

Appendix D

Shadow Flicker Impact Assessment (WSP)



MEMO

TO: Megan Richardson (Flyers Creek Wind Farm Pty Limited)
FROM: Jack Solano & Heather Hurree (WSP Australia Pty Limited)
SUBJECT: **Shadow Flicker – Flyers Creek Wind Farm**
OUR REF: PS108266-WIN-MEM-002 RevE.docx
DATE: **20 July 2018**

1. INTRODUCTION

Flyers Creek Wind Farm Pty Limited (FCWFPL) is currently developing Flyers Creek Wind Farm (FCWF) in New South Wales. FCWFPL has engaged WSP Australia Pty Limited (WSP) to carry out a shadow flicker assessment for the FCWF.

The shadow flicker assessment has been undertaken on the proposed 160 metre (m) tip height wind turbine generator (WTG). Several candidate WTG models are currently under consideration for installation at FCWF, therefore the largest case scenario has been used in the assessment. The candidate WTG assessed has the following parameters:

- WTG hub height of 92 m and max tip height of 160 m
- WTG rotor diameter of 136 m
- Max chord length of 4.1 m

It should be noted that the WTG dimensions within the maximum tip height of 160m may change based on the final WTG which is installed at the site. The following document outlines the methodology, assumptions and limitations used by WSP in developing the shadow flicker assessment.

2. SHADOW FLICKER ASSESSMENT

WSP has previously undertaken a shadow flicker assessment as part of the Environmental Assessment which accompanied the original planning application for FCWF and the results are presented in [1]. Calculation assumptions (such as locations of shadow receptors and window dimensions) have been kept consistent with the previous shadow flicker assessment. This updated analysis is now based on revised WTG layouts and increased WTG hub height related to planning modification 4. WSP has undertaken a realistic case scenario as well as a worst-case shadow flicker assessment.

The Australian guidelines for the allowable exposure for shadow flicker is typically 30 hrs per year [2] [3]. This corresponds to the existing Project Approval [4] Condition D23 which states “Shadow flicker from the Project must not exceed 30 hours per annum at any residence, unless the owner of the residence agrees to a higher level”.

The following section outlines the shadow flicker methodology and results in addition to the assumptions and limitations used by WSP in assessing the extent of shadow flicker at FCWF.

2.1 METHODOLOGY AND ASSUMPTIONS

WindPro v.3.1 has been used to assess the extent of shadow flicker at FCWF. WSP has used the WTG with the largest chord length in determining the estimated extent of shadow flicker at FCWF.



2.1.1 WORST CASE SCENARIO

The following assumptions have been made by WSP in assessing the extent of worst case shadow flicker at FCWF:

- The approved 38 No. WTG centrepoint locations have been modelled in the assessment [4];
- The shadow flicker assessment has been conducted for the worst-case shadow flicker scenario, which assumes;
 - Direct sunlight during all daylight hours (e.g. no clouds are ever experienced over the wind farm site).
 - WTGs are always operating (e.g. it is always windy, and the WTGs are never inoperable due to maintenance or faults).
 - WTGs are always turned in the horizontal plane to face the sun (e.g. the WTG rotor casts the maximum possible shadow).
- Eye level is 1.5 m, above ground level (AGL).

In addition to the above assumptions, these calculations are based on the turbine dimensions listed in Section 1. Results are presented in Appendix A.

2.1.2 REALISTIC CASE SCENARIO

For the realistic case, WSP has applied a reduction factor to account for cloud cover at FCWF to provide a statistical average annual estimate of shadow flicker. This is based on recorded information on sunlight and cloud cover by the Bureau of Meteorology (BoM). The closest reference site is located at Orange Agricultural Centre (Station Number 063254), approximately 23 km north of FCWF. The average daily sunshine hours are shown below in Table 2.1 .

Table 2.1 Average sunshine hours per day on a monthly mean basis [5]

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Orange Agricultural Centre	9.7	9.1	8.1	7.5	5.9	4.9	5.2	6.5	7.5	8.6	9.0	9.7

In addition, FCWFPL has provided wind speed and direction data from Meteorological Mast 8853, which has been collecting data at the site for approximately 7 years. The recorded data has been used as an input into the shadow flicker calculation to determine WTG orientation. The operational hours have been determined by applying the power curve, provided by FCWFPL, to the wind speed data at a sheared hub height of 92 m.

The following assumptions have been made by WSP in assessing the extent of the realistic scenario of shadow flicker at FCWF:

- The candidate WTG modelled in the assessment is the turbine model of the largest chord length;
- The approved 38 No. WTG centrepoint locations have been modelled in the assessment [4];
- The list of receptors surrounding the proposed site as [1];
- The shadow flicker assessment has been conducted for the realistic case shadow flicker scenario, which assumes;
 - Sunlight data obtained from Orange Agricultural Centre BoM site [5];
 - WTG operational hours based on the considered WTGs power curve and Mast 8853 wind data;
 - WTG orientation based on Mast 8853 wind data;
- Minimum sun height over the horizon for influence of 3°;
- Topographic shadow considered; and
- Eye level is 1.5 m AGL.

It should be noted that the final layout and turbine parameters will impact the results of this assessment. As such, should the turbine locations deviate by more than 100 m from their original locations assessed here and/or should



the final turbine model exceed the approximate dimensions assessed here, the resulting shadow flicker impacts may vary from the numbers presented here.

Results are presented in Appendix A.

3. RESULTS

The estimated extent of shadow flicker predicted at each receptor for the approved project layout and candidate WTG for the worst case and realistic case scenarios are included in Appendix A. Results show that no receptors will experience over 30 hours a year of shadow flicker under the realistic case scenario.

It should be noted however that five dwellings have been modelled to exceed the 30 hours limit under the worst case scenario. The worst-case scenario considers conservative assumptions which are deemed unlikely to occur in combination over an annual period. WSP also notes that the five (5) dwellings that exceed the worst case scenario limit are all Associated residences.

Consequently, based on the realistic case results, it is unlikely that the shadow flicker impacts resulting from the operation of FCWF will exceed the maximum allowable hours at any receptor. The realistic case scenario assessment indicates that the condition specified in the Planning Approval Condition D23 will still be satisfied with the revised turbine dimensions proposed in planning modification 4.

A handwritten signature in black ink, appearing to read 'Jack Solano'.

Jack Solano
Graduate Wind Engineer

A handwritten signature in black ink, appearing to read 'Heather Hurree'.

Heather Hurree
Technical Manager- Wind Engineering



4. REFERENCES

- [1] WSP - Parsons Brinckerhoff, “Environmental Assessment - Appendix C,” Flyers Creek Wind Farm Pty Ltd, Melbourne, December 2010.
- [2] Planning & Environment, “Wind Energy: Visual Assessment Bulletin,” NSW Government, [Online]. Available: <http://www.planning.nsw.gov.au/~media/Files/DPE/Bulletins-and-Community-Updates/wind-energy-visual-assessment-bulletin-2016-12.ashx>.
- [3] Environmental Protection and Heritage Council, “Draft National Wind Farm Development Guidelines,” Adelaide, 2010.
- [4] Flyers Creek Wind Farm Pty Ltd, “Project Approval - Application Number MP08_0252,” Infigen, March 2014.
- [5] Bureau of Meteorology, “Climate statistics for Australian locations,” 02 July 2018. [Online]. Available: <http://www.bom.gov.au/jsp/ncc/cdio/cvg/av>. [Accessed 2018 June 29].
- [6] International Organization for Standardization, *Acoustics — Attenuation of sound during propagation outdoors. Part 2: General method of calculation*, International Organization for Standardization, 1996.



APPENDIX A SHADOW FLICKER RESULTS FOR FCWF

Table A.1 Shadow flicker results for FCWF (UTM Zone 55H, WGS 84)

ID	NAME	EASTING	NORTHING	RESIDENCE STATUS	WORST CASE			REALISTIC CASE
					Hr:min/yr	days/yr	mins/day	Hr:min/yr
0	Stokefield	697170	6277991	Non-Associated Residence	0	0	0	0
1	Hillcrest	695480	6279583	Non-Associated Residence	0	0	0	0
2	Haverton	695919	6280995	Associated Residence	0	0	0	0
3	Glen Ayr	693290	6281079	Associated Residence	51:40	143	34	15:46
4	Lochewen	691740	6280418	Associated Residence	35:25	94	29	14:24
5	Glenarvon	689988	6279727	Non-Associated Residence	0	0	0	0
6	Tettenhall	686673	6280542	Non-Associated Residence	0	0	0	0
7	Glendale	686729	6281398	Non-Associated Residence	0	0	0	0
8	Rockdale	686895	6281635	Non-Associated Residence	0	0	0	0
9	Sunnyview	687863	6281361	Non-Associated Residence	0	0	0	0
10	Hill View	688196	6283545	Non-Associated Residence	0	0	0	0
11	Rhondda Villa	688548	6284390	Non-Associated Residence	0	0	0	0
12	Errowanbang	689697	6285992	Non-Associated Residence	0	0	0	0
13	Old Errowanbang	689493	6286700	Non-Associated Residence	0	0	0	0
14	Willow Park	691859	6287385	Non-Associated Residence	0	0	0	0
15	Stockton	688049	6286778	Non-Associated Residence	0	0	0	0
16	Meribah Cottage	688498	6288144	Non-Associated Residence	0	0	0	0
17	Triangle Park	688810	6288422	Non-Associated Residence	7:00	29	19	2:22
18	Meribah	687479	6287542	Non-Associated Residence	0	0	0	0
19	South Log	686400	6286566	Non-Associated Residence	0	0	0	0
20	North West	688821	6291307	Non-Associated Residence	0	0	0	0
21	Rembo	689845	6289617	Associated Residence	0	0	0	0
22	Wallaby	691254	6290797	Associated Residence	24:49	79	26	10:29



ID	NAME	EASTING	NORTHING	RESIDENCE STATUS	WORST CASE			REALISTIC CASE
					Hr:min/yr	days/yr	mins/day	Hr:min/yr
23	Towradgee	693998	6290034	Non-Associated Residence	28:23	147	22	9:42
24	Windella	694504	6290794	Non-Associated Residence	0	0	0	0
25	Bromley	693794	6291840	Non-Associated Residence	0	0	0	0
26	Thrushley	692827	6292548	Associated Residence	0	0	0	0
27	Willow Creek East	692030	6292590	Non-Associated Residence	0	0	0	0
28	Hillview	694887	6290992	Associated Residence	0	0	0	0
29	Fairview	695725	6291229	Non-Associated Residence	0	0	0	0
30	Vermont	695003	6292497	Non-Associated Residence	0	0	0	0
31	Strathfield	695822	6292571	Non-Associated Residence	0	0	0	0
32	Loloma	694991	6293599	Non-Associated Residence	0	0	0	0
33	Dogwind	694654	6293413	Non-Associated Residence	0	0	0	0
34	Westerham	693441	6293402	Non-Associated Residence	0	0	0	0
35	Timaru	692095	6293649	Non-Associated Residence	0	0	0	0
36	Willow Creek	690975	6292913	Non-Associated Residence	0	0	0	0
37	Braithwaite	690622	6292862	Non-Associated Residence	0	0	0	0
38	Carlingford	697744	6291449	Non-Associated Residence	0	0	0	0
39	Hillview	697156	6290613	Non-Associated Residence	0	0	0	0
40	The Cottage	697253	6291238	Non-Associated Residence	0	0	0	0
41	Crenvor	696957	6289196	Non-Associated Residence	0	0	0	0
42	Euronga	695744	6290256	Non-Associated Residence	0	0	0	0
43	Bellevue	695309	6288867	Non-Associated Residence	0	0	0	0
44	Willow Dale	694827	6288747	Non-Associated Residence	0	0	0	0
45	Castle Hill	696576	6287157	Non-Associated Residence	0	0	0	0
46	Bulwarra	695613	6286034	Associated Residence	0	0	0	0



ID	NAME	EASTING	NORTHING	RESIDENCE STATUS	WORST CASE			REALISTIC CASE
					Hr:min/yr	days/yr	mins/day	Hr:min/yr
47	Weston	697517	6285936	Non-Associated Residence	0	0	0	0
48	Fairbanks	696357	6285318	Non-Associated Residence	0	0	0	0
49	Wattlecomb	695841	6284902	Non-Associated Residence	0	0	0	0
50	Nullawonga	694452	6284339	Associated Residence	23:46	72	28	9:49
51	Beulah Park	696637	6281968	Associated Residence	23:28	79	24	7:49
51B	Beulah Park B - Barry Baker	696967	6282107	Associated Residence	13:15	53	20	5:08
52	Carramar	691683	6285950	Associated Residence	0	0	0	0
54	Hillcrest	692331	6284482	Associated Residence	71:35	110	54	14:59
55	House	695336	6285112	Associated Residence	0	0	0	0
56	Cooramilla	694850	6288242	Non-Associated Residence	0	0	0	0
57	Errowanbang School (residence)	690243	6286658	Non-Associated Residence	0	0	0	0
58	Ridge End	691558	6277254	Non-Associated Residence	0	0	0	0
59	House	693818	6276240	Non-Associated Residence	0	0	0	0
60	Carradowns	697959	6287754	Non-Associated Residence	0	0	0	0
61	Caithness	698124	6288446	Non-Associated Residence	0	0	0	0
62	Tralee	698615	6287506	Non-Associated Residence	0	0	0	0
63	Long View	698286	6289654	Non-Associated Residence	0	0	0	0
64	Sunnyside	695193	6294854	Non-Associated Residence	0	0	0	0
65	Greenbank	696414	6294288	Non-Associated Residence	0	0	0	0
66	Ferndale	696920	6293544	Non-Associated Residence	0	0	0	0
67	Karinya	691781	6294883	Non-Associated Residence	0	0	0	0
68	Mirraweena	691505	6294942	Non-Associated Residence	0	0	0	0
69	Narrawong	690656	6294539	Non-Associated Residence	0	0	0	0
70	Warrengong	690073	6294640	Non-Associated Residence	0	0	0	0



ID	NAME	EASTING	NORTHING	RESIDENCE STATUS	WORST CASE			REALISTIC CASE
					Hr:min/yr	days/yr	mins/day	Hr:min/yr
71	Platt	693808	6280666	Associated Residence	41:32	102	35	18:39
72	House	687821	6282338	Associated Residence	0	0	0	0
73	Braeburn	687953	6284796	Non-Associated Residence	0	0	0	0
74	Stuart	690651	6285519	Associated Residence	0	0	0	0
75	House	689275	6286492	Non-Associated Residence	0	0	0	0
76	Hart	694469	6284864	Associated Residence	25:30	99	25	12:33
77	House	694049	6285751	Non-Associated Residence	0	0	0	0
78	House	694012	6285598	Non-Associated Residence	0	0	0	0
79	House	692359	6288256	Associated Residence	37:37	71	41	7:49
80	House	695362	6289589	Non-Associated Residence	0	0	0	0
81	Unknown	693283	6295029	Non-Associated Residence	0	0	0	0
82	House	694183	6292036	Non-Associated Residence	0	0	0	0
83	House	694241	6293494	Non-Associated Residence	0	0	0	0
84	House	693969	6293621	Non-Associated Residence	0	0	0	0
85	House	690447	6291187	Non-Associated Residence	0	0	0	0
86	House	690308	6290617	Associated Residence	0	0	0	0
87	House	689734	6290127	Non-Associated Residence	0	0	0	0
88	McKensie	689502	6289460	Associated Residence	11:11	35	24	4:14
89	House	693550	6289600	Non-Associated Residence	25:30	100	26	11:04
90	House (empty)	694219	6289645	Non-Associated Residence	2:02	25	7	0:39
91	House	693030	6293126	Non-Associated Residence	0	0	0	0
92	House	693277	6292929	Non-Associated Residence	0	0	0	0
93	House	692306	6293308	Non-Associated Residence	0	0	0	0
94	House	692314	6293160	Non-Associated Residence	0	0	0	0



ID	NAME	EASTING	NORTHING	RESIDENCE STATUS	WORST CASE			REALISTIC CASE
					Hr:min/yr	days/yr	mins/day	Hr:min/yr
95		690018	6280556	Non-Associated Residence	0	0	0	0
96	House	694850	6291802	Non-Associated Residence	0	0	0	0
97	House	698279	6290936	Non-Associated Residence	0	0	0	0
98	House	695904	6290084	Non-Associated Residence	0	0	0	0
99	House	694392	6289672	Non-Associated Residence	0	0	0	0
100	House	694772	6290052	Non-Associated Residence	0	0	0	0
101	House	697785	6286217	Non-Associated Residence	0	0	0	0
102	House	697065	6281327	Non-Associated Residence	0	0	0	0
103	House	696332	6279079	Non-Associated Residence	0	0	0	0
104	House	696683	6278525	Non-Associated Residence	0	0	0	0
105	House	690596	6277280	Non-Associated Residence	0	0	0	0
106	House	688728	6279860	Associated Residence	0	0	0	0
107	House	687977	6285007	Non-Associated Residence	0	0	0	0
108	House	694704	6285394	Non-Associated Residence	0	0	0	0
109	Brendan Kilby	688500	6290500	Non-Associated Residence	0	0	0	0
110	House	690318	6277598	Non-Associated Residence	0	0	0	0
111	House	690304	6277759	Non-Associated Residence	0	0	0	0
112	Unknown	687709	6288967	Non-Associated Residence	0	0	0	0
114	Unknown	695751	6290438	Non-Associated Residence	0	0	0	0
115	Unknown	695087	6292048	Non-Associated Residence	0	0	0	0
116	Unknown	695091	6292246	Non-Associated Residence	0	0	0	0
117	Unknown	693441	6293890	Non-Associated Residence	0	0	0	0
118	Unknown	694196	6293386	Non-Associated Residence	0	0	0	0
119	Unknown	692045	6295040	Non-Associated Residence	0	0	0	0



ID	NAME	EASTING	NORTHING	RESIDENCE STATUS	WORST CASE			REALISTIC CASE
					Hr:min/yr	days/yr	mins/day	Hr:min/yr
120	Unknown	694438	6293383	Non-Associated Residence	0	0	0	0
121	Unknown	694640	6293697	Non-Associated Residence	0	0	0	0
122	Unknown	694220	6294171	Non-Associated Residence	0	0	0	0
123	Unknown	693138	6294634	Non-Associated Residence	0	0	0	0
124	Unknown	693533	6294569	Non-Associated Residence	0	0	0	0
125	Unknown	692443	6294799	Non-Associated Residence	0	0	0	0
126	Unknown	687625	6283504	Non-Associated Residence	0	0	0	0
127	Unknown	691799	6293599	Non-Associated Residence	0	0	0	0
128	Unknown	688104	6287804	Non-Associated Residence	0	0	0	0
129	Unknown	688852	6286757	Non-Associated Residence	0	0	0	0
130	Unknown	687105	6282971	Non-Associated Residence	0	0	0	0
131	Unknown	685837	6280004	Non-Associated Residence	0	0	0	0
132	Unknown	688837	6279448	Non-Associated Residence	0	0	0	0
133	Unknown	696510	6279699	Non-Associated Residence	0	0	0	0
134	Unknown	697944	6280180	Non-Associated Residence	0	0	0	0
136	Unknown	699920	6286420	Non-Associated Residence	0	0	0	0
137	Unknown	696604	6291909	Non-Associated Residence	0	0	0	0
138	Unknown	693623	6294311	Non-Associated Residence	0	0	0	0
139	Unknown	693835	6294380	Non-Associated Residence	0	0	0	0
140	Unknown	693913	6294091	Non-Associated Residence	0	0	0	0
141	Unknown	693957	6294212	Non-Associated Residence	0	0	0	0
142	Unknown	693165	6294750	Non-Associated Residence	0	0	0	0
143	Unknown	693788	6294889	Non-Associated Residence	0	0	0	0
144	Unknown	692299	6294767	Non-Associated Residence	0	0	0	0



ID	NAME	EASTING	NORTHING	RESIDENCE STATUS	WORST CASE			REALISTIC CASE
					Hr:min/yr	days/yr	mins/day	Hr:min/yr
145	Unknown	691475	6294777	Non-Associated Residence	0	0	0	0
146	Unknown	691058	6294683	Non-Associated Residence	0	0	0	0
147	Unknown	697406	6286869	Non-Associated Residence	0	0	0	0
148	Unknown	698405	6288043	Non-Associated Residence	0	0	0	0
149	Unknown	698465	6288564	Non-Associated Residence	0	0	0	0
150	Unknown	698346	6288483	Non-Associated Residence	0	0	0	0
151	Unknown	698324	6288379	Non-Associated Residence	0	0	0	0
152	Unknown	696605	6291705	Non-Associated Residence	0	0	0	0
153	Unknown	692763	6294447	Non-Associated Residence	0	0	0	0
154	Unknown	692694	6294781	Non-Associated Residence	0	0	0	0
155	Unknown	692513	6295017	Non-Associated Residence	0	0	0	0
156	Unknown	689967	6294937	Non-Associated Residence	0	0	0	0
157	Unknown	689987	6295452	Non-Associated Residence	0	0	0	0
158	Unknown	690162	6291224	Non-Associated Residence	0	0	0	0
159	Unknown	697048	6278361	Non-Associated Residence	0	0	0	0
160	Unknown	697471	6278353	Non-Associated Residence	0	0	0	0
161	Unknown	694314	6276458	Non-Associated Residence	0	0	0	0
162	Unknown	696326	6293916	Non-Associated Residence	0	0	0	0
163	Unknown	698875	6,289010	Non-Associated Residence	0	0	0	0
164	Unknown	691296	6295002	Non-Associated Residence	0	0	0	0
165	Unknown	691725	6295131	Non-Associated Residence	0	0	0	0