energy3

KAIMAI WIND FARM

Kaimai Wind Farm

Shadow Flicker Analysis

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Executive Summary

Kaimai Wind Farm Limited has contracted Energy3 Services Limited to undertake an assessment of the potential occurrence of Shadow Flicker on local dwellings as a component of the Kaimai Wind Farm Resource Consent Application.

Shadow flicker refers to the shadows that a wind turbine casts over structures and observers at times of the day when the sun is directly behind the turbine rotor from an observer's position. Shadow flicker does not occur when fog or clouds obscure the sun, or when turbines are not operating. The duration of shadow flicker experienced at a specific location can be determined using a purely geometric analysis which takes into account the relative positions of the sun throughout the year, wind turbine location, and the observer. The Wind Farm design software package "WindFarm" has been used to calculate shadow flicker in this analysis. However, the analysis method employed tends to be conservative and typically results in over-estimation of the actual number of hours of shadow flicker experienced at a dwelling. So as to calculate shadow flicker on a "worst case" scenario, no attempt has been made to quantify the likely reduction in shadow flicker duration due to turbine orientation, intervening structures or terrain. However probable exposure independent of any screening elements has been calculated from long term cloud cover data.

Kaimai Wind Farm Limited has supplied a layout for the wind farm consisting of 24 turbines, and surveyed locations of 39 dwellings in the vicinity of the wind farm. The dwellings range from a minimum distance of approximately 1 km, extending to a maximum distance of approximately 8.6 km from the turbine locations.

In New Zealand there are no specific guidelines as to how to assess shadow flicker generated by wind turbines. However, international guidelines state that the practical extent to which shadow flicker should be assessed is to a distance of 265 times the distance of the blade chord (the widest part of the turbine blade), or approximately 1.1 km. The assessment has identified that 13 dwellings fall within this distance from the wind farm. The dwellings within 2 km have been assessed for the total number of hours per year that these dwellings could be potentially exposed to shadow flicker. This calculated figure has been compared to the international guidelines for acceptable levels of exposure.

The 21 dwellings within a 2-kilometre radius were represented as an omnidirectional "greenhouse" receptor in the calculation, such that receptors consist of a 1 m x 1 m window, with the window centre being 2 m above ground level, on each wall of the house.

The generally accepted international exposure levels are deemed as 30 hours in total per year on a modelled basis, 10 hours per year actually experienced, or no more than 30 minutes per day.

The number of occupied residences registering more than 30 hours per year was 15, ranging from 33 hours to 103 hours.

Calculations were assessed a conservative basis, assuming all houses had an un-obscured window directly orientated towards the wind farm.

In the preparation of this report the following documents have considered and incorporated as necessary:

1. Memorandum – Kaimai Turbine Dimensions – rev 4; 21 May 2018; Kaimai Windfarm Ltd
2. Civil Engineering Drawings – Resource Consent Issue; Rev A; Tektus Consultants; Jun 2018
3. Civil Engineering Peer Review; May 2018; Tiaki Consultants

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1.0 INTRODUCTION

The proposed Kaimai Wind Farm is approximately 10 km to the north of Te Aroha, and 10km to the south of Paeroa. The site is typically characteristic of pastoral farming in the general area.

Elevation of the proposed turbine sites ranges from approximately 150m to 480 m above sea level, with the turbines located on various ridgelines and plateaus that are higher than surrounding land forms.

The site is covered by exotic grazing grasses, scattered native vegetation remnants, and adapted weed species. There are no significant forestry plantings on the immediate site, however the heavily vegetated Kaimai Mamaku Forest Park bounds the site to the east.

The Kaimai Wind Farm project consists of a proposed 24 wind turbine sites, consisting of two distinct groups, one on the higher ridgeline, and the other on the lower reaches of the Kaimai Range to the west.

The precise turbine model has yet to be selected for the project, however representative turbines have been modelled in this shadow flicker analysis. Possible options being considered are:

- Upper Ridge(turbines 18-24):
    - (i) 112m Hub Height, 136m rotor diameter, 180m tip height
    - (ii) 107m Hub Height, 146m rotor diameter, 180m tip height
    - (iii) 98m Hub Height, 146m rotor diameter, 171m tip height

- Lower Ridge(turbines 1-17):
    - (i) 132m Hub Height, 150m rotor diameter, 207m tip height
    - (ii) 128m Hub Height, 160m rotor diameter, 207m tip height
    - (iii)110m Hub Height, 160m rotor diameter, 190m tip height

The modelled hub height of the ridgeline turbines is 107m, with a rotor diameter of 146m. The lower turbines in the second group have a modelled hub height of 128m and a rotor diameter of 160m. This modelling selection represents the combination causing the greatest amount of potential shadow flicker.

The turbine sizes vary to match the wind characteristics experienced across the overall wind farm site.

Total nominal designed installed capacity is approximately 100MW, which is modelled to provide an annual energy yield of approximately 260GWh/annum, or generation equivalent to supply approximately 32,500 homes.

2.0 SHADOW FLICKER

Shadow flicker refers to the shadows that a wind turbine casts over structures and observers at times of the day when the sun is directly behind the turbine rotor from an observer's position. Shadow flicker is most pronounced in southern latitudes during winter months because of the lower angle of the sun in the winter sky. However, it is possible to encounter shadow flicker anytime of the year for brief periods shortly after sunrise and immediately prior to sunset. During intervals of sunshine, wind turbine generators when operating will cast a shadow on surrounding areas as the rotor blades pass in front of the sun, causing a flickering effect while the rotor is in motion. Shadow flicker does not occur when fog or clouds obscure the sun, or when turbines are not operating. The probability of shadow flicker, and its intensity is dependent upon the following factors:

1. Distance of the observer from the turbine;
2. Orientation of the observer relative to the turbine;
3. Height and rotor diameter of the turbine;
4. Time of day and time of year;
5. Prevailing wind direction;
6. Weather conditions (cloud cover reduces the occurrence of shadow flicker);
7. Screening impacts of vegetation, structures, and terrain.

The further the observer is from the turbine the less pronounced the shadow flicker effect will be. There are several reasons for this:

1. There are fewer times when the sun is low enough to cast a long shadow;
2. When the sun is low it is more likely to be obscured by either cloud on the horizon or intervening buildings and vegetation;
3. The centre of the rotor's shadow passes more quickly over the land reducing the duration of the effect;
4. At increasing distances the shadow is diffused such that the variation in light levels is not likely to be noticeable.

Shadow flicker is often alleged to cause the onset of epileptic seizures. Most people with photosensitive epilepsy are sensitive to flickering around 16-25 Hz, although some people may be sensitive to rates as low as 3 Hz and as high as 60 Hz. Currently available wind turbines for commercial power generation (including the proposed turbines) typically operate at a frequency of 1 Hz or less, and there is no evidence that wind turbines can trigger seizures (British Epilepsy Association, 2007; Ellenbogen et al., 2012; Parsons Brinckerhoff, 2011; NHMRC, 2010). The primary concern with shadow flicker is the annoyance it can cause for adjacent homeowners. Annoyance can trigger physiological reactions of the autonomic nervous and/or endocrine systems that increase the risk of cardiovascular disorders. However, it is important to note that annoyance is not a disease or physical illness in of itself; rather it is a variable and subjective response to stimuli that can include many other things besides shadow flicker.

3.0 ASSESSMENT GUIDELINES

There are currently no guidelines for the assessment of shadow flicker in New Zealand. However, other jurisdictions internationally have developed guidelines to address this issue. Of most relevant to New Zealand is the latest draft Australian “National Wind Farm Development Guidelines”, this document recommends a theoretical residential exposure limit of less than 30 hours per year, and that actual or measured shadow flicker duration should not exceed 10 hours per year. It states that shadow flicker must be considered within a distance from a turbine of 265 times the blade width at its widest part (maximum blade chord).

For the proposed Kaimai Wind Farm, the maximum blade chord is 4.2 metres. The Australian guidelines therefore suggest that for a blade of this width, the shadow flicker effects will be indiscernible at all dwellings further than 1113 metres from any of the wind turbines. The closest house (DW 44) to the wind farm is at a distance of approximately 840 metres from the nearest turbine, which is inside the zone of accepted potential shadow flicker effects.

Other international guidance documents adopt a fixed radius approach. The Danish Wind Industry Association suggests that at distances greater than 500-1000 metres from a wind turbine, the rotor will not appear to be “chopping" the light, but the turbine will be regarded as an object with the sun behind it, and it is therefore not necessary to consider shadow casting at such distances.

The South Australian Planning Bulletin (2002) notes that shadow flicker is unlikely to be a significant issue at distances greater than 500 metres.

The U.S. Department of Interior has noted in respect to wind farm planning that at a distance beyond 10 rotor diameters (1,500 metres in the case of Kaimai Wind Farm) shadow flicker effects are essentially undetectable (U.S. Department of Interior, 2005).

The UK wind industry and UK government consider that 10 rotor diameters is appropriate for the outer margin of discernible effects, which corresponds to approximately 800 to 1,500 m for commonly installed wind turbines on the market currently (which typically have rotor diameters ranging from 80 to 150 m).

4.0 WIND FARM LAYOUT

Kaimai Wind Farm Limited have provided the proposed coordinates of the Kaimai Wind Farm Turbines, these positions are presented Table 1, and are in the NZTM CRS. These positions are illustrated spatially within Figure 2.

The contour files that specify the terrain of the wind farm are firstly built up as an underlying layer using vector files derived from publicly available raster data obtained during the Shuttle Radar Topography Mission. A 100m square area surrounding the proposed turbine sites was extracted from 2m raster data supplied by Kaimai Wind Farm Limited, and converted to a vector file for use within WindFarm.

A point sample of the original raster data at the proposed turbine sites was compared with a turbine base elevation export from WindFarm to ensure accuracy was preserved during the various elevation data transformations.

5.0 DWELLING LOCATIONS

Kaimai Wind Farm Limited has provided the coordinates of the closest dwellings to the Kaimai Wind Farm; those with 2km of any turbine are presented in Table 2 again in the NZTM CRS, ranked by distance from the nearest turbine

These dwelling positions in conjunction with the proposed turbine locations are illustrated spatially within Figure 3.

Only houses within 2,000 m of the proposed wind farm have been considered in the current analysis. This distance has been selected to meet one of the more conservative general requirements; that shadow flicker zones of influence should be calculated to a minimum distance of a multiple of 265 times the maximum blade chord.

Contour data beyond the data which was supplied for the immediate wind farm site was supplemented with derived vector elevation contour files. As per the wind farm site data, these vector files were created with publicly available raster data obtained during the Shuttle Radar Topography Mission.

WindFarm allows for the accurate positioning and size of windows on houses. This data is not available to E3S and hence the conservative “greenhouse” method has been used where a 1m square window with its centre 2m above the ground is modelled. The orientation of the windows relative to north in the dwelling walls has been ascertained using aerial imagery, and recorded in the model.

6.0 SHADOW FLICKER ANALYSIS

The shadow flicker modelling analysis for proposed Kaimai Wind Farm was conducted using WindFarm 4.2.2.1 (Resoft.co.uk), and its associated shadow flicker module. WindFarm by Resoft is a widely accepted modelling software package developed specifically for the design and evaluation of wind power projects. The duration of the potential for shadow flicker throughout the year is calculated using a purely geometric algorithm within the WindFarm Shadow Flicker module.

The shadow flicker calculation within WindFarm requires specification of at least one window for each dwelling against which the passage of the sun and the shadow of the rotor can be measured. This module calculates times throughout a year when turbine rotor discs viewed from the window of a house are in line with the sun, and therefore the potential for shadow flicker exists. It assumes the sun is not obscured by either clouds or obstacles, that the turbine rotors are always turning, and that the rotors are facing the viewer which is a worst case scenario. The software also takes earth curvature and topographic elevation into consideration.

The major inputs to the WindFarm shadow flicker module include:

1. Computational radius;
2. Wind farm layout;
3. Dwelling locations;
4. Dwelling windows, these are represented as “greenhouse” using four 1 m x 1 m window on each wall axis of the identified dwellings, 2 m from ground level facing directly to the wind farm to model worst case. In reality, dwellings may have more than one window facing in this direction, have all windows facing away from the turbines, or be screened by vegetation;
5. 2m raster terrain contours for the 100m surrounding the proposed turbine positions, derived from raster height files provided by Kaimai Wind Farm Limited;
6. 5m vector terrain contours for the 100m surrounding the proposed turbine positions, where 2m data was not present, provided by Kaimai Wind Farm Limited;
7. 10m terrain contours that encompass the wind farm site and identified dwellings are extracted from SRTM raster files;
8. Site latitude and longitude;
9. Grid Convergence Angle;
10. The calculation year of the Suns position;
11. Turbine geometry;
12. Sun Elevation Threshold, shadow flicker is generally considered imperceptible when the sun is less than 3 degrees above the horizon (due to the scattering effect of the atmosphere on low angle sunlight) (States Committee for Pollution Control, 2002).

The model makes the following assumptions and simplifications:

13. There are clear skies every day of the year;
14. The turbine blades are always rotating;
15. The blades of the turbines are always perpendicular to the direction of the line of sight from the specified location to the sun.

Post processing to refine results requires the following inputs:

1. 20 months of 10-minute wind data measured at 60m height taken from the site meteorological station
2. 28 years of average monthly sunshine data
3. Theoretical monthly maximum day light hours

These simplifications mean that the results generated by the model are likely to be conservative. The following factors which reduce the actual occurrence of shadow flicker effect should be considered:

1. Cloudiness;
2. Downtime of turbines either from a lack of wind or maintenance;
3. Wind directions resulting in turbine blades rotating in parallel to any receptor;
4. Natural obstructions caused by trees, buildings, terrain, etc;
5. Aerosols (moisture, dust, smoke, etc.) in the atmosphere have the ability to influence shadows cast by a wind turbine.

Based on these variables, WindFarm was used to calculate the theoretical number of hours per year that shadow flicker could occur at the given dwelling locations; a 2,000-meter calculation radius was used based on available international assessment guidelines. It should be noted that at a distance beyond 265 times the blade chord or 10 rotor diameters (1113m and 1500m respectively), shadow flicker effects are deemed as essentially undetectable (U.S. Department of Interior, 2005; BERR, 2008). The current guidelines would indicate therefore that a calculation radius of 1,500m would be conservative; however 2,000m has been nevertheless used as an outer limit.

As an additional calculation step average monthly sunshine probability values were calculated for each month from January to December. Monthly sunlight hours were obtained from historical data downloaded via the NIWA Cliflo database for the Thames Metrological Station, which is closest to the proposed wind farm site. A total of 28 years' worth of data was analysed, the lengthy timeframe since 1990 was chosen to reduce the influence of annual variance.

Potential maximum monthly daylight hours were calculated via an application provided by USNO for the Kaimai Wind Farm site based on a longitude and latitude derived from the proposed mean turbine coordinates, and time zone. The resultant values are the probable percentages that the sun is expected to be sufficiently bright, where shadow flicker could occur during daylight hours. Table 6 provides summarised details of the Thames Meteorological station.

The model was also adjusted for the percentage of hours the wind turbines are expected to operate. This calculation is based on actual wind speed data collected by the on-site meteorological tower over a period of July 7, 2016 until March 18, 2018. Periods where the recorded wind speed was below 3 m/s and above 25 m/s at times where shadow flicker was modelled to occur were excluded on the basis that the turbines would not be operational. The resulting values were used to estimate the likely operational time and therefore enable the application of a shadow flicker reduction factor. In addition, a 3% loss of availability was factored for machine downtime either due to faults or due to servicing requirements. While an adjustment could be made for nacelle direction based on the wind direction distribution, this has not been done to model on a more conservative basis. When a turbine nacelle and therefore the rotor is at a more acute angle to the sun relative to a dwelling, the effective rotor disc diameter decreases, and therefore shadow flicker will decrease. There are however no definitive rules in literature about how this potential reduction should be calculated.

No attempt has been made to account for the remaining mitigating factors not considered within in the model as identified previously. It is therefore certain that the unadjusted shadow flicker durations presented in this report can be regarded as a conservative assessment.

The major software input parameters used by WindFarm are presented in Table 3.

7.0 ANALYSIS RESULTS

The theoretical maximum predicted shadow flicker durations at dwellings that are modelled to receive shadow flicker, within a 2 km vicinity of the nearest turbine of the Kaimai Wind Farm are presented in Table 4. The results are also presented in the form of a shadow flicker map in Figure 4.

The results indicate that 23 dwellings are predicted to experience some degree of calculated shadow flicker. Of these dwellings, 15 are expected to experience theoretical shadow flicker durations of more than 30 hours per year.

The modelling of the sunshine data from the Thames metrological station shows that on average the sun shines 45% of the total theoretical daylight hours. The modelling was conducted on a monthly basis to take account of annual variations so as not to skew the analysis. Table 5 presents the calculated percentage of sunshine hours by month, used to increase the accuracy of the predicted shadow flicker incidence.

The analysis assumed that the wind turbines would be technically available to operate 97% of the time. Assessment of the wind speed frequency distribution for the percentage of wind speeds in the range of the turbine operational wind speed window, within the modelled shadow flicker time slots, shows the turbines will be operating for 96% of the time. These percentages are calculated on an annual basis.

The application of the quantifiable reduction factors (sunshine, wind speed window, and operational availability) increased the number of dwellings above the threshold from 15 to 18, relative to the guideline of 10 hours of shadow flicker actually received. This is because the magnitude of the losses applied are less than the magnitude of reduction in the guideline limits from modelled to actual.

A summary of the projected shadow flicker at each of the total 39 receptors identified is presented below:

- 16 (41%) of the receptors are not expected to experience any shadow flicker,
- 2 (5%) of the receptors may be affected 0-1 hour/year,
- 0 (0%) of the receptors may be affected 1-10 hours/year,
- 2 (5%) of the receptors may be affected 10-20 hours/year,
- 4 (10%) of the receptors may be affected 20-30 hours/year,
- 12 (31%) of the receptors may be affected 30-60 hours/year,
- 1 (3%) of the receptors may be affected 60-90 hours/year,
- 2 (5%) of the receptors may be affected 90-120 hours/year,
- 0 (0%) of the receptors may be affected for more than 120 hours/year.

These results indicate, 62% of the receptors identified are predicted to receive less than 30 hours of shadow flicker per year. At most receptor locations shadow flicker will occur primarily in the early morning or late afternoon and range from as little as a few seconds to 52 minutes per day. Dwelling 20 will experience shadow both in the morning and evening, and experiences the highest overall shadow flicker for a modelled duration of 103 hours per year. Modelled unadjusted shadow flicker time windows are presented in Figure 5.

Turbine 15 causes the greatest number of hours of potential shadow flicker, with a total of 122.9 hours attributable, which is almost 50% greater than the next ranked turbine at 56.7 hours per annum. The average value per turbine is 31.6 hours per annum.

8.0 POTENTIAL MITIGATION MEASURES

In the event that shadow flicker from the Kaimai Wind Farm is a nuisance for nearby dwellings, there are various mitigation measures which could be employed. Mitigation measures could include:

- Planting vegetation or tree lines, which will block the line of sight to the turbines causing flicker.
- Installation of window blinds or awnings.
- Payments to affected parties.

A more technical mitigation measure is to shut down the turbines which are known to cause problematic flicker, during the times when it is possible to occur. Software such as WindFarm can output an annual shutdown schedule that can be paired with a sunlight detection system, such that the identified turbines which may cause shadow flicker are only shut down when sufficient sunlight is present to cause discernible shadow flicker. This measure completely removes the incidence of shadow flicker.

9.0 PHOTOGRAPHIC ASSESSMENT

In order to subjectively assess reductions to modelled shadow flicker, a site visit was undertaken by a photographer to available dwelling identified in the report. Photographs were taken looking towards the proposed wind farm site in the direction of windows that are modelled to experience potential shadow flicker. The photographs have been subjectively assessed to determine if blocking objects will likely reduce actual levels of shadow flicker. Not all potentially affected properties were able to be visited, Table 7 lists the properties that were able to be visited within 2,000 metre of the nearest turbine, these are summarised below.

DW27

The Curran Property at 452 Rawhiti road is modelled to be only subject to potential shadow flicker in the morning, thus the east facing windows are the most critical. Figure 6 shows views from the eastern windows of the house, they show some evergreen plantings on the house boundary, however most of the eastern view is onto open farm land and unscreened by any vegetation. The plantings that are present may provide a limited degree of screening.

DW22

The Aitchison Property at 636a Rawhiti is modelled to be only subject to potential shadow flicker in the morning, thus the east facing windows are the most critical. A large hedge on the eastern boundary obscures the view to the proposed wind farm site, the garage area is not however obscured.

DW54

The Tirohia School Property at 636b Rawhiti road is modelled to be only subject to potential shadow flicker in the morning, thus the east facing windows are the most critical. As with DW22 a hedge on the eastern boundary largely obscures the view to the proposed wind farm site, another hedge screen views to the north. The vegetation planted on the property boundary will significantly reduce the amount of potential shadow flicker experienced.

DW21

The Fielding Property at 649 Rawhiti road is modelled to be only subject to potential shadow flicker in the morning, thus the east facing windows are the most critical. Figure 8 shows views from the north eastern windows of the house, they show significant evergreen plantings within the house section. The house boundary is also planted in deciduous trees to the north and east which will offer reasonable screening when leaves are present on these plantings. While the plantings do not totally obscure the view to the proposed wind farm site they will offer a reasonable amount of screening.

DW44

The Parkinson property at 680 Rawhiti road is modelled to be only subject to potential shadow flicker in the morning, thus the east facing windows are the most critical. Figure 9 and Figure 10 show views from the north eastern and south eastern windows of the house, they show significant evergreen plantings on the house boundary. While the plantings do not totally obscure the view to the proposed wind farm site they will offer a reasonable amount of screening.

10.0 CONCLUSIONS

There will be exposure to shadow flicker above current guidelines for 15 dwellings surrounding the proposed Kaimai Wind Farm. The majority of the dwelling that exceed the exposure limits do so by a modest amount, however there are 8 dwellings that exceed the 30 hour limit by over 25%.

There are however a number of factors which can markedly reduce the likely occurrence of shadow flicker, and significant number of these factors have not been included. Factors which can have a large impact on reducing actual shadow flicker incidence include:

- Consideration for the blocking effects of vegetation or structures
- Receptors are modelled as being omni-directional rather than modelling as accurate specific facades in conjunction with actual windows.
- Nacelle direction

In addition, a significant portion of the modelled shadow flicker hours are likely to be of intensity due to the fact they occur either in the early morning or late afternoon, at times when the sun is low in the sky. As the sun sinks below the horizon it is subject to a greater level of atmospheric dispersion, dampening its brightness, and therefore reducing its ability to cast dark shadows (EMD, 2013).

Another mitigating element is that the houses are reasonably distant from the proposed turbines, the closest being 838m, which is outside the distance of assessment for the Danish standard, again contributing to lower intensity shadow flicker when experienced.

Therefore the assessment is conservative, and that realistically the number of hours of shadow flicker that are observed will be significantly less than those predicted by this study.

A number of mitigation measures are possible, and if required turbines that cause shadow flicker can be programmed to shut down at specific times to completely mitigate any potential shadow flicker.

Where possible properties have been assessed by photographs to subjectively assess screening objects that reduce or eliminate shadow flicker. Some of the properties are well screened, and others not at all.

8.0 TABLES

Turbine	NZTM Easting	NZTM Northing
1	1835526	5854128
2	1835835	5853903
3	1836207	5853831
4	1836423	5853509
5	1836461	5852993
6	1836808	5852736
7	1837200	5852578
8	1837544	5852544
9	1837741	5852226
10	1837776	5851735
11	1836145	5852126
12	1836506	5851952
13	1836813	5851773
14	1837521	5851031
15	1838145	5850545
16	1838626	5850750
17	1839083	5850780
18	1840066	5851894
19	1840461	5851829
20	1840443	5851460
21	1840978	5851591
22	1841234	5851278
23	1841412	5850995
24	1841359	5850490

Table 1: Turbine Locations

House	Distance (m)[1]	NZTM Easting	NZTM Northing
DW 44	838	1835662	5851441
DW 4	919	1835979	5854927
DW 24	947	1837044	5850213
DW 15	967	1838063	5853360
DW 19	1,016	1838481	5852935
DW 18	1,035	1838466	5853013
DW 5	1,038	1836237	5854883
DW 13	1,046	1838251	5853314
DW 26	1,053	1837045	5850092
DW 20	1,054	1838823	5851847
DW 9	1,088	1836651	5854824
DW 17	1,095	1838446	5853165
DW 53	1,110	1836567	5850461
DW 55	1,117	1834410	5854169
DW 6	1,123	1836343	5854946
DW 56	1,144	1834523	5854678
DW 8	1,145	1836545	5854925
DW 27	1,156	1837343	5849713
DW 54	1,171	1834370	5853940
DW 22	1,195	1835962	5850888
DW 47	1,219	1837175	5849808
DW 11	1,224	1838431	5853386
DW 30	1,228	1837214	5849745
DW 54	1,264	1834370	5853940
DW 48	1,375	1838318	5853680
DW 12	1,382	1838429	5853604
DW 21	1,407	1835765	5850757
DW 16	1,487	1837968	5853969
DW 52	1,511	1838453	5853751
DW 49	1,634	1838450	5853903
DW 50	1,669	1838373	5853992
DW 51	1,735	1838321	5854095

Table 2: Dwelling Locations

[1] Distance to nearest turbine

WindFarm Parameter	Value
Longitude	175 41 33 E
Latitude	-37 26 53 S
Time Zone	GMT +12
Grid Convergence Angle	-0.795
Turbine Type A	128 HH, 160m Rotor
Turbine Type B	107 HH, 146m Rotor
Calculation Radius	2,000m
Minimum Sun Angle	3°
Calculation year for Suns path	1984
CRS	UTM Zone 60H

Table 3: Model Input Settings

House	Days Per Year Possibly Affected	Maximum Hours Per Day	Average Hours Per Day	Total Hours Per Year (hh:mm)	Probable Hours Per Year (hh:mm)
DW 20	203	1.03	0.51	103:00	40:03
DW 44	196	0.72	0.51	99:13	34:42
DW 27	78	0.96	0.77	60:25	18:52
DW 30	94	0.87	0.56	52:27	16:58
DW 54	101	0.51	0.41	41:17	13:35
DW 22	96	0.54	0.42	40:43	13:06
DW 19	113	0.52	0.35	39:35	15:44
DW 55	75	0.84	0.51	38:01	15:26
DW 16	106	0.44	0.35	37:35	14:48
DW 47	67	0.82	0.55	37:05	12:43
DW 21	101	0.48	0.36	36:42	12:08
DW 53	86	0.58	0.41	35:05	13:22
DW 18	94	0.49	0.36	34:13	13:27
DW 54	76	0.56	0.44	33:41	13:24
DW 24	88	0.55	0.38	33:22	11:59
DW 17	98	0.42	0.29	28:45	11:21
DW 48	88	0.37	0.32	27:43	10:51
DW 15	90	0.42	0.29	25:46	10:12
DW 26	52	0.59	0.44	22:43	08:36
DW 51	59	0.36	0.27	16:04	06:23
DW 13	48	0.37	0.26	12:35	05:03
DW 56	7	0.08	0.07	00:28	00:10
DW 11	4	0.05	0.04	00:10	00:03

Table 4: Shadow Flicker Analysis > 0 Hours < 2,000m

Month	Possible Hours	Actual Hours	Percentage
Jan	446	222	50%
Feb	377	198	53%
Mar	381	194	51%
Apr	333	155	47%
May	313	130	41%
Jun	289	105	36%
Jul	306	117	38%
Aug	333	147	44%
Sep	356	150	42%
Oct	405	173	43%
Nov	424	186	44%
Dec	456	197	43%
Annual Average	4,419	1,975	45%

Table 5: Sunshine Analysis

Item	
Agent Number	1529
Network Number	B75152
Name	Thames 2
Lat (dec deg, S of equator is neg)	-37.15858
Longitude (dec deg, E of Greenwich is pos e.g. NZ)	175.55137
Position Precision	H
Height above MSL in metres	3m
Grid Reference (NZ Metric Map Series)	T12369463
Start Date	01-Oct-1957
End Date	-
Closed Indicator (Closed = 1)	0
Stty Station Type	1: Climate (Standard)
Synoptic Number (World Met. Organisation Number)	-
WRA No	751502
Observing Authority	N/A

Table 6: Thames Climate Station Details

Address	Dwelling Reference	Owner
452 Rawhiti	DW27	Curran Property
636a Rawhiti	DW22	Aitchison Property
636b Rawhiti	DW54	Tirohia School
649 Rawhiti	DW21	Fielding Property
680 Rawhiti	DW44	Parkinson Property

Table 7: Properties Photographically Assessed

9.0 FIGURES

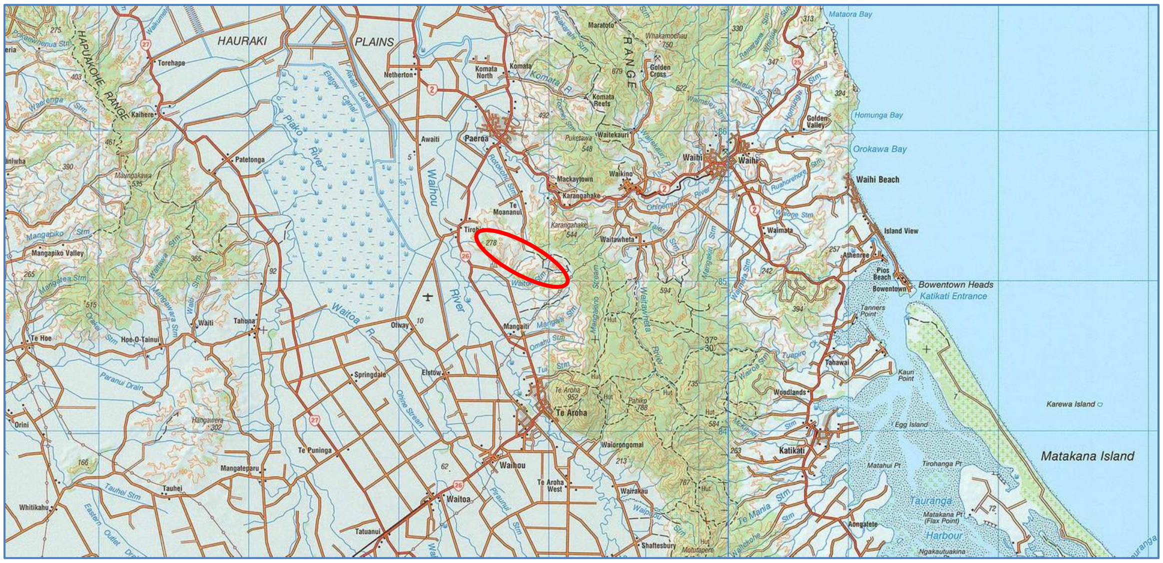

Figure 1: General Location of the Proposed Kaimai Wind Farm

Figure 2: Map Showing Proposed Turbine Locations

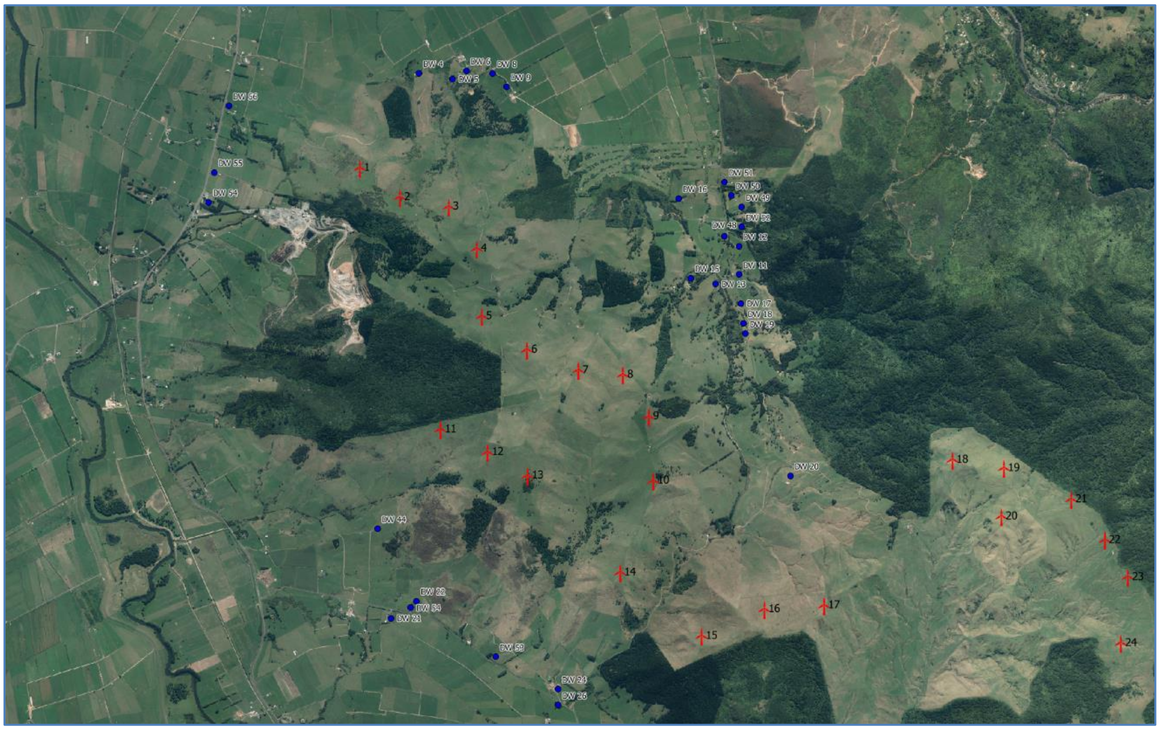

Figure 3: Map Showing Actual Turbine Locations and Identified Dwelling Locations

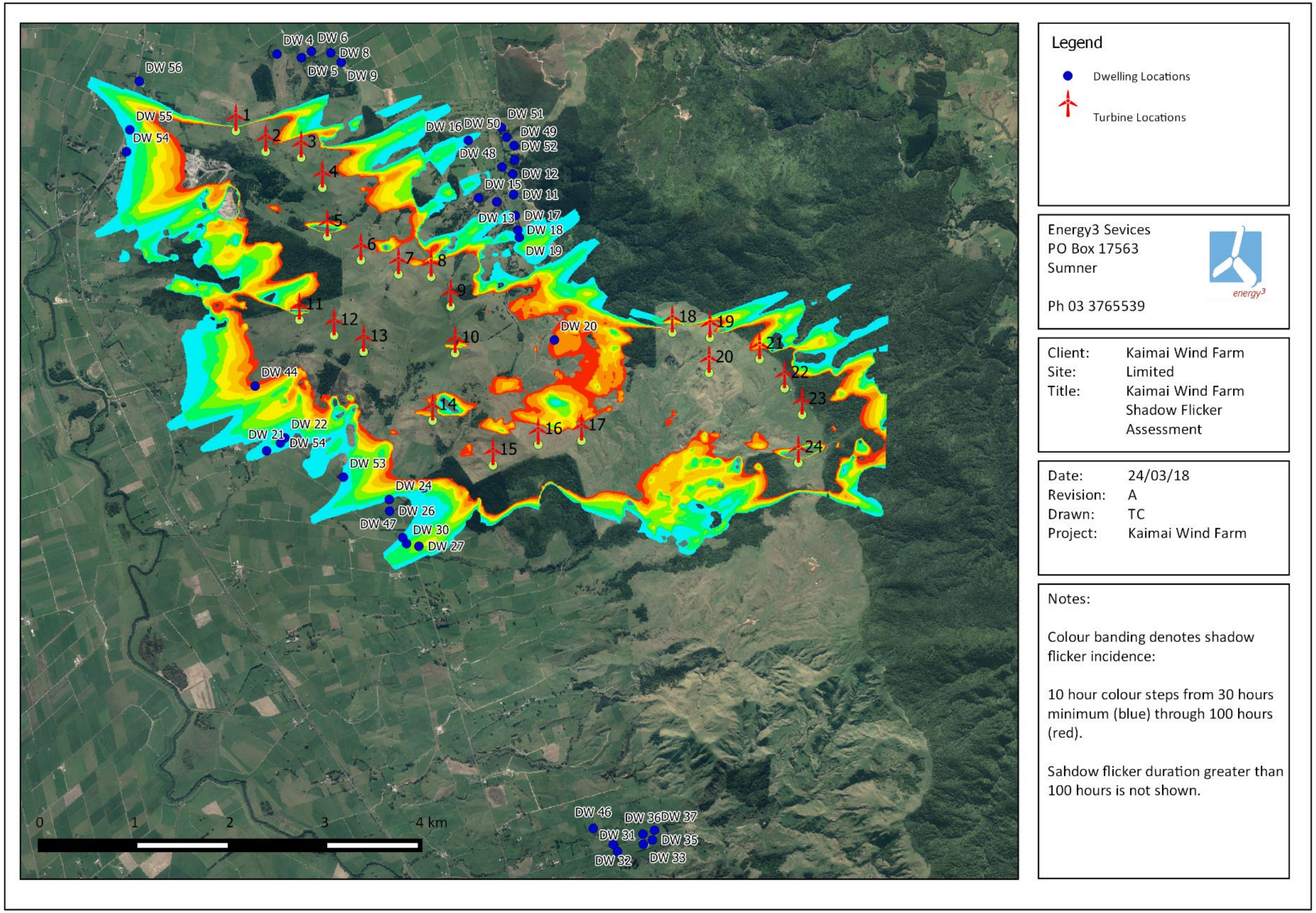

Figure 4: Shadow Flicker Assessment, the coloured contours of the map begin at 30 hours per annum (blue) of calculated shadow flicker exposure, and move through to 100 hours per annum (red).

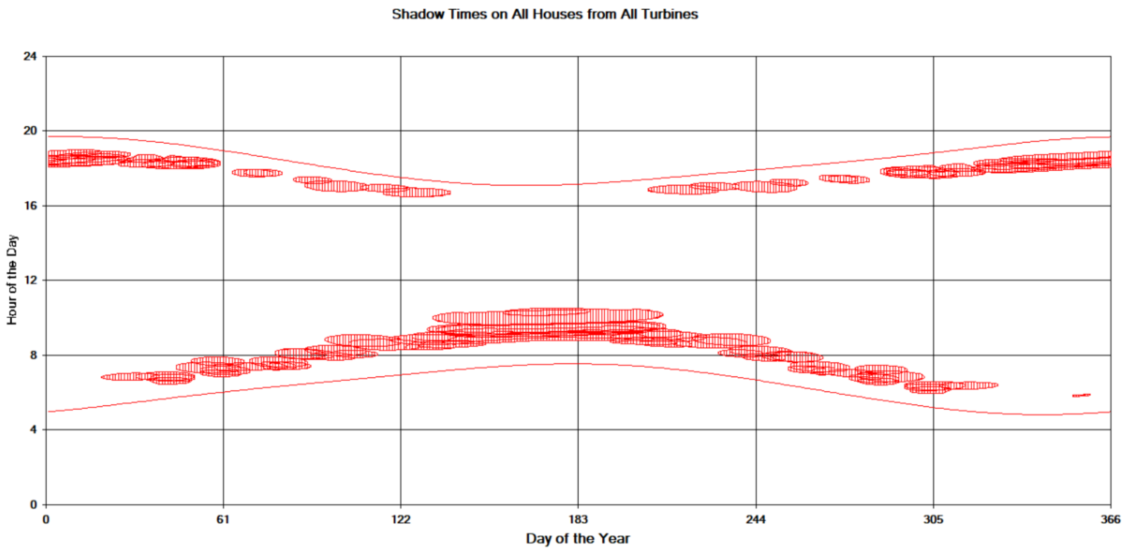

Figure 5: Modelled Shadow Flicker Time Windows

Figure 6: DW27 View from East Facing Windows

Figure 7: DW27 View North East

Figure 8: DW21 View from North East Windows

Figure 9: DW44 View from North East Windows


Figure 10: DW44 View from South East Windows

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