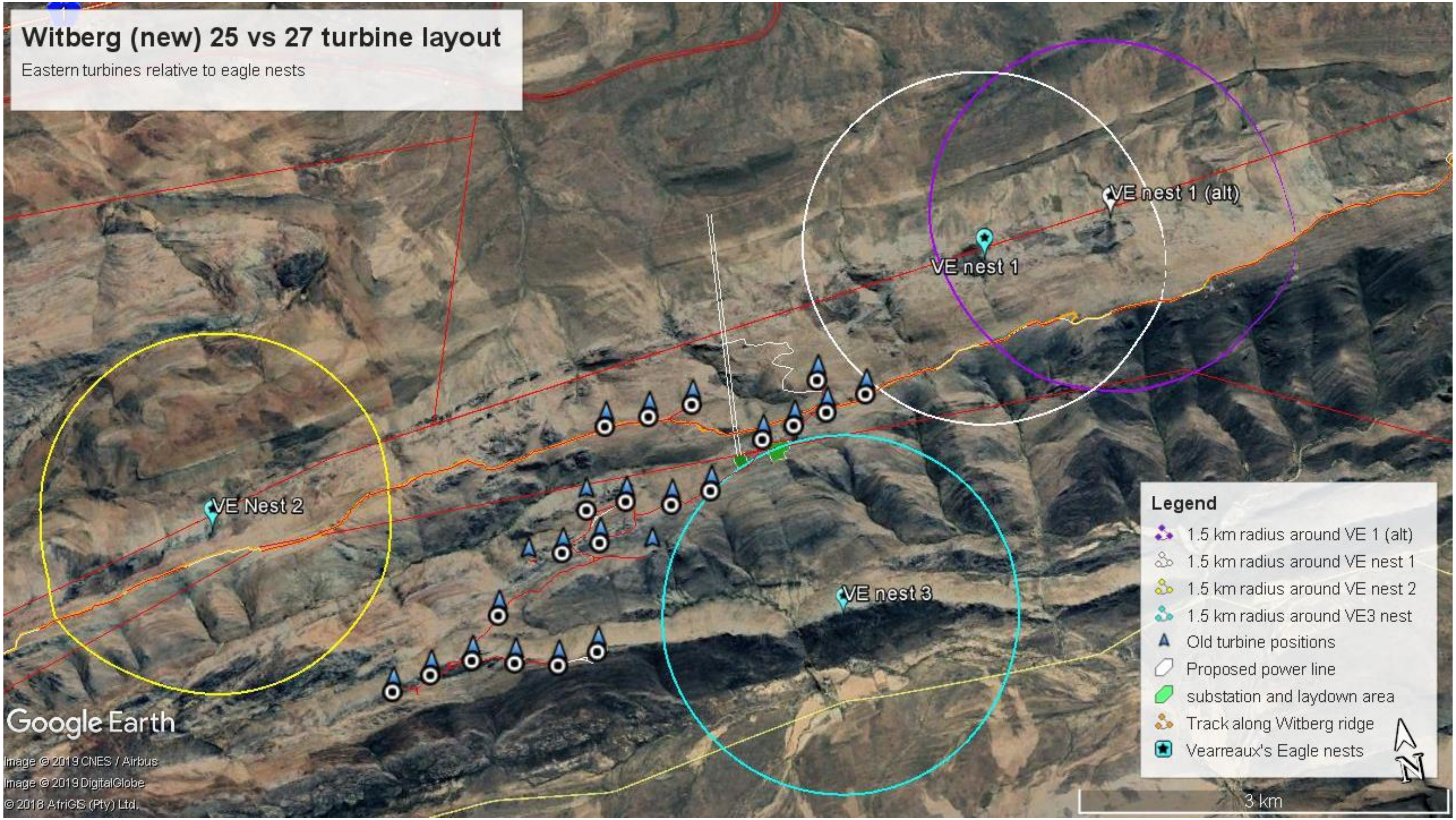


**Figure 2:** Detail of the eastern area of the turbine layout for 25 turbines (= white circles) for the August 2018 design, relative to known Verreaux's Eagle nests. The old authorized layout turbines (blue arrows) indicate that the turbines located in the 1.5km VE Buffers - the area of greatest potential use by the breeding Verreaux's Eagles- have been moved further away from the Verreaux's Eagle nests.

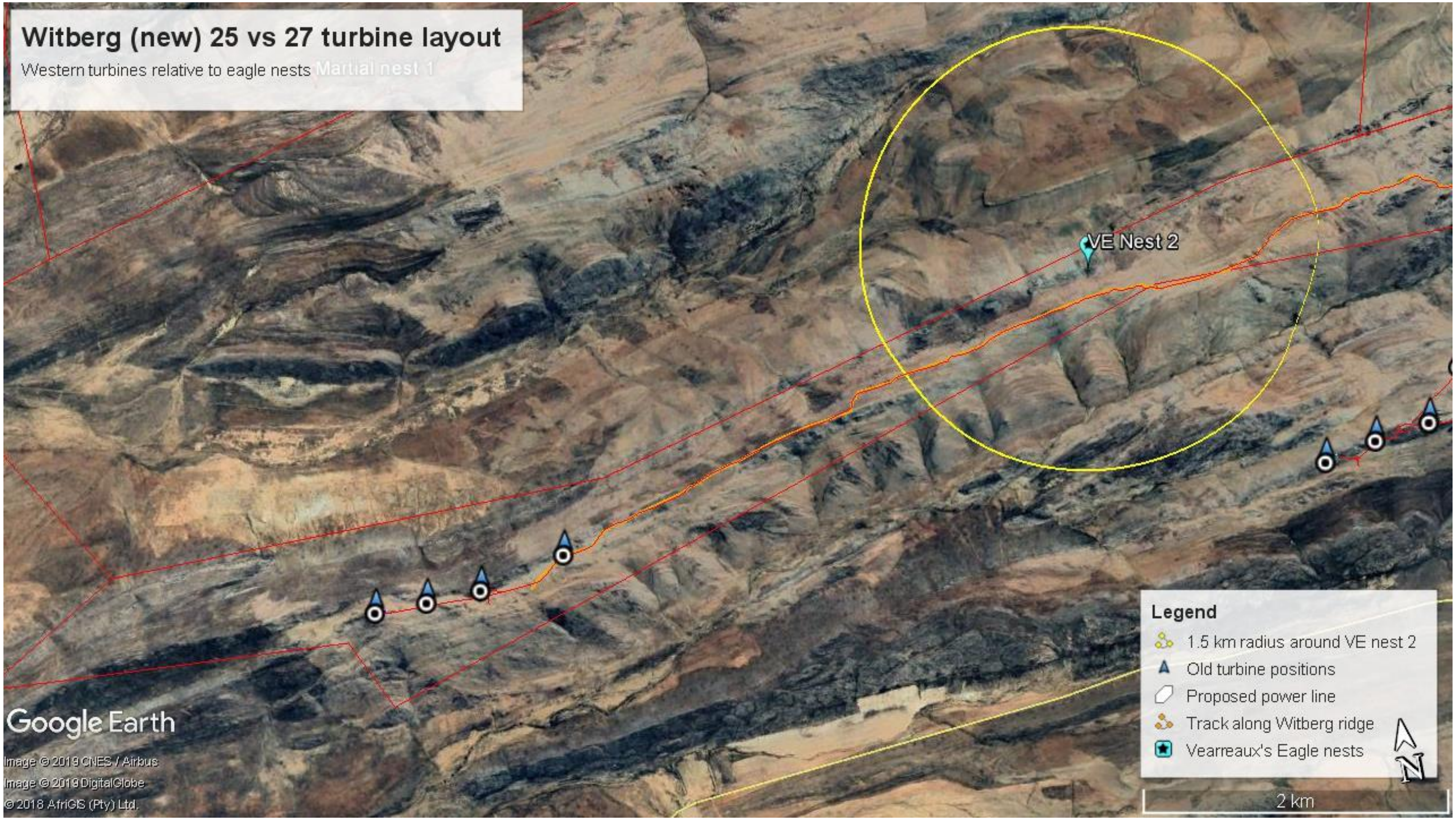

**Figure 3:** Detail of the western area of the turbine layout for the 25 turbines (= white circles) for the August 2018 design, relative to known Verreaux's Eagle and Booted Eagle nests. The authorized 27 wind turbine layout (blue arrows) are shown. All occur outside the 1.5-km circles, - the area of greatest potential use by the breeding Verreaux's Eagles.

# 4 REVIEW OF POTENTIAL AVIAN IMPACTS DUE TO CHANGES IN TURBINE NUMBERS AND DIMENSIONS

## 4.1 Interactions between wind energy facilities and birds

Literature reviews (e.g. Kingsley & Whittam 2005, Drewitt & Langston 2006, 2008, Kuvlevsky et al. 2007, Loss et al. 2013) and personal communications (S. Loss and P. Whitfield pers comm.) are excellent summaries of avoidance, displacements and impacts, due to wind farms in other parts of the world. Few data exist for southern Africa on the impacts of operational wind farms, partly because of the recent advent of operational farms (the first came on line in 2010), and partly because of non-disclosure agreements with clients. However, Birdlife South Africa have collated data on annual mortality at eight operational farms in South Africa (Ralston-Paton et al. 2017).

What will be assessed here is the likely change in risk to the birds passing through the wind farm where the following is altered:

- the number of turbines reduced to 25;
- the locations have been changed slightly from the 27 turbine layout, by densifying those wind turbines in the East;
- all turbines now lay outside the 1.5 km-buffer recommended as no-go for Verreaux's Eagles (Ralston-Paton 2017); that is, that no turbines can be placed in this buffer because of the negative impact they may have on the breeding Verreaux's Eagles;
- the hub height is increased from 80-m (original) to 92-m (authorised) to a range between 92m up to 120-m (proposed);
- the rotor diameter is increased from 116-m (authorised) to a range between 116m up to 136-m.

There are three major ways wind farms can influence birds:

a) **displacement and disturbance** (birds avoid the area, through the disturbance caused by the operation of the turbines);
b) **habitat loss and fragmentation** (the infrastructure and building phase directly destroys or divides habitat); and
c) **direct mortality** (birds are struck by the turbines and die).

The final report (Simmons and Martins 2015) covered all three points.

We can summarise **general** findings on bird-wind farm interactions as follows:

- On average 5.25 bird fatalities/turbine/year in the USA (range 2.92 - 7.85 birds killed); (Loss et al. 2013);

- Collisions in South Africa average 4.1 birds/turbine/year, (reviewed below);
- A few turbines are responsible for most deaths (Simmons and Martins 2019);
- Some wind farms on migration routes, and those employing lattice turbine towers, suffer high mortality rates (Loss et al. 2013) so, poorly sited wind farms can be risky;
- Identifying and mitigating turbines through Collision-Risk Modelling (Percival 2013) reduces that risk;
- Landscape features such as ridges for soaring, or valleys for commuting, are high-risk areas for raptors or migrants;
- Poor weather and high winds induce birds to fly lower and increases the chance of collision;
- Illuminating towers or buildings increases avian mortality, but gaps left in corridors of turbines may reduce overall mortality risk. Intermittent flashing lights (red or green) have been found to attract fewer birds;
- High risk species include those with low manoeuvrability (cranes, vultures); high air speed (raptors, wetland birds); distracted fliers (raptors chasing prey, courting birds displaying); and soaring species that seek lift off slopes (pelicans, storks);
- The most recent research shows exciting possibilities of reducing eagle mortalities by 100% by painting half of one blade black (Stokke et al. 2017);
- A sensitivity map for South Africa's most collision-prone species has been produced for bird-wind farm interactions and can be downloaded from: http://www.birdlife.org.za/conservation/terrestrial-bird-conservation/birds-and-renewable-energy/wind-farm-map/item/298-avian-wind-farm-sensitivity-map-documentation

**Mitigating** the risks is compromised by fast-moving objects being difficult to detect – even for raptors, due to retinal blur (i.e. turbine blades moving at 300-km/h). Raptors also have a low ability to see contrast – poorer than human abilities (Potier et al. 2018). However, exciting work has been done in Smøla, Norway, where a 2-year experiment with a black-painted turbine blade at four turbines showed a 100% reduction in fatalities of White-tailed Eagles *Haliaeetus albicilla* (Stokke et al. 2017). http://cww2017.pt/images/Congresso/presentations/oral/CWW17_talk_S07_5_Stokke%20et%20al.pdf

Other mitigations include:

❖ Site wind farms away from: (i) large concentrations of birds (e.g. roosts, wetlands or breeding colonies); (ii) migration corridors; (iii) slopes used by soaring birds; and (iv) breeding collision-prone birds,

- Monitor deaths per turbine and be prepared to shut down high-mortality turbines at times of high risk (i.e. migration or breeding seasons). Those individual turbines that kill more than one Red Data birds per year should be given particular attention. The likely position of these turbines can be identified pre-construction from the number of flights (Passage Rates) near them, and the proportion of flights at blade-swept height (BSH).
- The use of intense, flashing, short wavelength LED (light emitting diode) lights to deter raptors from close approaches to turbines in risky positions (Foss et al. 2017).

Here we review just the collisions with turbines, and particularly the effect of changing the number of turbines, hub height, and blade length.

## 4.2 Collision rates at wind farms in South Africa

Approximately 25 wind farms are currently operational in South Africa including facilities at Klipheuwel and Darling in the Western Cape (van Rooyen 2001, Jenkins 2001, 2003, Simmons et al. 2011), in the Karoo and several in the Eastern Cape (Doty and Martin 2011, Ralston-Paton et al. 2017). In a review of data from eight operational farms in South Africa monitored for over a year, Ralston-Paton et al. (2017) found that raptorial birds are the most impacted group, with 36% of all 271 known fatalities in 285 turbine-years to be small to large birds of prey. This gives a relatively median rate of mortality (adjusted for observer error and carcass removal) at 4.1 birds/turbine/year (Ralston-Paton et al. 2017). This ranges from 2.1 to 8.6 birds/turbine/year. This is similar to that reported elsewhere in the world at 5.2 birds/turbine/year (Loss et al. 2013).

## 4.3 Avian effects of changing hub heights and blade-swept area

Probably the two most important papers on mortality and the effect of increased hub height and blade length is that of Barclay et al. (2007) and Loss et al. (2013). They assessed collision rates of birds and bats at 33 and 53 sites (respectively) in North America, with a range of turbines from 3 to 454, and assessed the effect of variation in turbine height and blade-swept area on the mortality rates of birds and bats.

Barclay et al. (2007) found:

- no significant effect of increased height or blade length on the number of birds killed;
- However, he included lattice towers which are now known to bias mortality results upwards for shorter towers.

Loss et al (2013), re-analysing all data from Barclay et al and new studies, (minus the lattice towers that are no longer used) found:

- A significant effect of hub height on the number of avian mortalities at 53 wind farm sites in the USA. (Blade length could not be assessed because of statistical collinearity with hub height);
- In a model that included region and hub height, avian fatalities increased from about 2 birds/turbine/year at hub heights of 40-m to 6.2 birds/turbine/year at 80-m hub height;
- This represents a ~3-fold increase in mortalities between 40-m and 80-m hub height.

In their review of facilities in Europe and the USA combined, Drewitt and Langston (2008) found that taller communication towers were more likely to kill birds, than shorter ones. Similarly, taller transmission lines (i.e. 400 kV vs 220 kV lines) are more likely to kill collision-prone birds than shorter ones (J Pallett unpubl. data).

## 4.4 Collision-prone birds

Collision-prone birds (CPBs) are generally either:

- large species and/or species with high ratios of body weight to wing surface area, and low manoeuvrability (cranes, bustards, vultures, gamebirds, waterfowl, falcons);
- species that fly at high speeds (gamebirds, pigeons and sandgrouse, waterfowl, swifts, falcons);
- species that are distracted in flight – predators or species with aerial displays (many raptors, aerial insectivores, some open-country passerines);
- species that habitually fly in low light conditions (owls, dikkops, flamingos); and
- species with narrow fields of forward binocular vision (Drewitt & Langston 2006, 2008, Jenkins et al. 2010, Martin & Shaw 2010, Ralston-Paton et al. 2017).

Our own research data from a wind farm in the Eastern Cape indicates that fatalities of four Black Harriers *Circus maurus* were associated with the months when they spent more time at blade-swept height. No fatalities occurred when the harriers were flying at low levels (Simmons and Martins 2017).

These traits confer high levels of susceptibility, which may be compounded by high levels of exposure to man-made obstacles, such as overhead power lines and other wind farm infrastructure (Jenkins et al. 2010). Exposure is greatest in (i) highly aerial species; (ii) species that make regular and/or long distance movements (migrants and species with widely separated resources food, water, roost and nest sites); and (iii) species that fly in flocks such as vultures (increasing the chances of incurring multiple fatalities in single collision incidents). Soaring species may be particularly prone to colliding with wind turbines or power lines where these are placed along ridges – where turbines would exploit the same updrafts favoured by birds such as vultures, storks, cranes, and most raptors (Erickson et al.

2001, Drewitt & Langston 2006, 2008, Jenkins et al. 2010). In Europe, most mortalities recorded are large vultures and eagles (e.g. de Lucas et al. 2008).

# 5 IMPLICATIONS TO BIRDS FROM THE PROPOSED AMENDMENTS

## 5.1 General considerations: hub height and blade length

The question arises: do taller turbines (from 80-m or 92-m hub height to a range between 92m and up to 120-m) with longer blades (ranging from 58-m to 78-m), increase the risk of mortality of birds through direct impact?

The Loss et al. study, using a large data set (from 53 wind farms in the USA), showed that there was a *significant* effect of increasing height on bird fatalities. With an increase in hub height from 40-m to 80-m, avian fatalities increased from about 2 to 6.2 birds per turbine per year.

Therefore, the increase in hub height from 92-m to 120-m is predicted to have some influence on the background mortality rates for birds such as eagles in the Witberg setting. By exactly how much is the question we attempt to answer below.

## 5.2 Modelling fatalities for increased hub heights beyond 80-m

There are two methods to predict bird fatalities with increases in hub height

- (1) Modelling real fatality data at wind farms with different hub heights to determine if a relationship occurs between fatalities and hub height (Appendix 1) (note this does not use Witberg Wind Farm data because it is not operational);
- (2) Determine through collision-risk modelling (Band et al. 2007) the effect of taller turbines on the risk to eagles flying over the Witberg ridges. This was undertaken by Percival (2018, 2019) – based on site specific data;

**(1) Fatality data and hub height ("Loss model")**

We took the fatality-hub height data of Loss et al. (2013) and asked statisticians (Dr Birgit Erni and Francisco Cervantes) from UCT's Department of Statistics, Ecology and the Environment, to model the American data beyond 80-m hub heights. To strengthen the forecast for fatalities at 120-m hub heights, and to make them applicable to South Africa, we included the South African data (seven data points available from Ralston et al. 2017). These included two wind farms with 90-m and 95-m hub heights. The results (Appendix 1) indicate that fatalities are expected to increase exponentially 2.6-fold from

6.2 to 22.0 (95% CI = 12, 65) birds/turbine/year as turbines are increased from 80-m to 120-m. Fatalities are expected to increase two-fold for turbines increasing from 92-m to 120-m (Appendix 1).

This increased risk is supported by records of the flight heights of two main collision-prone eagles on a wind farm site at Springbok in similar montane terrain, where we recorded flight heights in 10-m bands over six site visits. (This was not done so accurately at the Witberg where flights were recorded in much larger bands). For both Verreaux's (n = 418 records) and Booted Eagles (n = 160 records), the proportion of flight heights at the higher blade-swept heights (BSH) there of 60-m to 220-m increased from about 35% to 69% for both species as hub heights increased from 80-m to 140-m.

We conclude, that given our statistical "Loss" model (Appendix 1) and the fact that twice as many eagle flights occur at these heights, for both small and large eagles, between 2.0- and 2.6-fold more avian fatalities are forecast by increasing turbines from 80-m or 92-m to 120-m.

**(2) Collision-risk modelling (CRM)**

Using data collected on eagle flights in the original site visits (Turpie at al. 2012), Percival (2018, 2019) found that the number of collisions likely by adult eagles with the turbines was lower at greater hub heights. The CRM model (Band et al. 2007) predicted that for 25 turbines in the August 2018 layout (Figure 2) the number of adult and juvenile eagles likely to be killed by the 120m turbines is 0.26 eagles per year (based on 98% avoidance rates, worst case). These are much lower rates than 0.86 eagles predicted for the previously authorised 27 turbines of 92 m hub height/ 116m rotor diameter per year (based on 98% avoidance rates) (Percival 2013). Thus, the new layout of 25 turbines is better than the previous layout for 27 turbines, based on 98% avoidance rates.

Thus, these two models (CRM and Loss model) give opposite predictions: the Loss model predicts increased fatalities, the CRM reduced fatalities. Both have their positives and downfalls.

- The CRM model uses eagle data collected on the Witberg site, while the Loss model uses all bird data from elsewhere;
- The CRM model gives no confidence limits, while the Loss model gives 95% confidence limits indicating how well the model predicts future outcomes;
- The Loss model forecasts beyond the present height of South African turbines (95 m) and requires verification for 120-m turbines;
- The Loss model is based on empirical data from 60 wind farms in the USA and South Africa, the CRM is based on the 1 wind farm in South Africa under assessment.

We are unable to determine why the two models give opposite results, but perhaps it is due to the data sets differing i.e. the Loss model is based on fatality data not collected on-site, and the CRM is based on site-specific data on flights. The proportion of eagles in the Loss model is also unknown, as it is based on all birds killed.

Why did the Loss model forecast that taller turbines would lead to high fatalities? There are two possible reasons, one ecological, one statistical:

(i) Ecologically, taller turbines and their greater blade-swept height are more likely to intersect migrating eagles. For example, Golden Eagles *Aquila chrysateos* studied in North America, tended to fly two- to four-fold higher (average 135-m to 341-m) than resident eagles (63-m to 83-m: Katzner et al. 2012). In Witberg this is corroborated by the higher proportion of flights at the Blade Swept Height (BSH) for two species of eagle (Percival 2013) outside the area proposed for turbine placement;

(ii) Statistically, longer blades are often (but not always) associated with taller turbines. For example, if blade length is doubled from 40-m to 80-m then the blade-swept area quadruples from 5,027-$m^2$ to 20,108-$m^2$. Thus, by chance, a passing bird has a four-fold higher probability of intersecting a blade from a taller turbine. With avoidance behaviour this may well be decreased, but data are lacking for South African species.

Thus, the *location* of turbines becomes increasingly important if increased heights increase the chances of fatalities. In this sense, choosing the best 25 sites from the 27 turbine that have already been authorised, will go a long way in reducing the higher number of fatalities expected for the 120-m turbines. This was one goal of the CRM modelling (Percival 2018, 2019) and is reflected in Figure 2.

To overcome the difficulties associated with the opposite results of the two models, we propose:

- that the two model results are combined. That is:
- Loss model (based on international fatality data and some South African data; not considering Witberg Wind Farm data), shows that collision fatality risk increases two-fold as turbine hub height increases.
- The CRM modelling shows that the collision risk decreased from 0.86 Verreaux's Eagles adults (27 turbines with 92-m hub height) to 0.26 adults (for 25 turbines) per year as Hub Height (HH) increased to 120-m.
- The proposed way forward is for the results of the CRM modelling (Table 2) to be combined with the predictions of the Loss model (Appendix 1). This allows us to take the results of both approaches into account without favouring one over the other. See 5.4 below. i.e. (0.26 adult Verreaux's Eagle collision risk) x2 = 0.52, below the level of 0.86 in the authorised layout.

## 5.3 Siting of turbines in relation to eagle activity and buffers

Rather than the eagles using all parts of their territory equally, most activity is aligned linearly east-west along the valley – along the rock faces where their nests and their prey (Rock Hyrax *Procavia capensis*) typically occur (Gargett 1990, Davies 1994, Simmons 2005). At Witberg this was true and, in addition, both eagle pairs on north-facing cliffs headed in a northerly direction when hunting. Using the data collected in 2012 and 2014 (Turpie et al. 2012, Simmons and Martins 2015) we showed that in a combined 333 hours of observation of eagles, the birds flew within the proposed wind farm boundary on only seven occasions. A very low Passage Rate of 0.021 eagles per hour. This included the juvenile eagle at Nest 1 (Bantam nest) in 2014/2015. Because of the unexpectedly low passage rate we recommend that some turbine positions fall within the 3-km, now promulgated as the preferred buffer around active eagle nests (Ralston-Paton 2017).

The low passage rates were confirmed in our follow-up assessment in 2019: in 28 hours observation overlooking the eagle nests no eagles were observed flying over the proposed turbines. The Passage Rate for the (6) eagle flights that were observed was low at 0.21 birds per hour.

To satisfy BLSA guidelines that (i) no turbines are allowed within 1.5-km of nests; and (ii) mitigations may be required as the turbines are erected, we suggest that mitigations may be required if eagles change their flight patterns.

Three systems are suggested:

- The DT bird system http://www.detect-inc.com/avian.html has been independently tested once on eagles in Norway (May et al. 2012). It correctly identified more than 80% of the eagle flights and took corrective action. However, the number of false positives (detecting birds that were not eagles) was also above 50%. This means that the system was successful in reducing mortality but was inefficient in that it stopped turbines when no risk to eagles was apparent. The system costs approximately ~ZAR500,000 per turbine (2017). Other, newer, systems may be required and available by the time the Witberg WEF becomes operational. Such a "multi-sensor" system is being tested now in South Africa (J Avni pers comm) and works on video surveillance in preference to radar-detection which has reliability issues.

- The use of black-blade mitigation (Stokke et al. 2017). Marking turbine rotors in this way has been tested recently with a clever experiment in Norway where turbines were killing large numbers of White-tailed Eagles *Haliaetus albicilla* and other ground-dwelling species. By painting one turbine blade black, researchers at the Norwegian Institute of Nature Research reduced the incidence of overall bird fatalities by 71% relative to unpainted controls (Stokke et al. 2017). More impressive was the fact that no further eagle mortalities were recorded over 2-years, relative to unpainted controls (R May in litt).
- The use of intense short wavelength LED lights. These were recently investigated on Red-tailed Hawks *Buteo jamaicensis* in the USA – one of the most collision-prone species there (Foss et al. 2017). The lights produced >5-fold more aborted approaches at hawk lures at a banding station than those at a control without the LED lights (Foss et al. 2017). This should be investigated in South Africa where hawks and other raptors feature prominently in all fatality reports (Ralston-Paton et al. 2017).

## 5.4 Numbers of turbines vs increased hub height

Will a decrease from 27 turbines, 92m hub height and 116m rotor diameter (authorised), to 25 turbines at 120-m hub height decrease the probability of avian fatalities? By quantifying the increased number of fatalities with a 120-m hub height (Loss model) we can determine if the reduced number of turbines can, indeed, compensate for this.

From the model forecasting the number of fatalities at the new hub heights of 120-m (Appendix 1) the predicted total number of fatalities for 25 turbines is 400 birds (with 95% confidence limits of 225 to 700). This is higher than the number predicted for 60 turbines at 80-m hub heights of 347 birds.

For eagles alone, the model (Appendix 1) suggests a 2.0-fold increase in fatalities when hub heights are increased from 92-m to 120-m.

This is supported by independent data from a montane wind farm in Springbok where we recorded the proportion of eagle flights in the blade swept area (35% of flights) doubled (to 70% of all flights) from 80-m hub height turbines (with 44-m blades) to 120-m turbines with 66-m blades (Appendix 1).

By employing these increased fatality rates to the Collision-Risk model results given in Percival (2018, 2019) we can gauge how many eagles may be affected at different avoidance rates. Avoidance Rates are a theoretical probability that a bird will see – and physically avoid – spinning turbine blades (Band et al. 2007).

The proportion of fatalities is forecast to decrease for the 120-m hub height turbines over 92-m turbines (Appendix 1). The 2019 Collision-Risk Modelling (Table 3) estimates that the total number of Verreaux's Eagles killed per year will decline as follows for adults and juveniles:

- (2 x 0.26=) **0.52 adults** for 120 m turbines from (2 x 0.33=) **0.66 adults** for 92m turbines, and
- (2 x 0.02=) **0.04 juveniles** for 120-m turbines from (2 x 0.03=) **0.06 juveniles** for 92-m turbines (Table 4);
- Giving a total of 0.56 Verreaux's Eagles killed / year for 25 turbines at 120-m hub height
- For Booted Eagles the estimates remain very low at 0.04 collisions/year (120-m turbines) and
- for Martial Eagles it remains at no fatalities.

These are relatively median levels of fatality at below one eagle per year.

**Table 3.** Collision risk modelling predictions for all eagles on site at the proposed Witberg wind farm (Percival 2013, 2018, 2019). The results are compared for 92 m (27 authorized in green) and 120m high turbines (25 proposed in pink). A range of avoidance rates for adults and juveniles are given (combining Table 5c and Table 6 in Percival 2013, 2018, 2019). This incorporates all **25 turbines** being moved to the least risk configuration. Predictions in bold represent the results thought to most likely represent reality.

| **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 (adults) **92 m** (27 Authorised) | 0.1 | 0.04 | 0.02 | 1.06 | 0.42 | 0.21 | 0.99 | 0.39 | 0.20 | 2.14 | **0.86** | 0.43 |
| Verreaux's Eagle (adults) **92m** (Proposed) | 0 | 0 | 0 | 0.55 | 0.22 | 0.11 | 0.27 | 0.11 | 0.05 | 0.83 | **0.33** | 0.17 |
| Verreaux's Eagle (adults) **105 m** (Proposed) | 0 | 0 | 0 | 0.49 | 0.20 | 0.10 | 0.24 | 0.10 | 0.05 | 0.73 | **0.29** | 0.15 |
| Verreaux's Eagle (adults) **120 m** (Proposed) | 0 | 0 | 0 | 0.43 | 0.17 | 0.09 | 0.21 | 0.09 | 0.04 | 0.65 | **0.26** | 0.13 |
| Verreaux's Eagle (juveniles) **92 m** (27 Authorised) | - | - | - | - | - | - | - | - | - | 0.21 | **0.08** | 0.04 |
| Verreaux's Eagle **(juv) 92 m** (Proposed) | | | | | | | | | | 0.08 | **0.03** | 0.02 |
| Verreaux's Eagle **(juv) 105 m** (Proposed) | | | | | | | | | | 0.07 | **0.03** | 0.01 |
| Verreaux's Eagle **(juv) 120 m** (Proposed) | - | - | - | - | - | - | - | - | - | 0.06 | **0.02** | 0.01 |
| Booted Eagle **92m** (Authorised) | 0.0 | 0.0 | 0.0 | 0.08 | 0.03 | 0.02 | 0 | 0 | 0 | 0.08 | **0.03** | 0.02 |
| Booted Eagle **92m** (Proposed) | 0 | 0 | 0 | 0.1 | 0.04 | 0.02 | 0 | 0 | 0 | 0.1 | **0.04** | 0.02 |
| Booted Eagle **105m** (Proposed) | 0 | 0 | 0 | 0.1 | 0.04 | 0.02 | 0 | 0 | 0 | 0.1 | **0.04** | 0.02 |
| Booted Eagle **120m** (Proposed) | 0 | 0 | 0 | 0.09 | 0.04 | 0.02 | 0 | 0 | 0 | 0.09 | **0.04** | 0.02 |
| Martial Eagle (both) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | 0 |

**Table 4**. Predictions for the number of eagle fatalities per year on the proposed Witberg wind farm combining the CRM model of Percival (2019) and taking account of the two-fold increased likelihood of fatalities due to increased hub height to 120m (Appendix 1). The results for 98% avoidance are the most likely to reflect reality. These estimates incorporate all 25 turbines being moved to the best locations to give the lowest risk configuration.

| Species | Estimated Number of eagle collisions per year assuming the (25) turbine heights increase from 92m to 120 m (combining Percival 2019 and the Loss model – Appendix 1) | | | | |
|---|---|---|---|---|---|
| | TOTAL | | | | |
| **Avoidance rate** | **95%** | **98%** | **99%** | **Proposed precautionary combination of models (CRM x Loss) at 98% avoidance** | **Conclusion** |
| **Verreaux's Eagle (adults)** Authorised (27) | 2.14 | **0.86** | 0.43 | | |
| 92m HH (25) | 0.83 | 0.33 | 0.17 | **0.66** | **Acceptable as it lies below 0.86 (the authorised level fatality rate)** |
| 105m HH (25) | 0.73 | 0.29 | 0.15 | **0.58** | |
| 120m HH (25) | 0.65 | 0.26 | 0.13 | **0.52** | |
| **Verreaux's Eagle (juveniles)** Authorised (27) | 0.21 | **0.08** | 0.04 | | |
| 92m HH (25) | 0.08 | 0.03 | 0.02 | **0.06** | **Acceptable as it is the same or below 0.08 (the authorised level fatality rate)** |
| 105m HH (25) | 0.07 | 0.03 | 0.02 | **0.06** | |
| 120m HH (25) | 0.06 | 0.02 | 0.01 | **0.04** | |
| **Booted Eagle** (120 m HH) (25) | 0.09 | **0.04** | 0.02 | **0.08** | |
| **Martial Eagle (25)** | 0 | **0** | 0 | **0.0** | |

## Updated CRM

These annual fatality rates for Verreaux's Eagles are, relatively low for healthy populations of Verreaux's Eagle but to reduce impacts to a minimum they require **mitigation as suggested below**. We note also that the Minister of Water and Environment Affairs in her judgement of the appealed conditions dated 13 August 2013, required the following conditions to be met:

> "(Condition 40) Should any unanticipated negative impacts be recorded, G7 commits to reducing these impacts. Mitigation measures to achieve this includes shutting down problematic turbines, if this is deemed necessary."

Following further appeals by I&APs the Minister also required (20 February 2016) that:

“(Condition 37) Pre-construction monitoring must be extended to record the flight paths of the juvenile Verreaux’s Eagle and the monitoring of breeding sites must be implemented both during and after the construction phase.”

“(Condition 41) After discussions with the Department and prior to the commencement of construction, the applicant must develop and implement a monitoring programme for the Verreaux’s Eagles, to the satisfaction of the Department. A copy of the monitoring programme must be provided to the Department and to Birdlife South Africa by the applicant within 30-days of being developed.”

In light of this, and based on our expert opinion of the threatened eagles at Witberg, the following mitigations are suggested:

(i) the turbines closest to the known eagle nests are moved to at least 1.5-km (the distance at which significant Verreaux’s Eagle flight activity falls away: [Percival 2013] and because this is the non-negotiable buffer recommended by BLSA [Ralston-Paton 2017]);

(ii) Birdlife South Africa Verreaux’s Eagle guidelines recommend a 3-km buffer around all active nest (Ralston-Paton 2017), but reduced that recommendation to 1.5-km where survey data show few flights occur. Our data now covering 401 hours, do show a very low Passage Rate of 0.021 eagles/hour;

(iii) Post-construction, all turbines killing one or more Red Data bird per year will need to be fitted either with (a) the highly effective black-blade mitigation; or its equivalent; or (b) automated deterrent or curtailment.

It is our understanding, following a meeting with Witberg Wind Power (Pty) Ltd (July 2018), that all of the requirements, which could have been met at this stage, have been met. That is:

- (condition 37) the behaviour, flight paths and high-risk areas of the juvenile eagle were mapped in 2014 (Simmons and Martins 2015). No flights of either the young bird or adult were observed within the 1.5-km buffer now complied with (this remained unchanged in the Feb 2019 site visit);
- (condition 37) Witberg Wind Power (Pty) Ltd agree to undertake eagle monitoring during and after construction;
- (condition 40) Witberg Wind Power (Pty) Ltd agree to following either shut down of problem turbines or implement other mitigation measures deemed appropriate;
- Witberg Wind Power (Pty) Ltd will develop and implement a monitoring programme for the Verreaux’s Eagles, to the satisfaction of the Department of Environment (DEA). A copy of the monitoring programme will be provided to the Department and to Birdlife South Africa by the applicant within 30-days of being developed.

## 5.5 Quantifying the impacts

Several raptors were previously identified (Avisense 2010, Turpie et al. 2012, Simmons and Martins 2015) as likely to be negatively affected by displacement, loss of habitat or direct mortality. These are all in the top 100 collision-prone species: Verreaux's Eagle (*Vulnerable*, 2nd), Martial Eagle (*Endangered*, 5th), Black Harrier (*Endangered*, 6th), Lanner Falcon (*Vulnerable*, 22nd), and Booted Eagle (55th). Given their abundance and susceptibility to collision (Ralston-Paton et al. 2017) Jackal Buzzards (42nd) may also be impacted. The following tables quantify the impacts for these raptors, particularly South African Red Data birds (Taylor et al. 2015). This incorporates the data from 2010, 2015 and 2019, reflects the amended layout, includes all the CRM modelling (Percival 2018, 2019) and accounts for the estimated two-fold increase in fatality due to increased hub heights (92-m to 120-m).

The first table indicates the Construction Phase impacts; the second, Operational Phase impacts.

The **Significance** of the impact (S) is given by the equation (NEMA 2010):

**S = (E+D+M)P**

Where
**E = Extent** (local or wide-scale, ranked from 1 to 5)
**D= Duration** (length of time of the effect, ranked from 1 to 5)
**M= Magnitude** (the size of the negative effect, ranked from 1 to 10)
**P=Probability** (the likelihood of the event happening, ranked from 1 to 5)

**The Nature** of the impact will be negative in that birds will either be: (i) displaced by habitat alteration; (ii) displaced by disturbance during or after construction; (iii) impacted by turbine blades directly; (iv) impacted by the existing and proposed 132 kV lines.

**The Extent** of the impact will be local **(1)** reducing foraging habitat in the immediate wind farm area for the raptors, but may be higher if the space created by the death of territorial individuals brings in other birds to be killed (the sink effect), or they are displaced from breeding through disturbance.

**The Duration** will be short-term (**2)** for the duration of the construction (18 months) but **(5)** for the operational lifetime of the wind farm for all species.

**The Magnitude** is ranked as a medium-high impact **(6)** for the raptors, particularly those frequently flying at 92 m rotor height (Verreaux's Eagles, Booted Eagles and Jackal Buzzards). However, this will increase to **(8)** as hub height increases to 120 m according to fatalities forecast by Loss et al. (2013) and statistical inference in Appendix 1.

**The Probability of occurrence** of the raptors flying into the rotor blades is ranked as probable **(4)** given their aerial nature and the high proportion of time that both Verreaux's and Booted Eagles spend at these blade-swept heights (see Appendix 1).

**The Significance [S = (E+D+M)P ]** is as follows for the species identified as at risk:

All raptors S = (1 + 5 + 8)4 = 56

These ratings indicate that, for all raptorial species, the resultant significance weightings (56) has a direct influence on the decision to develop and, therefore, must be mitigated.

**Table 5.** Significance table explaining the relevance of the scores used.

| Parameter | Scores | Interpretation |
|---|---|---|
| Extent (Area) **E** | 1-5 | 1-2 (Local), 3-4 (regional) 5 (national) |
| Duration (period of impact) **D** | 1-5 | 1 (v short term, 0-5 yr)<br>2 (short term, 2-5 yr)<br>3 (Medium term of 5-15 yr)<br>4 (long term > 15 yr)<br>5 (life time of the development) |
| Magnitude (size of impact) **M** | 1-10 | 1 (negligible)<br>2 (minor)<br>4 (low, and cause an impact on the process)<br>6 (moderate, process continue but modified)<br>8 (high)<br>10 (v high, destruction of patterns and cessation of processes) |
| Probability (likelihood the impact will occur) **P** | 1-5 | 1 (improbable)<br>2 (improbable, but still low likelihood)<br>3 (distinct probability)<br>4 (highly probably, most likely to occur)<br>5 (definite, will occur regardless of any prevention) |
| Significance **S** = (E+D+M)P | 3-100 | 3-30 (low, impact will not have a direct influence on decision to develop)<br>30-60 (Medium, impact could influence the decision to develop unless effectively mitigated)<br>60-100 (High, impact must have an influence on the decision to develop the area). |
| Confidence | | Sureness that the input variables are sound and well researched in determining the final significance level. |

**Table 6a**. A summary of the quantified impacts during construction to the raptors likely to be impacted by the wind farm for the amended layout and turbine dimensions. We compare the impacts with those estimated for the pre-construction report.

**Construction Phase**

| **Nature:** Direct mortality, disturbance or avoidance of area around the wind farm for the raptors identified as "at risk" above due to human disturbance, heavy machinery, or overhead lines, during construction. | | |
|---|---|---|
| | **Without mitigation** | **With mitigation** |
| **Extent** | 1 (local) | 1 (local) |
| **Duration** | 2 (short-term) | 2 (short-term) |
| **Magnitude** | 6 (moderate) | 4 (low) |
| **Probability** | 4 (highly probable) | 3 (distinct probability) |

| | | |
|---|---|---|
| **Significance (E+D+M)P** | **36** (Moderate= could influence the decision to develop unless effectively mitigated) | **21** (Low significance = impact will not have direct influence on decision to develop) |
| **Status (+ve or –ve)** | Negative | Negative to neutral |
| **Confidence** | High (Pearce-Higgins et al. 2012) | High |
| **Reversibility** | High | High |
| **Irreplaceable loss of species?** | No (Both Verreaux's and Booted Eagles may suffer short term disturbance, displacement, and loss of breeding but return after construction) | Reduced |
| **Can impacts be mitigated?** | | Partially, yes |

| | **Authorised Project*** | | **Proposed Amendment**** | |
|---|---|---|---|---|
| | **Pre-mitigation impact rating** | **Post-mitigation impact rating** | **Pre-mitigation impact rating** | **Post-mitigation impact rating** |
| **Extent** | **1** | **1** | **1** | **1** |
| **Duration** | **2** | **2** | **2** | **2** |
| **Magnitude** | **6** | **4** | **6** | **4** |
| **Probability** | **4** | **3** | **4** | **3** |
| **Reversibility** | High | High | High | high |
| **Irreplaceable loss of species?** | No (Both eagle species may suffer short term disturbance, displacement, and loss of breeding but return after construction) | | No (Both eagle species may suffer short term disturbance, displacement, and loss of breeding but return after construction) | |
| **Significance rating** | **36 (medium)** | **21 (low)** | **36 (medium)** | **21 (low)** |

*** 27 turbines at 92 m height**

**** 25 turbines at 120 m height**

**Mitigation:** Disturbance during wind farm construction was found to have greater impacts on birds in the UK than post-construction impacts (Pearce-Higgins et al. 2012). There are generally two classes of mitigation to avoid disturbing Red Data birds around wind farms during construction: (i) limit construction activities (building, blasting etc) to seasons when birds are not breeding – to reduce disturbance causing nest failure; (ii) limit construction activities (building, worker-presence, power-line-stringing) from areas within 1000-m of known Red Data species' nests at times when eagles or other Red Data species are incubating/feeding small nestlings. Verreaux's Eagles start breeding in April-July and have a small nestling on the nest from June – August (Simmons 2005).

We therefore, recommend as mitigations: (i) not constructing within 1000-m of Verreaux's Eagle nests or Booted Eagle nest during their early breeding season (May – June) or small-chick rearing season (June – July). For breeding Booted Eagles, the seasons to avoid are August – September; (ii) avoid blasting or causing noise disturbance in the same seasons anywhere within 3-km of active nests for all Red Data species.

**Table 6b**. A summary of the quantified impacts during operations to the raptors likely to be impacted by the wind farm for the amended layout and turbine dimensions. We compare the impacts with those estimated for the pre-construction report. Note, no quantified assessment was given in Turpie et al. (2012) so we have applied numbers to the qualitative assessments.

## Operational phase

| **Nature:** Direct mortality, disturbance or avoidance of area around the wind farm for the raptors identified as at risk above, due to disturbance, or impacts with turbine blades and overhead lines during operations. | | |
|---|---|---|
| | **Without mitigation** | **With mitigation** |

| | | |
|---|---|---|
| **Extent** | 1 (local) | 1 (local) |
| **Duration** | 5 (long-term) | 5 (long-term) |
| **Magnitude** | 8 (high) | 6 (moderate) |
| **Probability** | 4 (highly probable) | 3 (distinct probability) |
| **Significance (E+D+M)P** | 56 (Medium significance = impact should influence decision to develop unless mitigated) | 36 (Medium significance impact could influence the decision to develop unless effectively mitigated) |
| **Status (+ve or –ve)** | Negative | Negative to neutral |
| **Confidence** | High | High |
| **Reversibility** | Low | High |
| **Irreplaceable loss of species?** | No (Verreaux's Eagles are not uncommon, and the rarer Booted Eagles may be less susceptible to collision and displacement) | Reduced |
| **Can impacts be mitigated?** | Yes | Partially, yes |

| | **Authorised Project*** | | **Proposed Amendment**** | |
|---|---|---|---|---|
| | **Pre-mitigation impact rating** | **Post-mitigation impact rating** | **Pre-mitigation impact rating** | **Post-mitigation impact rating** |
| **Extent** | **1** | **1** | **1** | **1** |
| **Duration** | **5** | **5** | **5** | **5** |
| **Magnitude** | **8** | **6** | **8** | **6** |
| **Probability** | **4** | **3** | **4** | **3** |
| **Reversibility** | Low | Medium | Low | Medium |
| **Irreplaceable loss of species?** | No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement) | | No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement) | |
| **Significance rating** | **56 (medium-high)** | **36 (medium)** | **56 (medium-high)** | **36 (medium)** |

*** 27 turbines at 92 m height**

**** 25 turbines at 120 m height**

**Mitigation:** There are generally five classes of mitigation for birds around wind farms: (i) re-position the turbines to avoid impacts or disturbance for the birds; (ii) redesign the turbines to alter the present pattern/shape/size of the turbines so birds see them more readily and avoid contact; (iii) curtail or shut-down-on-demand the turbines when collision-prone birds approach; (iv) manipulate the habitat to reduce the attractiveness of the site to collision-prone raptors; (v) reduce the overall number/height of turbines.

Because the combination of the CRM (Percival 2019) and the Loss model (Appendix 1) forecasts that the taller turbines are predicted to increase fatalities to 0.56 adult and juvenile Verreaux's Eagles per year (at 98% avoidance rates: Table 4) this is judged to be an acceptable level of mortality because it reduces the number well below one eagle per year, and it reduces the fatalities to below that for the already authorized turbine layout (0.94 adult + juvenile Verreaux's Eagles). If the fatality rate is higher than these two models predict (i.e. >1.0 eagle per year) then mitigations will be required.

We recommend as mitigations:

(i) the turbines closest to the known eagle nests are moved to at least 1.5-km (the distance at which significant Verreaux's Eagle flight activity falls away: Percival 2013);

(ii) Birdlife South Africa Verreaux's Eagle guidelines recommend a 3-km buffer around all active nest and a 1.5-km no-go buffer (Ralston-Paton 2017). Since only seven eagle flights in 333 hours (a Passage Rate of 0.021 eagles/hour) were recorded we feel the 3-km buffer is not necessary and 1.5-km is recommended.

(iii) Post-construction, all turbines killing one or more Red Data bird per year will need to be fitted either with (a) the highly effective black-blade mitigation, or (b) automated deterrent or shut-down-on-demand; (this follows the Minister's recommendation too).

Operational phase monitoring is essential to determine the actual impacts on birds and therefore, the required mitigation measures and thresholds. This was also a stipulation of the EA. Such an approach requires a flexible Adaptive Management Plan to be implemented during operation. Such an Adaptive Management Plan must allow for changes to be implemented within a maximum time-frame of 3-4 weeks.

The Wind Farm must agree to follow the mitigation measures that may result from the operational monitoring and Adaptive Management Plan.

(i) In accordance with the Adaptive Management Plan, appropriate mitigation measures, such as curtailment at specific environmental conditions or during high-risk periods (i.e. post construction monitoring shows 1 Red Data species killed at these turbines per year, then the use of appropriate automatic shut down or deterrent technology will have to be implemented in the case of mortality of Red Data species [defined as: 1 Red Data species killed per year]).

The operational monitoring study design must determine the turbines that require appropriate mitigation measures. Through such monitoring, we have found at other operational wind farms that 25% of the turbines are responsible for 75% of the fatalities, allowing specific risky turbines to be targeted (Simmons and Martins 2019).

Two adaptive management mitigations are recommended if Red Data species are found to be killed:

(i) investigate painting half a blade black to deter raptors, as undertaken by Norwegian wind farms to reduce white-tailed Eagle deaths with great success (Stokke et al. 2017).

(ii) Implement the automated "Multi-sensor" video system, presently under test by J Avni, which deters incoming birds or feathers the blades, or turns off turbines as collision-prone species approach within 500-m of these turbines;

For **all** new overhead power lines to be fitted with diurnal and nocturnal bird diverters to reduce collisions and burying all internal power lines in the WEF, wherever that is possible. The shortest possible route from the wind farm to the existing power line be taken to reduce fatalities.

**Cumulative impacts:**

Cumulative impacts (Masden et al. 2010) are those that may affect a species in a small area (e.g. a wind farm) yet have a wide-scale influence. If resident territorial birds are killed by turbines for example, then other individuals will be pulled in to take up the vacant territory. A wide-spread population reduction may occur as a result of the WEF acting as a sink. This is less likely for the Verreaux's Eagles given that they are a relatively common (but iconic) montane species. For breeding Booted Eagles, however, this may have a greater impact on their population because there are an estimated 700 breeding pairs in South Africa (Martin 2005).

All renewable energy applications within 30-km of Witberg are assessed below (Table 8).

| |
|---|
| **Residual impacts:**<br>After mitigation, direct mortality or area avoidance by the species identified above may still occur and further mitigation (e.g. turbine shut-down) will be needed. |

Below we compare the impacts of the two turbine proposals to determine if the new Amendment of 25 turbines with higher hub heights and longer blades is better than the previous (Authorised) layout of 27 turbines of 92 m hub heights (Table 7). The table indicates that the 25 turbines of 120-m hub heights reduces the modelled impacts from medium-high (score 56) to medium (score 36). Indicating a nett reduction in risk for the Witberg Eagles for the Amended layout.

**Table 7**: A comparative assessment of the impacts of the Authorised Project (27 turbines at 92-m hub height) and the Proposed Amendment (25 turbines at between 92m and 120-m hub height) with mitigations.

| | **Authorised Project (27 turbines 92-m HH)** | **Proposed Amendment (25 turbines 92 -120-m HH)** |
|---|---|---|
| | | |
| **Nature** | **Negative:** Fatality of Red Data birds on site. Possible displacement of same species | **Negative:** Fatality of Red Data birds on site. Possible displacement of same species |
| **Extent** | **1** (local) | **1** (local) |
| **Duration** | **5** (lifetime of wind farm) | **5** (lifetime of wind farm) |
| **Magnitude** | **8** (high) | **6** (moderate) |
| **Probability** | **4** (highly probable) | **3** (distinct probability) |
| **Reversibility** | Low | Medium |
| **Irreplaceable loss of species?** | No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement)<br>Combination | No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement) |
| **Quantified loss of eagles per year** (CRM x Loss model) | **0.94** Verreaux's Eagles<br>**0.06** Booted Eagles | **0.56** Verreaux's Eagles<br>**0.08** Booted Eagles |
| **Significance rating** | **56 (medium-high)** | **36 (medium)** |

**Mitigation:** There are generally five classes of mitigation for birds around wind farms: (i) re-position the turbines to reduce impacts or disturbance for the birds; (ii) redesign the turbines to alter the present colour/shape/size of the turbines so birds see them more readily and avoid contact; (iii) curtail or shut-down-on-demand the turbines when collision-prone birds approach; (iv) manipulate the habitat to reduce the attractiveness of the site to collision-prone raptors; (v) reduce the overall number/height of turbines.

Because the combination of the CRM (Percival 2019) and the Loss model (Appendix 1) forecasts that the taller turbines are predicted to increase fatalities to 0.56 adult and juvenile Verreaux's Eagles per year (at 98% avoidance rates: Table 4) this is judged to be an acceptable level of mortality because it reduces the number well below one eagle per year, and it reduces the fatalities to below that for the already authorized turbine layout (0.94 adult + juvenile Verreaux's

Eagles). If the fatality rate is higher than these two models predict (i.e. >1.0 eagle per year) then mitigations will be required.

We recommend as mitigations:

(iv) the turbines closest to the known eagle nests are moved to at least 1.5-km (the distance at which significant Verreaux's Eagle flight activity falls away: Percival 2013);

(v) Birdlife South Africa Verreaux's Eagle guidelines recommend a 3-km buffer around all active nest and a 1.5-km no-go buffer (Ralston-Paton 2017). Since only seven eagle flights in 333 hours (a Passage Rate of 0.021 eagles/hour) were recorded we feel the 3-km buffer is not necessary and 1.5-km is recommended.

(vi) Post-construction, all turbines killing one or more Red Data bird per year will need to be fitted either with (a) the highly effective black-blade mitigation, or (b) automated deterrent or shut-down-on-demand; (this follows the Minister's recommendation too)

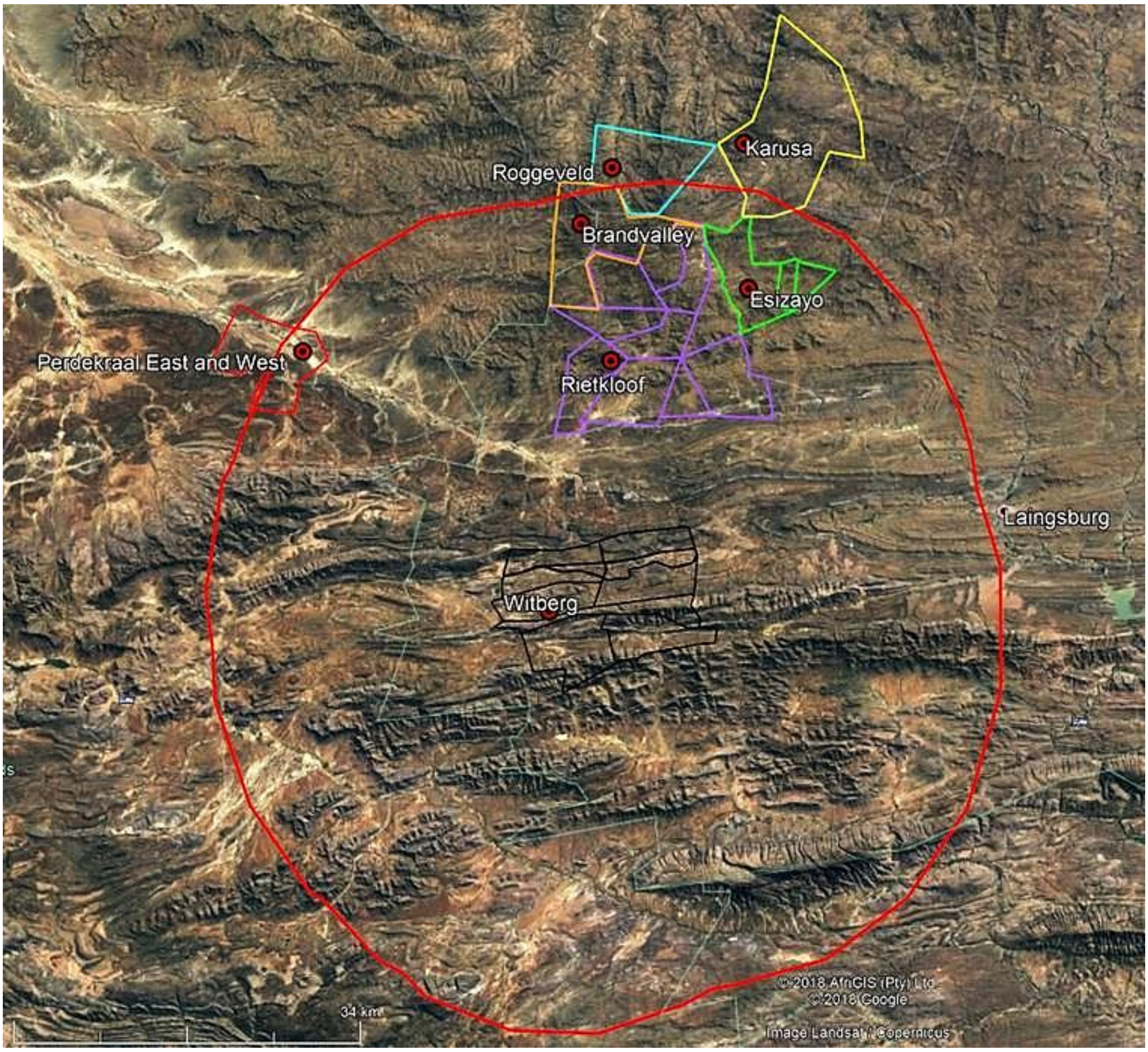


**Figure 4:** All renewable energy applications lodged with the DEA within a 30-km radius of the Witberg WEF site. All are wind farm sites.

## 5.6 Cumulative impacts

Cumulative impacts are defined as "impacts that result from incremental changes caused by either past, present or reasonably foreseeable actions together with the project" (Hyder 1999, in Masden et al. 2010).

In this context, cumulative impacts are those that will impact the avian communities in and around the Witberg development, mainly by other renewable energy facilities (wind and solar farms) and associated infrastructure in the Nama Karoo biome. This will happen via the same factors identified here viz: collision, avoidance and displacement.

As a starting point, we determined the number and nature of the renewable energy farms around the regions within a 30-km radius (Figure 4) and secondly, calculated their impact on avifauna.

**Table 8**: All renewable energy projects within a 30-km radius of the Witberg WEF, and their approval status with the DEA. Source: https://www.environment.gov.za/mapsgraphics DEA second quarter 2018 updated by Building Energy.

| | Project Title (Applicant) | Distance from Witberg WEF (km) | Technology | Megawatts | Current Status |
|---|---|---|---|---|---|
| 1 | Rietkloof (Rietkloof wind farm) | 21.0-km | Wind Power | 140 | Approved |
| 2 | Esizayo | ~25-km | Wind Power | 140 | Approved |
| 3 | Brand Valley | 30-km | Wind Power | 140 | Approved |
| 4 | Perdekraal East and West | 30-km | Wind Power | 140 | Approved |
| 5 | Roggeveld | 30 km | Wind Power | 140 | Approved |
| **Totals:** | **5 wind farms ( = 700 MW)** | | | | |

Given the general assumption that footprint size and bird impacts are probably linearly-related for wind farms, a starting point in determining cumulative impacts is to calculate:

- the number of birds displaced per unit area, by habitat destruction, or disturbed or displaced by human activity;
- the number of birds killed by collision with the turbines on site; and
- the number of birds killed by collision with infrastructure leading away from the site.

Five renewable energy developments within 30 km are currently on record with the DEA (Table 7) and all are approved. Most are north or west of the Witberg study site (Figure 4). The total output from the five approved sites is 700 MW (Table 7).

We searched for data to populate the Cumulative Impacts table from data from Birdlife South Africa on 1-2-years' post-construction monitoring of avian fatalities at wind farms (Ralston-Paton et al. 2017).

The national review of post-construction **avian fatalities at wind farms** (Table 7), including data from the Karoo and Eastern and Western Cape wind farms, indicate that

- South African wind farms kill about 4.1 birds/turbine/year (range 2.1 – 8.6 fatalities/turbine/year). This is similar to the international-derived mean of about 5.25 birds/turbine/year (Loss et al. 2013).
- In terms of avian fatalities per megawatts, an average of 2.43 birds/MW/year (range 0.95 – 5.9 fatalities/MW/year) occur in South Africa (Ralston-Paton et al. 2017).
- The majority of the fatalities recorded (36%) in South Africa are raptors (Table 7).

Using the median value of **2.43 bird fatalities/MW/year** we can calculate the average (and range) of fatalities expected for all wind farms:

1. the median number of (all) birds estimated to be killed by the five wind farms (totalling 700 MW) is 1700 birds/year (range 665 – 4130 birds/y).

Note that this may be a slightly inflated figure given that many early wind farms in South Africa did not have stringent mitigation measures to reduce impacts to birds, especially appropriate buffers and siting of turbines, potentially inflating fatality rates. Thus, the lower range (665 fatalities/year) is more likely. This includes all birds not just eagles or raptors.

**Table 9:** Summary of all birds and Red Data raptors killed at eight wind farms in South Africa from 2014–2016. From Birdlife South Africa (Ralston-Paton et al. 2017).

| Wind farms | Turbines | Months monitored | Avian fatalities | Adjusted mortality rate* |
|---|---|---|---|---|
| 6 | 46, 9, 41, 40, 60, 32 | 69 | 309 | 4.1 birds/turbine/year |
| Main groups | | Proportion of all avian fatalities | | Ranking |
| Raptors (small-medium) | | 33% | | 1 |
| Raptors (eagles) | | 3% | | 6 |
| Others/unknown | | 16% | | 2 |
| Swifts, swallow and martins | | 14% | | 3 |
| Passerine (small perching birds) | | 14% | | 3 |
| Waders and wetland birds | | 10% | | 5 |
| | | | | |
| Red Data raptors as a proportion of all birds killed | | 12/309 = 3.9% | | |

How many threatened (red data) species does this represent ?

- About 12 of 309 fatalities (4%) were Red Data species of raptors from the review of the seven wind farm sites (Table 9).
- Thus, from a wind farm output of 700MW and ~1700 fatalities, approximately (4% x 1700 =) 68 Red Data raptors are predicted to be killed per year. The range is 27 – 165 red data raptors.
- **Thus, a total of about 68 (range 27-165) Red Data raptors is estimated for the cumulative impacts for the five wind farms per year.**

**Table 10:** Cumulative impacts of the Witberg wind farm in the Western Cape, relative to five other renewable energy facilities within 30-km of the site.

**Nature*:*** The impact of the wind energy facilities proposed in the Western Cape is expected to be negative and arise from disturbance, displacement and collision for birds around the wind turbines. The associated infrastructure will also impact species in the form of impacts with un-marked power lines.

The direct impact of the wind farms (Table 8) was gauged using data released by Birdlife South Africa for fatalities at seven wind farms in South Africa (Ralston-Paton et al. 2017). About 4.1 birds/turbine/year, or ~2.43 birds/MW/year are killed annually. If a total of 700 MW is generated per year from these renewable energy farms, then we estimate <1700 (all) birds killed per year there (includes larks, swifts etc).

About 4% of the total of the wind farm fatalities are expected to be threatened Red Data raptors (Ralston-Paton et al. 2017). Thus, we can predict a maximum of 68 threatened raptors may be included in this total per year without mitigation. Thus, the likely impact varies from medium to high without mitigation. Careful mitigation can reduce this to acceptable levels.

| | **Cumulative Impact with Authorised project*** | **Cumulative Impact with Proposed Amended Project**** |
|---|---|---|
| ***Extent*** | Regional (3) | Regional (3) |
| ***Duration*** | Long-term (5) | Long-term (5) |
| ***Magnitude*** | Moderate (5) | Moderate (4) |
| ***Probability*** | Probable (3) | Probable (3) |
| ***Significance*** | **Medium (39)** | **Medium (36)** |
| ***Status (positive/negative)*** | Negative | Negative |
| ***Reversibility*** | Medium | Medium |
| ***Loss of resources/species?*** | Possible | Possible |
| ***Can impacts be mitigated?*** | Probably, Yes | Yes |

***Confidence in findings:***

**Medium**: the mortality data released by Birdlife South Africa for wind farms allows us to estimate the probable mortality, but the mitigation measures suggested to avoid major raptor fatalities are unknown for the other wind farms. Without mitigation measures (i.e. the avoidance of high-use and high-risk avian areas by turbines, or black-blade or curtailment mitigations) chances of mortality increase greatly. The rate of avian fatalities is likely to vary across years with different rainfall events.

Because individual wind farms in South Africa rarely release data, it is difficult to gain accurate data without specific studies in these areas. Thus, these cumulative impact assessments will remain of low confidence until all specialist studies are made public.

***Mitigation:***

Reducing avian impacts at wind energy facilities is in its infancy in South Africa. Recommended measures specifically for the proposed Witberg facility include:

- Avoiding all nest areas and foraging/roosting areas of Red Data species in the siting of said facilities, guided by the CRM and known flight paths. Given the increased likelihood of eagle fatalities due to the taller turbines (Appendix 1) buffers around nests must be maintained at the 1.5-km no-go buffer recommended in the Verreaux's Eagles guidelines (Ralston-Paton 2017); this means no wind farm-related development can take place within this no-go buffer with the exception of access roads;
- If operational-phase monitoring indicates that one or more Red Data bird is killed at any turbine per year, then we recommend that black-blade mitigation as the first method used to reduce eagle mortalities;
- Multi-sensor deterrent/shut down systems can be tried as a second-tier mitigation;
- Intense short-wave radiation (Foss et al. 2017) should also be tested as a deterrent;
- If audible or visual deterrence is ineffective then selective stopping of turbines should be tried;
- Marking all new overhead power lines with bird diverters and staggering pylons of adjacent lines to reduce large birds colliding with them;

# 6 CONCLUSIONS AND RECOMMENDATIONS

The presence of breeding collision-prone and Red Data bird species in the Witberg Wind Farm area (in the form of Verreaux's and Booted Eagles) and the presence of other collision-prone species requires careful siting of the proposed turbines. This was undertaken by Witberg Wind Power (Pty) Ltd for the authorised project, based on the original avian impact assessment (Avisense 2010, Turpie et al. 2012, Simmons and Martins 2015), and in discussions with the specialists and following Collision-Risk Modelling (Percival 2013, 2018 , 2019). The suggested amendments of increasing the hub height (and power output) and reducing the number of turbines and relocation of turbines (including associated infrastructure) is considered here, as an addendum, for the effect it may have on the large collision-prone eagles.

In general, the change in hub height of the proposed turbines is expected to have a negative influence on the mortality experienced by sensitive birds in the study area. This arises from an analysis of 53 wind farms in the USA by Loss et al. (2013). That indicates a significant effect of hub height on avian fatalities (the higher the turbine the greater the chance of avian fatality). To forecast how many fatalities 120-m high turbines may incur, we modelled the USA data, and incorporated South African data (Appendix 1). This does not include Witberg site-specific data because these data are for operational wind farms only. Fatalities of 6.2 birds/turbine/year for 80-m turbines were predicted to increase 2.6-fold to 16 fatalities/turbine/year (95% confidence limits 9-28) at 120-m hub heights. For 92-m (authorised) turbines the fatalities of 8.0 birds/turbine/year is forecast to rise 2.0-fold to 16.0 birds/turbine/year.

An independent specialist also undertook a Collision-Risk Model (Percival 2013, 2018, 2019) using site specific eagle data to determine mortality rates of between 0.26 and 0.13 adults and between 0.02 and 0.01 juvenile Verreaux's Eagles for 98% and 99% avoidance rates respectively, for the proposed 25 turbine layout and 120-m turbines.

By combining these different modelling approaches, we calculate the following is likely in terms of potential eagle fatalities:

- Authorised 27 turbines of 92-m hub height (0.92 adult + juvenile Verreaux's Eagles/year) will have higher avian (eagle) costs, than;
- 25 turbines of between 105-m and 120-m hub height between 0.62 and 0.56 adult + juvenile Verreaux's Eagle fatalities/year, respectively (Table 4).

Therefore, the proposed amendments (increased hub height and fewer turbines) will result in a change to the significance of the impact(s) assessed for birds in the original EIA (compared in Table 7). The expected decrease in eagle fatalities arises because (i) the CRM predicted fewer eagle fatalities at higher hub heights (Percival 2018, 2019), but (ii) the area swept by the blades increases exponentially (blade-length$^2$) with an increase in blade length, increasing the likelihood that birds will impact the blades (Appendix 1). The rotational speed of larger turbine blades is slower and this may assist in reducing fatalities for the larger turbines.

The significance will change in a positive manner (lower impact) if the turbine height is increased (to between 105m and 120-m). However, if the models incorrectly forecast the predicted fatalities, the significance of the impact can be reduced to acceptable levels (<1 eagle per year) through the mitigation suggested. On present evidence, few flights (7 in 333 hours) took place through the 3-km buffers on the wind farm; thus, the impact of turbines within 1.5-km will be of low significance.

If there are fatalities, we recommend: (i) black-blade painting, which was found to be highly effective for White-tailed Eagles in Norway (Stokke et al. 2017), subject to obtaining approval from the South African Civil Aviation Authority. Curtailment, as previously proposed (Simmons and Martins 2015) which includes shut-down-on-demand by automatic systems such as the Multi-sensor systems can also be used. New deterrent systems such as intense shortwave LED lighting (Foss et al. 2017) should also be considered if turbines are found to kill one or more Red Data birds per year from the post-construction monitoring. Mitigations during construction should include: (i) avoiding construction within 1000-m of active nests of Red Data species during the early breeding season and chick-rearing times (May-July).

**We previously recommended that a written-agreement** must be included in the Environmental Authorization with the land owners that they not persecute the *Vulnerable* red data eagles breeding on their property (Simmons and Martins 2015). This recommendation arose out of the finding that an active Verreaux's Eagle nest was removed from the Elandsfontein property and burned at the base of the cliff. Similarly, 2 of the 3 nests at VE nest area 2 (Figure 2) had been removed in February 2019. This rate of nest removal at the Witberg site (3 nests in 24 nest-years) is 15-fold higher than the nest removal rate (1 nest in 112 nest-years) from two other study sites in the Western Cape (M. Murgatroyd Unpubl. Data). We recommend that the eagle-persecution agreement must state that:

- Verreaux's Eagles, (or Martial Eagles) as threatened Red data species, cannot be persecuted on the Witberg wind farm, because it is illegal to do so anywhere in South Africa ( http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1727-37812013000400006.);
- This means that eagles (adults, juveniles, chicks or eggs) on the wind farm cannot be shot, poisoned, trapped, their nests removed or the nest contents taken or in any way interfered with.

It appears that this was not included in the Environmental Authorisation. This recommendation must be re-instituted, and the written agreement appended to the authorisation.

We argue that the farmer is ultimately responsible for everything that happens on his property and he must take responsibility for any illegal activity. This can be enforced by having trail cameras overlooking the nest cliff. The careful planning and risk modelling that has gone into this report by both the developer and the specialists is under-mined if this loophole to persecuting the eagles is not closed.

All overhead power lines should be marked with bird diverters. Where possible, on-site power lines should be buried, as typical within wind farms. Where that's not possible new lines should be aligned with existing lines where possible and the pylons staggered to reduce bustard deaths (Simmons, Pallett and Brown in prep). With all these mitigations considered, and the marking of the overhead lines, the risks to collision-prone birds on the WEF site can be reduced to minimal acceptable levels.

The cumulative impacts for the five renewable energy facilities within 30-km of the Witberg site are expected to be medium as gauged by an estimated 1700 birds (including species such as larks and swifts) and 68 (range 27-165) Red Data raptors per year. The lower end of the range (27 red data raptors per year) is expected given that many early wind farms did not have stringent mitigation measures. If all wind and solar farms enact suitable mitigation measures, these impacts, too, can be reduced to acceptable levels.

In conclusion, the currently proposed amendments (i.e. 25 turbines with hub heights of 92m up to 120-m) is likely to incur fewer eagle fatalities than the authorised 27 turbines of 92-m HH, with all turbines outside the 1.5 km buffer for all eagle nests. This is calculated to be 0.52 eagles per year (worst case). If this rate is exceeded suitable mitigations, including (i) all turbines killing one or more Red Data bird per year must be black-blade painted; or (ii) fitted with automated deterrent or shut-down-on-demand, then Witberg Wind Power (Pty) Ltd can reduce their environmental/avian footprint to acceptable levels.

Birdlife South Africa (Ralston 2017) recommend during-construction monitoring and a minimum of 24 months post-construction monitoring at wind farms where impacts to Verreaux's Eagles are expected. This will determine the effects of the wind farm on the Red Data species identified as at risk. With these mitigations, we can recommend that the Witberg wind farm, as amended, can be allowed to proceed.

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# 8 Appendix 1: The use of statistical inference to forecast possible bird fatalities when turbine heights are increased

**Please note: the turbine numbers and avian fatalities used here are for indicative purposes only. The statistical model uses empirically-derived real data from wind farm studies in North America and South Africa and is used to forecast what avian fatalities may occur for different hub heights in real-life situations in South Africa.**

## The use of statistical inference to forecast possible bird fatalities when turbine heights are increased

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Some South African wind farms are contemplating increasing hub height of the wind turbines from 80-m to 120-m or 140-m. Environmental Consultants, Birds & Bats Unlimited, were requested to assess the possible impact to birds of this increased height. This is a report of our findings based on the international published literature, and statistical interpolation by two specialists.

We have used the data and trends from the meta-analysis of Loss et al (2013) who analysed results from 53 studies of avian fatalities and hub height in the USA, once carcass-finding biases and scavenger removals were accounted for. They found a significant positive relationship between avian fatalities and hub height for turbines from 36-m to 80-m. Avian fatalities increased 10-fold over this size range (0.6 to 6.2 birds/turbine/year).

Note that Smallwood (2013) found the opposite trend (decreasing fatalities per turbine with increased height). However, his data were skewed by a plethora of older small turbines with lattice towers – that attract perching birds – with very high fatality rates. Since lattice towers are no longer employed, this bias no longer exists, and his results are not a true reflection of avian fatalities into the future. Loss et al. (2013) accounted for this bias in their re-assessment. Their results are shown below (Figure A1).

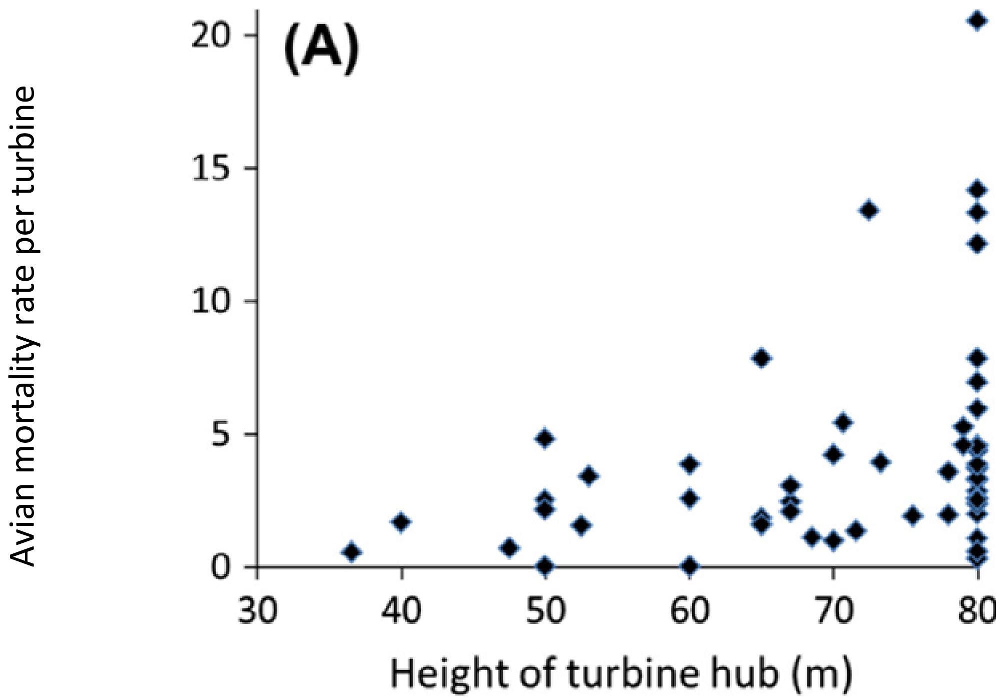


**Figure A1**: Results from Loss et al. (2013) indicating the significant relationship between hub height and avian mortality for 53 studies from the USA.

**Modelling fatality/hub height estimates**

To determine what the avian fatalities might be for taller turbines we asked two statisticians to help forecast what these rates might be, using statistical modelling. Dr Birgit Erni of the Department of Statistical Sciences at UCT and her PhD student Francisco Cervantes modelled the results provided by

**Figure A2:** Modelled results of avian fatalities in relation to hub height for turbines above 80-m . Data taken from Loss et al. (2013) and modelled with 95% confidence limits. Circled on the graph are the projected average number of fatalities for 120-m (22 fatalities/turbine/year).

Loss et al. (2013) to determine what the effects may be. The data for this analysis were available in the supplementary material provided in Loss et al.'s (2013) paper.

Their results are shown in Figure A2 using only the results from the USA.

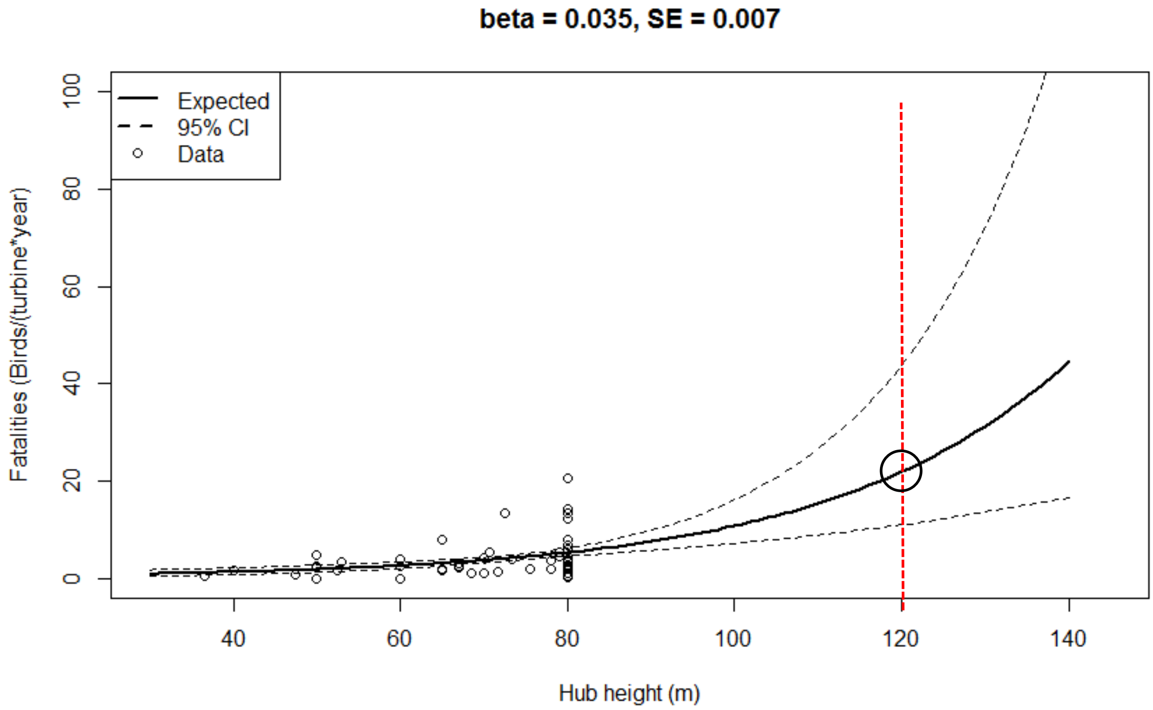


**Figure A2:** Modelled results of avian fatalities in relation to hub height for turbines above 80-m . Data taken from Loss et al. (2013) and modelled with 95% confidence limits. Circled on the graph are the projected average number of fatalities for 120-m (22 fatalities/turbine/year).

Their modelling indicates that the relationship between turbine height and fatalities was exponential and a predicted 22 birds (95% CI = 11, 44) may be killed on average per turbine per annum by 120-m turbines and 44 birds (95% CI = 17, 119) per annum by 140-m turbines (Figure A2) in the USA.

Such models are only statistical constructs of what may happen in reality, and it is dangerous to extrapolate too far beyond real data. This is reflected in the wide confidence intervals for the predicted average (dashed lines in the graph above).

To **test for robustness,** we went a step further and added empirically-derived South African data to the models from that reported by Ralston-Paton et al. (2017). These data, like those extracted from Loss et al. (2013), were corrected for observer biases and scavenger-removal of carcasses below turbines. They are useful because, of the eight South African wind farms with post-construction fatality data, two farms had (32) turbines of 90-m and (37) turbines of 95-m (Ralston-Paton 2017).

The results indicate (Figure A3) that the model predicts slightly lower average fatalities and decreases the uncertainty around the estimates of avian fatalities for turbines of 120-m (16 birds, 95% CI = 9, 28) and 140-m turbines (28 birds, 95% CI = 12, 65).

Thus fatalities

- increased by 2.6-fold (6.2 to 16 fatalities) from 80-m to 120-m hub heights
- increased by 2.0-fold (8.0 to 16 fatalities) from 92-m (authorised) to 120-m hub height

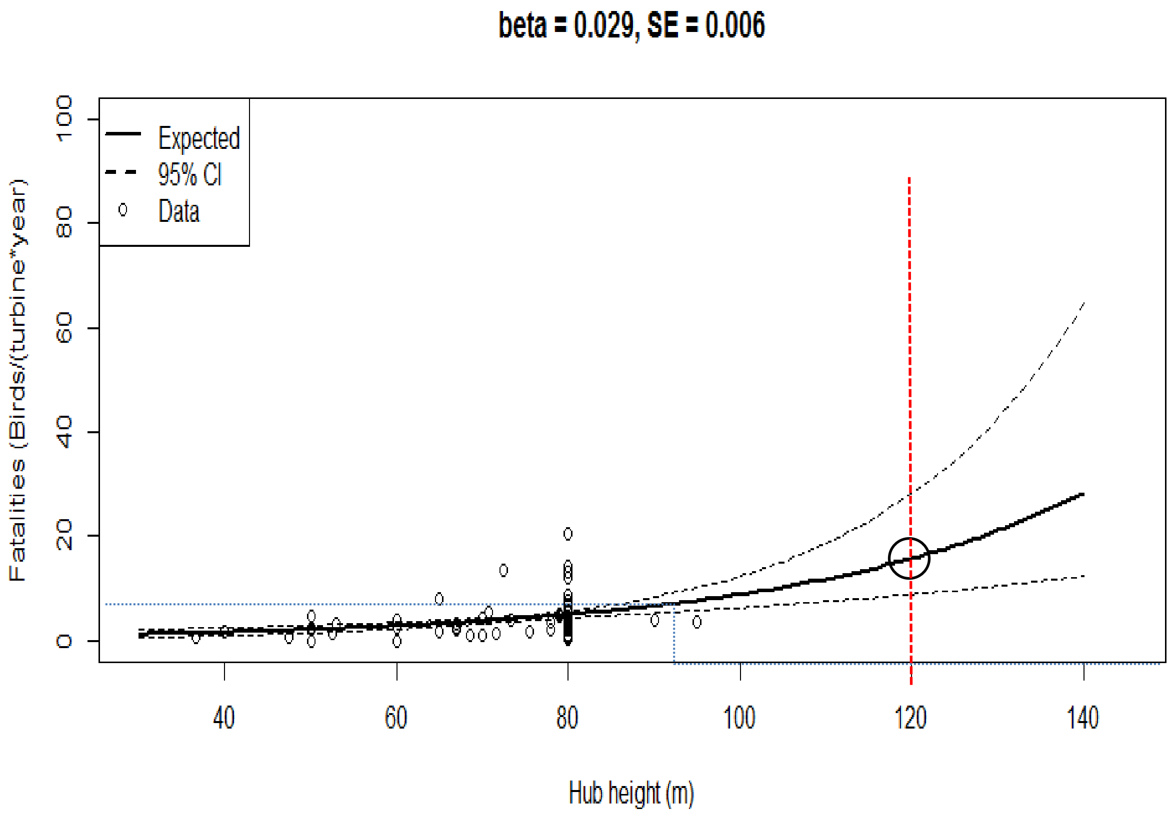


**Figure A3:** Modelled data combining avian fatalities **from the USA** (Loss et al. 2013) **and from South Africa** (Ralston-Paton et al. 2017) and their relation to hub height. The South African data (n = 7 farms) include two with hub heights of 90-m and 95-m. The combined data and 95% confidence limits predict 6.2 fatalities at 80-m, 16 birds (95% CI = 9, 28) will be killed on average per year for 120-m-high turbines and 28 (95% CI = 12, 65) birds on average for 140-m-high turbines.

We can also determine the confidence intervals around the extrapolated fatalities beyond 80-m hub height using a boot-strapping method. These are 95% bootstrap prediction intervals. These intervals predict the actual observations, rather than the average.

These confidence intervals are based on the original data of Loss et al (2013), and we used them to determine if the South African data points fall within the 95% confidence limits derived from the North American data (Figure 4). One would expect to see ~ 5% of actual observations to fall outside these limits.

The results indicate that the South African data all lie within the 95% confidence intervals. This means that the inference on fatalities at hub heights beyond 80-m, derived from the data of Loss et al. (2013) and applied to South African data (red points in Figure A4) is relatively robust, and we can draw some conclusions on South African wind farms where taller turbines may be used.

Again, these are only valid if the same relationship between fatalities and height holds beyond 90-95-m. Further data for taller turbines are, thus, required to validate these models.

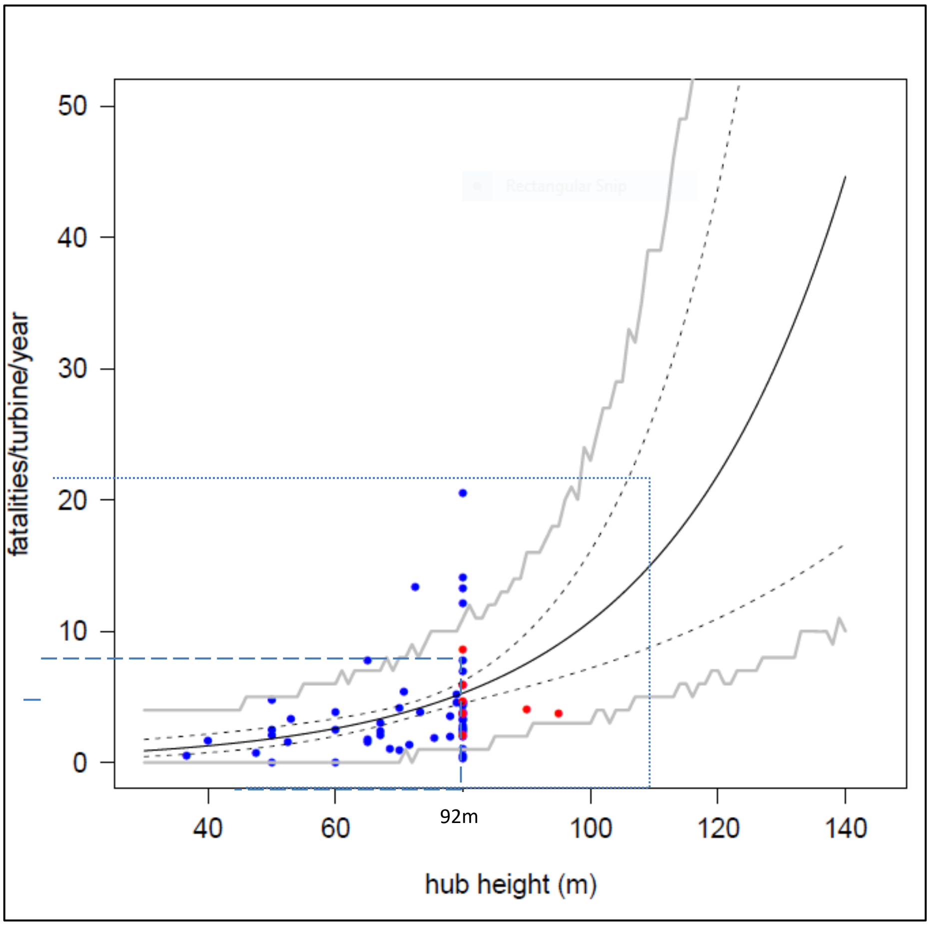


**Figure A4:** Prediction intervals from bootstrapping analyses based on North American hub height/fatality data (Loss et al. 2013 = blue data points) to determine if South African data (= Red Data points) fall within 95% confidence intervals.

### Validating predictions with eagle flight height data

We can only apply these fatality estimates as rough estimates to how many birds may be impacted, because:

- different wind farms will have a different suite of at-risk collision-prone species, and
- those species may also fly at different heights depending on topography, behaviour (hunting, displaying or commuting), or weather.

For one proposed wind farm site, we collected flying heights of the Collision-Prone raptors by estimating flight heights in each of six visits equally spaced throughout the year. We recorded heights in bands (1-20-m, 20-40-m, 40-120-m, 120-160-m, 160+m) at first sighting for one large, highly-collision-prone species, the **Verreaux's Eagle** *Aquila verreauxii,* and a smaller, less collision-prone eagle, the **Booted Eagle** *Aquila pennatus*. These two species are ranked 2nd and 55th respectively in the top 100 collision-prone species (Birdlife South Africa).

We calculated the proportion of flights for the following combination of hub-heights corresponding to the highest and lowest blade-swept heights (BSH) for the different turbines:

- 80-m turbines – BSH: 36 – 124-m
- 120-m turbines – BSH: 54 – 186-m
- 140-m turbines – BSH: 60 – 220-m

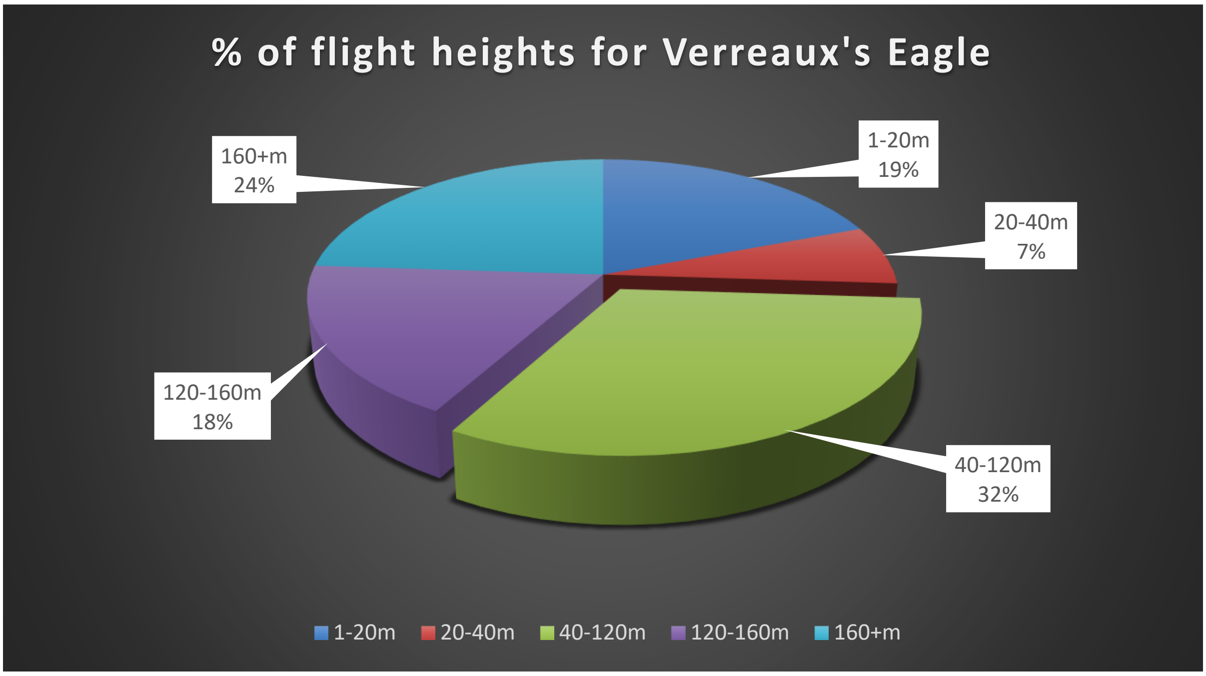


**Figure A5:** Flight heights recorded for Verreaux's Eagles at a proposed WEF in Springbok in montane habitat. Data collected January, April, June, August 2012; November 2014 and February 2015, covering all seasons, and based on 418 records of flying eagles.

The results (Figure A5) indicated that:

- most flights of Verreaux's Eagles were recorded in the height band 40-120-m (32%),
- fewest flights, of the 418 recorded across all seasons, were recorded in the band 20-40-m (7%). This is not necessarily surprising for large resident eagles.

**What proportion of flights occur in the "risky" blade-swept zone for different height turbines?**

Because we recorded in height bands (0-20-m, 20-40-m, 40–120-m, 120-160-m and 160$^{+}$ m) we had to estimate the proportions of flights in the important BSH category of 36-124-m for the 80-m turbines. We did so in the following way:

We started with the proportion of flights in the band 40-120-m (= **32%**). We then calculated the proportion of flights that occurred down to 36-m in the 20-40-m band as a fifth of the flights occurring there (4/20 of 7% = **1.4%**). At the upper end, for the proportion of flights from 120-130-m, we took the "first 4-m" of all flights in 120-160-m band, or 4-m/40-m = 10%. Thus 10% of 18% = **1.8%**.

Similar procedures were followed to estimate the proportion of risky flights for the 120-m and 140-m turbines (Table A1).

**Table A1.** The estimated proportion of risky flights by **Verreaux's Eagles** for different-sized turbines, based on 418 recorded flights, 2012-2105.

| Turbine Hub Height (blade length) | Blade-swept height (m) Lowest | : Highest | Proportion of flights in these risky zones |
|---|---|---|---|
| 80-m (44-m) | 36 | 124 | 35.2% |
| 120-m (66-m) | 54 | 186 | 60.4% |
| 140-m (80-m) | 60 | 220 | 68.7% |

The estimates of the proportion of risky flight at blade-swept heights (BSH) doubled from 35% for the 80-m turbines to almost 70% for the 140-m turbines (Table A1). The 120-m high turbines were intermediate at 60%.

Thus, for **Verreaux's Eagles**, the likelihood that more deaths might occur with taller turbines (from statistical models: Figure 4) is corroborated by the behaviour of the birds in their natural environments: the proportion of risky flights almost doubled from 35% for the 80-m turbines to 69% for the 140-m turbines.

For **Booted Eagles** the proportion of risky flight at BSH was similar to that for their larger-bodied cousins (Table A2). Based on 160 flights recorded from 2012 to 2015 across all seasons, the proportion of flights in the BSH rose from ~35% to ~70 % with an increase in hub height from 80-m to 140-m. For this species, equal numbers of risky flights were calculated for 120-m hub heights.

**Table A2.** The estimated proportion of risky flights by **Booted Eagles** for different-sized turbines, based on 160 recorded flights, 2012-2105.

| Turbine Hub Height (blade length) | Blade-swept height (m) Lowest | : Highest | Proportion of flights in these risky zones |
|---|---|---|---|
| 80-m (44-m) | 36 | 124 | 34.5% |
| 120-m (66-m) | 54 | 186 | 70.6% |
| 140-m (80-m) | 60 | 220 | 69.2% |

Thus, for both large and small eagle species recorded on the South African wind farm site, we can conclude that the proportion of risky flights in the BSA increase two-fold when turbines are increased from 80-m to 120-m. This concurs with the statistical inference based on North American and South African data that fatalities increase about 2.6 -fold when turbines are increased from 80-m to 120-m.

**Reasons for higher fatalities**

Why would higher turbines be predicted to kill more birds than smaller turbines? There are two possibilities, one ecological, one statistical:

(iii) Ecologically, taller turbines and their greater blade-swept height are more likely to intersect migrating eagles studied in North America which tend to fly 2- to 4-fold higher (average 135-341-m) than resident birds (63-83-m: Katzner et al. 2012);

(iv) Statistically, longer blades are associated with taller turbines. For example, 120-m high turbines have 68-m blades at Witberg (while 80-m turbines had 44-m blades). This 1.55-fold increase in blade-length more than doubles the blade-swept area from 6,083-$m^2$ to

14,530 $m^2$. Thus, by chance, a passing bird has a 2.4-fold higher probability of intersecting a blade from a taller turbine.

These possibilities can, therefore, explain why fatalities are predicted to increase from an average of 6 to 16 (95% CI = 9, 28) birds per turbine per year when hub height is increased from 80-m to 120-m.

**What combination of turbine numbers and height will minimise avian fatalities?**

In Table A3 below we use the statistically inferred fatality estimates for different numbers and heights of turbines to determine which combination gives the lowest number of fatalities.

**Table A3** Re-assessing the potential average number of avian fatalities per year with increases or decreases in turbine heights and turbine numbers. The number of turbines is based on the premise that turbine number x power/turbine output = 140MW. Hence (i) **56** turbines of 80-m turbines x 2.5MW = 140MW, or (ii) **31** turbines of 120-m x 4.5MW = 140MW; or (iii) **28** turbines of 120-m x 5.0MW = 140MW.  Based on fatality estimates modelled by Erni and Cervantes (see Figures 3 and 4). This increases the average fatality estimates (for 80-m turbines) from 6.2 birds.turbine.year$^{-1}$ to 16 birds.turbine.year$^{-1}$ for 120-m turbines, a 2.58-fold increase.

| | | **Turbine number** | | |
|---|---|---|---|---|
| **Turbine height** | Ave No. fatalities/ turbines/yr[a] (95% CI)[b] | **56 turbines** (of 2.5 MW) Total fatalities (95% CI) | **31 turbines** (of 4.5 MW) Total fatalities (95% CI) | **28 turbines** (of 5.0 MW) Total fatalities (95% CI) |
| 80-m | 6.2 | **347 birds** | **-** | **-** |
| 120-m | 16 (9-28) | 896 (504-1568) birds | 496 (279-868) birds | **448** (252-784) birds |

[a] extrapolated from trends in Figure 3. [b] CI= Confidence limits, derived from Figure 3

We conclude from these new fatality estimates that 28 turbines of 120-m hub-height will kill about 100 more birds per year than 56 turbines of 80-m. If fatalities due to taller turbines occur at the lower end of the 95% confidence limits modelled, then 28 turbines of 120-m hub height are the best option with 252 fatalities (Table 3, last column, bottom row).

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