Hexham Wind Farm

Shadow flicker assessment

E310478
22 May 2025

Prepared by Hydro-Electric Corporation ABN48 072 377 158

t/a Entura, Level 8, 530 Collins Street, Melbourne VIC 3000, Australia

We own. We operate. We consult.

Document information

Title	Hexham Wind Farm
	Shadow flicker assessment
Client organisation	Hexham Wind Farm Pty Ltd
Client contact	Mikhaela Gray
Document number	TR01-E310478
Project manager	Daniel Bennett
Project reference	P519456

Revision history

Revision 5

Revision description	Updated layout		
Prepared by	Daniel Bennett	On file	21/05/2025
Reviewed by	Andrew Wright	On file	22/05/2025
Approved by	Daniel Bennett	On file	22/05/2025
	(name)	(signature)	(date)
Distributed to	Mikhaela Gray (name)	Hexham Wind Farm Pty Ltd (organisation)	22/05/2025 (date)

Rev	Date	Revision Description	Prepared by	Reviewed by	Approved by
4	21/02/2025	Updated layout	LMcK, DB	AW	DB
3	8/11/2024	Reference update for final Environmental Effects Statement (EES) Scoping Requirements	LMcK	DB	DB
2	23/06/2024	Update based on Technical Reference Group (TRG) and client feedback	LMcK	DB	CB
1	15/03/2023	Update based on client feedback	DB	DB	CB
0	10/03/2023	Original issue	LMcK, AW	DB	AW

Contents

Appendices

List of figures

No table of figures entries found.

List of tables

Executive summary

Entura was engaged to undertake an independent assessment of shadow flicker for the proposed Hexham Wind Farm (the Project) by Hexham Wind Farm Pty Ltd (the Proponent). This shadow flicker assessment addresses the Scoping Requirements for the Project [1] that are relevant to impacts as part of an Environment Effects Statement (EES), as required under the *Environment Effects Act 1978.*

Shadow flicker modelling was carried out for the proposed Hexham Wind Farm located approximately 15 kilometres west of Mortlake and approximately 15 kilometres north-east of Woolsthorpe in the Moyne Shire of south-west Victoria.

Compliance has been assessed against the requirements of the Planning Guidelines for Development of Wind Energy Facilities [2], primarily:

> *"The shadow flicker experienced immediately surrounding the area of a dwelling (garden-fenced area) must not exceed 30 hours per year as a result of the operation of the wind energy facility."*

This limit is applicable for dwellings where there is no agreement with the Project proponent (*non-stakeholder receptors*). Where the landowner has consented to permit shadow flicker durations greater than the limit (*stakeholder receptor*), the aforementioned limit does not apply. Entura understands that the Proponent will commit (via legal agreement) to ensure actual shadow flicker post-construction at stakeholder receptors will not exceed the limits of the Planning Guidelines.

At the proposed Hexham Wind Farm, the theoretical modelled shadow flicker duration results (within 50 m, representing garden fenced area) predict:

- All non-stakeholder receptors are compliant, with two (2) **non-stakeholder receptors** predicted to receive some shadow flicker, of between 15 and 30 hours per year.
- Twenty-four (24) **stakeholder receptors** would receive some shadow flicker, of which twenty-one (21) receive greater than 30 hours, and three (3) receive less than 30 hours per year.

Thus, Hexham Wind Farm is compliant with the regulations at the modelled level of shadow flicker, without considering the effect of management measures.

It is noted the annual shadow flicker duration experienced at receptors is usually significant less than the modelled maximum due to factors including cloudy skies, rotor direction that is not perpendicular to the sun, stationary wind turbine rotors, and vegetation screening.

An assessment of the effect of cloud cover on expected actual shadow flicker duration demonstrated a significant reduction in hours. Data from several local Bureau of Meteorology stations was used to assess the coverage across the sky of cloud cover as percentage of each month and year. The results show a decrease of shadow flicker hours from the theoretical model of 63% for all receptors. Actual shadow flicker experienced when other factors are considered (as described above) is likely to be lower again.

An impact assessment based on the Scoping Requirements indicates the residual impacts of shadow flicker are assessed to be very low for the Hexham Wind Farm. Management measures such as screening (vegetation or artificial) or selective turbine control and shutdown could be used to significantly mitigate any issues raised if recorded data exceeds guidelines, agreements and/or modelled data.

As shadow flicker is an amenity issue, even at modelled levels demonstrating compliance, there is the potential for causing annoyance in exceptional cases. This may be pre-emptively mitigated by offering vegetation screening to those with identified shadow flicker occurrence that are not involved (via agreement) landowners, as well as those up to 1 km beyond the modelled shadow flicker range.

If there are issues raised with respect to shadow flicker following the project's operations start, or measured data shows a shadow flicker duration exceeding the modelled maximum, monitoring of this issue and mitigation measures should be employed to ensure compliance is achieved.

Blade glint should be mitigated by the application of a low reflectivity treatment on the wind turbine blades, a standard feature offered by all major wind turbine manufacturers. The residual impact will be negligible.

1. Introduction

Entura was engaged to undertake an independent assessment of shadow flicker for the proposed Hexham Wind Farm (the Project) by Hexham Wind Farm Pty Ltd (the Proponent). This report documents the findings of that assessment.

This shadow flicker assessment addresses the Scoping Requirements for the project that are relevant to visual impacts as part of an Environment Effects Statement (EES) [1], as required under the *Environment Effects Act 1978*. The report also supports the planning permit application for the project, as required under the *Planning and Environment Act 1987*.

Fundamentally, the rotating blades of wind turbines can cast intermittent shadows to a person located in the shadow of the wind turbine – termed shadow flicker. Because wind turbines are tall structures, shadow flicker can be observed at considerable distances but usually only for a brief time (a matter of a few hours a year) at any given location. Even though its duration is brief, ongoing exposure to shadow flicker can cause annoyance, and thus needs to be shown to comply with relevant standards and the Scoping Requirements. This is the basis and purpose for this assessment.

2. EES Scoping Requirements

The following EES Scoping Requirements evaluation objective is relevant to the shadow flicker assessment:

> ***4.3 Landscape and Visual:*** *Avoid and, where avoidance is not possible, minimise and manage potential adverse effects on landscape and visual amenity.*

The aspects from the Scoping Requirements relevant to shadow flicker evaluation objectives are shown in Table 2.1, as well as the location where these items have been addressed in this report.

Table 2.1: EES Scoping Requirements

Category	Requirement relevant to shadow flicker assessment	Sections of this document addressing this requirement
Key issues	*Potential for nearby residents/communities to be exposed to significant effects to the visual amenity, including blade glint and shadow flicker, from project infrastructure.*	Section 4, 7, 8
Existing environment	*Identify the components of the project that may result in a significant visual amenity effect.*	Section 6, 7.1
Likely effects	*Assess the landscape and visual effects of the project, including on public and private views, and effects of blade glint and shadow flicker on neighbouring dwellings and communities. Use photomontages, maps and other visual techniques to support the assessment.*	Section 7
	Assess the potential for cumulative impacts associated with the development of the project in the context of existing built infrastructures and nearby proposed/approved wind farm developments	Section 7.5
Design and mitigation	*Outline and evaluate any potential design and siting options that could avoid and minimise potential effects on landscape and visual amenity of neighbouring residences and communities and additional management strategies that may further minimise potential effects.*	Section 7.2, 7.6
Performance	*Describe contingency measures to be implemented in the event of unforeseen adverse residual effects on landscape and visual amenity are identified requiring further management.*	Section 8

3. Project description

Hexham Wind Farm Pty Ltd (the Proponent) is developing the proposed Hexham Wind Farm (the Project) in Moyne Shire, Victoria. The project will harness strong and reliable winds to generate renewable energy through the construction and operation of up to 106 wind turbine generators with a maximum tip height of 260 metres, maximum rotor diameter up to 190 metres and minimum tip height of 40 metres. The proposed blade length would be up to 93 metres.

The wind farm would operate for a period of at least 25 years following a two-year construction period. The wind farm would generate approximately 2,559 gigawatt hours (GWh) of renewable electricity each year. Electricity produced by the project would be fed through underground and overhead cables to a new on-site terminal station, where it would be exported to the national electricity network via the Moorabool to Heywood 500 kilovolt transmission line.

The project extends across approximately 16,000 hectares of private and public land located between the townships of Hexham, Caramut and Ellerslie in south-western Victoria. The main land use within the project site is agricultural (predominantly cattle and sheep grazing, along with some cropping). Much of the area has been cleared of native vegetation with remnant vegetation largely restricted to roadside reserves and along watercourses, with small, isolated areas on private land.

Other project infrastructure would include:

- a 200 Megawatt (MW) /800 Megawatt-hour (MWh) battery energy storage system (BESS).
- an operations and maintenance (O&M) facility, consisting of site offices and amenities.
- up to five meteorological masts, to be in place for the life of the project.
- a main temporary construction compound, consisting of office facilities, amenities and car parking. Three additional temporary construction compounds are also planned.
- up to 26 temporary staging areas.

Within 12 months of wind turbines permanently ceasing to generate electricity (assuming the turbines are not repowered), the wind farm would be decommissioned. This would include removing all above ground equipment, restoration of all areas associated with the project, unless otherwise useful to the ongoing management of the land, and post-decommissioning revegetation with pasture or crop (in consultation with and as agreed with the landowner).

4. Legislation, policy and guidelines

This assessment addresses the Scoping Requirements for the project [1] that are relevant to shadow flicker impacts as part of an Environment Effects Statement (EES), as required under the *Environment Effects Act 1978*. The report also supports the planning permit application for the project, as required under the *Planning and Environment Act 1987*.

In Victoria, the Department of Transport and Planning's *Planning Guidelines for the Development of Wind Energy Facilities* [2] indicates:

"The shadow flicker experienced immediately surrounding the area of a dwelling (garden-fenced area) must not exceed 30 hours per year as a result of the operation of the wind energy facility."

This limit is applicable for dwellings where there is no agreement with the Project (*non-stakeholder receptors*). Where the landowner has consented to permit shadow flicker durations greater than the limit (*stakeholder receptor*), the aforementioned limit does not apply.

Entura understands that the Proponent will commit (via legal agreement) to ensure actual shadow flicker post-construction at stakeholder receptors will not exceed the limits of the Planning Guidelines.

The Victorian Planning Guidelines do not specify a method of assessment. Entura has followed the Draft National Wind Farm Development Guidelines [3]. These guidelines are based on a worldwide review of existing shadow flicker assessment methods and are considered a 'good-practice' approach to the issue of analysing wind farm shadow flicker.

This methodology includes:

- An assessment area defined by a radial distance of 265 multiplied by the maximum blade chord[1].
- Theoretical annual shadow flicker duration calculated through modelling for each dwelling within the assessment area (as provided by HWF).
- A limit of 30 hours per year of theoretical shadow flicker when using conservative modelling assumptions.
- A limit of 10 hours per year of actual observed shadow flicker, noting that because of the conservatism in the modelling, where 'modelled' shadow flicker is less than 30 hours, the actual exposure limit is assumed to be met.

5. Literature review

Rotating wind turbine blades in the presence of direct sunlight cast intermittent shadows, referred to as 'shadow flicker', which can cause annoyance and reduced visual amenity for those exposed to shadows.

Australian best practice guidelines for the modelling and mitigation of shadow flicker have been developed from consideration of international guidelines, limits and regulations [3]. They specify a maximum modelled limit of 30 hours per year of shadow flicker experienced in the area of a dwelling (within 50 metres) and an actual limit of 10 hours following the start of operation of a wind farm facility, limits which follow international best practice [4].

While these limits have been used and applied to wind farm developments in Australia for over a decade [3], there is a limited body of evidence of the effects which drives shadow flicker impact and the degree to which 'annoyance' or feeling of displeasure is heightened as a result. Several studies have found the potential impact to human health of shadow flicker is an unlikely risk including to the potential of occurrences for seizures due to photosensitivity [5, 6, 7]. These have concluded the impact is mostly due to subjective 'annoyance'.

A recent study of 35,000 residences and 61 wind projects in the United States found shadow flicker annoyance (subjective) was not significantly correlated to shadow flicker exposure (objective, hours per day, or hours per year) [8]. The degree of annoyance assessed in the study was most closely correlated to negative feelings towards wind farm aesthetics, annoyance to other human activities in and around the wind development particularly related to noise, whether the resident had moved in after the wind farm was built, resident's level of education and the age of the respondent. Conclusions from this study suggest that rather than exceeding a prescribed duration of shadow flicker exposure, actual annoyance is more correlated with other sensitivities of residents. Noise levels were found to be a potential proxy of shadow flicker annoyance and, therefore, by minimising noise levels at receptors, which is also closely associated with distance from the nearest wind turbine, shadow flicker subjective annoyance and impact can also be minimised.

These findings are also supported by an earlier study which included the results of interviews with more than 1200 participants who lived within 0.25 km and 11.22 km of an operational wind farm in Canada [9]. This identified a low correlation between modelled shadow flicker and high annoyance levels. While

[1] The distance from the trailing edge of the blade to the leading edge of the blade, typically the longest dimension of the blade cross-section.

a high degree of uncertainty remained, the study found factors such as personality types, attitudes towards to wind farms and the level of community engagement between developers and the community were more likely to have a higher correlation with levels of annoyance than modelled or actual shadow flicker hours.

Therefore, annoyance due to shadow flicker, the impact of which is predominantly limited by current guidelines minimising the actual hours experienced, is shown in the body of research to correlate with more subjective elements which can be unrelated to the amount or level of shadow flicker occurring. This suggests that additional approaches which may limit impacts including maximising the distance of receptors to the nearest wind turbine, improving wind farm aesthetics where possible, developers engaging with community members to limit potential general annoyance, and providing information on actual shadow flicker to be experienced at a dwelling for new residents.

6. Methodology

6.1 Study area

The study area included all dwellings identified within a 5 km radius of the project site boundary.

In order to assess for any potential cumulative impacts, a wider region, within 30 km of the project site, was considered to enable identification of the nearest operating or proposed wind farms.

6.2 Impact assessment method

The method of assessment of the impact of shadow flicker is to demonstrate compliance with the 30-hour annual limit given in the Victorian Planning Guidelines, taking guidance from the Draft National Wind Farm Guidelines, as discussed in Section 4.

Entura has used the GL-Garrad Hassan WindFarmer 5.2.11 software package to model the maximum occurrence of shadow flicker at receptors within and immediately around the HWF development site using the following technical details in Table 6.1, as provided by the Proponent.

Table 6.1: Technical specifications of the proposed wind turbine

Number of WTGs	Hub Height [m]	Max Rotor Diameter [m]	Lower Tip Height [m]	Max Tip Height [m]	Max Blade Chord [m]
106	165	190	40	260	5.5

In completing this analysis, Entura has used the following additional inputs, supplied by the Proponent:

- Shapefiles of the following project elements:
    - Site boundaries (BOU_HXM_v024.shp)
    - Dwellings (LAN_HXM_Dwellings_v049_a.shp). Coordinates provided in Appendix A.1
    - Wind turbine locations (WTG_HXM_V162-6_8_v183.shp). Coordinates provided in Appendix A.2
- Terrain contour file (ELE_HXM_v003.shp). 1 m contour heights.

As the 'garden-fenced area' is not defined in the Victorian guidelines, or typically evident in the rural setting, the guidance in the Draft National Wind Farm Development Guidelines of identifying the highest value of shadow flicker within 50 m of the receptor is taken as a reasonable proxy for this area.

The modelling parameters and settings in Table 6.2 show the recommendations of the Draft National Wind Farm Development Guidelines in the centre column, and the corresponding values used in this analysis in the right-most column.

Table 6.2: Shadow flicker modelling parameters

Model parameter	**Setting required by the Draft National Guideline**	**Value**
Zone of influence of shadows	265 x maximum blade chord	1458 m
Minimum angle to the Sun	3 degrees	3 degrees
Shape of the Sun	Disk	Disk
Time and duration of modelling	One full year representing a non-leap year 12 to 15 years after the date of DA submission	The year 2038
Orientation of the rotor	Sphere or disk facing the Sun	Disk[2]
Offset between rotor and tower	Not required	-
Time step	10 minutes or less	5 minutes
Effects of topography	Include	Include
Receptor height	1.5 – 2 m	2 m
Receptor location	A map should be provided, and the highest level of annual shadow flicker reported.	Appendix B and Table 7.1 50 m radius from dwelling centre point is included to account for 'garden fenced area'
Grid size for mapping and assessment of shadow flicker at a receptor location.	Not more than 25 m	25 m

Table 6.3 summarises the key wind turbine geometry parameters input into the model.

[2] Sphere and disk facing the sun are generally equivalent and neither consider wind direction. Wind direction analysis is a mitigating measure and results in a lower 'actual' limit according to the guidelines.

Table 6.3: Wind turbine modelling parameter inputs

Model parameter	Value
Wind turbine generator type	Not specified
Maximum blade chord	5.5 m
Hub height	165 m (for effective maximum tip height of 260 m)
Rotor diameter	190 m

The actual observed shadow flicker at receptors in practice is reduced by the following factors:

- If the sun is blocked by cloudy skies, wind turbines do not cast pronounced shadows.
- When the wind turbine rotor is not oriented perpendicular to the line between the sun and the receptor, the region of shadow flicker is thinner than modelled, and may not therefore be cast over the receptor.
- When the wind turbine is not rotating due to low wind or during maintenance, no moving shadows will be cast and no shadow flicker would occur.
- If the wind turbine is screened by vegetation or other structures the amount of shadow flicker at the receptor will be reduced.

Adjustments to the modelling can be made to produce an estimate of the actual duration of shadow flicker. The results incorporating cloud cover mitigation are given in Section 7.4.1.

7. Impact assessment

7.1 Impact pathway

7.1.1 Shadow flicker

Rotating wind turbine blades can cast intermittent (flickering) shadows to a person located in the shadow of the blades of the wind turbine. Because wind turbines are tall structures, shadow flicker can be observed at considerable distances, for a short time when the sun is low on the horizon (generally less than 30 minutes per day). Ongoing exposure to shadow flicker throughout the year can cause annoyance, and thus needs to be shown to comply with relevant standards.

The Draft National Wind Farm Guidelines identify that the key impact of shadow flicker is the annoyance of residents. They state that these impacts are most closely associated with the duration of shadow flicker experienced above a certain intensity (the contrast in light level from alternating between shadow and no shadow), which decreases with distance from the source. The guideline’s methodology limits the assessment to ‘moderate’ levels of intensity, for which an annual exposure beyond the specified limit is considered an impact.

It is noted that findings in the observational studies discussed in Section 5 point to annoyance impact being extremely subjective, and potentially unrelated to the amount, intensity, or duration of actual shadow flicker occurring at a receptor. As such, there is the potential that impacts could be reported beyond the extent of the modelling at locations receiving shadow flicker at intensity or durations below those generally accepted as causing annoyance (the guideline basis). This would be considered an exceptional case.

The Draft National Wind Farm Guidelines also comment on other suggested impacts and determine that the risk of impact is negligible and does not require assessment. These include annoyance of land users other than residents, distraction of vehicle drivers, and initiation of epileptic seizures.

Shadow flicker varies season to season and will be experienced differently by receptors in different, sometimes opposing seasons or times of day. This is dependent upon sun angle, direction to the turbine casting the shadow, cloud cover, weather and seasonal climate in any given year.

7.1.2 Blade glint

Blade glint can be produced when the sun's light is reflected from the surface of wind turbine blades. Blade glint has potential to annoy people.

7.2 Design mitigation

7.2.1 Shadow flicker

The Proponent has developed the layout of the wind farm taking account of the duration of the occurrence of shadow flicker at receptors to the extent practical, through iterative modelling of shadow flicker to test the effect of layout modifications on impacts.

Additionally, the wind turbine parameters assumed for modelling (Table 6.3) are the worst-case envelope values, and the actual turbine selected to be installed may be smaller and hence have a lower impact than modelled.

7.2.2 Blade glint

Blade glint can potentially be produced when the sun's light is reflected from the surface of wind turbine blades.

As discussed in the Draft National Wind Farm Development Guidelines [3], all major wind turbine blade manufacturers currently finish their blades with a low reflectivity treatment. This prevents a potentially annoying reflective glint from the surface of the blades and the possibility of a strobing reflection when the turbine blades are spinning.

Therefore, the expected impact of blade glint from a new development is negligible.

7.3 Modelled shadow flicker

The results of the modelling at receptors with non-zero hours duration predicted are detailed in Table 7.1, with figures for a maximum duration of shadow flicker within a 50-metre radius of the receptor (representative of the 'garden fenced area'). The distribution of shadow flicker annual totals is shown across the site in the map in Appendix B.

Involvement key:

S Stakeholder dwelling

NS Non-stakeholder dwelling

Table 7.1: Modelled shadow flicker duration within 50 m of receptors predicted to experience shadow flicker

Receptor (House) ID	Involvement	Duration (hours per year)	Shadow flicker compliance
D32	S	**41**	Exceeding (>30 hours/year)
D34	S	**45**	Exceeding (>30 hours/year)
D35	S	**30**	Not exceeding
D343	S	**68**	Exceeding (>30 hours/year)
D344	S	**27**	Not exceeding
D357	S	**92**	Exceeding (>30 hours/year)
D361	S	**37**	Exceeding (>30 hours/year)
D366	S	**88**	Exceeding (>30 hours/year)
D378	S	**46**	Exceeding (>30 hours/year)
D380	S	**163**	Exceeding (>30 hours/year)
D397	S	**71**	Exceeding (>30 hours/year)
D417	S	**55**	Exceeding (>30 hours/year)
D418	S	**98**	Exceeding (>30 hours/year)
D422	S	**68**	Exceeding (>30 hours/year)
D423	S	**72**	Exceeding (>30 hours/year)
D438	S	**214**	Exceeding (>30 hours/year)
D297	S	**38**	Exceeding (>30 hours/year)
D441	S	**83**	Exceeding (>30 hours/year)
D442	S	**44**	Exceeding (>30 hours/year)
D448	S	**51**	Exceeding (>30 hours/year)
D197	S	**25**	Not exceeding
D428	S	**47**	Exceeding (>30 hours/year)
D429	S	**41**	Exceeding (>30 hours/year)
D430	S	**40**	Exceeding (>30 hours/year)
D620	NS	**29**	Not exceeding
D622	NS	**20**	Not exceeding

Red represents exceeding compliance duration (> 30 hours per year), orange represents complying (11 to 30 hours per year).

At the proposed Hexham Wind Farm, the theoretical modelled shadow flicker duration results (within 50 m, representing garden fenced area) predict:

- All non-stakeholder receptors are compliant, with two (2) non-stakeholder receptors predicted to receive some shadow flicker, of between 15 and 30 hours
- Twenty-four (24) stakeholder receptors would receive some shadow flicker, of which twenty-one (21) receive greater than 30 hours, and three (3) receive less than 30 hours

Based on the modelling the proposed wind farm is compliant with the Victorian Planning Guidelines [2] without the need to consider the actual levels of shadow flicker, or further mitigation measures.

7.4 Actual shadow flicker

There are several environmental and operational factors which mitigate or reduce the occurrence of shadow flicker and which are not considered in the theoretical modelling, including:

- **Wind turbine orientation and operation**: The modelling used to produce the results in Table 7.1 considered the turbine blades and hub as a sphere - facing all directions at all times – and considers the wind to be blowing sufficiently to cause the blades to spin constantly. Any shadow flicker modelled to theoretically occur is therefore considered 'worst case' or noticeable, and always cast toward receptors. In reality, there will be times when the direction of the wind will change the orientation of blades, and times when the blades are not spinning.
- **Aerosols:** Atmospheric solid, liquid or vapour particles such as dust, moisture, pollution or smoke can significantly reduce shadow flicker by causing dispersion of sunlight through the atmosphere, reducing the intensity of shadows.
- **Screening:** Vegetation or other natural or anthropogenic features may screen shadow flicker.
- **Cloud cover:** Cloud cover in the area blocking sunlight is not factored into the results presented in Table 7.1, but is assessed in Section 7.4.1 below.

7.4.1 Cloud cover affecting shadow flicker duration

The results presented in Section 7.2 are modelled on conditions ideal for creating shadow flicker (full sun, constant operation, etc.), however, there are several practical and limiting conditions which were not factored into the modelling. These include the orientation of the wind turbine, presence of aerosols such as moisture and dust, modelling considering wind turbines as spheres rather than individual components, and operational downtime due to low wind, curtailment, or maintenance.

One of the most significant conditions is cloud cover and the resulting reduction in shadow flicker. Cloud cover is reported in 'oktas', or eighths of the sky covered in cloud disregarding cloud thickness or height, and the Bureau of Meteorology (BoM) ground stations typically measure these at 9am and 3pm daily. Entura has averaged these values to obtain an average cloud cover across the day.

The local station data used by Entura to assess this effect is summarised in Table 7.2, noting that Terang VIC (090077) data was excluded due to only one recording per day, but is shown as a comparison with similar results compared to the other sites.

Table 7.2: BoM station cloud cover data obtained

ID	Station Name	Distance from Project	Average monthly cloud cover range	Average annual cloud cover
090077	Terang	35 km southeast	54 – 66 % (9 am only, excluded)	61 % (9am only, excluded)
089018	Lismore (Post Office)	65 km east	46 – 70 %	63 %
090173	Hamilton Airport	65 km northwest	48 – 70 %	62 %
090176	Mortlake Racecourse	20 km east	Cloud cover not recorded	N/A

While the effect of cloud cover is an estimation and not recorded in data at a high temporal or spatial resolution, given its influence and frequency it is considered reasonable to reduce the shadow flicker duration by the annual proportion of cloudy days.

In this analysis, Entura have used the annual averages of the two closest BoM stations with regular morning and afternoon cloud cover data (Lismore Post Office and Hamilton Airport), equating to a 63% cloud cover on average.

Table 7.3: Annual shadow flicker duration mitigated by cloud cover, within 50 m of receptors predicted to experience shadow flicker

Receptor (House) ID	Involvement	Duration (theoretical) (Hours per year)	Duration reduced by average annual cloud cover (Hours per year)
D32	S	41	15
D34	S	45	17
D35	S	30	11
D343	S	68	26
D344	S	27	10
D357	S	92	35
D361	S	37	14
D366	S	88	33
D378	S	46	17
D380	S	163	61
D397	S	71	27
D417	S	55	21
D418	S	98	37
D422	S	68	26

D423	S	72	27
D438	S	214	80
D297	S	38	15
D441	S	83	31
D442	S	44	17
D448	S	51	19
D197	S	25	10
D428	S	47	18
D429	S	41	16
D430	S	40	15
D620	NS	29	11
D622	NS	20	8

Red represents exceeding compliance duration (> 30 hours per year), orange represents complying (11 to 30 hours per year), green represents complying (0 – 10 hours per year).

As discussed earlier, additional mitigating effects that have not been assessed will further reduce actual shadow flicker experienced, and hence the values above are considered conservative estimates of resulting actual duration.

7.5 Cumulative impact

No cumulative shadow flicker impact is expected to occur as a result of the Project.

Based on publicly available information[3], the nearest proposed or operating wind turbine (which is located at the proposed Mount Fyans Wind Farm) is greater than 10 km from any HWF wind turbine location. As such, no dwelling would be within the extent of the modelled shadow flicker area of both wind farms, by a significant margin, and hence would not receive cumulative shadow flicker.

7.6 Management measures

Mitigating measures to reduce shadow flicker involves either eliminating the rotation of blades or screening to block the shadows themselves.

Screening and blocking the shadow flicker is a mitigation measure which usually involves vegetation or permanent or temporary constructed screening close to a receptor to block incoming shadow flicker. This can be an effective management and mitigation measure.

Wind turbine control strategies are an additional method of reducing the shadow flicker to within the hours of compliance. This involves both hardware (sensors) and software (control systems) to shut down specific wind turbines when shadow flicker duration is expected to be exceeded. Light sensors at the wind turbine tower, typically installed on the nacelle, detect the intensity and direction of light and

[3] VicPlan, Wind Energy Facilities – Operating, Approved and Under Consideration, https://mapshare.vic.gov.au/vicplan/ retrieved on 21/05/2025

coupled with locational data can communicate with a control system to predict when specific locations (receptors) will have prominent shadow flicker or levels exceeding the maximum. This information is then used in a control system or by an operator to shutdown specific turbines for the duration of shadow flicker predicted by the system to eliminate the flickering effect. Shadows may still be cast at a sensitive location, but no impact of rotating blades will be observed.

Once operational, if measured shadow flicker is recorded above the 10-hour limit per year at non-stakeholder receptors, mitigation measures described above may be required.

As shadow flicker is an amenity issue, even at modelled levels demonstrating compliance, there is the potential for causing annoyance in exceptional cases. This may be pre-emptively mitigated by offering vegetation screening to those with identified shadow flicker occurrence that are not involved (via agreement) landowners, as well as those up to 1 km beyond the modelled shadow flicker range.

7.7 Assessment of residual impacts and effects

As the modelled shadow flicker is below the limits specified in planning guidelines, the impact is assessed to be **very low** for the Project.

The following Table 7.4 summarises these findings in a format consistent with the Environmental Effects Statement (EES).

Table 7.4: Significance of shadow flicker and blade glint impact rating

Value	Impact Pathway	Project phase	Mitigation and management measures	Residual impact (considering magnitude, extent and duration)	Significance rating and justification
Receptors (dwellings) - Non-stakeholder	Shadow flicker due to wind turbine rotation and shadows cast within 50 metres of receptors or sensitive locations.	Commissioning, operation	None specified. Current layout reflects design optimisation to minimise impacts across the site. Refer to Section 7.6 for potential mitigation measures if issues raised or measured data exceeds limits upon the start of operation.	The magnitude, extent and duration of the impact is within the limits of the Victorian Planning Guidelines	**Very Low** The wind farms' modelled annual shadow flicker duration is compliant with the applicable Planning Guidelines for all non-stakeholder dwellings. Mitigating environmental and operating factors further reduce the actual duration of shadow flicker at receptors. Management measures can be put in place
Receptors (dwellings) – stakeholder	Shadow flicker annual duration exceeds guidance limit for annoyance	Commissioning, operation	Detailed communication with potentially impacted stakeholders to understand expected impact. Offer mitigation measures such as screening. Commitment to ensure actual shadow flicker post-construction at stakeholder receptors will not exceed the limits of the Planning Guidelines	The impact may be low-moderate for some receptors.	**Very Low** Mitigating environmental and operating factors further reduce the actual duration of shadow flicker at receptors. Management measures can be put in place

Receptors (dwellings) – exceptional sensitivity	Annoyance or sensitivity to shadow flicker at levels (intensity, duration) below generally accepted (the basis of the guideline)	Commissioning, operation	Refer to Section 7.6 for potential mitigation measures if issues raised. Option for general offer of screening within a given range of 1 km beyond modelled impact.	The magnitude of the impact is low, potentially affecting a small number of residents, for short periods of each year.	**Very Low** Considered an exceptional case. Impact could be mitigated during operation.
Sensitive receivers	Blade glint	Commissioning, operation	Modern wind turbine blades are supplied with low reflectivity treatment	None expected	**Negligible**

8. Monitoring during operation

If complaints were to arise during wind farm operation, the Draft National Wind Farm Guidelines recommend that independent modelling of shadow flicker, using as-constructed turbine positions and dimensions, should be carried out. If this shows non-compliance with the required limit(s), management measures (Section 7.6) should be implemented to achieve compliance.

Where a complainant is not satisfied by the outcome of this approach, an observational study may be recommended, noting that this is difficult and impractical to carry out over a full year. As an alternative, the guidelines propose a single day validation of the model predictions by an independent observer may be performed.

9. Conclusion

This assessment addresses the Scoping Requirements for the Hexham Wind Farm project that are relevant to shadow flicker and blade glint impacts as part of an Environment Effects Statement (EES).

The Hexham Wind Farm is compliant with the Victorian Planning Guidelines at the theoretical modelled level of shadow flicker for the provided 106 turbine layout.

The modelled shadow flicker duration results (within 50 m, representing garden fenced area) predict:

- All non-stakeholder receptors are compliant, with two (2) **non-stakeholder receptors** predicted to receive some shadow flicker, of between 15 and 30 hours per year.
- Twenty-four (24) **stakeholder receptors** would receive some shadow flicker, of which twenty-one (21) receive greater than 30 hours, and three (3) receive less than 30 hours per year.

An impact assessment based on the Scoping Requirements indicates the residual impacts of shadow flicker are assessed to be very low for the Project. Management measures such as screening (vegetation or artificial) or selective turbine control and shutdown could be used post-construction to significantly mitigate any issues raised if recorded data exceeds guidelines, agreements and/or modelled data.

If there are issues raised with respect to shadow flicker following the project's operations start, or measured data shows a shadow flicker duration exceeding the modelled maximum, monitoring of this issue and mitigation measures should be employed to ensure compliance is achieved.

As shadow flicker is an amenity issue, even at modelled levels demonstrating compliance, there is the potential for causing annoyance in exceptional cases. This may be pre-emptively mitigated by offering vegetation screening to those with identified shadow flicker occurrence that are not involved (via agreement) landowners, as well as those up to 1 km beyond the modelled shadow flicker range.

Blade glint should be mitigated by the application of a low reflectivity treatment on the wind turbine blades, a standard feature offered by all major wind turbine manufacturers. The residual impact will be negligible.

10. References

[1] The State of Victoria, Department of Transport and Planning, "Scoping Requirements Hexham Wind Farm Environment Effects Statement," September 2024.

[2] The State of Victoria, Department of Transport and Planning, "Planning Guidelines for Development of Wind Energy Facilities," September 2023.

[3] Environment Protection Heritage Council, "National Wind Farm Development Guidelines," http://www.nepc.gov.au/resource/ephc-archive-future-national-wind-farm-development-guidelines, 2010.

[4] Parsons Brinckerhoff, "Update of UK Shadow Flicker Evidence Base," William Sale Partnership, London, 2011.

[5] G. Harding, P. Harding and A. Wilkins, "Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them," *Epilepsia,* vol. 49, no. 6, pp. 1095-1098, 2008.

[6] L. Knopper, C. Ollson, L. McCallum, M. Whitfield Aslund, R. Berger, K. Souweine and M. McDaniel, "Wind turbines and human health," *Public Health,* vol. 2, no. 1, 2014.

[7] A. Smedley, A. Webb and A. Wilkins, "Potential of wind turbines to elicit seizures under various meteorological conditions," *Epilepsia,* vol. 51, no. 7, pp. 1146-1151, 2010.

[8] R. Haac, R. Darlow, K. Kaliski, J. Rand and B. Hoen, "In the shadow of wind energy: Predicting community exposure and annoyance to wind turbine shadow flicker in the United States," *Energy Research & Social Science,* vol. 87, no. May 2022, pp. 1-16, 2022.

[9] S. Viocescu, D. Michaud, K. Feder, L. Marro, J. Than, M. Guay, A. Denning, T. Bower, F. van den Berg, N. Broner and E. Lavigne, "Estimating annoyance to calculated wind turbine shadow flicker is improved when variables associated with wind turbine noise exposure are considered," *The Journal of the Acoustical Society of America,* vol. 139, pp. 1480-1492, 2016.

Appendices

A Coordinates

A.1 Dwellings

Table A.1: Dwellings coordinates used for shadow flicker receptors

ID	Easting	Northing	Stakeholder
D32	636850	5778945	Yes
D34	637257	5779660	Yes
D35	636378	5781156	Yes
D37	634807	5783584	No
D40	634988	5787652	Yes
D204	639529	5795076	Yes
D295	629557	5789592	No
D298	633627	5787802	Yes
D300	630779	5786797	No
D301	631006	5786667	No
D338	642174	5777409	Yes
D343	639462	5778522	Yes
D344	636841	5778781	Yes
D355	640386	5782525	Yes
D356	637617	5783106	Yes
D357	642347	5783026	Yes
D359	642078	5784531	Yes
D361	639708	5785297	Yes
D366	637867	5786585	Yes
D367	643362	5786992	No
D378	637997	5791680	Yes
D379	638503	5792638	Yes
D380	639676	5792323	Yes
D395	638601	5793314	Yes

D396	638160	5792382	Yes
D397	637086	5789899	Yes
D398	641799	5789551	Yes
D402	644056	5789694	No
D403	645039	5792149	Yes
D414	630743	5786843	No
D417	635962	5784411	Yes
D418	644469	5779694	Yes
D422	637552	5786570	Yes
D423	637533	5786478	Yes
D424	643204	5786989	No
D425	643113	5787489	No
D426	643081	5787386	No
D432	644587	5776701	No
D438	638164	5779757	Yes
D206	644686	5793854	Yes
D297	631265	5787970	Yes
D441	637189	5789832	Yes
D442	637035	5789854	Yes
D444	641877	5789629	Yes
D446	639602	5777711	Yes
D447	642135	5777506	Yes
D448	642462	5787298	Yes
D465	643621	5776878	No
D477	642401	5776118	No
D478	644468	5794331	Yes
D36	635828	5780862	No
D38	634118	5783402	Yes
D39	634133	5784996	No
D197	634878	5793424	Yes
D208	645490	5793469	Yes
D294	630677	5788818	No
D296	630352	5791247	No
D299	633385	5786842	No

D336	643539	5776846	No
D337	641824	5776994	No
D339	639742	5776991	No
D340	636785	5777078	Yes
D341	636588	5778086	No
D345	636747	5779043	No
D404	638575	5794136	No
D413	636197	5782273	No
D419	639519	5777423	No
D420	639580	5777057	No
D421	639514	5777286	No
D428	634915	5793690	Yes
D429	634807	5793806	Yes
D430	634802	5793733	Yes
D431	644165	5776780	No
D435	645609	5779492	No
D436	645648	5778690	No
D437	640471	5777187	No
D445	641380	5794784	No
D205	640481	5794744	No
D362	639380	5784803	Yes
D620	641579	5779470	No
D622	640002	5779485	No

Coordinates in GDA2020, MGA Zone 54

A.2 Wind turbines

Table A.2: Wind turbine coordinates – Layout v183

Turbine ID	Easting	Northing	Turbine ID	Easting	Northing
T1	631862	5789892	T56	638618	5779397
T2	632200	5788753	T57	639187	5786346
T3	632333	5790112	T58	639084	5787185
T4	633171	5788889	T59	639221	5788428
T5	632443	5789164	T60	639230	5791268

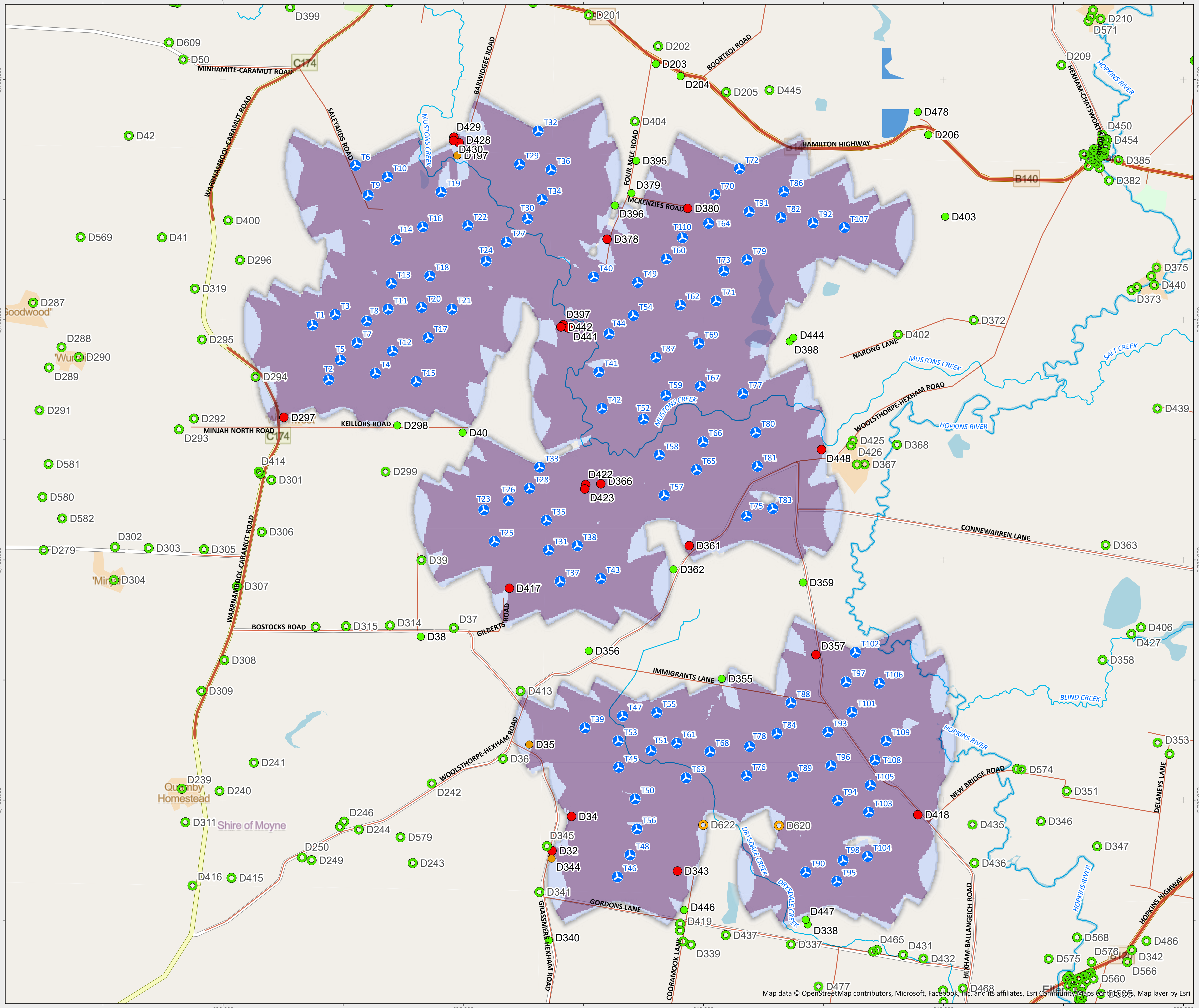
T6	632757	5793217	T61	639448	5781185
T7	632789	5789521	T62	639523	5790309
T8	632990	5789976	T63	639642	5780462
T9	633021	5792595	T64	640111	5792009
T10	633424	5792977	T65	639861	5786879
T11	633436	5790223	T66	639995	5787460
T12	633526	5789350	T67	639941	5788617
T13	633505	5790760	T68	640139	5781006
T14	633600	5791667	T69	639911	5789511
T15	634023	5788719	T70	640243	5792613
T16	634158	5791938	T71	640267	5790395
T17	634274	5789629	T72	640754	5793147
T18	634305	5790915	T73	640430	5791017
T19	634541	5792663	T75	640904	5785913
T20	634134	5790261	T76	640902	5780505
T21	634766	5790223	T77	640826	5788463
T22	635097	5791963	T78	640967	5781114
T23	635429	5786042	T79	640910	5791252
T24	635477	5791222	T80	641092	5787655
T25	635650	5785388	T81	641126	5786951
T26	635943	5786238	T82	641620	5792130
T27	635899	5791618	T83	641447	5786069
T28	636381	5786493	T84	641535	5781388
T29	636175	5793239	T86	641679	5792672
T30	636339	5792104	T87	639013	5789221
T31	636775	5785204	T88	641827	5782024
T32	636561	5793934	T89	641865	5780489
T33	636593	5786933	T90	642134	5778497
T34	636646	5792503	T91	640955	5792252
T35	636732	5785827	T92	642286	5792020
T36	636831	5793126	T93	642595	5781417
T37	637019	5784553	T94	642799	5779990
T38	637377	5785295	T95	642781	5778309
T39	637536	5781503	T96	642662	5780714

T40	637717	5790893	T97	642975	5782460
T41	637825	5788915	T98	642912	5778743
T42	637891	5788158	T101	643098	5781831
T43	637866	5784612	T102	643169	5783075
T44	638038	5789709	T103	643445	5779748
T45	638239	5780683	T104	643421	5778825
T46	638212	5778399	T105	643480	5780308
T47	638320	5781750	T106	643666	5782434
T48	638475	5778854	T107	642941	5791923
T49	638634	5790779	T108	643576	5780833
T50	638580	5780023	T109	643809	5781229
T51	638914	5781027	T110	639566	5791709
T52	638753	5787932			
T53	638227	5781232			
T54	638544	5790092			
T55	639032	5781819			

Coordinates in GDA2020, MGA Zone 54

This page is intentionally blank.

B Shadow flicker map



Hexham Wind Farm
Shadow Flicker Assessment – Theoretical modelled hours

Client:	Hexham Wind Farm Pty Ltd
Map no:	E312044 - P520986
Date:	Monday, 19 May 2025
Drawn:	Agung Wahyudi
Reviewed:	Lachlan McKenna
Approved:	Daniel Bennett

Map Legend:

WTG

Shadow Flicker (hours/year)

1 - 30

>30

Maximum Flicker Received by Stakeholder Dwelling (hours/year)

0.00

0.01 - 15.00

15.01 - 30.00

>30.00

Maximum Flicker Received by Non-stakeholder Dwelling (hours/year)

0.00

15.01 - 30..00

Public Roads ManagedBy

Public road - VicRoads

Public road - council

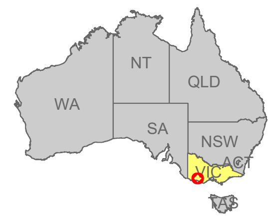
N

0 0.5 1 1.5 2 2.5 km

1:75,000 @ A3 paper size

Coordinate System: GDA2020 MGA Zone 54

Locality:



WE OWN. WE OPERATE. WE CONSULT.

We own.
We operate.
We consult.

entura

entura.com.au