WILLATOOK WIND FARM

Planning Application Report

Appendix Q Brolga

APRIL 2022

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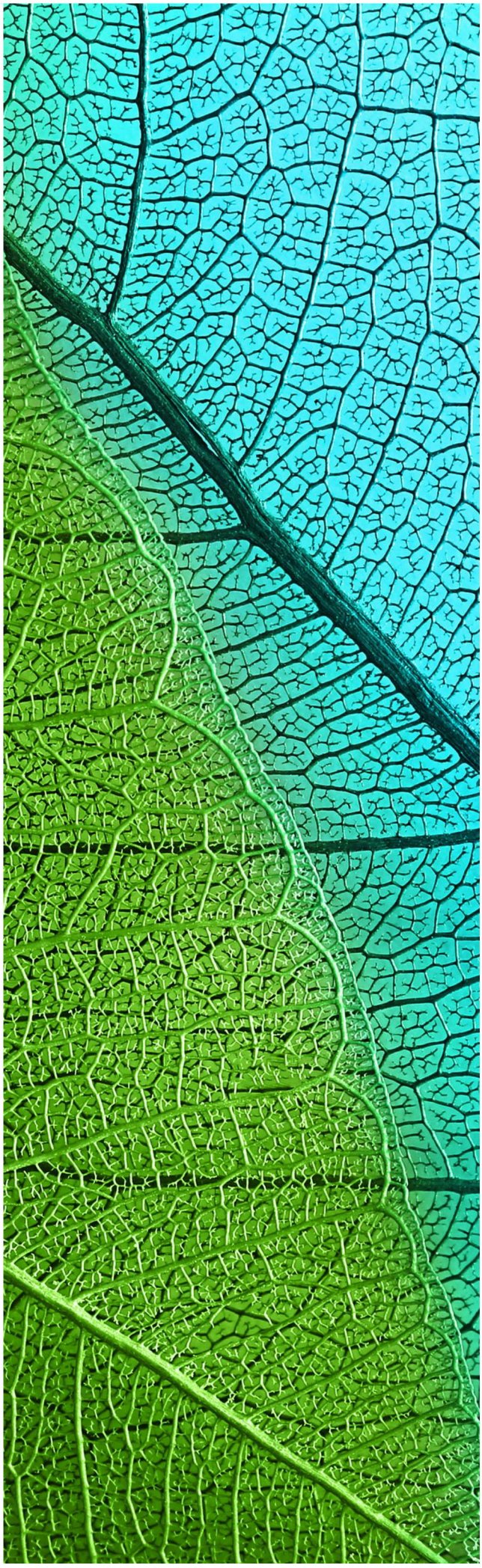

Willatook Wind Farm

Brolga Impact Assessment

Prepared for Willatook Wind Farm Pty Ltd

April 2022
Report No. 16087 (10.9)

Nature Advisory
(Formerly Brett Lane & Associates Pty Ltd)

[redacted]

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Executive summary

Willatook Wind Farm Pty Ltd engaged Nature Advisory Pty Ltd (Nature Advisory) to assess the impacts of the proposed Willatook Wind Farm in south-western Victoria on the state-threatened Brolga (*Antigone rubicunda*). This report has been prepared to support the Environment Effects Statement (EES) and planning permit application for the project. The assessment follows the methods in DSE (2012) *Interim guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga Population 2011* referred to hereafter as the 'Interim Brolga Guidelines'.

This report presents the methodology and results from the Brolga assessment based on field work undertaken by Nature Advisory Pty Ltd from 2018 to 2021 and earlier surveys by Ecology and Heritage Partners (EHP 2018) from 2009 to 2013. The report describes how impacts on the species have been avoided and minimised, and provides a strategy for the project to achieve the objective of the Interim Brolga Guidelines, namely to ensure that wind farm developments have a *zero net impact on the Victorian Brolga population* (DSE 2012, p.6), thereby avoiding any cumulative impact on the species from the wind energy industry in the state.

The Brolga is an iconic bird that is secure nationally but listed as endangered in Victoria under the *Flora and Fauna Guarantee Act 1988* (FFG Act). It has experienced significant decline in Victoria since European settlement attributed to habitat loss from agriculture and wetland drainage, predation from foxes and collisions with fences and powerlines. While Brolga collisions with wind turbines have not been reported, due to potential interaction with wind farms within the Brolga's range, the Victorian Government have issued the Interim Brolga Guidelines.

The Willatook Wind Farm (WWF) is situated in the Moyne Shire on primarily private land 4,154 hectares in size. The proposed wind farm comprises 59 wind turbines and a battery storage facility. Turbines would be connected by 60 km of access tracks to provide for construction and maintenance access. These will connect to the public road network in several places. Each wind turbine will have a rotor swept area from 40 to 250 metres above the ground, and will be connected to an onsite substation using underground cabling with a total trench length of 62 kilometres. The on-site substation will be connected via approximately 300 metres of overhead transmission line immediately to the north of the existing Tarrone Terminal Station, which will connect to the 500 kV Moorabool to Heywood transmission line. Three wind monitoring masts are proposed, each up to 141 metres high. Temporary infrastructure includes provision for construction compounds with office facilities, associated parking and toilet facilities, temporary laydown areas for wind turbines and electrical equipment, concrete batching plants and an on-site quarry.

The Interim Brolga Guidelines assessment framework involves three levels of assessment. Information is gathered at each assessment level to inform impact assessment, mitigation and compensation strategies. Each level also informs the next and all three levels are applied if there is potential for a significant impact that requires mitigation and offset. The Interim Brolga Guidelines require regular consultation with the state Department of Environment, Land, Water and Planning (DELWP).

WWF and Nature Advisory have undertaken extensive discussions with key environment, planning and technical personnel in DELWP to ensure that the application of the Interim Brolga Guidelines has been applied to the Willatook Wind Farm as required. DELWP have also been consulted in relation to the development of turbine-free buffers around breeding sites, as required by the Interim Brolga Guidelines, and this report has benefited from extensive technical discussions with DELWP

on how these buffers are defined and on the inputs to and results of the collision risk modelling (CRM) process.

Over the last decade, there have been extensive investigations of Brolga and their habitat for the project. This has included review of existing database records and landowner consultation, field surveys for Brolga during breeding and non-breeding periods, aerial surveys, and the assessment of habitat suitability based on both field assessment and hydrological modelling. The Radius of Investigation (RoI) for this project is a 10 kilometre radius from the edge of the original concept plan. As the size of the project has reduced, the RoI has reduced but all data collected from the original RoI is presented here. This accounts for some observations on maps lying beyond the latest RoI. To predict the potential impact of the project, collision risk modelling and population viability assessment was also conducted.

The findings from this assessment are summarised below.

- The project is located within the range of the species and there are scattered breeding records of Brolga within shallow, ephemeral wetlands that are inundated during winter and spring (depending on the seasonal rainfall).
- A high proportion (~67%) of the mapped wetlands in the Radius of Investigation (RoI – within and up to 10 km from the original concept plan of the wind farm) have been drained for agricultural purposes and are unlikely to remain inundated for long enough to support the development of a productive aquatic ecosystem with healthy food resources or the brlga, or are no longer functional and therefore capable of supporting successful Brolga breeding.
- A significant part of the RoI, in particular the southern portion, lacks wetlands and the Brolga has not historically been recorded there.
- Five breeding pairs of Brolga have been identified as inhabiting the RoI, with three breeding pairs occurring more than three kilometres to the south-west of the project, one pair adjacent to the wind farm and one pair well to the north on the out skirts of the RoI in the Macarthur Wind Farm.
- An estimated population of five pairs of Brolga occurs in the RoI, representing between 1.1% and 1.6% of the Victorian population of the species (estimated at 625 to 900 birds – Melbourne University PVA – See Appendix 6).
- Within three kilometres of the proposed wind farm, six wetlands that have records of Brolga breeding occur in or around the proposed wind farm site: five wetlands in the Cockatoo Swamp complex; and one isolated breeding wetland to the east.
- No Brolga have been recorded in flocks within the RoI during the non-breeding or flocking season where Brolga are known to congregate, with the closest flocking site being 28 kilometres to the north.
- Given the findings of this assessment on historical activity of the Brolga in the RoI, the focus of assessment and mitigation has been on the use of the area for breeding. Little risk to the Brolga population is considered to arise from the project during the flocking season.
- Minimisation of impacts to the Brolga has involved the establishment of turbine free buffers around breeding sites which extend to incorporate foraging areas, other potential night roost sites and movement corridors between them on and near the wind farm. Turbine-free buffers around known breeding wetlands have been developed by removing or moving the proposed

locations of 23 turbines that were near Brolga breeding sites in the turbine layout in the initial EES Referral.

- Turbine free buffers include wetlands used by Brolga for breeding (nesting and foraging) and night roosting, non-wetland areas around breeding wetlands used for foraging and movement corridors between breeding, foraging and potential roosting wetlands to other suitable breeding and potential roosting wetlands.
- Five potential breeding wetlands and non-wetland habitat between the wetlands, were incorporated into a single turbine-free buffer of the Cockatoo Swamp complex to allow barrier-free movement between wetlands and non-wetland foraging areas totalling more than 2,600 ha.
- All other confirmed Brolga breeding wetlands lie at least 1,800 metres from wind turbine, beyond the 1,369 metres distance within which Veltheim et al. (2019) found 95% of movements of satellite-tracked chicks (and, it is assumed, their parents) and risks to Brolga breeding in these wetlands from turbines are considered low and further buffering has not been considered necessary.
- Consistent with the Interim Brolga Guidelines, the impacts of the project on the Brolga have been assessed through the development of a collision risk model that integrates spatial modelling of the probability of occurrence of the Brolga at the rotor swept area (RSA) height across the landscape and the Scottish Natural Heritage turbine collision risk model. Model inputs have been developed from systematically collected data on Brolga flights at breeding sites elsewhere in its Victorian range.
- The impact of turbines across the proposed wind farm site were assessed to be very low based on collision risk. This is due to a combination of the proposed turbine free buffers, as well as the comparatively high minimum rotor swept area height of 40 metres above the ground. Most Brolga flights are less than this height.
- Under the 90% avoidance scenario (i.e., Brolga avoid turbines for 90% of flights), the collision risk modelling predicts on average 0.07 collisions per year, or 1.7 collisions over the 25-year life of the project. Statistically, there is a 95% chance that there would be between zero and five collisions over the life of the project. This compares with 0.13 collisions under the same modelling scenario for the original referred layout, or 3.3 collisions over the 25-year life of the project. This represents a reduction of collision risk of almost 50% through the adoption of turbine free buffers.
- The Brolga Population Viability Assessment predicts without compensation that after 25 years (the planned life of the wind farm project), the Victorian Brolga population size would reduce by between 0.1 and 0.9 birds compared with baseline conditions. The predicted result for 90% avoidance rate is considered the most conservative collision rate and represents a reduction of about 0.08% to 0.14% in the Victorian population. This impact will be compensated to ensure zero net impact on the Victorian Brolga population.

This impact assessment has relied upon a combination of empirical and modelled results. The modelled results have been based on conservative assumptions, including the following:

- The wind turbines will operate 24 hours per day, 365 days per year
- They will operate at their maximum rotation speed (4.76 seconds) continuously

- A greater number of Brolga pairs were modelled occurring in the site than have ever been recorded during field surveys. This included one breeding pair of Brolga breeding on or within the Cockatoo Swamp complex each year (based on historical data, landholder information and breeding surveys in the last decade) plus a DELWP-recommended precautionary additional pair in isolated wetlands east of the project for three in ten years.

These conservative assumptions ensure that the modelled results used to assess the impact of the wind farm on the Brolga are more likely to over-estimate impact than under-estimate it.

This assessment has resulted in impacts on up to a conservative maximum of five Brolga over the life of the project, which is considered feasible to replace through compensation in enhanced Brolga breeding wetlands, as required in the interim Brolga Guidelines. Consequently, the proposed WWF is not expected to lead to a significant incremental contribution to the cumulative impact of wind farms within the Brolga's range in Victoria.

1. Introduction

Willatook Wind Farm Pty Ltd engaged Nature Advisory to assess the impacts of proposed Willatook Wind Farm (WWF) in south western Victoria on the state-threatened Brolga (*Antigone rubicunda*).

The project is located approximately 22 kilometres to the north of Port Fairy and 32 kilometres to the north-west of Warrnambool. Locally, the project is situated approximately three kilometres north-east of the town of Orford and 10 kilometres south-west of the town of Hawkesdale.

The project situated to the south of Woolsthorpe–Heywood Road, and lies between Penhurst–Warrnambool Road to the east and Hamilton–Port Fairy Road to the west. The project site covers an area of approximately 4,154 hectares of private and public land that is mainly used for agriculture (predominantly sheep and cattle grazing) in the Moyne Shire. As a result of clearing for agriculture, native vegetation within the project site is largely restricted to roadside reserves and along watercourses. The proposed wind farm comprises 59 turbines and a battery storage facility. It is proposed to build 60 km of access tracks within the site to provide for construction and maintenance access. These will connect to the public road network in several places. Each wind turbine will be connected to an onsite substation using underground cabling with a total trench length of 62 kilometres. The on-site substation would be connected via approximately 300 m of overhead transmission line immediately to the north of the Tarrone Terminal Station, which would connect to the 500 kV Moorabool to Heywood transmission line. Three wind monitoring masts are proposed, each up to 141 m high. Temporary infrastructure would include a construction compound with office facilities, associated parking and toilet facilities, temporary laydown areas for wind turbines and electrical equipment, concrete batching plants and a temporary on-site quarry.

Over the last decade there has been a significant effort to assess Brolga and their habitat for the project. This has included review of existing database records and landowner consultation, field surveys for Brolga during breeding and non-breeding seasons, aerial surveys, and the assessment of habitat suitability based on both field assessment combined with hydrological modelling. To predict the potential impact of the project, collision risk modelling and population viability analysis was also conducted.

This report presents the methodology and results from the Brolga assessment based on field work undertaken by Nature Advisory from 2018 to 2021 and earlier surveys by Ecology and Heritage Partners (EHP 2018) from 2009 to 2013.

This assessment followed the methods in DSE (2012) *Interim guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga Population 2011* referred to hereafter as the 'Interim Brolga Guidelines' and also to address the project's Environmental Effects Statement (EES) scoping requirements. It describes how potential impacts to the species have been minimised and provides a strategy for the project to achieve the objective of the Interim Brolga Guidelines, namely to ensure that each wind farm development has *at a minimum a zero net impact on the Victorian Brolga population* (DSE 2012, p.6). The investigation area encompassed the proposed wind farm site as well as a ten-kilometre zone around it referred to as the Radius of Investigation (RoI), as defined in the Interim Brolga Guidelines (p. 13).

The results of the Brolga assessment are presented in accordance with the three-level approach prescribed in the Interim Brolga Guidelines, as follows.

- Level One Assessment
- Level Two Assessment, and

- Level Three Assessment.

This investigation was undertaken by a team from Nature Advisory, comprising Dion Iervasi (Ecologist), Beau Meney (Zoologist), Teisha Lay (Zoologist), Plaxy Barratt (Zoologist), Guille Mayor (Zoologist), Jackson Clerke (Zoologist), Peter Lansley (Senior Zoologist), Curtis Doughty (Senior Zoologist), Bernard O'Callaghan (Senior Ecologist & Project Manager) and Brett Lane (Principal Consultant and Project Director).

2. Brolga assessment overview

2.1. Species description

The Brolga is listed as endangered under the FFG Act. Brolga belong to the family Gruidae (cranes), of which two species (including the Brolga) occur in Australia (Marchant and Higgins 1993). Cranes are generally large-bodied, long-legged and long-lived, with Brolga being very similar to other cranes in general ecology and biology.

Adults can range in weight between four and eight kilograms and stand up to 1.8 metres tall with a wingspan of two metres. During the non-breeding season, Brolga can form large flocks (occasionally as large as 200 birds) but typically are seen in small groups (10 - 20 individuals). Breeding pairs can form long-term bonds and, if one of the pair dies, the remaining individual can take several seasons to find another mate (Marchant and Higgins 1993). The Brolga pair will aggressively maintain their breeding territory (Arnol *et al*. 1984) and have been observed to destroy other Brolga nests that attempt to nest within their breeding home range.

Typically, pairs only produce one or two offspring per breeding season and therefore recruitment into the population is low.

The Brolga's annual cycle is divided into two principal periods, as follows.

- The breeding season, from July to December, during which territorial pairs nest in shallow freshwater wetlands that are often ephemeral, holding water reliably only in winter and spring
- The non-breeding (or flocking) season, from December to June, when Brolga disperse from drying breeding wetlands to larger, often permanent wetlands to congregate with others to form flocks that roost at the wetland and move out to forage in adjacent terrestrial and wetland habitats (DSE 2012).

In between the breeding and flocking seasons, Brolga move about the landscape between breeding and flocking sites or *vice versa* during two migration periods that can overlap with the months above.

The Brolga is a secure species nationally, numbering in the tens of thousands across northern Australia (Marchant and Higgins 1993). However, in Victoria the range of the Brolga has contracted since European settlement because of wetland drainage, loss of habitat due to agricultural development and predation of eggs and young by the introduced Red Fox (*Vulpes vulpes)*. Its former range included northeast Victoria, Gippsland, and the formerly extensive wetlands of the Melbourne region. Currently, birds are found in the south-west and in the north of the state in parts of the Murray River basin (Du Guesclin 2003).

2.2. Brolga distribution in Victoria

The distribution of the Brolga in the main part of its Victorian range, the south-west, varies seasonally. In the breeding season adult pairs disperse to small and moderately sized seasonal or semi-permanent wetlands to breed as territorial pairs. At this time, small numbers of non-breeding birds can form flocks on larger wetlands. In the flocking season, birds congregate in larger wetlands as the smaller, seasonal wetlands dry out over summer.

Brolga movements in south-west Victoria are not yet completely understood. Seasonal movements, referred to as migration movements, occur in south-east Australia between flocking and breeding sites. Local movements can also take place when birds are moving between roosting and feeding sites. Long distance movements may take place in very dry years and populations may move from

dry inland wetlands to wetlands associated with the Murray River (Marchant and Higgins 1993). In very wet seasons, birds may remain at breeding sites throughout the year and not move to flocking sites. Therefore, Brolga movements and distribution are heavily dependent on climate and foraging opportunities.

Consistent Brolga flocking sites in south-west Victoria that account for a significant proportion of the population occurs in the locations listed below, based on information compiled by Sheldon (2004) and provided by DELWP.

- The Grampians region
- Strathdownie
- Cressy
- Streatham (mainly on Lake Wongan and in the Skipton area)
- Hamilton, Dunkeld and Penshurst areas
- Edenhope area
- Toolondo
- Willaura and Stavely areas and
- Darlington.

2.3. Brolga population size

The 1984 estimate of the Victoria brolga population was 600 – 650 birds, with approximately 550 – 600 of these birds (c. 92%) in south-west Victoria (Arnol *et al.* 1984). This and subsequent estimates are noted in Table 1.

Table 1: Brolga population estimates, south-west Victoria

Month/ year	Est. no.	% ≤2 yrs. old	Same day counts	Source
27/03/2021	413	9	Yes, subset of main flocking sites	http:// https://www.swifft.net.au/cb_pages/sp_brolga.php (viewed February 2022)
4/2019	635	6	Partial	
4/2018	377	13	Partial	
4/2017	278	18	Partial	
4/2016	348	8	Partial	
4/2015	449	10	Partial	
4/2013	907	17	Yes	
2012	448	16	Partial	
2011	250	20	No	
2010	401	10	No	
2004	675	-	No	Sheldon (2004)
2002	402	-	No	DSE (2007)
1984	550-600	-	No	Arnol *et al.* (1984)

Counts undertaken in March 2021 were observations from a subset of the main flocking sites in south-wester Victoria. Targeted flocking sites included Willaura, Penshurst, Lake Bolac, Streatham, Darlington, Camperdown, Cressy and Strathdownie.

From April 2012 to 2019 counts reported above were organised by DELWP and was conducted at Dundonnell, Penshurst, Willaura, Strathdownie, Lake Bolac, Streatham, Boole Lagoon (S.A.) and Lake Wongan. The counts were undertaken systematically by having different sites counted on the same day across the state, to avoid re-counting flocks that may have moved.

Earlier, non-simultaneous counts (from the 1980s to 2011) are not directly comparable to the counts from 2012 and 2013, as counts conducted over multiple days may result in over-estimation of the number of birds due to multiple counting of individuals or flocks that have moved between count days. Partial counts that miss flocking sites, such as occurred from 2015 onwards also don't provide an accurate estimate of the total Brolga population in south-eastern Australia.

From 2010, many young have been observed in flocks compared with the previous drought years. This indicates how effective improved availability of breeding habitat can be in increasing the number of young Brolgas produced. Years with high rainfall result in a larger number and longer inundation of breeding wetlands. This ensures habitat availability for adult and young birds for the entire breeding cycle until young fledge at more sites.

There is no evidence from counts that the Victorian population is trending significantly in any direction. For the purpose of the Population Viability Assessment (see Section 5.3), having regard to the incomplete coverage of wetlands during many counts, a population of 650 birds was assumed (at the lower end of the range of the two most complete counts, 2013 and 2019).

2.4. Brolga habitat

In Victoria Brolga occur in a variety of habitats and utilise different habitats in the breeding season compared with the non-breeding season (Arnol *et al*. 1984). In the breeding season territorial pairs nest in shallow freshwater wetlands that are often ephemeral, holding water reliably only in winter and spring (Herring 2005). During the non-breeding season Brolga congregate together at larger, often permanent waterbodies where they roost, drink and forage and venture out across the landscape to forage in terrestrial habitats (Johnsgaard 1983, Arnol *et al*. 1984).

Brolga rely on hydrologically and ecologically functional wetlands for nesting, and/or food resources and/or night-time roosting sites (Johnsguaard 1983). In the breeding season (July-December) this species nests in shallow freshwater marshes less than 50 centimetres deep and with emergent vegetation and freshwater meadows less than 30 centimetres deep dominated by annual herbs, rushes or tussock grass (Marchant and Higgins 1993). Emergent vegetation at these functional wetlands plays a crucial role in providing Brolga habitat as it provides nesting material (Myers 2001, Du Guesclin 2003), food resource (tubers, aquatic animals) (Herring 2018), provides shelter for prey (vertebrates and invertebrates) (Herring 2005) and cover from predators for young chicks (Johnsgaard 1983, Herring 2018).

A Brolga family will spend most of its time in the Brolga breeding wetland foraging but will move to other functional wetlands nearby to forage and/or roost as the chicks develop and food resources are depleted in the original Brolga breeding wetland. Brolga also forage in pasture and to a lesser degree (during the breeding season) cereal and canola crops in the vicinity of the Brolga breeding wetland and night-time roost. Brolga roost at a wetland during the night and move about during the day within, around and between them to forage (Veltheim 2018).

The key threat to Brolga is the drainage and alteration of hydrology of wetlands (Du Guesclin 2003). Wetlands that have been permanently drained, partially drained only holding water for brief periods during the breeding season and small, unvegetated farm dams have little habitat value for Brolga as they do not provide the physical and biotic resources the Brolga requires.

2.5. Threats

Key threats to the species outlined in the Action Statement (Du Guesclin 2003) are summarised below. The major threats that impact on the Brolga breeding site are as follows.

- Drainage and alteration to the hydrology of wetlands
- Altered flood regime
- Modification of vegetation structure and species composition, water quality or soil structure at breeding wetlands and terrestrial foraging areas
- Widespread use of herbicides and pesticides especially near breeding sites
- Disturbance by hunting activities where young birds are still in the breeding wetland
- Introduced predators, feeding on eggs and chicks
- Wildlife and burning programs, which remove nest material
- Grazing by stock can degrade wetlands
- Subdivision and fencing large private landholdings as chicks can caught in fences
- Erection of structures such as overhead powerlines can cause collisions
- Use of wetlands for irrigation and/or re-use systems.

Some of the key threats impacting the Brolga flocking sites are as follows.

- Disturbance by hunters during the duck season and deposition of lead shots in wetlands
- Loss of habitat due to changes in vegetation, for example, changes in agricultural practices
- Catchment degradation resulting in changes in water quality, including increased salinity, siltation or flooding
- Poisoning of agricultural pests e.g. crickets
- Erection of structures such as overhead powerlines.

To date there have been no Brolga collisions with operating wind turbines in Victoria

2.6. Policy framework for wind farms

The policy and planning guidelines for wind farms in Victoria (DELWP 2017) require that the potential impacts of wind farms on species listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) or the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) be assessed. Clause 52.32 of the Planning Scheme also required impacts on FFG Act listed species to be assessed.

One such species is the Brolga (listed as Endangered under the FFG Act but not on the EPBC Act), which occurs in the broader region around the proposed Willatook Wind Farm. Planning authorities must consider the impacts of wind farm developments on this species before making decisions on permit applications.

2.7. EES scoping requirements

The WWF was referred to the Minister for Planning (the Minister) in October 2018 under the *Environment Effects Act 1978* (EE Act). On 27th December 2018, the Minister determined that an EES was required for the project due to the potential for the project to have significant effects on environmental and social values.

Following consideration of the EES referral and public submissions on the draft scoping requirements, the final *Scoping Requirements for Willatook Wind Farm Environment Effects Statement* (scoping requirements) were issued by the Minister for Planning in August 2019. The scoping requirements specify the specific matters to be investigated and documented in the EES, including the draft evaluation objectives for each of the topics to be addressed.

The EES scoping requirements specify the following draft evaluation objective relevant to biodiversity, including Brolga, which have guided this assessment:

> *To avoid or minimise potential adverse effects on biodiversity values within and near the site including native vegetation, listed threatened species and ecological communities, and habitat for these species. Where relevant, offset requirements are to be addressed consistent with state and Commonwealth policies.*

Key issues to be addressed include the following.

- Disturbance and/or degradation of adjacent or nearby habitat that may support listed species or other protected flora, fauna or ecological communities
- Disturbance and/or individual to population level loss of flora and fauna species listed as threatened under the EPBC Act, FFG Act and/or DELWP advisory lists
- Indirect habitat loss or degradation resulting from other effects, such as edge effects, surface hydrological changes, groundwater drawdown, noise, vibration, light or the introduction of weeds/ pathogens
- Potential collision risk for protected bird and bat species with project infrastructure, including with wind turbine blades.

2.8. Interim Brolga guidelines

The objective of the Interim Brolga Guidelines is to ensure that each wind farm development has *at a minimum a zero net impact on the Victorian Brolga population* (DSE 2012, p.6). To meet this objective, three levels of investigations must be conducted. Information is gathered at each investigation level to inform the impact assessment and mitigation strategies. Each level also informs the next and all three levels are applied if there is potential for a significant impact that requires informed mitigation and offset. This Brolga assessment follows the methods in the Interim Brolga Guidelines.

This document outlines the methods and results of surveys completed to date to address levels one to three. This Brolga Impact Assessment provides the basis for discussions with key environment, planning and technical personnel on the project Environment Effects Statement (EES) Technical Reference Group (TRG), including key technical and planning personnel in DELWP. These discussions will review proposed turbine-free buffers around breeding sites as required by the Interim Brolga Guidelines.

Further details on the Interim Brolga Guidelines and their application in this work are summarised in Table 2. This also indicates where the relevant information can be found in this report.

Table 2: Three-level assessment of wind farm impact on Brolga: current investigation

Level	Step	Assessment triggers (as per DSE 2012)	Current investigation - outcomes and actions
Trigger for Level 1		The presence of Brolga within the radius of investigation (i.e. within 10 km of the proposed wind farm boundary). The presence of potential Brolga habitat within the radius of investigation OR The location of the proposed development is within an area that may be used by Brolga during seasonal movements between breeding and flocking habitats.	Level One Assessment triggered and completed (Section 3).
1	1	Undertake desktop studies into known and potential habitat areas for Brolga.	All available historical and recent Brolga records within the 10 km radius of investigation (RoI) have been collated and reviewed to identify the extent of Brolga occurrence in the RoI. (Section 3.2).
	2	Initial field inspection and local community consultation.	A site inspection was undertaken to identify potential Brolga breeding habitat on and around the proposed wind farm site (see section 3.1.3). Extensive landholder consultation within the radius of investigation has been undertaken and is ongoing to identify potential Brolga flocking and breeding sites that may not be in the available databases or accessible during field studies (Section 4.2.1).
Trigger for Level 2		Records of breeding or flocking habitats within the radius of investigation. The proposed development is located in an area which may be used by Brolga moving seasonally between breeding and foraging sites, and may potentially create a barrier reducing movements between these habitats OR The proposed location of new powerlines associated with the development may create new collision risks for Brolga.	Level Two Assessment triggered and completed (Section 4).
2	-	The Level 2 Assessment collects comprehensive data about the location, nature and extent of Brolga habitats, and patterns of habitat use and behaviour at breeding, flocking and foraging sites within the radius of investigation.	Extensive site-specific field investigations have been undertaken during breeding and non-breeding periods in 2009, 2010, 2018, 2019, 2020 and 2021 to document the extent of Brolga activity and current and

Level	Step	Assessment triggers (as per DSE 2012)	Current investigation - outcomes and actions
			historical spatial patterns of activity in the RoI (Section 4.2). A second aerial survey of wetlands was undertaken in October 2018 (Section 4.2.2). Observational flight movements of Brolga around breeding sites from past studies undertaken by Nature Advisory (Section 4.2.4). Hydrological modelling and ecology assessment was then used to determine the location and extent of suitable Brolga habitat from a hydrological perspective. Wetlands that met the define hydrological criteria for Brolga breeding wetlands were then visited and assessed for other ecological criteria (Section 4.2.5). The species does not flock within 10 kilometres of the wind farm (Section 3.2.1). Breeding was recorded in wetlands in the radius of investigation (See section 4.2.3)
Trigger for Level 3		Qualitative risk assessment (AusWEA 2005) of project following site design is greater than "low".	Potential for impact, level three triggered anyway - Section (5).
3	1	Avoid or mitigate all potential impacts to Brolga breeding and flocking home ranges within the RoI with turbine-free buffer areas.	Establishment of turbine free buffers around breeding and flocking sites to be agreed with DELWP (See section 5.1).
	2	Develop a site-specific collision risk model (CRM) for Brolga utilising or moving through the radius of investigation.	To be informed by Level 2 results and information on Brolga flight behaviours, together with turbine specifications and layout (See section 5.2 and Appendix 5).
	3	Use DELWP (Melbourne University) Brolga PVA to estimate the impact of the proposed development on the population.	Based on outcomes of CRM (See section 5.3 and Appendix 6).
	4	Identify appropriate compensation strategies to ensure a *zero net impact on the Victorian Brolga population*.	Based on outcome of CRM and PVA. (See section 5.4).

The rest of this report is structured around the Interim Brolga Guidelines to enable the reader to follow how they have been applied.

3. Level one assessment

All four Level one assessment triggers apply to the proposed Willatook Wind Farm. The level one assessment is described in this section.

3.1. Methods

3.1.1. Review of existing reporting and documentation

The existing documentation below, relating to the RoI was reviewed.

- Biodiversity Assessment: Willatook Wind Farm, Willatook, Victoria. Prepared for Willatook Wind Farm Pty Ltd, Ecology and Heritage Partners Pty Ltd (EHP 2018), September 2018
- Brolga Movements and Spatial Requirements During Breeding, south–west Victoria. Ecology and Heritage Partners Pty Ltd, November 2013 (EHP 2013)
- Utilisation of habitat by Brolga within the vicinity of the Macarthur Wind Farm – 2014 Prepared for AGL Energy Limited, Australian Ecological Research Services
- Utilisation of habitat by Brolga (*Grus rubicundra*) within the vicinity of the Macarthur Wind Farm during the breeding season of 2016. Prepared for AGL Energy Limited, Australian Ecological Research Services
- Breeding home range movements of pre-fledged brolga chicks, *Antigone rubicunda* (Gruidae) in Victoria, Australia – Implications for wind farm planning and conservation (Veltheim *et al* 2019)
- Breeding site home range mapping published in the EES Referrals for the Penshurst (Biosis Research 2011) and Mount Fyans Wind Farms (Biosis 2017)
- Bird utilisation and Brolga breeding season surveys: Ryan Corner Wind Farm (BL&A 2007). Prepared for Gamesa Energy Australia Pty Ltd. Brett Lane and Associates Pty Ltd. Report No. 6114 (3.0)
- Bird and bat risk assessment method: Hawkesdale Wind Farm (BL&A 2011). Prepared for Union Fenosa Wind Australia Pty Ltd. Report No. 9067 (1.3)
- Correspondence of Brolga sightings from local landholders.

3.1.2. Brolga flocking and breeding records

Existing databases were consulted to identify historic records of Brolga breeding, flocking and sighting records. These included the following.

- Victoria Biodiversity Atlas (DELWP) – records with an accuracy of 1,000 metres or less for south-western Victoria were obtained in 2021
- *The Atlas of Australian Birds and Birdata* (BirdLife Australia) accessed 2019
- The south-west Victorian flocking site database (compiled by Sheldon 2004 and provided by the then-Department of Sustainability and Environment).

The records from these databases were analysed for records in SW Victoria, in the Willatook Wind Farm ROI and within the proposed wind farm.

In this investigation, the RoI is the 10 km radius from the original (more extensive) wind farm concept design and all information collected from this area is presented in this report for completeness, even if some of it refers to areas outside the current, more limited RoI.

A number of Brolga breeding records are not associated with wetlands due to the accuracy of the record. DELWP have provided a protocol for addressing the Brolga breeding records that have an inaccurate record of greater than 100 metres where the co-ordinates are not at a wetland. The following steps were applied in these circumstances.

- Attempt to confirm the record location using the location and observer details
- Buffer the record according to the accuracy field
- Attribute the record to the closest wetland within the accuracy buffer
- If there are no wetlands within the accuracy buffer, disregard the record
- If the accuracy attribute is greater than one kilometre, disregard the record.

Flocking site definitions

The Interim Brolga Guidelines state that a flock roost site must meet all three criteria listed below in Table 3. (DSE 2012).

Table 3: Criteria used to identify a flock roost site

Criteria	Justification
More than one year of recording	To ensure the selection of traditional and regularly used sites.
One or more records of counts equal to or greater than 10 birds	To include sites which have been used often or traditionally by flocking Brolga. The assumption is made that if more than 10 birds are recorded on a wetland, flocking behaviour is likely.
Recorded in more than one month	To include sites where Brolga flock for periods greater than one day or one week, i.e. to include sites used traditionally for the majority of the flocking or non-breeding season.

For initial analysis and short-listing of possible flocking sites, including during the landholder surveys, sites that had supported ten or more birds were identified from existing records. These sites were divided into two categories, discussed below.

- **Traditional flocking sites** are not specifically defined in the Interim Brolga Guidelines, but are referred to as the wetland to which Brolga flocks return each night to roost during the dry, flocking season 'year after year'.
- **One-off flocking sites** are defined in the Interim Brolga Guidelines as sites where a flock of Brolgas has been observed on a single occasion, but the site is not a traditional and regularly-used site. This includes single records of a flock or repeat records once within a month or less, and flocks observed foraging during the day away from wetlands.

Traditional flocking sites are considered to have much greater value for Brolga than one-off flocking sites, as they represent a key habitat used for safe overnight roosting after a day of foraging in the surrounding landscape. Movements to and from one-off sites are more likely to resemble the movements Brolga make in the migration season, movements that the Interim Brolga Guidelines state can be considered in determining the residual risk of the project to the Victorian Brolga population. One-off flocking records may also correspond to an observation of a flock foraging during the day away from its traditional flocking site and can often be of birds using non-wetland habitats, such as crops or pasture.

Breeding site definitions

Each Brolga breeding record was analysed and location assessed to determine if the record is valid (i.e. can be attributed to a wetland). In addition, whether the wetland with the breeding record was permanently drained or met the hydrological criteria in Section 4.1.5 was considered. If a wetland was drained or did not have suitable hydrological characteristics then it was considered unsuitable for future breeding. A fuller explanation of this can be found in section 4.2.6.

All historical records of breeding associated with a wetland, were assumed to indicate sites where breeding could occur in the future and such sites were designated as Brolga breeding wetlands, unless they had been permanently drained and were no longer functional wetlands.

3.1.3. Initial surveys and community consultation

Initial field surveys for the project were completed by Ecology and Heritage Partners between 2009 and 2013. These surveys included:

- Brolga searches between November 2009 to February 2010. This included driving all roads within 20 km radius of the project area and searching for Brolga in potential wetland habitat with the aid of binoculars. Where access could be arranged all historical Brolga breeding records were visited and habitat assessed for its suitability as Breeding habitat;
- Aerial survey for Brolga in October 2010 by flying a light aircraft over the Project area and to a distance of 20 km recording potential Brolga nests. Nest locations were recorded and visited on the ground where this was possible;
- Initial community consultation in 2011 landholders with historical records of Brolga were contacted seeking information about Brolga habitat and requesting permission to visit the location. Landowners involved in the Project were surveyed and neighbours invited to participate through a mailout activity;

Brolga breeding season searches during 2012/2013 where five wetland areas within the project site were surveyed to identify Brolga breeding activity.

3.2. Results

3.2.1. Historical flocking sites

Figure 1 indicates the NVR2017 Habitat Importance Modelling (DELWP modelled Brolga habitat) together with the Nature Advisory potential flocking sites that were surveyed and VBA flocking Brolga records with 1,000 metre accuracy or lower (up to 2nd February 2021). The potential flocking sites that were surveyed were from location of records of Brolgas that had more than two birds from the VBA. These were not necessarily Brolga flocking sites, more where efforts were focussed on although the whole RoI was surveyed.

No Brolga flocking sites were identified through the desktop study and community consultations. No Brolga flocking activity was observed in the RoI during the Brolga flocking season surveys. Given the lack of records and the lack of large, permanent wetlands in the RoI there is no evidence that anywhere in the RoI is used as a Brolga flocking site.

The nearest flocking site is located near Penshurst, approximately 28 kilometres north of the study area.

Figure 1: Brolga VBA records and Nature Advisory flocking sites surveyed

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 28/02/2022

Legend

- Wind farm boundary
- NVR2017 Habitat Importance Modelling (DELWP modelled Brolga habitat)
- Brolga VBA flocking records (up to date of 03/02/2021, >1000m accuracy)
- BL&A identified potential flocking sites surveyed

F1
F2
F3
F4
F5

N

Metres
0 2,750 5,500

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3.2.2. Historical Brolga breeding sites

Information from the Victorian Biodiversity Atlas (VBA) on Brolga is presented in Figures 2 and 3.

Figure 2 shows the VBA records for Brolga with an accuracy of 1,000 metres or less and the Habitat Importance Modelling for Brolga prepared by DELWP for southwest Victoria. Figure 2 shows the following.

- The WWF site lies generally south of the higher concentrations of Brolga records in SW Victoria
- A number of Brolga records are from within the wind farm site
- A number of Brolga records are from wetlands some distance from the south-west boundary of the wind farm.

Figure 3 focusses on the WWF ROI (10 km from the boundary). It details VBA Brolga records (up to 2nd February 2021) and the NVR2017 Habitat Importance Modelling (DELWP modelled Brolga habitat). Figure 3 shows the following.

- There are Brolga records from five wetlands within the WWF site, designated Brolga breeding wetlands
- There is little modelled Brolga habitat within the WWF site with some patches within the northern part of the WWF site, and an area in the south-western part of the WWF site
- More extensive areas of modelled habitat occur to the north of the WWF site.

An analysis of Brolga breeding records from the VBA has been undertaken and presented in Table 4. A total of 28 Brolga breeding records were found within the RoI and of these 23 could be attributed to a functional wetland and were considered a Brolga breeding wetland. Wetland numbers used to label wetlands in Table 4 and the following text are presented later in the report in Figures 9 and 13.

Six of these 23 sites were adjacent to the proposed WWF site, of which the Cockatoo Swamp complex supported five different breeding sites. Five of these records were from four wetlands at Macarthur Wind Farm, north of the WWF. Four records were from Pallisters Reserve, a well-known Brolga breeding area.

In addition to the breeding records mentioned above, the VBA contained nine records to the west of the WWF extending from Bessiebelle southwards, including Broadwater and Orford to St. Helens. Four records occurred to the north-east of the WWF in the Willatook/Hawkesdale area, though one of these records could not be verified as it was not located at a wetland and there were no wetlands within the accuracy stated of 900 metres.

There was an additional Brolga breeding observation entered by the former Royal Australasian Ornithologists Union with an accuracy of 4500 metres. The location of the record is not associated with a wetland and therefore this record has been excluded from the analysis due to the accuracy of the record being over one kilometre.

Figure 2: Brolga VBA records and modelled habitat

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 28/02/2022

Legend

- Wind farm boundary
- Brolga VBA records (up to date of 03/02/2021, <1000m accuracy)
- NVR2017 Habitat Importance Modelling (DELWP modelled Brolga habitat)

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N

Metres
0 11,000 22,000

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Figure 3: Brolga VBA records and modelled habitat

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 28/02/2022

Legend

- Wind farm boundary
- Brolga VBA records (up to date of 03/02/2021, <1000m accuracy)
- NVR2017 Habitat Importance Modelling (DELWP modelled Brolga habitat)

N

Metres
0 1,250 2,500

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Table 4: Analysis of Brolga Breeding records from the VBA

Survey/ Observation ID	Survey Start Date	Survey End Date	Site Name (*See Figure 8 for wetland numbers)	Comments	Accuracy	Suitable for inclusion
1022798	5/12/2013		Wetland 26030, Macarthur Wind Farm	Wetland present at Macarthur Wind Farm	100	Yes
1022796	5/12/2013		Wetland 25650, Macarthur Wind Farm	Confirmed breeding wetland at Macarthur Wind Farm	100	Yes
1070275	21/10/2012	21/10/2012	Wetland 25623, Macarthur Wind Farm	Wetland present at Macarthur Wind Farm	50	Yes
968788	23/08/2012		Wetland 25699, Macarthur Wind Farm	Multiple breeding records at this wetland	100	Yes
1021255	7/08/2011	26/08/2011	Wetland 25836, Pallisters Reserve - East Bluegum Swamp	Wetland present at Pallisters Reserve	100	Yes
1021253	30/06/2011	7/08/2011	Wetland 25805, Pallisters Reserve - West Swamp	Wetland present at Pallisters Reserve	100	Yes
1021254	30/06/2011	20/09/2011	Wetland 25828, Pallisters Reserve - Manna Gum Swamp	No wetland at point, point outside of Pallisters, refers to Manna Gum Swamp at Pallisters Reserves.	100	Yes
1185952	16/10/2004	16/10/2004	Could not allocate to an individual wetland.	No wetland at point, inaccurate co-ordinates, in-between previous breeding record location at Pallisters Reserve	1000	No
520586	14/01/2004		Wetland 25777	Wetland present and local landholder also confirmed	100	Yes
944302	1/01/1984	31/12/1984	Wetland 4	No wetland mapped at point though looking at aerial mapping there is a small wetland 100 metres from point (wetland number 4) where it is plausible for a Brolga to nest.	900	Yes
944303	1/01/1984	31/12/1984	Gorrie Swamp.	Point is located at a rocky rise, the area does become inundated to the north and south of this barrier. Breeding record is most likely from the Gorrie Swamp or wetland 23718.	900	Yes
944304	1/01/1984	31/12/1984	No wetland at point, located between two potential Brolga breeding wetlands (Wetland 25866 more likely)	This record is located between two wetlands (Wetlands 25866 and 26055), and is also within 440m of a known historical breeding site (Wetland 5).	900	Yes

Survey/ Observation ID	Survey Start Date	Survey End Date	Site Name (*See Figure 8 for wetland numbers)	Comments	Accuracy	Suitable for inclusion
944310	1/01/1984	31/12/1984	Wetland W12e (26028), Cockatoo Swamp	This breeding record is within the Cockatoo Swamp, a wetland considered to provide suitable breeding habitat.	900	Yes
944313	1/01/1984	31/12/1984	W4	No wetland at point, it is within 830 metres of Wetland W4 which is a confirmed Brolga breeding site.	900	Yes
944321	1/01/1984	31/12/1984	Wetland 25944	This wetland has been highly modified and has large drainage lines running through it. It was identified through the hydrology assessment as holding water for 120 days. Did not hold water during the 2018 and 2019 breeding seasons.	900	Yes
944409	1/01/1984	31/12/1984	Wetland 25634	This point is located within a plantation, the closest wetland is within 420m to the east. Likely this wetland could provide breeding opportunities in the future.	900	Yes
944315	1/01/1984	31/12/1984	No wetland within 900m	This point is located along the Moyne River. There are no wetlands within 900m hence this record has been discarded.	900	No
944311	1/01/1984	31/12/1984	No wetland within 900m	There are no wetlands within 900 metres of this point so the record has been discarded.	900	No
944319	1/01/1984	31/12/1984	Wetland 25841, Bartlett Swamp	This was once a large swamp, has many drainage lines running through it now, does hold water certain times of year though did not hold water for long enough during the Brolga breeding season in 2018 and 2019, may be possible in wetter years. Brolga have been observed foraging at this wetland.	900	Yes
944305	1/01/1984	31/12/1984	St Helens	The point may have once been a wetland, looks to be drained and located next to a house. No other wetlands within 900m.	900	No
813972	1/01/1951	31/12/1966	Record not accurate enough	Point is in a Blue Gum plantation with no wetland associated with it. A 4.5km accuracy is not accurate enough to locate the breeding site.	4500	No
1812597	1/10/2017		Wetland 25741	There is a suitable breeding wetland at this point, and it was verified by the landholder.	10	Yes

Survey/ Observation ID	Survey Start Date	Survey End Date	Site Name (*See Figure 8 for wetland numbers)	Comments	Accuracy	Suitable for inclusion
1759062	14/08/2018		Wetland W4	This is a Nature Advisory record, suitable wetland present, confirmed nesting here over the past four years.	25	Yes
1759063	5/09/2018		Wetland 25650	This is a Nature Advisory record, confirmed breeding wetland at Macarthur Wind Farm	25	Yes
1759064	23/10/2018		Wetland 25867	This is a Nature Advisory record, confirmed breeding wetland in the Orford area.	25	Yes
2014991	17/09/2019		Wetland W4	This is a Nature Advisory record, suitable wetland present, confirmed nesting here over the past four years.	25	Yes
1852021	28/09/2019		Wetland W4	Suitable wetland present, confirmed nesting here over the past four years.	100	Yes
2014992	15/10/2019		Wetland W4	This is a Nature Advisory record, suitable wetland present, confirmed nesting here over the past four years.	25	Yes

3.2.3. *Initial Brolga surveys*

The results of the initial surveys between 2009 and 2013 are summarised below.

- One brolga nest was recorded adjacent to the current wind farm boundary in the 2010 breeding season from the aerial survey and ground truthing (wetland W4)
- A nesting site of Brolga/Black Swan was recorded at wetland 26055 approximately six kilometres to the south-west from the WWF. It was not confirmed if this nest was a Black Swan or a Brolga nest but there was suitable habitat present for either species
- With the exception of the above two observations no other Brolga breeding activities were observed in the RoI during this initial survey period.

3.3. Conclusions

Based on the level one assessments it was concluded that the project would meet at least the first and third triggers for a level two assessment from the Interim Brolga Guidelines. There were records of breeding habitats within the RoI (trigger one). The proposed WWF is located in an area which may be used by Brolga for diurnal movements between foraging and roosting sites (trigger three). As such the Brolga assessment continued to level two investigations, described in the next section of this report.

4. Level two assessment

The level two Brolga assessment collects comprehensive data about the location, nature and extent of Brolga habitats, and patterns of habitat use and behaviour at breeding, flocking and foraging sites within the radius of investigation. Extensive investigations to meet the level two criteria were completed for the project between 2018 and 2021.

4.1. Methods

A variety of survey methods may be used to gather information on the occurrence of the Brolga on the proposed wind farm and surrounding RoI. It involves roaming surveys, aerial surveys, habitat assessments flight behaviour studies and gradient studies, where possible. The following methods were used in this assessment:

- A comprehensive aerial survey of the 10-kilometre RoI for breeding Brolga
- Detailed consultation with landholders in the RoI
- Ground-based roaming observational surveys for six Brolga breeding seasons between 2009 and 2021 (greatest survey effort between 2018 and 2020)
- Review of previous data collected on Brolga flights and movements (Nature Advisory data)
- Functional wetland assessments and hydrological assessments to show wetlands that most likely to be used by Brolga for breeding, foraging and roosting.

These methods and relevant survey dates are summarised below.

4.1.1. Aerial survey

The aerial survey was undertaken during fine weather conditions on 25th and 26th October 2018. This is typically an optimal time to identify Brolga breeding. In the 2018 season, many wetlands dried out prematurely due to the below average rainfall. However, from observations in and around the site, breeding attempts were continuing where water remained.

The aerial survey covered the complete RoI except for Macarthur Wind Farm (due to flight height constraints). The aerial survey was designed to identify Brolga breeding sites within the proposed wind farm site, and in the RoI. Prior to undertaking the survey, east-west flight lines were defined throughout the study area at 500 metre (north-south) intervals.

The survey was undertaken in a fixed-wing, four-seat Cessna 182 RG (retractable undercarriage) flying an average of 180 metres above ground, at a speed ranging between 209 and 240 km/hour. Variations were made in height and speed depended on flight safety and regulatory requirements near powerlines and towns.

The survey team comprised the pilot, a navigator and two observers. The two observers (Plaxy Barratt and Brett Lane) were experienced aerial wildlife surveyors who have undertaken aerial surveys of Brolga and other waterbirds in the past. Transect details were provided to the observers by the navigator (Domenic Peake, Wind Prospect). One observer was located on each side of the plane. Observers scanned an area approximately 250 metres either side of the plane, using binoculars when necessary. When Brolga were observed, their location was recorded on an aerial photograph and transect information was noted. This included the transect number, the direction and distance of the birds from the observer, a general description of habitat and the wetland number (DELWP mapped wetland number) on which the Brolga was sighted.

Limitations of aerial surveys

Aerial surveys can miss individuals of targeted species. Flight speed means that some nests and birds may be missed; the distance at which aerial observers operate may miss birds hidden in vegetation. Notwithstanding this, at 250 metres, most Brolga are visible in wetlands. Furthermore, the observers involved in the survey are experienced at detecting birds during aerial surveys; experience is a significant factor in the accuracy of such surveys.

The combination of the initial on-ground assessment and the aerial surveys provided information consistent with historical records of breeding Brolga. Therefore, the combination of ground and aerial survey results is considered to generate representative data on breeding locations and Brolga numbers.

4.1.2. Detailed community consultation

The results of detailed landholder surveys, when combined with historical data, enabled a complete and more longer-term picture to be assembled of Brolga activity in the RoI to supplement and provide context for the field investigations.

Extensive interviews were held with landholders within the wind farm and the RoI from 3rd to 7th December 2018. As the RoI is extensive, those landowners within five kilometres of the wind farm were prioritised for contact, although a number of landholders beyond this distance also participated in interviews. Information gathered can be seen in the community questionnaire in Appendix 1.

Landholder surveys were undertaken within the RoI to identify additional Brolga flocking and breeding sites that may not be recorded in the available databases. All landowners, including absent landowners, and dwelling owners within 10 kilometres of the boundary of the wind farm were contacted by letter and invited to take part. Where possible and if information was available follow up calls were made with all RoI landowners. If the phone numbers were not available, it was not possible to contact these additional landholders.

Interviews were undertaken with landholders at the Willatook Community Hall from 3rd to 7th December 2018. During the interviews, each participant was questioned for a period of up to 30 minutes. Additional consultations were held by telephone on the 4th and 6th February 2019 with landowners in the RoI. Efforts are ongoing to engage participants not interviewed to-date. Information sought from landholders is noted below.

Table 5 presents the area of the RoI held by local landholders that participated in the consultations (up to mid-February 2021). Note Table 5 also includes areas of land within the 5–10-kilometre boundary from the wind farm from unsurveyed landholders but that have been identified as timber plantations from current aerial imagery. These areas are assumed not to be current Brolga breeding areas given the species avoids wetlands that are surrounded by heavy treed vegetation or are treed themselves (Herring 2005, DSE 2012).

The Landholders in the ROI were questioned about their current and past farming history to provide a more accurate picture of land use/type within the local landscape Figure 4. In addition to presence and location of historic and current Brolga activity on their property, landholders were queried about broader historical and current land use/s, and the other biodiversity values of their properties' and surrounding properties.

Table 5: Percentage by area of wind farm and RoI surveyed by landholder interviews

Area	Area of land surveyed (ha)	Total area of land (ha)	Percentage of area surveyed
Within wind farm boundary	3225	4154	78%
Within 5km of wind farm boundary	14,777	32,743	45%
Within 10km of wind farm boundary	22,362	74,289	30%

In addition to landholders, representatives from Australian Blue Gum Plantations and Trust for Nature were interviewed. Data was provided for Pallisters Reserve managed by Friends of Pallisters Reserve Inc. and owned by Trust for Nature for Brolga records from 1995 to 2018. Pallisters Reserve is a 254-hectare bushland reserve with multiple wetlands. It is situated approximately six kilometres south-west of WWF. Wetlands in Pallisters Reserve provided high quality habitat for Brolga breeding.

The quality of landholder survey data is likely to vary due to landholder interest and length of residency; however, the data obtained has added information to the overall picture of Brolga activity and, importantly, provided evidence on Brolga activity from a much longer period than the period of the current project-specific field investigations. While not all landowners provided input into the assessment and therefore there is uncertainty regarding potential for Brolga breeding on these properties, a range of other methods including review of databases, aerial surveys, field observations and wetland assessments were used to consider these areas.

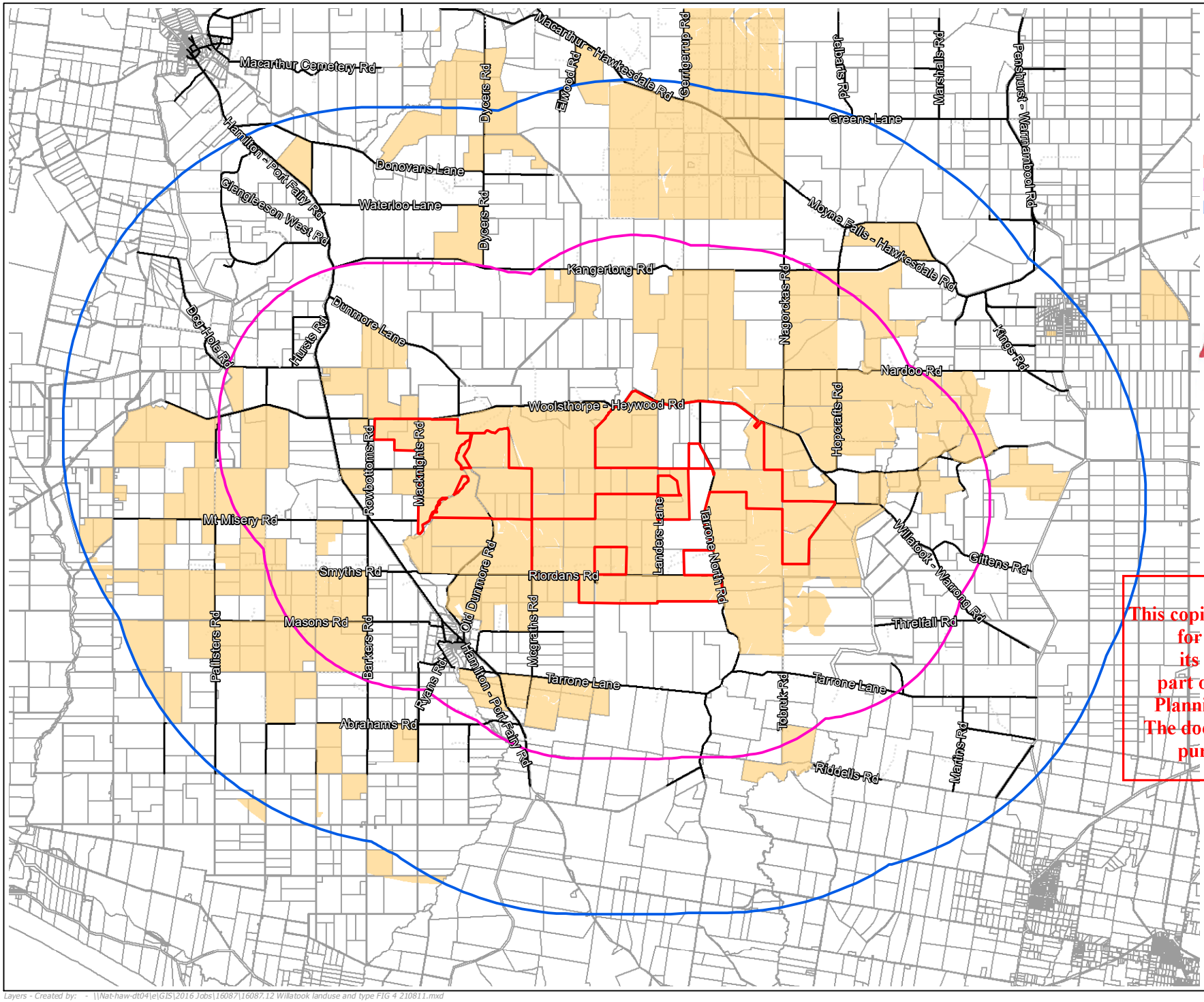

Figure 4: Willatook Wind Farm - land use surveyed areas

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 28/02/2022

- Wind farm boundary
- Willatook WF 5km buffer
- Willatook WF 10km buffer
- Surveyed areas

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Metres
0 2,600

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Layers - Created by: - \\Nat-haw-dt04\e\GIS\2016 Jobs\16087\16087.12 Willatook landuse and type FIG 4 210811.mxd

4.1.3. Brolga surveys

Based on the review of historical information, it was concluded that the RoI was used by the Brolga during the breeding period. However, methods and results presented below are for both the breeding and flocking seasons.

A range of methods were used to maximise the detection of breeding Brolga. Between 2018 and 2021, ground-based searches were undertaken for breeding Brolga, as well as assessments of wetland quality.

The roaming survey area was the wind farm site and within five kilometers from the boundary of the wind farm as far as possible, all wetlands not subject to private land access limitations were visited and surveyed. All wetlands within the wind farm boundary were assessed in the field. Within the five-kilometre radius 112 wetlands were assessed in the field totalling 92% of the wetlands in that radius, based on the DELWP wetland map layer (2014). The searches between 5 and 10 km from the boundary focussed on areas where breeding had been recorded in the past, e.g. Pallisters Reserve and the St. Helen area to the SW and Muddy Dam Road to the west of the proposed WWF. All remaining wetlands that were not visited in the field were assessed using aerial photography imagery and notes collected from the aerial survey to determine the suitability to provide Brolga breeding habitat.

Wetlands were visited multiple times throughout the survey period if they continued to hold water. Once they were dry, they were no longer surveyed for breeding Brolga. If a wetland was initially classified as drained, it was not surveyed again for breeding activities.

To provide information on the likelihood of Brolga using any area in the search region as a flocking site a Brolga flocking survey was undertaken in the RoI by Nature Advisory observers over a two to four day period each in May to June 2018, January to June 2019 and January to June 2020. A total of 15 survey events (totalling 48 days of survey effort) were conducted during the non-breeding (flocking) season. The survey focused on areas that had records from databases of four or more Brolga within the wider area and at permanent wetlands that held water throughout the year. The dates the Brolga flocking surveys were undertaken were as follows.

- 2nd – 3rd May 2018
- 31st May – 1st June 2018
- 23rd – 24th January 2019
- 5th – 6th February 2019
- 25th February – 1st March 2019
- 25th – 27th March 2019
- 30th April – 2nd May 2019
- 25th – 27th May 2019
- 19th – 20th June 2019
- 21st – 24th January 2020
- 17th February – 21st February 2020
- 10th – 13th March 2020
- 27th April – 1st May 2020

- 19th – 22nd May 2020
- 15th – 18th June 2020.

Roaming surveys of potential Brolga breeding wetlands were made each month between July and December to assess the suitability of the wetland to provide breeding habitat and to see if any Brolga were present. If Brolga were present at a wetland, then an effort was made to find a nest or young chicks through prolonged observation, without disturbing birds.

Monthly surveys were undertaken as Brolga will spend a few days at a wetland performing mating displays and making their nest then at least a further 30 days incubating their eggs. Thus, monthly surveys will identify if a pair of Brolga is utilising a wetland for a concerted breeding attempt[1]. It is possible that failed incubation may have been missed but experience (Nature Advisory data) indicates birds will attend a wetland for a period after egg loss and will often attempt to nest again if conditions are suitable.

Initial Brolga breeding season roaming surveys (EHP 2018) were undertaken in the 2009, 2010 and 2011 breeding seasons.

To provide recent information on the status, distribution and possible occurrence of breeding Brolga on wetlands in the search region, Brolga breeding season surveys were undertaken of the RoI by Nature Advisory observers over a period of two to five days once a month from July to December 2018, July to December 2019, July to December 2020 and August 2021. A total of 19 survey events (totalling 70 days of survey effort) were conducted during the breeding season between 2018 and 2021.The dates the surveys were undertaken are as follows.

- 30th July – 3rd August 2018
- 13th – 17th August 2018
- 24th – 27th September 2018
- 22nd – 26th October 2018
- 19th – 23rd November 2018
- 4th – 7th December 2018
- 15th – 18th July 2019
- 12th – 15th August 2019
- 16th – 19th September 2019
- 15th – 18th October 2019
- 11th – 14th November 2019
- 9th –12th December 2019
- 27th – 28th July 2020

1 The average duration of breeding events monitored in south-western Victoria across wind farm projects on which Nature Advisory has worked is 50 days and only in six out of 36 breeding attempts were young successfully raised (Nature Advisory data).

- 29th –31st August 2020
- 27th – 29th September 2020
- 27th – 29th October 2020
- 16th – 17th November 2020
- 14th –15th December 2020
- 2nd – 4th August 2021.

Rainfall and runoff in autumn, winter and spring 2018 was below average and therefore most seasonal wetlands were dry by November. For this reason, the survey period was considered to represent below average conditions for breeding.

Rainfall and runoff in autumn, winter and spring 2019 was considered to be average with most wetlands being inundated up until December. This was a wetter year to previous and considered better breeding conditions of the two years of surveying for Brolga due to wetlands holding water for a longer period.

The 2020 breeding season experienced higher than average rainfall across the region during spring which led to flooding. Wetlands were full throughout the breeding season extending into summer.

A survey was undertaken during the beginning of the breeding season in August 2021. At the time of the monitoring all wetlands were full of water and Brolga had begun nesting in the study area.

Wetlands identified as permanently drained were unsuitable for breeding purposes. Further hydrological investigations were commissioned to make a definitive assessment on all wetlands on the wind farm site as to their suitability to provide Brolga breeding habitat (see section 5.1.5 below).

The breeding season survey effort has totalled seven breeding seasons out of 12 between 2009 and 2021. This is considered to provide a reliable indication of Brolga breeding activity on the proposed wind farm site and in the surrounding RoI.

4.1.4. Brolga behaviour and movements

Home range mapping of individuals were recorded during the 2018 field surveys for the project to gather site-specific data. Three pairs were observed breeding in the RoI in 2018, one pair at the Cockatoo Swamp complex, one near Orford and one at Macarthur Wind Farm.

The pair at the Cockatoo Swamp complex abandoned their nest after it was flooded and left the area soon after. They did not hatch or rear any chicks during the 2018 breeding season and data was only collected for one day before they departed the area. This made it difficult to gather any meaningful home range data for this pair.

The home ranging mapping exercise was not repeated in subsequent years as the research undertaken by Veltheim *et al* (2019) with a more robust dataset was published and it was decided that the data presented in that research would be used to guide the home range mapping process.

Flight behaviour data of Brolga has been gathered by Nature Advisory (formerly Brett Lane & Associates Pty Ltd) over 15 years in southwestern Victoria. This monitoring included observations of 24 breeding Brolga pairs and involved 12 hours of continuous observation in a single day of each breeding pair and three separate four-hour daylight observation periods. This mix of observation periods aimed to gather representative data on Brolga flights from breeding wetlands.

Data were collected on time spent in the breeding wetland, flight times (outward and return), height, distance and the destination habitat. A total of 163 flights from breeding wetlands were recorded of breeding Brolga in south-west Victoria and this data set was used to predict distances flown from breeding sites and inform collision risk modelling. The analysis of this data is presented later in this report in Section 4.2.4.

4.1.5. Wetland assessment

A functional wetland potentially provides nesting, foraging and/or night time roosting habitat for Brolga. Several features influence the functionality of wetland habitat for Brolga. These include.

- Hydrological function, such as depth and duration of inundation
- Physical features of wetlands including the total size and wetland basin shape (e.g. shoreline slope)
- Type and cover of vegetation and associated biological productivity.

To assess potential Brolga, habitat several methods were used including assessment of mapped wetlands in the Victorian Wetland Inventory (VWI), hydrological modelling and ecological field surveys.

The wetland assessment undertaken involved determining which wetlands were functional and likely to remain functional in the future given current and predicted conditions. An overview of the steps involved in the wetland assessment is provided below.

- The Victorian Wetland Inventory (VWI) was reviewed and wetlands within the inventory were assessed using the following methods (outlined in Sections 4.1.1 and 4.1.3 above)
    - Aerial surveys and imagery (RoI)
    - Field assessments (majority of wetlands within five kilometres were surveyed each month during the breeding season during 2018 – 2019)
- Hydrological modelling was then undertaken on and adjacent to the proposed wind farm site as it was noted from the review of the VWI that many wetlands in the database were inaccurately mapped and did not represent the size and shape of wetlands on the ground due to hydrological changes in the agricultural landscape, inaccurate mapping and wetlands being permanently drained
- The hydrological modelling was undertaken by Water Technology to provide a more accurate wetland map for the area that encompassed the wind farm project and immediate surrounds (approximately up to two kilometres from where turbines were proposed)
- Field assessments were then undertaken of the wetlands short-listed from the hydraulic assessment to document other functional wetland characteristics that are required for Brolga breeding habitat including the size of the wetland and the presence of aquatic vegetation (sedges, *Poa* Tussock Grass)

The specific methods of each step of the functional wetland assessment is provided below.

Victorian Wetland Inventory

Identifying functional wetlands first considered those mapped in the VWI database. The VWI database, last updated in 2017, is administered by DELWP and shows the extent and types of wetlands in Victoria, incorporating local and regional wetland datasets. Wetlands in the VWI database are categorised based on the following.

- Wetland system type (lake, marsh/swamp, marine, estuarine)
- Salinity regime (e.g. fresh, saline)
- Water regime (permanent or periodically inundated)
- Water source (e.g. groundwater, river)
- Dominant vegetation
- Wetland origin (naturally occurring or human-made).

Wetlands were considered here as functional wetlands if they provided habitat for Brolga breeding, foraging or night time roosting. Wetlands were considered functional wetlands if they had habitat characteristics as follows.

- Held water for at least 120 days during the Brolga breeding season surveys (or modelled to do so at least once every ten years)[2]
- Were at least 0.6 hectares in size (the minimum defined size based on review of known breeding wetland sizes (see Section 4.2.5))
- Had a component of emergent vegetation cover of at least 20% cover.

Wetlands that were considered unlikely to provide habitat for Brolga were classified as unsuitable wetlands. Unsuitable wetlands were those that were permanently drained or partially drained and did not meet the 120-day minimum inundation period at least once in ten years, were less than 0.6 hectares in size, had little to no emergent vegetation or were mapped incorrectly based on topographic characteristics.

Wetlands within the wind farm development boundary or adjacent to the wind farm were included in the hydrological assessment outlined below.

Hydrological wetland assessment

After two years of Brolga surveys, it was noticed that many of the wetlands in the VWI were inaccurate in terms of size, shape or presence of water. Hydrology investigations were commissioned across the project area and immediate surrounds (within two kilometres of proposed turbine locations) to develop a surface water model to accurately redefine the location and extent of wetlands. The hydrological assessment is attached in Appendix 2.

A number of steps were involved in this process. This included the following.

- A LIDAR surveys of the proposed wind farm and its immediate surrounds was undertaken with sub-metre accuracy to produce a digital elevation model (DEM - topography) of the surveyed area.
- The hydraulic model identified wet areas that to be included in a more detailed hydrologic assessment by modelling the extent of the 1:100 year flood (72-hour rainfall event) on the area subject to the DEM.

[2] The 120-day inundation period (comprising a 30 day incubation period plus a 90 day chick rearing period) is the minimum considered adequate to support a complete, successful Brolga breeding season, a criterion established with advice from DELWP early in the assessment (DELWP, in litt.).

- The model was then allowed to run for seven days to allow the flood to flow away, leaving any functional wetlands full. Wetlands less than 0.1 hectares were then excluded from modelling.
- Water balance modelling of each individual or series of linked wetlands was undertaken to estimate both runoff volumes and wetland levels (including evaporation) to determine if the wetland will hold water for a 120-day minimum inundation period at least once in ten years.
- The 120-day inundation period is the minimum considered adequate to support a complete, successful Brolga breeding season, a criterion established with advice from DELWP early in the assessment (DELWP, in litt.).

Mapping was provided of wetlands and farm dams that were assessed to be functional wetlands and provide habitat for Brolga including potential Brolga breeding wetlands or night-time roosts from the outputs from the hydrological modelling.

Field assessment of short-listed wetlands

Functional wetlands that may provide potential breeding, foraging and night-time roosting habitat for Brolga were identified using the following criteria:

- At least 0.6 hectares in area (see later)
- Holds water continuously for 120 days during the period from July to December in at least a one in ten-year flood event
- Had aquatic vegetation cover, indicating a recently functional wetland ecosystem.

A wetland in the modelled area was considered unsuitable if it was smaller than 0.6 ha or was permanently drained and did not hold water for the minimum 120-days once in a ten-year flood event.

Ecological field assessments were completed for each of the mapped wetlands that met the hydrological criteria. These surveys focussed on the size of the wetlands and the presence of aquatic vegetation that is crucial for nest building and foraging. Aquatic vegetation is required to provide nesting materials (Myers 2001, Du Guesclin 2003), food resource (tubers, aquatic animals) (Herring 2018), shelter for prey (vertebrates and invertebrates) (Herring 2005) and cover from predators for young chicks (Johnsgaard 1983, Herring 2018). If wetlands did not have any aquatic vegetation associated with them they were considered unsuitable for Brolga breeding and chick rearing.

In the instance where a wetland would usually not fill but was predicted by the modelling to fill in a one in ten-year rainfall event, habitat conditions of the site were taken into consideration. If a wetland identified by the hydrology assessment was deemed to hold water for at least 120 days on average at least once in ten years, and it supported aquatic vegetation such as sedges and/or Poa Tussock Grass, it was considered suitable Brolga breeding habitat. This was because the existing aquatic vegetation would recover from the dry period relatively quickly after filing and create higher quality habitat while still holding water in that year to support Brolga. The same approach was taken for farm dam overflow and floodplain areas. As there is no literature on the habitat characteristics of a Brolga night-time roost, it has been assumed that Brolga will use the same wetlands that are considered to provide breeding and foraging habitat as night roosts.

The field assessment was conducted on 11th September 2020. Wetlands and farm dams were visited on foot, photographs and notes taken on habitat characteristics, including surface water

cover, drainage, emergent vegetation present and evidence of grazing pressure, such as stock pugging and grazed vegetation.

4.1.6. Brolga breeding wetlands

A Brolga breeding wetland is a wetland that has had Brolga breeding either during the current investigations or in the past and is considered likely to provide Brolga breeding habitat in the future. A wetland is considered to provide Brolga breeding habitat in the future if it is a functional wetland providing Brolga habitat, as described above.

The results of all field surveys for the Willatook Wind Farm assessments were included in the Brolga breeding wetland assessment and all Brolga breeding activities observed at a wetland (nest building, incubation, young chick-rearing) were considered as confirmed Brolga breeding attempts.

Wetlands where previous Brolga breeding records have been reported though the wetland no longer meets the criteria of a functional wetland were excluded as a Brolga breeding wetland and considered unlikely to support successful Brolga breeding in the future.

4.2. Results

4.2.1. Detailed community consultation

A total of 38 landholders/managers participated in the interviews, occasionally representing multiple properties or multiple family owners of properties. These built upon the landholder consultations conducted in 2010 (EHP 2018). Landholder observations of Brolga are summarised below.

- Twenty-one landholders reported not having seen a Brolga on their property
- Four landholders reported observing breeding events on wetlands on their property or their neighbour's property (total five wetlands)
- No landholders reported flocking events or larger groups (more than four) Brolga on their property
- Eleven landholders reported general observations of Brolga occurring on their property but no breeding or flocking.

The results from these interviews and informal discussions with other landholders identified additional Brolga sightings within the RoI. The majority of landholders commented that if recorded, Brolgas would forage in their paddocks over a number of days then disperse into the wider landscape.

Brolga breeding wetlands documented during the consultations included those historic breeding records within Macarthur Wind Farm and Pallisters Reserve (both more than five kilometres from the proposed wind farm) and one site within two kilometres of the proposed wind farm boundary along Nagorckas Road (wetland 25741).

Informal discussions with local landholders identified additional breeding sites at the following locations.

- A breeding pair in the St. Helens area (confirmed in August 2021 at wetland 25894)
- A wetland within a Blue Gum plantation prior to the plantation being planted at St. Helens (wetland 5).

Landholders within the proposed wind farm site were questioned about the current and past farming history of their property to provide a more accurate picture of land use/type within the

local landscape. The survey found that the majority of the RoI is dominated by a mixture of stony outcrops and cleared/semi-cleared land for pasture, either cut to hay or grazed (cattle and/or sheep).

In addition to landholders, representatives from Australian Blue Gum Plantations and Trust for Nature were interviewed. The distribution of Blue Gum plantations were generally located to the west and south-west of the wind farm. Habitats in the area included plantations, patches of Messmate, Swamp Gum and Manna Gum woodland, derived grasslands and wetlands.

Pallisters Reserve is a 254-hectare wetland reserve. It is situated approximately six kilometres south-west of WWF. Wetlands in the reserve provided high quality habitat for Brolga breeding and breeding has been recorded at this site in the past.

Five statutory declarations were provided to the WWF project and forwarded to Nature Advisory. The statutory declarations were reviewed and if additional information was required the person that made the statutory declaration was contacted. A summary of the outcome of each statutory declaration is below.

A statutory declaration was completed by the landholder for Wetland 25741 on the 31st July 2019 at the Honorary Justice Office in Melbourne. It stated that Brolga have nested at a wetland on his farm most years since he has owned it for the past 25 years. This same breeding event has also been added to the VBA and was reported during the formal consultation surveys. Photos were provided of Brolga at Wetland 25741 in 2017. Nature Advisory visited the farm and assessed the wetland condition and it met the criteria described earlier for suitable Brolga breeding habitat and was accepted as a Brolga breeding site. Brolga was not reported as breeding at this site during the Brolga monitoring period from 2018 to 2021.

A statutory declaration was completed by a local landholder on the 6th August 2019 at the Warrnambool Police Station. In it, it was stated that Brolga nesting was seen at Wetland 25816 (Wild Dog Swamp), a large wetland on the property that provided suitable habitat for breeding Brolga and met the foregoing criteria. While breeding was not confirmed at this site during the current 2018 to 2021 monitoring period, a pair was observed foraging there during 2020 surveys. Given the given the high quality habitat in the wetland it was accepted as a breeding site.

A statutory declaration was completed by a landholder on the 12th August 2019 at the Koroit Pharmacy. It stated that her family has owned a property along the Woolsthorpe-Heywood Rd for over 30 years and during this time they have seen Brolga on the farm. It was acknowledged that Brolga are in the vicinity and are likely to occur anywhere across the landscape at any given time. There was no indication of Brolga breeding activities at the farm.

A statutory declaration was completed on the 12th August 2019 at the Hawkesdale Post Office. It stated that Brolga have nested on the property in Wetland 25932 and provided co-ordinates. The wetland indicated is isolated from other wetlands. Photographs were provided of an immature Brolga at the wetland. This Brolga was alone and was not with its adult parents indicating that it had moved from its natal wetland and was independent. The photos of the wetland were not typical of breeding habitat and lacked emergent vegetation that provides the Brolga with nesting material and foraging opportunities. The wetland has significant drains running through it. No Brolga were observed at this wetland during the 2018 to 2021 Brolga breeding season surveys. A hydrology assessment was undertaken by Water Technology by conservatively modelling the wetland assuming there were no drains as well as assuming that the upstream catchment flows into the wetland even though it also has drains. This concluded that even if there were no drains that Wetland 25932 does not meet the minimum threshold of holding water for atleast 120 days once

every 10 years. It is acknowledged that the wetland may have provided Brolga breeding habitat during very wet years prior to it being drained. However, given its current condition, the wetland was assessed not to provide suitable breeding habitat for Brolga in the future.

A statutory declaration was completed on the 22nd August 2019 at the Hawkesdale Post Office. It stated that Brolga visit Wetland 25729 on the property annually and co-ordinates were provided. Nature Advisory contacted the landowner on 18th September 2019 to follow up on his observations. He explained that a pair of Brolga with a young chick were seen at the wetland five to six years earlier. The wetland does meet the criteria for suitable breeding habitat and was accepted as a Brolga breeding site. Monitoring during 2018 to 2021 did not confirm any Brolga activity at the wetland during this time.

4.2.2. Breeding-season aerial survey

In the two days of the aerial survey, no Brolga were identified, however several nests were recorded. These nests were Black Swan nests, evidenced by the presence of Black Swans on or near them in most cases. No Brolga were found on or near any unoccupied nests.

In addition, the aerial survey undertook a wetland assessment that included the following.

- Identification of wetlands in the VWI
- Assessment of whether the wetlands were drained or otherwise unsuitable
- Identification of additional wetlands that were not included in the VWI.

This information has been included in the functional wetland assessment outlined in the preceding sub-sections section.

4.2.3. Brolga surveys

Extensive site-specific field investigations have been undertaken during breeding and non-breeding periods in 2018, 2019, 2020 and 2021 to document the extent of Brolga activity and current and historical spatial patterns of activity in the radius of investigation. The roaming field surveys periods occurred during various weather conditions, including high and low rainfall seasons. A summary of the survey results is provided in Table 6.

Table 6: Summary of Brolga roaming surveys

Year	Brolga Breeding Observations	Other Brolga Observations
2018	Breeding attempt at Wetland W4. Nest was flooded and attempt failed to hatch any chicks. Breeding attempt at Wetland 25867 near Mt Misery Road. The pair successfully reared a chick to fledging. Breeding attempt at Wetland 25650 at Macarthur Wind Farm. The pair successfully reared a chick.	
2019	Brolga returned to Wetland W4 where they successfully reared a young chick. Were observed foraging at W12c in July prior to breeding. A pair of Brolga at Macarthur Wind Farm in July observed foraging at Wetland 25699, no	A pair of Brolga were observed by a local landholder foraging on seed along hay trails in the floodplain of the Moyne River early in the breeding season. No breeding activity was reported.

Year	Brolga Breeding Observations	Other Brolga Observations
	breeding activity observed. A pair of Brolga with chick observed at Wetland 25650, nesting wetland was not confirmed but was nearby. Local land manager reported a pair of Brolga breeding in the St. Helens area. Adult pair reported with young chick. Likely nesting site at Wetland 25894.	A single Brolga was reported by a local landholder at Wetland 25906 in July. No Brolga were observed here for the rest of the year. Likely an immature bird roaming the landscape. A pair of Brolga observed foraging in October at Wetlands 25784 and 25788 along Muddy Dam Road, no breeding activities observed. A pair of Brolga seen with last years young bird foraging together at Wetland 25841 near Mt Misery Road. Seen on two occasions August and November. Their breeding attempt in this year was missed. This pair nested at Wetland 25867 the previous year.
2020	Brolga returned to Wetland W4 where they successfully reared a young chick. Observed foraging at W12w and W12e before nesting commenced. A pair heard duetting at Wetland 25829 at Pallisters Reserve. Likely breeding attempt. A pair of Brolga with young chick observed in December in the St Helens area near Wetland 25913. Breeding site was not confirmed. The Brolga pair at Macarthur Wind Farm were not monitored this year.	In June a pair of Brolga were reported by a local landholder foraging in paddocks in the Moyne River floodplain. No breeding activity reported. Later in July the pair were observed foraging at 25816 (Wild Dog Swamp), no breeding activity observed. In June a pair observed foraging at Wetland 25797 along Muddy Dam Road. No breeding activity observed. In June a pair observed foraging in a wetland south of Mt Misery Rd. Seen again in November, observed foraging near wetland 25868 near Mt Misery Road. No breeding activity observed. In July a pair observed foraging at wetland 25698 along the Tarrone North Road. No breeding activity observed.
2021	Brolga returned to Wetland W4 where they were observed sitting on a nest in August. The Brolga pair in the St Helens area observed sitting on a nest in August at Wetland 25894. This wetland is likely to be the wetland the pair have been using to breed in previous years. Brolga returned to Wetland 25650 at Macarthur Wind Farm where they were observed sitting on a nest in August.	A local landholder reported seeing a pair of Brolga foraging in a wetland on private property south of Riordans Road in June. This pair likely to be the same pair breeding at Wetland W4 before they started breeding and were still roaming the landscape.

Five pairs of Brolga were observed breeding within the RoI during the 2018 - 2021 Brolga breeding surveys. Confirmed breeding wetlands during the four-year monitoring period included the following.

- One breeding Brolga pair was located within three kilometres of the proposed wind farm site. This was:
    - Wetland W4 (Cockatoo Swamp complex) - One pair was observed nesting near the wind farm boundary during all four-years of monitoring from 2018 - 2021. During 2018 the eggs were lost as the nest was abandoned when water levels rose, flooding the nest. During 2019 and 2020 the pair were observed at the nesting site for several months

with a young bird. Early in the 2021 breeding season the pair was observed sitting on a nest. This pair of Brolga were only in the area during the breeding season and were observed in the area from June/July to October/November each year. During the monitoring period, Brolga were rarely present in the Cockatoo Swamp complex area during the non-breeding season from December to May with one exception when a pair of Brolga was seen in April 2020 foraging in a flood plain at W12w.

- In addition, other breeding records in the RoI included:
  - Wetland 25650 (Macarthur Wind Farm) - One pair nested at Macarthur wind farm during 2018 and successfully raised one chick. They did not nest at this wetland in 2019 though they did breed nearby in that year as they were sighted later in the breeding season with a young bird at this wetland. This nesting site was not monitored during 2020. A pair of Brolga were observed incubating eggs early in the 2021 breeding season.
  - Wetland 25867 (Mt Misery Road) – One pair nested at a felled Blue Gum plantation during 2018 where they successfully raised a chick.
  - Pallisters Reserve – A pair was observed in the area during the 2020 surveys, actual breeding wetland was not confirmed. Though historical data suggests that they breed here year after year.
  - Wetland 25894 (St. Helens area) – A pair of Brolgas was regularly seen in this area. Locals reported with a chick during 2019 and Nature Advisory confirmed a chick in 2020 breeding seasons. Breeding wetland was confirmed early in the 2021 breeding season at wetland 25894 where nesting was observed.

In addition to the five breeding pairs of Brolga, there were two to three additional pairs of Brolga observed in the RoI, though breeding behaviour was not observed in these birds.

- A pair was seen foraging at two wetlands on Muddy Dam Road, Broadwater during 2019 and at another wetland nearby in 2020.
- A pair of Brolga were observed foraging at Wild Dog Swamp (Wetland 25816) in Willatook on one occasion in 2020 and local landholders have also reported a pair of Brolga foraging in the floodplain of the Moyne River south of Wild Dog Swamp prior to 2020. This may be the same pair revisiting.
- A pair was observed foraging at a drained wetland along Tarrone North Road in July 2020 at Wetland 25698. This wetland is located between the breeding site at Wetland W4 and Wild Dog Swamp. It is not clear if this pair was the pair that usually breed at Wetland W4, the pair that has been seen at Wild Dog Swamp and associated Moyne River floodplain or was an additional pair visiting the area. It was only recorded in the area once. July is the time of year when Brolga have left their flocking sites and roam the landscape in search of potential breeding sites and foraging areas.

4.2.4. Brolga movements

Attempts were made to monitor the pair of Brolga breeding at Wetland W4 in 2018 to gain some understanding of its home range and areas they used around Cockatoo Swamp complex. Unfortunately, the pair abandoned their nest after it was flooded and departed the area soon after, resulting in a very short monitoring period. As it was not feasible to gather enough site specific data on Brolga movements, a combination of pre-existing information on the behaviour of Brolgas at

their breeding wetlands (Nature Advisory data) and research presented by Veltheim *et al.* (2019) was relied upon.

Work by Nature Advisory over the last 15 years (observations of flight distances and destinations from 24 Brolga nests, n = 163) showed that 54% of Brolga flights were within 400 metres of the breeding wetland, 71% within 800 metres, and 86% within 1,600 metres. The remaining flights (14%) were between 1,600 and 3,200 metres. Figure 5 provides a summary of the findings of this observational work.

Flight height observations were also made for 67 of the 163 flights from a breeding wetland and most flights were found to be less than 40 metres above the ground (see Figure 6).

The same Nature Advisory dataset also includes data on the habitat at the flight destination away from the breeding wetland. This was recorded for 99 of the 163 flights. Figure 7 illustrates that Brolga's use wetlands as well as other habitats, including pasture (dominated by exotic grass species), grassland (has a component of native grass species) and crop (canola or cereal grain).

Brolgas showed no preference for a particular habitat when flying up to 400 metres from their breeding site. Observations indicated that when moving over 400 metres from the breeding site the Brolga showed a statistically significant difference from the expected habitat choice for wetlands when the area of wetland relative to other habitats was taken into consideration (Binomial Test, $p < 0.001$)[3]. The preference became stronger with increasing distance from the breeding site. This is not unexpected as Brolga are a wetland-dependent species.

More recently, Veltheim *et al*. (2019) used satellite-tracker generated point data (4 points per 24 hours) to determine movement patterns of Brolga pairs with pre-fledging chicks based on locations of chicks (assumed to be accompanied by adult birds). The satellite recordings were made every six hours from midnight. Nature Advisory observations indicate birds spend up to 15 minutes per day flying (depending on distance) and spend up to 1.5 hour away from their breeding wetland, with an average time away of 45 minutes. Therefore, most of the data on which Veltheim et al. (2019) based their analysis would have been of birds on the ground, not flying. Collision risk from wind turbines arises from birds flying, so the Nature Advisory flight observations are particularly valuable additional data set for assessing impacts.

The data of Veltheim *et al.* (2019) showed that 95% of Brolga observations were within 1,369 metres from night roosts[4] to daytime foraging areas and that their home range varied from 70 to 523 hectares.

A spatial model was then used by Veltheim *et al*. (2019) to determine the likely 'utilisation distribution' of a Brolga family. The 95% utilisation distribution was found to be within two kilometres of the night roost/breeding wetland. This is the zone predicted by statistical modelling within which 95% of Brolga movements would occur. DELWP (in litt. to Willatook Wind Farm Pty Ltd) have indicated a preference to use this 95% utilisation distribution distance as a basis for determining which wetlands to encompass within a Brolga breeding site home range. It is noteworthy that the average distance Brolgas moved from night roost found by Veltheim *et al*.

[3] The binomial test is used to compare if values are in line with an assumed expected proportion (in this case based on the area of wetland versus non-wetland habitats available more than 400 metres from the breeding site)

[4] A night roost was the wetland in which adults and chicks spent the night. This was not always the same wetland in which the nest had been constructed if that was no longer suitable and an alternative was used.

(2019) work was 442 metres, with 50% of observations being less than 315 metres, an observation broadly consistent with the Nature Advisory flight data showing that the majority of flights from breeding wetlands were less than 400 metres.

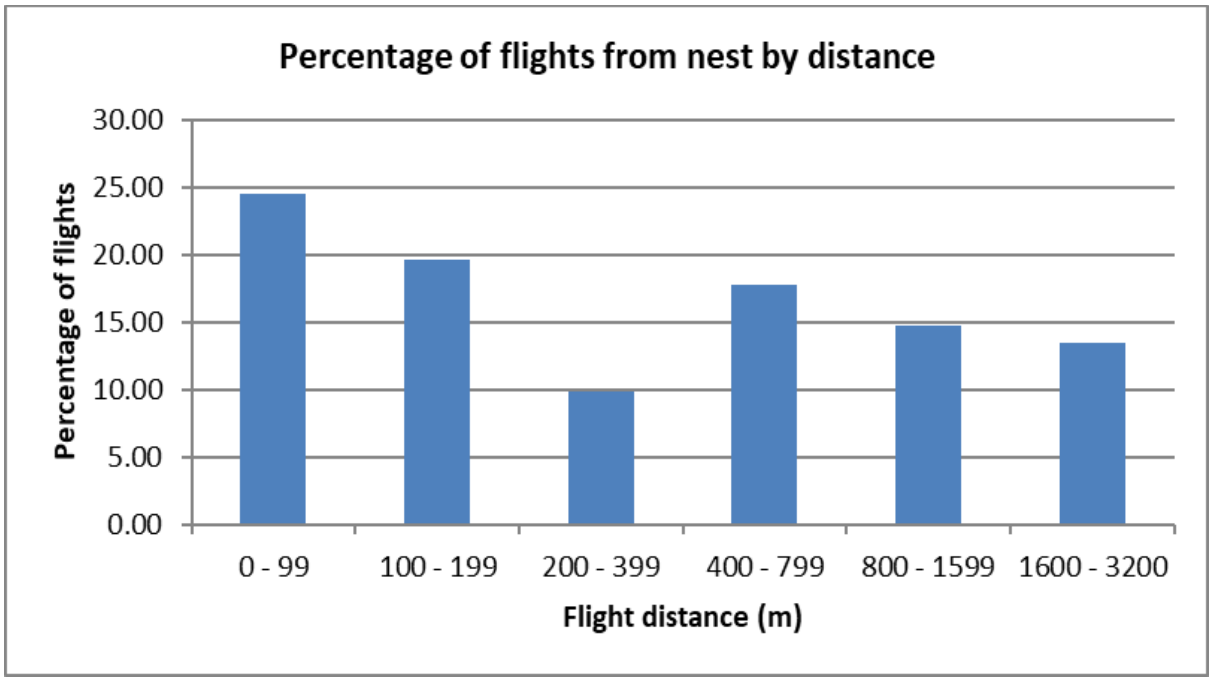


Figure 5: Distance of breeding Brolga flights from 24 breeding wetlands (2007 – 2015, n = 163)

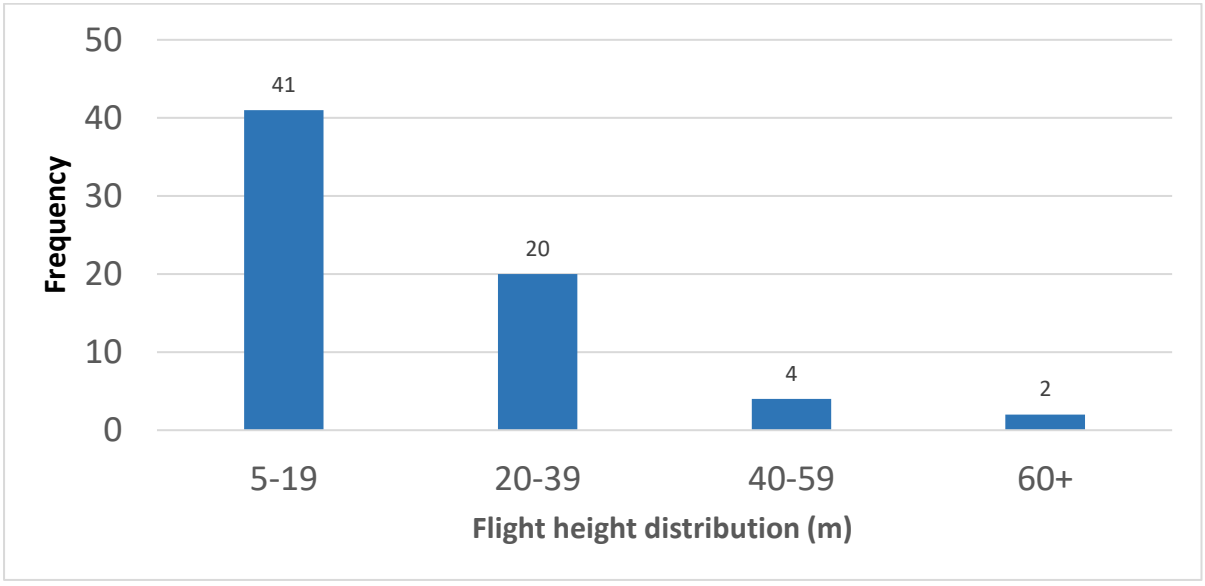
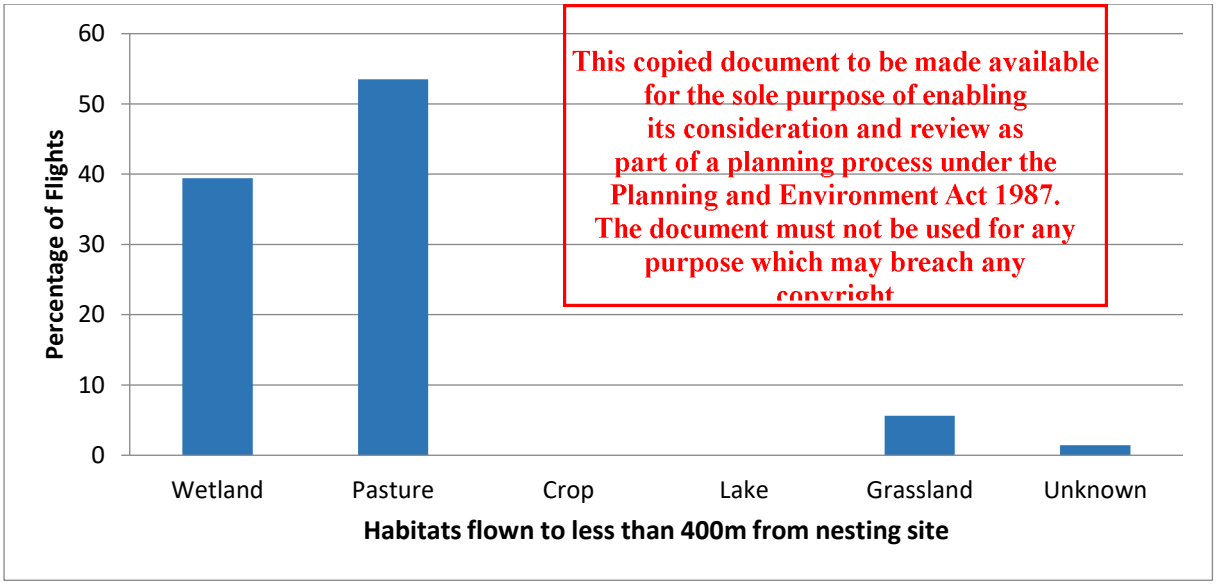


Figure 6: Flight height distribution of Brolga flights from breeding wetlands (n = 67)



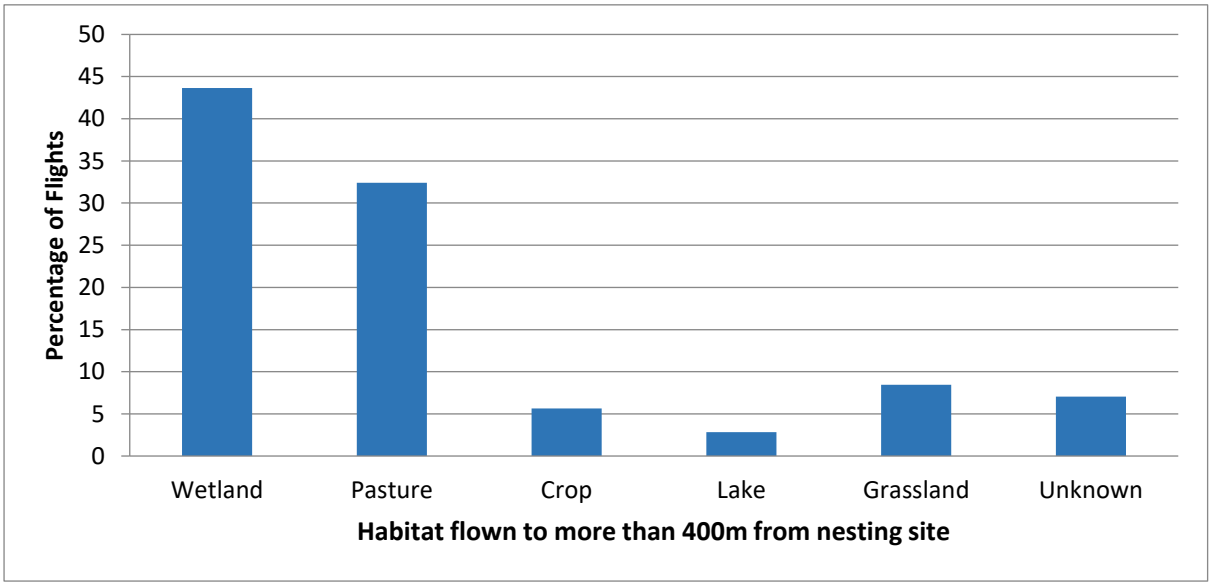


Figure 7: Habitats at flight destination from breeding wetlands (n = 99)

4.2.5. *Brolga habitat assessments*

Brolga nest in wetlands with emergent vegetation that holds water for at least 120 days, permitting nest building, egg laying and incubation (c.30 days), hatching and the growth of chicks to an age (90 days) and size at which they're less vulnerable to predation and can walk to nearby wetlands should the original breeding wetland dry out (Herring 2001, Myers 2001). This total duration of 120 days has also been confirmed by DELWP (in litt. to Willatook Wind Farm Pty Ltd) as the minimum that would support a successful Brolga breeding attempt.

Suitable breeding habitat is dominated by aquatic vegetation including sedges, rushes, annual herbs, Tussock Grass *Poa* sp., Sweet Grass *Glyceria* sp., Spike–rush *Elocharis* sp. or Common Sword Sedge *Gahnia* (Marchant and Higgins 1993). Nests are usually constructed within the shallows of wetlands from a variety of plant matter where a platform of vegetation is constructed approximately 1.5 metres in diameter (White 1987).

They use the emergent vegetation for nest building and also provides a food source (e.g. tubers) and habitat for vertebrate and invertebrate food. They spend most of their time in the nesting wetland foraging but will move to other wetlands nearby to forage and/or roost as the chicks develop. Brolga also forage in pasture and to a lesser degree (during the breeding season) cereal and canola crops.

Food density and habitat quality can influence home range (Veltheim *et al*. 2019) and the higher quality the wetland the less likely Brolga move out to other areas to forage, however their satellite tracking of Brolga chicks found no relationship between home range size and the connectivity measure. Dense vegetation, water depth and food availability are the most important habitat features for breeding success (Herring 2001, Myers 2001). Individual wetland condition and quality is thus most likely to be the most important habitat feature for Brolga breeding success (Veltheim *et al*. 2019). Veltheim *et al*. (2019) found that use of multiple wetlands increased breeding success and optimum breeding success occurred where Brolga families had access to at least three wetlands.

Veltheim *at al*. (2019) identified wetlands that act as night-time roosts, particularly once the adults and chicks have left the nest. These wetlands may or may not have been where the nest was originally constructed. Once nests are not used, these night-time roosts become the focus of activity for Brolga families.

Brolga are unlikely to utilise or breed successfully in wetlands that are less than 0.6 hectares (the minimum observed by Veltheim *et al*. (2019) - see Section 4.2.6). A wetland that does not hold water for 120 days at least once in ten years was considered unsuitable. Wetlands that are unfenced and grazed by cattle, near sources of human disturbance or have little or no emergent vegetation are also less suitable to provide habitat for Brolga (Nature Advisory data). Brolga are unlikely to breed in drainage lines flowing into and out of wetlands due to flooding risk and they prefer larger expanses of water to protect them from ground predators. Equally Brolga do not breed in flowing creeks and rivers though they will if they have been dammed and flows stilled.

Victorian Wetland Inventory (VWI)

A total of 335 wetlands in the RoI were assessed (100% of total VWI). The detailed Brolga breeding wetland assessment is presented in Appendix 3. A map showing the shape and locations of the VWI is presented in Figure 8.

A summary of the results from the wetland assessment is presented in Table 7. Many wetlands assessed (67%) were deemed unsuitable to provide Brolga habitat due to changes in hydrological regimes (i.e. drained), too small (<than 0.6ha) or inaccurate wetland mapping. A total of 109 wetlands (33%) were still functional hydrologically and had not been permanently drained. Hydrological assessment of wetlands within and adjacent to the proposed wind farm identified wetlands that persist for 120 days or more at least once in ten years.

Table 7: Summary of Brolga breeding wetland habitat assessment

Wetland suitability	No. of wetlands	% of wetlands
Drained, too small or inaccurately mapped	226	67.5
Functional wetland	109	32.5
Total	**335**	**100**

Many wetlands in the VWI were dry during the survey, or had been dry for many years, as they had been permanently drained and converted for agricultural use. These sites no longer held water and were considered unsuitable as Brolga habitat. Only on one occasion were Brolga observed foraging at a drained wetland.

Of the 335 wetlands assessed, 109 wetlands were considered further as they were found to be potentially functional hydrologically and not too seriously damaged by draining and agricultural development.

Redefining mapped wetlands

The undulating landscape of the Willatook Wind Farm site and its surrounds created challenges in reconciling wetland conditions on the WWF site with the VWI. As the study progressed it became apparent that the VWI layer was inaccurate and did not represent the wetlands that were observed in the field and from aerial imagery. Hydrological specialists (Water Technology 2022a) were engaged to develop a surface water model to redefine the wetland boundaries more accurately within the project area and areas close to the boundary (Figure 9). Wetlands were redefined using a digital elevation model from a LIDAR survey, an inundation model for the area based on the 1:100 ARI (72 hour) rainfall event, rainfall data for a ten-year period (from 2009 – 2019) to identify wetland filling and inundation duration to locate wetlands that remain inundated for at least 120 days (Water Technology 2022a) as per the parameters above.

While water depth is also a critical factor that influences the suitability of wetlands for Brolga breeding, this factor was excluded from the hydrological modelling in response to feedback from DELWP (in litt. to Willatook Wind Farm Pty Ltd) making the hydrological modelling a conservative model of functional wetlands that provide Brolga habitat (i.e. more likely to over-estimate than underestimate the number of functional wetlands).

The more accurately defined wetland boundaries (Appendix 2) meant the movement of Brolga could be more accurately predicted. This in turn helped to apply turbine free buffer zones around wetlands that the Brolga are likely to utilise while moving to nearby foraging areas from the breeding site. Figure 9 presents the wetland layer that was used for this assessment and states whether the wetlands were functional or unsuitable for Brolga habitat.

The hydrology assessments found that within or close to the boundary of the proposed Willatook Wind Farm there were 38 farm dams and 17 wetlands that met the hydrological criteria (Water Technology 2022a) presented in Appendix 2. Further ecological field assessments were then completed for each of the mapped wetlands that met the hydrological criteria. These surveys focussed on the size of the wetlands and the presence of emergent vegetation that is crucial for nest building and foraging (Herring 2001, Myers 2001). The farm dams and wetlands that were functional wetlands and provided Brolga habitat are included in the development of turbine free buffers. These buffers have been developed encompassing these wetlands around confirmed Brolga breeding wetlands if they were close enough (see Section 5).

Of the 38 farm dams and 17 wetlands that were assessed, three farm dams and 11 wetlands were considered likely to provide suitable habitat for Brolga breeding and foraging based on the hydrological modelling and field assessment (Appendix 4).

Figure 8: Victorian Wetland Inventory with wetland numbers

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 28/02/2022

Legend

- Wind farm boundary
- Willatook WF 10km buffer
- DELWP mapped wetlands
- Historical or confirmed Brolga breeding wetlands

N

Metres
0 1,250 2,500

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Figure 9: Redefined wetlands with wetland numbers

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 28/02/2022

Legend

- Wind farm boundary
- Willatook WF 10km buffer
- Historical or confirmed Brolga breeding wetlands

Wetland assessment

- Functional wetlands
- Unsuitable wetlands

N

Metres
0 1,250 2,500

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Review of Brolga breeding wetland sizes

Brolga breeding wetlands vary in size. Herring (2001) found Brolga in the Victorian and NSW Riverina bred in wetlands ranging from 2.5 to 1,280 hectares (n = 11). Myers (2001) did not publish a size range but found 54% of 99 breeding wetlands were less than five hectares in extent. Sheldon (2005) found breeding wetlands averaged 15.7 hectares (n = 29), ranging from 1.3 to 79.8 hectares. Veltheim *et al*. (2019) recorded an average night roosting wetland size of 7.6 hectares (n = 11), ranging from 0.6 to 40.7 hectares, while known breeding wetlands (n = 5) ranged from 3.0 to 40.7 hectares. The smallest size wetland that was utilised by Brolga in all breeding site research was 0.6 hectares, used for night roosting (combined n = 51) or 1.3 hectares for confirmed breeding (combined n = 46).

A separate analysis of the Victorian Biodiversity Atlas (VBA) Brolga breeding records in the southwestern Victorian part of their range was undertaken. Of the VBA Brolga breeding records, 452 were sufficiently accurate to be in a wetland. Allowing for multiple records at one site, these records came from 156 wetlands in the VWI. Four of these wetlands were larger than 1,000 hectares. The following histograms show the size distributions and mean areas of Brolga breeding wetlands less than 1,000 hectares (Figure 10), less than 100 hectares (Figure 11) and less than 10 hectares (Figure 12).

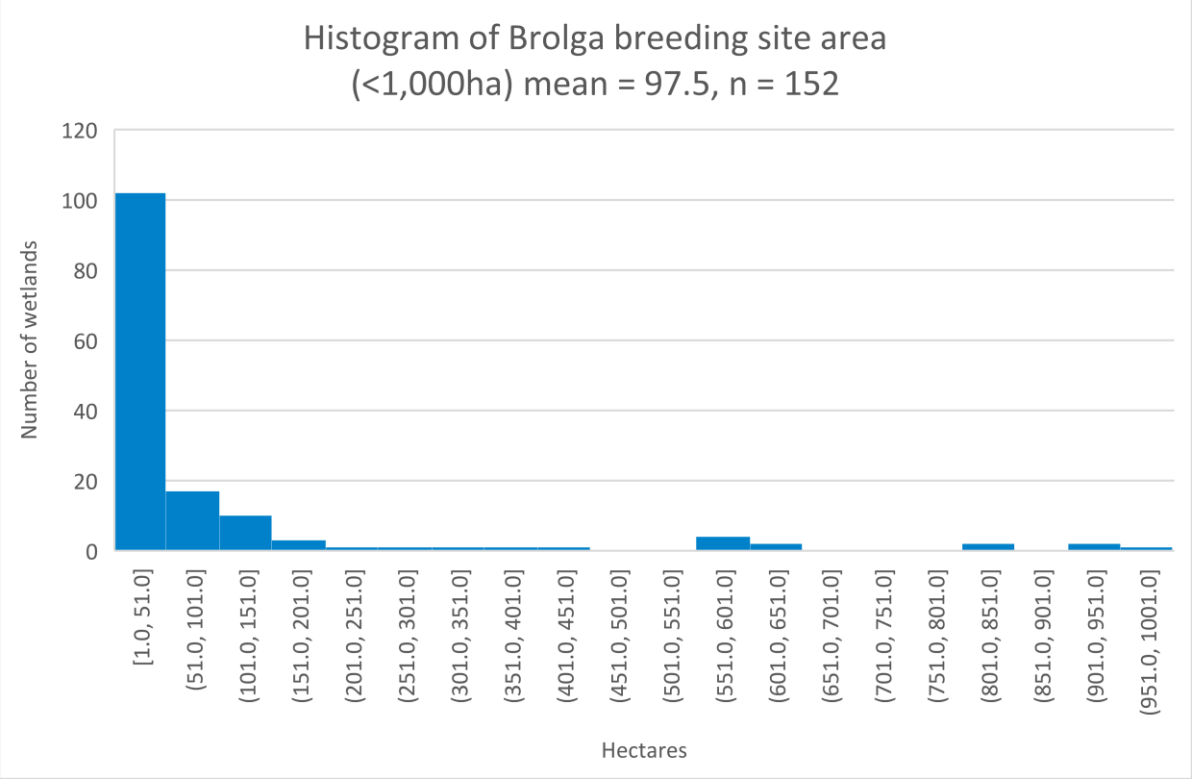

Figure 10: Brolga breeding wetlands less than 1,000 hectares

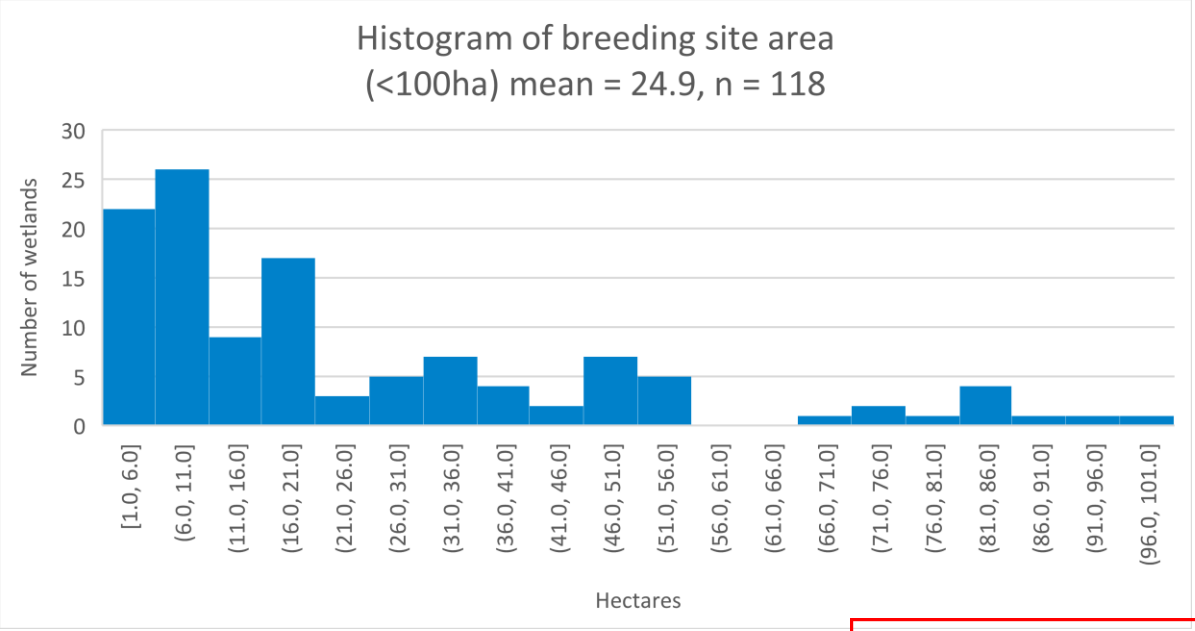

Figure 11: Brolga breeding wetlands less than 100 hectares

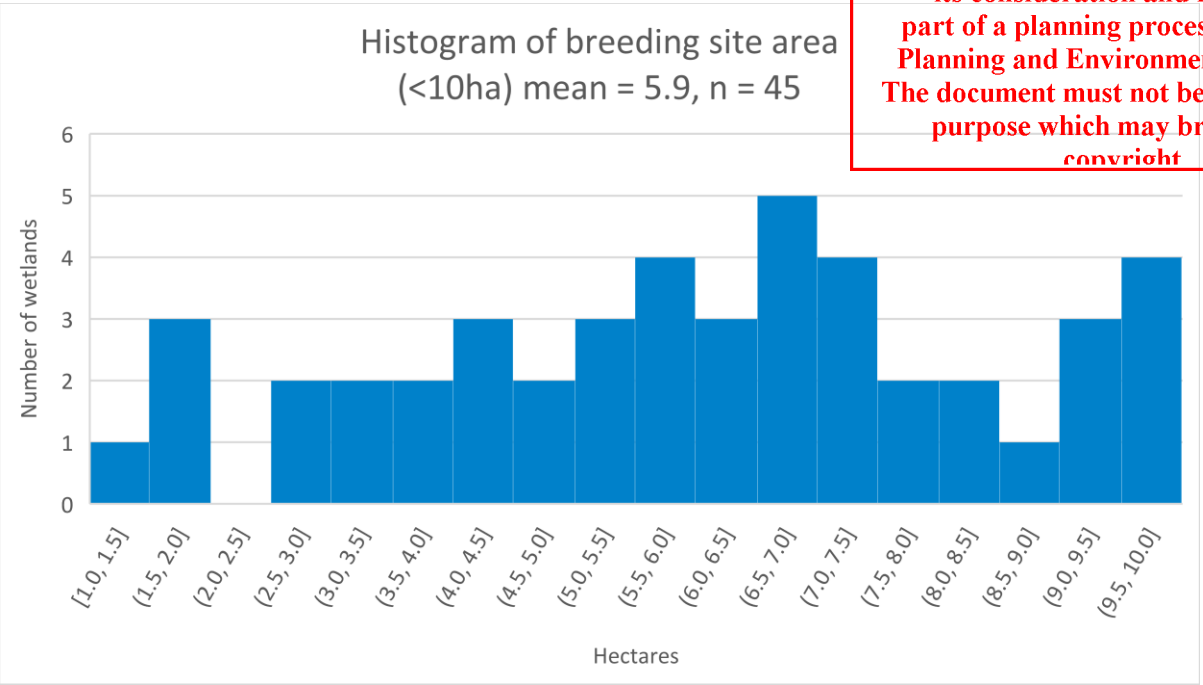

Figure 12: Brolga breeding wetlands less than 10 hectares

This indicates that Brolga breed in wetlands with an average size of 97.5 hectares. The smallest breeding wetland in the VBA was one hectare (one record at one wetland), all other breeding records came from wetlands of 1.7 hectares or larger.

Based on this research, for mapping Brolga home ranges and associated turbine-free buffers, any wetland above one hectare is potentially suitable for breeding by Brolga. That said the area of the smallest wetland in which Brolga were observed roosting overnight (not breeding) by Veltheim *et al*. (2019) was 0.6 hectares, which was therefore used as the minimum viable size for Brolga breeding or roosting.

4.2.6. Brolga breeding wetlands

A total of 32 wetlands in the RoI have had at least one previous Brolga breeding record associated with them. Of these 32 wetlands, 30 wetlands have been tentatively identified within the RoI as being Brolga breeding sites either currently or able to continue to provide habitat in the future (Table 8, Figure 13). Two breeding sites were considered unlikely to provide breeding habitat currently or in the future due to them not meeting the minimum 120-day inundation period (based on hydrological modelling) required to successfully rear chicks.

Based on the field observations during the past four years of monitoring, five Brolga pairs continued to return to the RoI each year to breed. From the potential 30 wetlands in the RoI that may be used for Brolga breeding it is likely that at least five of these wetlands will be used for breeding in any year given the presence of five pairs of breeding Brolgas within the RoI.

Table 8: Analysis of Brolga breeding wetlands

Wetland No.	Date of record	Dataset	Comments	Likelihood of future breeding attempts	Brolga breeding spatial layer
1	2005	Local landholder	This record was from a floodplain next to the Kangaroo Creek. Only one breeding record from this site and was dry throughout the 2018 and 2019 surveys. This wetland will only fill in wet years when creek bursts its banks and floods. Hydrology assessment did not identify this wetland as being able to hold water for the 120-day period, which suggests that it is unlikely to provide habitat for successfully rearing young.	Unlikely	Wetland unlikely to provide resources to successfully rear young
2		Local landholder	This wetland is part of a larger flood plain. When flood waters recede, it may hold water long enough for a breeding.	Likely	Breeding site
4	1984	VBA (literature review)	No wetland mapped at point though looking at aerial mapping there is small wetland 100 metres from point where it is plausible for a Brolga to nest.	Likely	Breeding site
5	1990's	Local landholder	A pair of Brolga nested on this wetland once before the Blue Gum plantation. Have not bred there since the Blue Gums were planted.	Possible if Blue Gum plantations cease.	Breeding site
6	2001	Trust for Nature	Wetland next to woodland, good cover of water and emergent vegetation. No grazing though signs of Feral Pigs.	Likely	Breeding site
25623	2012	VBA	Previous record of Brolga breeding at this wetland.	Likely	Breeding site
25650	2012	Australian Ecological Research Services (AEC)	Breeding site at Macarthur Wind Farm in a high quality wetland which is used often for breeding.	Likely	Breeding site
	2013	VBA, AEC			
	2016	AEC			
	2018	VBA & Nature Advisory			
	2021	Nature Advisory			

Wetland No.	Date of record	Dataset	Comments	Likelihood of future breeding attempts	Brolga breeding spatial layer
25699	2012	VBA, EHP Report	Wetland has been drained though Brolga still use it for breeding even when it does not fill.	Likely	Breeding site
	2014	Australian Ecological Research Services			
W4 (25721)	2010	Ecology and Heritage Partners	Nest was seen from Aerial survey and ground truthed.	Likely	Breeding site
	2018	VBA & Nature Advisory	Wetland has been partially drained, there is a decent sized pool in the western section. Nature Advisory recorded Brolga sitting on a nest in 2018 though did not successfully hatch any young.		
	2019	VBA & Nature Advisory	The pair were nesting in September and October, had a young chick in November. Were not seen in December.		
	2020	Nature Advisory	An adult pair with chick were seen from September - November, nest was in the wetland.		
	2021	Nature Advisory	A pair observed incubating a nest in early August.		
25729	2013 (approximately)	Local landholder	Nature Advisory spoke with the landholder (Simon Cozens) on the 18th Sep 2019 and he has indicated he has seen a Brolga pair with a young bird approximately 5-6 years earlier. Given that the wetland is isolated from other wetlands it is therefore possible to be a Brolga breeding site.	Likely	Breeding site
25741	2017	VBA & Local landholder	This wetland is a small wetland that had some surface water at the time and a lot of emergent vegetation. It will hold more water for longer in wetter years.	Possible in wet years	Breeding site
25766	2009	VBA	Medium sized wetland surrounded by Blue Gum plantation. Previous breeding site.	Likely	Breeding site
25771	2006	VBA	Wetland holding some water, Blue Gum plantation around three quarters of the wetland. Some emergent vegetation present, dried out by September. Likely to hold water for longer periods if Blue Gum plantation ceased. There are wetlands nearby.	Likely	Breeding site
25772	2005	Local landholder		Likely	Breeding site

Wetland No.	Date of record	Dataset	Comments	Likelihood of future breeding attempts	Brolga breeding spatial layer
	2009	VBA	Medium sized wetland surrounded by Blue Gum plantation on most sides and a road abuts it. Stock excluded and has good cover of emergent vegetation.		
25777	2004	VBA	Small wetland with a Blue Gum plantation on south side, a lot of rushes and stock excluded.	Likely	Breeding site
	2011	local landholder			
25800	2010	Trust for Nature	Medium sized wetland with good cover of surface water and emergent vegetation.	Likely	Breeding site
25805	2011	VBA	Wetland is located on the border of Pallisters Reserve and a Blue Gum plantation.	Likely	Breeding site
25816	Not stated	Local landholder	This wetland is a large wetland that holds a lot of water during the breeding season. Many waterbirds congregate here and many Black Swan breed here. While Brolga were not confirmed to breed here during the past four years during monitoring, the wetland is considered to provide suitable breeding habitat and Brolga are considered likely to breed here in the future.	Likely	Breeding site
25825	2010	Trust for Nature	Small wetland in Pallisters Reserve with some surface water and good cover of emergent vegetation. No stock present though signs of Feral Pig.	Likely	Breeding site
25828	2011	VBA	Manna Gum Swamp, Brolga breeding record associated with this wetland.	Likely	Breeding site.
25829		Trust for Nature	Small wetland in Pallisters Reserve with some surface water and good cover of emergent vegetation. No stock present though signs of Feral Pig.	Likely	Breeding site
25836	2011	VBA	Wetland located within Pallisters Reserve, good cover of water and emergent vegetation, stock excluded though signs of Feral Pig in reserve.	Likely	Breeding site
25841 (Bartlett Swamp)	1984	VBA (literature review), Local landholder	This wetland drains quite quickly, though hydrology analysis has stated that it does hold water long enough for a breeding attempt. Brolga have been observed foraging here during monitoring but breeding has not been confirmed.	Likely	Breeding site

Wetland No.	Date of record	Dataset	Comments	Likelihood of future breeding attempts	Brolga breeding spatial layer
25850	2008	Trust for Nature	Small wetland surrounded by Blue Gum plantation, unlikely to support breeding Brolga in current condition while trees are still tall and surrounding wetland.	Unlikely while Blue Gum plantation surrounds the wetland. Possibly after the trees are harvested.	Possible when Blue Gum plantation ceases
	2009				
25867	2018	VBA & Nature Advisory	Medium sized wetland with cumbungi covering a lot of it and also water ribbon and other aquatic plants. Located in a harvested Blue Gum plantation block that had been recently planted with Blue Gum tube stock.	Likely	Breeding site
25894	2021	Nature Advisory	Medium size wetland that has been partially drained, with emergent vegetation growing within. Wetland across two grazing paddocks, usually grazed by cattle.	Suitable	Breeding site
25932	Not stated	Local landholder	Isolated wetland with many drains running through it. Wetland had limited emergent vegetation and was grazed by sheep. Due to the drainage of the wetland, the outcomes of hydrology assessment was that the wetland does not hold water for the minimum 120-days. This wetland does not meet the criteria of a functional wetland in its current condition.	Unlikely	Not a breeding site
W1 (25944)	1984	VBA (literature review)	This is an old breeding record, the wetland has been well drained since, with deep channels running through the wetland. No surface water present through the breeding season surveys. Grazed by cattle. Hydrology analysis indicates that it may become inundated in a one in ten-year flood to support Brolga.	Suitable	Possible in one in ten-year flood
W12e, W12c, W12w (26028)	1984	VBA (literature review)	The location of this point is in Cockatoo Swamp and is considered to be suitable habitat.	Likely	Breeding site
26029	2013	VBA	Wetland was originally very large though it has been drained throughout, now only holds water in north-eastern section of mapped wetland.	Likely	Breeding site
	2016	Australian Ecological Research Services			

Figure 13: Brolga breeding wetlands

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 28/02/2022

Legend

- Wind farm boundary
- Willatook WF 10km buffer

Hydology assessment and Brolga breeding wetlands

- Historical or confirmed Brolga breeding wetlands
- 25816 Wetland number

N

Metres
0 1,250 2,500

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4.3. Conclusions

Conclusions from the Level Two assessment include the following.

- A significant proportion (~67%) of the mapped wetlands in the RoI have been permanently drained and are considered unsuitable for Brolga breeding. A significant proportion of the RoI, in particular the southern portion, lacks wetlands and the Brolga has not historically been recorded there.
- A total of 112 wetlands within five kilometres of the WWF site were assessed in the field totalling 92% of the mapped wetlands. A total of 100% of wetlands within the RoI were assessed either by field assessments, aerial surveys or aerial imagery.
- No Brolga flocking activities have been recorded during the flocking season within the RoI, with the closest flocking site being 28 kilometres to the north. Based on the historical activity of the Brolga in the RoI and the findings of this assessment, the focus of assessment and mitigation has been on the use of the area for breeding. Little risk to the Brolga population is considered to arise from the use of the region during the flocking season.
- There are 30 Brolga breeding wetlands within 10 kilometres from the WWF site either currently or likely to provide breeding habitat in the future. Five breeding pairs of Brolga have continued to return to the RoI each year to breed, with the majority of breeding occurring more than three kilometres from the wind farm. One pair has bred regularly within three kilometres of the proposed wind farm. This represents, between 1.1% and 1.6% of the South-western Victorian population of the species.
- Within three kilometres of the proposed wind farm, six wetlands that have records of Brolga breeding occur in or around the proposed wind farm site: five wetlands in the Cockatoo Swamp complex; and one isolated breeding wetland to the east.
- Given that there is one breeding pair and up to six breeding wetlands within three kilometres of the proposed wind farm the level three assessment was triggered.

5. Level three assessment

A level three assessment involves four steps, as summarised in Table 2. Each step is described in more detail below.

Step One: Avoid and mitigate impacts on the Brolga

Avoiding or mitigating the impact of a wind farm on the Victorian Brolga population is primarily based on establishing turbine free buffer zones surrounding Brolga breeding sites. Turbine-free buffers avoid or mitigate the impacts of turbines on these home ranges to achieve the objectives outlined below.

The Interim Brolga Guidelines require that turbine free buffers be established to avoid impacts within Brolga breeding and flocking home ranges such that:

- For **breeding sites**, "turbine siting would be used to exclude any significant reduction in breeding success caused by turbines" (DSE 2012, p. 8); and
- For **flocking sites**, "turbine-free buffers should be designed to exclude any significant impact on the survivorship of Brolga whilst occupying that flocking site" (DSE 2012, p. 8).

It is noteworthy that Brolga do not use every breeding (or flocking) wetland every year or perhaps for a long period of time. Thus, generating site specific approaches for every breeding (and flocking) location within and near a wind farm is not possible. Thus, home ranges and turbine free buffers must be based on assumptions, drawn from evidence and observations, about bird activity in and around these sites.

As no flocking sites occur within 10 kilometres of the proposed Willatook Wind Farm site, mitigation needs only to address impacts on breeding sites.

Step Two: Collision risk model (CRM)

The objective of CRM is to estimate the residual number of Brolga flights which have the potential to interact with wind turbines on the proposed site and from this estimate the annual collision rate then extrapolate that to the assumed 25 year operating life of the project.

Step Three: Population Viability Analysis (PVA) model

The site-specific collision risk output is then used in the PVA to model the potential impact of the proposed wind farm on the Victorian Brolga population. The PVA was undertaken for the development application by Dr Michael McCarthy of Melbourne University, who prepared the PVA for DELWP's predecessor some years ago. It provides an indication of the impact of the wind farm on the future population size of the Brolga in Victoria.

Step Four: Compensation to achieve zero net impact on the Victorian Brolga population

Improving Brolga breeding habitat to enhance breeding success is considered an appropriate compensation strategy to replace the birds lost to the population because of the proposed wind farm (DSE 2012).

5.1. Step One: Avoid or mitigate potential impacts

5.1.1. Potential impacts

Wind farms may impact on Brolgas in four key ways listed below.

- Direct effects, particularly mortality resulting from collision with turbines or powerlines

- Indirect effects including the following
  - Habitat avoidance
  - Disturbance from construction activities
  - Barrier effects.

Collision with turbines or powerlines

To date there have not been reported incidents of Brolga collision with wind turbines. Brolga collisions with powerlines have been reported from Victoria (Goldstraw & Du Guesclin 1991; Herring 2005). While wind turbines have not been shown to be a key threat to the Victorian Brolga population, it has been suggested that they may be vulnerable to collision due to their large size and relatively low mobility.

In the absence of extensive and replicated observations on the interactions of flying Brolga with wind turbines, international research from closely related species was considered. The Brolga belongs to the crane family and wind turbine interactions have been observed for two other crane species: the European Common Crane (*Grus grus*) and the North American Sandhill Crane (*G. canadensis*).

In the United States of America, Navarrete and Griffins-Kyle (2016) undertook a monitoring program in Texas along the Sandhill Crane migratory route. Sandhill Crane increasingly come into contact with wind turbines during migration as the associated infrastructure expands across the landscape. The study area was the High Plains in Texas and the area has experienced large increase in wind farm sites where the cranes use this area during migration and part of winter where they forage in agricultural areas and roost at night in playas. Sandhill Crane collision with turbines was reported on two occasions in these foraging and roosting areas.

In Germany, Stübing and Korn (2006) observed cranes near wind farms on 88 occasions over a seven-year period in Rhineland. They found that in-flight cranes never approached closer than 100 metres to turbines, with distances usually between 300 and 700 metres. In summer, after breeding, the cranes approached wind farms to within 150 to 250 metres but no closer. This contrasts with Wood's (2014, 2017) observations at least twice of Brolga flying low directly under operating turbines at the Macarthur Wind Farm. This may be because flocking birds (European Crane observations) react collectively and more significantly to turbines than individuals or pairs of breeding birds.

Langgemach (2013) found that avoidance action by flying cranes in response to operating wind turbines was observed for individuals and small flocks up to a distance of 750 metres from turbines while for larger flocks, turbines were avoided by greater distances, between 1,000 and 1,350 metres.

The observations of Gerjets (2006) for European Crane, again at a wind farm in northern Germany, are summarised below.

- Cranes avoided flying close to wind turbines
- Cranes have been observed flying within 200 metres of operating wind turbines where turbine lines are oriented parallel with the direction of flight
- The range of distances from turbines that cranes were observed flying in one systematic study was between 150 and 670 metres, with a median distance of 300 metres, where turbines were not parallel with the direction of flight

- In another, less systematic study, crane flocks flew around operating wind turbines at distances of between 400 and 500 metres where turbine lines were not parallel with the flight direction
- Flocks of cranes have been observed flying quite close to turbines, in one case about 100 metres from one and in another between two operating turbines, quite close to the rotor tips and
- Another observation involved a "V" formation flock breaking up, possibly due to downwind turbulence from a wind turbine, at a distance of 750 metres from the turbine. The flock eventually flew around the turbine and regrouped after 1.5 kilometres.

The reaction of cranes to wind turbines therefore varies but it is clear that they generally avoid wind turbines when in flight.

Habitat avoidance

There is strong circumstantial evidence that Brolgas adapt to the indirect impacts of wind turbines.

Information on the impacts of wind turbines on Brolga behaviour from Wood (2014, 2017) and Veltheim *et al*. (2019) is informative. The nesting Brolgas at the Macarthur Wind Farm lie within the RoI for the Willatook Wind Farm and were monitored in 2018, 2019 and 2021 (July – August so far) as part of the Level Two investigations for the project. The same breeding wetland and presumably pair were again observed in all three years breeding within 400 metres of operating wind turbines. This new information indicates that at the Macarthur Wind Farm, Brolga have bred within 400 metres of constructed and operating turbines for at least six out of the last ten years and that they will forage consistently within 100 metres of the base of operating turbines (Wood 2014 & 2017, Nature Advisory data). Maps plotting the Brolga movements are presented in Appendix 5.

The Interim Brolga Guidelines provide for an additional 300-metre disturbance buffer around the Brolga breeding home range. This distance was chosen based on anecdotal evidence from the observed reactions of Brolgas to human and vehicle disturbance. Wind turbines are a static, fixed source of disturbance and the foregoing evidence indicates that continued deterrence from the 300-metre zone around a turbine is unlikely to occur consistently suggesting that it is a conservative measure. Notwithstanding this, the 300-metre additional disturbance buffer is adopted for the WWF.

Disturbance from construction activities

The Brolga is susceptible to disturbance from frequent human activity. Habitat selection away from farmhouses and nearby sheds reflect this (Veltheim *et al*. 2019). Construction activities including making tracks, erecting turbines, increased traffic and activities at the quarry have the potential to impact on the Brolga.

The Brolga Scientific Panel recommend a minimum indirect disturbance buffer of 300 metre from breeding home ranges (DSE 2012) to prevent such disturbance.

Barrier effects

Long arrays of turbines have the potential to create partial barriers to some bird movements, this in turn forces birds to travel further and increases their energy requirement (Drewitt and Langston 2006). Layout, orientation and spacing of wind turbines are important factors to reduce barrier effects. Occasional gaps between turbine clusters may be appropriate to facilitate movement of Brolga from high density breeding areas to flocking sites (DSE 2012).

The design of the proposed WWF has avoided long arrays of turbines. Gaps between turbines allows birds to move past turbines safely avoiding them.

5.1.2. Turbine free buffers

The main measure implemented during the project design to avoid or mitigate impacts to the Victorian Brolga population has been the development of turbine free buffers around confirmed or valid historical Brolga breeding wetlands. Turbine-free buffers represent the area around a Brolga breeding site beyond which a wind turbine tower can be placed to avoid impacts on Brolga breeding success from collision or disturbance. The turbine free buffer areas were designed to protect Brolga breeding wetlands from potential impact both during construction (i.e., disturbance) and operation (i.e., collision with wind turbines).

Turbine free buffers developed for the project consider key habitats listed below.

- Confirmed or valid historical **Brolga breeding wetlands** used for breeding (nesting, egg incubation and foraging for early stage chicks) and for night roosting
- **Non-wetland areas** around breeding site wetlands used for foraging
- **Functional wetlands** used for foraging and/or alternate night time roost within two kilometres of breeding wetlands
- **Movement corridors** between breeding site wetlands and functional wetlands.

Turbine-free buffers were informed by knowledge of the movements of Brolga around Brolga breeding wetlands from a number of observational studies of Brolga flight behaviour by Nature Advisory, observations of the movements of Brolga breeding at the Macarthur Wind Farm since 2012, breeding site home range mapping published in the EES Referrals for the Penshurst (Biosis Research 2011) and Mount Fyans Wind Farms (Biosis 2017) and the recent satellite tracking studies undertaken by Veltheim *et al.* (2019).

The turbine free buffer design proposed has relied upon the most recent research on Brolga behaviour in south-west Victoria undertaken by Veltheim *et al*. (2019) together with actual flight observations by the Nature Advisory team over many years in south western Victoria.

Turbine free buffers include the following:

- The home range of the Brolga defined based on movements of Brolga chicks (Veltheim et al. 2019) and flights of adults from breeding sites(Nature Advisory data); and
- An extra area comprising, a 300-metre disturbance buffer plus the 95-metre turbine blade length buffer.

How these two components of the buffer were derived is described below, preceded by an account of how the Brolga breeding wetlands were defined and identified.

Brolga breeding wetlands

Brolga breeding wetlands (which includes potential night-roosting wetlands, *sensu* Veltheim et al. 2019) were identified as part of Level 2 assessments (see Section 4). These have been identified in Figure 9 and confirmed Brolga breeding wetlands are presented in Figure 13. It is noteworthy that on four occasions during the current surveys, Brolga have been recorded breeding in Wetland 4 most consistently.

While functional wetlands did not necessarily have Brolga breeding records associated with them, they were considered likely the most suitable wetlands to provide reliable food and shelter, therefore likely to form part of the home range around the confirmed Brolga breeding wetland

Such wetlands were more likely than others to support a productive wetland ecosystem as post-filling ecological succession progresses through winter and spring, producing increased emergent plant and algal cover and associated fauna populations, including frogs. Combined with their duration, these wetlands would therefore be disproportionately important sources of food and potentially alternate night time roosts as they are more likely to hold water during a breeding attempt.

The hydrological modelling mapped many small farm dams that met the Brolga breeding site hydrological criteria advised by DELWP. However, small farm dams are not considered core habitat for the species. Based on a review of existing information, functional wetlands were defined also based on size, with any wetland less than 0.6 hectares in extent being excluded from further consideration (Section 5.2.5).

With regard to the Cockatoo Swamp, the large, complex wetland in the central part of the Willatook Wind Farm site, the hydrological investigation of Water Technology (2022a) identified and mapped that proportion of the wetland suitable as a Brolga breeding wetland and night time roost (i.e. 120 days or more of inundation at least once in 10 years). As one pair of Brolga uses this area, they could breed in any part of the wetland habitat, so a home range has been generated for each confirmed breeding wetland within the complex. This included three separate parts of the large wetland in the centre of Cockatoo Swamp (designated W12e (eastern), W12c (central) and W12w (western)) and also W1 and W4. The combined home ranges across wetlands in this part of the site was used as the basis for a turbine-free buffer in this wetland complex.

Non-wetland foraging areas and movement corridors

Based on the satellite tracking of Brolga chicks undertaken by Veltheim *et al.* (2019), the most important consideration for breeding site protection and enhancement at wind farms is the inclusion of multiple wetlands within breeding home ranges within turbine free buffers. They note that both breeding wetlands and non-wetland habitat should be incorporated into turbine-free buffers to allow barrier-free movement between wetlands and non-wetland foraging areas. They also stress the importance of ensuring habitat elements of breeding sites, night roost, and foraging areas, and movement corridors, are incorporated into buffers at each site, based on their spatial arrangement in the landscape, as opposed to applying estimates of distances moved or home ranges alone.

Veltheim *et al.* (2019) concluded that a distance of 2,000 metres from a nesting or roosting wetland or, in the case of multiple wetlands, the 'centroid' of the wetlands used, encompassed foraging habitat and movement corridors within a 95% utilisation distribution for a Brolga family. This distance from breeding wetlands was therefore used to develop turbine-free buffers, as described in the next sub-section. All wetlands within 2,000 metres of turbines at the proposed Willatook Wind Farm are shows in Figure 14.

There are five Brolga breeding wetlands (W1, W12w, W12c, W12e, W4) in the Cockatoo Swamp complex within 2,000 metres of each other. These were therefore treated as a complex wetland area with a single turbine-free buffer created to allow barrier-free movement between breeding wetlands, functional wetlands and non-wetland foraging areas.

Wetland 25816 was the only confirmed Brolga breeding wetland within three kilometres of the wind farm other than those in the Cockatoo Swamp complex. This isolated wetland was more than 2,000 metres from any other wetlands and did not form part of a complex.

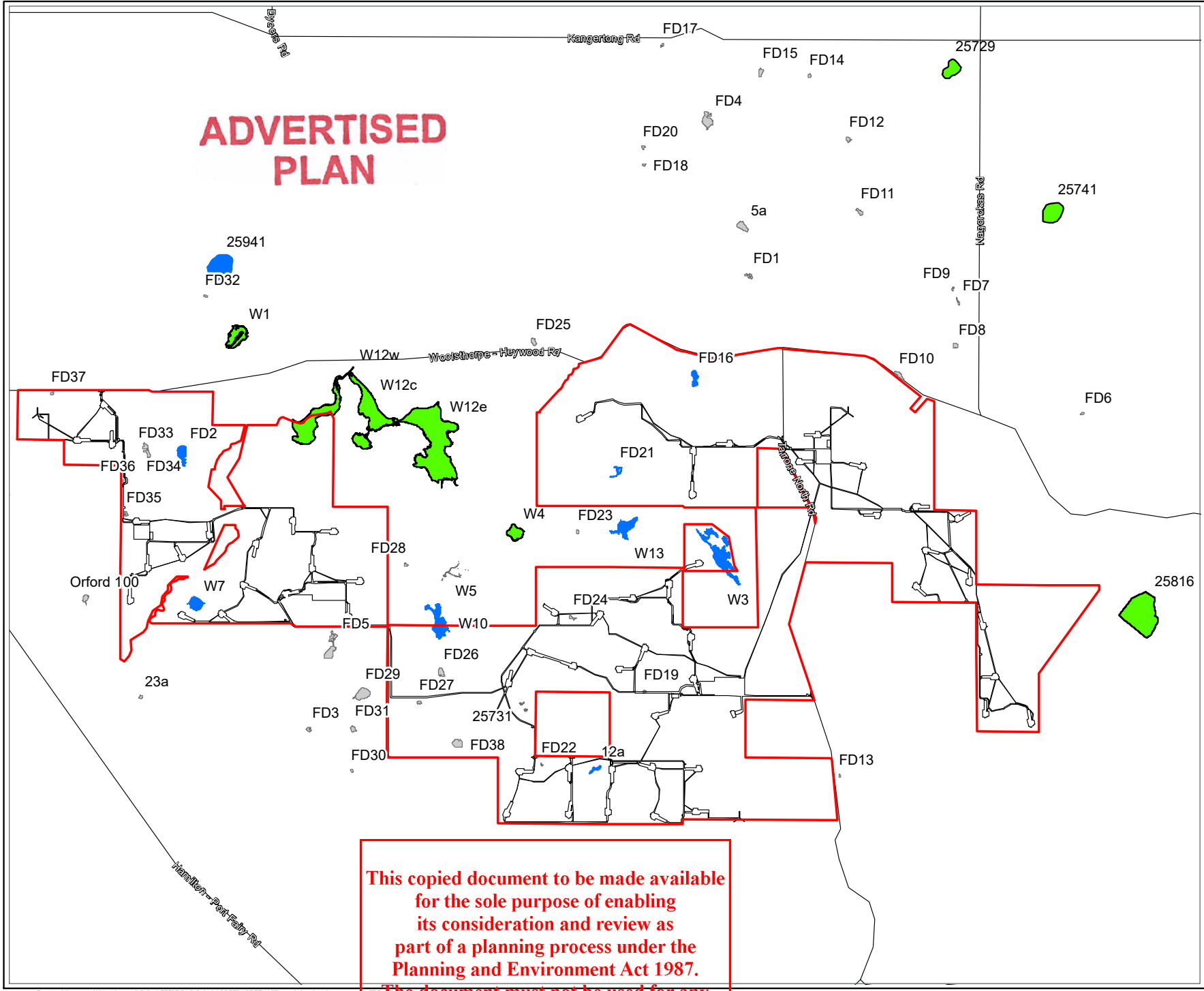

Figure 14: Wetland locations within 2km of proposed turbines

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 10/03/2022

Legend

- Wind farm boundary
- Construction footprint

Wetland assessment

- Confirmed brolga breeding site
- Functional wetland
- Not suitable

FD25 Wetland number

N

Metres
0 1,000

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Defining Brolga breeding wetland home ranges

This sub-section describes how breeding wetland home ranges were delineated for **the Cockatoo Swamp complex**. The home range includes the first two components of the turbine free buffer and represents the area within which Brolgas are estimated to occur for most of their breeding season. It includes two components:

- Clusters of functional wetlands within two kilometres of confirmed Brolga breeding wetlands;
- A 400-metre buffer around each suitable wetland in a cluster; and

These components are described below.

As wetlands provide greater food resources for Brolga, wetlands in the complex combined with the intervening non-wetland terrestrial habitat were considered sufficient to provide adequate resources for successful breeding. The method for determining Brolga home range for Cockatoo Swamp is based on existing observations by Nature Advisory of Brolga flight behaviour at breeding sites (see above) and distances moved within, between and around wetlands by Brolga families from Veltheim *et al*. (2019). It represents an update of the habitat modelling method used by Nature Advisory Pty Ltd (formerly Brett Lane & Associates Pty Ltd) at Dundonnell and Golden Plains Wind Farms.

Based on the Veltheim *et al.* (2019) findings (see above), all functional wetlands within two kilometres of confirmed breeding wetlands that have the potential to provide foraging and roosting habitat for 120 days or more at least once in ten years, based on the Water Technology hydrological modelling, were included in the home range (Figure 14). This was considered the most likely area in which the Cockatoo Swamp breeding pair was likely to move to forage or roost (based on examples illustrated in Figures 2 & 3 of the Veltheim *et al.* (2019) study).

Areas still functioning as wetlands (holding water for at least 120 days at least once every 10 years) were considered to provide additional foraging areas for Brolga away from the breeding wetland. Brolga will move out to these wetlands particularly when young Brolga are getting larger and can move greater distances, and when resources at their breeding wetland become depleted. Permanently drained or partially drained wetlands holding water less than 120-days are less likely to provide season-long food supplies for Brolga as they are unlikely to be as rich, having been subject to shorter ecological succession and production of food sources.

The greatest risk to Brolga from wind farms is collision with turbines, which happens when Brolga are flying. To provide for Brolga movements, a **400-metre buffer** is provided from the edge of confirmed Brolga breeding wetlands and from each functional wetland that encompasses the majority of Brolga flights from nesting wetlands based on Nature Advisory movement data in Section 4.2.4 (and as adopted in past home range mapping for Dundonnell and Golden Plains wind farms).

The 400-metre value was adopted based on flight observations by Nature Advisory (see Section 4.2.4) that showed 54% of all flights recorded were within 400 metres of the breeding wetland. Veltheim *et al*. (2019) also recorded 50% of Brolga observations less than 315 metres from the breeding wetlands. Flight observations by Nature Advisory showed that Brolga showed no preference for a particular habitat when flying up to 400 metres from their breeding site. For flights beyond 400 metres from the breeding site, the Brolga showed a preference for wetland areas compared with other habitats. The preference became stronger with increasing distance from the breeding site.

Based on the Veltheim *et al.* (2019) findings, an average of 2.82 wetlands were used within a Brolga home range. All home ranges within the Cockatoo Swamp wetland complex from the five breeding wetlands there have an average of 4.2 wetlands within each home range. Home ranges also encompass non-wetland habitat areas between these buffers for wetlands that are two kilometres or less apart.

Brolga home range extent

Table 9 below summarises the area of each of the eight Brolga home ranges delineated for the Willatook Wind Farm using this technique.

Table 9: Area of estimated home range at each Brolga breeding wetland in the Cockatoo Swamp complex.

Area (ha)	Wetland (Home Range)
737	W12c
837	W1
917	W4
939	W12e
942	W12w

Veltheim *et al*. (2019) found Brolga home ranges vary in extent from 70 to 523 hectares. The home ranges mapped around Brolga breeding wetlands near the Willatook Wind Farm are all larger than the largest Brolga home range identified in the Veltheim *et al.* (2019) study and can therefore be considered conservative.

Outcome of home range mapping

The Interim Brolga guidelines acknowledge that home ranges are likely to vary with local habitat quality and extent and seasonal conditions (DSE 2012). The methods outlined above have been carefully generated with input from DELWP and recent research undertaken by Nature Advisory and the Veltheim *et al.* (2019) study. The home ranges show with a high level of confidence the size and shapes of home ranges around Brolga breeding wetlands. A conservative approach has been adopted as follows. Brolga breeding home ranges are mapped in Figure 15.

- In the Cockatoo Swamp wetland complex home range, a minimum of four wetlands (average 5.2 wetlands) have been included in each of the home ranges from the five Brolga breeding wetlands. Veltheim *et al*. (2019) have stated that three wetlands are required for successful breeding.
- The area of the five home ranges are each considerably larger than any of the home ranges observed in the Veltheim *et al*. (2019) study. The areas of home ranges calculated for the Willatook Wind Farm project are from 737 to 942 hectares compared with 70 to 523 hectares in the Veltheim *et al*. (2019) study.

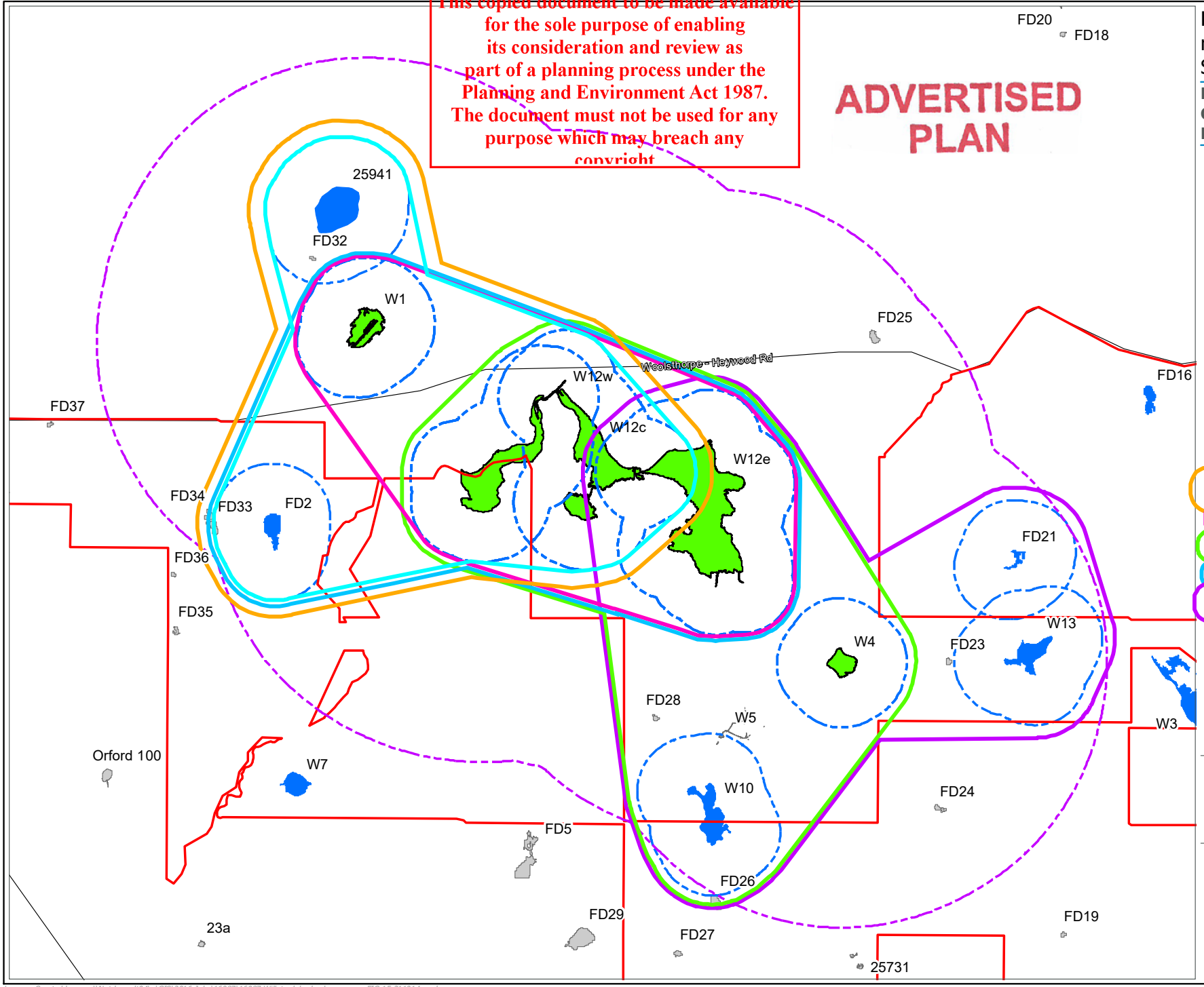

Figure 15: : Brolga home ranges in the Cockatoo Swamp wetland complex

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 11/03/2022

Legend

- Wind farm boundary
- 400 m buffer from wetland
- 2km buffer of breeding wetland
- Confirmed brolga breeding site
- Functional wetland
- Not suitable

Individual homeranges

- Breeding site 1
- Breeding site 2
- Breeding site 3
- Breeding site 4
- Breeding site 5

FD25
Wetland number

N

Metres
0 600

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Layers - Created by: - \\Nat-haw-dt04\e\GIS\2016 Jobs\16087\16087 Willatook brolga homerange FIG 15 211014.mxd

In conclusion, the home ranges determined for the Cockatoo Swamp complex breeding wetlands used by the pair of Brolgas that breeds near the Willatook Wind Farm provide more options for wetland food resources (i.e. number of wetlands) and are considerably larger in area than observed home ranges based on research on the species to date. The risk of Brolgas not breeding successfully under favourable rainfall conditions within such home ranges is considered low.

Isolated wetlands (> 2 km from another wetland)

Brolga also breed in wetlands that are isolated from other wetlands by more than two kilometres. Observational data of Veltheim *et al*. (2019) indicated that 95% of the movements of Brolgas around their breeding wetland were to 1,369 metres. This distance has been assumed to encompass the likely range of most Brolga movements to terrestrial habitats from an isolated wetland in the absence of additional wetlands to support foraging. This is considered conservative for an isolated wetland as Veltheim et al. (2019) observed movements mostly by family groups using wetland clusters more likely to extend movement away from wetlands. No turbines at the proposed Willatook Wind Farm are located within this distance of confirmed, isolated, Brolga breeding wetlands. The closest turbines in proximity to an isolated breeding wetland are more than 1,800 metres away. As such, further buffering was not implemented around this wetland.

Final turbine-free buffers

The final turbine-free buffer proposed for Brolga breeding wetlands is a combination of the Brolga breeding home range plus:

- an additional disturbance buffer of 300 metres; and
- a turbine blade length buffer of 95 metres.

The Interim Brolga Guidelines recommend a 300-metre buffer to prevent disturbance to breeding Brolga. This has been applied around each Brolga home range.

The final component of the turbine-free buffer is an additional distance to account for the turbine blade length specific to the Willatook Wind Farm project, which is a maximum of 95-metres.

The outer edge of these additional zones around the home range represents the turbine free buffer for Brolga breeding sites outside which turbine poles can be located. This is shown for all breeding sites on and near the Willatook Wind Farm in Figure 16, which also includes in different colours the various wetlands and buffers that make up the turbine-free buffer for the project.

It is noteworthy that the 300-metre disturbance buffer was based on observations of the distance at which Brolga react to the presence of people and unfamiliar vehicles not static sources of disturbance like wind turbines.

The resulting turbine free buffer consists of a 795-metre buffer around the perimeter of known Brolga breeding wetlands and functional wetlands (potential foraging and/or roosting wetlands) within 2,000 metres of one another. Based on flight observations by Nature Advisory this area would contain 71% of Brolga flights noting that approximately nine percent of all flights are at the proposed 40 metre minimum rotor swept area height of wind turbine blades at the Willatook Wind Farm.

Disturbance buffers

The following is an overview of Brolga observations at Macarthur Wind Farm over the past decade (Veltheim *et al*. 2019, Wood 2014, Wood 2017, Nature Advisory data).

Brolgas have been observed foraging at two wetlands at the Macarthur wind farm in the past decade including wetlands 25650 and 25699.

At Wetland 25650, breeding has occurred during the 2012, 2013, 2016, 2018 and 2021 breeding seasons (Veltheim *et al*. 2019, Wood 2014, Wood 2017, Nature Advisory data). No monitoring occurred in 2015, 2017 and 2020 so it is not known if Brolga bred here in those years. The wetland is surrounded by three turbines at distances of 200, 280 and 290 metres each from the edge of the wetland.

One of the chicks was satellite tracked as part of the Veltheim *et al*. (2019) study and it was reported as foraging within 80 metres of the base of a turbine. Tracking results are presented spatially in Appendix 6 (Figure 3 of the Veltheim *et al*. (2019) report).

During the 2018 breeding season, Nature Advisory, as part of its Brolga breeding season surveys for the proposed Willatook Wind Farm, monitored an adult pair on the Macarthur Wind Farm and plotted their location as they moved across their home range. The pair were observed as close as 150 metres from the base of operating turbines. Similar behaviours were observed as those documented in the Veltheim *et al*. (2019) study, with the pair foraging close to the breeding wetland early in the breeding season then moving further to the north-west later in the breeding season.

At Wetland 25699, a pair of Brolgas was observed breeding at this wetland in 2013 and 2014 (Wood 2014). This wetland has six turbines surrounding it located between 50 and 420 metres from the edge of the breeding wetland. Observations were made in 2014 and the Brolga were observed foraging as close as 50 metres from a turbine in the 2014 breeding season (Wood 2014) and within 90 metres of a turbine during the 2016 breeding season (Wood 2017). Spatial images of the Brolga monitoring are presented in Appendix 6.

The recommended disturbance buffer in the Interim Brolga Guidelines was applied to develop turbine free buffers for the Willatook Wind Farm. Based on actual behavioural observations of brolgas near wind turbines, this buffer is considered conservative and therefore appropriate for determining turbine-free buffers.

Conclusion

The Veltheim *et al.* (2019) recommendations acknowledge that Brolga home range variations can make it challenging to apply generic buffers, based on average home range size or movement ability of pre-fledged chicks. It states that it is more appropriate to ensure that habitat elements including breeding site, night roost, foraging areas and potential movement corridors between these habitats are incorporated into buffers at each breeding site, based on their spatial arrangement in the landscape. The proposed turbine-free buffers for Willatook Wind Farm are consistent with this and are considered appropriate to ensure continued breeding success by the Brolga pair that uses the wetlands near the proposed wind farm.

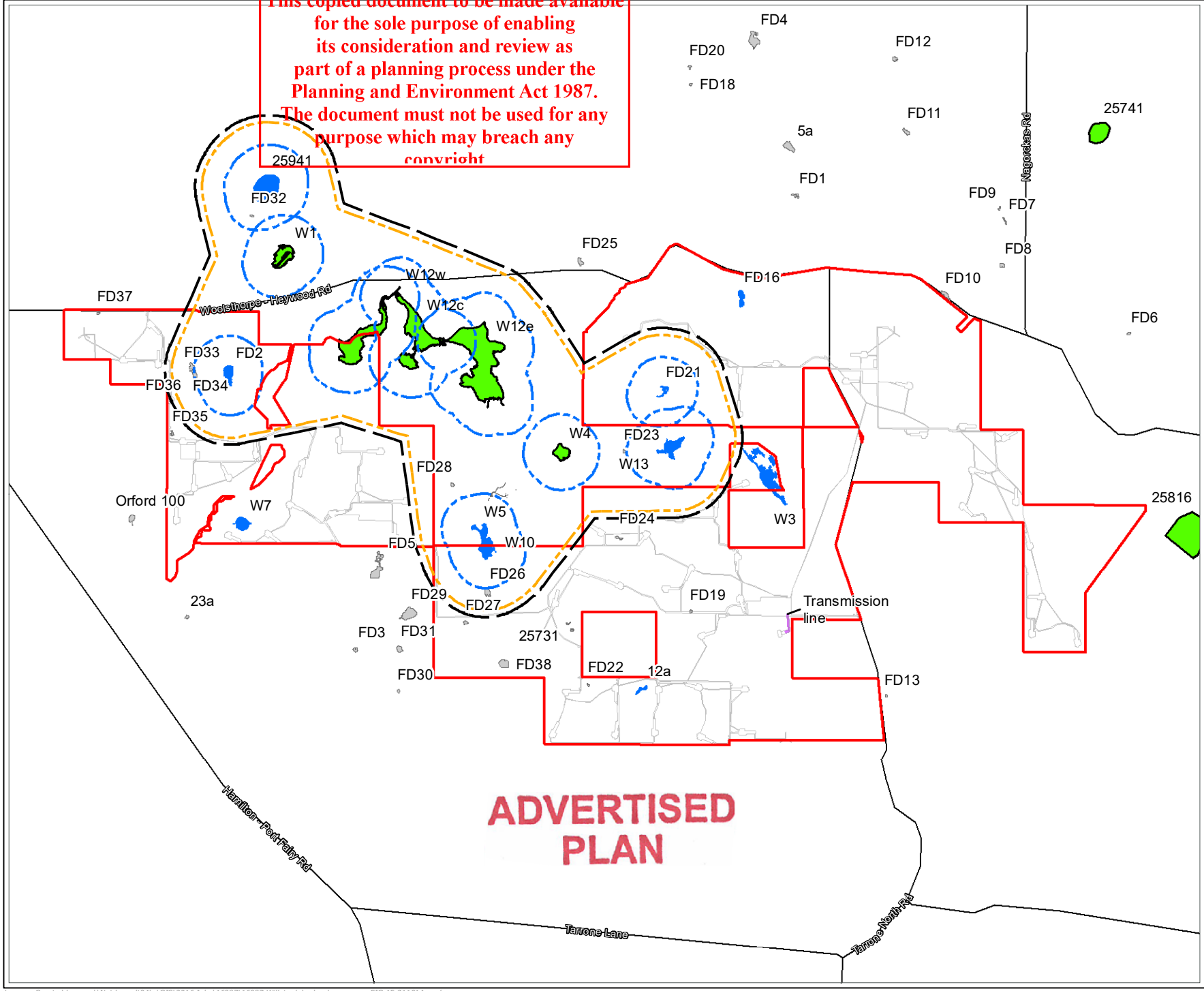

Figure 16: Turbine-free buffers for the Willatook Wind Farm

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 1/03/2022

Legend

- Wind farm boundary
- Construction footprint
- Overhead transmission line
- 400 m buffer from wetland
- Disturbance buffer (300m)
- Turbine free buffer (incl 95m blade buffer)
- Confirmed brolga breeding site
- Functional wetland
- Not suitable
- FD25 Wetland number

N

Metres
0 1,000

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Comparison with other approved wind farms

Turbine-free buffers are implemented to reduce collision risk and disturbance from turbines and wind farm operations to avoid any significant impact on Brolga breeding success. A formalised approach to buffering Brolga breeding sites has been adopted at three previous large wind farm projects in south-western Victoria that have been issued a planning permit: Stockyard Hill, Dundonnell and Golden Plains wind farms. These methods have evolved and been informed by Brolga research, extensive site-specific field surveys and engagement with specialists (incl. DELWP). Table 10 below summarises some statistics for these projects and presents the same statistics for Willatook Wind Farm.

Table 10: Brolga breeding statistics for different wind farms in south-west Victoria

Project	No, Brolga breeding wetlands within 10 km	Est. No. breeding Brolga pairs within 10 km	No. sites requiring turbine-free buffers
Stockyard Hill	60	7	23
Dundonnell	44	7	12
Golden Plains	28	8	17
Willatook	30	5	5 (6*)

* Note that applying the same (3 km) buffer to breeding sites at Willatook as the other sites would increase this number to six wetlands.

The comparison in Table 10 shows that the overall Brolga risk profile for this wind farm is comparatively low, with less than two percent of the southeast Australian Brolga population breeding within the 10-kilometre RoI around the proposed wind farm. One pair breeds close to the wind farm project boundary triggering the requirement for turbine-free buffers. All other breeding pairs during the monitoring period are further from any proposed wind turbines than the distance to which 95% of Brolga flights have been recorded by Veltheim et al. (2019). This information indicates that this pair may use one of up to five breeding wetlands on and near the wind farm site for breeding.

5.1.1. Minimum tip height

A minimum tip height of 40 metres (i.e., all wind turbine blades will be at least 40 metres from ground level) has been adopted for the project. This limit was selected to minimise potential collision risk with Brolga (and other birds and bats). This was informed from flight behaviour data gathered by Nature Advisory (over 15 years) in southwestern Victoria. These monitoring observations of 24 breeding Brolga pairs showed that approximately nine percent of flights were estimated to be above the minimum tip height of 40 metres, with the balance below that height (see Figure 6).

5.1.2. Overhead transmission line

An overhead transmission line of approximately 300 metres will be required to connect the on-site substation to the Tarrone Terminal Station. The location of this overhead transmission line is near the existing 500 kV Moorabool to Heywood transmission line (running east-west) and the 220 kV transmission line to the Macarthur Wind Farm (running north-south), which both join at the terminal station. The remainder of the power cables will be trenched underground. The terminal station will

lie within the wind farm boundary and connect directly into the existing east-west transmission line through the site.

Powerline collision risk has been reduced by trenching all power cables underground between turbines and the substation. The overhead transmission line was reduced from about 4.5 kilometres to 300 metres and has been positioned away from all Brolga breeding sites to reduce collision risk (Figure 17).

5.1.3. Hydrological connectivity

The construction of roads and hardstand areas has the potential to alter existing drainage patterns if not accounted for during design. Hydrological effects have the potential to occur over a larger area, due to the nature of the shallow topographical relief of floodplain systems. Hydrological flood modelling was used to inform the placement of turbine locations outside of water flow paths (Water Technology 2022b). In areas where inundation is predicted, hardstands will be designed to ensure drainage flows away from wind turbine locations. Hardstands will be slightly raised above surrounding ground level and, in several instances, foundations will be raised further to ensure floodwaters do not reach the base of the wind turbine in one precent AEP event. Permanent surface structures, including the substation and the Battery Energy Storage System (BESS), would be designed to maintain existing overland flow paths and not result in increased flood levels upstream of the infrastructure sites.

5.2. Step Two: Collision risk modelling

The Interim Brolga Guidelines indicate that the objective of collision risk modelling is:

> *"to estimate the residual number of Brolga movements which have the potential to interact with wind turbines on the proposed site and from this estimate the annual collision risk."*

The way the Nature Advisory turbine bird collision risk model works and a description of how it derives the estimated collision rate is described in detail in Appendix 6 by Symbolix Pty Ltd. The techniques involved are used regularly for the same purposes and have been published and peer reviewed in relevant professional journals (Band *et al*. 2007; Band 2012). An overview of how the model works and its results are provided here.

The Nature Advisory application (NA-BAND) updates the model to accept spatial data inputs. This modification extends the Band *et al*. 2007 and Band 2012 to calculate the probability of collision more correctly after interaction is a geometric calculation. The NA-BAND has previously been applied and accepted for various other wind farms in south-west Victoria including Dundonnell and Golden Plains wind farms.

Six wetlands were identified as potential Brolga breeding sites in and within three kilometres of the wind farm based on the Brolga monitoring that was undertaken and previous Brolga breeding records from the VBA and local landholders. Three scenarios were explored at these wetlands as to the probability of the wetlands being occupied in any given year (Appendix 6). With the advice of DELWP, a conservative scenario was modelled 9the results of which are presented here) that comprised 100% occupancy of the NW wetlands (Cockatoo Swamp complex) by one breeding pair every year and occupancy of the three eastern, isolated wetlands (between 1,850 and 3,700 metres from turbines) by a second pair for three out of ten years.

5.2.1. Model inputs

Details of the turbine layout and turbines to be used were provided by the proponent and factored into the application of the model (see Appendix 6). The turbine specifications are summarised below.

- A total of 59 turbines in the final layout
- Rotor swept area (RSA) between 40 and 250 metres above the ground
- Three blades per turbine
- Blade length of 105 metres (conservative approach as the maximum blade length proposed is 95 metres)
- Hub height of 145 metres
- Maximum chord of 5 metres
- Rotation period of 4.76 seconds
- All turbines operating 24 hours per day, 365 days per year, including all daylight hours when Brolgas are active.

The inputs used for the model were conservative and were the same as inputs used in other projects such as Golden Plains Wind Farm are described in BL&A (2018) in Appendix 5. Key inputs in relation to these Brolga movements, from and back to breeding wetlands, have informed the turbine collision risk modelling.

Notably, the modelling has factored in the movements at RSA height of Brolga around breeding sites. Movements during the flocking season were not considered as Brolga move away from the study area during these times. Movements are estimated from one Brolga pair occupying the area of 2.1 birds.

The **breeding season** scenario has been developed based on observations of flights from and back to 24 breeding sites by Nature Advisory in the past 15-years (BL&A 2018). The scenario involved the following assumptions.

- A total of eight confirmed breeding sites has been used (Figure 13)
- One pair is assumed to use the Cockatoo Swamp complex every year;
- At DELWP's recommendation, one additional pair is assumed to use the three isolated wetlands to the east of the wind farm three out of ten years, with a small proportion of those flights reaching the wind farm.
- Each member of the breeding pair makes a flight into the country around the breeding site once per day (a total therefore of two outward and two inward flights per day), in accordance with the distance and height distributions documented in BL&A (2018)
- A proportion of the flights are at a height and distance where turbine interaction is possible, being 40 metres above the ground (BL&A 2018)
- An average breeding event of 130 days for each pair comprising 30 days of incubation and 100 days of chick rearing until fledging (Marchant & Higgins 1993).

The final assumption is conservative. The duration of occupation of a breeding site (and therefore the number of assumed flights by that pair from the breeding site) has been estimated by Nature

Advisory (unpubl. records) as averaging 50 days as most breeding attempts fail due to predation of eggs or chicks by foxes, flooding or the rapid drying of the breeding wetland.

Three avoidance rates were modelled: 90%, 95% and 99%. Determining an appropriate wind turbine avoidance rate for the Brolga is challenging given the lack of past interactions between Brolga and wind turbines. Apart from the Macarthur Wind Farm, there are no operating wind farms in areas where Brolga could regularly interact with turbines where their interactions have been observed. Such rates have not been measured at Macarthur. Therefore, information on the behaviour of other crane species has been referred to.

Before discussing avoidance behaviour, it is worth considering definitions of avoidance. Cook *et al.* (2012) highlight the difference between 'macro-avoidance' and 'micro-avoidance'. Macro-avoidance refers to changes in flight behaviour that result in a bird avoiding a wind farm altogether. Micro-avoidance refers to the flight behaviour of a bird to avoid a turbine once within a wind farm. In practice, if birds avoid a turbine at 100 metres distance, they could do so at the edge of a wind farm or several turbine 'rows' into a wind farm, where they might come across the first turbine in front of their flight path, so the distinction is not necessarily always useful for collision risk modelling.

In a mathematical sense, avoidance is dealt with in the collision risk model as micro-avoidance. The avoidance rate actually includes both forms of avoidance. In practice, the only available evidence for similar species combines both forms of avoidance, with an emphasis on macro-avoidance. What these studies show is that cranes can avoid wind turbines at a range of scales. In acknowledgement of the uncertainty of estimating the exact proportion of flights that will avoid turbines, a range of avoidance rates is presented. This is an accepted way of dealing with this uncertainty in Australian wind farm impact assessments, and is discussed in Appendix 7.

A small number of observations of flying Brolgas reacting to wind turbines have been made at the Macarthur Wind Farm (Wood 2014), indicating that they are aware of turbines and actively avoid them, although they appear not to be deterred by them (even flying low under them). Apart from that, the only other relevant observations are from crane species in Europe and North America. These observations refer to flocking and migrating birds rather than breeding birds. This information is presented for completeness.

Langgemach (2013) reviewed the impact of wind farms throughout Germany and found that up to 2013 there were seven recorded instances of cranes colliding fatally with wind turbines, mostly during night-time autumn migration, from a population numbering in the thousands in an area with many more turbines (e.g. in 2000, Germany had around 9,300 operating wind turbines; by 2012 this figure had risen to 23,000). It is noteworthy that, unlike European Crane, Brolga do not undertake long-distance night migration. It is well known that night-migrating birds are more susceptible to collision with wind turbines and other structures (Drewitt and Langston 2008, Erickson *et al.* 2001).

Observations of Sandhill Crane in North America are also informative[5]. Observations at a wind farm in South Dakota showed that out of 66 flocks that approached wind turbines, totalling more

[5] Note that a recent study of Sandhill Cranes at four Texas wind farms by Navarrete (2011) has not been used, as a review of its statistical design found it to be flawed as it used parametric statistical tests on frequency and category data, thereby violating the assumptions of the statistical methods.

than 4,000 individuals, 92 per cent of birds showed an avoidance response (https://cleanpower.org/blog/windpower-report-whooping-cranes-may-avoid-wind-farms-more-research-ahead/ viewed 2nd February 2022).

A recent review (Nations *et al.* 2012) suggested a turbine avoidance rate of between 90 and 95 per cent for collision risk modelling for the Whooping Crane.

The true turbine avoidance rate for the Brolga is unlikely to be determined in the near future, given the small number of wind farms operating and being monitored specifically for Brolga impacts in south-western Victoria. An informed assumption is therefore unavoidable and has been used in previous wind farm studies in Victoria (e.g. Stockyard Hill, Mortlake, Dundonnell, Golden Plains) and been found by decision-makers to be informative. Based on the foregoing information, it was considered appropriate to use avoidance rates of 90%, 95% and 99% and to present the collision risk modelling results for this range of avoidance rates.

Flight speed is another key input to the CRM. A literature review on the flight speed of cranes showed the average flight speed range is between 48 to 64 km/hour (see Table 11). Given that the average weight of Brolga (6.15 kilograms) lies between the average weight of Whooping and Common Cranes, an average speed of 60 km/hour (or 16.7 m/s) was assumed for Brolga for the purpose of the CRM input.

Table 11: Flight speed of Cranes

Species	low weight kg	high weight kg	av. Weight kg	low speed km/h	high speed km/h	av. Speed km/h	Source	estimated speed range	av. Speed/ av. weight
Sandhill Crane	2.7	6.4	4.55	40	56	48	Journey North 2014	40-56km/h	10.5
Sandhill Crane	2.7	6.4	4.55	23	83	53	Melvin & Temple 1982	23-83 km/h	11.6
Whooping Crane	6.4	7.7	7.05	56	72	64	Journey North 2014	56 - 72 km/h	9.1
Common Crane	4	6	5	40	80	60	LPO 2014	40 - 80 km/h	12

To summarise, key model inputs in relation to the Brolga's flight behaviour were as follows.

- Flight speed, 60 kilometres per hour
- Wing Span, two metres
- Total length, 1.65 metres
- Typical flight, flapping.

5.2.2. Model results

The collision risk model has been run on the following two wind farm layouts.

- An original layout from a wind energy production viewpoint that includes no turbine-free buffers around Brolga breeding sites;
- An updated layout that integrates the Brolga breeding site turbine free buffers.

The number of Brolga flights modelled to be at risk of collision with turbines (90% avoidance rate) over the life of the project by each of these turbine-free buffer options is presented in Table 12.

Table 12: Comparison of collision risk of wind farm layouts using expanded turbine-free buffers (90% avoidance rate and including the lower turbine height)

Turbine-free buffer scenario	Number of turbines removed or adjusted for turbine free buffers	Brolgas affected by collision risk at 90% avoidance over the project life
Original layout - no turbine free buffers	NA	2.8
Updated layout - with turbine-free buffers	23	1.7

The collision risk modelling predicts that the final wind farm layout with the 40 to 250 metre RSA height range will lead to a long term, annual average number of Brolga collisions with wind turbines of between 0.01 (99% avoidance rate) to 0.07 (90% avoidance rate) per year. Over the 25-year life of the project, this amounts to between zero and five birds (95% confidence limits of the estimate) assuming a bird death with each collision, with an average of 1.5 in 25 years. This is significantly less than the assessed impact of the recently approved Golden Plains Wind Farm (i.e. annual total of between 0.035 and 0.341 Brolga collisions with wind turbines and powerlines), which equates to less than one to less than nine birds over the 25-year life of the project (BL&A 2018).

5.3. Step Three: Population Viability Assessment (PVA)

Step three of the Level Three assessment in the Interim Brolga Guidelines requires that a Population Viability Assessment (PVA) be undertaken. Dr M. McCarthy of Melbourne University was commissioned by DELWP (then DSE) to develop the PVA for the south-east Australian Brolga population. He was commissioned to apply this model to determine the impact of the Willatook Wind Farm, without compensation, on the future population size of the Brolga in south eastern Australia.

The PVA is a widely accepted modelling method (DSE 2012) that attempts to predict the trajectory of the population of a plant or animal and calculates the quasi-extinction probability. Quasi-extinction is not actual extinction but a reduction in population size to a point where recovery of the population is very challenging. The PVA is required by the Interim Brolga Guidelines to be used as part of any Level Three Assessment of a wind farm proposal. Appendix 7 presents the PVA for Brolga for the proposed Willatook Wind Farm.

The PVA relies on inputs about baseline or current population levels (numbers), population age structure, reproduction rate and survival rate. Using this information, the PVA can predict the population of a species at a range of future times and how this might alter if any parameter changes (e.g. reproduction rate increases or adult survival rates decline). Predictions are made based on an iterative sampling method that averages the findings from 10,000 runs of the model.

The purpose of the Victorian Brolga PVA is to model population scenarios given estimates of the impacts on Brolga survival rate of wind farm developments (using collision risk modelling results) and to set targets for compensation and offset measures to ensure zero net impact on the Victorian Brolga population.

Dr McCarthy was commissioned by Willatook Wind Farm Pty Ltd to apply the Victorian Brolga PVA to the results of the collision risk modelling for the proposed Willatook Wind Farm presented in the

previous section of this chapter and specifically to the scenario of an RSA height range of 40 to 250 metres above the ground. This PVA report is provided in Appendix 7. The results are summarised in Table 13 below, which estimates the population size after 25 years of operation of the proposed Willatook Wind Farm.

Table 13: Results of Brolga PVA (59 turbine layout, RSA height range 40 to 250 metres)

Brolga population size	No turbines	90% avoidance	95% avoidance	99% avoidance
Expected minimum south-west Victorian population (625 birds)	59	554.7	555.1	555.3
Change in population	N/A	– 0.8	– 0.5	– 0.3

Based on an expected minimum population of 625 birds, the PVA predicts without compensation that after 25 years (the planned life of the wind farm project), the population size will be between 554.7 birds (90% avoidance rate) and 555.3 (99% avoidance rate), a reduction of between 0.8 and 0.3 birds compared with baseline conditions. The predicted result for 90% avoidance rate is considered the most conservative collision rate and represents a reduction of about 0.1% in the Victorian population.

5.4. Step Four: Zero Net Impact – the Brolga Compensation Plan

The Interim Brolga Guidelines require that the impacts on the Victorian Brolga population predicted in Step Three (i.e. the PVA) are 'fully offset'.

In the case of the proposed Willatook Wind Farm, 'fully offset' would mean that the Victorian Brolga population should have between zero and five more breeding adult Brolgas (estimated impact at 90% avoidance rate) added to it over the 25 year life of the project. This can be achieved through replacement of this maximum estimated loss. Adding five birds allows for the expected mortality of some of the five new birds from a combination of natural and human-related causes over the 25-year life of the project, thereby preventing the PVA modelled decline in the Victorian population of less than one bird.

The Brolga Compensation Plan will be prepared in consultation with DELWP as a condition of any planning permit. More detail on matters addressed in the plan are provided below.

5.4.1. Aim of compensation plan

The aim of the plan will be to replace the estimated number of Brolga affected by the WWF. The collision risk modelling of the worst-case scenario estimated that at 90% avoidance rate, zero to four birds would be lost. The objective of the compensation plan will therefore be:

> *To replace four adult birds estimated to be lost to the Victorian population of the Brolga as a consequence of the WWF through the restoration of lost breeding habitat so that additional breeding pairs can produce increased numbers of young that survive to become breeding adults.*

The compensation plan will including over-arching objective and management objectives that will be implemented to restore a wetland. This wetland will provide additional Brolga breeding habitat to generate a surplus of fledged young to replace affected Brolga.

5.4.2. Criteria for wetland selection

Criteria have been developed for identifying a site suitable for the restoration for Brolga breeding purposes. These criteria have included the following.

- Past wetland type (i.e. freshwater meadow or shallow freshwater marsh)
- History of drainage and alteration (with an emphasis on cost-effective restoration options)
- History of Brolga breeding activity on or near the compensation site (with sites having a track record in the last 50 years of Brolga breeding activity within several kilometres or, ideally, at the site itself before it was made unsuitable)
- Adequate catchment water yield to ensure regular (at least one in every three years) substantial filling for at least 120 days to support a Brolga breeding attempt given expected annual differences in future rainfall (to take account of future climate change projections)
- The availability of any artificial top-up water supplies (optional, depending on catchment yield)
- The compatibility of land uses surrounding the wetlands with requirements for Brolga breeding, including water supply, catchment inputs and disturbance levels
- Landholder considerations, such as willingness to set aside wetland *and* water for conservation purposes, and to provide on-title security (s. 69 agreement) for the life of the project.

5.4.3. Hydrology considerations

Water security is a significant consideration in selecting future restored Brolga breeding sites. It is important that the catchment of a restored breeding site delivers sufficient water to substantially fill the wetland in as many years as possible, in accordance with the criteria above.

The services of a hydrologist will be used to evaluate the catchment yield and likely future fill extent and level of the wetland to test if it meets the required criteria. This analysis will take into consideration annual rainfall variability and the impact of future climate change on this.

5.4.4. Land tenure and security

In line with current environmental offset policies at Commonwealth and state levels, all private land compensation sites will need to be protected for the duration of the impact (i.e. the project life) through on-title security, such as an agreement between the landholder and DELWP under section 69 of the *Conservation Forests and Lands Act 1986* (CFL Act).

This agreement will include a site-specific management plan agreed by all parties. It will require any future owner of the property to continue implementing the plan for the required period.

The s.69 agreement is expected to be similar to those currently in use by DELWP for private land native vegetation offset sites on the state Native Vegetation Credit Register. These agreements provide for annual reporting to DELWP against management plan objectives. In practice, DELWP usually aims to make three visits in the first ten years of such agreements to audit the implementation on the associated management plan. These requirements will apply to the compensation site in the Brolga Compensation Plan for the Willatook Wind Farm.

5.4.5. Monitoring, evaluation and reporting

A framework for periodic monitoring, evaluation and reporting (MER) of the compensation plan will be developed in consultation with DELWP and its successors. DELWP has well-developed systems

for MER for its environmental management activities and it is anticipated that a suitable model can be developed in consultation with DELWP for the proposed site management plans. This will be vital to ensure the plan achieves its aim and objectives.

The MER framework will ensure that each site management plan will be managed adaptively to achieve its objectives. This will be documented annually in a management progress report that will be submitted to DELWP under the auspices of the s. 69 on-title agreement with the landholder that protects the compensation site.

It is anticipated that every five years, a significant review of the compensation plan and site management plans will be undertaken to ascertain progress in meeting the plan aim of replacing the estimated number of Brolga affected by the project.

The adaptive management of the compensation site will depend on good monitoring data. In addition, the advent of pro-active management of restoration sites provides a range of research opportunities. In implementing the plan, the proponent is recommended to investigate and encourage the involvement of research institutions in the monitoring and investigation of ecological processes and management techniques in restored wetlands. More details of required monitoring is provided below.

Brolga monitoring regime

The purpose of monitoring the impacts of the wind farm on Brolgas and of Brolga breeding outcomes at compensation sites is to ensure that actual Brolga impacts are determined, thereby testing the efficacy of the impact assessment and, if necessary, informing any changes to the outcomes required of the Brolga Compensation Plan. The second aspect of monitoring is ensuring that the management of restored Brolga breeding sites is producing the required number of fledged brolgas to replace those lost from the population because of the wind farm. These two aspects of monitoring are described below.

The impact of the wind farm on the Brolga will be monitored by searching under operating wind turbines for carcasses. This monitoring (and its associated reporting and adaptive management framework) will form an integral part of the Bat and Avifauna Management Plan (BAM plan) that larger wind farms in Victoria are required to prepare and implement to the satisfaction of the Responsible Authority and DELWP. As Brolga carcasses are too large to be completely scavenged, if present under a turbine, they will be readily detectable for at least a month given their size and weight[6]. Monthly visual carcass searches under each turbine will be undertaken to search for this species.

The monitoring program for restoration sites in the Brolga Compensation Plan would be based on but not limited to the monitoring activities detailed in Table 14, with the final monitoring requirements to be agreed with DELWP during finalisation of the Brolga Compensation Plan for the project. Monitoring of restored breeding sites in the first two years is less likely to detect Brlga breeding as it will take this time for a functional wetland to become established.

[6] Nature Advisory experience indicates that almost all Wedge-tailed Eagle carcasses are too large to be removed in their entirety by scavengers where investigated at wind farms in Victoria and New South Wales and persist on the ground for over 30 days, making monthly searches complete and accurate. Wedge-tailed Eagles weigh between two and five kilograms and Brolga between four and eight kilograms.

Table 14: Brolga utilisation and breeding monitoring

Measure	Method	Timing	
		First 2 years	Years 3 to 25 (or earlier if breeding attempt observed)
Utilisation of restoration site			
Brolga use of wetland	Observations of the number and age of birds. Observations of evidence of breeding activity, including: ▪ Stage of breeding (i.e. nest building, laying, incubation, parental care, fledging); ▪ The outcomes of breeding attempts; and ▪ Observations on factors that affect breeding activities and outcomes (e.g. water level fluctuations, predation, disturbance). If breeding activity is observed, then Breeding Activity Monitoring (as outlined below) will commence. Any Brolga breeding activity will be reported immediately to DELWP to be added annually to the Victorian Biodiversity Atlas (VBA) database administered by DELWP.	Every two months, during breeding season.	Monthly, during breeding season.
Breeding Activities at restoration site			
Breeding behaviour	Field-based observations of evidence of breeding activity (as per the 'Utilisation' method above). Location of nest, pair and chicks on each visit must be mapped.	Fortnightly from first observation of breeding behaviour.	
Hatched chicks	Field-based observations of breeding success and survival of chicks. Location of nest, pair and chicks on each visit must be mapped.	Weekly until chick is 6-8 weeks.	

5.4.6. Feasibility

It is known that pro-actively managed wetlands regularly produce young Brolga that successfully fledge (Herring 2005). It is anticipated that the targeted site management that the compensation plan will require will expand breeding opportunities for the Brolga permanently and more reliably than currently occurs, replicating (more reliably) what occurs when habitat availability increases naturally during wetter seasons.

A test of the feasibility of the compensation plan is provided in Table 12. This is based on a mix of sites of varying assumed capacity to produce young Brolga. It should be noted that these estimates

are partly speculative. Available information (Marchant & Higgins 1993) indicates that approximately 30% of eggs result in fledged young (from an annual clutch of two eggs per pair). Sites are likely to vary in their capacity to produce young and this has been defined based on whether a site produces more, the same or less than this fledging rate from breeding attempts. This test is based on the following:

- No Brolga breed successfully in the first two years of the program as wetland habitat is still being restored and Brolga are still finding the new breeding sites;
- High capacity sites produce young every second year from the fourth year, with one being produced in one successful breeding year and two being produced in the second successful breeding year (i.e. more than 30% of eggs fledging);
- Moderate capacity sites produce young every second year from the fourth year, with one young being produced in three successful breeding attempts then two young being produced on the fourth breeding attempt (i.e. 30% of eggs fledged);
- Low capacity sites produce one young every third year from the fourth year (i.e. less than 30% of eggs fledged); and
- No re-laying occurs once eggs are lost (although re-laying often can occur during wetter seasons).

Possible compensation scenarios are shown in Table 15.

As some fledged young will not survive to breeding age, it is expected that the plan will define an objective for fledged young that is higher than the required maximum number of four adult birds to replace those affected by the Willatook Wind Farm.

Table 12 shows that by managing a wetland, it would be possible to generate a surplus of fledged young to replace affected Brolga, assuming the natural rate of fledging can be achieved. Given the more intense management of the site it is more likely that the natural (i.e. without management) fledging rate can be exceeded and more fledglings produced than are required.

The number of sites that the plan ultimately includes will be a matter for agreement between the proponent and DELWP and the proposed oversight group of experts will assist in reviewing plan objectives and outcomes. The MER framework will ensure that implementing the compensation plan responds to the outcomes of management and, if necessary, increases the number of wetlands in the plan should the initial wetland not produce young at the rate required.

Table 15: Number of young Brolgas produced by different compensation site scenarios

Sites	Duration of Plan																									Total young	Young required	Surplus
Year - >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25			
Scenario 1 (wetland has high capacity)			1		2		1		2		1		2		1		2		1		2		1		2	18	4	14
Scenario 2 (wetland has moderate capacity)			1		1		1		2		1		1		1		2		1		1		1		2	15	4	11
Scenario 3 (wetland has low capacity)			1			1			1			1			1			1			1			1		8	4	4

5.5. Conclusions

Conclusions from the Level Three assessment in accordance with the Interim Brolga Guidelines are presented below.

- Five breeding sites are part of the Cockatoo Swamp wetland complex within 2 kilometres of one another
- All information reviewed and generated during investigations indicates that these sites are used by one pair of Brolgas
- Turbine-free buffers to protect this Brolga pair have been developed for the confirmed Brolga breeding wetlands (three of which are linked), including turbine free corridors to other functional wetlands with the potential to provide foraging and/or night roosting opportunities within 2,000 metres and a 40 metre terrestrial habitat zone around these.
- The collision risk modelling predicts that the final wind farm layout with the 40 to 250 metre RSA height range will lead to a long term, annual average of between 0.01 to 0.07 Brolga collisions with wind turbines, depending on avoidance rate. Over the 25-year life of the project, this amounts to between zero and four birds lost from the population using a conservative 90% avoidance rate. This assumes continuous occupation of the site by Brolga for the life of the project.
- The residual collision risk for the updated turbine layout for 40 to 250 metre RSA height range is a significantly lesser impact than the recently approved Golden Plains Wind Farm.

6. Cumulative Impacts

The scoping requirements for the Willatook Wind Farm Environmental Effects Statement (DELWP 2019) states:

> "Assess *the potential cumulative effects on relevant listed threatened species and communities of flora and/or fauna, in particular Brolga and Southern bent-wing bat, from the project in combination with the construction and operations of other energy facilities*."

The Interim Brolga Guidelines state that there is a requirement to avoid cumulative impacts of the wind farm industry on the Victorian Brolga population. The specific objective of the Interim Brolga Guidelines is to manage each wind farm development to achieve a *zero net impact* on the Brolga population, with an overall objective to avoid cumulative impacts of multiple wind farms operating independently within the Brolga range in Victoria.

The cumulative effects of wind farms may impact on Brolga in three key ways, including the following.

- Direct effects, such as collision with turbines
- Indirect effects, such as displacement or disturbance resulting in decreased habitat use
- Barrier effects, where wind turbines may create barriers to seasonal or local flights.

The following wind farms within the south western Victoria Brolga territory are operating, are approved or have started their public development approval process within roughly 100 kilometres of Willatook Wind Farm.

- Cape Bridgewater Wind Farm (operating): 29 turbines
- Cape Nelson North and Cape Sir William Grant Wind Farm (operating): 23 turbines
- Cape Nelson South Wind Farm (operating): 22 turbines
- Codrington Wind Farm (operating): 14 turbines
- Macarthur Wind Farm (operating): 140 turbines
- Dundonnell Wind Farm (operating): 80 turbines
- Maroona Wind Farm (operating): two turbines
- Salt Creek Wind Farm (operating): 15 turbines
- Timboon West Wind Farm (operating): two turbines
- Yambuk Wind Farm (operating): 20 turbines.
- Oaklands Hill Wind Farm (operating): 32 turbines
- Mount Mercer Wind Farm (operating): 64 turbines
- Morton's Lane Wind Farm (operating): 13 turbines
- Mortlake South Wind Farm (under construction): 35 turbines
- Ferguson Wind Farm (under construction): three turbines
- Hawkesdale Wind Farm (approved): 23 turbines
- Ryan Corner Wind Farm (approved): 52 turbines

- Woolsthorpe Wind Farm (approved): 20 turbines
- Mount Fyans Wind Farm (EES Referral submitted): 80-85 turbines
- Darlington Wind Farm (EES referral submitted): 150 turbines

Cumulatively, it is possible that the above wind farms could lead to an increased risk of collision as an individual Brolga ranges across the area that includes these projects. This may be particularly pertinent to the Brolga as during the non-breeding season they may fly up to 100 kilometres in a short time between habitats (I. Veltheim, pers. comm.). To date, there have been no reported collisions of Brolga associated with wind farm infrastructure.

As each of these wind farms has been assessed for its impacts on the Brolga in different ways, it is not possible to combine quantitative estimates of Brolga impacts and arrive at a definitive number of Brolgas affected. This is primarily because most of the information available on the impacts of these wind farms was prepared before the advent of the consistent assessment method in the Interim Brolga Guidelines.

The Willatook Wind Farm was assessed in accordance with the Interim Brolga Guidelines, using an approach agreed with DELWP. This assessment has used all available techniques in the Interim Brolga Guidelines to understand and mitigate the impact of the Willatook Wind Farm on the Victorian Brolga population. By adopting this approach, and including a Brolga Compensation Plan, the project will achieve the over-arching policy requirement of the Interim Brolga Guidelines of Zero Net Impact on the Victorian Brolga population. Consequently, the proposed Willatook Wind Farm project is not expected to lead to a significant incremental contribution to the cumulative impact of wind farms within the Brolga's distribution range in Victoria.

7. Overview of findings

The findings arising from the application of the methods and techniques of the Victorian Interim Brolga Guidelines (DSE 2012) are summarised below.

- A total of 38 landholders participated in consultations from December 2018 to February 2019 and four of those reported breeding events on wetlands on their or their neighbour's property
- The majority of land use/type within the RoI is dominated by a mixture of stony outcrops and cleared/semi-cleared land for pasture. Grazing by cattle and/or sheep occurred throughout most of the area surveyed.
- No Brolga were observed in the RoI during the flocking season survey in 2018 and 2019. The proposed wind farm is over 30 km from known flocking sites
- No Brolga flocking sites were identified in the RoI through the desktop study, community consultations and during the Brolga flocking survey
- There is currently no evidence of Brolga use of the area during the flocking season.
- Many wetlands were dry during the survey, or had been dry for many years, as they had been permanently drained and converted for agricultural use, and were no longer considered suitable for future use by Brolga
- Willatook Wind Farm is not located within an area of intensive Brolga breeding usage
- Five pairs of Brolga were observed breeding within the RoI during the 2018 to 2020 Brolga breeding surveys. One pair of Brolga was observed breeding within the wind farm boundary and an additional four pairs outside the wind farm boundary. This is generally in line with the pattern from past studies (EHP 2018) which recorded only one breeding pair within the boundary of the wind farm
- The single pair observed nesting within the wind farm boundary was at wetland W4 and the pair nested in this wetland during spring of 2018, 2019, 2020 and 2021;
- Of the 335 wetlands on the Victorian Wetland Inventory within the extended RoI 111 were considered suitable Brolga breeding habitat and the vast majority occurred in the south-west of the RoI
- Based on consideration of Brolga records, detailed hydrological modelling and further field investigations, a total of 30 wetlands were confirmed as Brolga breeding sites within the RoI, with six of these were located within or just outside the WWF study area.
- Based on the activity of the Brolga in the RoI, the focus of assessment and mitigation has been on the use of the area for breeding, as there is considered no risk to arise from the use of the area during the flocking season.
- Mitigation of risks to the Brolga involves the establishment of turbine free buffers around breeding sites on and near the wind farm. Turbine-free buffers have been developed by removing or adjusting the positions of 23 turbines near Brolga breeding sites
- The impacts of the project on the Brolga have been assessed through the development of a collision risk model that integrates the Band *et al*. 2007 and Band 2012 models with the Nature Advisory application (NA-BAND) and updates the model to accept spatial data inputs.

- Model inputs have been developed from available information on the movements of Brolga around breeding sites elsewhere in its Victorian range as studies of the lone Brolga pair at the wind farm site didn't las long enough to collect robust spatial data due to the flooding out of the breeding attempt early in the breeding season.
- The collision risk model results indicate that from zero to four Brolga may collide with turbines over the 25-year life of the project
- Adding four Brolga to the population through the enhancement of a Brolga breeding site will replace the expected mortality from the Willatook Wind Farm of between zero to four birds over the 25-year life of the project.

In summary, there is evidence from previous (EHP 2018) and current field surveys that one pair of Brolga breed near the boundary of the WWF site. There were five wetlands within the Cockatoo Swamp wetland complex that have been identified as Brolga breeding sites through the desktop and community consultation process. These wetlands were assessed to require turbine free buffers. One isolated wetland over 1,800 metres to the east of the proposed wind farm has a Brolga breeding record.

The Interim Brolga Guidelines are designed to prevent the Victorian wind energy industry from having a cumulative, unacceptable impact on the Victorian Brolga population by requiring Zero Net Impact from each project. This assessment has demonstrated that this is feasible for the Willatook Wind Farm.

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Appendix 1: Community Questionnaire

Community Survey Questionnaire- Willatook WF

Date:_____

Landholder's Name:_____

Property Address:_____

The aim of the following survey is to establish a broad-scale understanding of the environment on and around local landholder properties in the region through acquiring information such as; land use, historical land use, management practices, habitats and what flora and fauna are present. This information will inform the design and operation of Willatook Wind Farm.

LAND USE

What is the primary use for your land? E.g. cropping, grazing, mixed, alternating (indicate areas on map) – use attached spreadsheet

What broad land types exist on your land? E.g. arable, stony, aquatic, mixed, cleared (indicate on map) – use attached spreadsheet

How long have you owned or farmed the land?

_____

History / previous land use? – use attached spreadsheet

(If sheep grazing) When and where does lambing typically occur?

_____

_____

Do you remove the carcasses of dead stock? If so, what is the process?

_____

_____

Do you artificially feed stock on your property? - use attached spreadsheet

FLORA

Are there native plant communities / habitats on your property you are aware of?

Yes / No

What type? E.g. wetlands, woodlands, grasslands, rocky outcrops (indicate on map)

_____

How do you manage these areas? (i.e. fencing stock, weed control)

_____

_____

Has there been changes to wetlands in and around your land? When, what caused this?
(i.e. drainage for cropping purposes)

_____

_____

_____

_____

Are you aware of any of the following threatened flora species on your property?

Matted Flax Lily Yes / No

Spiny Rice Flower Yes / No

Others?

_____

FAUNA

Are you aware of feral animals on your land? E.g. Rabbits and warrens, foxes, deer etc...

_____

_____

Do you manage feral animals on your land?

Yes / No

Are you aware of any of the following species on your land?

Wedge-tailed Eagle	Yes / No	Nests present?	Yes / No
Fat-tailed Dunnart	Yes / No		
Striped Legless Lizard	Yes / No		
Swamp Skink	Yes / No		
Growling Grass Frog	Yes / No		
Golden Sun Moth	Yes / No		
Brolga	Yes / No	Nests present?	Yes / No
Owl Species	Yes / No		

Bats (followed-up with all participants):

Supplementary question: Are you are aware of bat caves or bat daytime roosting areas in and around your property?

BROLGA SPECIFIC

Have Brolgas occurred on your land? Yes /no

Explain _____

_____

For each sub-area (paddock) of your land subject to different land use histories, how often and in what numbers have you seen Brolgas?

Area No (see map)	1	2	3	4	5	6	7
>10 birds*							
5-10 birds							
3-5 birds							
1-2 birds							
None							
Never							
>20 yrs ago							
10-20 yrs ago							
<10 yrs ago							

* If more than 10, estimate actual observed numbers or range of numbers.

If yes to the above - locate areas on maps

Have there been changes in the wetlands in and around your land?

When ? What was the cause ?

_____

_____

_____

Additional Comments on Brolgas

_____

_____

_____

Appendix 2: Willatook Wind Farm – Wetland Analysis

Willatook Windfarm – Wetland Analysis

Willatook Wind Farm Pty Ltd

29 April 2021

Document Status

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Project Details

Project Name	Willatook Windfarm – Wetland Analysis
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29 April 2021

Rory McManus
Development Manager
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Suite 10 | 19-35 Gertrude St | Fitzroy | Victoria 3065
Via email rory.mcmanus@windprospect.com.au

Dear Rory

Willatook Windfarm – Wetland Analysis

This report documents an assessment of the long term inundation regime of depressions within and surrounding the Willatook Wind Farm. The inundation regime of these depressions has been used to identify potential brolga breeding habitat by specialist ecologists.

Yours sincerely

Ben Hughes
Principal Engineer

Ben.hughes@watertech.com.au

WATER TECHNOLOGY PTY LTD

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1 INTRODUCTION

1.1 Overview

Willatook Wind Farm Pty Ltd (WWF) are completing investigations into their proposed wind farm located between Orford and Hawkesdale in south-west Victoria (Figure 1-1). Hydrological modelling was completed to inform the assessment of potential impacts on Brolga and their potential breeding and night roosting habitat. This modelling was then used as a basis for more detailed review and site assessment by specialist ecologists Nature Advisory.

1.2 Purpose of the report

This report details the assessment methodology and the surface water modelling results dictating which areas were highlighted as potential brolga breeding habitat. The objectives of this assessment are summarised below:

- Determine which areas within and surrounding the Willatook Wind Farm have the potential to have water pooling.
- Assess the likelihood water will remain in these pools for a time sufficient to support successful Brolga breeding and night roosting.

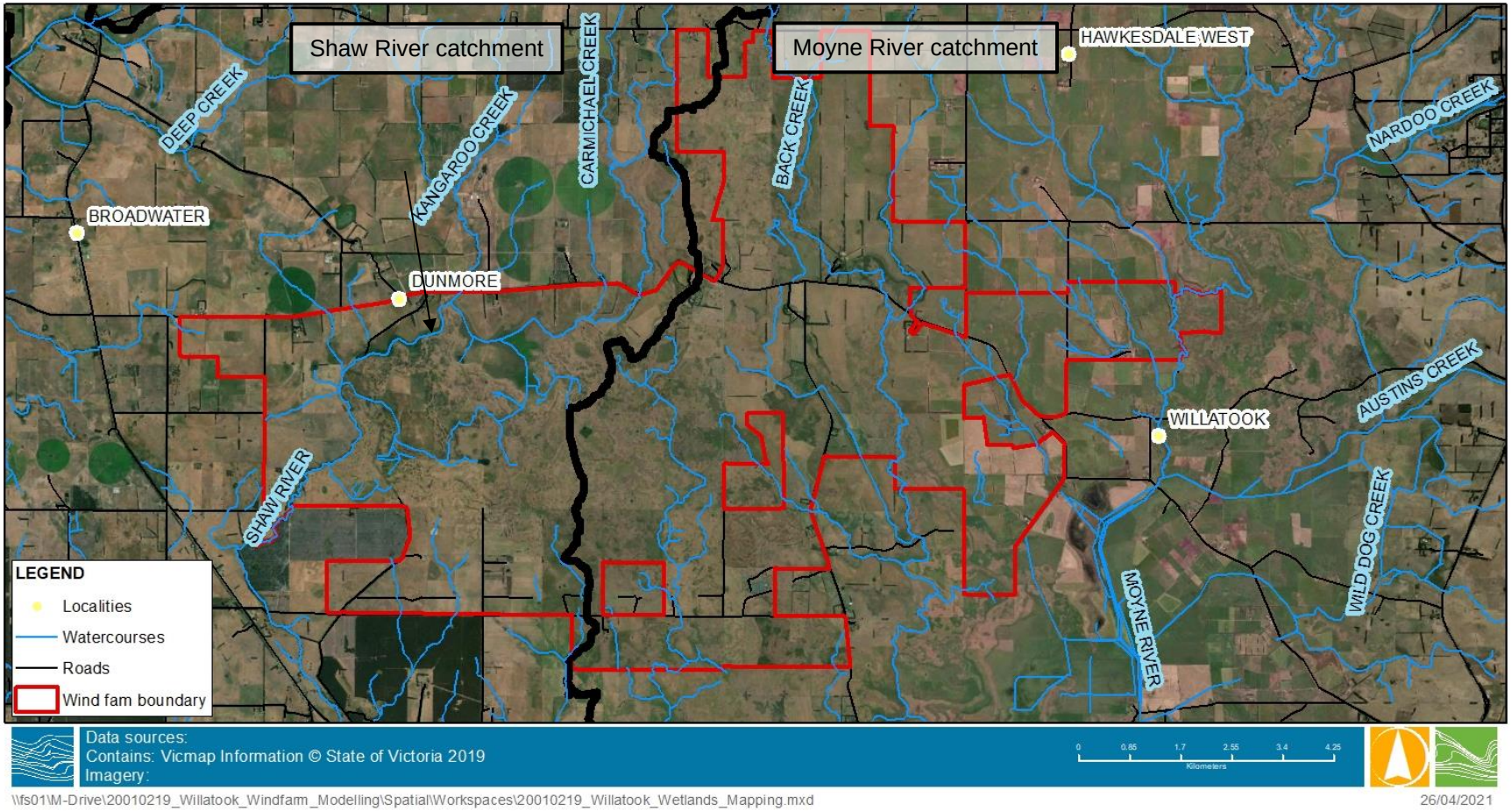

FIGURE 1-1 SITE LOCALITY

2 METHODOLOGY

2.1 Overview

The assessment methodology aimed to identify areas which held water for more than 120 consecutive days between July and December from the beginning of 2009 to the end of 2019 within and surrounding the proposed Willatook Wind Farm.

The inundation period of 120 days and the 10 year time period was advised by the Department of Environment, Land, Water and Planning. Brolga nest in wetlands with emergent vegetation that holds water for at least 120 days, permitting nest building, egg laying and incubation, hatching and the growth of chicks to an age where they can walk to nearby wetlands should the original breeding wetland dry out (Nature Advisory, 2021).

Given the large and hydrologically complex nature of the windfarm area several steps and modelling tools were used to complete this assessment, an overview of these tasks is provided below with detail included in the sections that follow.

- A 'Rain on Grid' hydraulic model of the proposed windfarm and upstream catchment area was developed and modelling of the 1% Annual Exceedance Probability (AEP[1]), 72-hour event was undertaken to gain an understanding of overland flow paths, wetland interrelationships and wetland extents. The hydraulic model was run for seven days post rainfall ceasing allowing all water to flow to its terminal wetland/waterway
- All current Department of Environment, Land, Water and Planning (DELWP) mapped wetlands were modelled (hydraulic model results provided more accurate representation of the DELWP mapped wetland extents rather than relying on those digitised by DELWP relying on aerial imagery).
- All areas with a depth of greater than 2cm were filtered from the hydraulic model results and polygons of areas with depths greater than 2cm were created. It is standard practice in 'Rain on Grid' models to remove shallow depths which may be inaccurate due to minor incontinences in the model topography.
- All inundated areas less than 0.1 Ha (1,000 m^2) were removed. Nature Advisory advised that wetlands less than 0.1 Ha (1,000m^2) are not suitable for breeding habitat based on a review of Brolga nesting habitat sites.
- Manual assessment of the remaining wetlands was completed, screening those from detailed analysis if they met the following criteria:
  - The wetland was permanently drained – a wetland was considered permanently drained if an excavated earthen channel had been constructed from the wetland invert to a connecting drain, downstream waterway or downstream wetland.
  - The wetland had a relatively small size (only slightly above 0.1 Ha), was shallow (less than 300mm - the Source model results showed wetlands generally need to have a maximum depth of at least 300mm to maintain water for more than 120 days) and had a small catchment area.
  - Incorrect topographic representation resulted in the water pooling – e.g. a road culvert was not represented.

[1] Annual Exceedance Probability (AEP) refers to the probability of a flood event occurring in any year. The probability is expressed as a percentage. For example, a large flood which may be calculated to have a 1% chance of occurring in any one year, would be described as 1% AEP flood event.

- A Source hydrologic model was developed of the remaining wetlands to determine a daily water level series for each from 2010-2019 inclusive.
- All areas modelled in Source that held water for at least 120 days during the July to December period were mapped.

2.2 Hydraulic Modelling

Hydraulic modelling of the Willatook Wind Farm project area and upstream catchment was completed using TUFLOW[2]. TUFLOW is one of the most widely used hydraulic modelling software packages in Australia and is the preferable modelling package for Glenelg Hopkins CMA (which the Willatook Wind Farm is within). The software is considered an appropriate modelling tool for modelling of the site. A Rain on Grid approach was used, allowing the simulation of runoff generated from local rainfall on a two-dimensional (2D) grid representative of the site topography (i.e. a 2D grid of cells with assigned topographic values). The TUFLOW model was used to identify how wetlands and other depressions are filled, their maximum expected extent and interconnections. The TUFLOW model had four key inputs, these included:

- A Digital Elevation Model (DEM) – The DEM was constructed by combining LiDAR data specifically flown for the Willatook Wind Farm (and provided by Willatook Wind Farm Pty Ltd at a 1m grid resolution) within the proposed windfarm and the VicMap10m DEM outside the proposed windfarm area. The combined DEMs were resampled to a 5x5 m grid resolution and were adopted in the model development to enable reasonable model run times.
- Hydraulic roughness – Roughness was modelled using a Manning's 'n'[3], determined using planning layers and verified using aerial imagery, the adopted values are highlighted in Table 2-1.
- Rainfall depths and temporal pattern - Bureau of Meteorology 2016[4] recommended Intensity Frequency Duration (IFD) rainfall data was adopted for modelling of the 1% AEP, 72-hour event. Temporal Pattern 08 was applied.
- Losses – The recommended Australian Rainfall and Runoff 2019 (ARR2019[5]) losses were adopted, determined using planning layers and verified using aerial imagery, the adopted values are highlighted in Table 2-1.

TABLE 2-1 MANNING ROUGHNESS COEFFICIENTS AND LOSSES

Land Use Type	Manning 'n'	Initial Loss (mm)	Continuing Loss (mm/hr)
Open Space or Waterway - minimal vegetation	0.04	10	4.6
Open Space or Waterway - moderate vegetation	0.06	10	0.1
Open Space or Waterway - heavy vegetation	0.09	0	0.1
Open water (with reedy vegetation)	0.06	0	0.1
Open water (with submerged vegetation)	0.02	10	4.6

[2] https://www.tuflow.com/

[3] Manning's roughness coefficient is used in the Manning's formula to calculate flow in open channels - Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

[4] http://www.bom.gov.au/waterdata/

[5] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

The hydraulic model was run for seven days post rainfall had ceased to allow water to drain to each depression. Results were also filtered to remove all depths less than 2cm ensuring very shallow areas were not erroneously indicating inundation.

The hydraulic model results at seven days post rainfall are shown in Figure 2-1.

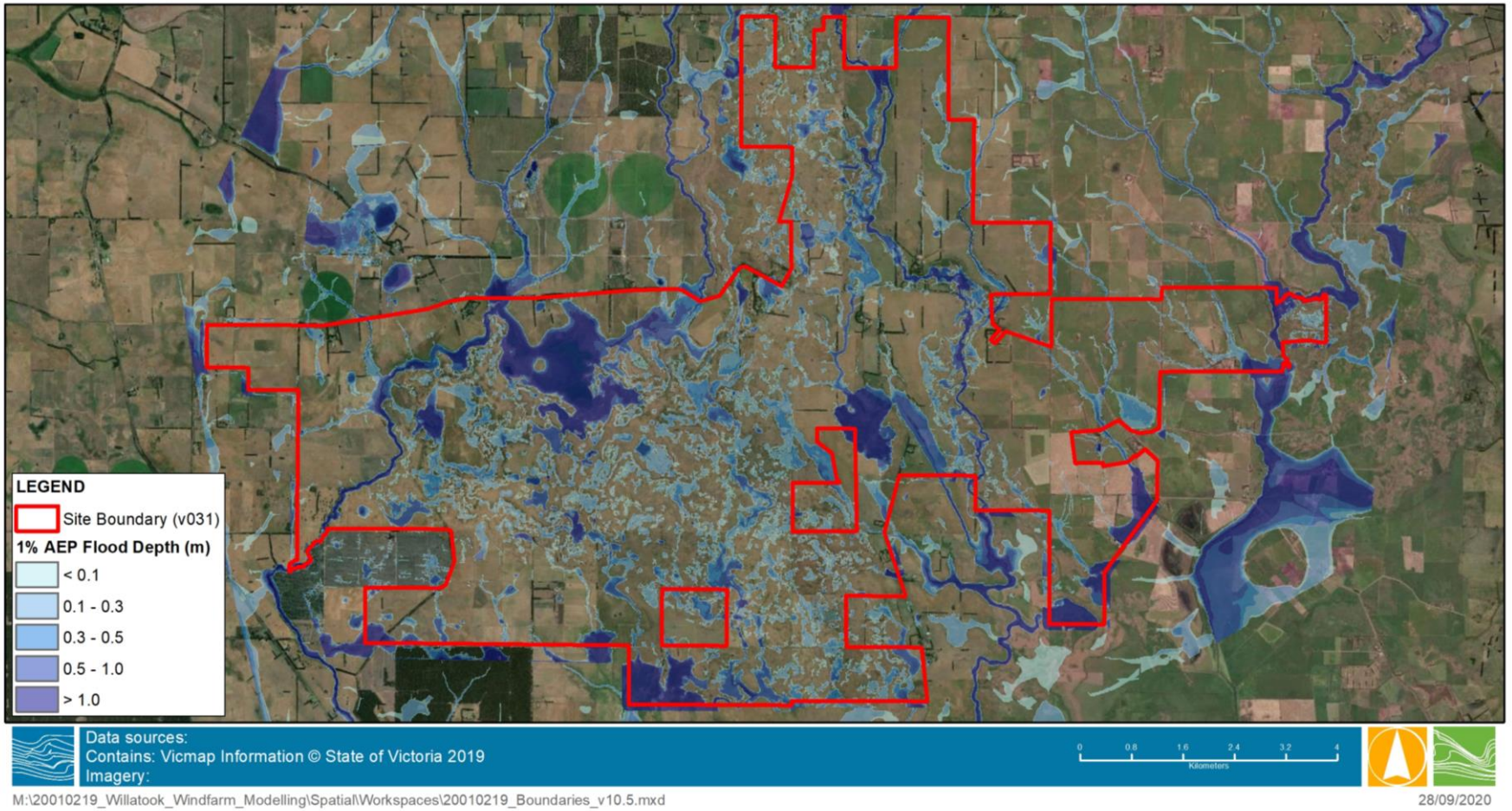

FIGURE 2-1 INUNDATION WITHIN THE PROPOSED WILLATOOK WINDFARM – 1% AEP, 72 HOUR EVENT, 7 DAYS POST RAINFALL OCCURRING.

2.3 Wetland Selection

As discussed in Section 2.1, the hydraulic model results were used to delineate which wet areas would move to a more detailed hydrologic assessment. Inundated areas with an area of less than 0.1 Ha were removed, this left approximately 800 potential wetland sites across the windfarm area. These areas were assessed using a desktop assessment of LiDAR, hydraulic model results and aerial imagery to exclude those that did not require detailed modelling. There were three main reasons a wetland could be excluded from detailed modelling, these were as follows, with an example of each shown in Table 2-2.

- The wetland was permanently drained – a wetland was considered permanently drained if an excavated earthen channel had been constructed from the wetland invert to a connecting drain, downstream waterway or downstream wetland.
- The area had a relatively small size (only slightly above 0.1Ha), was shallow (less than 300mm – the Source model results showed wetlands generally need to have a maximum depth of at least 300mm to maintain water for more than 120 days) and had a small catchment area.
- Incorrect topographic representation resulted in the water pooling – e.g. a road culvert was not represented.

Farm dams were also excluded from the detailed assessment as they were guaranteed to meet the 120 day inundation criteria. These dams automatically progressed for further assessment by Nature Advisory.

TABLE 2-2 EXAMPLE EXCLUSIONS

Reason for exclusion	Explanation	Figure
Drained area	Drainage lines are observed on satellite imagery and topography. The drains are smaller than the hydraulic model resolution but have been constructed to prevent water from accumulating for long periods.	
Relatively small size (only slightly above 0.1Ha), was shallow (less than 300mm) and had a small catchment area	The wetland has an area of 1500 m^2, maximum depth of 0.18 m and there is no obvious upstream catchment that could contribute water or connectivity to nearby wetland areas.	

Reason for exclusion	Explanation	Figure
Incorrect topographic representation	The roads representation in the DEM prevents the area from draining, however a culvert under the road not modelled would enable water to move from one side to the other.	

2.4 Hydrologic Modelling

Wetlands which were selected for longer term hydrologic analysis were modelled in Source[6]. Source was used to conduct water balance modelling of each wetland individually or as a series of connected wetlands.

Source was used to estimate runoff volumes and wetland levels and included the following key components:

- Sources of inflow water to the water bodies (watercourses and wetlands) was rainfall and rainfall runoff.
- Outflows from the watercourses and wetlands modelled included evapotranspiration, evaporation (from the surface areas of wetlands and watercourses), interflow with soil layers and deep seepage to groundwater.

The interactions between these components over time produced a water level time series for each modelled wetland. An example of how one of the Source models was schematised is shown in Figure 2-2.

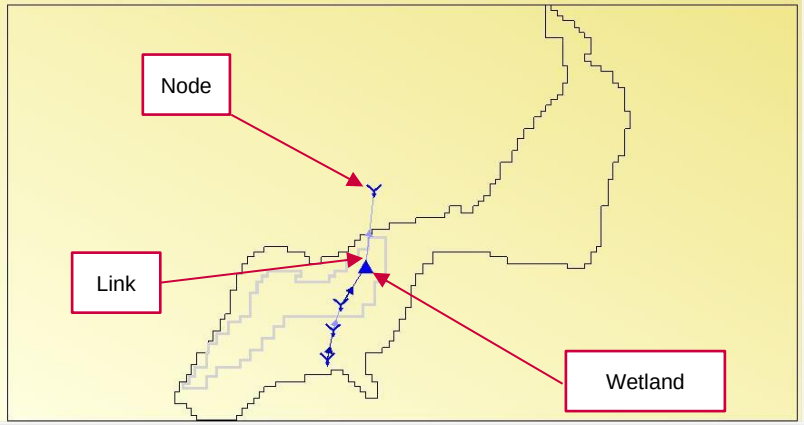

FIGURE 2-2 SOURCE MODEL FOR WETLAND NO.12

The rainfall runoff model adopted in Source was SIMHYD, estimating the flow generated from each sub-catchment based on the applied climatic data (rainfall and evapotranspiration). Climatic data was obtained from SILO Queensland Point Data and applied to the sub-catchments based on closest proximity. The model used the default parameter values outlined for the SIMHYD model in eWater Source documentation[2] as there was no gauge data available to calibrate the models. Catchments are represented by nodes, watercourses by links, and storage nodes for wetlands.

The model required daily rainfall and potential evapotranspiration data and had nine parameters as shown in Table 2-3, along with their recommended range.

TABLE 2-3 MODEL PARAMETERS

Parameter	Description	Units	Min	Max
Baseflow coeff.	Base flow Coefficient		0.0	1.0
Impervious Threshold	Impervious Threshold	mm	0.0	5.0
Infiltration Coeff.	Infiltration Coefficient		0.0	400
Infiltration shape	Infiltration Shape		0.0	10.0

[6] https://ewater.org.au/products/ewater-source/

Parameter	Description	Units	Min	Max
Interflow Coeff.	Interflow Coefficient		0.0	1.0
Perv. Fraction	Pervious Fraction		0.0	1.0
Recharge coefficient	Recharge Coefficient		0.0	1.0
RISC	Rainfall Interception Store Capacity	mm	0.0	5.0
SMSC	Soil Moisture Store Capacity	mm	1.0	500

Given the lack of gauge data, to provide some form of model parameter verification, a single catchment was used as the basis for comparing model results to estimates made using the Australian Rainfall and Runoff (2019) Regional Flood Frequency Estimation (RFFE) model[7].

The comparison showed adopting the default Source parameters resulted in flow estimates higher than those recommended by the RFFE model, but within the estimated confidence limits. The default Source parameters were modified to achieve a closer match to the RFFE model estimates. A comparison of the RFFE model estimates and confidence limits was made against the modelled Source flows adopting both the default and modified model parameters, as highlighted in Table 2-4 and Figure 2-3.

TABLE 2-4 ADJUSTED PARAMETERS IN SOURCE

	SMSC	Infiltration Coefficient	Interflow Coefficient
Default parameters	320	200	0.1
Modified parameters	450	350	0.5

[7] https://rffe.arr-software.org/

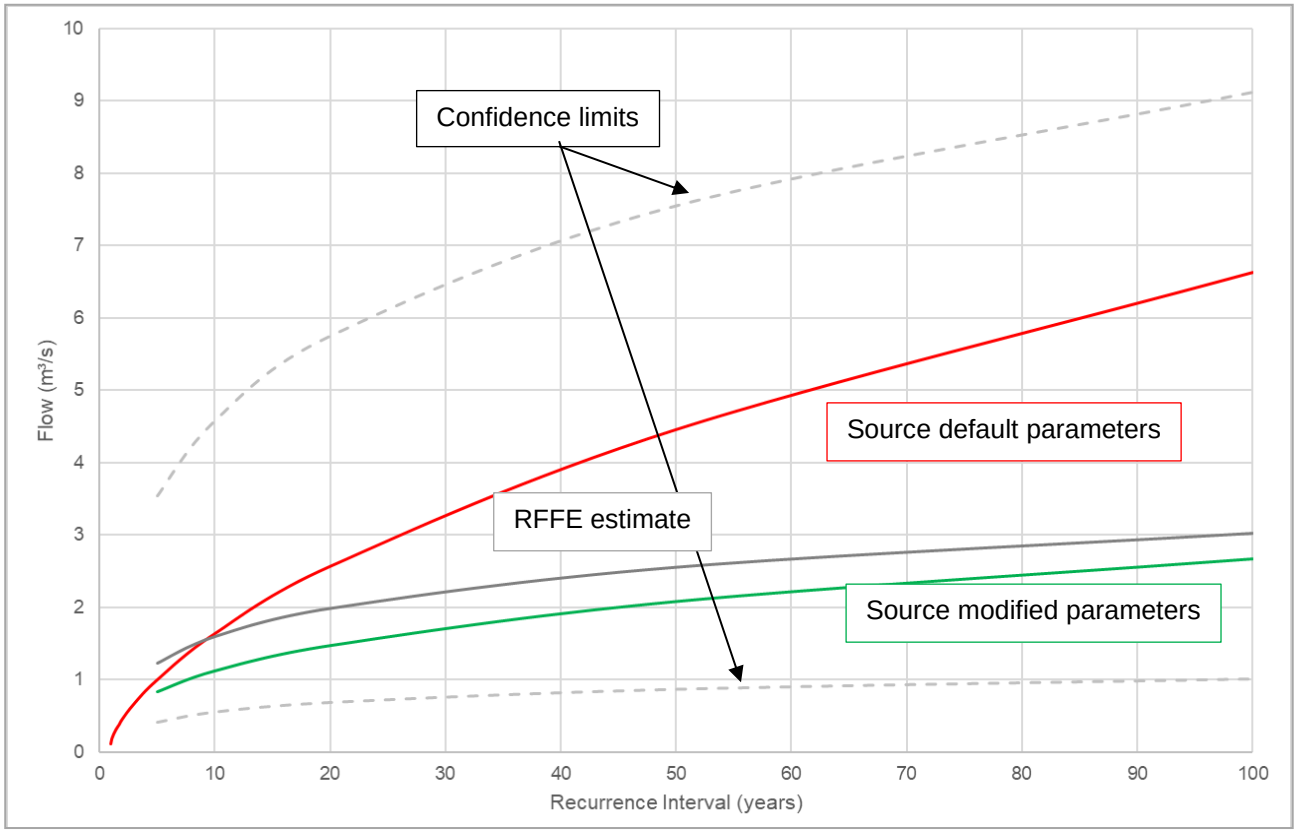

FIGURE 2-3 COMPARISON OF RFFE AND SOURCE DISCHARGES FOR DIFFERENT RECURRENCE INTERVALS

The wetlands were modelled as part of the catchment they were located within, with zero infiltration loss to rain applied to the wetland area. Each wetland was assigned rainfall and evapotranspiration data associated with its location, zero infiltration occurred within each wetland. Each wetland was also set to start with zero initial volume.

The water level between 01 Jan 2009 to the 31 December 2019 was determined for each wetland and those which met the 120-day continuous inundation criteria in any instance from July to December were highlighted as prospective brolga breeding and night roosting habitat for further assessment.

3 RESULTS

From the modelling undertaken the following was identified:

- The hydraulic modelled identified 804 areas which required further assessment. Of these:
  - 12 had an incorrect topographic representation within the model.
  - 145 had constructed drainage from the invert of the depression.
  - 41 were excluded because of their limited size, depth and catchment area. This combination of low depth, the size being close to 0.1 Ha and the small catchment mean these areas would dry quickly.
  - 38 were farm dams – automatically meeting the inundation criteria.
  - 26 were deemed suitable and required further assessment.
- The detailed hydrologic assessment determined 17 of the 26 wetlands assessed in detail met the inundation criteria required for the areas to be hydrologically suitable for brolga breeding and night roosting.

The areas modelled and those highlighted for further assessment are shown in Figure 3-1, those that met the inundation criteria, including farm dams are shown in Figure 3-2.

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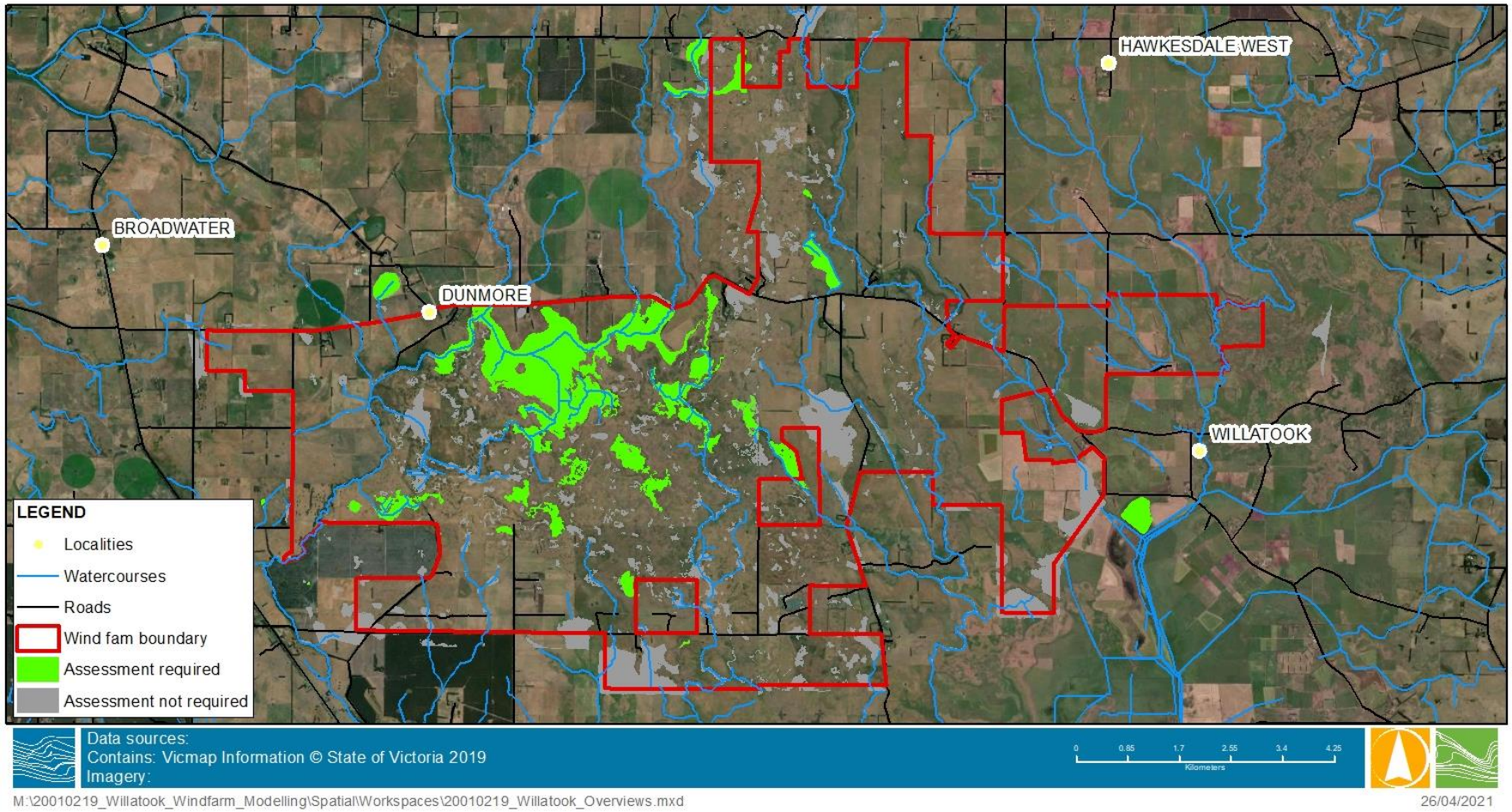

FIGURE 3-1 AREAS HIGHLIGHTED AS REQUIRING DETAILED HYDROLOGIC ASSESSMENT

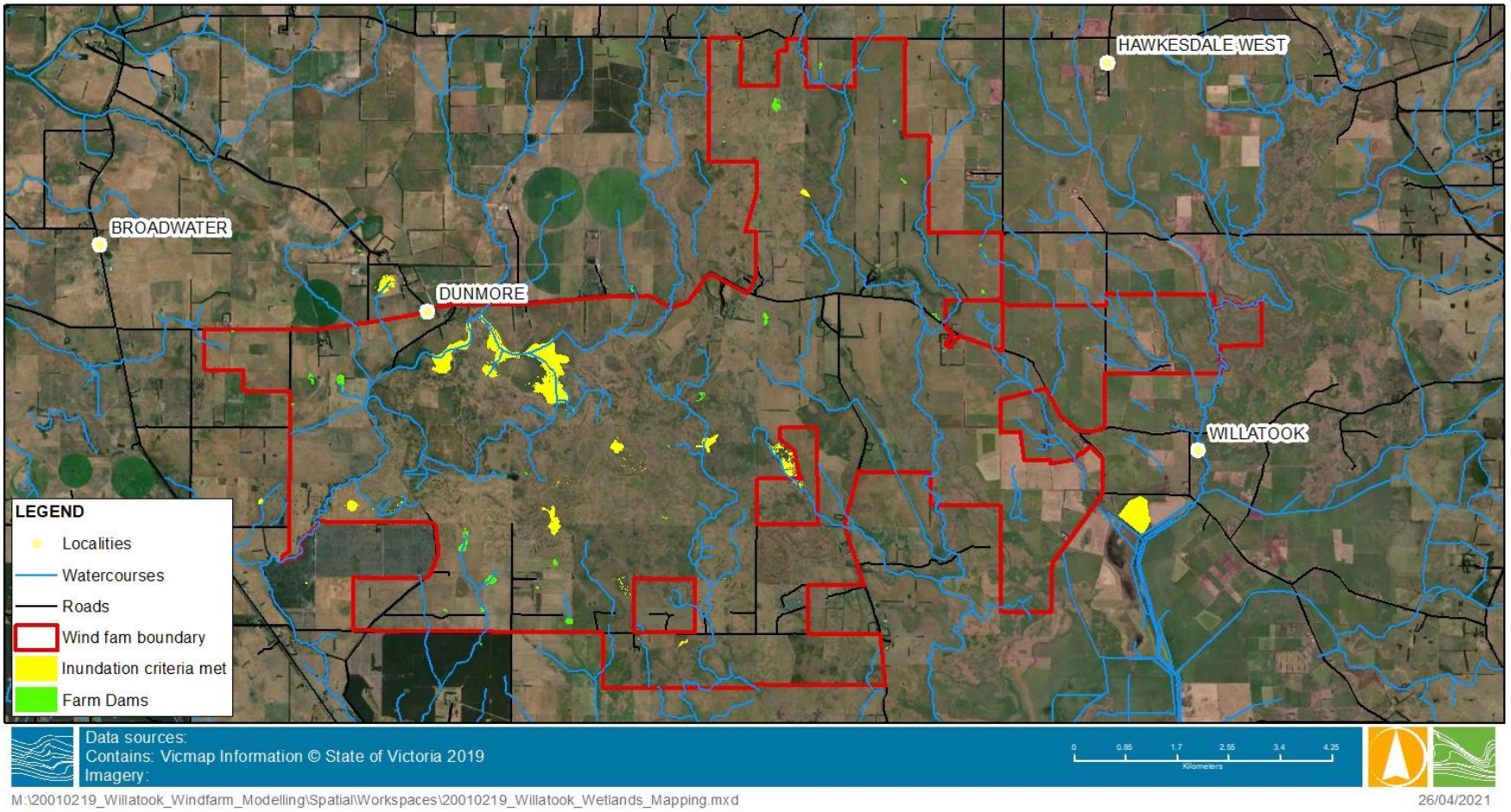

FIGURE 3-2 AREAS HIGHLIGHTED AS MEETING THE INUNDATION CRITERIA

Melbourne

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Brisbane

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Fax (07) 3846 5144

Adelaide

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Eastwood SA 5063
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Fax (08) 8357 8988

Perth

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Geelong

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Telephone 0458 015 664

Gippsland

154 Macleod Street
Bairnsdale VIC 3875
Telephone (03) 5152 5833

Wangaratta

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Wimmera

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Appendix 3: Brolga breeding wetland assessment results table

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
1	2005 (Local landholder, VBA)		Unsuitable during 2018 and 2019. Hydrology assessment did not recognise as a breeding site. Brolga may have attempted to nest here but unlikely to successfully rear young.	This breeding site was located in a floodplain, and may only holds water in particularly wet years. There are several drainage lines running through the area and it did not hold water during any time during the two breeding seasons when field work was undertaken. Grazed by cattle. The hydrology assessment did not recognise this as a possible Brolga breeding site.
2	Local landholder		Functional wetland	Wetland is in a low-lying area that filled with water by August and held water up until December, there was plenty of emergent vegetation and was grazed by sheep throughout the breeding season.
3	1984 (VBA)		Unsuitable	No wetland mapped here in VWI, the point is located next to Moyne River which may become inundated when the river bursts it banks. It is an old record with an accuracy of 900 metres. There are no wetlands within 900 metres of the point.
4	1984 (VBA)		Functional	No wetland mapped at point though looking at aerial mapping there is a small wetland 100 metres from point where it is plausible for a Brolga to nest.
5	1990's (local landholder)		Functional wetland	Wetland in a Blue Gum plantation, recently harvested. Blue gums were planted in 1999. A pair of Brolga nested at this wetland pre-plantation. Good cover of water and emergent vegetation, ungrazed.
6	2001 (Trust for Nature)		Functional wetland	Wetland next to woodland, good cover of water and emergent vegetation. No grazing though signs of Feral Pigs.
12a			Functional wetland	Wetland identified through the hydrology assessment, not a mapped VWI wetland. Wetland covered in poa tussock grass and sedges, meets minimum criteria in size. May provide habitat during a one in ten-year flooding event only.
23707			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23708			Unsuitable	This wetland has been permanently drained.
23711			Unsuitable	Wetland has been drained, unlikely to hold water long enough to support a breeding pair of Brolga.
23712			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23713			Unsuitable	This wetland has been permanently drained.
23718			Functional wetland	Wetland holds water for long periods, swans nesting here.
23719			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23720			Unsuitable	This wetland is in a harvested Blue Gum plantation. Wetland has been drained.
23722			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23723			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23724			Unsuitable	Wetland has been drained, unlikely to hold water long enough to support a breeding pair of Brolga.
23725			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23726			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23727			Unsuitable	This wetland has been permanently drained.
23728			Unsuitable	This wetland has been permanently drained.
23729			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23730			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23731			Unsuitable	This wetland has been permanently drained.
23732			Unsuitable	This wetland has been permanently drained.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
23734			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23735			Unsuitable	This wetland has been permanently drained.
23766			Unsuitable	This wetland has been permanently drained.
23771			Functional wetland	Holds a lot of surface water for extended period, many swans nesting here. Wetland is larger than shown on VWI mapping.
23849			Unsuitable	Wetland has been drained.
23850			Unsuitable	This wetland has been permanently drained.
23851			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23852			Unsuitable	This wetland is surrounded by Blue Gum plantation. May be suitable habitat once timber harvested.
23858			Unsuitable	This wetland has been permanently drained.
23990			Functional wetland	Signs of drainage though in a low-lying area, may hold water long enough to support breeding pair of Brolga.
25602			Unsuitable	This wetland has been permanently drained.
25603			Unsuitable	This wetland has been almost completely drained, holds small amount of surface water, unlikely to support a breeding pair of Brolga.
25604			Unsuitable	This wetland has been permanently drained.
25605			Unsuitable	Wetland has been drained and dammed.
25606			Unsuitable	Drained, not a lot of surface water, shallow surface water. Tussock grass, sedges, grazed by sheep. Would have been a high quality wetland if not drained.
25608			Functional wetland	Small isolated wetland.
25610			Unsuitable	Permanently drained, no surface water, tussock grasses and sedges present, grazed by sheep.
25611			Unsuitable	Permanently drained, there was some surface water in small section on the northern side of the road, surface water only in drainage lines on southern side of the road, no emergent vegetation and grazed by sheep.
25612			Unsuitable	Wetland has been permanently drained.
25613			Unsuitable	Permanently drained, pasture, grazed by cattle.
25615			Unsuitable	Permanently drained, pasture, grazed by cattle.
25616			Unsuitable	Permanently drained, pasture, grazed by cattle.
25619			Functional wetland	Wetland has been partially drained, still holds some water.
25621			Unsuitable	Wetland has been drained, unlikely to hold water long enough to support a breeding pair of Brolga.
25622			Functional wetland	Partially drained.
25623	2012 (VBA)		Functional wetland	Wetland is partially drained though does hold water.
25624			Unsuitable	Wetland has been permanently drained.
25625			Functional wetland	Wetland holds a good amount of water and emergent vegetation.
25626			Functional wetland	Wetland holds a good amount of water though partially drained.
25627			Unsuitable	Wetland is a lot smaller than what is mapped, surface water only in north-west corner, other parts have been drained. Water levels started to recede in considerably in October and by December it was almost completely dry. Sheep grazing the wetland.
25628			Functional wetland	Wetland has many drains through it but may hold water long enough for breeding.
25629			Unsuitable	Wetland dry, introduced pasture with a few weeds. No aquatic vegetation visible from the road.
25633			Unsuitable	Wetland has been drained and surrounded by timber plantation.
25634			Unsuitable	Wetland has been drained and surrounded by timber plantation.
25637			Functional wetland	Wetland has been partially drained, still holds some water.
25639			Unsuitable	Permanently drained, surface water only present in drainage line for a short time, usually no surface water. Sedges in northern section and heavily grazed by cattle.
25641			Unsuitable	Wetland has been permanently drained.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
25643			Functional wetland	Small wetland, holds water, swans nesting.
25644			Unsuitable	Wetland has been permanently drained.
25645			Unsuitable	Wetland has been permanently drained.
25650	2018 & 2020 (Nature Advisory), 2013 (VBA), 2012 (Australian Ecological)	A pair with a chick in Nov 2019 (chick approx. 3 months old). Likely nested in a wetland nearby.	Functional wetland	Wetland filled in August and had a good cover of emergent vegetation from September. Mostly ungrazed though cattle grazing in the area in October.
25658			Unsuitable	Drained, Tussock Grass present.
25659			Unsuitable	Wetland has been permanently drained.
25663			Functional wetland	Wetland holds water, partially drained.
25665			Unsuitable	Wetland has been permanently drained.
25668			Functional wetland	Wetland has been drained and only partially filled this season. Come October surface water was only in drainage lines and was dry by December. There was emergent vegetation throughout though not a lot of aquatic vegetation mostly pasture grasses and was grazed by cattle.
25670			Unsuitable	Mapped wetland is part of Carmichael Creek. The creek itself is choked by Cumbungi and unsuitable for nesting. There is a small isolated wetland on the western side of the creek that has some surface water.
25671			Functional wetland	Partially drained.
25672			Unsuitable	Wetland has been permanently drained.
25673			Unsuitable	Drained, Tussock Grass present.
W3 (25677)			Functional wetland	Large tussock swamp, had water throughout the breeding season, many water birds and frogs congregate here throughout the wet season. Partly fenced, some parts grazed by sheep and cattle. The LIDAR assessment reduced the boundary of this wetland and considered it suitable habitat for Brolga.
25678			Unsuitable	Permanently drained, grazed by cattle.
25679			Unsuitable	Permanently drained and has been cropped.
25680			Unsuitable	Permanently grazed, grazed by sheep.
25682			Unsuitable	Permanently drained, grazed by cattle.
25684			Unsuitable	Permanently drained, grazed by cattle.
25686			Unsuitable	Permanently drained, pasture land.
25687			Unsuitable	Drained, surface water only present in drainage lines.
25696			Unsuitable	Medium sized tussock swamp, surface water only in northern section, grazed by cattle. LiDAR results indicated it does not hold water long enough to support Brolga.
25697			Unsuitable	Wetland has been drained, with tussock grass on eastern side of boundary fence and exotic pasture on western side of fence. Not enough surface water for nesting. Grazed by cattle.
25698			Unsuitable	Permanently drained, surface water patchy in July, no surface water in August. Reeds and sedges present, grazed by cattle.
25699	2012 (VBA, EHP report), 2014 (Australian Ecological Research Services).	Pair of Brolga foraging in wetland in July 2019, not breeding.	Functional wetland	Wetland has been drained was holding the most water in August where it was 30% full, water only in drainage lines other times, was dry by December. Grazed by cattle.
25700			Unsuitable	Wetland is permanently drained, surface water patchy. Tussock grass present and grazed by cattle.
25705			Unsuitable	Wetland is permanently drained.
25708			Unsuitable	Permanently drained, drainage line choked by reeds and planted with exotic trees.
25709			Functional wetland	Large wetland that had a good cover of surface water and emergent vegetation throughout the breeding season.
25710			Functional wetland	Small tussock swamp, partially filled in July, holding water in August and September, only had water in drainage lines from October, dry by December. Grazed by cattle or sheep at times.
25711			Functional wetland	Medium sized wetland with good cover of surface water and emergent vegetation. Black Swan nesting.
25714			Unsuitable	Wetland has been drained.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
25715			Unsuitable	Wetland has been permanently drained.
W4 (25721)	2010 (EHP) 2018, 2019, 2020 & 2021 (Nature Advisory)	This Brolga pair has returned three years in a row to breed at the wetland. They are present at the wetland while nesting and rearing young.	Functional wetland	Large wetland has a drain running into it. Had surface water throughout the breeding season.
25724			Unsuitable	Wetland has been drained, no surface water, poa tussock grassland, grazed by sheep and cattle. No waterbirds.
25727			Unsuitable	Wetland has been drained, there was a little surface water in north-west section. No emergent vegetation and no other waterbirds.
25728			Unsuitable	Tussock swamp did not hold any water from September 2018. Unlikely that it will hold water long enough to support a breeding pair of Brolga.
25729	Approximately 2013 (landholder record)		Functional wetland	Small wetland fenced off from stock and well vegetated.
25730			Functional wetland	Partially drained, was holding 60% surface water during aerial surveys.
25731			Functional wetland	Ephemeral tussock swamp, shallow water from July to September, dry by December. Some patches of sedges, grazed by cattle.
25735			Functional wetland	Partially drained, was holding 60% surface water during aerial surveys.
25736			Unsuitable	Partially drained, choked by reeds.
25738			Unsuitable	Permanently drained, pasture land, grazed by sheep.
25739			Unsuitable	Permanently drained, pasture.
25740			Unsuitable	Partially drained, will not hold water long enough to support a breeding pair of Brolga.
25741	2017 (Local landholder)		Functional wetland	Small isolated wetland, partially drained though still holds water for long periods during the breeding season and has emergent vegetation.
25745			Unsuitable	Permanently drained.
25746			Functional wetland	Large wetland held good cover of water and emergent vegetation throughout the breeding season, fenced off from stock.
25747			Unsuitable	Permanently drained, pasture.
25748			Unsuitable	Permanently drained, pasture.
25749			Unsuitable	Permanently drained.
25750			Unsuitable	Small drained wetland in a young Blue Gum plantation.
25752			Unsuitable	Permanently drained.
25753			Unsuitable	Permanently drained.
25754			Unsuitable	Permanently drained.
25755			Unsuitable	Partially drained, surrounded by Blue Gum plantation.
25756			Unsuitable	Partially drained, surrounded by Blue Gum plantation.
25757			Functional wetland	This wetland had 50% surface water cover during aerial surveys, almost completely surrounded by Blue Gum plantation.
25758			Unsuitable	Permanently drained.
25759			Unsuitable	Drained and partially surrounded by Blue Gum plantation.
25760			Unsuitable	Small wetland has been drained, in a road reserve.
25761			Unsuitable	Wetland is located in a harvested Blue Gum block, did not hold any water during aerial surveys.
25762			Unsuitable	Surrounded by Blue Gum plantation, wetland was dry during aerial survey.
25765			Unsuitable	Wetland has been drained and partially planted with Blue Gum.
25766	2009 (VBA)		Unsuitable	Medium wetland with drainage line going through it and surrounded by Blue Gum plantation. May become suitable habitat when Blue Gum harvest ceases.
25769			Unsuitable	Permanently drained, held no water during aerial survey.
25770			Unsuitable	Small wetland surrounded by Blue Gum plantation
25771	2006 (VBA)		Functional wetland	Wetland is drained and does not hold water for a great period of time. Was dry by September in 2018. There is a complex of wetlands nearby. Some Blue Gum plantation around the wetland. Likely to hold water for longer periods if Blue Gum plantation was no longer there.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
25772	2005, 2009 (local landholder, VBA)		Functional wetland	Medium sized wetland surrounded by Blue Gum plantation on most sides and a road abuts it. Stock excluded and has good cover of emergent vegetation. Held water for all of the breeding season.
25774			Functional wetland	Small wetland with emergent vegetation, was still holding water in October 2018. Grazed by cattle.
25775			Unsuitable	Permanently drained, grazed by cattle.
25776			Unsuitable	Medium sized wetland surrounded by Blue Gum plantation. Was dry during aerial survey in October.
25777	2004 (VBA), 2011 (local landholder)		Functional wetland	Medium sized wetland which held water throughout the breeding season, stock excluded, Blue Gum plantation surrounding to the south and west. Lots of emergent vegetation.
25779			Unsuitable	Permanently drained, grazed by cattle.
25781			Functional wetland	There is a drain coming out of the wetland. Small wetland in size, dry during October aerial survey, two swan nests in wetland.
25782			Functional wetland	Small wetland has been drained, from aerial looks like it does hold water.
25783			Unsuitable	Permanently drained, grazed by cattle.
25784		A pair of Brolga foraging at the wetland in October 2019.	Functional wetland	Medium sized wetland, it is drained and does not hold water for as long as the other three wetlands nearby. Was grazed by sheep early in the season. Good cover of emergent vegetation throughout the breeding season.
25786			Unsuitable	Wetland has a drain running through it and is surrounded by Blue Gum plantation.
25787			Unsuitable	Wetland has a drain running through it and is surrounded by Blue Gum plantation.
25788			Functional wetland	Medium sized wetland held water throughout the breeding season. Vegetation started emerging in August and had a good cover of vegetation from September to December. Grazed by sheep for most of the season.
25789			Unsuitable	Wetland has been drained.
25790			Unsuitable	Wetland has been drained.
25791			Unsuitable	Wetland surrounded by Blue Gum plantation, appears to be drained and dry from the aerial survey.
25792			Unsuitable	A small dam surrounded by Blue Gum plantation and a row of cypress pine trees. Some emergent sedges in dam, ungrazed.
25793			Functional wetland	Wetland does have a drain running out of it, though from the aerial looks like it does hold water, grazed by stock.
25794			Unsuitable	Wetland has been drained.
25795			Unsuitable	Small wetland surrounded by Blue Gum plantation, has a drain running through it, may hold some water, was dry during aerial survey.
25796			Functional wetland	Wetland does have a drain running through it though looks like it may hold water from aerial photography.
25797			Functional wetland	Large wetland with drainage lines running through it. Is made up of three main pools of water connected by the drainage lines. Good cover of emergent vegetation, rushes, sedges and tussock grass. Sheep grazing and Black Swan nesting.
25798			Functional wetland	Medium sized wetland which does have drains in it and had 80% surface water cover during aerial surveys.
25800	2010 (Trust for Nature)		Functional wetland	Medium sized wetland with good cover of surface water and emergent vegetation. Black Swan nesting here in 2018.
25801			Functional wetland	Wetland has been drained and a small dam remains. Surface water only in two small areas, mapped wetland is significantly smaller than what is mapped. Plausible breeding site though unlikely.
25802			Unsuitable	Wetland is surrounded by Blue Gum plantation and was dry during the aerial survey.
25803			Unsuitable	Wetland is surrounded by Blue Gum plantation and was dry during the aerial survey.
25805	2011 (VBA)		Functional wetland	Wetland is located on the border of Pallisters Reserve and a Blue Gum plantation. Past breeding record from here, good cover of surface water and emergent vegetation. Stock excluded though signs of Feral Pig in the reserve.
25806			Unsuitable	Small wetland with a road dissecting it. Drained on north side of road, surface water only on south side of road. Fenced and ungrazed. Too small to support a breeding pair of Brolga.
25808			Unsuitable	Wetland doesn't appear to hold a lot of water from aerial photography. Possibly due to Blue Gum plantations, no signs of drainage.
25809			Unsuitable	Drained, grazed by cattle. No surface water.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
25810			Functional wetland	Wetland holds a good cover of water, Black Swan nesting here.
25811			Unsuitable	Wetland within a woodland.
25813			Unsuitable	Wetland has been drained and was completely dry during aerial survey.
25814			Unsuitable	Does not appear to be a wetland, inaccurate wetland mapping.
25815			Unsuitable	Wetland has been drained, only very small area of surface water remains, there is a bigger pool outside where the wetland has been mapped.
25816			Functional wetland	This is a large wetland (Wild Dog Swamp) which was inundated throughout the entire breeding season. It had a good cover of emergent vegetation throughout the breeding season, cattle grazing some months of the breeding season. Many Black Swan nesting, large congregations of waterbirds and high diversity of waterbirds and frogs.
25819			Functional wetland	Wetland has been drained though still holds water. Black Swan nesting here.
25820			Unsuitable	Wetland doesn't appear to hold a lot of water, may be due to Blue Gum plantations nearby.
25821			Functional wetland	Wetland is very shallow, may not hold as much water due to Blue Gum plantation. No grazing though signs of Feral Pigs.
25822			Unsuitable	Drained, completely dry.
25823			Unsuitable	Wetland has been drained, does not hold water long enough to support breeding pair of Brolga.
25825	2010 (Trust for Nature)		Functional wetland	Small wetland in Pallisters Reserve with some surface water and good cover of emergent vegetation. No stock present though signs of Feral Pig.
25826			Unsuitable	Wetland a lot smaller than what is mapped, shallow water, would not hold water long enough of deep enough for nesting.
25827			Unsuitable	Wetland is surrounded by woodland.
25828	2011 (VBA)		Functional wetland	Manna Gum Swamp. Wetland holding good cover of surface water and emergent vegetation.
25829	Trust for Nature		Functional wetland	Small wetland in Pallisters Reserve with some surface water and good cover of emergent vegetation. No stock present though signs of Feral Pig.
25830			Unsuitable	Wetland has been drained and was dry during aerial survey.
25832			Unsuitable	Wetland is a lot smaller than what is mapped, only very small area of surface water, not large enough to support breeding Brolga pair.
25833			Unsuitable	Wetland has been drained and small dam remains.
25834			Unsuitable	Permanently drained via a deep channel, no surface water.
25835			Unsuitable	Wetland is located within a woodland.
25836	2011 (VBA)		Functional wetland	Wetland located within Pallisters Reserve, good cover of water and emergent vegetation, stock excluded though signs of Feral Pig in reserve.
25839			Functional wetland	Wetland had 50% water cover during aerial survey, heavily grazed.
25840			Unsuitable	Wetland still holds water and has emergent vegetation though is surrounded by Blue Gum plantation.
25841	1984 (VBA)	A pair with last years juvenile bird at this wetland in August 2019, not breeding. Pair was seen again with last year's chick in November 2019 foraging in paddock across the road from this wetland to the south.	Unsuitable	This is a large wetland locally known as Bartlett Swamp. It has been drained and only held water and significant water in August 2019, was dry by October. Grazed by cattle and sheep some emergent vegetation. Brolga have been seen foraging in this wetland though does not hold water long enough for breeding purposes.
25843			Unsuitable	This wetland lies across two properties and is surrounded by trees, Blue Gum plantation surrounds the majority of the wetland and woodland surrounds to the west.
25844			Unsuitable	This wetland does hold water and have emergent vegetation though is surrounded by Blue Gum plantation.
25845			Unsuitable	Small wetland surrounded by Blue Gum plantation, was dry during aerial survey.
25846			Functional wetland	Medium sized wetland that held water throughout the breeding season in 2019, had emergent vegetation, was ungrazed during breeding season though was on a dairy farm. Black Swan nesting here. An immature Brolga was observed foraging here on one day in 2018.
25847			Unsuitable	Wetland has been drained, farm dam remains, grazed by sheep.
25849			Unsuitable	Small wetland, heavily grazed.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
25850	2008, 2009 (Trust for Nature)		Currently unsuitable, will be suitable if Blue Gum plantation ceases	A series of small wetlands surrounded by Blue Gum plantation. Unlikely to continue to provide breeding habitat while trees are standing, possible when trees have been harvested or when plantation ceases.
25851			Functional wetland	Wetland has been partially drained, still holds some water during breeding season, heavily grazed.
25852			Unsuitable	Wetland has been permanently drained there was a small area of surface water covering approximately 10% of wetland in July 2018, grazed by sheep and cattle, no emergent aquatic vegetation, pasture.
25854			Functional wetland	This wetland has been partially drained, had 25% surface water cover during aerial survey, grazed be stock.
25855			Unsuitable	A series of small wetlands within a Blue Gum plantation, was dry during aerial survey.
25856			Unsuitable	Small wetland surrounded by Blue Gum plantation, had sedges emerging from the water, was dry by November.
25857			Unsuitable	Wetland has been dammed, no emergent vegetation, grazed by cattle.
25858			Unsuitable	Wetland has been planted with Blue Gums.
25859			Unsuitable	Wetland is surrounded by Blue Gum plantation, held water throughout the breeding season and had emergent vegetation.
25860			Unsuitable	Wetland is surrounded by Blue Gum plantation.
25861			Functional wetland	Small sedgy wetland held water for majority of the breeding season drying in December. This wetland is located in a harvested Blue Gum plantation.
25862			Unsuitable	Permanently drained, surface water only in drainage lines. Tussock grassland surrounding.
25864			Unsuitable	Wetland has been permanently drained.
25865			Functional wetland	Wetland has been partially drained, still holds some water and emergent vegetation, grazed by cattle.
25866			Functional wetland	Small wetland, heavily grazed by cattle, still holds some water, located next to harvested Blue Gum plantation.
25867	2018 (Nature Advisory)		Functional wetland	This wetland was located within a Blue Gum plantation. Was harvested with last few years, replanted in 2018. A Brolga pair did successfully breed here in 2018 though in 2019 the trees were approximately 2 metres high which is not ideal for Brolga. Brolga were not seen near this wetland or in the plantation during the 2019 breeding season.
25868			Functional wetland	Wetland has been drained on west side of road, surface water only on east side of road. The wetland has a good cover of surface water and emergent vegetation. Held water throughout the breeding season, Black Swan nesting here and many waterbirds congregating. Grazed by sheep at times.
25869			Functional wetland	Wetland has been dammed, emergent vegetation present, grazed at times, Black Swan nesting.
25870			Unsuitable	Wetland has been almost completely drained, does not hold water long enough to support breeding Brolga, heavily grazed by cattle.
25871			Unsuitable	Surrounded by Blue Gum plantation, very shallow with some scattered emergent vegetation. Overall, not suitable habitat for Brolga.
25872			Functional wetland	A farm dam has been dug in the middle of the wetland, dam has flooded creating a wetland. Emergent vegetation present in shallow areas. Many waterbirds present throughout the assessment.
25873			Functional wetland	Wetland has been partially drained, surface water only present in 1/6 of mapped wetland. The smaller wetland did have good cover of emergent vegetation and held water for the breeding season. Some waterbirds here throughout the survey.
25875			Functional wetland	Wetland has been partially drained, still holds water and has emergent vegetation, grazed by cattle.
25876			Functional wetland	Small wetland, holds water and has emergent vegetation, grazed by cattle.
25877			Functional wetland	Wetland has Blue Gum plantation on north and south side, open to the east and west. Holds water only approximately 15% of area that is mapped. Black Swan nested here.
25878			Functional wetland	Wetland has a drain running into it, holds water and has emergent vegetation, grazed by cattle.
25879			Unsuitable	Permanently drained, no emergent vegetation.
25880			Unsuitable	Wetland has been partially drained, holds water for limited time, heavily grazed by cattle.
25881			Unsuitable	Small wetland, unlikely to hold water long enough to support a breeding pair of Brolga.
25883			Unsuitable	Small wetland, unlikely to hold water long enough to support a breeding pair of Brolga.
25884			Functional wetland	Small wetland holds water and has emergent vegetation, grazed by cattle.
25885			Functional wetland	Small wetland holds water and has emergent vegetation, grazed by cattle.

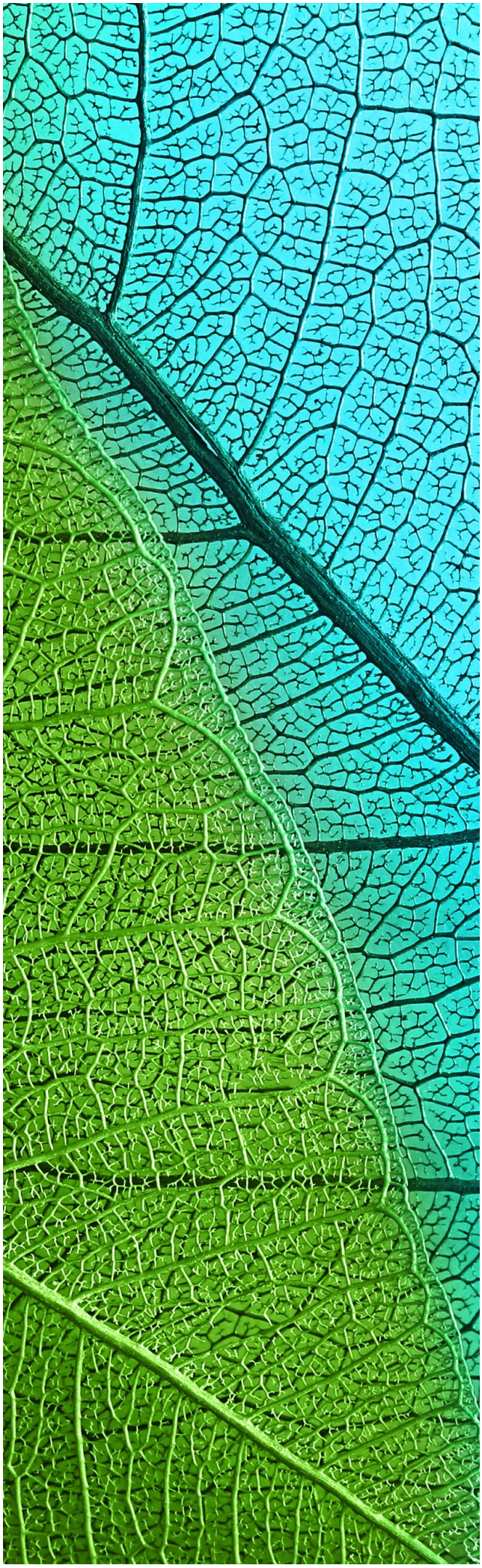
Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
25886			Functional wetland	Small wetland, looks like it would hold water throughout the breeding season, has emergent vegetation, grazed by cattle.
25887			Functional wetland	There are a series of three wetlands, they held water throughout the breeding season and had a good cover of emergent vegetation, grazed by sheep.
25888			Unsuitable	Permanently drained.
25890			Unsuitable	There is no wetland at the location mapped.
25891			Functional wetland	Medium sized wetland has a drain running through it though still held water throughout the breeding season, emergent vegetation present from September, grazed by sheep.
25892			Unsuitable	Permanently drained, no native vegetation.
25893			Unsuitable	Wetland has been drained, limited surface water and emergent vegetation, grazed by cattle.
25894	2021 (Nature Advisory)	Nesting August 2021	Functional wetland	Wetland has been partially drained, still holds water and has emergent vegetation, grazed by cattle.
25895			Unsuitable	Wetland is surrounded by Blue Gum plantation, was dry during aerial survey, unlikely to hold water long enough to support breeding Brolga.
25896			Unsuitable	Wetland surrounded by Blue Gum plantation.
25898			Functional wetland	Small wetland held water for the majority of the year, almost dry by December. Good cover of emergent vegetation, grazed by cattle.
25899			Unsuitable	Wetland has been drained and is surrounded by Blue Gum plantation.
25900			Unsuitable	Small wetland, patchy emergent vegetation.
25901			Unsuitable	Small wetland, limited surface water and emergent vegetation, grazed by cattle.
25902			Unsuitable	Wetland was cultivated during the breeding season, had previously been drained.
25903			Unsuitable	Permanently drained, pasture, grazed by cattle.
25905			Functional wetland	Small wetland has been partially drained, held water throughout the breeding season starting to dry in December, good cover of emergent vegetation, Black Swan nesting here in 2018.
25906		Landholder reported a single Brolga the week prior in July 2019. Not here during any visits during field work.	Functional wetland	Small wetland, held water throughout the breeding season, good cover of emergent vegetation from September, grazed by sheep.
25908			Functional wetland	Medium sized wetland held water throughout the breeding season, good cover of emergent vegetation, Black Swan nesting.
25909			Unsuitable	Wetland has been permanently drained or was never a wetland to begin with. Located in a plantation.
25911			Functional wetland	Small wetland with good cover of surface water starting to dry in December and emergent vegetation from September. Black Swan nested here, grazed by cattle.
25912			Unsuitable	No wetland present here, majority of mapped wetland is Blue Gum plantation.
25913			Functional wetland	Wetland has a drain running through it though still holds water and has emergent vegetation.
25916			Functional wetland	Small wetland with good cover of surface water and emergent vegetation. Grazed by cattle, Black Swan nested here.
25918			Functional wetland	Wetland has been drained though still holds some water approximately 50% surface water. Grazed.
25920			Unsuitable	Wetland surrounded by Blue Gum plantation.
25922			Unsuitable	Small wetland has been drained, limited emergent vegetation, too small and isolated to support a breeding pair of Brolga.
25923			Unsuitable	Wetland has been drained.
25926			Unsuitable	Wetland has been permanently drained.
25929			Functional wetland	Wetland has been partially drained, had 15% surface water cover during aerial survey.
25930			Functional wetland	Wetland has been dammed, well vegetated, Black Swan nesting in 2018.
25932			Unsuitable	Wetland has been permanently drained.
FD2 (25933)			Functional wetland	Medium sized wetland has been drained and dammed though still holds good cover of water and emergent vegetation. Grazed be sheep, Black Swan nested here.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
25934			Unsuitable	Is not a wetland where mapped, Blue Gum plantation.
(W7) 25936			Functional wetland	Small wetland with good cover of surface water, aquatic vegetation emerged in September, water levels started to recede in October though considered to hold water long enough for breeding purposes. Grazed by sheep.
25941			Functional wetland	Medium sized wetland with good cover of surface water and emergent vegetation throughout the breeding season. Cattle excluded for majority of the breeding season only seen grazing in September.
W1 (25944)	1984 (VBA)		Functional wetland	This wetland was once large though has very deep channels draining it and is now permanently drained. No waterbirds observed here throughout the surveys. Hydrology assessment has modified the outline of the wetland and indicated that this wetland may hold water for long enough to support breeding in a one in ten-year flood.
25947			Unsuitable	Permanently drained, holds very little water.
25948			Unsuitable	Tussock swamp, has been drained.
25949			Unsuitable	Large wetland though has been drained, does not hold water long enough to support breeding pair of Brolga. Wetland mapping is incorrect wetland more to the north.
25950			Unsuitable	Wetland surrounded by Blue Gum plantation.
25952			Unsuitable	Large wetland partially drained, surface water present in parts, started to dry in October and little surface water remaining by November due to drainage. Did not meet the minimum 120-day inundation period. Black Swan nesting though was not enough water to sustain them. Sparse emergent vegetation, grazed by sheep.
25953			Unsuitable	Tussock swamp, has been drained.
25955			Unsuitable	Wetland has been drained and dammed, no emergent vegetation, grazed by cattle.
25956			Unsuitable	Large wetland that is mostly permanently drained. Surface water in the east and west of wetland mapped, emergent vegetation in wet areas, grazed by sheep and cattle. Did not meet the minimum 120-day inundation period.
25957			Functional wetland	The majority of this mapped wetland is part of the Shaw River and is choked by Cumbungi and is not suitable for Brolga. At the far eastern end of the mapped wetland there is a floodplain that is plausible for Brolga breeding. This section had a good cover of water and emergent vegetation throughout the breeding season.
25959			Unsuitable	Tussock swamp, has been drained.
25961			Unsuitable	Tussock swamp, has been drained.
25962			Unsuitable	This wetland is partially drained and is 20% smaller than what is mapped. Surrounded by Blue Gum plantation on the northern edge.
25964			Unsuitable	No wetland in area mapped.
25965			Unsuitable	No wetland in area mapped.
25967			Unsuitable	Wetland has been permanently drained.
25968			Unsuitable	Wetland has been drained and dammed.
25969			Unsuitable	Medium sized wetland that has been partially drained. Emergent vegetation was present and was grazed by cattle and sheep. Unlikely to hold water long enough to support breeding Brolga.
25972			Unsuitable	No wetland present, Blue Gum plantation.
25974			Functional wetland	Medium sized wetland with good cover of surface water and emergent vegetation. It was inundated throughout the breeding season. Black Swan nesting on the wetland, grazed by cattle and sheep, many waterbirds congregating.
25975			Unsuitable	Tussock Swamp, drained.
25979			Unsuitable	Wetland has been permanently drained.
25981			Unsuitable	Wetland has been permanently drained.
25982			Unsuitable	Wetland has been permanently drained.
25985			Unsuitable	Tussock Swamp, drained.
25988			Unsuitable	Tussock Swamp, drained.
25989			Unsuitable	Not a wetland, mapped wetland is in a rocky rise area.
25991			Unsuitable	Wetland has been permanently drained.
25992			Unsuitable	Wetland has been permanently drained.
26002			Unsuitable	Wetland has been dammed, no emergent vegetation, grazed by stock.
26017			Functional wetland	Wetland is partially drained, still holds water and has emergent vegetation. Grazed by stock.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
26018			Unsuitable	This wetland has been drained and dammed. No emergent vegetation, grazed by stock.
26019			Unsuitable	Small wetland that has been dammed.
26020			Functional wetland	Large wetland has been dammed, emergent vegetation, Black Swan nesting here.
26025			Unsuitable	Wetland has been drained and dammed.
26026			Unsuitable	Wetland has been dammed, no emergent vegetation, grazed by cattle.
26027			Unsuitable	Wetland has been permanently drained.
W12e, W12c & W12w (26028)	1984 (VBA)	Brolga were observed foraging here early in the breeding season in 2019 and 2020 before heading to their breeding site at wetland W4 where they spent the majority of the breeding season.	Functional wetland	Very large and expansive wetland known as Cockatoo Swamp where the Shaw River flows though this swamp and had good cover of surface water and emergent vegetation. Was inundated up until November started drying out in December, Black Swan nesting here, many waterbirds and frogs present. Grazed by cattle. The hydrology assessment modified the wetland boundary from the VWI wetland layer, receding in the southern section due to drainage, receding in the central section due to elevation and extending to the west to include a flood plain of the Shaw River.
26029	2013 (VBA), 2016 (Australian Ecological Research Services)		Functional wetland	Wetland was originally very large though it has been drained throughout, now only holds water in north-eastern section of mapped wetland.
26030			Unsuitable	Large wetland has been permanently drained.
26031			Unsuitable	Tussock Swamp has been permanently drained.
26032			Unsuitable	Large wetland mapped, has been permanently drained.
26033			Unsuitable	Wet pasture, some scattered sedges but mostly dry.
26034			Unsuitable	Permanently drained, grazed by cattle.
26035			Unsuitable	Permanently drained, some surface water at eastern side, no emergent vegetation, grazed by cattle.
26036			Unsuitable	Permanently drained, surface water only present in drainage lines, pasture, grazed by cattle.
26037			Unsuitable	Permanently drained, pasture, grazed by cattle.
26038			Unsuitable	Permanently drained, surface water only in drainage lines, pasture, grazed by cattle.
26039			Unsuitable	Wetland has been permanently drained.
26040			Functional wetland	Wetland has been almost completely drained, small pool to the south-east of the mapped wetland.
26042			Unsuitable	Wetland has been permanently drained.
26043			Unsuitable	Natural swamp, has been fenced off from stock and parts have been planted. Dominated by Woollybutt, reeds, cumbungi, gahnia, rushes. Not open enough for Brolga.
26044			Unsuitable	Permanently drained, pasture.
26045			Unsuitable	Wetland borders onto Austins Creek. There is a drainage line at western side. Dry throughout the breeding season.
W10 (26046)			Functional wetland	Large wetland on the VWI wetland layer, has a series of drains running through it, surface water patchy, only really in 1m wide drainage lines. The hydrology assessment outlined a small section of 5.95ha of this wetland that would hold water long enough to support Brolga breeding indicated as W10. This wetland crosses a property boundary and is quite different habitat on each side. The north side is dominated by Poa Tussock Grass with scattered sedges while the southern side is dominated by pasture grasses. Northern section is wetter. Potential to provide Brolga breeding habitat in a one in ten-year flood on the northern property only of W10. Only a very small section of wetland 26046 is considered likely to provide suitable breeding habitat.
26047			Unsuitable	Permanently drained, no emergent vegetation.
26048			Unsuitable	Permanently drained, no emergent vegetation.
26049			Unsuitable	Series of three wetlands within Blue Gum plantation.
26050			Unsuitable	Series of two wetlands within Blue Gum plantation.
26051			Unsuitable	Wetland is surrounded by Blue Gum plantation.
26052			Unsuitable	Series of three wetlands within Blue Gum plantation.
26053			Unsuitable	Series of two wetlands within Blue Gum plantation.
26054			Unsuitable	Small wetland has been drained, little surface water or emergent vegetation, grazed by cattle.
26055			Unsuitable	Small wetland, little surface water or emergent vegetation, grazed by cattle.

Wetland Number	Past breeding record (year)	Brolga present	Wetland habitat assessment	Wetland description
26056			Functional wetland	Wetland has drains running through it though still holds water and has some emergent vegetation. Grazed by stock.
26057			Functional wetland	Wetland is 60% the size of what is mapped, still holds water and has emergent vegetation, grazed by stock.
26058			Unsuitable	Wetland has been partially drained some small pools of water located in northern end of mapped wetland.
26059			Functional wetland	Large wetland has been partially drained, two medium sized pools of water remain within mapped wetland with emergent vegetation. Grazed by stock.
26060			Unsuitable	Wetland has been partially drained, water gathers in two small pools, was dry during aerial survey.
26062			Unsuitable	Wetland has been permanently drained.
27133			Functional wetland	Wetland has been partially drained, still holds some water and has emergent vegetation. Grazed by stock.
FD16			Functional wetland	The dam dose overflow in spring and has emergent vegetation. A pair of Brolga were observed foraging here in July 2020, believed to be the pair that nest at wetland W4. Overflow is dominated by Poa Tussock and sedges, grazed by sheep.
FD21			Functional wetland	Farm dam is too small to support breeding Brolga most years, during a one in ten-year flooding event the wetland would extend into the pasture dominated by Poa Tussock Grass and sedges. May provide Brolga breeding habitat in a one in ten-year flood.
W13			Functional wetland	Wetland has many drains in it, mostly drained though some drains silted up. Dominated by Poa Tussock Grass and sedges, soils were saturated with wetland herbs present. Surface water cover 1% in drains.

Appendix 4: Brolga habitat assessment of wetlands identified from hydrological assessment



Willatook Wind Farm

Brolga Habitat Assessment

Prepared for Wind Prospect Pty Ltd

February 2022
Report No. 16087 (9.2)

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1. Introduction

Wind Prospect Pty Ltd engaged Nature Advisory Pty Ltd to conduct a Brolga (*Antigone rubicunda*) habitat assessment at the proposed Willatook Wind Farm. The specific area investigated, referred to herein as the 'study area', comprised the properties involved in the proposed wind farm and an extended two-kilometre buffer around them.

This investigation was commissioned to provide information on the extent and condition of brolga habitat in the study area according to Victoria's *Interim Guidelines for the assessment, Avoidance, Mitigation and Offsetting of Potential Wind Farm Impacts on the Victorian Brolga Population 2011* (DSE 2012), as well as the revised Brolga habitat buffering methodology for the proposed Willatook Wind Farm and Hexham Wind Farm (Wind Prospect 2020).

Specifically, the scope of the investigation was to assess the farm dams and wetlands indicated by Wind Prospect Pty Ltd based on hydrological modelling as potential habitat for Brolga for their suitability to provide breeding, foraging and night roost habitat based on other factors, including the presence of emergent aquatic vegetative cover, and habitat for food sources for the Brolga (e.g. frogs and tubers).

This report is divided into the following sections.

Section 2 describes the sources of information, including the methods used for the field survey.

Section 3 discusses the results of the assessment.

Section 4 discusses the conclusions of the assessment.

This investigation was undertaken by a team from Nature Advisory comprising Elinor Ebsworth (Senior Botanist), Curtis Doughty (Senior Zoologist), Bernard O'Callaghan (Director) and Brett Lane (Principal Consultant).

2. Existing information and methods

2.1. Existing information

Existing information used for this investigation is described below.

2.1.1. Existing reporting and documentation

The existing documentation below, relating to the study area was reviewed.

- Shape files provided by Wind Prospect Pty Ltd of wetlands that meet hydrological characteristics agreed by them with DELWP based on the results of a detailed hydrological modelling exercise (Water Technology 2022).
- Mapping provided by Wind Prospect Pty Ltd with results from the hydrological assessment.

2.1.2. Background information

The Brolga is a crane that occurs in south-western and northern Victoria as well as south-eastern South Australia and more abundantly across northern Australia. It relies on wetlands for foraging, breeding and roosting. Many of these wetlands are located on private land within its Victorian range.

In south-western Victoria the Brolga population occupies different habitats during the non–breeding season (January to June) and breeding season (July to December). In the non-breeding season, the Brolga congregates in flocks at permanent lakes. During the breeding season, once ephemeral wetlands have filled, Brolga pairs move to smaller breeding wetlands (DSE 2003).

Preferred wetlands chosen for breeding in western Victoria are shallow freshwater marshes and freshwater meadows, usually ephemeral, they need to hold water for at least 120 days during the breeding season (July – December), the wetlands need to have emergent vegetation that provides food and nesting material. Suitable breeding habitat is dominated by aquatic vegetation including sedges, rushes, annual herbs, Tussock Grass *Poa* sp., Sweet Grass *Glyceria* sp., Spike–rush *Elocharis* sp. or Common Sword Sedge *Gahnia* (Marchant and Higgins 1993). Nests are usually constructed within the shallows of wetlands from a variety of plant matter where a platform of vegetation is constructed approximately 1.5 metres in diameter (White 1987).

Brolga are unlikely to utilise or breed successfully in wetlands that are less than 0.6 hectares, do not hold water for 120 days, are unfenced and grazed by cattle, in close proximity to human disturbance or have little or no emergent vegetation. Brolga are unlikely to breed in drainage lines flowing into and out of wetlands as they prefer larger expanses of water to protect them from ground predators. Equally Brolga do not breed in flowing creeks and rivers though they will if they have been dammed and flows stilled.

Veltheim *at al.* (2019) identified wetlands that act as night-time roosts, particularly once the adults and chicks have left the nest. These wetlands may or may not have been where the nest was originally constructed. Once nests are not used, these night-time roosts become the focus of activity for Brolga families. As Brolga activity are focused on functional wetlands for food resources, they are likely to use these same wetlands as night-time roosts.

2.1.3. Desktop assessment of wetlands and farm dams

A list was generated of wetlands and farm dams that that met the 120-day inundation period at least once in ten-years from outputs of the hydrological modelling. The list included 38 farm dams and 17 wetlands. Their locations are presented in Figure 1.

A functional wetland was considered to provide breeding, foraging and night-time roosting habitat for Brolga. A functional wetland was considered to include the following.

- At least 0.6 hectares in area
- Holds water continuously for 120 days during the period from July to December
- Had at least 20% aquatic/emergent vegetation cover.

In the instance where a wetland would usually not fill but was predicted by the modelling to fill in a one in ten-year rainfall event, habitat conditions of the site were taken into consideration, as follows. If a wetland identified by the hydrology assessment was deemed to hold water for at least 120 days on average at least once in ten years, and the ground cover supported aquatic vegetation such as sedges and/or *Poa* Tussock Grass, it was considered that it could indeed provide Brolga breeding habitat. This was because the existing aquatic vegetation would recover from the dry period relatively quickly after filing and create higher quality breeding habitat while still holding water in that year to support Brolga breeding. The same approach was taken for farm dam overflow and floodplain areas.

As there is no literature on the habitat characteristics of a Brolga night-time roost, it has been assumed that Brolga will use the same wetlands that are considered as functional wetlands as night roosts. As Brolga activity are focused on these functional wetlands for food resources, they are likely to use these same wetlands as night-time roosts.

2.2. Field methods

The field assessment was conducted on 11th September 2020. Wetlands that could not be assessed from aerial photography or had not been previously assessed by Nature Advisory were assessed in the field. Wetlands and farm dams were visited on foot, photographs and notes taken on habitat characteristics, including surface water cover, drainage, emergent vegetation present and grazing pressures. An assessment was made of whether it meets the requirements of a functional wetland that would be used by Brolga using the above criteria (Section 2.1.3).

Figure 1: Location of farm dams and wetlands assessed

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 23/09/2020

Legend

- Wind farm boundary
- Wind farm 5km buffer
- Assessed farm dams and wetlands

ADVERTISED PLAN

N

Metres
0 500 1,000

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3. Assessment results

3.1. Wetland and farm dam assessment

A total of 38 farm dams and 17 wetlands were assessed as functional wetlands for their suitability to provide Brolga breeding, foraging and night-time roosting habitat based on the criteria presented in Section 2.1.3. The results of the assessment are presented in Table 1 and are mapped in Figure 2. A total of three farm dams and 12 wetlands were considered as functional wetlands and likely to provide habitat for Brolga.

FD2 (see Figure 2) has previously been identified by Nature Advisory as likely to provide suitable breeding habitat for Brolga. FD16 has had a Brolga pair foraging in it during surveys in July 2020. FD21 is a small farm dam that overflows into low-lying land to provide possible nesting and feeding opportunities for Brolga.

The following wetlands have been previously assessed by Nature Advisory and have been confirmed as functional wetlands providing Brolga habitat or are considered likely to provide breeding habitat in the future.

- W1
- W3
- W4
- 25729
- 25731
- 25741
- 25816
- W7
- W12
- W10.

Wetlands 12a and W13 were also assessed in the field during September 2020. Wetland 12a did not hold water during the assessment though the hydrology assessment identified that this wetland will hold water in a one in ten-year rainfall event. Wetland W13 had many drains and only had 1% surface water in the drainage lines across the whole wetland during the field visit. Both of these areas were dominated by *Poa* tussock grass and sedges, hence they were considered to be a functional wetland during flooding events.

It is noteworthy that some of these wetlands include contiguous drains and waterways. These narrow habitats are not considered suitable Brolga breeding habitat and are not proposed to be used to determine turbine-free buffers (see Section 4).

Table 1: Wetland and farm dam assessment at Willatook Wind Farm

Hydrology reference	VWI number	Area (ha)	Habitat description	Functional wetland
FD1	25696	0.3075	Farm dam is too small to support breeding pair of Brolga. Farm dam does not have any emergent vegetation, aquatic vegetation present in dam overflow.	No
FD2	25933	2.2675	Farm dam is the right size and has already been identified in the wetland assessment as suitable breeding habitat.	Yes
FD3	25955	0.2375	Wetland has been drained and dammed. Dam very small and has no aquatic vegetation. Area too small to support a breeding pair of Brolga.	No
FD4	25682	1.9325	Drained, grazed by cattle, dominated by pasture grasses, no aquatic vegetation in dam.	No
FD5	26026	2.49	Wetland has been dammed, no emergent vegetation, grazed by cattle, some aquatic vegetation to the north of dam.	No
FD6		0.11	Very small dam, too small to support Breeding pair of Brolga, isolated, no emergent or aquatic vegetation, grazed by cattle.	No
FD7		0.1475	Farm dam, no emergent vegetation, grazed by cattle, too small.	No
FD8		0.32	Farm dam, no emergent vegetation, grazed by cattle, wetland is too small, wetland surrounded by pasture.	No
FD9		0.12	Farm dam, no emergent vegetation, grazed by cattle, wetland is too small, wetland surrounded by pasture.	No
FD10		0.57	Farm dam is too small and has no emergent vegetation, surrounded by pasture grasses.	No
FD11		0.415	Two farm dams, no emergent vegetation, grazed by cattle, surrounded by pasture dominated by pasture grasses.	No
FD12		0.305	Farm dam, no emergent vegetation, grazed by cattle, wetland is too small, overflow area does have some Poa Tussock Grass and sedges.	No
FD13		0.11	Wetland is too small, no emergent vegetation, some planted trees around it and close to sheds and housing.	No
FD14		0.15	Farm dam no emergent vegetation, wetland is too small, surrounded by pasture dominated by pasture grasses.	No
FD15		0.485	Farm dam is too small, no emergent vegetation, surrounded by pasture dominated by pasture grasses, grazed by cattle.	No
FD16	9	1.31	The dam dose overflow in spring and has emergent vegetation. A pair of Brolga were observed foraging here in July 2020. Overflow is dominated by Poa Tussock and sedges, grazed by sheep.	Yes
FD17		0.175	Farm dam is too small, does have emergent vegetation, surrounded by pasture dominated by pasture grasses.	No
FD18		0.13	Farm dam is too small, no emergent vegetation, surrounded by pasture dominated by pasture grasses.	No
FD19		0.11	Farm dam is too small, no emergent vegetation, surrounded by pasture dominated by pasture grasses.	No
FD20		0.13	Farm dam is too small, no emergent vegetation, dominated by pasture grasses.	No
FD21		0.725	Farm dam is too small to support breeding Brolga most years, during a one in ten-year flooding event the wetland would extend into the pasture dominated by Poa Tussock Grass and sedges. May provide Brolga breeding habitat in a one in ten-year flood.	Yes
FD22		0.1025	Farm dam is too small, no emergent vegetation, surrounded by pasture dominated by pasture grasses.	No
FD23		0.1725	Farm dam is too small, no emergent vegetation, overflow is dominated by Poa Tussock Grass and sedges.	No
FD24		0.245	Farm dam is too small, no emergent vegetation, surrounding area dominated by pasture grasses.	No
FD25		0.5275	Farm dam is too small, no emergent vegetation, surrounded by planted trees and pasture grasses.	No
FD26		0.665	Farm dam is too small, no emergent vegetation, surrounded by pasture dominated by pasture grasses.	No
FD27		0.2325	Wetland is too small and too deep, no emergent vegetation and close to farm house.	No
FD28		0.1575	Farm dam is too small and too deep, no emergent vegetation and grazed by cattle.	No
FD29		2.2	Farm dam located in a pasture paddock used for cattle grazing, no emergent vegetation in the dam. The dam overflow area has a drain running through it, unlikely to hold water long enough to support a breeding pair of Brolga.	No
FD30		0.118821	Wetland is too small and surrounded by Blue Gum plantation.	No
FD31		0.4775	Two small farm dams, grazed by cattle, bare banks no emergent vegetation, surrounded by pasture dominated by pasture grasses.	No
FD32		0.1125	Wetland is too small and close to a dairy, waters likely high in nutrient.	No
FD33		0.53	Farm dam, no emergent vegetation, surrounded by pasture grasses, grazed by sheep and cattle, wetland is too small.	No
FD34		0.385	Farm dam, no emergent vegetation, surrounded by pasture grasses, grazed by sheep and cattle, wetland is too small.	No
FD35		0.19	Farm dam is too small, grazed by sheep, no emergent vegetation, surrounded by pasture dominated by pasture grasses.	No

Hydrology reference	VWI number	Area (ha)	Habitat description	Functional wetland
FD36		0.1125	Farm dam is too small, grazed by cattle, no emergent vegetation, surrounded by pasture dominated by pasture grasses.	No
FD37		0.1275	Farm dam is too small, no emergent vegetation, bordered by a road reserve and pasture dominated by pasture grasses and close to farm house.	No
FD38		1.157578	Farm dam in pasture paddock, high stocking rate of dairy cows trampling the dam. Emergent vegetation in the centre of the dam where cattle can't trample it. Overflow to paddock only pasture species no aquatic species.	No
25611	25611	42.19045	Permanently drained, there was some surface water in small section on the northern side of the road, surface water only in drainage lines on southern side of the road, no emergent vegetation and grazed by sheep.	No
W3	25677	8.9275	Large tussock swamp, had water throughout the breeding season, many waterbirds and frogs congregate here throughout the wet season. Partly fenced, some parts grazed by sheep and cattle.	Yes
W4	25721	3.738	Large wetland has a drain running into it. Had surface water throughout the breeding season. Confirmed Brolga breeding site, Brolga unlikely to breed in drainage line.	Yes
25729	25729	4.020058	Small wetland fenced off from stock and well vegetated. Landholder states that this is a Brolga breeding site and has seen young at this wetland with parents.	Yes
25731	25731	0.722095	Ephemeral tussock swamp, shallow water from July to September, dry by December. Some patches of sedges, grazed by cattle.	Yes
25741	25741	6.108657	Small isolated wetland, partially drained though still holds water and has emergent vegetation. Landholder has recorded Brolga breeding here previously.	Yes
25816	25816	20.01215	This is a large wetland (Wild Dog Swamp) which was inundated throughout the entire breeding season. It had a good cover of emergent vegetation throughout the breeding season, cattle grazing some months of the breeding season. Many Black Swan nesting, large congregations of waterbirds and high diversity of waterbirds and frogs.	Yes
W7	25936	2.5642	Small wetland with good cover of surface water, aquatic vegetation emerged in September, water levels started to recede in October. Grazed by sheep.	Yes
W1	25944	5.0651	This wetland was once large though has very deep channels draining it. No waterbirds observed here throughout the surveys. Drainage line to the south is deep with high walls. Inundation period, the size of the wetland and presence of aquatic vegetation suggest a functional wetland.	Yes
W12	26028	75.469	Very large and expansive wetland known as Cockatoo Swamp which had good cover of surface water and emergent vegetation. Grazed by cattle. Brolga have been observed foraging here. Creek line coming into and from this wetland are considered unsuitable breeding habitat.	Yes
5a	26035	1.20411	Permanently drained, some surface water at eastern side, no emergent vegetation, grazed by cattle.	No
W5	26046	0.1507	Part of a large wetland mapped by DELWP, lots of drainage, most has been permanently drained, on ephemeral drainage line, 1% surface water cover at time of field assessment. Dominated by pasture grasses, Poa Tussock Grass and sedges. No waterbirds. Too small to provide enough resources to support a breeding pair.	No
W10	26046	5.9573	Part of a large wetland mapped by DELWP, lots of drainage, most has been permanently drained. This wetland crosses a property boundary and is quite different habitat on each side. The north side is dominated by Poa Tussock Grass with scattered sedges while the southern side is dominated by pasture grasses. Northern section is wetter though not holding water at the time of the field assessment. Surface water covers 5% of wetland in drains and small puddles. Potential to provide Brolga breeding habitat in a one in ten-year flood on the northern property only.	Yes
Orford 100		0.592069	Small isolated wetland, it does have emergent vegetation though unlikely to provide enough food resources to sustain a breeding pair of Brolga given its size and isolation.	No
12a		0.61704	Wetland did not have any surface water, no waterbirds, Poa tussock grass and sedges present, meets minimum criteria in size. May provide suitable breeding habitat during a one in ten-year flooding event only.	Yes
W13		4.1851	Wetland has many drains in it, mostly drained though some drains silted up. Dominated by Poa Tussock Grass and sedges, soils were saturated with wetland herbs present. Surface water cover 1% in drains.	Yes
23a		0.171688	Wetland is too small and surrounded by Blue Gum plantation.	No

Figure 2: Farm dams and wetlands considered to provide suitable breeding habitat for Brolga

Project: Willatook Wind Farm
Client: Wind Prospect Pty Ltd
Date: 14/04/2021

Legend

Wind farm 5km buffer

Suitable breeding habitat

Yes

No

N

Metres

0 500 1,000

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4. Conclusion

Of the 38 farm dams and 17 wetlands that were assessed, three farm dams and 12 wetlands were considered to be functional wetlands. These wetlands provide breeding, foraging or night-time roosts. These wetlands, excluding any contiguous waterways or drains are to be subject to the method discussed with DELWP to develop turbine free buffers from confirmed or valid Brolga breeding wetlands for the Willatook Wind Farm development.

5. References

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Veltheim I, Cook S, Palmer G, Hill R and McCarthy M 2019. Breeding home range movements of pre-fledged brolga chicks, *Antigone rubicunda* (Gruidae) in Victoria, Australia – Implications for wind farm planning and conservation, *Global Ecology and Conservation* (2019), doi: https://doi.org/10.1016/j.gecco.2019.e00703.

Appendix 5: Observations of the Brolga pair that regularly nest and forage at Macarthur Wind Farm

A pair of Brolga regularly breed at the Macarthur Wind Farm site in two different wetlands surrounded by turbines. Monitoring activities have been undertaken in the past decade since the wind farm has become operational. Below are the results of the monitoring activities that have been undertaken.

Wetland 25650

This wetland is surrounded by three turbines all within 290 metres from the edge of the breeding wetland.

Figure 1: Monitoring undertaken during the 2012 breeding season (Source: Figure 3 in Veltheim *et al.* 2019)

Figure 1 above shows the results of the satellite tracking of pre-fledged Brolga chicks at the Macarthur wind farm. Brolga were recorded forging within 80 metres of the base of one of the turbines.

Figure 2 below shows the results of a monitoring exercise undertaken by Nature Advisory during the 2018 breeding season. Points were recorded of adult birds every two hours while monitoring over 13 days from 5th September to 21st October 2021. Birds were observed foraging within 150 metres from the base of a turbine. It is noteworthy that similar observations were made as Veltheim in that early in the breeding season the Brolga pair were confined to areas around the breeding wetland. Later in the breeding season the birds moved further from the breeding wetland to the north west.

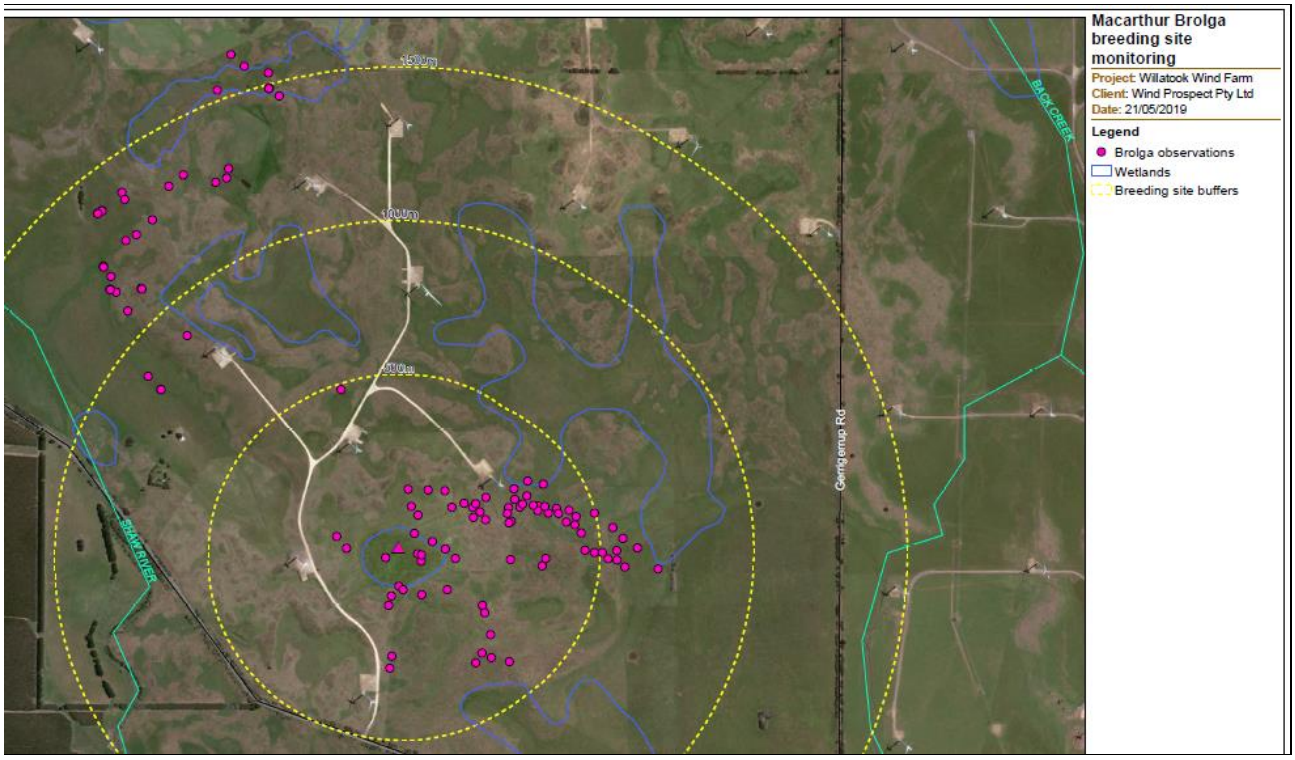

Figure 2: Monitoring undertaken by Nature Advisory during the 2018 breeding season

Wetland 25699

This wetland is surrounded by six turbines all within 420 metres from the edge of the breeding wetland.

Figure 3 below shows the results of the Brolga monitoring during the 2014 breeding season. It shows that Brolga were foraging on the hard stand under turbine 45 within 50 metres of the base of the operating tower.

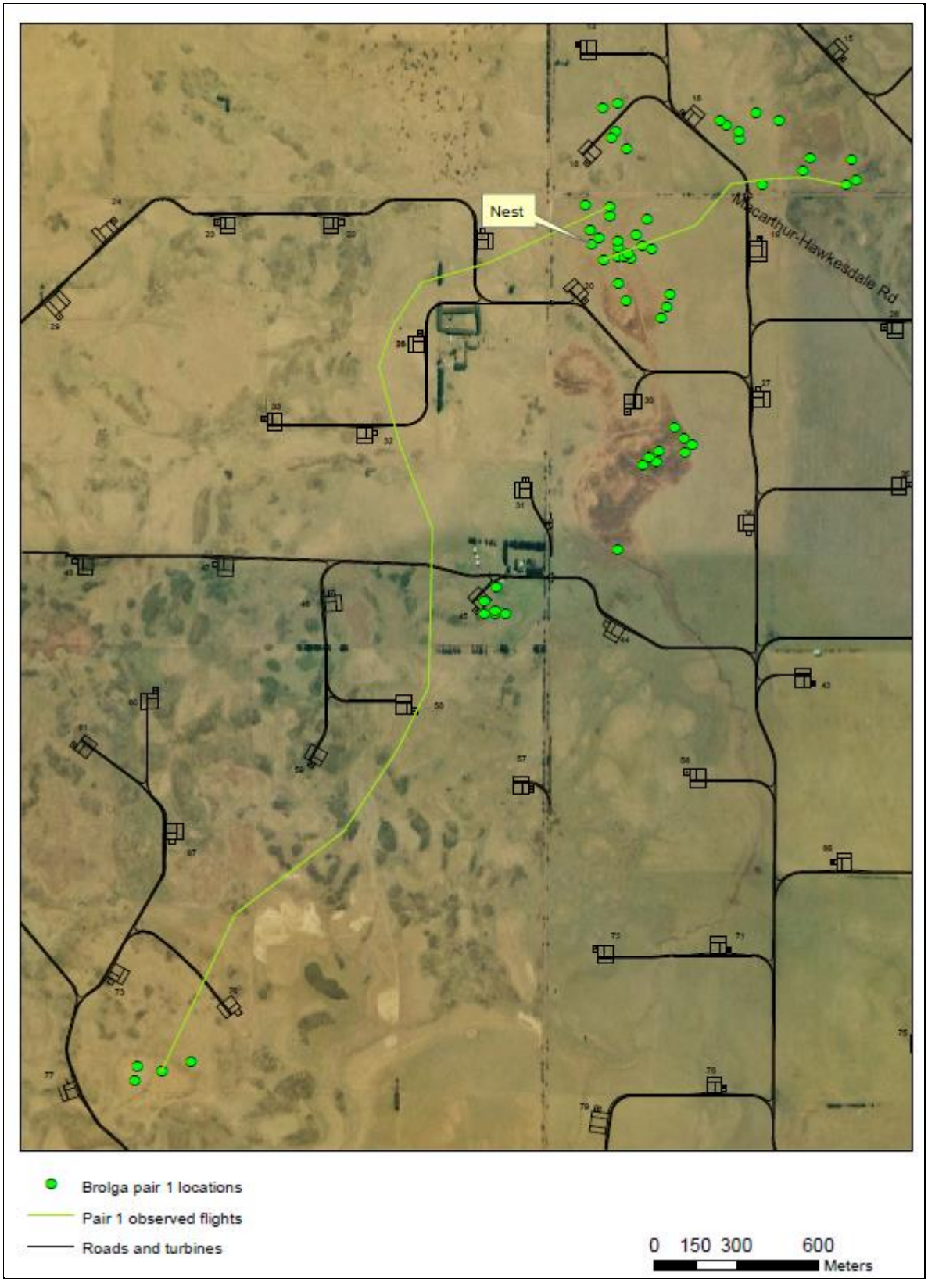

Figure 3: Monitoring undertaken during the 2014 breeding season (Source: Figure 4 in Wood 2014)

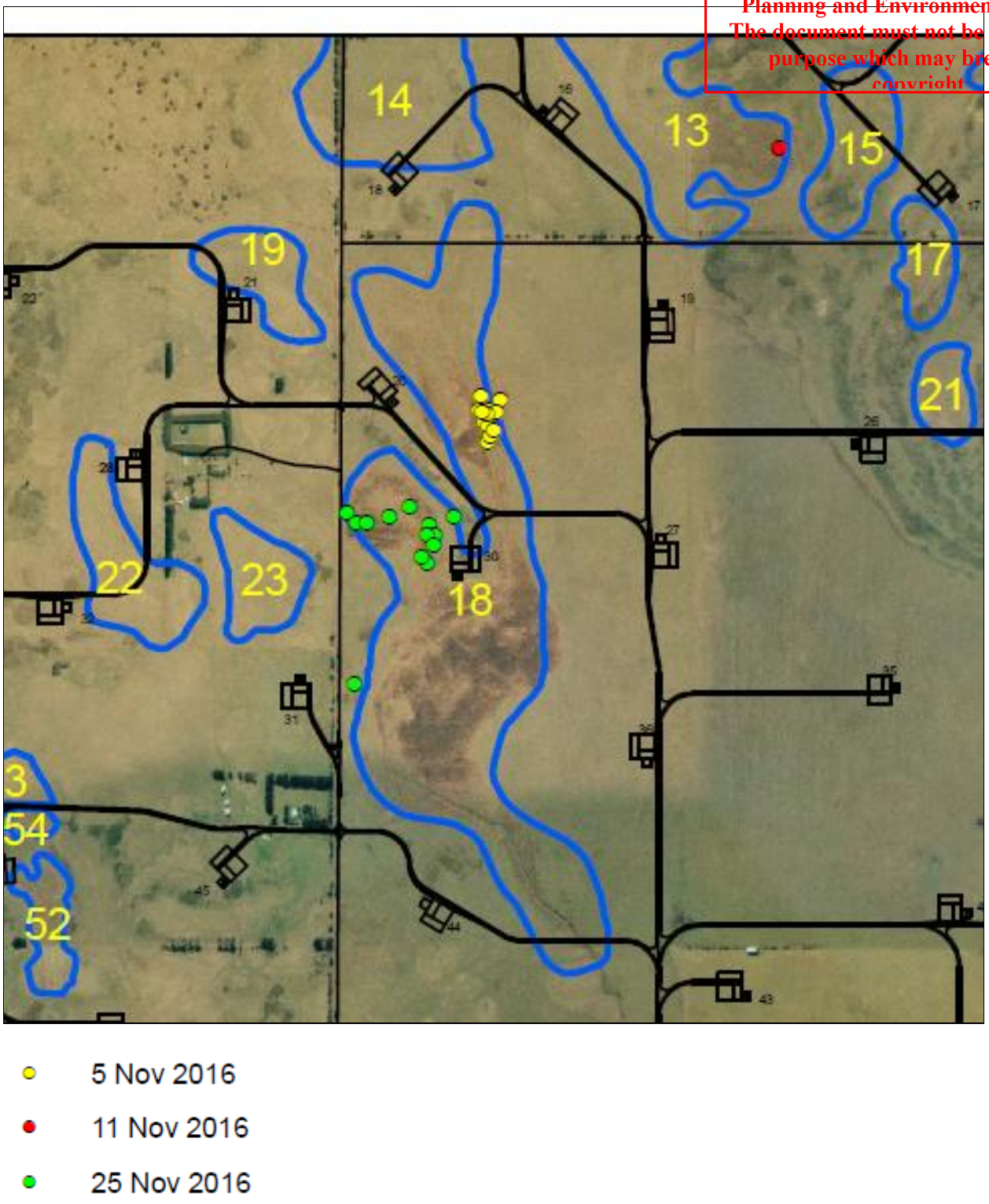

Figure 4: Monitoring undertaken during the 2016 breeding season (Source: Figure 10 in Wood 2017)

Wetland 18 in the above Figure 4 is wetland 25699 and is one of the wetlands where Brolga have nested in the past. Monitoring of the Brolga movements during the 2016 breeding season showed that Brolga were recorded foraging within approximately 90 metres of an operating turbine.

Appendix 6: Willatook Wind Farm – Brolga Collision Risk Modelling

Willatook Wind Farm - Collision Risk Modelling

Alex Jackson

4 March 2022

Ver. 1.2

Submitted to Nature Advisory

symbolix

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Version Control

Version	Status	Date	Approved For Release	Comments
0.1	Draft	2021-04-01	Internal	-
0.9	For review	2021-04-09	E. Stark	-
1.0	Release	2021-08-20	E. Stark	Updated layout
1.1	Release	2021-12-03	E. Stark	New scenario
1.2	Release	2022-03-04	E. Stark	Updated layout

Approved for release: 2022-03-04

Elizabeth Stark Date

Limitation: This report has been prepared in accordance with the scope of services described in communications between Symbolix Pty Ltd and Nature Advisory. Any findings, conclusions or recommendations only apply to the aforementioned circumstances and no greater reliance should be assumed or drawn by Nature Advisory.

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1 Executive summary

This document summarises the estimated annual collision rate of Brolga (*Antigone rubicunda*) at the proposed Willatook Wind Farm. The model results rely on the methods and Brolga activity inputs outlined in the following sections.

Turbine collision risk was estimated using an avian collision risk model, based directly on W. Band, Madders, and Whitfield (2007) and B. Band (2012). The Nature Advisory (NA) application NA-BAND updates the model to accept spatial data inputs. This modification extends W. Band, Madders, and Whitfield (2007) and B. Band (2012) to more correctly calculate the probably that a flight will interact with a turbine (if a flight occurs on-site) for general sites. The probability of collision after interaction is a geometric calculation using W. Band, Madders, and Whitfield (2007) and B. Band (2012). The NA-BAND model has previously been applied and peer reviewed as part of the approvals process for a number of Australian Wind Farms, for example Golden Plains Wind Farm (Victoria). For full details see Section 2.

Eight wetlands were identified as potential Brolga breeding sites - five in the north-west, and three in the east. In the original iteration of the report (Version 1.0) we explored three scenarios of wetland occupancy[1], balancing field survey data, data from the DELWP Victorian Biodiversity Atlas, and landholder reports. The scenarios were "90/10" (90% probability of a NW wetland being occupied, 10% chance of an E wetland being occupied), "70/30" (70% probability of a NW wetland being occupied, 30% chance of an E wetland being occupied), and "flat" (equal chance of any of the eight wetlands being occupied). In Version 1.1, we add an additional scenario, "100/30" (100% chance of a NW wetland being occupied, 30% chance of an E wetland being occupied)[2].

An important note is that the NA-BAND model estimates the number of flights that are at risk of collision under the assumption that any breeding resident Brolga is immediately replaced. This estimate of flight collisions is likely to be higher than the actual individual collision rate.

This document presents an overview of the model methodology, the inputs used, and scenario results.

1.1 Summary of results (original scenarios)

Table 2 summarises the output of the turbine collision risk model for under the updated and original turbine layouts. We use the 90/10 wetland occupancy scenario, which is the most conservative. We use avoidance rates of 90%, 95% and 99%.

Note: the original layout gives the turbine locations before any collision avoidance measures were taken. The updated layout is the applies Brolga buffers around recorded and historical breeding sites.

The final set of turbine specifications are displayed in Table 1.

[1] For more detail, see Section 2.3.
[2] Note: 100/30 has 1.3 breeding pairs per year, while the other three scenarios have one breeding pair per year.

Table 1: Final turbine parameters.

Parameter	Value
Blade length (m)	105
Min blade height (m)	40
Max blade height (m)	250
Number of blades	3
Maximum chord (m)	5
Rotation period (s)	4.76
Hub height (m)	145

Table 2: Summary of collision risk modelling results - 90/10 scenario.

Avoidance	Layout	Collisions/yr	Expected coll. (25 yrs)	25 yr 95% pred. interval
0.90	Updated	0.06	1.5	[0, 4]
0.95	Updated	0.03	0.7	[0, 3]
0.99	Updated	0.01	0.1	[0, 1]
0.90	Original	0.11	2.8	[0, 7]
0.95	Original	0.06	1.4	[0, 4]
0.99	Original	0.01	0.3	[0, 2]

Using these parameters and the updated layout, the annual rate (assuming 90% avoidance) is 0.06 collisions per year. This could manifest as between zero and four Brolgas struck in the life of the wind farm (25 years). If we assume a 95% avoidance (an annual collision rate of 0.03 collisions per year), this could manifest as zero to three collisions over 25 years.

The numbers in the final column of Table 2, and in the above paragraph, represent 95% prediction bounds.

1.2 Summary of results (additional 100/30 scenario)

In the 100/30 scenario, the turbine parameters and layout are unchanged - the only components that changed are the number of breeding pairs (increased from 1 to 1.3), and the utilisation of wetlands (one breeding pair always uses the NW wetlands, and in 30% of years a second breeding pair will use the E wetlands).

Table 3: Summary of collision risk modelling results - 100/30 scenario.

Avoidance	Layout	Collisions/yr	Expected coll. (25 yrs)	25 yr 95% pred. interval
0.90	Updated	0.07	1.7	[0, 5]
0.95	Updated	0.03	0.9	[0, 3]
0.99	Updated	0.01	0.2	[0, 1]
0.90	Original	0.13	3.3	[0, 7]
0.95	Original	0.07	1.6	[0, 5]
0.99	Original	0.01	0.3	[0, 2]

Using these parameters and the updated layout, the annual rate (assuming 90% avoidance) is 0.07 collisions per year. This could manifest as between zero and five Brolgas struck in the life of the wind farm (25 years). If we assume a 95% avoidance (an annual collision rate of 0.03 collisions per year), this could manifest as zero to three collisions over 25 years.

The numbers in the final column of Table 3, and in the above paragraph, represent 95% prediction bounds.

2 Methods

2.1 Collision risk model

Collision risk modelling (CRM) requires a step-wise risk model (Reason (1997)), where the total risk is the probabilistic combination of the risk of each step in the process. The process can be summarised by the equation:

$$N_{\text{collision}} = F \times P(I|F) \times P(C|I) \times (1 - \text{AR})$$

where:

- $N_{\text{collision}}$ is the estimated number of flights ending in collision over some time period
- F is the estimated activity rate of flights in the area over some time period
- $P(I|F)$ is the probability of a flight interacting with a turbine, given a flight in the study region
- $P(C|I)$ is the probability of collision, given an interaction occurs
- AR is the avoidance rate

The probability of collision given interaction (the fourth dot point above) is generated using the exact model published in W. Band, Madders, and Whitfield (2007) and B. Band (2012))

The probability of interaction component in W. Band, Madders, and Whitfield (2007) and B. Band (2012) (the third dot point above) includes an unreasonable assumption that every flight interacts with every turbine. The NA-BAND model uses spatial statistics to estimate the probability of interaction for each turbine, removing the reliance on the W. Band, Madders, and Whitfield (2007) and B. Band (2012) assumption. This use of B. Band (2012) with spatial input parameters has been peer reviewed in Australia as part of the approvals process for sites such as Dundonnell and Golden Plains Wind Farms.

2.2 Probability of interaction of a flight with infrastructure

In the Brolga breeding season we assumed that flights are centred on wetlands and can radiate from there in any direction. The **probability of interaction** $P(I|F)$ is given by:

$$P(I|F) = P(\text{wetland occupied}) \times P(\text{direction}) \times P(\text{distance}) \times P(\text{height}|\text{distance})$$

where:

- $P(\text{wetland occupied})$ is the probability that a given wetland will be occupied in a given year.
- $P(\text{direction})$ is the proportion of flights which travel in the right direction to interact with a turbine. This is a geometric calculation of the ratio between the angle subtended by the infrastructure and the 360 degree circle around the wetland (assuming that Brolga might

fly in any direction).

- P(distance) is the probability that a flight will travel far enough to reach a turbine from any wetland.
- P(height|distance) is the probability that the flight will be at rotor swept height height, given that it travelled the requisite distance.

In addition:

- The distribution of flight distance is taken from combined NA breeding data from a range of sites through south-west Victoria (Brett Lane & Associates 2018).
- The distribution of flight height at a given distance is taken from combined breeding and flocking season data (obtained by Nature Advisory) from sites in south-west Victoria (Brett Lane & Associates 2018). Breeding and flocking season was not a significant factor in the relationship between flight height and distance so the data sets were combined to increase the size of the dataset.

2.3 Probability of wetland occupancy

Eight wetlands were identified as potential breeding location for Brolga (B. Lane, *pers. comm.*). See Figure 1 for their locations. Spatially, these are in two distinct parts of the site - the east, and the north-west.

Brolga breeding records for the western wetlands come from data in the DELWP Victorian Biodiversity Atlas (VBA) and the results of detailed field surveys conducted for the Willatook Wind Farm since 2009. Although these surveys included wetlands to the east of the wind farm site, Brolga were not found breeding in these wetland; however, breeding records were reported to Nature Advisory and the wind farm proponent by local landholders (B. Lane, *pers. comm.*).

Therefore, we explored a few ecological breeding scenario models:

- **Flat**: in a given year, a breeding pair is equally likely to utilise any of the eight wetlands.
- **70/30**: in a given year, a breeding pair has a 70% chance of using any one of the five NW wetlands, and a 30% chance of using any one of the three E wetlands.
- **90/10**: in a given year, a breeding pair has a 90% chance of using any one of the five NW wetlands, and a 10% chance of using any one of the three E wetlands.
- **100/30**: in a given year, a breeding pair will use any one of the five NW wetlands. In 30% of years, a second breeding pair will use any of of the three E wetlands.

Increasing the probability that the breeding pair uses the NW wetland, places more weight on the survey and VBA data, and less on the landholder reporting.

Unless otherwise stated, throughout this report we use the 90/10 scenario model. We have chosen this as:

- it is the most conservative of the original three scenarios (i.e. gives higher collision risk estimates); and
- it is most reflective of the NA survey results and the VBA data.

Table 4 displays the probabilities of occupancy under this scenario.

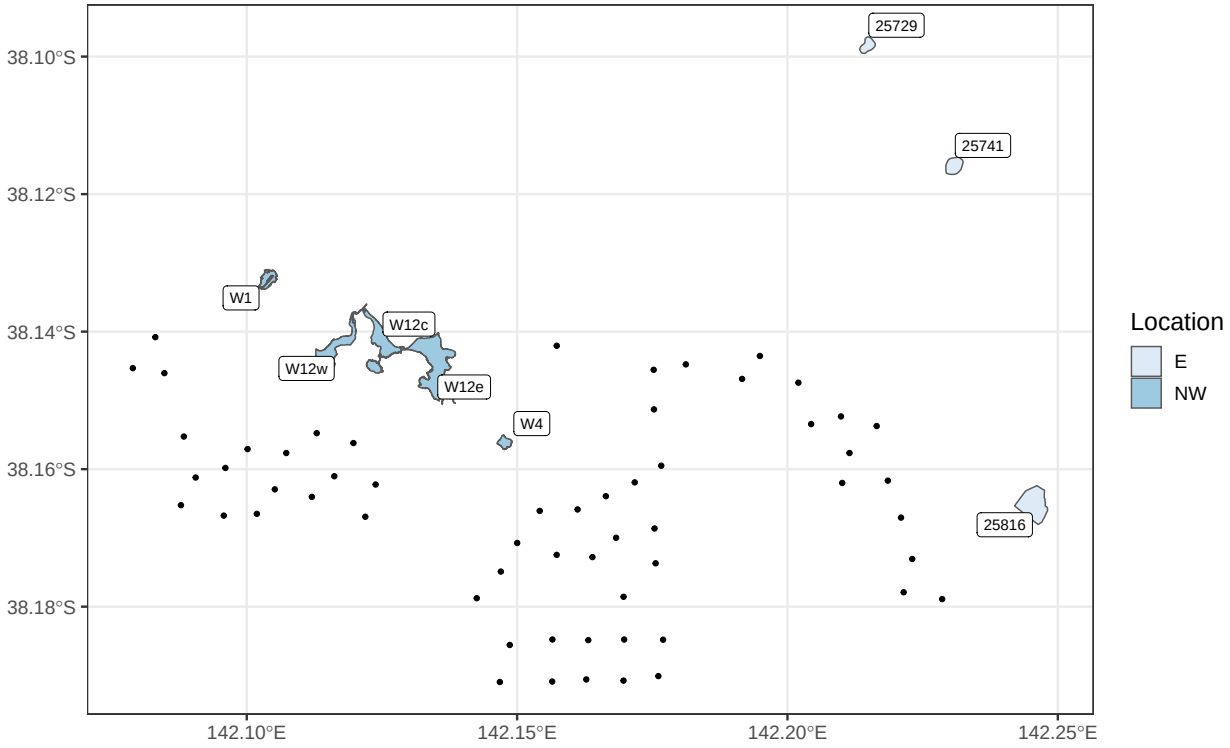

Figure 1: North-west and eastern wetlands, with turbine locations (under the updated layout) for reference.

Table 4: Probability of wetland occupancy under the 90:10 breeding scenario.

Wetland name	Location	P(wetland occupied)
25816	E	1/30
25741	E	1/30
25729	E	1/30
W1	NW	9/50
W12c	NW	9/50
W12e	NW	9/50
W12w	NW	9/50
W4	NW	9/50

2.4 Probability of flight length exceeding distance to turbine

The distribution of flight distance is taken from combined NA breeding data from a range of sites through south-west Victoria (Brett Lane & Associates 2018). The dataset was small (163 records) but demonstrates a clear preference for shorter flights (up to one kilometre).

We fit a gamma distribution to the data, which allowed us to infer the probability that a flight

would travel a given distance (i.e. the $P(\text{distance})$ component), even if no observations were recorded at that distance. A histogram of observed distances is given in Figure 2.

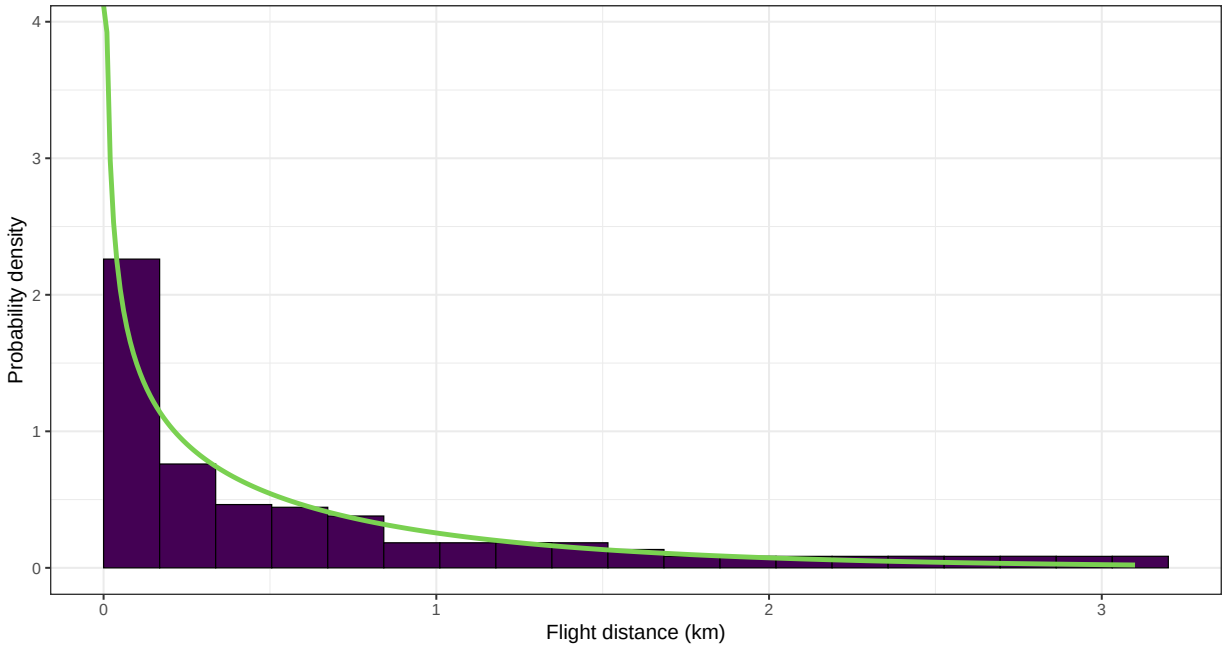

Figure 2: Empiricial flight distance distribution (histogram) and fitted gamma probability density function (curve).

2.5 Probability of flying at rotor height given flight distance

The dataset of breeding season observations used in the previous section also contains flight height data. The dataset used for the distance distribution included 67 records for which height data was also recorded. To supplement this data, we included matched flight and height data from 547 flocking season flights at Dundonnell Wind Farm, also provided by NA.

As seen in Figure 3 there is a clear linear relationship between flight height and distance (if we pre-transform both variables using the natural log function). We fit linear models to quantify this relationship. Testing breeding/non-breeding as a factor showed no significant difference between the two seasons (thereby justifying our combining of the data).

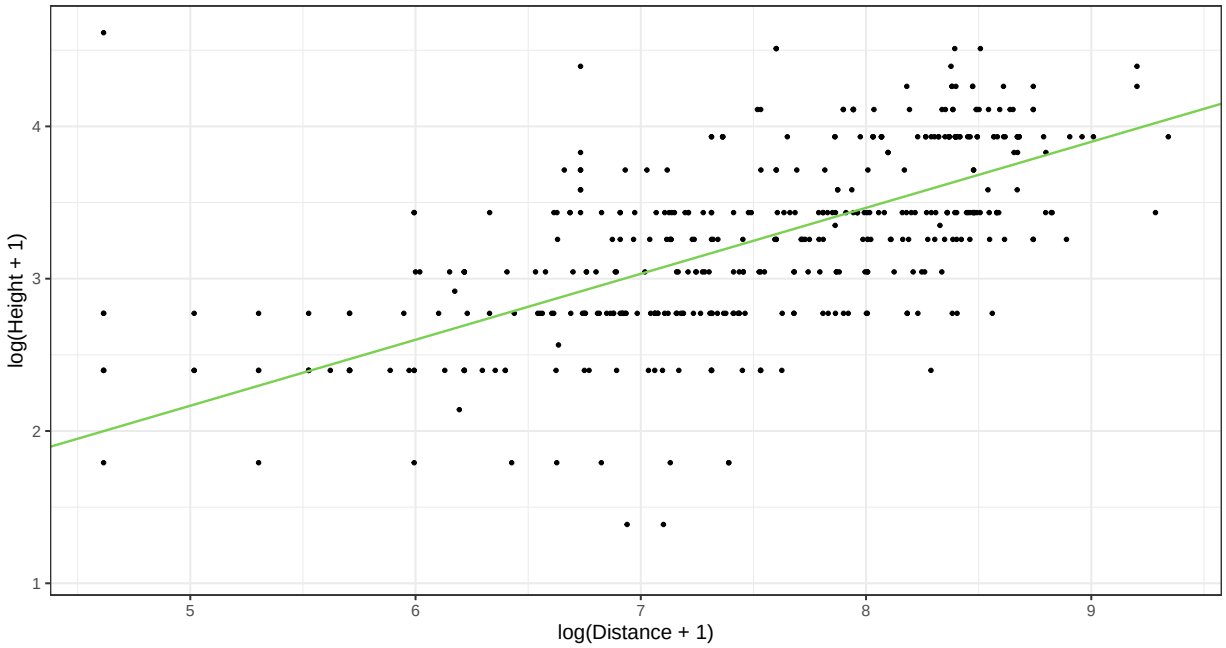

Figure 3: Relationship between flight height and distance. The pre-transformed units of height are metres, and distance is in kilometres.

The linear model allowed us to predict the expected height at a given flight distance, but to estimate the probability that a flight will occur in the rotor swept height range we need to know more than the average height. We also need to consider the variability of the data around this expected value (i.e. we want to know the distribution of model residuals).

At any given distance, the probability of seeing a given flight height is described by the percentiles of the distribution of the residuals around the modelled value. $P(\text{height}|\text{distance})$ is the proportion of this distribution that falls in the height range (see Table 5) of the infrastructure being modelled.

2.6 Mapping the probability of interaction

We refresh the reader that the probability of interaction term is defined by the equation:

$$P(I|F) = P(\text{wetland occupied}) \times P(\text{direction}) \times P(\text{distance}) \times P(\text{height}|\text{distance})$$

At this stage:

- The probability that a wetland is occupied is taken from our breeding scenario model.
- The probability of direction (at any point on the site) is taken by assuming that a turbine is placed there, and then using geometry to calculate the angle.
- The probability of travelling the requisite distance is taken from the gamma distribution fit to empirical data.

- The probability of being at the rotor swept height, given distance, is taken from the log-log linear model fit to empirical data.

We therefore have all the components to calculate $P(I|F)$ at any point in the landscape. The probability of interaction at any point in the landscape is the sum of $P(I|F)$ over all wetlands. The probability is displayed as a contour map in Figure 4.

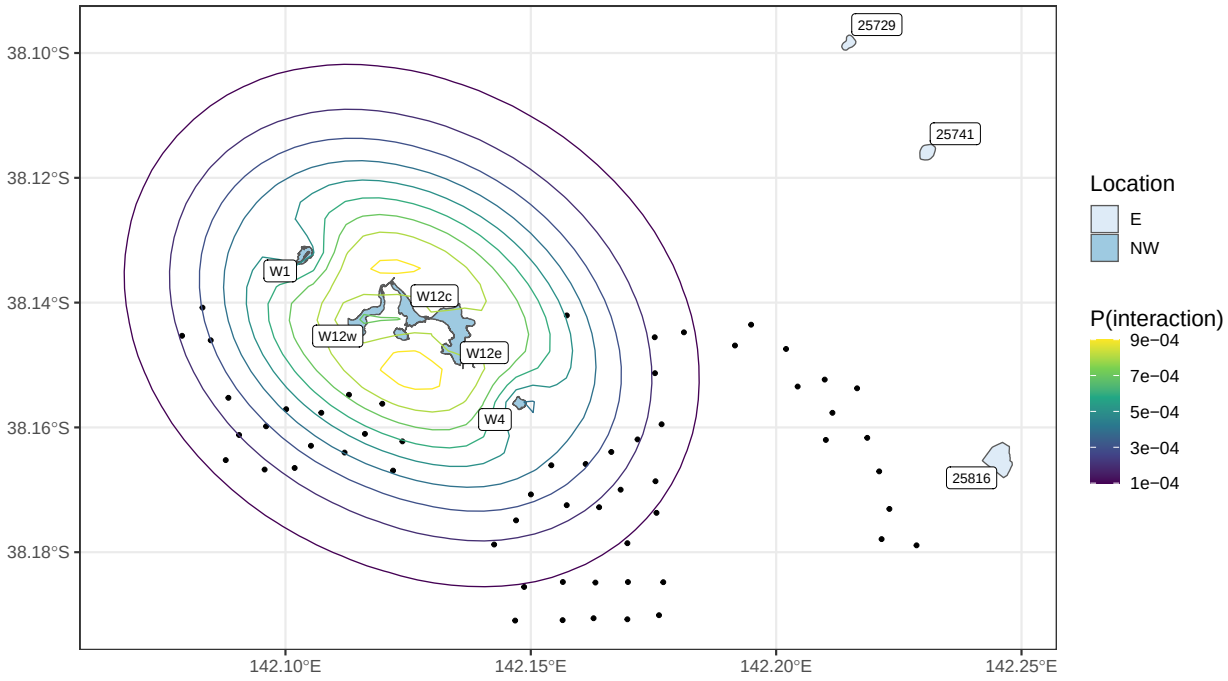

Figure 4: Contour plot of the probability of interaction. For reference, the points display the turbine locations under the updated layout. Note however that the contours are independent of the layout. Note that contour lines (or isolines) are a way to visualise two-dimensional probability functons, and show the lines of constant value.

2.7 Probability of collision given turbine interaction

Turbine collision risk was estimated using an avian collision risk model, based directly on W. Band, Madders, and Whitfield (2007) and B. Band (2012). The Nature Advisory (NA-BAND) application updates the model to accept spatial data inputs. This modification extends W. Band, Madders, and Whitfield (2007) to more correctly calculate the probably that a flight will interact with a turbine (if a flight occurs on-site) for general sites. The probability of collision after interaction is a geometric calculation using W. Band, Madders, and Whitfield (2007) and B. Band (2012). The NA-BAND model has previously been applied to assess collision risk for Moorabool Wind Farm, Dundonnell Wind Farm, and Golden Plains Wind Farm (Victoria).

An important note is that the NA-BAND model has no assumption about the likelihood that an individual bird would be replaced in the local area if it is struck. The model estimates the number of flights that are at risk of collision under the assumption that any breeding resident bird is immediately replaced. This estimate of flight collisions is likely to be higher than the

actual individual collision rate.

The NA-BAND model requires a number of turbine-related and bird-related inputs, which are summarised in Table 5 and 6 respectively.

Table 5: Turbine inputs for the NA-BAND model.

Variable	Value
Blade length (m)	105
Hub height (m)	145
Max blade height (m)	250
Maximum chord (m)	5
Min blade height (m)	40
Number of blades	3
Pitch (degrees)	6
Rotation period (s)	4.76
Rotor diameter (m)	210

Table 6: Bird inputs for the NA-BAND model.

Variable	Value
Length (m)	1.65
Wingspan (m)	2
Flight speed (m/s)	16.7
Flapping (0 = flapping, 1 = gliding)	0
Breeding season length (days)	130
Breeding pairs	1 (1.3 for 100/30 scenario)
Brolga per breeding pair	2.1
Breeding flights per day	2

3 Data preparation

Datasets were provided by Nature Advisory and Wind Prospect, including:

- Turbine physical parameters
- Brolga physical parameters
- Distance data
- Height given distance data
- Turbine layout data
- Wetland location data

3.1 Pre-processing

The following data pre-processing steps were performed:

- Wetland spatial data was filtered to the eight relevant wetlands.
- For the height modelling, the response variable was taken to be the mean of the minimum and maximum height of each observation.
- For the distance modelling, flights with unspecified end points were set to be right-censored.

3.2 Dataset summary

Table 7 reports the parameters, data sources, and model input values for the collision risk model.

Table 7: Collision risk model - input parameters.

Variable	Input data	Data source	Model input value
Number of flights	Scenario for Brolga breeding flights, based on estimate of 1 breeding pair in the region (1.3 in the 100/30 scenario). A breeding pairs is 2.1 individuals on average, and makes an average of two flights daily. Breeding attempts were assumed to last an average of 130 days. We have assumed brolgas are on-site during breeding season, and there are no flocking flights (C. Doughty, *pers. comm.*).	Regional population and activity estimates provided by Nature Advisory based on breeding season surveys and historical records at Willatook Wind Farm. The number of birds per breeding pair uses the juvenile to adult ratio of 0.05 (Herring (2001), in McCarthy (2008)).	546 flights in a year (original scenarios). 710 (additional scenario).

P(wetland occupied)	Eight wetlands were identified as potential breeding sites. Under the 90/10 scenario, those classified as 'NW' were each given a 9/50 chance of occupancy, while those classified as 'E' were each given a 1/30 chance of occupancy.	Spatial layer provided by Nature Advisory.	For scenario X/Y; an X% chance of utilising one of the 'NW' wetlands and a Y% chance of using one of the 'E' wetlands. Given 'NW' or 'E,' a flat probability of selecting one of the eight wetlands. See Table 4 for more detail.
P(distance)	A gamma distribution was fit to breeding season flight distance data to estimate the probability that a flight from a wetland will travel (at least) the distance to a given turbine.	Breeding season survey data provided by Nature Advisory.	A probability was generated for each suitable wetland and each turbine location. The total probability is the sum of these values.
P(height|distance)	We fit a linear (log-log) model to predict the expected height for a given flight distance. The proportion of flights within rotor swept height was then calculated by the proportion of the residuals within this range at the given distance.	Nature Advisory provided regional breeding and flocking season flight data with both heights and distances from other Victorian sites. The rotor swept height was assumed to be 40 to 250 metres, as provided by Wind Prospect.	A value was calculated for each turbine/wetland combination.
AR (avoidance rate)			0.9, 0.95 and 0.99

4 Results

We summarise the collision risk under the original (Section 4.1) and updated (Section 4.2) turbine layouts. Additionally, we briefly explore additional wetland occupancy scenarios in Section 4.3.

Figure 5 compares the layouts, and overlays them on the contour map of probability of interaction.

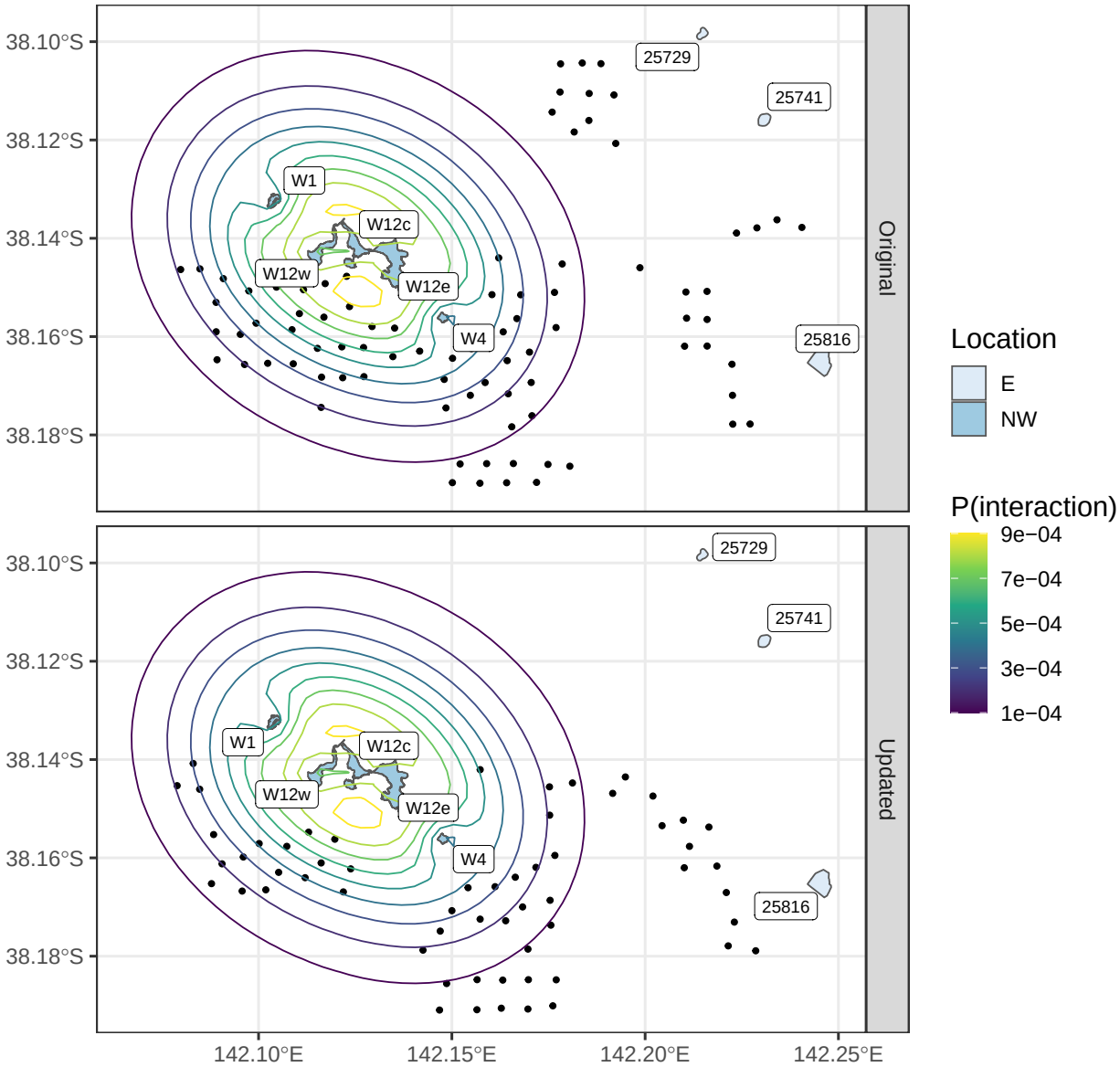

Figure 5: Comparison of the original and updated layouts.

4.1 Original layout

The upper panel of Figure 5 shows the risk of brolga flight interaction with turbines, under the original layout (turbine layout from an engineering perspective, with no buffers applied). Comparatively higher risk areas are shown in yellow and green, while lower risk areas are in blue and purple.

Table 8 shows the collision risk modelling results. Under the 90% avoidance scenario, we expect on average 0.11 collisions per year, or 2.8 collisions over the 25 year lifetime of the farm. There is a 95% chance that the expectation could actually manifest as between 0 and 7 collisions.

The plausible range of cumulative mortalities for each species (over a 25 year period assuming 90% avoidance) is shown in Figure 6. These counts represent the potential yearly manifestation of the long-term rate. Over time, the long-term rate should regress to the values in this Figure.

Table 8: Original layout - collision risk modelling results.

Avoidance	Layout	Collisions/yr	Expected coll. (25 yrs)	25 yr 95% pred. interval
0.90	Original	0.11	2.8	[0, 7]
0.95	Original	0.06	1.4	[0, 4]
0.99	Original	0.01	0.3	[0, 2]

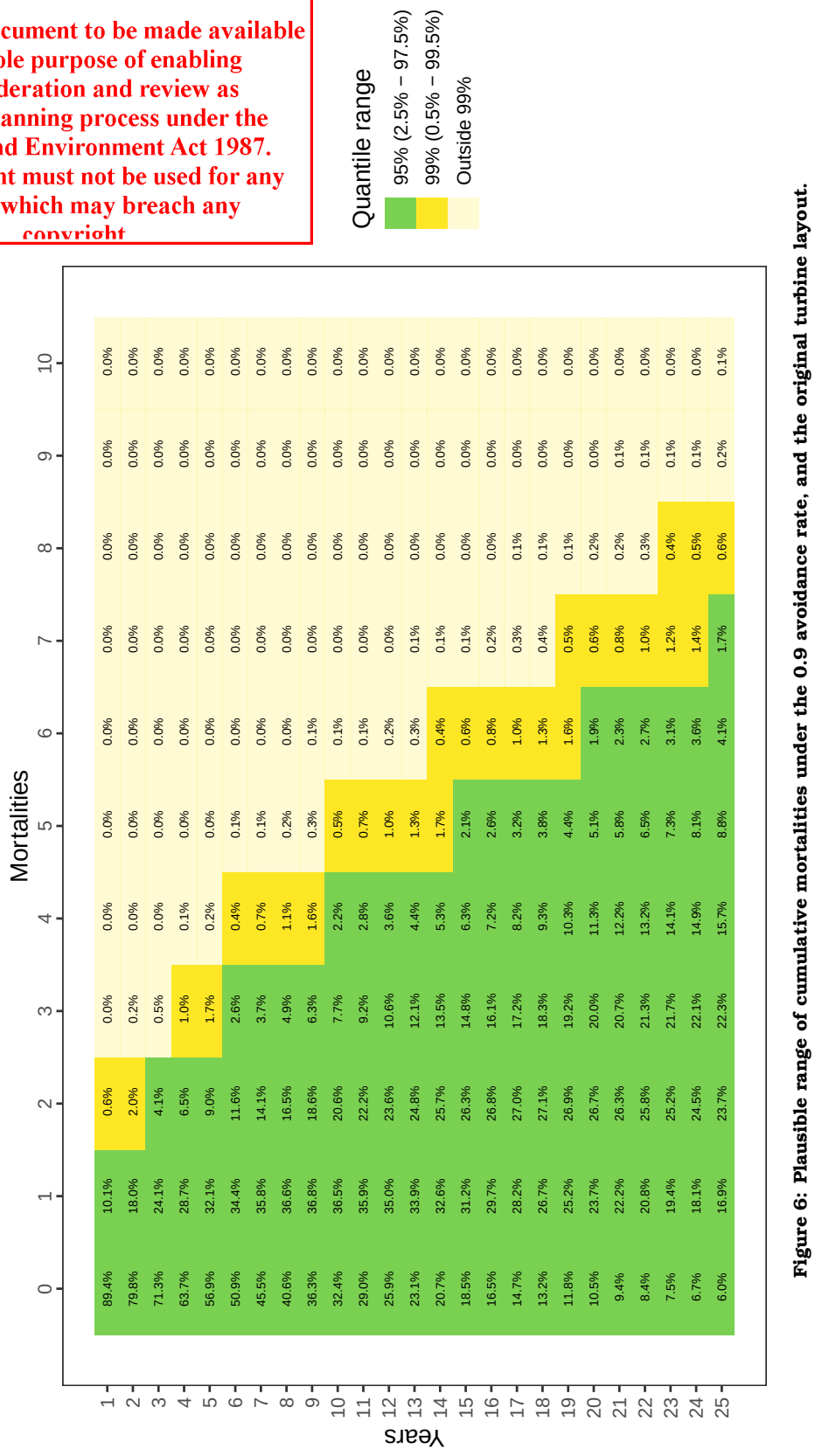

Figure 6: Plausible range of cumulative mortalities under the 0.9 avoidance rate, and the original turbine layout.

4.2 Updated layout

The lower panel of Figure 5 shows the risk of brolga flight interaction with turbines, under the updated layout. The updated layout adds buffers around potential Brolga breeding wetlands.

Table 9 shows the collision risk modelling results. Under the 90% avoidance scenario, we expect on average 0.06 collisions per year, or 1.5 collisions over the 25 year lifetime of the farm. There is a 95% chance that the expectation could actually manifest as between 0 and 4 collisions.

The plausible range of cumulative mortalities for each species (over a 25 year period assuming 90% avoidance) is shown in Figure 7.

Table 9: Updated layout - collision risk modelling results.

Avoidance	Layout	Collisions/yr	Expected coll. (25 yrs)	25 yr 95% pred. interval
0.90	Updated	0.06	1.5	[0, 4]
0.95	Updated	0.03	0.7	[0, 3]
0.99	Updated	0.01	0.1	[0, 1]

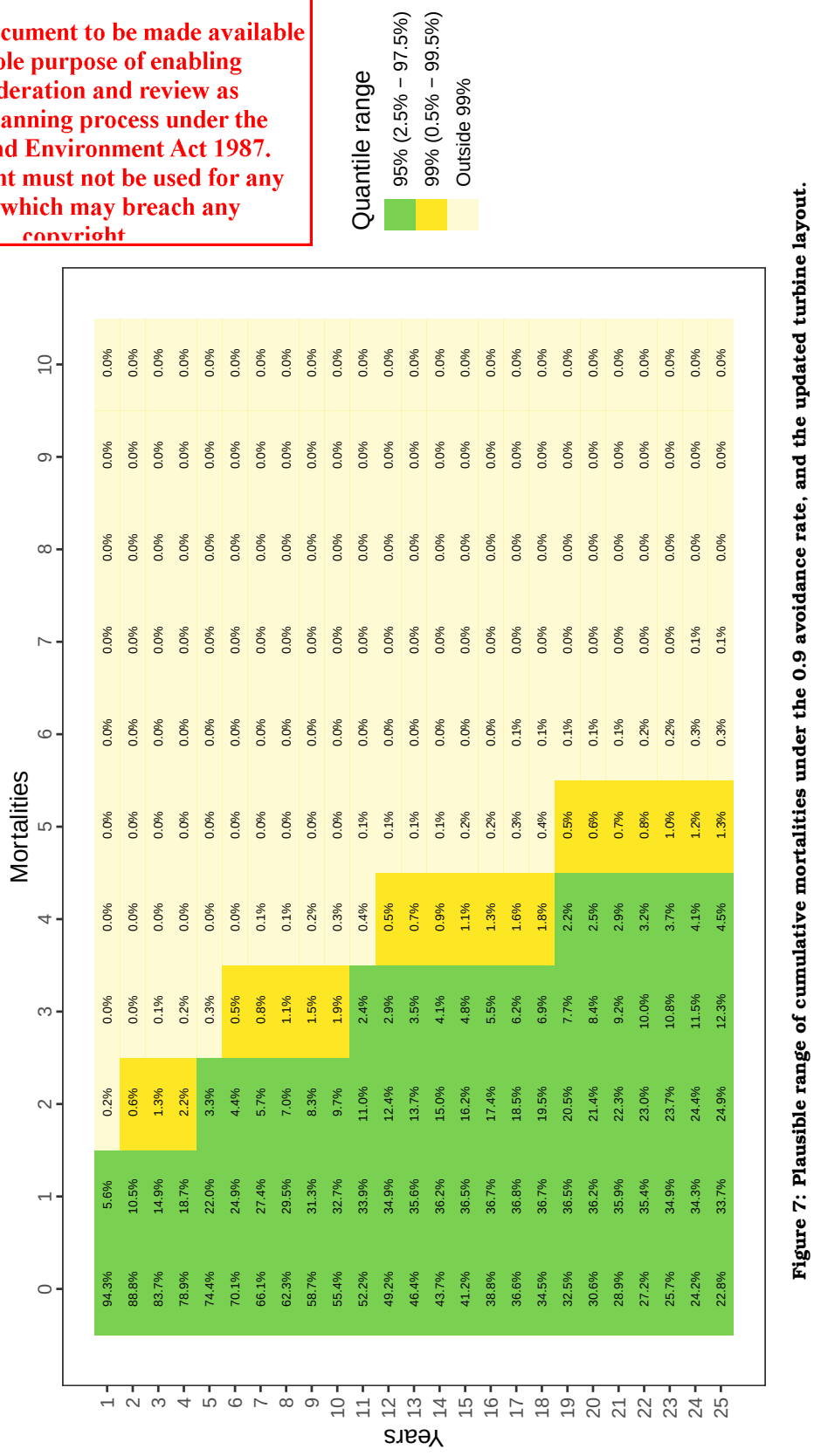

Figure 7: Plausible range of cumulative mortalities under the 0.9 avoidance rate, and the updated turbine layout.

4.3 Ecological scenario modelling

The other ecological scenarios we explored involved changing the probability of wetland occupancy. Table 10 shows the collision risk results under these other scenarios, using the 90% avoidance rate. We can see that the 90/10 scenario is the most conservative.

Table 10: Various wetland occupancy probability scenarios, under both layouts.

Avoidance	Layout	Scenario	Collisions/yr	Expected coll. (25 yrs)	25 yr 95% pred. interval
0.9	Original	90_10	0.11	2.8	[0, 7]
0.9	Original	70_30	0.09	2.3	[0, 6]
0.9	Original	flat	0.09	2.2	[0, 5]
0.9	Updated	90_10	0.06	1.5	[0, 4]
0.9	Updated	70_30	0.05	1.2	[0, 4]
0.9	Updated	flat	0.04	1.1	[0, 4]

Additionally, in Figure 8, we present the contour maps of the probability of interaction, under the different scenarios.

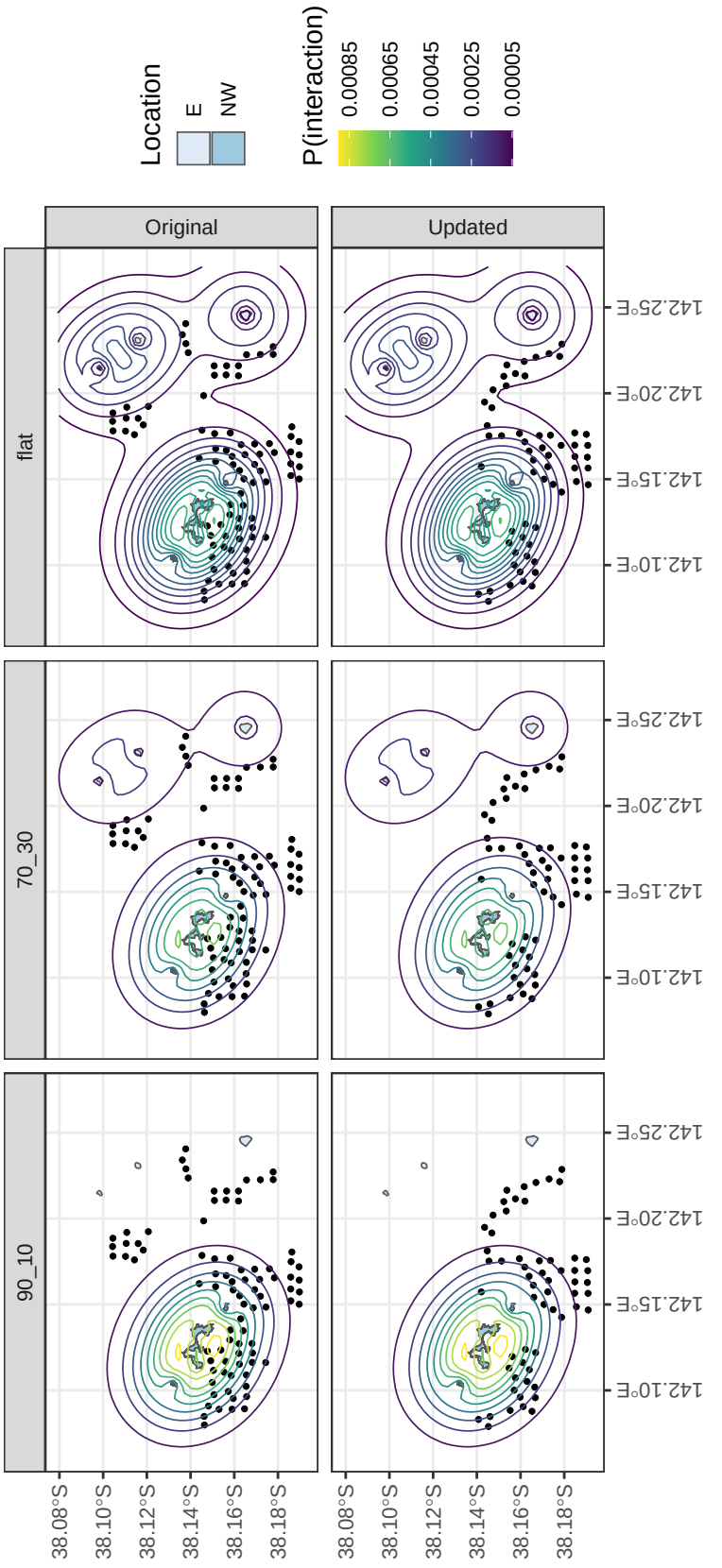

Figure 8: Comparison of the contour maps under the various occupancy scenarios.

4.3.1 Additional ecological scenario (100/30)

In this section we explore a new ecological scenario in which up to two breeding pairs may be on site. One breeding pair occupies one of the five NW wetlands every year and a second breeding pair occupies one of the three E wetlands in 30% of years[3].

Table 11 shows the collision risk results under this scenario and both layouts. We use avoidance rates of 90%, 95% and 99%.

Table 11: Summary of collision risk modelling results under new occupancy scenario.

Avoidance	Layout	scenario	Collisions/yr	Expected coll. (25 yrs)	25 yr 95% pred. interval
0.90	Original	100_30	0.13	3.3	[0, 7]
0.95	Original	100_30	0.07	1.6	[0, 5]
0.99	Original	100_30	0.01	0.3	[0, 2]
0.90	Updated	100_30	0.07	1.7	[0, 5]
0.95	Updated	100_30	0.03	0.9	[0, 3]
0.99	Updated	100_30	0.01	0.2	[0, 1]

In Figure 9, we present the contour map of the probability of interaction under the new occupancy scenario.

[3]Note - within the NW wetlands, the chance of each of the five being occupied is flat, and likewise with the E wetlands.

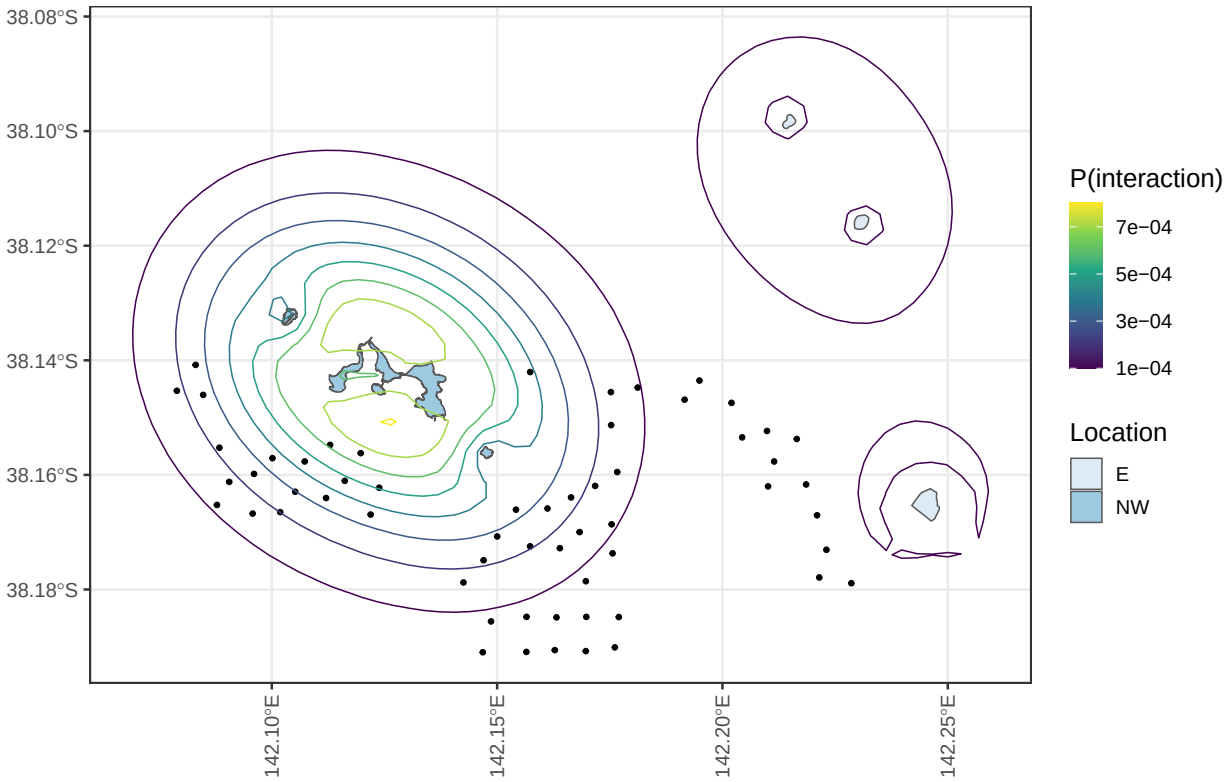

Figure 9: Contour plot of the probability of interaction under the new occupancy scenario and updated layout. The points display the turbine locations.

The plausible range of cumulative mortalities for each species (over a 25 year period assuming 90% avoidance) under the original and updated turbine layouts are shown in Figures 10 and 11, respectively. These counts represent the potential yearly manifestation of the long-term rate. Over time, the long-term rate should regress to the values in these Figures.

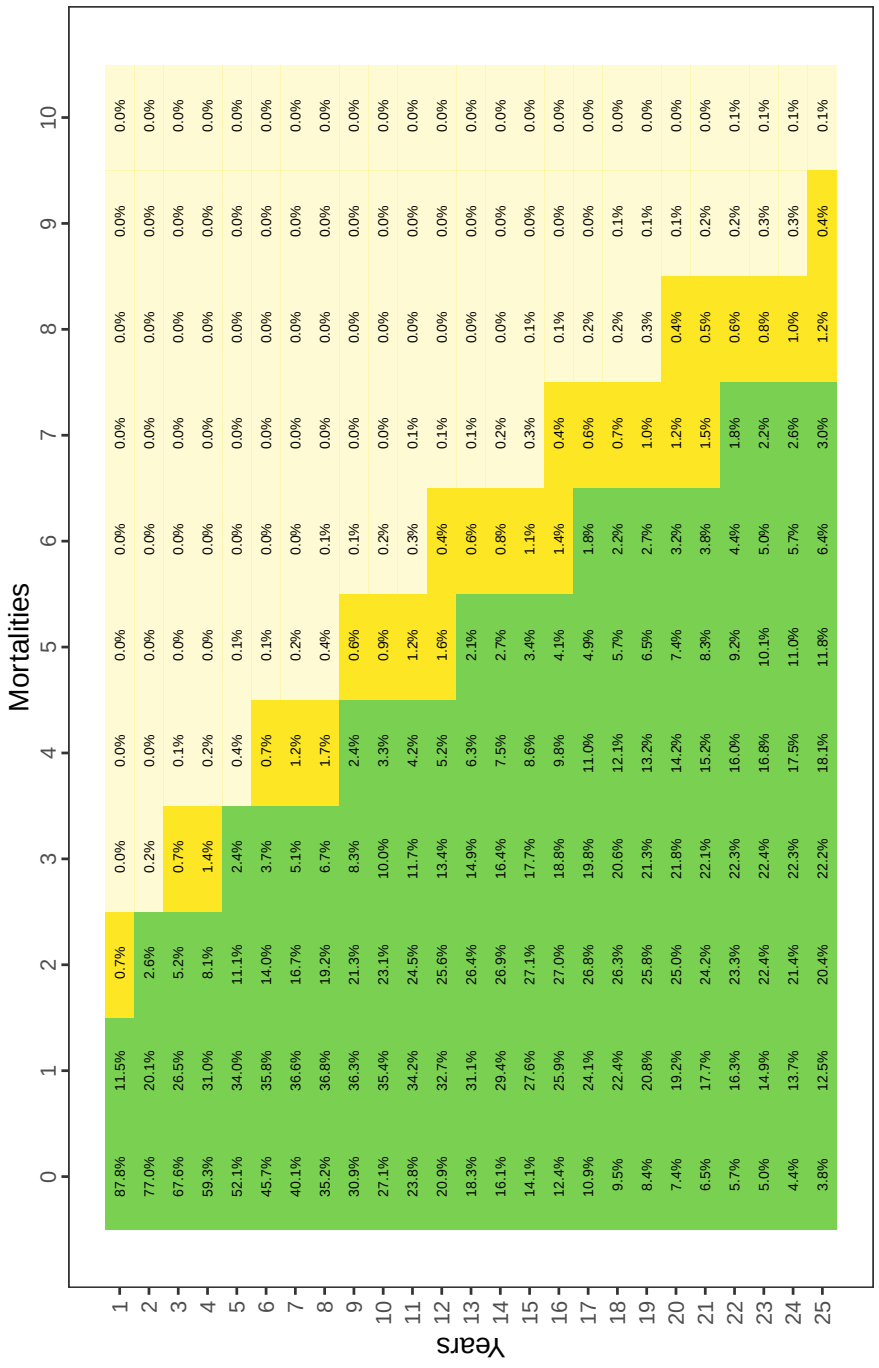

Figure 10: Plausible range of cumulative mortalities under the 0.9 avoidance rate under the new occupancy scenario and the original turbine layout.

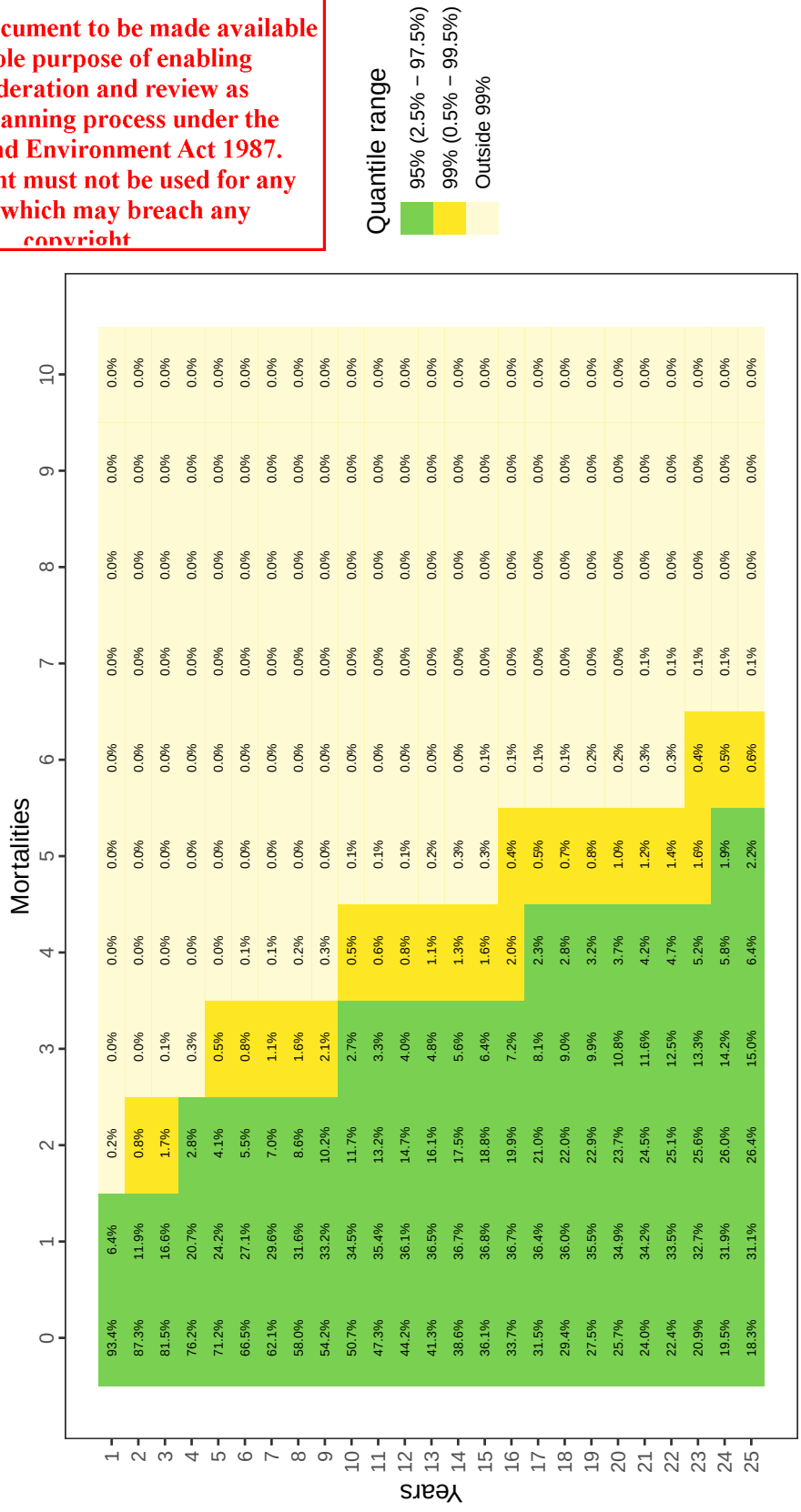

Figure 11: Plausible range of cumulative mortalities under the 0.9 avoidance rate under the new occupancy scenario and the updated turbine layout.

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Appendix 7: Population Viability Assessment

Results for Brolga PVA at Willatook

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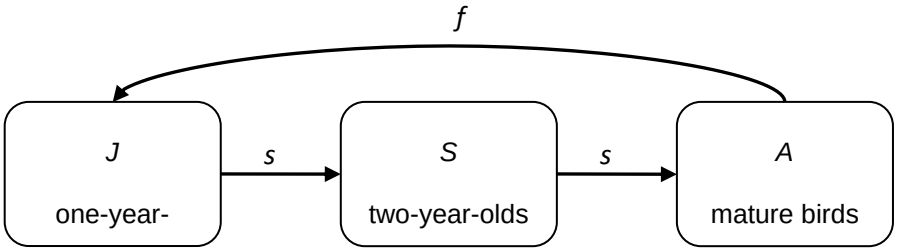
14 March 2022

This report documents a population viability analysis (PVA) of brolga to predict the impacts of a proposed wind farm at Willatook. The report uses updated projections of the number of annual collisions. The predictions of impacts on the brolga population in south-western Victoria are based on three different avoidance rates (90%, 95%, 99%) that correspond to 0.07, 0.03 and 0.01 collisions per year (calculated as 1.7, 0.9 and 0.2 collisions per 25 years). These annual rates were converted to a per-capita annual rate by assuming the population size of brolga is 625 birds. The same scenarios were also run assuming the initial population size was 907 birds (DSE report of simultaneous flock counts in April 2013). The expected minimum population size (EMP) was calculated for each of these scenarios, and compared to the EMP in the absence of any turbines.

The population viability analysis was based on an age-structured model, with individuals classified as being one year old birds (juveniles), two year-old birds (sub-adults) and mature birds (adults). Let *J*, *S* and *A* be the abundances in each of these age classes. The per capita fecundity rate (*f*) and survival rate (*s*) define the transitions among these age classes, which can be represented diagrammatically:



The fecundity rate *f* is the product of the probability that an adult breeds, the average number of chicks produced, and the survival of any chicks to one year of age. The transitions between age classes can be defined by a matrix (**M**):

$$\mathbf{M} = \begin{bmatrix} 0 & 0 & f \\ s & 0 & 0 \\ 0 & s & s \end{bmatrix}$$

Estimation of the parameters *s* and *f* is problematic for brolga because mark-resighting data are not available. However, estimates can be derived from the observed ratio of immature (one-year-old and two-year-old birds) to mature birds and assumptions about the population trend with particular

assumptions. If the population is stable (abundances of each of the age classes are the same from year to year):

$J = f A$,
$S = s J$, and
$A = s (S + A)$.

Solving these equations leads to:

$f = (1 - s) / s^2$, and
$s = \sqrt{(R + 1) / (R + 1)}$,

where R equals the ratio of immature to mature birds ($(J + S) / A$). Therefore, if $R = 0.05$, which is approximately the case for contemporary populations in southeastern Australia (Herring 2001), $s = 0.976$ and $f = 0.025$, which are used as the standard set of parameter values. The estimate of s can be compared to predictions from an allometric model (McCarthy et al. 2008, but with additional data on cranes: Bennett and Bennett 1990, Link et al. 2003, Masatomi et al. 2007) that predicts the annual survival rate of adult birds from body mass. Based on a body mass of 6 kg, the predicted annual survival rate of cranes is 0.91 with a 95% credible interval of [0.77, 0.96]. Therefore, the estimate based on age structure is higher than might be expected for a crane of this size but not inconceivably so. Nevertheless, a survival rate less than 0.976 may be possible, and in fact may be likely.

The population growth rate based on the matrix model can be obtained by eigenanalysis of the transition matrix **M**, and is the (real) solution to the cubic equation:

$\lambda^3 - s \lambda^2 - f s^2 = 0$.

A closed form solution can be obtained, but it is unhelpfully complicated (result not shown). However, the solution can be approximated using a first-order Taylor series expansion around the point $f = 0$, leading to $\lambda \approx s + f$. The next term in the expansion is $-f^2/s$, which is small when f is small and s is large. Therefore, $\lambda \approx s + f$ is a good approximation if $f \approx 0$ and $s \approx 1$, which is the case for the brolga. This means that reductions in the population growth rate due to decreased survival of brolgas can be approximately compensated by an increase in fecundity of the same magnitude.

Initial abundances in the simulation were set at 79 1-year-olds, 75 2-year olds, and 753 adults, reflecting the 2013 simultaneous flock counts, or 54 1-year-olds, 52 2-year olds, and 519 adults when assuming an initial population size of 625 birds. The numerous younger birds (17% of the population) suggests that annual recruitment rate in the last two years has been approximately 10% in the last couple of years following high rainfall. Assuming annual survival of 0.976, and a reproduction rate of 2.5% on average to obtain a stable population size, this suggests large variation in reproduction – a value of 100% for the CV seems plausible. This value was chosen for the CV for fecundity, and 50% was chosen for the CV of mortality (which translates to small variation in survival).

Simulations were based on 1,000,000 stochastic iterations for each set of parameters with analyses done within the statistical programming language R. This model is structurally identical to the previous analyses conducted in RAMAS/GIS (Akçakaya and Root 2002).

Results

In the absence of losses to wind turbines and powerlines, the expected minimum population size over the next 25 years was 555.5 brolgas when the initial population size was 625 brolgas, and was 807.2 when the initial population size was 907 brolgas. Impacts of the turbines and powerlines can be compared to these values (Tables 1).

Table 1. Expected minimum population (EMP) size of the south-west Victorian brolga population for each of the three different turbine avoidance rates when the initial population size was 625 brolgas. The reduction in the EMP compared to the absence of turbines is given in brackets.

	Expected minimum population (EMP) size over 25 years, and the reduction in EMP due to collisions (in brackets).		
Initial brolga population size	90% avoidance rate	95% avoidance rate	99% avoidance rate
625 birds	554.6 (0.9)	555.2 (0.3)	555.4 (0.1)
907 birds	806.4 (0.8)	806.8 (0.4)	807.2 (0.1)

The expected minimum population size (EMP) is a useful metric of the risk of decline. It is calculated from stochastic simulations of the model. The smallest population size in each of the simulations is recorded. The EMP is the average of these, representing the average degree by which a quasi-extinction risk curve is from extinction (McCarthy 1996; McCarthy and Thompson 2001).

The linear approximation of the population growth rate ($\lambda = f + s$) indicates the number of births that would required to offset mortality events from collisions. Because fecundity and survival have approximately additive effects on growth rate, each mortality event would need to be mitigated by an extra bird being raised to adulthood. This might be achieved by improvement to breeding habitats or reduced collision with other infrastructure such as existing powerlines or fences (Beaulaurier 1981; Alonso et al. 1994; Brown & Drewien 1995). For example, with a 95% avoidance rate, the expected number of extra deaths is 0.9 over the 25-year period. If survival of juveniles to adulthood is j, then the required number of extra juveniles can be calculated as $1/j$, which is on the order of one or two birds.

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Glossary of acronyms

CV	coefficient of variation, equal to the standard deviation divided by the mean.
EMP	expected minimum population size; a measure of risk of decline of a population.
PVA	population viability analysis; a model-based analysis of the risk of decline of populations.

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