Assessment of effectiveness of the IdentiFlight® avian detection system

Wild Cattle Hill Wind Farm

Prepared in satisfaction of EPBC Approval 2009/4838
Conditions 6A - 6C

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WILD CATTLE HILL PTY LTD

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Acronyms

AEMO	Australian Energy Market Operator
AER	Annual Environment Review required by Condition G10 of State EPN 10105/1
ASL	Above Sea Level
AGL	Above Ground Level
BBMMP	Bird and Bat Mortality Monitoring Plan required by Condition FF10 of State EPN 10105/1
CADP	Collision Avoidance and Detection Plan, required by Condition 6A of EPBC Approval Notice 2009/4839
Cmin	Lower cylinder height
Cmax	Upper cylinder height
CHWF	Cattle Hill Wind Farm, comprising 48 wind turbines and 150 MW capacity
CNN	Convolutional neural network
CMZ	Carcass Monitoring Zone
CHC	Central Highlands Council
CRM	Collision Risk Modelling
Cs	Confidence (%)
DPEMP	Development Proposal and Environmental Management Plan
DPIPWE	The Tasmanian Department of Primary Industry, Parks, Water and Environment
EMOP	Eagle Mortality Offset Plan
EMPCA	Environmental Management and Pollution Control Act 1994 (Tasmania)
EMS	Environmental Management System
ENPP	Eagle Nest Productivity Plan required by Condition FF5 of EPN 10105/1)
ENUMP	Eagle Nest Utilisation Monitoring Plan required by Condition FF6 of EPN 10105/1
EPA	Tasmanian Environment Protection Authority
EPBC	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
EPN	Environmental Protection Notice
FPA	Forest Practice Authority
GPS	Geographic Positioning System
GWA	Goldwind Australia Pty Ltd
GWI	Goldwind International
GWTC	Goldwind Tasmania Constructions Pty Ltd
IDF	IdentiFlight
KWh	Kilowatt hour
MWh	Megawatt hour
NVA	Natural Values Atlas, managed by DPIPWE
OEMP	Environment Management Plan – Operations required by condition G9 of EPN 10105/1
O&M	Operations and Maintenance
PTU	Pan Tilt Unit
PCR	Power China
PCAB	Policy and Conservation Advice Branch of DPIPWE
Ri	Radius (inner circle)
Ro	Radius (outer circle)
RSA	Rotor Swept Area
SCADA	Supervisory Control and Data Acquisition
Tc	Time to Clear
TTC	Time to Collision
TSMP	Turbine Shut Down Management Plan required by condition FF16 of EPN 10105/1
TSPA	Threatened Species Protection Act 1995 (Tasmania)
WBSE	White-bellied sea-eagle (Haliaeetus leucogaster)
WCHPL	Wild Cattle Hill Pty Ltd, the CHWF proponent and holder of EPN 10105/1
WFOV	Wide Field of View
WOM	Warranty Operations and Maintenance Service Team
WTE	Tasmanian wedge-tailed eagle (Aquila audax fleayi)
WTSH	Wind Turbine Shut Down hours

Definitions

Activity	Means any environmentally relevant activity as defined in section 3 of EMPCA
Audit	A systematic and independent examination to determine whether activities and results comply with GWA established systems, whether these systems have been implemented effectively and are suitable to achieve the conformity to ISO14001: 2015.
Central Highlands Region	Is that described in EPN10105/1 as the area north of Bothwell, east of Bronte Park and surrounds, south of Liawenee and west of the Great Western Tiers
Commissioning	Refers to the testing of turbines and is taken to be completed when 90% of the turbines are being operated in the course of normal commercial operations
Environment	Means the surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans and their interrelationships (ISO14001: 2015)
Environmental impact	Means a change in the environment whether adverse or beneficial, wholly or partially resulting from organisation activities, products or services (ISO14001: 2015)
Eagle	In this report, refers to the Tasmanian wedge-tailed eagle (*Aquila audax fleayi*) or the white-bellied sea-eagle (*Haliaeetus leucogaster*)
Featherspot	For the purpose of carcass monitoring, means collection of ten feathers and/or three flight feathers (primaries, secondaries, tertiaries or retrices)
First Full Operation	Means the first date the Tasmanian electricity network operator allows for all Cattle Hill Wind Farm turbines to simultaneously operate and expert electricity up to the maximum output
Incident	An event or occurrence that hinders completion of a task and may cause injury or other damage
Indicator	Measurable representation of the condition / status of operations, management or conditions (ISO14031:2013
Known eagle nest	For the purpose of nest activity and productivity monitoring, means an eagle nest (either WTE or WBSE) that was known at the time the Cattle Hill Wind Farm layout was finalised (EPN10105/1 Schedule 1)
The Land	Defined as that situated immediately to the east of Lake Echo and off Bashan Rd, approximately 3km southwest of Waddamana in central Tasmania and includes part or all of the following titles: 135246/1; 29897/1; 29897/3; 29897/5; 248810/1; 135247/1; 135247/2; 29888/4; 29897/6 (as defined in the EPN 7925/1)
Person responsible	Means any person who is or was responsible for the environmentally relevant activity to which this document relates, including the employees, contractors, joint venture partners and agents of that person (EPN10105/1 Schedule 1)
The Proponent	Wild Cattle Hill Pty Ltd (ACN 610 777 369) WCHPL

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Assessment of the IdentiFlight Avian Detection System

Purpose

This report presents the findings of an assessment of the IdentiFlight® (IDF) avian detection system installed at Cattle Hill Wind Farm (CHWF) in Tasmania's Central Highlands region. The IDF system was designed in the United States specifically to reduce Golden Eagle mortalities on wind farms and has been installed at CHWF as part of a technology trial to assess the effectiveness of the system at preventing collisions of threatened Tasmanian eagles on wind farms. The species of concern are the Tasmanian Wedge Tailed Eagle (*Aquila audax fleayi*) (WTE) and the White Bellied Sea Eagle (*Haliaeetus leucogaster*) (WBSE).

CHWF is the first Australian project to implement this innovative technology.

This report has been prepared by Goldwind Australia Pty Ltd on behalf of Wild Cattle Hill Pty Ltd (WCHPL) in satisfaction of EPBC Approval 2009/4839 Condition 6C, which requires an 18-month trial of the technology, incorporating an end of trial report assessing effectiveness against requirements outlined in the Collision Avoidance Detection Plan (CADP) approved under condition 6A.

The Cattle Hill Wind Farm

CHWF comprises 48 Goldwind 3S turbines with a combined total generation capacity of 148 MW. Clean energy from the wind farm is distributed via the pre-existing TasNetworks transmission system which runs through the site. CHWF was constructed during 2018-19 and commenced first full operation (refer definitions) on 4 August 2020.

A Collision Detection and Avoidance System has been required by the EPBC Approval due to the Critically Endangered conservation status of the Tasmanian WTE and high number of eagles and eagle nests within and surrounding the project site.

Following a global review of available technologies and practices undertaken in 2017, the IdentiFlight system was selected to install and subsequently operate at CHWF.

Technology Trial Areas of Assessment

CHWF approvals require assessment of the technology over an 18-month period commencing with full wind farm operations, incorporating a report assessing its effectiveness in the following areas:

- Monitoring the movement of eagles within the wind farm
- Avoiding or reducing eagle collisions with wind turbines
- Detecting and documenting eagle collisions with wind turbines.

For an automated system to effectively monitor the movement of eagles, it must first be able to recognise which birds are eagles and which are not. The same is true of a system aiming to avoid eagle collisions with turbines, but not other birds. On this basis, Goldwind has added an area of assessment, 'identify and classify avifauna species' recognising that the ability of the technology to recognise eagles and distinguishing them from other species underpins all three areas listed above.

The CADP also requires assessment of the reliability of the system (broadly, interpreted as 'does the system do what it is supposed to') and documentation of any modifications or rework required.

Methodology for the assessment is presented in Section 1 of this report.

Trial Evaluation Period

The trial period defined in the CADP is the 18-month period from 4 August 2020, when full operation of the wind farm commenced, to 4 February 2022.

As Wind Farms often experience eagle collisions during wind farm commissioning, performance of IDF system during commissioning is also discussed. The IDF system was installed and operational prior to the commencement of wind farm commissioning activities on 19 November 2019.

Relevant Approvals and Management Plans

The Trial has been undertaken in conjunction with the following approved management plans, required by the Commonwealth, State and Local development approvals for the CHWF:

- The Collision Avoidance Detection Plan (CADP) required by Condition 6A B, and C of Commonwealth EPBC Approval Notice 2009/4839.
- The Turbine Shutdown Management Plan (TSMP) required by Condition FF16 of State EPN 10105/1
- The Bird and Bat Mortality Monitoring Plan (BBMMP) required by Condition FF10 of State EPN 10105/1
- The Eagle Utilisation Management Plan (EUMP) required by Condition FF6 of State EPN 10105/1.

The requirements of these plans and their relationship to the trial are explained in Section 1.

Description of Identiflight® Avian Detection System

The IDF system at CHWF consists of 16 monopole towers with high precision optical cameras at the top of each tower, which track the movement of eagles and calculate the trajectory of the eagle relative to the rotor swept area of (RSA) of turbines in real time. Each IDF station has visibility of an approximate one-kilometre hemisphere, and all cameras have overlapping view fields, providing coverage of the entire airspace above and around the wind farm.

The IDF system was installed during construction of the CHWF and several iterations to the layout were made during siting of both the wind turbines and IdentiFlight stations to avoid impacts on known site environmental values. Site constraints resulted in some towers within the forested section near Lake Echo not being able to achieve optimum coverage.

Each IDF station is connected to a nearby turbine by power and communications cables which link the 16 IDF stations to an IDF Base Station near the CHWF Substation.

The IDF System tracks the movement of objects in the sky around the wind farm and quickly determines whether they are birds, then whether the bird is an eagle. If a bird is identified as an eagle, IDF commences tracking the eagle, recording its position, and trajectory in real time relative to turbines. Pre-defined curtailment conditions are then used to shut down (curtail) turbines if the trajectory of the bird indicates it would cross the rotor swept area of a turbine.

When an eagle is at risk, the IDF Base Station issues a signal to the wind farm SCADA system, which sends control signals to curtail one or more turbines to avert risk of eagle collision. When the eagle is no longer at risk, another signal is sent to restart the turbine. The IDF system can track multiple eagles simultaneously and shut down any number of turbines required to avoid a collision.

The parameters which determine when turbines will be curtailed 'the curtailment prescription' were established by Goldwind prior to commencement of wind farm commissioning on 19 November 2019 and are based on two imaginary cylinders around each turbine, with an inner cylinder radius (Ri) outer cylinder radius (Ro), upper cylinder height (Cmax) and lower cylinder height (Cmin).

These dimensions are thresholds, which if crossed by an eagle, may trigger curtailment signals in combination with other parameters, and were established based on the average speed in metres/second of a Wedge Tailed Eagle flying laterally, and the average time in seconds for the GW rotor to decelerate from full generation (RPM speed) to idle, based on field measurements of rotor deceleration time over a range of wind conditions and at different turbines.

The IDF system was installed during the late stages of construction of the CHWF, and progressively brought online in the early stages of wind farm commissioning. The commissioning schedule was managed such that IDF stations observing turbines about to commence commissioning, had already been tested, and validated as fully operational, before commissioning of those turbines began.

The commissioning stage is a particularly high collision risk period for eagles, as regardless of turbine operation being partial, it represents the first-time eagles will encounter spinning blades. This was evidenced by high curtailment counts and many dangerous eagle flights detected by IDF during the 8.5-month commissioning period, resulting in several adjustments to the curtailment prescription.

Since full wind farm operations commenced on 4 August 2020, the IDF curtailment prescription has been through several further iterations as knowledge of the population of eagles utilising the site has increased. Additional SCADA controls and internal management processes have been introduced and improved alert, communications and reporting functions developed in collaboration with IDF.

Key findings from the assessment of effectiveness of the IDF System are as follows:

Identifying and Classifying Avian Species

A major factor which distinguishes the IDF system from radar and other technological approaches to automated curtailments, is its ability to recognise different species and make targeted curtailment decisions based on protected species.

For the IDF system to be able to distinguish eagles from other species a convolutional neural network (CNN) first had to be developed to replace the existing American Golden Eagle CNN established by the US developers of IDF with a new CNN based on the Tasmanian WTE, listed as Endangered under the Commonwealth Environment Protection and Biodiversity Act 1999, and the White Bellied Sea Eagle (WBSE) listed as Vulnerable under the Tasmanian Threatened Species Act 1985.

To develop the CNN required a huge volume of images of WTE to be collected, capturing the full range of movements and behaviours and various angles of approach. These images were collected by each IDF stations as they came online during wind farm commissioning. It took around four months to collect enough WTE images to develop the CNN during which time, all ‘difficult’ bird images were classified by independent avifauna experts to ensure the learning process was as robust as possible.

Following implementation of the new CNN, ‘false positive’ curtailments dropped significantly, which led to a corresponding reduction in overall curtailment duration across the wind farm.

Reviews of classification accuracy have shown the IDF system to be able to recognize and correctly classify WTE with a very high level of confidence.

Low levels of WBSE activity in the early stages of the project meant there were not enough WBSE images collected to incorporate WBSE to the CNN, so as a failsafe, the system was programmed to assume any species which was not a WTE, but had a similar wingspan, was an eagle.

While this resulted in increased false positives (curtailments for a bird which is not a target species) associated with other large birds moving through the wind farm (e.g., Great Cormorant, Black Swan), it has allowed the IDF system to effectively protect the WBSE.

From about mid-2021 WBSE activity within the wind farm increased significantly and has since allowed the requisite WBSE images to be collected to upgrade the CNN to incorporate WBSE.

At the time of writing, the project is in the early stages of a CNN upgrade to recognise the WBSE which is scheduled completion by end March 2022.

Monitoring the Movement of Eagles within the Wind Farm

One of the very useful applications of IDF is its ability to continually monitor avifauna activity.

Huge amounts of data collected have not only added to the understanding of WTE eagle behaviors at CHWF; the data has been used to develop a detailed record of other species utilizing the site, and seasonal patterns such as the timing of migratory species arriving and leaving the site.

The volume and quality of information captured by IDF is considered far more comprehensive than what is possible using traditional bird survey methods conducted by human observers.

As an example, over a period of 4 months during development of the WTE CNN, IDF cameras captured a greater diversity of bird species than the total of all previous human bird surveys dating back to 2009. This included species such as the Grey Goshawk, thought to be present, but not previously detected by human observers over many years of monitoring.

IDF's automated record keeping quickly builds up a large dataset of avifauna information which is geo-referenced, dated, and timestamped, includes photographic evidence, and is continuously growing. The data collected is not confined to static points in time and captures species over greater distances and heights than the human eye can perceive.

Eagle movement data from IDF was compared with data arising from human observations from monitoring conducted in accordance with the approved Eagle Utilisation Monitoring Plan, however direct comparison was not possible for the following reasons:

- IDF data is generated from 16 IDF stations, whereas the human eagle monitoring data was generated by 6 human observers.
- The location of the 16 IDF stations differ from the 6 (previously established) human monitoring locations.
- The IDF monitoring is continuous and has captured eagle movements as early as 4.30am and as late as 9.30pm, whereas the human eagle utilization monitoring has been confined to five seasonal eagle survey periods, with monitoring undertaken between 8.15am to 4.15pm.
- Since commencement of operations, IDF has collected 550 days of monitoring at all turbines. In comparison, human eagle utilization monitoring at seasonal monitoring periods has collected 25 days in total.
- At the time of writing, the 2-year post commissioning eagle utilization monitoring is still ongoing, so only a truncated dataset was available for comparison.

Heat maps from both datasets showed broadly similar patterns, and it is considered likely both datasets would align over time once sufficient human eagle observation minutes had been collected to allow comparison with IDF.

However, many additional observers, as well as additional survey locations would be required to match IDF's coverage, and recording may still be less systematic or less reliably georeferenced.

Both IDF and the human observers have a visibility range exceeding one kilometer, however the results suggest IDF has a higher visibility range in the vertical dimension. The additional number of stations also mean IDF is better equipped to track multiple eagles simultaneously.

The IDF data is excellent for monitoring eagle movements within the wind farm but is confined to a 1km hemisphere of each IDF station, so cannot match data generated by GPS tracking devices affixed to eagles for monitoring eagle movements over longer distances. An additional limitation is that tracks are often truncated when a curtailment is made and the IDF station commences tracking another bird.

Overall, monitoring of movements of eagles within the wind farm by IDF is considered far superior to equivalent monitoring conducted by human observers over the same periods, due to the significant additional data collected. If the goal was purely to establish high eagle activity zones, it is reasonable to expect both methods would generate similar results over time, assuming equivalent survey efforts were possible.

Preventing Eagle Collisions with Turbines

The project approvals outline predicted cumulative WTE mortalities as five WTE mortalities by the end of the first year of full operations, eight by the end of the second year, and eleven by the end of the third year. Commissioning was excluded from the CRM. Over the 25-year lifespan of the CHWF, the project was predicted to accumulate up to 59 WTE mortalities.

At the time of writing, IDF has been operating for 27 months (2.25 years) consisting of 8.5 months of wind farm commissioning (19 November 2019 – 3 August 2020) and 18 months of full operations (4 August 2020 – 4 February 2022). Turbine activity during these periods is described as follows:

- During commissioning, turbines were increasingly brought online and tested for periods of 500 continuous hours as the wind farm went through a staged process of increasing generation output. For the latter half of commissioning, all 48 turbines were operating, albeit on a partial basis.
- Full wind farm operations commenced on 4 August 2020 and during the 18-month IDF assessment period, all 48 turbines were continuously operating, excepting periods of unsuitable wind conditions, planned or unplanned maintenance activities, and AEMO restrictions on generation.

During the period of IDF operation to date there have been three WTE mortalities, and no WBSE mortalities. Goldwind believes the mortalities, while less than predicted, may understate the effectiveness of IDF, as with the benefit of hindsight, all three mortalities could have been avoided. Actions have been undertaken to eliminate the root cause of the first mortality and reduce the risk of recurrence of the second and third mortalities.

The first WTE mortality at Turbine 2 cannot be ascribed to IDF, as IDF had already initiated a curtailment to prevent the collision, which was accidentally overridden by an operator.

- In the weeks leading up to the incident, turbines had occasionally been failing to restart for unknown reasons, which led to a manual restart process being introduced while the issue was being investigated.

- The process included a visual check for eagles prior to restarting a turbine, however this unfortunately did not prevent the mortality.
- Following the incident review, processes, and controls to prevent recurrence were implemented, such that an IDF curtailment signal cannot be overridden, for any reason.

The second mortality occurred in an area identified by GWA and IDF from the beginning of the trial as a risk, due to the densely forested location of the turbines and inadequate clearance around the turbines due to site constraints and landowner preferences.

- There is no direct evidence of the mortality being the result of a collision with the rotor; this was assumed primarily because of the location of the bird (90m from the tower) and its injuries, which were not inconsistent with a fall from height or collision with a slow-moving rotor.
- IDF data review revealed evidence of conflict between WTE and WBSE on the day, and several flights involving the deceased bird over the days prior, but none of the flights captured by IDF could have resulted in the mortality.
- Following the incident investigation, a stand of trees near the controlling IDF station was found to result in a blind spot over the lower parts of turbines 45 and 46.
- These turbines had been considered protected by IDF due to consistently high curtailment counts since the trial commenced, however the investigation revealed an eagle beneath 70m AGL would not be visible if approaching from the south or southwest.
- Site staff had observed eagles perching and hopping between trees in the area, and it was assumed that due to a combination of low altitude, angle of approach, and obstructing vegetation, the eagle was not visible to the IDF station, and as a result no curtailment signal was issued.
- Following ecological checks landowner permission to remove the trees was sought but not provided.

Following a third WTE mortality at turbine 46 due to the same vegetation occlusion, landowner permission to remove the obstructing vegetation was again sought and this time was provided.

- Removal of a small stand of trees has led to a noticeable improvement in visibility of turbines 45 and 46 and the area around them.
- Further clearance would still be needed to optimize IDF performance but is restricted by carbon forest protection provisions which prohibit removal of vegetation.
- Alternative options to reduce collision risk are being investigated, including a taller IDF tower, mobile tower, black blade trial and removal of perch branches.

Review of IDF data suggests collision risk in this area appears greatest in the colder months when there is an absence of thermals, leading eagles to hunt for prey from perches. During the winter months IDF data shows average eagle flight heights drop beneath the tip height of the rotor, whereas during summer, average eagle flight heights are well above rotor tip height.

Most of the turbines within the CHWF are not subject to the same visibility occlusions as turbines 45 and 46 and at these locations IDF has proven effective – no WTE or WBSE collisions have occurred at any other turbine since November 2019 despite high eagle activity across the wind farm. This includes zero collisions at turbines 8, 9, 40, and 41 which have the highest eagle activity in the wind farm.

In comparing mortalities with those predicted, Goldwind is of the view that without IDF, WTE mortalities could have been higher than predicted, a view shared by eagle experts on the project.

- IDF data has shown an increase in the population of eagles utilizing the site since pre-construction eagle utilization monitoring was undertaken over 2008-2010, and a corresponding increase in the number of nests.
- At DPEMP stage, collision risk was based on four nests inside the CHWF, no nests outside the wind farm, with a population of 10 WTEs utilizing the site, with no WBSE, and zero observations of conflict flights.
- By comparison, in 2020 when wind farm operations commenced, there were 7 nests inside the wind farm, and 35 known nests within 10 km of the wind farm, including several active nests just outside the boundary of the wind farm.
- IDF data has revealed a population of up to 15 eagles currently utilizing the site, with regular WBSE presence observed since about May 2021, and juveniles of both species.
- Inter-species conflict between WTE and WBSE has been observed by IDF cameras and WTE have been noted displaying throughout the year, not just within the display period.
- Diving eagles are regularly picked up by IDF, however as these occur within seconds, they could easily be missed by human observers.

Because of these factors, IDF's effectiveness preventing mortalities is arguably better than the on-paper comparison against predicted mortalities would suggest.

It is also noted that parts of CHWF are particularly challenging; many wind farms could achieve better results, potentially even avoiding all eagle collisions, depending on topography and vegetation.

In conclusion, it is considered IDF performance is in line with published research and does significantly reduce eagle collisions. However, where an IDF station does not have full visibility of the wind turbine, rotor, and surrounding areas, it may not be able to prevent all collisions, a factor which should be considered during development of the turbine and IDF layout.

Overall, the effectiveness of the system is likely to vary between sites and performance will largely be driven by site topography, vegetation, the wind farm layout, and the number of IDF towers a project is able to accommodate.

Detecting and Documenting Eagle Collisions with Turbines

- IDF is designed to avoid eagle collisions and does not detect or document collisions *per se*.
- Once a curtailment is made to avert an eagle collision, IDF ceases tracking that eagle and reverts to scanning the sky for other eagles in the area which may also warrant protection.
- To detect and document bird and bat collisions at the CHWF, a three-tiered carcass monitoring program has been undertaken which includes:
  - Detailed searches of all turbines to 120m of every tower on a bi-monthly basis
  - 'Pulse' surveys to 60m of each tower are undertaken within three days of each search.
  - Drive-by surveys of all turbines on a weekly basis at 45 and 80m transects.
  - Use of detection dogs to increase the efficacy of searches.
- Data collected by IDF could be used to help understand why a collision occurred, and in some cases could pinpoint exactly when the collision occurred.
- As IDF does not detect collisions, it cannot replace carcass monitoring to quantify the impact of a wind farm, however it could be re-configured to do so, and may be used in this way for offshore

wind projects in future (*pers comm Carlos Jorquera, IDF*). The use of IDF to detect collisions has been outside the scope of this trial.

- Carcass monitoring varies across wind farms; an exhaustive monitoring program may give higher confidence in the results but will consume large resources which could be better diverted to species conservation; a casual survey approach is likely to under-report collisions.
- This inconsistency makes comparison of performance across projects difficult. Over the longer term, automated approaches such as blade sensors and artificial intelligence camera-based systems, are considered more suitable and reliable approaches.

Technical Reliability

Having installed, operated, and maintained IDF for over two years, Goldwind's experience is that:

- IDF operates as intended and has not resulted in any major unresolvable issues.
- IDF can be serviced locally by wind farm technicians without the need for extensive technical support from the US.
- No major modifications have been required.
- Some modifications were undertaken to improve management of the IDF asset, including introduction of an alert system.

Performance Efficiency

The trial has demonstrated that:

- The IDF system can reliably communicate with the wind farm SCADA system and send signals to curtail turbines with sufficient time to avoid an eagle colliding with turbine blades.
- The IDF system can distinguish between eagles and other birds on site, and issue curtailment signals only for the target species (eagles).
- The IDF system can operate without incurring excessive generation losses.
- The technology can protect bird species while also operating the wind farm efficiently.

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1. Introduction

1.1 This Document

This report presents the findings of a technology trial of the eagle collision avoidance system referred to as "IdentiFlight", which has been installed at Cattle Hill Wind Farm (CHWF) in Tasmania's Central Highlands. CHWF is the first Australian wind farm to implement the technology, and the first in the world to integrate the system during construction of the wind farm. This report responds to Condition 6C of EPBC Approval 2009/4839, which states:

> *6C Within 18 months after commissioning submit to the Minister a detailed assessment of the effectiveness of the collision avoidance and detection system, including complete records of detected WTE collisions at the wind farm site and information about and comparison of relevant technologies and practices available at the time of preparing the report.*

The report covers technical aspects of the trial, which evaluates the technology against specific requirements outlined in the Commonwealth approved CADP; and information based on GWA's experience installing, commissioning, operating, maintaining, and optimizing the IDF system over the past three years, for the purpose of sharing lessons with Regulators, industry, and the public. This report will be published on the CHWF website.

1.2 CHWF Proponent

Wild Cattle Hill Wind Farm Pty Ltd (WCHPL) is the holder of EPBC Approval 2009/4839 under which the IDF Trial is required. WCHPL is also the project proponent for the Planning Permit DA2010/19 and the 'Responsible Person' referred to by EPN 10105/1. As the Responsible Person, WCHPL has ultimate responsibility for operation of the wind farm in accordance with the EPBC Approval and conditions of the Permit and EPN.

1.3 Background to the Technology Trial

The selection of IdentiFlight for the technology trial was described in the approved Collision Avoidance Detection Plan (CADP) submitted in response to Condition 6A of the CHWF Commonwealth EPBC Approval 2009/4839 and prepared by renewable energy and environment consultants Joule Logic (2018).

The CADP outlines objectives of the Plan as being to investigate:

- The options for monitoring WTE (Tasmanian Wedge-tailed Eagle) movements.
- Strategies to detect and document WTE collisions with wind turbines.
- Strategies to prevent WTE collisions with wind turbines.

The plan also notes:

> *As there is no one technology or strategy that is currently demonstrably effective at achieving these three objectives, the purpose of the CADP is to evaluate the options available and select the most suitable strategy, which will then be trialled at the wind farm.*

The CADP included a report (*Strategies for Monitoring Bird and Bat Collisions (Joule Logic, 2018)*) which assessed the available technologies for the three CADP objectives (tracking the movement of eagles, detecting eagle collisions, and preventing eagle collisions). The report concluded no single technology could demonstrably achieve all three objectives.

Of the approaches reviewed, an imaging system with diurnal cameras was considered to have the most potential, and two systems, 'DTBird' and 'IdentiFlight' (IDF) were identified for further review. At the time of preparation of the CADP, both systems had undergone trials by the manufacturers, but were yet to be independently trialled by the US Department of Energy.

After further consideration of the merits of both systems, IDF was selected as the most suitable technology to install and trial at CHWF.

1.4 Project Approval Conditions

The CHWF project has three levels of approvals (Commonwealth, State and Local) with conditions and obligations that affect the IdentiFlight trial:

- EPBC Approval Notice EPBC 2009/4839, issued by DoEE (now DAWE) on 15 December 2014, as amended, most recently 03 July 2020;
- Environment Protection Notice 10105/1, issued by the Tasmanian EPA on 13 March 2019;
- Planning Permit DA2010/19 Cattle Hill Wind Farm, issued by CHC and amended by RMPAC on 2 April 2012; and
- Planning Permit DA 2017/56, to use and develop land to install and operate the IdentiFlight system, issued by CHC on 30 January 2018.

Relevant approval conditions and their relationship to the trial are explained in Table 1.1 and 1.2.

1.5 Scope of Technology Trial

The technology trial evaluation period spans the 18-month period from 4 August 2020, when first full operation of the wind farm commenced, to 4 February 2022, and has been undertaken in conjunction with various management plans developed and approved in accordance with Commonwealth, State and Local development approvals for the CHWF (outlined in Section 1.6).

The approved CADP indicated a full IdentiFlight system would be installed during construction of the wind farm, with an 18-month trial undertaken once the system was fully installed. The CADP requires testing the system for its technical and monitoring reliability and validation with other monitoring undertaken as part of the broader project approvals.

The CADP outlines the following aspects of the system to be tested as part of the trial:

- Detecting eagles and distinguishing them from other species
- Tracking the movement of eagles within the wind farm
- Avoiding or reducing collisions of eagles with turbines
- Detecting and documenting bird collisions with turbines
- Technical reliability of the system.

The approach to evaluating the technology in each of these areas is described in Section 1.6.

Table 1.1 Commonwealth approval conditions and relationship to IdentiFlight Trial

Commonwealth Conditions - EPBC Approval 2009/3839		
Ref.	Condition Summary	Relationship to Trial
6A	*Within three months following the commencement of construction, submit to the Minister for approval a Collision Avoidance and Detection Plan (CADP) containing details of the collision avoidance and detection system to be implemented (including technologies installed and practices undertaken) for monitoring WTE movements, preventing WTE collisions with turbines and recording collisions. The CADP must conform with Guidelines for its preparation which the Department must confirm at least three months prior to the commencement of construction. The CADP must include information about and comparison of relevant available technologies and practices.*	Outlines requirements for a Collision Avoidance Detection Plan (CADP). • Confirms IdentiFlight as the technology to be tested • Defines the scope of the technology trial, and • Outlines the aspects to be tested.
6B	*Not commission until the CADP has been approved by the Minister. The Minister will not unreasonably withhold or delay approval of the CADP.*	Establishes that commissioning of the wind farm cannot commence until the CADP had been approved by the Minister.
6C	*Within 18 months after commissioning submit to the Minister a detailed assessment of the effectiveness of the collision avoidance and detection system including complete records of detected WTE collisions at the wind farm site and information about and comparison of relevant technologies and practices available at the time of preparing the report.*	Outlines information to be included in the assessment report provided at the conclusion of the 18-month technology trial (this report).

Table 1.2 State Approval conditions and relationship to IdentiFlight Trial

State Conditions - EPN 10105/1		
Ref.	Title	Description
G10	Annual Environmental Review	Requires public reporting of collisions with birds and bats via the AER.
FF5	Eagle Nest Productivity Monitoring Plan	Requires two years of Eagle Nest Productivity Surveys to check WTE and WBSE nests within the site, and out to 10 km from the site boundary. The location of nests is used to inform eagle collision risk. Bird tracks captured by IdentiFlight are also used to help identify potential nest locations to check.
FF6	Eagle Utilisation Monitoring Plan	Requires two years of post- commissioning eagle utilisation monitoring within the wind farm. Data from human observers is compared against data generated by IdentiFlight.
FF9	Strategies for Monitoring Bird and Bat Mortalities	Required a review of available technologies with potential to meet CADP objectives. This review concluded IdentiFlight was the most suitable technology to trial for effectiveness at meeting CADP objectives.
FF10	Bird & Bat Mortality Monitoring Plan	Requires five years of carcass monitoring beneath turbines and outlines the methodology for conducting the surveys. The survey results are used to validate IdentiFlight performance by confirming whether collisions occurred.
FF11	Notifications	Requires notification of bird and bat mortalities to regulators
FF16	Turbine Shutdown Management Plan	Outlines measures to be undertaken if WTE collisions exceed the predicted numbers in Attachment 3 of the EPN, or in response to a new or previously unknown WBSE or WTE nest within 1,000m of a turbine. Includes a limit of no more than 4,292 wind turbine shutdown hours (WTSH) over any 12-month period from all eagle related shutdowns.

1.6 Approach and Methodology

Methodology for assessing performance of the IDF system against each of the evaluation areas (aspects) is broadly discussed in the CADP and has been expanded upon in this document.

Each aspect of the assessment was considered for its effectiveness in terms of technical reliability, monitoring effectiveness, and was validated in the field by conducting 'equivalent' surveys and monitoring using alternative methods.

The approach to the assessment is summarized in Tables 1.3 (objectives) 1.4 (performance criteria) and 1.5 (methodology). Table 1.3 provides a cross reference to relevant sections of this report.

Table 1.3 Aspects of the Assessment and Related Objectives

Aspect	Objectives	Reference
Identifying and classifying avian species	• *To assess how effectively the technology can detect moving objects and distinguish birds from other objects.* • *To assess how accurately the technology can recognise a bird as being a Tasmanian Wedge Tailed Eagle and distinguish it from other bird species.* • *To assess whether the technology can distinguish between the Tasmanian Wedge Tailed Eagle and the White Bellied Sea Eagle, and to what degree of confidence.* • *To assess the classification accuracy and false positive / false negative rates by classifying the same bird species images using independent human avifauna*	*Section 5*
Tracking the movement of eagles within the wind farm	• *To assess the ability of the technology to track eagles and the distance over which the technology can accurately survey.* • *To validate the ability of the technology to track movement of eagles within the wind farm by comparing data generated regarding eagle movements with eagle movement data generated by human observers over the same periods in accordance with the approved Eagle Utilisation Monitoring Plan required by Condition FF6 of EPN 10105/1.*	*Section 6*
Preventing eagle collisions with wind turbines	• *To assess the potential of the technology to avoid or significantly reduce eagle mortalities on operating wind farms, by comparing pre-construction Collision Risk Modelling and estimated Mortalities with actual mortalities.* • *To describe effectiveness of the technology in instigating shutdowns of turbines, the size of buffers required to initiative a shutdown before an eagle reaches the turbine, and other relevant factors, for the purpose of sharing lessons with the wind industry.* • *To assess how data generated by the system can inform eagle collision risk, in comparison with methods currently adopted on wind farms.*	*Section 7*
Detecting and documenting eagle collisions with turbines	• *To assess the best ways of detecting and documenting collisions on wind farms.* • *To validate the ability of the technology to prevent collisions by conducting a comprehensive program of mortality monitoring at every turbine using human searchers and detection dogs in accordance with the approved Bird and Bat Mortality Monitoring Plan required by Condition FF10 of EPN 10105/1.* • *To assess whether data generated by the technology can contribute to mortality investigations or understanding eagle behaviours which lead to collision risk.*	*Section 8*
Technical reliability of the system.	• *To evaluate the overall reliability of the system and document any modifications required in relation to powering the system, storing data, and communicating with turbines.*	*Section 10*

Table 1.4 –Assessment Methodology

Aspect	Objectives	How Performance against Objectives will be Evaluated	Data Considerations

Detecting and classifying eagles	• System can detect moving objects and determine they are birds.
	• System can distinguish eagles from other birds.
	• System can classify WTE without human aid
	• System can distinguish between WTE and WBSE.
		• Comparison of birds detected with bird utilization monitoring conducted by human observers.
		• Comparison of performance following neural network upgrades and setting changes implemented.
		• Comparison of simulated results (e.g., effect of setting changes) with actual results.
		• Use of experts for bird image classification during machine learning
		• Review of Classification accuracy
			• Number of images classified
			• Classification accuracy:
			  ○ Detection rate
			  ○ False Positive Rate
			  ○ False Negative Rate
			• Confidence interval (i.e., level of confidence detected bird is target species).
			• Error rate

Tracking the movement of eagles within the wind farm	• System can track movement of eagles to a high degree of accuracy. • Data is superior to surveys undertaken by humans.	• Consistency of IDF data with observations from specialists. • Comparison of eagle utilization monitoring outputs using human observers with GPS data, utilization data, heat maps, and KML files generated by IDF.	• GPS / location accuracy • Availability of data • Quality of data • Accuracy of Measurements

Preventing eagle collisions with turbines	• System significantly reduces eagle collisions compared with CRM modelling.
	• System generates reliable data on eagle movements that could progress understanding of eagle behaviour and collision risk.
		• Comparison of mortalities with predicted mortalities
		• Comparison of system against alternative approaches to avoiding eagle collisions with turbines.
		• Incident investigations following each WTE mortality.
		• Comparison of eagle collisions other Tasmanian wind farms
		• Comparison of carcass monitoring results with Industry benchmarks.
			• Size of buffers required around turbines
			• Rotor deceleration time
			• Number of curtailments
			• Duration of each curtailment
			• Results of carcass monitoring surveys.
			  ○ Number of WTE collisions that occurred
			  ○ Number of WBSE collisions that occurred

Detecting and documenting eagle collisions with turbines	• System generates useful data that contributes to understanding of why collision occurred.	• Comparison of data on movement of WTE near turbines with post-collision and eagle utilization monitoring • Comparison against existing approaches for detecting collisions.	• Number of collisions recorded • Root cause analysis. • Information supporting collision investigation.
Technical Reliability of the system.	• System operates as intended without major unresolvable issues. • System installed can be operated locally without extensive need for technical support from US.	• Issues encountered during construction, commissioning, and operations, and whether they were resolved. • Ability to integrate IDF communications with SCADA. • Sophistication of system diagnostics, alerts, and alarms. • Training required to operate and maintain the system.	• System Availability / Outages • Generation Loss / Efficiency • Downtime due to faults or maintenance issues • Downtime due to communications issues.

Table 1.5 – Technology Trial Performance Indicators

Aspect	Great Result	Average Result	Unsatisfactory Result
Detecting and classifying eagles	• System can detect moving objects and determine they are birds. • System can distinguish eagles from other birds with a satisfactory error rate. • System can classify WTE without human aid • System can distinguish between WTE and WBSE with a satisfactory error rate.	• Birds can be detected, and eagles can be distinguished from other birds, but not with a satisfactory error rate. • Species of eagle cannot be distinguished.	• Eagles cannot be identified from other birds, or • Eagles cannot be detected beyond a limited range, or • The system does not function in certain weather or light conditions.
Tracking the movement of eagles within the wind farm	• WTE can be tracked across the wind farm site • WTE movements across the site are detected at the same or better level than eagle utilization monitoring using humans.	• Eagles can be tracked across the wind farm, but not with a satisfactory level of accuracy.	• Eagle movement data obtained by IdentiFlight is less reliable than the data collected by monitoring using human observers to track eagles.
Preventing eagle collisions with turbines	• Shutdowns can be reliably instigated before an eagle reaches a turbine • Shutdown can occur at a distance that does not trigger unnecessary shutdowns on other turbines. • No collisions occur or significant (i.e., 80%) reduction in mortalities.	• Collisions occur but do not exceed predicted mortalities. • Collisions occur but mitigative actions to prevent recurrence were implemented. • Shutdowns can be reliably instigated before an eagle reaches a turbine, but not at a distance that avoids shutdowns on other turbines	• Shutdowns cannot be managed in a manner that allows eagles to be protected and the wind farm to operate. • Number of eagle mortalities exceeds number of predicted mortalities.
Detecting and documenting eagle collisions with turbines	• WTE collisions are detected at the same or better level than post-collision monitoring / CRM predictions. • System generates useful data that contributes to understanding of why collision occurred.	• WTE collisions are detected, but to a lesser degree than collision monitoring using human searchers, dogs, or other techniques. • Collisions can be documented, but there are limitations.	• Eagle collisions are not detected and / or are less reliable than the collision monitoring using human observers.
Technical Reliability of the system.	• System functions as required	• Modifications required but issues resolvable.	• System does not function as stated or significant faults or maintenance issues occur.

1.7 IDF Project Timeline and Development Phases

The IDF system for CHWF was developed over about 3 years. The layout of IDF towers within the wind farm was undertaken by IDF during initial site visits to CHWF and designed with the intention that all 48 wind turbines would have full coverage (visibility) by one or more IDF towers.

Due to site constraints (detailed in Section 2) some IDF towers had to be micro-sited to avoid protected flora and vegetation communities, resulting in minor adjustments to the final IDF layout.

A Planning permit was required for the 16 IDF Units and obtained from CHC. The Application included a supporting ecological assessment for installation of the IDF units based on the final layout.

The construction of the IDF system commenced with five IDF Units installed between 1 July 2018 and 30 June 2019 and the remaining eleven IDF towers installed between July 2019 and April 2020.

Commissioning of the IDF units was progressively undertaken prior to commissioning of the respective wind turbines, with IDF units progressively coming online as each wind turbine collector group was energized.

1.8 Report Structure

This report is structured as follows:

Section 1	Explains trial objectives, approach, and relevant approval conditions
Section 2	Describes Cattle Hill Wind Farm, subject site of the installed IdentiFlight system
Section 3	Describes the IdentiFlight system, the subject of the technology trial
Section 4	Provides an overview of lessons learned during implementation of the IDF system
Section 5	Findings from the evaluation of IDF's ability to detect and classify avian species
Section 6	Findings from the evaluation of IDF's ability to track eagles within the wind farm
Section 7	Findings from the evaluation of IDF's ability to detect and document collisions
Section 8	Findings from the evaluation of IDF's ability to prevent or reduce eagle fatalities
Section 9	Review of performance against Turbine Shutdown Management Plan requirements
Section 10	Findings from evaluation of the reliability of the IDF system
Section 11	Comparison of alternative technologies
Section 12	Findings and conclusions of the trial
Section 13	References

2 Cattle Hill Wind Farm

2.1 Site Location and Description

The Cattle Hill Wind Farm (CHWF) shown in Plate 1, is located on privately-owned land to the east of Lake Echo in Tasmania's Central Highlands, approximately 93 kilometres north-west of Hobart, within the Central Highlands Council municipal area.

Plate 1: Cattle Hill Wind Farm (Western turbines)

The CHWF comprises 48 wind turbines, with a generating capacity of 144 MW (about 5% of Tasmania's renewable energy generation capacity) - enough renewable energy to power 63,500 Tasmanian homes.

The CHWF is sited in a sparsely populated and isolated location, on land with an elevation ranging between approximately 760 to 920 metres ASL (for turbine sites). The site is in a low rainfall area and has been largely cleared for farming purposes (grazing and cattle) but retains areas of woodland and conservation significant vegetation and habitat, some within covenants. The wind farm site is approximately 4,121 ha and is bounded by Lake Echo to the west and grazing and forestry land to the north, east and south, and the small unpopulated settlement of Waddamana to the northeast. The site is predominantly used for grazing, small forestry operations and hunting, and comprises nine lots owned by two landowners.

The project was approved by Tasmanian State Regulators in April 2012 and by the (now) Commonwealth Department of Agriculture, Water, and Environment (DAWE) in December 2014.

The CHWF was developed, constructed, and is now operated by Goldwind, and is owned by Wild Cattle Hill Pty Ltd (WCHPL) (80% Powerchina (PCR) and 20% Goldwind (GWA).

Figure 2.2 shows the location of the CHWF. Plates 2.1 to 2.3 indicate the site and vegetation from cleared pasture to dense forest with trees with an average canopy height of around 35 metres.

2.2 Turbine Layout

Originally a 100-turbine project, the project was amended by Goldwind following acquisition to a 48-turbine project occupying significantly less footprint but utilising larger turbines with a greater rotor swept area (RSA).

The wind farm layout is shown in Figure 2.3 and incorporates 16 IdentiFlight units designed to protect eagles, including the Tasmanian Wedge Tailed Eagle (WTE), listed as endangered under the Commonwealth *EPBC Act 1999*, and with the White Bellied Sea Eagle (WBSE), listed as vulnerable under the Tasmanian *Threatened Species Protection Act 1985* (TSPA).

The operation of the IdentiFlight units is described in Section 3.

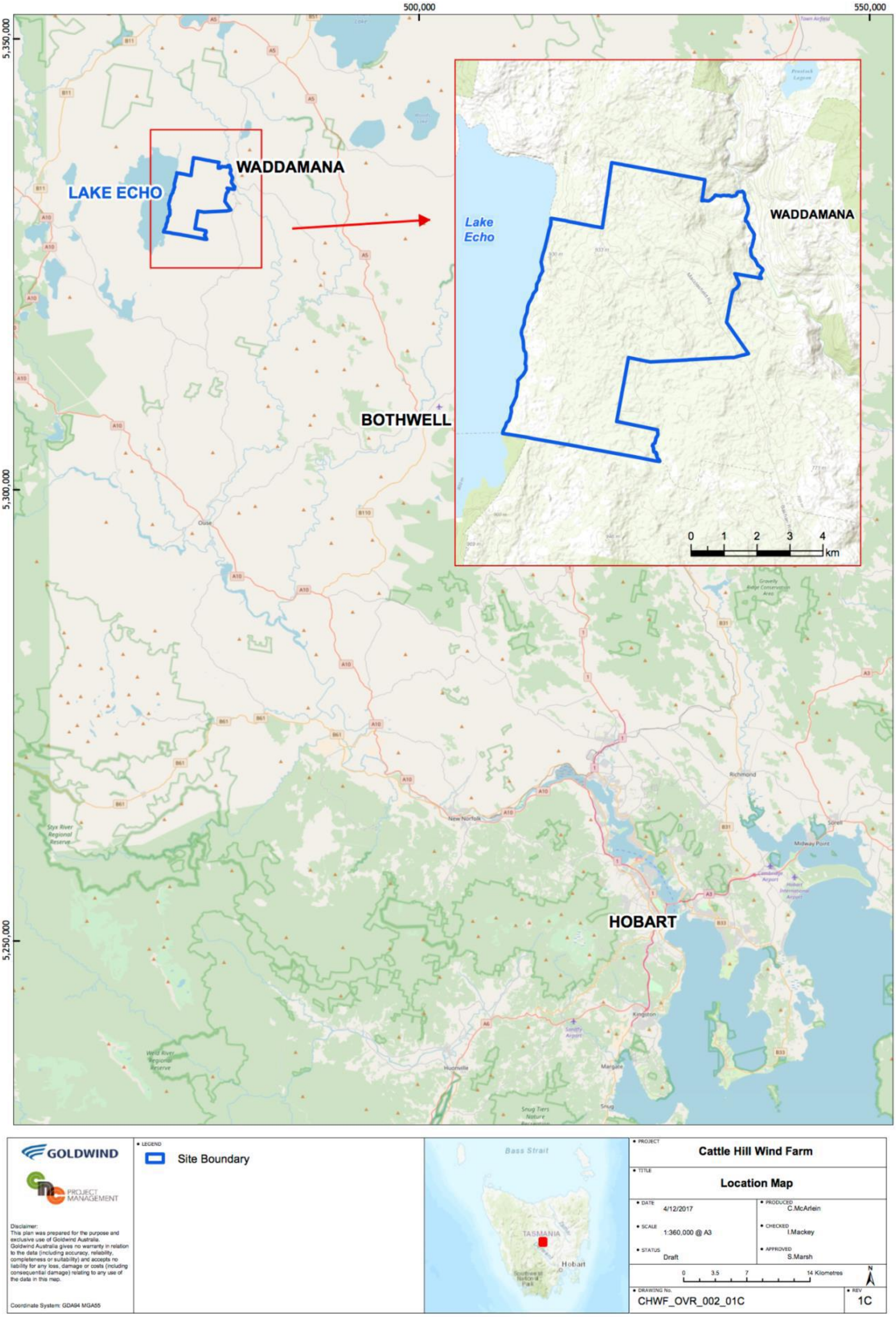


Figure 2.1: Cattle Hill Wind Farm location

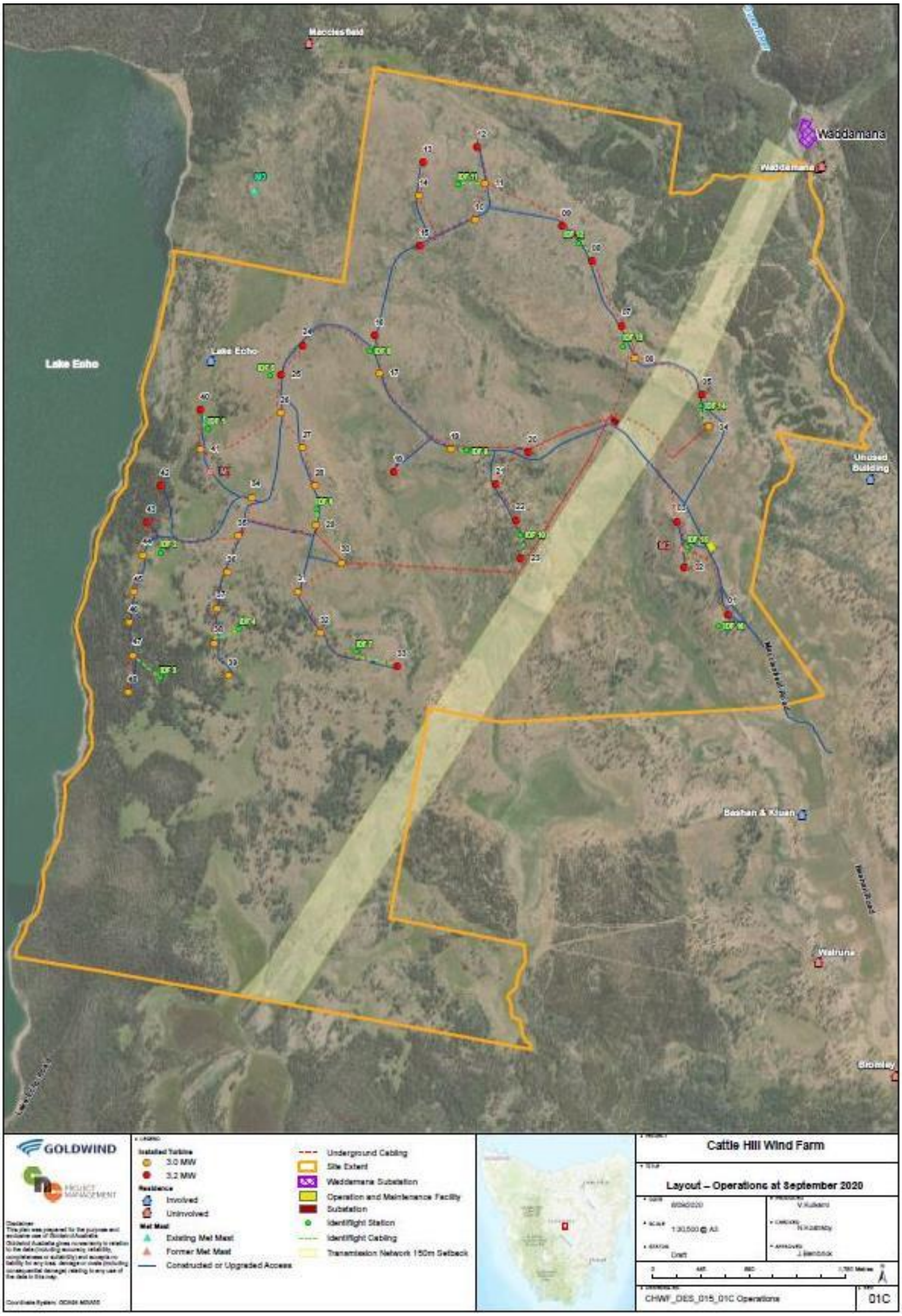


Figure 2.2: Cattle Hill Wind Farm Final (As-Built) Layout

Plate 2: View to western sites, grading into woodland on eastern shore of Lake Echo

Plate 3: View south through central CHWF in upland pasture and heath, few trees.

Plate 4: Eastern part of CHWF with turbines on ridgelines west of Ouse River Valley.

2.3 Site Constraints

The following planning and environmental constraints have been incorporated into the CHWF design and are to be adhered to by all persons on site for the life of the wind farm:

Plate 5: Western part of the site, showing protected Carbon Forest area.

- A pre-existing 'Lake Echo' conservation covenant which prevents placement of infrastructure within 100m of the high-water mark of Lake Echo.
- A 1,000 m infrastructure buffer around WTE or WBSE nests which were known as of December 2017 (when the wind farm layout was finalized via the EPA Approved Design Report).
- An approved Carbon Credits Forest under the Forests Alive project administered by the Commonwealth Clean Energy Regulator, which:
  - Includes allowances to clear vegetation for construction of the wind farm;
  - Prevents clearance of vegetation for any other purpose.
- A Hunting and Culling Management Plan, which:
  - Prohibits shooting within 200 metres of turbines.
  - Requires any animal carcasses within 500 m of turbines to be removed and disposed of in DAWE approved carcass pits.
- A conservation covenant for protection of Commonwealth listed orchid species.
- A conservation covenant for protection of State listed species *Discaria pubescens.*
- The following site exclusion areas:
  - A 30 m exclusion area around known mammal dens and nests.
  - A 30 m exclusion area around flora and vegetation communities to be protected.
  - A 50 m exclusion area around European (Huts) and Aboriginal cultural heritage (TASI) sites.

Plate 6: CHWF during winter, showing extensive snow cover.

3 Description of IdentiFlight® System

3.1 Overview

IdentiFlight is an autonomous aerial monitoring and detection system with the critical mission of preventing protected avian species from colliding with rotating wind turbines. The system uses high-precision optical technology to detect and classify protected avian species flying within a one-kilometer hemisphere around each IdentiFlight station. Proprietary software analyzes images of detected birds to determine their three-dimensional position, size, velocity, and trajectory towards turbines within the wind farm. When target species are at risk of collision, the system sends signals via the wind farm SCADA system to curtail the affected turbine(s) until the bird is no longer at risk.

The system uses sophisticated technology in both image sensors and software, including:

- State-of-the-art image-sensor arrays for hemispherical spatial detection.
- High-magnification stereoscopic optical sensors for position, trajectory, and species identification.
- High-performance artificial intelligence algorithms for autonomous real time image processing.

The IdentiFlight system was installed at CHWF during 2018 and 2019 during construction of the windfarm and includes 16 IdentiFlight stations (15 of 7 meters height and one of 10 meters high). Each station observes the airspace surrounding it and can detect moving objects within an approximate one-kilometer hemisphere.

The stations communicate with each other and have been positioned within the wind farm such that collectively, the 16 IdentiFlight stations observe the entire airspace above and around all 48 turbines. Plate 7 shows an installed IDF station within a stock-proof fence also housing the power and communications junction box.

Plate 7: One of the Sixteen IdentiFlight Units installed at Cattle Hill Wind Farm

3.2 Key Components of the IdentiFlight System

3.2.1 Tower

Each unit has a tower located on a concrete footing. The unit connects to power and communications cabling that are routed underground from one of the nearby turbines that has power supply components for the IDF unit. There are 15 7m high towers and one within woodland that is ten meters tall. The towers are rated to (53 m/s) wind speed and units are designed to operate in harsh environments. The towers are designed to disconnect and pivot downward using a screw jack to bring the imaging head to ground level where maintenance can be performed. The single 10m tower needs heavier duty equipment.

3.2.2 Imaging Head

On top of each tower is an imaging head (Figure 3.1) with two main parts; a lower part consisting of eight fixed-position Wide Field of View (WFOV) optical sensors, and an upper part containing two stereo high-resolution optical sensors, within a moveable camera housing unit referred to as the pan-tilt unit (PTU). The PTU has the capability to rotate 360^{0} whereas the WFOV sensors beneath it are fixed. Also housed within the imaging head are diagnostics boards and wireless devices for transmission of hi-resolution camera data.

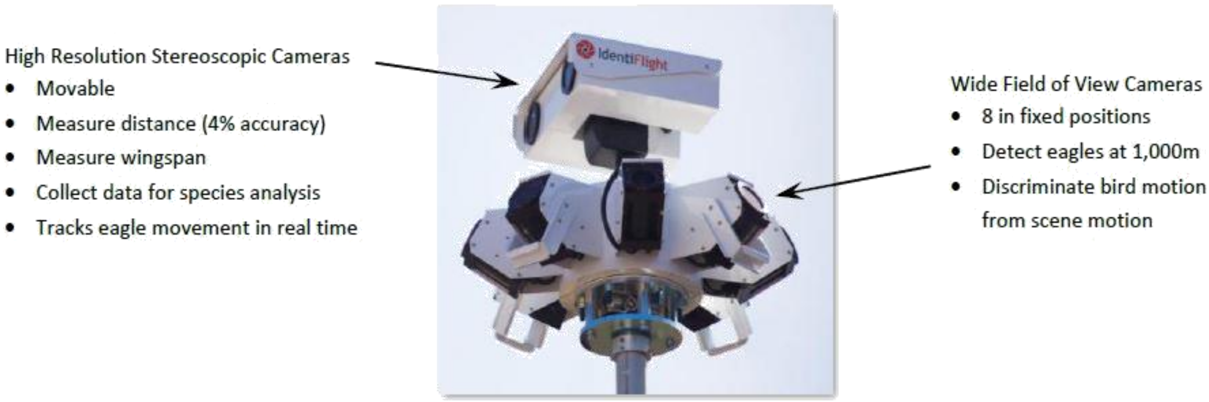


Figure 3.1: IdentiFlight Imaging head

The eight WFOV optical sensors (Figure 3.2) in fixed positions which form a hemispherical view around each tower (+64^{0} to -1^{0} from horizontal). The primary function of the WFOV optical sensors is to detect motion in the sky and report the object in motion.

Once detected by the WFOV sensors, objects are tracked by the two high resolution stereoscopic cameras within the PTU, which can rotate 360^{0} and track birds within +83^{0} and -18^{0} from horizontal (Figure 3.3).

The stereo configuration of the sensors makes it possible to perform detailed calculations of the distance, three-dimensional position, and velocity of moving objects.

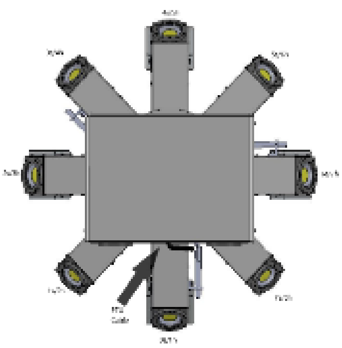


Figure 3.2: WFOV camera array

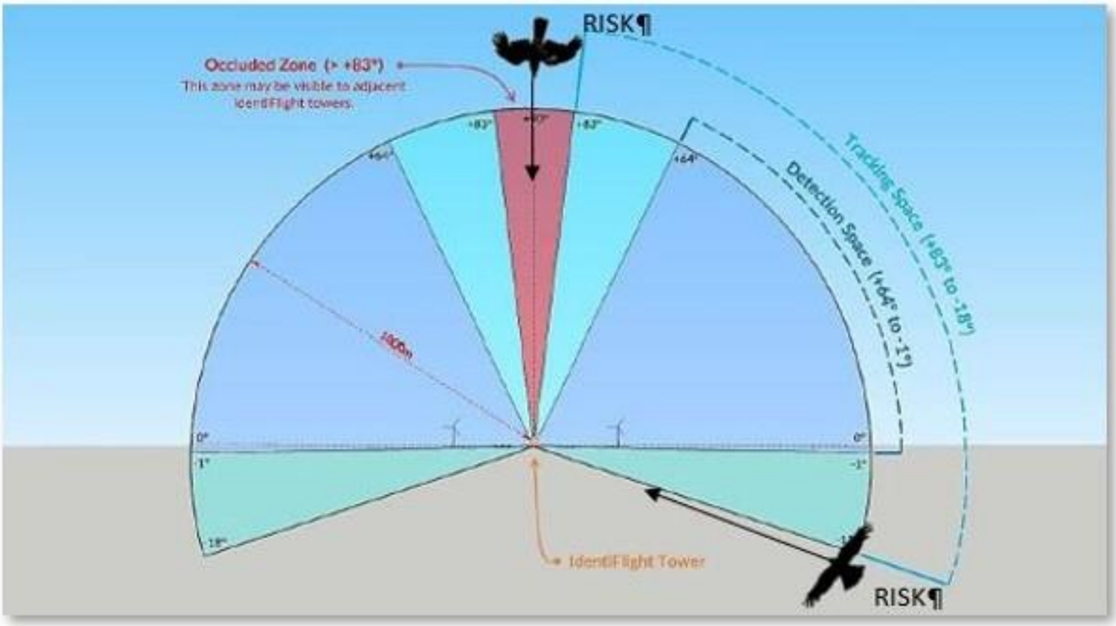


Figure 3.3: IDF vertical plane range and Zones of Occlusion

3.3 Key Components of IDF Communications and Analysis Systems

Optic fiber circuits link the IDF units to the IDF Base Station where commands are sent to the SCADA System and forwarded to specific turbines to curtail turbines and restart turbines after a curtailment.

3.3.1 IDF Network Architecture

Figure 3.4 shows a schematic of the network architecture of the overall IDF System, which is accessed by the U.S-based IDF team to perform upgrades, monitor performance and respond to faults and alerts. All equipment and data is protected through hardware and software protection layers, with routers and firewalls used to control access and protect against external attacks.

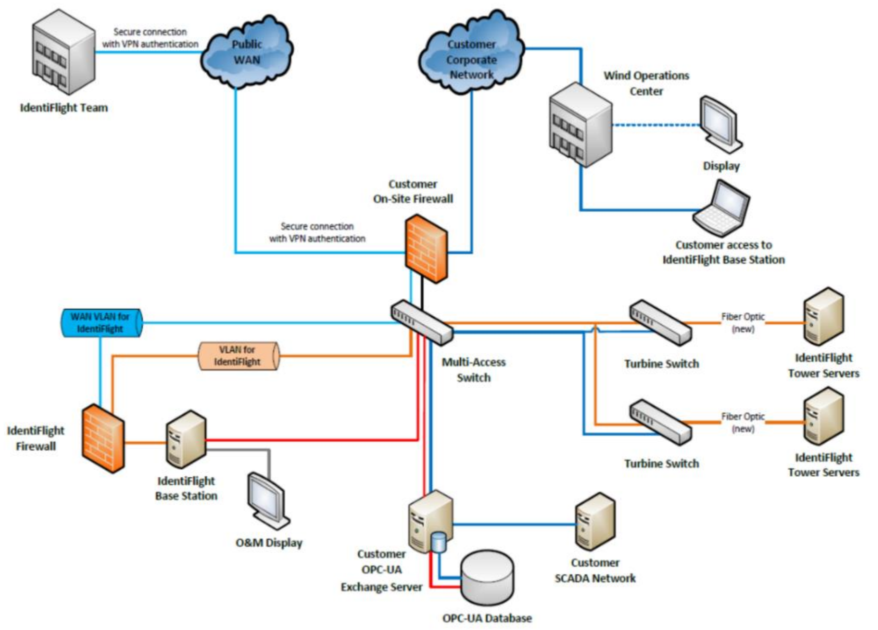


Figure 3.4: IdentiFlight Indicative Network Architecture

3.3.2 Base Station and Electronics Cabinet

The IDF Base Station is centrally located near the substation and hosts all critical curtailment logic. Components within the Base Station include the main server cabinet which houses the power system, network equipment, and a dedicated computer ("the inspector") which continually performs self-diagnostics of the overall system. A weather station is also included within the Base Station Compound.

3.3.3 Dashboard

The IDF Dashboard (Example Screen in Figure 3.5) is the interface which provides access to all data and reporting. Users can be assigned different permissions and rights to access various parts of the dashboard.

The dashboard receives data from the wind farm SCADA system, which is used for reporting, including turbine RPM data, and includes a classification section available to authorized users, which is used to classify bird species for development of the neural network.

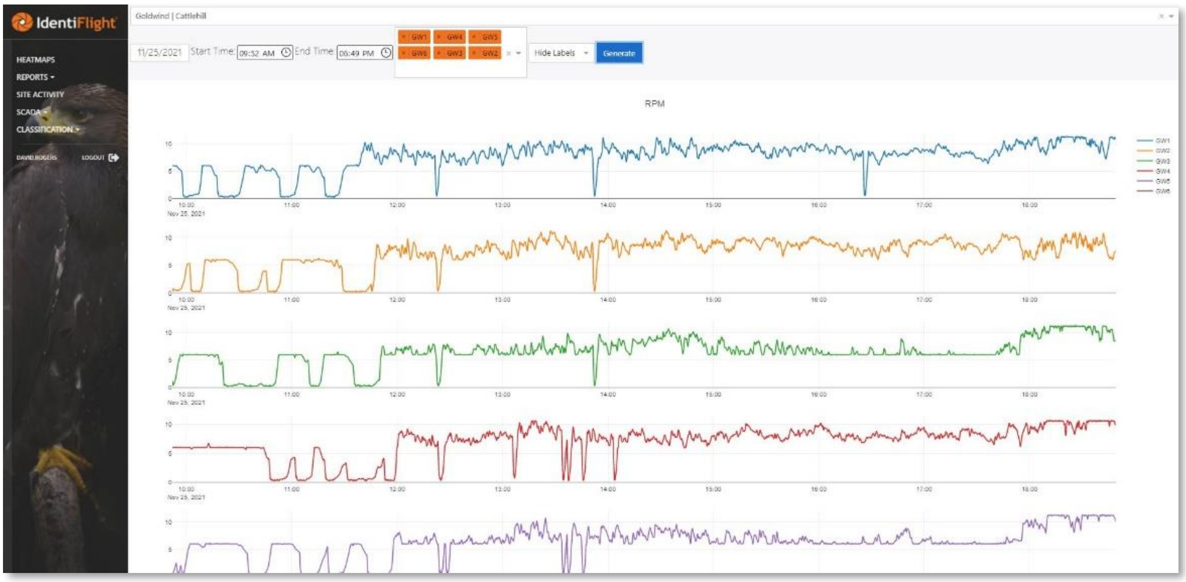


Figure 3.5: IdentiFlight Dashboard – Screenshot example display

A range of reporting tools can be accessed via the dashboard to track performance over time. Tables 3.1 provides a summary of available reports. Data can be aggregated on a daily, weekly, or monthly basis, or between set date ranges.

Table 3.2 provides a summary of data from the cause of curtailment (with tracks) report. This report is an excel spreadsheet which contains most of the detailed positional information for each bird that was tracked and is available daily.

Further detail on reports and data available is included in *Appendix A*.

Table 3.1 Summary of IdentiFlight reports

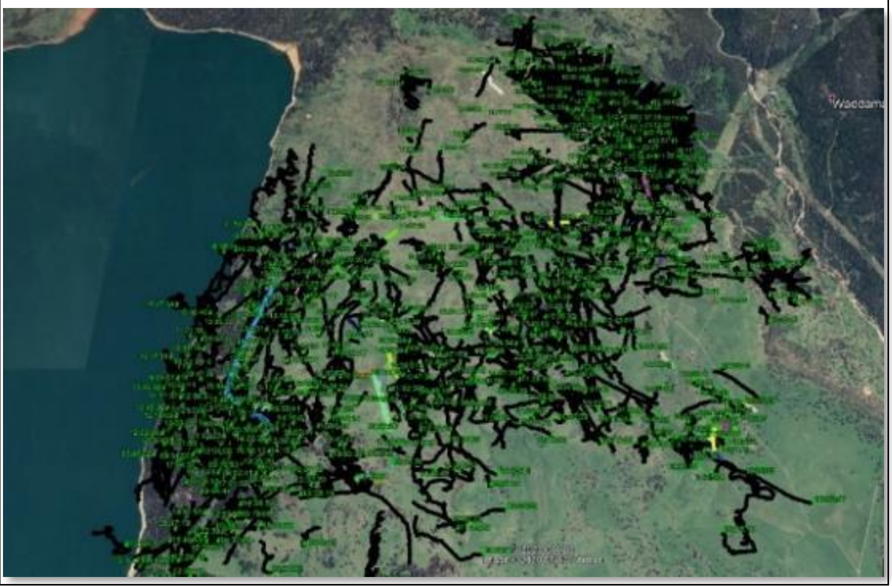
Report	Explanation
Daily email summary	Provides the high-level curtailment and track summary at the end of the day for the full set of systems at the site.
Bird Position Histogram	Reports the position of the bird and turbine being curtailed at time the curtailment signal was issued, for the day
Total curtailment report	Shows the total curtailments across all turbines being actively curtailed at the site, for the day. Curtailed duration does not take account of the turbine actual slowdown RPM nor the restart time. IdentiFlight is not receiving continuous data to report on this data point. Curtailed duration is just the time that the IDF initiated the curtailment and the time that IDF released the curtailment.
Total curtailment per turbine (with tracks) report	This report shows the total curtailed time of the entire project for the day. It details the sum of curtailment hours and number of times a turbine was curtailed. Cells containing Curtailment duration (hours) can be expanded to show additional decimal places (over ten significant figures.) The report also details individual curtailment periods with the IDF station that initiated the curtailment.
Totals over Time	This report includes another view of the curtailment data for the day with bar graphs at hour steps through the day
Cause of curtailment report	This report shows details of the tracks that caused a curtailment signal with the bird image, throughout the day. The report can be used in conjunction with the 'Total Curtailment Per Turbine (with Tracks)' report to review specific details on the bird that caused a curtailment
Cause of curtailment KML file	This file shows representations of a curtailed birds tracks as 3D lines over a Google Earth KMZ of the project site. 

Table 3.2 IdentiFlight Cause of Curtailment Report

Data	Description	Example
Track ID	A unique reference for each bird track	1bc82ff3-3855-4524-a65b-2bf35dd401c2
Date/timestamp	The time of the first bird image	30/06/2021 1:30:13 PM
Radial Distance (m)	The radial distance of the track	633.2084
Radial Distance Error (m)	the radial distance error	31.6604
Theta	The angle and position of the bird	224.7522
Phi		41.1089
X		473423
Y		5331346
Latitude	The coordinates of the bird in decimal format	48.1348210751142
Longitude		146.642791083646
Species Type/ Name	The IDF classification of bird species	WEDGE TAILED EAGLE
Confidence Level	Confidence the bird was the species named	0.994%
Tower Number	The IDF tower that was tracking the bird	IDF 4-38
WFOV camera	The WFOV that identified the bird	4
Horizontal Distance (m)	The horizontal distance from the tower	416
Height AGL (m)	The height of the bird above ground level	479
Elevation ASL (m)	The height of the bird above sea level	1376
Major Axis (mm)	The bird wingspan based on its position /angle	1854.9
Area	The area visible to the camera	784564.98
Closest Turbine	Closest wind turbine at first frame of track	GW38
Turbine Distance (m)	The distance between the bird and turbine	426.056334303341
Image	A compressed image of the bird	

3.3.4 Graphical User Interface

The IdentiFlight graphical user interface (GUI), installed within the Operations and Maintenance (O&M) facility shows eagles being tracked and turbine curtailments in real time. The GUI is also accessible to authorized users via phone or remote access to the IDF dashboard.

Figure 3.6 shows the IDF GUI. The Figure shows four WTEs being tracked simultaneously, resulting in curtailment of 9 turbines.

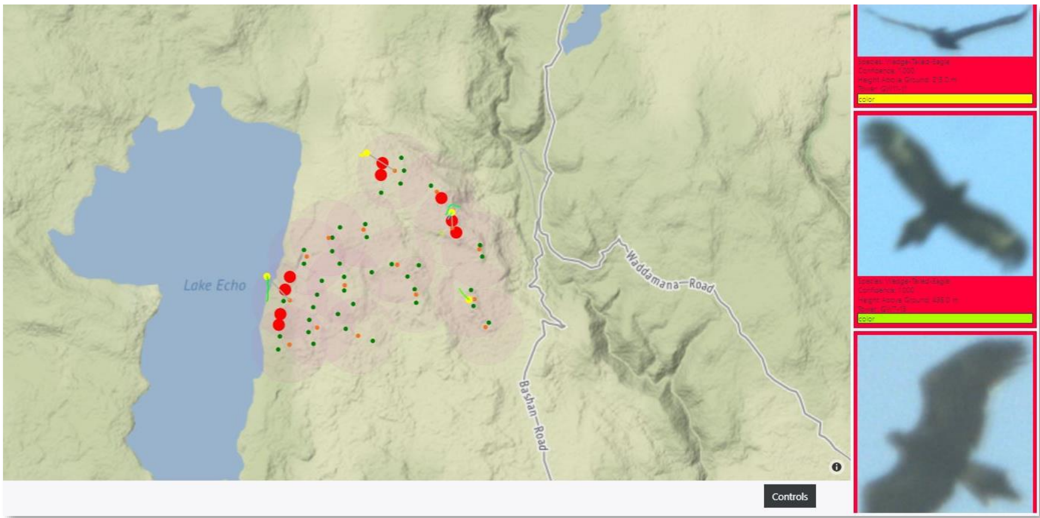


Figure 3.6: IDF Graphical User Interface

3.4 How IdentiFlight Detects and Classifies Objects

3.4.1 Identification and Classification

Birds, or protected (target) species, identification and classification can occur within five seconds using WFOV optical sensors and Stereo optical sensors functioning at different levels and communicating with the IdentiFlight® software. This is a dynamic process with continuous updates and adjustments at the software level and the internal neural net learning process to make the best possible identification in consideration of weather, lighting, and other changing variables.

3.4.2 Neural Network

Machine vision techniques consist of analyzing images against a set of rules to determine the degree to which an image matches the features (e.g., a bird's size, colour characteristics and wing profiles in flight) with that of the target species. Each frame gathered by the high-resolution stereo cameras (HRSC) is analyzed for the degree it matches a predetermined set of rules. Pattern recognition technology has developed catalogues of rules that analyze images obtained by the HRSC.

In addition to machine vision techniques, IdentiFlight incorporates convolutional neural network technology, using millions of images of target species to train a neural network. This process is tuned to reduce errors in predicting the species against a massive validation set of known bird images and is considered superior even to machine vision techniques. Using the convolutional neural network data allows the system to be periodically updated based on the cumulative data collected and continue to improve performance as the data set grows. To date over 6 million images of the WTE have been captured by IDF cameras.

3.4.3 Classification Certainty

Each of the ten images per second has a level of certainty associated with it. The system preserves the image with the highest classification certainty over the ten per second period and makes the final classification decision based on the image with the highest certainty over this period.

The system also includes fail-safes that will account for geometry of a given species. For example, with larger birds the fail-safe can be set based on wingspan and overall size. In the event a bird of a given size or wingspan is observed, it can be classified based on the settings of the fail-safe. Over time, as the system gathers images, those images will be periodically fed back into the system neural network and the fail-safe process will adjust (decrease) until the classification accuracy reaches the desired level and the neural net image classification is mostly responsible for classifying a bird.

3.4.4 Detection of objects in motion

A moving object that can be tracked through multiple frames is captured at a rate of ~5 frames per second. The initial detection reports anything in motion, then the software filters out objects of no interest based on brightness, size, movement, repetitive motion, or location exclusions. For example, if the object is too small or too large, or is moving too slow or too fast, to be a bird, it is excluded.

The size of the bird is determined with geometric model functions/calculations embedded in the software filters. Variables considered to determine a size value include the overall wingspan and tail to front measurement. The model will often make estimates since the bird will not always be in the appropriate or perpendicular position.

3.4.5 Masking

Any of the WFOV cameras can be configured to exclude specific locations within its field-of-view, via an image mask.

Figure 3.7 shows an example of excluding image regions (marked in black) such as buildings (for privacy motivations) or nearby trees (to ignore branches that move with wind and can distract the cameras). The WFOV cameras are completely blind to anything moving within these black regions.

Figure 3.7: WFOV Masking

3.4.6 WFOV Tracking

Multiple objects are tracked by the WFOV optical sensors, which are marked with color-coded circles to signify the level of interest.

Objects of low interest are marked with white circles once tracked for at least half a second. These objects are tracked and continue to be marked white while additional information is collected.

Once objects have been confirmed as a potential bird in flight via the system's filter analysis and predictive algorithms, they are marked with blue circles (Figure 3.8).

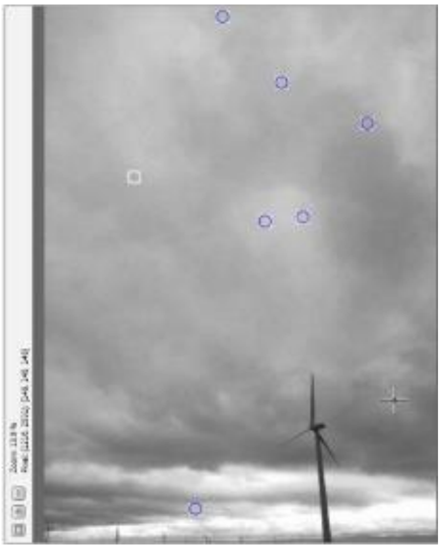


Figure 3.8: Tracked Objects and Potential

3.4.7 Stereo-Optical Sensor Tracking and Hi-Res Classification

When an object is assessed as a potential bird in flight, the location for the bird is sent to the hi-res stereo optical sensors to point and follow the bird using the PTU. If multiple objects are confirmed as birds in flight, the highest priority is initially sent to the hi-res stereo optical sensors. Each bird is tracked by the stereo sensors for 7 seconds, at 10 frames per second, then the next highest priority bird is tracked. If no other potential birds have been identified, the first bird continues to be tracked.

Tracking priority is established using a Prioritization Algorithm (Figure 3.9) which considers proximity to turbines, direction of flight, previous record of the bird, including its wingspan, species classification, and the confidence level of the classification.

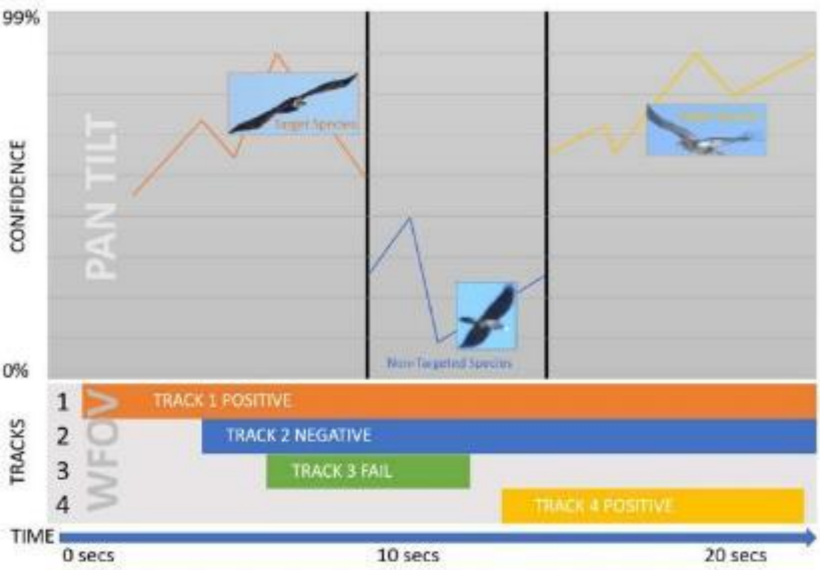


Figure 3.9: Tracking Priorities

The proximity of bird to turbine assumes that all objects are birds, and any bird could be an eagle. The distance measurement occurs every second with positional information recorded.

The previous record of the bird allows birds that may fly out-of-sight (e.g., behind a cloud) to reappear and continue being tracked using the same unique Tracking ID. If a bird reappears within 15 seconds, the same ID is used.

The stereo configuration of the HRSC sensors makes it possible to calculate distance, 3D spatial position, velocity, and estimate bird wingspan. The calculation applies posture compensation to allow for variables in the apparent wingspan due to the flight position of the bird. The estimate for bird size is used to quickly exclude birds or objects that are either too small or too large to be considered a species of interest.

Velocity and position of a bird is determined based on averaging the radial distance and angular measurement per second. Once the radial distance is averaged and determined, the angular measurement is then used to determine the position of the bird, which is reported in spreadsheet format via the IdentiFlight Dashboard, along with the Track-ID for that bird.

The track ID is used to access the bird track in KML format, which can be viewed in 3D along with the imported wind farm infrastructure in Google Earth or mapped with GIS.

4 Project Implementation and Lessons Learnt

4.1 How Curtailment Decisions are Made

IdentiFlight makes curtailment decisions based on a set of parameters referred to as the curtailment prescription (Table 4.1) which are set and adjusted by GWA. When an eagle being tracked breaches one or more of these parameters, a signal is sent via SCADA to shut down the affected turbine(s). Once the conditions of curtailment are not being met (i.e., no parameters are in breach) the eagle is considered no longer at risk of collision and a signal is sent via SCADA to restart the turbine(s).

Table 4.1: Curtailment prescription parameters

Inner Radius (Ri)	*Radius of a cylinder around a turbine known as the inner cylinder. If the protected bird is detected inside Ri at any time, a curtailment signal will be sent.*
Outer Radius (Ro)	*Radius of a cylinder around a turbine known as the outer cylinder. If the protected bird is detected outside Ro at any time, regardless of its velocity vector toward the turbine, a curtailment signal will never be sent.*
Upper cylinder (C max)	*Height of the outer cylinder around a wind turbine. If the protected bird is above C max, regardless of its velocity vector toward the turbine, a curtailment signal will not be sent.*
Lower cylinder (C min)	*Height of the outer cylinder around a wind turbine. If the protected bird is detected inside the C min and Ri a curtailment signal will be sent.*
Time to Collision. (TTC)	*IdentiFlight calculates the velocity vector of a protected bird each second and determines an imaginary cone from the bird to the outer extent of the RSA. If the bird, on its current speed travelling on a direct line within the cone would intersect the RSA within the TTC, a curtailment signal will be sent.*
Confidence (Cs)	*Confidence the detected bird is the protected bird. This metric ranges up to 99.9%. The higher the Cs the more confident the species determination.*
Time to Clear Tc	*The amount of time after a curtailment signal has been sent and the protected bird is no longer meeting any curtailment criteria, that the curtailment recommendation will be removed.*

Individual turbines can be assigned different parameters based on their risk profile. The settings and monitored by CHWF's environmental scientist and adjusted based on data from IDF, simulations, discussion with experts, and site observations.

The settings which most influence curtailments are Ro, Ri, and TTC, shown in Figure 4.1).

A key distinction in how the curtailment settings operate is that an eagle breaching Ri will always trigger a curtailment regardless of the bird's speed or trajectory, whereas an eagle between Ri and Ro will only trigger a curtailment if its speed and trajectory indicate a collision course with the turbine within the timespan defined by the TTC.

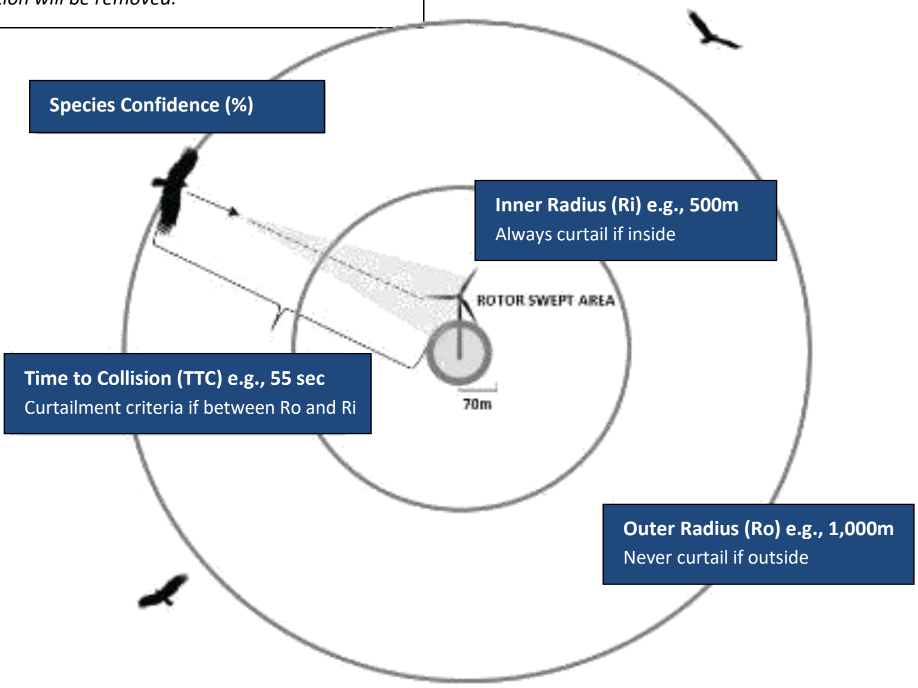


Figure 4.1: Schematic of IdentiFlight settings

4.1.1 Defining the Curtailment Prescription

Defining the conditions under which turbines would be shut down, a task coordinated by GWA's environmental scientist for the CHWF project, was initially difficult, as despite decades of monitoring the impact of wind farms on eagles in Australia and globally there was very little information was available on which to base decisions such as what a 'safe' cylinder height would be. Questions to eagle experts intended to inform the initial settings often resulted in different opinions and reliable eagle data (e.g., maximum speed of a diving eagle or average speed of an eagle flying laterally) was often not available and / or had to be specified as a range.

Another unknown was how the resident WTE population would react to commencement of wind farm operations after two years of stationary rotors during the construction phase. Faced with this uncertainty, internal cross-departmental discussions were undertaken, and GWA elected to adopt a conservative approach to the settings, favoring eagle protection over energy production, with the view to making incremental adjustments where safe to do so, as information became available and closely monitoring performance to better understand the IDF system capabilities, effectiveness, and its intricacies.

All subsequent setting changes were subject to prior risk assessment, simulations to test the effect of setting changes, and management briefings prior to changes being made.

4.1.2 Rotor Deceleration Testing

Prior to commissioning the first turbine on 19 November 2019 a series of measurements was taken to record the time between an IDF curtailment signal being sent and received by SCADA, and the total time between the IDF signal and rotor reaching idle state. In the U.S, 'safe' rotor speed is generally accepted as 2.5 RPM, however in Australia, there is no accepted definition of a 'safe' rotor speed, so the time for the rotor to reach idle state was conservatively used. This also considered the larger blade size and faster tip speed associated with the GW turbine installed at CHWF, than most operating U.S wind farms at the time.

Further measurements were undertaken to record the time for the rotor to decelerate to a safe speed under varying wind conditions, at different turbines, and various levels of generation output (i.e., higher and lower RPMs).

The TTC parameter was initially established based on the average speed of a Golden eagle (18 m/s) which was validated against measured WTE flight speeds using IDF data.

The combination of average eagle flight speed and measured rotor deceleration time was then used to establish the inner and outer radius parameters; with precautionary settings adopted that were greater than the US examples provided by IDF. The reasoning behind this approach was that future changes to the curtailment prescription would be better informed after a period of data collection and analysis, to provide some assurance eagle collision risk would not increase with any setting changes proposed.

4.1.3 SCADA configuration

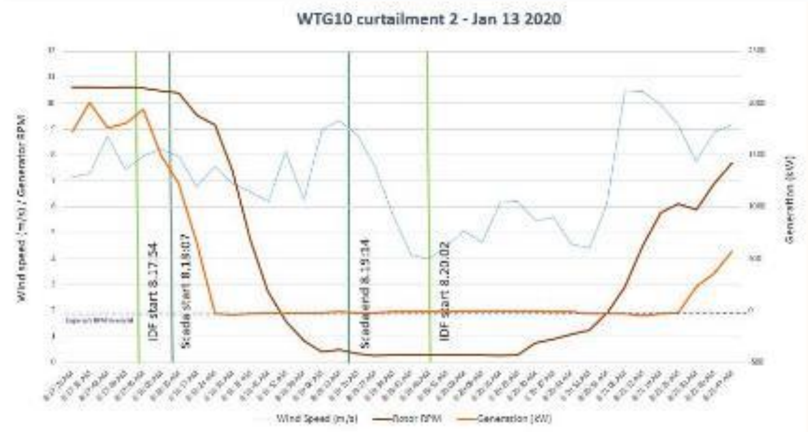


Figure 4.2: Example of initial IDF / SCADA testing during commissioning

Electrical and communications interfaces and controls were established and tested, including a series of tests to record the time between an IDF signal being sent, and received by SCADA (Figure 4.2).

These tests identified a signal delay of 10 seconds between the IDF signal being sent and received by SCADA, which was subsequently optimized to a delay of under a second by project SCADA engineers.

4.1.4 Developing the Neural Network

A critical component of establishing the IDF system was development of the neural network that would allow the IDF system to detect and automatically classify the Tasmanian Wedge Tailed Eagle, a new species for IDF which has similar attributes, behaviours, and size to the U.S Golden Eagle, the existing IDF neural network was based on, but unlike the Golden eagle, does not migrate - the population of WTE utilizing the CHWF are resident all year round.

To develop the neural network, it was critical for the system to learn to identify birds that were eagles, and birds that were not eagles. None of the previous eagle and avifauna monitoring included images which could be used for this purpose, so the images captured by each IDF station were used to collect a large databank of images which could then be used for machine learning.

Between November 2019 – April 2020 hundreds of thousands of bird images were collected and classified via a controlled-access classification dashboard set up for this purpose (Figure 4.3). To ensure the process was as robust as it could be, the US bird classification team was supported by a local team of specialists coordinated by GWA's environmental scientist, including local raptor expert Nick Mooney, who generously donated time validating any images of uncertainty.

4.1.5 Species Diversity Matrix

In addition to being used for machine learning, avifauna images captured by IDF were used to develop a species diversity matrix (Appendix B). The matrix provides a record of species present on site and is updated each time a new species is caught on camera.

Over time, IDF has enabled development of a comprehensive record of the avifauna species present on site, and the seasonal timeframes they occur.

This method of avifauna data collection is compared with traditional human-based survey techniques in Section 5.

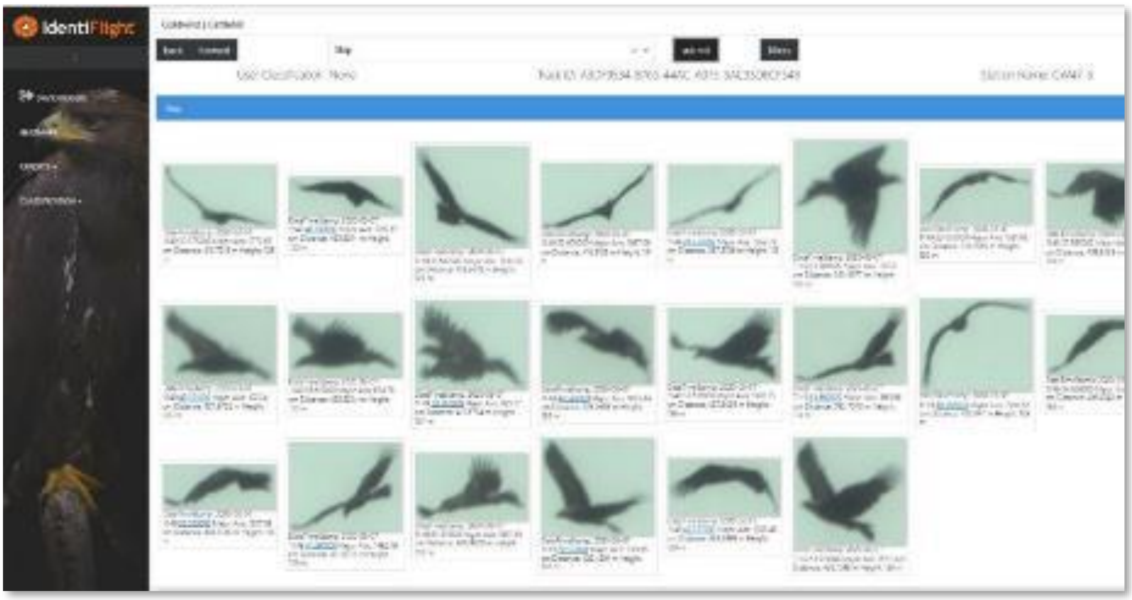


Fig 4.3: Classification Interface used for Machine Learning

4.2 Operations

4.2.1 Collection and analysis of data

IdentiFlight generates a series of reports daily, which can be accessed via the system dashboard. Reports are also available on an aggregated basis for weekly and monthly data. The continuous tracking of birds on a per second basis quickly builds up large volumes of data which is both invaluable, and resource intensive to manage.

IDF data was collated and analyzed from the start of commissioning of the wind farm and continued throughout the IDF trial period. This data was used to identify seasonal risk timeframes, at risk turbines within the wind farm, and track compliance and performance against project requirements and targets.

Figures 4.4 – 4.6 show some examples of analysis of data collected by IDF. Further examples of IDF data and reporting capabilities are provided in Appendix A.

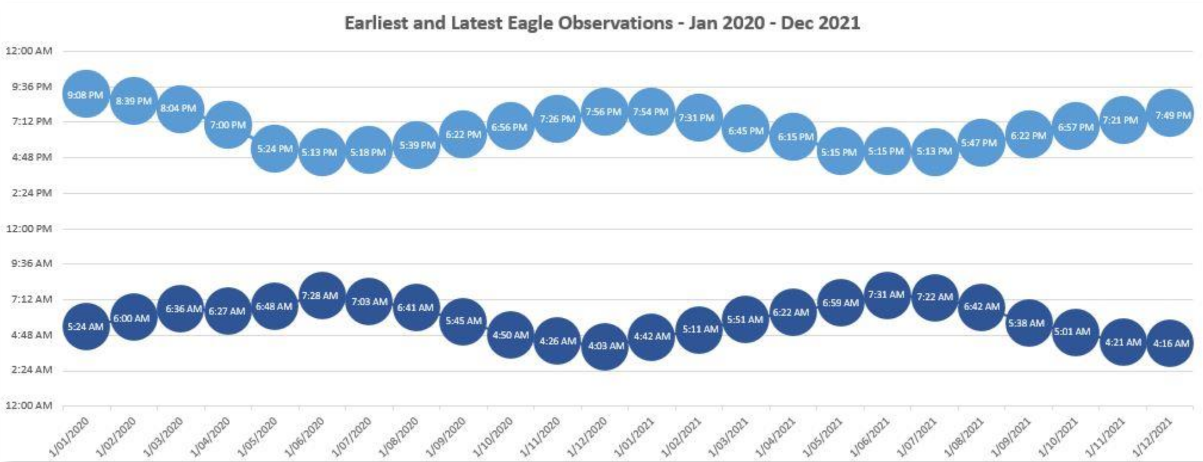


Figure 4.4: Chart generated from IDF data showing earliest and latest eagle observations

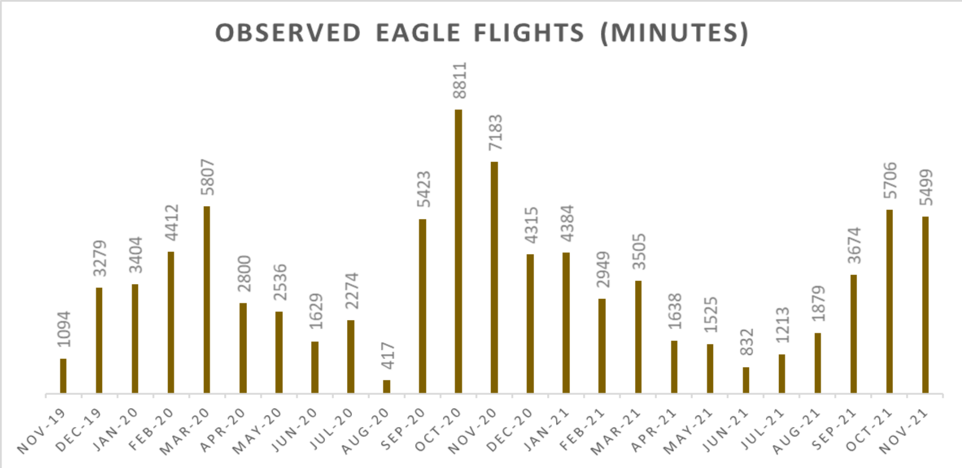


Figure 4.5: Eagle flights recorded by IDF

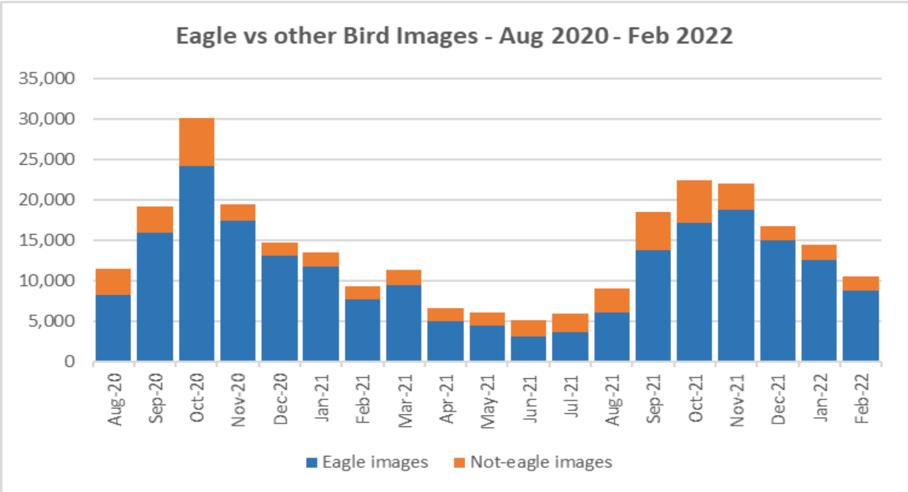


Figure 4.6: Eagle and other Bird images collected by IDF

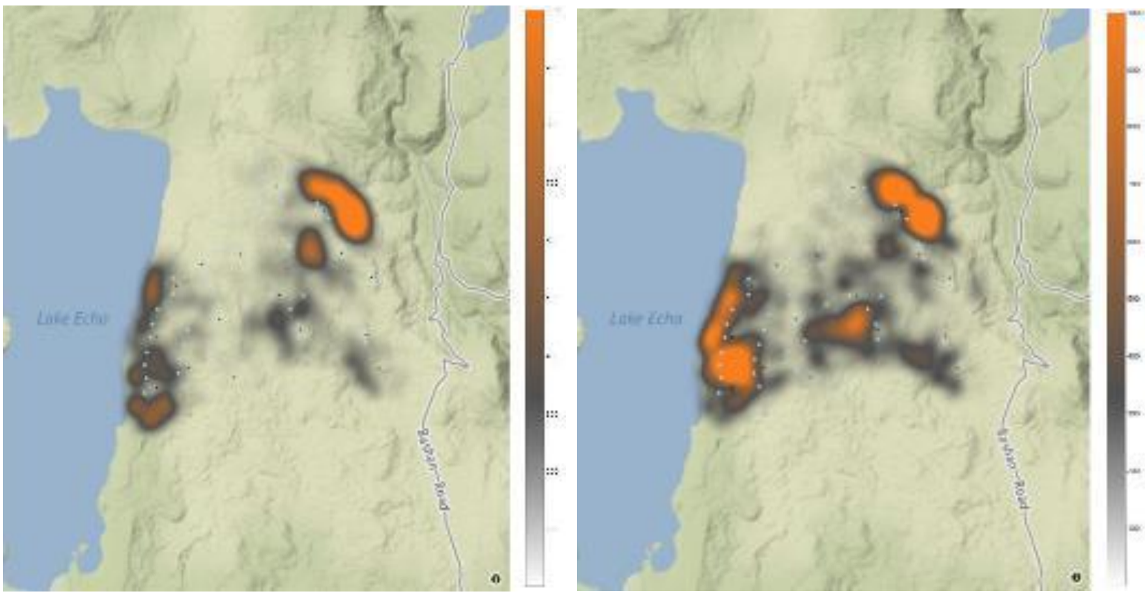


Figure 4.7 Heat Map showing increased eagle activity between November 2020 (left) and November 2021

Figure 4.8 summarizes the key activities undertaken in each stage of the project.

Planning	Construction		Operations	
Design	**Construction**	**Commissioning**	**Operations**	**Maintenance**
From April 2017 to June 2018	From 1 July 2018 to 30 June 2020	From 19 Nov 2019 to 3 Aug 2020	From 4 Aug 2020 ongoing	From 4 Aug 2020 ongoing
• Develop IDF layout • Review IDF tower locations against site constraints. • Microsite IDF towers in consultation with IDF. • Carry out Environmental Impact Assessment • Obtain consent for IDF Tower locations in covenant areas from Dept Crown Land. • Obtain Planning Permit from Central Highlands Council for installation and operation of IDF. • Procurement and shipping of IDF components	• Revise IDF tower footing design to withstand extreme conditions. • IDF tower installation • Electrical connections • Collect and classify bird images for machine vision learning. • Develop species diversity matrix based on past studies and bird images collected • Carry out ecological assessment of vegetation with potential to screen visibility of IDF cameras. • Develop GWA curtailment strategy in consultation with all relevant departments. • Define curtailment prescription to be initially adopted. • Develop neural network to enable auto-classification of Tas WTE.	• Tower Commissioning • Rotor deceleration testing • Commence Phase 1 carcass monitoring • Implement new neural network • Installation of GUI in operations facility • IDF service team training • Vegetation management • SCADA configuration • Monitor IDF data • Conduct simulations to test effect of changing settings • Review and revise curtailment settings	• Collect and analyze IDF data • Commence Phase 2 carcass monitoring • Monitor bird data • Regulator notifications • Incident investigations • Vegetation assessments and management • Landowner liaison • Liaise with avifauna experts • Conduct simulations to optimize performance • Improve communications and alerts functionality • Review and revise curtailment settings • Eagle utilization monitoring	• Planned Maintenance o Quarterly IDF tower Maintenance o Annual Tower maintenance • Reactive Maintenance o Respond to IDF requests (e.g., installation of software patches, updates) o Maintenance of Calibration targets

Figure 4.8: Key Activities undertaken During Each Phase OF Project implementation

5 Detecting and Classifying Avian Species

5.1 Summary of methods

Bird monitoring requires assessing the distribution, abundance, and movement of birds through space and time (McClure et al, 2018) and is traditionally undertaken by human observers conducting surveys over short periods of time at seasonal monitoring periods. Past studies have tested alternative automated approaches (e.g., camera-based systems, radar-based systems) and these studies assume the automated system is useful if it detected a substantial proportion of the birds detected by human observers.

To assess the ability of the IDF system to detect birds, independently classified bird images captured by IDF cameras were compared with the equivalent information generated by human observers during pre-construction and post commissioning surveys.

The records from carcass (or mortality) monitoring conducted during the trial period, which record each bird / bat species found beneath turbines, was compared against IDF bird data, and previous bird survey data.

To test IDF's ability to classify the target species (WTE) and distinguish them from other birds, a review of the classification accuracy of IDF was undertaken. Independent avifauna and eagle experts were used to classify IDF images for the sake of removing doubt.

5.2 Bird Species Detection

5.2.1 Comparison of Bird Species Detected by various methods

Bird species utilizing the CHWF site have been detected in various ways, as follows:

- Pre-construction bird surveys undertaken over two years at seasonal monitoring periods;
- Pre-construction eagle utilization monitoring undertaken over two years at seasonal periods;
- Post commissioning eagle utilization monitoring undertaken over two years at seasonal periods;
- Birds found beneath turbines during carcass monitoring over the 18-month IDF trial periods;
- Bird images captured by IDF cameras over 5 months during development of the neural network.

Bird species detected by seasonal surveys, carcass monitoring, and IDF are listed separately in *Appendix B*, and a comparison of species detected by each of these methods provided in Table 5.1.

As Table 5.1 shows, IDF identified a larger range of species than either of the human methods, despite a significantly shorter monitoring duration. This included two EPBC-listed species not detected by seasonal bird monitoring conducted by humans.

Note this does not represent a formal comparison of methods, as each of the monitoring approaches are for different purposes, however it does highlight IDF has several advantages over traditional human-based approaches for monitoring bird species on a site due to the continuous data collection and level of detail in the data collected.

Advantages and disadvantages of each approach are presented in Table 5.2.

Table 5.1: Comparison of Bird species detection at CWHF

Species Name / Scientific Name	*Seasonal Bird surveys*	*Carcass Monitoring*	*IdentiFlight*
Australian Magpie (Gymnorhina tibicen)	✓	✓	✓
Australasian Pipit (Anthus novaeseelandiae)	✓	✓	✓
Australian Peregrine Falcon (Falco peregrinus)	✓	✓	✓
Australian Swamphen (Porphyrio melanotus)	X	X	✓
Black Currawong (Strepera fuliginosa)	✓	✓	✓
Black faced Cuckoo-shrike (Coracina novaehollandiae)	✓	X	✓
Black Swan (Cygnus atratus)	X	X	✓
Blue Winged Parrot (Neophema chrysostoma)	✓	✓	✓
Brown Falcon (Falco berigora)	✓	✓	✓
Cape Barren Goose (Cereopsis novaehollandiae)	X	X	✓
Common (Indian) Myna (Acridotheres tristis)	✓	✓	✓
Common Starling (Sturnus vulgaris)	✓	✓	✓
Crested Pidgeon (Ocyphaps lophotes)	X	X	✓
Crimson Rosella (Platycercus elegans)	X	X	✓
Dusky Moorhen (Gallinula tenebrosa)	X	X	✓
Dusky Woodswallow (Artamus cyanopterus)	✓	✓	✓
Eastern Rosella (Platycercus eximius)	✓	✓	✓
Eurasian skylark (Alauda arvensis)	✓	✓	X
Forest Raven (Corvus tasmanicus)	✓	✓	✓
Great Cormorant (Phalacrocorax carbo)	✓	X	✓
Green Rosella (Platycercus caledonicus)	✓	✓	✓
Grey Currawong (Strepera versicolor)	✓	✓	✓
Grey Fantail (Rhipidura Fuliginosa)	✓	✓	X
Grey Goshawk (Accipiter novaehollandiae)	X	X	✓
Grey Teal (Anas Gracillis)	✓	✓	X
Ground parrot (Pezoporus wallicus)	X	X	✓
Laughing kookaburra (Dacelo novaeguineae)	✓	X	✓
Little Raven (Corvus mellori)	X	X	✓
Magpie Goose (Anseranas semipalmata)	X	X	✓
Magpie Lark (Grallina cyanoleuca)	X	X	✓
Masked Lapwing (Vanellus miles)	X	X	✓
Nankeen Kestral (Falso cenchroides)	X	X	✓
Noisy Miner (Manorina melanocephala)	✓	✓	✓
Pacific Black Duck (Anas superciliosa)	✓	✓	✓
Pied Currawong (Strepera graculina)	X	X	✓
Rainbow Lorrikeet (Trichoglossus haemotodus)	X	X	✓
Striated Pardolote (Pardalotus striatus)	✓	✓	✓
Sulphur Crested Cockatoo (Cacatua galerita)	X	X	✓
Swamp Harrier (Circus approximans)	X	X	✓
Tasmanian Native Hen (Tribonyx mortierii)	X	X	✓
Tasmanian Silvereye (Zosterops laterali)	✓	✓	✓
Tree martin (Petrochelidon nigricans)	✓	✓	✓
Wedge-tailed Eagle (Aquila audax)	✓	✓	✓
Welcome Swallow (Hirundo neoxena)	✓	✓	✓
White Bellied Sea Eagle (Haliaeetus leucogaster)	✓	X	✓
White Faced Heron (Egretta novaehollandiae)	X	X	✓
White-Throated Needletail (Hirundapus caudacutus)	X	✓	✓
Yellow Throated Miner (Manorina flavigula)	X	X	✓
Yellow Tipped Pardalote (Pardalotus striatus)	X	✓	X
Yellow-tailed Black Cockatoo (Calyptorhynchus funereus)	✓	X	✓

Table 5.2: Advantages and Disadvantages of various approaches to monitoring bird species

Approach	Advantages	Disadvantages
Seasonal Bird surveys	• Easy to implement • Relatively low cost	• Labour intensive • Relies on availability of specialists • Results generally cannot be verified • Duration limited to seasonal periods • Limited by human eyesight range
Carcass Monitoring	• Results can be independently verified • Bats and nocturnal species can be detected	• Expensive to implement • Resource intensive • Limited to species which collide with turbines • Limited area (carcass monitoring zones)
IdentiFlight	• Minimal resources required • Images of each bird are collected • Collects height, date/time, and other data • No uncertainty about species present • Generates ongoing record of bird activity • Birds observed over greater distance and height than human methods.	• Expensive to implement • Does not capture species at night (e.g., bats and owls).

5.3 Eagle Classification

The process for collecting and classifying bird images to develop the WTE convolutional neural network is described in Section 4.1.4.

By the time wind farm operations commenced, IDF had captured sufficient WTE images to develop the WTE neural network, which was implemented in July 2020.

The system is currently able to recognize WTE with a very high level of confidence and can group some other bird species which have similar morphological characteristics, based on their wingspan and dimensional data (Table 5.3).

Table 5.3: IDF Classification Groupings

IDF Classification	Interpretation	Species known to utilize the site
Wedge-Tailed Eagle	A bird classified by IDF as a Wedge Tailed Eagle (WTE)	Wedge-Tailed Eagle
Eagle	A bird classified by IDF as an eagle, but not a WTE	White Bellied Sea Eagle
Not Eagle	A bird classified by IDF as not being an eagle	Any species which is not an eagle.
Falcon-Hawk	A bird grouping applied to falcons and hawks	Brown Falcon, Peregrine Falcon, Grey Goshawk
Raven	A bird grouping applied to all ravens.	Australian Raven, Little Raven, Forest Raven

5.3.1 Classification Accuracy

WTE classification accuracy is measured based on key metrics (refer adjacent inset) and was reviewed several times before and after implementation of the WTE CNN.

- **Classification Accuracy** = % of all classifications that were correct
- **Classification False Discovery Rate** = % of protected that were not eagles
- **Classification False Positive Rate** = % of non-eagles that were called eagles
- **Classification False Negative Rate** = % of eagles that were called non-eagles
- **Track** = Collection of data points and images associated with a bird fly-by
- **Frame, Image** = Curtailment decisions are executed for every image processed by the BaseStation, at ~1 image per second

Figure 5.1 shows classification results before and after implementation of the WTE CNN in July 2020 which led to a reduction in false positives, false discoveries, and false negatives, and a significant improvement in overall classification accuracy.

Customer	April 2020*		July 2020		October 2020		January 2021		April 2021		July 2021	
	Tracks	Frames	Tracks	Frames	Tracks	Frames	Tracks	Frames	Tracks	Frames	Tracks	Frames
Overall Classification Accuracy	65.32%	82.22%	61.08%	77.56%	92.14%	95.94%	91.34%	94.79%	93.00%	95.78%	92.24%	94.38%
False Discovery %	43.20% 51.89% of Non-Protected	15.62% 52.45% of Non-Protected	70.78% 45.02% of Non-Protected	29.46% 43.43% of Non-Protected	20.16% 10.70% of Non-Protected	5.67% 10.87% of Non-Protected	15.48% 14.12% of Non-Protected	6.16% 18.42% of Non-Protected	14.04% 11.14% of Non-Protected	4.80% 14.12% of Non-Protected	24.13% 9.19% of Non-Protected	7.40% 10.85% of Non-Protected
False Negative %	9.46%	5.54%	6.13%	2.26%	1.17%	0.30%	1.57%	0.50%	0.92%	0.69%	2.82%	1.76%
False Positive Error Rate	0.72%	2.71%	0.62%	1.95%	0.62%	1.47%	1.05%	2.92%	0.78%	2.58%	0.60%	1.92%
False Negative Error Rate	0.26%	0.24%	0.83%	0.47%	0.36%	0.20%	0.34%	0.26%	0.29%	0.23%	0.52%	0.35%
Total	4,668	84,829	3,854	62,717	4,604	114,542	3,361	78,178	4,303	88,439	4,263	73,690
Protected	1,893	62,698	604	31,974	1,370	73,765	1,463	57,644	1,745	65,188	956	42,437
Protected %	40.55%	73.91%	15.67%	50.98%	29.76%	64.40%	43.53%	73.73%	40.55%	73.71%	22.243%	57.59%
False Positives	1,440	11,608	1,463	13,352	346	4,433	268	3,782	285	3,284	304	3,391
False Negatives	179	3,476	37	724	16	220	23	288	16	452	27	749

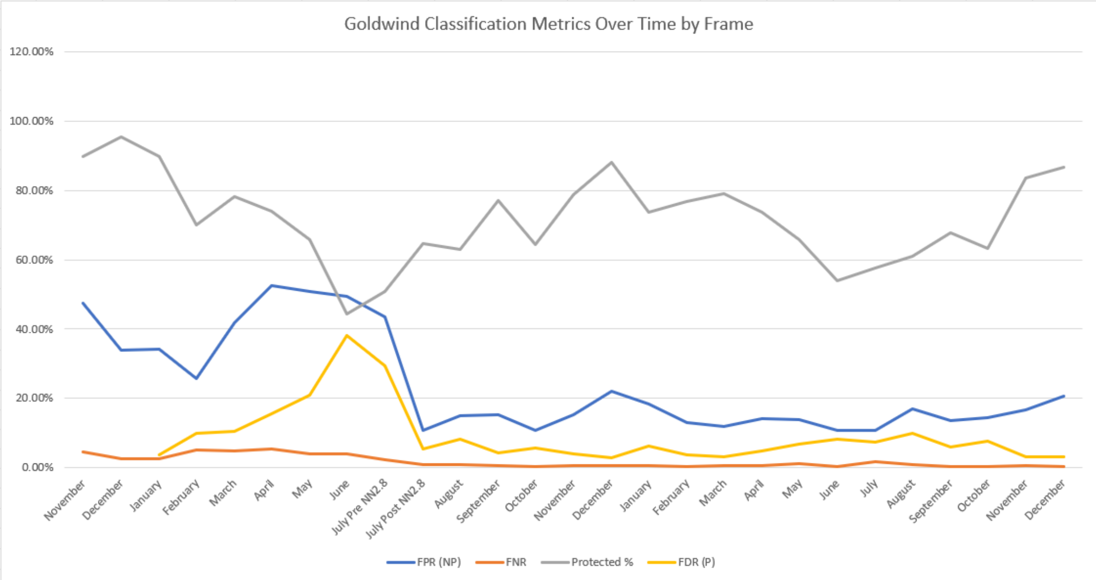


Figure 5.1: WTE Classification Accuracy Post Implementation of Neural Network (source: IdentiFlight)

Spot checks of classification accuracy have also been undertaken periodically since commencement of wind farm operations, with the help of independent avifauna experts (Figure 5.2).

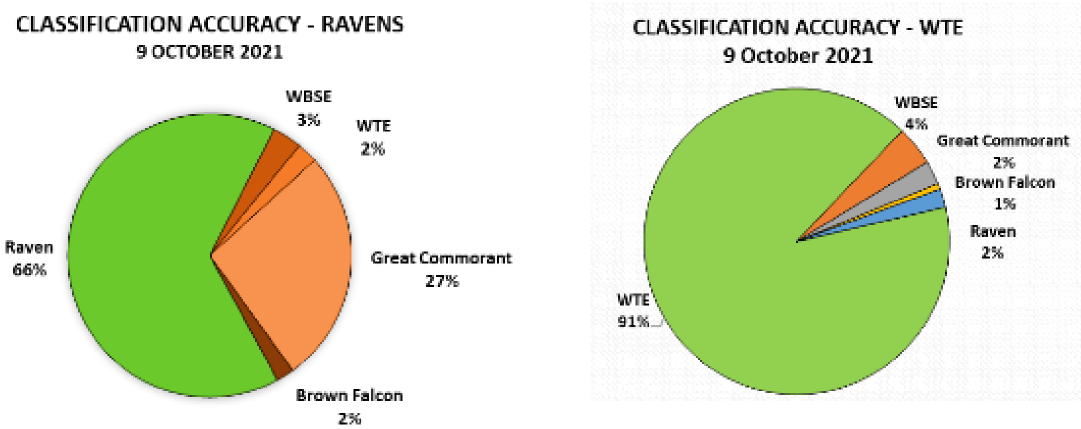


Figure 5.2: Example of IDF Classification Accuracy Results

5.4 Findings and Conclusions

The use of motion-detection cameras and machine vision learning techniques has proven effective at auto-classifying the target species, the Tasmanian WTE to a high degree of accuracy.

The IDF system is currently able to auto-classify the WTE and recognize the WBSE as an eagle based on its wing size and profile in flight.

Reviews have indicated classification errors to be fewer than 20% false positives and less than 0.5% false negatives.

Most of the false positives are ravens misclassified as WTEs, particularly in the early hours of the morning: A raven can result in a false positive curtailment if viewed at close range, with only a few frames available for IDF to make a classification decision. Anecdotally, the similar wing tip feathers of a raven to an eagle is also a likely factor affecting false positives (pers comm Carlos Jorquera).

While false positives do occur, it is noted they have no negative consequence from a bird conservation perspective. The system appears to be having an indirect benefit on ravens, which are the most prominent species on the site: only two raven mortalities in total have been identified from an extensive program of carcass monitoring at all turbines, since IDF was installed.

The ability to distinguish WBSE from WTE requires development of a new WBSE CNN which as of February 2022 is now in its final stages. Sufficient WBSE images have been collected, a WBSE CNN developed, and initial test results have been positive. Planning for implementation of the WBSE CNN is underway at the time of preparation of this report.

As IDF monitors and makes classification decisions on a continuous basis, with similar visibility range but higher accuracy than humans, it is considered a better and more reliable than use of humans for making curtailment decisions, however the investment may not be justifiable all wind farms with low eagle activity or target species which are unsuitable for protection by IDF.

The IDF trial at CHWF has been focused on the Tasmanian WTE and the WBSE, experience implementing the system indicates IDF could be used to protect other endangered species with large wingspans (for example the Victorian Brolga) subject to sufficient images being available to develop a species-specific CNN.

6 Tracking the Movement of Eagles within the Wind Farm

6.1 Summary of methods

To test IDF's ability to track the movement of eagles within the wind farm, eagle monitoring data provided by Wildspot from human observations was compared with the equivalent data generated by IDF over the same days.

Human observation data was extrapolated to estimate at risk flights over the period of the trial, and this was compared with data generated by IDF.

The tracks of Eagle flights collected from ground based human observations were digitized into GIS files, with each flight having a unique identifier. These GIS files were compared with IdentiFlight GIS data and KML files plotting the movement of birds.

6.2 Comparison of Human vs Automated Eagle Monitoring

6.2.1 Pre-Construction Eagle Utilisation Monitoring

Eagle utilisation monitoring was undertaken by Wildspot over the 2008 and 2009 seasonal monitoring periods, with further monitoring being undertaken in 2010. Key findings of these studies included:

- An annual average of ten WTE might use the site (this includes adults and fledged juveniles)
- Nest searches carried out over 2009 and 2010 identified four nests within the wind farm site.
- Areas of high utilisation were in the north-east and south-west, consistent with the 2009 data
- There is a clear seasonal pattern in activity levels with more flight activity in the breeding season
- Soaring and flying dominate the observed behaviours
- Minimal conflict behaviour was recorded at any observer location at any time
- There were no observed interactions between WTE and WBSE.
- 36% of observed flight were at or below turbine height.
- The full two years observational data set indicated use of site by WBSE is minimal.

A summary of data from these surveys is presented in Table 6.1

Table 6.1: Summary of Wildspot Pre-Construction Eagle Utilisation Monitoring Data (2008-2010)

	Human Eagle Utilization Monitoring Data – 2008 - 2010		
Seasonal period / year	**2008**	**2009**	**2010**
Monitoring Duration	11 days	20 days	5 days
Total observer minutes	3,950	3,000	950
WTE observed	179	330	42
WBSE observed	0	0	0
Average eagle observations/ day	16	17	8
Flights above 125 m	219	642	83
Flights below 125 m	74	625	96
Mixed Flights	75	86	17
Flights Above 300m	214	341	9

6.2.2 Post Commissioning Eagle Utilisation Monitoring

The Post Commissioning Eagle Utilization Monitoring Plan (EUMP) was developed in accordance with Condition FF6 of EPN 10105/1 which specifies a period of two years of post-commissioning eagle monitoring at the following periods:

- Breeding season (8 days in mid-November) – completed two events in 2020 and 2021
- Breeding season (3 days in mid-December) – completed two events in 2020 and 2021
- Post breeding (4 days in late February) – completed one event in 2021
- Non-breeding (5 days in early May) – completed one event in 2021
- Display period (6 days in Mid-August). – completed one event in 2021

Monitoring in accordance with the EUMP commenced in November 2020 by Wildspot, using six established monitoring locations to allow comparison with pre-construction monitoring data. As the pre-construction monitoring locations were associated with the original 100 turbine layout, two of the locations were no longer suitable and required repositioning, while the remainder were unchanged. All locations were monitored simultaneously for eight hours per day. Monitoring Locations are shown in *Appendix B1*.

Table 6.2 summarises data from the human eagle utilisation monitoring, with eagle activity heat maps generated from the data collected provided in *Appendix B3.*

Table 6.2: Summary of Wildspot Post Commissioning Eagle Utilisation Monitoring Data (2020-2021)

	Human Eagle Utilization Monitoring Data – Aug 2020 – Aug 2021				
Seasonal period	**24 - 27 Nov 2020**	**14-19 Dec 2020**	**22-25 Feb 2021**	**17-21 May 2021**	**26-31 Aug 2021**
Monitoring Duration	4 days	6 days	4 days	5 Days	6 Days
Observers / locations	6	6	6	6	6
Total observer minutes	11432	3118	2078	2598	3118
WTE observed	79	100	56	102	210
WBSE observed	3	2	1	4	3
Eagle observations/ day	21	17	14	21	36
Max Eagle Height	500 m	350 m	138 m	96 m	108 m
AVG estimated height	146m	164 m	300 m	250 m	300 m

Data from IDF based on the same monitoring periods is shown in Table 6.3.

Figure 6.1 shows a composite heat map produced from the human observer results for the August 2021 monitoring period (undertaken between 26-31 August).

Figure 6.2 and 6.3 shows bird tracks plotted as KML files, and a heat map generated by IDF based on the same monitoring period.

Table 6.3: IDF eagle monitoring over the 2020-2021 seasonal monitoring periods

	IDF Eagle Utilization Monitoring Data –Nov 2020 – Aug 2021				
Seasonal period	**24 - 27 Nov 2020**	**14-19 Dec 2020**	**22-25 Feb 2021**	**17-21 May 2021**	**26-31 Aug 2021**
Monitoring period	4 days	6 days	4 days	5 Days	6 Days
Monitoring duration[1]	58.32 hours	79.21 hours	48.96 hours	48.16 hours	60.70 hours
Average duration/day	14.58 hours	13.20 hours	12.24 hours	9.63 hours	10.10 hours
First eagle observation	4.26 AM	4.33 AM	5.39 AM	7.18 AM	6.41 AM
Last eagle observation	7.33 PM	7.31 PM	6.59 PM	5.11 PM	5.39 PM
Total observer minutes[2]	55,987 mins	76,041 mins	47,002 mins	46,233 mins	58,252 mins
All tracks	2,179	2,184	1,492	1,919	2,988
Eagle tracks[3]	1,393	1,319	942	1,372	1,560
Min track length	1 sec	1 sec	1 sec	1 sec	1 sec
Max track length	437 secs	405 secs	182 secs	270 sec	334 secs
Average track length	26 secs	20 secs	15 secs	11 secs	15 secs
Eagle images	43,042	33,502	15,822	14,393	27,334
Not-eagle images	5,444	6,328	2,583	3,971	6,579
Min eagle height	0 m	0 m	0 m	0 m	0 m
Max eagle height	1064 m	1147 m	809 m	741 m	695 m
Average eagle height	320 m	233 m	241 m	142 m	146 m

Notes
[1] Monitoring duration is measured from time of first eagle observation to time of last eagle observation
[2] Observed minutes are calculated from the combined observations of all 16 IDF towers over the period of days listed
[3] Includes both WTE and WBSE

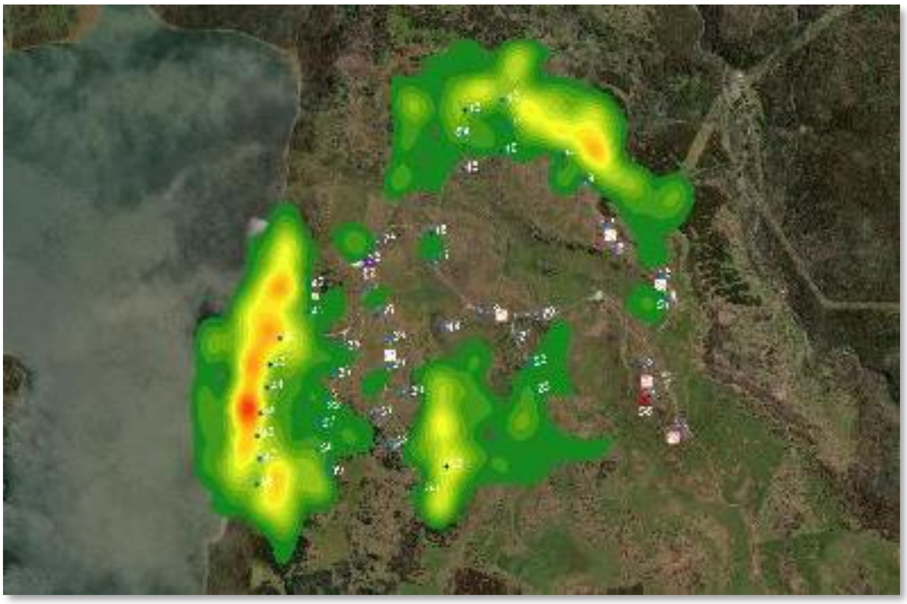


Figure 6.1: Eagle Utilization Heat Map based on Human Observations –over 26-31 August 2021

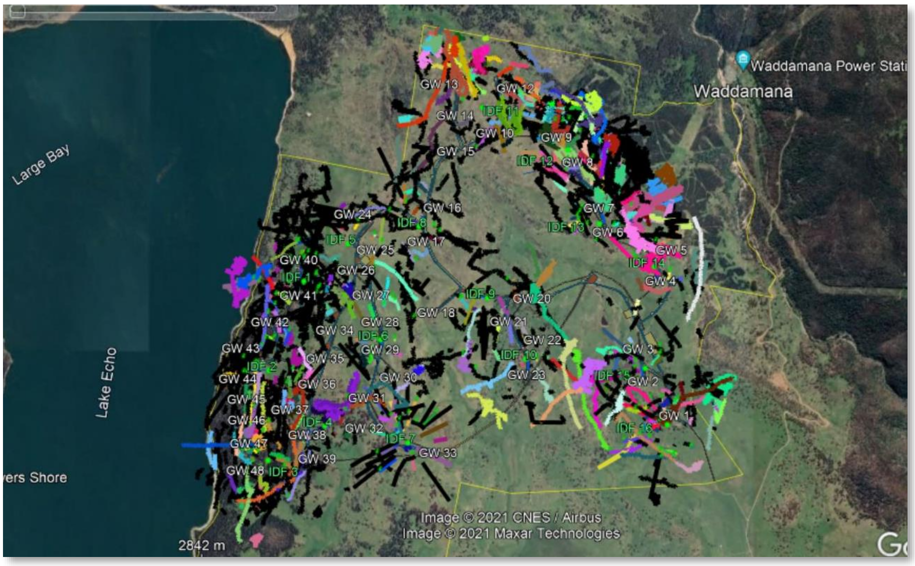


Figure 6.2: Eagle Tracks based on IDF data– 26-31 August 2021

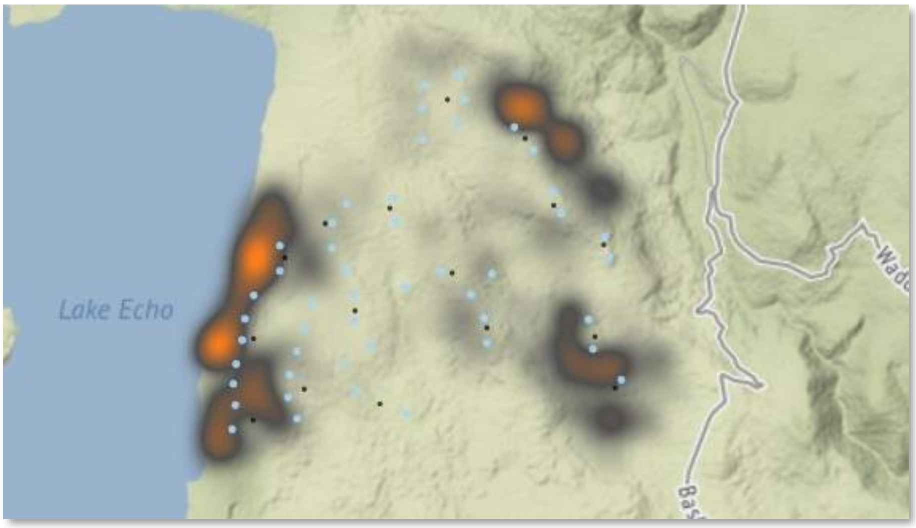


Figure 6.3: Eagle Utilization Heat Map based on IDF data– 26-31 August 2021

6.2.3 Comparison of IdentiFlight and Human-based Eagle Monitoring

In comparing the human-based data with IDF data, a direct comparison was not possible, since the type and range of eagle data, number of observers, monitoring locations, monitoring duration, and monitoring frequency all differed between the two datasets. For example:

- Six humans were used to carry out monitoring at set (previously established) locations, confined to the above eagle survey periods, with monitoring undertaken from 8.14am to 4.15pm each day.
- In contrast, IDF data is generated by 16 IDF towers (at different locations) operating continuously operate every day, from the first eagle observation to the last (approximately 4.30am to 9.30pm).
- Additionally, IDF collects significantly more eagle and other avifauna information which is outside the scope of the human surveys.

Noting these limitations in comparing the two datasets, the following observations are provided:

- The human monitoring resulted in 22,344 observer minutes.
- Over the same period, the IDF data resulted in 283,515 observer minutes.
- Both the human based and IDF data generated similar eagle activity hot spots (forested section near Lake Echo in the south part of the wind farm and along Bashan ridge in the northeast part of the wind farm).
- The IDF data is more comprehensive and shows eagle activity down to the individual turbine level, with significantly more data are available for analysis.
- The IDF data is continuous and ongoing, whereas the human monitoring represents a snapshot of activity at set periods in time.
- To collect equivalent data using humans would require significantly more humans carrying out monitoring over a much longer duration.
- If this were possible it is reasonable to expect the human monitoring data would result in comparable high activity eagle zones as IDF, at a broad level, however it would not result in equivalent additional data which could be used for other purposes.
- The additional data collected by IDF gives the camera-based system several major advantages over human-based monitoring:
  - The ability to interrogate every eagle track in detail removes any uncertainty about whether a species was present.
  - The greater visibility range of the camera-based system revealed the presence of species not able to be seen by human observers.
  - The continuous recording of information at one second intervals revealed eagle behaviors such as diving and displaying which were not seen by human observers or recorded in detail.
  - The greater accuracy of eagle positional measurements and times reveals trends which are not evident from review of the equivalent human data.

Figure 6.4: WBSE near Turbine 45, 31 August 2021

For example, over the 26-31 August 2021 monitoring period, no WBSE were observed by the team of six human observers. However, IDF cameras captured an adult WBSE and tracked for some time while foraging for food in the vicinity of GW 30 on 29 August (Fig 6.4).

This WBSE, recognizable by the missing wingtip feathers, has been regularly observed in this part of the wind farm by CHWF's environmental scientist who is able to monitor the data remotely via the IDF dashboard.

Figure 6.5: WBSE near Turbine 30, 29 August 2021

On 31 August 2021 a different adult WBSE was observed by IDF which triggered curtailment of turbine 47 at 10.13am – at this time the WBSE was 338m from GW45 and 47m AGL (Figure 6.5).

Similarly, eagle utilization monitoring by humans over the 2020-2021 monitoring periods recorded no conflict flights, and few records of diving and displaying.

However, IDF captured regular instances of WTEs diving and displaying over the same monitoring intervals (Fig. 6.6).

As these behaviours often take place over only a few seconds, they could easily be missed by human observers.

Figure 6.6: WTE diving and displaying Turbine 30, 29 August 2021

Figure 6.7: WTE with prey, captured by IDF cameras

6.3 Conclusions

Two years of pre-construction eagle utilization monitoring using human observers generated 7,900 minutes of observational data, which was used to inform the CRM for the revised CHWF layout.

In comparison, two years of IDF data captured between 19 November 2019 and 19 November 2021 generated 309,606 eagle tracks (i.e., recorded flights) with an average duration of 17 seconds per track, representing over 86,900 minutes of eagle utilization data.

For each track, the height, speed, and position of the eagle relative to ground level and the nearest turbine(s) is calculated at a rate of 10x/sec, with images taken at 1 sec intervals.

Additional data collected includes the earliest and latest eagle observations, minimum and maximum height, and confidence level of classification of the species, which occurs automatically via the neural network.

The use of IDF to collect bird data was considered to have significant advantages over traditional human survey techniques. Records generated by IDF are automated, can be independently verified, and include data which either cannot be obtained by humans, or cannot be obtained to the same level of accuracy.

The collective images and data provide a continuous record of eagle and other avian species flights and behaviours within the wind farm; a volume and accuracy of data that cannot be matched by human observers, however the data still requires interpretation, so the system does not fully replace the benefit or need for human observations or expertise.

7 Detecting and Documenting Eagle Collisions

7.1 Bird and Bat Mortality Monitoring Methodology

As IDF is not designed to detect collisions, the technology trial is supported by an extensive program of carcass monitoring that is considered best current best practise in Tasmania and involves three teams working in parallel in accordance with the approved Bird and Bat Mortality Monitoring Plan (BBMMP). Survey methodologies are provided in *Appendix B1* and are summarised below:

- One human team searches all 48 turbines once per week from a slow-moving low impact vehicle, which circles the carcass monitoring zone (CMZ) of each turbine at 45m from the tower, and at 80m from the tower ("Phase 1 surveys").
- A second team of human searchers and a third with a trained detection dog and handler, conduct a more intensive survey of all 48 turbines over a two-month period, surveying 24 turbines each month on a rotating basis, to complete all 48 turbines over a two month period ("Phase 2 surveys").
- Detection dogs were introduced to ensure a robust search program and enable comparison of performance of human vs dogs for detecting carcasses. The initiative represented the first use of detection dogs on wind farms in Tasmania. A GPS collar is affixed to the dog so there can be no doubt about the validity of extent of searches undertaken (Figure 7.1).
- The human searchers walk around each turbine at 6m transects from 0 – 60m from the tower, then 12m transects out to 120m, the full extent of the CMZ. The detection dog and handler cover the same area, but as the dog uses scent rather than sight to detect carcasses, a more freestyle approach is adopted.
- Three days after each Phase 2 survey, the inner "fall zone" (to 60m from the base of each tower) is searched again ("Pulse surveys").
- The Phase 1 searchers cover around 160 kilometres each month,
- The Phase 2 searchers collectively cover about 160 kilometres each month (130 kilometres / month conducting main surveys and 30 kilometres / month conducting pulse surveys).
- Each CMZ covers an area of 15,386 m2, and the total search area for all 48 turbines is 738,528 m^2 (approx. 73.8 hectares or 182.5 acres).

Phase 1 weekly surveys of all turbines commenced prior to the start of commissioning on 19 November 2019 and have continued throughout the commissioning phase and wind farm operations to date.

Phase 2 surveys of all turbines over a two-month period, including Pulse surveys within 3 days of each main survey, commenced in August 2020, prior to commencement of full wind farm operations.

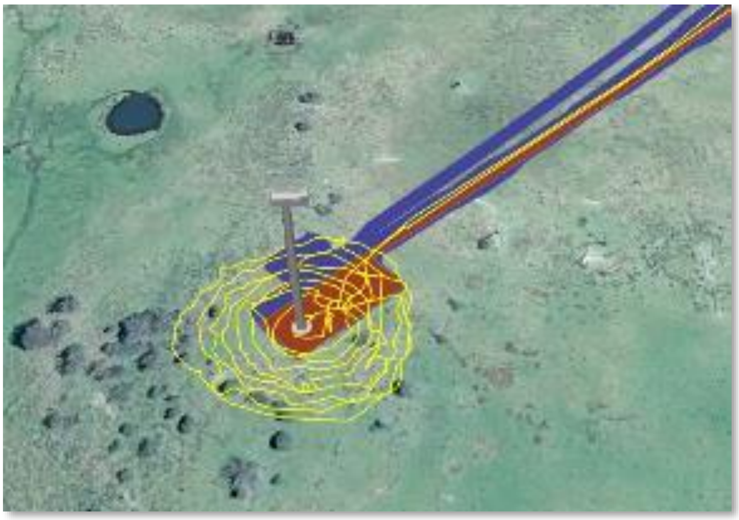


Figure 7.1 – GPS track of pulse survey carried out by detection dog at CHWF

Plate 8: Zorro, one of the detection dogs used for carcass monitoring at CHWF

7.2 Mortality Monitoring Results

The results of carcass monitoring conducted during the IDF trial period are shown below in Table 7.1 (Phase 1 surveys), Table 7.2 (Phase 2 main surveys) and Table 7.3 (Phase 2 Pulse Surveys) and summarized beneath each table.

Table 7.1 Phase 1 Carcass Monitoring Results (3 August 2020 – 4 February 2022)

	2020					2021												2022	
Species / Month	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Wedge Tailed Eagle	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
White Bellied Sea Eagle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other listed bird species	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Non-listed bird species	2	5	4	2	2	0	2	5	2	7	3	0	1	2	4	7	8	7	1
All bat species	0	0	1	1	0	0	4	5	1	1	0	0	0	0	1	3	2	1	2

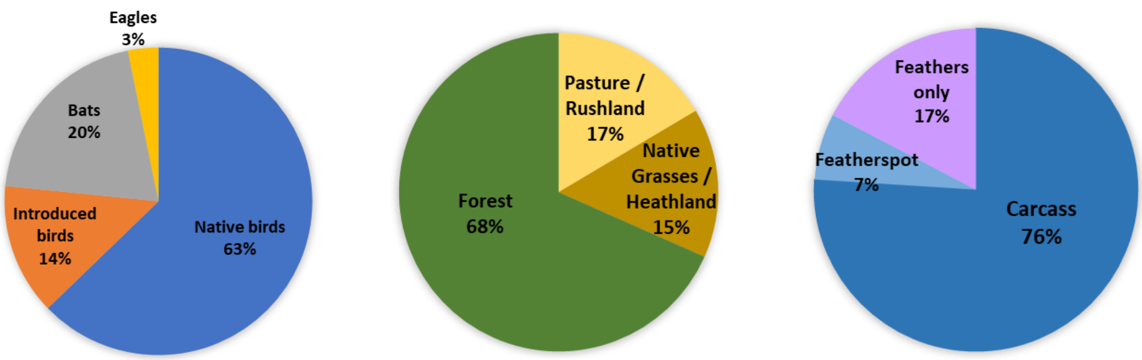


Figure 7.2 –Phase 1 Carcass Monitoring Results (4 August 2020 – 4 February 2022)

Table 7.2 Phase 2 Carcass Monitoring Results – Main Surveys (4 August 2020– 4 February 2022)

	2020					2021												2022	
Species / Month	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Wedge Tailed Eagle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White Bellied Sea Eagle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other listed species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other (non-listed) birds	2	3	5	5	5	2	5	1	2	3	1	2	1	0	4	3	11	10	0
All bat species	0	1	2	4	2	2	4	7	5	3	0	1	0	0	2	4	7	3	0

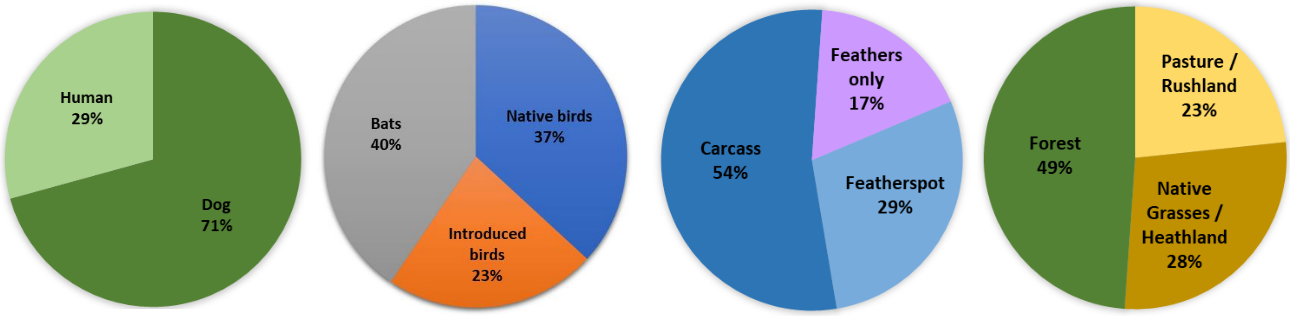


Figure 7.3 –Phase 2 Carcass Monitoring Results – Main Surveys to 120m (4 August 2020– 4 February 2022)

Table 7.3 Phase 2 Carcass Monitoring Results – Pulse Surveys (4 August 2020– 4 February 2022)

	2021					2021												2022	
Species / Month	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Wedge Tailed Eagle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White Bellied Sea Eagle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other listed species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other (non-listed) birds	0	0	1	0	1	0	3	0	0	0	3	0	1	5	0	0	0	2	0
All bat species	0	0	1	2	0	0	4	3	1	1	1	0	0	0	1	1	0	1	0

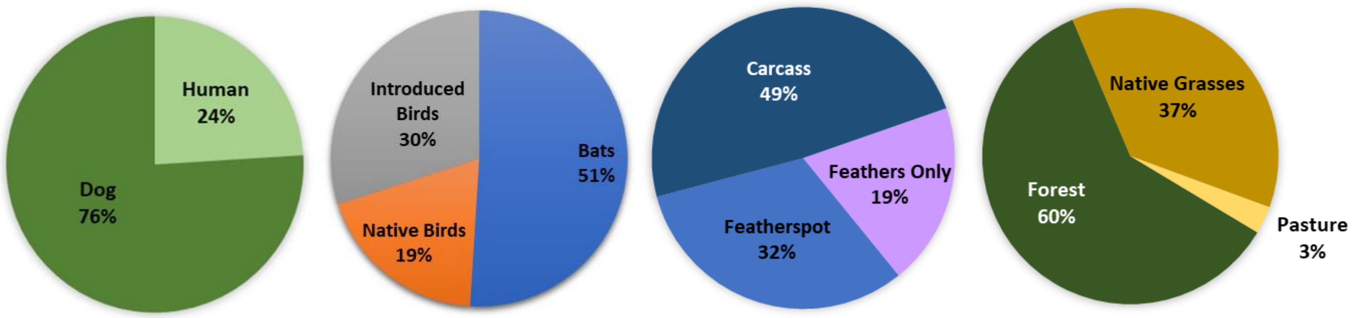
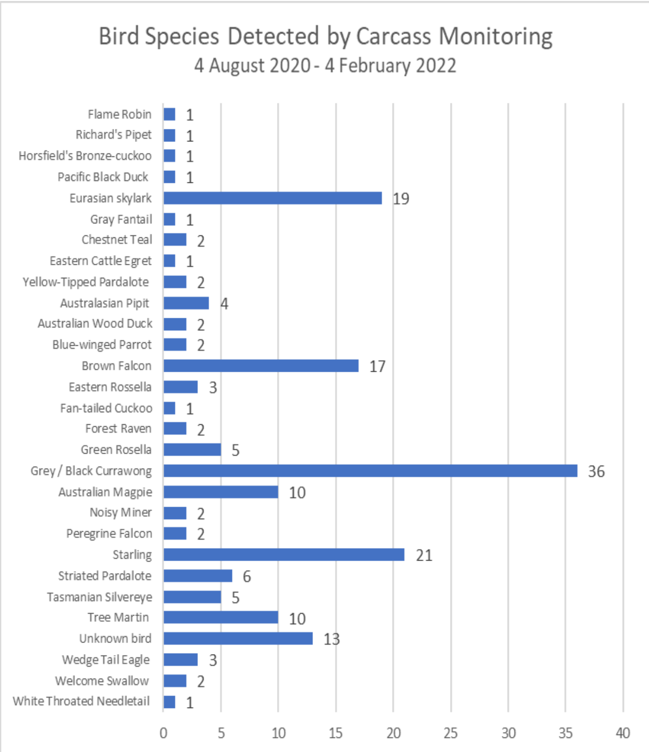


Figure 7.4 –Phase 2 Carcass Monitoring Results – Pulse Surveys to 60m (4 August 2020 – 4 February 2022)



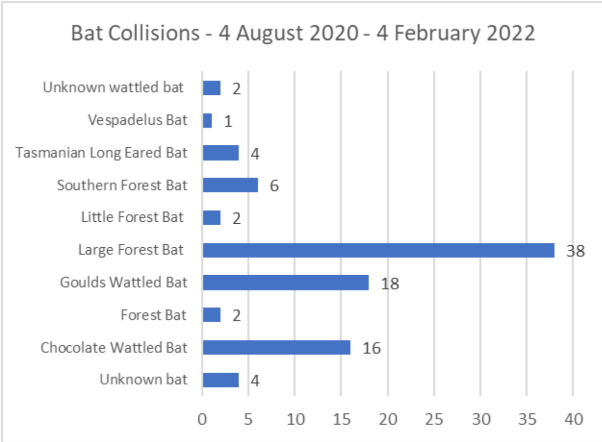


Figure 7.5 –Total Bird and Bat Mortalities identified by Carcass Surveys (4 August 2020 – 4 February 2022)

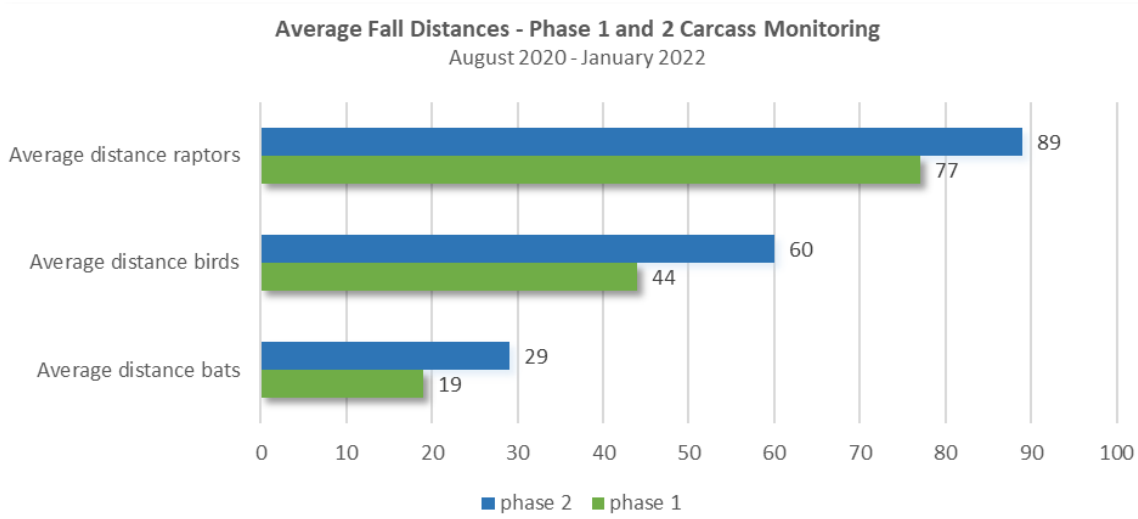


Figure 7.6: Average fall distances from turbine tower – Phase 1 and 2 Carcass Monitoring (August 2020 –Feb 2022)

7.3 Findings

Findings from review of data from the carcass monitoring programs are as follows:

- The Phase 1 (weekly drive-by surveys of all turbines) identified 100% of all eagle collisions, 93% of all raptor collisions, and 79% of all falcon collisions.
- As eagle carcasses persist in the environment, a higher frequency but less exhaustive survey is considered more likely to pin-point when the collision may have occurred.
- Of all raptors, WTE and Brown Falcon are considered the most prone to collision (*Arthur Rylah Institute for Environmental Research (ARI) 2019*) however only eagles are protected by IDF in accordance with the approved CADP - the falcon collisions that have occurred during the same period of operation is an indication IDF is distinguishing eagles from other raptors and initiating curtailments to protect the intended target species.
- Scavenger and detectability trials indicate a high confidence all eagle collisions have been detected within the period of IDF operation to date. However, vegetation maintenance and clearance of undergrowth in forested sections will be necessary on an ongoing basis to maintain ground cover visibility for searches to continue to be effective.
- Total bird and bat collisions over the 18-month trial averaged 1.8 bird collisions and 1.4 bat collisions per turbine per year respectively. For comparison, average bird and bat collisions for large wind farms have been reported as 5 to 6.7 birds and 7 to 10.8 bats per turbine per year (source: ARI, 2019).
- Of the bird mortalities detected during the trial period, over 25% were introduced species, with the Common Starling (Sturnus vulgaris) representing 11.9% of all collisions and the Eurasian Skylark (Alauda arvensis) representing 10.8 % of all collisions (as of February 2022).
- The most frequent species of all collisions detected by carcass monitoring was the native currawong (both grey and black) which accounted for 20.5% of all collisions.
- The most prominent species on site (ravens) accounted for only 1.1% in collisions in comparison, which was proportionally far lower than expected. Review of IDF data has revealed that raven's are responsible for over 80% of the false positive curtailments made for WTEs, indicating the system is indirectly benefiting this species.
- Detection dogs have proven an effective method of carcass monitoring and are particularly effective identifying bats in comparison with human surveyors (refer previous graphs and tables). However, for birds, the human and dog survey methods were comparable.
- Design of an appropriate monitoring program should differ across different target species, as each species occurs at different timeframes, in different densities, and is subject to different threats (*Arthur Rylah Institute for Environmental Research, 2019).* For example:
    - If the monitoring objective was purely to detect eagle collisions, a higher frequency, less detailed search of all turbines would be more suitable, than full searches at a less frequent interval, and pulse surveys would not be warranted (based on fall distances);
    - If the monitoring goal was to detect bat collisions, pulse surveys should be undertaken, and the use of detection dogs would be considered likely to improve the efficacy of searches;
    - If the monitoring goal was to detect migratory species collisions, the survey program should be confined to the seasonal periods the species of concern are known to occur on site.

8 Preventing Eagle Collisions with Turbines

8.1 Summary of methods

To assess IDF's effectiveness preventing or reducing eagle collisions with wind turbines, eagle mortalities over the 18-month period of the trial are compared with the number of eagle mortalities predicted by pre-construction Collision Risk Modelling. The Collision Risk Modelling inputs are also compared with the equivalent IDF data outputs.

To validate performance, the results of an extensive program of monitoring for carcasses beneath turbines is presented. Though outside the period of the trial, performance of IDF during the 9-month period of commissioning of the wind farm is also considered relevant.

8.2 Evaluation of Performance

8.2.1 Eagle Mortality Incidents

At the time of writing, IDF has been in operation for a period of 808 days (2.21 years) comprising 259 days of commissioning (during which wind turbines were partially operating on an increasing basis) and 545 days of full wind farm operations, which commenced on 4 August 2020, the start of the 18-month IDF trial period. No Eagle mortalities occurred during the 259-day commissioning phase. During the 18-month operations phase, there have been three WTE mortalities within the wind farm, which IDF was unable to prevent, and no WBSE mortalities. The timing of each mortality is shown in Table 8.2 along with the AER and EPBC reporting periods outlined in the project approvals.

Table 8.1 – WTE and WBSE Mortalities

Year	2019		2020 Calendar Year												2021 Calendar Year												2022	
Month	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Phase	Wind Farm Commissioning Phase									Wind Farm Operations – / 18-month IDF Trial Period																		
IDF	← Period of IDF operation →																											
EPBC	2020 EPBC Compliance Review Period										2021 EPBC Compliance Review Period												2022 EPBC Review Period					
AER	2020 AER Review Period								2021 AER Review Period												2022 AER Review Period							
WTE	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	**1**	0	0	0	**1**	0	0	0	0
WBSE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRM	Predicted WTE mortalities not included in scope of CRM									CRM predicted five WTE mortalities within year 1 o													Eight WTE mortalities within year 2o					

Prior to the first incident on 9 September 2020, there had been no WTE or WBSE mortalities throughout the 259-day period of wind farm commissioning and the first five weeks of wind farm operations. To date, no incidents involving White Bellied Sea Eagles have occurred, despite recent high activity and regular occurrence within the site.

Table 8.2 – 8.4 provides details of each WTE mortality (listed below) and the corrective and preventative actions undertaken in response.

- WTE Mortality 1 –Carcass found on 9 September 2020 – south of Turbine 2
- WTE Mortality 2 –Carcass found on 30 June 2021 – 24m west of Turbine 45
- WTE Mortality 3 – Carcass found on 22 September 2021 – 90m east of Turbine 46

Table 8.2: Eagle Mortality Incident 1 at Turbine 2 - Condition 10, Notification and Reporting

EPBC Condition 10 Requirement		WCHPL Response to Condition 10 requirement
	Notification within 24 hours of collision	Time of collision estimated. Notified within 24 hours of detection of deceased Eagle, found approx. 1:45pm on 9 September 2020.
	Submit Incident (detailed collision) Report within 1 week of notification	An Incident Report was submitted to DAWE and EPA on Monday, 14 September 2020.
a	*Species of eagle, sex, and estimated age*	WTE. Sex and age were unable to be confirmed due to missing organs, however the specimen was considered likely to be an adult female.
b	*The nature of injuries or mortality and cause as reported by a veterinarian*	Internal injuries were described in a Necropsy Report provided by Bonorong Wildlife Sanctuary and were diagnosed as severe trauma compatible with a wind turbine collision.
c	*The nearest turbine to where the injured eagle or carcass was found*	Turbine 2.
d	*Details of how the injury or mortality was caused and proposed response to prevent further mortalities occurring*	The 1st WTE Mortality was attributed to operator error and corrective action has been implemented to prevent recurrence. The incident investigation led to changes to procedures for re-starting turbines so that an operator can no longer manually override an IDF curtailment, for any reason. Additionally, three trees between IDF15 and Turbine 2 were removed to improve IDF Station visibility.

Table 8.3: Eagle Mortality Incident 2 at Turbine 45 - Condition 10, Notification and Reporting

	EPBC Condition 10 Requirement	WCHPL Response to Condition 10 requirement
	Notification within 24 hours of collision	Time of collision unable to be confirmed however notification to regulators occurred within 24 hours of detection of the specimen, found at approx. 11am on 30 June 2021
	Submit Incident (detailed collision) Report within 1 week of initial notification	An Incident Report was submitted to DAWE and EPA on 5 July 2021 and updated on 21 July 2021, when the necropsy became available. The report was supplemented by detailed analysis of IDF records.
a	*Species of eagle, sex, and estimated age*	The Necropsy reported the species as an adult male WTE.
b	*The nature of injuries or mortality and cause as reported by a veterinarian*	External and internal injuries were described in the necropsy Report provided with the Incident Report. The specimen was intact, and the bird indicated to have been healthy and well fed. The veterinarian indicated the mortality was likely due to a collision with a hard object and that injuries were consistent with collision with a wind turbine, but also could have arisen from collision with a vehicle. As no vehicles had been in the area, collision with a rotor blade (most likely a slow-moving blade) was assumed.
c	*The nearest turbine to where the injured eagle or carcass was found*	The carcass was found about 24 metres WNW of Turbine 45
d	*Details of how the injury or mortality was caused and proposed response to prevent further mortalities occurring*	A Heat Map provided by IDF revealed vegetation occlusion as the root cause of the incident. Turbine 45 is located near dense forest on land that slopes moderately steeply to the eastern shore of Lake Echo. The trees and topography create difficulties for the IDF station in this area to detect all eagle movements when the bird is beneath canopy level. Initial discussions with the landowner did not result in permission to clear the vegetation, however discussions following the 3rd mortality, the landowner permitted removal of a small stand of trees which has led to a noticeable improvement in IDF visibility.

Table 8.4: Eagle Mortality Incident 2 at Turbine 46 - Condition 10, Notification and Reporting

	EPBC Condition 10 Requirement	WCHPL Response to Condition 10 requirement
	Notification within 24 hours of collision	Notified within 24 hours of detection of the deceased Eagle, found at approx. 10:25 am on 22 September 2021
	Submit Incident (detailed collision) Report within 1 week of initial notification	Incident Report submitted to DAWE and EPA on 24 September 2021.
a	*The species of eagle, sex, and estimated age*	The Necropsy reported the species as a WTE, adult male.
b	*The nature of injuries or mortality and cause as reported by a veterinarian*	The carcass was found intact, with no visible external injuries, as with the previous WTE mortality at turbine 45. However, the necropsy revealed internal injuries which were compatible with collision with a broad-based object, such as a wind turbine.
c	*The nearest turbine to where the injured eagle or carcass was found*	Turbine 46.
d	*Details of how the injury or mortality was caused and proposed response to prevent further mortalities occurring*	No evidence of the mortality was found, and it was considered possible it could have occurred from one of the following: • Collision with a wind turbine • A result of an avian conflict (WTE / WBSE conflict was observed by IDF in the area in the days prior to the incident • Heavy landing after avian conflict or • injury due to collision with a slow turning blade No evidence of a collision was available despite exhaustive searches of the area and review of IDF records however collision was assumed due to the location of the bird when found. Following investigation, the 3rd WTE Mortality was again attributed to obstruction of the IDF viewfield by vegetation. Recommendations provided by IDF included removal of 7 trees to improve coverage of turbine 46 from IDF-2. Following landowner approval, the trees were removed in October 2021.

8.3 Preventative Actions

8.3.1 Turbine Shutdown Protocol

To avoid recurrence of the first incident (operator accidentally starting turbine during an IDF curtailment, a turbine shutdown protocol was introduced, and SCADA controls revised so this situation cannot occur again (i.e., an operator can no longer override an IDF curtailment, for any reason). This measure will prevent recurrence of the root cause of the incident. Other improvements were also implemented following the incident including three trees between IDF-15 and Turbine 2 which were removed to improve IDF visibility.

8.3.2 Removal of Vegetation to Improve IDF Camera Visibility

The second eagle mortality occurred at Turbine 45 in the forested section of the wind farm near Lake Echo. The subsequent incident investigation revealed a significant vegetation occlusion issue which indicated that eagles flying below ~975m in altitude would not be detected west of Turbine 45. 975m is the height of the tree-occlusion when projected out to Turbine 45, whose base elevation is 885m ASL. The investigation also revealed similar occlusion issues existed at Turbines 43, 46, 47 and 48, particularly Turbine 46.

Following the mortality, ecological checks of the vegetation and habitat value were undertaken, and permission to remove vegetation in accordance with IDF recommendations for optimal visibility was sought from the landowner but not provided. Achieving full visibility of turbines in this area is complicated as the turbines are partly located in a carbon forest area where removal of vegetation is prohibited, resulting in dense forest as close as 40 metres to turbines (Plate 9).

Plate 9: Turbine within protected Carbon Credit Forest area (Lake Echo in background)

Additionally, the land falls away towards Lake Echo, west of the controlling IDF stations on higher ground, and alternative options for siting IDF stations were ruled out by either existing planning and environmental constraints, or land being prone to subsidence.

Following the third mortality at Turbine 46, and the subsequent incident investigation confirming vegetation occlusion as the root cause, further discussions were held with the landowner and permission obtained to remove seven obstructing trees located within the CMZ of Turbine 45 (Figure 8.1).

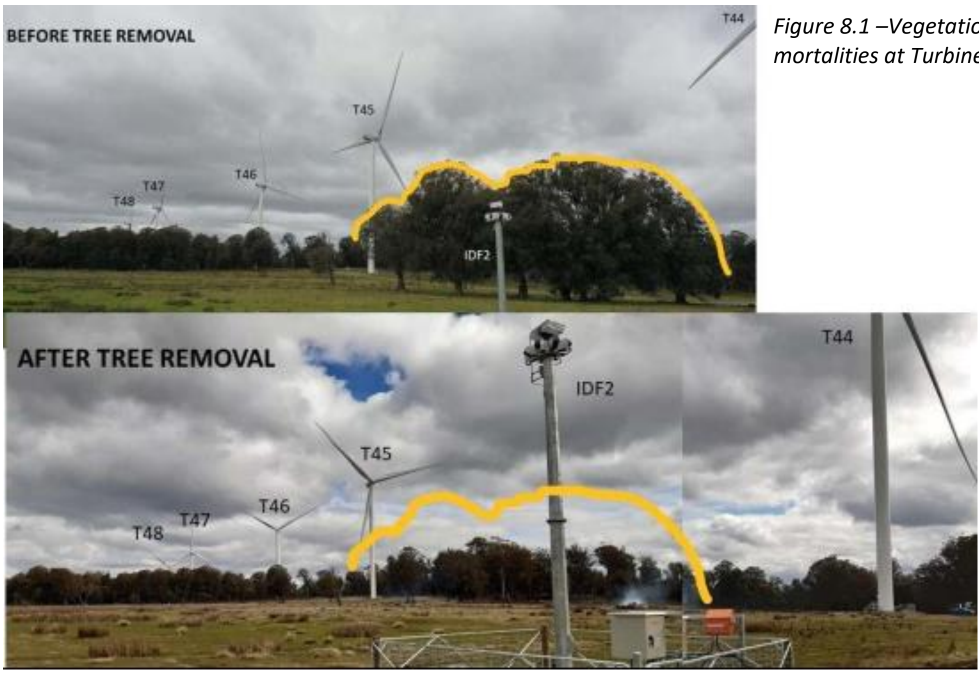


Figure 8.1 –Vegetation removed following mortalities at Turbine 45 and Turbine 46.

Figure 8.2 shows heat maps from IDF showing the extent of the vegetation occlusion and improvement in visibility from IDF2 before and after removal of the seven trees. The figure shows: (left) flights above 975m (shown in orange) indicating no significant occlusion issues; (middle) flights beneath 975m before the seven trees were removed; (right) flights beneath 975m after the seven trees were removed. The figure shows visibility shows removal of the seven trees has increased visibility of low altitude flights around Turbines 44, 45 and 46, however there are still major occlusion issues at Turbines 43, 45, 46, 47, and 48 in general.

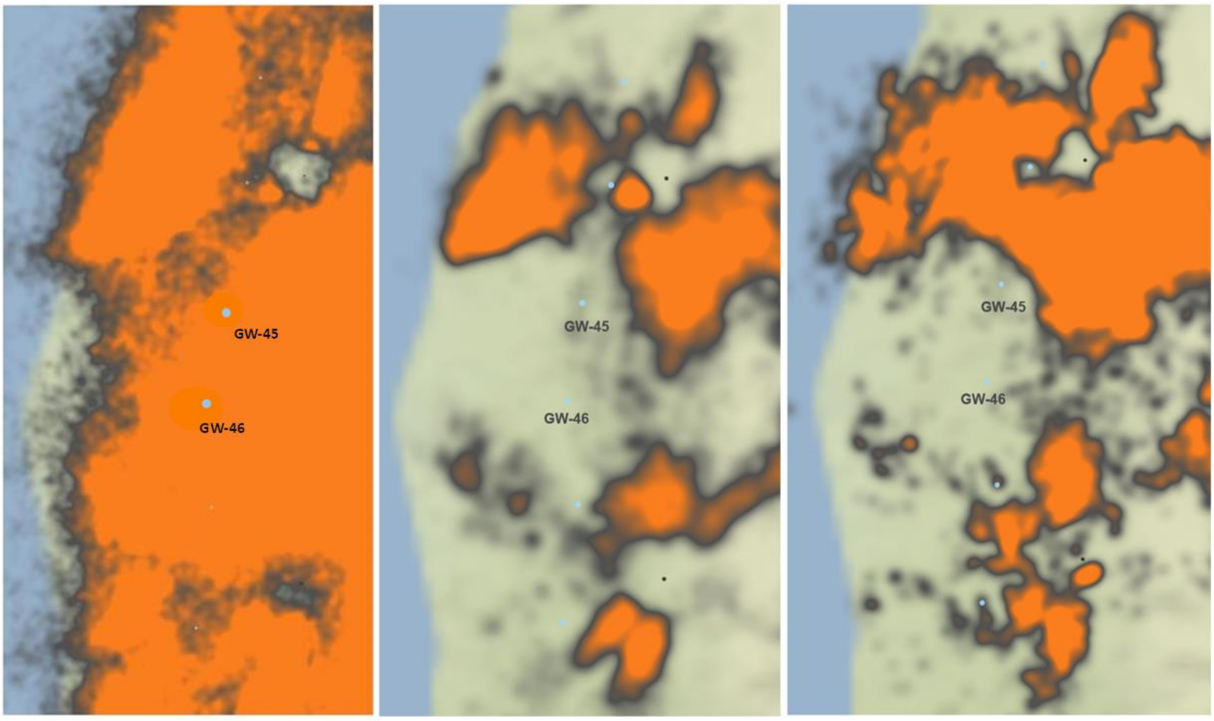


Figure 8.2 Improved IDF visibility associated with the removal of trees shown in Figure 8.1

At the time of writing, investigations are ongoing into alternative options which could be practically undertaken to further improve IDF station visibility and / or reduce eagle collision risk in the forested section of the wind farm, particularly Turbine 45 and 46. Options being considered include:

- Installation of a taller 20m IDF tower near IDF3;
- Procurement of a mobile IDF station which could be used at various locations around the site,
- Trial of a black blade at one or more turbines to improve visibility of the blade tip by eagles;
- Simulation of alternative curtailment settings for TTC and Ri;
- Ongoing review of IDF data to target risk periods; and
- Targeted removal of perch branches to deter eagles from perching close to turbines.

It is expected that a combination of mitigating action may reduce collision risk but will not be able to eliminate it due to the constraints around removal of vegetation.

Since the WTE mortality in September 2021, no further WTE collisions have occurred, and no WBSE collisions have occurred since the IDF system was commissioned in November 2019.

8.4 Findings and Conclusions

8.4.1 Increased Risk Factors

It is evident that since the original EPN containing the mortality thresholds in Attachment 3 was issued, there has been an increase in eagle nests both within and outside the wind farm, and an increase in the number of eagles utilizing the wind farm site. White Bellied Sea Eagles had not been observed during eagle utilization monitoring undertaken for the DPEMP in 2009-10 and had also been observed only infrequently in monitoring undertaken since, but at the time of writing, are being detected by IDF cameras on a regular (almost daily) basis, with one WBSE pair occupying a nest on the shore of Lake Echo.

Anecdotally, eagle experts working at the CHWF have indicated the wind farm could conceivably have resulted in eight or more eagle fatalities within its first year of operations, had IDF not been installed.

Based on this, and the verifiable increase in eagle activity from data generated by IDF, Goldwind believes performance regarding reduction in eagle mortalities, is likely to be better than the on-paper comparison against Attachment 3 values would suggest.

8.4.2 Potential Application of IdentiFlight Data to Collision Risk Modelling

Flight characteristics such as height and avoidance rates are used to estimate species-specific collision risk of birds with wind turbines. However, traditional means of obtaining this data via human observers are constrained to specific intervals, and have limited positional accuracy, as they are estimated from the ground. Data generated by IDF has potential to overcome many of these limitations, e.g.:

- Flight behaviours such as diving or displaying can be identified and assessed using the timestamped images captured by IDF at 10 frames per second.
  - The proportion of flight behaviors exhibited by eagles (e.g., soaring, conflict) can be determined with a higher accuracy compared with human based estimates.
  - Figure 8.3 shows an at-risk WTE from a review of flights during the first week of September 2021 which showed 3% of flights included at risk behaviours.
- Seasonal variations in activity can be reviewed over any period (e.g., day, week, year…) giving a better understanding of the changing dynamics of species on a site.
  - Numbers of target species on site can be determined rather than estimated.
  - Data is not confined to set intervals but is continuously building. Over time, the resulting dataset could be used to identify bird behaviors, turbine locations, weather conditions and other factors which increase eagle collision risk.
- Data can be used to enhance existing approaches to CRM, for example:
  - CRM predictions could be validated;
  - Avoidance rates could be accurately assessed;
  - Flights within RSA (i.e., at-risk flights) could be accurately determined;
  - The improved input data re: flight heights, proportion of at-risk flights, and avoidance rates could be used to improve CRM predictions.

Figure 8.3: At risk WTE behaviour

The data has many potential applications to bird researchers, and from a wind farm perspective, represents a significant advancement over human-based methods for gathering fundamental input data such as avoidance rates, that currently can only be estimated.

8.4.3 Reduction of Eagle Mortalities

The IDF installation at CHWF has been the first implementation of the technology in Australia, and there were unforeseeable outcomes associated with some of the testing, unfortunately resulting in one eagle fatality due to operator error. A second mortality occurred in the first year of full operations, due to occlusion from vegetation, and a third in the second year of operations in the same forested section of the wind farm, the root cause also being occlusion from vegetation.

Two Wedge-tailed Eagle mortalities (in the first year of operations) and a cumulative three WTE mortalities after 18 months, is less than the pre-construction predicted mortalities of five and eight mortalities after the first and second year of operations respectively.

Figure 8.4 shows predicted WTE mortalities, and the current trajectory based on actual (cumulative) mortalities.

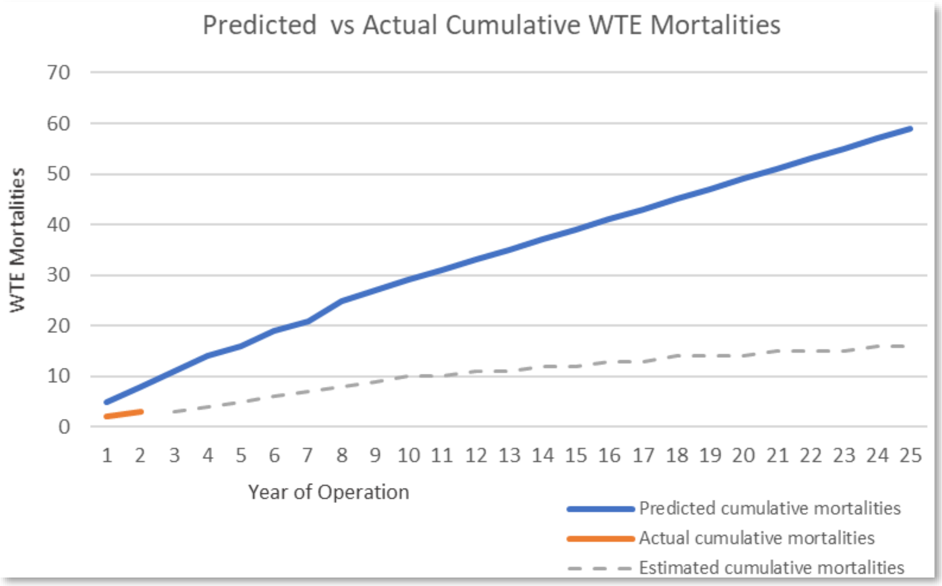


Figure 8.4: Predicted versus actual WTE mortalities (Operations Phase)

The figure should be read as indicative only and does not account for factors not considered by the CRM when undertaken, including:

- the 8.5-month period of wind farm commissioning
- the increased eagle utilisation and eagle nests since the CRM was undertaken; or
- predicted white bellied sea eagle collisions.

Regulators, interested parties, and eagle experts conducting monitoring at the site have commented on the Turbines shutting down as Eagles approach, evidence the system is triggering shutdowns to reduce risk to eagles.

Eagle expert Simon Plowright and his team of eagle observers regularly witness IDF in action while carrying out eagle utilisation monitoring at CHWF and are well placed to comment on its effectiveness (refer insert).

As preventative and corrective actions have been implemented and improvements are ongoing, it is expected performance of IDF based on comparison of mortalities with predicted mortalities, will improve over time.

GWA is confident that the reason for the reduced impact is due to the successful installation and application of the IDF system. It is considered IDF provides very effective mitigation of the risk to eagles, however in areas of dense vegetation or major topographical occlusions, the system may not be able to prevent all eagle collisions with turbines.

"After spending 25 days observing the IdentiFlight system at work on the Cattle Hill Wind Farm, I could not be more impressed. It is simply astounding! Given the high number of eagles utilising the Cattle Hill Wind Farm and the high population of eagles in the surrounding landscape, there would undoubtedly have been a significant number of deaths without this system.

As the person who has had to deal with most of the turbine related eagle deaths in Tasmania, this system provides real hope.

In my opinion IdentiFlight should be installed as a minimum requirement for any new wind farm developments where eagles are identified as an issue of concern. This would significantly help the development process and all concerned parties would benefit but most of all the eagles would have a good chance of coexisting with an operating wind farm"

Simon Plowright
Wildspot Consulting.

8.4.4 Layout and Tower Siting Considerations

Table 8.5 outlines some considerations based on GWA's experience with IDF which should be taken account in developing a suitable layout at sites which intend to utilize this technology:

Table 8.5: Layout considerations to maximize IDF effectiveness

Limitation	Explanation
Zones of Occlusion	IdentiFlight can track moving objects with a range of between approximately +83˚ to -18˚ of each tower but may not be able to accurately detect and classify birds as belonging to a particular species unless they are within the detection space. Birds directly above an IDF station may not always be observed by that IDF station due to the movement range of the PTU, and visibility of birds above each tower is also reduced when the sun is directly overhead. However, these birds may be visible to surrounding IDF stations.
Topographical Screening	The topography of a site can result in "bird pop-up effect" – birds screened from view by topography such as a mound or hill will not be visible until they emerge from behind the hill. Likewise, birds flying within a valley which is below the ground level of the controlling IDF tower will not be visible until they rise above ground level.
Vegetation Screening	Vegetation can limit the performance of IDF cameras in some instances; large trees which are too close to IDF cameras can distract the cameras, and dense vegetation can impair IDF camera visibility, particularly when the bird is below canopy height. As with topographical effects, an eagle may not be visible until it rises above canopy level.

9 Performance Efficiency

9.1 Turbine Shutdown Management Plan Requirements

This section reviews performance against requirements outlined in the approved Turbine Shutdown Management Plan (TSMP) developed in response to condition FF16 of EPN 9715/1 (now updated as EPN 10105/1). The TSMP notes that Condition FF16 relates to Conditions FF2, FF12 and Attachment 3 of the EPN.

Section 2 of the TSMP states the over-arching objective of the TSMP is to comply with all the requirements of Conditions FF2, FF12 and FF16 (note that FF2 was modified 13 Mar 2019, after the TSMP was prepared in July 2018*).* The Guideline for preparation of the TSMP states the objective of the TSMP is:

- *to manage wind turbine shutdowns to prevent Wedge-tailed Eagle (WTE) collisions with turbines, when the collision rate exceeds the values in Attachment 3, or when a new or previously unknown active WTE or WBSE nest is found within 1,000 metres of wind turbines. The latter aspect has to some extent been modified by EPN 10105/1.*

The TSMP also includes the requirement to develop a turbine shut down strategy (TSS). The principles for the TSS are included in the TSMP and include the following efficiency related requirement regarding capping wind turbine shutdown hours:

- *The TSS shall not result in a loss of more than 4,292 Wind Turbine Shutdown Hours (WTSH) over any rolling 12-month period (calculated from ALL eagle related shutdowns).*

In addressing the above requirement, details are to be provided regarding how turbine shutdown hours instigated for WTE collision prevention will be recorded, and how these will be distinguished from other types of shutdowns (such as those for maintenance).

9.2 Review of Performance

To date, neither of the triggers referred to above (WTE Collision rate exceeding the values in Attachment 3, or new active WTE or WBSE nest found within 1,000m of turbines) has occurred, therefore the overall intended goal of the TSMP has been achieved, and no TSS has been required.

9.2.1 How Wind Turbine Shut-Down Hours are Tracked

The following describes how turbine shutdown hours instigated to reduce eagle collision risk are recorded, and distinguished from other types of shutdowns, in the process of tracking performance against the target of no more than 4,292 shut down hours attributable to eagle protection.

- The target of 4,292 shut down hours is the equivalent of 1% of generation over a calendar year and performance against the target is based on a 12-month moving average.
- Data for all curtailments is obtained directly from IDF via the Dashboard interface each month. This data includes the curtailment periods of each turbine for each day of the month.
- Curtailments for eagle protection are measured from the time an IDF signal was sent to stop a turbine, to the time an IDF signal was sent to restart the turbine. This data is used as it represents the period of time that the eagle would have been at risk, had the turbine not been curtailed.

- SCADA data is used to identify and screen out periods that specific turbines received curtailments but were not operating at the time, due to other (non-bird related) reasons, e.g., maintenance.
- The period of commissioning of the wind farm prior to the 18-month trial commencing, was used to test and refine settings, while learning about the IDF system and responding to the many intricacies involved with integration of IDF to the wind farm SCADA and communication systems.

9.2.2 Simulations

To test the effect of changing curtailment parameter settings (e.g., reducing the inner radius), simulations can be undertaken using historical data collected by the system. During the IDF trial, simulations were undertaken to test the effect of the following setting changes at selected turbines:

- Increasing cylinder height / reducing cylinder height
- Increasing outer radius / reducing outer radius
- Increasing inner radius / reducing inner radius
- Increasing Time to Clear / reducing Time to Clear
- Increasing Time to Collision / Reducing Time to Collision.

9.2.3 Optimisations

Results of simulations, and assessment of IDF data were used to optimize settings of the IDF system.

Optimizations undertaken since IDF was installed are shown in Figure 9.1.

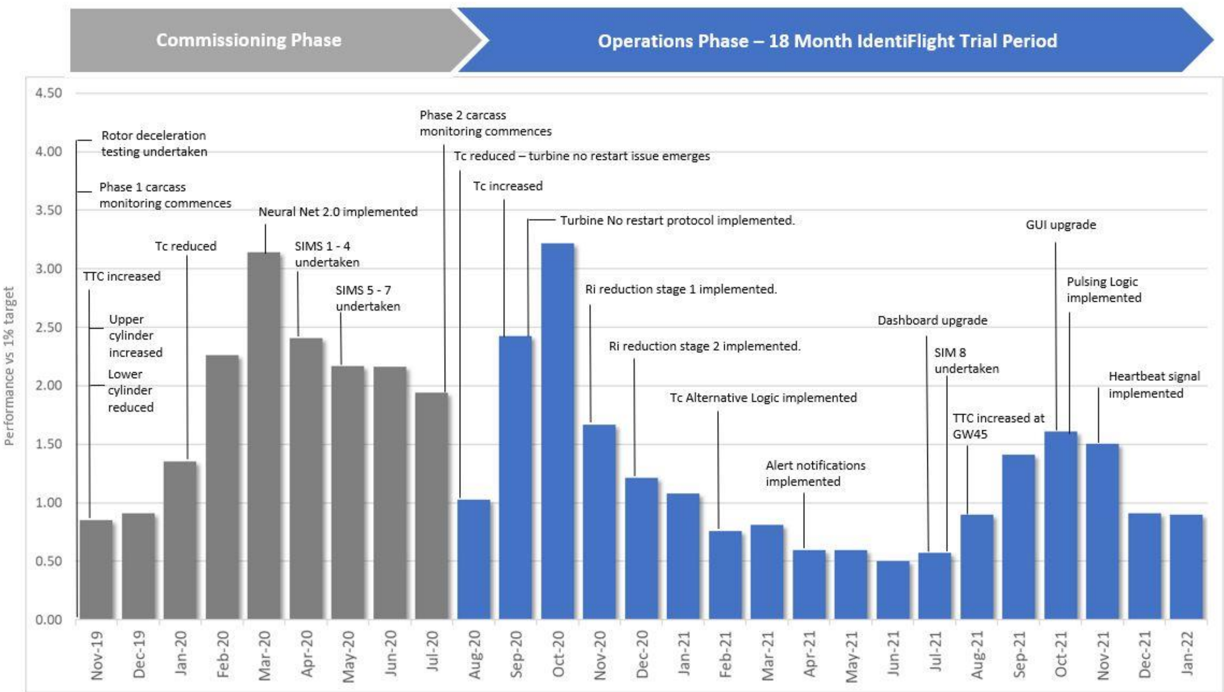


Figure 9.1 – Optimisations undertaken during IDF trial

9.2.4 Achievement of Performance efficiency target

Figure 9.2 shows performance against the 12-month rolling average, against the overall goal of achieving the 1% efficiency target before the end of the 18-month technology trial. This was a challenging target, given the many unknowns, including how changing curtailment settings would affect SCADA controls and turbine response, and how eagles utilizing the site would react to turbines being curtailed. As the chart shows, the efficiency target was achieved in October 2021 and has remained below target for the remainder of the trial.

At the time of writing, IDF is operating at 0.9% of target WTSH (i.e., 3,862 hours vs target of 4,292 hours attributed to bird protection).

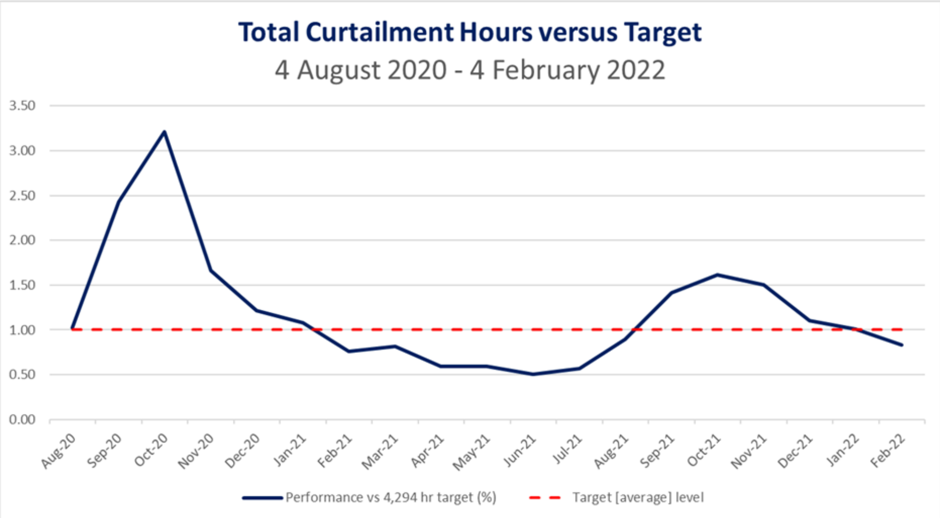


Figure 9.2 – Performance vs 1% Target, IdentiFlight Trial Evaluation Period

Over the course of the trial, discussions were held with wind farm operators and technology developers in the U.S, Denmark, Tasmania, and Germany, to compare performance against other wind farms with comparable bird mitigation technology installed to automate curtailments.

While the IDF installation at CHWF does not represent the highest levels of efficiency (around 0.6% of generation) it is higher than the majority of installations, which generally operate at around 2-3% generation loss.

9.3 Conclusions

In conclusion, as a TSS has not been required due to eagle mortalities being beneath the threshold levels in Attachment 3 of the EPN, and the 1% performance efficiency target has been achieved, both key requirements of the TSMP have been met.

The IDF technology is therefore considered to be able to operate at a high level of efficiency, while reducing risk of impacts on eagles.

Further optimizations have been identified for the IDF system at CHWF and will be implemented during 2022. It is anticipated these will further improve project efficiency to around 0.85% generation loss attributable to bird protection, without increasing risk to eagles.

10 Technical Reliability

10.1 Summary of methods

While the subject of 'Reliability' is very broad from an asset management perspective, the reliability requirements outlined in the CADP are very simple, and come down to the following questions:

- *'Does the system perform as it is intended to?'; and*
- *'Can the system operate effectively and protect eagles without significant modifications being required?'.*

The approved CADP outlines the requirement to document modifications required in relation to powering the system, storing data, and communicating with turbines.

This section of the report addresses these requirements.

10.2 System Performance

10.2.1 Curtailment Count

During the two-year period of operation of the IDF system at CHWF, there have been over 370,000 curtailments successfully implemented for eagle protection via the IDF system. On average over 400 curtailments signals per day are sent by IDF and received by SCADA. This high curtailment count led to concerns by Goldwind regarding the impact of excessive shutting down and starting up of turbines, however no turbine related maintenance issues associated with the high curtailments have occurred yet, following over two years of continuous operation.

10.2.2 Availability

The IDF system is required to operate during daylight hours, with IDF stating a performance availability level of 99%.

GWA has adopted a protocol whereby if an IDF station is down, all turbines observed or partially observed by that IDF station are shut down and only re-started once the IDF station is back online and has been verified as being fully operational. This approach may have averted any eagle collisions during the periods an IDF station was not operating, however as each IDF station within the CHWF observes between one to six turbines, there is a need to have access to technical and software support from the US-based IDF team to minimise lost generation time.

During the last two years, the CHWF WOM service team, SCADA engineers, and GWA environment and compliance representatives, have worked collaboratively with IDF to address issues when they arise to minimise turbine downtime, with most issues generally being resolved within one day or less. The largest delays experienced were associated with lack of replacement stock for failed IDF camera components, which had to be shipped from the US. This issue has since been addressed via improved stocking levels of parts and projected forecasting of failures based on an alert tracking system which was also implemented. Further improvements being considered include real-time tracking of IDF station alerts via the IDF dashboard.

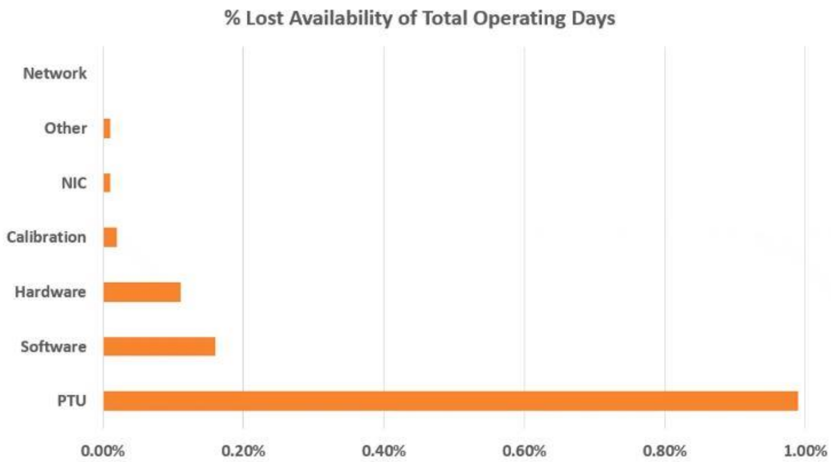
Figure 10.1 shows availability performance from November 2019 to December 2021 which indicates the availability target of 99% has been achieved.

IDF Availability	
Cattle Hill Availability (with excusable events)	99.30%
IDF *Operating* Availability	99.60%
IDF *Guaranteed* Availability	95.00% If spare imaging head and cabinet are in stock

Lost Availability (%)	
Lost Availability (Cattle Hill)	0.31%
Lost Availability (IDF)	0.41%
Total Lost Availability (Goldwind)	0.72%

IDF Response Time (Days*)	
Average	0.70
Maximum	21.98**
Minimum	0.0004

* Days = IDF tower days of operation
** IDI worked with GWA on improved on-site spares and increasing service inventory. This 21-day outage was before the practice of shutting turbines down during IDF outages.



Lost Availability Count	
Type	Count
Network	0
Other	2
NIC	2
Calibration	34
Hardware	15
Software	3
PTU	20

Figure 10.1: availability performance summary (Nov 19 – Dec 21) (Source: IDF)

As Figure 10.1 shows, most of the downtime associated with the IDF system at CHWF to date has been associated with failure of PTU units. Most of these failures occurred in the early stages of full operation of the wind farm. The lost availability associated with these failures, while relatively minor, may be overrepresented, as in the early stages of operation only one spare PTU was held on site – when two PTU units both failed in a similar timeframe, all turbines observed by one of the IDF stations with the failed PTU had to be shut down until a replacement PTU from the US had arrived, been installed, and successfully brought back online.

The early string of PTU failures led to implementation of several process improvements:

- Improved inventory management, such that the CHWF service team always has replacement components in stock for any component which can fail;
- Introduction of an alerts system, which acts as an early warning system for parts about to fail;
- An ‘opportunistic’ rather than standardized approach to scheduling maintenance activities; maintenance activities on individual IDF stations are now brought forward or pushed back from the initial schedule in consultation with the U.S IDF team, to capitalize on low wind days or AEMO regulated shutdowns, and minimise generation downtime.

Since these changes, no PTU failures have occurred since April 2021.

10.3 Modifications Required

10.3.1 Powering the system

No modifications have been required in relation to powering the IDF system. Each IDF station draws power from a connected turbine within the wind farm.

10.3.2 Storing data

No modifications have been required in relation to storing data, though it is noted the IDF system is 'data heavy' and requires ample server space for users to access and use the system remotely, due to the volume of data generated daily. On average, most days generate around 100MB of data. Higher eagle activity days can generate around 400 MB of data, and a high eagle activity month about 12-15 GB. Simulations to test setting changes result in several GB of data per simulation.

10.3.3 Communicating with Turbines

Modifications have been undertaken in relation to improved integration of IDF signals and commands within the Goldwind SCADA system, however these modifications were generally required because the Goldwind SCADA system was a pre-existing system had not been designed to accommodate IDF from the outset. For future projects, Goldwind would design the SCADA system at the outset, so it was 'fit for purpose' considering the requirements of the IDF system.

The main issue in terms of IDF / SCADA communications has been the occasional occurrence of IDF start signals being missed following an IDF curtailment. This can occur when a bird enters Ri, leaves Ri and enters Ri again in quick succession, and was first encountered in August 2020 during a trial of reducing the Tc setting to 1 minute. The issue was unforeseen by IDF and GWA and resulted in a temporary process of operators having to manually restart turbines to minimise lost generation, while the root cause issue was being diagnosed. One of these manual restarts led to the first WTE mortality discussed in the previous section.

Modifications to the IDF system during the 18-month trial period are shown in Table 10.1:

Table 10.1: Modifications undertaken during IDF trial period

System Modification	Purpose
Heartbeat logic.	When an IDF signal is sent, it will be repeated at 5 second intervals to ensure a turbine restart command is not missed (shown by the green lines in Figure 10.2).
Signal delay optimisation	To minimise delay between an IDF signal being sent and received by SCADA
Stop Mode reallocation	Recoding was undertaken to ensure IDF recognizes the SCADA codes which show– when a wind turbine is already stopped, and for what reason (e.g., low wind, high wind, cable untwisting).
Calibration target upgrade	To replace existing calibration targets with more durable magnetic targets.
Tc alternative logic	the SCADA / IDF interface was redeveloped so instead of a mandatory 2 min wait period after each curtailment, turbines would be able to receive a start signal as soon as they were ready to receive it.
Introduction of alerts system	To improve forecasting of PTU or other component failures, IDF and GWA developed an alert system, which notifies service team personal of alerts for each IDF tower or the IDF base Station.
Dashboard upgrade	Improved user interface and access to reporting.

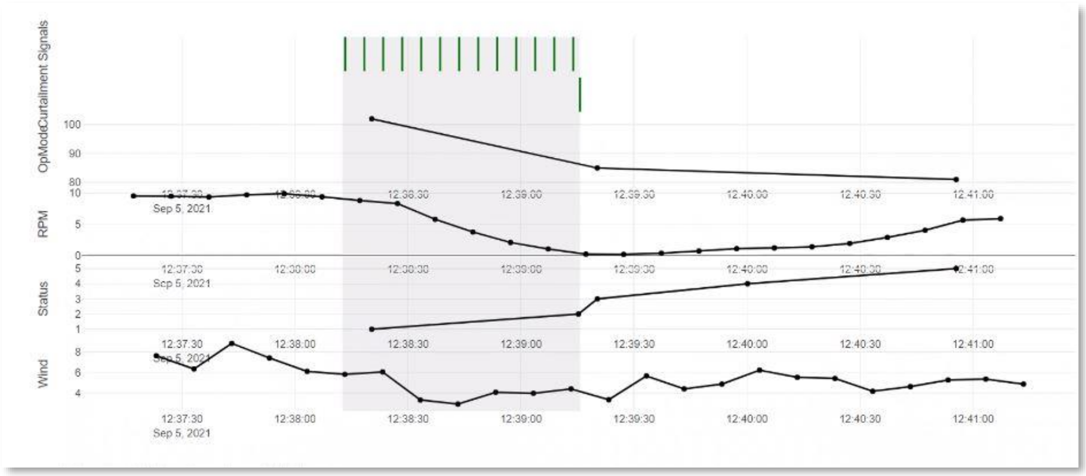


Figure 10.2: Testing showing successful implementation of IDF heartbeat signal

A timeline of the major changes and modifications is shown in Figure 10.3.

Figure 10.3: Modifications and enhancements undertaken during trial period

10.4 Maintenance

The CHWF service team is able to carry out most of the maintenance required for operation of IDF, following training provided by IDF and familiarization of the system over the past 2 years. As with other asset management tasks carried out for wind farm infrastructure, IDF maintenance falls into two categories, planned and reactive maintenance:

Planned maintenance activities include tasks required to ensure continued operation of the IDF system, which are scheduled in advance. While most of these tasks are scheduled on a quarterly or annual basis, the service team works with the US-based IDF team to take the opportunity to carry out IDF tower or imaging head maintenance on low wind days, or during wind farm outages or AEMO initiated stoppages, to minimise potential for generation losses.

Reactive maintenance tasks are essentially unplanned maintenance and are usually associated with faults or outages of IDF hardware or software.

Table 10.2 shows planned, and reactive maintenance tasks typically carried out throughout the year.

Table 10.2: Planned and Reactive Maintenance Tasks

Planned Maintenance Task	Reactive Maintenance Examples
Seal/gasket evaluation/replacement.	Responding to communications losses
PTU checks.	Responding to PTU failure
Full system inspection & bolt check.	Responding to calibration target adjustment requests
Full system viewport cleaning.	Responding to faults
IDF Control Cabinet Filter Check.	Responding to IDF requests
Calibration Target Checks	Responding to alerts
Lightning mitigation system connections.	Bringing the IDF system back online after outages

Software updates, patches, and calibration checks continue to be performed by IDF remotely from the US.

10.5 Conclusions

Goldwind's experience having installed, operated, and maintained the IDF system for a period of over two years is that:

- The IDF system operates as intended and has not resulted in any major unresolvable issues.
- The IDF system can be operated locally by the CHWF service team who are now able to respond to most issues without requiring extensive technical support from the US.
- Some modifications have been undertaken, however these generally relate to enhancements such as improved alert notifications and communications, to better manage the IDF asset.

Plate 10: PTU units at IDF production facility (source: IdentiFlight)

11 Comparison of Alternative Technologies and Approaches

11.1 Introduction

Condition 6C of the EPBC Approval 2009/4839 included the requirement to include in this report, '*comparison of relevant technologies and practices available at the time of preparing the report*'.

This report has already described the intensive mortality monitoring undertaken and including the use of GPS tracked detection dogs and searcher arrangements. Regarding performance of IDF versus alternative technologies (e.g., Robin Radar, DTBird) however, without sufficient knowledge of site-specific factors and eagle activity at the locations these technologies have been implemented, GWA is unable to make a meaningful comparison, and any attempt to do so may mislead. GWA remains satisfied with its initial decision to implement IdentiFlight based on its demonstrated ability to significantly reduce eagle collisions.

11.2 Review of Alternative Technologies

During the trial period, discussions were held with wind farm operators and technology developers in the U.S, Denmark, Tasmania, and Germany, to compare performance against other wind farms with comparable bird mitigation technology installed and automated curtailments occurring. While the installation at Cattle Hill does not represent the highest levels of efficiency identified in these discussions (around 0.6% of generation) it is certainly higher than most comparable installations, most of which are operating at between 2-3% generation loss and some of which are not effectively reducing eagle collisions and mortalities.

The 2018 Joule Logic Report '*Strategies for Monitoring Bird and Bat Collisions at the Cattle Hill Wind Farm'* provided a review various approaches and technologies at the time, which could potentially be adopted to achieve the objectives of the CADP, i.e.:

- Monitoring the movement of eagles within the wind farm
- Detecting and documenting collisions with Turbines.
- Preventing eagle collisions with turbines.

The report states:

> *There is a considerable amount of research being conducted around the World on the impact of wind farms on wildlife (see for example, Hull et al. 2015, Köppel and Schuster 2015, PNWWRM XI. 2017). Included in this research is the development and trial of approaches to monitor collisions of birds and bats with wind turbines. While there is a reasonable understanding of how to monitor using ground searches, there is no single off-the-shelf automated system currently available that is suitable for all wind farms and circumstances. All systems have their pros and cons and it is hard to compare them (Dr Roel May, Norwegian Institute for Nature Research, NINA, pers. comm. 2016). The evaluation of which system is the most appropriate needs to consider the objectives of the site-specific monitoring, whether species identification is required, and the environmental and other details of the site (per Collier et al. 2012).*

At the time of writing, this is still the case – there is no single off-the-shelf system or approach which achieves all three CADP objectives.

DTBird was previously considered as an alternative to Identiflight prior to selection of Identiflight but GWA has not received detailed information on DTBird and is unable to provide meaningful comment on its performance.

GWA is aware of sites using Radar based technology but is not sufficiently informed to be able to assess its merits. Informal discussions with users of Robin Radar had indicated disappointment that it was not effective in preventing eagle collisions. Anecdotally, based on GWA's discussions to date, Robin Radar is widely regarded as the best of the radar-based systems, and IdentiFlight the best of the camera-based systems. Other systems such as MUSE combine aspects of the two, and look promising, but have either not yet been sufficiently field tested and / or GWA does not have sufficient information to comment further on their merits and performance.

Table 11.1 presents various approaches and technologies which can be undertaken to address each of the objectives.

Table 11.1: Various approaches and technologies to achieving CADP objectives

CADP Objective	Alternative Approaches / Technologies
Identifying and classifying avian species	• IdentiFlight • Human surveyors • Radar (e.g., Robin Radar) • Other automated camera-based systems (e.g., MUSE, dBird)
Monitoring the movement of eagles within the wind farm	• IdentiFlight • Monitoring using human observers • Radar (e.g., Robin Radar) • GPS tracking devices affixed to eagles • Static surveillance cameras (e.g., wildlife cameras) • Genetic sampling of the local eagle population.
Preventing eagle collisions with turbines	• IdentiFlight • Appropriate Siting of turbines • Black Blade • Radar (e.g., Robin Radar) • Acoustic Deterrents • Exclusion zones around nests • Measures to deter eagles from turbines (e.g., removal of carrion) • Human-based curtailment of turbines
Detecting and documenting eagle collisions with turbines	• Installing sensors on blades • Radar (e.g., Robin Radar) • Human searches beneath turbines • Use of detection dogs for searches beneath turbines • Drones integrated with machine learning / object recognition • IdentiFlight (if re-worked specifically for this purpose).

While the various technologies listed above, have each been considered, including some discussions held with manufacturers and operators (e.g., MUSE, Robin Radar) GWA does not have sufficient reliable information to compare with the huge, accumulated knowledge of IdentiFlight, to allow a meaningful comparison.

GWA has explored the use of blade marking (Black blade) with WCHPL based on promising initial trials overseas, as a supplement IdentiFlight, given limitations with removal of vegetation in the forested section near Lake Echo where mortalities have occurred. At this stage no decision has been made to proceed with a Black Blade trial and further research is being undertaken prior to making any decision. For a new wind farm the process would be relatively straight-forward, but there are challenges and costs associated with painting blades on an already operating wind farm due to the lifting equipment required to access the blade, difficulties associated with painting the blade when in a vertical position, likely weather delays, and lost generation time.

12 Conclusions

The IDF installation at CHWF has been the first implementation of the technology in Australia and has been successfully adapted to the local WTE species and the CHWF site conditions. Nevertheless, there were incidents that occurred during the 18-month trial period while the IDF system was undergoing initial operation fine-tuning, that have provided valuable experience to refine the system and further reduce risk to eagles and potentially lessen the number of eagle fatalities below the three that did occur.

Based on the experience gained and the preventative measures implemented following each incident, it is expected the rate of mortalities relative to predicted mortalities will improve over time.

Conclusions for each area of assessment required by the CADP are provided as follows:

Identifying and classifying avian species

- The volume and quality of information captured by IDF is considered far more comprehensive than what is possible using traditional bird survey methods conducted by human observers.
- IDF's automated record keeping quickly builds up a large dataset of avifauna information which is geo-referenced, date and timestamped, includes photographic evidence, and is continuously growing. The data collected is not confined to static points in time and captures species over greater distances and heights than the human eye can perceive.
- Over a period of 4 months during development of the WTE neural network, IDF cameras captured a greater diversity of bird species than the total recorded by all previous human surveys, which date back to 2009. This included species thought to be present but not previously detected by human observers over many years of monitoring.
- IDF is now able to recognize and classify WTE with a very high level of confidence, over greater distances than human methods.
- A WBSE neural network is currently in the process of being implemented at the CHWF.

Monitoring the movement of Eagles within the Wind Farm

- Huge amounts of data collected have added to the understanding of eagle behaviors at the CHWF and their interaction with other species inhabiting the site.
- IDF data is excellent for monitoring eagle movements within the wind farm but is limited to 1km around each IDF station, so cannot replace GPS tracking devices affixed to eagles for monitoring movements over longer distances.
- Many human observers would be needed to match the coverage and recording would be less systematic or less reliably georeferenced.
- Monitoring of movements of eagles within the wind farm is considered superior to equivalent monitoring conducted by human observers over the same periods, though both approaches generated similar results at a high *level (i.e., heat maps).*

Preventing Eagle Collisions with Turbines

- The project approvals outline predicted cumulative WTE mortalities as five WTE mortalities by the end of the first year of full operations, eight by the end of the second year, and eleven by the end of the third. Over its 25-year lifespan, the CHWF was predicted to result in up to 59 WTE mortalities.
- At the time of writing, the IDF system has been operating for 27 months (2.25 years) consisting of approximately 8.5 months of wind farm commissioning, commencing on 19 November 2019 and 18 months of full operations, commencing on 4 August 2020. During this period there have been three WTE mortalities, and zero WBSE mortalities.
- Goldwind firmly believes the reduced rate of eagle mortalities in comparison with predicted cumulative WTE mortalities is due to the effective installation, operation, and maintenance of IDF and its integration with the wind farm control and communication systems. This has included several enhancements and fail-safe measures undertaken collaboratively by Goldwind and IDF.
- Goldwind also believes the mortalities, while less than predicted, may understate the effectiveness of IDF over the longer term, as one of the mortalities could have been avoided, and actions have been undertaken to prevent or reduce recurrence following each mortality.
- CHWF has shown consistently high eagle activity from multiple eagle territories within and outside the boundary of the wind farm.
- In comparing mortality estimates with those predicted, Goldwind is of the view that without IDF, WTE mortalities could have been higher than predicted, a view shared by eagle experts working on the project, due to the increase in eagles and nests within and outside the site since the time the mortality predictions were undertaken.
- Because of these factors, IDF's effectiveness preventing mortalities is arguably better than the on-paper comparison against predicted mortalities would suggest.
- For the majority of turbines, IDF has proven effective; no WTE or WBSE collisions have occurred at 45 out of 48 of the CHWF's turbines, including Turbines 8, 9, 40, and 41, which consistently have the highest activity and curtailment counts within the wind farm.
- Where the mortalities did occur, one was due to human error, and two have occurred in areas with major vegetation occlusion resulting in only partial IDF coverage.
- Each mortality has been followed by an investigation with corrective and preventative actions that are expected to reduce the risk of recurrence. In the case of the first mortality, the root cause of the mortality has been identified and eliminated across the wind farm.
- It should be noted that CHWF is a challenging site, and many wind farms could achieve even better results, potentially avoiding all eagle collisions.
- To achieve optimal performance, IDF stations require full visibility of the wind turbine, rotor, and surrounding areas, a factor which should be addressed during development of the IDF layout.
- In conclusion, it is considered IDF performance is in line with published research and does significantly reduce eagle collisions. How much the system will reduce collisions will be largely driven by site conditions and the number of IDF towers a project is able to accommodate.

Detecting and Documenting Eagle Collisions with Turbines

- IDF is designed to avoid eagle collisions and does not detect or document collisions *per se*.
- Once a curtailment is made to avert an eagle collision, IDF ceases tracking that eagle and reverts to scanning the sky for other eagles in the area which may also warrant protection.
- To detect and document bird and bat collisions at the CHWF, a three-tiered carcass monitoring program has been undertaken which includes:
  - Detailed searches of all turbines to 120m of every tower on a bi-monthly basis
  - 'Pulse' surveys to 60m of each tower are undertaken within three days of each search.
  - Drive-by surveys of all turbines on a weekly basis at 45 and 80m transects.
  - Use of detection dogs to increase the efficacy of searches.
- Though IDF does not detect collisions, data collected by IDF could be used to help understand why a collision occurred, and in some cases could pinpoint exactly when the collision occurred.
- As IDF does not detect collisions, it cannot replace carcass monitoring to quantify the impact of a wind farm, however it could be re-configured to do so, and may be used in this way for offshore wind projects in future (*pers comm Carlos Jorquera, IDF*). The use of IDF to detect collisions has been outside the scope of this trial.
- Carcass monitoring varies across wind farms; an exhaustive monitoring program may give higher confidence in the results but will consume large resources which could be better diverted to species conservation; a casual survey approach is likely to under-report collisions.
- This inconsistency makes comparison of performance across projects difficult. Over the longer term, automated approaches such as blade sensors and artificial intelligence camera-based systems, are considered more suitable and reliable approaches.

Performance Efficiency

The trial has demonstrated that:

- The IDF system can reliably communicate with the wind farm SCADA system and send signals to curtail turbines with sufficient time to avoid an eagle colliding with turbine blades.
- The IDF system can distinguish between eagles and other birds on site, and issue curtailment signals only for the target species (eagles).
- The IDF system can operate without incurring excessive generation losses.
- The trial has demonstrated the technology can protect bird species while also operating the wind farm efficiently.

Technical Reliability

Having installed, operated, and maintained IDF for over two years, Goldwind's experience is that:

- The IDF system operates as intended and has not resulted in any major unresolvable issues.
- The IDF system can be maintained locally by wind farm service technicians
- The CHWF service team can respond to most issues without technical support from the US.
- No major modifications were required for the system to operate effectively. The only modifications undertaken were to improve management of the IDF asset, including introduction of an alert system to warn of potential failures.

13 References

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Strategies for Monitoring Bird and Bat Collisions at the Cattle Hill Wind Farm. Developed to satisfy Condition FF9 of the State EPN 9715/1 for the Cattle Hill Wind Farm. Author: Hull., C. (Joule Logic, 2018)

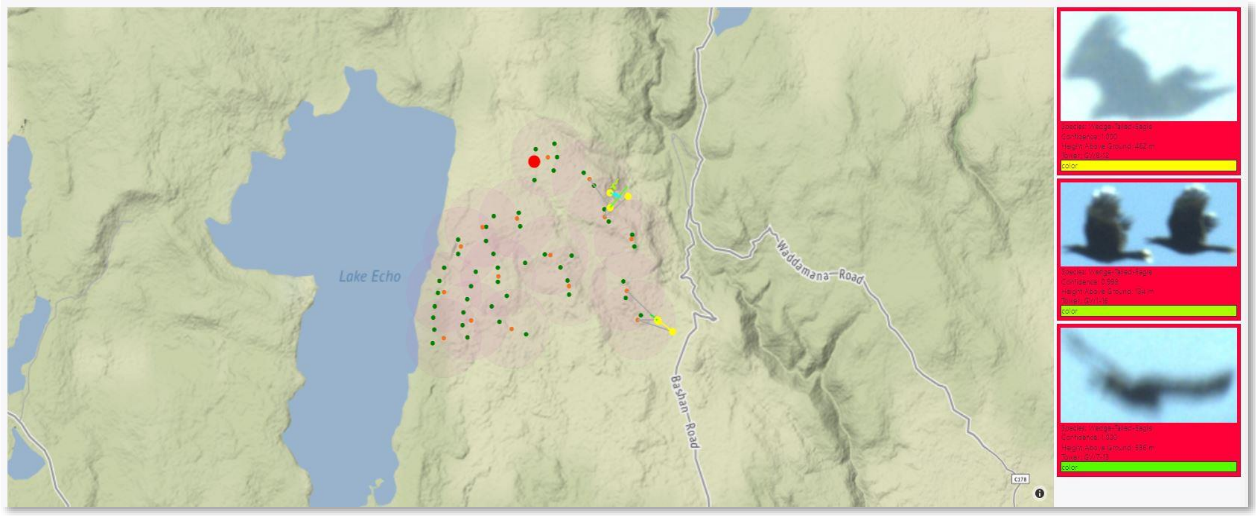
A: Example IDF reporting outputs

B: Supporting Information

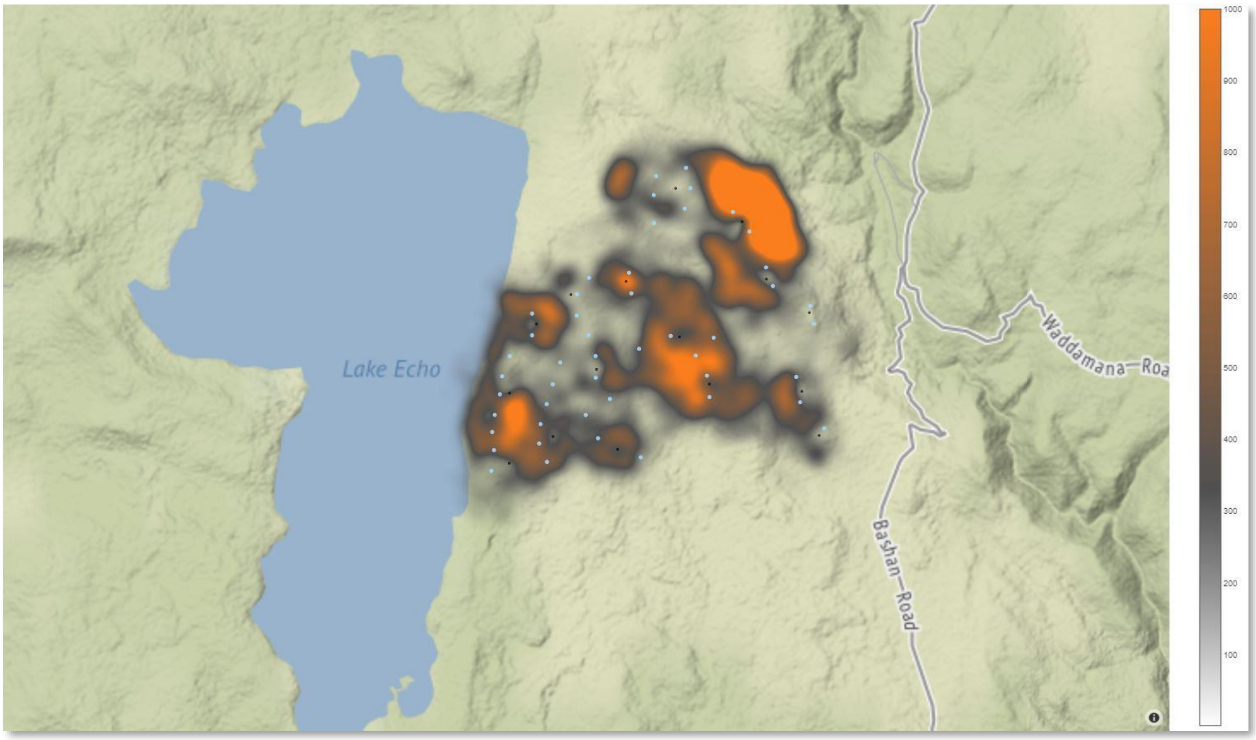
Appendix A

IdentiFlight data and report examples

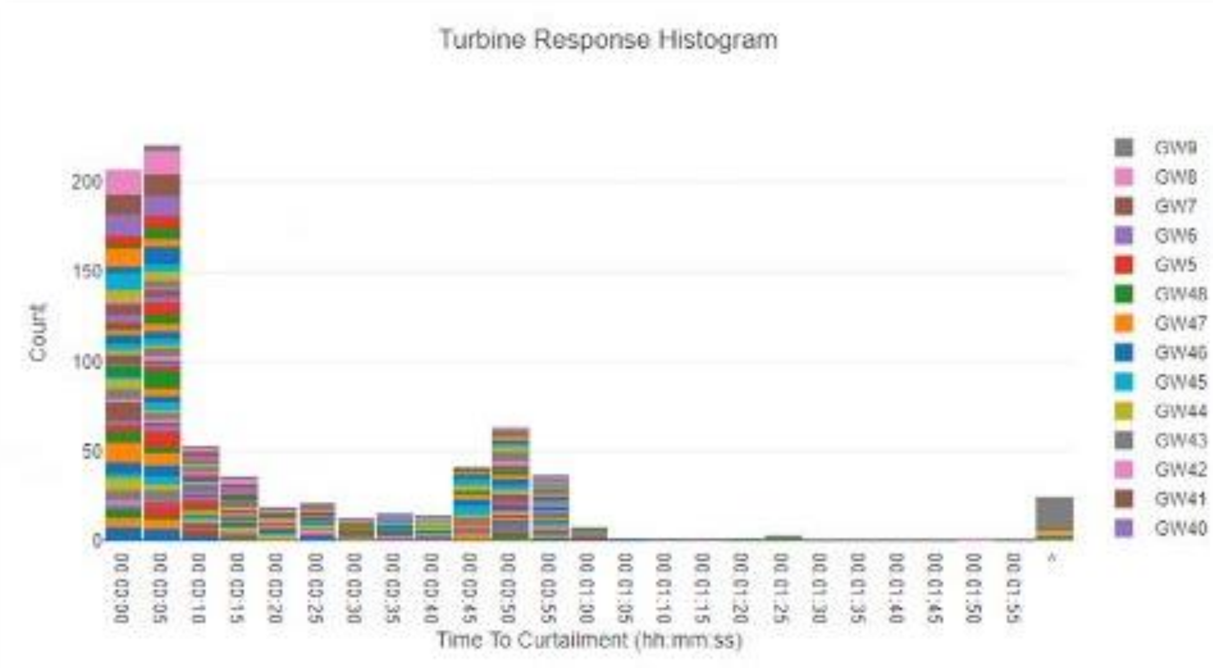
Example Report Outputs



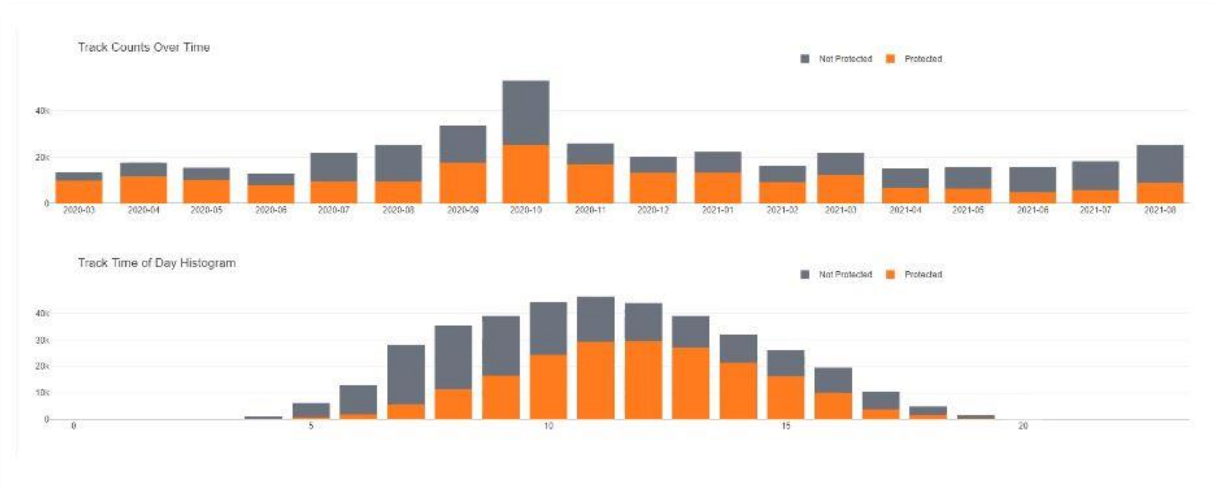
IdentiFlight GUI



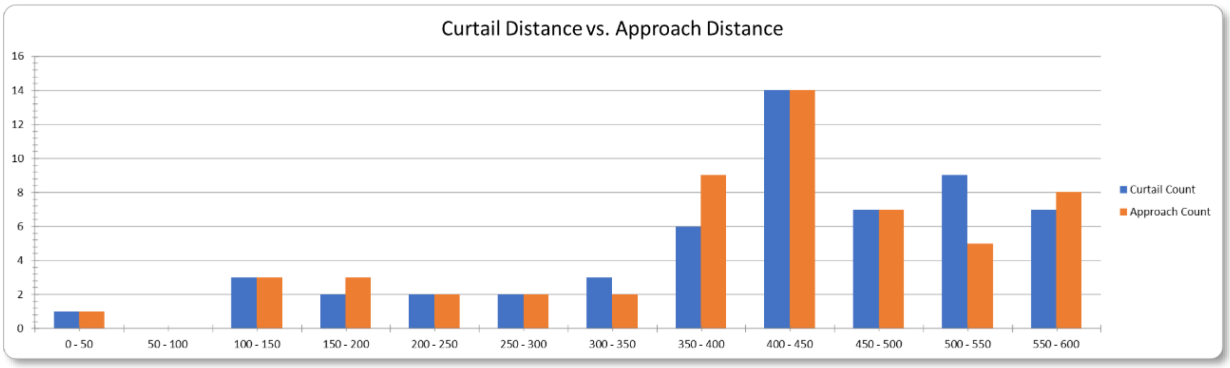
Heat Maps



Turbine Response Histogram



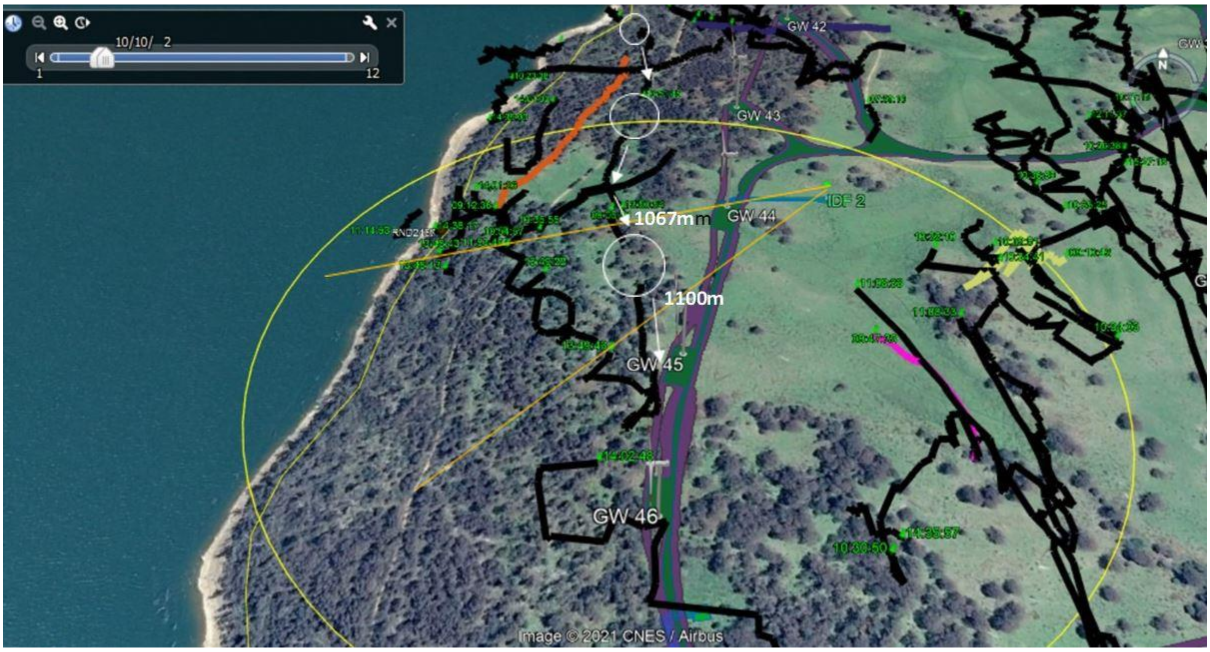
Totals over Time Histogram



Curtailment vs Approach Distance Histogram

Date:	Sunday, December 19, 2021
First Observation:	4:31 AM
Last Observation:	7:51 PM
First Eagle Observation:	5:02 AM
Last Eagle Observation:	6:54 PM
All Tracks:	330
Eagle Tracks:	115
Min Track Length:	1 Second
Max Track Length:	96 Seconds
Average Track Length:	12 Seconds
Eagle Images:	1500
Not-Eagle Images:	1389
Total Images:	2889
Min Eagle Height AGL:	14 Meters
Max Eagle Height AGL:	741 Meters
Average Eagle Height AGL:	216 Meters
Number of Curtailments:	208
Curtailment to Track Ratio:	180.87%

Daily Email Summary



Bird Tracks within Wind Farm (Oblique View)

TrackID	DateTimeStamp	Theta	Phi	X	Y	Latituc	Longitu	SpeciesTypeName	ConfidenceL	TowerNur	WFOV_c	HeightAGL_	HorizontalDistance	ElevationASL	MajorA	Area	ClosestTu	TurbineDistance	Image
750791-2818-4a84-9f1c-c883b35d12	8/26/2021 12:02:03.285	233.34	48.39	5E+05	5E+06	48.151	146.67	WEDGE-TAILED-EAGLE	1	19	5	191	194	1045	1851.9	728433	GW19	188.8597363	
750791-2818-4a84-9f1c-c883b35d12	8/26/2021 12:02:05.287	235.11	46.9	5E+05	5E+06	48.151	146.67	WEDGE-TAILED-EAGLE	1	19	5	190	182	1044	1687.6	544347	GW19	185.1431878	
750791-2818-4a84-9f1c-c883b35d12	8/26/2021 12:02:06.289	236.37	45.89	5E+05	5E+06	48.151	146.67	WEDGE-TAILED-EAGLE	1	19	5	189	175	1043	1814.6	587559	GW19	183.1529416	
750791-2818-4a84-9f1c-c883b35d12	8/26/2021 12:02:07.292	236.79	44.6	5E+05	5E+06	48.151	146.67	WEDGE-TAILED-EAGLE	1	19	5	187	166	1041	1807.3	598308	GW19	177.9719079	
0b0e36-04bb-4df4-ae19-d2da449f3a	8/26/2021 12:03:19.327	159.49	45.79	5E+05	5E+06	48.153	146.67	WEDGE-TAILED-EAGLE	1	19	6	179	183	1051	1915.1	649622	GW19	95.20504188	
0b0e36-04bb-4df4-ae19-d2da449f3a	8/26/2021 12:03:24.337	165.41	42.96	5E+05	5E+06	48.153	146.67	WEDGE-TAILED-EAGLE	1	19	6	180	167	1052	1784.8	641590	GW19	84.69356528	
0b0e36-04bb-4df4-ae19-d2da449f3a	8/26/2021 12:03:25.342	168.19	43.7	5E+05	5E+06	48.153	146.67	WEDGE-TAILED-EAGLE	1	19	6	177	168	1049	1790.8	639228	GW19	80.61017306	
0b0e36-04bb-4df4-ae19-d2da449f3a	8/26/2021 12:03:30.351	185.03	47.16	5E+05	5E+06	48.152	146.67	WEDGE-TAILED-EAGLE	1	19	6	169	177	1037	989.23	422021	GW19	77.18160403	
0b0e36-04bb-4df4-ae19-d2da449f3a	8/26/2021 12:03:33.357	197.36	53	5E+05	5E+06	48.152	146.67	WEDGE-TAILED-EAGLE	1	19	6	161	202	1025	1308.1	468254	GW19	103.3876201	

Cause of Curtailment Report (extract only)

Appendix B

Supporting Information

B1 - Species Diversity Matrix

B2 - Carcass Monitoring Methodology

B3 - Eagle Monitoring Methodology

B4 - Eagle Utilisation Heat Maps (Human)

B5 - Eagle Utilisation Heat Maps (IDF)

B6 - Bird Species Recorded at CHWF

Appendix B1: Species Diversity Matrix

APPROXIMATIONS OF FREQUENCY OF OCCURRENCE			
	Estimated Observations Per Month		
Relative Abundance	High	Expected	Low
High	500	350	200
Medium	100	70	50
Low	35	20	5

Notes

Birds with 1.0m or greater wingspan (IDF min protection range) are shaded grey. Wingspans are upper range figures

Commonwealth Protected Species are shown in **Bold**

WTE Breeding Period (J–F) · WTE Fledging (F–M) · WTE Low activity (A–J) · WTE Display Period (J–A) · WTE Breeding Period (A–D)

Common Name	Species	Length (m)	Wingspan (m)	Resident/ Migratory	EPBC Status	TSPA Status	J	F	M	A	M	J	J	A	S	O	N	D
Wedge-tailed Eagle	**Aquila audax**	**1.00**	**2.35**	**Resident**	**Endangered**	**Endangered**												
White Bellied Sea Eagle	Haliaeetus leucogaster	0.80	2.20	Resident	Least Concern	Vulnerable												
Black Swan	Cygnus atratus	0.75	2.00	Resident	Least Concern	not listed												
Cape Barren Goose	Cereopsis novaehollandiae	0.85	1.75	Resident	Least Concern	not listed												
Great Comorant	Phalacrocorax carbo	0.60	1.60	Resident	Least Concern	not listed												
Magpie Goose	Anseranas semipalmata	0.75	1.50	Resident	Least Concern	not listed												
Swamp Harrier	Circus approximans	0.55	1.45	Resident	Least Concern	not listed												
Masked Owl	**Tyto novaehollandiae**	**0.51**	**1.28**	**Resident**	**Endangered**	**Endangered**												
Australian Peregrin Falcon	Falco peregrinus	0.50	1.20	Resident	Least Concern	not listed												
Brown Falcon	Falco berigora	0.50	1.15	Migratory	Least Concern	not listed					Migrates to mainland Australia							
Grey Goshawk	**Accipiter novaehollandiae**	**0.50**	**1.10**	**Resident**	**Least Concern**	**Endangered**												
Forest Raven	Corvus tasmanicus	0.50	1.10	Resident	Least Concern	not listed												
Yellow-tailed Black Cockatoo	Calyptorhynchus funereus	0.65	1.10	Resident	Least Concern	not listed												
White Faced Heron	Egretta novaehollandiae	0.69	1.06	Resident	Least Concern	not listed												
Sulphur Crested Cockatoo	Cacatua galerita	0.55	1.03	Resident	Least Concern	not listed												
Grey Currawong	Strepera versicolor	0.52	0.85	Resident	Least Concern	not listed												
Little Raven	Corvus mellori	0.40	0.80	Resident	Least Concern	not listed												
Black Currawong	Strepera fuliginosa	0.50	0.80	Resident	Least Concern	not listed												
Masked Lapwing	Vanellus miles	0.37	0.80	Resident	Least Concern	not listed												
Nankeen Kestral	Falso cenchroides	0.35	0.78	Resident	Least Concern	not listed												
Pied Currawong	Strepera graculina	0.44	0.75	Resident	Least Concern	not listed												
Australian Magpie	Gymnorhina tibicen	0.40	0.68	Resident	Least Concern	not listed												
Tasmanian Native Hen	Tribonyx mortierii	0.45	0.68	Resident	Least Concern	not listed												
Laughing kookaburra	Dacelo novaeguineae	0.45	0.66	Resident	Least Concern	not listed												
Australian Swamphen	Porphyrio melanotus	0.35	0.65	Resident	Least Concern	not listed												
Dusky Moorhen	Gallinula tenebrosa	0.35	0.65	Resident	Least Concern	not listed												
Green Rossella	Platycercus caledonicus	0.36	0.56	Resident	Least Concern	not listed												
Ground parrot	Pezoporus wallicus	0.30	0.55	Resident	Least Concern	not listed												
White-throated Needletail	**Hirundapus caudacutus**	**0.22**	**0.48**	**Migratory**	**Threatened**	Not listed				Migrates to Europe - not present on site								
Eastern Rossella	Platycercus eximius	0.30	0.48	Resident	Least Concern	Not listed												
Crested Pidgeon	Ocyphaps lophotes	0.36	0.45	Resident	Least Concern	Not listed												
Black faced Cuckoo-shrike	Coracina novaehollandiae	0.35	0.45	Resident	Least Concern	Not listed												
Rainbow Lorrikeet	Trichoglossus haemotodus	0.30	0.45	Resident	Least Concern	Not listed												
Crimson Rossella	Platycercus elegans	0.36	0.44	Resident	Least Concern	Not listed												
Common (Indian) Myna	Acridotheres tristis	0.24	0.40	Resident	Least Concern	Not listed												
Blue Winged Parrot	Neophema chrysostoma	0.24	0.40	Resident	Least Concern	Not listed												
Magpie Lark	Grallina cyanoleuca	0.25	0.40	Resident	Least Concern	Not listed												
Common Starling	Sturnus vulgaris	0.23	0.40	Resident	Least Concern	Not listed												
Noisy Miner	Manorina melanocephala	0.24	0.39	Resident	Least Concern	Not listed												
Australasian Pipit	Anthus novaeseelandiae	0.18	0.33	Resident	Least Concern	Not listed												
Dusky Woodswallow	Artamus cyanopterus	0.18	0.32	Resident	Least Concern	Not listed												

Appendix B2 - Carcass Monitoring Methodology
(Bird and Bat Mortality Monitoring Plan)

The Bird and Bat Mortality Monitoring Plan (BBMMP) addresses the requirements of EPN Condition FF10 and has been approved by EPA. The Plan outlines requirements for monitoring at Carcass Monitoring Zones (CMZ) beneath each of the 48 turbines, and procedures to be followed in the event of discovery of any injured or dead birds or bats. The following monitoring is undertaken:

1. Drive-by surveys of all 48 wind turbines on a weekly basis using a low impact vehicle circling each turbine at 45m and 80m transects (Phase 1 surveys).
2. Full surveys of 24 turbines on a monthly rotating basis, to complete all 48 turbines every two months (Phase 2 surveys)
3. Surveys of the inner 60m CMZ for 24 turbines, undertaken within 3 days following each Phase 2 survey (Pulse surveys).

Survey requirements for Birds (including eagles) and Bats

- All 48 turbines are to be surveyed over a two-month period (24 randomly selected per session).
- Searches are to be undertaken at 6m transects from 0-60 m of the tower, and 12m transects from 61-120 m. The entire survey area is referred to as the CMZ.
- Once each session, the full CMZ of every turbine will be surveyed, and the inner region surveyed again three days later to detect any additional carcasses. Survey records are to include:
  - Date
  - Weather conditions
  - Turbine number
  - Start and finish time for each turbine survey
  - Any injured birds or bats, carcasses or featherspots.
- If a carcass or featherspot is found, the location (distance from tower, GPS); species (incl sex, and age if possible) and any evidence of scavenging will be recorded using the incidental carcass find form.
- Eagle carcasses will be transported to a veterinarian, and a necropsy undertaken for all mortalities.

Additional survey requirements during Identiflight trial

- During the Identiflight trial drive-bys of **ALL** 48 turbines will be undertaken weekly to detect eagle carcasses, injured eagles or featherspots. Each turbine will be circled twice, at 45 m and 80m from the tower centre.

Record Keeping

A log will be maintained of drive-bys undertaken.

- Veterinarian records are to be kept and made available to EPA and DPIPWE).
- Condition 26 of the EPBC Approval requires accurate records to be kept substantiating all activities associated with conditions of approval. Such records may be subject to audit.
- Completed Incidental Carcass Find Forms are required for each find.

Notification of Collisions

- Any evidence of a collision will be reported to EPA within 24 hours, and a full strike report submitted to the Director within three days of detection (refer details in BBMMP)
- All birds and bats not listed under TSPA will be reported within 3 days of detection.

Reporting

- The results of each year's surveys will be presented in the AER (Condition G10)
- Annual compliance reports are required under Condition 27 of the EPBC Approval

Searching Fall Zone using Dogs	
Methods	Searching by dogs exploits the dog's sense of smell. Dogs need to be specifically trained for this task, which can take up to a year and requires continual reinforcement training (Bennett 2015). Generally formal transects are not followed, but the dog is left to roam and pursue scent trails. Dogs are known to have higher detection rates than human observers, but the adequacy of training is very important (Bennett 2015). Detectability is affected by wind conditions (scent is not carried when there is no wind, or there are too many scents when there is high wind), topography (steep sites reduces scents), vegetation (can block scents) and temperature (few scents in cold weather, Bennett 2015). As with humans, after recording details of the find, the carcass is removed to avoid double counting.
Advantages	• Documented higher detection rate than humans (Matthews 2011, Bennett 2015). • Dogs suffer less fatigue and boredom than humans, if trained properly. • Faster than humans. • Cheaper than humans, depending on housing costs, etc. • Can trigger an action when a high priority species is found because the handler is present.
Disadvantages	• Requires good quality training and continual reinforcement (Bennett 2015). • Requires high quality handlers (Bennett 2015). • Sub-sampling of turbines is required (as one handler and dog can only cover a certain amount in one day, Bennett 2015). • May miss some carcasses if they are moved a considerable distance from search area. • Date and time of collision cannot usually be precisely determined. • Cannot always determine turbine responsible, particularly if scavengers have moved a carcass.

Appendix B3 - Eagle Monitoring Methodology

(Post-Commissioning Eagle Utilisation Monitoring Plan)

Species

- Wedge-tailed eagle (WTE)
- White bellied Sea Eagle (WBSE)

Survey points

- Two points for WBSE and 4 points for WTE as shown on attached map

Survey times

- Breeding season (approx. 8 days around mid-November and 3 days mid-December);
- Post breeding (approximately 4 days late February);
- Non-breeding (approximately 5 days early May); and
- Displaying (approximately 6 days mid-August).

Survey requirements

Observations will be conducted for a maximum of 8 hours between 8am – 4 pm, as this is when most flights occur (ref: DPEMP, p. 14 Volume 3). The following will be documented during observations:

- Species of eagle
- Age class of eagle (immature, juvenile or adult) if it can be determined
- Time first observed
- Height category when the eagle was first observed (see below)
- Category of behaviour (soaring, displaying, flying, conflict, see below)
- Sector in which behaviour was observed
- Time at which eagle disappeared from view
- Ground track of the flight digitised into a GIS shapefile (each flight having an identification field to allow connection of survey and observation metadata).

Wind speed and direction will be recorded every three hours during the observations.

Height categories

- Below 125m
- Above 125m
- Mixed height
- Above 300m

Eagle behaviour categories

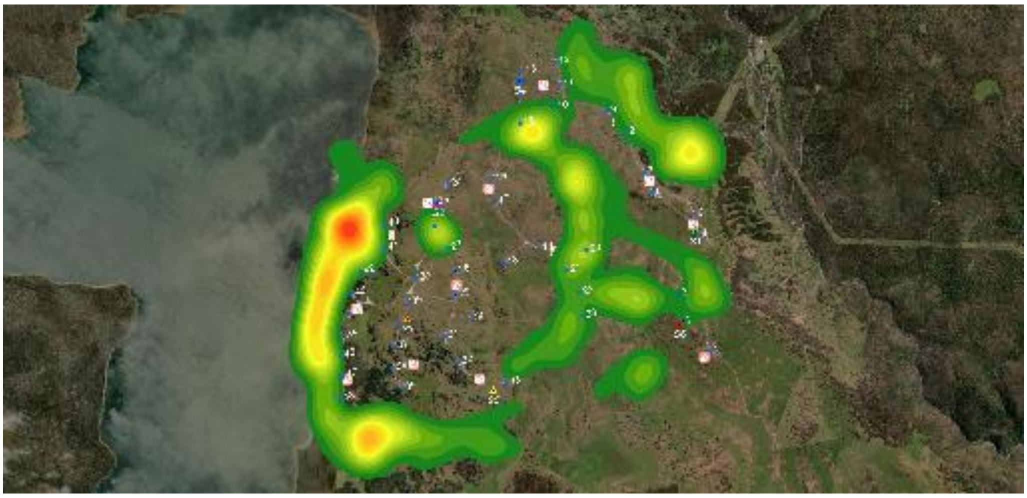
The following definitions will be used (ref: p. 15, Appendix H, Volume 3 DPEMP):

- Soaring - where birds are riding thermals and updrafts and not flapping their wings
- Flying – birds in direct flight with wing flapping
- Displaying – where birds are exhibiting flight behaviours associated with displaying such as mutual soaring, rolling, talon-grappling and undulating displays (e.g., pot-hook display)
- Conflict – chasing and diving at intruders and fighting

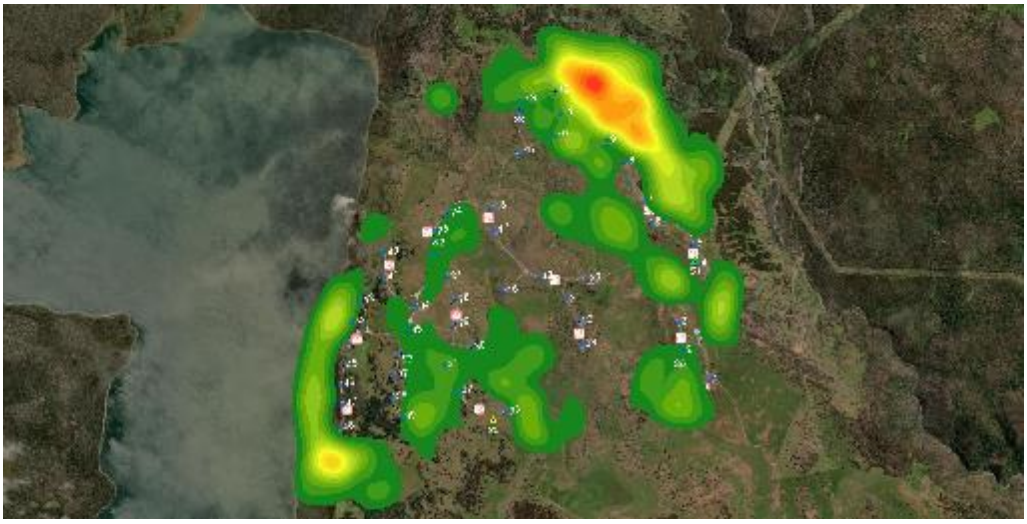
Original Eagle Utilisation Survey Locations

Revised Eagle Utilisation Survey Locations

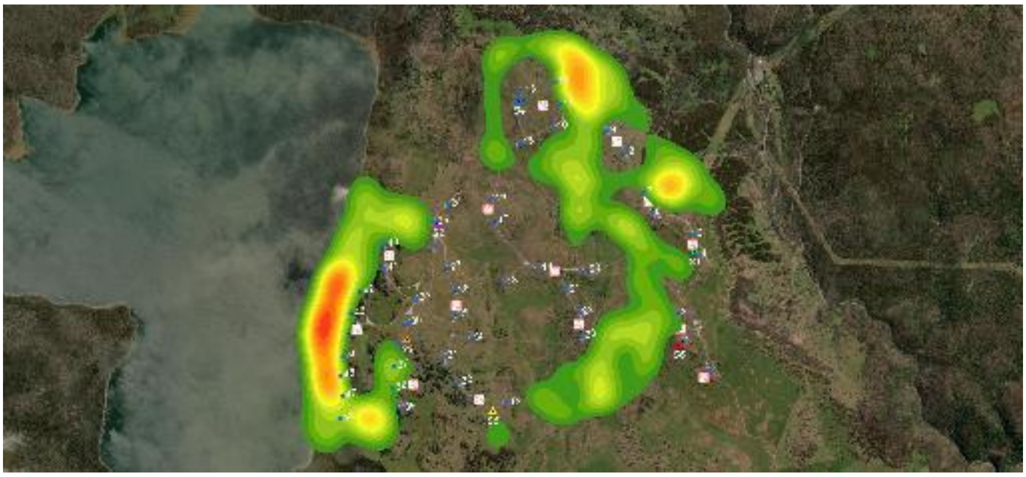
Appendix B4 – Eagle Utilisation Heat Maps
(Prepared from Human Observations)



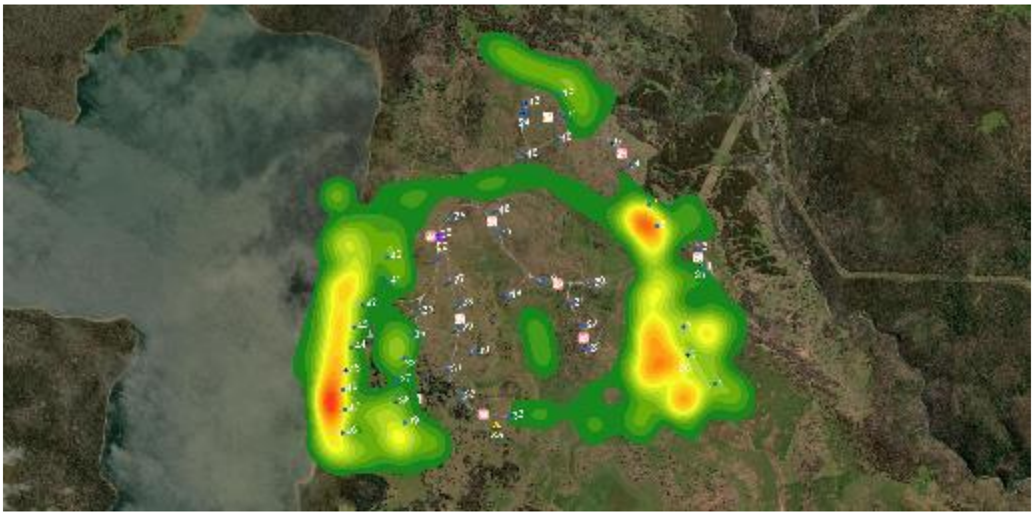
November 2020 Eagle Utilisation Heat Map based on Human Observations (Wildspot)



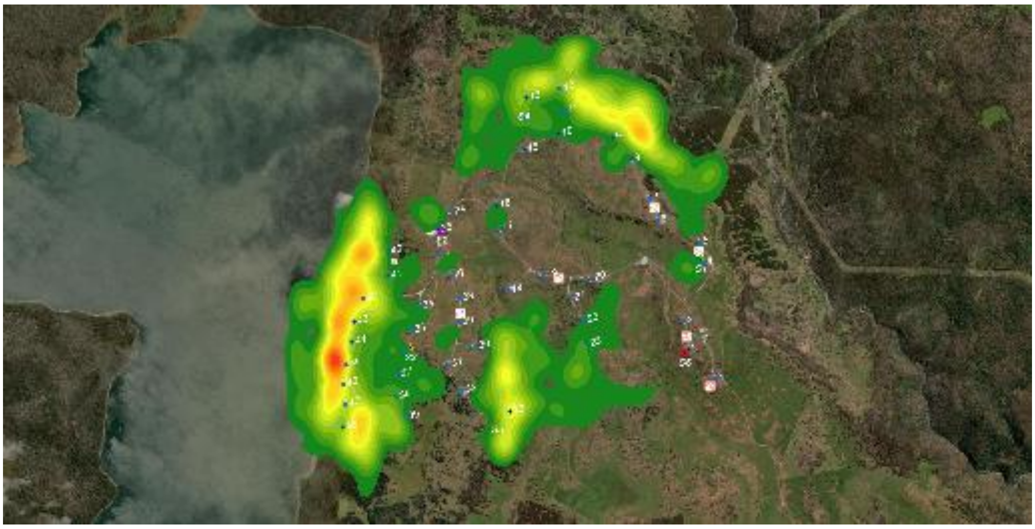
December 2020 Eagle Utilisation Heat Map based on Human Observations (Wildspot)



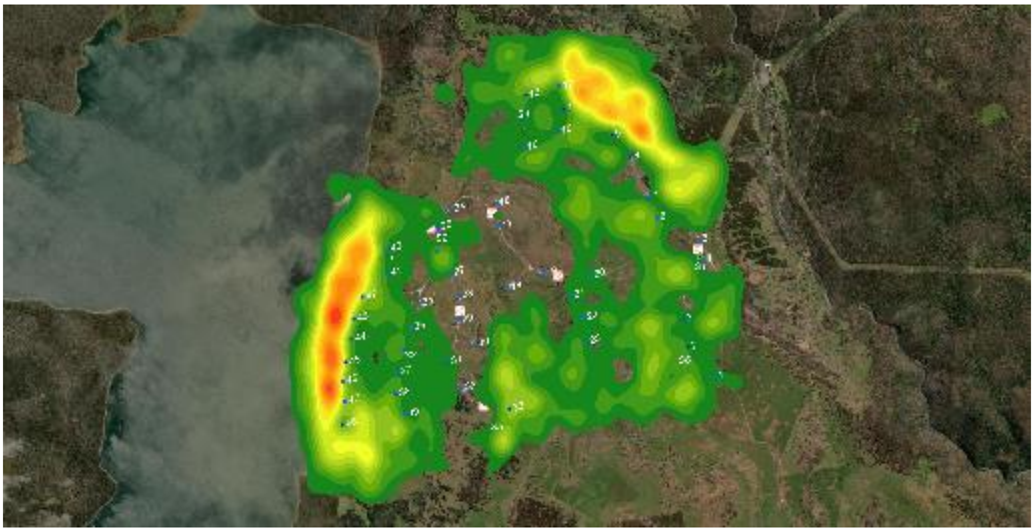
February 2021 Eagle Utilisation Heat Map based on Human Observations (Wildspot)



May 2021 Eagle Utilisation Heat Map based on Human Observations (Wildspot)

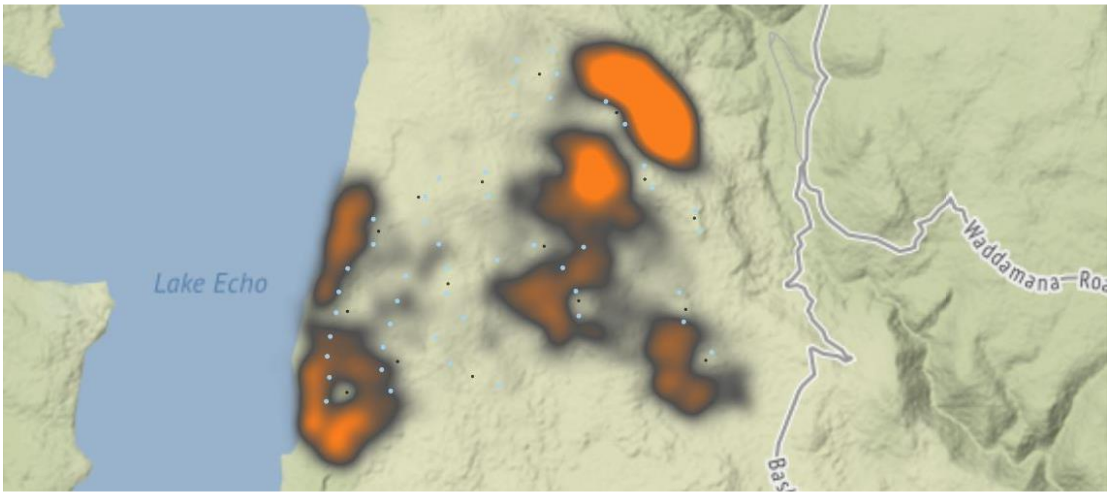


August 2021 Eagle Utilisation Heat Map based on Human Observations (Wildspot)

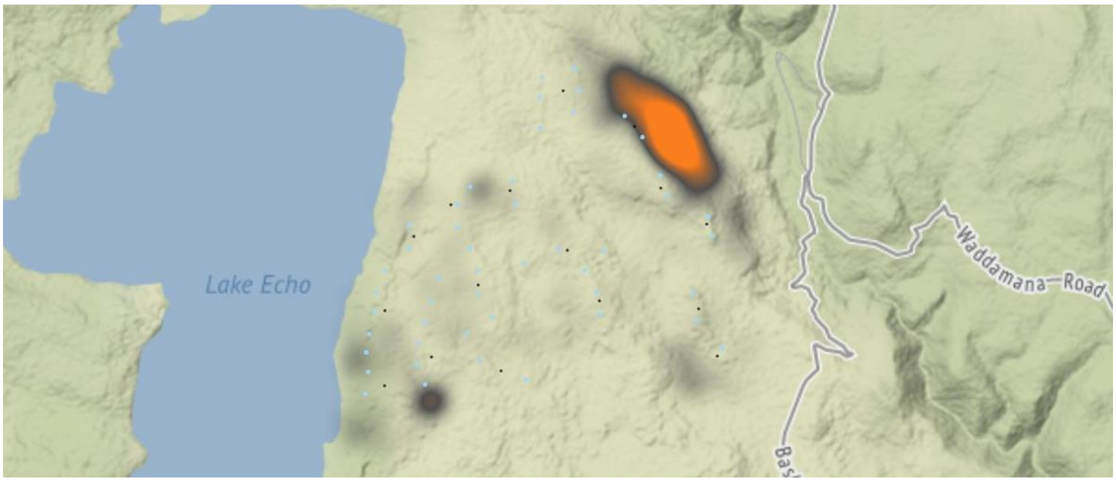


Composite Eagle Utilisation Heat Map based on Human Observations (Wildspot)

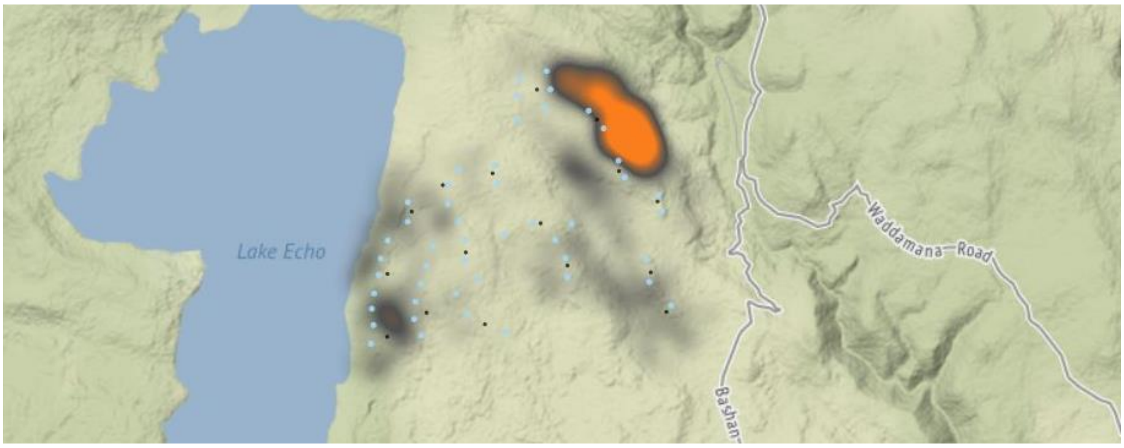
Appendix B5 – Eagle Utilisation Heat Maps
(Prepared from IDF data)



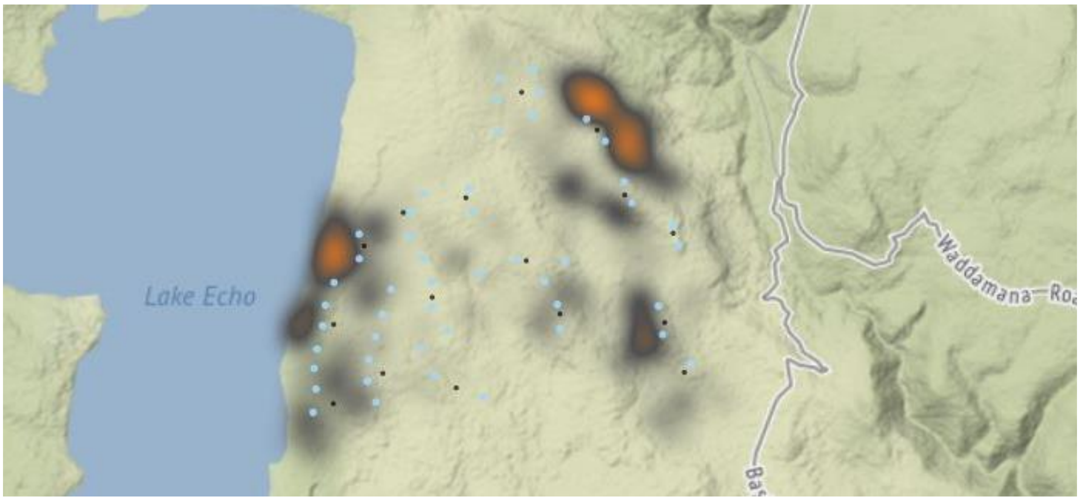
November 2020 Eagle Utilisation Heat Map generated by IDF



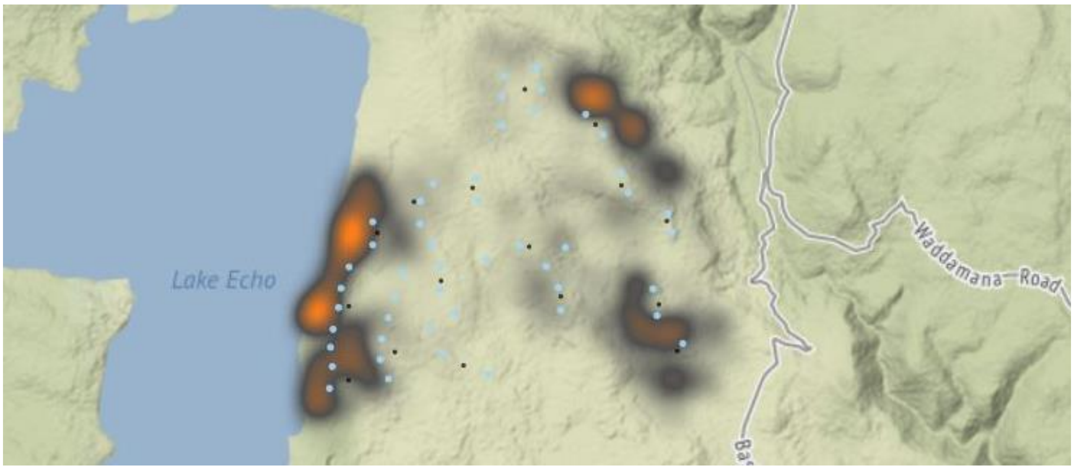
December 2020 Eagle Utilisation Heat Map generated by IDF



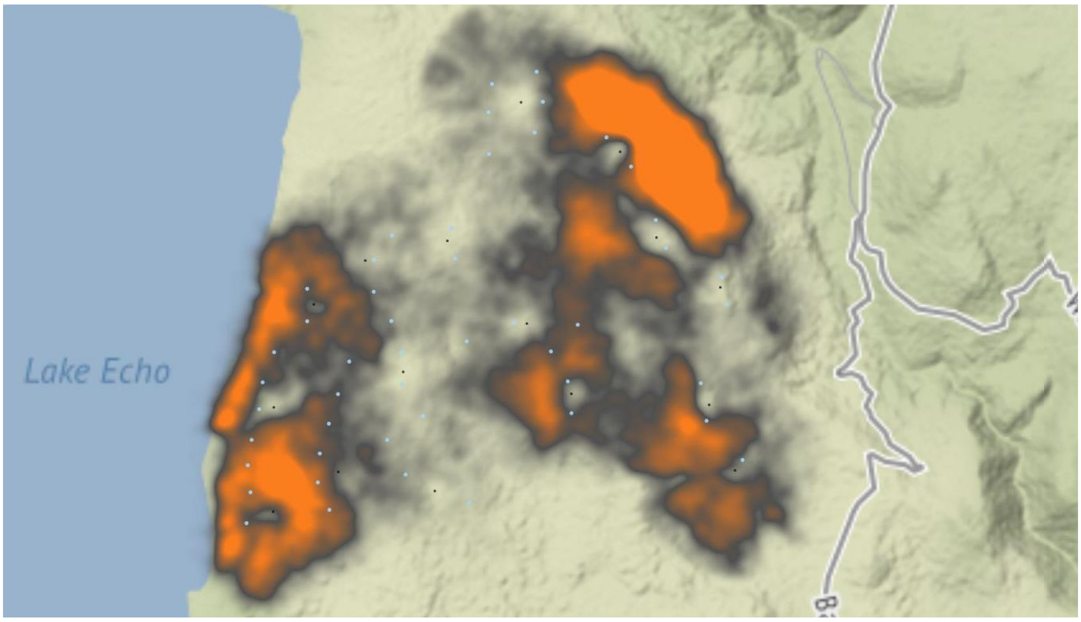
February 2021 Eagle Utilisation Heat Map generated by IDF



May 2021 Eagle Utilisation Heat Map generated by IDF



August 2021 Eagle Utilisation Heat Map generated by IDF



Composite Eagle Utilisation Heat Map generated by IDF

Appendix B6 – Bird Species Recorded at Cattle Hill Wind Farm

Species detected by seasonal bird monitoring surveys (2008-2010)

Australian Magpie	*Common Starling*	*Green Teal*	*Superb Fairy Wren*
Australian Shelduck	*Dusky Robin*	*Laughing Kookaburra*	*Tasmanian Native Hen*
Australian Wood duck	*Dusky Woodswallow*	*Masked Lapwing*	*Tasmanian Scrub wren*
Black Currawong	*Eastern Spinebill*	*New Holland Honeyeater*	*Tasmanian Thornbill*
Back-faced Cuckoo Shrive	*Eastern Rosella*	*Noisy Miner*	*Tree Martin*
Black Headed-honey Eater	*Fan-tailed Cuckoo*	*Pacific Black Duck*	*Wedge Tailed Eagle*
Blue Winged Parrot	*Flame Robin*	*Peregrine Falcon*	*Welcome Swallow*
Brown Falcon	*Forest Raven*	*Richard's Pipit*	*White Bellied Sea Eagle*
Brown Thornbill	*Grey Butcherbird*	*Scarlett Robin*	*Yellow-Rumped Thornbill*
Bush Bronzewing	*Great Cormorant*	*Silvereye*	*Yellow-Tailed Black Cockatoo*
Chestnut Teal	*Green Rosella*	*Spotted Pardalote*	*Yellow-Throated Honey Eater*
Common Blackbird	*Grey Fantail*	*Striated Forest Wren*	*Yellow Wattlebird*
Common Bronzewing	*Grey Strike Thrush*	*Striated Pardalote*	

Species captured by IDF cameras (2020-2021)

Australasian Pipit (*Anthus novaeseelandiae)*	Laughing kookaburra *(Dacelo novaeguineae)*
Australian Magpie *(Gymnorhina tibicen)*	Little Raven *(Corvus mellori)*
Australian Peregrin Falcon *(Falco peregrinus)*	Magpie Goose *(Anseranas semipalmata)*
Australian Swamphen *(Porphyrio melanotus)*	Magpie Lark *(Grallina cyanoleuca)*
Black Currawong *(Strepera fuliginosa)*	Masked Lapwing *(Vanellus miles)*
Black faced Cuckoo-shrike *(Coracina novaehollandiae)*	Nankeen Kestral *(Falso cenchroides)*
Black Swan *(Cygnus atratus)*	Noisy Miner *(Manorina melanocephala)*
Blue Winged Parrot *(Neophema chrysostoma)*	Pacific Black Duck *(Anas superciliosa)*
Brown Falcon *(Falco berigora)*	Pied Currawong *(Strepera graculina)*
Cape Barren Goose *(Cereopsis novaehollandiae)*	Rainbow Lorrikeet *(Trichoglossus haemotodus)*
Common (Indian) Myna *(Acridotheres tristis)*	Striated Pardolote *(Pardalotus striatus)*
Common Starling *(Sturnus vulgaris)*	Sulphur Crested Cockatoo *(Cacatua galerita)*
Crested Pidgeon *(Ocyphaps lophotes)*	Swamp Harrier *(Circus approximans)*
Crimson Rossella *(Platycercus elegans)*	Tasmanian Native Hen *(Tribonyx mortierii)*
Dusky Moorhen *(Gallinula tenebrosa)*	Tasmanian Silvereye *(Zosterops laterali)*
Dusky Woodswallow *(Artamus cyanopterus)*	Tree martin *(Petrochelidon nigricans)*
Eastern Rossella *(Platycercus eximius)*	Wedge-tailed Eagle *(Aquila audax)*
Forest Raven *(Corvus tasmanicus)*	Welcome Swallow (Hirundo neoxena)
Great Comorant *(Phalacrocorax carbo)*	White Bellied Sea Eagle *(Haliaeetus leucogaster)*
Green Rossella *(Platycercus caledonicus)*	White Faced Heron *(Egretta novaehollandiae)*
Grey Currawong *(Strepera versicolor)*	White-throated Needletail *(Hirundapus caudacutus)*
Grey Goshawk *(Accipiter novaehollandiae)*	Yellow Throated Miner *(Manorina flavigula)*
Ground parrot *(Pezoporus wallicus)*	Yellow-tailed Black Cockatoo *(Calyptorhynchus funereus)*