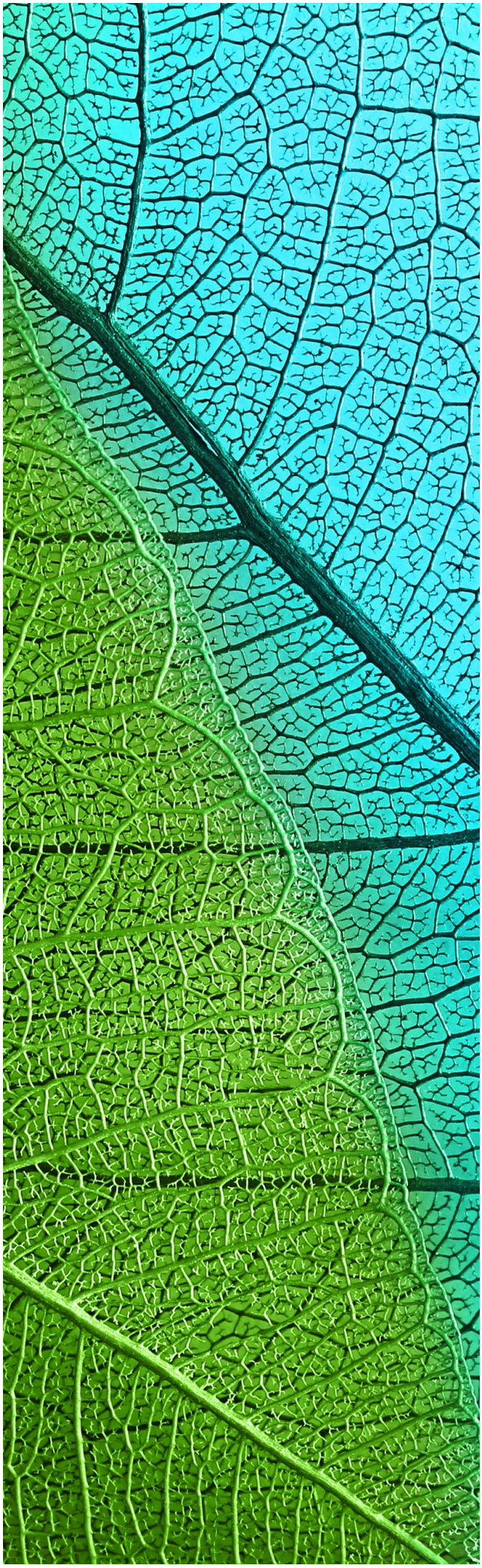

Hexham Wind Farm

Brolga Impact Assessment

Prepared for Hexham Wind Farm Pty Ltd

March 2022
Report No. 18088 (8.4)

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Hexham Wind Farm Pty Ltd (Hexham Wind Farm) engaged Nature Advisory Pty Ltd (Nature Advisory) to undertake an assessment of the impacts on the state-threatened Brolga (*Antigone rubicunda*) from the proposed Hexham Wind Farm in south-western Victoria. This report has been specifically prepared to accompany the Environment Effects Statement (EES) Referral, which is required under the *Environment Effects Act 1978.*

The proposed Hexham Wind Farm is spread over 16,104 hectares of land in the Moyne Shire. It comprises up to 108 turbines and associated access tracks. The access tracks on the wind farm site will be permanent and will connect to the public road network in several places.

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 guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga Population 2011* (DSE 2012), referred to hereafter as the 'Interim Brolga Guidelines'.

This report presents the methodology and results from the first two levels of investigation required under the Interim Brolga Guidelines. It reports the results of field work undertaken by Nature Advisory from 2018 to 2021 and earlier surveys by Ecology and Heritage Partners (EHP 2013) from 2010 to 2013. This report lays the foundation for the Level Three assessment under the Interim Brolga Guidelines that will determine how impacts on the species can be avoided, minimised and offset to achieve the objective of the Interim Brolga Guidelines. This objective is to ensure that each wind farm development has zero net impact on the Victorian Brolga population (DSE 2012, p.6), thereby avoiding any cumulative impact on the species from the development of the wind energy industry in the state.

The Interim Brolga Guidelines require regular consultation with the state Department of Environment, Land, Water and Planning (DELWP), which has been important in the development of the project. Hexham Wind Farm 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 Hexham Wind Farm as required. The purpose of this report is to present the methods and results of Brolga studies at Hexham Wind Farm and in its surrounding Radius of Investigation (RoI) and inform an EES to DELWP. It includes the methods and findings of all investigations required under the Interim Brolga Guidelines up to Level Three, Step1, namely the development of turbine-free buffers around key Brolga habitats. A final Brolga Assessment Report will be prepared to accompany a Development Application or EES if required that presents the results of all three levels of assessment, including the final collision risk modelling, population viability assessment and Brolga compensation measures required to address the Interim Brolga Guidelines.

Over the last decade there have been significant efforts 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 periods, aerial surveys, and the assessment of habitat suitability based on field assessment combined with hydrological modelling.

The findings from this assessment are summarised below.

- A significant proportion (62%) of wetlands in the Radius of Investigation (RoI – within and up to 10 kilometres from the wind farm site) have been permanently drained and are no longer functional or capable of supporting Brolga.
- A significant proportion of the RoI, in particular the southern and north-western portions, lacks wetlands and the Brolga has not historically been recorded there.
- Eight breeding pairs of Brolga were confirmed inhabiting the RoI during 2019. Breeding success and attempts were greater during this year (due to good rainfall and related wetland availability) and therefore eight breeding pairs of Brolga are likely to be the maximum that would occur in the RoI in any given year.
- No Brolga flocking activities have been recorded during the flocking season within the RoI, with the closest flocking site being 20 kilometres to the north-west in Penshurst.
- Based on the historical activity of the Brolga in the RoI and the findings of this assessment, the focus of assessment has been on the use of the area for breeding. Little risk to the Brolga is considered to arise from the use of the region during the flocking season.
- A level three assessment as per the Interim Brolga Guidelines has been commenced due to Brolga breeding within the wind farm boundary and outside the northern and eastern boundary.
- There are 23 functional wetlands that are considered to provide Brolga breeding habitat now and in the future and appropriate turbine free buffers around these wetlands have been delineated to ensure the protection of breeding Brolgas and their habitat.

1. Introduction

Hexham Wind Farm (HWF) engaged Nature Advisory to undertake an assessment of the impacts on the state-threatened Brolga (*Antigone rubicunda*) of the proposed HWF in western Victoria.

The proposed HWF site is approximately 16,104 hectares of private land and adjacent roadside in the western Victorian localities of Hexham, Caramut, Ellerslie, Minjah and Woolsthorpe, 20 kilometres west of Mortlake and 200 kilometres west of Melbourne. 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 up to 108 turbines and associated access tracks. The access tracks on the wind farm site will be permanent and will connect to the public road network in several places.

The region is characterised by an extensive flat to undulating basaltic plain with stony rises, old lava flows, numerous volcanic eruption points and scattered shallow wetlands, both saline and freshwater. Volcanic cones occur across the region rising up to 120–150 metres and although basalt cones are present (such as; Mt Cotteril and Mt Hamilton), scoria cones are more common (such as; Mt Elephant, Mt Misery, Mt Napier, Mt Noorat and Red Rock). Maars and calderas are also common (e.g. Lake Bullenmerri, Lake Purdigulluc, and Tower Hill) (VicFlora 2021).

This report presents the methods and results of the Brolga assessment based on field work undertaken by Nature Advisory from 2018 to 2020 and earlier surveys by Ecology and Heritage Partners from 2009 to 2013 in accordance with the Interim Brolga Guidelines (DSE 2012).

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 field assessment combined with hydrological modelling.

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. At this stage level one, level two and step one of level three has been completed. Assessments have been undertaken and reported here to inform an EES referral.

This report is divided into the following sections.

Section 3 provides an overview of the Brolga assessment approach.

Section 4 describes the level one assessment methods and results.

Section 5 describes the level two assessment methods and results.

Section 6 describes the level three assessment undertaken to date.

Section 7 provides an overview of findings from the assessments.

This investigation was undertaken by a team from Nature Advisory, comprising, Eamon O'Meara (Zoologist), Elizabeth Browne (Zoologist), Guille Mayor (Zoologist), Jackson Clerke (Senior Zoologist), Khalid Al-Dabbagh (Senior Zoologist), Peter Lansley (Senior Zoologist), Dion Iervasi (Ecologist), Curtis Doughty (Senior Zoologist), Inga Kulik (Senior Ecologist and Project Manager) and Brett Lane (Principal Consultant).

2. Brolga assessment overview

2.1. Species description

The Brolga is listed as endangered under the Victorian state *Flora and Fauna Guarantee Act 1988* (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 birds, 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).

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 in consultations with 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
3/2021	413	9	Yes	http://swifft.net.au/cb_pages/survey_results_summary.php#Brolga (viewed January 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 were 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 move between sites between days.

Earlier, non-simultaneous counts (from the 1980s to 2011) are not directly comparable to the counts from 2012 and 2019, 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 do not 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 at more sites for adult and young birds for the entire breeding cycle until young fledge.

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, or flocking, 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, food resources and 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, food resource (tubers, aquatic animals), provides shelter for prey (vertebrates and invertebrates) and cover from predators for young chicks (Johnsgaard 1983).

A Brolga family will spend most of its time in the nesting wetland foraging but will move to other wetlands nearby to forage and/or roost as the chicks develop and food resources are depleted. Brolga also forage in pasture and to a lesser degree (during the breeding season) cereal and canola crops in the vicinity of the 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; Veltheim et al. 2019).

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 to build nests, incubate eggs, feed and shelter young chicks from ground predators or feed older chicks until they fledge.

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 due to careful planning and design of wind farm projects.

2.6. Policy framework for wind farms

The policy and planning guidelines for wind farms in Victoria (DELWP 2019) 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 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 HWF. Planning authorities must consider the impacts of wind farm developments on this species before making decisions on permit applications.

2.6.1. 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 may be required. 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 DSE (2012) Interim Brolga Guidelines.

This document outlines the investigations completed to date to address levels one and two of the assessment and provides the basis for discussions with key environment, planning and technical personnel in DELWP, HWF and Nature Advisory to ensure that the method of achieving the outcome of a Zero Net Impact on the Victorian Brolga population is acceptable. The level three investigation is a four-step process and only step one: avoid or mitigate potential impacts, has been completed at this stage of the planning process. Steps two to four of level three assessment from the Interim Brolga Guidelines, will be undertaken later in the planning process.

Further details on the levels of assessment and steps in 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, as well as the work that remains to be completed.

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 conducted (see 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. (see 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. Extensive landholder consultation within the radius of investigation has been undertaken and is ongoing to identify current and historical Brolga flocking and breeding sites that may not be in the available databases or accessible during field studies (see Section 4.1.1).
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 (see Section 4).

Level	Step	Assessment triggers (as per DSE 2012)	Current investigation - outcomes and actions
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.	Site-specific investigations determined that the Brolga occasionally utilised the landscape within and surrounding the proposed Hexham Wind Farm. Breeding was recorded in wetlands in the RoI. The species does not flock within 10 kilometres of the wind farm (see Section 4.2.3). Extensive site-specific field investigations are in progress and have been undertaken during breeding and non-breeding periods in 2009, 2010, 2011, 2013, 2018, 2019 and 2020 to document the extent of Brolga activity and current spatial patterns of activity in the RoI (see Sections 3.2 & 4.2).
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 (yet to be completed).
	3	Use DELWP (Melbourne University) Brolga PVA to estimate the impact of the proposed development on the population.	Based on outcomes of CRM (yet to be completed).
	4	Identify appropriate compensation strategies to ensure a zero net impact on the Victorian Brolga population.	Based on outcome of CRM and PVA. (yet to be completed).

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 three level one assessment triggers apply to the proposed HWF. 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.

- Preliminary Flora & Fauna Assessment for the Proposed Hexham Wind Farm, Hexham, Victoria. Ecology Partners Pty Ltd, April 2011 (EP 2011)
- Spiny Rice-flower and Brolga Winter Surveys: Hexham Wind Farm. Draft report prepared for Wind Prospect WA Pty Ltd, Ecology and Heritage Partners Pty Ltd, August 2011 (EHP 2011)
- Brolga Movements and Spatial Requirements During Breeding, south–west Victoria. Ecology and Heritage Partners Pty Ltd, November 2013 (EHP 2013)
- Fauna and Flora Assessment: Detailed Fauna and Flora Investigations: Hexham Wind Farm, Hexham, Victoria. Prepared for Hexham Wind Farm Pty Ltd, Ecology and Heritage Partners Pty Ltd, June 2014 (EHP 2014)
- 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)
- Final Report - Biodiversity Assessment: Hexham Wind Farm, Hexham, Victoria. Prepared for Hexham Wind Farm Pty Ltd. Ecology and Heritage Partners September 2018 (EHP 2018)
- Breeding site home range mapping published in the EES Referrals for the Penshurst (Biosis Research 2011) and Mount Fyans (Biosis 2017) Wind Farms
- 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 2021) – high accuracy records for south-western Victoria were obtained in 2021
- *The Atlas of Australian Birds and Birdata* (BirdLife Australia 2019) accessed 2019
- The south-west Victorian flocking site database (compiled by Sheldon (2004) and provided by the then-Department of Sustainability and Environment).

These databases were reviewed for records of Brolga in south-west Victoria, in the Hexham Wind Farm RoI and within the proposed wind farm site.

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 Brolga breeding records greater than 100 metres from 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 (source: DSE 2012)

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 reviewed, and the location assessed to determine if the record is valid (i.e. can be attributed to a wetland) and the location can support a breeding pair of Brolga to successfully rear a chick. A wetland was suitable if it had the following characteristics (see Sections 4.1.5 & 4.2.5 for a discussion of Brolga habitat requirements):

- Held water for at least 120–days during the breeding season (based on observations or hydrological modelling);

- Was larger than 0.6 hectares; and
- Had a component of aquatic and/or emergent vegetation.

If a wetland did not have the characteristics described above than it was unsuitable for breeding purposes.

All historical records of breeding associated with a wetland, were assumed to indicate sites where breeding could occur in the future. The only exception was, where the historical records of breeding was located at a wetland that had been permanently drained.

3.1.3. Initial surveys undertaken by EHP

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

- Brolga searches between November 2009 to February 2010. This included driving all roads within a 20 kilometre 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 for breeding habitat.
- Aerial survey for Brolga in October 2010 by flying a light aircraft over the Project area and within a 20 kilometre radius to identify potential Brolga nests. Nest locations were then recorded and visited on the ground where this was possible.
- Initial community consultation in 2011 involved contacting landholders with historical records of Brolga to seek information about Brolga habitat and request 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 of 11 wetland areas within the project site 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 Victorian Biodiversity Atlas (VBA) Brolga flocking records with 1,000 metre accuracy or lower (up to 2nd February 2021). The entire RoI was surveyed during the Brolga flocking surveys. Areas targeted included locations where three or more Brolga had been previous recorded from the VBA.p

There was one record within the RoI in the VBA of 18 Brolga together . This record was from June 2008 entered by a local landholder. The location description of the record states 'Blackwood Lake (Caramut-Dunkeld Road)'. Blackwood Lake is located 20 kilometres from the proposed wind farm (outside the RoI) on a private property along the Woolsthorpe Rd between Caramut and Dunkeld. It is likely that there is a co-ordinate error with this record and the record was indeed intended to be at Blackwood Lake.

A review of the Sheldon Brolga Flocking Database found one flocking record within the RoI (Sheldon 2004). In April of 2003, 35 Brolga were recorded near Wetland 28243 which is located within the proposed wind farm site. In addition, there was a Brolga record at this site in May 1997 although the number of Brolga observed was not disclosed. The landholder has not observed Brolga flocking on his property and he owned the property at the time of the record in 2003 (EHP 2014). Wetland

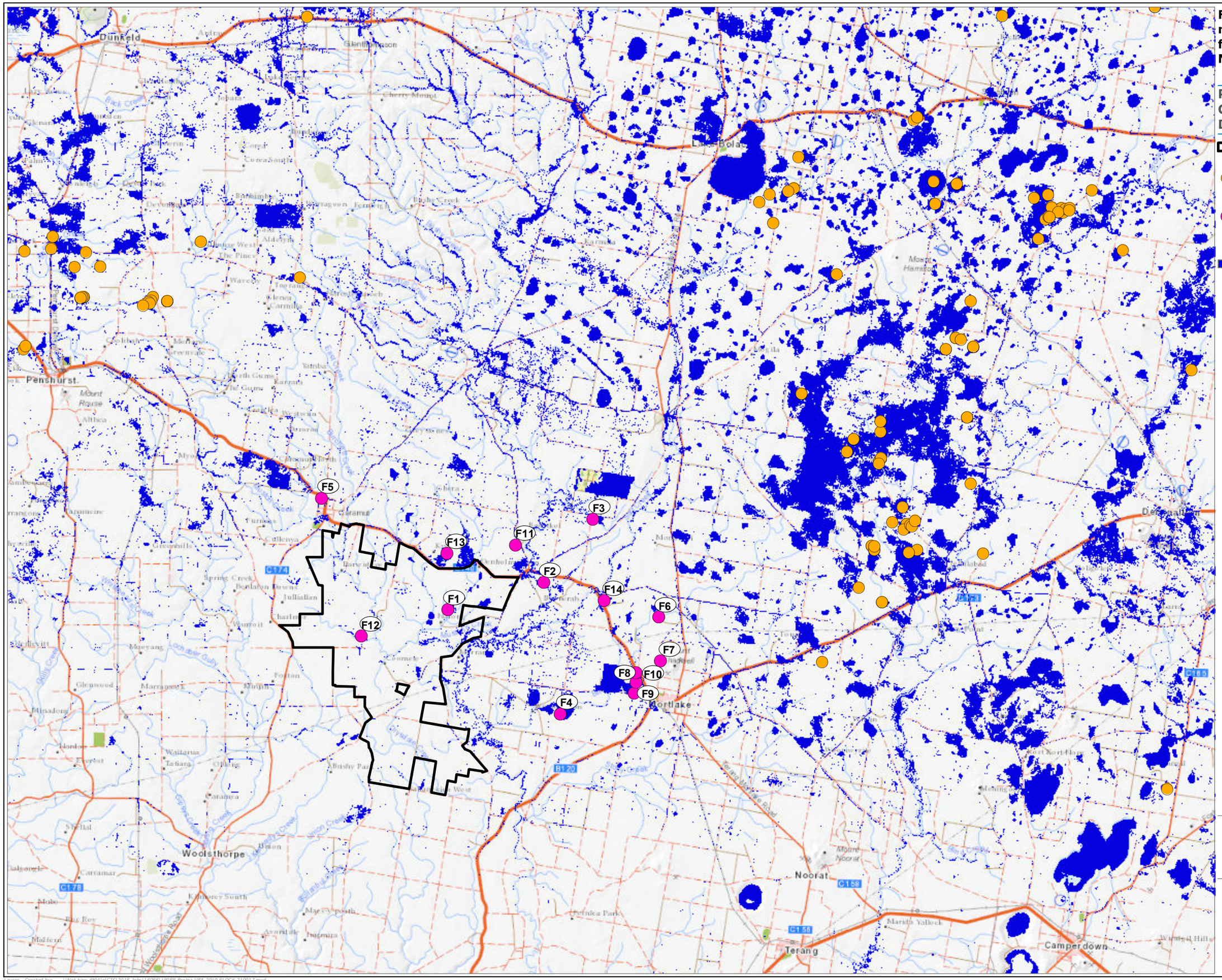

Figure 1: Brolga VBA flocking records and potential flocking sites surveyed by Nature Advisory

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 21/09/2021

- Wind farm boundary
- High accuracy Brolga VBA flocking records (up to date of 21/10/2020)
- NA identified potential flocking sites surveyed
- NVR2017 Habitat Importance Modelling (DELWP modelled Brolga habitat)

N

Metres
0 3,600

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Layers - Created by: - \\Nat-haw-dt04\e\GIS\2018 Jobs\18088\18088 Brolga VBA 2019 FLOCK 210917.mxd

28243 fails to meet the criteria for a flocking site and is considered to have supported a one-off flocking record.

No Brolga flocking activity was observed in the RoI during the Brolga flocking season surveys reported here. Given the lack of records and the lack of large, permanent wetlands in the RoI there is no evidence of any traditional Brolga flocking sites in the RoI.

The nearest flocking site is located near Penshurst, approximately 20 kilometres north-east of the study area.

3.2.2. Historical breeding sites

Information from the 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 south-west Victoria. Figure 2 shows the following.

- The HWF site lies generally in the southern area of distribution of Brolga records in SW Victoria
- A number of Brolga records are from within the wind farm site
- Higher concentrations of Brolga records occur to the north-west, north-east and east of the HWF

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

- There are seven Brolga records within the HWF
- There are scattered Brolga records directly to the east and north-east
- Modelled Brolga habitat within the HWF is patchy with larger areas in the north-east of the HWF
- Larger patches of modelled habitat occur to the north and east of the HWF.

An analysis of Brolga breeding records from the VBA has been undertaken and presented in Table 4. A total of 22 Brolga breeding records were reviewed within the RoI. Of these records, 15 were considered suitable for inclusion, which included 10 wetlands (due to duplicate records at some wetlands) considered suitable for providing Brolga breeding habitat in the future.

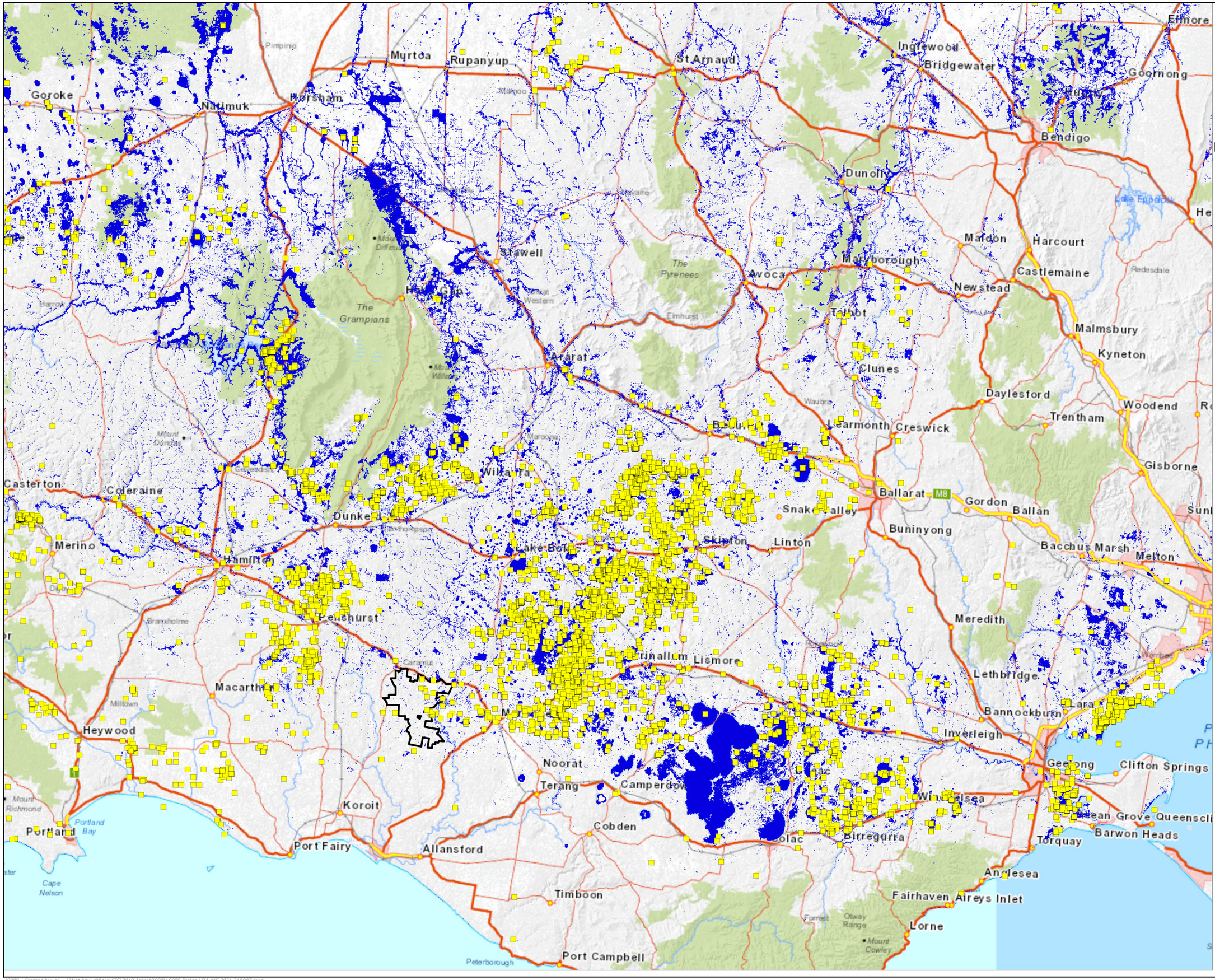

Figure 2: Brolga VBA records and modelled habitat southwest Victoria

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 17/09/2021

- 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 12,000

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Figure 3: Brolga VBA records and modelled habitat within the ROI

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 17/09/2021

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 2,200

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Table 4: Analysis of Brolga Breeding records from the VBA

VBA Survey Observation number	Start date	End date	Location description	Wetland number	Comments	Accuracy (m)	Suitable for inclusion
944400	1/01/1984	31/12/1984	Mortlake		Location not situated at a wetland and there is no wetland within 900m (record accuracy).	900	No
944364	1/01/1984	31/12/1984	Minjah		Location not situated at a wetland and there is no wetland within 900m.	900	No
944381	1/01/1984	31/12/1984	Caramut		Location not situated at a wetland and there are no wetlands considered to be suitable Brolga breeding habitat within 900m.	900	No
944382	1/01/1984	31/12/1984	South Caramut		Location not at a wetland. It is situated next to Wetland 28203 though this wetland has been permanently drained and is considered unsuitable for breeding purposes.	900	No
944383	1/01/1984	31/12/1984	Hexham		Location not situated at a wetland and there are no wetlands considered to be suitable Brolga breeding habitat within 900m.	900	No
944385	1/01/1984	31/12/1984	Hexham	29411	Point located next to Wetland 28252.	900	Yes
944399	1/01/1984	31/12/1984	Mortlake		Location not situated at a wetland and there are no wetlands considered to be suitable Brolga breeding habitat within 900m.	900	No
856455	1/01/1987		Not provided	29404	Point located next to Wetland 29047.	100	Yes
854277	2/12/1991		Not provided	25651	Point located at Wetland 25651.	100	Yes
952123	1/01/2002	31/12/2002	Darlington/Dundonnell - BAP map derived sites		Location not situated at a wetland and there are no wetlands considered to be suitable Brolga breeding habitat within 900m.	900	No
954316	22/08/2007		Mortlake Common	28282	Located at Wetland 28282 (Mortlake Common), a confirmed Brolga breeding site.	900	Yes
954318	22/08/2007		Hexham district	9	Located next to Wetland 3, a confirmed Brolga breeding site.	900	Yes
952147	11/09/2007		Darlington/Dundonnell - map derived sites - BL & A; Ecology Partners	29416	Located at Wetland 28264, a confirmed Brolga breeding site.	900	Yes
952148	11/09/2007		Darlington/Dundonnell - map derived sites - BL & A; Ecology Partners	9	Located next to Wetland 3, a confirmed Brolga breeding site.	900	Yes
954358	1/10/2007		Thulborn Rd	28282	Located at Wetland 28282 (Mortlake Common), a confirmed Brolga breeding site.	900	Yes

VBA Survey Observation number	Start date	End date	Location description	Wetland number	Comments	Accuracy (m)	Suitable for inclusion
954361	1/10/2007		Hexham - Ballangeich Rd	9	Located next to Wetland 3, a confirmed Brolga breeding site.	900	Yes
954333	18/09/2008		Mortlake	28366	Located at Wetland 28366, a confirmed Brolga breeding site.	900	Yes
954334	18/09/2008		Mortlake	D	Located at Wetland 4.	900	Yes
2340239	15/09/2020		10km SW of Hexham	9	This is a Nature Advisory breeding record, confirmed breeding site at Wetland 3.	200	Yes
2340242	15/09/2020		3.8km SW of Hexham	23	This is a Nature Advisory breeding record, confirmed breeding site at Wetland 28249.	200	Yes
2340240	15/10/2020		10.5km SW of Hexham	28240	This is a Nature Advisory breeding record, confirmed breeding site at Wetland 28240.	200	Yes
2340243	15/11/2020		3.8km SW of Hexham	23	This is a Nature Advisory breeding record, confirmed breeding site at Wetland 28249.	200	Yes

3.2.3. *Initial Brolga surveys*

No Brolga flocking activity was observed or reported by any landholders during the initial survey period.

The results of the initial surveys between 2012 and 2013 are summarised below (EHP 2013).

- Nine Brolga breeding sites were monitored within the broader search area:
  - Six breeding sites were located around the Darlington area to the east
  - Three breeding sites were located to the east of the proposed wind farm
- No Brolga breeding sites were observed within the RoI.

During the aerial survey on 8th October 2010 one breeding site was confirmed in the RoI at Wetland 28282 - Mortlake Common (EHP 2014).

During the initial community consultation period eight Brolga breeding sites were identified (EHP 2014). Of these seven were considered to provide Brolga breeding habitat and likely to be utilised again in the future (Table 5).

Table 5: Breeding sites identified during initial community consultations

EHP reference	Wetland number	Redefined wetland number	Comments	Suitable for inclusion
RW1	28252	29411	Wetland present.	Yes
RW2	28261	29414	Wetland present.	Yes
RW3	A	N/A	Area is low lying and has drains running through it. No wetland present.	No
RW4	D	N/A	Wetland present.	Yes
RW5	28259	N/A	Wetland present.	Yes
RW6	28366	N/A	Wetland present.	Yes
RW7	E	N/A	Wetland present.	Yes
RW9	28267	29415	Wetland present.	Yes

3.3. Conclusions

Based on the level one assessment it was concluded that the project would meet at least the first and third trigger for a level two assessment as outlined in the Interim Brolga Guidelines. There were records of breeding habitats within the RoI (trigger one). The proposed HWF 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 progressed to level two investigations, described in the next section of this report.

4. Level two assessment

The level two 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 2020.

4.1. Methods

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

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

These methods and relevant survey dates are summarised below.

4.1.1. Detailed community consultation

The results of detailed landholder consultations, when combined with historical data, enable a more complete and long-term picture to be assembled of Brolga activity in the RoI to supplement and provide context for the field investigations. Information gathered is presented in the community questionnaire in Appendix 1.

Landholders within the RoI were interviewed to identify additional Brolga flocking and breeding sites that may not be recorded in the available public databases. All landowners, including absent landowners within 10 kilometres of the proposed wind farm boundary were contacted by newsletter and invited to participate. Where information was available, landowners within the RoI were also emailed or contacted by telephone phone call encouraging participation. As not all the phone numbers were available, it was not possible to contact all landholders.

Extensive interviews were undertaken with landholders in 2018 at the Caramut Hall on 12th and 13th August and Ellerslie Community Hall on 15th and 16th August. During the interviews, each participant was questioned for up to 30 minutes. Additional consultations were held by telephone and in person during the study period with landowners in the RoI. Where possible, landholders were also sent surveys via email when other methods of contact failed. Efforts are ongoing to engage participants not interviewed to date.

Table 6 presents the area of the RoI held by local landholders that participated in the consultations up to the present date. Figure 4 shows the properties that participated in the community consultation process.

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

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. Importantly,

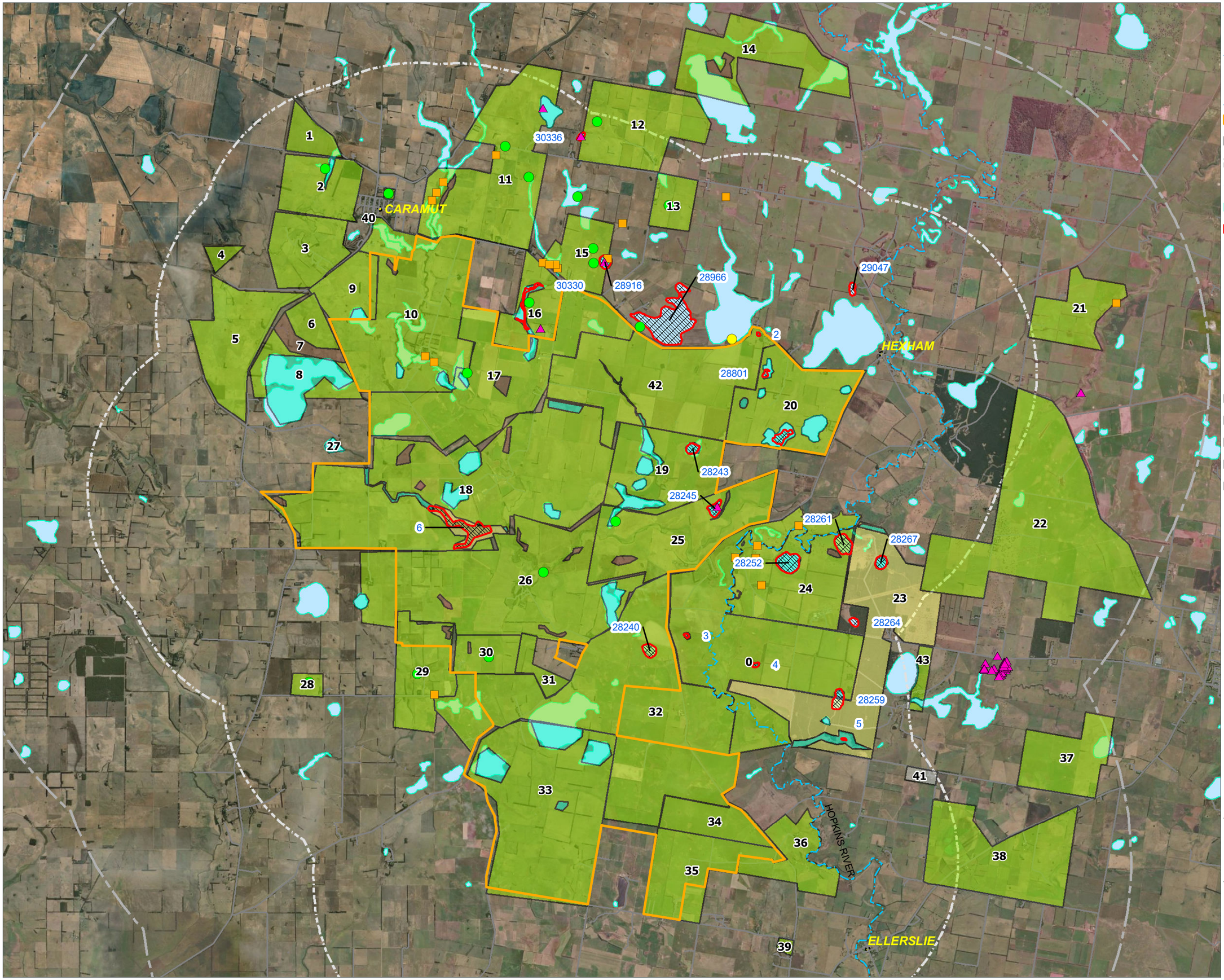

Figure 4: Landholder survey in ROI in 2018-2021

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 17/09/2021

- Wind farm boundary
- Wind farm 10km buffer
- Wind farm 5km buffer
- Hopkins River
- DELWP wetlands
- Breeding wetlands

Landholder Observations

- Breeding
- Flocking
- General observations/sightings
- Other

LandType

- Aquatic
- Arable
- Mixed
- Other
- Stony

N

Metres
0 1,600

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land holder surveys provided additional evidence on Brolga activity from a much longer period than the period of the current project-specific field investigations, or information on activity that may be missing from available databases.

Table 6: 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	15,905	16,104	98.7%
Within 5km of wind farm boundary	26,076	58,862	44.3%
Within 10km of wind farm boundary	30,580	11,2974	27%

4.1.2. Breeding-season aerial survey

An aerial survey to search for Brolga was undertaken by Nature Advisory during fine weather conditions on 2nd ,3rd, and 14th October 2019. This is typically an optimal time to identify Brolga breeding. In the 2019 season, rainfall was average therefore observations were considered representative of an average Brolga breeding-season.

The aerial survey covered the complete RoI to 10 kilometres from the wind farm. The aerial survey was designed to detect Brolga and to identify Brolga breeding sites within the proposed wind farm site, and in the RoI. Prior to undertaking the survey, north-south flight lines were defined throughout the study area at 500 metre (east-west) intervals.

The survey was undertaken in a fixed-wing, four-seat Cessna 182 RG (retractable undercarriage) flying between 90 and 120 metres above ground, at a speed ranging between 209 and 240 km/hour. Variations were made in height and speed dependant on flight safety and regulatory requirements near powerlines and towns.

The survey team comprised the pilot, a navigator and two observers. The two observers (Curtis Doughty 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 (Eamon O'Meara or Jackson Clerke). One observer was located on each side of the plane. Observers scanned an area of approximately 250 metres either side of each transect, 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 and general description of habitat and the wetland number (Victorian Wetland Inventory number) on which the Brolga was sighted. Evidence of breeding, such as birds standing next to or incubating on nests was also recorded.

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 which is a significant factor in the accuracy of such surveys.

The aerial survey added a few additional breeding sites not previously documented. The combination of the initial on-ground surveys, the aerial surveys (to overcome access limitations) and landholder interviews, combined with historical information on breeding sites in public databases, has generated representative data on breeding locations and Brolga numbers on the wind farm site and in the surrounding RoI. This combination of information sources is consistent with the requirements of the level two assessment in the Interim Brolga Guidelines.

4.1.3. Brolga surveys

Brolga flocking season assessment

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 monthly from May to June 2018, January to June 2019 and January to June 2020. The survey focused on areas that had records from databases of more than two Brolga within the wider area and at permanent wetlands that held water throughout the year.

The dates the Brolga flocking surveys were undertaken were:

- 1st – 4th May 2018
- 29th May – 1st June 2018
- 9th – 11th, 21st – 23rd January 2019
- 7th – 8th, 26th – 27th February 2019
- 27th – 29th March 2019
- 23rd – 24th April 2019
- 23rd – 24th May 2019
- 19th – 21st June 2019
- 21st – 24th January 2020
- 17th – 21st February 2020
- 10th – 13th March 2020
- 27th April – 1st May 2020
- 19th – 22nd May 2020
- 15th – 18th June 2020.

Brolga breeding season assessment

Wetland quality was assessed for suitability for breeding Brolga. If a site was deemed suitable, surveys were conducted. During 2018 -2020, two methods (ground based surveys and aerial surveys) were used to detect the presence of Brolga and their breeding status. Methods used for the ground based surveys are outlined below.

Ground based surveys

Between September 2018 and December 2020 ground searches for breeding Brolga were undertaken within the RoI by Nature Advisory. Over a period of four to five days once a month from September to December 2018 and July to December 2019, and two to three days from July to December 2020. The 2020 surveys focussed on the windfarm site and the five-kilometre zone around it, hence the shorter duration of those surveys.

If Brolga were recorded at a wetland extended observations were made to determine if the Brolga had a nest or young. Brolga breeding activity and locations were recorded. Surveys were undertaken on the following dates:

- 25th – 27th September 2018
- 24th – 29th October 2018
- 14th – 16th November 2018
- 17th – 20th December 2018
- 23rd – 26th July 2019
- 5th – 8th August 2019
- 2nd – 5th September 2019
- 14th – 17th October 2019
- 11th – 14th November 2019
- 9th – 13th December 2019
- 27th – 28th July 2020
- 29th –31st August 2020
- 27th – 29th September 2020
- 27th – 29th October 2020
- 16th – 17th November 2020
- 14th –15th December 2020.

Rainfall and runoff in autumn, winter and spring 2018 was below average and therefore most seasonal wetlands were dry by November 2018. 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 until December 2019. This was a wetter year than the previous year with better breeding conditions for Brolga due to wetlands holding water for a longer period. Appendix 2 shows monthly rainfall totals compared with overall means recorded at a weather station near Mortlake (BOM 2021). The 2020 breeding season showed signs of an early start with pairs already seen in breeding wetlands in June. Nesting was confirmed in some wetlands however an above average rainfall spring saw pairs losing their nests due to flooding, although some re-nesting occurred later in the season.

Wetlands identified as permanently drained were considered unsuitable breeding habitat. Further hydrological investigations were undertaken to make a definitive assessment of all wetlands on the wind farm site for their suitability to provide Brolga breeding habitat (Nature Advisory 2020, Water Technology 2021). During this study, a Lidar survey was undertaken across the wind farm site to generate a digital elevation model (DEM - 10 cm vertical interval) and the past ten years of rainfall data was used to assess which wetlands held water at least once in ten years for a 120–day period, as required by Brolga to breed successfully. This criterion was agreed with DELWP (in litt. to Wind Prospect via email dated 24th June 2020).

The survey area for the field inspection consisted of the wind farm site and the surrounding five kilometers of the RoI. All wetlands in this area not subject to private land access limitations were visited and surveyed. In addition, searches were undertaken between 5 and 10 kilometres from the wind farm boundary focussing on areas where breeding had been recorded in the past, e.g., Mortlake Common Reserve and nearby wetlands. All remaining wetlands that could not be visited in the field (mostly due to

private land access limitations) were assessed using aerial photography and aerial survey to determine their suitability as 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 during that season. If a wetland was initially classified as unsuitable for Brolga breeding due to the wetland having been permanently drained, it was not surveyed again for breeding activities.

4.1.4. Brolga behaviour and movements

Flight behaviour data of Brolga has been gathered by Nature Advisory (formerly Brett Lane & Associates Pty Ltd) over 15 years in south-western 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 (see Section 4.2.4). This information is used in establishing turbine free buffers and in the collision risk modelling, both part of the level Three assessment.

4.1.5. Wetland assessment

A functional wetland potentially provides nesting, foraging and/or night time roost habitat for Brolga.

Several features influence the suitability of wetland habitat for Brolga breeding. These include:

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

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.

Victorian Wetland Inventory (VWI)

Potential Brolga breeding habitat first considered wetlands mapped in the Victorian Wetland Inventory (Current) (VWI) database for suitability for Brolga breeding. 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).

Hydrological wetland assessment

After two years of monitoring, 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 to develop a surface water model to redefine accurately the location and extent of wetlands (Water Technology 2021).

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

- A Lidar survey was undertaken across the wind farm site with a vertical accuracy of 10 centimetres;
- The past ten years of rainfall data was determined and analysed to contribute to the model; and
- The surface water hydrological model was developed to assess which wetlands can hold water at least once in ten years for a 120–day period, which is what the Brolga requires to breed successfully (see Section 5.2.5).

Shapefiles were provided to Nature Advisory with the results of the hydrology assessment. The hydrological assessment generated a list of wetlands and farm dams that were potentially suitable for Brolga breeding or night-time roosting. The list included 27 farm dams and 23 wetlands. This list of wetlands was assessed by Nature Advisory (2020) to ensure that the farm dams and wetlands identified through the hydrology assessment met the definition of a suitable Brolga breeding site.

Field assessment of short-listed wetlands

A list was generated of wetlands and farm dams that were potential Brolga breeding wetlands or night - time roosts from the outputs from the hydrological modelling.

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 Section 4.2.5)
- Hold water continuously for 120 days during the period from July to December in at least a one in ten-year flood event
- Supported aquatic/emergent vegetation, 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 in a one in 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, ecological productivity and food resources, and cover for young chicks from predators.

In the instance where a wetland did not hold water for the required period but was predicted by the modelling to do so 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 that it was suitable Brolga breeding habitat. This was because the existing aquatic vegetation would recover from the dry period relatively quickly after filling 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 25th November 2020. Wetlands and farm dams were visited on foot, photographs and notes taken on habitat characteristics, including surface water cover, drainage channels, emergent vegetation present and grazing pressure.

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 considered a functional wetland providing Brolga habitat, as described above.

The results of all field surveys of the Hexham Wind Farm were included in the Brolga breeding wetland assessment and all Brolga breeding activities observed at a wetland (nest building, incubation, etc.) were considered 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 33 landholders/managers participated in the interviews, occasionally representing multiple properties or multiple family owners of properties. Landholder observations of Brolga are summarised below.

- A total of 12 landholders reported not having seen a Brolga on their property
- Nine landholders reported observing breeding events on wetlands, or being aware of a historical breeding site, on their property or their neighbour's property (total six wetlands)
- Five landholders reported larger groups (3-5 birds) but no flocking events on their property. One landholder recorded a one-off flocking event in which 10-15 birds were observed near a dam approximately a decade ago. An additional one-off flocking event was reported by a landholder directly to the north of the Hexham Wind Farm where 10 Brolga were observed on their property in November 2020
- A total of 12 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. Most landholders commented that when recorded, Brolga foraged in their paddocks over a number of days then dispersed elsewhere.

The dominant land use within the RoI is mixed cropping, and grazing by sheep and cattle.

4.2.2. Breeding-season aerial survey

During the three-day aerial survey, five Brolga pairs were identified, and three nests were located. The pairs and nests were later ground-truthed by a zoologist.

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

- Identification of Victorian Wetland Inventory (VWI) wetlands
- Assessment of whether the wetlands were drained or otherwise unsuitable (e.g., surrounded by tree plantations)
- Identification of additional wetlands that were not included in the VWI wetlands.

This information was included in the functional wetland assessment outlined in the following sub-sections.

4.2.3. Brolga surveys

Brolga flocking assessment results

No traditional Brolga flocking sites were identified through the desktop study, community consultations or the 2018 – 2020 field assessments. Two one-off flocking events have been reported by landholders.

- The first was report by a property in the north of the Hexham Wind Farm where 10-15 Brolga were observed at a farm dam south of the Hamilton Hwy approximately in 2011.
- The second was a report from a property to the north of the Hexham Wind Farm where 10 Brolga were observed north of the Hamilton Hwy in November 2020.

During the non-breeding season a small number of Brolga pairs remained at or near their breeding wetlands outside the wind farm boundary, and in one case two neighbouring pairs (four birds) were seen foraging together in the overlapping area of their territory to the north of the proposed wind farm at wetland 28966.

Brolga flocking field surveys were undertaken during the period May 2018 to June 2020. No evidence of Brolga flocking was observed over this period. Therefore, there is no evidence to suggest that the wind farm site or surrounds is used as a traditional flocking area for Brolga. The closest documented traditional flocking site is 20 kilometres north-east from the proposed wind farm.

Brolga breeding assessment results

Extensive site-specific field investigations have been undertaken during breeding periods in 2018, 2019 and 2020 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 7.

Table 7: Summary of Brolga roaming surveys during breeding seasons

Year	Brolga breeding observation	Other Brolga observation (non-breeding)
2018	A local landholder reported a pair of Brolga breeding at wetland H. A local landholder reported a pair of Brolga breeding at wetland 30336.	A pair of Brolga observed in May and June at wetland 30369. This is a non-breeding season foraging and roosting site. A pair of Brolga observed in September and October at wetland 29420 (VWI 28245). Breeding unconfirmed though likely attempted. A pair of Brolga observed in October and December foraging in open paddocks at the northern end of wetland 29405. A pair of Brolga observed in November foraging at drained wetland 29402 (VWI 28966). A pair of Brolga observed in November foraging along the Mustons Creek (Nature advisory observation K).
2019	Nesting attempt in July at wetland 28366. The pair failed to raise any chicks though stayed in the area until November. Nesting attempt in August at wetland 29420 (VWI 28245). Breeding attempt failed; no chicks raised. Observed nesting in August at wetland 28282. Successfully reared one chick. Brolga confirmed nesting at wetland 25656 during aerial survey in October. Nesting attempt in October at wetland 29460 (VWI 28916). The pair was present in November though no chicks were confirmed. Sight was limited by tall grass. Nesting attempt observed during November at wetland 30336. The landholder reported Brolga raising a chick at wetland 20 (VWI 30330). A local landholder reported a pair of Brolga breeding at wetland H.	A pair of Brolga observed in January foraging in paddocks near wetland 29405. A pair of Brolga observed in March and June at wetland 30369. This is a non-breeding season foraging and roosting site. Three Brolga seen in the vicinity of the Mortlake sale yards in July. Flew from the east side of Hamilton in a westerly direction. A single Brolga observed at wetland 18 (VWI 28236). A pair of Brolga observed in October foraging at wetland 23 (VWI 28249). No breeding activities observed. A pair were observed during aerial surveys in October at wetland 28269. No breeding activity observed. Likely to be the pair that nest to the east at wetland 28366. A pair of Brolga observed in July and August foraging at a drained wetland number 28890. No breeding here, likely to be the pair that nest at wetland 30336. A Brolga pair reported by local landholder in November foraging at wetland 29402 (VWI 28966). Likely the pair the nested at wetland 29460 (VWI 28916).

Year	Brolga breeding observation	Other Brolga observation (non-breeding)
2020	Nesting observed in September at wetland 9. No chicks raised. Nesting observed in September at wetland 23 (VWI 28249). Nesting observed in September at wetland 29420 (VWI 28245). Heavy rains flooded the nest. The pair nested again in November. Unknown if the pair raised any chicks. Nesting attempt in October at wetland 28240. No chicks raised. A pair observed nesting in October at wetland 29460 (VWI 28916).	Two pairs of Brolga observed during the non-breeding season in January and one pair in February, March, May and June foraging at wetland 29402 (VWI 28966). A pair with their fledgling observed in February foraging at wetland 28278. A pair of Brolga observed foraging in May in the overflow swampy area of wetland 29405. During the breeding season a pair of Brolga observed foraging in November at wetland 29402 (VWI 28966). No breeding activity observed. A local landholder reported 10 Brolga foraging in November at a an adjoining property to the north of the wind farm.

4.2.4. Brolga behaviour and movements

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.

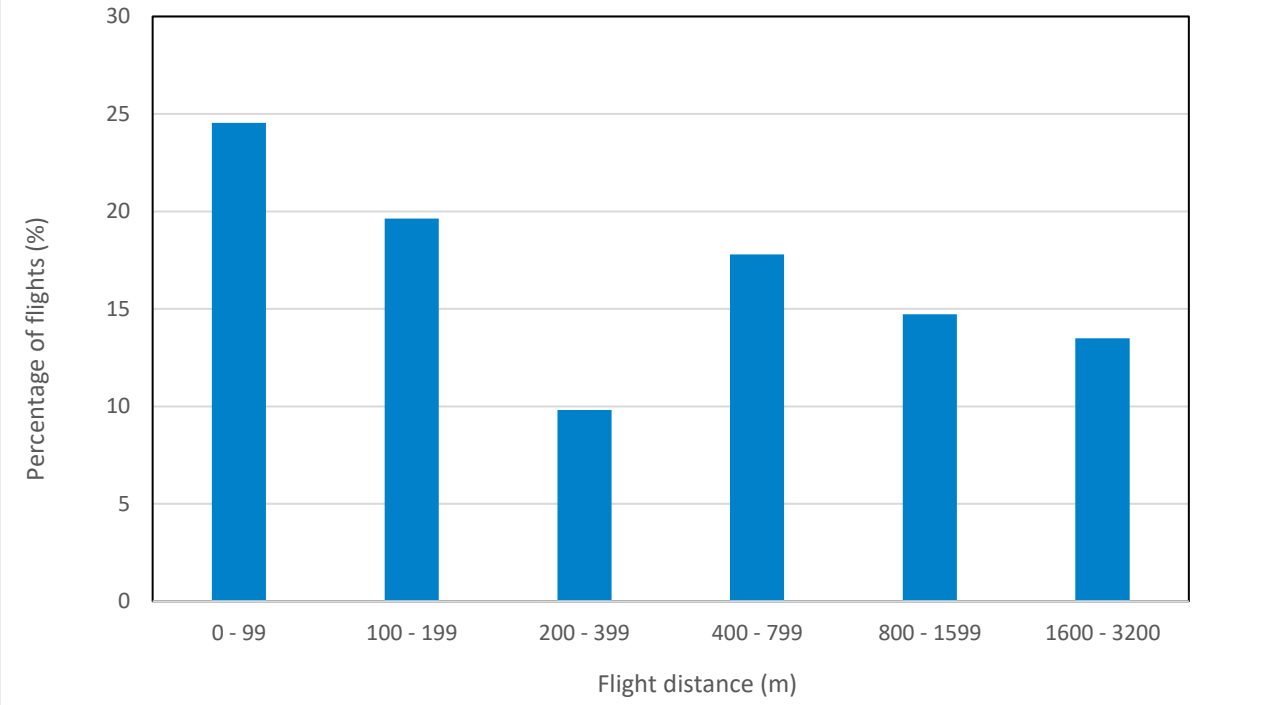


Figure 5: Distance of breeding Brolga flights from 24 breeding wetlands (2007 – 2015, n = 163)

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 (Figure 6).

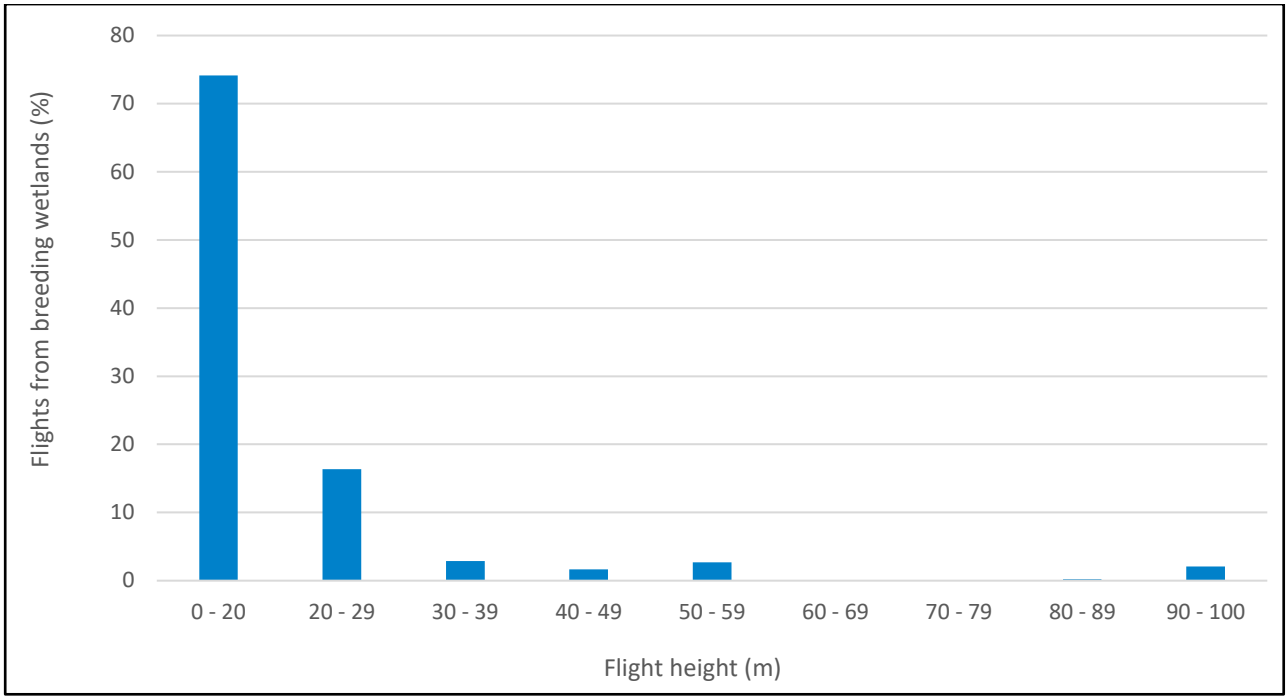
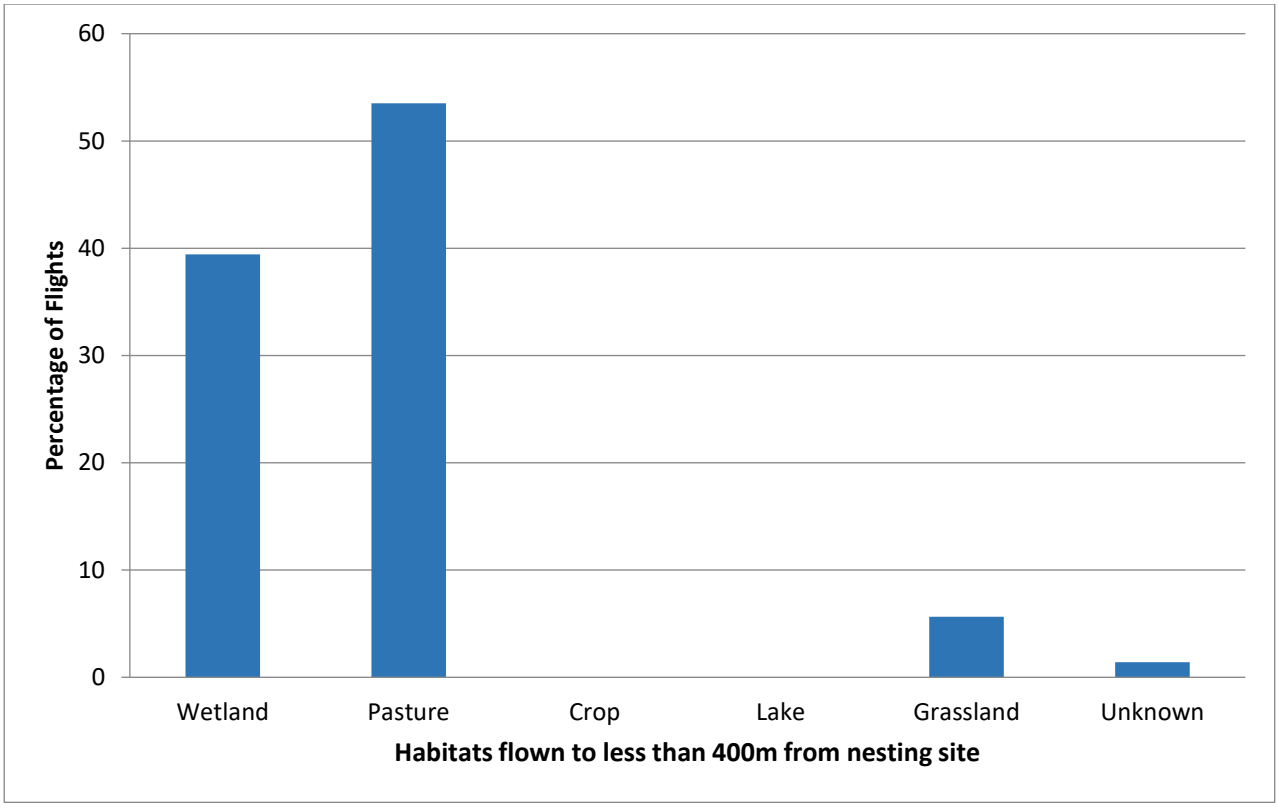


Figure 6: Height (m) of Brolga flights from breeding wetlands (n = 67)

The Nature Advisory dataset also includes data on habitat type at the flight destination. 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 (supports native grass species) and crop (canola or cereal).



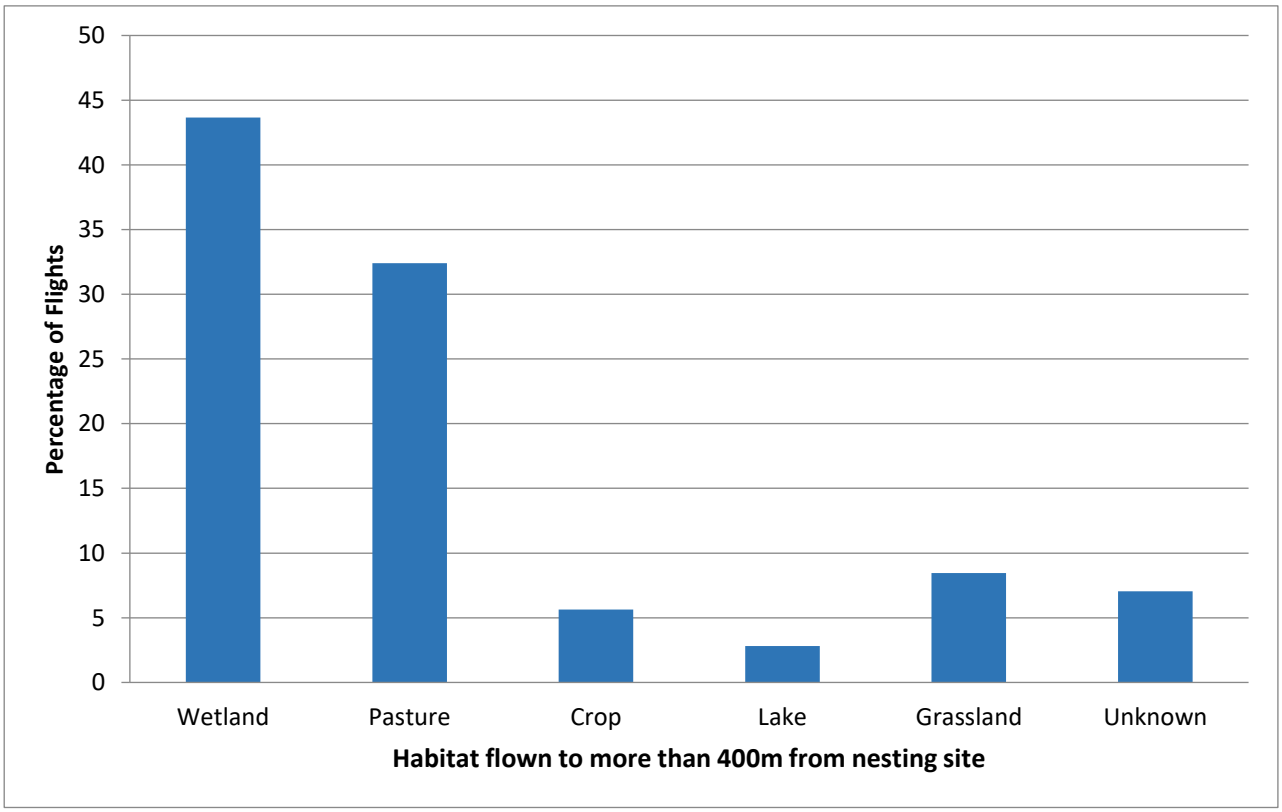


Figure 7: Habitats at flight destination from breeding wetlands (n = 99)

Brolgas did not show a preference for wetlands when flying up to 400 metres from their breeding site. Observations indicated that when moving over 400 metres from the breeding site Brolga demonstrate 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)[1]. 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 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.

Veltheim *et al.* (2019) showed that 95% of Brolga observations were within 1,369 metres from night roosts[2] to daytime foraging areas and that their home range varied from 70 to 523 hectares. A spatial model was then used 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. For previous projects DELWP 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 breeding wetlands found by Veltheim *et al*. (2019) 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.

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 a particularly valuable additional data set for assessing impacts and designing mitigation measures, such as turbine-free buffers.

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 duration has also been previously confirmed by DELWP as the minimum that would support a successful Brolga breeding attempt (in litt. to Wind Prospect via email dated 24th June 2020).

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).

[1] 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)

[2] 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.

They use the emergent vegetation for nest building and it 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 the Brolga chick satellite tracking data 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). Both breeding and nearby foraging wetlands provide food to support a successful breeding outcome and Veltheim *et al*. (2019) found that optimum breeding success occurred where 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. Night-time roosts 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 later). 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 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.

Wetland assessment

A total of 206 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 8. Many wetlands assessed (62%) were deemed unsuitable for Brolga habitat due to changes in hydrological regimes or inaccurate wetland mapping. A total of 79 wetlands (38%) were assessed as functional wetlands suitable for Brolga habitat. Hydrological assessment of wetlands within the wind farm enabled a more refined wetland assessment to be completed to inform the avoid and mitigate impacts on Brolga through the development of turbine free buffer zones.

Table 8: Summary of the functional wetland assessment

Wetland assessment	No. of wetlands	% of wetlands
Drained, too small or inaccurately mapped	127	62
Functional wetland	79	38
Total	**206**	**100**

Many wetlands in the RoI were dry during the survey, or had been dry for many years, as they had been permanently drained and converted to agricultural use. These sites no longer held water and were considered unsuitable as Brolga habitat. Brolga were observed once foraging at a drained wetland next to a breeding site. No other drained wetlands were observed to be used by Brolga.

Of the 206 wetlands assessed, 79 wetlands were considered further as they were found to be functional hydrologically and not seriously damaged by draining and agricultural development.

Hydrological wetland assessment

The undulating landscape of the HWF site and its surrounds created challenges in reconciling the landscape 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. Water Technology (Hydrological specialists) 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 8).

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 2021) as per the parameters above. The Water Technology (2021) report is presented in Appendix 4 .

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 making the hydrological modelling a conservative model of wetlands suitable for Brolga breeding (i.e., more likely to over-estimate than underestimate suitability).

The more accurately defined wetland boundaries meant the movement of Brolga could be more accurately predicted. This in turn helped to develop turbine free buffer zones around wetlands that the Brolga was likely to utilise while traversing across the landscape to other foraging areas from the breeding site. Figure 8 presents the wetland layer used for this assessment and states whether the wetlands were considered to be functional or unsuitable for Brolga habitat (Water Technology 2021).

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 hydrology assessments found that within in or close to the boundary of the proposed Hexham Wind Farm there were 27 farm dams and 19 wetlands that met the hydrological criteria (Water Technology 2021). Subsequently, Nature Advisory (2020) assessed these farm dams and wetlands that met the hydrology criteria to provide suitable Brolga breeding habitat. 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), as well as cover for chicks from predators. Two farm dams and 16 wetlands were considered to be functional wetlands, likely to provide suitable habitat for Brolga breeding and night-time roosting based on the hydrological modelling and field assessment (Appendix 5).

Figure 8: Redefined wetlands with wetland numbers

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 24/01/2022

- Wind farm boundary
- Radius of Investigation
- Hopkins River
- NA assessed wetlands
- Hydrology assessment wetlands

Brolga habitat

- Functional wetlands
- Unsuitable

8 Hydrologist assessed wetland number

9 VWI wetland number

A Nature Advisory assesed wetland labels

HOPKINS RIVER

N

Metres
0 2,200

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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 (2004) 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 - 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 VBA Brolga breeding records in the south-western 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 9), less than 100 hectares (Figure 10) and less than 10 hectares (Figure 11).

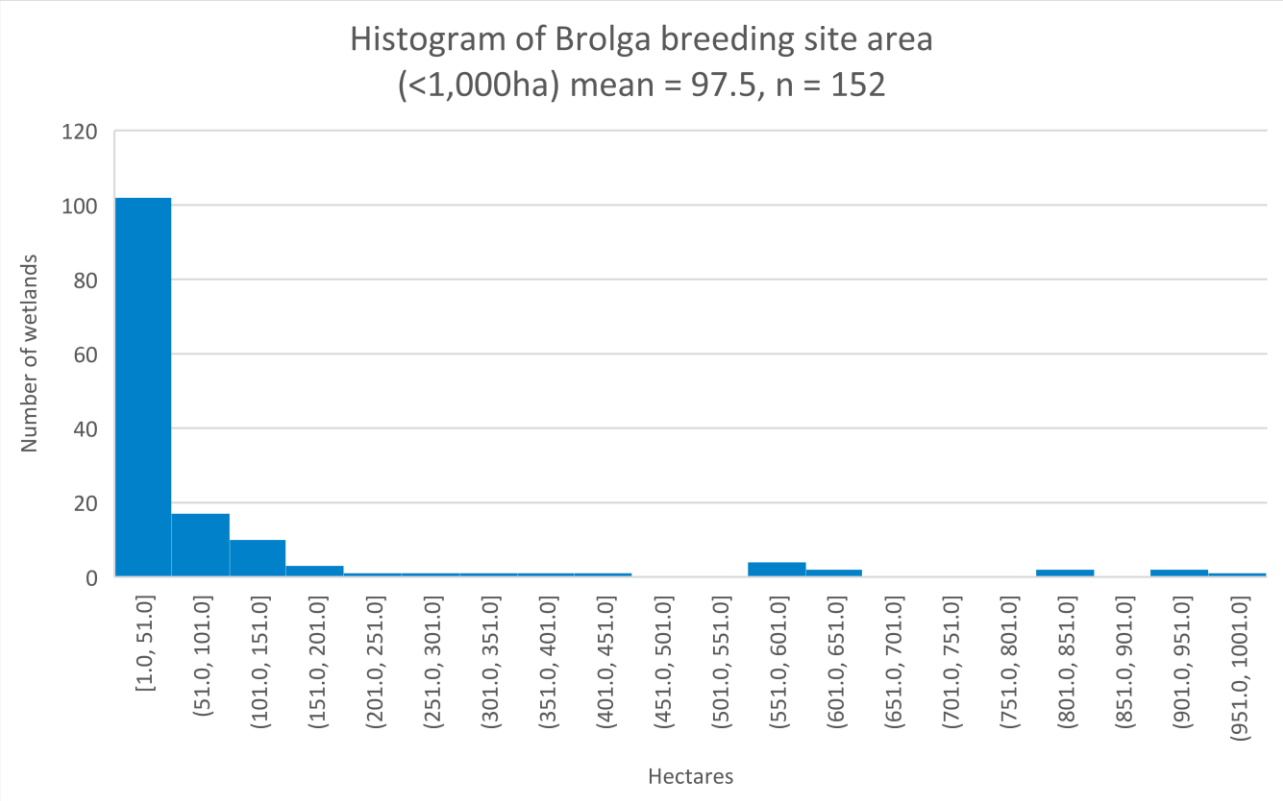

Figure 9: Brolga breeding wetlands less than 1,000 hectares

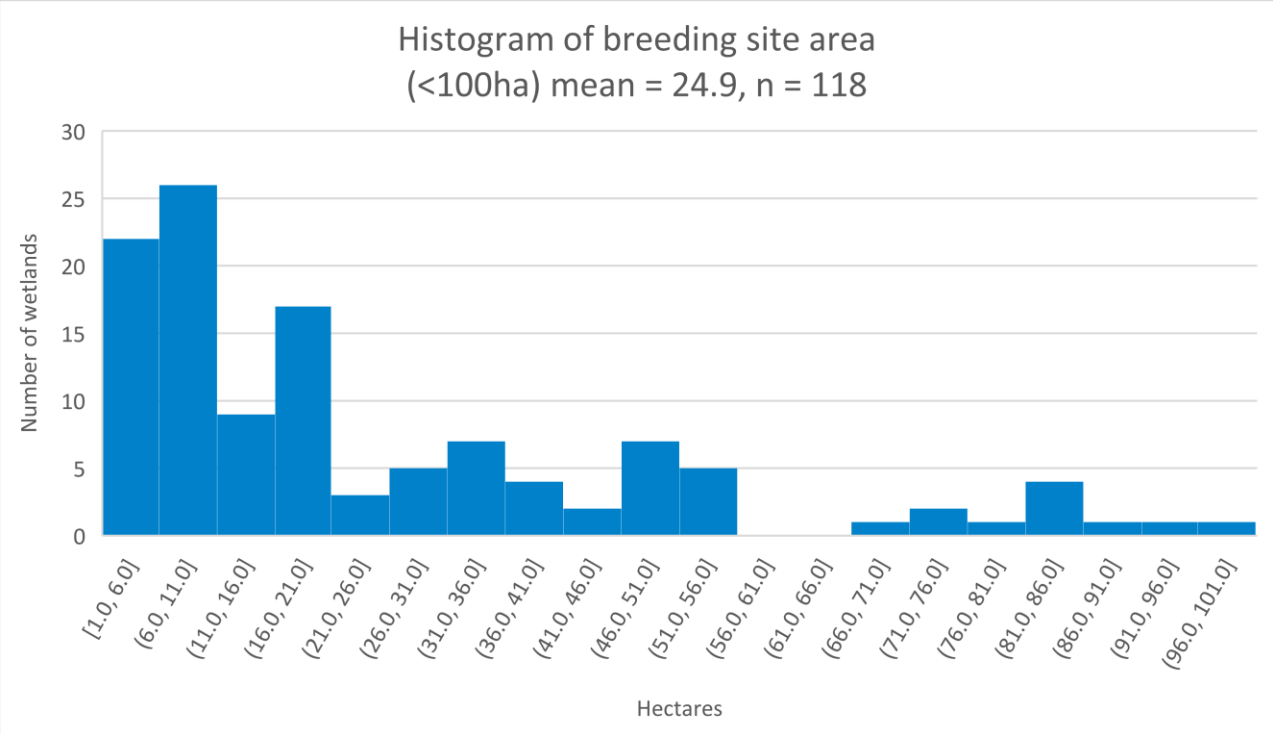

Figure 10: Brolga breeding wetlands less than 100 hectares

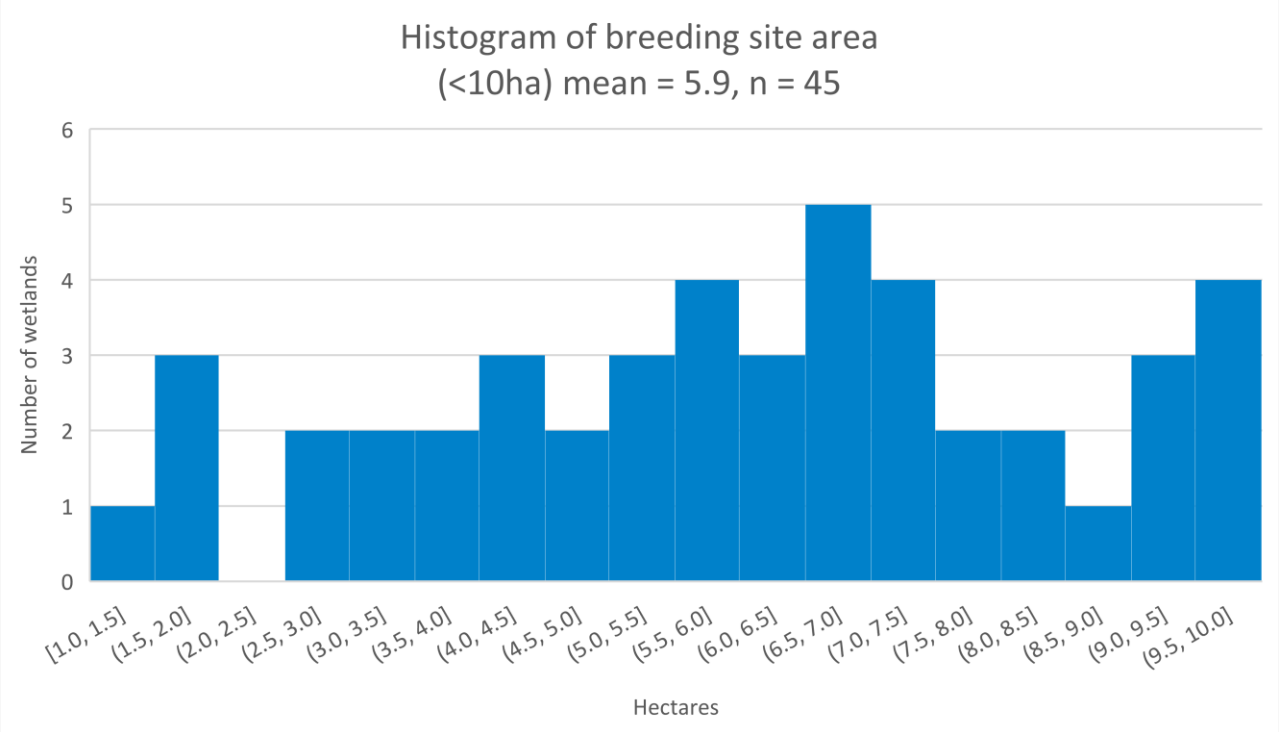

Figure 11: Brolga breeding wetlands less than 10 hectares

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.

4.2.6. Brolga breeding wetlands

An analysis was undertaken on wetlands that are likely to provide breeding habitat for Brolga based on the review of existing information, previous breeding records from databases, landholder interviews, ground truthing, and hydrological modelling (Appendix 3). A total of 26 sites were confirmed as likely to provide breeding habitat for Brolga based on these criteria. An assessment was undertaken to determine if these previous Brolga breeding sites were likely to provide Brolga breeding habitat in the future (Table 9). A site was considered unlikely to provide breeding habitat in the future if there was no wetland present or if the wetland had been permanently drained and/or was unable to remain inundated for a minimum of 120-days.

Of the 26 breeding sites 23 were considered likely to continue to provide Brolga breeding habitat in the future given the condition and flow regime of the wetland and three sites were considered unlikely to support a breeding pair of Brolga in future (Table 9). Breeding activity was confirmed at nine of these wetlands during the level two assessment (2018-2020) and landholders confirmed an additional two wetlands where Brolga nested during this time.

In the Level Three assessment, wetlands that have been identified as likely to provide Brolga breeding habitat in the future (Figure 12) will need to have appropriate turbine free buffers around them to protect the habitat and the Brolga that reside within them.

Table 9: Analysis of Brolga breeding wetlands

Wetland number	Redefined wetland number	Past breeding record	2018	2019	2020	Likelihood of future breeding attempt	Likelihood
A		Local landholder (no date specified)				Wetland has been drained, unlikely to hold water for long periods.	Unlikely
D		2008 (VBA and local landholder)				Likely to continue to provide breeding habitat.	Likely
E		Local landholder observation (no date specified)				Small wetland along a creek. Plausible to continue to provide breeding habitat in the future.	Likely
H			Landholder Observation	Landholder observation		Large drained wetland with scattered dams which holds water and vegetation in rainy years, allowing Brolga to breed.	Likely
J		Local landholder observation (no date specified)				No wetland at point indicated by local landholder. Hydrologist analysis indicates that the area indicated does not meet the minimum inundation period.	Unlikely
	9	2008 & 2007, (VBA, local landholder)			Nature Advisory record	Regular nesting site. Likely to continue to provide breeding habitat in the future.	Likely

Wetland number	Redefined wetland number	Past breeding record	2018	2019	2020	Likelihood of future breeding attempt	Likelihood
	29401	Local landholder (no date specified)				A deep well inundated dam. Contains an island with a tree. No emergent vegetation in water. May be viable for breeding in some years. No visible emergent vegetation. Hydrology report suggests it meets minimum inundation period.	Likely
	29405	2009 (local landholder observation)				Observation of nesting once in the south-eastern section of the dam in the shallows.	Likely
25651		1991 (VBA record)				From aerial, wetland shows emergent vegetation and seasonal flooding. Neighbouring semi-drained wetlands present.	Likely
25656				Nature Advisory record		Medium sized wetland with good cover of surface water and emergent vegetation.	Likely
28203		1/01/1984 (VBA literature report)				Wetland has been permanently drained and is no longer suitable habitat for breeding purposes.	Unlikely
28240					Nature Advisory record	Likely to keep providing breeding habitat in the future.	Likely
28245	29420			Nature Advisory record	Nature Advisory record	Medium wetland holding water during breeding season and covered in high emergent vegetation. Likely.	Likely
28249	23				Nature Advisory record	Large wetland holding water during most of the breeding season, abundant emerging vegetation. Likely to keep providing breeding habitat in the future.	Likely
28252	29411	1/01/1984 (VBA literature report and local landholder)				Large wetland that regularly holds water. Likely to continue to provide breeding habitat for Brolga.	Likely
28259		Local landholder observation (no date specified)				Wetland half drained. Northern end of wetland looks to hold water and provide emergent vegetation for breeding.	Likely
28261	29414	Local landholder observation (no date specified)				Wetland present, likely to continue to provide breeding habitat for Brolga.	Likely
28264	29416	Record from EHP report				Wetland present, holds water and has emergent vegetation. Likely to continue to provide breeding habitat for Brolga.	Likely

Wetland number	Redefined wetland number	Past breeding record	2018	2019	2020	Likelihood of future breeding attempt	Likelihood
28267	29415	Local landholder observation (no date specified)				Large wetland with some drainage. From aerial photography suitable breeding habitat for Brolga.	Likely
28282		2007 (VBA)		Nature Advisory record		Brolga breed regularly at this wetland (Mortlake Common).	Likely
28366		2008 (VBA and local landholder)		Nature Advisory record		Large wetland that holds water. Likely to continue to provide breeding habitat in the future.	Likely
28916	29460			Nature Advisory record	Nature Advisory record	Large wetland fenced off from livestock, holds reasonable water levels throughout the breeding season, and emergent vegetation covers most of the wetland.	Likely
28966	29402	Local landholder record from EHP report				Likely to continue to provide breeding habitat in the future.	Likely
29047	29404	1/01/1987 (VBA and local landholder)				Likely to continue to provide breeding habitat in the future.	Likely
30330	20			Landholder observation		Likely to continue to provide breeding habitat in the future.	Likely
30336			Local landholder observation	Nature Advisory record		Farm dam with permanent water and emerging vegetation. Confirmed Brolga breeding site.	Likely

Figure 12: Confirmed brolga breeding wetlands

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 25/01/2022

Wind farm boundary
Radius of Investigation
Hopkins River

Wetland likely to provide breeding habitat in the future

Likely
Unlikely

Brolga records

EHP
Landholder
NA
VBA

8 Hydrologist assessed wetland number

9 VWI wetland number

A Nature Advisory assesed wetland labels

30336
29460
20
29402
29404
29401
23
29420
29405
J
29414
29411
29415
H
28282
28203
A
HOPKINS RIVER
29416
25651
28240
9
D
28366
25656
28259
E

N

Metres
0 1,400

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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 Hexham 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 will be 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).

Steps two to four remain to be completed. The purpose of the report is to accompany the EES Referral with the final Brolga impact assessment to appear in the EES, which will include the remaining three steps.

5.1. Potential impacts

Wind farms may impact on Brolgas in four 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 can 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 is approximately 45 kilometres west from the Hexham Wind Farm and were monitored in 2018, 2019 and 2021 for a separate project by Wind Prospect 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 showing this are provided in Appendix 6.

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 metres 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.

5.1.1. 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 the key habitats listed below.

- Confirmed or valid historical breeding wetlands used for breeding and night roosting
- Non-wetland areas around breeding wetlands used for foraging
- Functional wetlands used for foraging and/or alternate night time roosting within two kilometres of breeding wetlands
- Movement corridors between breeding wetlands and functional wetlands.

Turbine-free buffers were informed by knowledge of the movements of Brolga around breeding sites 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 incorporated the most recent research on Brolga behaviour in south-west Victoria undertaken by Veltheim *et al*. (2019). This research was undertaken so that land managers and decision makers can use the results to inform the development of turbine free buffer zones around Brolga breeding and flocking sites. Information on the movement of birds around breeding sites is relevant to the Hexham project.

Turbine free buffers include the following:

- The home range of the Brolga (defined based on movement patterns of the species according to Veltheim *et al*. (2019) and based on flight data collected on breeding pairs in south-western Victoria – see below); and
- An extra area comprising, a 300-metre disturbance buffer plus the 95-metre turbine blade length buffer.

Brolga breeding and roosting wetlands

Brolga breeding and roosting wetlands were identified as part of Level 2 assessments (see Section 4). These have been identified in Figure 8 and confirmed Brolga breeding wetlands are presented in Figure 12.

While functional wetlands did not necessarily have Brolga breeding records associated with them, they were considered potential sources of food and therefore likely to form part of the home range around the 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.

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 wetland complexes where wetlands are in close proximation to one another, the hydrological investigation of Water Technology (2021) identified and mapped the 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). Home ranges have been generated for each confirmed breeding wetland within the complexes. The combined home ranges across wetlands in these parts of the site were used as the basis for a turbine-free buffer for wetland complexes.

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 the edge of breeding wetlands was therefore used to develop turbine-free buffers, as described in the next sub-section. All Brolga breeding wetland located within 2,000 metres of proposed turbines are presented in Figure 13 and have turbine free buffers protecting them (discussed later in this section).

The Brolga breeding wetlands and functional wetlands that are within 2,000 metres of each other are treated as wetland complexes. A single turbine-free buffer was created around these wetland complexes to allow barrier-free movement between breeding wetlands, functional wetlands and non-wetland foraging areas.

Figure 13: Wetland locations within 2km of proposed turbines

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 2/03/2022

- Wind farm boundary
- Development footprint
- 2km radius of proposed turbines
- Confirmed breeding wetland
- Functional wetland
- Unsuitable wetland
- 8 Hydrologist assessed wetland number
- 9 VWI wetland number
- A Nature Advisory assesed wetland labels

N

Metres
0 1,200

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Defining Brolga breeding home ranges

This sub-section describes how Brolga breeding home ranges were delineated. The home range includes the first two components of the turbine free buffer and represents the area within which Brolgas are to occur more frequently throughout their breeding season. It includes two components:

- Grouping functional wetlands within 2,000 metres of confirmed Brolga breeding wetlands which form a wetland complex; and
- A 400-metre buffer around each functional and breeding wetland within a complex.

These components are described below.

As wetlands provide greater food resources for Brolga, **wetland complexes** combined with the intervening non-wetland terrestrial habitat are considered sufficient to provide adequate resources for successful breeding and formed the core of the defined home range. The method for determining Brolga home range for wetland complexes 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 Brolga 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). These wetlands and the terrestrial habitat between them were considered the areas in which Brolga was most likely to move to forage or roost (as illustrated in Figures 2 & 3 of the Veltheim *et al.* (2019) study). Areas still functioning as wetlands (holding water for at least 120 days) can provide additional foraging areas for Brolga away from their 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 around the breeding wetland and each functional wetland, **a 400-metre buffer** is provided that encompasses the majority of Brolga flights from nesting wetlands based on Nature Advisory movement data in Section 4.2.4 (as per 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. The home ranges mapped from the 18 confirmed and valid breeding wetlands on or within five kilometres of the wind farm boundary have an average of 3.6 wetlands within each home range. This ensures that plenty of food resources are available to maximise breeding success.

Home ranges also encompass non-wetland habitat areas between these buffers for wetlands that are two kilometres or less apart. Functional wetlands within the home range that are greater than two kilometres apart are unlikely to have Brolga movements directly between them (given the Veltheim *et al*. 2019 findings) so the home range boundary is drawn between the outer limits of the 400 metre buffers to delineate the home ranges between wetlands within two kilometres of one another. This explains why the home range map in Figure 14 does not follow straight lines encompassing all wetlands associated with the wetland complex breeding sites. Rather, it follows the zones of greatest between-wetland movement (i.e. functional wetlands within two kilometres and their associated 400-metre buffers).

Non-wetland habitat that Brolga are most likely to utilise is either within 400 metres of a functional wetland or between two wetlands within 2,000 metres of one another (as observed in Figures 2 & 3 of the Veltheim *et al.* (2019) study). The above method ensures that non-wetland areas most likely to be utilised by Brolga are included in the breeding home range.

Isolated Brolga breeding wetlands (> 2 km from another wetland)

Brolga also breed in wetlands that are isolated from other wetlands by more than two kilometres. No such wetlands occurred within two kilometres of a proposed wind turbine at the Hexham Wind Farm so defining a home range was not required. That said, observational data found in the Veltheim *et al*. (2019) study that 95% of the movements of Brolgas around their breeding wetland were to 1,369 metres. Where there are no nearby wetlands (i.e. part of a wetland complex) to attract breeding Brolgas from their breeding wetland, this distance is assumed to encompass the likely home range of a Brolga in an isolated wetland. No turbines at the proposed Hexham Wind Farm are located within this distance of confirmed isolated, Brolga breeding wetlands

Figure 14: Brolga home range

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 2/03/2022

- Wind farm boundary
- 2km radius of breeding site
- Confirmed breeding wetland
- Functional wetland
- Unsuitable wetland
- 400m buffer around suitable wetlands
- Brolga home range
- 8 Hydrologist assessed wetland number
- 9 VWI wetland number
- A Nature Advisory assesed wetland labels

N

Metres
0 1,000

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Brolga home range extent

Table 10 below summarises the extent of each of the 10 Brolga home ranges delineated for the Hexham Wind Farm using this technique.

Table 10: Area of predicted home range for each confirmed Brolga breeding wetland

Wetland (home range)	Area (ha)
9	428.455
20	776.563
23	336.284
28240	215.849
29401	1620.67
29402	1683.73
29405	693.428
29420	858.22
29460	1211.8
D	282.087

Veltheim *et al*. (2019) found Brolga home ranges vary in extent from 70 to 523 hectares. The home ranges mapped for the breeding wetlands at Hexham Wind Farm are all larger than 70 hectares, four are within the 70 to 523 hectares and the remaining five are all over the 523 hectares with the largest home range being 1,683.73 hectares. As half of the Brolga home ranges calculated for this assessment are above the largest Brolga home range identified in the Veltheim *et al.* (2019) study, the delineated home ranges used to define turbine free buffers at the Hexham Wind Farm can 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.

- Of the 18 Brolga breeding wetlands an average of 3.6 wetlands have been included in each of the home ranges. Veltheim et al. (2019) have stated that three wetlands are required for successful breeding
- The areas of all 18 home ranges are within the 70 to 523 hectares home range or larger. With the vast majority being considerably larger than any of the home ranges observed in the Veltheim *et al*. (2019) study. The areas of home ranges calculated for the Hexham Wind Farm project are from 215.85 to 1,683.73 hectares compared with 70 to 523 hectares in the Veltheim *et al*. (2019) study.

In conclusion, the home ranges determined for the 18 breeding wetlands used by Brolgas that breed near the Hexham 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.

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 Hexham 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. This is shown for all breeding sites on and near the Hexham Wind Farm in Figure 15, 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 eight percent of all Brolga flights are at the proposed height of wind turbines blades at the Hexham 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 (Appendix 6).

At Wetland 25650 (Appendix 6), 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 the adult pair 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 (Appendix 6), 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 Hexham 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.

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 Hexham Wind Farm are consistent with this and are considered appropriate to ensure continued breeding success by Brolga pairs that use the wetlands near the proposed wind farm.

Figure 15: Turbine free buffer for the Hexham Wind Farm project

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 2/03/2022

- Wind farm boundary
- Development footprint
- Confirmed breeding wetland
- Functional wetland
- Unsuitable wetland
- 400m buffer around suitable wetlands
- Brolga home range
- Disturbance buffer (300m)
- Turbine free buffer (incl 95m blade buffer)
- 8 Hydrologist assessed wetland number
- 9 VWI wetland number
- A Nature Advisory assesed wetland labels

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 11 below summarises some statistics for these projects and presents the same statistics for Hexham Wind Farm.

Table 11: Brolga breeding statistics for different wind farms in south-west Victoria

Project	No, Brolga breeding sites 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
Hexham	23	8	18

The comparison in Table 11 shows that the overall Brolga risk profile for this wind farm is comparatively low, with less than three percent of the southeast Australian Brolga population breeding within the 10-kilometre RoI around the proposed wind farm. Several Brolga pairs breed within or close to the wind farm project boundary triggering the requirement for turbine-free buffers. All other breeding pairs during the monitoring period were more than five kilometres away from any proposed wind turbines. This information indicates that Brolga pairs may use up to 18 breeding wetlands on or 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 by flight behaviour data gathered by Nature Advisory (over 15 years) in southwestern Victoria. These monitoring observations of 24 breeding Brolga pairs showed that approximately six percent of flights were estimated to be above the minimum tip height of 40-metres, with the remaining 94 percent below that height (see Figure 6).

6. Overview of findings

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

Brolga Flocking

- No Brolga flocking activities were observed in the RoI during the flocking season survey in the period 2018 - 2020. The proposed wind farm is approximately 20 kilometres from the nearest known flocking site
- No traditional flocking sites were identified in the RoI through the desktop study or community consultations
- There is currently no evidence that Brolga use the RoI regularly as a flocking site and therefore no impact on Brolga flocking sites is likely from the project.

Brolga Breeding

- There is evidence of Brolga using wetlands within the RoI for breeding
- Two pairs of Brolga were observed breeding within the RoI during the 2018 Brolga breeding surveys, eight pairs in 2019 and five pairs in 2020.
- In the period 2018-2020 three wetlands were used by Brolga for breeding within the wind farm boundary. These wetlands were:
    - Wetland 29420 – August 2019 (Incubating)
    - Wetland 28240 – October 2020 (Nesting)
    - Wetland 23 – September 2020 (Nesting).
- Two additional wetlands within the wind farm have previous Brolga breeding records observed by local landholders. Wetlands 29401 and 29405 were reported to support Brolga breeding activities. Brolga were sighted at wetland 29405 during the monitoring period though breeding activities were never confirmed. These two wetlands are likely to continue to provide Brolga breeding habitat in the future.
- Two areas within the wind farm boundary were reported to have been used for breeding Brolga in the past by a local landholder. These two areas are marked as wetlands A and J. Wetland A has been permanently drained and the area identified as wetland J is not a wetland and does not meet the minimum inundation period of 120-days. These two areas are considered highly unlikely to provide Brolga breeding habitat in the future.
- Eighteen wetlands outside the wind farm boundary and within the RoI were confirmed as having Brolga breeding activities or had previous records of Brolga breeding at them and were considered likely to provide Brolga breeding habitat in the future.
- One wetland outside the wind farm boundary and within the RoI (wetland 28203) had a previous Brolga breeding record nearby in the VBA. This wetland has since been permanently drained and considered unlikely to provide Brolga breeding habitat in the future.
- Given that there are Brolga breeding at wetlands within the wind farm boundary and outside the wind farm boundary particularly to the north and east, a level three assessment was triggered and will need to be implemented.

- A total of 23 wetlands were considered as likely to continue to provide breeding habitat in the future of these, 10 were located within 2,000 metres of proposed turbine locations at the Hexham Wind Farm.
- Mitigation of risks to the Brolga involves the establishment of turbine free buffers around 10 Brolga breeding wetlands on and near the wind farm.

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Appendix 1: Community Questionnaire

Community Survey Questionnaire- Hexham 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 Hexham 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: Total and mean rainfall for the region taken from Mortlake (BOM 2021)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2010	23.6	78.8	57.2	50.8	31.8	51.4	40.6	167	65.6	70.2	64.8	129	830.8
2011	134.4	87	63.2	55	66.2	59.6	58.8	41	43.6	39	39.2	15.4	702.4
2012	17	3.6	45	30.2	55.8	57	92.4	74.6	55	46	26	45	547.6
2013	1.6	22.6	16.6	11.6	60.8	63.8	66.8	106.4	60.6	85.4	39.4	24.2	559.8
2014	30.4	7.2	19	69.4	35.6	100.4	59.2	39.4	23.6	18	36.6	20.8	459.6
2015	65.6	36.2	45.8	23.6	64.8	38.2	58.2	40.6	35.2	12.8	19.6	29.2	469.8
2016	37	17.6	31.6	37.6	102.4	62.8	103	51.4	119.8	95.4	38	32.6	729.2
2017	42.8	37.8	40	117.2	52.2	12	48.2	71.8	69.6	42.4	83.4	24.4	641.8
2018	13	17	21.2	23	104.4	61.8	65.4	57.4	23.4	14.8	39.6	39	480
2019	5.6	23.4	33.2	12.4	132	92.2	67.4	82	55.6	51	42.6	18.2	615.6
2020	19.2	75.2	18.6	67.6	88.4	49.6	27.2	74.6	94	101.6	71.2	42.6	729.8
2021	93.8	8.4	24.2	36.4	68	67.2	71.8						
Mean	**35.1**	**32.2**	**31.2**	**43.9**	**58.5**	**52.7**	**62.5**	**66.6**	**58.1**	**51.8**	**49.1**	**40.3**	**582.3**

Appendix 3: Summary of wetland assessment from 2018-2020 for the ROI

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
A		(Local landholders)	Suitable	Black Swan nesting at this site suggesting suitability.
B	29401	(Local landholder).	Suitable	A well inundated dam. Contains an island with planted trees. No emergent vegetation. Possible breeding habitat in times when dam floods. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
C	9	2007 (Nature Advisory VBA record) and local landholder, 2020 (Nature Advisory).	Suitable	Some emergent vegetation present, with a reasonable coverage of water. Water >70% throughout breeding season.
D		2008 (Nature Advisory VBA record, and local landholder).	Suitable	Wetland is present.
E		(Local landholder).	Suitable	Wetland is present.
F	29405	2009 (local landholder).	Suitable	Permanent waterbody. Fenced off from stock. Contains planted eucalypts and associated veg on the fringes. Phalaris up to the edge. N arm of wetland holds a suitable swampy area covered in emerging vegetation. Water levels in some areas may be suitable. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
G			Suitable	Water levels decrease until >50% towards the end of the breeding season
K (Muston Creek)				Muston Creek on Cameron property - Was completely inundated in November. Observed to be utilised by Brolga in November but no evidence of breeding occurred there.
H		2018 & 2019 (landholder).	Suitable	Large drained wetland with scattered dams which holds water and vegetation in rainy years, allowing brolgas to breed. Likely.
20320			Unsuitable	Part of a watercourse.
25640			Suitable	Found to be holding water during time of aerial survey. Large in size.
25642			Unsuitable	Part of a waterway.
25648			Unsuitable	Found to be drained during aerial survey.
25649			Suitable	Large drain that held water at 50% capacity during aerial survey.
25651		1991 (VBA)	Suitable	Black Swan seen to be nesting here during aerial survey.
25652			Unsuitable	Consists of Melaleuca swamp.
25654			Unsuitable	Found to be drained during aerial survey.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
25655			Suitable	Black Swan seen during aerial survey.
25656		2019 (Nature Advisory)	Suitable	Brolga seen nesting during aerial survey.
25681			Suitable	Large wetland, but currently the area of standing water is well below capacity, and dry by October. Some emergent veg, but little in extent. Cattle are currently excluded from the site and are present in neighbouring paddocks.
26008			Unsuitable	Waterbody is a farm dam.
26012			Suitable	Large dam containing fringing veg.
26014			Unsuitable	Found to be a dam during aerial survey. Some birdlife present.
26967			Suitable	Black Swan nest found during aerial survey.
28200			Unsuitable	Water below minimum capacity. Appears drained, with sheep present in the wetland area.
28201			Unsuitable	No wetland present, with drainage channel observed.
28202			Unsuitable	Site does contain water, moist but not holding any water by October. Unlikely to hold sufficient water for Brolga breeding this season. Records of Latham's snipe and good habitat for it. Serves more as a watercourse than wetland.
28203		1984 (VBA literature report)	Unsuitable	No wetland at point though likely to refer to wetland 28203. From aerial photography the wetland looks to be drained and most likely unsuitable for breeding Brolga.
28207			Unsuitable	The wetland has been drained and the area now holds pasture for cattle. Several small dams across the wetlands original extent still hold water but do not support wetland vegetation. Only introduced pasture grasses visible.
28209			Unsuitable	Wetland was drained and now holds pasture for cattle grazing.
28210			Unsuitable	Drained wetland
28212			Unsuitable	Wetland was drained and now holds pasture for cattle grazing. Does not support any wetland vegetation, only pasture grasses.
28213			Suitable	Drained wetland which currently only holds notable water within drainage channel. Reasonable amount of tussock cover present around drainage line. Still held water at the time of aerial surveys.
28214			Unsuitable	Wetland was drained and now holds pasture for cattle grazing. Does not support any wetland vegetation, only pasture grasses.
28215			Unsuitable	Wetland is drained and 'improved' for pasture
28223			Unsuitable	Wetland is drained and 'improved' for pasture, still holds a small farm dam in the centre of the original extent with very little wetland vegetation. The wetland could hold water in a wet year. Grazed by cattle and sheep.
28224			Unsuitable	Drained. Several drains and a gravel road bisect the wetland. The remaining extent has been 'improved' for pasture. Some thistles are present throughout. No waterbirds were present.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
28226			Unsuitable	Found to be drained during aerial survey.
28227			Unsuitable	Wetland was drained and dry. Now holds pasture for cattle grazing. Does not support any wetland vegetation, only pasture grasses.
28230			Unsuitable	Wetland was drained and dry and now holds pasture for sheep and cattle grazing. Does not support any wetland vegetation, only pasture grasses.
28231			Suitable	Good wetland, water 50%. Grassy plant cover on edges and covering the main wetland in some parts, dry by November. Unlikely to have the depth required for Brolga breeding in a wet year (no water plants evident). Seen to be partially drained during aerial surveys.
28235			Suitable	Brolga presumably walks into this wetland but due to road conditions I cannot check it. Open creek line with good tussocks and abundant water birds and herons. Was dry by November. There's also a dam just east of the wetland with minimal vegetation that supported some waterbird species
28236	18		Suitable	This wetland was an open freshwater marsh with some emergent and extensive low fringing vegetation. Supports approximately 12 pairs of Black Swan, with potentially one old nest on site. Likely to be too shallow for Brolga nesting most years. Grazed by cattle. The wetland held water until the last survey in December. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28237			Unsuitable	Largely drained and would rarely be inundated. The drain line held some water but was otherwise dry and surrounded by crop.
28238			Unsuitable	Largely drained and converted to wheat crop except immediately adjacent to drain whereby vegetated with rushes. Some water in drain (approximately 20m wide). Masked Lapwing present.
28239			Suitable	Wetland was holding water during aerial surveys, with 5 Black Swans found to be present.
28240		2020 (Nature Advisory).	Suitable	Very good wetland covered in emergent vegetation (rush-water ribbon). Water looks about 70% in December. Drainage from northern dam feeds this wetland. Tussock grasses and rocks are emergent in standing water across the site. Island of three trees present in centre. Pair foraging in NW side of wetland. Large nest just E close to the island.
28242			Unsuitable	Found to be drained during aerial survey.
28243	16		Suitable	Largely permanent waterbody. Little emergent veg present, only fringing. Would hold enough water for successful breeding. Down to 60% in December.
28245	29420	2019, 2020 (Nature Advisory)	Suitable	A Large marshy wetland, well vegetated with Poa Tussocks. Fenced (Landcare) and some sheep present but only lightly grazed. Breeding attempt in 2019. The wetland was still at 50% in December. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28247			Suitable	Wetland has been dammed. Permanently holds water.
28248			Suitable	Aerial surveys found a swan nest to be present. Habitat also includes billabongs.
28249	23		Suitable	A Shallow freshwater marsh containing extensive emergent vegetation for Black Swan to nest, (5 nests and cygnets seen). A pair of Brolga seen foraging and a large empty nest seen. Poa tussocks extensive on

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
				western side, but grazed. Waterbirds include Black Swan, Masked Lapwing, Yellow-billed Spoonbill, Black-winged Stilt, Pacific Black Duck, Grey Teal, White-faced Heron, Pink-eared Duck were present and Common Froglet. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28252	29411	1984 (VBA literature report and local landholder)	Suitable	Ephemeral wetland that could provide nesting habitat in a wet year. Partially drained as determined by aerial survey. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28256			Unsuitable	Wetland is drained and 'improved' for pasture. Sheep and cattle observed grazing.
28259		(Local landholder).	Suitable	Wetland half drained, northern half looks to hold water and have emergent vegetation. Likely to provide breeding habitat.
28261	29414	(Local landholder).	Suitable	Wetland still present, likely to continue to provide breeding habitat for Brolga. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28263	11		Suitable	Appeared to be drained. Held 30% by November and 10% by December. The extent is mostly pasture grasses with a small cluster of rush in the middle. A small creek flows through which held some water and vegetation and lined with River Red-gum. Confirmed to be drained by aerial survey. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28264	29416	Record from EHP report	Suitable	Power line development piling soil on its W side and lots of machinery around. 50% water in December and good fringe vegetation of tussocks and high grasses. May provide good habitat once works cease. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28265			Suitable	No access, they look suitable from aerial photography and they form part of a larger wetland system.
28266			Suitable	No access, they look suitable from aerial photography and they form part of a larger wetland system.
28267	29415	(Local landholder).	Suitable	Large wetland with some drainage. From aerial photography it looks like it is good breeding habitat for Brolga. One Black Swan observed during aerial survey. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28269			Suitable	Two Brolgas found to be present during aerial survey. View is very restricted from the roadside due to trees. But wetland is currently a large body of water that appears to be free of stock. Little to no fringing or emergent veg present. Appears at least semi permanent. No access (Tom Gubbins).
28270			Unsuitable	Initially not accessible. Found to be drained during aerial survey.
28271			Suitable	Initially not accessible. One Black Swan found to be present during aerial survey.
28273			Unsuitable	Wetland has been permanently drained and only a small dam remains. Currently surrounded by plantation.
28274			Unsuitable	Site was not accessible due to OH&S requirements. Appeared from the road to be in generally the same condition as it was in July .Habitat quality unclear, but looks to support a healthy amount of tussock vegetation which if inundated, would provide high quality breeding conditions for brolga.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
28275			Unsuitable	Drained
28276			Unsuitable	Drained
28278			Suitable	Wetland holding water during aerial survey, swans nesting.
28278			Unsuitable	
28281			Suitable	Wetland partially drained during aerial survey though still holding some water.
28282		2007 (Nature Advisory, VBA record), 2019 Nature Advisory	Suitable	Brolga pair successfully raised chick, last seen on December 2019 in the southerly section of this wetland. Good coverage of water with abundant emergent vegetation and tussock grasses surrounding the site. This site also supports several Black Swan pairs which also have bred.
28284			Suitable	Wetland holding water during aerial survey, swans nesting.
28285			Unsuitable	Completely drained
28293			Unsuitable	Drained
28348	107		Unsuitable	Drained. Appears to be former flooded creek flats that would have flooded after major rain. Now supports 'improved' pasture. Part of the wetlands original extent borders a creek. The creek mostly supports phragmites and planted eucalypts. The area is grazed by cattle.
28349			Unsuitable	Large grazed dam seen during aerial survey.
28350			Unsuitable	Site surrounded by trees.
28351	108		Unsuitable	A large dam with steep banks and deep water. Supports no fringing, floating or emergent vegetation. Grazed in surrounding paddocks by sheep.
28352	102 & 103		Unsuitable	River meander floodplain with good vegetation cover but no water. No standing water visible beyond large built up dams with steep banks. Lacks most resources required for breeding. Cattle present. Both drained and dammed.
28353			Unsuitable	Small farm dam surrounded by trees and bushes.
28354	127		Unsuitable	Appears at least semi permanent. Steep banks, deep water, and lack of fringing and emerging vegetation. No waterbirds present. Farm yard immediately over looking the wetland/dam may be a source of disturbance. Wetland has experienced some drainage.
28355			Unsuitable	An open dam lined by grass and a few rocks scattered around the banks. No aquatic vegetation present.
28358			Suitable	Wetland may hold water during wet years.
28359			Unsuitable	Artificial dam which contained a couple of islands supporting only grass vegetation. No fringing or emergent vegetation. Unlikely to provide breeding habitat for Brolga.
28360			Suitable	Black Swan found to be present during aerial survey.
28362			Unsuitable	Degraded farm dam. Unsuitable.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
28364			Unsuitable	Degraded farm dam. Unsuitable.
28366		2008 (Nature Advisory, VBA record and local landholder), 2019 (Nature Advisory).	Suitable	Brolga sighted incubating 26/7/19. Great wetland, large in size. Abundant emergent and fringing veg. Many waterbirds present, incl Black Swans breeding. Water permanent or semi-permanent. One swan present during aerial survey.
28387			Unsuitable	Wetland has been permanently drained.
28388			Unsuitable	Drained. Only a small dam in the south west corner of the original extent remains, which held water. The area is mostly pasture grass with a few remnant Juncus. Grazed by cattle.
28389			Suitable	Wetland holding water during aerial survey, swans nesting.
28414			Unsuitable	Drained. Doubtful whether most of mapped area was ever a wetland because it is elevated stony rise (with stones collected in two heaps). Small area of scattered rushes near western edge of mapped area. The area was dry and grazed by sheep.
28801	14		Suitable	Currently water at a desirable depth for brolga breeding. Some tussock grasses present. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28802			Unsuitable	Drained with no emergent veg.
28803			Suitable	Site currently supports sheep and has quite a few fences interspersed across the small property. Limited areas of standing water, though where water does occur, suitable tussocky veg also occurs. Level and extent of water currently observed is not suitable for breeding, but the site has some potential if conditions are to improve with more rainfall. Water levels down to 20% in December.
28806			Unsuitable	Drained. The area supports mainly introduced pasture which were grazed by cattle and sheep. The northern end had longer grass which may indicate it occasionally holds water and the southern end held a small dam lined with rock and grass.
28890			Unsuitable	A pair of brolgas sighted feeding together at this wetland. A predominantly dry wetland which currently supports sheep. Clearly no breeding occurring, but this pair may likely attempt to breed in surrounding area in the near future. Wetland is drained, as seen during aerial survey.
28894			Unsuitable	Wetland completely drained.
28910			Unsuitable	No standing water is visible from the road, except for a drainage channel. Suspected drained. Reasonable extent of tussocks veg present, with sheep currently grazing on the site.
28916	29460	2019, 2020 (Nature Advisory)	Suitable	Pair seen incubating in September 2019. Landowner says they have been around for the last 7 years. Water down to 40% in December, 2 swan pairs and large nests seen. Wetland has tall sedgy vegetation covering almost entirely and has been fenced by GHCMA in July. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28951			Unsuitable	Found to be drained during aerial survey.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
28953			Unsuitable	Presumably drained, there is no standing water visible here except from a couple small dams. Cattle present. Reasonably heavily grazed. Confirmed to be drained during aerial survey.
28956			Unsuitable	Water is absent in mapped area, appears to be drained. No water is present immediately north of the road either (ephemeral). No emergent veg present. Evidence suggests regularly grazing here.
28966	29402	Local landholder record from EHP report	Suitable	Brolgas often forage here according to landowner Rob. Most of this wetland site is not currently inundated, with much of the land closest to the road comprising thistles and heavily grazed currently supporting sheep. However, there is a section to the rear of the wetland which is currently holding water and in at least moderate condition for breeding. Multiple Swan pairs at this location. Water levels were still high in December. Aerial surveys concluded this wetland to be subject to drainage. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
28978			Unsuitable	Found to be drained during aerial survey.
28986			Suitable	Permanent water in dam. Floodplain moist but no water seen. Large tussocks and overall good wetland vegetation remains intact. Some cows in area.
29005			Unsuitable	Found to be drained during aerial survey.
29033			Unsuitable	No wetland appears present from the views from the roadside. Seen to be mostly drained from aerial survey. No visible water. Grazing cattle present.
29045			Unsuitable	Supporting little water in July and dry by October. Difficult to see from road, but likely drained. Both Sheep and Cattle are present. Sheep grazing in the area. Some paddocks retain wetland grasses
29047	29404	1987 (VBA and local landholder)	Suitable	Fenced off and free of stock. Lined along edges with planted River Red Gum. Wetland itself appears full of water. Depth of wetland unclear from road. Grassy islets. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
29055			Unsuitable	No wetlands are apparent from the roadside. Cattle present. No standing water visible. Found to be drained during aerial survey.
29066			Suitable	View from quite a distance from the roadside. Little to no emergent veg present, though appears to be at least semi permanent. Black Swan present. Observation during aerial survey suggest it is drained.
29080			Unsuitable	Dry wetland adjacent to the creek, probably inundated when creek overflows. Great coverage of tussocks.
29081			Unsuitable	Found to be drained during aerial survey.
29140			Suitable	Good quality but too close to track. Full of water and marshy grass vegetation on edges. Pair of swans nesting. Found to hold water during aerial survey, with one Black Swan still present.
29140			Suitable	
29193			Unsuitable	Wetland completely drained.
29239			Suitable	Wetland holding water during aerial survey, swans nesting.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
29934			Unsuitable	Creek running through the centre serves as a drain. Much of the site if currently unsuitable due to a lack of water. Almost no standing water now present. Tussocky veg and a somewhat reasonable amount of water. Cattle a partially present on site, excluded from other sections. Mapped area is on a hill and currently grazed - no water present.
30266			Suitable	Creek serves as a drain. Good amount of vegetation (tussocks/rushes), but insufficient water makes the wetland unsuitable. It is also quite narrow and lined by planted trees, which may be undesirable for Brolga. Black Swan nest observed during aerial survey.
30267			Unsuitable	Contains a good amount of water and appears full. Tussock veg surrounds the wetland, but no emergent veg is present within the wetland itself. Some sections of the wetland appear almost certainly too deep. Looks like sheep have access to this site. Further south it becomes narrower, but small pools may provide ideal condition. Unlikely to hold water long enough here.
30268			Unsuitable	Site really only consists of a chain of dams, which currently offer little resources for Brolga breeding. Sheep present.
30269			Unsuitable	Found to be drained during aerial survey.
30270			Unsuitable	Not a wetland, in a cultivated paddock.
30271			Unsuitable	Creek serves as a drain and is the only area currently holding water here. Some tussocky veg present. Insufficient water.
30272			Suitable	Creek serves as a drain and is the only area currently holding water here. Some tussocky veg present. Insufficient water.
30273			Suitable	West of the road: No water present, with cattle present. Perhaps drained. East of the road: Currently holding suitable amounts of water, with good amounts of fringing veg and some emergent veg. Largely permanent. Black Swan breeding. Some raised island sections may hinder the preferred 360 degree view for brolga breeding.
30274			Unsuitable	Part of a waterway.
30275			Unsuitable	Waterway, not a wetland.
30276			Suitable	For the most part is Low quality and ephemeral, water down to 60% in December, with cropping and draining evident. Nice patch of tussock veg that does become inundated to the far east of this wetland. Sheep present.
30277			Unsuitable	Waterway, not a wetland. Site does not currently hold any water and is absent of tussock veg. Heavily grazed with sheep currently present.
30278			Unsuitable	Does not appear to be an area that holds water and is dominated by trees. View from road is restricted although water is currently absent here. Waterway, not a wetland.
30279			Unsuitable	Does not currently hold water, but does contain tussocks and other suitable veg. Small in extent and close to treed veg. Waterway, not a wetland.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
30280			Suitable	Creek serves as a drain. Currently grazed by sheep and does not hold water or support any desirable habitat features in its current state. Some potential if holding water.
30281			Unsuitable	Generally narrow and likely unsuitable topography for a brolga nesting site. Areas down south of this site support cattle and are not currently inundated.
30282			Unsuitable	Found to be drained during aerial surveys.
30283			Unsuitable	Appears to be drained, with the only available water at this site occurring within dams.
30284			Unsuitable	Wooded creek line with no apparent surface water. From the road appears to be too deep and narrow to be suitable. Drainage found to occur here during aerial survey.
30293			Unsuitable	Found to be drained during aerial survey.
30294			Unsuitable	
30295			Suitable	
30296			Unsuitable	Wetland found to be drained during aerial survey.
30296			Suitable	
30297			Unsuitable	Wetland found to be drained during aerial survey.
30299			Unsuitable	Wetland found to be drained during aerial survey.
30300			Unsuitable	
30301			Unsuitable	Wetland found to be drained during aerial survey.
30302			Suitable	Currently not inundated, but does have great coverage of tussocks. Offline wetland to the waterway. Stock appear absent from site. If inundated, could be come a high quality site.
30304			Suitable	
30305			Unsuitable	
30306			Unsuitable	
30307			Unsuitable	Dammed creek line, very shrubby with no open areas for nesting or surface water.
30307			Unsuitable	Drained
30308			Unsuitable	Confirmed to be drained during aerial survey.
30309			Unsuitable	Found to be drained during aerial survey.
30312	106		Unsuitable	A large, open water permanent farm dam with planted eucalypts lining the southern edge. The dam has steep banks and deep water. No floating, emergent or fringing vegetation. The dam supports a variety of waterbirds and one Growling Grass Frog was heard in 2018.
30314			Unsuitable	Found to be dammed during aerial survey.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
30315			Unsuitable	Found to be dammed during aerial survey.
30316			Unsuitable	Found to be dammed during aerial survey.
30320	101		Unsuitable	Farm dam with permanent water but no fringing or emergent vegetation. Access by cattle.
30330	20	2019 (Local landholder).	Suitable	South side areas are suitable, with permanent water and fringing and emergent vegetation. Landowners see brolgas often and have seen them breeding, being followed by a small chick. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
30336		2018 (local landholder), 2019 (Nature Advisory).	Suitable	Black Swan with young found to be present at this site during aerial surveys.
30337			Unsuitable	Found to be dammed during aerial survey.
30339			Unsuitable	Found to be drained during aerial survey.
30340			Unsuitable	Not a wetland, creek line floodplain.
30344			Suitable	Black Swan found to be present during aerial survey.
30349			Suitable	Appears to have the potential to hold water for an extended period of time (at least semi permanent). Waterbody appears to be reasonably deep, perhaps too deep for breeding. No emergent veg present. North western section similar condition to last visit.
30351			Unsuitable	
30352			Suitable	Dammed, does hold water and likely to have emergent vegetation.
30365			Suitable	
30366			Suitable	Open creek line with open woodland and tussocks. Black swan nesting. Water levels still good in December.
30367			Suitable	Wetland holding water during aerial survey, swans nesting.
30369			Suitable	Large permanent wetland with little fringing and no emergent vegetation. However it is the largest of small system of 4 wetlands, three of them having the perfect conditions of water and vegetation. 80 swans seen, full of water. Holds large amounts of waterbirds. A pair of Brolga observed foraging here and likely roosting here in non-breeding season.
30420			Unsuitable	Found to be dammed during aerial survey.
30442			Unsuitable	Waterway, not a wetland.
30443			Suitable	Creek serves as a drain and is the only area currently holding water here. Some tussocky veg present. No breeding evident. Black Swan breeding seen during aerial survey.
30444			Unsuitable	Appears drained, with nearly no standing water present. Cattle and sheep currently on-site. Lacks emergent veg currently.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
30445			Unsuitable	Not accessible due to on-ground conditions. Found to be drained during aerial survey.
30448			Suitable	Found to be mostly drained during aerial survey, but may still provide suitable conditions.
30450			Suitable	Very good wetland with grassy cover and abundant waterbirds, down to 10% in December. Close to road and settlements.
30459			Suitable	Mostly drained as seen during aerial survey. Though it may still provide suitable conditions.
30816			Unsuitable	River floodplain, grazed. No open water or nesting vegetation. Part of a waterway.
30903			Unsuitable	Found to be drained during aerial survey.
B1			Unsuitable	
B3			Unsuitable	
RW3			Unsuitable	
B7			Unsuitable	
	8		Unsuitable	Very shallow, reaches up to 0.1m deep. Too shallow for safely nesting.
	12		Unsuitable	Semi-drained wetland. No suitable vegetation.
	104		Suitable	Small dam with seasonal overflow in wet years. Glyceria present. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
	105		Unsuitable	Small dam with seasonal overflow in wet years. No emergent vegetation or littoral zone.
	109		Unsuitable	Small farm dam with access by animals and no vegetation.
	110		Unsuitable	Wetland fully drained, road crossing over.
	111		Unsuitable	Farm dam with high banks and pasture grass.
	112		Unsuitable	Roadside farm dam. Brolgas seen foraging here due to proximity to suitable wetlands.
	113		Unsuitable	Farm dam lacking fringing and emerging vegetation.
	114		Unsuitable	Farm dam that overflows in wet years. Access of cattle keeps it vegetation free.
	115		Unsuitable	Semi-permanent farm dam. No fringing or emerging vegetation. The wetland did not/did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
	116		Unsuitable	Farm dam that may overflow in wet years. No emerging vegetation. Brolgas may forage due to proximity to suitable wetland.
	117		Unsuitable	Small farm dam.
	118		Unsuitable	Farm dam. Does not seem to overflow in wet years to allow Brolga to breed.
	119		Unsuitable	Farm dam that overflows in wet years. Lack of vegetation and too close to main road.

Wetland Number	Redefined wetland number	Past breeding record	Functional wetland	Wetland description summary
	120		Unsuitable	Farm dam. Does not seem to overflow enough in wet years to create a larger wetland.
	121		Unsuitable	Farm dam surrounded by trees. No fringing vegetation.
	122		Unsuitable	Farm dam with some fringing/emergent vegetation when overflows.
	123		Unsuitable	Dam with gum plantation. Semi permanent and showing fringing vegetation in wet years.
	124		Suitable	Permanent farm dam with fringing and some emergent vegetation. Wetland expands in wet years creating suitable habitat. The wetland did meet the minimum breeding habitat suitability criteria in the hydrologist assessment.
	125		Unsuitable	Drained. Only farm dam keeps water.
	126		Unsuitable	Semi-permanent farm dam. Minimal emerging vegetation. Island vegetation high with willows.

Hexham Wind Farm – Wetland Analysis

Hexham Wind Farm Pty Ltd

20 September 2021

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20 September 2021

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Dear Rory

Hexham Wind Farm – Wetland Analysis

This report documents an assessment of the long term inundation regime of depressions within and surrounding the Hexham Wind Farm. The inundation regime of these depressions has been used to identify their potential as 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

Hexham Wind Farm Pty Ltd are completing investigations into their proposed wind farm located between Hexham, Caramut and Ellerslie in south-west Victoria (Figure 1-1). Hydrological and hydraulic 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 Hexham 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.

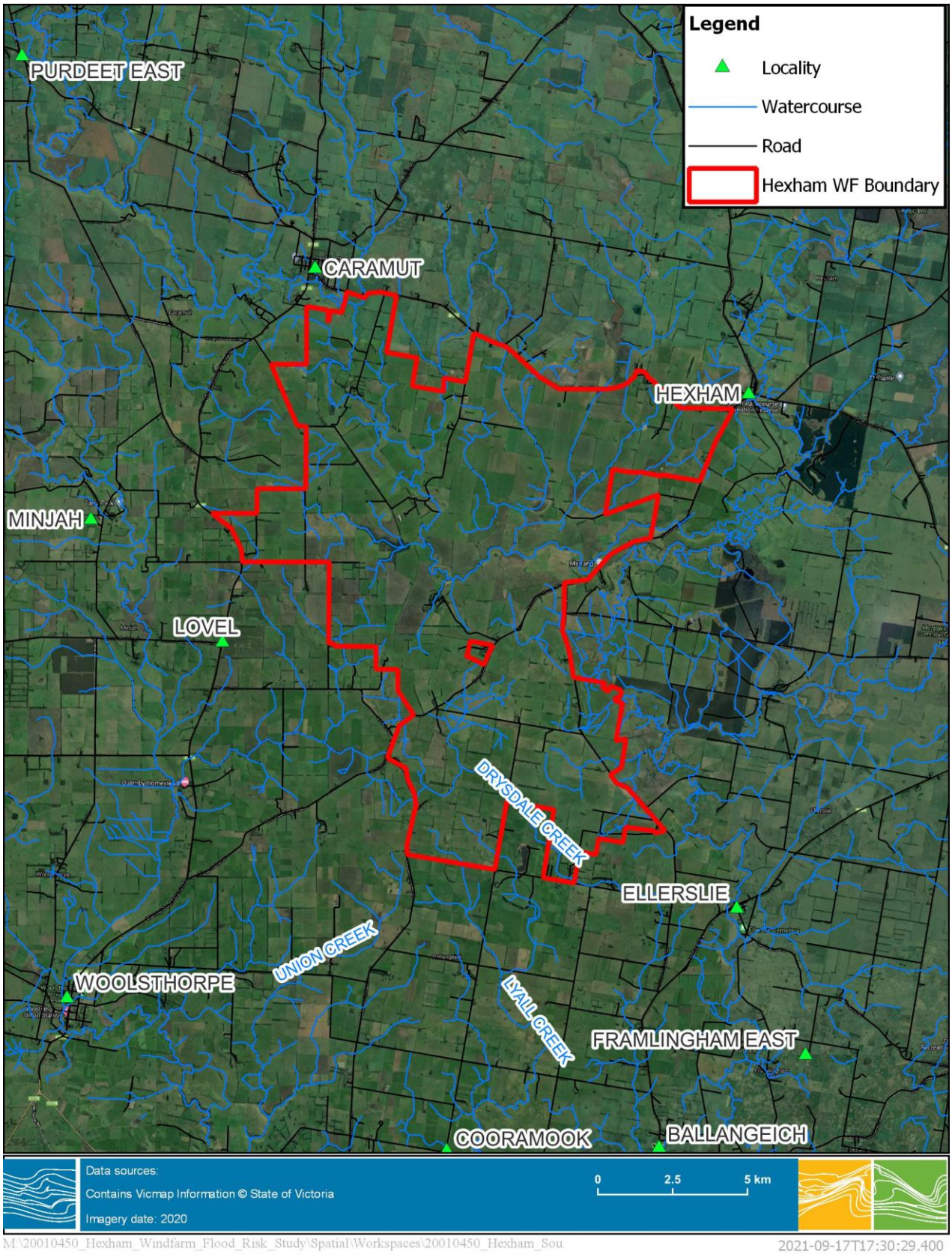

FIGURE 1-1 SITE LOCALITY

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 Hexham 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 (DELWP). 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 2000-2020 inclusive.
- The wetlands located adjacent to and potentially impacted by Mustons Creek are not suitable for hydrologic modelling using Source. These wetlands were assessed using a separate detailed hydraulic model with determined flow rate in the creek.
- 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 Hexham Wind Farm project area 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 Hexham 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 Hexham Wind Farm (and provided by Hexham Wind Farm Pty Ltd at a 1m grid resolution) within the proposed windfarm and the VicMap20m DTM 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 – No losses were used in the hydraulic modelling which determined the wetlands which required further assessment.

TABLE 2-1 MANNING ROUGHNESS COEFFICIENTS AND LOSSES

Land Use Type	Manning 'n'
Residential footprint – rural	0.04
Industrial/Commercial	0.03
Road	0.025
Farming zone	0.045

[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/

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.

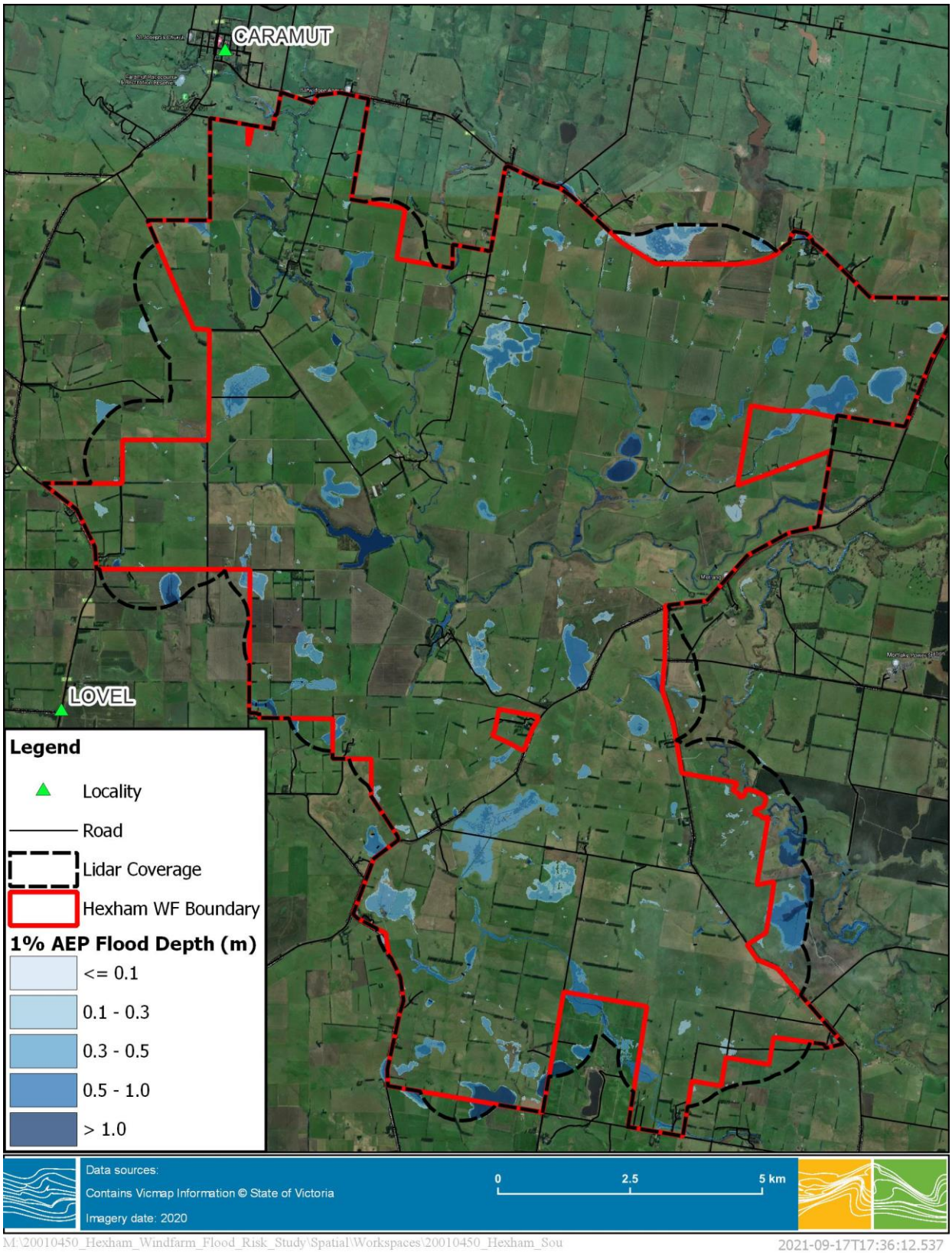

FIGURE 2-1 INUNDATION WITHIN THE PROPOSED HEXHAM WIND FARM – 1% AEP, 72 HOUR EVENT, 7 DAYS POST RAINFALL OCCURRING.

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 750 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.

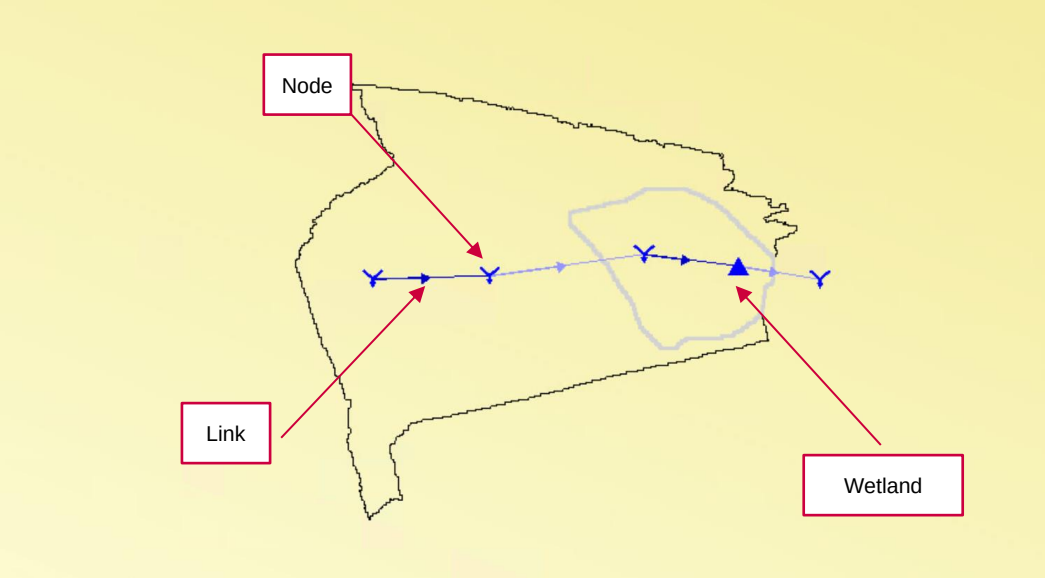

FIGURE 2-2 SOURCE MODEL

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

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

Parameter	Description	Units	Min	Max
Impervious Threshold	Impervious Threshold	mm	0.0	5.0
Infiltration Coeff.	Infiltration Coefficient		0.0	400
Infiltration shape	Infiltration Shape		0.0	10.0
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 similarity of the landform, the rainfall runoff parameters were adopted using the values for Willatook Windfarm Wetland Analysis undertaken by Water Technology (2021). During the Willatook study, 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/

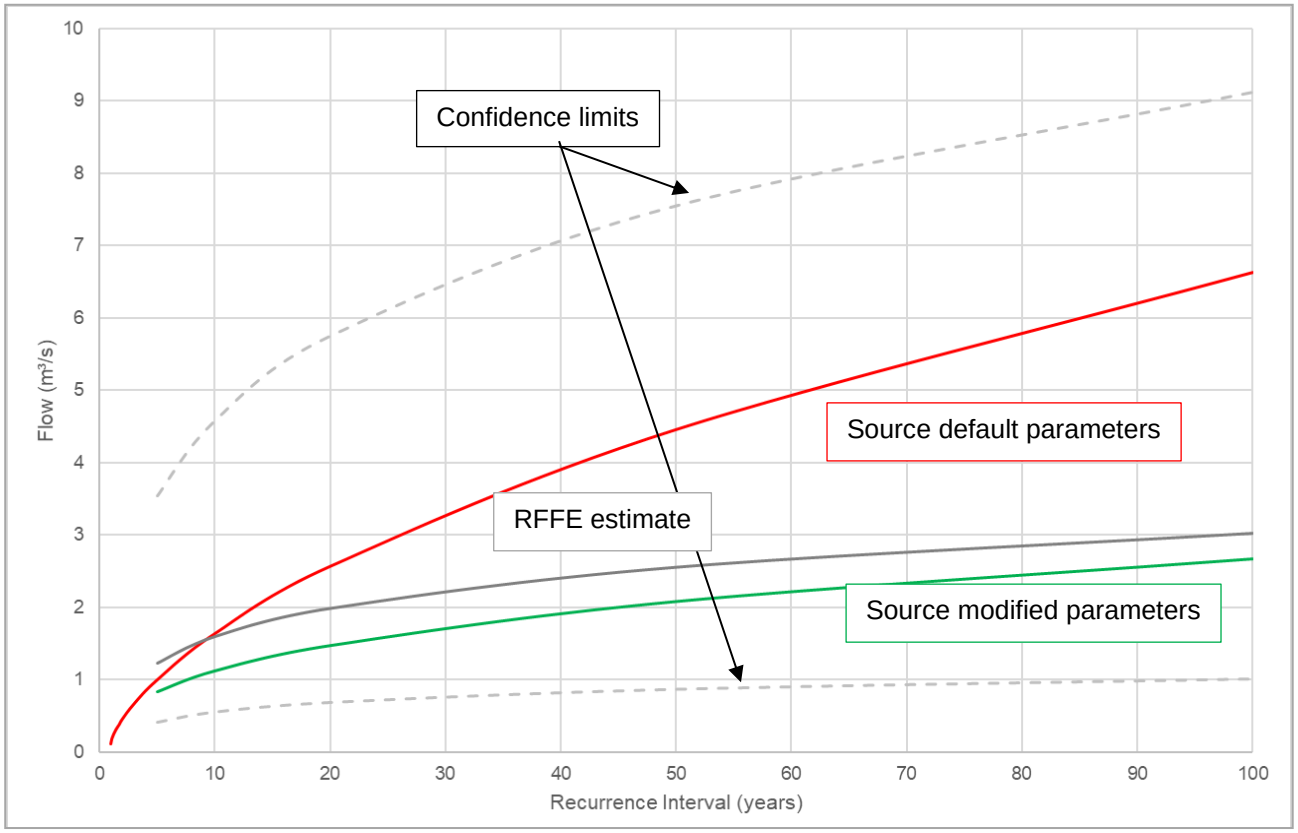

FIGURE 2-3 COMPARISON OF RFFE AND SOURCE DISCHARGES FOR DIFFERENT RECURRENCE INTERVALS

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 01 Jan 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 745 areas which required further assessment. Of these:
  - 75 had incorrect topographic representation within the model.
  - 497 had constructed drainage from the invert of the depression.
  - 46 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.
  - 97 were farm dams – automatically meeting the inundation criteria.
  - 24 were deemed suitable and required further hydrologic assessment.
  - 4 wetlands were assessed using hydraulic model as they were potentially impacted by riverine inundation in addition to local runoff.
  - 2 wetlands were determined as suitable for brolga breeding and night roosting directly from the aerial image.
- The detailed hydrologic assessment determined 18 of the 24 wetlands assessed in detail met the inundation criteria required for the areas to be hydrologically suitable for brolga breeding and night roosting.
- The detailed hydraulic assessment determined all 3 assessed wetlands were inundated by flooding from Mustons Creek, hence suitable for brolga breeding and night roosting.

The areas modelled and those highlighted for further assessment are shown in Figure 3-1. The inundation of assessed wetlands from Mustons Creek are outlined in Figure 3-2. Those that met the inundation criteria, including farm dams are shown in Figure 3-3.

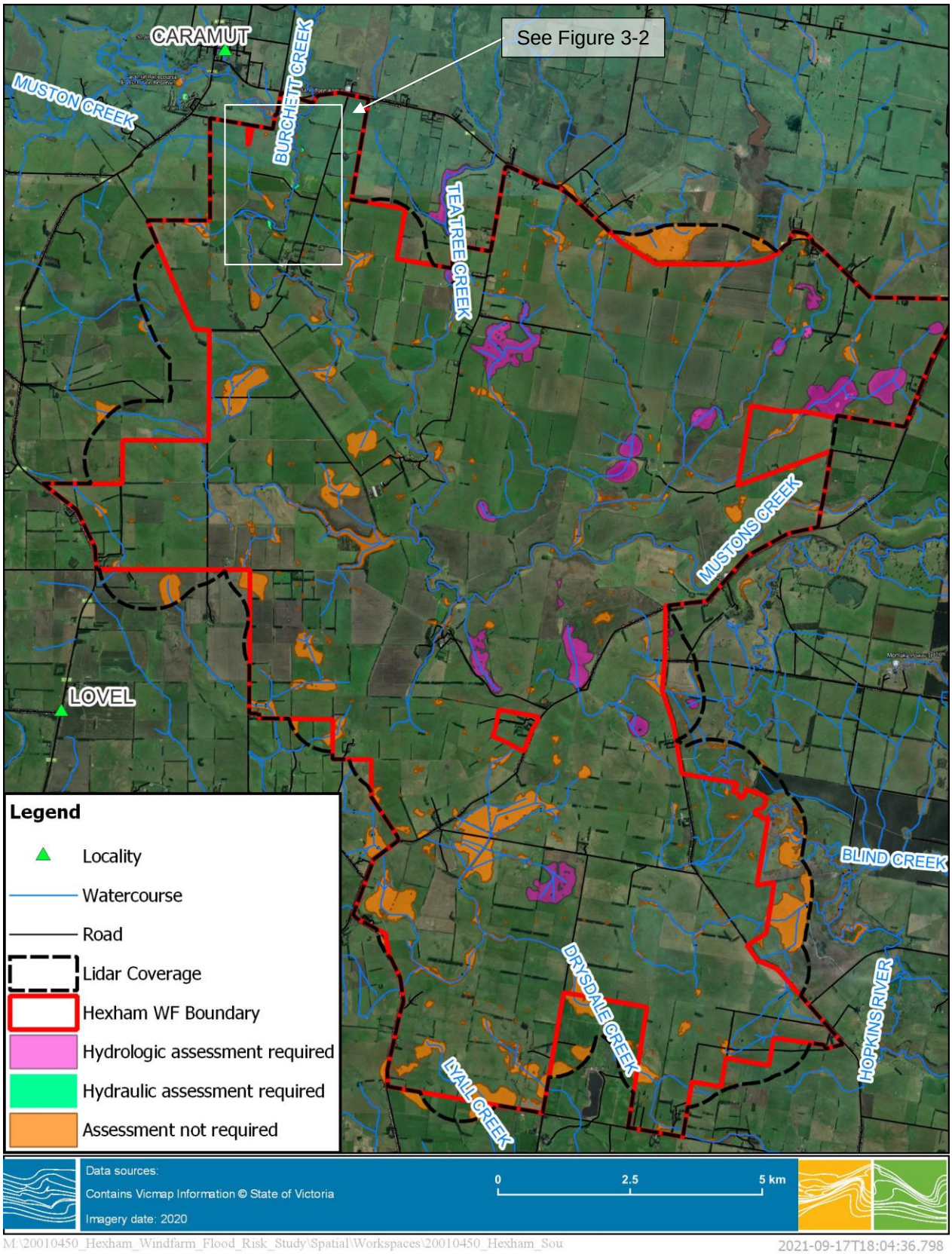

FIGURE 3-1 AREAS HIGHLIGHTED AS REQUIRING DETAILED HYDROLOGIC ASSESSMENT

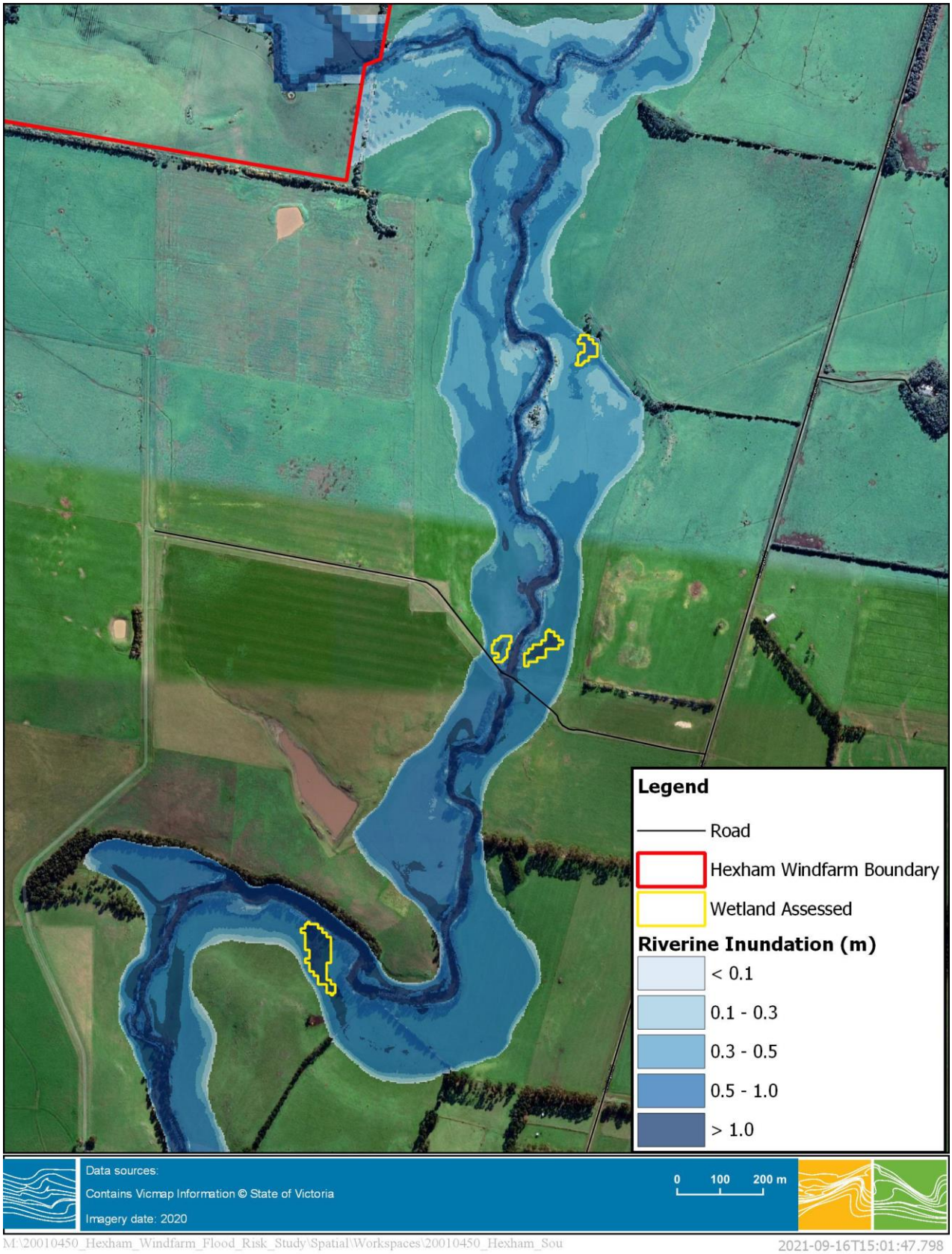

FIGURE 3-2 WETLANDS IMPACTED BY RIVERINE INUNDATION

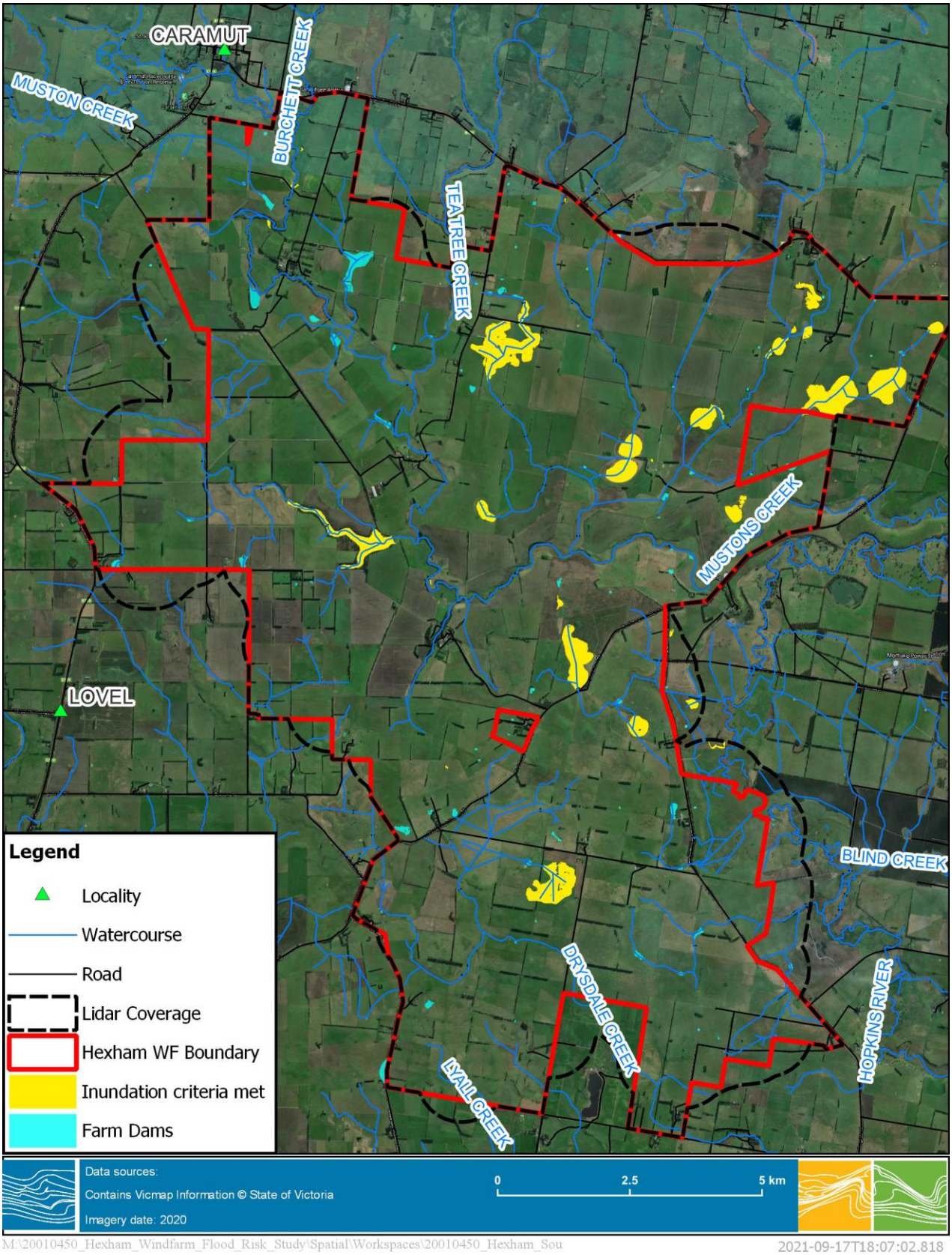

FIGURE 3-3 AREAS HIGHLIGHTED AS MEETING THE INUNDATION CRITERIA

Melbourne

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Telephone (03) 8526 0800
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Geelong

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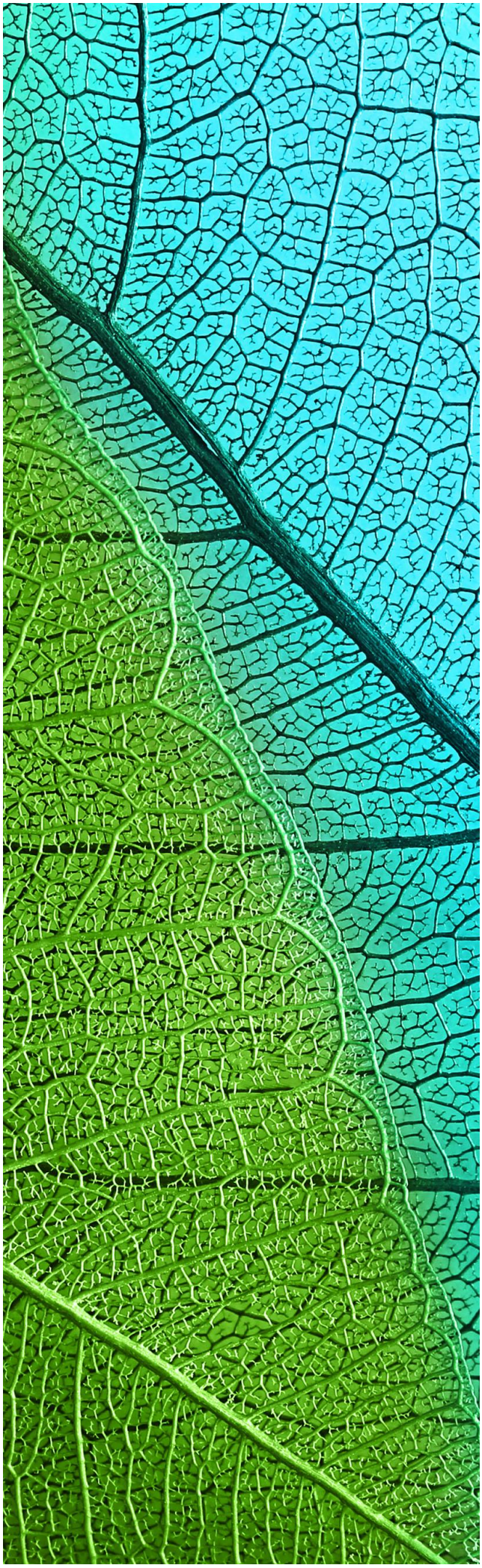

Hexham Wind Farm

Brolga Habitat Assessment

Prepared for Wind Prospect

January 2022
Report No. 18088 (7.1)

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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 Hexham 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 five-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 functional wetlands. Functional wetlands are considered to provide habitat for Brolga for breeding, foraging and night roost 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), Guille Mayor (Zoologist), Curtis Doughty (Senior Zoologist), Inga Kulik (Senior Ecologist and Project Manager) 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 2020)
- 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 et 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 27 farm dams and 19 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 floodplains 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 25th November 2020 by a Senior Botanist from Nature Advisory, Elinor Ebsworth. Wetlands that were assessed as suitable by the hydrological assessment in holding water continuously for 120 days during the period from July to December and were larger than 0.6 hectares and 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 wetlands and farm dams assessed

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 24/01/2022

Wind farm boundary
Wind farm 5km buffer
Hopkins River
Hydrology assessment wetlands
8 Hydrologist assessed wetland number
9 VWI wetland number

HOPKINS RIVER

N

Metres
0 1,600

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3. Assessment results

3.1. Wetland and farm dam assessment

A total of 27 farm dams and 19 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 mapped in Figure 2. A total of two farm dams and 16 wetlands were considered as functional wetlands and likely to provide habitat for Brolga, highlighted in grey in Table 1 below.

Table 1: Farm dam and wetland assessment at Hexham Wind Farm

Hydrology Reference	VWI Number	Area (ha)	Breeding Record	Habitat Quality	Hydrology and desktop assessment	Site Assessment 25/11/2020	Functional wetland
8		0.895		Low-moderate	Very shallow, reaches up to 0.1m deep. Too shallow for safely nesting.		Unsuitable
9	3	1.249	Landholder	High	Nesting confirmed in 2020. Fringing and emerging vegetation, suitable depth and size.		Suitable
11	28263	3.736		Unsuitable	Reaches up to 0.2m deep. Meets 120 day criteria only once.	Not suitable - Pasture, wetland drained.	Unsuitable
12		2.297		Low	Semi-drained wetland with some emerging vegetation. May become suitable with lower grazing pressure.	Not suitable - no vegetation	Unsuitable
14	28801	2.471		Low	Semi-drained wetland. May become suitable with lower grazing pressure.	Suitable - Vegetation of Water Ribbons and Glyceria	Suitable
16	28243	8.625		Low	Reaches up to 0.4m deep. Almost continually inundated. Little emerging vegetation but it could become suitable in dryer years.		Suitable
18	28236	7.397		Low-moderate	Reaches up to 0.9m deep. Almost continually inundated. Brolgas seen foraging. Emerging vegetation when sheep not allowed in.	Potential - Only narrow zone, brackish, cane grass	Suitable
20	30330	9.349	Landholder	Moderate	Two weir pools on an active waterway. Landowner has seen brolgas with chicks in 2019. Suitable vegetated areas for nesting.		Suitable
23	28249	12.103	Nature Advisory	Moderate-High	Brolgas nesting in 2020. Fringing and emerging vegetation. Some grazing.	Suitable - Vegetation of Glyceria and Poa	Suitable
101	30320	3.055		Low	Dam with no vegetation. Access by cattle.		Unsuitable
102	28352	14.345		Low-moderate	Dams with moderate vegetation. Middle islands can facilitate nesting.	Not suitable - Drained pasture, high dam banks	Unsuitable
103	28352	2.320		Low-moderate	Dams with moderate vegetation. Middle islands can facilitate nesting.	Not suitable - High dam banks with willow.	Unsuitable
104		1.413		Low	Small dam with seasonal overflow in wet years.	Potential - small wetland, but with Glyceria	Suitable
105		0.920		Low	Small dam with seasonal overflow in wet years.	Not suitable - no emergent vegetation or littoral zone	Unsuitable
106	30312	5.570		Unsuitable	Large dam with steep banks and no vegetation. Deep water.		Unsuitable
107	28348	1.640		Unsuitable	Large dam with steep banks and no vegetation. Deep water.		Unsuitable
108	28351	2.898		Unsuitable	Large dam with steep banks and no vegetation. Deep water.		Unsuitable
109		1.078		Low	Small farm dam with no vegetation and access by animals.		Unsuitable
110		0.893		Unsuitable	Wetland fully drained, road crossing over.		Unsuitable
111		2.688		Low-moderate	Farm dam that creates a shallow arm in wet years. Creekline nearby with foraging areas.	Not suitable - High banks with pasture grass.	Unsuitable
112		1.113		Low	Roadside farm dam. Brolgas seen foraging due to proximity of suitable wetlands.		Unsuitable
113		1.150		Low	Farm dam lacking fringing and emerging vegetation		Unsuitable
114		0.828		Low	Farm dam that overflows in wet years. Access of cattle keeps it vegetation free.		Unsuitable
115		1.990		Low	Semi-permanent farm dam. No fringing or emerging vegetation.		Unsuitable
116		2.613		Low	Farm dam that may overflow in wet years. No emerging vegetation. Brolgas may forage due to proximity of 29405		Unsuitable
117		0.648		Low	Small farm dam.		Unsuitable
118		2.693		Low	Farm dam. Does not seem to overflow long enough to allow Brolgas to breed.		Unsuitable
119		1.500		Low	Farm dam that overflows in wet years. Lack of vegetation and too close from main road.		Unsuitable
120		2.875		Low	Farm dam. Does not seem to overflow in wet years creating a larger wetland.		Unsuitable
121		0.850		Low	Farm dam surrounded by trees. No fringing vegetation.		Unsuitable
122		0.763		Low-moderate	Farm dam with some fringing/emergent vegetation when overflows.		Unsuitable
123		0.655		Low-moderate	Dam within a gum plantation. Semi permanent and showing fringing vegetation in wet years.		Unsuitable
124		1.653		Moderate	Permanent farm dam with fringing and some emergent vegetation. Wetland expands in wet years creating suitable habitat.	Suitable - Glyceria and Elo (?) dominated, medium size.	Suitable
125		5.090		Low	Drained. Only farm dam keeps water.		Unsuitable
126		1.285		Low-moderate	Semi-permanent farm dam. Vegetation grazed on the edges but middle islet may provide nesting habitat.	Not suitable - minimal emerging vegetation. Island vegetation high with willows.	Unsuitable
127	28354	19.186		Low	Lack of fringing and emerging vegetation, steep banks, deep water		Unsuitable
29401	2	0.815	Landholder	Low	Islet with emerging vegetation and fenced from animals. Fence too close to the water edge, and wetland adjacent to a highway. Breeding observed by Landholder (RW).		Suitable

Hydrology Reference	VWI Number	Area (ha)	Breeding Record	Habitat Quality	Hydrology and desktop assessment	Site Assessment 25/11/2020	Functional wetland
29402	28966	134.829	Landholder	Moderate-high	Brolgas permanently visiting the area and breeding in adjacent wetlands. Suitable habitat.		Suitable
29404	29047	5.567	Landholder, VBA	Low-moderate	Permanent treed dam with some islets. Past breeding records. Overflow creates a shallow wetland in the south.		Suitable
29405	6	48.139	Landholder, EHP	High	Nesting confirmed in previous years. Large permanent wetland with multiple areas of shallow emerging vegetation suitable for nesting.		Suitable
29411	28252	30.881	Landholder, VBA	Low-moderate	Seasonal wetland fringed by trees. Lack of emerging vegetation however islet may offer nesting habitat.		Suitable
29414	28261	22.619	Landholder	Moderate	Historical breeding records. Semi-drained detached meanders. May provide habitat in wet years.		Suitable
29415	28267	10.334	Landholder	High	Ephemeral wetland with a small dam. Landowner breeding records. Abundant emerging vegetation.		Suitable
29416	28264	4.805	VBA	Not assessed	Ephemeral wetland with a small dam. Landowner breeding records. Abundant emerging vegetation when flooded.		Suitable
29420	28245	10.680	Nature Advisory	High	Known breeding wetland. Fenced from livestock and abundant emerging vegetation.		Suitable
29460	28916	10.153	Nature Advisory	High	Nesting confirmed in 2019. Fenced off and with good water levels and vegetation cover.		Suitable

Figure 2: Wetland assessed as fuctional wetlands

Project: Hexham Wind Farm
Client: Wind Prospect Pty Ltd
Date: 24/01/2022

Wind farm boundary
Wind farm 5km buffer
Hopkins River

Wetland suitability

Functional wetlands
Unsuitable
8 Hydrologist assessed wetland number
9 VWI wetland number

N

Metres
0 1,600

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4. Conclusion

Of the 27 farm dams and 19 wetlands that were assessed, two farm dams and 16 wetlands were considered to be functional wetlands. These wetlands may provide, breeding, foraging or night-time roosts habitat. 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 Hexham Wind Farm development.

5. References

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Appendix 6: 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.

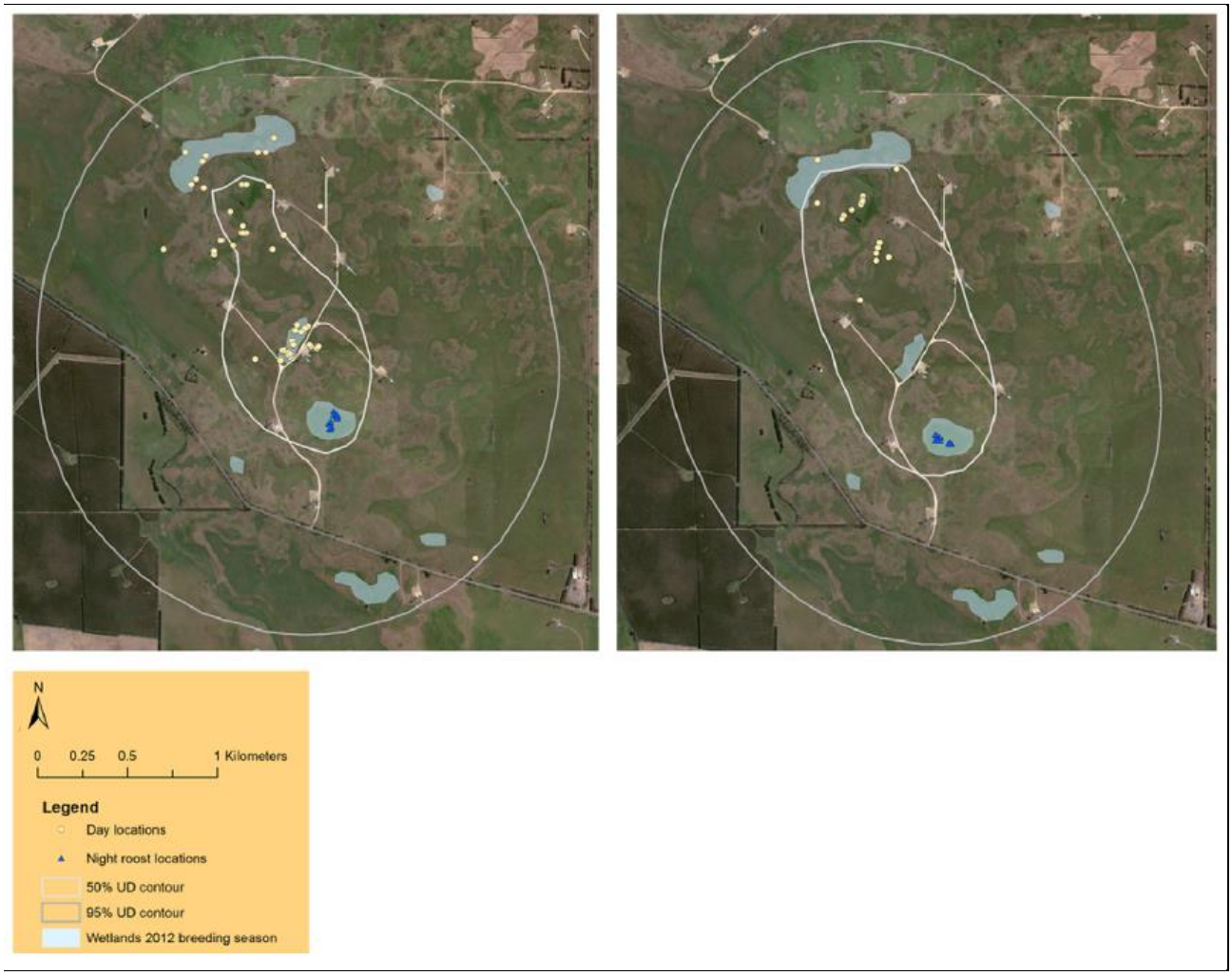

Figure 1: Monitoring undertaken during the 2012 breeding season (Source: Figure 3 in Veltheim *et al*. 2019)

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.

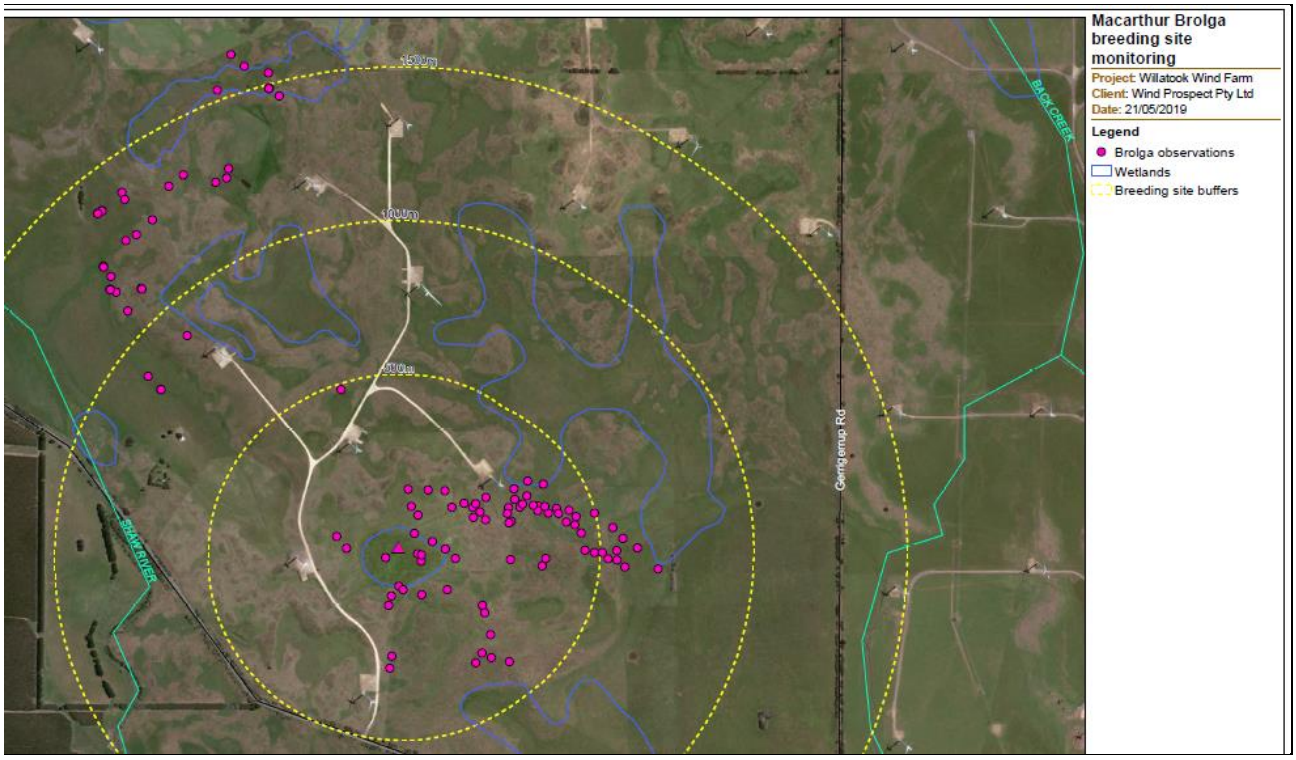

Figure 2: Monitoring undertaken by Nature Advisory during the 2018 breeding season

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.

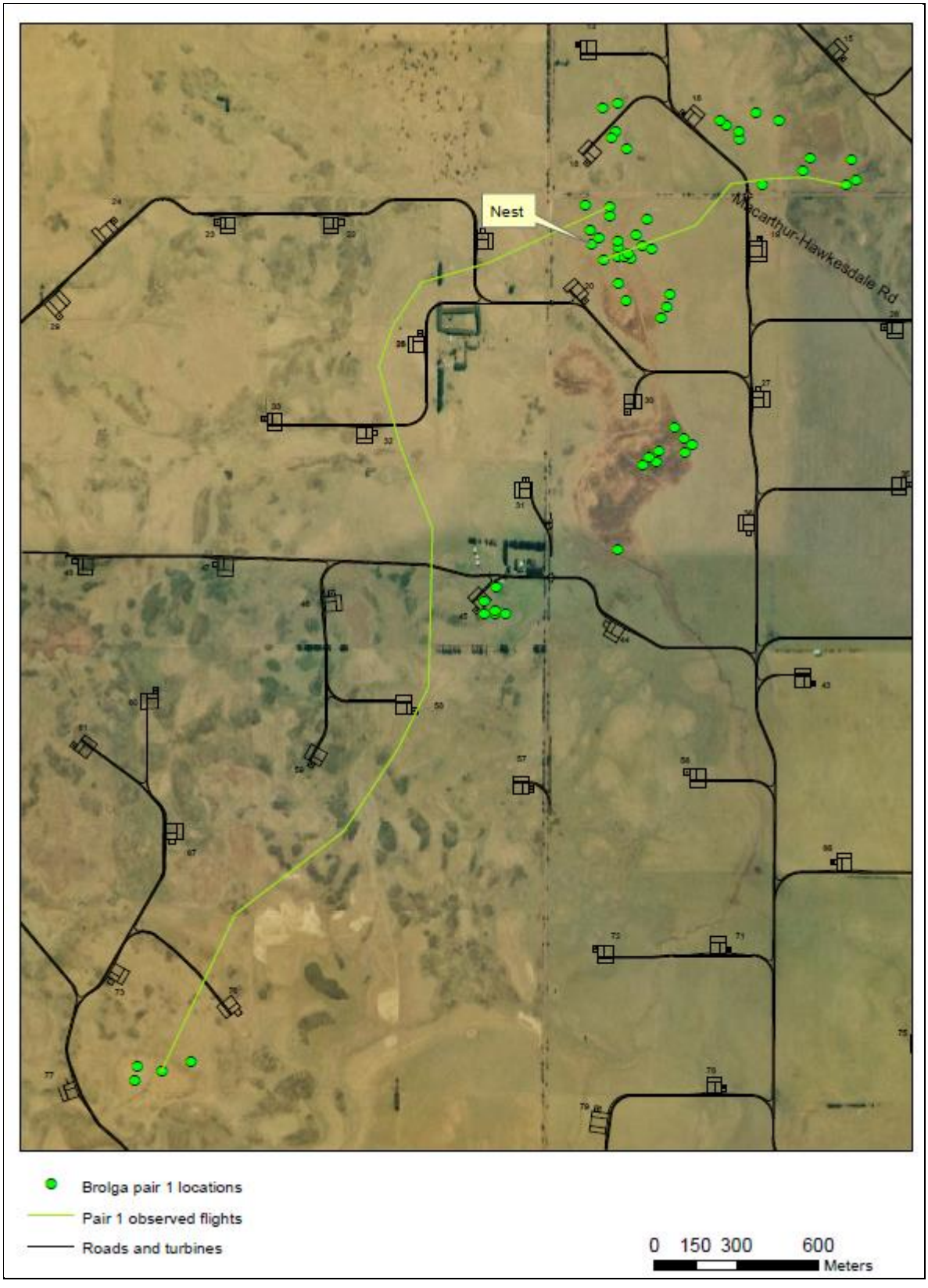

Figure 3: Monitoring undertaken during the 2014 breeding season (Source: Figure 4 in Wood 2014)

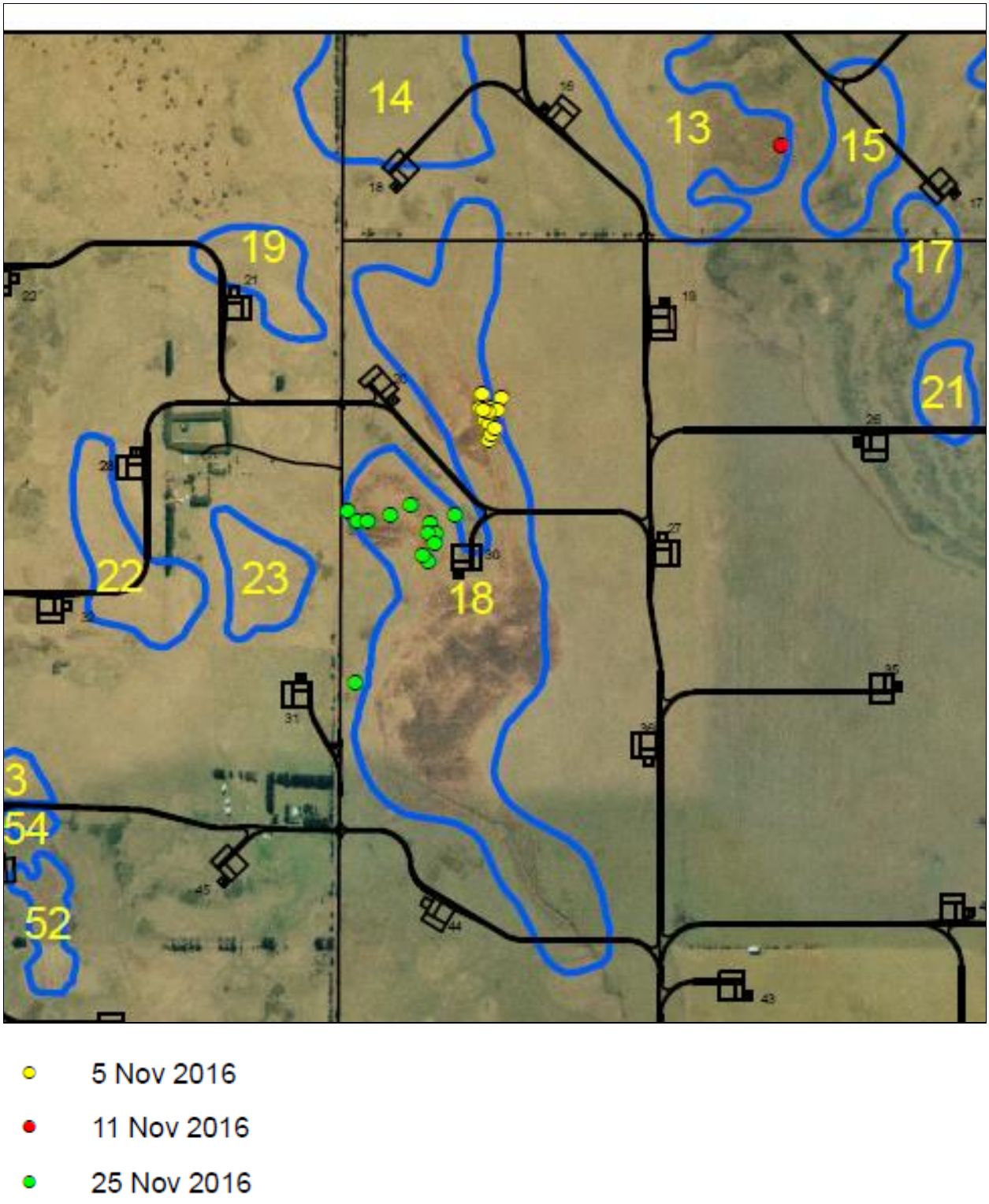

Figure 4: Monitoring undertaken during the 2016 breeding season (Source: Figure 10 in Wood 2017)

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.