# Stockyard Hill Wind Farm

# Bird & Bat Impact Assessment

## Assessment to Accompany Application to Amend Planning Permit No. PL-SP/05/0548

Prepared for Origin Energy

1 May 2016

## Biosis offices

**AUSTRALIAN CAPITAL TERRITORY**

**Canberra**
Floor 1, Unit 3, 38 Essington Street
Mitchell ACT 2911

Phone: (02) 6102 1200
Email: canberra@biosis.com.au

**NEW SOUTH WALES**

**Newcastle**
39 Platt Street
Waratah NSW 2298

Phone: (02) 4911 4040
Email: newcastle@biosis.com.au

**Sydney**
Unit 14 17-27 Power Avenue
Alexandria NSW 2015

Phone: (02) 9101 8700
Email: sydney@biosis.com.au

**Wollongong**
8 Tate Street
Wollongong NSW 2500

Phone: (02) 4201 1090
Email: wollongong@biosis.com.au

**QUEENSLAND**

**Brisbane**
Suite 4 First Floor, 72 Wickham Street
Fortitude Valley QLD 4006

Phone: (07) 3014 1110
Email: brisbane@biosis.com.au

**VICTORIA**

**Ballarat**
506 Macarthur Street
Ballarat VIC 3350

Phone: (03) 5304 4250
Email: ballarat@biosis.com.au

**Melbourne (Head Office)**
38 Bertie Street
Port Melbourne VIC 3207

Phone: (03) 8686 4800
Fax: (03) 9646 9242
Email: melbourne@biosis.com.au

**Wangaratta**
16 Templeton Street
Wangaratta VIC 3677

Phone: (03) 5718 6900

Email: wangaratta@biosis.com.au


## Document information

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| **Report to:** | Origin Energy |
| **Prepared by:** | Ian Smales |
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# Contents

# Executive summary

Stockyard Hill Wind Farm Pty Ltd (SHWFPL) (a subsidiary of Origin Energy) is developing a wind farm project in south-west Victoria, known as the Stockyard Hill Wind Farm (SHWF).

Planning Permit No. PL-SP/05/0548 (Pyrenees Planning Scheme) (the Permit) was issued by the Minister for Planning in October 2010 to enable the use and development of the SHWF Wind Energy Facility (WEF).

SHWFPL has now decided to progress the preparation of an application to amend the Permit to seek approval for taller turbines to achieve more efficient generation of energy. Additionally, as a result of the proposed taller turbines and to ensure the Permit reflects current standards, guidelines and departments, there are a number of other amendments proposed as part of the application.

This document was prepared with the purpose to support an application to amend the Permit, and inform self-assessments (and referrals, if deemed required) under the Environment Effects Act 1978 (EE Act), and/or Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), specifically the assessment of:

- Potential impacts on species of birds and bats listed as threatened under provisions of the EPBC Act;
- Potential impacts on species of birds listed as migratory under provisions of the EPBC Act;
- Potential impacts on species of birds and bats listed as threatened under provisions of the FFG Act, particularly in relation to potential impacts on the Brolga, as outlined in a specific Victorian Government guideline for that species.

This document provides an assessment of the overall impact of the proposed amended WEF, whilst also describing the resulting change in potential impact from the permitted WEF.

**Approach**

Assessment of all listed threatened and migratory bird and bat species for the amended WEF has been undertaken as a desktop evaluation in which potential impacts of the amended WEF have been considered and compared with the permitted WEF. This included review and consideration of information about occurrence of relevant species within 10 kilometres of the WEF, including information reported in Brett Lane & Associates (2009, 2010a) used for assessment of the SHWF as proposed in 2009. In addition, changes to legislation and government policies that have been implemented since assessment of the permitted WEF has been evaluated for their relevance to the amended WEF.

The three-step approach set out in the Victorian Brolga Guidelines for consideration of potential impacts on Brolgas was followed. Collision risk modelling has been undertaken to assess potential risk of Brolgas colliding with turbines and with overhead powerlines within the wind farm. This modelling was first done for the permitted WEF and then for the amended WEF in order to compare their potential impacts on the Victorian Brolga population. Risk modelling was undertaken using informed scenarios for likely activities of Brolgas in the vicinity of the wind farm. We consider the assumptions used for modelling of risks are reasonable and ecologically sound and that the results of the modelling offer a logical basis for consideration of likely risks for the species.

**Regulatory requirements**

An assessment of the SHWF WEF in relation to key biodiversity legislation and policy is summarised in Table 1, below.

**Table 1 - Summary of legislation and policies relevant to this assessment**

| Legislation / policy | Relevant ecological feature on site | Permit / approval required | Notes |
|---|---|---|---|
| **EPBC Act** | Listed threatened & migratory bird & bat species | Seek advice from DoE regarding potential EPBC Act referral | Significant impact is not considered likely but advice should be sought from the Department of the Environment about whether the amended SHWF WEF warrants referral under the EPBC Act |
| **EE Act** | FFG Act-listed threatened bird & bat species; defined habitats for those species | Referral under EE Act not considered warranted | Significant effect criteria not triggered. |
| **FFG Act** | Listed threatened bird & bat species | No permit requirements or other regulatory implications for fauna | |
| **Victorian Brolga Guideline** | Brolga | | Brolga Guidelines stipulate achievement of no net impact on Victorian population of Brolgas |

**Assessment Findings**

*Permitted Project*
For all listed threatened and migratory bird and bat species, this assessment considers that any potential impacts of the permitted SHWF WEF on relevant species would be low or negligible and that no significant impacts are likely.

For scenarios modelled for Brolgas for the permitted WEF, this assessment found there was potential for a low impact. At 95% turbine avoidance rate, the modelled estimate is for an annual average of 0.086 Brolga collisions with turbines and internal overhead powerlines. In accordance with methods stipulated in the Brolga Guidelines (DSE 2012), including population viability analysis, it is considered that mitigation and offset mechanisms could be implemented and can achieve the requirement for no net impact on the Victorian Brolga population. Recommendations are made about potential offset mechanisms designed to achieve that requirement.

*Amended Project*
For all listed threatened and migratory bird and bat species, this assessment considers that any potential impacts of the amended WEF on relevant species would be low or negligible and that no significant impacts are likely.

For scenarios modelled for Brolgas for the amended WEF, this assessment found there was potential for a low impact. At 95% turbine avoidance rate, the modelled estimate is for an annual average of 0.093 Brolga collisions with turbines and internal overhead powerlines. In accordance with methods stipulated in the Brolga Guidelines (DSE 2012), including population viability analysis, it is considered that mitigation and offset mechanisms can be implemented that will achieve the required no net impact on the Victorian Brolga population.

*Anticipated Change*
For all listed threatened and migratory bird and bat species, other than Brolga, this assessment considers that any potential impacts of the amended WEF on relevant species would be low or negligible and that this is unchanged from the permitted to the amended SHWF WEF.

For Brolgas, detailed collision risk assessments indicate that the amended SHWF WEF entails a marginally higher risk to the species than does the permitted SHWF WEF. However, the estimated levels of risk under the assumptions used are so low for both the permitted and amended projects that they require rounding to the same level in order to use population viability analysis. The differences between modelled effects of the permitted and amended SHWF WEFs on the Victorian Brolga population are negligible and likely to be too small to be measurable in reality.

**Conclusion and Recommendations**

Results of this assessment are that neither the permitted SHWF WEF nor the amended SHWF WEF will result in a significant impact on any species listed as threatened under the EPBC Act or the FFG Act or on any species listed as migratory under the EPBC Act. Hence, the amended project does not represent any changed conclusion about significance of impacts on birds and bats.

Results of turbine and internal powerline collision risk modelling and population viability analysis for scenarios encompassing potential activities of Brolgas in the vicinity of the permitted WEF and amended WEF indicate low risk of collisions. Population viability analysis suggests that compensatory measures can be designed to achieve no net impact on the Victorian Brolga population. We recommend that rehabilitation of a degraded wetland is the best option for any offsetting of effects of the amended wind farm on the Victorian Brolga population, recognizing that specifics of any such measures will need to be determined in consultation with regulatory authorities, including DELWP, as part of the preparation of a Bat and Avifauna Management Plan in accordance with Condition 15 of the Permit.

# 1. Introduction

## 1.1 Project background

Stockyard Hill Wind Farm Pty Ltd (SHWFPL) (a subsidiary of Origin Energy) is developing a wind farm project in south-west Victoria, known as the Stockyard Hill Wind Farm (SHWF).

The project has three components - a wind energy facility (WEF), a grid connection (approximately 75 kilometre of overhead powerlines and terminal station) and a quarry. This document relates to the WEF component of the project.

It was determined on 29 September 2008 that no Environment Effects Statement (EES) was required to be prepared, subject to three conditions under the Environment Effects Act 1978 (EE Act)[1] and that the *Planning and Environment Act 1987* could adequately assess the Project.

Planning Permit No. PL-SP/05/0548 (Pyrenees Planning Scheme) (the Permit) was issued by the Minister for Planning on 26 October 2010 to enable the use and development of the SHWF WEF.

SHWFPL has now decided to progress the preparation of an application to amend the Permit under Section 97I of the *Planning and Environment Act 1987*.

The primary driver for the amendment application is to seek approval for taller turbines to achieve more efficient generation of energy. The proposed amendments to the Permit are discussed in Section 2 of this document.

In addition, the WEF was approved as a 'controlled action' under the *Environment Protection and Biodiversity and Conservation Act 1999* (EPBC Act) on 11 February 2011 (Approval 2009/4719).

1 Planning Permit Nos. 2009/104 and 2009/105 were also issued by the Minister for Planning on 26 October 2010 to enable the construction of a 132kV/500kV terminal station near Berrybank and for the removal of native vegetation associated with the construction of a 132kV overhead powerline between the SHWF and the terminal station. Approval was also granted under the EPBC Act in February 2011 for the SHWF and for the grid connection and terminal station near Berrybank (EPBC Act Approval 2009/4719).
During the latter half of 2011, the 'permitted' overhead powerline route and terminal station site were reviewed and it was determined that a site closer to the crossover of the 500kV and 220kV lines was preferable and that a site to the south of Lismore on Lower Darlington Road was identified as suitable. A permit was issued for the Lismore Terminal Station by the Shire of Corangamite in 2013.

## 1.2 Purpose of document

This document was prepared with the purpose to accompany an application to amend the Permit, and inform self-assessments and referrals under the EE Act, and EPBC Act, including the assessment of:

- Potential for significant impacts on species of birds and bats that are listed as threatened or as migratory under Australian and Victorian legislation and policy and that have some potential to be affected by the SHWF WEF.
- Potential risk of Brolgas colliding with turbines and overhead powerlines internal to the SHWF WEF.

These two aspects are addressed in separate sections of this report.

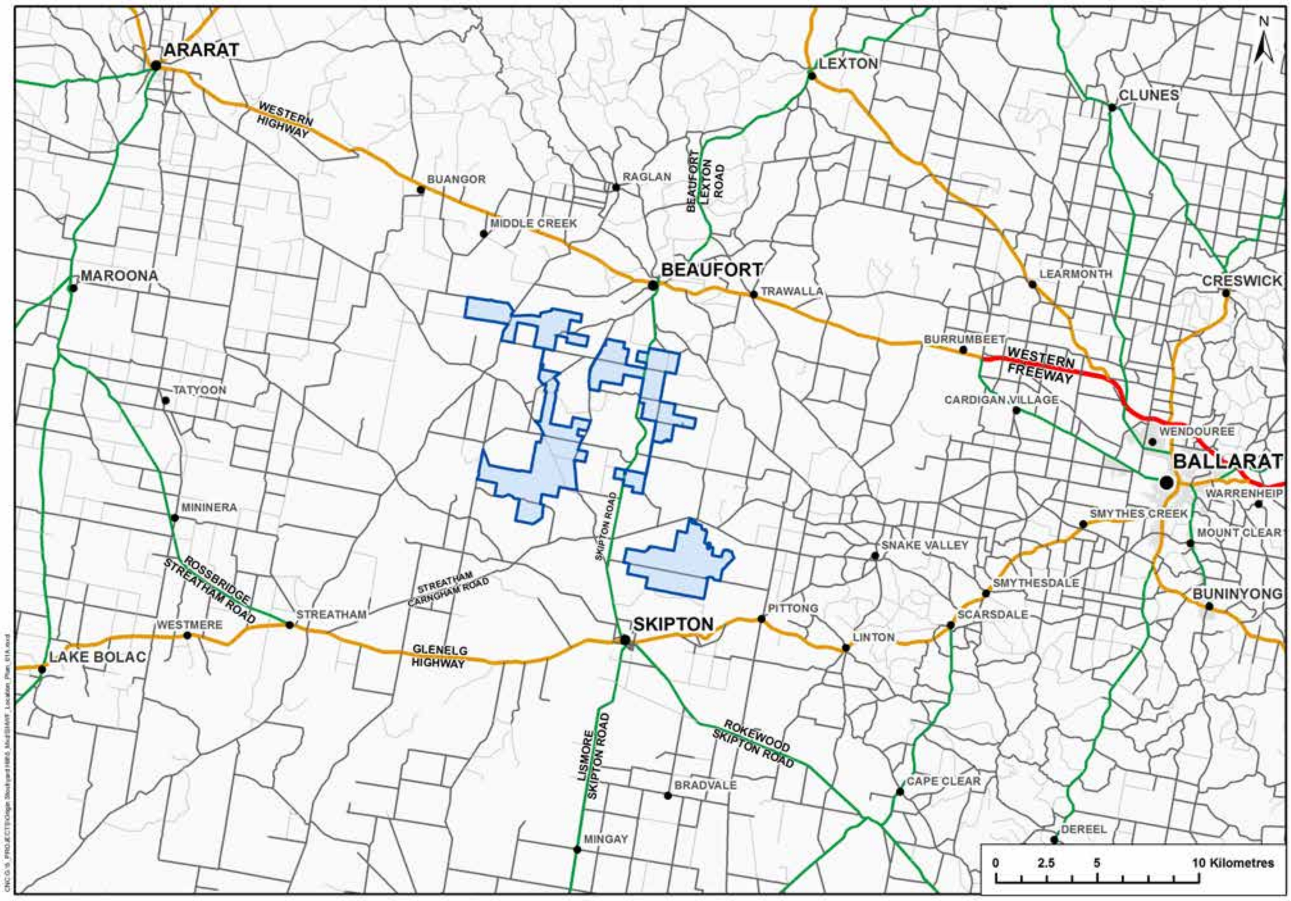
This document provides an assessment of the overall impact of the proposed amended WEF, whilst describing the resulting change in potential impact from the permitted WEF.

# 2. The project

## 2.1 WEF site

The WEF site is located in the Pyrenees Shire Council, approximately 150 kilometres west, north-west of Melbourne and approximately 35 kilometres west of Ballarat (see Figure 1 below).

**Figure 1 – WEF Site Location**




The closest townships to the WEF site include Beaufort (approximately 4.5 kilometre north of the site) and Skipton (approximately 4 kilometre south of the site).

The site comprises approximately 155.3 kilometre$^2$ (approximately 45.8 kilometre$^2$ less than the permitted WEF) and is generally bound by Eurambeen-Streatham Road and Beaufort-Carranballac Road to the west, Stockyard Hill Road and Mt Emu Settlement Road in the south, Mount Emu Creek in the east and Ballrogan Road, Long Gully Road and Dalgleishs Road in the north. Skipton Road bisects the subject site.

The WEF site is primarily located in the Victorian Volcanic Plain bioregion, with hill country north of Lake Goldsmith in the northern part of the site occurring within the Central Victorian Uplands bioregion.

Wetlands close to the WEF site boundary or occurring within the site include Lake Goldsmith and Black Lake. Several other smaller wetlands, including freshwater meadows and shallow freshwater marshes, are scattered within the site, in addition to minor drainage lines and creeks which traverse the site, mostly in the west and north. Some areas of pasture also become seasonally inundated or waterlogged. The shallow wetlands are ephemeral and do not hold water every year. These wetlands represent habitats of primary importance to species of birds considered in this report.

The great majority of the study area is agricultural grazing and cropping land. Some ephemeral wetlands are used for these purposes during dry years. The majority of the site has been significantly modified from its pre-European settlement condition.

## 2.2 Permitted WEF

The Permit was issued by the Minister for Planning in October 2010 to enable the use and development of the SHWF WEF, subject to 48 conditions. In summary, the Permit allows for:

- Up to 157 turbines sites (with a maximum tower height of 80m, blade length of 52m and tip height of 132m);
- Underground electrical reticulation network;
- Access track network;
- Up to 5 electricity substations;
- 132 kV overhead powerlines;
- A maintenance facility;
- 3 temporary staging areas allowing for three temporary concrete batching plants;
- Up to 8 anemometers (monitoring masts);
- Removal of native vegetation; and
- Car parking and bicycle facilities.

The permitted layout is shown on the map contained in Appendix A[2], whilst the Permit conditions, as relevant to birds and bats are outlined in the Appendix B.

## 2.3 Amended WEF

The amendment is proposed to enable physical changes to the project and amendments to the permit conditions.

Non-physical changes proposed include amendments to the Permit conditions as a result of the proposed physical changes and/ or administrative improvements (departmental name changes, changes to guidelines etc.). The proposed changes to the Permit conditions, as relevant to listed birds and bats, are outlined in the Appendix B.

The 'physical' amendments proposed to be undertaken to the permitted project are described in Table 2 below and shown in Figure 2.

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[2] For the purposes of this assessment, the permitted layout is considered to be the layout shown on the indicative layout plan referenced within condition 1 of PL-SP/05/0548 (*Map No. WF 02C; Rev. 01; dated 23/05/2010*), but modified to show the deletion of turbines, removal of other infrastructure associated with the deleted turbines and resiting of turbines as required by condition 1(a), (b) and (c). Additionally, whilst the original referrals made under the EE Act and EPBC Act related to a larger project (e.g. before the loss of 85 turbine locations during the planning permit process), for the purpose of self-assessments and referrals under the EE Act and EPBC Act the project 'permitted' under PL-SP/05/0548 will be used to understand any change in impacts.

### Table 2 – Summary of proposed 'physical' amendments to the SHWF WEF

| Proposed amendments | | Reason for amendment |
|---|---|---|
| **Turbine dimensions** | The turbine envelope proposed includes: | • To allow for taller turbines to achieve more efficient generation of energy. |
| | • overall maximum tip height must not exceed 180m above natural ground level; | |
| | • hub-height of no greater than 120m above natural ground level; and | |
| | • rotor diameter no greater than 140m. | |
| **Layout** | Turbine locations | • In response to the spacing required for larger turbines. |
| | • Ultimate design for up to 149 wind turbine locations, consisting of the following changes: | • To ensure compliance with shadow flicker and noise conditions of PL-SP/05/0548. |
| | • Relocation of 3 turbines onto 3 new titles within the centre of the WEF site (adjoining existing permitted address of lands). | |
| | • Addition of 4 new turbine locations within the existing permit address of lands. | |
| | • Deletion of 12 turbine locations. | |
| | • Movement of most turbine positions, but generally limiting movement to 250m from the original permitted layout. | |
| | Civil and electrical infrastructure | |
| | • Optimisation and relocation of the associated civil and electrical infrastructure within the WEF area. | |
| **WEF boundary** | Deletion and addition of land parcels in the Address of Lands. | • Re-design / optimisation process. |
| | | • Relocation of 3 turbines onto land currently not included in the Address of Lands. |

# 3. Approach to assessment of listed birds and bats

This assessment has been prepared to accompany an application to amend Planning Permit No. PL-SP/05/0548, and inform self-assessments and referrals under the EE Act, and/or EPBC Act. It provides an assessment of the overall impact of the WEF proposal, whilst describing resulting changed impact from the permitted WEF to the amended WEF.

This section of the report covers listed species of birds and bats other than the Brolga, which is covered specifically in later sections of the report.

## 3.1 Review of original assessment

Assessment of potential impacts on birds and bats of the SHWF WEF, as proposed in 2009, was provided in Brett Lane & Associates (2009, 2010a). Those assessments were reviewed for their relevance and applicability to evaluation of the amended SHWF WEF.

## 3.2 Assessment of permitted WEF

As outlined above, a permit was issued by the Minister for Planning in October 2010 to enable the use and development of the SHWF WEF, subject to conditions. The permit allows for 157 turbines which was a substantial reduction from the 242-turbine wind farm that was the subject of original assessments. As a consequence of this process, no previous documented assessment of potential impacts of the permitted SHWF WEF exists, although it is apparent that any effects would be less than those of the originally proposed wind farm.

In order to appropriately consider potential impacts of the amended SHWF WEF on birds and bats it has first been necessary to consider those for the permitted SHWF WEF in light of current information.

## 3.3 Assessment of change in impact as a result of the amended WEF

The primary consideration of the current assessment is to evaluate whether potential impacts of the permitted and amended SHWF WEF on listed species of birds and bats are likely to substantially differ.

## 3.4 Database review

In order to provide a context for the study area, information about listed species of birds and bats from within 10 kilometre of the study area (the 'local area') was obtained from relevant biodiversity databases. The purpose of the review is to ensure the application to amend the Permit is informed by current data records including any that have been added to relevant databases since the preparation of the 2009/10 development application and panel hearing, including those detailed in Brett Lane & Associates (2010b).

Records from the following databases were collated and reviewed:

- Victorian Biodiversity Atlas 'VBA_FAUNA25, FAUNA100 & FAUNA Restricted' August 2015 © The State of Victoria
- BirdLife Australia Atlas of Australian Birds (BA)

- Protected Matters Search Tool of the Australian Government Department of the Environment for matters protected by the EPBC Act.
- Sheldon Brolga Flocking Database (compiled 2004)

## 3.5 Regulatory requirements

The implications of the project for species of birds and bats were assessed for:

- Species of birds and bats listed as threatened and/or are listed as migratory under the EPBC Act
- Species of birds and bats listed under Section 10 of the *Flora & Fauna Guarantee Act 1988* (FFG Act)
- Species of birds and bats included on the *Advisory list of threatened vertebrate fauna in Victoria* (DEPI 2013).

The consideration of potential for significant impacts on relevant species listed under the EPBC Act, was informed by, and evaluated against EPBC Act policy statements, significant impacts guidelines, listing advice and key threatening processes published by the Australian Government.

A specific policy of relevance, *EPBC Act Policy Statement 2.3 Wind Farm Industry* (Commonwealth of Australia 2009), was considered in the assessment of potential for the amended SHWF to have significant impacts on bird and bat species that are listed as threatened and/or are listed as migratory under the EPBC Act.

### 3.5.1 Updated regulatory requirements

The following changes to legislation and policies have occurred since the Permit was issued in 2010 and are of relevance to assessment of the amended SHWF:

- Publication of *EPBC Act Policy statement 3.21 Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (Commonwealth of Australia 2015).
- Substantial changes were made in 2013 to the list of species included under the EPBC Act provisions for migratory species. In November 2013 a large number of species were removed from the list of species included under the EPBC Act provisions for migratory species. These were virtually all species that are, in fact, not migratory between Australia and other countries and had been included in error at the time of the passage of the EPBC Act in 1999. The changes do not require consideration of any species that were not addressed in the 2009 assessment for SHWF WEF. International migratory shorebirds, including the Sharp-tailed Sandpiper *Calidris acuminata*, are not affected and the changes to listed species have no effect for the species included under the EPBC Act approval of the SHWF WEF in 2010.
- Alterations to categories of threat for some species of shorebirds in 2015. On the basis of new information, categories of threat status for some species listed under the EPBC Act have been revised. In May 2015 the status of a number of species was upgraded to Critically Endangered. These included two migratory shorebirds, Curlew Sandpiper *Calidris ferruginea* and Eastern Curlew *Numenius madagascariensis*. It is understood that the primary threats to these species are at locations outside of Australia. The two species are substantially reliant on coastal environments but during wet years they may visit large inland wetlands such as Lake Goldsmith.
- A general guideline for Victoria, which includes aspects related to effects on birds and bats, is *Policy and Planning Guidelines for Development of Wind Energy Facilities in Victoria* (State of Victoria 2015). Consideration was given to this guideline and particularly to the relevance of example permit conditions it outlines related to birds and bats and the existing Permit conditions.

## 3.6 Current suitability of wetland habitats for listed shorebirds

On 17 September 2015 Ian Smales inspected Lake Goldsmith and wetlands visible from roads within a five kilometer radius of Lake Goldsmith. The inspection was carried out to determine whether shallow wetlands contained water and thus were likely to offer habitat to listed threatened or migratory shorebirds at present. All natural, shallow wetlands were entirely dry with no visible surface water.

On 7 October 2015 a meeting was held in Ballarat to discuss aspects of the amended assessment with officers of DELWP. At that meeting it was agreed that the dry condition of potential shorebird habitats in proximity to SHWF WEF meant that they were not suitable for use by shorebirds and were highly unlikely to receive water during the 2015/16 spring – summer and thus that field surveys for shorebirds during that period were not warranted.

# 4. Assessment of listed birds & bats

This component of the assessment addresses potential effects of SHWF WEF on species of birds and bats that are listed as threatened under provisions of the EPBC Act or the FFG Act or are listed as migratory under provisions of the EPBC Act. Some species are listed under the EPBC Act under provisions for both threatened and migratory species.

Effects on birds and bats may include habitat loss or alienation and disturbance caused by construction and/or operation of the WEF. However, the major concern for birds and bats is because they fly and may thus be at some risk of collision with wind turbines.

## 4.1 Review of original application

The conclusions of assessments provided by Brett Lane & Associates for the original SHWF WEF application and approval process (Brett Lane & Associates 2009, 2010a) can be summarized as follows:

- **Habitat loss:** Suitable habitat for listed threatened bird and bat species was avoided in design of the WEF and possible impacts of habitat loss on listed species were considered not to be significant.
- **Disturbance:** Distances between turbines and areas of potential habitats, in particular wetlands for listed birds and trees for listed bats, had been designed to be sufficient to minimise potential disturbance effects on any listed species so that they were considered to be negligible.
- **Turbine collision risk:** The infrequent occurrence of almost all threatened bird and bat taxa in the local region, combined with their flight behaviours, especially for listed migratory shorebirds, meant that the likelihood of any significant impact on relevant species was very low or negligible. One species, Brolga *Antigone runicunda*, was identified as being potentially susceptible to collision impacts.

The original 2009 application for SHWF was for a WEF comprised of 242 turbines. As part of the approval process a number of turbines were removed from the design to create turbine-free buffers around wetlands, particularly those that represent breeding habitat for Brolgas. The permitted SHWF WEF allows for a total of 157 turbines.

## 4.2 Permitted Project

On the basis of current information about birds and bats an evaluation of the potential effects of the permitted SHWF WEF is provided below.

### 4.2.1 Listed threatened bird and bat species

A list of relevant threatened bird species is provided in Table 3. The list includes all species listed as threatened under the EPBC Act and the FFG Act. The records were obtained from databases detailed in Section 3.2. They include all listed threatened taxa that have either been recorded within 10 kilometres of the permitted WEF layout, or were included in results of a search of the EPBC Protected Matters Search Tool for that area.

All records of listed threatened species for the search area are birds and there are no records of listed threatened bat species.

Table 3 -. Species listed as threatened under the EPBC Act and the FFG Act, showing conservation status & likelihood of occurrence in study area.

| Scientific name | Common name | Conservation status | | | Most recent database record | Other sources | Habitat description | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | EPBC | VIC | FFG | | | | | |
| *Pedionomus torquatus* | Plains-wanderer | CR | cr | L | 1988 | PMST | The Plains-wanderer is a small ground-dwelling bird that occupies high quality native grassland with a sparse, open structure. | Low | Substantial decline in from southern Victoria. Populations are now patchily distributed throughout south-west Queensland, the Riverina district of NSW and north-central Victoria. |
| *Gelochelidon nilotica* | Gull-billed Tern | | en | L | 2010 | | Usually occurs on shallow terrestrial wetlands, less often using sheltered bays, estuaries, tidal mudflats and beaches. In Australia mainly breeds in inland areas following major flooding events. | Medium | Availability of suitable wetlands during years of high rainfall. |

| Scientific name | Common name | Conservation status | | | Most recent database record | Other sources | Habitat description | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | EPBC | VIC | FFG | | | | | |
| *Calidris ferruginea* | Curlew Sandpiper | CR | en | | 1986 | | Curlew Sandpipers occur in intertidal mudflats in sheltered coastal areas and ponds in saltworks and sewage farms. Less commonly they are found inland, around ephemeral and permanent lakes, dams and waterholes, usually with bare edges of mud or sand. | Medium | Occasional previous records of small numbers at suitable wetlands during years of high rainfall. |
| *Rostratula australis* | Australian Painted Snipe | EN | cr | L | - | PMST | Generally found in shallow, terrestrial freshwater wetlands with rank, emergent tussocks of grass, sedges and rushes. Australian Painted Snipe can occur in well vegetated lakes, swamps, inundated pasture, saltmarsh and dams. | Negligible | Species is extremely rarely recorded in Victoria. It has continental dispersal capacity & is not reliant on potential habitats in the state. |
| *Burhinus grallarius* | Bush Stone-curlew | | en | L | 1960 | | This species generally occurs in open woodland habitats, including mallee and mulga, which have a sparse layer of small shrubs, grass and litter. The species is mostly restricted to low rainfall areas in the north central and western regions of Victoria. | Negligible | Study area is outside generally accepted range and habitat preferences of this species. |

| Scientific name | Common name | Conservation status | | | Most recent database record | Other sources | Habitat description | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | EPBC | VIC | FFG | | | | | |
| *Antigone rubicunda* | Brolga | | vu | L | 2013 | | Prefers shallow marshland areas, usually less than 50 cm deep with emergent vegetation. Most commonly found in south-west Victoria, the Northern Plains and associated parts of the Murray River. Feeds predominantly on wetland plants, but also forages in crops and pasture. | High | Multiple records from local area. |
| *Ardea intermedia* | Intermediate Egret | | cr | L | 1988 | | Breeds in flooded or fringing trees alongside wetlands. | Low | Southern Victoria is outside general range of this species |
| *Ardea modesta* | Eastern Great Egret | | vu | L | 2012 | PMST | Usually found in terrestrial wetland, estuarine and wet grassland habitats. Forages by wading on shallow open water, preferring moist, low-lying, poorly drained areas. Uses estuarine mudflats as summer-autumn or drought refuges. | High | Suitable wetland habitats and area is within non-breeding range of the species. |
| *Botaurus poiciloptilus* | Australasian Bittern | EN | en | L | 1986 | PMST | Occurs in wetlands with tall, dense vegetation where it forages in shallow water at the edges of pools or waterways. Prefers permanent freshwater habitats, particularly when dominated by sedges, rushes and reeds. | Low | Available wetlands do not generally offer suitable microhabitats for this species. |

| Scientific name | Common name | Conservation status | | | Most recent database record | Other sources | Habitat description | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | EPBC | VIC | FFG | | | | | |
| *Stictonetta naevosa* | Freckled Duck | | en | L | 2012 | | Freckled Ducks are usually found on densely vegetated freshwater wetlands. During dry conditions the birds move from ephemeral wetlands to large areas of permanent open water, particularly lakes and reservoirs. | Low | Available wetlands do not generally offer suitable microhabitats for this species. Occasional individuals or small groups may visit the area. |
| *Oxyura australis* | Blue-billed Duck | | en | L | 2011 | | A largely aquatic species preferring deep, large permanent wetlands with stable conditions and abundant aquatic vegetation, including Melaleuca swamps. Occurs less commonly on river frontages, billabongs and flooded depressions. It is a secretive bird, rarely venturing far from dense vegetative cover in wetland areas. | Low | Available wetlands do not generally offer suitable microhabitats for this species. Occasional individuals or small groups may visit the area. |
| *Ninox strenua* | Powerful Owl | | vu | L | 2011 | | Prefers tall open sclerophyll forest and woodlands and requires large, hollow-bearing eucalypts for breeding. | Negligible | Study area is outside generally accepted range and habitat preferences of this species. |

| Scientific name | Common name | Conservation status | | | Most recent database record | Other sources | Habitat description | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | EPBC | VIC | FFG | | | | | |
| *Grantiella picta* | Painted Honeyeater | VU | vu | L | 1972 | PMST | A migratory species that breeds in southern Australia. It occupies dry open woodlands and forests located on the inland foothills of the Great Dividing Range. Typically forages for fruit and nectar in mistletoes and in tree canopies. | Low | Study area is outside generally accepted range and habitat preferences of this species. Occasional individuals or small groups may visit the area. |
| *Anthochaera phrygia* | Regent Honeyeater | CR | cr | L | 1971 | PMST | Inhabits dry woodlands and forests dominated by Box Ironbark eucalypts. Victorian distribution currently restricted to the Chiltern - Mt Pilot National Park in north-eastern following severe range contraction and population decline. | Negligible | Species is now extinct in south-western Victoria. |
| *Stagonopleura guttata* | Diamond Firetail | | vu | L | 1977 | | Occurs mostly in the lowlands and foothills in the north of Victoria. It has specific habitat requirements, which include grassy woodlands with tree cover for refuge and an undisturbed ground layer with grasses. | Low | Available wetlands do not generally offer suitable microhabitats for this species. Occasional individuals or small groups may visit the area. |

The assessment of habitat loss, disturbance and turbine collisions for all listed threatened species for the original SHWF WEF application, as summarized in Section 4.1, remains relevant to the permitted SHWF WEF. In accordance with criteria for 'significant impacts' set out in EPBC Act policy statement 1.1, we do not consider there is any likelihood of a significant impact on any listed threatened species posed by the permitted SHWF WEF. A specific assessment of turbine collision risk for the Brolga (listed as threatened under the FFG Act) at the permitted SHWF WEF is provided later in this report.

### 4.2.2 Listed migratory bird species

Table 4 is a list of all relevant species listed as migratory under the EPBC Act. The records were obtained from databases detailed in Section 3.2. They include all listed migratory taxa that either have been recorded within 10 kilometres of the permitted SHWF WEF, or were included in results of a search of the EPBC Protected Matters Search Tool for that area.

**Table 4 - Relevant species listed as migratory under the EPBC Act, showing likelihood of occurrence in study area.**

| Scientific name | Common name | Most recent record in local area | Other sources | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|
| *Gelochelidon nilotica* | Gull-billed Tern | 2010 | | Medium | Availability of suitable wetlands during years of high rainfall. |
| *Hydroprogne caspia* | Caspian Tern | 1999 | | Medium | Availability of suitable wetlands during occasional years of high rainfall. |
| *Charadrius bicinctus* | Double-banded Plover | 2011 | | Medium | Availability of suitable wetlands during occasional years of high rainfall. |
| *Tringa nebularia* | Common Greenshank | 1997 | | Medium | Availability of suitable wetlands during occasional years of high rainfall |
| *Tringa stagnatilis* | Marsh Sandpiper | 2011 | | Medium | Availability of suitable wetlands during occasional years of high rainfall |
| *Calidris ferruginea* | Curlew Sandpiper | 1986 | | Medium | Availability of suitable wetlands during occasional years of high rainfall |
| *Calidris ruficollis* | Red-necked Stint | 2000 | | Medium | Availability of suitable wetlands during occasional years of high rainfall |

| Scientific name | Common name | Most recent record in local area | Other sources | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|
| *Calidris acuminata* | Sharp-tailed Sandpiper | 1992 | | Medium | Availability of suitable wetlands during occasional years of high rainfall |
| *Calidris canutus* | Red Knot | 1988 | | Low | The species is principally confined to coastal regions when in Australia. Very few previous records from local area |
| *Gallinago hardwickii* | Latham's Snipe | 2011 | | Medium | Availability of suitable wetlands during years of high rainfall. |
| *Rostratula australis* | Australian Painted Snipe | | PMST | Negligible | Species is extremely rarely recorded in Victoria. It has continental dispersal capacity & is not reliant on potential habitats in the state. |
| *Plegadis falcinellus* | Glossy Ibis | 2012 | | Medium | Suitable wetland habitats and area is within non-breeding range of the species. Occasional individuals or small groups may visit the area. |
| *Ardea modesta* | Eastern Great Egret | 2012 | | High | Suitable wetland habitats and area is within non-breeding range of the species. |
| *Merops ornatus* | Rainbow Bee-eater | 1978 | | Medium | During annual migration some birds likely to occur across landscape |
| *Hirundapus caudacutus* | White-throated Needletail | 1975 | | High | During annual season in Australia flocks likely to move through airspace over study area |

| Scientific name | Common name | Most recent record in local area | Other sources | Likely occurrence in study area | Rationale for likelihood ranking |
|---|---|---|---|---|---|
| *Apus pacificus* | Fork-tailed Swift | 1988 | | High | During annual season in Australia flocks likely to move through airspace over study area |
| *Rhipidura rufifrons* | Rufous Fantail | | PMST | High | During annual migration some birds likely to occur across landscape |
| *Myiagra cyanoleuca* | Satin Flycatcher | 1978 | | High | During annual migration some birds likely to occur across landscape |
| *Motacilla flava* | Yellow Wagtail | | PMST | Negligible | Study area is outside known range of the species |
| *Acrocephalus stentoreus* | Clamorous Reed Warbler | 2000 | | High | Presence of small areas of suitably vegetated dams & other more permanent waterbodies |
| *Ardea ibis* | Cattle Egret | 2011 | | High | Some birds likely to occur in low-lying agricultural pasture at times |

Condition 15 of the Permit requires consideration of one EPBC Act listed migratory species, the Sharp-tailed Sandpiper *Calidris acuminataa*, in the preparation of the required Bat and Avifauna Management Plan. Additionally the EPBC Act Decision Notice for the permitted SHWF WEF specifically mentions this species. We believe the species was nominated because there is at least one recorded instance of 1600 Sharp-tailed Sandpipers at nearby Lake Goldsmith. The East Asian-Australasian Flyway population of Sharp-tailed Sandpipers is estimated at 160,000, with approximately 140,000 annually occurring in Australia (http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=874#population_information). Sharp-tailed Sandpiper is not a listed threatened species.

On the basis of current information, categories of threat status for various species listed under the EPBC Act are revised from time to time. In May 2015 the status of a number of species was upgraded to Critically Endangered. These included two migratory shorebirds, Curlew Sandpiper *Calidris ferruginea* and Eastern Curlew *Numenius madagascariensis*. It is understood that the primary threats to these species are at locations outside of Australia. During their annual sojourn in Australia the two species are substantially reliant on coastal environments but may visit large inland wetlands such as Lake Goldsmith. There are a few records of Curlew Sandpipers from Lake Goldsmith with a maximum of 200 individuals recorded. There are no known records of Eastern Curlews in the local area. We do not consider that the revised conservation status of these two species in any way affects assessment that potential risks associated with the permitted SHWF WEF to both species are negligible.

In November 2013 a substantial number of species were removed from the list of species included under the EPBC Act provisions for migratory species. These were virtually all species that are, in fact, not migratory between Australia and other countries and had been included in error at the time of the passage of the EPBC Act in 1999. The changes do not require consideration of any species that were not addressed in the 2010 assessment for SHWF. International migratory shorebirds, including the Sharp-tailed Sandpiper, are not affected and the changes to listed species have no effect on assessment of migratory species for the permitted SHWF project.

The *EPBC Act Policy statement 3.21 Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (Commonwealth of Australia 2015) has been published since the approval of the permitted WEF. It outlines the key concept of 'important habitat' for migratory shorebirds and the substantive link between important habitat and 'significant' impacts on migratory shorebirds. According to this approach, wetland habitat should be considered <u>internationally important</u> if it regularly supports:

- 1 per cent of the individuals in a population of one species or subspecies of waterbird **or**
- a total abundance of at least 20,000 waterbirds.

Wetland habitat should be considered <u>nationally important</u> for migratory shorebirds if it regularly supports:

- 0.1 per cent of the flyway population of a single species of migratory shorebird **or**
- 2000 migratory shorebirds **or**
- 15 migratory shorebird species.

Available information indicates that no wetland in the area local to the amended SHWF WEF meets the criteria for an important habitat at the national or international level. This is especially because, while migratory shorebirds are known to use some shallow wetlands in the area on occasions when they hold water, such events are unpredictable and not regular. The wetlands experience lengthy periods, sometimes spanning multiple years, in which they are dry and unsuitable for shorebirds.

Development of turbines and other infrastructure associated with the permitted SHWF WEF will not include removal of habitat for any migratory species.

Brett Lane & Associates (2009, 2010a) have summarized information about flight behaviours and flight heights of migratory shorebirds and their conclusion was that these may reduce the risk of turbine collisions for these taxa relative to some other birds. We consider their conclusions are appropriate and that flight behaviours and flight heights of migratory shorebirds are also likely to reduce the risk of turbine collisions for these birds at the permitted SHWF.

The risk of any species of migratory birds colliding with turbines proposed for the permitted SHWF WEF is considered to be negligible. A significant impact due to direct mortality of migratory shorebirds is defined in EPBC Act policy statement 3.21 (Commonwealth of Australia 2015) as one "leading to a *substantial reduction* in migratory shorebird numbers" [italics theirs]. We recognize that published information about turbine collisions in south-eastern Australia is limited, but empirical experience is growing. A few wind farms are now operational in coastal locations where migratory shorebirds occur. Of particular relevance is the Musselroe Wind Farm in north-eastern Tasmania where eight species of migratory waders have been recorded on the site since the wind farm became operational in 2013. To-date no migratory shorebirds have been recorded as collision fatalities, despite a very intensive program of monitoring targeted specifically at turbines close to wetlands used by these species (Woolnorth Wind Farm Holding 2014, 2015).

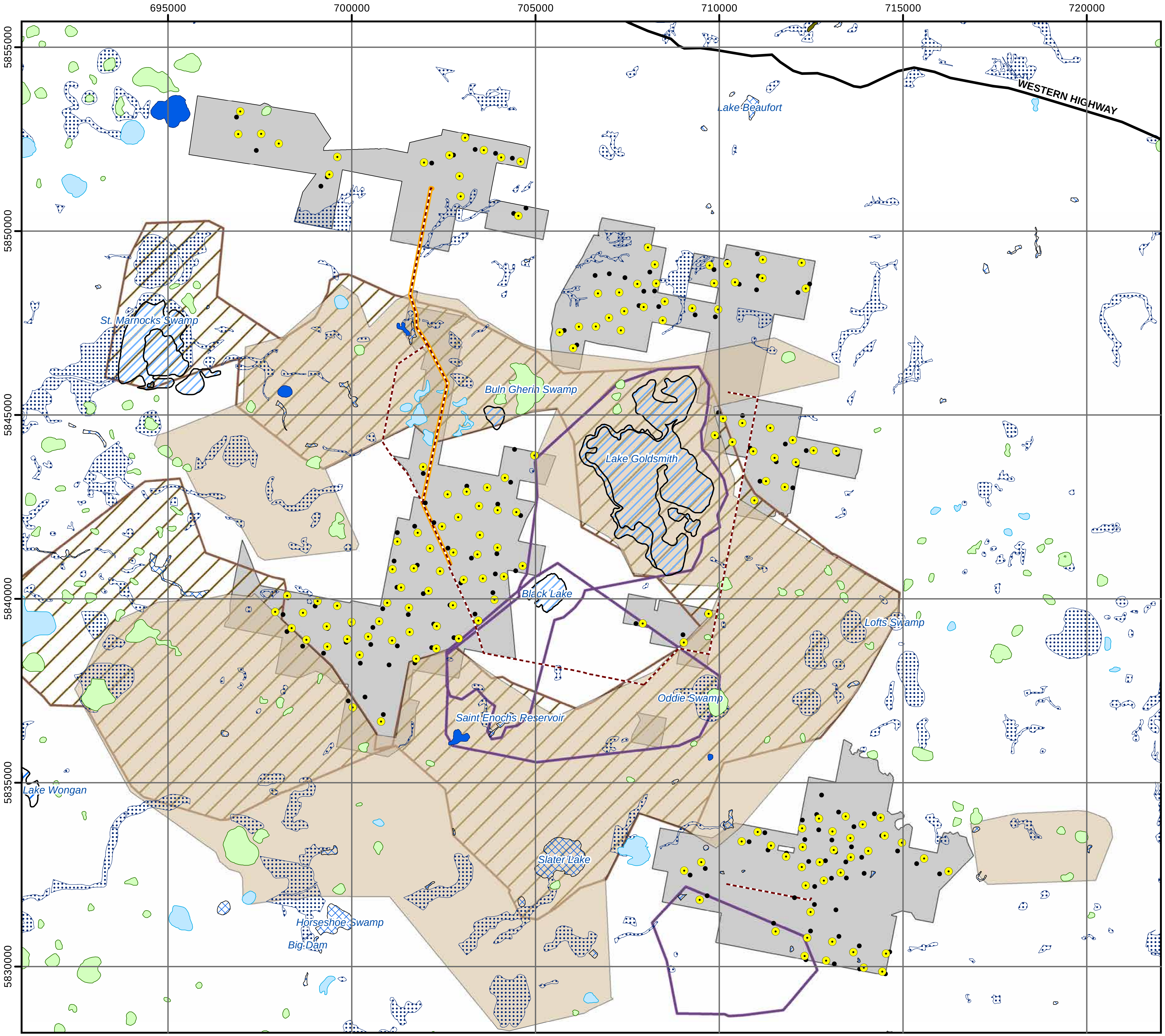
We do not consider there is likely to be a risk of significant impact on any listed migratory species from the permitted SHWF WEF.

## 4.3 Amended Project

The physical differences between the permitted and amended WEF are detailed in Table 2 (Section 2.3). In summary the amended project covers a smaller land area and includes eight fewer turbines within the same local area. All zones designated as turbine-free buffers around wetlands in the permitted SHWF WEF remain free of turbines in the layout of the amended SHWF WEF (Figure 2). The turbines for the amended WEF are taller and have larger rotors.

The physical changes entailed in the amended WEF are not sufficient to measurably alter the assessment made for the permitted WEF. We do not consider that the amended WEF will result in a significant impact on any species listed as threatened under the EPBC Act or the FFG Act nor on any species listed as migratory under the EPBC Act.

**Figure 2 (overleaf) – Map of Stockyard Hill Wind Farm showing locations of turbines in the permitted and amended WEFs. Internal overhead powerlines are also shown, as are turbine-free buffers placed over wetlands. Buffer zones are unchanged between the permitted and amended WEFs.**




PROJECT

**Stockyard Hill Wind Farm**

TITLE

Brolga Buffers & Wetlands

LEGEND

- Wind Energy Facility
- Turbine location (Amended)
- Turbine Location (Permitted)
- Internal OH Powerline (Permitted)
- Internal OH Powerline (Amended)

**Wetland**

- 2 - Freshwater meadow
- 20 - Sewage oxidation basin
- 3 - Shallow freshwater marsh
- 4 - Deep freshwater marsh
- 5 - Permanent open freshwater
- 6 - Semi-permanent saline
- 7 - Permanent saline
- 99 - No Category

**Brolga Buffer (post 1988)**

**Habitat Quality**

- High
- Low

**Brolga Buffer (pre 1988)**

- High Habitat Quality


Origin Energy
321 Exhibition Street
Melbourne
VIC 3000



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Source: DELWP Wetlands 2013

Projection: GDA94 Zone54

| | |
|---|---|
| DATE 1/03/2016 | PRODUCED IMackey |
| SCALE 1:100,000 | CHECKED CLayton |
| STATUS Draft | APPROVED PMarriott |

0 1.25 2.5 5 Kilometres

| DRAWING No. | REV |
|---|---|
| SHWF_0_0117_02A | 1B |

# 5. Approach to collision risk assessment for Brolga

The Brolga *Antigone rubicunda* (until recently *Grus rubicunda*) is listed as threatened under the FFG Act and as vulnerable on the *Advisory list of threatened vertebrate fauna in Victoria*. A specific guideline for that species has been published by the Victorian Government as *Interim Guidelines for assessment, avoidance mitigation and offsetting of potential wind farm impacts on the Victorian Brolga Population 2011* (DSE 2012) ('Brolga Guidelines') and has been used to guide both the assessment process undertaken and the consideration of potential impacts on that species.

The Brolga Guidelines stipulate a three-level process in consideration of potential wind farm impacts on the Victorian Brolga population. All three levels of assessment are triggered by the proposed Stockyard Hill Wind Farm. Within each level are assessment steps to be undertaken.

The publication of the Brolga Guidelines largely formalised methods for survey and impact assessment for Brolgas that were informally in place and used during the 2009/10 approval process for SHWF WEF. The published Brolga Guidelines do not materially alter assessment requirements or criteria for impact on the species from those used in 2009/10, which formed the basis for planning approval of the permitted SHWF WEF.

With one exception (the use of aerial survey, see below) the requirements of Level 1 and Level 2 assessments were fulfilled prior to issue of planning approval for the permitted SHWF WEF. The assessments of Levels 1 and 2 used the methods set out in the Brolga Guidelines to collect required information about the Brolga population and activities of the species necessary for those assessment levels. To ensure that information is current for assessment of the amended SHWF WEF we have obtained available database information about distribution, breeding and flocking of Brolgas in the local area up to and including 2015.

The use of aerial survey to document Brolga breeding locations was introduced with publication of the Brolga Guidelines. This occurred after the planning permit for SHWF WEF was issued. Advice from DELWP in 2015 was to the effect that aerial survey would not be required for the amended proposal because the dry condition of most potential breeding wetlands in 2015 meant that survey for the species would not be usefully informative.

The current assessment is concentrated on the Level 3 assessment component, especially turbine collision risk, because it is at this level that the amended SHWF WEF may materially differ from the permitted project. Data about Brolga behaviours that was required to conduct the 2009 quantified collision risk assessment, including frequency of Brolga flights and their mean heights and lengths were drawn from data collected for that purpose for the permitted SHWF WEF. Data from which those values were calculated were considered appropriate and adequate to provide input values for the scenario collision risk assessments which resulted in planning approval for the permitted SHWF. We consider that data remains equally valid as the basis for values used in collision risk modelling for the amended SHWF WEF.

An underlying principle of the Brolga Guidelines is that a WEF should have no net impact on the Victorian Brolga population. That principle was applied to modelled impacts of the WEF and powerlines for the SHWF project as proposed in 2009/10 and is applied again now for the amended SHWF WEF. In order to achieve that result the Brolga Guidelines provide for mechanisms to offset any deleterious effects so that there will be no net impact on the overall population inhabiting Victoria. The results of collision risk modelling for wind turbines and overhead powerlines were used in population viability analysis to determine potential effects of projected numbers of collisions on the population and to determine the consequent offset requirements.

In light of the discussion above, the assessment below addresses potential risk of Brolgas colliding with wind turbines and with new internal overhead powerlines at SHWF WEF. A new powerline from the amended SHWF WEF to the external electricity grid is subject to a separate approval process and potential risks of Brolgas colliding with that powerline are considered in a separate assessment report.

The Brolga is listed as threatened under provisions of the FFG Act. The requirement for quantitative assessment of turbine collision risk for this species is stipulated in the Brolga Guidelines (DSE 2012). This section of the report provides the required quantitative assessment by modelling potential collision risks for the species. It does so for both the permitted and amended SHWF WEFs to allow direct comparison between them.

## 5.1 Background to quantitative risk modelling

Collisions of birds and bats with wind turbines and with powerlines have been documented to occur at various frequencies around the world. Quantitative modelling to estimate the number of collision mortalities of threatened taxa is widely used as part of environmental impact assessments for proposed WEFs (Huppop *et al.* 2006, Masden & Cook 2015).

The impact of any collisions on the viability of threatened fauna populations is more important than determination of simple numbers of mortalities and population models can be used in combination with results of collision risk models to evaluate such impacts.

Mathematical modelling of risk is intended to provide an articulated, transparent and replicable evaluation of what may occur in the real world. The rationale behind predictions is explicitly stated in the mathematics of a model, which means that the logical consistency of the predictions can be easily evaluated. The explicit nature of inputs and rigour entailed in modelling means that the process is replicable and consistent and it is open to analysis, criticism or modification when new information becomes available. Although it is necessary to include some assumptions and arbitrary choices when deciding on the structure and parameters of a model, these choices are stated explicitly.

Models are also valuable for their heuristic capacities as they focus attention on important processes and parameters entailed in risk (Brook et al. 2002). Their very nature facilitates incorporation of information as it is learnt (Burgman 2005) and refinements should thus be expected of any model.

The risk modelling detailed here entails the use of informed scenarios. We consider the assumptions and values used are reasonable and they are informed by available information about the ecology of Brolgas in south-western Victoria. As a consequence, we consider the results of modelling detailed here provide a basis for evaluation of likely effects of SHWF WEF on Brolgas. The only alternative to a quantitative modelling approach is one of qualitative subjective judgement. All the benefits of using mathematical modelling outlined above are difficult, if not impossible to achieve with a qualitative assessment.

### 5.1.1 Purposes of collision risk & population models

There are two fundamental questions an assessment of potential effects of bird and bat collisions with turbines and powerlines should attempt to address.

The first asks, *'how many individual animals are likely to be killed in collisions with turbines at the proposed wind farm?'*

The second asks, '*what impact will the expected number of mortalities have on the viability of the species or population?'*

Collision risk models are designed to address the first question. Population models have potential to address the second question. Collision risk modelling and population modelling have been undertaken to evaluate these questions related to Brolgas and the permitted WEF and amended WEF and are described in detail here.

## 5.2 Background to collision impact assessment for Brolgas at SHWF WEF

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 annual rainfall and, more permanently, by drainage of wetlands. Outside of the flocking season pairs of Brolgas are territorial and do not tolerant close proximity of other Brolgas. As a result of these factors Brolgas are relatively scarce and, for much of the year are widely dispersed even in suitable areas of their range. During the annual flocking season they congregate at a few key sites where they roost and undertake key social activities. During this period of the year they also disperse out into the local landscape to feed.

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.

Assessments of the potential for Brolga mortalities to occur as a result of collisions with wind turbines and with powerlines were undertaken as components of impact assessment in 2009 for the then proposed SHWF WEF (Biosis Research 2009a).

In 2009, impact assessments of collision risk for Brolgas was undertaken on the basis of scenario modelling. The scenarios were 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 about frequency and heights of Brolga flights obtained from field observations recorded 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 (2008a) 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 obtained from the field data.

The rationale, parameters and values used for scenarios for the different seasonal activities of Brolgas were described in a turbine collision assessment report (Biosis Research 2009a). Predictions of mean annual numbers of Brolga fatalities that might occur due to collisions with wind turbines, under the scenarios modelled were calculated using the Biosis Deterministic Collision Risk Model. Predictions of mean annual numbers of Brolga fatalities that might occur due to collisions with overhead powerlines were also calculated using a defined set of assumptions.

Turbine 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 birds in the area of the wind farm including their frequency, heights and distance according to the birds' seasonal behaviours. Using this information and assuming any collision will be fatal, the model provides forecasts for an annual average number of interactions between Brolgas and turbines.

Collision risk modelling was undertaken in 2009 also using scenarios for likely interactions by Brolgas with proposed overhead powerlines that then included alignments within the overall wind farm area and a longer southern section connecting to the external electricity grid (Biosis Research 2009b). It was assumed that Brolga flights to and from breeding sites within a given proximity of the powerline are at some risk of collision and, since no quantified rate for such collisions is available for Brolgas, a rate was determined from published rates for powerline collisions by other species of cranes overseas.

Potential numbers of Brolga mortalities predicted by the models 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.

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 on extinction risk for the Victorian Brolga population of mortalities that might occur due to the wind farm.

The collision risk models and population viability analysis are predictive mathematical models. All such models are mathematical representations of what might occur in reality. Modelling for scenarios necessarily incorporates various well-informed assumptions and it should be understood that the results of modelling are reliant on the assumptions used. However, the assumptions and modelling processes are transparent in that every parameter and values used as inputs to the models are defined and explicit.

The same processes used in 2009 for collision risk modelling for the original SHWF, have been used again to evaluate this risk for the permitted and the proposed amended SHWF WEF.

Draft guidelines for evaluation of the possible effects on Brolgas of wind farms in south-western Victoria were under development in 2009/10 whilst assessment for the then proposed SHWF WEF was underway. Through liaison with the then Department of Sustainability and Environment (DSE), the impact assessment undertaken at that time followed the processes outlined in the draft guidelines. The guidelines were finalized and published by DSE in 2011 and revised in 2012.

The permitted SHWF WEF includes up to 157 turbines (with a maximum tower height of 80 m, blade length of 52 m and tip height of 132 m). An assessment of the permitted SHWF WEF has been undertaken to provide a baseline against which to assess potential turbine collision risk for Brolgas associated with the amended WEF.

### 5.2.1 Seasonal activities of Brolgas

As described above, the activities of Brolgas that may place them at some risk of interaction with turbines fall into distinct seasonal categories:

1. breeding season
2. 'migration' flights
3. non-breeding season flocking aggregation

Due to differences in the frequency and other characters of Brolga flights and of the number of birds that may be involved, a scenario has been modelled for each of these seasonal behaviours. An annual estimate of risk has been determined as the sum of the results for these three modelled seasonal activities.

### 5.2.2 Brolga utilization & data analyses

A measure of the number and frequency of bird flights is termed the 'utilization rate' for the particular species at the site in question. Investigations to obtain empirical data for Brolga utilization at SHWF WEF are detailed in Brett Lane & Associates (2009). The utilization data obtained then were appropriate to determine required input values for use in collision risk modelling for submission of the WEF as then proposed. The same values have been used here and this provides consistency in modelling of the permitted and amended SHWF WEFs.

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 (2008a) 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. This mechanism substantially increases the potential number of Brolga flights incorporated into the modelling.

### 5.2.3 Turbine collision risk model

The risk of Brolgas colliding with turbines at SHWF WEF has been assessed using the Biosis Pty. Ltd. Deterministic Collision Risk Model. The model was developed in 2002 and 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. A full description of the model (Smales *et al.* 2013) is provided in Appendix B.

Generally, results of modelling are expressed in terms of the expected number of flights per annum by particular bird species that pose a risk of collision with turbines. Where an estimate is available for the number of individual birds 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 for a bird to avoid a collision, whether that occurs due to a cognitive response on the part of a bird or not. Thus a 95% avoidance rate equates to one flight in 20 in which a bird takes no action to 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

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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 with the moving rotor. For this reason, results are provided for 95%, 98% and 99% avoidance rates for the dynamic components of turbines.

In the model, the turbine is decomposed into its static and dynamic components. The entire turbine (including the tower, nacelle and the rotor *when stationary*) represents the static component. The dynamic component is the volume swept by the leading edge of the rotor blades in the time it takes the species of interest to pass safely across the depth of the swept disk.

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 and allocating different risk rates to these height classes.

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

- The numbers of Brolga flights below rotor height, and for which just the lower portion of turbine towers present a collision risk.
- 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.
- The numbers of bird movements-at-risk, as recorded Brolgas during timed point counts, were 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 WEF site and that they may thus be at risk.
- 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 for specific make and model of turbine. It represents the average area presented to an incoming flight from any direction.
- The additional area ($m^2$ 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.
- The model assumes that all turbines in the WEF represent equal risk.
- A calculation of the average number of turbines a Brolga is likely to encounter in a given flight through the WEF. This is based on the scattered configuration of turbines in the landscape and the total number of turbines proposed for the WEF.

Wherever bird utilization 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 the SHWF WEF site, empirical data was 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 WEF and Brolgas may be at risk of collision during such events. Scenarios were developed for short-term flocking events on the basis of Brolga behaviours recorded at distant flocking locations in early 2008 combined with information about historical flocking events within, or close to, the WEF site. The rationale and input values used for each of the three elements of the Brolga's annual cycle are outlined below.

### 5.2.4 Powerline collision risk model

The risk of Brolgas colliding with overhead powerlines at SHWF WEF has been evaluated using the principles and methods as used in 2009 (Biosis Research 2009b). However, the 2009 assessment was for all overhead powerlines associated with the SHWF WEF as then proposed, including those within the wind farm and the alignment from the wind farm to the external electricity grid. In that assessment the risks of Brolga collisions were combined for the entire length of those overhead powerlines as one. The approvals processes for the amended SHWF now considers powerlines that are internal to the wind farm separately from the powerline connecting the wind farm to the external electricity grid. The present report considers powerlines internal to the SHWF WEF only. The external alignment is considered in a separate report (Biosis 2016). In order to compare the permitted and amended SHWF WEFs, the assessment here considers alignments of overhead powerline within the permitted SHWF WEF (i.e. the portions linking electricity substations that are integral to the wind farm and excluding the powerlines transferring electricity to the external grid).

Brolgas are known to occasionally fatally collide with powerlines in Victoria, although published documentation of this is limited and is not recent (White 1987; Goldstraw and du Guesclin 1991). There are no empirical data about Brolga collisions with powerlines in south-western Victoria that might provide a basis for quantifying them. While there is a substantial international literature about bird collisions with powerlines, there are relatively few rigorous studies that have attempted to quantify rates of collision and fewer still of them have investigated effects on cranes. .In the absence of empirical data for Brolgas, the approach to assess potential risk is based on the annual cycle of Brolga activities and behaviours and specific information including the following:

- Alignment location information for overhead powerlines for the permitted SHWF WEF and those proposed for the amended SHWF WEF.
- Data from the local Brolga population quantifying numbers of flights made by individual Brolgas per annum at breeding sites and the lengths of those flights (Brett Lane and Associates 2008).
- Data from the local Brolga population quantifying the number of birds using breeding sites per annum (Brett Lane and Associates 2008).
- Distances from core of breeding territories to the nearest location of the powerline for all Brolga sites within five kilometres of the powerline.
- A collision rate for powerline crossings, based on studies of other crane species reported in the international literature. Two published studies provide calculated rates or values from which rates could be calculated for the number of powerline crossings that resulted in collisions. Janss and Ferrer (2000) studied the Common Crane and Morkill and Anderson (1991) studied the Sandhill Crane. These investigations were both substantial and encompassed thousands of potential interactions by cranes with powerlines. These studies of cranes that provide quantified rates of collision with powerlines have been used to provide 'benchmark' values for the purposes of evaluating possible collision rates for Brolgas.

### 5.2.5 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 SHWF WEF 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 models cannot forecast the frequency of collisions around the predicted annual average and it is important to recognize that the number of any actual collisions that might occur can be expected to vary from year to year.

### 5.2.6 Qualifications

Empirical data for Brolga flight activity in and near the SHWF WEF site were obtained by Brett Lane & Associates during 2007 and 2008. Input values to collision risk modelling are derived from that empirical data. Consultation with DELWP in 2015 indicated their satisfaction with this approach, for the purposes of assessing the incremental impact of the amended WEF design. It is possible that this data is not representative of longer timeframes encompassing different environmental conditions. Where input values were required and empirical data was not available, values are informed by assumptions based on relevant available information.

### 5.2.7 Population viability analysis

As noted in the Brolga Guidelines, a species-specific Population Viability Analysis (PVA) model has been developed for the Victorian Brolga population (McCarthy 2008a). On the basis of PVA that was run for the original SHWF WEF planning permit application (McCarthy 2008b) estimates of Brolga mortality from turbine collision risk modelling for the amended SHWF WEF have been used to derive potential effects on the Victorian Brolga population.

## 5.3 Approach to comparison of turbine collision risk modelling for Brolgas of permitted and amended SHWF WEF

As outlined above, collision risk modelling undertaken to inform the original planning permit application was based on a number of informed assumptions about aspects such as numbers and frequency of Brolga flights. The same approach is used here to assess risk that may be associated with the turbines and their configuration proposed under the amended WEF. Assumptions used in 2009 have been reviewed, and as necessary revised, to account for differences between the permitted WEF and the amended WEF. Collision risk modelling undertaken for the 2009 planning permit application was based on 242 turbines. The Permit was granted for up to 157 turbines but collision risk modelling was not undertaken for that permitted number. In order to validly compare risk for the number and configuration of turbines proposed in the amended WEF with the permitted WEF, it is necessary to model risk for both using identical assumptions for Brolga flights.

Hence, the following iterations of collision risk modelling for Brolgas were undertaken as part of the current assessment:

1. Collision risk modelling for 157 turbines as per permitted WEF; and

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2. Collision risk modelling for 149 turbines as per the amended WEF.
3. A review of data for Brolgas in the zone within 10 kilometres of the SHWF includes 31 records for the species submitted since 2009. These indicate that Brolgas used no breeding or flocking sites that were not already known and used to inform collision risk modelling for the species in the original planning permit application. As a consequence, virtually all assumptions about Brolgas used to inform inputs to the collision risk modelling for the original planning permit application remain relevant and have been used for new modelling for the permitted WEF and amended WEF. The height and size of turbine rotor-swept areas differ between turbines for the permitted and amended SHWF WEFs. This influences the assumed number of Brolga flights that might encounter turbines and is a primary factor in resultant differences in risks posed by the permitted and amended WEFs.

### 5.3.1 Rationale and input values

Specifics of the rationale and input values used for assessments of the permitted and amended SHWF WEFs are set out below. Parameter values that differ between the permitted WEF and amended WEF are detailed and are summarized in Table 5, Table 6 and Table 7.

#### 5.3.1.1 Turbines

The collision risk model uses multiple dimensions and rotor speed to calculate the area presented by a turbine to a bird in flight.

For the purpose of this assessment 157 of turbine model Senvion 3.4M104 has been modelled for the permitted WEF. These turbines represent the maximum overall dimensions for the permitted SHWF WEF. They have an 80 metre high hub centre and 104 metre rotor diameter. The height zone swept by the rotor spans 28 metres to 132 metres above the ground. Rotor speed is variable between 7.1 and 13.8 rpm.

The amended WEF is modelled on 149 of the newer turbine model Senvion 3.4M140. These have a 104 metre high hub centre height of 110 metres and 140 metre rotor diameter. The height zone swept by the rotor spans 40 metres to 180 metres above the ground. Rotor speed is variable between 5.2 and 9.6 rpm.

#### 5.3.1.2 Brolga size & flight speed

A length of 1.96 metres, measured from museum specimens, is used in all modelling for a Brolga in flight. No published flight speed for Brolga has been located but an average ground flight speed of 45 kilometres per hour is used and has been obtained from data for similar-sized crane species from overseas studies.

#### 5.3.1.3 Breeding season

**Number of turbines presenting risk**

For both the permitted WEF and amended WEF, it is assumed that during the breeding season it is possible for Brolgas to interact with the entire complement of turbines permitted for the entire WEF.

**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 is considered reasonable for the population.

This parameter is constant for both the permitted WEF and amended WEF.

**Number of individuals at risk**

Six pairs of Brolgas (12 adults) were documented within 3 kilometres of SHWF WEF during the 2007 and 2008 breeding seasons (Brett Lane pers. comm. 6th Oct. 2008). A review of all available sources of data for Brolga breeding sites within this area up to early 2010 is provided in Brett Lane & Associates (2010b). This includes localities of some Brolga breeding wetlands that were not included in Brett Lane & Associates (2009 and 2010a). However, given the very close proximity to each other of many of these locality records, the spread years over which the records have been made and the territorial nature of breeding Brolgas, it is not feasible that Brolgas will breed simultaneously at any more than a small number of these sites. We consider that an average of no more than six breeding pairs would be likely to use the zone within 3 kilometres of SHWF WEF in any given year, and this number has been used in modelling of both the permitted WEF and amended WEF.

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. The mean population ratio of juveniles to adults is estimated at 0.05 (Herring 2001). There is thus an expectation that there will be an annual average of 0.6 juveniles accompanying 12 adults per annum.

Thus we have modelled for a mean total of 12.6 birds at risk per annum. This average allows for years in which higher or lower numbers of Brolgas may be present and at some risk.

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.

This parameter is constant for both the permitted WEF and amended WEF.

**Numbers of movements at risk**

Brolga flights of sufficient length to reach from any of various breeding sites within 3.2 kilometres of any turbine in the WEF site, and within the height zone occupied by turbines are considered to have potential to interact with, turbines. Numbers of such flights are derived from records provided by Brett Lane & Associates (2008) and factored by Symbolix (2008a) to an 80% confidence bound.

The numbers of potential flights at risk differ according to the different height and rotor-sweep dimensions of turbines in the permitted WEF and amended WEF.

For the permitted WEF the number of Brolga flights per breeding season modelled as within rotor-swept height is 22 and flights below rotor-swept height is 40.

For the amended WEF the number of Brolga flights per breeding season modelled as within rotor-swept height is 31 and flights below rotor-swept height is 53.

A summary of key input values used for turbine collision risk modelling for Brolga flights during the annual breeding season for the permitted WEF and amended WEF is provided in Table 5.

**Table 5 - Comparison of input values between permitted WEF and amended WEF used for turbine collision risk modelling of Brolga breeding season**

| Comparison of input values between permitted WEF and amended WEF used for collision risk modelling of Brolga breeding season | | |
|---|---|---|
| | **Permitted WEF** | **Amended WEF** |
| **Duration of breeding season** | 130 days | 130 days |
| **Annual average number of Brolgas at risk** | 12.6 | 12.6 |
| **Total number of turbines presenting potential risk** | 157 | 149 |
| **Turbine height below rotor sweep** | 28 metres | 40 metres |
| **Turbine height within rotor sweep** | 28 - 132 metres (104 metre span) | 40 - 180 metres (140 metre span) |
| **Modelled flights at risk below rotor sweep** | 40 | 53 |
| **Modelled flights at risk within rotor sweep** | 22 | 31 |

#### 5.3.1.4 Migration seasons

**Migration season period**

Brolgas in the Victorian population are not truly 'migratory'. True migration involves regular seasonal movements of the majority of a population from one region to distinctly separate region. Brolgas tend to aggregate into large flocks concentrated on a number of particular wetlands outside the breeding season and many (but not necessarily all) birds move from breeding territories to join these flocks. Movements to and from these sites is often termed 'migration' however, the population remains within the same overall geographic range throughout. 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 is considered reasonable and has been used in modelling.

This parameter is constant for both the permitted WEF and amended WEF.

**Number of individuals at risk**

A maximum population size of 58 birds for the region has been reported by Brett Lane & Associates (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). 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.

This parameter is constant for both the permitted WEF and amended WEF.

**Numbers of movements at risk**

Numbers are derived from records provided by Brett Lane & Associates (2008) and factored by Symbolix (2008a) to an 80% confidence bound. The numbers of potential flights at risk differ according to the different height dimensions of turbines in the permitted WEF and amended WEF.

For the permitted WEF, numbers of Brolga flights of sufficient length to reach, and thus potentially to interact with, turbines calculated for the modelling are 69 within rotor-swept height and 129 below rotor-swept height.

For the amended WEF, numbers of Brolga flights of sufficient length to reach, and thus potentially to interact with, turbines calculated for the modelling are 97 within rotor-swept height and 172 below rotor-swept height.

**Number of turbines presenting risk**

It is assumed that birds preferentially utilise lower-lying and generally the most direct route in making these movements. Both the permitted and amended turbine layouts exclude turbines from the most obvious such area between the large mid sector and a smaller south-eastern sector of the WEF. This zone has a minimum width, devoid of turbines, of approximately 4 kilometres. The scenario models for Brolgas making 'migration' flights to potentially encounter the first turbines only on either side of the turbine exclusion corridor. In both the permitted and amended turbine configurations the total number of turbines along both sides of this corridor is 30. This number of turbines has been used in modelling of risks during the migration period for both the permitted and the amended SHWF WEFs.

A summary of key input values used for turbine collision risk modelling for annual Brolga migration flights for the permitted WEF and amended WEF is provided in Table 6.

**Table 6 - Comparison of input values between permitted WEF and amended WEF used for turbine collision risk modelling of annual Brolga migration flights**

| Comparison of input values between permitted WEF and amended WEF used for collision risk modelling of annual Brolga migration flights | | |
|---|---|---|
| | **Permitted WEF** | **Amended WEF** |
| **Duration of 'migration season'** | 100 days | 100 days |
| **Annual average number of Brolgas at risk** | 58 | 58 |
| **Total number of turbines presenting potential risk** | 30 | 30 |
| **Turbine height below rotor sweep** | 28 metres | 40 metres |
| **Turbine height within rotor sweep** | 28 - 132 metres (104 metre span) | 40 - 180 metres (140 metre span) |
| **Modelled flights at risk below rotor sweep** | 129 | 172 |
| **Modelled flights at risk within rotor sweep** | 69 | 97 |

#### 5.3.1.5 Incidental flocking aggregations

Traditional and routine flocking sites are all further than 3 kilometres from the WEF and Brolga flights to, from and within them are considered to be too distant to be at risk of collision with turbines on the permitted WEF and amended WEF. These include two traditional flocking sites identified in Brett Lane & Associates (2010b) as wetlands 205 and 207. However, temporary short-term flocking ('one-off flocking') has been recorded occasionally at other locations. Brett Lane & Associates (2010b) list 8 such locations within 3 kilometres of the permitted WEF and amended WEF, although records of Brolga flocking at 4 of them are from prior to 1988. At another 3 locations a short-term flocking event has been noted since 1990 and at 1 location the date was not reported. One instance of incidental flocking was of 52 Brolgas at a small wetland west of Lake Goldsmith in 1995. 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 for numbers of Brolga flights or for the heights and lengths of flights is available from any one-off flocking events, modelling has been undertaken using data recorded at traditional flocking sites by Brett Lane & Associates (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 out on the basis of the duration and frequency with which they have been observed in the past 20 years, which has been for an average of 21 days, and, on average, has occurred once every 5 years.

**Input parameters**

Mathematical methods used to develop inputs for one-off flocking events into collision risk modelling were provided by Symbolix (2008b). These incorporate the following which are constant for the permitted WEF and amended WEF:

- 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 kilometres (based on absolute maximum flight distance of 5 kilometres).

The numbers of potential flights at risk differ according to the different height dimensions of turbines in the permitted WEF and amended WEF.

For the permitted WEF the numbers of Brolga flights modelled for the zone within rotor-swept height were 647 and flights below rotor-swept height were 1019.

For the amended WEF the numbers of Brolga flights modelled for the zone within rotor-swept height were 906 and flights below rotor-swept height were 1359.

**Number of turbines**

The number of turbines with which Brolgas could potentially collide was calculated from the number within a 5 kilometre 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 kilometre radius plots across the entire WEF site, in which the only criterion was that the plot incorporated at least one turbine. The result was a mean number of 20 turbines presenting a risk during a one-off flocking event. Probably due to the similar total number of turbines between the permitted WEF and amended WEF, this number was constant for both.

Results of this process provide an estimate of Brolga collisions with turbines during a flocking event that may occur once every 5 years. For the purposes of deriving an annual average, the results were divided by 5.

A summary of key input values used for turbine collision risk modelling for Brolga flights during one-off flocking events for the permitted WEF and amended WEF is provided in Table 7.

Table 7 - Comparison of input values between permitted WEF and amended WEF used for turbine collision risk modelling of one-off Brolga flocking events

| Comparison of input values between permitted WEF and amended WEF used for collision risk modelling of one-off Brolga flocking events | | |
|---|---|---|
| | **Permitted WEF** | **Amended WEF** |
| **Average duration of one-off flocking events** | 21 days | 21 days |
| **Annual average number of Brolgas at risk** | 40 | 40 |
| **Total number of turbines presenting potential risk** | 20 | 20 |
| **Turbine height below rotor sweep** | 28 metres | 40 metres |
| **Turbine height within rotor sweep** | 28 - 132 metres (104 metre span) | 40 - 180 metres (140 metre span) |
| **Modelled flights at risk below rotor sweep** | 1019 | 1359 |
| **Modelled flights at risk within rotor sweep** | 647 | 906 |

## 5.4 Approach to comparison of internal powerline collision risk modelling for Brolgas of permitted and amended SHWF WEF

As discussed in relation to turbine collision risk, Brolga activity within the area of the SHWF WEF is substantially concentrated on their annual breeding season and assessment of powerline collision risk is for Brolgas during that period.

Brolga utilization rates; analyses of the numbers of Brolgas occupying breeding sites; numbers of flights made by individual Brolgas at breeding sites; and the lengths of flights used for modelling of Brolga powerline collision risk are as outlined here for turbine collision risk.

Data for the lengths of Brolga flights were used to calculate the mean percentage of all flights that would be long enough to reach or cross the powerline, given it runs in a straight line past a breeding site at a specified minimum distance. While the longest flight recorded during the field investigation was 3.2 kilometres, this may have been limited by the capacity of observers to record movements of Brolgas beyond a certain distance (Brett Lane pers. comm.) and longer flights may occur. The data for the numbers of flights of all distances recorded during breeding periods allow extrapolation using a 'decay curve' which indicates that flights may, albeit rarely, be up to 5 kilometres in length.

The average number of individual Brolgas present in breeding territories and that had capacity to fly far enough to reach or cross the powerline was multiplied by the mean number of flights made by an individual bird per breeding season, as supplied from Brolga movement data collected and provided by Brett Lane & Assoc. (2008a). This provided an annual average total for the number of Brolga flights per breeding season.

The internal overhead powerlines for the permitted SHWF WEF are substantially longer than those of the amended SHWF WEF. There are records of 17 Brolga breeding territories within five kilometres of the internal powerlines for the permitted SHWF WEF, whereas a total of 4 Brolga breeding territories are within the same distance of internal powerlines proposed for the amended SHWF WEF. Database records indicate that relatively few breeding territories are occupied in any given year. In dry years such as 2015, none of them may be used. As a consequence of the different configurations of internal powerlines for the permitted and amended WEFs, in modelling for the permitted WEF we have assumed that, on average, 8 of the 17 breeding territories may be occupied by Brolgas in any given year and for the amended SHWF WEF, that on average 2 of the 4 may be occupied in any given year.

A breeding territory will be occupied by a pair of adult birds. 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).

On the basis of the assumptions set out above we have modelled for a mean annual population of 16.8 birds (at 8 breeding sites) that may encounter internal powerlines at the permitted SHWF and for 4.2 birds (at 2 breeding sites) that may do so at the amended SHWF WEF. We have no basis on which to differentiate risk for 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.

A comparison of fundamental differences between the internal powerline assessments of the permitted and amended SHWF WEFs is set out in Table 8.

**Table 8 - Comparison of input values between permitted WEF and amended WEF used for internal powerline collision risk modelling of Brolga flights**

| Comparison of input values between permitted WEF and amended WEF used for internal powerline collision risk modelling of Brolga flights | | |
|---|---|---|
| | **Permitted WEF** | **Amended WEF** |
| **Total number of breeding territories within 5 km of powerline** | 17 | 4 |
| **Average number of breeding territories considered likely to be occupied in a given year** | 8 | 2 |
| **Annual average number of Brolgas at risk** | 16.8 | 4.2 |

Brolga utilization data indicate that on average each bird makes 220 flights during a breeding season.

For the permitted SHWF WEF, the percentage of Brolga flights that might reach or cross the powerline for each territory is shown in the right hand column of Table 9, below. Sites are numbered as per Biosis Research (2009b). The mean percentage of flights that may reach and cross the powerline from the 17 breeding sites is 7.9%

**Table 9 - Distances from centrepoint of breeding site and percentages of Brolga flights with potential to encounter overhead powerlines internal to the permitted SHWF WEF**

| Breeding site | Distance to powerline from territory centre (kilometres) | % of flights crossing the powerline route |
|---|---|---|
| 1 | 1.75 | 4% |
| 2 | 1.59 | 5% |
| 3 | 2.10 | 3% |
| 4 | 0.42 | 17% |
| 5 | 2.19 | 3% |
| 6 | 1.23 | 7% |
| 7 | 1.05 | 8% |
| 8 | 0.19 | 24% |
| 9 | 1.04 | 8% |
| 10 | 1.34 | 6% |
| 11 | 1.17 | 7% |
| 12 | 1.43 | 6% |
| 13 | 1.18 | 7% |
| 14 | 0.45 | 16% |
| 15 | 1.91 | 4% |
| 16 | 1.27 | 7% |
| 17 | 2.32 | 3% |

For the amended SHWF WEF, the percentage of Brolga flights that might reach or cross the powerline for each territory is shown in the right hand column of Table 10, below. Sites are numbered as per Biosis Research (2009b). The mean percentage of flights that may reach and cross the powerline from the 4 breeding sites is 14.0%

**Table 10 – Distances from centrepoint of breeding site and percentages of Brolga flights with potential to encounter overhead powerlines internal to the amended SHWF WEF**

| Breeding | Distance to powerline from territory centre (kilometres) | % of flights crossing the powerline route |
|---|---|---|
| 7 | 0.35 | 18% |
| 12 | 0.90 | 10% |
| 13 | 0.70 | 12% |
| 14 | 0.45 | 16% |

### 5.4.1 Calculation of flights at risk

The total number of Brolga flights per annum was multiplied by the percentage of flights that are of sufficient length to reach or cross the mean distance to the powerline, given that it runs in a straight line past a breeding site at a specified minimum distance.

This calculation provides an annual average number of Brolga flights that might cross the internal powerline route.

Table 11 shows the derived number of flights to and from each of the total of 17 breeding sites that are at risk of encountering internal powerlines under the scenario modelled for the permitted SHWF WEF. The combined total of such flights is an average of 625 per annum.

**Table 11 - Modelled number of Brolga flights at risk of encountering internal powerlines at permitted SHWF**

| Breeding site | Annual number of flights that may encounter internal powerlines |
|---|---|
| 1 | 19.6 |
| 2 | 22.7 |
| 3 | 14.2 |
| 4 | 78.2 |
| 5 | 13.1 |
| 6 | 32.0 |
| 7 | 38.3 |
| 8 | 110.5 |
| 9 | 38.7 |
| 10 | 28.8 |
| 11 | 34.0 |
| 12 | 26.4 |
| 13 | 33.6 |
| 14 | 75.2 |
| 15 | 16.9 |
| 16 | 30.8 |
| 17 | 11.7 |

On the assumption that on average, 8 of the above territories were to be occupied in a given year, the annual average number of flights at risk of encountering powerlines at the permitted SHWF would be 294 (625 / 17 x 8).

Table 12 shows the derived number of flights to and from each of the total of 4 breeding sites that are at risk of encountering internal powerlines under the scenario modelled for the amended SHWF WEF. The combined total of flights to and from these sites is an average of 291 per annum.

**Table 12 - Modelled number of Brolga flights at risk of encountering internal powerlines at amended SHWF**

| Site | Annual number of flights that may encounter internal powerlines |
|---|---|
| 7 | 110.9 |
| 12 | 46.2 |
| 13 | 60.1 |
| 14 | 73.9 |

On the assumption that on average, 2 of the above territories were to be occupied in a given year, the annual average number of flights at risk of encountering powerlines at the permitted SHWF would be 146 (384 / 4 x 2).

Finally, the annual average number of Brolga flights that might cross the powerline route was multiplied by a proportion of powerline crossings that might result in a collision.

On the assumption that every powerline collision results in a fatality, the final value is considered to represent a potential number of Brolga mortalities that could occur per annum.

Based on values provided by Morkill and Anderson (1991), we have calculated that they recorded 2.5 collisions per 100,000 powerline crossings by Sandhill Cranes ($2.5 \times 10^{-5}$ collisions per crossing). Janss and Ferrer (2000) provide estimate values ranging from 1.9 to 4.76 collisions per 100,000 powerline crossings by Common Cranes (from $1.9 \times 10^{-5}$ to $4.76 \times 10^{-5}$ collisions per crossing).

These published studies of cranes are the closest comparable information available for evaluation of the situation for Brolgas. However, we do not know how closely Brolga behaviour conforms to that of these other species. In order to provide a conservation approach we have chosen to use 1 collision per 10,000 powerline crossings ($1.0 \times 10^{-4}$ collisions per crossing) for our evaluation of risk to Brolgas.

Following the methods outlined above we have the following equation to determine a potential annual number of Brolga fatalities that might occur as a result of collisions with the proposed internal overhead powerlines:

- number of birds in the population x 220 flights per bird x relevant percentage of flights that could encounter the powerline x $1.0 \times 10^{-4}$ collisions per powerline crossing.

# 6. Assessment of collision risk for Brolga

Results of modelling scenarios for turbine collision risk for Brolgas at the SHWF WEF are set out below. Results are tabulated for each of the annual breeding season, for annual 'migration' flights from breeding to non-breeding locations within their range, and for an 'average', occasional one-off flocking event near the WEF. The sum of these provides an estimated annual average number of Brolga collisions with turbines that might occur under the scenarios modelled. We consider that these results represent an ecologically reasonable basis for assessment of potential numbers of Brolga collisions with turbines that might occur.

Results are provided for both for the permitted WEF consisting of 157 turbines and for the amended WEF consisting of 149 larger turbines.

For both the permitted WEF and amended WEF the results indicate extremely low risk of collisions under the scenarios modelled. It is worth noting that, to-date, no Brolga collisions are known to have occurred at any wind farm in Australia. In large measure this is undoubtedly due to the small number of operational wind farms within the range of the species, however Brolgas have recently been documented using and even attempting to breed within very close proximity of turbines at the Macarthur Wind Farm in south-western Victoria (Australian Ecological Research Services 2015), so empirical evidence to address the question of turbine collision risk for the species is now accumulating. However at the time of writing there is no strong empirical basis for suggesting a precise avoidance rate for Brolgas in south-western Victoria. Turbine collision avoidance rates for a wide variety of bird taxa are virtually all above 95%, with many being above 98% (e.g. Cook *et al* 2012). We consider that avoidance capacity of Brolgas is likely to be above 95%.

## 6.1 Results of collision risk modelling for permitted WEF

Table 13 shows the estimated annual mortality of Brolgas for 157 permitted turbines (104 metre rotor diameter with 80 metre centre of hub above ground level).

**Table 13 - Estimated annual number of Brolga collisions with turbines and internal overhead powerlines at permitted WEF (157 turbines)**

| Estimated annual number of Brolga collisions with permitted WEF (157 turbines) | | | |
|---|---|---|---|
| **Turbine avoidance rate** | **95%** | **98%** | **99%** |
| ***Breeding season*** | 0.003 | 0.002 | 0.001 |
| ***Migration season*** | 0.021 | 0.011 | 0.008 |
| ***Flocking season*** | 0.033 | 0.017 | 0.012 |
| **Annual average total (turbines)** | **0.057** | **0.030** | **0.021** |
| **Internal overhead powerlines** | | | |
| ***Annual average total (overhead powerlines)*** | **0.029** | **0.029** | **0.029** |
| **Annual average total (permitted WEF)** | **0.086** | **0.059** | **0.050** |

Results of modelling of potential Brolga collisions with permitted internal powerlines indicate that an annual average of 0.029 collisions may occur.

## 6.2 Results of collision risk modelling for amended WEF

Table 14 shows the estimated annual mortality of Brolgas for 149 amended turbines (140 metre rotor diameter with 110 metre centre of hub above ground level).

**Table 14 - Estimated annual number of Brolga collisions with turbines and internal overhead powerlines at amended WEF (149 turbines)**

| Estimated annual number of Brolga collisions with permitted WEF (149 turbines) | | | |
|---|---|---|---|
| **Turbine avoidance rate** | **95%** | **98%** | **99%** |
| ***Breeding season*** | 0.004 | 0.002 | 0.002 |
| ***Migration season*** | 0.030 | 0.016 | 0.011 |
| ***Flocking season*** | 0.046 | 0.024 | 0.017 |
| **Annual average total (turbines)** | **0.080** | **0.042** | **0.030** |
| **Internal overhead powerlines** | | | |
| ***Annual average total (overhead powerlines)*** | **0.013** | **0.013** | **0.013** |
| **Annual average total (permitted WEF)** | **0.093** | **0.055** | **0.043** |

Results of modelling of potential Brolga collisions with the proposed amended internal powerlines indicate that an annual average of 0.013 collisions may occur.

At 95% avoidance rate the annual average projection for the permitted WEF is 0.057 Brolga collisions with turbines per annum. Addition of the modelled annual average of 0.029 collisions with internal powerlines brings this total to 0.086

By comparison, at 95% avoidance rate the annual average projection for the amended WEF is 0.080 Brolga turbine collisions per annum. Addition of the modelled annual average of 0.013 collisions with internal powerlines brings this total to 0.093. On this basis there is little meaningful difference in potential effects of collisions on Brolgas between the permitted and amended SHWF WEF. It is worth noting that projections for both the permitted and amended SHWF WEF indicate that collision risk for Brolgas will likely be measured in single collisions occurring over many years of the WEF operation. For the purposes of demographic analyses (see *Population viability analysis*, below) these values are so low that they require rounding to the same low value to provide for meaningful evaluation.

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## 6.3 Population viability analysis

It is intended that any reduction of the Brolga population resulting from development of the SHWF WEF will be mitigated by management actions (implemented through the preparation of a Bat and Avifauna Management Plan, in accordance with Condition 15 of the Planning Permit) so that there will be, at most, a zero net impact on the population (Brolga Guidelines DSE 2012). A number of recommended refinements to permit conditions 15 and 16 are set out in Appendix A. They are suggested with a view to improving capacity to achieve beneficial effects on threatened and migratory birds and bats, including the Victorian Brolga population. Potential effects of the predicted levels of mortality on the south-western Victorian Brolga population have been assessed on the basis of Population Viability Analysis specifically developed using demographic information for the population (McCarthy 2008a) and subsequently applied to the original SHWF WEF (McCarthy 2008b).

Depending on avoidance capacity of Brolgas, the assessment here indicates that the annual Brolga mortality due to collisions with wind turbines at the amended WEF may be in the range from 0.043 to 0.093. We conservatively choose to use the higher rate of 0.093. On the basis of using a 95% avoidance rate for interactions with turbines and combining the results of that risk assessment with the scenarios modelled for internal overhead powerlines, there is no meaningful difference in the projected rates of Brolga collisions at the permitted and the amended SHWF WEF. There is thus no requirement to undertake separate PVA assessments for the two proposed SHWF WEFs and for the purpose of the PVA assessment the modelled result is rounded to 0.1. This expected average loss of Brolgas thus equates to approximately 1 bird every 10 years, but the frequency distribution of mortalities cannot be predicted.

For the purposes of modelling of the Victorian Brolga population we have assumed that it consists of 600 birds. We are aware that there is some level of uncertainty about the total population and that there is not a routine count available. We understand that up to 900 birds has been counted in one simultaneous count attempt in recent years, however, that count is thought to have included a substantial cohort of juveniles following a particularly good breeding season. While the use of a total population of 600 may be conservative, it also errs on the side of the population being more, rather than less, threatened.

Based on demographics of the Victorian Brolga population, assuming 600 birds, and a combined estimated annual loss of 0.1 birds due to turbine collisions at the amended WEF the population's annual mortality rate would increase by 0.16% per annum. McCarthy (2008b) has estimated the annual fecundity rate of the Victorian Brolga population as 0.025. Thus an increased fecundity rate of 0.02516 would be sufficient to mitigate the modelled impacts of turbine collisions at the amended SHWF on the Victorian Brolga population. In real terms, and without any effect of the potential effects of turbine collisions and to maintain a stable population, for a population of 600 birds that have an average life-expectancy of the Brolga, an annual average fecundity rate of 0.025 equates to 15 fledglings that survive. Increasing this rate to 0.02516 equates to increasing the annual average number of surviving fledglings to 15.1, or 1 additional fledgling every 10 years.

As mentioned by McCarthy (2009), the increase required to compensate for the expected loss in the Victorian Brolga population is very small and is unlikely to be measurable with precision. Within the Victorian population of approximately 600 birds, this level of impact is very small and would be masked by natural demographic variability. As noted above, the collision estimates are so low that they require rounding to provide for a meaningful evaluation in a population model. As a consequence there is no distinction in PVA results for the permitted WEF and the amended WEF. Nonetheless, it is intended that there should be no net impact on this vulnerable population and the present work is aimed at informing subsequent decisions about measures to be implemented to ensure that is achieved. These are discussed in Section 7 *Potential offset & mitigation options*.

# 7. Potential offset & mitigation options

All management to reduce potential effects of the amended SHWF WEF on birds and bats will be set out in a detailed Bird and Bat Management Plan to be prepared in accordance with Condition 15 of the Permit.

## 7.1 Options for Brolgas

The Brolga Guidelines (DSE 2012) describe the purpose of offsetting (or mitigation) measures as *"to increase the population growth rates or reduce another source of mortality commensurate with the increased mortality expected to result from the wind farm's operation, thereby cancelling out impact of the wind farm on the Victorian Brolga population"*.

The Guideline suggests a number of possible measures that may achieve this end, including marking of powerlines to reduce Brolga mortality due to powerline collisions and various methods of protection and enhancement of Brolga breeding sites.

The Guideline also suggests that where there is a lack of information about effectiveness of measures, the implementation of any measure should be accompanied by a program aimed at quantifying its effectiveness.

The results of turbine collision risk assessment and population viability analysis detailed above provide an indication (under the assumptions described) of potential mortalities due to turbine collisions and the number of additional birds required to be recruited into the Victorian population to ensure compensation such that there is no net impact on it. As detailed above, the numbers of Brolgas likely to collide with turbines and the number required to compensate for them, are extremely low and, to the point where they may not be measurable in the real situation. That being the case, it is considered that the best approach will be to determine an agreed level of measures to be implemented that offset the estimated impact and that will be beneficial to the Brolga population regardless of whether collisions are detected at the operational SHWF. This concept has precedent in the approach adopted for Orange-bellied Parrots *Neophema chysogaster* at Bluff Point and Studland Bay Wind Farms in Tasmania. If at any time during the operational life of the SHWF WEF, collisions occur at a higher rate than suggested by our modelling, that would trigger an increase in offset and/or mitigation measures of the kind recommended below.

### 7.1.1 Reducing powerline collisions as an offset measure

Condition 15 of the Permit for the permitted SHWF requires marking of the uppermost wires of new overhead powerlines required to service the WEF, that pass within 3 km of all breeding sites known to have been occupied by Brolgas within the last 20 years. This is considered to represent a mechanism aimed at reduction of additional mortalities caused by the overhead powerline itself and not mitigation for other impacts of the wind farm such as turbine collisions.

The following discussion is focused on the potential to compensate for Brolga mortalities that might occur due to the amended SHWF WEF, including those that may occur due to collisions with turbines and internal overhead powerlines by reducing Brolga collisions at locations outside of the project area.

Martin & Shaw (2010) investigated the question of why birds collide with powerlines and determined that the forward vision of cranes is such that it may significantly limit their ability to detect powerlines. They showed that the visual fields of such birds are very different from those of humans. That is likely because, amongst other things, they have evolved to fly in the open sky where there are few obstacles to avoid.

Brolga collisions with powerlines have been reported from Victoria (Goldstraw & Du Guesclin 1991) and marking of powerlines has been demonstrated to reduce collisions by cranes in some overseas studies (e.g. Brown & Drewien 1995, see also review in Barrientos *et al.* 2011). Management to reduce Brolga collisions with powelines is one option to offset Brolga mortalities that may occur due to collisions with turbines at the amended SHWF.

Burial of single-strand overhead distribution powerlines would be a complete resolution to powerline collision risk at key locations. It may be applicable to some existing distribution lines in close proximity to Brolga flocking or breeding sites.

In a study of Sarus Cranes *Antigone antigone* (the most closely related species of crane to the Brolga) by Sundar & Choudhury (2005), collisions with low voltage distribution lines occurred more frequently per unit of powerline length than they did with larger, higher voltage lines. In line with this, marking of electricity distribution lines near well-used flocking sites anywhere within the Victorian Brolga population's range is a measure that could be applied to reduce net negative effects of anthropogenic sources of impacts on the Brolga population.

Some types of line markers designed to increase the visibility of wires, have been shown to substantially reduce incidence of collision. Morkill & Anderson (1991) measured reactions of Sandhill Cranes *Grus canadensis* to marked and unmarked lines, rather than differences in mortality rates. Markers were 30 centimetre yellow balls with black stripes positioned at 100 metre intervals. Cranes were significantly more likely to increase altitude in response to marked versus unmarked lines and initiated their change in height further away from the lines.

Alonso *et al.* (1994) measured differences in mortality rates of Common Cranes *Grus grus* at marked and unmarked powerlines. Markers were red PVC spirals 1 metre long with 30 centimetres maximum diameter positioned on groundwires at 10 metre intervals. They found that collisions by all bird species decreased by 61% after the installation of markers. Their sample size for cranes appears too small for the difference to be statistically significant but collisions were lower for marked lines.

Janss and Ferrer (1998) measured differences in mortality rates of various bird species for three different line markers. Results for Common Crane were only recorded with white PVC spirals 1 metre long and 30 centimetres maximum diameter positioned on groundwires at 10 metre intervals. Results were *"convincing (eight dead under unmarked spans, one under marked span) but not significant".*

It is likely that appropriate marking of powerline wires would reduce the frequency of Brolga collisions with powerlines, but that has not been tested for this species. In addition, Brolga collisions with powerlines are infrequent and unpredictable across the wide south-western Victorian distribution of the species and there is no meaningful way to measure the actual value of marking powerlines.

### 7.1.2 Protection & enhancement of breeding sites

Other actions that could be undertaken to offset potential effects of the amended SHWF on Brolgas include rehabilitation of previous breeding wetlands that are now drained for agriculture or habitat improvement and enhanced protection of known or potential breeding sites. For SHWFPL, these measures could include funding of protective measures to be undertaken by landowners with Brolga breeding habitat on their property or the preparation and funding of management plans for breeding sites. It could also include revegetation, weed control, targeted fox control around breeding sites to reduce predation of chicks and manipulation of local hydrology to increase volume and reliability of wetland watering. Long-term benefits can be obtained by placement of covenants for appropriate management on land titles.

## 7.1.3 Recommended measures for Brolgas

Condition 15(c) of the Permit requires that the contribution of all mitigation and offset measures to be implemented should be evaluated in light of metrics that allow their effectiveness to be quantified. For most of the possible management measures that have been suggested we consider that it will be extremely difficult, or realistically impossible, to measure their effects on the Brolga population.

It is an underlying ecological principle that the Victorian Brolga population is limited in a density dependent manner by availability of resources such as suitable breeding sites and food. As a consequence, management actions such as these that do not alter density-dependant limitations cannot improve the overall conservation status of the population. They can also provide an offset only during the period in which they operate and they have high implementation and maintenance costs.

By comparison, rehabilitation and protection of a breeding wetland has capacity to increase the overall population of Victorian Brolgas and can be expected to provide such a beneficial effect in the long-term. Effectiveness of wetland rehabilitation can be readily measured by its use and breeding success of Brolgas. We recommend that rehabilitation and protection of a breeding wetland be given priority in consideration of offset options for any deleterious effects of the amended SHWF WEF on the Brolga population.

Given the intention of no net impact on the Victorian Brolga population, we recommend that beneficial management activities will be most effective at locations within the species range where deleterious anthropogenic effects are relatively low.

The specifics of offset and mitigation actions will be developed in consultation with DELWP and should be included in revised conditions of a Planning Permit for the amended SHWF. A series of amendments to the bird and bat related conditions of the Permit are recommended to be included in the amendment application and are set out in Appendix A. The adjustments suggested are aimed at increased emphasis on listed threatened taxa and on focussing conditions onto the population-level effects of the SHWF WEF on those taxa. For example, it is recommended that threshold levels for collision mortalities that would invoke management or mitigation measures should be set in response to the effect they might have on functioning of the population or conservation status of the threatened species involved. This will increase certainty for the wind farm operator and for regulators. We consider it will also facilitate better capacity for learning which may be of value for future wind farm proposals.

## 7.1.4 Options for other threatened & migratory bird and bat taxa

A program of monitoring for turbine collisions by all listed threatened and migratory taxa will be undertaken during an initial period of operation of the SHWF WEF. The primary objective of that program will be to determine whether significant impacts on key threatened and migratory species occur as a result of the operations of the amended SHWF.

Conditions for the permitted SHWF WEF require a regime of monitoring for turbine collisions. We recommend that specific thresholds at which wind farm management or other mitigation measures should be set out in a Bird and Bat Management Plan for the WEF. We suggest that, In principle these should reflect the levels that would constitute a significant impact, as defined in published EPBC Act policies. No criteria for significant impacts on species listed only under the FFG Act or DEPI Advisory List (2013) are available but we consider that the same criteria as used for EPBC Act-listed taxa should be used.

The assessment detailed here is that significant impacts on any listed threatened or migratory taxa are unlikely to result from operation of the amended SHWF. If they were to occur then appropriate offsetting strategies will be developed in consultation with DELWP, through the preparation of a Bat and Avifauna Management Plan in accordance with Condition 15 of the Permit. In light of the diversity of any listed threatened and migratory species it is not practical to consider specific strategies here. Any such measures should be determined on a case-by-case basis and should be proportional to the level of mortality incurred. They should be targeted towards positive conservation outcomes for any affected taxon.

# 8. Biodiversity legislation and government policy

This section provides an assessment of the SHWF WEF in relation to key biodiversity legislation and government policy. This section does not describe the legislation and policy in detail.

## 8.1 Commonwealth

### 8.1.1 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act applies to developments and associated activities that have the potential to significantly impact on Matters of National Environmental Significance protected under the Act.

Matters of National Environmental Significance relevant to the amended WEF are summarised in Table . It includes an assessment against the EPBC Act policy statements published by the Australian Government which provide guidance on the practical application of EPBC Act.

**Table 15 - Assessment bird and bat species that are Matters of National Environmental Significance under the EPBC Act**

| Matter of NES | Project specifics | Assessment against significant impact guidelines |
|---|---|---|
| **Threatened species** | Six species have been recorded or are listed on the PMST as having potential to occur in the project search area. The likelihood of these species occurring in the study area is assessed in Section 4.3.1. | The likelihood of five of these species occurring in the local area is considered to be negligible or low and no listed threatened species are permanent residents of the region.<br><br>Past records indicate that one species, Curlew Sandpiper, occasionally visits the study area when shallow wetlands contain water. This does not occur regularly and the wetlands are not considered to constitute important habitat for this species.<br><br>Our assessment is that there is no material difference between development and operation of the permitted and the amended SHWF WEF. Neither is considered likely to result in a significant impact on any listed threatened species. |
| **Migratory species** | Twenty-one species have been recorded or are listed on the PMST as having potential to occur in the project search | The likelihood of three of these species occurring in the local area is considered to be negligible or low. |

| Matter of NES | Project specifics | Assessment against significant impact guidelines |
|---|---|---|
| | area. The likelihood of these species occurring in the study area is assessed in Section 4.3.2. | Eight of the relevant species are migratory shorebirds. While some of these are known to use local shallow wetlands occasionally when they contain water, this does not occur regularly and the wetlands are not considered to constitute important habitat for these species.<br><br>When and where habitat is available within the local area, it does not provide for an ecologically significant proportion of any of the relevant migratory species.<br><br>Our assessment is that there is no material difference between development and operation of the permitted and the amended SHWF WEF. Neither is considered likely to result in a significant impact on any listed migratory species. |

On the basis of criteria outlined in the relevant *Significant Impact Guidelines* it is considered unlikely that a significant impact on any species of bird or bat that is a Matter of National Environmental Significance would result from the proposed development of the SHWF WEF.

## 8.2 State

### 8.2.1 Flora and Fauna Guarantee Act 1988

The FFG Act is the key piece of Victorian legislation for the conservation of threatened species and communities and for the management of potentially threatening processes. However, there is no applicable permit requirement under the Act for impacts on species of fauna listed as threatened under the Act on any land tenure. Decision-makers are recommended to give consideration to requirements of listed threatened species when assessing development proposals.

### 8.2.2 Environment Effects Act 1978

The Environment Effects Act 1978 (EE Act) provides for assessment of proposed projects (works) that are capable of having a significant effect on the environment. The Act does this by enabling the Minister administering the Environment Effects Act to decide that an Environment Effects Statement (EES) should be prepared. Criteria for what may constitute a significant effect, and hence whether an EES may be required, are provided in *Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978* (DSE 2006). The following criteria are relevant to the present assessment of birds and bats:

- Potential long term loss of a significant proportion (e.g. 1 to 5 percent depending on the conservation status of the species) of known remaining habitat or population of a threatened species within Victoria
- Matters listed under the Flora and Fauna Guarantee Act 1988:
  - potential loss of a significant area of a listed ecological community; or
  - potential loss of a genetically important population of an endangered or threatened species (listed or nominated for listing), including as a result of loss or fragmentation of habitats; or
  - potential loss of critical habitat; or,
  - potential significant effects on habitat values of a wetland supporting migratory bird species.

On the basis of these criteria the assessment here considers that there is no likely difference between effects of the permitted and the amended SHWF WEFs on the Victorian Brolga population and it is unlikely that a significant impact on any species of bird or bat will result from development of the amended SHWF WEF.

# 9. Conclusion and recommendations

We consider that differences between the permitted and amended SHWF WEFs in their potential effects on birds and bats are insignificant. The assessment does not consider there is any likelihood of either the permitted WEF or the amended WEF resulting in a significant impact on any species listed as threatened under the EPBC Act or the FFG Act.

The assessment also does not consider there is any likelihood of either the permitted WEF or the amended WEF project resulting in a significant impact on any species listed as migratory under the EPBC Act.

The assessment also does not consider there is any likelihood of either the permitted or the amended SHWF WEF resulting in a significant effect on any species of bird or bat, or on their habitats, under the criteria for significant effects as defined for purposes of the EE Act.

Collision risk modelling and population viability analysis for scenarios encompassing potential activities of Brolgas that may represent a risk of collisions with turbines and with internal overhead powerlines at the permitted WEF and amended WEF have been undertaken. The results indicate low risk of collisions and that compensatory measures can be designed to achieve no net impact on the Victorian Brolga population.

We recommend that rehabilitation and protection of a breeding wetland should be given priority in consideration as an offset for any deleterious effects WEF on the Brolga population that may occur due to turbine collisions at the amended SHWF. However specifics of any offset measures will need to be determined in consultation with regulatory authorities, including DELWP and DoE, through the preparation of a Bat and Avifauna Management Plan in accordance with Condition 15 of the Permit.

## Glossary

| | Description |
|---|---|
| **Amended project** | Permitted project, amended as per changes described in Section 2.3 of this report. |
| **BAM Plan** | Bird and Bat Management Plan |
| **Brolga Guideline** | *Interim Guidelines for assessment, avoidance mitigation and offsetting of potential wind farm impacts on the Victorian Brolga Population 2011* (Revised 1 February 2012) |
| **DELWP** | Department of Environment, Land, Water and Planning (formally, Department of Planning and Community Development, and Department of Sustainability and Environment) |
| **DoE** | Commonwealth Department of the Environment |
| **DSE** | (former) Department of Sustainability and Environment |
| **EE Act** | Environment Effects Act 1978 |
| **EPBC Act** | Environment Protection and Biodiversity Conservation Act 1999 (Cth) |
| **EPBC Act Approval** | Decision (2009/4719) to approve the WEF (as a controlled action) was made under the *EPBC Act 1999* |
| **FFG Act** | Flora and Fauna Guarantee Act 1988 |
| **P&E Act** | Planning and Environment Act 1987 |
| **Permit conditions** | Conditions 15 and 16 of Planning Permit No. PL-SP/05/0548 (Pyrenees Planning Scheme) |
| **Permitted project** | Project permitted by the Permit (Planning Permit No. PL-SP/05/0548 Pyrenees Planning Scheme)) |
| **PVA** | Population Viability Analysis, a quantitative process for modelling change in natural populations. |
| **SHWF** | Stockyard Hill Wind Farm |
| **SHWFPL** | Stockyard Hill Wind Farm Pty Ltd |
| **the Permit** | Planning Permit No. PL-SP/05/0548 (Pyrenees Planning Scheme) issued by the Minister for Planning in October 2010 to enable the use and development of the SHWF |
| **WEF** | Wind Energy Facility |
| **Wind farm boundary** | Land referenced in 'Address of the Land' in the Permit. |
| | |

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# Appendices

# Appendix A – Planning Permit Conditions

Note: in addition to recommended refinements to permit conditions, it is also suggested that the sequence of conditions is adjusted so that conditions with a common theme (i.e, those related to monitoring of turbine collisions; those to monitoring of bird usage of the site; and those related to mitigation measures, are together. Condition numbering here remains as per existing permit.

| Condition | Proposed Amendments | Reason |
|---|---|---|
| **Condition 15 Bats and Avifauna** | Before the development starts, a Bat and Avifauna Management Plan (BAM Plan) must be prepared in consultation with the **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~Department of Sustainability and Environment~~ to the satisfaction of the Minister for Planning. When approved the plan will be endorsed and will then form part of the permit. The use must thereafter accord with the endorsed plan to the satisfaction of the responsible authority on the advice of **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~DSE~~. | Administrative Improvement - reference to department name |
| | The BAM Plan must include: | |
| | a) a statement of the objectives and overall strategy for managing and mitigating ~~any~~ significant **impact on** bird and bat ~~strike~~ **taxa listed as threatened under the EPBC Act or the FFG Act due to collisions** arising from the wind energy facility operations. **Definition of 'significant impact' will be to the satisfaction of the Secretary to the Department as constituted under Part 2 of the Conservation, Forests and Lands Act 1987 and in accordance with policies published by the Australian Government for the EPBC Act.**; | Refined with a view to focus on threatened taxa and provide definition of important criteria. |

| Condition | Proposed Amendments | Reason |
|---|---|---|
| | b) a comprehensive science-based ~~bird and bat~~ monitoring program **designed to detect and document collisions with turbines by listed threatened bird and bat taxa** must be developed to the satisfaction of the Minister for Planning upon the advice of **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~DSE~~. Threshold levels for bird and bat mortality should also be established in the BAM for the wind farm and if exceeded agreed mitigation measures are to be put in place. **Threshold levels will be determined in accord with criteria defining significant impacts as defined.** | Refined with a view to focus on threatened taxa and provide definition of important criteria. |
| | h ) procedures for the reporting of any strikes **of listed threatened or migratory birds and bats** to the **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~Department of Sustainability and Environment~~ within 7 days of becoming aware of any strike. | **Conditions h), i), j) and k of the permit have been inserted here for continuity as they relate to bird & bat strikes to be monitored as set out in condition b).**<br><br>Refined with a view to focus on threatened taxa and administrative improvement - reference to department name. |
| | i) information on the efficacy of searches for carcasses of birds and bats, and, where practicable, information on the rate of removal of carcasses by scavengers, so that correction factors can be determined to enable **quantified estimates to be made** ~~calculations~~ of the total number of mortalities. | Improved clarity. The process can only provide estimates within a defined range. |
| | j) procedures for the regular removal of carcasses likely to attract raptors to areas near turbines. | No amendments proposed. |
| | k) procedures for periodic reporting, within agreed timeframes, of the findings of the monitoring to the **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~Department of Sustainability and Environment~~ and the local community. | Administrative Improvement - reference to department name. |

| Condition | Proposed Amendments | Reason |
|---|---|---|
| | d) measures to avoid brolga collision with powerlines such as marking the upper most wires of sections of the powerline that pass within 3kilometre of all breeding sites known to have been occupied by brolgas within the past 20 years. | No amendments proposed. |
| | e) the development of a contingency turbine shut down protocol in the event of a major migration of shorebirds to and from Lake Goldsmith to the satisfaction of the Minister for Planning on the advice of **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~DSE~~. **Definition of 'major migration' will be to the satisfaction of the Secretary to the Department as constituted under Part 2 of the Conservation, Forests and Lands Act 1987.** | Refined with a view to provide definition of important criteria and administrative Improvement - reference to department name |
| | f) an evaluation of the likely effects of the wind farm on the Sharp-tailed Sandpiper to be undertaken in accordance with EPBC Act Policy Statement 3.21. | No amendments proposed |
| | g) a comprehensive science-based **program for** monitoring ~~program~~ **use of the wind farm site by listed threatened and migratory** ~~for~~ bats and bird **taxa** ~~species~~ of at least 2 years' duration from the commissioning of the last turbine of the first stage of the development or alternatively such other time of commencement as is to the satisfaction of the Minister for Planning. The monitoring program must be to the satisfaction of the Minister for Planning upon the advice of **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~DSE~~. | Refined with a view to focus on threatened taxa and administrative improvement - reference to department name. |
| | The monitoring program must include surveys during breeding and migratory seasons to ascertain: | No amendments proposed. |
| | § the location of potentially at risk Brolga breeding, migration and flocking activities; | No amendments proposed. |

| Condition | Proposed Amendments | Reason |
| --- | --- | --- |
| | § the species, number, age, sex (if possible) and date of any **listed threatened and migratory** bird or bat strike; | Refined with a view to focus on threatened & migratory taxa. |
| | § any seasonal and yearly variation in the number of **listed threatened and migratory** bird and bat strikes; | Refined with a view to focus on threatened & migratory taxa. |
| | § whether further detailed investigations of any potential impacts on **listed threatened and migratory** birds and bats are warranted. | Refined with a view to focus on threatened & migratory taxa. |
| | c) a mitigation plan for Brolga to the satisfaction of the Minister for Planning on the advice of **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~DSE~~ that includes ~~a program of powerline marking (in accordance with d) below) and evaluation and~~ a program to develop metrics to enable the assessment of the contribution of all mitigation and offset measures that are proposed for implementation. | As discussed in Section 7 of this report, it is considered that measures other than marking of powerlines will allow better outcomes for Brolga conservation. |
| | ~~h) procedures for the reporting of any bird and bat strikes to the **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** Department of Sustainability and Environment within 7 days of becoming aware of any strike.~~ | **Conditions h), i), j) and k) of permit are proposed to be moved for continuity to position immediately following condition b).** |
| | ~~i) information on the efficacy of searches for carcasses of birds and bats, and, where practicable, information on the rate of removal of carcasses by scavengers, so that correction factors can be determined to enable calculations of the total number of mortalities.~~ | **Conditions h) , i), j) and k) of permit are proposed to be moved for continuity to position immediately following condition b).** |
| | ~~j) procedures for the regular removal of carcasses likely to attract raptors to areas near turbines.~~ | **Conditions h), i), j) and k) of permit are proposed to be moved for continuity to position immediately following condition b).** |
| | ~~k) procedures for periodic reporting, within agreed timeframes, of the findings of the monitoring to the **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** Department of Sustainability and Environment and the~~ | **Conditions h), i), j) and k) of permit are proposed to be moved for continuity to position immediately following condition b).** |

| Condition | Proposed Amendments | Reason |
| --- | --- | --- |
| | ~~local community.~~ | |
| | ~~l) recommendations in relation to threshold mortality rates for specified species which if exceeded would trigger the requirement for responsive mitigation measures to be undertaken by the operator of the wind energy facility to the satisfaction of the Minister for Planning.~~ | **Conditions l) and m) appear to repeat condition b) and are suggested to be deleted.** |
| | ~~m) implementation measures developed in consultation with the **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** Department of Sustainability and Environment to offset any impacts detected during monitoring including turbine operation management and on-site or off-site habitat enhancement (including management or improvement of habitat or breeding sites).~~ | **Conditions l) and m) appear to repeat condition b) and are suggested to be deleted.** |
| **Condition 16 Bats and avifauna** | Following the completion of the monitoring program of at least 2 years duration as specified in Condition 15 (g), a report must be prepared by the operator of the wind energy facility setting out the findings of the program to the satisfaction of the Minister for Planning. If, after consideration of this report, the Minister for Planning directs that further investigation of potential or actual impacts on **listed threatened and migratory** birds and bats is to be undertaken, the extent and details of the further investigation must be to the satisfaction of the **Secretary to the Department as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*** ~~Department of Sustainability and Environment~~ and the investigation must be carried out to the satisfaction of the Minister for Planning. | Refined with a view to focus on threatened taxa and administrative improvement - reference to department name. |

# Appendix B – Description of the Biosis collision risk model

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*Wind Energy and Wildlife Conservation*

# A Description of the Biosis Model to Assess Risk of Bird Collisions With Wind Turbines

**IAN SMALES,**[1] *Biosis Propriety Limited 38, Bertie Street, Port Melbourne, Vic. 3027, Australia*
**STUART MUIR,** *Symbolix Propriety Limited, 1A/14 Akuna Drive, Williamstown North, Vic. 3016, Australia*
**CHARLES MEREDITH,** *Biosis Propriety Limited 38, Bertie Street, Port Melbourne, Vic. 3027, Australia*
**ROBERT BAIRD,** *Biosis Propriety Limited 38, Bertie Street, Port Melbourne, Vic. 3027, Australia*

**ABSTRACT** We describe the model of Biosis Propriety Limited for quantifying potential risk to birds of collisions with wind turbines. The description follows the sequence of the model's processes from input parameters, through modules of the model itself. Aspects of the model that differentiate it from similar models are the primary focus of the description. These include its capacity to evaluate risk for multi-directional flights by its calculation of a mean presented area of a turbine; its use of bird flight data to determine annual flux of movements; a mathematical solution to a typical number of turbines that might be encountered in a given bird flight; capacity to assess wind-farm configurations ranging from turbines scattered in the landscape to linear rows of turbines; and the option of assigning different avoidance rates to structural elements of turbines that pose more or less risk. We also integrate estimates of the population of birds at risk with data for numbers of their flights to predict a number of individual birds that are at risk of collision. Our model has been widely applied in assessments of potential wind-energy developments in Australia. We provide a case history of the model's application to 2 eagle species and its performance relative to empirical experience of collisions by those species. © 2013 The Wildlife Society.

**KEY WORDS** bird, collision, model, risk, turbine, wind energy.

A number of mathematical models have been developed for the purposes of either describing the interaction of a bird with a wind turbine or to predict the risks of bird collisions with turbines (Tucker 1996*a*, *b*; Podolsky 2003, 2005; Bolker et al. 2006; Band et al. 2007). Tucker (1996*a*, *b*) and Band et al. (2007) detailed their models in the peer-reviewed literature. The collision risk model developed by Biosis Propriety Limited has been widely used to assess wind-energy developments in Australia since 2002, but it has not previously been described in detail. Given high levels of interest in effects of wind turbines on fauna, we believe it is important for the model to be accessible.

Our model provides a predicted number of collisions between turbines and a local or migrating population of birds. It has the potential to be modified to accommodate Monte-Carlo simulation, although at its core it uses a deterministic approach. It is modular by design, and allows various customizations, depending upon the unique configuration of the wind facility and characteristics of the taxa modeled.

The initial calculation involves species-specific parameters for speed and size of birds and specifications of the turbine, including its dimensions and rotational speed of its blades. Using these parameters, we derive the mean area of turbine presented to a bird in flight. This allows the model to accommodate flight approaches from any potential direction. Alternatively, unidirectional flights can be modeled by using the relevant turbine surface area presented to birds approaching from a given direction.

Data for bird flights are collected at the wind-farm site according to a specific and consistent field methodology. These data are used to determine the flux (density) of bird flights. When combined with turbine specifications, this yields the probability of collision during a single flight–turbine interaction. The density flux approach has not been used for this application previously.

The number of movements at risk of collision with one turbine is then scaled according to a typical number of turbines that a bird might encounter in a given flight. This is further refined by a metric for the capacity of the particular species to avoid collisions. Where a population census or estimate is available for the number of birds that may be at risk, a further deduction is used to attribute the number of flights-at-risk to individuals, and hence provide a final model output as the number of individuals at risk of collisions. The ability to transform from flights-at-risk to individuals-at-risk has been uniquely developed and applied as a routine component of our model.

## DESCRIPTION OF THE MODEL

The model requires data for input parameters and, using these, functions in a sequence of modules (Fig. 1).

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[1]*E-mail: ismales@biosis.com.au*

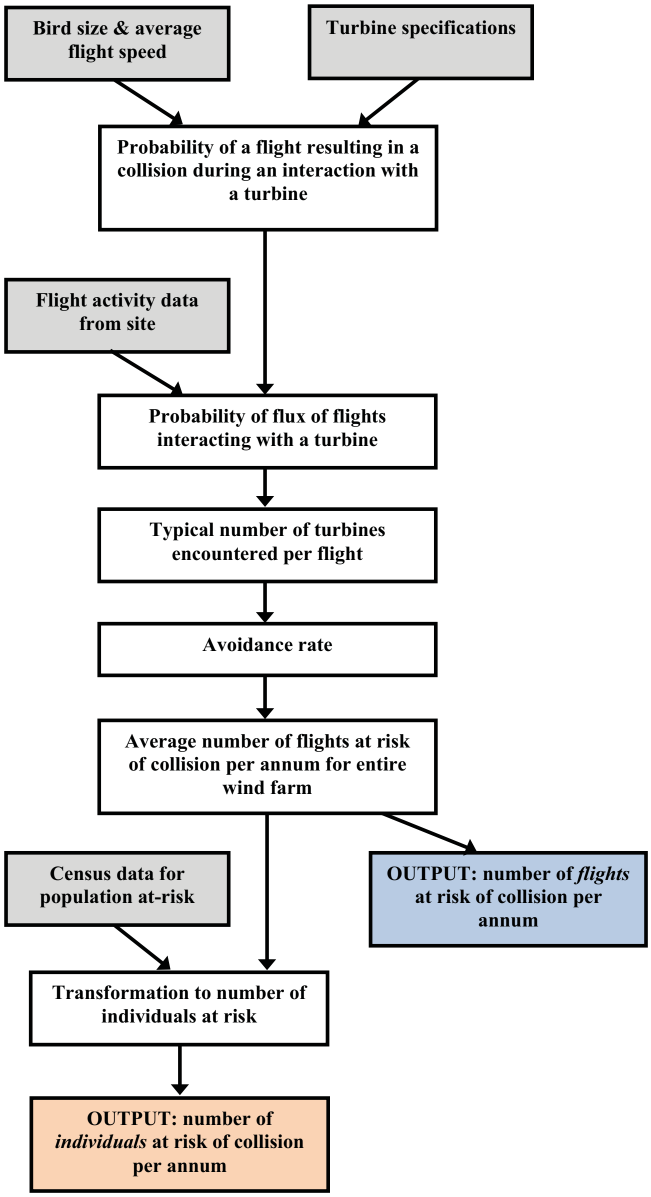


**Figure 1.** Overview of the collision risk model that quantifies risk to birds of colliding with wind turbines, showing input parameters (gray boxes), modules, and sequence.

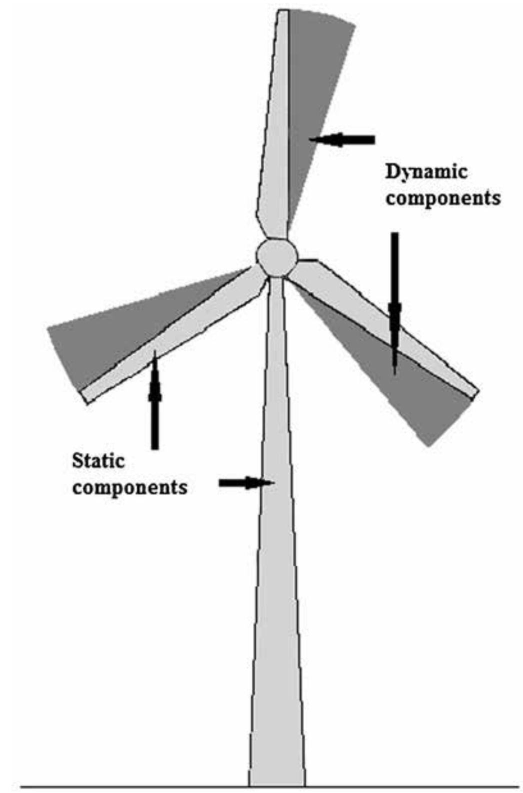


**Figure 2.** Schematic indication of the static and dynamic components of a wind turbine that may be encountered by a flying bird. The dynamic component is the area swept by rotor blades during the time that a bird of a particular species would take to pass through the rotor-swept zone.

## Model Inputs

*Turbine parameters.*—The primary risk faced by a flying bird, whether it may strike or be struck by a turbine, is that the machine presents a potential obstacle in its path. Ultimately this equates to the surface area of the turbine presented to the bird from whatever its angle of approach. Other models, such as probably Band et al. (2007), use individualistic representations of birds. Our model uses a projection of the presented area onto all possible flight angles. For this reason, multiple dimensions of turbine components and rotor speed for the particular type of turbine are used as input values to the risk model. Turbine specifications are as provided by the machine's manufacturer.

The modeled wind turbine consists of 2 fundamental components representing potentially different risks. We refer to these as the static and dynamic components (Fig. 2). The static areas of a turbine include all surfaces of the entire machine comprising a tower, which in current turbines is a simple taper with known base and top diameters; a rectangular nacelle housing the generator; a hemi-spherical hub; and rotor blades that taper in 2 planes. The dynamic component is the area swept by the leading edges of rotor blades during the time that a bird would take to pass through the rotor-swept zone.

*Size and flight speed of birds.*—For each taxon, the model requires values for the total length of the bird in flight, from bill tip to tip of the tail or outstretched legs, and the average speed of the species' flights. We obtained bird lengths either from museum specimens or from standard ornithological texts.

Accurate determinations of bird flight speeds can be complex and difficult to obtain (Videler 2005, Pennycuick 2008) and published data are not available for most species. However, published radar studies (e.g., Bruderer 1995, Bruderer and Boldt 2001) provide ranges of flight speeds for a variety of species, including congenerics with similar morphologies and ecological traits to a number of species we have assessed. Use of radar to collect bird flight data at the wind-farm site may provide flight speeds for species of interest. We consider that average ground speed (as opposed to air speed) is appropriate for modeling of multidirectional movements of birds.

*Bird flight data.*—The model requires data from the wind-farm site for the number of flights made by species of interest within a measured time and volume of airspace. Movement data may be obtained from fixed-time point counts using a methodology adapted from Reynolds et al. (1980), incorporating an effective detection range (Buckland et al. 1993). It may be collected by human observers or by using horizontal and vertical radar combined with call recording or visual species identification (e.g., Gauthreaux and Belser 2003, Desholm et al. 2006). Data represent the number of flights that birds make within a cylinder of airspace that is centered horizontally on the observer and the height of which is the maximum reached by rotor blades of the turbines. The data collection regime is designed with the aim of providing a representative sample of flight activity across the local range of diel, seasonal, and other environmental variables.

**Model Modules**

*Probability of a single flight interacting with a turbine.*—In some situations, such as during highly directional migratory passage, the presented area of turbines is determined from the angle of the birds' flight relative to the compass orientation of turbines. However, for the great majority of species (including temporary or permanent residents at an on-shore wind farm) this does not apply, and flights can be expected to approach turbines from any direction. For this situation, all dimensions of the turbine contribute to the area with which a flying bird might collide and the model uses a simple integration to determine a mean presented area. This represents a substantial advance over other collision risk models that depend on the assumption of a specific angle of approach as a bird encounters a turbine (e.g., Tucker 1996*a*, *b*; Bolker et al. 2006; Band et al. 2007).

We calculate the area presented by the static components of a turbine using a conservative assumption that none of them overlap or obscure any others. The area of each component is calculated individually, and these are then summed to determine a total static area for the turbine. Static areas are calculated from the simple length $\times$ width dimensions of all components visible by line of sight. These are then projected onto an arbitrary approach direction (effectively scaling by the cosine of the approach angle). For example, viewed directly from one side, only the side panel of the nacelle is visible. However, approached from 45° to the turbine, both the front and side panels are visible, and are thus scaled by $\cos(45)\varrho 1/\sqrt{2}$ to match that particular angle of view.

We calculate the dynamic area, swept during the movement of blades, from the dimensions of the stationary blades and the distance they travel at their average speed during the time taken by a bird to fly through the rotor-swept area. We assume that all flights involve forward movement, so the swept-area is derived from the length and speed of the particular species of bird, in combination with the thickness of the sweeping blade.

Each rotor blade is tapered in 2 planes. Thus the thickness of the blades, used to determine the time taken for a bird to cross through the swept area, is actually a function of the point in the rotor radius at which an individual bird's flight intersects the swept area. This presents a complication that we overcome by defining an effective blade, which is a simple rectangular cross-section that sweeps out precisely the same volume of space as the physical blade. In doing so, we calculate a constant thickness of blade that accounts for the fact that the thinner tips actually sweep far more space than the thicker base of the blade. This ensures also that our flux calculation is not compromised by introduction of a spatial variation at odds with other aspects of the model.

A further input parameter is the percentage of time per annum when rotors are not turning due to inappropriate wind speeds and routine turbine maintenance. Prior to commissioning of a wind farm, wind speed data are usually gathered and the expected percentage of downtime due to inappropriate wind speeds is determined. During downtime periods the rotor simply stops turning; and so risks associated with dynamic components only are reduced by this percentage of time, while all static components of the turbine remain as potential obstacles to flying birds.

*Combining all presented areas of the turbine.*—Modeling for multidirectional bird movements requires no dependence on approach angles nor on complexities of interactions between flight direction and wind direction. We thus reduce the turbine to its mean presented area. This is solved by the equation

$$\frac{1}{\pi}\int_{0}^{\pi} A(\theta)\,\mathrm{d}\theta$$

where $A$ is the presented area of the turbine as a function of approach angle $\theta$. We solve this numerically using a trapezoidal integrator (Press et al. 1992).

*Probability of multiple flights interacting with a turbine.*—Because counts of bird flights have been made across the wind-farm site and there is no obligatory relationship between point-count locations and particular sites proposed for turbines, we combine the data collected from all point counts. This provides a measure of flight activity, which is assumed to be constant across the site. Thus the field data reduce to a single ratio value for the subject species, which is the sum of all flights documented during all counts divided by the total time of observations. This equates to a maximum likelihood estimation of the mean of an assumed Poisson distribution.

To calculate a number of flights at risk of collision, we first reduce documented bird movements ($M$) to a measure of flux ($F$) using the equation

$$F = \frac{M}{T_{\mathrm{obs}} A_{\mathrm{obs}}}$$

where $T_{\mathrm{obs}}$ is the combined total time of all point counts and $A_{\mathrm{obs}}$ is the area of the vertical plane dissecting the observation cylinder. This flux is a measure of bird movements per time per square meter of vertical airspace. The third dimension, volume of airspace, is redundant (or tacit) due to the assumption that, unless involved in a collision, flight paths do not end arbitrarily in space.

We next multiply activity measure by the number of minutes in which the species is active during the 24-hour diel period, T, and the total presented area of the turbine, A. For year-round resident species, the "active minutes" are calculated for the entire year, while for seasonal or migratory species, they are calculated for the portion of the year that the species is present at the site. This then gives a measure of risk to the bird movements, $M_{\text{risk}} = \text{FTA}$.

Because the flight data are a measure of movements by the species in question and do not discriminate the number of individuals making the movements, the measure ($M_{\text{risk}}$) quantifies the total movements-at-risk for the species and does not reflect risk to individual birds.

To determine a risk rate from total of recorded movements-at-risk, it is necessary to extrapolate to a total number of expected bird movements per annum, $M_{\text{yearly}}$. We calculate this from the flight data, extrapolating the movements to a yearly total through the equation

$$M_{\text{yearly}} = M \frac{T_{\text{yearly}}}{T_{\text{obs}}}$$

We then deduce a probability of flights at risk of collision as $M_{\text{risk}}/M_{\text{yearly}}$. Note that $T_{\text{year}}$ is the total time in a year, and not the diel activity period of the species, which has already been factored into the calculation of movements at risk.

The resultant value is now a probability of flights being at risk of collision with a single turbine. To this point, no account is taken of the bird's own ability to avert a collision. This is modified later through use of an avoidance factor.

*Estimating number of turbines encountered per flight.*—Every turbine is presumed to represent some risk for birds, so the total number of turbines proposed for the wind farm is an input to the model. Turbine layout of modern wind farms is primarily determined by the wind resource and turbines are micro-sited accordingly. Consequently, the machines are usually scattered on the landscape. Older wind farms had turbines arrayed in rows, and occasional modern facilities may be linear where they follow a single topographic feature.

To account for the number of turbines with which a single flight might interact, it would be necessary either to know precisely the route of every flight or to make informed assumptions about flight paths. The manner in which turbines are arrayed in the landscape is important to ascertain a typical number of turbines that a bird might encounter in a given flight. This number differs according to whether turbines are in a scattered array or a single row, and these require different calculations.

For a row of turbines, the likely number of encounters can be visualized by considering a row of $N$ turbines in plan view and a flight path at angle $\Phi$ to the row. A flight directly along the line of turbines ($\Phi'$) will interact with all $N$ turbines. As the angle of flight relative to the row increases toward 90°, flight paths have potential to interact with fewer turbines until an angle ($\Phi''$) is reached at which the path has potential to interact with a maximum of one turbine.

For a single row of turbines, we define the piecewise smooth function, which gives the number of turbines for a given angle of crossing with,

$$n_{\text{interaction}} = \begin{cases} N, & \text{if } \theta \leq \phi\prime \\ \cot(\theta), & \text{if } \phi' < \theta \leq \phi'' \\ 1, & \text{if } \phi'' < \theta \leq \frac{\pi}{2} \end{cases}$$

This gives us an expected number of interactions as

$$\langle n_{\text{interaction}} \rangle = \frac{2}{\pi} \left[ N \arctan\left(\frac{1}{N}\right) + \frac{\pi}{4} - \ln\left(\sqrt{2}\sin\left(\arctan\left(\frac{1}{N}\right)\right)\right) \right]$$

For scattered turbine arrays it is not realistic to assume that a bird will encounter all turbines in the wind farm in a given flight. We assume each flight has potential to cross between any 2 points on the outer edges of the farm. Given the size of most on-shore wind farms, this is a reasonable assumption for typical species of concern, such as raptors. When multiple flight paths are drawn randomly across the plan view of a wind farm, some paths may be circuitous and have potential to encounter many turbines, while others will pass through a small portion of the site and have potential to encounter relatively few turbines.

To deduce an average number of turbines likely to be encountered by any flight we use a topological, non-affine mapping technique. This spatial transformation can be illustrated as follows: if we were to throw a lasso around the perimeter of the site and shorten it to its minimum, we would find that all the turbines had collected in a circle. A straight flight path through this "lassoed" site is mathematically equivalent to a random walk across the unconstrained layout. The average of all flight paths crossing the center of this remapped farm will intersect with $\sqrt{N}$ turbines (where $N$ is the total no. of turbines in the wind farm). This value is used in the model for the number of turbines that might be encountered per flight within a scattered turbine array.

For arrays that are neither entirely scattered nor linear, the model employs a simple weighted average of the values for fully scattered and entirely linear arrays.

*Application of turbine avoidance capacity.*—Birds have substantial ability to avoid obstacles; therefore, it is necessary to incorporate this capacity into the model. In common with other workers (Percival et al. 1999), we use "avoidance" in specific reference to behavior on the part of a bird that averts a potential collision with a turbine. The "avoidance rate" equates to the proportion of flights that might otherwise have involved interaction with a turbine but where the bird alters course and the flight does not result in a collision. For the purposes of the model it is of no consequence whether or not this is a result of a cognitive response by the bird to the presence of the turbine.

Turbine avoidance remains little-studied for any species, and empirical information about actual avoidance can be obtained for a given site only by studying the responses of birds in the presence of operational turbines (Chamberlain et al. 2006). One recent investigation has compared flight behaviors of 2 species of eagles in the presence of turbines at

2 operating wind farms with their behaviors at a site without turbines (Hull and Muir 2013).

Avoidance rate is incorporated into the model by scaling the movements at risk by $(1 - v)$, where $v$ is a measure of the bird's ability to avoid objects. In this scenario, $v = 0$ corresponds to a blind, non-responsive projectile, and $v = 1$ represents a perfectly responsive bird able to avoid any object.

A novel feature of our model is its capacity to apply different avoidance values to the static and dynamic portions of a turbine. As noted by Martin (2011), birds are known to collide with both stationary and moving parts of turbines. This aspect of our model allows for differences in capacity of birds to detect and avoid the large, static components of modern turbines relative to their capacity to detect and avoid the small and fast-moving leading edges of rotor blades.

*Size of population at risk.*—When information about the size of the population at-risk is available, this can be factored directly into our model to provide results in the form of an expected number of individuals at risk of collision per annum. This is an important consideration because an input measured in terms of bird movements cannot provide an output in terms of individual birds. This aspect appears to have been largely overlooked by other workers, although Chamberlain et al. (2006) alluded to the use of a number of flights only, without incorporation of the number of individuals, as a potential issue in evaluation of collision estimates provided by the Band model (Band et al. 2007).

To deduce a predicted number of individual birds that are at risk of collision, a valid estimate is required of the number of individuals that may interact with turbines at the wind farm in the course of a year. If it is not feasible to obtain this for a species, then the output of the collision risk model will necessarily be the number of flights-at-risk per annum. Although this metric is not predictive of the number of individuals that might collide, it permits risk to be compared for various designs of a wind farm or between one facility and another. In rare cases, such as where there is a single migration passage through the site per annum, the number of movements may equate with the number of individual birds that are at risk. The great majority of risk modeling we have undertaken has been for raptors that are year-round residents. Due to their territoriality and relatively low densities, our studies at wind-farm sites have been able to ascertain the number of individuals using a site per annum, including both resident adults and juveniles, with a high level of confidence. For some other species, such as cranes (Gruidae), we have undertaken home-range studies to determine numbers present during the breeding season, and we have obtained local census data to estimate numbers of individuals that might encounter turbines during non-breeding seasons.

Given a population estimate, the number of flights at risk is attributed equally to the relevant number of individuals through the simple relation $M_{\text{individuals}} = \text{Yearly Movements}/\text{Population}$. We can then attribute individual mortality through

$$\text{mortality} = \text{Population}\left(1 - \frac{\text{Movements At Risk}}{\text{Yearly Movements}}\right)^{M_{\text{individuals}}}$$

# MODEL VALIDATION

The model we describe here has been used to assess potential turbine collision risk for numerous species of birds for 23 commercial-scale wind farms proposed in Australia and one in Fiji. Eleven of these facilities have subsequently been built and are now operational. The model's projections have been used by regulatory authorities in determination of approval or modification to wind-farm designs for a range of species of concern. These include taxa as diverse as the orange-bellied parrot (*Neophema chrysogaster*), wedge-tailed eagle (*Aquila audax*), brolga (*Grus rubicunda*), and the large and readily observable Pacific fruit-bat (*Pteropus tonganus*) in Fiji.

The model's performance can be validated only when it can be compared with post-construction mortality data that are sufficient to permit calculation of an actual annual mortality rate and a 95% confidence interval for that rate. Conditions of regulatory approval for most wind farms that have been built to-date in Australia have varied considerably between state jurisdictions and over time. Generally they have not required rigorous investigation or public reporting of avian collisions that occur during operation. We have thus had limited opportunity to validate our model against empirical information for actual collisions. However, where these are available, we can compare the model's predicted average estimates with the measured confidence interval for actual mortalities to assess its predictive capacity. We present one such case study below.

## Comparing the Model's Predictions With Empirical Data—A Case History

Substantial investigations have been undertaken at Bluff Point and Studland Bay wind farms in northwestern Tasmania entailing a number of studies of wedge-tailed eagle and white-bellied sea-eagle (*Haliaeetus leucogaster*). These have included utilization surveys designed to measure eagle activity before and after development of the wind farm; collision monitoring; eagle breeding success; eagle behaviors and movements relative to turbines and observers; and investigations and trials aimed at reduction of collisions (Hull et al. 2013). Commissioning of turbines began at Bluff Point Wind Farm in 2002 and at Studland Bay Wind Farm in 2007. Bluff Point Wind Farm consisted of 37 Vestas V66 turbines in a scattered array on an area of 1,524 ha. Studland Bay Wind Farm was situated 3 km south of Bluff Point and comprised 25 Vesta V90 turbines in a scattered array over an area of 1,410 ha. Both wind farms were close to the coast of northwestern Tasmania and resident white-bellied sea-eagles and Tasmanian subspecies of wedge-tailed eagle (*A. a. fleayi*) occurred at both sites.

## Monitoring Eagle Flights

Movement data for both species were collected during point counts at Bluff Point Wind Farm site in 3 years prior to construction of turbines and in 4 years after they commenced operating. At Studland Bay, they were collected in 6 years prior to turbine construction and in 3 years after turbines commenced operation. As prescribed by regulatory authorities, point counts were undertaken in the austral autumn and spring. Ten replicate point counts were made in each season at 18 locations per wind farm. There were 545 point counts undertaken at Bluff Point between 1999 and 2007 and 854 point counts at Studland Bay between 1999 and 2009.

### Collision Risk Model Results

We used the model to estimate risk based on movement data collected prior to construction for populations of 6 wedge-tailed eagles and 4 white-bellied sea-eagles at-risk per annum at each of the 2 wind farms.

State regulatory authorities have required that the collision risk model be re-run with the accumulated sum of eagle movement data obtained during the entire period of both pre-construction and operation of the 2 wind farms spanning the period from 1999 to 2009 (Table 1). We modeled static avoidance rate at 99% in all cases.

### Documented Eagle Collisions

Carcass monitoring surveys were conducted at the Bluff Point and Studland Bay wind farms since they commenced operating. Fences to exclude mammalian scavengers were maintained at 27% of turbines across the 2 sites. All turbines, both fenced and unfenced, were searched routinely within a 100-m radius of the tower base. Search frequency was initially informed by trials to determine rates of loss to scavengers and of observers' capacity to detect carcasses. Since 2007, searches were carried out twice weekly during periods that may have represented higher risk to the species (i.e., eagle display period Jun–Aug, inclusive; and eagle fledging period mid-Dec–Feb, inclusive) and fortnightly outside these periods (Hull et al. 2013). Assessment of the extent of undetected eagle collisions (Hydro Tasmania 2012; Hull et al. 2013) concluded that it is unlikely that significant numbers of eagle carcasses were missed because they are conspicuous; the search zone around turbines was adequate to detect eagle carcasses where they will fall after colliding with turbines (Hull and Muir 2010); personnel on site had capacity to detect carcasses that may have been moved from the formal search zones; eagle carcasses in vegetation were found not to decompose readily and, even when scavenged, remains were identifiable; avian scavengers did not remove all evidence of carcasses and, although mammalian scavengers could remove carcasses, this was controlled at the subset of fenced turbines; survey intensity was informed by predetermined scavenger removal rates; and, although a small number of eagles survived collision with a turbine, in all documented cases such birds were unable to fly and are likely to have been detected because both scavenger exclusion and farm fences prevented them from leaving the site.

**Table 1.** Modeled mean annual turbine collision estimates for 2 eagle species based on movement data collected over the span of pre-construction and operation of 2 wind farms in northwestern Tasmania, Australia, from 1999 to 2009. Estimates are shown for 4 potential dynamic avoidance rates. Static avoidance rate was modeled at 99% in all cases

| | White-bellied sea-eagle | | Wedge-tailed eagle | |
|---|---|---|---|---|
| Dynamic avoidance rate (%) | Bluff Point | Studland Bay | Bluff Point | Studland Bay |
| 90 | 0.9 | 0.8 | 2.7 | 1.9 |
| 95 | 0.5 | 0.4 | 1.5 | 1.1 |
| 98 | 0.2 | 0.2 | 0.7 | 0.5 |
| 99 | 0.1 | 0.1 | 0.4 | 0.3 |

### Comparison of Collision Risk Model Estimates With Actual Mortality Rates

Given constraints of statistically low collision numbers, the model's estimates of annual collisions, based on the combined total of movement data from pre-construction and operation of the 2 wind farms from 1999 until 2009 (Table 1), compare well with actual mortality of the 2 eagle species at both wind farms (Table 2). The model's estimate of the number of wedge-tailed eagle collisions per annum at Bluff Point at a 95% avoidance rate was 1.5, which is the same as the mean number of documented mortalities per annum. Estimates provided for this case by model iterations for 90% and 95% avoidance rates fell within the 95% confidence interval of measured mortality rates. The model's estimates for number of collisions at a 95% avoidance rate for white-bellied sea-eagles at Bluff Point (0.5) and for wedge-tailed eagles at Studland Bay (1.1; Table 1) also closely approximated the mean numbers of documented mortalities per annum for the 2 species (0.4 and 1.0, respectively; Table 2). For those cases, the model's estimates for the range of avoidance rates between 90% and 99% fell within the 95% confidence interval of measured mortality rates. No white-bellied sea-eagle collisions have yet been reported from Studland Bay so, to date, the model's estimates are higher than actual experience for that species there.

## MANAGEMENT IMPLICATIONS

We consider that there are 2 different, although not mutually exclusive, applications for modeling of bird collision risks at prospective wind farms. These are to provide projections of long-term effects of a particular wind-energy facility on key bird species; and to determine relative risks for key species that are associated with different wind-farm sites, different portions of large wind farms, and different types of turbines and/or turbine configurations.

In many respects, we consider the latter use of collision risk modeling is the most important contribution it offers. This application provides a tool for planning of wind farms to avoid, reduce, or mitigate potential risks to birds. The model we describe here has now been used in such an iterative manner for a number of prospective sites to evaluate relative risks to key species posed by different types, sizes, numbers, and layouts of turbines.

The integration in our model of data for numbers of bird flights with numbers of birds in the population at-risk is key to the accurate prediction of potential numbers of collisions. This aspect appears not to have been adequately considered previously but has real implications to the appropriate determination of actual risks posed by a wind farm. Our model's use of bird flight data to determine annual flux of movements; a mathematical solution to the typical number of turbines that might be encountered in a bird flight; capacity to assess wind-farm configurations ranging from turbines scattered in the landscape to linear rows of turbines; and the option of assigning different avoidance rates to components

Table 2. Average annual mortality rate and variance for 2 eagle species based on carcasses detected at 2 wind farms in northwestern Tasmania, Australia

| Wind farm | White-bellied sea-eagle | | Wedge-tailed eagle | |
|---|---|---|---|---|
| | Mean annual mortality | Annual variance (95% CI) | Mean annual mortality | Annual variance (95% CI) |
| Bluff Point 2002–2012 | 0.4 | 0.1–1.0 | 1.5 | 0.8–2.6 |
| Studland Bay 2007–2012 | 0.0 | 0.0–0.7 | 1.0 | 0.3–2.2 |

of turbines that pose more or less risk, all represent refinements designed to improve the predictive capacity of turbine collision risk modeling.

In the cases outlined here, where long-term mortality data sets have permitted validation of the model's collision estimates at given avoidance rates, the two have closely approximated each other. We will seek further opportunities to compare the results of our model with empirical mortality information from operating wind farms, with a view to wider application of the model.


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