SHADOW FLICKER ASSESSMENT FOR THE BERRYBANK WIND FARM, VICTORIA

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CONTENTS

1 EXECUTIVE SUMMARY

Garrad Hassan Pacific Pty Ltd (GH) has been commissioned by Robert Luxmore on behalf of Union Fenosa Australia Pty Ltd (Union Fenosa), to carry out an independent assessment of the shadow flicker durations for locations in the vicinity of the proposed Berrybank wind farm. The wind farm is to be located 50 kilometres southwest of Ballarat in Western Victoria, and will consist of 100 wind turbines.

As part of the guidelines for the development of wind farms in Victoria [1], the issue of shadow flicker is addressed where it is stated that:

> *"The shadow flicker experienced at any dwelling in the surrounding area must not exceed 30 hours per year as a result of the operation of the wind energy facility."*

Whilst the guidelines suggest that it is possible to determine the seasonal duration of shadow flicker, this is far from straightforward. The simplest method to calculate shadow flicker examines the quantity of shadow flicker from a purely geometrical standpoint. Such a style of calculation tends to over estimate the number of hours of shadow flicker experienced at a dwelling [2, 3]. The variation of light intensity, the incidence of cloud cover, the level of humidity and other dispersants in the air, and other factors all influence the quantity and intensity of shadow flicker experienced by a dwelling.

The analysis conducted here involved a simple geometric analysis using a list of nominated shadow flicker receptors (i.e.: house locations) in combination with a proposed layout and turbine specification for the wind farm. Co-ordinates of shadow flicker receptors and turbine locations have been supplied by Robert Luxmore [4]. This information was combined with previously supplied topographical data for the area to assess the duration of shadow flicker experienced by houses on and around the site.

Diffusion of a shadow with distance has been considered by assuming that the maximum distance a shadow can be cast that is likely to cause shadow flicker is approximately 1 km [2, 5].

The results of this analysis indicate that no off-site dwellings are likely to experience any shadow flicker.

Six on-site dwellings are predicted to experience shadow flicker, with three of these experiencing durations of greater than 30 hours per annum.

An assessment of the level of conservatism associated with the analysis has been conducted. After applying suitable reduction factors based on the wind rose at the site and the likely variation in turbine orientation, three on-site dwellings are still expected to experience shadow flicker durations of greater than 30 hours per year. Out of these three houses, two houses have been identified by Union Fenosa as being uninhabitable. The remaining house (66) has an estimated shadow flicker duration of 38 hours per annum. This result is still likely to be conservative as cloud cover, reduced turbine dimensions, and the screening effect of vegetation have not been considered. If appropriate vegetation is planted to screen these turbines it is likely that less than 30 hours of shadow flicker per annum will be experienced at house 66.

GH considers that the effects of shadow flicker to road users, while passing the Berrybank Wind Farm, will not be significant.

2 SITE DESCRIPTION

2.1 Site description

The area examined in this report for potential wind farm development is located approximately 50 kilometres southwest of Ballarat in Victoria, Australia. The general location of the area of interest is shown in Figure 2.1. A more detailed contour map of the region surrounding Berrybank can be seen in Figure 2.2 which also includes proposed turbine locations.

The proposed wind farm is located on a hill system that rises gently from the plains and lakes to the south to an elevation ranging from approximately 150 m to 200 m above sea level. Mount Kinross at an elevation of 276 m lies approximately 5 km to the northwest of the closest turbine.

2.2 House locations

A list of co-ordinates of dwellings to be considered as shadow flicker receptors has been provided by Robert Luxmoore [4]. This list of dwellings and the distances to the nearest turbines are presented in Table 2.1.

2.3 Road locations

The roads surrounding the project are shown in Figure 2.2. The key roads that pass within 1 km of wind turbines include the primary road of Hamilton Highway, and several secondary and local roads including Berrybank-Wallinduc Road, Lismore Station Road, Urchs Road, Berrybank-Werneth Road, and Padgetts Lane.

2.4 Proposed Wind Farm layout

Union Fenosa has advised that the Berrybank wind farm development application includes provision for 100 turbines. The maximum turbine dimensions considered in the analysis are are summarised in Table 2.2. It is understood that the maximum turbine dimensions currently under consideration for the site have reduced from those covered in the analysis, as indicated in Table 2.2. The maximum calculated shadow flicker impact presented here is therefore likely to be slightly conservative compared to the case with reduced turbine dimensions.

A list of co-ordinates of proposed turbine locations has been provided by Robert Luxmoore [4]. These co-ordinates, together with the identifiers are shown in Table 2.3.

3 SHADOW FLICKER ASSESSMENT

3.1 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 variable factors as follows:

- Direction of the property relative to the turbine.
- Distance from turbine. (The further the observer is from the turbine, the less pronounced the effect would be);
- Wind direction. The shape of the shadow will be determined by the position of the sun relative to the blades (which will be rotated to face the wind);
- Turbine height and rotor diameter;
- Time of year and day (the height of the sun in the sky);
- Weather conditions (cloud cover reduces the risk of shadow flicker)

3.2 Assessment Methodology

The 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 wind farm site and wind turbine details such as rotor diameter and hub height.

The shadow flicker calculations have been undertaken using a computer model of the wind farm. The model makes the following simplifications:

- There are clear skies every day of the year;
- The turbines are always rotating;
- The sun can be represented as a single point;
- The blades of the turbines are always perpendicular to the direction of the line of sight from the specified location to the sun.
- The sun is modelled as a point source.

Shadow flicker has been calculated at the receptors at a height of 2 m to represent ground floor windows. The shadow receptors are simulated as mounted horizontal plates, representing the worst case scenario, whereas real windows would be facing towards a particular, selective direction. The simulations have been carried out with a resolution of 1 minute; if shadow flicker occurs in any 1 minute period, the model records this as 1 minute of shadow flicker.

It is generally accepted that shadow flicker from wind turbines does not occur at distances greater than approximately 10 rotor diameters from a wind turbine, or at a distance between 500 m to 1000 m. Beyond this distance the shadow intensity is reduced such that the variation in light levels is unlikely to cause annoyance for an observer, and a viewer does not perceive the turbine blade to be chopping the light, but rather as an object passing in front of the sun [5,6].

To illustrate typical results, an indicative theoretical shadow flicker map, for a flat area, is shown in Figure 3.1. 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 solstice and conversely the lobes to the south result from the winter solstice. 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 the shadows cast by the turbine increases, increasing the areas around the turbine affected by shadow flicker.

3.3 Factors Affecting Shadow Flicker Duration

Shadow flicker duration calculated in this manner overestimates the annual number of hours of shadow flicker experienced at a specified location for several reasons.

1. The wind turbine will not always be yawed such that its rotor is in the worst case orientation (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 [2].

4. The modelling of the wind turbine blades as discs 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 dependant on the thickness of the turbine blade, and the human threshold for perception of light intensity variation [2]. As such, a shadow cast by the blade tip will be shorter than the shadow cast by the thickest part of the blade.

5. Modelling the sun as a point light source rather than a disc results in an overestimate of the shadow flicker duration. Light from different portions of the sun disc can superimpose around a turbine blade resulting in reduced shadow intensity.

6. 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.

7. 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.

8. 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 shadow flicker duration.

3.4 Current Analysis

The modelling of shadow flicker at the Berrybank wind farm has been conducted using the method described in section 3.2 above. The wind turbine has been modelled assuming all wind turbines are disc objects oriented perpendicular to the sun-turbine vector, representing the worst case scenario for shadow flicker.

An assessment of the possible reduction in shadow flicker duration due to turbine orientation has also been conducted. Wind direction data at the site has been supplied to GH and the site wind rose is overlaid as a wind rose on the indicative shadow flicker map in Figure 3.1. The wind rose shows that although the rotor will face a wide variety of directions, the proportion of time that the wind blows from any single direction is no greater than 13 %. Furthermore, the proportion of time that the wind blows from or to a given direction is no greater than 25 %. This has been modelled using GH Windfarmer individually for each dwelling. Overall, this results in a reduction in shadow flicker duration at affected receptors on average of approximately 35 %.

A review of the possible reduction in shadow flicker duration due to cloud cover has also been conducted. A review of observed cloud cover data from the Bureau of Meteorology for stations in the region has been undertaken to determine the likely level of cloud cover at the proposed Berrybank wind farm. Based on the historical data, an average cloud cover of greater than 50 % is typically observed for the region for both morning and evening, as is shown in Figure 3.2. Based on this data, the average cloud cover at the Berrybank site is assumed to be also greater than 50 %. It is assumed that cloud cover results in a proportional reduction in shadow flicker duration. However this reduction has not been applied to the shadow flicker duration results, and therefore the results can be regarded as conservative.

An assumption has been made regarding the maximum length a shadow can be cast that will cause flicker and annoyance for an observer. Guidance from the South Australian Government indicates that this distance is 500 m [7]. The UK wind industry considers that 10 rotor diameters is appropriate [6,8], while the Danish wind industry suggests this distance is between 500 m and 1 km [5]. GH has adopted the approach of taking the upper limit of the Danish wind industry and has limited the length a shadow can be cast that will cause flicker to 1 km.

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 due

to low wind or scheduled maintenance has not been considered. It is therefore likely that the adjusted shadow flicker durations presented here can still be regarded as a conservative assessment.

3.5 Mitigation

Because no flicker is expected at the off-site dwellings at the Berrybank site, GH does not believe that mitigation of shadow flicker is warranted or necessary. The mitigation of shadow flicker at on-site dwellings may be considered if the owners feel this is necessary. There are a number of mitigation options available, if required;

- Screen the turbine causing flicker from the house location via vegetation. In order to limit the size of screening to realistic levels, the screening would likely have to be installed relatively close to the house location; and would still need to block the view of the turbine from affected windows. Another option may involve simply drawing the curtains at the times that flicker occurs.

- Move the turbine causing flicker. Often small movements of turbine locations can result in significant reductions in flicker. This option may result in a reduction in energy output from the wind farm, or other additional cost (for example additional roading and cabling) compared to a layout where flicker is not a driving factor. This option is not practicable after construction of the wind farm.

- Stop the turbine at times flicker would otherwise occur. A stopped turbine does not create a moving shadow, and hence does not cause shadow flicker. The dates and times at which specific turbines can cause shadow flicker can be calculated and these specific turbines can be stopped. To further reduce the time for which the turbines are stopped, the turbines can often be fitted with a light sensor so that the turbine is only stopped when there is direct sunlight. If implemented in this way, the energy loss from flicker control should be able to be reduced to very low levels. This option can be implemented (if necessary) following construction of the wind farm.

4 RESULTS AND DISCUSSION

4.1 Dwellings

The maximum theoretical predicted shadow flicker duration at dwellings in the vicinity of the Berrybank Wind Farm, based on a geometric analysis and the maximum dimensions of the turbines considered, can be seen in Table 4.1. The results are also presented in the form of a shadow flicker map in Figure 4.1.

The result of this analysis is that no off-site dwellings are predicted to experience any shadow flicker, and six on-site dwellings are predicted to experience some shadow flicker. Three of the on-site dwellings are expected to experience a shadow flicker duration of greater than 30 hours per annum. These include house 65, house 66, and house 76, which are expected to receive 182 hours per annum, 58 hours per annum and 298 hours per annum respectively.

The geometric analysis assumes that the wind turbine is constantly yawed to the worst case position of facing into or away from the sun. Therefore a further analysis of the site wind direction frequency data was conducted and this was applied to the calculations for each residence. This reduced the shadow flicker durations on average by 35% for those that experienced any at all. The results are also presented in Table 4.1.

The result after this directional analysis was performed was that three of the on-site dwellings experienced shadow flicker estimated to be above 30 hours per year, based on a typical year. These are house 65, house 66, and house 76, with 119 hours per annum, 38 hours per annum and 134 hours per annum respectively. Of these three houses, house 65 and house 76, have been identified by Union Fenosa as being uninhabitable. The remaining house (66) has an estimated shadow flicker duration of 38 hours per annum. Turbines 29 and 56 have been identified as contributing to the majority of shadow flicker experienced at house 66. If appropriate vegetation is planted to screen these turbines it is likely that less than 30 hours of shadow flicker per annum will be experienced at house 66.

These figures do not include an allowance for the effect of cloud cover. Investigations into historical cloud cover observations indicate that the average cloud cover for the general region is greater than 50 % illustrating that the actual hours of shadow flicker around the proposed wind farm will be significantly less than the modelled hours.

The modelling process does not take into account any reduction due to the effect of any vegetation or other shielding effects around each house in calculating the number of shadow flicker hours, and may therefore be regarded as a conservative assessment.

4.2 Roads

It is generally accepted that wind turbines do not create a hazard to road users, and that the potential distractions caused by wind turbines are no greater than those faced during a normal journey [5]. All drivers are expected to be able to maintain safe control of their vehicle when confronted with visual distractions while driving.

The impact of shadow flicker on a driver is similar to the periodic variation in light intensity caused when driving past a row of trees through which the sun is shining. This is an event which occurs commonly, particularly when driving in rural areas, and which drivers must be able to manage as part of their normal driving practice.

GH therefore considers that the effects of shadow flicker to road users, while passing the Berrybank wind farm will not be significant.

5 CONCLUSION

An analysis has been conducted to determine the duration of shadow flicker experienced at shadow receptors in the vicinity of the Berrybank wind farm under development by Union Fenosa. The maximum turbine blade tip height analysed was 152 m. It is noted that the maximum tip height currently under consideration for the site is lower, at 131 m. The shadow flicker duration results presented may therefore be slightly conservative compared to those that would be obtained using the turbine dimensions currently under consideration.

The assessment has been conducted using a simple geometric analysis with approximation of shadow diffusion with distance.

The result of this analysis is that no off-site dwellings are predicted to experience any hours of shadow flicker. Six on-site dwellings are predicted to experience shadow flicker, with three of these experiencing greater than 30 hours per year. The results are presented in table 4.1.

An assessment of the possible reduction in the number of predicted shadow flicker hours due to variation in turbine orientation has been conducted. This involved applying reduction factors to the results from the simple geometric analysis based on the likely wind turbine orientation as determined from the wind rose measured at the site. After this reduction, three on-site dwellings are still expected to experience greater than 30 hours of shadow flicker per annum. Of these three houses, two houses have been identified by Union Fenosa as being uninhabitable. The remaining house (66) has an estimated shadow flicker duration of 38 hours per annum. The modelling process can be considered conservative as cloud cover and the screening effect of vegetation have not been considered. Two turbines have been identified as contributing to the majority of shadow flicker experienced at house 66. If appropriate vegetation is planted to screen these turbines it is likely that less than 30 hours of shadow flicker per annum will be experienced at house 66.

GH considers that the effects of shadow flicker to road users, while passing the Berrybank Wind Farm will not be significant.

6 REFERENCES

1 "Policy and planning guidelines for development of wind energy facilities in Victoria", Sustainable Energy Authority Victoria, 2003.

2 Freund H-D., Kiel F.H., "Influences of the opaqueness of the atmosphere, the extension of the sun and the rotor blade profile on the shadow impact of wind turbines", DEWI Magazin 20, Feb 2002.

3 Osten, T. & Pahlke T., "Shadow Impact on the surrounding of Wind Turbines", DEWI Magazin 13., Aug 1998.

4 Email from A. Murchie of Robert Luxmoore Project Management to S. Yeo of GH, 26 Feb 2009.

5 "Shadow Variations from Wind Turbines", Danish Wind Industry Association, May 2003, viewed 15 October 2008, http://www.windpower.org/en/tour/env/shadow/shadow2.htm

6 "Onshore Wind: Shadow Flicker", Department for Business Enterprise & Regulatory Reform, UK, 2008, viewed 15 October 2008, http://www.berr.gov.uk/energy/sources/renewables/planning/onshore-wind/shadow-flicker/page18736.html

7 Planning SA, Planning Bulletin "Wind Farms, Draft for Consultation", South Australian Government, 2002.

8 "Planning for Renewable Energy: A Companion Guide to PPS22", Office of the Deputy Prime Minister, UK, 2004, http://www.communities.gov.uk/documents/planningandbuilding/pdf/147447.pdf

LIST OF TABLES

LIST OF FIGURES

Receptor ID	Easting[1] [m]	Northing[1] [m]	Involvement in the Project
House 9	724123	5799807	Licence Agreement
House 54	720176	5800321	Licence Agreement
House 55	719613	5799970	Licence Agreement
House 61	719390	5796269	Licence Agreement
House 62	721670	5796577	Licence Agreement
House 65	723797	5798337	Licence Agreement
House 66	722414	5798736	Licence Agreement
House 67	718431	5793106	Licence Agreement
House 68	718429	5793061	Licence Agreement
House 71	718590	5793405	Licence Agreement
House 76	722703	5792293	Licence Agreement
House 78	720663	5793064	Licence Agreement
House 81	719130	5793548	Licence Agreement
House 10	718587	5797888	No Licence Agreement
House 18	719391	5803724	No Licence Agreement
House 19	719185	5805026	No Licence Agreement
House 20	718656	5804668	No Licence Agreement
House 21	717547	5803608	No Licence Agreement
House 22	715098	5801127	No Licence Agreement
House 23	714589	5801057	No Licence Agreement
House 24	713788	5795489	No Licence Agreement
House 25	714049	5795420	No Licence Agreement
House 26	714511	5795536	No Licence Agreement
House 27	716501	5793929	No Licence Agreement
House 28	715923	5793021	No Licence Agreement
House 29	716065	5791501	No Licence Agreement
House 30	715431	5790719	No Licence Agreement
House 37	716656	5798944	No Licence Agreement
House 38	720714	5788267	No Licence Agreement
House 39	722143	5787638	No Licence Agreement
House 41	725172	5789858	No Licence Agreement
House 42	725866	5790427	No Licence Agreement
House 43	725385	5792233	No Licence Agreement
House 45	726590	5794934	No Licence Agreement
House 47	727033	5797127	No Licence Agreement
House 48	727061	5797842	No Licence Agreement
House 53	720577	5803778	No Licence Agreement
House 56	719602	5799532	No Licence Agreement
House 57	719459	5799651	No Licence Agreement
House 58	717818	5801367	No Licence Agreement
House 60	717667	5797118	No Licence Agreement
House 63	722798	5796160	No Licence Agreement

[1] Co-ordinate system is UTM Zone 54 (WGS 84 datum)

Table 2.1. Shadow Receptor list for the Berrybank wind farm. (continued)

Receptor ID	Easting[1] [m]	Northing[1] [m]	Involvement in the Project
House 64	724012	5796148	No Licence Agreement
House 69	718535	5793693	No Licence Agreement
House 70	718346	5793752	No Licence Agreement
House 72	718520	5793406	No Licence Agreement
House 73	718619	5792068	No Licence Agreement
House 74	718006	5791092	No Licence Agreement
House 75	717955	5789787	No Licence Agreement
House 79	719983	5793140	No Licence Agreement
House 80	719684	5793375	No Licence Agreement
House 82	716793	5795383	No Licence Agreement
House 83	721502	5791385	No Licence Agreement
House 84	723128	5790975	No Licence Agreement
House 85	724101	5791516	No Licence Agreement
House 86	724815	5788076	No Licence Agreement
House 101	726673	5796189	No Licence Agreement
House 102	725109	5796692	No Licence Agreement
House 103	723431	5793860	No Licence Agreement
House 104	718137	5804335	No Licence Agreement
House 105	717630	5797179	No Licence Agreement
House 106	716455	5804551	No Licence Agreement
House 107	715247	5802080	No Licence Agreement
House 108	718494	5793339	No Licence Agreement
House 109	718502	5793373	No Licence Agreement
Shed	719657	5788404	No Licence Agreement

[1] Co-ordinate system is UTM Zone 54 (WGS 84 datum)

Table 2.1 Shadow Receptor list for the Berrybank wind farm. (concluded)

Item	Maximum dimension analysed [m]	Maximum dimension currently under consideration [m]
Max Hub Height	100	80
Maximum Blade Diameter	104	98
Maximum Tip Height[1]	152	131

Table 2.2. Turbine Specifications for Berrybank Wind Farm.

Turbine Identifier	Easting[1] [m]	Northing[1] [m]	Turbine Identifier	Easting[1] [m]	Northing[1] [m]
001	718652	5802179	**026**	721074	5799204
002	719235	5802626	**027**	721740	5799891
003	719733	5802777	**028**	722189	5799497
004	719936	5797730	**029**	723033	5799194
005	720688	5799940	**030**	723214	5800286
006	719874	5802200	**031**	720422	5791181
007	719492	5801285	**032**	721000	5794218
008	720804	5800436	**033**	717508	5792561
009	719732	5801689	**034**	719266	5801952
010	718676	5800842	**035**	719142	5800615
011	719731	5800833	**036**	719980	5798538
012	718962	5801349	**037**	720501	5798512
013	720348	5801559	**038**	720993	5798686
014	720538	5801008	**039**	723772	5798807
015	721874	5797354	**040**	722821	5792881
016	720318	5796959	**041**	723294	5792785
017	721257	5799665	**042**	721414	5792432
018	720639	5799429	**043**	722465	5792519
019	721859	5800552	**044**	725612	5797947
020	722425	5800859	**045**	724851	5798766
021	721248	5800291	**046**	724753	5797738
022	722296	5800211	**047**	724224	5798169
023	722885	5799651	**048**	717298	5793181
024	722859	5800594	**049**	724010	5797749
025	719616	5798063	**050**	717461	5792083

[1] Co-ordinate system is UTM Zone 54 (WGS 84 datum)

Table 2.3. Proposed layout of the Berrybank Wind farm.

Turbine Identifier	Easting[1] [m]	Northing[1] [m]	Turbine Identifier	Easting[1] [m]	Northing[1] [m]
051	725119	5798064	**076**	719471	5794946
052	722855	5798177	**077**	720541	5794620
053	720587	5791995	**078**	720275	5795050
054	722629	5797663	**079**	720870	5795207
055	720424	5790132	**080**	722317	5794011
056	721670	5798544	**081**	719402	5794354
057	720523	5797897	**082**	719846	5794581
058	720571	5795722	**083**	721497	5794841
059	721034	5795908	**084**	721290	5793778
060	721985	5798032	**085**	721955	5795028
061	721349	5797952	**086**	722325	5793119
062	717031	5792289	**087**	721819	5795491
063	720447	5790715	**088**	720398	5794077
064	723429	5798264	**089**	721028	5794742
065	719881	5797190	**090**	721490	5794283
066	720654	5796315	**091**	722412	5795231
067	719389	5797117	**092**	722473	5793558
068	720853	5796843	**093**	722543	5794720
069	720991	5797527	**094**	722107	5794470
070	717579	5794455	**095**	720802	5793780
071	720170	5796044	**096**	721796	5793825
072	719092	5795312	**097**	721975	5792779
073	719643	5795613	**098**	721749	5793249
074	717068	5792757	**099**	722975	5792402
075	719009	5794594	**100**	721359	5795356

[1] Co-ordinate system is UTM Zone 54 (WGS 84 datum)

Table 2.4. Proposed layout of the Berrybank Wind farm.

				Expected Shadow Flicker		
Receptor ID[1]	**Easting [m]**	**Northing [m]**	**Information**	**Longest Theoretical Day [min]**	**Theoretical Max [hr/yr]**	**Turbine Orientation Adjusted [hr/yr]**
House 54	720176	5800321	Licence Agreement	38	23	14
House 61	719390	5796269	Licence Agreement	30	21	14
House 62	721670	5796577	Licence Agreement	29	14	9
House 65	723797	5798337	Licence Agreement	109	182	119
House 66	722414	5798736	Licence Agreement	35	58	38
House 76	722703	5792293	Licence Agreement	125	298	194

[1] Residences with zero hours shadow flicker have been omitted from this table

Table 4.1. Predicted theoretical maximum and turbine orientation adjusted annual shadow flicker durations for the Berrybank wind farm

Figure 2.1. Location of the proposed Berrybank wind farm site.

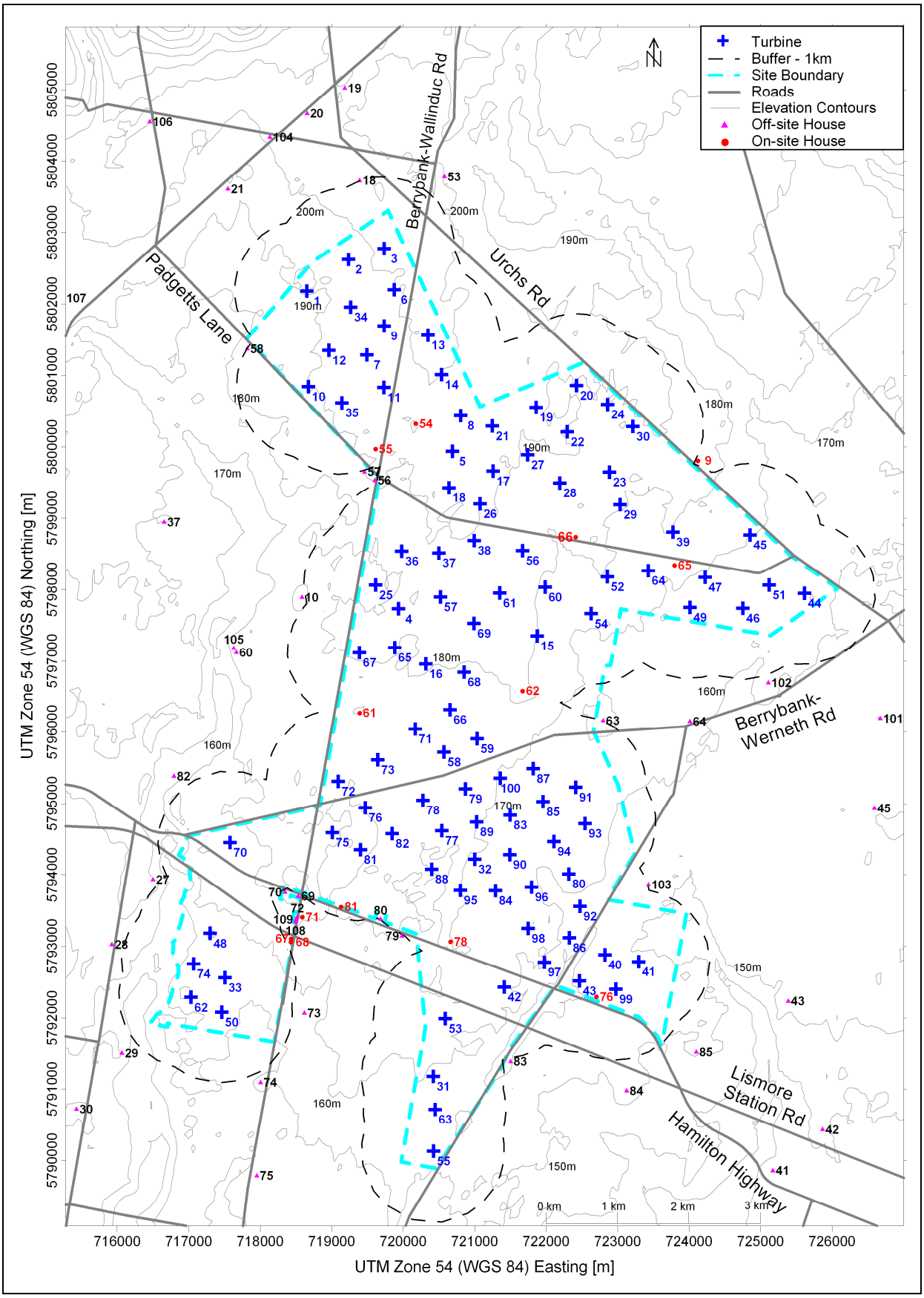

Figure 2.2. General region of interest including proposed layout.

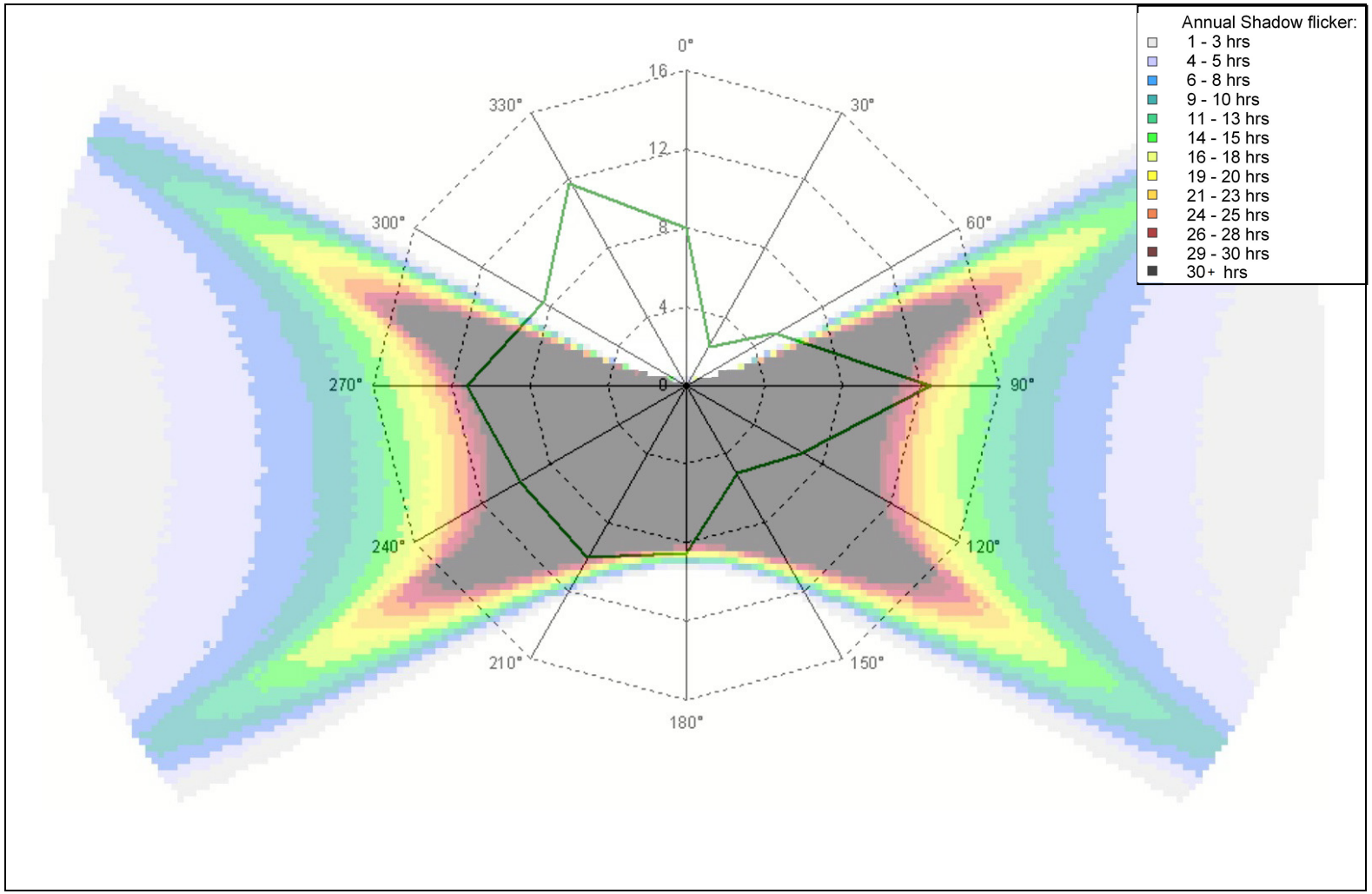

Figure 3.1. Indicative shadow flicker map with Berrybank wind direction frequency distribution.

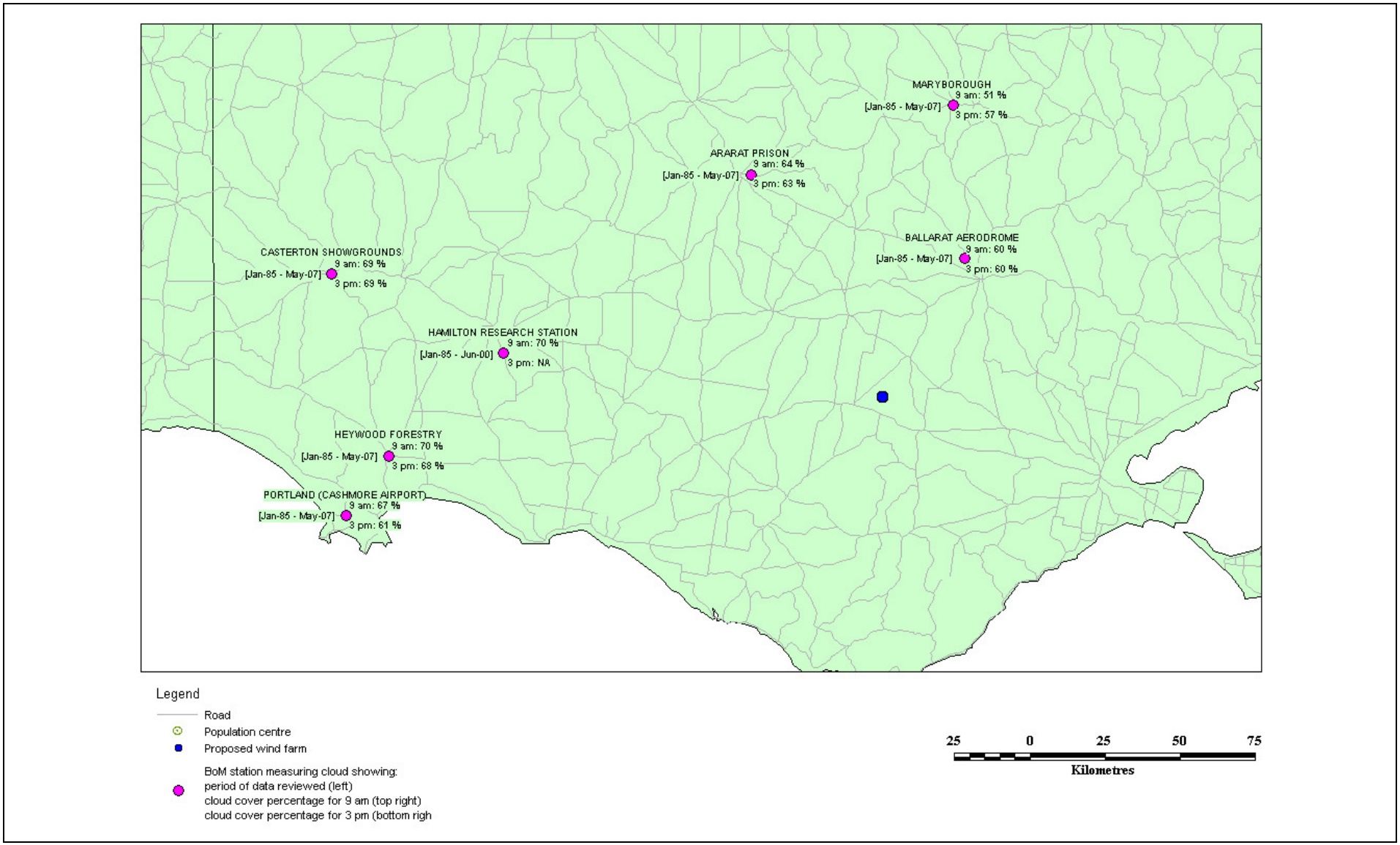

Figure 3.2. Average of historic morning and afternoon cloud cover data for nearby Bureau of Meteorology stations.

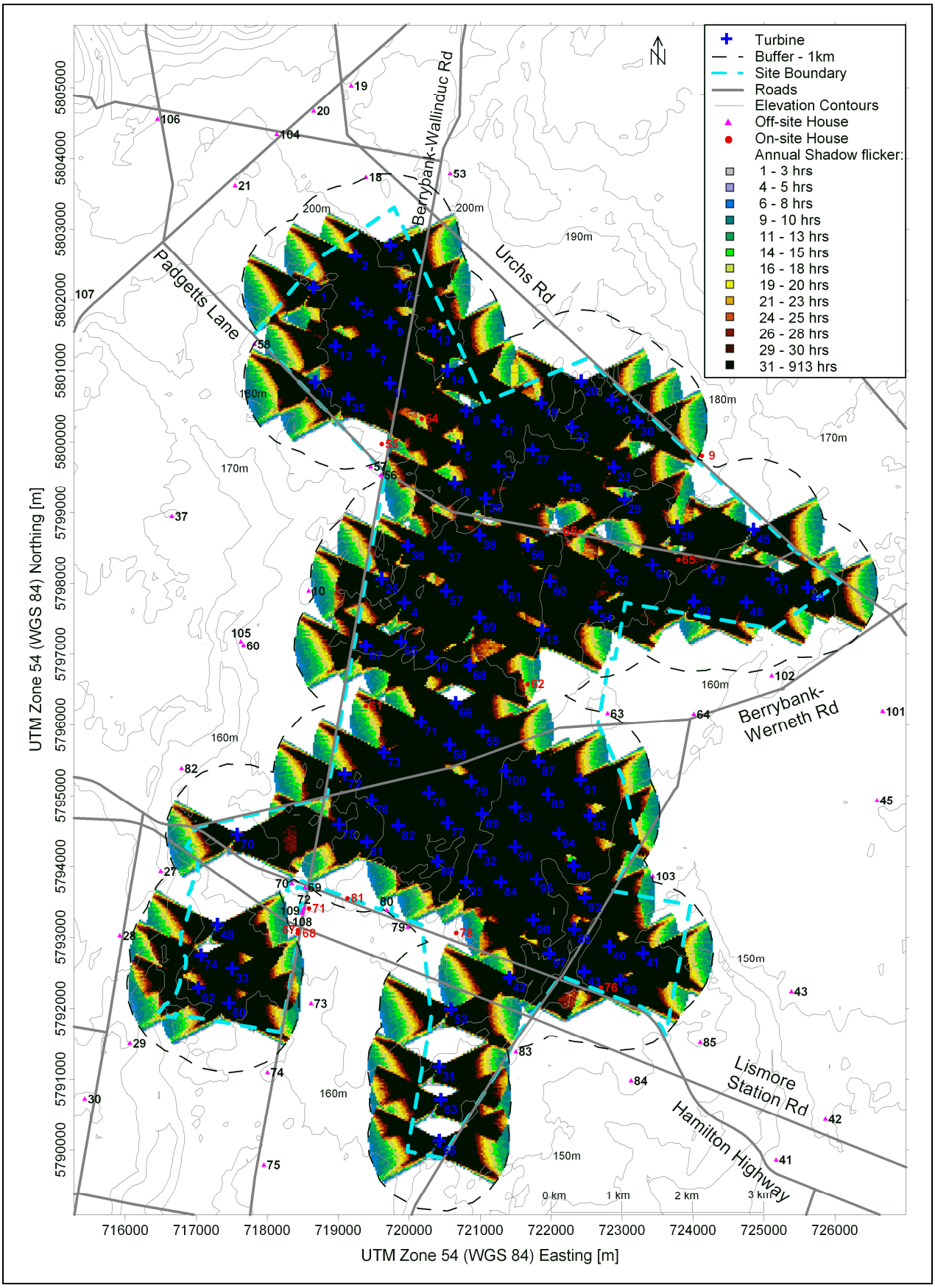

Figure 4.1. Map showing maximum theoretical annual shadow flicker at the Berrybank Wind Farm