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Delburn Wind Farm
Preliminary Shadow Flicker Assessment

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1 Introduction

OSMI Australia has commissioned K2 Management to undertake a shadow flicker assessment for the Delburn Wind Farm. This shadow flicker assessment corresponds to layout version 2.1.

The turbine dimensions that have been modelled in this assessment are summarized in the table below. The candidate turbines under consideration at the Delburn Wind Farm all have rotor diameters less than 180 m.

	Number of turbines	Rotor diameter [m]	Hub height [m]	Maximum blade chord [m]
Modelled turbine	35	180.0	160.0	4.5

Table 1.1 Turbine dimensions used in shadow flicker modelling

1.1 Site location

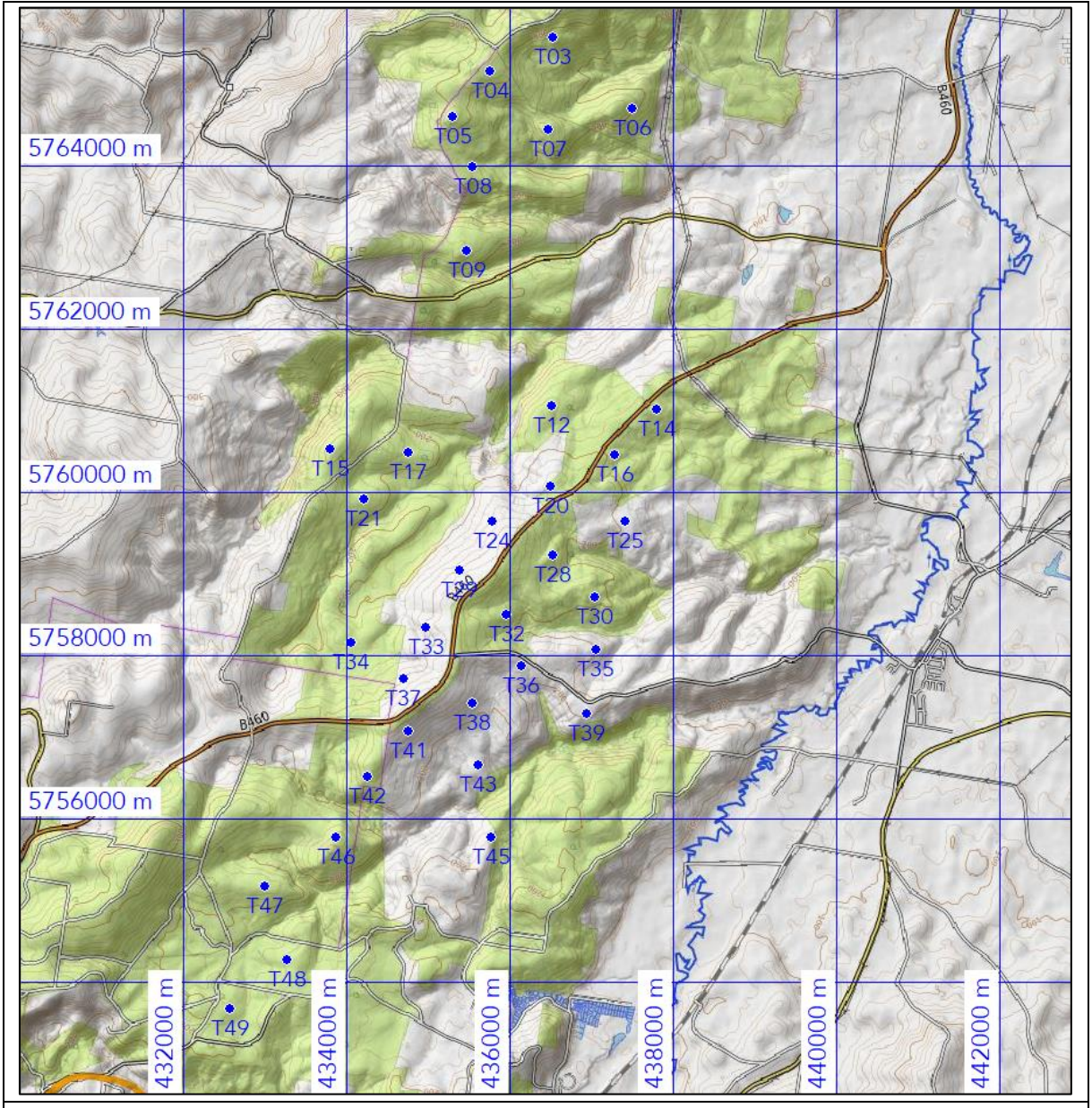
The location of the proposed wind farm is shown in Figure 1.1. The Delburn site is located approximately 126 km southeast of Melbourne.

Figure 1.1 Delburn Wind Farm location

1.2 Site description

The site area is presented in Figure 1.1. K2 Management staff have not visited the site. This shadow flicker assessment corresponds to layout version 2.1. Turbine coordinates are presented in Appendix Table A1.

The proposed wind farm is situated on an elevated plain, 10 km south-east of Morwell in Victoria. The site area extends approximately 6km east to west and 15 km north to south. The terrain is forested and varies in elevation between 100 m in the south west corner to 300 m towards the centre of site. The Bass Highway runs through the centre of the proposed site, 40 km from the coast of Bass Straight, to the south. The site is also in proximity to a number of open cut coal mines.



Legend

Proposed Delburn Wind Farm turbine

Notes

- Coordinate system is UTM Grid Zone-55 WGS84 Datum.

Figure 1.2 Indicative turbine layout (layout version 2.1)

2 Shadow flicker

At the request of the Client, K2 Management has undertaken indicative shadow flicker modelling for the latest layout at the Delburn Wind Farm. The following sections describe the methodology and assumptions applied.

2.1 Applicable guidelines

The Policy and Planning Guidelines for Wind Farm Development in Victoria state that 'shadow flicker experienced immediately surrounding the area of a dwelling (garden fenced area) must not exceed 30 hours per year'.

The methodology applied to assess the annual shadow flicker exposure at each dwelling follows the approach prescribed in the Australian National Guidelines[1].

The National Guidelines determine that the optimum method of assessment is to:

- Evaluate the shadow flicker impact up to a distance of 265 x maximum blade chord (no assessment is required for dwellings beyond this distance).
- Identify all residences within the extent of shadows from proposed turbine positions.
- Use modelling software with relevant modelling parameters, to calculate the theoretical annual shadow flicker duration at each residence, accounting for topography and cumulative effects.
- If necessary, modify turbine layout and repeat calculations, or introduce mitigation measures to achieve compliance.
- Depending on jurisdictions, shadow flicker assessment may not be required for associated landowners.

The National Guidelines state the following with respect to the recommended modelling assumptions:

"Calculation of shadow flicker in an ideal model (with the assumptions specified here) will provide a conservative estimate of the actual shadow flicker. In most circumstances where a dwelling experiences a 'Modelled' level of shadow flicker less than 30 hours per year, no further investigation is required. However, if this level is exceeded in the modelled scenario, mitigation measures may be introduced and the 'actual' or 'measured' level of shadow flicker will need to be determined".

Further detail is provided in the guidelines for how to estimate the "actual" number of annual shadow flicker hours accounting for cloud cover.

[1] National Wind Farm Development Guidelines – Draft, July 2010

2.2 Modelling methodology

Under certain combinations of geographical position and time of day, the sun may pass behind the moving turbine rotor blades and cast a shadow that alternates on and off. The frequency of the flicker depends on the rate of rotation and the number of blades of the wind turbine. Shadow flicker is more evident inside a residence as compared to out in the open as light outside comes from all directions. The number of annual hours of shadow flicker at a given location can be calculated using geometric models that incorporate the following information:

- The sun path across the sky for the specific site latitude and longitude;
- The topography of the site and its surroundings;
- The wind turbine rotor diameter, hub height and number and dimensions of blades;
- The location of the wind turbines and residences.

The Client provided a list of dwellings[2] in the vicinity of the wind farm. A wind turbine rotor diameter of 180 m and hub height of 160m have been modelled. A maximum blade chord length of 4.5 m has been assumed based on the candidate turbine models under consideration for this project.

The guidelines require that the impact of shadow flicker on dwellings within a distance of 1192.5 m (265 x maximum chord length) of any wind turbine is assessed. The coordinates of all dwellings assessed as part of this analysis are provided in Appendix Table A2.

The following assumptions are made in the worst-case model:

- The minimum sun height for influence is 3° above the horizon line because when the sun is below this limit, the shadow dissipates before it reaches the ground (or the receptor);
- Blade flicker is calculated only when more than 20% of the sun is covered by the blade.
- The sun is assumed to be shining all day, from sunrise to sunset, that is, there are never any clouds in the sky;
- The wind turbine rotor is modelled as a disc and assumed to be in the "worst case" orientation, that is, perpendicular to the sun-rotor vector at all times;
- The wind turbines are always operating;
- Each residence is modelled as an open area or "greenhouse" of 100 m^2.

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

- The amount of dispersants in the atmosphere has the ability to influence any shadows that may be cast. The amount of dispersants in the air varies with time and has the potential to vary the air density, which affects the refraction of light. This in turn affects the intensity of direct sunlight, which causes the shadows;

[2] "DWF_Dwelling_Pt_20190530.kmz", Dwelling coordinates .kmz file, 30 May 2019.

- There are substantial periods of time during daylight hours when clouds will prevent any shadow flicker effect;
- The wind turbines will not constantly yaw to the “worst case” position where the wind turbine is facing into or away from the sun-rotor vector;
- Periods where the wind turbine is not in operation due to low winds, high winds or operational and maintenance reasons are not taken into consideration;
- Vegetation may partially block visibility of turbines from residences, and is not taken into consideration;
- Houses will have screening afforded by the walls and roof; the windows are only in specific directions.

2.2.1 Results

The preliminary shadow flicker results are presented in Figure 2.1 and Appendix Table A2. The results show that no dwellings experience shadow flicker in excess of 30 hours per year.

Garden fenced areas have not been confirmed, therefore the results below indicate the impact of shadow flicker at each dwelling. However, a high level review of satellite imagery to determine the extent of garden fenced areas suggests that they will not be subject to shadow flicker. It is recommended that a site survey is undertaken to confirm the extent of garden fenced areas for dwellings in close proximity to the turbines.

Should the turbine locations change, or additional dwellings be identified in proximity to the turbine locations, the shadow flicker analysis would need to be updated.

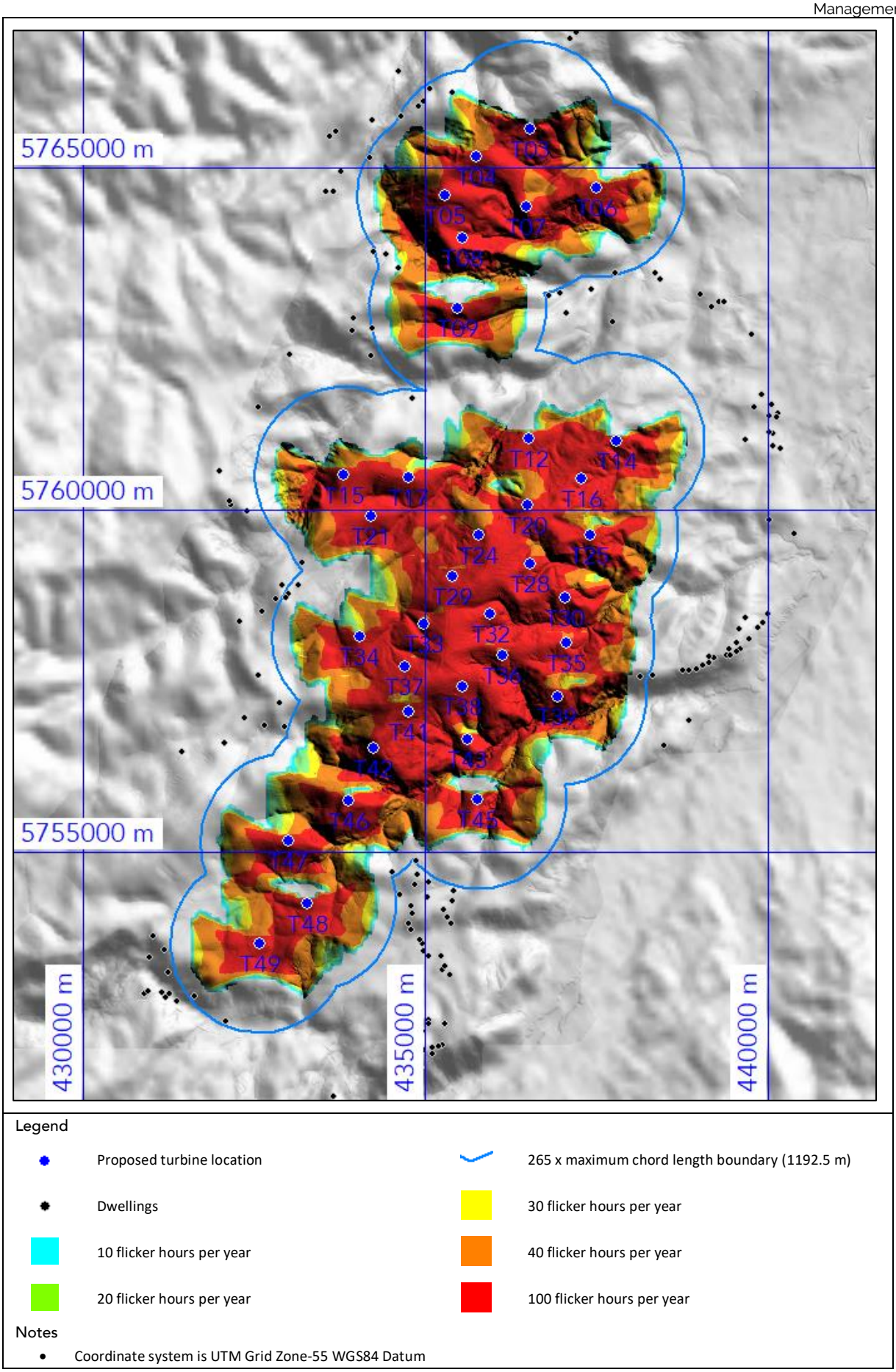


Figure 2.1 Shadow flicker results for Delburn Wind Farm for a rotor diameter of 180 m

3 Conclusions and recommendations

3.1 Conclusions

Shadow-flicker modelling at the Delburn Wind Farm, undertaken in accordance with the National and Victoria State planning guidelines, confirms compliance with the specified limit of 30 hours per year for all dwellings within the assumed shadow flicker zone of 1192.5 m.

3.2 Recommendations

In the event that any changes to the layout, hub heights, or turbine rotor diameter are made, it is recommended that the shadow flicker analysis is updated.

A high level review of garden fenced areas using satellite imagery indicates that these are not subject to shadow flicker, however a site survey should be undertaken to confirm the extent of garden areas of dwellings in close proximity to turbines.

Appendix A

A1 Wind turbine layout coordinates

Turbine	Easting [m]	Northing [m]	Elevation [m]
T03	436525	5765561	273
T04	435750	5765156	305
T05	435296	5764592	299
T06	437495	5764699	197
T07	436473	5764438	237
T08	435544	5763978	238
T09	435470	5762948	222
T12	436508	5761045	178
T14	437790	5761008	177
T15	433800	5760517	243
T16	437282	5760458	177
T17	434760	5760476	203
T20	436493	5760073	217
T21	434216	5759907	205
T24	435788	5759640	218
T25	437408	5759641	191
T28	436532	5759218	210
T29	435389	5759043	235
T30	437040	5758715	195
T32	435954	5758492	227
T33	434976	5758338	239
T34	434051	5758153	208
T35	437056	5758069	183
T36	436134	5757873	207
T37	434704	5757718	242
T38	435544	5757416	224
T39	436935	5757281	189
T41	434751	5757067	258
T42	434253	5756519	258
T43	435616	5756655	176
T45	435767	5755772	182
T46	433871	5755768	242
T47	433005	5755169	216
T48	433276	5754264	188
T49	432573	5753672	187

Appendix Table A.1 Wind turbine layout coordinates

A2 Dwelling coordinates

These coordinates have been provided by the Client and have not been verified by K2 Management.

Dwelling number	Easting [m]	Northing [m]	Shadow flicker hours per year
605	434527	5754713	0.0
610	437773	5763466	0.0
766	431631	5752912	0.0
794	432088	5752531	0.0
827	432992	5758778	0.0
828	432961	5758727	0.0
830	433148	5758915	0.0
831	433210	5759227	0.0
847	434224	5762666	0.0
852	434817	5761632	0.0
862	434420	5763736	0.0
863	434602	5763540	0.0
870	434644	5765749	0.0
871	434898	5765905	0.0
872	434968	5765965	0.0
873	435068	5766147	0.0
874	435401	5766095	0.0
1170	438146	5757568	0.0
4151	434865	5754880	0.0
4374	434182	5765138	0.0

Appendix Table A.2 Dwelling coordinates within 1192.5 m of turbine locations