Appendix E

Shadow Flicker & Blade Glint Assessment by DNV Energy Systems Renewables Advisory (July 2021)

FLAT ROCKS WIND FARM

Shadow Flicker and Blade Glint Assessment

Moonies Hill Energy Pty Ltd

Report No.: 10284364-AUME-R-01, Rev. E
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EXECUTIVE SUMMARY

DNV has been commissioned by Moonies Hill Energy Pty Ltd ("MHE" or "the Customer") to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Flat Rocks Wind Farm ("the Project") in Western Australia. The results of the shadow flicker assessment are described in this document.

Background and methodology

DNV has assessed the expected annual shadow flicker durations for the Project in accordance with the Western Australia Planning Commission (WAPC) *Position Statement: Renewable energy facilities* [1] (Position Statement) and *Visual Landscape Planning in Western Australia: a manual for evaluation, assessment, siting and design* [2] (Visual Planning Manual), as well as the Environment Protection and Heritage Commission (EPHC) *Draft National Wind Farm Development Guidelines* [3] (Draft National Guidelines). The methodology used in this study has been primarily informed by the Draft National Guidelines and various standard industry practices. The Draft National Guidelines recommend limits of 30 hours per year on the theoretical shadow flicker duration, and 10 hours per year on the actual shadow flicker duration.

A Project layout consisting of 42 wind turbines with a maximum proposed rotor diameter of 150 m and tip height of 200 m has been considered. Fifteen dwellings have been identified within 2300 m of the Project, four of which are stakeholder dwellings.

The theoretical shadow flicker durations at dwellings in the vicinity of the Project have been determined using a purely geometric analysis. The actual shadow flicker duration likely to be experienced at each dwelling has also been predicted by estimating the possible reduction in shadow flicker due to turbine orientation and cloud cover.

Assessment results

The results of the shadow flicker assessment are summarised in Table 5.

Based on this assessment, a total of nine dwellings are expected to experience some shadow flicker, four of which are stakeholder dwellings. Out of the four stakeholder dwellings, all are predicted to experience theoretical shadow flicker durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction due to cloud cover and rotor orientation, the shadow flicker at two of the dwellings are predicted to be above the recommended limit of 10 hours per year within 50 m of the dwelling. It should be noted that for certain states or jurisdictions, theoretical shadow flicker durations above the recommended limit of 30 hours/year may be considered acceptable for *stakeholder* dwellings. However, in some cases, it may be necessary to have an agreement in place with the stakeholder indicating that they accept higher shadow flicker durations. DNV considers that theoretical shadow flicker durations of up to 60 hours/year may be appropriate at stakeholder dwellings, provided that the stakeholder is aware of, and accepts, the increased durations.

Out of the five non-stakeholder dwellings that are predicted to experience shadow flicker, none are predicted to experience theoretical shadow flicker durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction due to cloud cover and rotor orientation, none of those dwellings are predicted to experience shadow flicker above the recommended limit of 10 hours per year within 50 m of the dwelling.

The effects of shadow flicker may be reduced through a number of mitigation measures such as the removal or relocation of turbines, installation of screening structures or planting of trees to block shadows cast by the turbines, or the use of turbine control strategies which shut down turbines when shadow flicker is likely to occur.

The calculation of the predicted actual shadow flicker duration does not take into account other potential reductions due to low wind speed, vegetation, or other shielding effects around each house in calculating the number of shadow flicker hours.

Since a non-reflective finish is generally applied to the wind turbine blades, blade glint is not expected to be an issue for the Project.

1 INTRODUCTION

Moonies Hill Energy Pty Ltd ("MHE" or "the Customer") has commissioned DNV to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Flat Rocks Wind Farm ("the Project") in Western Australia. The results of this work are reported here. This document has been prepared in accordance with DNV proposal L2C-212386-AUME-P-01 Issue A, dated 15 February 2021, and is subject to the terms and conditions in that agreement.

DNV has previously conducted a shadow flicker assessment for the Project site, as reported in DNV GL report PP165333-AUME-R-01 Issue B dated 4 November 2016 [4], based on a different turbine layout and configuration.

This assessment evaluates the shadow flicker durations in the vicinity of the Project for the current proposed turbine layout and configuration in accordance with the National Wind Farm Development Guidelines – Draft (Draft National Guidelines) prepared by the Environment Protection and Heritage Council (EPHC) in July 2010 [3].

2 DESCRIPTION OF THE SITE AND PROJECT

2.1 The site

The proposed Project is located approximately 260 km south-east of Perth and 30 km south-west of the township of Katanning. An overview of the site is location is presented in Figure 1.

The terrain on and around the site is considered to be undulating, with elevations ranging from approximately 340 m to 380 m above sea level. The digital elevation model used to define the terrain at the site was taken from another assessment previously completed by DNV for the Project [5].

2.2 The Project

2.2.1 Proposed wind farm layout

The Project is proposed to consist of 42 wind turbines [6, 7, 8], which will be constructed over two stages. A map of the site with the proposed turbine layout is shown in Figure 2, and the coordinates of the proposed turbine locations for Stage 1 and Stage 2 are given in Table 1 and Table 2 respectively.

As requested by the Customer, DNV has modelled the shadow flicker based on a hypothetical turbine model with a rotor diameter of 150 m and a maximum upper tip height of 200 m [9].

2.2.2 Shadow receptor locations

A list of dwellings neighbouring the Project was provided to DNV by the Customer [10]. The coordinates of those dwellings within 2300 m of proposed turbine locations (which corresponds to 15 times the maximum proposed rotor diameter plus 50 m) are presented in Table 3.

Dwellings situated more than 2300 m from turbine locations are considered unlikely to be impacted by shadow flicker, as discussed further in Sections 3.1 and 4.1. DNV has not carried out a detailed and comprehensive survey of sensitive land uses and building locations in the area and is relying on information provided by the Customer.

3 REGULATORY REQUIREMENTS

3.1 Shadow flicker

The Western Australia Planning Commission has recently released guidelines to facilitate the development of renewable energy facilities in Western Australia, which are currently specified in the *Position Statement: Renewable energy facilities* document [1] (Position Statement). The Position Statement makes further reference to *Visual Landscape Planning in Western Australia: a manual for evaluation, assessment, siting and design* [2] (Visual Planning Manual), which briefly mentions an objective of mitigating the impact of blade glint and shadow flicker.

However these documents do not provide specific guidance regarding a suitable shadow flicker modelling methodology, recommended exposure limits, modelling assumptions, allowable mitigations, or other considerations. DNV have therefore used on the Environment Protection and Heritage Commission (EPHC) *Draft National Wind Farm Development Guidelines* [3] (Draft National Guidelines) to inform the modelling parameters and acceptable shadow flicker limits, assuming the information detailed are also broadly applicable to the wind farm development guidelines in Western Australia.

The Draft National Guidelines include recommendations for shadow flicker limits relevant to wind farms in Australia, such that the modelled theoretical shadow flicker duration should not exceed 30 hours per year, and that the actual or measured shadow flicker duration should not exceed 10 hours per year. The guidelines also recommend that the shadow flicker duration at a dwelling be assessed by calculating the maximum shadow flicker occurring within 50 m of the centre of a dwelling.

These limits are assumed to apply to a single dwelling, and it is noted that there is no requirement under the Draft National Guidelines to assess shadow flicker durations at locations other than in the vicinity of dwellings. The Draft National Guidelines also provide background information, a proposed methodology, and a suite of assumptions for assessing shadow flicker durations in the vicinity of a wind farm.

The impact of shadow flicker is typically only significant up to a distance of around 10 rotor diameters from a turbine [11] or approximately 1200 m to 1700 m for modern wind turbines (which typically have rotor diameters of 120 m to 170 m). Beyond this distance limit the shadow is diffused such that the variation in light levels is not likely to be sufficient to cause annoyance. This issue is discussed in the Draft National Guidelines where it is stated that:

> *"Shadow flicker can theoretically extend many kilometres from a wind turbine. However the intensity of the shadows decreases with distance. While acknowledging that different individuals have different levels of sensitivity and may be annoyed by different levels of shadow intensity, these guidelines limit assessment to moderate levels of intensity (i.e., well above the minimum theoretically detectable threshold) commensurate with the nature of the impact and the environment in which it is experienced."*

The Draft National Guidelines therefore suggest a distance equivalent to 265 times the maximum blade chord as an appropriate limit, which corresponds to approximately 1000 m to 1600 m for modern wind turbines (which typically have maximum blade chord lengths of 4 m to 6 m).

3.2 Blade glint

The Draft National Guidelines provide guidance on blade glint and state that:

> *"The sun's light may be reflected from the surface of wind turbine blades. Blade Glint has the potential to annoy people. All major wind turbine 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 risk of blade glint from a new development is considered to be very low."*

4 ASSESSMENT METHODOLOGY

4.1 Shadow flicker

4.1.1 Overview

Shadow flicker may occur under certain combinations of geographical position and time of day, when the sun passes behind the rotating blades of a wind turbine and casts a moving shadow over neighbouring areas. When viewed from a stationary position the moving shadows cause periodic flickering of the light from the sun, giving rise to the phenomenon of 'shadow flicker'.

The effect is most noticeable inside buildings, where the flicker appears through a window opening. The likelihood and duration of the effect depends upon a number of factors, including:

- the direction of the property relative to the turbine
- the distance from the turbine (the further the observer is from the turbine, the less pronounced the effect will be)
- the wind direction (the shape of the shadow will be determined by the position of the sun relative to the blades which will be oriented to face the wind)
- the turbine height and rotor diameter
- the time of year and day (the position of the sun in the sky)
- the weather conditions (cloud cover reduces the occurrence of shadow flicker).

4.1.2 Theoretical modelled duration

The theoretical number of hours of shadow flicker experienced annually at a given location can be calculated using a geometrical model which incorporates the sun path, topographic variation over the site area, and wind turbine details such as rotor diameter and hub height.

The wind turbines have been modelled assuming they are spherical objects, which is equivalent to assuming the turbines are always oriented perpendicular to the sun-turbine vector. This assumption will mean the model calculates the maximum duration for which there is potential for shadow flicker to occur, up to a specified distance limit.

In line with the methodology proposed in the Draft National Guidelines, DNV has assessed the shadow flicker at the surveyed house locations and has determined the highest shadow flicker duration within 50 m of each of the provided house location.

Shadow flicker has been calculated at dwellings at heights of 2 m, to represent ground floor windows, and 6 m, to represent second floor windows. The shadow receptors are simulated as fixed points, representing the worst-case scenario, as real windows could be facing a particular direction less affected by shadows cast from the turbines. The shadow flicker calculations for dwelling locations have been carried out with a temporal resolution of 1 minute. The shadow flicker map was generated using a temporal resolution of 5 minutes and a spatial resolution of 10 m to reduce computational requirements to acceptable levels.

As part of the shadow flicker assessment, it is necessary to make an assumption regarding the maximum length of a shadow cast by a wind turbine that is likely to cause annoyance due to shadow flicker. The UK wind industry considers that 10 rotor diameters is appropriate [11], while the Draft National Guidelines suggest a distance equivalent to 265 times the maximum blade chord as an appropriate limit.

For the current assessment, DNV has applied a maximum shadow length of 10 times the rotor diameter (10D), which corresponds to a distance limit of 1500 m. Under the Draft National Guidelines, this limit would be considered appropriate for any turbine with a maximum blade chord of less than 5.7 m. Beyond this distance limit, it is assumed that any shadow flicker experienced will be below a "moderate level of intensity" and unlikely to cause annoyance. However, it is recognised that different people have different levels of sensitivity to shadow flicker and may therefore be affected by shadow flicker intensities below the "moderate level of intensity" assumed by this distance limit. To account for this possibility, DNV has also assessed the shadow flicker for an increased distance limit of 15 times the rotor diameter (15D), or 2250 m, which should also include shadow flicker below a "moderate level of intensity".

The model also makes the following assumptions and simplifications:

- there are clear skies every day of the year
- the blades of the turbines are always perpendicular to the direction of the line of sight from the location of interest to the sun
- the turbines are always rotating.

The first two of these items are addressed in the calculation of the predicted actual shadow flicker duration as described in Section 4.1.4. The third item is not considered but is unlikely to have a significant impact on the results. The settings used to execute the model can be seen in Table 4.

To illustrate typical results, an indicative shadow flicker map for a turbine located in a flat area is shown in Figure 3. The geometry of the shadow flicker map can be characterised as a butterfly shape, with the four protruding lobes corresponding to slowing of solar north-south travel around the summer and winter solstices for morning and evening. The lobes to the north of the indicative turbine location result from the summer months and conversely the lobes to the south result from the winter months. The lobes to the west result from morning sun while the lobes to the east result from evening sun. When the sun is low in the sky, the length of shadows cast by the turbine increases, increasing the area around the turbine affected by shadow flicker.

4.1.3 Factors affecting duration

Shadow flicker duration calculated in this manner can overestimate the annual number of hours of shadow flicker experienced at a specified location for several reasons, including:

1. The wind turbine will not always be oriented such that its rotor is in the worst-case position (i.e., perpendicular to the sun-turbine vector). Any other rotor orientation will reduce the area of the projected shadow and hence the shadow flicker duration.

   The wind speed frequency distribution or wind rose at the site can be used to determine probable turbine orientation and to calculate the resulting reduction in shadow flicker duration.

2. The occurrence of cloud cover has the potential to significantly reduce the number of hours of shadow flicker.

   Cloud cover measurements recorded at nearby meteorological stations may be used to estimate probable levels of cloud cover and to provide an indication of the resulting reduction in shadow flicker duration.

3. Aerosols (moisture, dust, smoke, etc.) in the atmosphere have the ability to influence shadows cast by a wind turbine.

The length of the shadow cast by a wind turbine is dependent on the degree that direct sunlight is diffused, which is in turn dependent on the amount of dispersants (humidity, smoke, and other aerosols) in the path between the light source (sun) and the receiver.

4. The modelling of the wind turbine rotor as a sphere rather than individual blades results in an overestimate of shadow flicker duration.

   Turbine blades are of non-uniform thickness with the thickest part of the blade (maximum chord) close to the hub and the thinnest part (minimum chord) at the tip. Diffusion of sunlight, as discussed above, results in a limit to the maximum distance that a shadow can be perceived. This maximum distance will also be dependent on the thickness of the turbine blade, and the human threshold for perception of light intensity variation. As such, a shadow cast by the blade tip will be shorter than the shadow cast by the thickest part of the blade.

5. The analysis does not consider that when the sun is positioned directly behind the wind turbine hub, there is no variation in light intensity at the receiver location and therefore no shadow flicker.

6. The presence of vegetation or other physical barriers around a shadow receptor location may shield the view of the wind turbine, and therefore reduce the incidence of shadow flicker.

7. Periods where the wind turbine is not in operation due to low winds, high winds, or for operational and maintenance reasons will also reduce the annual shadow flicker duration.

4.1.4 Predicted actual duration

As discussed above in Section 4.1.3, there are a number of factors which may reduce the incidence of shadow flicker that are not taken into account in the calculation of the theoretical shadow flicker duration. An attempt has been made to quantify the likely reduction in shadow flicker duration due to cloud cover and, therefore, produce a prediction of the actual shadow flicker duration likely to be experienced at a receptor.

Cloud cover is typically measured in 'oktas', effectively eighths of the sky covered with cloud. DNV has obtained data from the following four Bureau of Meteorology (BoM) stations:

- Kojonup (010582), located approximately 22 km from the site [12]
- Frankland Vineyards (009843), located approximately 64 km from the site [13]
- Wagin (010647), located approximately 70 km from the site [14]
- Mount Barker (009581), located approximately 80 km from the site [15]

The number of oktas of cloud cover visible across the sky at these stations is recorded twice daily, at 9 am and 3 pm, and the observations are provided as monthly averages. After averaging the 9 am and 3 pm observations for the stations considered, the results indicate that the average monthly cloud cover in the region ranges between 41% and 66%, and the average annual cloud cover is approximately 58%. This means that on an average day, 58% of the sky in the vicinity of the wind farm is covered with clouds. Although it is not possible to definitively calculate the effect of cloud cover on shadow flicker duration, a reduction in the shadow flicker duration proportional to the amount of cloud cover is a reasonable assumption.

Similarly, turbine orientation can have an impact on the shadow flicker duration. The shadow flicker duration is greatest when the turbine rotor plane is approximately perpendicular to a line joining the sun and an observer, and a minimum when the rotor plane is approximately parallel to a line joining the sun and an observer. Wind direction frequency distributions derived from wind measurements at the site were provided used from the previous shadow flicker assessment [4] and used to estimate the reduction in shadow flicker duration due to rotor orientation. The measured wind rose is shown overlaid on the indicative shadow flicker map in Figure 3. An assessment of the likely reduction in shadow flicker duration due to variation in turbine orientation was conducted on an annual basis.

It should be noted that the method prescribed by the Draft National Guidelines for assessing actual shadow flicker duration recommends that only reductions due to cloud cover, and not turbine orientation, be included. However, DNV considers that the additional reduction due to turbine orientation is appropriate as the projected area of the turbine, and therefore the expected shadow flicker duration, is reduced when the turbine rotor is not perpendicular to the line joining the sun and dwelling. Due to limitations in the availability of suitable cloud cover data, the methodology used in this assessment also deviates somewhat from the method recommended by the Draft National Guidelines for assessing the reduction in shadow flicker due to cloud cover. However, considering the available cloud cover data, the approach described above is deemed to provide a reasonable estimate of the likely impact of cloud cover on the shadow flicker duration.

No attempt has been made to account for vegetation or other shielding effects around each shadow receptor in calculating the shadow flicker duration. Similarly, turbine shutdown has not been considered.

4.2 Blade glint

Blade glint involves the regular reflection of sun off rotating turbine blades. Its occurrence depends on a combination of circumstances arising from the orientation of the nacelle, angle of the blade and the angle of the sun. The reflectiveness of the surface of the blades is also important. Blade glint is not generally a problem for modern wind turbines, provided the blades are coated with a non-reflective paint, and it is not considered further here.

5 ASSESSMENT RESULTS

5.1 Shadow flicker

Shadow flicker assessments were carried out at all provided habitable dwelling locations, or ‘receptors’, as outlined in Table 3.

The theoretical and predicted actual shadow flicker durations at all dwellings identified to be affected by shadow flicker are presented in Table 5. The maximum predicted shadow flicker durations within 50 m of these receptors are also presented in this table. Furthermore, the results are shown in the form of shadow flicker maps in Figure 4 and Figure 5. The shadow flicker values presented in these maps represent the worst case between the results at 2 m and 6 m above ground for each modelled grid point.

Based on DNV’s modelling, nine dwellings are predicted to experience some shadow flicker based on the methodology recommended by the Draft National Guidelines, four of which are stakeholder dwellings. Out of the four stakeholder dwellings, all are predicted to experience theoretical shadow flicker durations within 50 m of the dwelling that exceed the limit recommended by the current guidelines. When considering the likely reduction due to cloud cover and rotor orientation, the shadow flicker at two of the dwellings is predicted to be above the recommended limit of 10 hours per year within 50 m of the dwelling. It should be noted that for certain states or jurisdictions, theoretical shadow flicker durations above the recommended limit of 30 hours/year may be considered acceptable for *stakeholder* dwellings. However, in some cases, it may be necessary to have an agreement in place with the stakeholder indicating that they accept higher shadow flicker durations. DNV considers that theoretical shadow flicker durations of up to 60 hours/year may be appropriate at stakeholder dwellings, provided that the stakeholder is aware of, and accepts, the increased durations.

For the five non-stakeholder dwellings that are predicted to experience shadow flicker, none are predicted to experience theoretical shadow flicker durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction due to cloud cover and rotor orientation, none of those dwellings are predicted to experience shadow flicker above the recommended limit of 10 hours per year within 50 m of the dwelling.

Beyond the 10D distance limit, it is assumed that any shadow flicker experienced will be below a “moderate level of intensity” and unlikely to cause annoyance. However, it is recognised that different people have different levels of sensitivity to shadow flicker and may therefore be affected by shadow flicker intensities below the “moderate level of intensity” assumed by this distance limit. To account for this possibility, although not part of the methodology outlined in the Draft National Guidelines, DNV has also assessed the shadow flicker impacts for the Project for an increased distance limit that is intended to include shadow flicker below a “moderate level of intensity”. For the purpose of this assessment, the distance limit has been increased by 50% (to 15D), and the results of this additional assessment are illustrated in the map presented in Figure 4. These results indicate that three additional dwellings have the potential to be exposed to shadow flicker below a “moderate level of intensity”. These dwellings are noted in Table 5.

Shadow flicker impacts can be reduced through a number of measures. These include the removal or relocation of turbines, installation of screening structures or planting of trees to block shadows cast by the turbines, or the use of turbine control strategies which shut down turbines when shadow flicker is likely to occur.

5.2 Blade glint

As discussed in Section 4.2, blade glint is generally not a problem for modern wind turbines provided that the blades are coated with a non-reflective paint.

6 CONCLUSION

A shadow flicker assessment was carried out at all dwelling locations in the vicinity of the Project. For the purpose of this assessment, DNV has considered a layout consisting of 42 turbines with a rotor diameter of 150 m and a tip height of 200 m. The results of the shadow flicker assessment based on this layout configuration are summarised in Table 5.

Based on DNV's modelling, nine dwellings are predicted to experience some shadow flicker based on the methodology recommended by the Draft National Guidelines, four of which are stakeholder dwellings. Out of the four stakeholder dwellings, all are predicted to experience theoretical shadow flicker durations within 50 m of the dwelling that exceed the limit recommended by the current guidelines. When considering the predicted actual shadow flicker duration, which takes into account the reduction in shadow flicker due to cloud cover and rotor orientation, two stakeholder dwellings are expected to experience actual shadow flicker durations above the limit recommended in the guidelines. It should be noted that for certain states or jurisdictions, theoretical shadow flicker durations above the recommended limit of 30 hours/year may be considered acceptable for *stakeholder* dwellings. However, in some cases, it may be necessary to have an agreement in place with the stakeholder indicating that they accept higher shadow flicker durations. DNV considers that theoretical shadow flicker durations of up to 60 hours/year may be appropriate at stakeholder dwellings, provided that the stakeholder is aware of, and accepts, the increased durations.

For the five non-stakeholder dwellings that are predicted to experience shadow flicker, none are predicted to experience theoretical shadow flicker durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction due to cloud cover and rotor orientation, none of those dwellings are predicted to be above the recommended limit of 10 hours per year within 50 m of the dwelling.

The effects of shadow flicker may be reduced through a number of mitigation measures such as the removal or relocation of turbines, installation of screening structures or planting of trees to block shadows cast by the turbines, or the use of turbine control strategies which shut down turbines when shadow flicker is likely to occur.

The prediction of the actual shadow flicker duration presented here does not take into account any reduction due to low wind speed, vegetation, or other shielding effects around each receptor in calculating the number of shadow flicker hours.

Since a non-reflective finish is proposed for the wind turbine blades, blade glint is not expected to be an issue for the Project.

7 REFERENCES

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Table 1 Proposed Stage 1 turbine layout for the Project [6, 7, 8]

Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]	Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]
T001	531854	6241757	381	T010	533258	6238736	365
T002	532100	6241227	379	T011	533253	6238266	362
T003	530604	6240976	370	T055	529580	6239739	358
T004	532458	6240750	379	T013	531248	6246180	360
T005	530327	6240492	366	T014	531662	6245363	366
T006	532764	6240255	382	T015	531924	6244916	370
T007	530265	6240031	370	T016	531682	6237572	351
T008	533006	6239787	374	T017	531927	6244440	370
T009	533224	6239233	370	T018	533574	6244165	370

1. Coordinate system: UTM zone 50 south, WGS84 datum.

Table 2 Proposed Stage 2 turbine layout for the Project [6, 7]

Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]	Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]
T001	533353	6251758	359	T015	536201	6247429	362
T003	532675	6251443	358	T016	534497	6246947	362
T004	533626	6251119	361	T017	530818	6247319	342
T005	532328	6250880	357	T018	536269	6246950	360
T006	533248	6250736	367	T019	534021	6246789	369
T007	533756	6250500	363	T020	535002	6246668	364
T008	531575	6250252	350	T021	531467	6246454	353
T009	532922	6250191	366	T023	535002	6245864	374
T010	532333	6250139	361	T024	535977	6246267	372
T011	533464	6250113	364	T026	534675	6246351	379
T012	533791	6249619	358	T027	535305	6246210	375
T013	533260	6249574	368	T029	534457	6245858	369

2. Coordinate system: UTM zone 50 south, WGS84 datum.

Table 3 Shadow receptor locations within 2300 m of turbines at the Project [10]

Receptor ID	Landowner status	Easting[1] [m]	Northing[1] [m]	Nearest Turbine[2]	Distance to nearest turbine [m]
NSH 03	Non-stakeholder	534715	6252104	S2_T001	1405
NSH 04	Non-stakeholder	533708	6248507	S2_T012	1116
NSH 06	Non-stakeholder	536092	6244487	S2_T023	1756
NSH 08	Non-stakeholder	533602	6237033	S1_T011	1281
NSH 09	Non-stakeholder	533299	6237262	S1_T011	1005
NSH 12	Non-stakeholder	529822	6247171	S2_T017	1007
NSH 13	Non-stakeholder	530084	6245361	S1_T013	1423
NSH 14	Non-stakeholder	531650	6243477	S1_T017	1002
NSH 15	Non-stakeholder	532980	6242569	S1_T001	1388
NSH 22	Non-stakeholder	529707	6247138	S2_T017	1126
NSH 24	Non-stakeholder	529664	6247150	S2_T017	1167
SH 27	Stakeholder	534087	6239798	S1_T009	1031
SH 28	Stakeholder	531662	6251703	S2_T003	1045
SH 29	Stakeholder	533630	6245188	S1_T018	1024
SH 30	Stakeholder	528911	6240554	S1_T055	1055

1. Coordinate system: UTM zone 50 south, WGS84 datum.
2. Turbines prefixed with "S1" or "S2" are from Stage 1 or Stage 2 respectively

Table 4 Shadow flicker model settings for theoretical shadow flicker calculation

Model setting	
Shadow distance limit (10D)	1500 m
Year of calculation	2033
Minimum elevation of the sun	3°
Time step	1 min (5 min for map)
Rotor modelled as	Sphere (disc for turbine orientation reduction calculation)
Sun modelled as	Disc
Offset between rotor and tower	None
Receptor height (single storey)	2 m
Receptor height (double storey)	6 m
Locations used for determining maximum shadow flicker within 50 m of each dwelling	8 points evenly spaced (every 45°) on 25 m and 50 m radius circles centred on the provided house location

Table 5 Theoretical and predicted actual annual shadow flicker duration

House ID[1]	Status	Easting[2] [m]	Northing[2] [m]	Contributing turbines	Theoretical annual				Predicted actual annual[3]			
					At dwelling [hr/yr]		Max within 50 m [hr/yr]		At dwelling [hr/yr]		Max within 50 m [hr/yr]	
					2 m	6 m	2 m	6 m	2 m	6 m	2 m	6 m
NSH 03	Non-stakeholder	534715	6252104	S2_T001	13.1	12.7	14.9	14.4	4.1	3.9	4.7	4.5
NSH 08[4]	Non-stakeholder	533602	6237033	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NSH 09[4]	Non-stakeholder	533299	6237262	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NSH 12	Non-stakeholder	529822	6247171	S2_T017	20.0	19.6	22.2	22.0	5.4	5.2	6.0	5.8
NSH 13	Non-stakeholder	530084	6245361	S1_T013	14.1	13.3	24.6	24.1	2.7	2.5	5.5	5.3
NSH 15[4]	Non-stakeholder	532980	6242569	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NSH 22	Non-stakeholder	529707	6247138	S2_T017	15.6	15.2	17.4	16.9	4.1	4.0	4.6	4.5
NSH 24	Non-stakeholder	529664	6247150	S2_T017	14.4	13.8	15.9	15.4	3.8	3.7	4.3	4.1
SH 27	Stakeholder	534087	6239798	S1_T006 S1_T008	**33.3**	**33.4**	**36.2**	**36.4**	9.1	9.1	9.9	9.9
SH 28	Stakeholder	531662	6251703	S2_T003	26.1	25.5	**32.0**	**30.9**	8.5	8.3	**10.6**	**10.3**
SH 29	Stakeholder	533630	6245188	S2_T023 S2_T029	8.8	7.2	**32.1**	**30.3**	1.0	0.8	6.2	5.7
SH 30	Stakeholder	528911	6240554	S1_T005 S1_T007	**41.0**	**40.8**	**43.3**	**43.4**	**13.9**	**13.7**	**15.6**	**15.6**
Recommended duration limits					***30 hr/yr***				***10 hr/yr***			

1. *Dwellings identified in Table 3 for which there is no theoretical shadow flicker occurrence up to a distance limit of 15 times the rotor diameter have been omitted from this table.*
2. *Coordinate system: UTM zone 50 south , WGS84 datum.*
3. *Considering likely reductions in shadow flicker duration due to cloud cover and turbine orientation.*
4. *Dwelling is not predicted to experience any shadow flicker above a moderate level of intensity, but may experience some shadow flicker below a moderate level of intensity.*

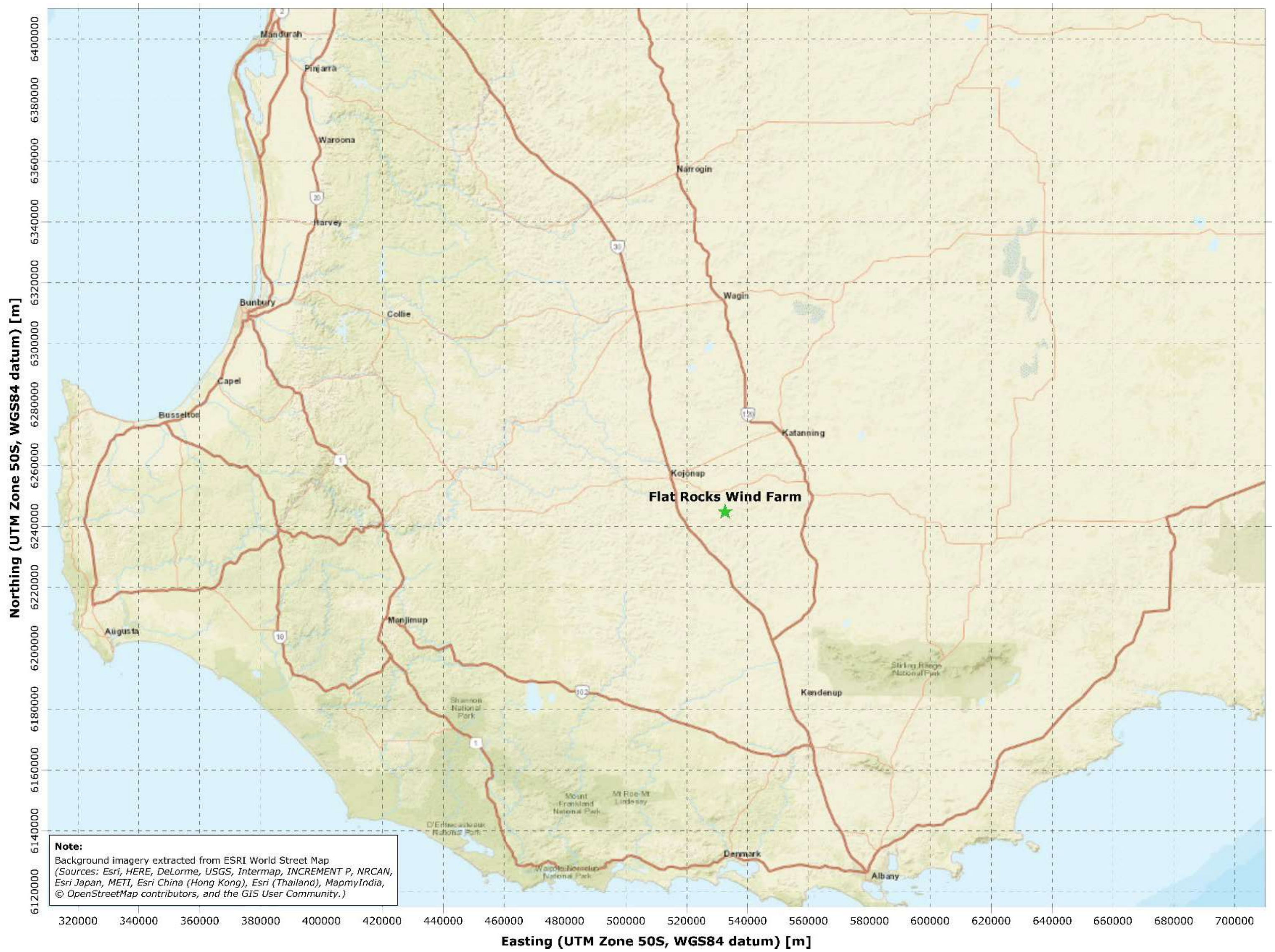

Figure 1 Location of the Project

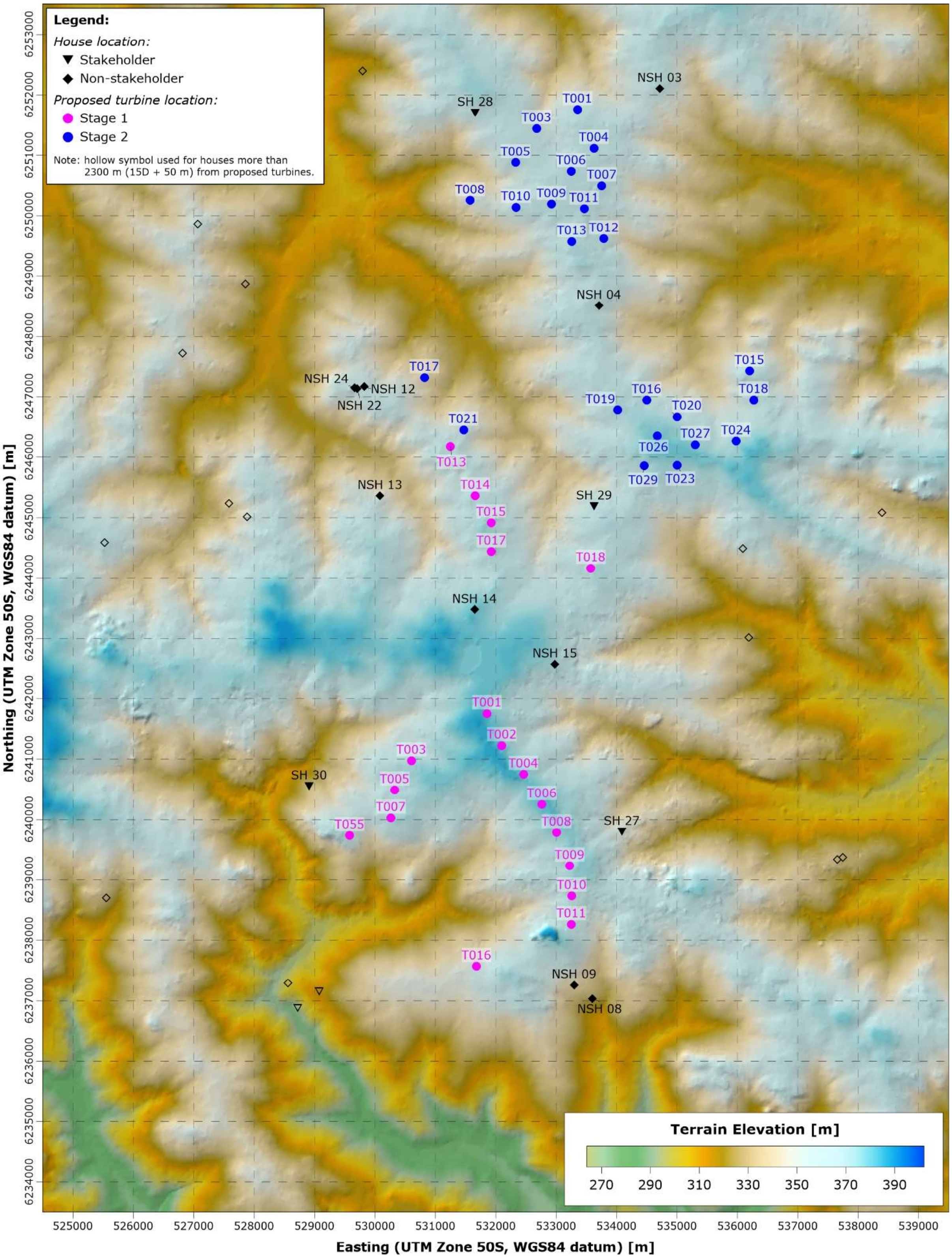

Figure 2 Elevation map of the Project

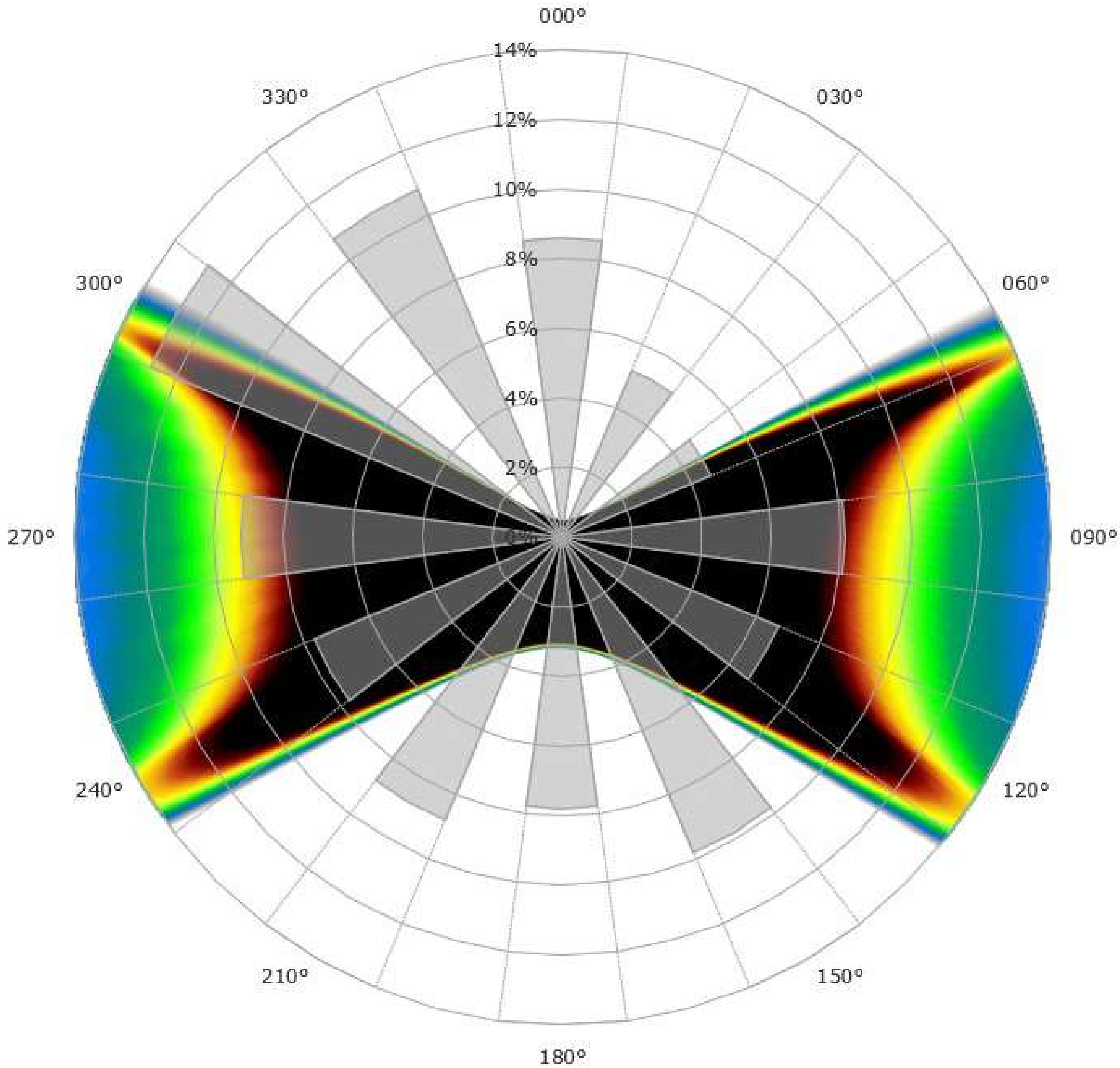

Figure 3 Indicative shadow flicker map and wind direction frequency distribution

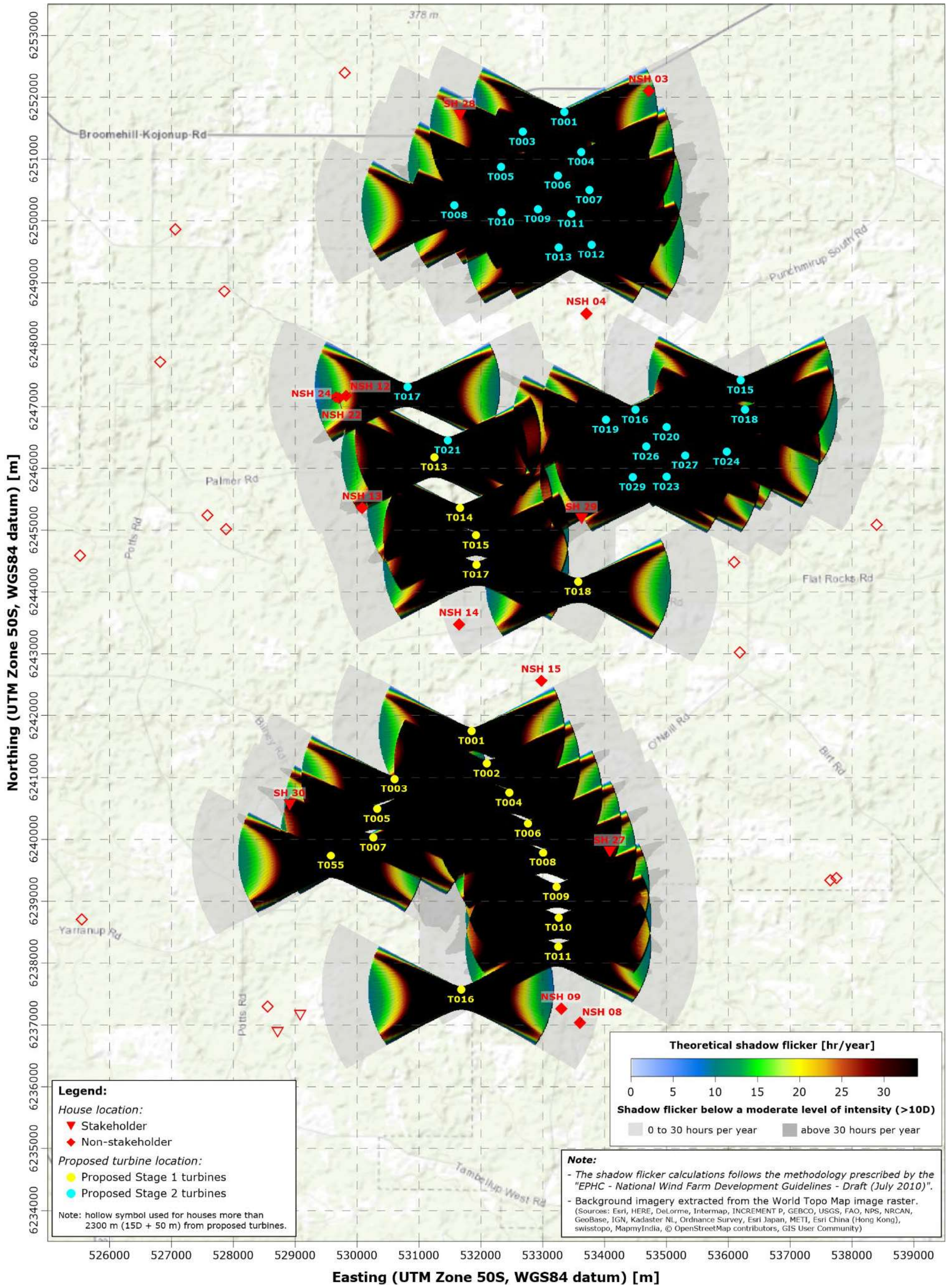

Figure 4 Theoretical annual shadow flicker duration map

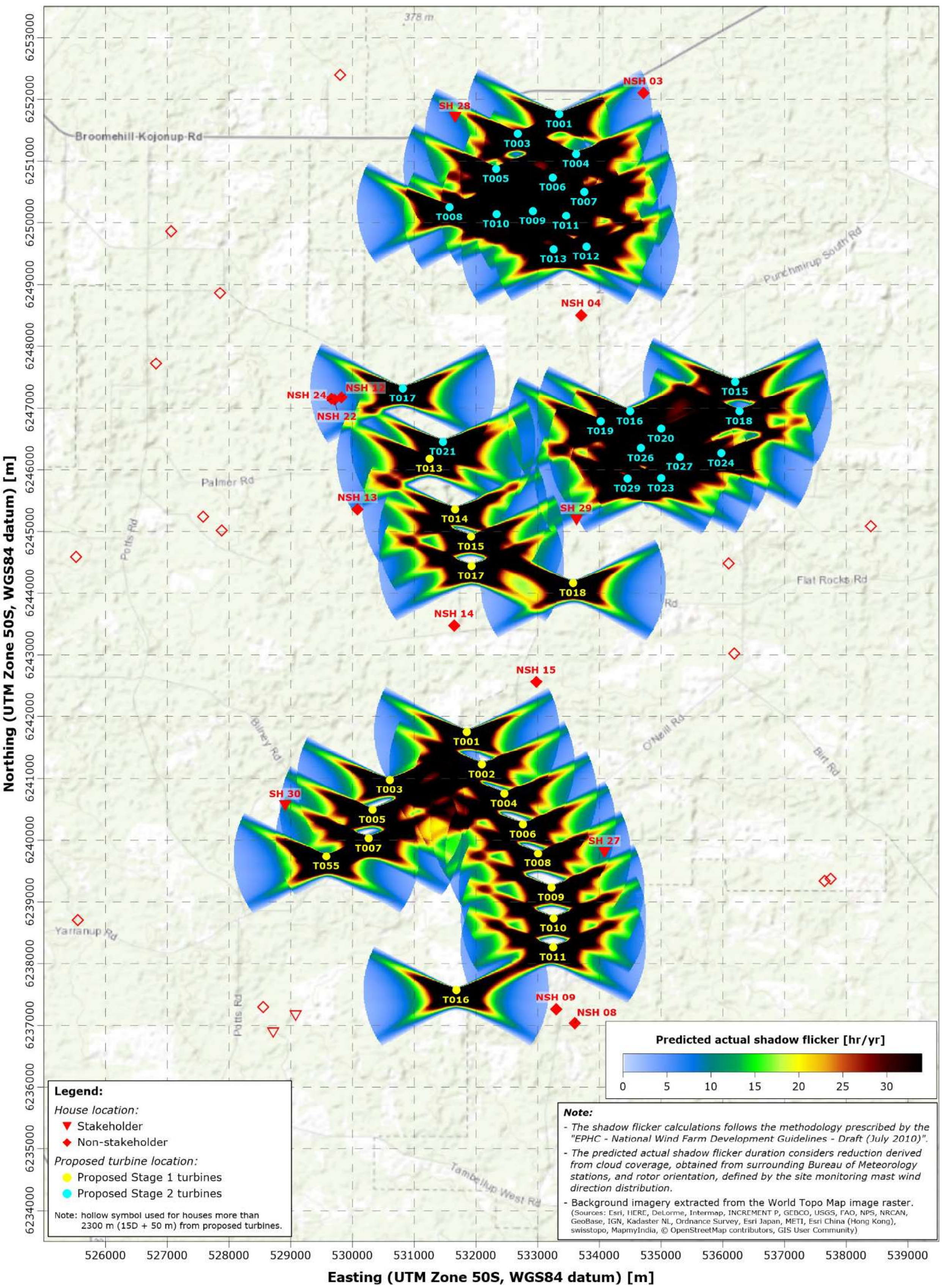

Figure 5 Predicted actual annual shadow flicker duration map

About DNV

Driven by our purpose of safeguarding life, property and the environment, DNV enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.