

**Modelled risk of Brolga collisions  
with turbines at the proposed  
Stockyard Hill Wind Farm**

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**Biosis Research**

**Report to Stockyard Hill Wind Farm Pty.  
Ltd.**

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with turbines at the proposed  
Stockyard Hill Wind Farm**

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# SUMMARY

## Introduction

Stockyard Hill Wind Farm Pty. Ltd. is in the process of developing the Stockyard Hill Wind Farm, near Skipton in Victoria. Modelling has been undertaken using the Biosis Research Deterministic Collision Risk Model, to assess potential risk to Brolgas of collisions with turbines at the wind farm. This report details the modelling processes and predictions for two turbine designs.

The annual cycle of the Brolga includes seasonal periods of residence at breeding and flocking sites and movements between them. The birds' behaviour differs according to this annual cycle and modelling has thus been undertaken for each of the seasonal components and results have then been summed to provide average annual predictions of Brolga mortality.

Depending on the size of rotors used, mean avoidance capacity of Brolgas, and routes used by the birds during migratory movements, the predictions of the modelling range from an annual average maximum of 0.196 collisions per annum to an annual average minimum of 0.026 collisions per annum. On the basis of what is considered to be the most ecologically reasonable of these variables, the annual average number collisions with turbines are predicted to be 0.101 or fewer.

Potential effects of the predicted levels of mortality on the south-western Victorian Brolga population will be assessed using a Population Viability Analysis specifically developed for population.

## 1.0 INTRODUCTION

Stockyard Hill Wind Farm Pty. Ltd. is in the process of developing a wind energy facility, named Stockyard Hill Wind Farm, near Skipton in Victoria. In order to better assess the potential impact of these developments on the Brolga *Grus rubicundus*, studies have collected data about the birds' utilisation of the wind farm area and the local region during 2007 and 2008. Some contextual and historical information about Brolga use of the area has also been made available from databases held by the Department of Sustainability and environment.

Biosis Research has been commissioned to use available information from those sources to provide modelled predictions of the potential risks to Brolgas of collisions with turbines proposed to be installed at the site. Activity of Brolgas relevant to the Stockyard Hill Wind Farm was investigated in late 2007 as reported by Brett Lane and Associates (2008).

The modelling has been undertaken using the Biosis Research Deterministic Collision Risk Model.

Modelling of risk is provided here for turbines with two different rotor blade lengths and enables comparison to be made of the relative risks they pose.

The annual cycle of Brolgas in south-western Victoria encompasses the breeding season, and, for most birds, a period of 'migration' to flocking locations where they reside for a period, and subsequent return 'migration' to breeding sites. Breeding and flocking occurs at discrete locations within relatively local regions where distances between them may be measured in tens of kilometres or less. Breeding, and especially flocking, sites used by Brolgas in a given season are dependant on local conditions and thus movements between sites are not predictable year to year. In this respect, annual movements between flocking and breeding sites are not true migrations, but the term is widely applied to these movements and is used here for convenience.

Behaviour of Brolgas is different during breeding, migration and flocking. Flight frequency, height and distance have been documented to be different for these activities. For this reason, evaluation of collision risks for the regional Brolga population requires separate modelling for each of these activities. The annual predicted risk is the sum of the predictions for the seasonal activities comprising the birds' annual cycle.

A Population Viability Analysis (PVA) has been developed as a means to assess potential effects of wind farms on the viability of the south-western Victorian Brolga population (McCarthy 2008). PVA modelling also provides a mechanism to evaluate positive effects of various mitigation options against predicted

negative effects on the population. Results of collision risk modelling have been provided for inputs to the PVA model.

## 1.1 Process for assessment of collision risk for Brolgas

Assessment of the potential for Brolga mortalities to occur as a result of collisions with wind turbines and powerlines proposed for the Stockyard Hill Wind Farm, and of the consequent potential effect on the Victorian Brolga population, has been a collaborative process requiring a number of steps as outlined below.

Draft Guidelines for evaluation of the possible effects of wind farms in south-western Victoria have been under development by the Victorian Brolga Wind Farm Scientific Panel led by DSE, whilst the assessment for the proposed Stockyard Hill Wind Farm project has been underway. The assessment for Stockyard Hill has entailed liaison throughout with DSE and has followed the processes outlined in the Draft Guidelines.

The Victorian Brolga population is estimated at between 400 and 600 birds with the great majority of the population centred on the south-western volcanic plains. Habitat suitable for Brolgas has quite specific characteristics including shallow wetlands and meadows traditionally used for breeding and flocking. The birds also forage out from wetlands into low-lying pasture and cropped agricultural land. Availability of suitable wetlands is heavily influenced by drought and, more permanently, by drainage works. Outside of the flocking season pairs of Brolgas are territorial and do not tolerate close proximity of other Brolgas. As a result of these factors Brolgas are relatively scarce and widely dispersed even in suitable areas of their range for much of the year. During the annual flocking season they congregate at a few key sites. As a consequence, there is limited capacity for ornithologists to obtain a large body of numerical data for Brolga utilisation from field observations.

Brolgas spend significant portions of their time on the ground. They obtain their food whilst walking and this activity occupies a large part of their activity cycle. Flights are relatively infrequent and are undertaken primarily when moving between locations of concentrated terrestrial activity, such as between a nest site and preferred foraging areas, between foraging areas and during displays. Thus long periods of field observation generally document few flights.

Records of Brolgas were obtained from the area encompassed by the proposed Stockyard Hill Wind Farm and adjacent areas during fieldwork undertaken by Brett Lane & Associates. From early in the assessment program it was recognised by DSE that collection of a large body of empirical data for Brolgas was not feasible. Thus field data collected for the project was obtained with the primary purpose of providing information about current Brolga use of the area as an

adjunct to pre-existing records for the area. It also obtained some key information, such as records of Brolga flight heights, for which no previous information existed. Monitoring of Brolgas was naturally concentrated on areas used by the birds. Its results apply only to areas of habitat for the birds and are not indicative of their use of the great majority of the landscape of the proposed wind farm which is not suitable habitat for them.

Collision risk assessments for Brolgas have been undertaken on the basis of informed scenario modelling. The scenarios have been informed by general ornithological knowledge and published information about the biology of the south-western Victorian Brolga population; previous database records of Brolgas from the relevant area; and specific information obtained from the field by Brett Lane & Associates.

Algorithms and mathematical computations for some key inputs to collision risk modelling, such as for the lengths and heights of Brolga flights, were determined by Symbolix on the basis of data provided by Brett Lane & Associates. Due to uncertainties and the likelihood of variables that were not encompassed by the available field data, a level of conservatism was introduced by the use of an 80 percentile confidence boundary on values derived from the field data.

The rationale, parameters and values used for various scenarios for the different seasonal activities of Brolgas are described in turbine and powerline collision assessment reports prepared by Biosis Research. Predictions of mean annual numbers of Brolga fatalities that might occur under the scenarios modelled were calculated using the Biosis Research deterministic collision risk model.

Potential numbers of Brolga mortalities predicted by the model were provided to Dr Michael McCarthy of Melbourne University and input into a Brolga Population Viability Analysis model. This demographic model evaluated the effect of predicted mortalities on extinction risk for the Victorian Brolga population.

The collision risk model and population viability analysis are predictive mathematical models. All such models are mathematical representations designed to represent what might occur in reality. They are transparent in that every parameter and values used as inputs to the models are defined and explicit.

Collision risk modelling accounts for a range of factors that describe how wind turbines will function based on multiple specifications of their physical dimensions, geometry, movements and positioning in the landscape. It also accounts for the expected flights of Brolgas in the area of the wind farm including their frequency, heights and distance according to the birds' seasonal behaviours. Using this information the model provides forecasts for an annual average number of interactions between Brolgas and turbines that pose a risk of collision, which is

the subject of the present report. A similar process has been applied to model risk of collisions with a powerline proposed to transfer electricity from the wind farm to the power grid.

Population viability analysis uses information about the demographic functioning of a wildlife population, including rates of survival, mortality, fecundity, immigration and emigration to evaluate the threats faced by the species in terms of its risks of extinction or decline. In the present case it has been used to evaluate the potential influence of mortalities that might occur due to the wind farm on extinction risk for the Victorian Brolga population.

## 2.0 BACKGROUND TO COLLISION RISK MODELLING

The fundamental objective of modelling of risk is to provide a rigorous process by which probability can be assessed and to do so in a manner that can be replicated.

When making predictions of risk using a model, the rationale behind the predictions is explicitly stated in the mathematics of a model, which means that the logical consistency of the predictions can be readily evaluated. This is the case regardless of the type of model used.

The only real alternative to the use of a model is the use of subjective judgement to predict risks. Compared to subjective judgement, the explicit nature of inputs and rigour entailed in modelling makes models more open to analysis, review or modification when new information becomes available. Although there may be assumptions used and some arbitrary choices made when deciding on the structure and parameters of a model, these choices are stated explicitly when using a model but this is difficult to do when making subjective judgements. The assumptions underlying a model can be tested. Models can be used to help design data collection strategies. They can also help to resolve and avoid inconsistencies, and the rigorous analysis of data provides clarity.

Models are often also valuable for their heuristic capacities, by focussing attention on the important processes and parameters when assessing risks (Brook *et al.* 2002). All risk assessment must incorporate processes for refinement and improvement as data come to hand. It is vital that there is a feedback loop allowing this to occur (Burgman 2005). This should be expected of a model and the use of a model explicitly facilitates that process.

All of these benefits are difficult, if not impossible to achieve with subjective judgement. Another drawback of subjective judgement is that it may lead to biased predictions of risk, and the biases vary unpredictably among people (Tversky and Kahneman 1974; Ayton and Wright 1994; Gigerenzer and Hoffrage 1995; Anderson 1998). The predictions of models tend to be less biased (Brook *et al.* 2000, McCarthy *et al.* 2004).

It is important to recognise that while a model such as the one used here attempts to quantify risks, it makes no assessment of the 'value' of its subject. Whether predicted risks to Brolgas are 'acceptable' or not, is a further evaluation that must be made. Use of a model allows a clear distinction to be made between potential risks and subsequent judgements about those risks. Using subjective assessment of risk it is almost impossible to distinguish between these aspects.

For the purposes of determining impacts on fauna, criteria should evaluate effects on the viability of populations, rather than on individuals, since populations are the key units of conservation.

## **3.0 METHODS**

### **3.1 Brolga Utilisation Studies**

Investigations of Brolga utilisation for Stockyard Hill Wind Farm are detailed in Brett Lane and Associates (2008).

### **3.2 Data Analysis**

Estimates of annual numbers of Brolga movements that might interact with turbines were provided by Brett Lane (pers. comm. to I. Smales 10<sup>th</sup> June 2008).

Since empirical data for Brolga activity in and near the site have been obtained only during 2007 and 2008, it is possible that they are not truly representative of longer timeframes encompassing different conditions. With this in mind, confidence limits have been placed on values derived from the Brolga movement data (Symbolix Appendix 1) and the 80% confidence bound has been applied to data to determine input values used for modelling. This is considered appropriate to cover a range of realistic variables that might occur.

### **3.3 Risk Model**

Biosis Research Pty. Ltd. developed a model for the assessment of avian collision risk with wind turbines, initially for the Woolnorth Wind Farm (the name formerly applied to the combined Bluff Point and Studland Bay wind farms). This Deterministic Collision Risk Model has been refined over time, to incorporate new data and knowledge, and has been applied at a wide range of proposed wind farm sites in Australia.

Generally, results of modelling are expressed in terms of the expected number of flights by particular bird species that pose a risk of collision with turbines per annum. Where an estimate is available for the number of individuals that have potential to interact with turbines, the movements-at-risk may be converted into a number of individuals-at-risk by incorporating the population estimate for the site into calculations. This is the case for the Brolga population modelled here.

Results are provided for three avoidance rates. Avoidance rate is the capacity to avoid a collision, whether that occurs due to a cognitive (behavioural) response on the part of a bird or not. A 95% avoidance rate equates to one flight in 20 in which a bird does not avoid a turbine, 98% avoidance rate equates to one flight in 50 in which a bird does not avoid a turbine, and 99% avoidance rate equates to one flight in 100 in which a bird does not avoid a turbine. Based on experience with a wide range of bird species, it is assumed that virtually all species have high

capacity to avoid collision with the static components of turbines. Avoidance rate for these components is thus consistently considered to be 99% in all modelling. Various avoidance rates are modelled for the dynamic turbine components because it is not certain how adept Brolgas might be at evading collision. For this reason results are provided for 95%, 98% and 99% avoidance rates for the dynamic components of turbines.

Since the turbine tower below rotor swept height is always a static component and poses minimal collision risk, the model takes this into account by dividing flights into those below turbine rotor height, and those within the height zone swept by turbine rotors.

REpower Systems MM92 turbines with two different rotor blade lengths are under consideration for use at the Stockyard Hill Wind Farm and thus collision risk modelling has been undertaken for both. For the purposes of the modelling, a rotor blade length of 45.2 metres is referred to as ‘turbine type 1’ and a rotor blade length of 51.2 metres is referred to as ‘turbine type 2’. Other dimensions of the turbines do not differ between the two designs, but the different blade lengths create a difference in the height range below- and within- rotor swept height between them.

In the model, the turbine is decomposed into its static and dynamic components. The static components are the nacelle, tower structure and the body of the blades. The dynamic component is the volume swept by the leading edge of the blade in the time it takes the species of interest to pass safely across the depth of the swept disk.

The risk assessment accounts for a combination of variables that are specific to the Stockyard Hill Wind Farm and to data for Brolgas from the vicinity of the farm. They include the following:

- a) The numbers of Brolga flights below rotor height, and for which just the lower portion of turbine towers present a collision risk.
- b) The numbers of Brolga flights at heights within the zone swept by turbine rotors, and for which the upper portion of towers, nacelles and rotors present a collision risk.
- c) The numbers of bird movements-at-risk, as recorded Brolgas during timed point counts, are extrapolated to determine an estimated number of movements-at-risk the species makes in an entire year. Account is taken of the portion of the year that birds are within proximity of the wind farm site and that they may thus be at risk.
- d) The mean area ( $m^2$  per turbine), of tower nacelle and stationary rotor

blades of a wind generator that present a risk to birds. Thus, the mean area presented by a turbine is between the maximum (where the direction of the bird is perpendicular to the plane of the rotor sweep) and the minimum (where the direction of the bird is parallel to the plane of the rotor sweep). The mean presented area is determined from turbine specifications supplied to Biosis Research for individual turbine makes and models. It represents the area presented to an incoming flight from a random direction.

- e) The additional area (m<sup>2</sup> per turbine) presented by the movement of rotors during the potential flight of a bird through a turbine. This information is determined via a calculation involving species specific, independent parameters of flight speed and body length and supplied turbine specifications.
- f) A calculation, based on the total number of turbines proposed for the wind farm, of the number of turbines likely to be encountered by a bird in any one flight. This involves a two step process. Two possible extremes exist depending on the way that turbines are arrayed in the landscape. In the first, the turbines are clustered or scattered. The alternative is that the site consists of a single linear array of turbines. Analytic expectations for the number of turbines interacted with are generated for each of these alternatives and the model then uses a weighted average of the two values to generate a site specific value of risk.

Wherever bird utilisation data are available from point count surveys, these provide values for Brolga movements for use in the modelling process. However, where empirical data are not available, informed scenarios can be used. In the case of Brolgas at Stockyard Hill, empirical data were available from the 2007 breeding season and from 2007/08 migration activity. During 2007/08 no flocking sites were within close enough proximity to the wind farm site to pose any risk to Brolgas. However, short-term flocking events have occurred from time to time historically within closer proximity to the wind farm and Brolgas may be at risk of collision during such events. Scenarios were developed for short-term flocking events on the basis of Brolga behaviour recorded at distant flocking locations in early 2008 combined with information about historical flocking events within or close to the wind farm site. The rationale and input values used for each of the three elements of the Brolga's annual cycle are outlined below.

## 3.4 Rationale and input values

### 3.4.1 Breeding season

#### Breeding season duration

The annual breeding season for Brolgas in south-western Victoria spans approximately 130 days and this period has been used for the model.

Information suggests that this period may be longer for occasional birds in some seasons, but in the absence of data for this, 130 days seems reasonable for the population.

#### Number of individuals at risk

Six pairs of Brolgas (12 adults) were documented within 3 km of Stockyard Hill Wind Farm during the 2007 and 2008 breeding seasons (Brett Lane & Assoc. pers. comm. 6<sup>th</sup> Oct. 2008)

The number of juveniles has been derived as follows. Chicks of a given breeding season are at minimal risk in that season because they generally are not fledged until late in the breeding season. However, many fledged juveniles remain with parents for up to 11 months (Marchant & Higgins 1993) and thus may be at risk in a substantial portion of their second season. Population ratio of juveniles to adults is estimated at 0.05 (Herring 2001 *in* McCarthy 2008). There is thus an expected average of 0.6 juveniles with 12 adults per annum.

Thus we have modelled for an average total of 12.6 birds at risk per annum.

We have no basis on which to differentiate risk to adults and first-year juveniles, so risk prediction for the two age-classes is directly proportional to ratio of adults to juveniles in the population.

#### Numbers of movements at risk

Numbers of Brolga flights of sufficient length to reach, and thus potentially to interact with, turbines are 22 within rotor-swept height and 40 below rotor-swept height. Numbers are derived from records provided by Brett Lane & Assoc. (2008) and factored by Symbolix to an 80% confidence bound. Since data for a single season only are available, this factoring provides a conservative probability distribution to account for potential variables that might influence these values over a range of years and environmental conditions.

### **Number of turbines**

It is assumed that during the breeding season it is possible for Brolgas to interact with the complement of 242 turbines proposed for the entire wind farm.

## **3.4.2 Migration seasons**

### **Migration season period**

The period in which movements from breeding to flocking sites occurs may span from mid November to mid February (or occasionally for some birds as late as May (Marchant & Higgins 1993). Movements from flocking sites back to breeding locations are presumed to span a much shorter period. An annual average of 100 days for the two periods combined seems reasonable and has been used in modelling.

### **Number of individuals at risk**

A maximum population size of 58 birds for the region has been reported by Brett Lane & Assoc. (2008). For this population, the number of adults and juveniles has been derived from the estimated population ratio of juveniles to adults of 0.05 (Herring 2001 *in* McCarthy 2008). There is thus an expected average of 2.9 juveniles and 55.1 adults within a population of 58 birds and these values have been used for the purposes of modelling.

We have no basis on which to differentiate risk to adults and first-year juveniles, so risk prediction for the two age-classes is directly proportional to ratio of adults to juveniles in the population.

### **Numbers of movements at risk**

Numbers of Brolga flights of sufficient length to reach, and thus potentially to interact with, turbines are 69 within rotor-swept height and 129 below rotor-swept height. Numbers are derived from records provided by Brett Lane & Assoc. (2008) and factored by Symbolix to an 80% confidence bound. Since data for a single season only are available, this factoring provides a conservative probability distribution to account for potential variables that might influence these values over a range of years and environmental conditions.

### **Number of turbines**

Modelling has been undertaken for two scenarios for migration season movements by Brolgas.

Scenario 1: Assumes that birds may fly between breeding and flocking sites by any random route and thus that it is possible for them to encounter any of the total complement of 242 turbines within the entire wind farm array.

Scenario 2: Assumes that birds preferentially utilise lower-lying and generally the most direct route in making these movements. A revised turbine layout has excluded turbines within the most obvious such area between the large mid sector and a smaller south-eastern sector of the wind farm (on revised turbine layout October 2008 Stockyard Hill Wind Farm Pty. Ltd.). This zone has a minimum width, devoid of turbines, of approximately four kilometres. The second scenario models for Brolgas making ‘migration’ flights to potentially encounter the first turbines only on either side of the turbine exclusion corridor. Results indicated that a subset of 15 turbines presented potential risk in this scenario.

### 3.4.3 Incidental flocking aggregations

Traditional and routine flocking sites are all further than 3 km from the wind farm and Brolga flights to, from and within them are considered to be too distant to be at risk of collision with turbines on the wind farm. However, temporary short-term flocking (‘one-off flocking’) has been recorded occasionally at other locations. These include four instances within, or in much closer proximity, to the wind farm during the past twenty years. One such instance was of 52 Brolgas at Lake Goldsmith. Modelling has been undertaken to account for the potential risks posed by these infrequent flocking events. These may occur during the flocking season, or as incidental aggregations of Brolgas that might occur in the course of migrations between breeding and flocking season locations.

Because no data are available for any one-off flocking events, modelling has been undertaken using data recorded at traditional flocking sites by Brett Lane & Assoc. (2008) as surrogate measures of numbers and heights of Brolga flights that might occur during one-off flocking events. Modelling of these flocking events has been carried on the basis of the duration and frequency with which they have been observed in the past twenty years, which has been for an average of 21 days, and, on average, has occurred once every five years.

Mathematical methods used to develop inputs for one-off flocking events into collision risk modelling have been provided by Symbolix (Appendix 2). These incorporate the following:

- Average duration (number of days) of a one-off flocking event: 21
- Expected number of birds involved (40 – 56 in flocking events elsewhere in 2008): 40
- Proportion of the flock involved in an average flight event (~40 – 50% in

2008): 40%

- Number of foraging flights per bird per day: 4
- Number of foraging sites used: 3 in 2008, or 2 if there is a preference for a particular, close site
- Number of foraging sites that are likely to dictate the location of the flocking site: 1
- Likely average maximum flight distance between flocking and foraging sites: 4 km (based on absolute maximum flight distance of 5 km).

Using these values in equations provided in Symbolix (Appendix 2) the following numbers of Brolga flights were derived per one-off flocking event:

- Within RSH: 647
- Below RSH: 1019

The number of turbines with which Brolgas could potentially collide was calculated from the number within a 5 km radius of any potential flocking location (considered to be absolute maximum flight distance during flocking events). For the purposes of modelling, the mean number of turbines was derived from a random sample of 5 km radius plots across the entire wind farm site, in which the only criterion was that the plot incorporated at least one turbine.

- Mean number of turbines presenting a risk during a one-off flocking event: 32.

### 3.5 Reporting Measures

Model predictions are in terms of mean number of collisions per annum. It is assumed that a collision results in a mortality. In the real event, deaths are measured in whole birds (not fractions of birds). The model provides a predicted annual average number of collisions, but the number of actual collisions that might occur in a given year can obviously vary in a distribution around an average, from zero to some maximum. One-off flocking events have been recorded to occur within, or in close proximity to, the Stockyard Hill Wind Farm on average once every five years. Results of collision risk modelling for one-off flocking events have thus been scaled to an annual average for inclusion in overall per annum predictions.

The model cannot forecast the frequency of collisions around the predicted annual average and it should be expected that the number of actual collisions that might occur will vary from year to year.

## 3.6 Qualifications

Input values to collision risk modelling are derived from empirical data provided by others, wherever that was available. Empirical data for Brolga activity in and near the Stockyard Hill site have been obtained only during 2007 and 2008. It is possible that those data are not truly representative of longer timeframes encompassing different environmental conditions. Where input values were required and empirical data was not available, values are informed assumptions based on relevant available information.

## 4.0 RESULTS

### 4.1 Type 1 turbines

#### 4.1.1 Breeding season

Modelled estimates of mean annual number of Brolga collisions with ‘type 1’ turbines during breeding seasons at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.007

98% avoidance rate: 0.003

99% avoidance rate: 0.002

#### 4.1.2 Migration seasons

*Scenario 1* (all turbines present potential risk) modelled estimates of mean annual number of Brolga collisions with ‘type 1’ turbines during migration seasons at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.115

98% avoidance rate: 0.056

99% avoidance rate: 0.036

*Scenario 2* (subset of turbines present potential risk) modelled estimates of mean annual number of Brolga collisions with ‘type 1’ turbines during migration seasons at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.029

98% avoidance rate: 0.014

99% avoidance rate: 0.009

#### 4.1.3 Flocking season (one-off flocking only)

Modelled estimates of mean annual number of Brolga collisions with ‘type 1’ turbines during occasional, temporary flocking events at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.043

98% avoidance rate: 0.022

99% avoidance rate: 0.015

#### 4.1.4 Annual risk predictions ‘Type 1’ turbines

The estimated mean number of Brolga collisions at the Stockyard Hill Wind Farm for the entire annual cycle is the sum of modelled estimates for the annual

breeding, migration and flocking seasons. Table 1 provides these estimates incorporating Scenario 1 for annual migration seasons and Table 2 shows them incorporating Scenario 2 for migration seasons.

**Table 1 Estimated annual number of Brolga collisions with ‘type 1’ turbines incorporating migration season scenario 1**

<b>Avoidance rate</b>	<b>95%</b>	<b>98%</b>	<b>99%</b>
Breeding season	0.007	0.003	0.002
Migration season	0.115	0.056	0.036
Temporary flocking season	0.043	0.022	0.015
<b>Annual total</b>	<b>0.165</b>	<b>0.081</b>	<b>0.053</b>

**Table 2 Estimated annual number of Brolga collisions with ‘type 1’ turbines incorporating migration season scenario 2**

<b>Avoidance rate</b>	<b>95%</b>	<b>98%</b>	<b>99%</b>
Breeding season	0.007	0.003	0.002
Migration season	0.029	0.014	0.009
Flocking season	0.043	0.022	0.015
<b>Annual total</b>	<b>0.079</b>	<b>0.039</b>	<b>0.026</b>

## 4.2 Type 2 turbines

### 4.2.1 Breeding season

Modelled estimates of mean annual number of Brolga collisions with ‘type 2’ turbines during breeding seasons at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.008

98% avoidance rate: 0.004

99% avoidance rate: 0.003

#### **4.2.2 Migration seasons**

Scenario 1 (all turbines present potential risk) modelled estimates of mean annual number of Brolga collisions with ‘type 2’ turbines during migration seasons at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.137

98% avoidance rate: 0.065

99% avoidance rate: 0.041

Scenario 2 (subset of turbines present potential risk) modelled estimates of mean annual number of Brolga collisions with ‘type 2’ turbines during migration seasons at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.034

98% avoidance rate: 0.016

99% avoidance rate: 0.010

#### **4.2.3 Flocking season (one-off flocking only)**

Modelled estimates of mean annual number of Brolga collisions with ‘type 2’ turbines during occasional, temporary flocking events at the Stockyard Hill Wind Farm are:

95% avoidance rate: 0.051

98% avoidance rate: 0.025

99% avoidance rate: 0.016

#### **4.2.4 Annual risk predictions ‘Type 2’ turbines**

The estimated mean number of Brolga collisions at the Stockyard Hill Wind Farm for the entire annual cycle is the sum of modelled estimates for the annual breeding, migration and flocking seasons. Table 3 provides these estimates incorporating Scenario 1 for annual migration seasons and Table 4 shows them incorporating Scenario 2 for migration seasons.

**Table 3 Estimated annual number of Brolga collisions with 'type 2' turbines incorporating migration season scenario 1**

<b>Avoidance rate</b>	<b>95%</b>	<b>98%</b>	<b>99%</b>
Breeding season	0.008	0.004	0.003
Migration season	0.137	0.065	0.041
Temporary flocking season	0.051	0.025	0.016
<b>Annual total</b>	<b>0.196</b>	<b>0.094</b>	<b>0.060</b>

**Table 4 Estimated annual number of Brolga collisions with 'type 2' turbines incorporating migration season scenario 2**

<b>Avoidance rate</b>	<b>95%</b>	<b>98%</b>	<b>99%</b>
Breeding season	0.008	0.004	0.003
Migration season	0.034	0.016	0.010
Flocking season	0.051	0.025	0.016
<b>Annual total</b>	<b>0.101</b>	<b>0.045</b>	<b>0.029</b>

## 5.0 CONCLUSION

This report provides results of collision risk modelling as estimates of annual average numbers of Brolga collisions with two types of turbines at the proposed Stockyard Hill Wind Farm. Results are based on behaviours of Brolgas in the absence of turbines as there are currently no data available for actual interactions between the species and wind turbines.

Depending on the size of rotors used, mean avoidance capacity of Brolgas, and routes used by the birds during migratory movements, predictions range from an annual average maximum of 0.196 collisions per annum to an annual average minimum of 0.026 collisions per annum. Overall, the modelling suggests that relatively few collisions are likely to occur. Potential effects of the predicted levels of mortality on the south-western Victorian Brolga population will be assessed using a Population Viability Analysis specifically developed for population.

Given that 242 turbines are proposed, regardless of which rotor blade length is used, the predicted number of collisions is naturally slightly lower for turbines with the shorter rotor blade design than for those with the longer blade.

Turbine collision avoidance rates for a wide variety of bird taxa are virtually all above 90%, with many being above 98%. Brolgas are known to collide with powerlines, which demonstrates that their capacity to avoid man-made obstacles is not flawless. We consider that avoidance capacity of Brolgas is likely to be above 95%, however other than that, we do not consider that there is, as yet, any basis for suggesting an appropriate avoidance rate for the Brolga in south-western Victoria.

The ecology of Brolgas suggests it is likely that they use direct routes over low-lying ground in migration movements between breeding and flocking sites. There is little reason to expect that they take circuitous routes over hills. Scenario 2 for migration season movements models for the use of direct routes over low-lying ground and is thus considered to be the more ecologically reasonable of the two scenarios modelled.

On the basis that Brolga migrations are more likely to conform to behaviours modelled for Scenario 2 than for Scenario 1, and that the species' avoidance capacity is 95% or higher, the annual average number collisions with turbines are predicted to be 0.101 or fewer. This equates to an average of approximately one Brolga collision in ten years. As noted above, the model cannot forecast the frequency of collisions around the predicted annual average and it should be expected that, if collisions actually occur, the number may vary from year to year in a fashion that cannot be predicted. This is particularly the case because real collisions entail whole birds and, since Brolgas frequently fly in flocks, more than

one individual may be involved in a particular collision event.

It is acknowledged that a body of experience with the European or Common Crane *Grus grus* suggests that they rarely collide with wind turbines in Europe and may have high avoidance capacity. Nonetheless, we are cautious about suggestions that this may be indicative of the situation for Brolgas because of substantial differences between the ecologies of the two species. These include the long, international annual migrations of European Cranes, for which there appears to be the most knowledge in Europe about their interactions with wind farms. The south-western Victorian Brolga population makes short-distance ‘migrations’ between breeding and flocking sites within a regional context and does not undertake long-distance migrations similar to those of the European Crane. In addition, these movements by Brolgas are quite variable in that they are responsive to local conditions and, within the region under consideration, temporary use of irregularly available resources like flocking sites has been documented and has been incorporated into the present modelling. In this respect these movements are likely to be much less predictable than are the long-distance migrations of European Cranes.

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