Appendix D

Shadow Flicker and Blade Glint Assessment

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Normanville Energy Park

Shadow Flicker and Blade Glint Assessment

WestWind Energy Pty Ltd

13 November 2024

→ The Power of Commitment

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Executive Summary

GHD Pty Ltd (GHD) was engaged by WestWind Energy Pty Ltd (WestWind) in 2023 to prepare a shadow flicker and blade glint impact assessment for the proposed Normanville Energy Park. The assessment comprised of a desktop study which involved modelling the proposed wind turbine generator (WTG) configuration and calculating the shadow flicker at nearby receptors.

WestWind has recently provided GHD with a revised WTG configuration and has requested an update to the shadow flicker assessment.

This report summarises the findings of the shadow flicker and blade glint assessment for the revised WTG layout and provides an overview of the relevant guideline requirements.

Shadow flicker calculations for the proposed wind farm layout at Normanville Energy Park were undertaken in accordance with the *Draft National Wind Farm Development Guidelines for Australia (2010)* (Draft National Guidelines) and the current Victorian legislation and guidelines, notably Section 5.1.2 of the Victorian Department of Transport and Planning's Policy and Planning Guidelines - Development of Wind Energy Facilities, 2023 (Victorian Guidelines).

The Draft National Guidelines suggest an acceptable amount of 30 hours/ year (modelled) for worst case theoretical shadow flicker and 10 hours/year cloud-cover adjusted shadow flicker per receptor. The Victorian Guidelines state that the shadow flicker experienced immediately surrounding the area of a dwelling (garden-fenced area) must not exceed 30 hours per year. GHD has initially assessed the worst case theoretical shadow flicker for compliance against the 30 hours per year limit. Only receptors which are non-compliant with this criteria have been assessed for compliance against the cloud cover adjusted or "expected case" 10 hours per year limit.

This assessment has been undertaken for 17 turbines and 93 receptor locations as provided by WestWind. Five of 93 receptors are subject to a theoretical worst case shadow flicker greater than zero. Four of these receptors have worst-case theoretical and cloud cover adjusted "expected case" shadow flicker exceeding the acceptable limits in the Victorian Guidelines and Draft National Guidelines, as illustrated in Table 1. The five receptors with non-zero shadow flicker are subject to landowner agreements. All other receptors have zero calculated shadow flicker.

Table 1 ***Shadow flicker summary***

Receptor	Calculated worst case shadow flicker (hours/year)	Compliant with 30 hours/year maximum worst case shadow flicker	Calculated expected case shadow flicker (hours/year)	Compliant with 10 hours/year maximum expected case shadow flicker	Landowner agreement status
AA30-a	50:49	No	26:10	No	Agreement in place
AA30-b	45:53	No	23:22	No	Agreement in place
AD30-a	130:19	No	59:15	No	Agreement in place
AE30-a	99:31	No	43:06	No	Agreement in place
AF30-a	15:51	Yes	Not calculated, worst case compliant		Agreement in place

It should be noted that the shadow flicker modelling calculation has been calculated in accordance with the Draft National Guidelines and Victorian Guidelines. These guidelines describe a consistent approach to modelling shadow flicker; however, this approach is conservative and calculated results may not be completely representative of the actual shadow flicker experienced once the wind farm is operational.

If further changes are implemented to turbine siting, upon finalisation of the turbine locations prior to construction, WestWind should undertake an updated shadow flicker assessment to verify that there has been no increase in shadow flicker. To minimise the effects of blade glint, all wind turbine technical specifications and procurement documents should ensure wind turbine blades are coated with a low reflectivity finish.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.5 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Background

GHD Pty Ltd (GHD) was engaged by WestWind Energy Pty Ltd (WestWind) to prepare a shadow flicker and blade glint impact assessment for the proposed Normanville Energy Park. The assessment comprised of a desktop study which involved modelling the proposed wind turbine generator (WTG) configuration and the surrounding sensitive receptors. A shadow flicker assessment was then undertaken for the proposed turbine layout provided by WestWind. This report summarises the findings of the shadow flicker and blade glint assessment and provides an overview of the relevant guideline requirements.

This report summarises the shadow flicker assessment completed for the revised WTG layout provided by WestWind via email on the 3rd of June 2024.

1.2 Purpose of this report

The purpose of this report is to assess the potential impacts of shadow flicker and blade glint caused by the proposed WTG layout at Normanville Energy Park. The study assesses the potential impact on sensitive receptors located in close proximity of the proposed wind farm. WestWind intends to use the findings to support regulatory approvals for the development of a wind farm and associated infrastructure at Normanville Energy Park.

1.3 Project Overview

The proposed wind farm is to be developed at Normanville Energy Park, which is located in Gannawarra Shire, near Normanville, approximately 15 km south-west of Kerang township in the North of Victoria. The proposed wind farm will have up to 17 wind turbines with capacity 5 – 8 MW each.

Figure 1 outlines the location of Normanville Energy Park and Figure 2 depicts the indicative site layout for the proposed wind farm.

Figure 1 *Normanville Energy Park project location*

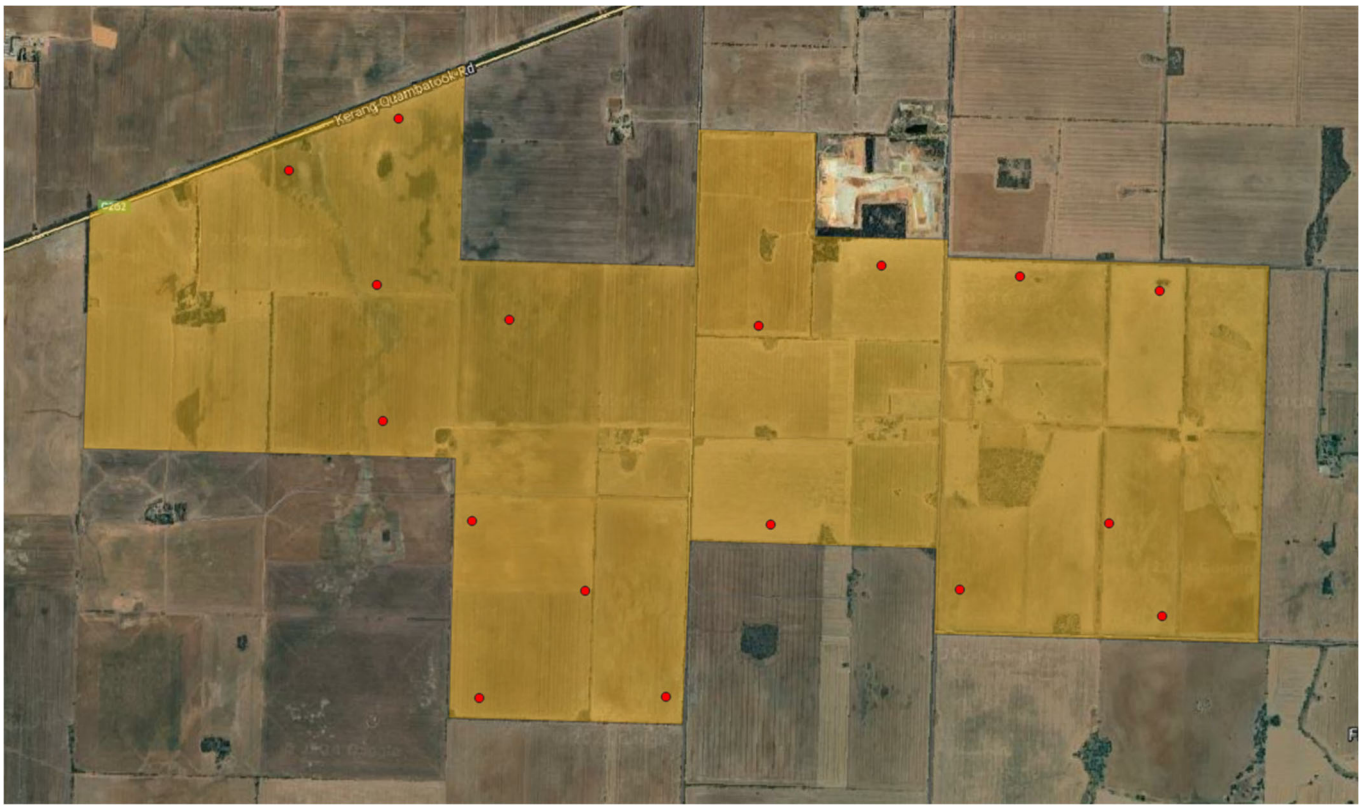

Figure 2 *Normanville Energy Park site layout (WTG locations shown in red and project area highlighted in yellow)*

1.4 Shadow Flicker Simulation

GHD has undertaken a desktop-based shadow flicker assessment using the EMD WindPRO 4.0 software package for the wind turbine layout and sensitive receptor locations provided by WestWind.

The shadow flicker model simulates the path of the sun during the year and calculates the position of the sun relative to wind turbines, residences, and terrain, thus predicting the possible shadow flicker durations in the vicinity of the wind farm from a purely geometric standpoint. The calculation provides the theoretical number of hours of shadow flicker experienced at each receptor location.

1.5 Scope and limitations

This report has been prepared by GHD for WestWind Energy Pty Ltd and may only be used and relied on by WestWind Energy Pty Ltd for the purpose agreed between GHD and WestWind Energy Pty Ltd as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than WestWind Energy Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by WestWind Energy Pty Ltd and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

This assessment has been undertaken based on 17 specific turbines and 93 receptor locations as provided by WestWind Energy Pty Ltd. Development approvals typically allow for some degree of flexibility in turbine siting. Prior to finalisation and micro siting of the turbine locations and construction, WestWind Energy Pty Ltd should undertake an updated shadow flicker assessment to verify that no increase in shadow flicker occurs.

GHD engineers have not visited Normanville Energy Park as part of this assessment and therefore have not examined local conditions near the sensitive receptors assessed, such as blockage from trees or other obstacles.

2. Methodology

The following methodology was used to complete the shadow flicker and blade glint assessment.

1. Request for information, including:
   a. Turbine layout (turbine designations and coordinates)
   b. Turbine model technical parameters (i.e. hub height, rotor diameter, etc.)
   c. Proposed infrastructure/buildings (sensitive receptors) designation and coordinates
2. Input of information into EMD windPRO 4.0 wind farm modelling software package
3. Selection of shadow flicker calculation parameters
4. Shadow flicker simulation
5. Recommendations on blade glint
6. Reporting

2.1 Information Provided

The site layout and proposed turbine locations were originally obtained from WestWind on 23 February 2023[1]. Further information for the proposed turbine model, including hub height, rotor diameter, and maximum blade chord was obtained over email from WestWind on 28 March 2023. Contours were provided on 28 March 2023[2], whilst coordinates for the receptor locations were provided on 29 March 2023[3].

Subsequently, a revised turbine layout was provided on 3rd June 2024[4]. For clarity, this shadow flicker assessment uses the new turbine layout and the original turbine characteristics, surface contours and receptor locations.

2.2 Reference Documents and Assessment Requirements

GHD has conducted the shadow flicker assessment in accordance with the *Draft National Wind Farm Development Guidelines for Australia (2010)* (Draft Guidelines) and the current Victorian guidelines, notably:

– Section 5.1.2 in the Victorian Government Department of Transport and Planning's Policy and Planning Guidelines - Development of Wind Energy Facilities in Victoria, September 2023

The Draft National Guidelines suggest an acceptable amount of 30 hours/ year (modelled) for worst case theoretical shadow flicker and 10 hours/year cloud-cover adjusted shadow flicker per receptor. The Victorian Guidelines state that the shadow flicker experienced immediately surrounding the area of a dwelling (garden-fenced area) must not exceed 30 hours per year.

The following parameters outlined in Table 2 have been adopted from the Draft National Guidelines and Victorian Guidelines.

Table 2 Draft Guideline Parameters

Parameter	Limit/Description
Shadow flicker limit	30 h/year at each Receptor (worst case) 10 h/year at each receptor (expected case)
Zone of influence of shadows	Distance limit of 265 x maximum blade chord in metres (1,246 m)

[1] DataSupply_230223_ShadowFlicker
[2] DataSupply_230328_ShadowFlicker
[3] NMEP_Structures_Footprint_v03-04_Redacted_WindProImport
[4] NMEP_WTGLayout_V11-01

2.3 Inputs

The following inputs were used for the shadow flicker assessment.

– Turbine characteristics[5] (refer to section 2.3.1)
– Turbine layout[6]
– Receptor locations (based on site layout[7])

It should be noted that publicly sourced height contour information from windPRO was used for this study as the contours provided by WestWind did not provide height data for all receptor locations provided.

2.3.1 Turbine Characteristics

The turbine dimensions used for the shadow flicker model are depicted in Table 3. These dimensions are intended to provide a worst-case, conservative basis for the shadow flicker assessment. The rotor diameter and hub height used for this assessment are larger than the actual dimensions for the proposed turbine model, the Vestas V172, which are expected to give conservative shadow flicker results.

Table 3 Turbine Specifications

Part	Dimension
Turbine type	Vestas V172
Maximum blade chord width	4.7 m
Hub height	180 m
Rotor diameter	200 m

2.4 Assumptions

The shadow flicker model was calculated for a distance of 1,246 m from the turbines and was conducted at 1-minute intervals with a grid resolution of 10 m. The turbine orientation within the shadow flicker model is such that the turbine and rotor plane is facing the azimuth at 180° relative to all Receptors. The following key assumptions in Table 4 were used for the model.

Table 4 Draft Guideline Parameters

Parameter	Limit / Description
Receptor height	1.5 m
Receptor model	A 100 m x 100 m flat-area centred on each receptor at 1.5 metre eye height was used to simulate garden-fenced areas[8].
Turbine orientation and rotation	Worst case scenario (the turbines are always rotating and perpendicular to the direction of incident sunlight)
Maximum distance of influence	1,246 m (265 x maximum blade chord)
Minimum sun angle	3 degrees
Turbine model	Vestas V172 (using the specifications outlined in Table 3)
Flicker map grid resolution	10 m
Time step for calculation	1 minute
Day step for calculation	1 day
Reference year	2029

[5] Email from WestWind dated 28 March 2023
[6] NMEP_WTGLayout_V11-01
[7] NMEP_Structures_Footprint_v03-04_Redacted_WindProImport
[8] In the absence of detailed information describing the outline of garden-fenced receptor areas, WestWind advised that a 100 m x 100 m receptor shape should be assumed, in line with section E.4.3 of the Draft National Guidelines which recommends reporting the maximum value of shadow flicker duration within 50 m of the centre of the dwelling.

93 receptor locations were provided by Westwind. The locations of these 93 receptors relative to the project area boundary are indicated in Figure 3.

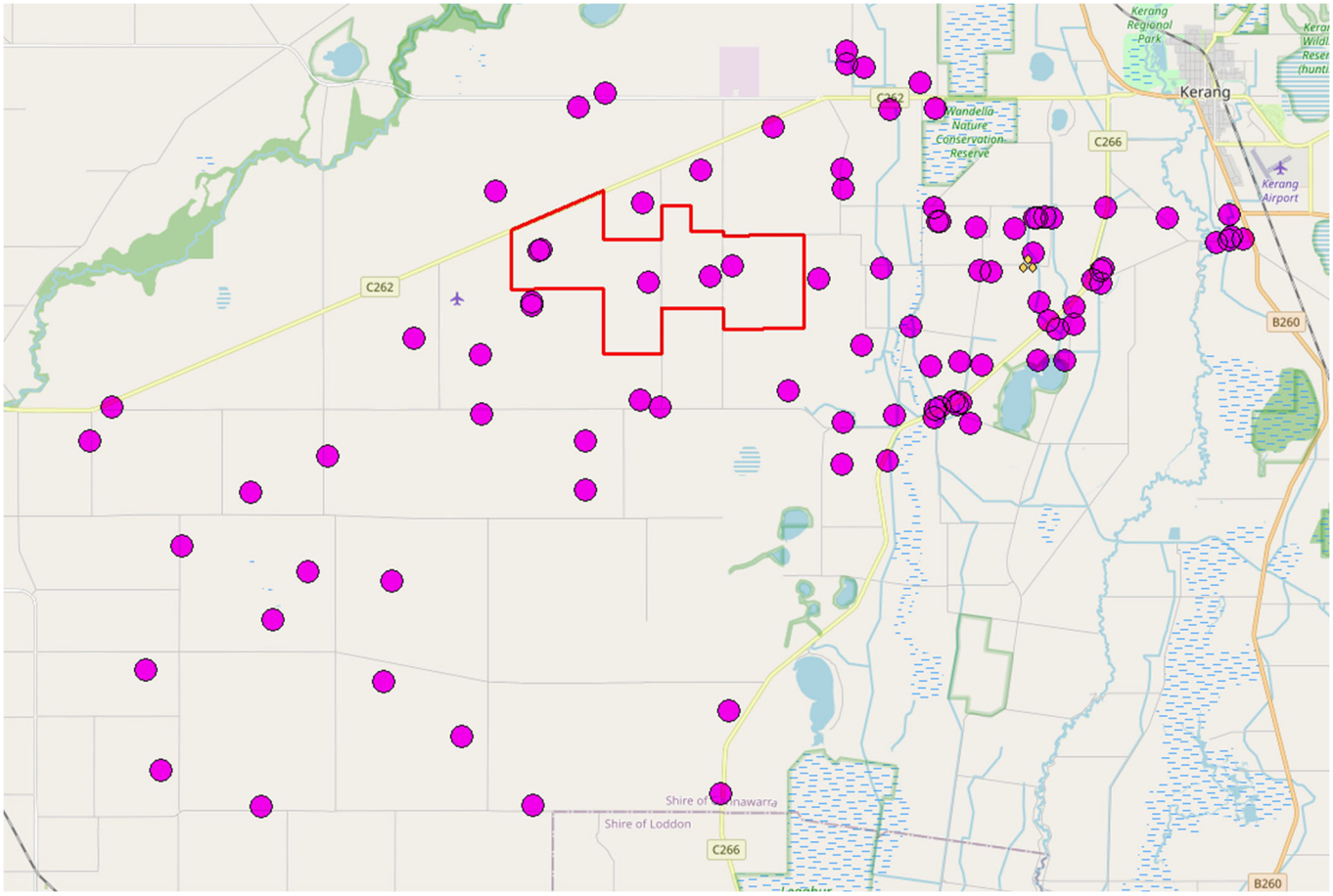

Figure 3 *WTG and receptor locations (receptors shown in magenta, project boundary in red)*

Due to the large number of potential receptors provided by WestWind, an initial screening process was completed prior to the shadow flicker modelling. All receptors located further than 1,600 m from the nearest turbine were excluded. The 1,600 m threshold was used to allow for some uncertainty in the extent of garden-fenced areas, noting that the maximum distance of shadow flicker influence is calculated as 1,246 m. Receptors within the study area are illustrated in Figure 4.

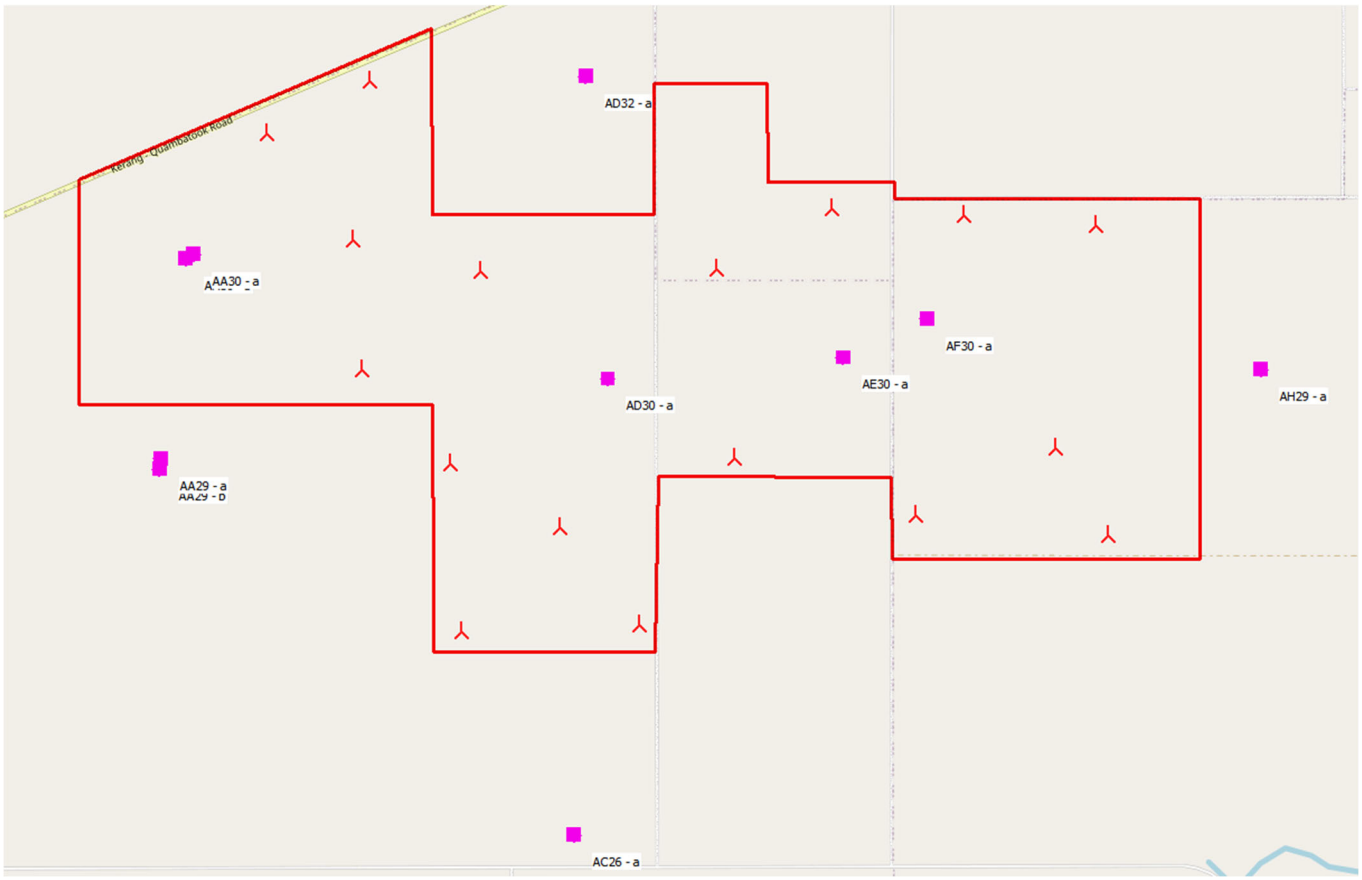

Figure 4 *Shadow flicker receptors within 1600 metre study area*

It is noted that the worst-case shadow flicker model is conservative and does not consider the following:

- Cloud cover
- Impact of wind direction on the orientation of the WTG during periods of potential shadow flicker, and whether this might reduce the shadow flicker experienced at the receptors (as opposed to the assumption that turbines will always be perpendicular to the sun)
- Any potential changes to the wind farms operating regime to minimise operation of wind turbines contributing to shadow flicker
- Turbine down-time due to wind speeds below the cut-in wind speed
- Turbine down-time during maintenance
- Existing screening in the vicinity of affected properties (i.e. vegetation)
- Any vegetation blocking the visibility of wind turbines

Where exceedances of the worst case theoretical shadow flicker allowance were calculated, the cloud-cover adjusted, or “expected case” shadow flicker was also calculated. The maximum allowable expected case shadow flicker is 10 hours/year as defined in the Draft National Guidelines.

The “expected case” shadow flicker includes a correction for cloud-cover based on historical weather statistics from the nearest weather station (Laverton). All other assumptions for the “expected case” assessment are identical to the worst case assessment.

3. Calculations and Results

3.1 Worst Case Shadow Flicker

3.1.1 Results

Receptors with theoretical worst case calculated shadow flicker greater than zero are depicted in Table 5. All other receptors were calculated to have zero hours of shadow flicker.

Table 5 windPRO shadow flicker results

Receptor	Easting (m)*	Southing (m)*	Z (m)	Worst Case Shadow Flicker (h/year)	Compliant	Status
AA30-a	746311	6037972	90	50:49	No	Under Agreement
AA30-b	746257	6037940	90	45:53	No	Under Agreement
AD30-a	749161	6037030	90	130:19	No	Under Agreement
AE30-a	750796	6037131	99	99:31	No	Under Agreement
AF30-a	751386	6037384	97	15:51	Yes	Under Agreement

** GDA2020 MGA Zone 54*

3.1.2 Shadow Flicker Map

An indicative worst case shadow flicker map is included in Figure 5.

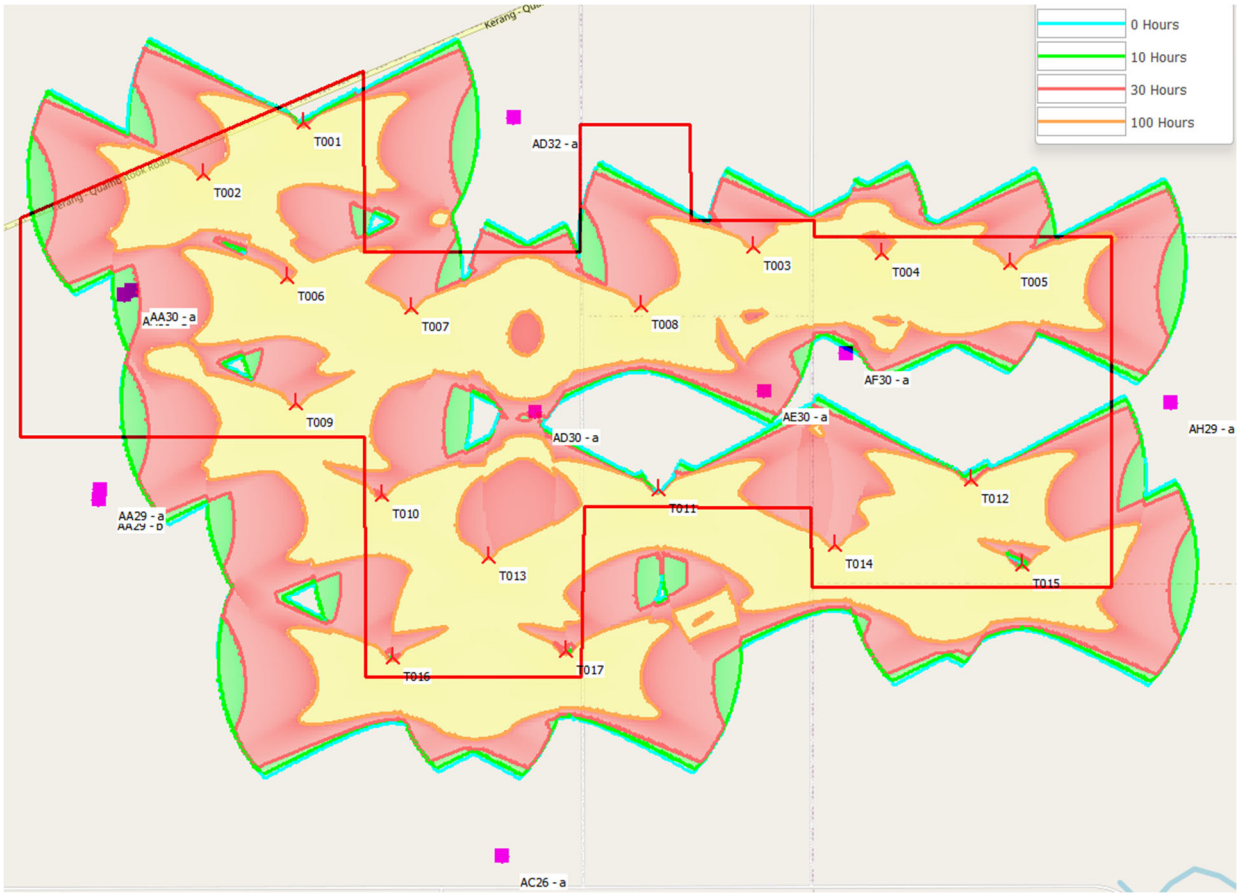

Figure 5 Worst case shadow flicker map

3.2 Expected Case Shadow Flicker

For the expected case shadow flicker, cloud cover statistics were used, as described in section 2.4. All other assumptions from the theoretical worst-case calculation were identical, including that turbines are assumed to always be operating and always orientated perpendicular to receptors.

3.2.1 Results

Expected case calculated shadow flicker results are depicted in Table 6. Expected case shadow flicker was only assessed for receptors with more than 30 hours/year theoretical worst case shadow flicker.

Table 6 Expected case shadow flicker

Receptor	Easting (m)*	Southing (m)*	Z (m)	Expected Case Shadow Flicker (h/year)	Compliant	Status
AA30-a	746311	6037972	90	26:10	No	Under Agreement
AA30-b	746257	6037940	90	23:22	No	Under Agreement
AD30-a	749161	6037030	90	59:15	No	Under Agreement
AE30-a	750796	6037131	99	43:06	No	Under Agreement

3.2.2 Shadow Flicker Map

An indicative cloud cover adjusted “expected case” shadow flicker map is included in Figure 6.

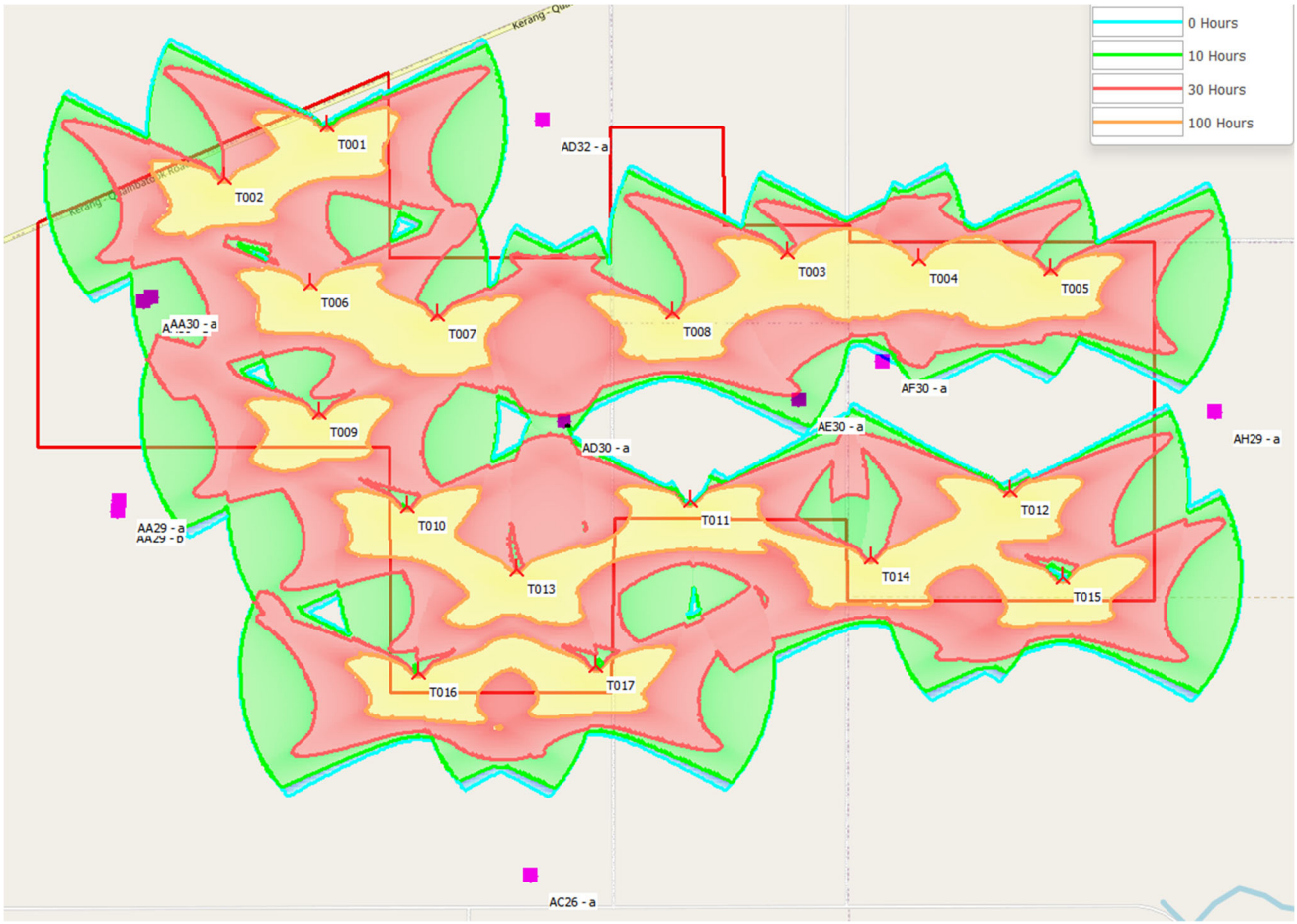

Figure 6 Expected case shadow flicker map

3.3 Blade Glint

As per the Draft National Guidelines, wind turbine blades must be finished using a low-reflective treatment such that reflective glinting from the blade surface or strobing reflections caused by blade rotation is minimised. As many wind turbine blade manufacturers are currently applying the aforementioned treatment to their blades, the risk of blade glint is considered low and no further assessment was undertaken in this report. Project-specific blade specifications should ensure that a low reflective coating is applied to the blades.

4. Conclusions and Recommendations

4.1 Conclusions

Shadow flicker calculations were undertaken for a revised WTG layout at Normanville Energy Park in accordance with the Victorian Guidelines and Draft National Guidelines. These guidelines describe a consistent approach to modelling shadow flicker; however, this approach is conservative and calculated results may not be completely representative of the actual shadow flicker experienced once the wind farm is operational.

Five receptors were found to have a theoretical worst case shadow flicker greater than zero. The shadow flicker for four of these receptors exceeds the acceptable limits according to the Victorian Guidelines and the Draft National Guidelines for both the theoretical worst-case and the cloud-cover adjusted cases.

All five receptors with non-zero shadow flicker are subject to landowner agreements. All other receptors are calculated to have zero hours/year shadow flicker.

In accordance with Section 5.1.2 of the Victorian Guidelines, turbine blades should be finished with a low reflectivity surface treatment to minimise blade glint.

4.2 Recommendations

Development approvals typically allow for some degree of flexibility in turbine siting. Prior to finalisation and micro-siting of the turbine locations and construction, WestWind Energy Pty Ltd should undertake an updated shadow flicker assessment to verify that no increase in shadow flicker occurs.

All wind turbine technical specifications and procurement documents should ensure wind turbine blades are coated with a low reflectivity finish to avoid the possible effects of blade glint to the surrounding residences.

Attachments

Appendix A

WTG Coordinates

Table 7 WTG Coordinates (GDA2020 MGA Zone 54)

WTG #	WWE ID	Easting (m)	Southing (m)	Z (m)
WTG01	T003	750749	6038165	94.2
WTG02	T014	751265	6036026	90
WTG03	T002	746839	6038787	90
WTG04	T016	748098	6035316	91.9
WTG05	T005	752578	6037995	88.2
WTG06	T010	748049	6036478	90
WTG07	T015	752597	6035853	88.2
WTG08	T017	749331	6035323	90
WTG09	T006	747421	6038037	90
WTG10	T004	751658	6038092	91
WTG11	T009	747458	6037139	90
WTG12	T007	748295	6037801	90
WTG13	T001	747564	6039129	90
WTG14	T012	752251	6036461	90
WTG15	T013	748795	6036017	90
WTG16	T011	750019	6036458	90
WTG17	T008	749937	6037769	90

Appendix B

Shadow Flicker Receptor Coordinates

Table 8 Shadow flicker receptor coordinates

Receptor coordinates provided by WestWind			
Receptor	Easting (m)	Southing (m)	Z (m)
AG34 - a	752589	6041027	90
AB34 - a	747406	6041693	87.4
AE32 - a	750649	6039950	82.8
AD32 - a	749068	6039124	90
Z32 - a	745141	6039542	83.7
AA30 - b	746257	6037940	90
AA30 - a	746311	6037972	90
AD30 - a	749161	6037030	90
AA29 - b	746034	6036494	90
AA29 - a	746045	6036565	90
Y28 - a	744621	6035234	90
Y26 - a	744629	6033633	98.1
AC26 - a	748836	6033886	93
AD26 - a	749383	6033712	90
AJ34 - a	755696	6041398	80
AI32 - a	754405	6039862	80.1
AI32 - b	754407	6039354	80.6
AJ30 - a	755359	6037199	80
AF30 - a	751386	6037384	97.4
AE30 - a	750796	6037131	98.8
AH29 - a	753694	6036966	83.3
AK28 - a	756091	6035642	80.7
AJ26 - a	755610	6033321	80
AI28 - a	754786	6035188	82.6
AI26 - a	754243	6033152	80
AG27 - a	752806	6034044	84.5
AC35 - a	748139	6042061	86.9
AI35 - a	754604	6042641	80
AI36 - a	754597	6042985	80
AJ35 - a	755064	6042532	80
AK35 - a	756547	6042080	80
AK34 - a	756936	6041396	80
AK31 - a	756813	6038770	80
AK31 - b	756899	6038402	80
AK31 - c	756967	6038390	80
AK27 - a	756614	6034560	80
AK26 - a	756828	6033481	80
AK26 - b	756683	6033441	80
AK26 - c	756652	6033217	80

Receptor coordinates provided by WestWind			
AJ25 - a	755394	6032099	80
AI25 - a	754156	6032036	80
AL26 - d	757616	6033024	80
AL26 - a	757188	6033619	80
AL26 - c	757291	6033525	80
AL26 - b	757383	6033593	80
AL27 - a	757380	6034663	80
AL27 - b	757979	6034574	80
AL30 - a	757989	6037065	80
AL31 - a	757903	6038222	80
AN28 - a	759771	6035682	80
AO28 - b	760025	6035454	80
AO28 - a	760440	6035575	80
AO29 - b	760472	6036030	80
AO29 - a	760970	6036738	80
AP29 - a	761204	6036966	80
AP30 - a	761268	6037048	80
AP29 - b	761203	6036625	80
AN27 - a	759455	6034637	80
AO27 - a	760169	6034633	80
AM31 - a	758937	6038172	80
AN31 - b	759464	6038423	80
AN31 - c	759529	6038419	80
AN31 - a	759742	6038439	80
AN31 - d	759955	6038401	80
AS30 - a	764721	6037756	80
AT30 - a	765013	6037686	80
AS30 - b	764292	6037624	80
AS31 - a	764656	6038345	80
AP31 - a	761381	6038645	80
AM30 - a	758275	6037020	80
AN30 - a	759419	6037507	80
AR31 - a	763013	6038315	80
W28 - a	742885	6035718	90
AB25 - a	747362	6032873	101
AN30 - b	759551	6036175	80
AB24 - a	747324	6031553	103.7
AE18 - a	750982	6025586	89.1
AE16 - a	750693	6023418	92.6
Z16 - a	745694	6023232	110
X18 - a	743852	6025113	110

Receptor coordinates provided by WestWind			
S16 - a	738484	6023400	110
P17 - a	735847	6024442	110
P20 - a	735503	6027109	100.6
Q23 - a	736538	6030386	92.4
S24 - a	738412	6031757	90
O27 - a	734798	6034111	90
O26 - a	734163	6033205	90
U25 - a	740495	6032645	90.9
T22 - a	739891	6029601	100
S21 - a	738909	6028341	100
W22 - a	742119	6029288	100.7
V19 - a	741809	6026604	104.9
AS31 – aa*	764658	6037689	80

*The list of receptors provided by Westwind included two receptors labelled AS31 – a. The second receptor has been labelled AS31-aa above.

Table 9 Assumed garden-fenced areas

Receptor ID	Western bound (Easting, m)	Eastern bound (Easting, m)	Northern bound (Southing, m)	Southern bound (Southing, m)
AD32 - a	749019	749119	6039175	6039075
AA30 - b	746208	746308	6037991	6037891
AA30 - a	746262	746362	6038023	6037923
AD30 - a	749112	749212	6037081	6036981
AA29 - b	745985	746085	6036545	6036445
AA29 - a	745996	746096	6036616	6036516
AC26 - a	748787	748887	6033937	6033837
AF30 - a	751337	751437	6037435	6037335
AE30 - a	750747	750847	6037182	6037082
AH29 - a	753645	753745	6037017	6036917

As discussed in Section 2.4, garden-fenced areas have only been defined within a 1600 m study area. As per the Draft National Guidelines, shadow flicker is not expected to occur outside this area.

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