Joule Logic

Renewable Energy and Environment Specialists

Cattle Hill Wind Farm

Collision Avoidance and Detection Plan (CADP)

Developed to satisfy the requirements of Condition 6A of the Commonwealth Approval EPBC 2009/4839 for the Cattle Hill Wind Farm

Date	Revision	Prepared	Reviewed	Approved
22/05/2018	5	Cindy Hull Joule Logic	Sue Marsh Joule Logic	Jeff Bembrick Goldwind Australia

Definitions

In this Collision Avoidance and Detection Plan the following definitions apply:

Cattle Hill Wind Farm	Comprising 48 wind turbines and 150 MW capacity
Central Highlands Region	Is that described in Environment Protection Notice No. 9715/1, as the area north of Bothwell, east of Bronte Park and surrounds, south of Liawenee and west of the Great Western Tiers
Commissioning	When the Cattle Hill Wind Farm commences the generation of electricity for sale
DoEE	Commonwealth Department of Environment and Energy
DPEMP	Development Proposal and Environmental Management Plan, June 2010
EMPCA	Tasmanian *Environmental Management and Pollution Control Act 1994*
Eagle	Tasmanian wedge-tailed eagle (*Aquila audax fleayi*) or the white-bellied sea-eagle (*Haliaeetus leucogaster*)
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)
The Proponent	Wild Cattle Hill Pty Ltd (ACN 610 777 369)
WTE	Tasmanian wedge-tailed eagle (*Aquila audax fleayi*)
WBSE	White-bellied sea-eagle (*Haliaeetus leucogaster*)

Contents

1. Introduction

1.1 The Project

The Cattle Hill Wind Farm occupies privately-owned land situated east of Lake Echo in Tasmania's Central Highlands approximately 93 kilometres to the north-west of Hobart (Figure 1). The wind farm consists of 48 wind turbines and associated infrastructure (Figure 2).

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. The small unpopulated settlement of Waddamana is located to the north east. The site is currently used for grazing, small forestry operations and hunting and comprises nine lots owned by two land owners.

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

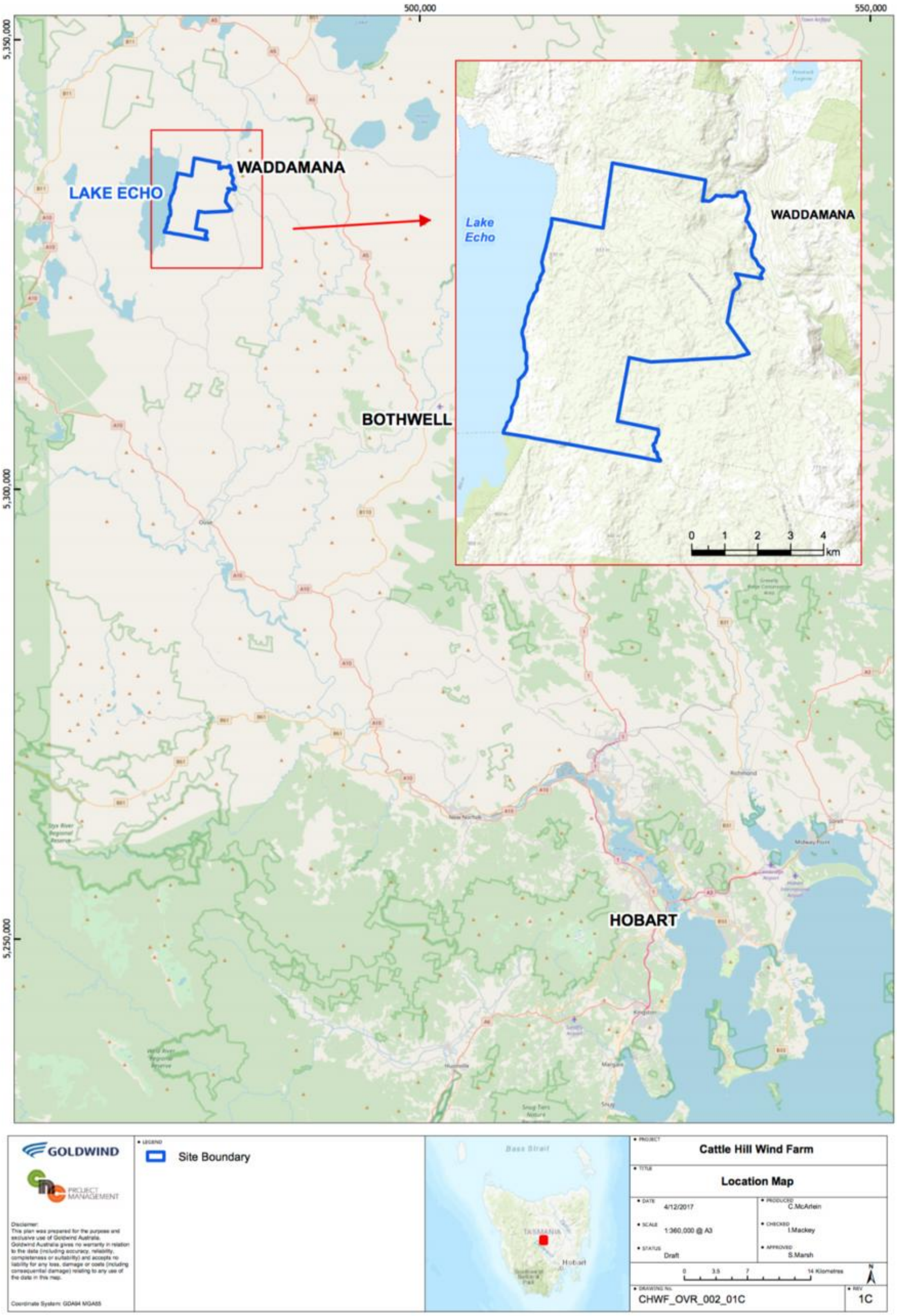

Figure 1: Location of Cattle Hill Wind Farm

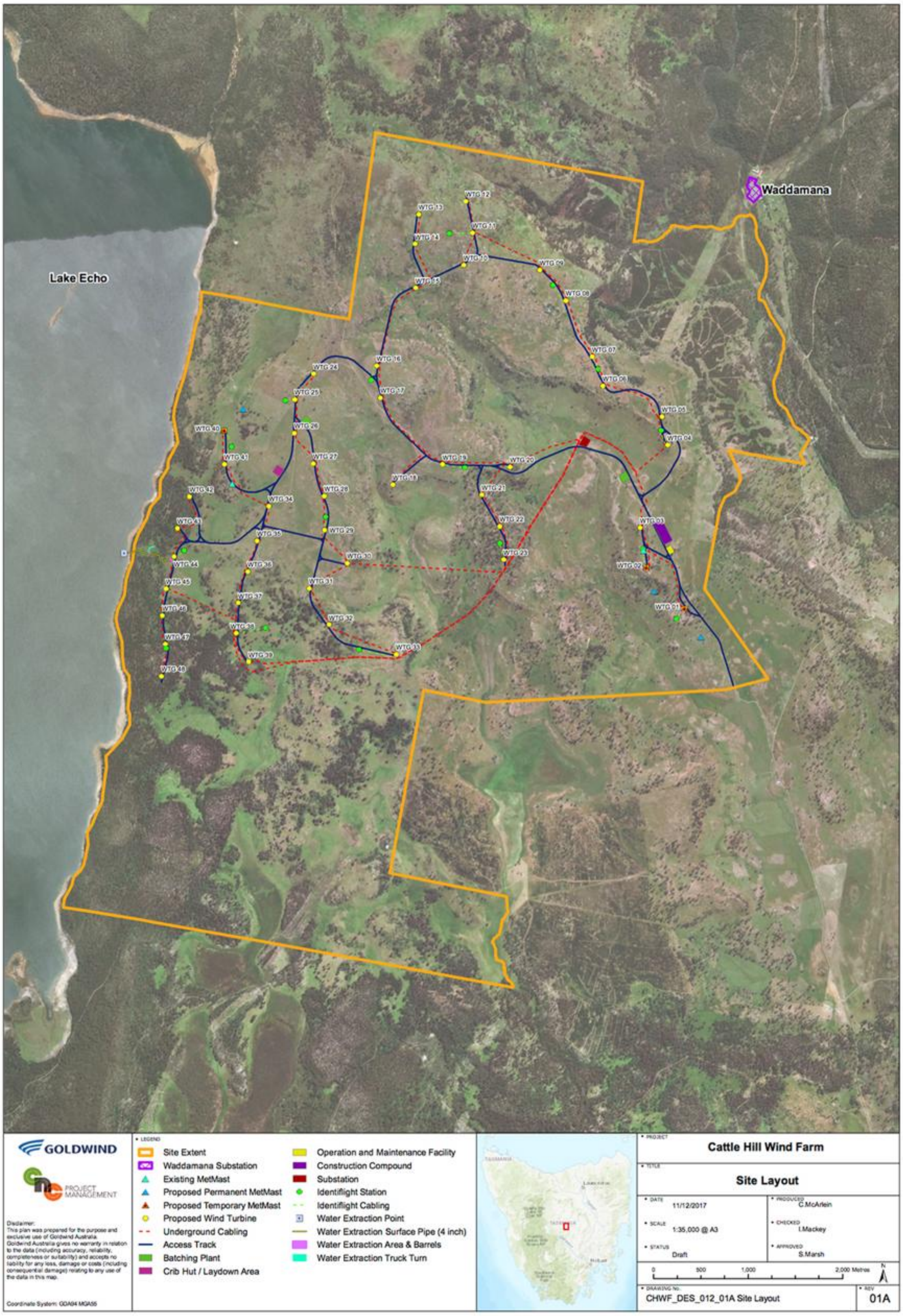

Figure 2: Cattle Hill Wind Farm infrastructure

1.2 The Proponent (Approval Holder)

The Proponent for the Cattle Hill Wind Farm is:

Wild Cattle Hill Pty Ltd

ACN 610 777 369

Suite 2, Level 23,

201 Elizabeth Street,

Sydney NSW 2000

1.3 The Person Taking the Action

The Person taking the Action is Wild Cattle Hill Pty Ltd.

1.4 Relevant Approval Condition

The Collision Avoidance and Detection Plan (CADP) has been developed to satisfy the requirements of Condition 6A of the Commonwealth Consolidated Notice for EPBC Act Approval 2009/4974. Condition 6 states:

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.

6B. Not commission until the CADP has been approved by the Minister. The Minister will not unreasonably withhold or delay approval of the CADP.

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.

1.5 Guidelines for the CADP

The Guidelines for the Collision Avoidance and Detection Plan (CADP) were approved on the 27th June 2017 and require the following:

- *Introduction, containing the following:*
    - *Brief description of the project and its location.*
    - *The approval holder.*
    - *A table setting out the relevant condition(s) and where these are addressed.*
- *Objective of the CADP, specifically the potential impacts it aims to manage.*
- *Management actions to achieve the stated objective must include:*

- *A report detailing the relevant technologies and practices available at the time of writing to achieve the objective of the CADP, including a comparison of the advantages and disadvantages of each technology or practice.*
- *A description of the technology/ies and practices selected to be trialled and the reasons for their selection.*
- *Details of the trials of the selected technology/practices, including details of the:*
  - *Objectives of trials.*
  - *Methodology of the trials that will be undertaken to evaluate the effectiveness of the selected technology/practice.*
  - *Provision of a report of the trials. This will include a discussion of results and conclusions as to the effectiveness and practicality of the technology and/or practice trialled.*
  - *Conclusions as to whether the trials will effectively achieve the objective or if another method will need to be identified and trialled.*
- *Ongoing management strategy to achieve the objectives of the CADP. A description of the future actions to be implemented based on the outcome of the trials and any new technology/practices available at the time of writing.*
- *In relation to any carcass monitoring studies, to undertake and report on scavenger trials conducted at the site, and how these will inform the survey strategy to detect WTE (Tasmanian wedge-tailed eagle) collisions.*

- *Performance indicators and proposed corrective actions. The CADP will detail the time frames as to when each of the management actions will be submitted to the Minister or his/her delegate.*
- *Reporting. A commitment to provide all results of the management actions in the annual environment reports provided under condition 27, which will also be made publicly available.*

2. Relevant Conditions and Environmental Management Plans

The Collison Avoidance and Detection Plan either overlaps or is relevant to the following:

- State EPN 9715/1 Condition FF6, Post-Commissioning Eagle Utilisation Monitoring Plan
- State EPN 9715/1 Condition FF9, Report on Strategies for Monitoring Bird and Bat Mortalities and Injuries
- State EPN 9715/1 Condition FF10, Bird and Bat Mortality Monitoring Plan
- State EPN 9715/1 Condition FF16, Turbine Shutdown Management Plan

3. Objectives of the Collision Avoidance and Detection Plan

The objectives of the Collison Avoidance and Detection Plan are 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.

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.

4. Management Actions

As indicated above, there are three actions required under the CADP (monitoring WTE movements, documenting WTE collisions and a mitigation strategy to try and prevent WTE collisions with wind turbines). In summary, these three actions require the following:

1. Monitoring WTE movements at the wind farm. The objective of this aspect of the program is not described, but it has been assumed it relates to obtaining information on how WTEs interact with the wind turbines. This type of study requires either observers documenting eagle movements, tracking eagles through the attachment of devices, or using an automated system that can detect, identify and track eagles. Therefore, a reasonable coverage of the wind farm, and the ability to identify WTE and track them is required.
2. Detecting and documenting WTE collisions. This can potentially be achieved by searching the fall zone underneath turbines for evidence of a WTE collision (post-collision monitoring), attaching specific devices to eagles, or the installation of an automated system which uses either sensors, radar or imaging to detect collisions. The focus of the monitoring is on the turbines and requires the ability to identify WTE.
3. Mitigation strategy. There are only two potential options to try and mitigate eagle collisions, a deterrence system (that alerts an eagle to a wind turbine when it is close, with the intention of persuading it to move further from the turbine) or a shutdown strategy (where turbines are shutdown temporarily when there is a potential collision risk). In order for these systems to work they require monitoring of the site, the ability to identify WTE and the ability to instigate an action.

Some of these requirements are not necessarily compatible with each other and it is possible they all may not be achieved with the one system.

4.1 Review of Relevant Technologies and Practices

The report assessing the technologies/strategies to achieve the three objectives (document eagle movements, eagle collisions and collision mitigation strategies) that are currently available can be found in Appendix 1. It concluded that there is currently no one off-the-shelf system that can demonstrably achieve the three objectives. The various strategies have their pros and cons, and a number of systems are still in the developmental stage or have not been sufficiently trialled.

The report found that of the approaches available, an imaging system using diurnal cameras appears to have the most potential to achieve the objectives of the CADP. This is because cameras have the capacity to identify WTEs, to track their movements and, some camera systems can communicate with the SCADA system of the turbines to initiate an action.

There are currently two systems that appear most able to achieve this, DTBird and IdentiFlight. While both systems have undergone some trials by the manufacturers, they are in the process of being independently trialled by the US Department of Energy. These trials are due to be completed in 2020 (P. Johnson NWCC pers. comm.). The attached report (Appendix 1) determined that IdentiFlight is the most suitable technology to install and trial.

4.2 Trials of the Selected Technology

A full IdentiFlight system will be installed during the construction phase of the wind farm. Trials will be conducted once the system is fully installed and will run for 18 months. The system will be tested for its technical and monitoring reliability and validated with other monitoring.

4.2.1 Aspects to be tested during the trials

The trials will determine:

- The technical reliability of the system. To determine if any modifications are required in relation to powering the system, storing data, or communicating with turbines;
- Its monitoring reliability. That is, how reliably can it:
    - detect eagles;
    - differentiate between WTE and WBSE;
    - the distance it can accurately survey (detectability range, which may be determined using tennis balls, kites or similar);
    - how well it can track eagles;
    - what errors are involved in its detections;
    - its effectiveness in instigating shutdowns of turbines; and
    - the size of buffers required to initiate a turbine shutdown before an eagle reaches the turbine.
- Validation trials, to:
    - Compare IdentiFlight's WTE collision detection capabilities with that detected by post-collision monitoring (as part of the State Bird and Bat Mortality Monitoring Plan, FF10); and
    - Compare the movements of WTE across the site from data collected by IdentiFlight and that obtained from human observers (as part of the State Post Commissioning Eagle Utilisation Monitoring Plan, FF6).

As a full system will be installed and trials will be run for the required 18 months, this will allow testing of its capabilities across the site under different weather conditions and different times of year.

4.2.2 Reliability and Effectiveness of IdentiFlight - Key Desired Outcomes

The following approach will be used to determine the effectiveness of IdentiFlight in achieving the objectives of the CADP:

- Technical trials.

Outcome	*Indicator*
Great result	System functions as required
Acceptable result	Modifications are required, but the issues are resolvable
Unacceptable result	Cannot resolve some issues

- Monitoring reliability.

Outcome	*Indicator*
Great result	WTE can be identified reliably, they can be identified and tracked across the wind farm site, and a shutdown can be reliably instigated before an eagle reaches a turbine, but at a distance that does not trigger unnecessary shutdowns on other turbines.
Acceptable result	Eagles can be identified from other birds, collisions can be detected and shutdowns can be reliably instigated before an eagle reaches a turbine, but at a distance that does not trigger unnecessary shutdowns on other turbines.
Unacceptable result	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, or shutdowns cannot be managed in a manner that allows eagles to be protected and the wind farm to operate.

- Validation trials

Outcome	*Indicator*
Great result	WTE collisions and WTE movements across the site are detected at the same or better level than post-collision and eagle utilisation monitoring.
Acceptable result	Eagle collisions can be detected and that data on the movement of WTE near turbines is obtained at a level comparable with post-collision and eagle utilisation monitoring.
Unacceptable result	Eagle collisions and eagle movement data obtained by IdentiFlight are less reliable than that collected by post-collision monitoring and using human observers to track eagles.

4.2.3 Reporting

A report evaluating the effectiveness and practicality of the technology will be completed within three months of the completion of the trials and submitted to the Minister or his/her delegate.

4.3 Strategy to Monitor Eagle Collision Risk

Within three months of the final report being submitted to the Minister or his/her delegate, a revised CADP will be submitted to the Minister or his/her delegate, detailing the ongoing management strategy to achieve the objectives of the CADP. This will include whether the trials demonstrated that the objectives could be met by IdentiFlight or whether an alternate technology or approach will be identified and trialled to achieve the objectives of the CADP, namely:

- How best to monitor WTE collisions;
- If further information is required on WTE movements at the site, a monitoring strategy best suited to obtain these data; and
- A mitigation strategy to minimise WTE collisions, if required.

4.4 Scavenger Trials

Scavenger trials were undertaken at the Cattle Hill Wind Farm in Spring/Summer of 2017/18 and late Summer/Autumn 2018 (consistent with the requirements of the State Bird and Bat Mortality Monitoring Plan, FF10).

The objective of the trials was to determine how long carcasses survive (can be detected) at the Cattle Hill Wind Farm site. The results from the trials were used to inform the search frequency for WTE collisions and to assist with the estimation of undetected mortalities (consistent with the requirements of the State Bird and Bat Mortality Monitoring Plan, FF10).

The methodology was:

Two trials were conducted, one in late Spring/early Summer (commencing mid-November 2017) and one in late Summer/early Autumn (commencing mid-February 2018). During each trial, 10 replicates of a large bird surrogate (a brown chicken) and 10 replicates of a small to medium sized bird (a young brown chicken) were used. Each of the carcasses was weighed prior to the trial to allow categorisation to a weight class. Each trial was conducted for 30 days. The carcasses sampled the three dominant vegetation types on site (woodland and forest, grassland and heathland and agricultural land and regenerating cleared land).

Scavenger searches were conducted in the following manner:

- Days 1 to 3 - two searches per day (the searches for the detectability trials will form part of the scavenger trials);
- Days 4 to 7 – one search per day;
- Days 7 to 30 – twice weekly.

During each scavenger survey, the observer visited the GPS location of each carcass and noted whether any remains are present and whether there is evidence of scavenging (the area 50m around the location was regarded as still present, but if the carcass was moved further than 50m it was regarded as lost). The following information was recorded at each site:

- Date and time of the survey;
- GPS location;
- Whether the carcass was still present (if not, is it in the nearby area. What distance was it moved);
- Whether there was evidence of scavenging.

A detectability trial was also conducted in February 2018. During this trial an observer placed 5 carcasses at locations sampling the three habitats and noted their position with a GPS. A different observer to the one that placed the carcasses conducted the surveys. The observer was required to search the fall area using the standard search strategy. Once the detectability trial was completed, any carcasses not found were double checked to ensure that they had not been scavenged. If the carcass could not be relocated, it was noted in the dataset and not used to calculate searcher efficiency (we cannot confirm if it was missed or scavenged).

A report will be submitted to the Minister or his/her delegate 30 days after the completion of the trials and analysis describing the results.

4.4.1 Analysis of the scavenger and detectability trial data

The results of the scavenger and detectability trials were reviewed and the results applied to the post-collision monitoring strategy in the following way:

- The monitoring strategy is based on the requirement to have an unbiased (and as confident as possible) estimate of the overall bird mortality (there will always be uncertainty around how many specific birds or bats have collided, although in the case of WTEs this is addressed separately with the additional surveys from drive-bys and IdentiFlight monitoring). We want to ensure that the overall mortality estimate is as reliable as it can be, so that we can compare to across the wind farm, other sites and year-on-year. Note that there is always a level of uncertainty around the estimate (even if you visited every turbine every day, because carcasses can still be missed) - the goal is to get the best result possible with the best-practice tools.
- Using mortality estimation software (owned by Symbolix) the proposed survey scenario will be simulated. The model takes the detected carcass count (and survey design and scavenger and search efficiency (detectability) rate) and estimates total mortality. This would be run for a range of possible detected carcass counts (e.g. five carcasses and 15 carcasses in a year).
- The scenarios for one or two other proposed survey design changes (e.g. more frequent surveys or less/more turbines each month) will be run;

The bias and precision of the estimator for these different scenarios will be determined and an evaluation of the best configuration and the resources required to increase the precision by some amount will be made.

5. Reporting

Reports describing the onsite trials of IdentiFlight and scavenger/detectability trials will be submitted to the Minister or his/her delegate 30 days after their completion. All results will also be provided in an Annual Environment report to the Minister or his/her delegate, which will be made publicly available.

6. Performance Indicators

Table 1 summarises the requirements of Condition 6A and how these are addressed in the Plan.

Table 1. Summary of conditions and guidelines that are covered in the CADP

Condition/guidelines	*Where it is addressed*	*Time frame*
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.	Management Actions and Appendix 1.	Within three months of the commencement of construction
Wind Farm not commissioned until the CADP has been approved by the Minister.	-	-
Submit to the Minister a detailed assessment of the effectiveness of the collision avoidance and detection system.	-	Three months after the completion of the field trials, which will run for 18 months after construction is completed.
CADP Guidelines: - Description of the project and its location, the approval holder. A table setting out the relevant condition(s).	Introduction	Guidelines approved 22 June 2017. Submitted with this plan
- Objective of the CADP	Objective	Submitted with this plan
- A report detailing the relevant technologies and practices available	Appendix 1	Submitted with this plan
- A description of the technology/ies and practices to be trialled	Management Actions – review of technologies and practices Appendix 1	Submitted with this plan
- Trials	Management Actions – trials of the selected technology	To commence after the system is fully installed
- Ongoing management strategy	Management Actions – strategy to monitor eagle collision risk	After full commissioning and the report evaluating the onsite trials is submitted.
- Scavenger trials	Management Actions – scavenger trials	Spring/Summer 2017/18 and late Summer/Autumn 2018

7. Corrective Actions and Triggers

In light of the objectives of this plan (detailed in Section 3 above), the following corrective actions and triggers will be used.

7.1 Trials of IdentiFlight

If an "unacceptable result" is attained in the three trials of IdentiFlight (detailed in Section 4.2), an alternate technology or action will be identified and trialled in the manner described in Section 4.3.

7.2 WTE mortalities

If WTE mortalities exceed that described in the State EPN 9715/1 Attachment 3, the actions detailed in the State Turbine Shutdown Management Plan (EPN Condition FF16) relating to WTE will be implemented. In summary, this comprises:

1. An investigation to determine if there are any mitigating circumstances contributing to the mortalities.
2. A Turbine Shutdown Strategy will be developed, designed in relation to data obtained from point 1. The strategy (which will be submitted to the Director of the EPA within 90 days of being notified), will detail:
    - A review of information collected (including the age and sex of the bird, possible genetic analysis to determine the source of the eagle, any relevant weather conditions, time of year and time of day);
    - Statistical analysis of the collision data (if possible) to ascertain if there are any spatial (specific turbines) or temporal (time of year or time of day) patterns in the collisions;
    - Any data collected such as that from observations or IdentiFlight;
    - A review of the latest strategies to reduce eagle collision risk;
    - Any other relevant information;
    - Details of trials of any potentially suitable strategies to reduce the collision rate to be implemented; and
3. Any required offsets undertaken.

7.3 Scavenger and detectability trials

If the data obtained in the scavenger and detectability trials are unable to satisfactorily achieve the objective of the trials (see Section 4.4), an additional trial will be conducted as soon as practicable.

Appendix 1

Report on the technologies and practices available to monitor eagle movements, collisions with wind turbines and to instigate actions to minimise collision risk.

Joule Logic

Renewable Energy and Environment Specialists

Report on strategies to monitor Wedge-tailed Eagle movements, collisions with wind turbines and collision mitigation at the Cattle Hill Wind Farm

A report to satisfy Condition 6A of the EPBC 2009/4839 Approval for the Cattle Hill Wind Farm

Date	Revision	Prepared	Reviewed	Approved	Regulator reviews
27/09/2017	2	Cindy Hull Joule Logic	Sue Marsh Joule Logic	Jeff Bembrick Goldwind Australia	

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Definitions

CADP	Collision Avoidance and Detection Plan, Condition 6A of the Commonwealth EPBC 2009/4839 Approval
CAPEX	Capital Expenditure
DoEE	Commonwealth Department of the Environment and Energy
DPEMP	Development Proposal and Environmental Management Plan
EMP	Environmental Management Plan
EPBC	Commonwealth *Environment Protection and Biodiversity Conservation Act 1995*
Featherspot	A collection of ten feathers and/or three flight feathers (primaries, secondaries, tertiaries or retrices)
OPEX	Operational Expenditure
RSA	Rotor Swept Area of a wind turbine (the area the blades sweep through)
SCADA	Supervisory Control and Data Acquisition
TSP	Tasmanian *Threatened Species Protection Act 1995*
WBSE	White-bellied Sea-eagle *Haliaeetus leucogaster*
WTE	Tasmanian Wedge-tailed Eagle *Aquila audax fleayi*

1. Introduction

This report has been developed to satisfy the requirements of part of Condition 6A of the EPBC 2009/4839 Approval for the Cattle Hill Wind Farm, namely an evaluation of the suitability of different technologies to achieve the objective of the CADP (Collision Avoidance and Detection Plan).

The purpose of this report is to assess the options for monitoring WTE (Tasmanian Wedge-tailed Eagle, *Aquila audax*) movements, WTE collisions and to develop a strategy to minimise WTE collision risk (with wind turbines) at the Cattle Hill Wind Farm. This report evaluates the various options and recommends a system to trial at the Cattle Hill Wind Farm.

2. Monitoring of wildlife at wind farms

2.1 Objectives of monitoring

Wildlife monitoring at wind farms can have various objectives, but generally it aims to obtain evidence for direct (mortalities due to collisions with wind turbines) or indirect (changes to the behaviour of birds on site due to the operation of wind turbines) impacts on birds and bats (per Hull et al. 2013). The issues discussed in this report relate to direct impacts to WTE at the Cattle Hill Wind Farm, how to better understand them and attempt to mitigate them.

2.2 General comments about monitoring and mitigation of direct impacts

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 and mitigate collisions of birds and bats with wind turbines. While there is a reasonable understanding of how to monitor collisions using ground searches, there is no one off-the-shelf automated system currently available that is suitable for monitoring at all wind farms and is demonstrably effective at mitigating collisions. 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).

According to the CADP, the technology to be trialled at the Cattle Hill Wind Farm needs to achieve three things:

1. Document WTE movements.
2. Document WTE collisions.
3. Initiate an intervention to minimise WTE collisions.

The evaluation of any system needs to consider whether it is practical and feasible to implement. For example, consideration needs to be given to determining if it can be used without impacting on the operation of the wind farm or creating issues around safety, etc. Finally, it should be cost-effective, where the cost of the monitoring is commensurate with the level of impact and the conservation value derived from it (PNWWRM XI. 2017, see discussion on page 11).

Given that the State and Commonwealth permit conditions for the Cattle Hill Wind Farm require a range of monitoring and management actions, the evaluation conducted for this report is relevant to other Environmental Management Plans (EMPs). For example, the monitoring of bird and bat collisions needs to be undertaken for the State Bird and Bat Mortality Monitoring Plan (Condition FF10 of EPN No. 9715/1) and of post-commissioning eagle utilisation monitoring needs to be undertaken for FF6 (State Eagle Utilisation Plan). Therefore, the assessment considers strategies that are compatible with these requirements.

3. Methodology used in this assessment

The approach used in this report was to:

- Conduct a literature review, including scientific papers, reports and conferences proceedings, to determine the latest monitoring approaches used in Australia and overseas;
- Discuss with current researchers and operators, or their consultants, the approaches they used and how effective they found them;
- Attendance at the Wind-Wildlife Research Meeting XI in Broomfield, CO, USA, November 30 - December 2, 2016 and visit to Top of the World Wind Farm operated by Duke Energy Wyoming to talk to staff and see IdentiFlight in action (attended by the former project proponent and the current project proponent); and
- Discuss with companies that offer remote sensing systems the capabilities of their system and its suitability for the monitoring at Cattle Hill.

Given that there are three actions required of the technology/approach, these will be reviewed under separate headings WTE movements, WTE collisions and WTE collision mitigation.

When evaluating automated systems, the following key questions were considered:

- Has the system or approach previously been used at wind farms?;
- Has it been tested or validated to determine its effectiveness?;
- What are its advantages and disadvantages?;
- Is it likely to be suitable for the Cattle Hill Wind Farm site?;
- Can it achieve the objectives of the monitoring required the CADP?

3.1 Capability assessment

It is recommended that a capability assessment be conducted to determine the following about the supplier of the technology:

- The financial stability of the company and product (therefore is the company likely to still exist in a few years, to ensure that parts or expertise would be available in the future);
- The details of the technology, in particular whether the system is:
    - a prototype or more mature technology;
    - how well it has performed at wind farms and achieved the objectives of the monitoring;
    - how well it integrates with the operating system of various wind turbines, or whether it is specific to one turbine type;
    - how well it manages software updates and whether experts are required to implement these;
    - whether it void warranties on infrastructure, such as turbines.
- Commercial issues – what sort of warranties etc are included;
- What is the CAPEX (Capital Expenditure) and OPEX (Operational Expenditure) of the system? Therefore, how cost-effective it is.

4. Monitoring WTE movements

Documenting the movement of WTEs at a site can be achieved by:

- Field observers describing and plotting the movements of eagles;
- Telemetry - attaching devices to eagles to track their movements; or
- Remote monitoring using radars or cameras.

4.1 Monitoring using observers

Observers are placed at vantage points and note the presence of eagles and then plot their movements on maps of the site.

Examples used at wind farms:

- Cattle Hill Wind Farm during the pre-approval stage to obtain data on eagle use of the site for the DPEMP;
- The Bluff Point, Studland Bay and Musselroe Wind Farms in Tasmania (see the Annual Reports and Public Environment Reports, http://www.woolnorthwind.com.au/health-safety, Hull and Muir 2013).

Advantages:

- Easy to implement;
- Can identify species;
- Can track individuals during a single flight;
- Can sometimes identify age and sex of the eagle.

Disadvantages:

- Observer fatigue occurs after about one hour of monitoring (Woolnorth Wind Farm Holding 2013), which is likely to impact on the quality of data;
- Detection range is limited to about 1500 m, but observers vary in their detection ranges (Woolnorth Wind Farm Holding 2013);
- Inter-observer variability occurs (Woolnorth Wind Farm Holding 2013);
- Less precise (in both distance and height estimates) compared to other forms of monitoring;
- Cannot identify individual eagles (unless they are marked with wing tags or similar).

Suitability of using observers for Cattle Hill

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes
Has it been tested to determine its suitability?	Yes
Could it be used to monitor the movements of WTE?	Yes, although it has limitations

While there are limitations with using observers to document the movement of eagles, there is a requirement in FF6 of EPN No. 9715/1 to document eagle utilisation post-commissioning. Given that this is a before/after study to document how eagle behaviour changes after the wind farm is operating, it will be necessary to use the same methods as the baseline studies, which is observers.

4.2 Telemetry

Wildlife radio-tracking is used to document the movement of animals and is achieved by monitoring the radio signals sent from a device attached to the animal. Telemetry is the process of transmitting the information through the atmosphere. There are a number of systems used to monitor animal movements:

- VHF (Very High Frequency) radio-tracking;
- GPS (Global Positioning System) tracking;
- Satellite tracking using the Argos system; and
- A combination of GPS and the Argos satellites.

(source: https://www.fs.fed.us/t-d/programs/im/satellite_gps_telemetry/wildlifetrackingtelementry.htm)

4.2.1 VHF tracking telemetry

VHF telemetry began in the mid-1960s, and typically requires the VHF transmissions to be detected via a hand-held antenna. Location of the device is calculated by triangulating the signals received at three (or more) different locations.

VHF transmitters attached to eagles could potentially be coupled with receivers on turbines to detect an eagle close to a wind turbine, which could potentially activate an action (shutdown or deterrence). However, our investigations did not identify an off-the-shelf system currently available.

4.2.2 GPS tracking telemetry

GPS technology involves a GPS receiver (the device attached to the animal) that detects signals from a number of the 24-plus GPS satellites that orbit the earth. A device that detects signals from three satellites can locate itself in two dimensions (latitude and longitude), while signals from four satellites allow the receiver to locate itself in three dimensions (source: https://www.fs.fed.us/t-d/programs/im/satellite_gps_telemetry/wildlifetrackingtelementry.htm). The GPS device stores the location and time data until downloaded either by retrieving the device (hence the animal needs to be captured and the device removed) or remotely (by downloading the data to a portable receiver, or remotely relaying the data to the Argos Satellite system. The latter method is referred to as GPS/ satellite telemetry, see Tomkiewicz et al. 2010 for more details).

4.2.3 Satellite tracking telemetry

Satellite tracking has been used since the mid-1980s. Most current satellite telemetry uses the two polar-orbiting Argos satellites to receive ultra-high frequency signals from Platform Transmitter Terminals (PTTs). The Argos satellite system is operated under an agreement with the French Government (French Space Agency) exclusively for the collection and distribution of environmental and natural resource data. Most (about 80 percent) of the transmitters are on drifting or moored buoys, fixed land locations, or on ships and transmit meteorological and/or oceanographic data, but once devices were miniaturised in the mid-1990s, they were used to track movements of animals through the attachment of small PTTs. Since the two Argos satellites have a mostly polar orbit, they operate best at locations greater than 60 degrees latitude. In these regions, the satellites receive signals from PTTs during a 10–12 minute window as it passes over sites about 28 times per day. A network of ground and atmospheric communication links transfer the satellite data to processing centres in Toulouse, France, which distribute results to users worldwide. The location of an animal-borne PTT is determined by calculations that rely on the Doppler Effect; that is, the perceived change in frequency that results from the movement of a transmitter and receiver (source: https://www.fs.fed.us/t-d/programs/im/satellite_gps_telemetry/wildlifetrackingtelementry.htm).

The locations of the animal-borne PTTs have an accuracy between 100 m to 4 km, with most readings in the middle of this range, making this technology more suitable for far-ranging species (source: https://www.fs.fed.us/t-d/programs/im/satellite_gps_telemetry/wildlifetrackingtelementry.htm).

4.2.4 GPS/Satellite telemetry

GPS/satellite telemetry combines the technology of a GPS receiver and satellite transmitter in one device to document the movement of animals with a limited range. The device stores its GPS location data and then transmits it every few days to the Argos satellite, where it distributes the data worldwide. This technology allows a user to collect fine-scale movement data of animals with limited ranges and have this data transmitted to any location (source: https://www.fs.fed.us/t-d/programs/im/satellite_gps_telemetry/wildlifetrackingtelementry.htm).

Of the devices discussed above, only VHF or GPS/Satellite telemetry are capable of obtaining the fine-scale locational data required to describe eagle use of the wind farm site. There are a number of issues to consider in relation to attaching devices to eagles, these are:

- The attachment of devices to WTE is reliant on catching the target eagles (resident on site or transients, i.e. those which might be at risk of collision), which is not guaranteed;
- Catching and attaching devices to eagles has some risks. Eagles can be injured from the trapping process and there are potential energetic costs associated with carrying devices (there are many references, but see for example Peniche et al. 2011, Dixon et al. 2016);
- Devices are powered by batteries or solar panels. Batteries have a finite life and will need to be changed;
- Devices are either glued to feathers (therefore are moulted off once a year), leg-mounted (eagles may be able to remove or damage these mounts) or attached to the eagles' back with a harness;
- Size of the battery is determined by the power needs of the device e.g. whether data need to be transmitted to satellites. Heavier devices will require a harness attachment on the eagle, which creates a risk of injury (such as entanglement or wear of feathers) or energetic cost. Deployments should therefore be short-term. Devices can have inbuilt release mechanisms so they fall from the bird after a prescribed period, but no matter the strategy, the attachment of devices is not a long-term solution to monitoring or mitigating collisions at the Cattle Hill Wind Farm.

Note that Animal Ethics Approval (and Scientific Permits) would be required to attach devices to eagles, and some Animal Ethics Committees may be reluctant to provide approval. For example, the Animal Research Review Panel of NSW recommends alternate methods than telemetry be used (http://www.animalethics.org.au/policies-and-guidelines/wildlife-research/radio-tracking) stating the following:

> *Radio tracking transmitters should only be used by individuals with extensive expertise and in exceptional circumstances. The relative high cost precludes their use except when other*

methods are totally unsuitable for rare, endangered or vulnerable species. Full justification and a detailed description of the methods, equipment, monitoring and impact on the animals will be required by the AEC.

Use alternative methods wherever possible.

The methods used, including weight and attachment should be one that has been previously used on the same or similar species and has been proved to be satisfactory.

Total package weight (collar, transmitter, battery, aerial and bonding material) should ideally be less than 5% of the animal's bodyweight and no greater than 10%.

Therefore, careful consideration about the attachment of devices to WTE should be made, balancing the value of the data being collected with the risks to individual eagles.

Examples of use at a wind farm:

- Red kites were tracked with radio tags and satellite transmitters in Germany (Hötker et al. 2015);
- Wing tags and GPS satellites were used to document movements of vultures in northern Spain (Camiña 2011);
- GPS satellite transmitters were used on White-tailed Eagles in Norway (May et al. 2011);
- GPS devices were used on golden eagles in Northern Sweden (Dettki et al. 2011);
- VHF and GPS transmitters were used on raptors in Germany (Grünkorn et al. 2011);
- GPS devices were used to track Golden eagles at proposed wind farm sites and reference areas in Northern Sweden, to better understand their movements and ranging behaviour (Hipkiss et al. 2011);
- GPS satellite telemetry was used on white-tailed sea-eagles at Smøla Wind Farm, Norway (Nygård et al. 2011);
- GPS telemetry was used to monitor the behaviour of black-backed gulls at two offshore wind farms in the UK (Thaxter et al. 2015).

Advantages:

- Provided an appropriate device is selected, it would be possible to obtain detailed information about use of the site (including height), with a higher reliability than data collected by observers. This might provide some insight into the factors involved in collision risk;
- Data on activity budgets could be obtained (to better understand their use of the site throughout a 24 hour period);
- Could identify individuals;
- Can detect and find eagles that have died, although not necessarily immediately (this is dependent on the device used);
- Could use mortality switches in some devices and receive an alert when the device stops moving, or for devices without this capability, to locate an individual that has not moved for some time. This could indicate a collision event;
- Date, time and location of collision could potentially be known;
- Could potentially be linked to an action (shutdown of a turbine or deterrence) with VHF.

Disadvantages:

- Reliant on catching the target individuals (it can be hard to catch eagles, and may not be possible to catch some individuals);
- There are risks involved in trapping eagles;
- Attaching devices poses a risk to the eagle, including entanglement with vegetation, additional weight for the bird to carry, damage to feathers, irritant to the bird etc;
- Need specialist staff;
- Animal Ethics approval and scientific permits will be required;
- If satellite tracking is involved, satellite time will be required;
- GPS/satellite devices are probably most suitable for documenting fine-scale movements of WTE on site (satellite trackers would not be suitable), but the data are only transmitted every few days which would not allow real time collision detection or strategies to detect and deter or shutdown turbines;
- There are errors in the quality of locations from some devices. Need to determine that these errors are not too large to achieve the objectives of the monitoring;
- Often there isn't 100 percent reliability of devices;
- Devices that transmit data require more power and therefore larger batteries or solar systems. This makes the devices heavier for the bird to carry;
- Long-term deployments are not possible due to potential impacts to the eagle and/or any attachments to feathers (they will be lost after the annual moult). Therefore, this is not a long-term strategy.

Suitability of using telemetry for Cattle Hill

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes
Has it been tested to determine its suitability?	Yes
Could it be used to monitor the movements of WTE?	Yes and potential links to shutdowns (depending on the device)

Probably the most reliable means of describing eagle movements at the Cattle Hill Wind Farm is using a GPS/satellite device which can potentially document fine-scale movements with a higher precision than observers can provide. However, due to the issues with attaching devices, only short term deployments are recommended. There are also risks to the eagles from capture and attachment of devices and the target eagles may not be captured.

4.3 Remote monitoring

4.3.1 Radar

Radar (which is an acronym for RAdio Detection And Ranging, or Radio Direction and Ranging, Wikipedia) uses radio waves to obtain information on the range, angle and velocity of an object. It was designed in World War II to detect aircraft, ships, missiles and similar objects (Wikipedia). Given that radars were developed for a purpose other than wildlife monitoring, they have had to undergo modifications to be suitable for this task.

Radars can survey a large area (up to 10 km on low power and 200 km on high power, Collier et al. 2011), far beyond the capabilities of other systems, such as cameras. However, horizontal radars only detect targets parallel to the ground while vertical radars (tilted 90° to the ground) can scan cross-sections of the sky. Vertical radar is necessary to obtain height estimates of birds and bats (G. Kessels Kessel Ecology, New Zealand pers. comm.). However, vertical radars only scan small sections of the sky, as demonstrated in Figure 1 below, resulting in an incomplete coverage.

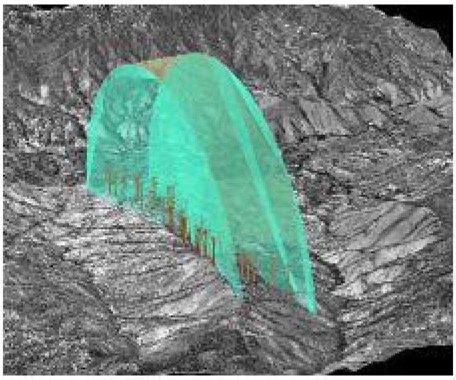

Figure 1. Demonstration of the area scanned by a vertical radar. Source: DeTect Inc (http://detect-inc.com/avian.html).

Radars can monitor at any time of day, as light level is irrelevant to their operation (as opposed to camera systems), but one of their key limitations is that they cannot identify species, because the data obtained are a pulse. Some manufacturers have developed algorithms which endeavour to estimate the taxa of a target (using variables such as size and wing beat), but these are currently imperfect and can only categorise the target as biological or not, or insect or bird. Some manufacturers are continuing to refine their systems to improve the identification of taxa.

Another limitation of radars is that they cannot quantify the number of individuals in a target when animals are close together. If, for example, a flock of birds is detected, the radar may be unable to determine if the target is one large bird, or a number of small birds (Collier et al. 2011).

Radars detect all objects in their range, and features such as the ground, sea, rain and vegetation will generate clutter which obscures any birds and bats present. A number of manufacturers have developed clutter maps to attempt to reduce this effect, but they are only partially successful (Collier et al. 2011).

The different radar systems vary in their power, format (scanning or fixed beam) and software (Collier et al. 2011). Some of the systems are very complex (e.g. DeTect) and all require expertise to interpret and analyse the data, particularly discriminating false echoes due to clutter (Collier et al. 2011, G. Kessels Kessel Ecology, New Zealand). G. Kessels (Kessel Ecology, New Zealand) found it necessary to have observers conduct surveys to compliment the radar data, and made the comment to the author that, “like all monitoring tools, radar won’t give you all the answers in isolation”.

Radars can potentially be linked with a detect and deter, or detect and shutdown system.

<u>Examples of systems used at wind farms:</u>

- DeTect MERLIN Avian Radar System combines solid-state Doppler radar customised to detect birds. It involves horizontal and vertical radars, and can be combined with MERLIN SCADA (Supervisory Control and Data Acquisition) software (along with weather and turbine data) to activate turbine shutdowns. These data can be accessed remotely providing a sufficient connection is available. A 'turbine centric' model (SCADA-R™), which detects flying birds close to the turbine in real-time, has also been developed to shutdown individual turbines in response to an approaching raptor (BirdLife International 2015). DeTect's MERLIN radar has over 100 systems operating around the world, at airports and wind farms (e.g. Brabant and Jacques 2009, Krijgsveld et al. 2011, Steinheim et al. 2011, Tomé et al 2011, BSH and BMU 2014);
- Robin 3D Flex Bird Radar comprises vertical and horizontal radars. Data, including flight speed, height, position and direction are logged. The radars can be viewed and controlled remotely. Frequency Modulation Continuous Wave (FMCW) radar can also be used for species recognition although this component is not yet automated. The system is capable of sending a deterrence to approaching birds or initiating a shutdown on turbines. The Robin Radar system includes a weather station for the collection of meteorological data used for assessing the flight speeds of targets, filtering of clutter and to aid any early-warning system. (BirdLife International 2015);
- Birdscan is a fixed beam radar and is being used at German offshore wind farms to measure "macro avoidance" (avoidance of an entire wind farm) based on the number of movements of birds inside and outside the wind farm (Coppack et al. 2011). They are also coupling it with infra-red cameras to monitor the RSA (Rotor Swept Area) and document the interaction of nocturnal species and the turbines;
- Swiss Birdradar is developing a vertical fixed-beam radar to quantify flying bird activity. The BirdScanMV1 calculates and monitors the rates of flying bird activity passing a specified area. Birds (and their approximate size) are separated from other objects such as weather, insects and ground clutter using wing beat patterns. The system can be used to shut down and restart turbines based on the recorded bird activity. However, it is primarily used for documenting general bird migration patterns at higher altitudes and less suited to monitoring and mitigation at wind farms (BirdLife International 2015).

STRIX Birdtrack® is specialist software developed to identify, track and log bird movements and altitudes in real-time. The software has been developed for use with horizontal and vertical radars. Birdtrack® currently requires an operator to be present, although remote access to data and settings is being developed. This system does not currently allow the automatic assessment of shutdown criteria or automatic turbine shutdown. It cannot identify species, although developers are working towards distinguishing species groups, such as gulls, large raptors and passerines (BirdLife International 2015).

<u>Advantages:</u>

- Can work at night or in low light conditions (although this is not necessarily relevant to documenting eagle movements);
- Horizontal radars can survey a large area (although Steinheim et al. 2011 found the detection of White-tailed Eagles *Haliaeetus albicilla*, was limited to 1700 m at the Smøla Wind Farm);
- Can be accessed remotely (providing there is a suitable connection);

- Images can be saved for validation or reference and can be used to improve algorithms;
- Could be programmed to alert an operator of a collision.
- Fully automated shutdown with some systems.

Disadvantages:

- "Get false alarms" triggered by clutter such as rain or fog (Vang et al. 2011);
- Limited in bad weather (BSH and BMU 2014);
- May need multiple systems to provide adequate coverage (get "shadows" caused by topography, vegetation etc);
- Vertical radar would be required, but it would only scan sections of the sky, limiting its value in documenting movements of eagles;
- Cannot identify species. While it might be able to differentiate "eagles" from insects and smaller birds at Cattle Hill, it is unlikely to ever be able to differentiate between the two species (WTE and WBSE, White-bellied Sea-eagle *Haliaeetus leucogaster*);
- High initial costs for systems and installation;
- Specialists often required to operate the system;
- Requires time for initial setup and fine-tuning of radar and settings (BirdLife International 2015).

Suitability of radar for Cattle Hill

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes, at multiple wind farms around the World (none yet at operational wind farms in Australia)
Has it been tested to determine its suitability?	Yes
Can it monitor the movements of WTE?	To some extent (although radars usually cannot track individuals) and possibly linked to a shutdown system. Clutter (ground, vegetation and rain) is likely to be an issue

While radar can scan a considerable distance in the horizontal plane, issues around clutter, vertical scanning, the inability to identify species, the number of individuals or track individuals makes it unsuitable for this purpose.

4.3.2 Imaging

Cameras (still and video) are designed to detect either visible or infrared light (infrared is either active which detects a shorter wavelength, or passive which detects longer wavelength, Collier et al. 2011). These systems have a key advantage over radars in that images are obtained from which species can be identified. However, cameras can only detect out to a limited range (cameras have a detection curve with high detection rates up to 100 m which then decline out to 400 m, where it becomes unreliable, Adams et al. 2017). Given the limited field of view of camera systems, it is often only possible to monitor the RSA of turbines, and very difficult to reconcile monitoring a large RSA (which often has a diameter of 100 m or more) while detecting and identifying small birds or bats. For this reason, it is usually necessary to have multiple camera systems to survey a wind farm site, thereby increasing the cost and complexity.

There are currently several systems in existence or under development. Some are based on infrared or thermal imaging cameras for nocturnal monitoring, but this limits their use for species recognition and diurnal monitoring.

Examples of systems used at wind farms:

- VARS (Visual Automatic Recording System, includes infrared). It was developed in the mid-2000s at the Institute of Applied Ecology (IfAÖ) in Germany. It uses motion detection infrared (active infrared) video cameras together with infrared lamps for detecting and recording flying birds and bats (Collier et al. 2011, May 2015). Cameras are mounted on the nacelle of turbines, have a limited field of view and the data require human interpretation (Collier et al. 2011). It is of limited use for detection during daytime and over great distances (BirdLife International 2015);
- MOBOTIX (Taniguchi et al. 2015). Webcam surveillance, comprising two cameras and a NAS server, was used to monitor a wind turbine in Japan with a high risk of strikes by white-tailed Sea eagles. It documented a strike, which provided insights into the reason for the collision;
- DTBird (LIQUEN, Spain, http://dtbird.com/) was developed in 2005. It uses video cameras (visible light) and image recognition software to identify and mitigate bird collisions with wind turbines. It detects flying birds in real-time and can carry out pre-programmed actions if birds are detected within a pre-defined risk-zone. DTBird® - Dissuasion aims to deter birds near turbines and DTBird® - Stop Control instigates shutdowns of turbines if the system determines a bird is at risk of colliding. It may be able to scan more than one turbine with the one system. It is currently installed in more than ten wind farms in at least six countries, including Spain, Italy, Poland, Greece, France and Norway (BirdLife International 2015). Trials have indicated that it cannot detect at night or during poor light (heavy fog or rain), and is currently best suited to raptors (Collier et al. 2011). It is useful for collecting information on avoidance behaviour but it requires observer interpretation (Collier et al. 2011). Ashwanden et al. (2015) found the system did not detect small birds well, but was adequate for large birds. They also found the system generated a number of false positives because it could not determine distance, meaning that a close insect had the same pixel size as a distant aircraft. Note that a new validation program funded by the USA Department of Energy commenced during 2017 (see Research on Eagle Impact Minimization Technologies Supported by the U.S. Department of Energy at https://www.nationalwind.org/research/webinars/);
- TADS (Thermal Animal Detection System) was developed at the National Environmental Research Institute (NERI) in Denmark during the early 2000s (Desholm 2003). This infrared imaging system was developed for assessing collisions and avoidance of birds in the direct vicinity of offshore wind turbines. Three cameras were mounted at the base of the turbine tower (to provide sufficient coverage of the RSA). Trials found the detection range for large birds was 120-170 m and 50 m for small birds, and that the majority of events recorded by the system were non-bird events (Collier et al. 2011). Interpretation of data by observers was required;
- A stereoscopic camera system was developed and trialled at Bluff Point and Studland Bay Wind Farms, but a number of issues could not be resolved (data storage, determining distance, and limited field of view, see Woolnorth Wind Farm Holding 2016a);
- IdentiFlight (Boulder Imaging, USA) has recently been trialled by the developers, but details of the trials had not been released at the time of writing. At the trial site eight fixed position wide-angle cameras were mounted on towers, which the company states can detect birds out to 1000 m. The cameras take five colour frames per second (P. Downie observation). The cameras

measure wingspan and profile shape to determine target species and can track an individual bird. The shape profile of target species is programmed into the system and when the target is identified within 400 m of turbines, a shutdown is triggered. While it has the potential to identify eagles, it is likely additional refinement would be needed to enable it to discriminate between WTE and WBSE. The system can generate false positives triggering shutdowns (Hiester et al. 2017). Note that a validation program funded by the USA Department of Energy commenced during 2017 (see Research on Eagle Impact Minimization Technologies Supported by the U.S. Department of Energy at https://www.nationalwind.org/research/webinars/;

- ATOM (Acoustic/Thermographic Offshore Monitoring System, Normandeau Associates, USA) comprises infrared video cameras in combination with microphones that record both audible and ultrasonic sound of bats (Collier et al. 2011). Cameras are mounted on turbines, with each camera recording half a rotor diameter. Ultrasound is detected up to 20 m from the microphones. It is of limited use for the detection of diurnal birds and cannot cover large distances (BirdLife International 2015). Insufficient trials have been conducted (it is too early in its development) and there is no software to provide alerts (Collier et al. 2011);
- BirdsVision (http://birdsvision.net/142826/Solutions.html). Very few details are available on their website, including the country they are located in, but it is purportedly a fully integrated system for the detection and deterrence of flying birds in the vicinity of wind turbines.

Advantages:

- Can be accessed remotely (providing there is a suitable connection);
- Images can be saved for validation or reference and can be used to inform algorithms and shutdown criteria (BirdLife International 2015);
- Could be programmed to alert an operator of a collision and trigger a response.

Disadvantages:

- Limited field of view, hence multiple systems would be required to scan a large area;
- Limited to periods of daylight and good visibility (poor weather conditions such as rain or fog could reduce detections);
- Possibility that substantial costs required for maintenance and servicing such as for cleaning cameras in harsh environments (BirdLife International 2015);
- Unless there is a mechanism for the system to only store relevant data (collision events), large volumes of data could be obtained which require storage and checking.

Suitability of imaging systems for Cattle Hill

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes to some extent. A number of systems are in development, but some (e.g. DT Bird) have been used at a number of sites
Has it been tested to determine its suitability?	Some trials, some results available
Can it be used to monitor WTE movements?	Yes potentially and potential links to shutdowns

Potentially suitable, but it has some limitations (field of view is limited, reduced visibility in poor weather). Many are still in the developmental stage. The results of trials currently underway in the

USA are important to review, which are due to be completed in 2020 (P. Johnson, NWCC pers. comm.).

4.4 Conclusion - monitoring WTE movements

The strategy that would potentially yield the best data on movements of WTE at the Cattle Hill Wind Farm is GPS/Satellite trackers, but these could only be deployed short-term and require that the target eagles be captured. There are risks associated with catching and attaching devices to WTE. Observers can obtain data on movements, albeit with a lower precision than trackers. Radar would not be suitable for the task, but cameras may be suitable if there is sufficient coverage of relevant parts of the site. Cameras have the advantage of having no impact to the eagles.

5. Monitoring WTE collisions

Documenting WTE collisions can be undertaken either by conducting surveys in the fall zone around turbines for carcasses (hence, post-collision), or monitoring collision events "live" using sensors (accelerometers or fibre optic, or acoustic), radar or imaging (cameras, still or video) (Collier et al. 2011). Much of the research into automated systems has been driven by offshore wind farms because it is impossible to conduct post-collision monitoring (Collier et al. 2011). Monitoring of particular species can also potentially be undertaken by attaching transmitters to the target animals to document movements, with a lack of movement possibly indicating a mortality or using a device that has a mortality switch. Each of these strategies are discussed in detail below.

5.1 Post-collision monitoring

Post collision monitoring can be undertaken using humans or dogs.

5.1.1 Human observers

Post-collision monitoring by human observers relies on seeing the bird or bat carcass, and involves walking (or using a slow moving 4wd motor bike) on either straight line transects or in concentric circles around the turbine from the tower out to the distance that a bird or bat is expected to fall (the fall zone). The extent of the fall zone has been described for various turbine heights from ballistic modelling and validation work (Hull and Muir 2010). Birds and bats do not fall evenly within this fall zone, with a greater concentration closer to the tower. This has prompted some researchers, to alter the survey design to account for this variability, focussing searches on areas of higher concentration and extrapolating to other parts of the fall zone (see Huso 2010). This sub-sampling method is utilised because ground searches around turbines are time consuming and can lead to fatigue which can lead to a reduction in detection.

The distance between transects or concentric circles is dictated by the focus of the monitoring. For example, searching for small objects such as bats or small birds necessitates closer transects for detection, while more widely spaced transects can be used for large birds as they are more conspicuous.

Previous studies have found an average detection rate by human observers of 80% examined in blind trials (Woolnorth Wind Farm Holding 2016b). Detectability can be improved through management of vegetation in the survey zone (assuming there are no constraints on the site in regards to slashing or removing vegetation). Further, conspicuous birds like eagles are easier to detect (Woolnorth Wind Farm Holding 2013);

<u>Examples of use:</u>

Bluff Point, Studland Bay and Musselroe Wind Farms in Tasmania, sites on the mainland (see discussion in Smales et al. 2013), and overseas including Germany (Grünkorn et al. 2011).

<u>Advantages:</u>

- Easy to deploy;
- Little training required;
- An action could be triggered when an eagle is found;
- Injured eagle could be dealt with as soon as found.

Disadvantages:

- Can be unreliable under some circumstances (e.g. certain vegetation types, terrain and weather). Quoted as ranging from 13-87% effective (see Bennett 2015);
- Labour intensive, but expected to have lower initial costs compared to automated systems (BirdLife International 2015);
- Need access to suitable staff, for long periods;
- Unrealistic to expect that observers can survey all turbines every day. Sub-sampling is necessary;
- Fatigue or boredom can result in lowered detection rates;
- Injured eagles will only be detected when monitoring is conducted;
- Undetected mortalities (missed carcasses) are possible if scavengers move evidence from search zone, although eagles are large and potentially more difficult to move;
- Date and time of collision cannot usually be determined precisely;
- Cannot always determine the turbine responsible, particularly if scavengers have moved a carcass.

5.1.2 Dogs

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).

Examples of use:

Challicum Hills Australia (Bennett 2015), UK (Matthews 2011), Sweden (Bernhold et al. 2011), Smøla Wind Farm in Norway (Reitan and Bevanger 2011).

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 an eagle is found because the handler is present.

Disadvantages:

- Requires good quality training and continual reinforcement (Bennett 2015);
- Requires high quality handlers (Bennett 2015);
- Need to manage on no wind and high wind days;
- 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 the turbine responsible, particularly if scavengers have moved a carcass.

Suitability of post-collision monitoring for Cattle Hill

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes, widely
Has it been tested to determine its suitability?	Yes. Survey design is important to reduce undetected mortalities
Can it be used to monitor WTE collisions?	Yes

5.1.3 Issues to consider with observer searches

Survey frequency

The frequency of wind turbine surveys is informed by the "survival rate" of a carcass. That is, how long evidence of the bird is expected to remain in the survey zone. A carcass does not have to remain intact to allow detection of a collision event. Studies at the Bluff Point and Studland Bay Wind Farms have revealed that avian scavengers usually scavenge *in situ*, leaving evidence of a mortality, while mammalian scavengers tend to remove a carcass (Hull et al. 2013). The size of the carcass likely determines the extent to which it is removed from the survey zone. Fencing survey areas can reduce removal of carcasses by scavengers, but fencing turbines can be incompatible with wind farm or farming operations, hence it is not always a practical option. Scavenger trials conducted at the site give an indication of the survival rate of carcasses of the size of an eagle, and are therefore a valuable input to the survey design, and also provide input to estimates of what was not detected.

Survey intensity

In order to determine the collision impact of a wind farm it is not necessary to monitor all wind turbines, sub-sampling is suitable. Post-collision monitoring is quite onerous, for example to survey the area around a wind turbine out to 108 m on transects 12 m apart, an observer needs to walk 6 km. Therefore, surveying in the order of 50 wind turbines would require observers walking or riding 300 km.

Wind turbine collisions are rare events, and considerable effort is expended before a carcass is found. Studies at the Musselroe Wind Farm found that it took on average 12 hours of searching per turbine for each find (Woolnorth Wind Farm Holding 2016). Blind trials at the Musselroe Wind Farm found that this low detectability was related to few collisions and not low detection on the part of observers (Woolnorth Wind Farm Holding 2016).

It is statistically valid to sub-sample the turbines, provided the survey design is representative, and that different parts of the site (e.g. if there are different habitats or other differences) are adequately surveyed.

Undetected mortalities

It is possible that some collisions will be not detected, either because they are not observed (very unlikely with eagles, due to their size) or because a scavenger has removed the evidence before the next survey period. Both scavenger and detectability trials allow estimates of undetected mortalities. However, these estimates are accurate, but not precise.

5.2 Automated monitoring

Real time monitoring of collisions uses one or more of the following strategies:

- Sensors, either contact (accelerometers or fibre-optic) or non-contact (acoustic or microphones) sensors (Collier et al. 2011). They are sometimes coupled with a camera system to confirm a collision event and identify the bird or bat;
- Radar, usually using adapted marine radars. (Weather radars, such as NEXRAD, Next generation S-band Doppler radar, are used in the USA to document large-scale migrations of birds and bats, but not for collision monitoring at wind farms);
- Imaging (visual), using still or video, either measuring the visible light or infrared (active or passive at night) (Collier et al. 2011).

These systems are usually installed to operate remotely and automatically. Depending on the system, they may be able to activate a deterrence or shutdown on turbines to reduce collision risk.

5.2.1 Sensors

Sensors are mounted in turbine blades to detect a collision. Generally, non-contact sensors (particularly acoustic) are more suitable for collision monitoring as they are less sensitive to vibrations and other turbine noise (Collier et al. 2011 and references therein). Tests have revealed sensors can detect the majority of collisions, with 5-10 false triggers per day due to noise and weather (Collier et al. 2011). Good quality microphones are required.

Example of systems used at wind farms:

- WT Bird (ECN, Energy Research Centre of The Netherlands) uses accelerometers and microphones linked to an active infra-red video. Software is used to filter out background and turbine noise. Video images are recorded continually, but only stored if a collision event is detected. It has been found to be relatively effective at onshore wind farms, but is not as effective at night (Collier et a. 2011).
- Id Stat (France). Comprises directional microphones in the hub of the turbine and base of each blade. The system filters background noise to reduce false positives. If a detection is identified, it stores the data and sends a message to a designated person. The system is still being trialled, but the developers believe it is capable of detecting an object as small as 2.5 g. As this system is not linked to cameras, ground searches need to be conducted when a collision alert is triggered;
- Farnsworth et al. (2011) has been trialling acoustic recorders to detect movements of nocturnal birds and bats. They are not aiming to detect collisions. The program is a collaboration between the Cornell University Laboratory of Ornithology, government the private sector, other Universities and environmental groups in the USA.

Advantages:

- Will provide precise date and time of collision and turbine responsible;
- Some systems provide an alert to an operator when a collision is detected.

Disadvantages:

- Can get false positives from turbine and background noise;
- Would only be useful at Cattle Hill if it was linked to a camera system to confirm a collision and the species involved;

- Cannot perform other tasks such as triggering shutdowns or documenting flight behaviour.

Suitability of automated monitoring for Cattle Hill:

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes somewhat, but still being developed
Has it been tested to determine its suitability?	Trials are being conducted. Need to eliminate false positives.
Can it be used to monitor WTE collisions?	Unknown, but given the priority of WTE, diurnal cameras would be essential.

Somewhat suitable for collision monitoring, but there are a number of issues (requires cameras) and false positives would need to be minimised.

5.2.2 Radar

A full description of radar systems is provided in Section 4.3 above. Radar is more commonly used for documenting movements of birds and bats than collision monitoring.

Suitability of radar for collision monitoring at Cattle Hill

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes, at multiple wind farms around the World (none yet at operational wind farms in Australia), but less so for collision monitoring
Has it been tested to determine its suitability?	Yes
Can it be used to monitor WTE collisions?	Probably not. Clutter (ground, vegetation and rain) is likely to be an issue

Most likely unsuitable for collision monitoring due to clutter, and reduced value due to the inability to identify species and number of individuals.

5.2.3 Imaging

Cameras are discussed in detail in Section 4.3 above.

Suitability of imaging for collision monitoring at for Cattle Hill

Question	*Result*
Has the system or approach previously been used at wind farms?	Yes potentially. A number of systems are in development, but some (DT Bird) have been used at a number of sites
Has it been tested to determine its suitability?	Some trials, some results available
Can it be used to monitor WTE collisions?	Yes potentially, to some extent

Potentially suitable, but it may have limitations (field of view is limited, reduced visibility in poor weather). Many are still in the developmental stage.

5.3 Conclusions – monitoring WTE collisions

Post-collision monitoring using humans or dogs is commonly used at onshore wind farms in Australia and overseas. While it will not necessarily detect every carcass (particularly small, cryptic ones), site-specific strategies (e.g. a survey design based on the species of interest, informed by scavenger removal rates, and management of vegetation in search zones) can minimise undetected carcasses. Dogs are faster and have higher detection rates than humans, but suitable dogs, and adequate training is required. Post-collision monitoring is regarded as a suitable monitoring strategy for the Cattle Hill Wind Farm.

There are advantages of having an automated system that continuously monitors and documents collisions in real time. A number of systems have the potential to alert a designated person (allowing an operator to respond to injured animals), can provide precise data on when and where the collision occurred. Of the automated systems available, diurnal cameras are more suited because they can potentially identify species and some can be linked to actions such as alerting a designated person (allowing an operator to respond to injured animals), and deterrents or shutdowns of turbines. DT Bird and IdentiFlight appear to be the most suitable, and are currently being trialled at overseas sites. It is likely that multiple camera systems would be required (due to their limited field of view) to cover a site like Cattle Hill (IdentiFlight has calculated that 15 systems would be required to cover all turbines, P. Downie). Consideration needs to be given to whether there are any issues associated with multiple units (permits, hazards, risks to infrastructure, etc).

6. Mitigating WTE collisions

6.1 Background

There is considerable evidence that eagles continue to use a wind farm once the turbines are installed (see for example Hull and Muir 2013 and references therein), which means "macro-avoidance" (avoiding the entire wind farm) is not occurring. However, for species that fly at the height of the RSA such as eagles, there is a risk of a collision with a turbine. Previous studies have demonstrated that WTEs actively avoid wind turbines, but for reasons not yet fully understood, they occasionally collide (Hull and Muir 2013).

Until there is an understanding of why an animal such as WTE, which has high visual acuity and actively avoids turbines occasionally collides, management actions need to be reactive and make assumptions about collision risk. The two broad approaches currently used to attempt to reduce avian collision risk are either to trigger an alert (visual or auditory) or shutdown a turbine. Few alerts have thus far been found to be effective on eagles. For example, trials on auditory alerts on WTE at the Bluff Point and Studland Bay Wind Farms had no effect on eagle behaviour (Sims et al. 2015). This lack of success is probably a result of the poor understanding of how birds (specifically eagles) see and hear, and relies on the flawed assumption that birds do so in the same manner as humans (see for example Martin 2011). Research is being conducted in this area, but results are not expected until 2020 (see the investigations being conducted by the US Department of Energy, https://www.nationalwind.org/research/webinars/).

As an alert that alters the behaviour of WTEs has not yet been identified, shutdowns are the only alternative, but they are an imperfect strategy. This is again because the factors involved in collision risk are not understood, so triggers for shutdowns rely on buffers around turbines. Given the time to shutdown a turbine (in the order of 8-15 seconds, P. Fulton pers. comm.) and the potential speed an eagle can fly, these buffers often need to be large (in the order of 400 m). When an eagle breaches this buffer, a shutdown is triggered, but a buffer of this size risks shutdowns on multiple turbines, although an eagle is not at risk from these turbines. The challenge is to refine the shutdown response so that collision risk is reduced while allowing the wind farm to operate in a viable manner. However, until there is a better understanding of why eagles collide a shutdown strategy is problematic.

Unfortunately, there is also a risk with a shutdown strategy designed to protect eagles. Studies on the behaviour of WTE at the Bluff Point and Studland Bay Wind Farms found that eagles approached closer to a turbine when it was shutdown (Hull and Muir 2013). This demonstrates two important facts, firstly that eagles are very aware of the turbines and their operation and respond to them, and more importantly, shutting down a turbine when an eagle approaches may teach eagles that if they approach a turbine it will shutdown, which could reduce their attentiveness (Hull and Muir 2013).

6.2 Strategies that can detect an eagle and initiate a shutdown

The approaches that can potentially detect and eagle and then initiate are shutdown can use:

- Human observers;
- VHF telemetry;
- Radar;
- Diurnal cameras.

6.2.1 Human observers

Human observers were used to monitor the movements of WTE and WBSE at the Bluff Point and Studland Bay Wind Farms during the period 2006 - 2008 (see Hull et al. 2015). The observers had direct access to the SCADA system of the turbines and could initiate shutdowns on individual turbines when they perceived an eagle was at risk of colliding. A thorough evaluation of the program determined that these shutdowns did not reduce the eagle collision rate, presumably because the reasons for eagle collisions are not understood and therefore collision risk could not be anticipated (see Hull et al. 2015).

This approach is not recommended as it is extremely onerous and had no demonstrable benefit at other wind farms.

6.2.2 VHF telemetry

Theoretically a VHF transmitter could be attached to an eagle and a VHF receiver placed on or near turbines to detect an eagle if it approaches a prescribed distance to the receiver. The receiver could theoretically be designed to instigate a shutdown on that turbine. We did not identify an off-the-shelf system currently available. Obviously, such a system is reliant on catching all the target eagles and maintaining long-term deployments of devices, both of which are unfeasible.

This approach is not available at this time and has drawbacks relating to catching the target eagles and long-term deployments of transmitters.

6.2.3 Radar

While there are some very sophisticated radar systems available that can communicate with the SCADA systems of turbines (e.g. DeTect), the issues with radar reduce their utility as a mitigation strategy. Radars have been found to be effective at airports in the US because runways are linear and hence easy to survey, and identification of species is unnecessary (it is only necessary to determine if a flock of birds is approaching the runway and then to instigate a response). Wind farms in contrast are often spread across undulating landscapes, and species identification is critical to trigger a targeted response. Given these issues and likely clutter problems with radars, they are not deemed suitable for WTE collision mitigation.

6.2.4 Diurnal cameras

Diurnal cameras have the advantage of potentially identifying species, and two systems are designed to communicate with the SCADA system of turbines (DT Bird and IdentiFlight). Provided the cameras can observe reliably out to a distance that allows time to shutdown turbines (probably in the order of 400 m) they could be suitable.

6.3 Conclusions – WTE collision mitigation

Until there is a better understanding of why birds such as WTE occasionally collide with turbines, which they demonstrably observe and usually avoid, management options are limited. At present the only option to reduce WTE collision risk is a triggered shutdown of turbines, but this is both an inexact science and has some potential downsides. The systems currently available that are most suited to undertake this task are diurnal cameras, with a buffer around turbines.

7. Overall conclusions

Currently there is no one system perfectly suited to undertake all the monitoring tasks required of the CADP. Table 1 provides a summary of the expected ability of the various approaches to achieve the objectives of the CADP.

Table 1. Comparison of the utility of various approaches to achieve the objectives of the CADP

Strategy	*WTE movements*	*WTE collisions*	*WTE collision mitigation*
Observers	Yes, but with some limitations	Yes, using post-collision monitoring	No (failed to work at Bluff Point and Studland Bay)
Telemetry	Yes	Short term only (need all WTEs permanently marked)	Short term only (need all WTEs permanently marked)
Radar	Somewhat (limitations of the system)	Somewhat (limitations of the system)	Perhaps (limitations of the system)
Cameras	Yes although depends on coverage of the site	Yes	Perhaps (further trials required)

This table demonstrates that the approach assessed to be most likely to achieve the objectives of the CADP is a camera system. Its main advantage is its potential to identify species, the possibility of documenting a collision event (and possibly providing insights into why it occurred) and the triggering of shutdowns. The limited field of view of cameras will require multiple systems to provide adequate coverage of a site such as Cattle Hill. However, there are a number of unknowns about the capabilities of the systems, particularly under the conditions at Cattle Hill.

Two camera systems appear the most suited for these tasks, DT Bird and IdentiFlight, both of which are currently being trialled overseas by the US Department of Energy. Trials are expected to be completed in 2020. Below is additional information about the two systems.

7.1 DT Bird

The DT Bird website (http://dtbird.com/) contains detailed information about the system and the results of trials they have conducted. The site states there are currently 15 systems installed at onshore wind farms around the world. The system is attached to turbine towers and scans into the RSA. Cameras survey 360° around a turbine and they can target species. Birds collisions are recorded and by monitoring the collision risk area, it can initiate a shutdown when the target species enters this zone. A system with eight cameras has been used for a turbine with a tower height of 130 m, a RSA of 120 m targeting golden eagles (*Aquila chrysaetos*) and white-tailed eagles. They found the eight camera system could scan out to 600 m, which would be applicable for monitoring WTE. They state turbines can be shutdown in the order of 25 seconds.

Its strengths are that it appears to have good coverage of the collision zone, has been demonstrated to be capable of identifying species and initiating shutdowns to reduce collision risk. It also has been in development for a number of years and the results of trials are available providing comfort about its level of development and its capabilities. The manufacturers state that it has reduced collision risk to 1 collision per 10,000 birds, or 0.05 collisions per turbine per year. However, trials by Ashwanden et al.

(2015) found that its inability to determine distance to objects generated false positives. This reduces its value for use at the Cattle Hill Wind Farm.

7.2 IdentiFlight

There is less information about IdentiFlight (see https://www.identiflight.com/), but the website states that the system can scan out to 1 km from the IdentiFlight tower (which is a structure independent of the turbines). Given that the cameras are installed on an independent structure, it has the potential to be moved around the site. Trials have been conducted on the reliability of the system (T. Hiester RES pers. comm.), but the report had not been released at the time of writing. The former proponent of Cattle Hill Wind Farm visited the Top of the World site to see IdentiFlight *in situ*, where staff praised its capabilities.

7.3 Conclusion

DT Bird appears to be more advanced in its development than IdentiFlight, but the latter appears to be able to scan larger areas and can determine distances, giving it greater potential to document WTE movements. IdentiFlight also has the advantage of being portable and not attached to the turbines, which eliminates any problems with attachment to turbines and would allow the system to be moved somewhat if necessary.

8. Recommended strategy

It is recommended that IdentiFlight be trialled at the Cattle Hill Wind Farm.It will be installed across the site during the construction phase of the wind farm and trialled for 18 months (as required in the CADP) to determine its capabilities, and validated using post-collision carcass monitoring and eagle utilisation studies to determine its effectiveness. It is assumed that if the system is demonstrably effective and practical to implement, it would supersede the need for post-collision monitoring.

8.1 Technical trials of IdentiFlight

Technical trials will be undertaken throughout the 18 month period. The purpose of these is to ascertain whether the system performs as required, whether there are issues around powering it, how adequately data are managed and how effectively it provides alerts and shuts down turbines. Trials using objects such as kites or tennis balls will be used to determine its detection distance.

8.2 Post-collision monitoring

Post collision monitoring using humans or dogs which will be conducted as part of the State Bird and Bat Mortality Monitoring Plan (FF10) and the results compared to collisions detected by IdentiFlight to determine its reliability in detecting WTE collisions.

8.3 Eagle utilisation studies

Studies conducted for the State Post-commissioning Eagle Utilisation Plan (FF6) will be used to determine the effectiveness of IdentiFlight at detecting and monitoring the movements of WTE.

8.4 WTE collision mitigation

If there are WTE collisions at the Cattle Hill Wind Farm while IdentiFlight is operating, an evaluation will be undertaken to determine why the mitigation was unsuccessful, and whether any changes to the system are required.

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