Kalgoorlie Wind Farm

Shadow Flicker Impact Assessment

Northern Star Resources

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The Power of Commitment

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S3	B	R.Njowa	C.Deans		M.Lee		04/07/2025

GHD Pty Ltd | ABN 39 008 488 373
145 Ann Street, Level 9
Brisbane, Queensland 4000, Australia
T +61 7 3316 3000 | **F** +61 7 3319 6038 | **E** bnemail@ghd.com | **ghd.com**

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1. Introduction

GHD Pty Ltd (GHD) was engaged by Northern Star Resources (NSR) to undertake an updated shadow flicker impact assessment for a potential wind farm being considered near Kalgoorlie mine, Western Australia. The assessment involved simulating the shadow flicker impact on the project footprint area and the surrounding area, particularly on the neighbouring proposed solar farm.

A separate study is being conducted to assess the impact of static shading from the wind farm on the solar farm.

1.1 Purpose of this report

The purpose of this report is to assess the potential shadow flicker impacts caused by the proposed wind farm on the proposed solar farm[1] located nearby. As no sensitive receptors have been identified nearby the wind farm, this study does not investigate regulatory compliance.

1.2 Project overview

The proposed Kalgoorlie Wind Farm is located approximately 13 km northeast of Kalgoorlie and 560 km northeast of Perth, Western Australia. The proposed wind farm consists of 33 Goldwind wind turbine generators (WTGs) with a rotor diameter of 182 m, hub height of 150 m AGL and a nominal capacity of 6.2 MW or 7.2 MW (TBC), to achieve a nameplate installed capacity of 204.6 MW or 237.6 MW respectively. The layout and turbine characteristics for the proposed wind farm were provided by NSR.

The wind turbine capacity and power curve does not affect the shadow flicker study; therefore, the results of this study are valid for either the 6.2 MW or 7.2 MW WTG.

Coordinates of the proposed wind turbines modelled in this assessment are given in Appendix A of this report.

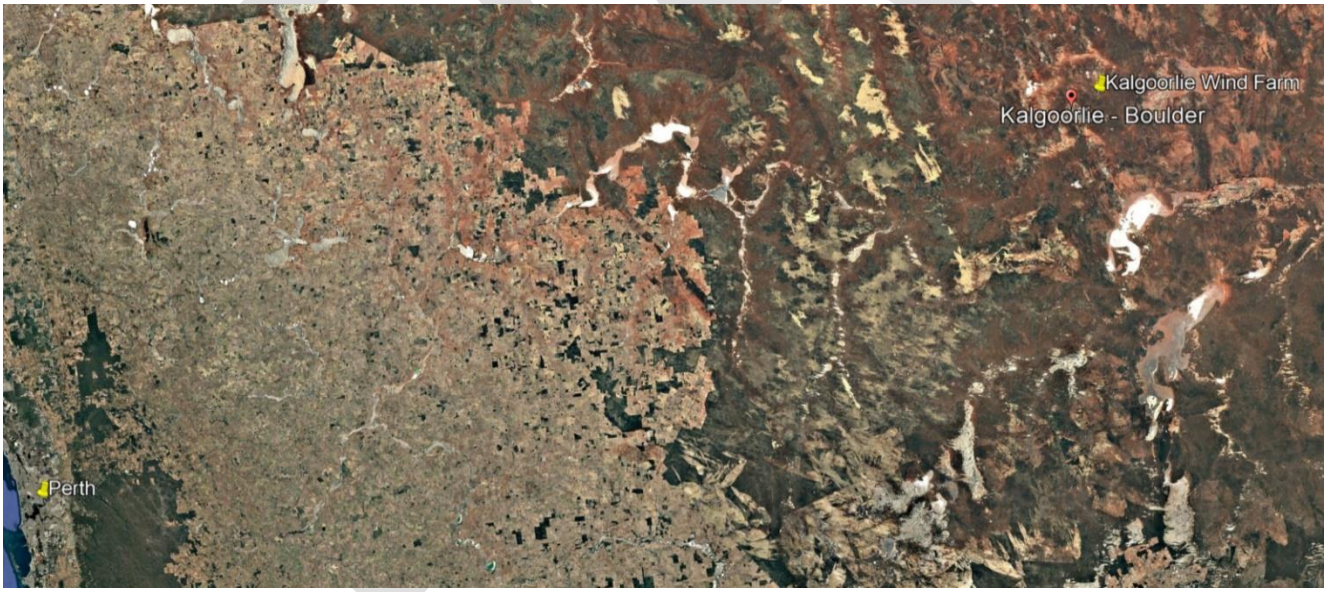

Figure 1 Kalgoorlie Wind Farm location

[1] Potential solar location04Feb25.kmz

Figure 2 *Overview of WTG arrangement for Kalgoorlie Wind Farm: 33 x GW182 7.2/6.2MW – 150 m hub height*

1.3 Scope and limitations

This report has been prepared by GHD for Northern Star Resources and may only be used and relied on by Northern Star Resources for the purpose agreed between GHD and Northern Star Resources as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Northern Star Resources 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 engineers have not visited the Kalgoorlie Wind Farm site as part of this assessment and have therefore not examined local conditions near the receptors assessed, such as blockage from trees or other obstacles. The shadow flicker worst case is modelled on the basis of no tree coverage or obstacles blocking shadow flicker.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

GHD has prepared this report on the basis of information provided by Northern Star Resources 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.

2. Shadow flicker model

2.1 Shadow flicker

Shadow flicker from wind farms is the result of turbine blade rotation casting intermittent shadows which can be observed as a flicker from the observer at a fixed ground position. The key impact associated with shadow flicker is the potential for it to cause nuisance to residents nearby to the wind farm.

The shadow flicker effect duration, intensity and location will depend on the relative position of the sun to the turbine, and the position of the receptor. The position of the sun varies with latitude, time of day and time of year, resulting in the shadow flicker impact, which is also dependent on the following factors:

– Wind turbine type: rotor and height of the tower
– Surface topography
– Surrounding vegetation or objects
– Direction of the wind and resulting direction of the rotor plane
– Weather, including cloud cover
– General visibility (i.e. presence of mist, fog, or smoke, etc.)

In Western Australia, the *Planning and Development Act 2005* defines the framework for land use and the *Position Statement: Renewable energy facilities 2020* specifies the criteria for enabling the systematic evaluation and establishment of renewable energy facilities in Western Australia. The position statement does not include specific guidelines for the assessment of shadow flicker impacts of wind farm developments. Local government areas may also define specific guidelines and codes to follow; however the Town of Kalgoorlie and the Shire of Boulder do not have a specific policy defining wind farm developments.

In the absence of any local or WA-specific guidelines, the *Draft National Wind Farm Development Guidelines for Australia (2010)* (Draft Guidelines) provide a best-practice methodology for assessing the shadow flicker impact for proposed wind farm developments. The Draft Guidelines identify the potential for annoyance to residents as the key risk resulting from shadow flicker and include methodology in the Draft Guidelines provides a consistent set of modelling assumptions for calculating shadow flicker exposure at nearby residences (also known as sensitive receptors), along with criteria for determining acceptable levels of shadow flicker.

The intensity of shadows decreases with distance. Many standards, including the Draft Guidelines, refer to a “zone of influence” of shadow flicker, beyond which shadows are considered to not be detectable or insufficiently intense to cause annoyance to residences (or sensitive receptors) near wind farms.

No sensitive receptors have been identified for the proposed Kalgoorlie Wind Farm; however, the methodology described in the Draft Guidelines has been used for guidance for assessing the shadow flicker impacts on the nearby solar farm.

2.2 Methodology

GHD has undertaken a desktop-based shadow flicker assessment using the EMD windPRO 4.1 software package using the wind turbine layout provided by NSR (see Figure 2).

The shadow flicker model simulates the path of the sun relative to wind turbines and terrain and thereby predicts the possible shadow flicker durations from blades in the vicinity of the wind farm development from a purely geometrical standpoint. This calculation gives the theoretical number of hours of shadow flicker experienced across the surrounding footprint due to sunlight passing through the swept area of the turbine blades, known as ‘dynamic shading’[2]. The model does not consider the shadow impacts from the wind turbine towers and nacelles, known as ‘static shading’[3] because these do not cause shadow flicker.

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

[2] ‘Dynamic shading’ refers to the shadow cast over the land due to the rotating wind turbine blades.
[3] ‘Static shading’ refers to the shadow cast over the land due to tower of the wind turbine.

1. Input of turbine layout (i.e. turbine designations and coordinates) and turbine model technical parameters (i.e. hub height, rotor diameter, etc) provided by NSR.
2. Input of base information into EMD windPRO 4.1 wind farm modelling software package.
3. Selection of shadow flicker calculation parameters.
4. Shadow flicker simulation.
5. Visualisation of predicted shadow flicker impact on the proposed solar farm (shadow flicker maps).

Calculations were completed for two cases: the theoretical worst case scenario and a cloud-cover adjusted case.

2.3 Inputs

The following inputs were used for the shadow flicker assessment:

– Turbine characteristics[4] (refer to Table 1),
– Turbine layout[4] (refer to Figure 2) based on the v14 WTG layout,
– The solar farm boundary[5]
– Height elevation contours obtained from Renewable Energy Area – Survey Data[6]. Additional contours to extend the provided contours were sourced from Australian elevation models in 1-arc-second resolution digital terrain models (DTM's) produced by Geoscience Australia.

NSR has provided turbine characteristics to be modelled for this assessment as shown in Table 1.

Table 1 Wind turbine generator modelled

WTG Qty	Type	Rotor Diameter (m)	Hub Height AGL (m)
33	Goldwind GW182-7.2 MW/6.2 MW	182	150

A summary of modelling parameters is included in Table 2.

Table 2 Model parameters

Parameter	Limit / Description
Maximum distance of influence	Not applicable
Minimum sun angle	3 degrees above horizon
'Eye height' (representing 'average solar panel height')	1.5 m
Impact of cloud cover	Worst case: Not considered Cloud cover adjusted case: Considered using historic statistics from Perth Airport Climate Station as it is the closest weather station to Kalgoorlie WF in windPRO 4.1
Turbine orientation	The rotor plane is always perpendicular to the line from the WTG to the sun
Grid resolution	10 m
Time step for calculation	2 minutes
Day step for calculation	3 days

The historic cloud cover statistics used in the calculation were sourced from Perth Airport Climate Station as it is the nearest weather station to Kalgoorlie WF with historic data available in windPRO 4.1. Figure 3 shows that the average daily sunshine hours are 8 for Perth and 7 for Kalgoorlie annually, indicating broadly similar solar exposure patterns, which supports the validity of using Perth data for this analysis.

[4] KCGM Renewables V14 SHP File.zip
[5] Potential solar location04Feb25.kmz
[6] July 2018 - MGA94Z51 - 2.0m contours_decimated

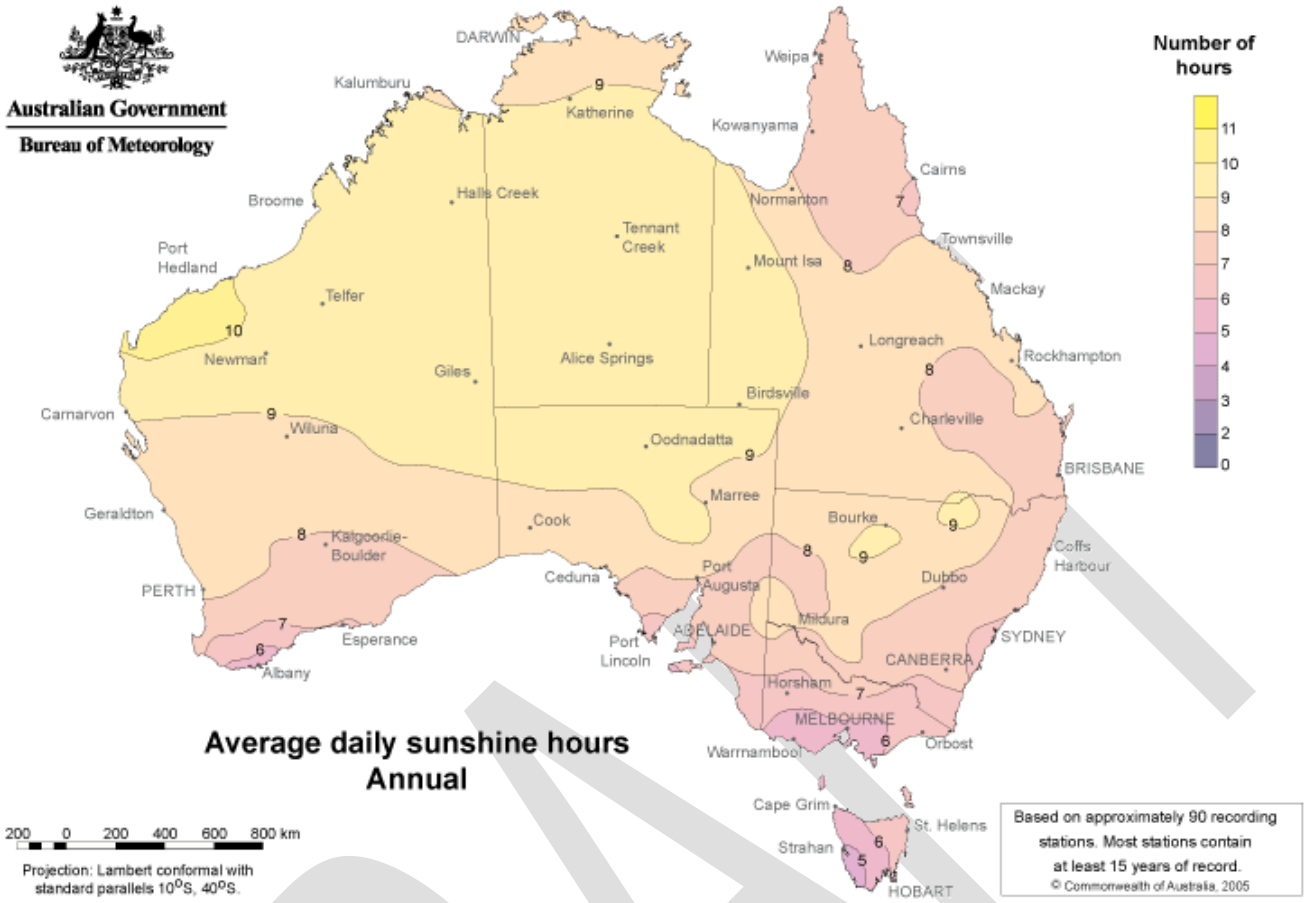

Figure 3 Average daily sunshine hours (annual) [7]

2.4 Assumptions

Conservative assumptions have been used for both the worst-case and cloud cover adjusted cases. For both scenarios, the shadow flicker assessment excludes:

– The 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,
– Any potential changes to the wind farm's 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, and
– Any vegetation blocking the visibility of wind turbines.

As no sensitive receptors have been identified, the basis for the "zone of influence" of shadow flicker in the Draft Guidelines has been assumed not to apply, as it is based on the threshold for causing annoyance to residences. As such, no "zone of influence" constraint has been included in the shadow flicker maps. The impact of this assumption is that the flicker maps will include low intensity shadow flicker at large distances from the wind farm. This shadow flicker would not normally be considered sufficiently intense to cause annoyance to sensitive receptors but may impact the solar farm.

No quantitative assessment of impacts on the solar farm has been included in this study.

[7] http://www.bom.gov.au/watl/sunshine/, Accessed June 2025

3. Results

Shadow flicker was modelled for the worst-case and cloud cover adjusted scenarios. Results for each scenario are included below.

3.1 Shadow flicker map – worst case

Figure 4 shows the predicted shadow flicker for the worst case scenario.

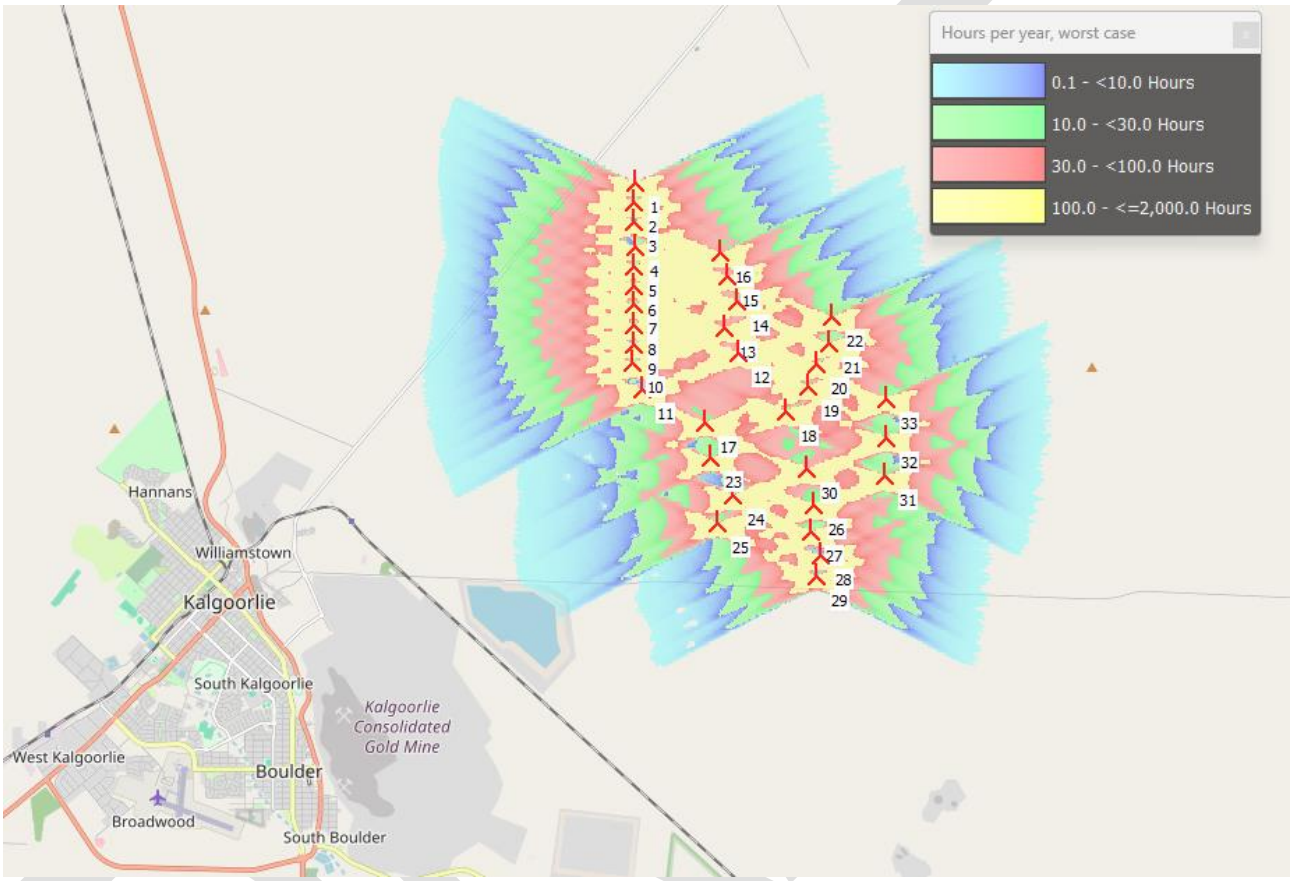

Figure 4 Shadow flicker map (hours per year) - worst case

3.2 Shadow flicker map – cloud cover adjusted case

The shadow flicker model was completed for a cloud cover-adjusted case scenario, meaning the results seen below used historical cloud cover data to provide a more realistic estimate of shadow flicker.

Figure 5 shows the predicted shadow flicker for the cloud cover-adjusted case.

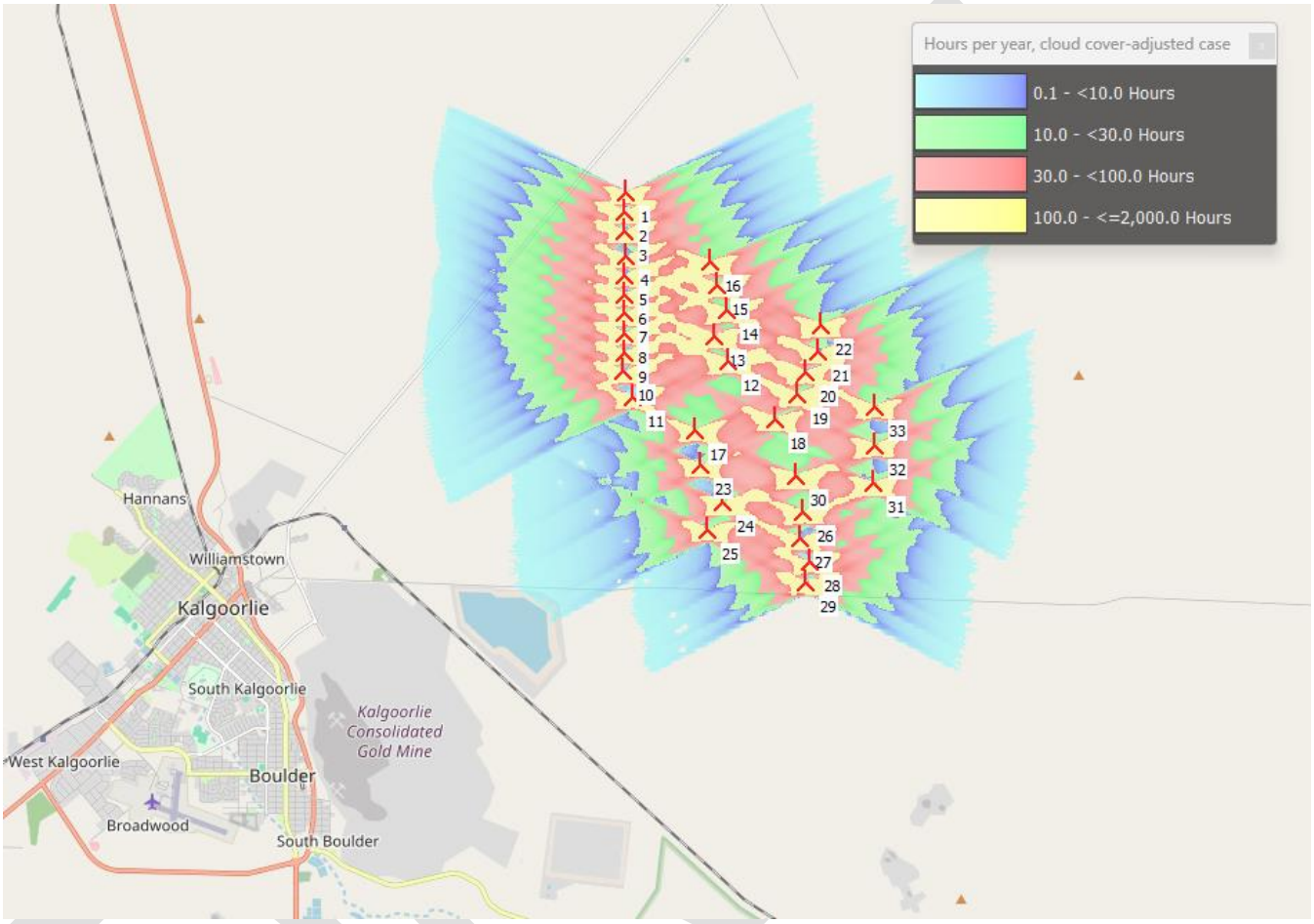

Figure 5 Shadow flicker map (hours per year) – cloud cover-adjusted case

3.3 Impact on nearby solar farm

The overlap between the shadow flicker map and the proposed Kalgoorlie Solar Farm is shown in Figure 6 and Figure 7 for the worst case and cloud cover-adjusted case respectively. For both cases, there are regions of the site where the predicted shadow flicker is above 100 hours per year.

This indicates that there are expected shading losses on the solar farm due to the shadows cast by the turbines. There are no negative implications environmentally as the solar farm is not identified as a sensitive receptor.

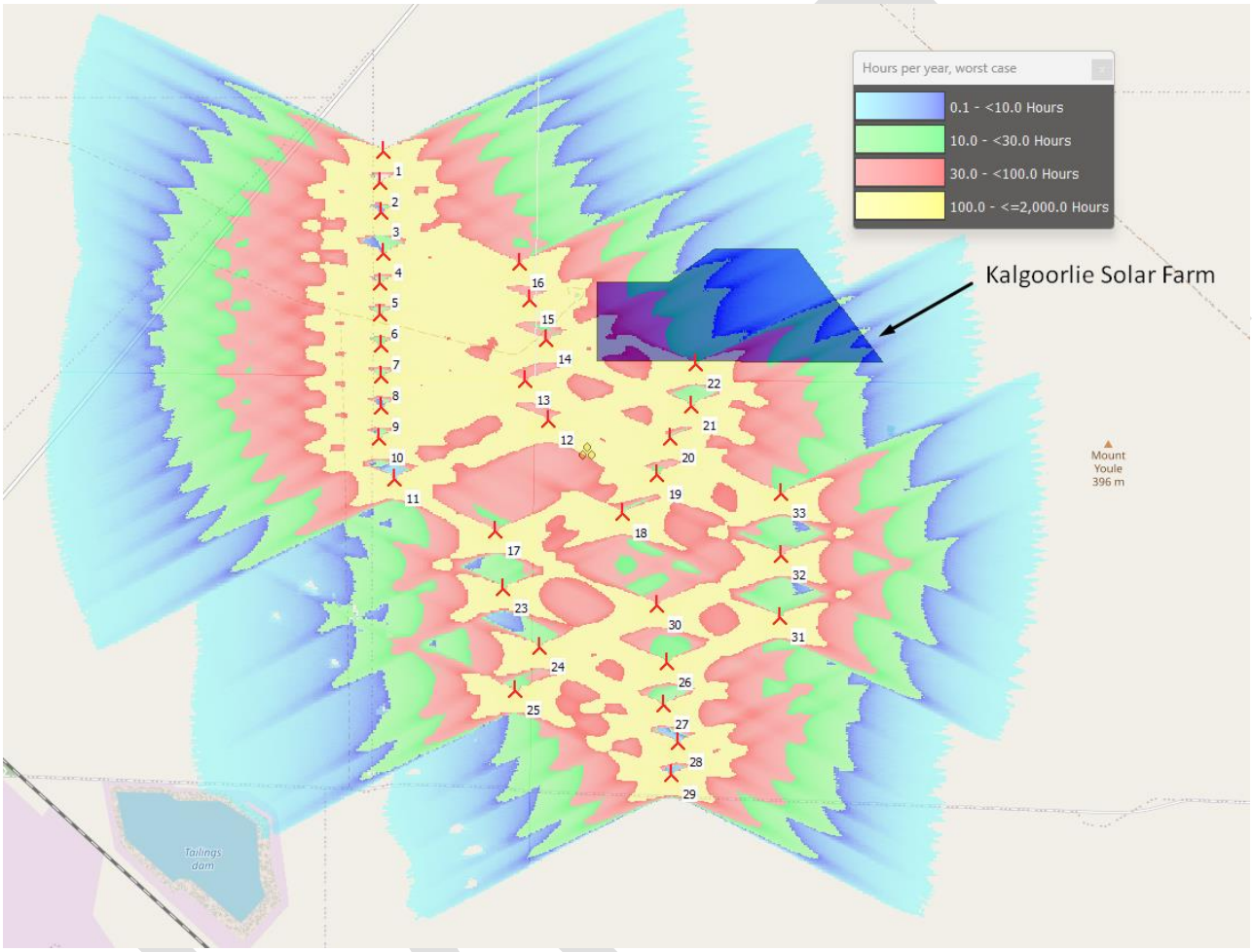

Figure 6 *Shadow flicker map overlap with proposed solar farm location – worst case scenario*

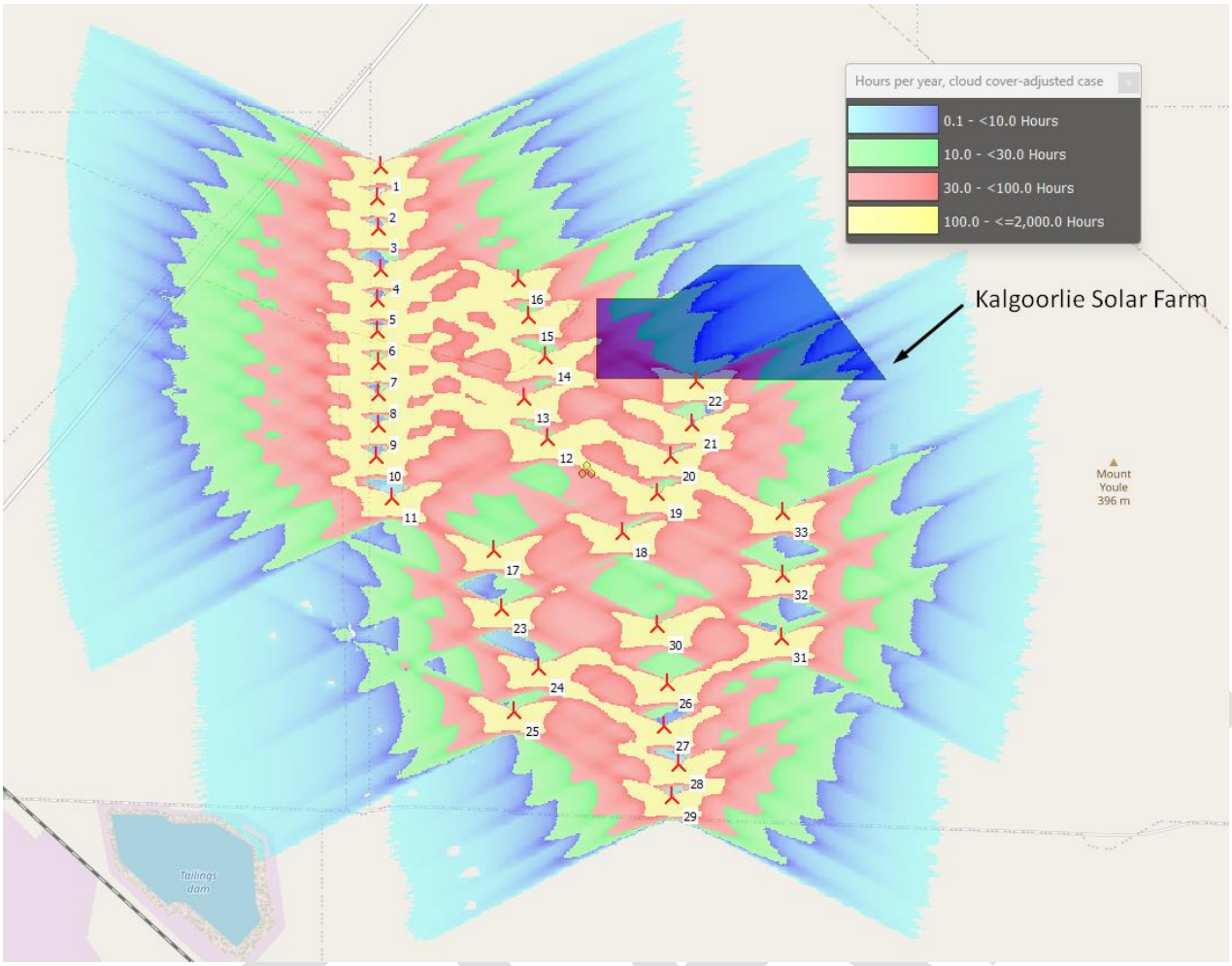

Figure 7 ***Shadow flicker map overlap with proposed solar farm location – cloud cover-adjusted case***

4. Conclusions and Recommendations

Shadow flicker calculations for the proposed Kalgoorlie Wind Farm assessed the predicted shadow flicker impacts in the vicinity of the wind farm, including at the nearby proposed Kalgoorlie Solar Farm. The overlap between the generated shadow flicker maps indicates that shadow flicker is predicted to exceed 100 hours per year in some parts of the solar farm.

As no sensitive receptors were identified by NSR, this study has not assessed whether the shadow flicker impacts comply with the Draft Guidelines. The Draft Guidelines specifically focus on shadow flicker impacts to residences and are therefore not strictly applicable when no sensitive receptors have been identified.

It is recommended that an updated shadow flicker be undertaken if any sensitive receptors are identified close to the Kalgoorlie wind farm. If sensitive receptors are identified in future, the zone of influence of shadow flicker would need to be considered in an updated assessment according to the Draft Guidelines.

If the wind turbine layout changes GHD recommends completing an updated shadow flicker study to assess any changes to the impacts of the nearby solar farm.

Appendix A

Coordinates of proposed wind turbines

Table 3 Modelled Wind Turbines Locations (GDA2020, MGA94 Zone 51)

WTG ID	Easting (m)	Southing (m)	Elevation (m ASL)
1	363280	6607468	392.1
2	363236	6607013	390.1
3	363252	6606557	390.1
4	363301	6605965	392.8
5	363259	6605514	395.3
6	363261	6605054	395.8
7	363275	6604603	399.1
8	363290	6604139	393.8
9	363287	6603684	398
10	363272	6603229	402
11	363504	6602632	399.4
12	365777	6603514	384.1
13	365419	6604100	382
14	365729	6604706	375.8
15	365481	6605307	376.4
16	365316	6605844	378
17	365010	6601874	386.8
18	366902	6602158	380.4
19	367407	6602744	373.1
20	367594	6603280	371.7
21	367904	6603764	364.9
22	367953	6604389	362.8
23	365142	6601030	387.1
24	365689	6600173	384.9
25	365334	6599518	393.5
26	367591	6599966	372.8
27	367539	6599331	375.9
28	367763	6598778	376.2
29	367666	6598301	378
30	367424	6600815	373.3
31	369246	6600652	366.3
32	369264	6601566	365.3
33	369251	6602477	364