Shadow Flicker Study Report of 50 MW Wind Power Project of GAWPL, Sindh Province, Pakistan

Gul Ahmed Wind Power Limited (GAWPL)

Draft Report

August 2014

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CONTENTS

1 SHADOW FLICKER

1.1 INTRODUCTION

Environmental Resources Management (ERM) had conducted an update of Initial Environmental Examination (IEE) of the 50 MW Wind Power Project of Gul Ahmed Wind Power Limited (GAWPL) at Jhimpir area of taluka and district Thatta in the Sindh Province of Pakistan in December 2013. One of the key recommendations in that study was to conduct a shadow flicker study for the wind farm in order to assess the impacts of shadow flickering in the neighbouring settlements around the GAWPL site. This shadow flicker study has been conducted as an addendum to the updated IEE study report (December 2013).

1.2 OVERVIEW

Shadow flicker is a term used to describe the pattern of alternating light intensity observed when the rotating blades of a wind turbine cast a shadow on a receptor under certain wind and light conditions. Shadow flicker occurs under a limited range of conditions when the sun passes behind the hub of a wind turbine and casts an intermittent shadow over neighbouring properties.

Pakistan energy and planning policy contains limited shadow flicker requirements and recommendations, therefore United Kingdom policy/recommendations have been substituted for some aspects of this assessment. Shadow flicker is usefully defined in paragraph 73 of the United Kingdom companion guide *PPS22 (2004) Renewable Energy* (1):

> *"Under certain combinations of geographical position and time of day, the sun may pass behind the rotor of a wind turbine and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as 'shadow flicker'. It only occurs inside buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the potential site. For sites where existing or proposed developments may be subject to this problem, applicants for planning permission for wind turbine installations should provide calculations to quantify the effect."*

The draft Pakistan Sectoral Guidelines for Environmental Reports – Wind Power Projects (2010) (2) provides a number of guidelines and statements in relation to shadow flicker analysis. The maximum horizontal distance between a receptor affected by shadow flicker and turbine location for

(1) ODPM (2004) Planning for Renewable Energy: A Companion Guide to PPS22

(2) Pakistan Environment Protection (2010) Sectoral Guidelines for Environmental Reports - Wind Power Projects. (These guidelines are in draft and have not been adopted by the Pakistan EPA.)

example has been identified as being equal to the diameter of the turbine multiplied by ten. In this instance, turbine rotor diameter is 100 m therefore an area envelope of 1000 m from the nearest turbine is used in shadow flicker analyses.

At present, Germany has detailed guidelines on limits and conditions for calculating shadow impact. These are found in "Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergianlagen" (WEA-Shattenwurf-Hinweise).

According to the German guidelines, the limit of the shadow is set by two factors:

- The angle of the sun over the horizon must be at least 3 degrees
- The blade of the WTG must cover at least 20% of the sun.

The maximum shadow impact for a neighbour to a wind farm according to the German guidelines is:

- Maximum 30 hours per year of astronomical maximum shadow (worst case)
- Maximum 30 minutes worst day of astronomical maximum shadow (worst case)
- If automatic regulation is used, the real shadow impact must be limited to 8 hours per year.

In Sweden and Denmark there are no official guidelines as yet on shadow flickering, but for practical purposes, 10 hours (Denmark) and 8 hours (Sweden) real case (weather-dependent) shadow impact is used as the limit. In the UK, no official limits are in force, however an assessment must be made at all dwellings within ten rotor diameters of the turbine locations (PPS22 (2004) for England(1), TAN8 for Wales). In Ireland, a worst-case 30 hours per year, 30 minutes per day limit has been set.

The United Kingdom companion guide to PPS22 also provides additional guidelines in relation to shadow flicker. It states that properties within 130 degrees either side of north, relative to the turbines, can be affected at these latitudes.

Weather conditions at the site, such as bright sunshine, will greatly enhance the occurrence and intensity of shadow flicker, whereas haze or fog will cause a reduction. Receptors further away from the turbines which may have experienced a shadow flicker effect under bright sunshine conditions will, as a result of haze or fog, experience either no effect or one which is greatly reduced in intensity.

The distance between receptors and turbines has a large effect on the intensity of shadow flicker. Shadow flicker intensity can be defined as the difference in

(1) ODPM (2004) Planning for Renewable Energy: A Companion Guide to PPS22

brightness between the presence and absence of a shadow at any given location. This study does not examine variations in intensity but rather the occurrence in number of hours shadow flicker may occur, whether or not this is clearly distinct or barely noticeable. The assessment assumes a conservative worst case of bright sunshine conditions in all periods when flicker may occur.

The time of the day for which shadow impact is critical and the definition of a shadow receptor for which shadow impact is calculated are less rigidly defined by the guides and is often something which should be evaluated in each individual case.

Shadow flicker is most pronounced at sunrise and sunset when shadows are the longest, and at high wind speeds (faster rotating blades leading to faster flicker). A UK government report recommends that for inhabitants near wind turbines, shadow flicker should be limited to 30 hours in a year and 30 minutes in a day[1]. There is anecdotal evidence internationally that shadow flicker could lead to stress and headaches. There is also a fear that shadow flicker, especially in the range of 2.5-50 Hertz (2.5-50 cycles per second) could lead to seizures in epileptics and may also scare away livestock.

An analysis of those conditions that may lead to shadow flicker and the location of potential sensitive receptors (residential and community properties) is provided in this section. The timing and duration of this effect can be theoretically calculated from the geometry of the proposed wind turbines, their orientation relative to nearby houses and the latitude of the potential site, using specialised software such as *WindPro 2.6.29*.

The results provide the total number of hours in a year when a theoretical shadow flicker will occur. This is most pronounced during sunrise and sunset when the sun's angle is lower and the resulting shadows are longer. Shadow flicker does not occur where there is vegetation or other obstructions such as terrain between the turbines and houses; if windows facing a turbine are fitted with blinds or shutters; or if the sun is not shining brightly enough to cause shadows.

The theoretical calculations done by *WindPro Shadow* does take into account the reduction in shadow flicker due to topographic features, however it does not take into account the reduction in shadow flicker due to these onsite factors i.e. vegetation. Simple geometry relating to the position of the sun and the angle of the turbine blades can also eliminate or significantly reduce the effects of shadow flicker. In addition, shadow flicker will only occur inside buildings where the flicker is occurring through a narrow window opening

Weather conditions at the site, such as bright sunshine, will greatly enhance the occurrence and intensity of shadow flicker, whereas cloud density, haze or

(1) ([1]) Draft EIA Guidelines Wind Power Sector, prepared by Centre for Science and Environment, New Delhi

fog will cause a reduction. Receptors further away from the turbines which may have experienced a shadow flicker effect under bright sunshine conditions will, as a result of these weather conditions, experience either no effect or one which is greatly reduced in intensity.

The distance between receptors and turbines has a large effect on the intensity of shadow flicker. Shadow flicker intensity can be defined as the difference in brightness between the presence and absence of a shadow at any given location. This study does not examine variations in intensity but rather the occurrence in number of hours shadow flicker may occur, whether or not this is clearly distinct or barely noticeable. The assessment assumes a conservative worst case of bright sunshine conditions in all periods when flicker may occur.

Considering all of the above points, the likelihood of shadow flicker occurring is greatest when the circumstances listed below exist simultaneously.

- The receptor is at a position which is between 130° clockwise (1) and anticlockwise from north and located within 20 turbine rotor diameters of the wind turbine (~2000 m).
- The sun is shining and visible in the sky in line with the monthly mean sun-shine hours at nearby location.
- The wind speeds are between 3 m/s and 22 m/s and the turbine is therefore in operation.
- The turbine blades are perpendicular to the line between the sun and the observer or receptor most of time as per reported wind mast data.

Due to lack of data regarding epilepsy rates in Pakistan and operation levels below of 1 Hz for modern turbines, seizures caused by shadow flicker are considered to be extremely unlikely. The NORDEX N100/2500 turbines being considered operate at a frequency outside the range where negative health effects may result (2). Potential effects on people are likely to be limited to nuisance.

1.3 *THE MODEL – WINDPRO SHADOW*

SHADOW is the WindPRO calculation module that calculates how often and in which intervals a specific neighbour or area will be affected by shadows generated by one or more WTGs. These calculations are worst-case scenarios (astronomical maximum shadow, i.e. calculations which are solely based on the positions of the sun relative to the WTG). Shadow impact may occur when the blades of a WTG pass through the sun's rays seen from a specific spot (e.g.

(1) It is acknowledged by this assessment however that India is at a lower latitude than the European countries and therefore angles of shadow flicker may be narrower.
(2) See Health and Safety Executive/Local Authority Enforcement Liaison Committee (HELA) circular, entitled 'Disco Lights and Flicker Sensitive Epilepsy' (available at http://www.hse.gov.uk/lau/lacs/51-1.htm). It provides medical details on flicker frequencies likely to give rise to epileptic effects. It states: 'In 1971 the Greater London Council banned the use of flicker rates greater than 8 fps but to be effective the above figures show that any advice on restriction of flicker rate has to limit the frequency to below 5 fps.'

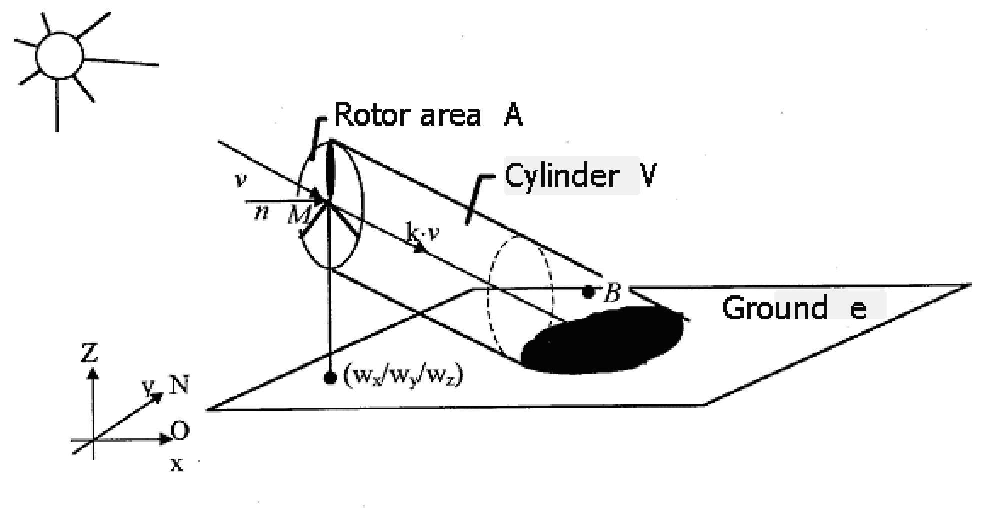
a window in an adjacent settlement). If the weather is overcast or calm, or if the wind direction forces the rotor plane of the WTG to stand parallel with the line between the sun and the neighbour, the WTG will not produce shadow impacts, but the impact will still appear in the calculations. In other words, the calculation is a worst-case scenario, which represents the maximum potential risk of shadow impact. A calendar can be printed for any specific point of observation, which indicates the exact days, and time periods where shadow impact may occur.

Apart from calculating the potential shadow impact at a given neighbour, a map rendering the iso-lines of the shadow impact can also be printed. This printout will render the amount of shadow impact for any spot within the project area.

The calculation of the potential shadow impact at a given shadow receptor is carried out simulating the situation. The position of the sun relative to the WTG rotor disk and the resulting shadow is calculated in steps of 1 minute throughout a complete year. If the shadow of the rotor disk (which in the calculation is assumed solid) at any time casts a shadow reflection on the window, which has been defined as a shadow receptor object, then this step will be registered as 1 minute of potential shadow impact. The following information is required:

- The position of the WTGs (x, y, z coordinates)
- The hub height and rotor diameter of the WTGs
- The position of the shadow receptor object (x, y, z coordinates)
- The size of the window and its orientation, both directional (relative to south) and tilt (angle of window plane to the horizontal).
- The geographic position (latitude and longitude) together with time zone and daylight saving time information.
- A simulation model, which holds information about the earth's orbit and rotation relative to the sun.

Figure 1.1 An illustration of shadow effect from WTG



1.4 *POTENTIAL SIGNIFICANT IMPACTS*

In Pakistan at present, there is no agreed level of shadow flicker identified as causing a significant effect. However, the Danish Wind Industry Association note on their website that in Germany, the rule of thumb is that 30 hours shadow flicker a year received at a property is acceptable (1). The 'Wind Energy Development Guidelines, 2006' published by the Irish Government Department of the Environment, Heritage and Local Government recommend that shadow flicker at neighbouring offices and dwellings within 500 m should not exceed 30 hours per year or 30 minutes (0.5 hours) per day. A threshold of 30 hours per year has therefore been considered and applied for this assessment.

1.5 *ASSESSMENT METHODOLOGY AND MODELLING*

Shadow flicker calculations have been made using WindPro software. Following meteorological data and conditions have been taken into consideration for modelling purpose:

- the mean monthly sunshine hours have been taken from the WindPro database available for Karachi Airport, located about 88 km aerial distance from the Project site covering the data period (1969 - 1991);
- the wind turbines have been considered operational with wind speed more than 3 m/s and for the same wind mast data of about at 80 m height has been considered, which indicates that about 95% time of the year, the wind turbines will be operational;
- the blades of the wind turbines are perpendicular with southwest-northeast orientation have been considered based on the predominant wind direction available from the wind mast data at site, which could result in maximum possible size circular/ elliptical;
- there are no trees, buildings or vegetation on the surface which may obscure the line of sight between receptor and turbine;
- the sun can be represented as a single point;
- flicker is ignored if sun is less than 3° above horizon (due to atmospheric diffusion/ low radiation/ sheltering);
- structures within settlements are considered as residential receptors; and
- all structure openings have been considered as "Green House" mode, which means that window is perpendicular to all WTGs for assessment of worst case scenario.

The following data inputs were used in this study:

(1) www.windpower.org

- a digital elevation model of the site (National Aeronautic and Space Administration (NASA) Shuttle Radar Topography Mission (SRTM) Data at 90 m resolution);
- latitude and longitude at centre of the site used to calculate the position of the sun (calculated in GIS using WGS84);
- mean monthly sun-shine hours recorded over a period of 23 years at a nearby solar radiation station (Karachi);
- wind mast data at 80 m height for wind class and frequency distribution;
- turbine locations – coordinates (identified in GIS);
- turbine rotor diameter (100 m);
- height to bottom of Turbine hub (80 m);
- tilt angle of the 'window' (always assumed vertical);
- residential receptors contain on average one opening measuring 1.2 m by 0.9 m facing towards wind turbines; and height above ground level of the 'window' 0.9 m.

1.6 RECEPTORS

The maximum horizontal distance between a receptor affected by shadow flicker and turbine location for example has been identified as being equal to the diameter of the turbine multiplied by twenty. In this instance, turbine rotor diameter is 100 m therefore an area envelope of 2000 m from the nearest turbine is used in shadow flicker analyses. A total of 59 structures have been identified for the modelling study as being within the study area of the GAWPL site (refer Map 1). These properties area a mix of residential and community receptors (see Figure 1 and 2).

Figure 1.2 Typical Residential Receptors

Figure 1.3 Typical Community Receptors – School

Map 1 shows the study area of the assessment (within 2000 m) of a proposed turbine location) with the surrounding nearby settlements and a total of 59 structures have been identified for the modelling study within these settlements.

1.7 IMPACT ASSESSMENT

The results of the shadow flicker assessment are shown in ***Map 2*** and ***Table 1.1*** below and the supporting graphs provided in ***Annex A***. The graphs shown in

Annex A illustrate the times of the year at each of the 59 receptors in the analysis where theoretical shadow flicker was predicted to occur.

Table 1.1 Shadow Flicker Effects at Each Receptor

S. No.	Shadow Receptor	UTM Co-ordinates**		Shadow hours per year [hr/year]	WTGs causing shadow
		X (m E)	Y (m N)		
1	A	389,707	2,784,356	15:24	GA1, GA2, GA3
2	B	389,741	2,784,381	22:05	GA1, GA2, GA3
3	C	389,785	2,784,381	24:11	GA1, GA2, GA3
4	D	389,810	2,784,336	28:47	GA1, GA2, GA3, GA4
5	E	389,737	2,784,350	18:57	GA1, GA2, GA3
6	F	389,803	2,784,361	26:51	GA1, GA2, GA3
7	G	389,821	2,784,280	20:16	GA1, GA2, GA3, GA4
8	H	390,996	2,784,341	7:42	GA1
9	I	391,007	2,784,351	7:29	GA1
10	J	391,017	2,784,338	7:03	GA1
11	K	391,019	2,784,330	6:50	GA1
12	L	391,144	2,784,277	**32:19**	GA1, GA2
13	M	391,148	2,784,251	**35:11**	GA1, GA2
14	N	391,849	2,784,617	6:16	GA1, GA2
15	O	391,882	2,784,610	5:05	GA2
16	P	391,888	2,784,600	4:41	GA2
17	Q	391,859	2,784,616	6:11	GA1, GA2
18	R	391,847	2,784,596	6:21	GA1, GA2
19	S	392,178	2,785,160	0:00	-
20	T	391,883	2,784,090	7:20	GA1, GA2, GA3
21	U	391,876	2,784,087	7:28	GA1, GA2, GA3
22	V	391,865	2,784,078	8:30	GA1, GA2, GA3, GA4
23	W	391,850	2,784,072	8:26	GA1, GA2, GA3, GA4
24	X	391,836	2,784,069	8:20	GA1, GA2, GA3
25	Y	391,857	2,784,056	17:38	GA1, GA2, GA3, GA4
26	Z	391,848	2,784,033	26:45	GA1, GA2, GA3, GA4
27	AA	391,842	2,784,022	**30:59**	GA1, GA2, GA3, GA4
28	AB	391,922	2,784,012	**35:33**	GA1, GA2, GA3, GA4
29	AC	391,903	2,783,990	**38:54**	GA1, GA2, GA3, GA4
30	AD	391,874	2,783,982	**41:58**	GA1, GA2, GA3, GA4
31	AE	391,882	2,783,970	**40:57**	GA1, GA2, GA3, GA4
32	AF	391,900	2,783,973	**38:05**	GA1, GA2, GA3, GA4
33	AG	395,221	2,784,504	0:00	-
34	AH	395,321	2,784,468	0:00	-
35	AI	395,394	2,784,364	0:00	-
36	AJ	395,442	2,784,372	0:00	-
37	AK	395,514	2,784,274	0:00	-
38	AL	395,532	2,784,272	0:00	-
39	AM	399,496	2,782,599	0:00	-
40	AN	399,530	2,782,544	0:00	-
41	AO	399,606	2,782,616	0:00	-
42	AP	399,675	2,782,621	0:00	-
43	AQ	399,700	2,782,588	0:00	-
44	AR	399,689	2,782,576	0:00	-
45	AS	397,236	2,781,634	17:20	GA15, GA16, GA17
46	AT	397,216	2,781,651	14:30	GA15, GA16, GA17
47	AU	397,171	2,781,712	12:34	GA13, GA15, GA16, GA17
48	AV	397,173	2,781,754	14:10	GA13, GA15, GA16, GA17
49	AW	397,153	2,781,763	13:47	GA13, GA14, GA15, GA16, GA17
50	AX	397,134	2,781,782	13:21	GA12, GA13, GA14, GA15, GA16, GA17

S. No.	Shadow Receptor	UTM Co-ordinates**		Shadow hours per year [hr/year]	WTGs causing shadow
		X (m E)	Y (m N)		
51	AY	397,099	2,781,811	13:53	GA12, GA13, GA14, GA15, GA16,
52	AZ	397,098	2,781,785	12:06	GA12, GA13, GA15, GA16, GA17
53	BA	397,122	2,781,910	23:00	GA13, GA14, GA15, GA16,
54	BB	397,117	2,781,933	21:11	GA13, GA14, GA15, GA16,
55	BC	397,095	2,781,884	24:43	GA13, GA14, GA15, GA16,
56	BD	395,302	2,781,960	11:31	GA13, GA14
57	BE	395,270	2,781,961	8:32	GA13, GA14
58	BF	395,248	2,781,955	7:49	GA13, GA14
59	BG	395,334	2,781,931	11:16	GA13, GA14

* Figures highlighted and bold represent greater than 30 hours per year of shadow flicker
** WGS84 Zone: 42
WTGs GA5 to GA11 and GA18 to GA20 do not contribute any shadow flickering at any of the shadow receptor.

The results show that theoretical shadow flicker occurs at 46 shadow receptors out of total 59 receptors, within the zone of potential impact. The number of hours per year when shadow flicker occurs ranges between 4:41 and 41:58. All shadow receptors are located on the western/south-western side of WTGs get affected between the hours of 5:30 a.m. and 8:30 a.m., whereas those located on the eastern/ north-eastern side of WTGs get affected between 4:30 p.m. and 7:00 p.m. ***Map 2*** illustrates the extent of theoretical shadow flicker at levels of 30 hours per year. Theoretical shadow flicker occurs above this level at only two shadow receptors in the study area.

Given the guidelines of 30 hours or less per year is considered to be acceptable, the operation of the wind farm theoretically results in shadow flicker impacts that could be considered as significant for the purposes of this study. In this case, 8 shadow receptors out of total 59 considered will experience a shadow flicker impact as maximum hours per year of shadow flicker exceed this value. Maximum shadow flicker will be caused at shadow receptor – AD (S. No. 30), with 41:58 hrs/year. Out of the total 20 WTGs, 10 WTGs do not contribute to any shadow flickering at any of the 59 identified shadow receptors in this study.

It is relevant to emphasise that predicted hours of shadow flicker effects are real case scenarios with certain assumptions. Assumptions made during the analysis include optimal meteorological, natural light and geometrical conditions for the generation of shadow flicker. The assessment does not account for trees or other obstructions that intervene between receptor and turbine during times when effects may occur. The assessment calculation is therefore an over estimation in the probability of effects. It should also be noted that for shadow effects to occur, properties need to be occupied, with blinds or curtains open and views to the wind turbine unobstructed. However, for the purposes of assessment, it has been assumed that all worst-case circumstances apply.

1.8 MITIGATION MEASURES

1.8.1 *Measures to Mitigate Potential Impacts*

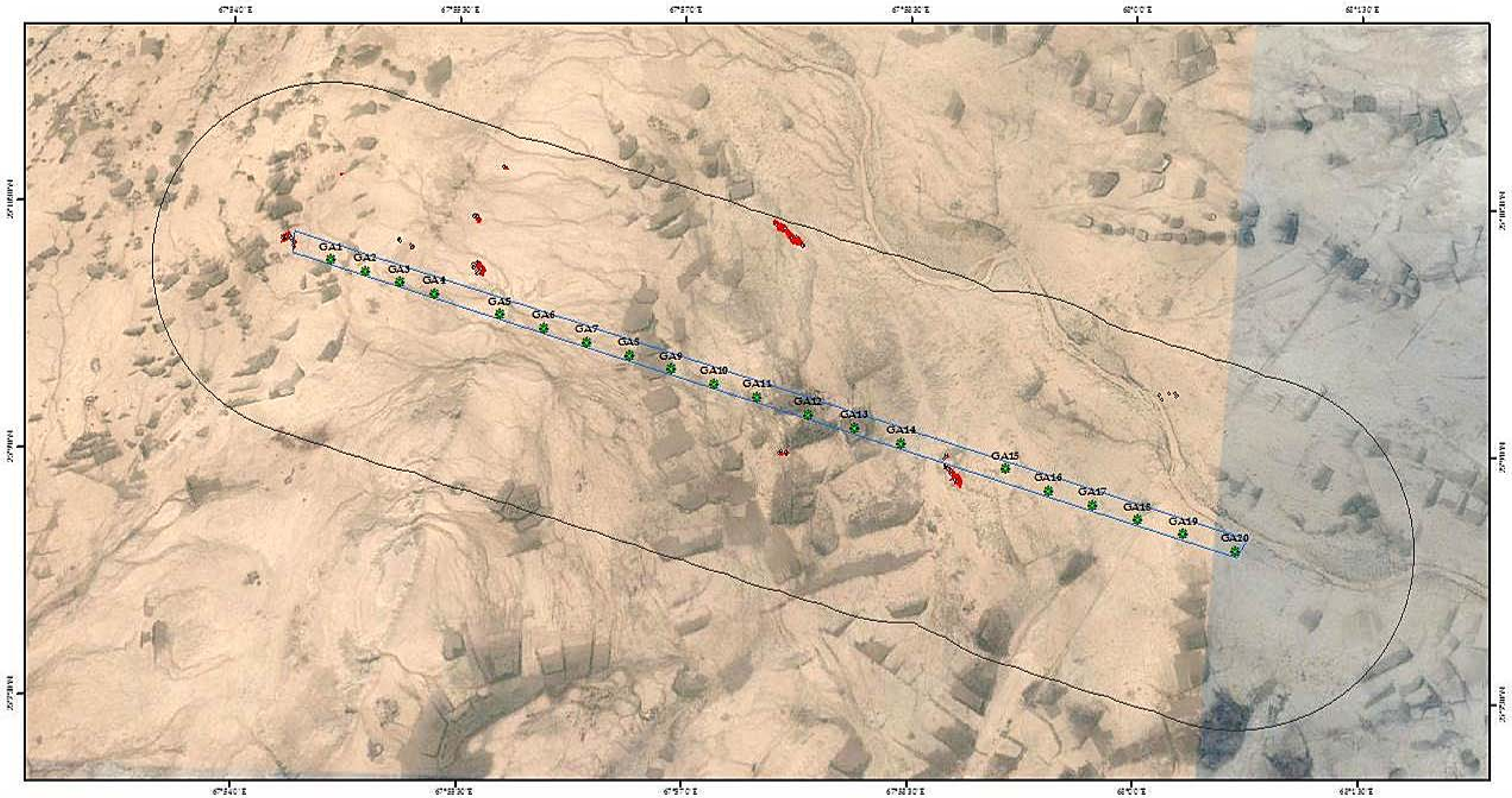
There will be close monitoring through engagement with residents during the operational phase where there are predicted impacts from shadow flicker. The likelihood of direct line of sight to the location of proposed turbine locations can be assessed visually and the potential for using screening like higher fencing and planting trees can be explored at problem locations. The use of curtains can also be explored. If these prove effective and the impacts mitigated, the shutting down of turbines during certain environmental conditions, which meet the physical requirements for theoretical shadow flicker to occur, will not be required.

Should the impact of shadow flicker be identified, and the mitigation measures proposed above prove ineffective, further analysis can be carried out to identify the exact timings and conditions under which shadow flicker occurs, and a technical solution sought. This is likely to involve pre-programming the turbine with dates and times when shadow flicker would cause a nuisance for nearby receptors. A photosensitive cell can be used to monitor sunlight, and the turbine could potentially then be shut down, when the strength of the sun, wind speed and the angle and position of the sun combines to cause a flicker nuisance.

1.8.2 *Assessment of Residual Impacts*

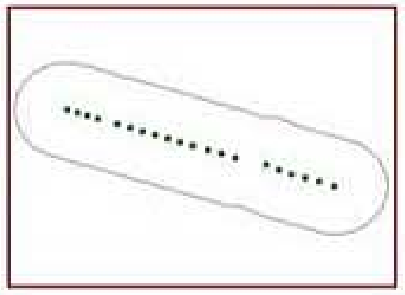
The results of the WindPRO shadow flicker assessment show a real case estimate with certain assumptions and the mitigation measures above will be implemented for the identified properties that experiences shadow flicker.

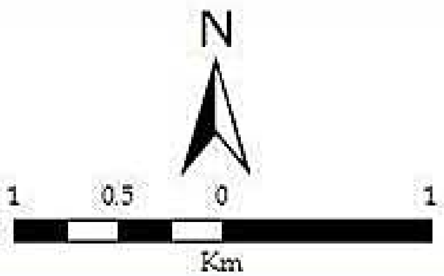
Residual impacts following the application of required mitigation measures, as discussed above, is likely to result in no significant impacts.



Legend

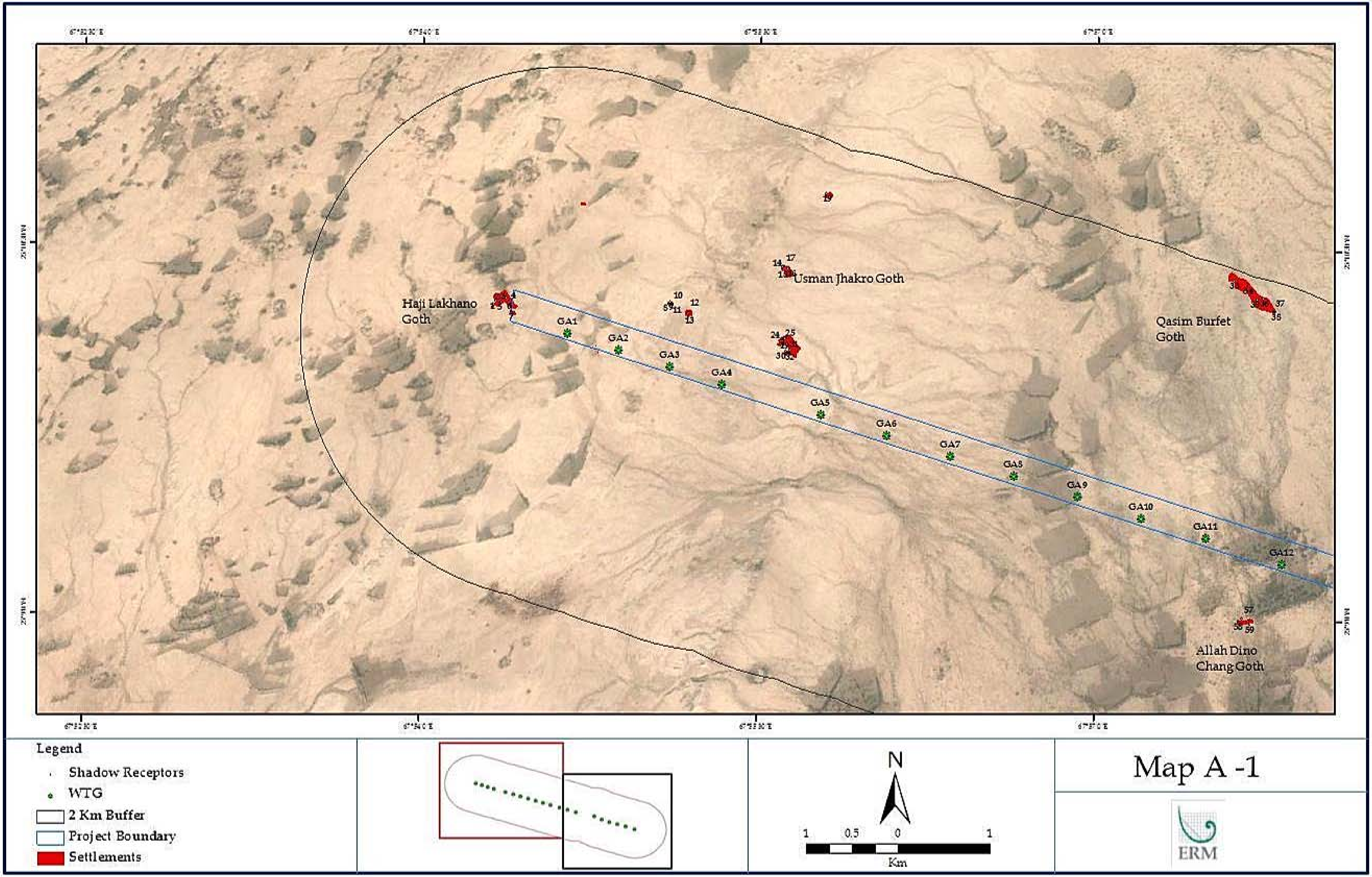
- Shadow Receptors
- WTG
- 2 Km Buffer
- Project Boundary
- Settlements





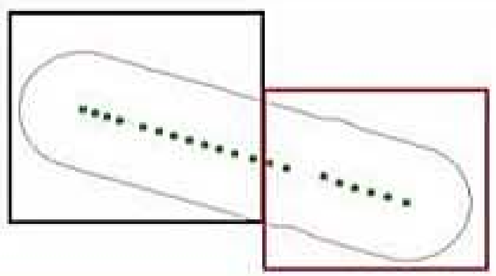
Map A

ERM


GA1
GA2
GA3
GA4
GA5
GA6
GA7
GA8
GA9
GA10
GA11
GA12
Haji Lakhano Goth
Usman Jhakro Goth
Qasim Burfet Goth
Allah Dino Chang Goth
Legend
Shadow Receptors
WTG
2 Km Buffer
Project Boundary
Settlements
N
1 0.5 0 1
Km
Map A -1
ERM

Legend

- Shadow Receptors
- WTG
- 2 Km Buffer
- Project Boundary
- Settlements



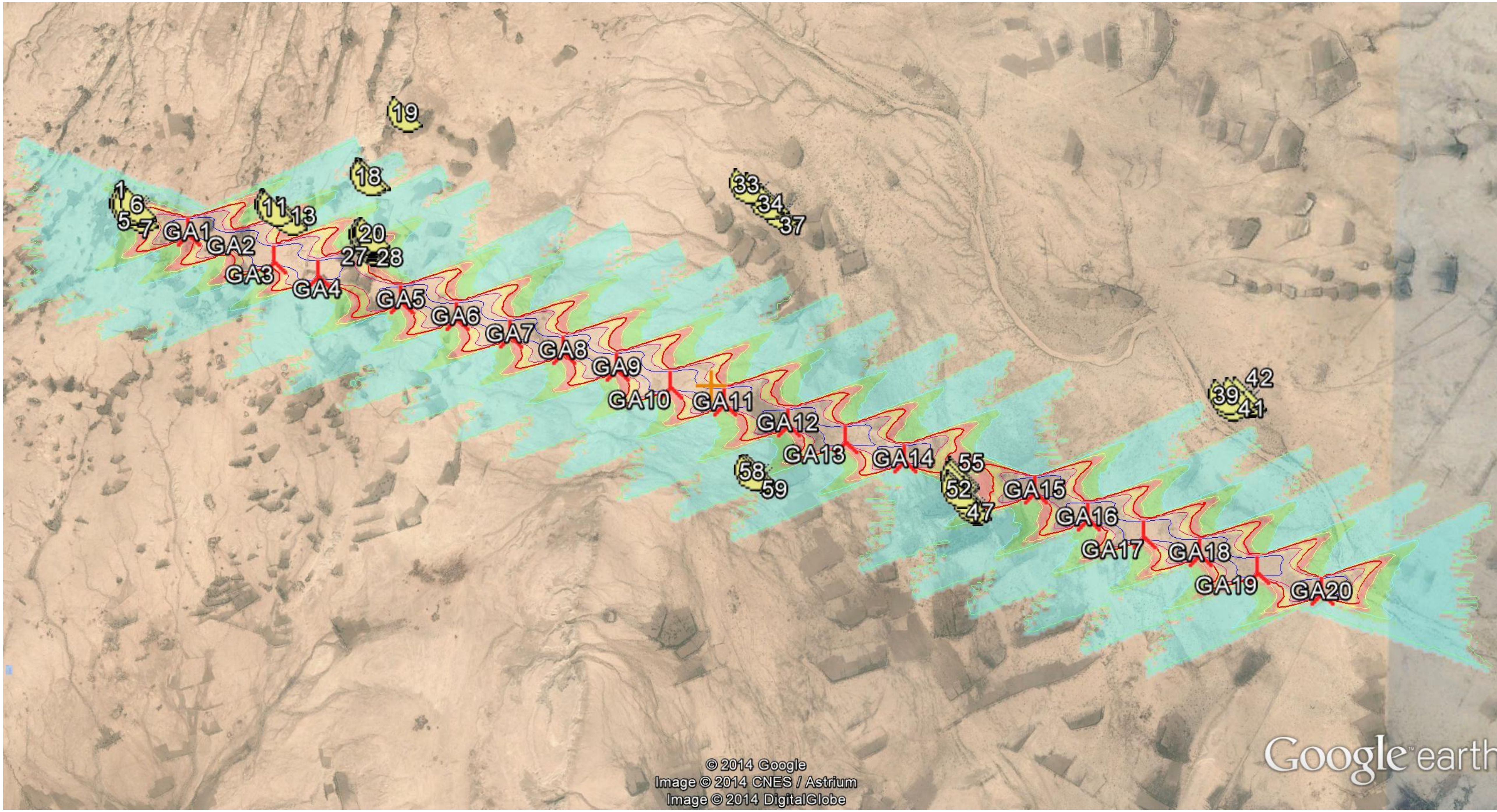
N

1 0.5 0 1

Km

Map A -2

ERM



Shadow Receptor

New WTG

Real Case Scenario: Hours per year, real case

1 - 10 Hours

10 - 20 Hours

20 - 30 Hours

30 - 50 Hours

1 Hours

10 Hours

20 Hours

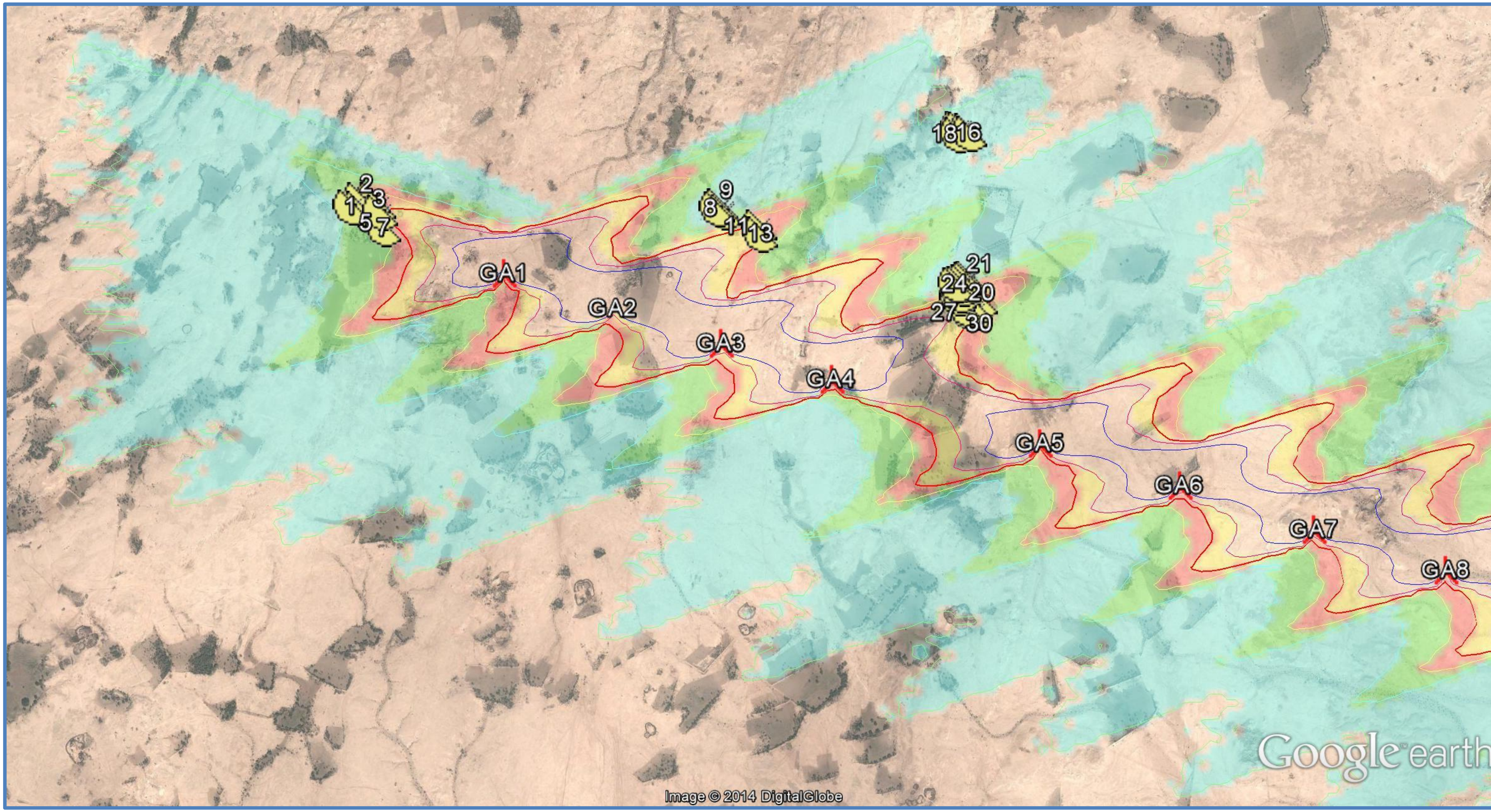
30 Hours

50 Hours

N

Map B

ERM



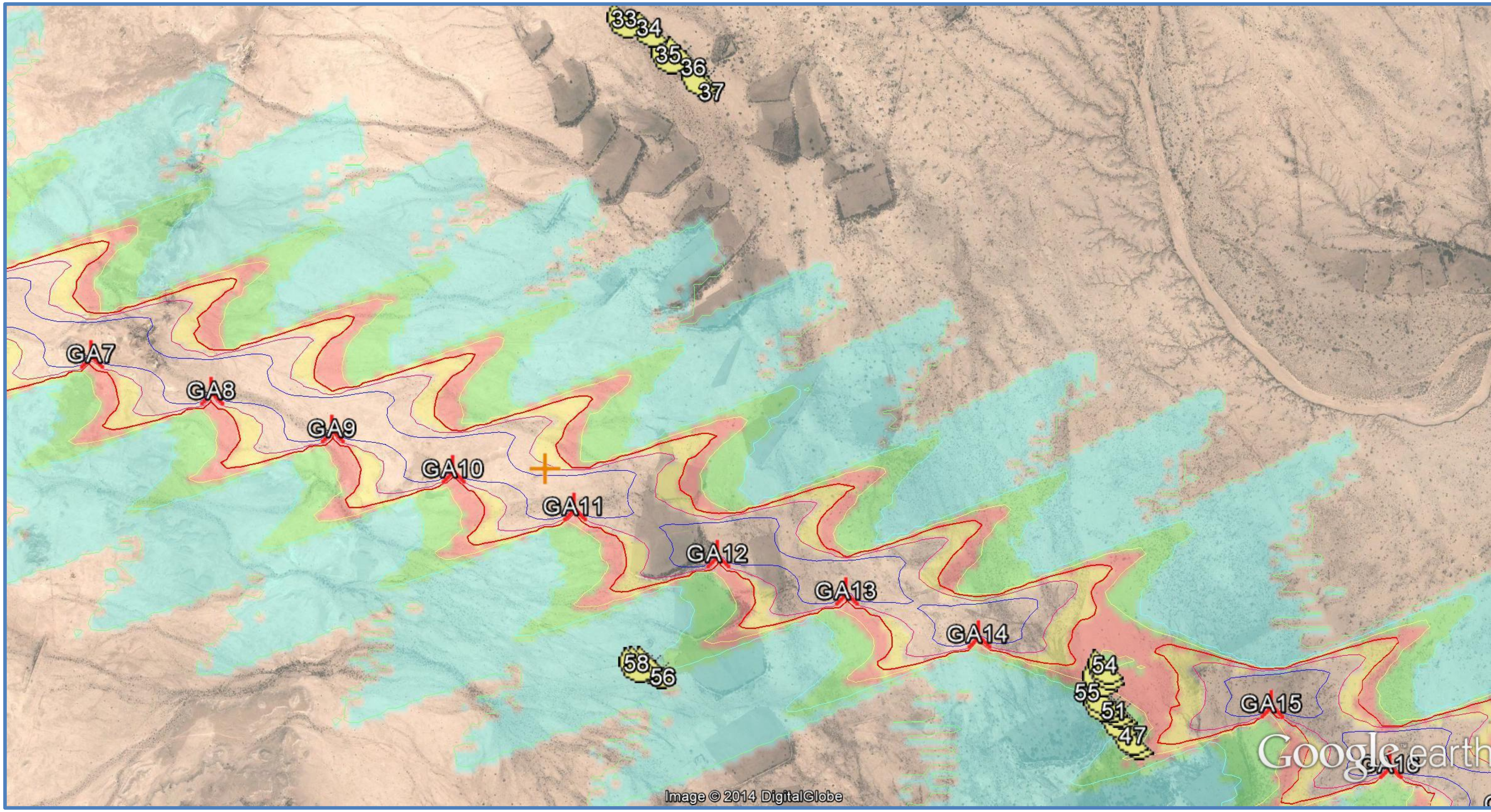
Shadow Receptor
New WTG
Real Case Scenario: Hours per year, real case
1 - 10 Hours
10 - 20 Hours
20 - 30 Hours
30 - 50 Hours

1 Hours
10 Hours
20 Hours
30 Hours
50 Hours

N

Map B-1

ERM



Shadow Receptor

New WTG

Real Case Scenario: Hours per year, real case

1 - 10 Hours

10 - 20 Hours

20 - 30 Hours

30 - 50 Hours

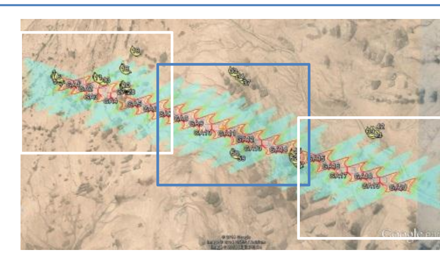
1 Hours

10 Hours

20 Hours

30 Hours

50 Hours



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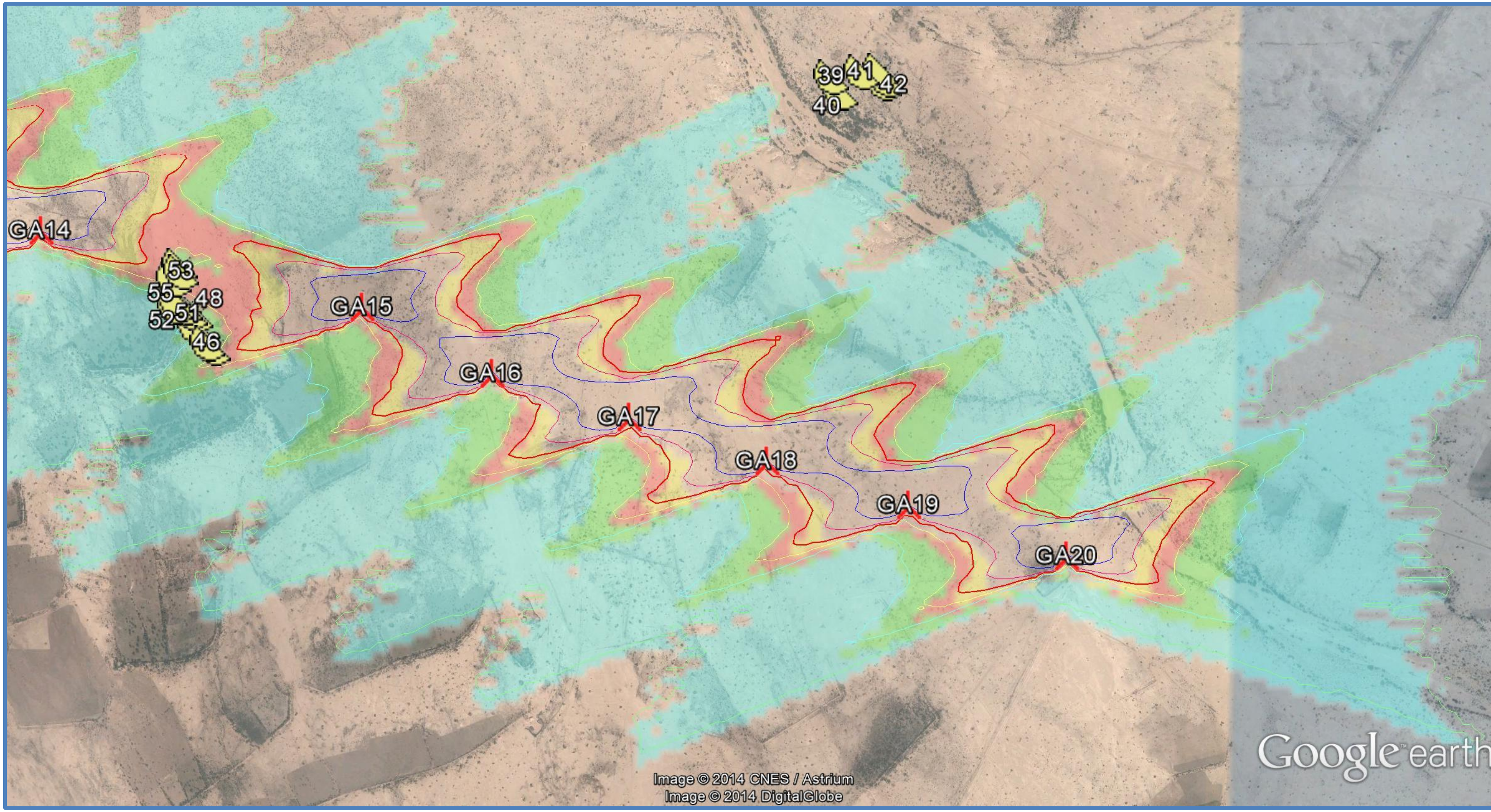
Map B-2

ERM



Shadow Receptor

New WTG

Real Case Scenario: Hours per year, real case

1 - 10 Hours

10 - 20 Hours

20 - 30 Hours

30 - 50 Hours

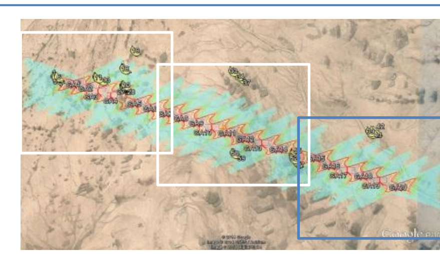
1 Hours

10 Hours

20 Hours

30 Hours

50 Hours



N

Map B-3

ERM

Annex A

Shadow - Calendar Graphical

Project:
GAWPL 50 MW

Description:
50 MW Wind Power Project of Gul Ahmed Wind Power Limited (GAWPL), Nooriabad, Sindh Province, Pakistan

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+91 124 4170300
Naval Chaudhary / naval.chaudhary@erm.com

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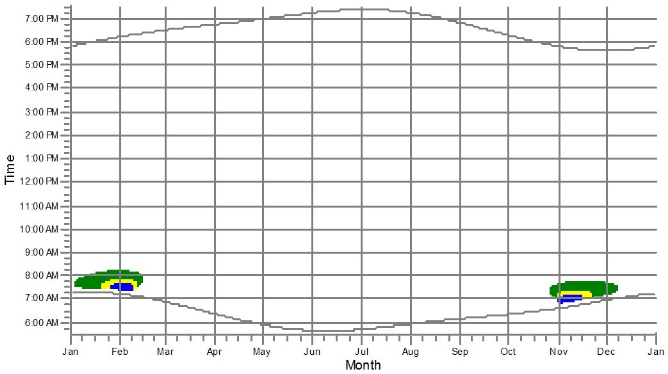
8/10/2014 9:22 AM/2.9.269

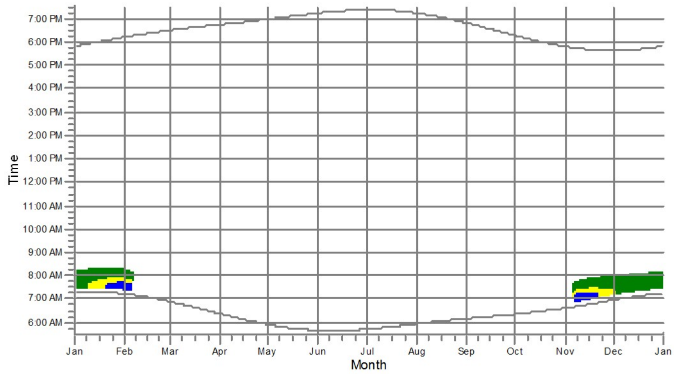
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

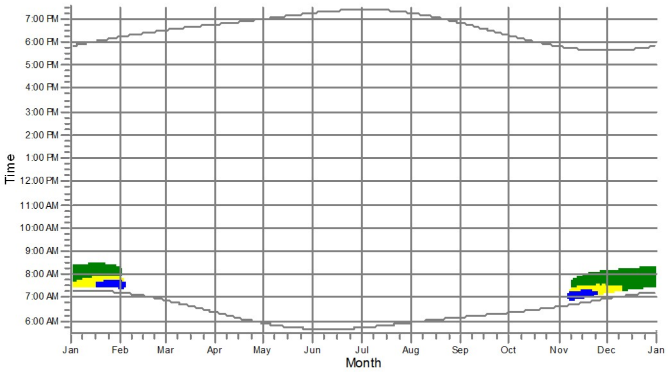
A: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (1)



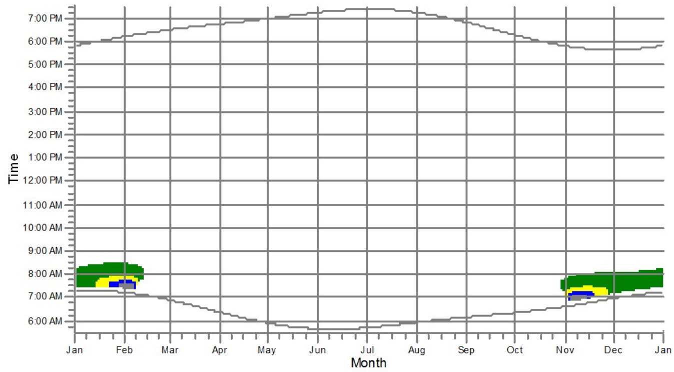
B: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (2)



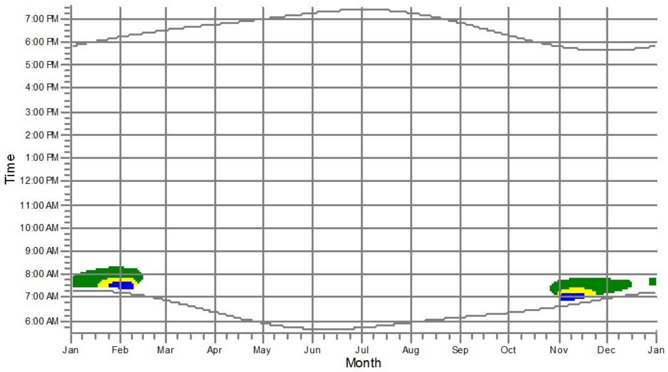
C: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (3)



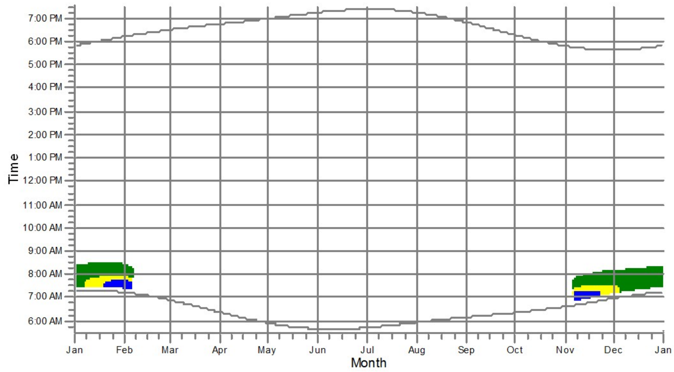
D: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (4)



E: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (5)



F: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (6)



WTGs

- 1: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (1)
- 2: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (2)
- 3: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (3)
- 4: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (4)

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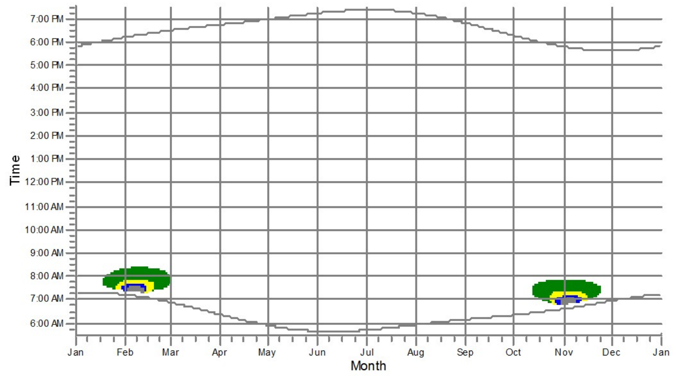
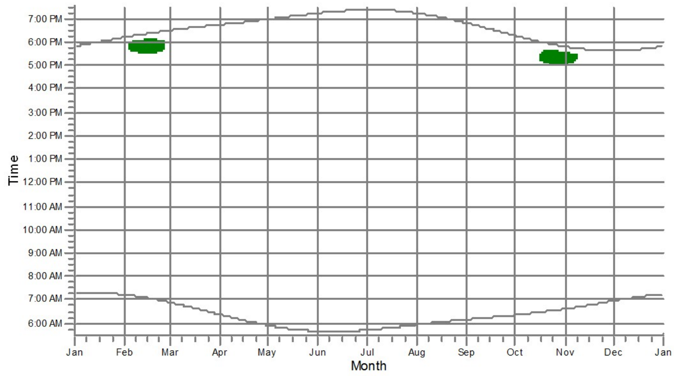
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

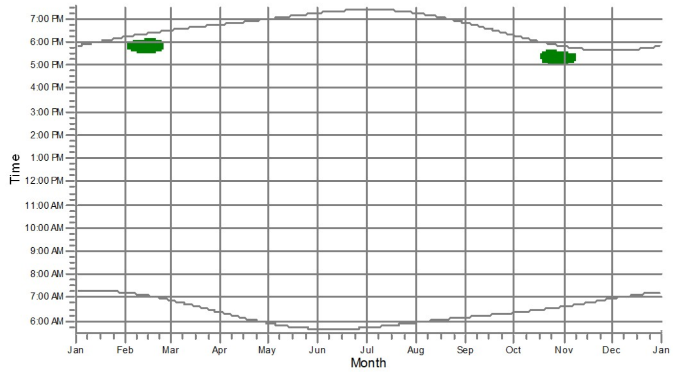
G: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (7)



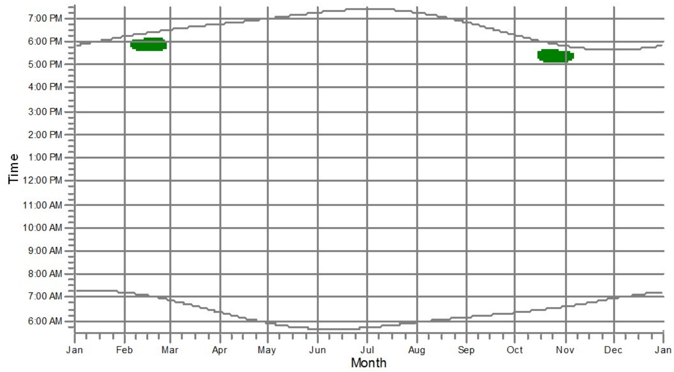
H: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (8)



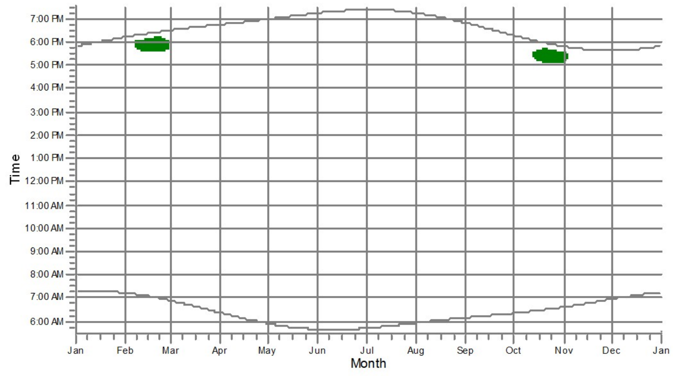
I: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (9)



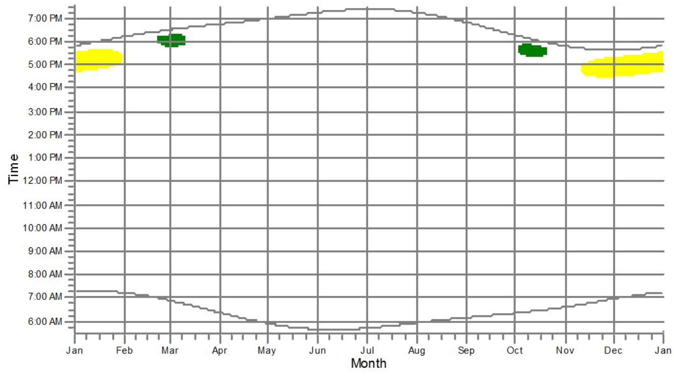
J: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (10)



K: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (11)



L: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (12)



WTGs

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2: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (2)
3: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (3)
4: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (4)

Project:
GAWPL 50 MW

Description:
50 MW Wind Power Project of Gul Ahmed Wind Power Limited (GAWPL), Nooriabad, Sindh Province, Pakistan

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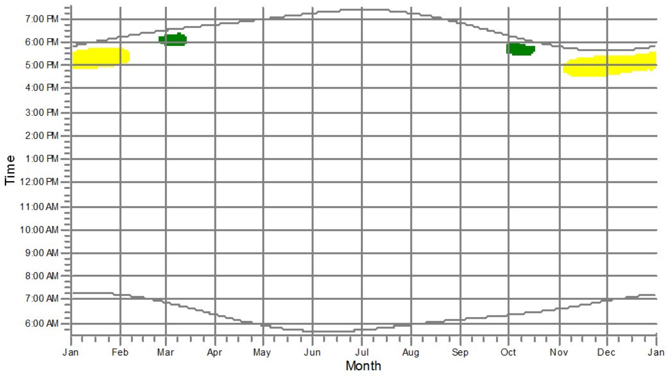
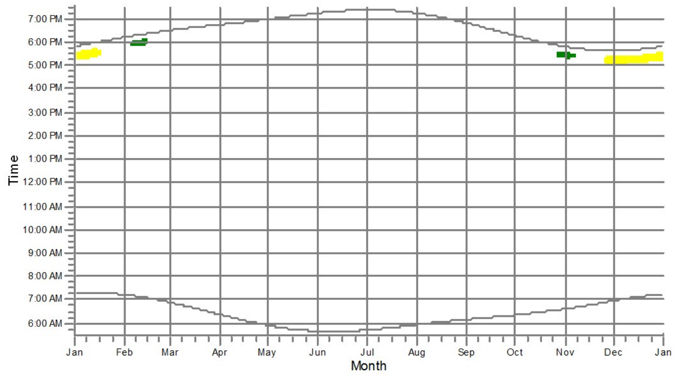
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

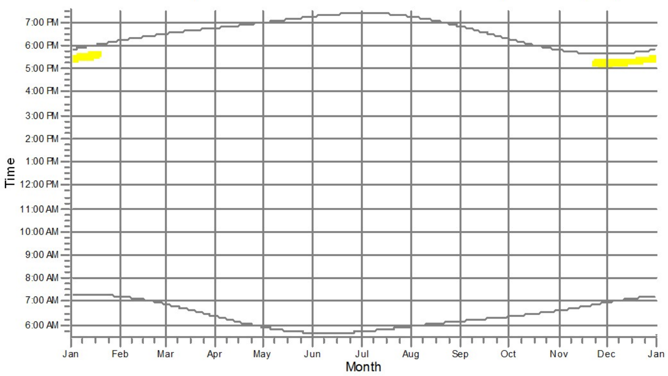
M: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (13)



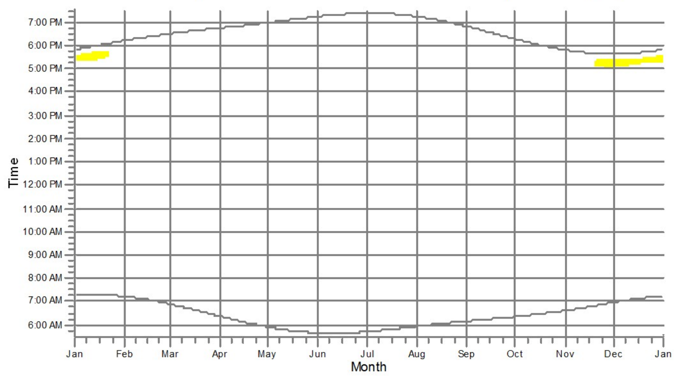
N: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (14)



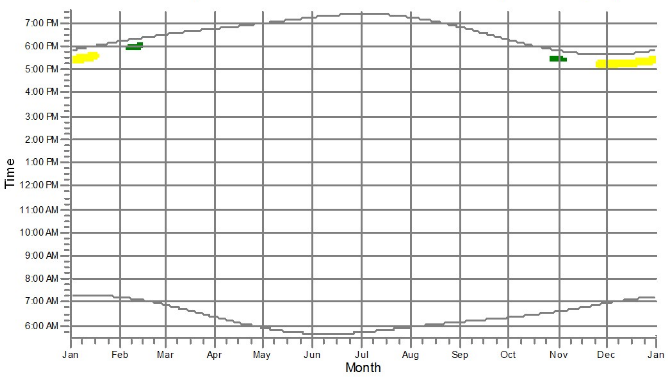
O: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (15)



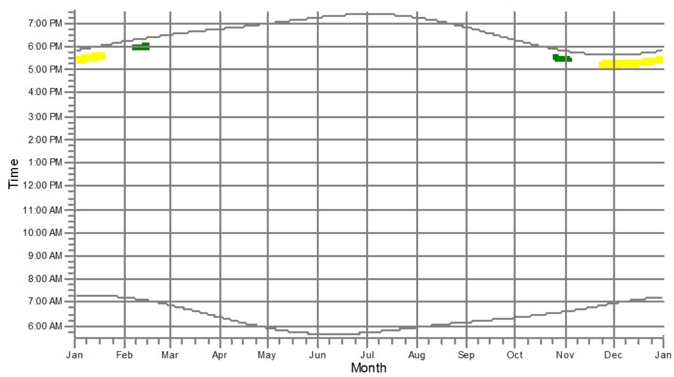
P: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (16)



Q: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (17)



R: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (18)



WTGs

1: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (1)

2: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (2)

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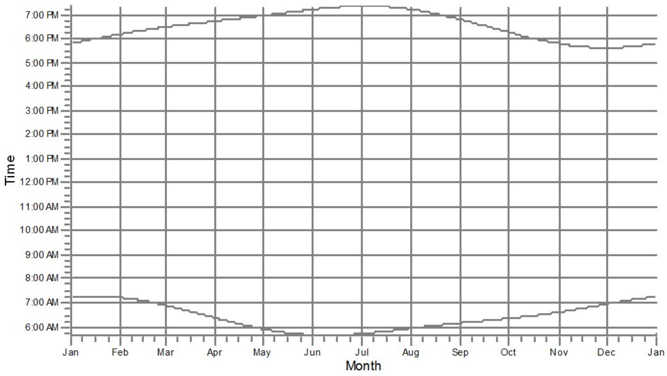
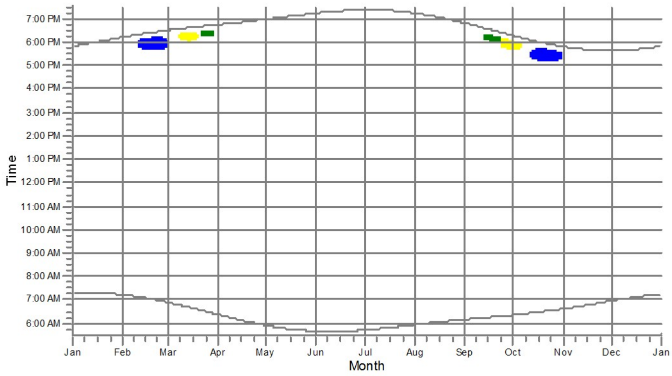
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

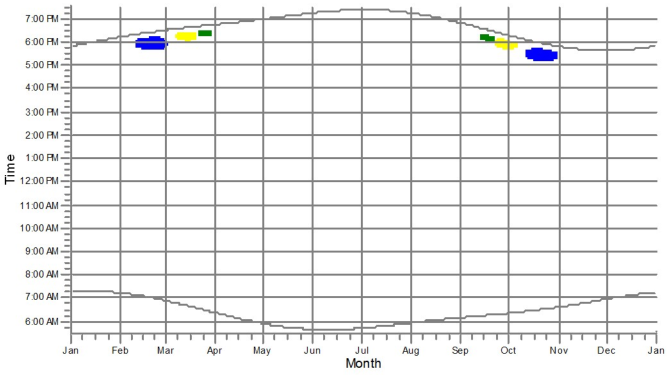
S: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (19)



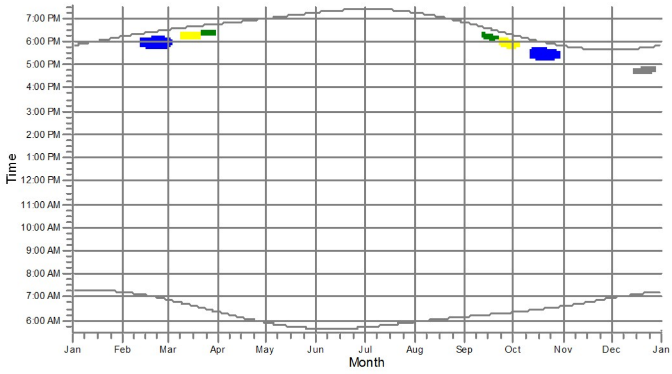
T: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (20)



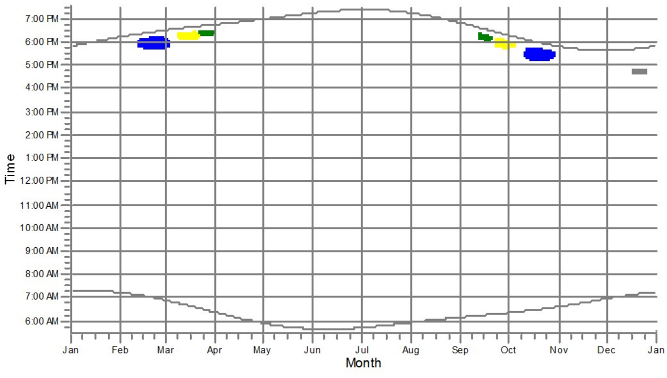
U: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (21)



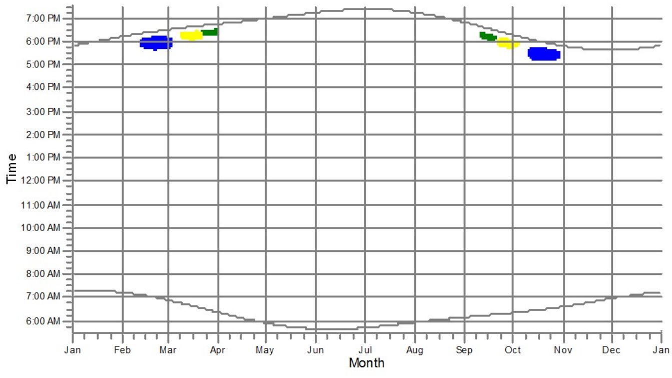
V: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (22)



W: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (23)



X: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (24)



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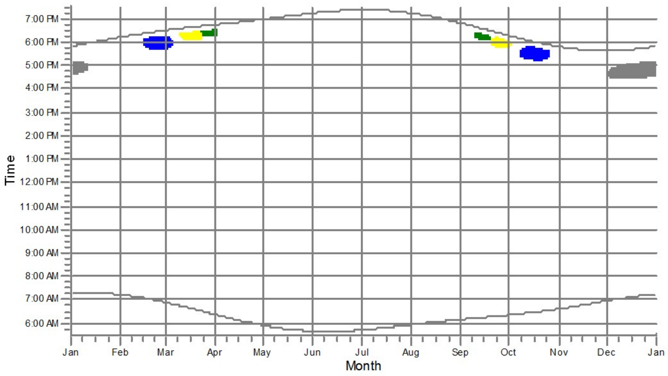
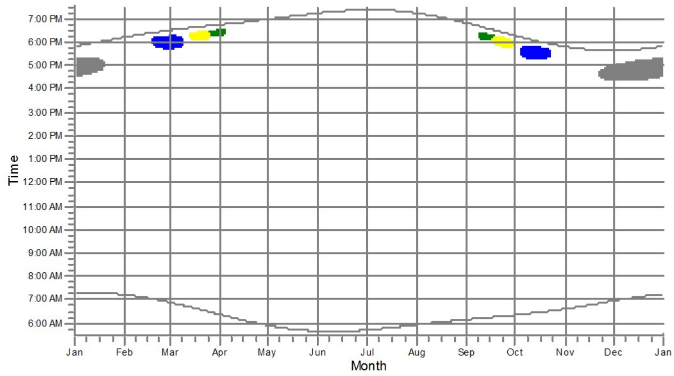
Calculation: Real Case Scenario

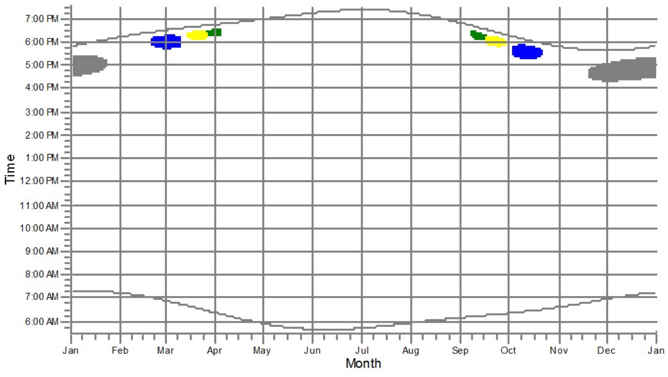
Y: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (25)



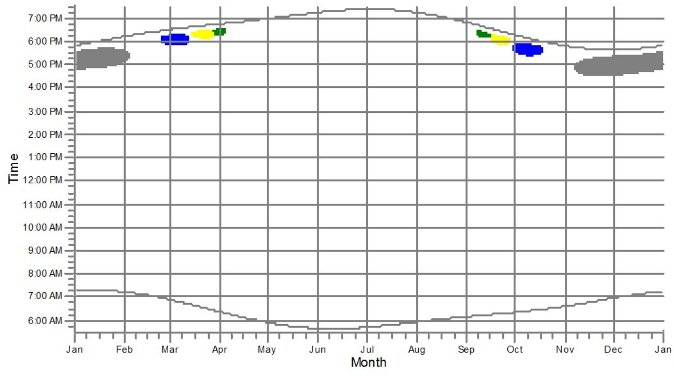
Z: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (26)



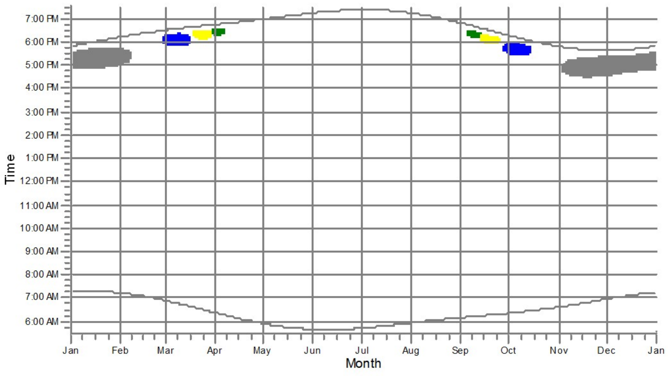
AA: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (27)



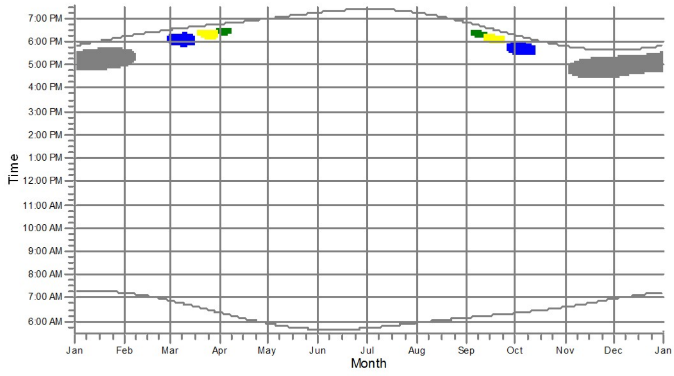
AB: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (28)



AC: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (29)



AD: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (30)



WTGs

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Project:
GAWPL 50 MW

Description:
50 MW Wind Power Project of Gul Ahmed Wind Power Limited (GAWPL), Nooriabad, Sindh Province, Pakistan

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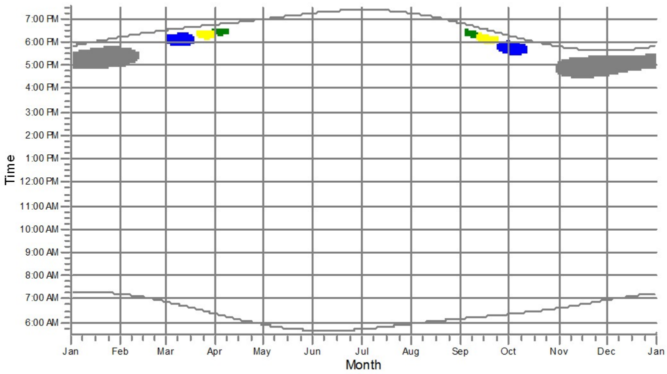
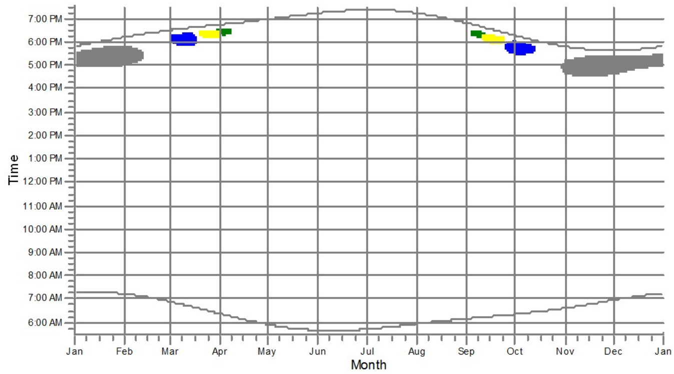
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

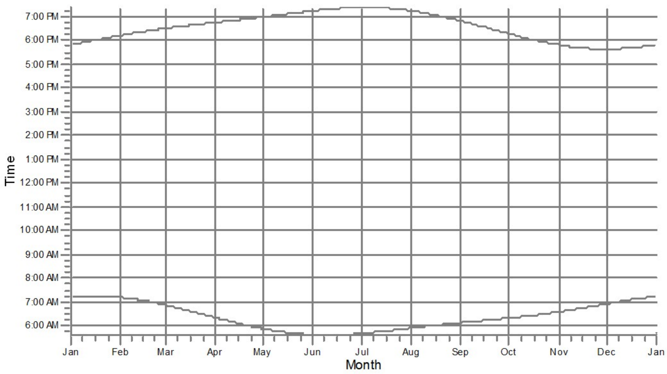
AE: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (31)



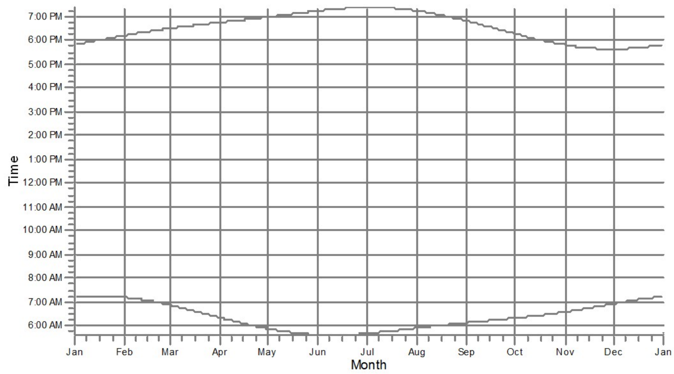
AF: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (32)



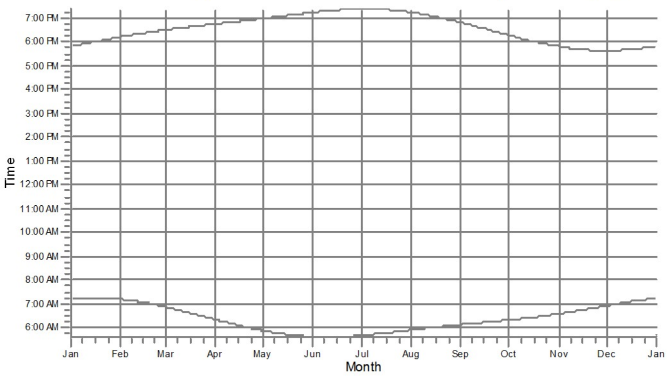
AG: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (33)



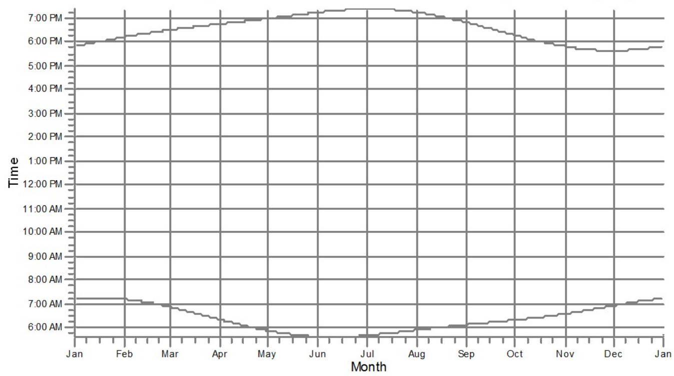
AH: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (34)



AI: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (35)



AJ: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (36)



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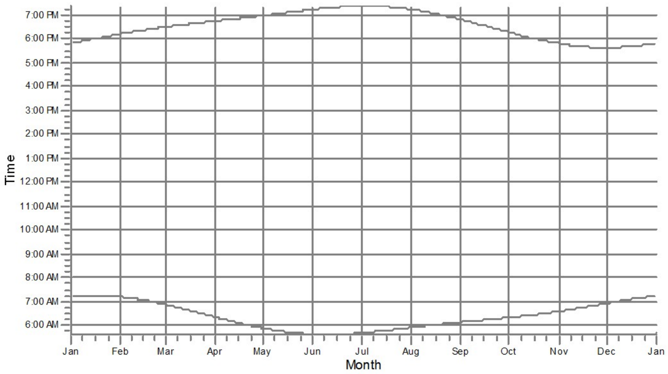
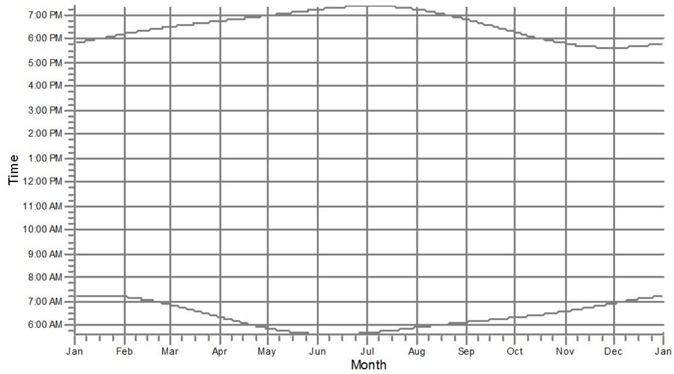
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

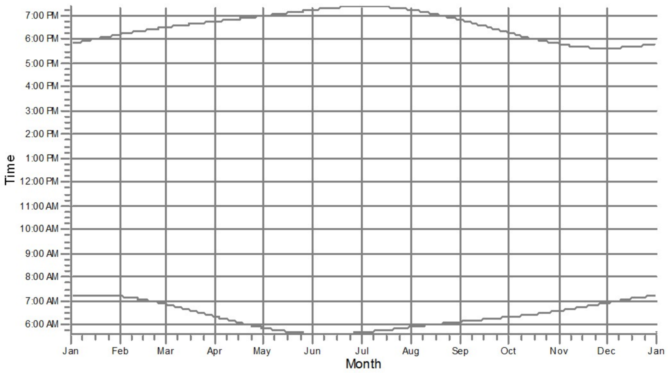
AK: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (37)



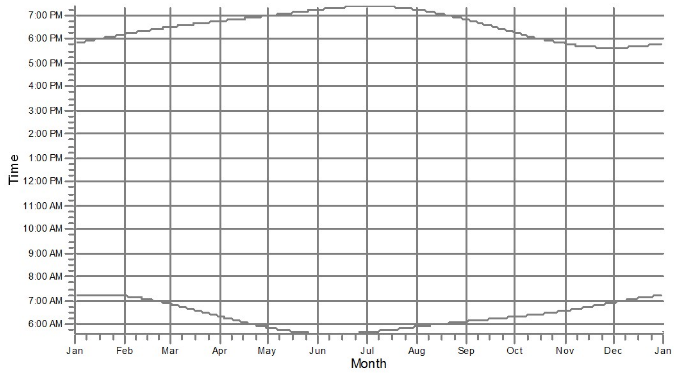
AL: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (38)



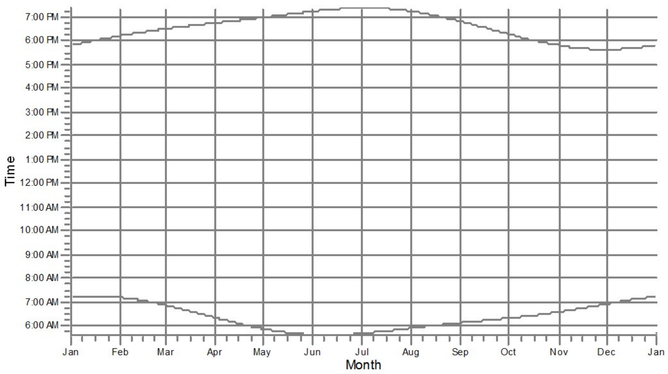
AM: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (39)



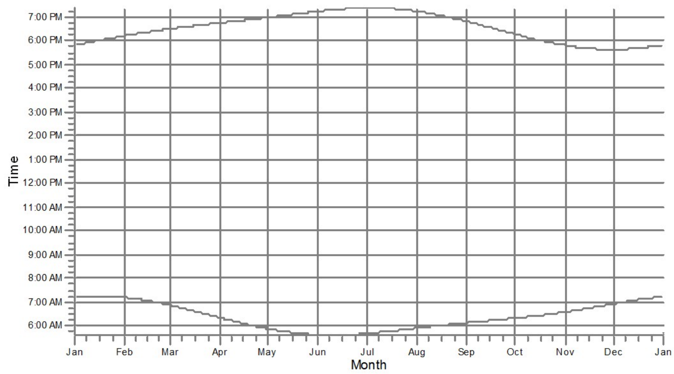
AN: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (40)



AO: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (41)



AP: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (42)



WTGs

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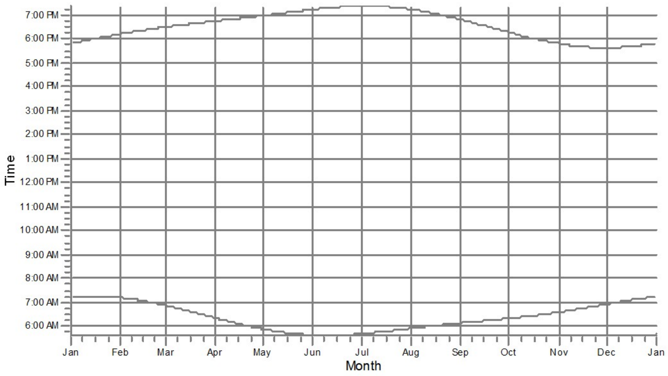
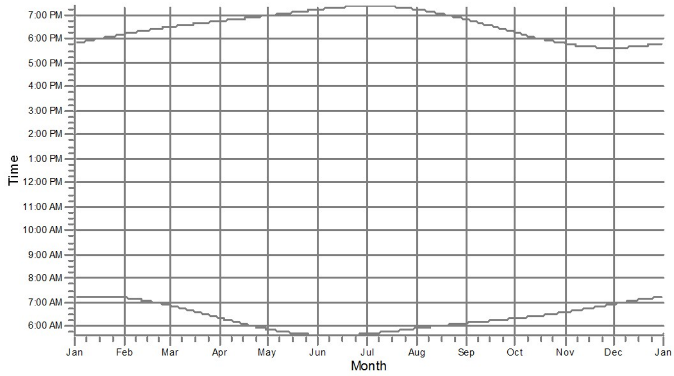
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

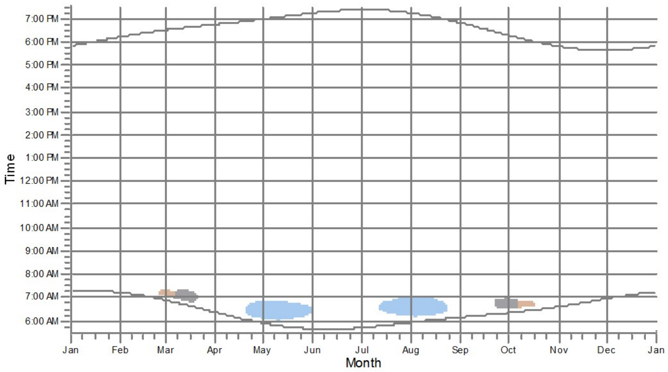
AQ: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (43)



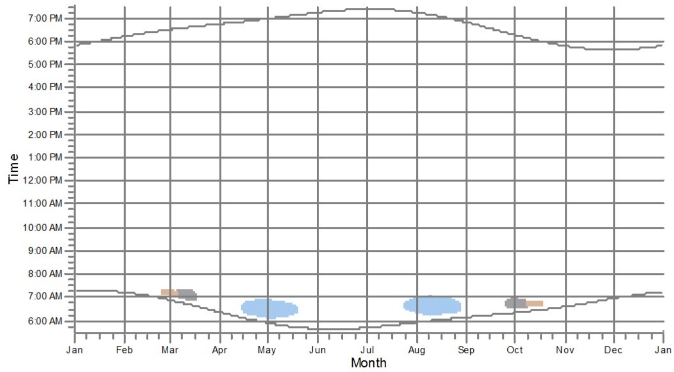
AR: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (44)



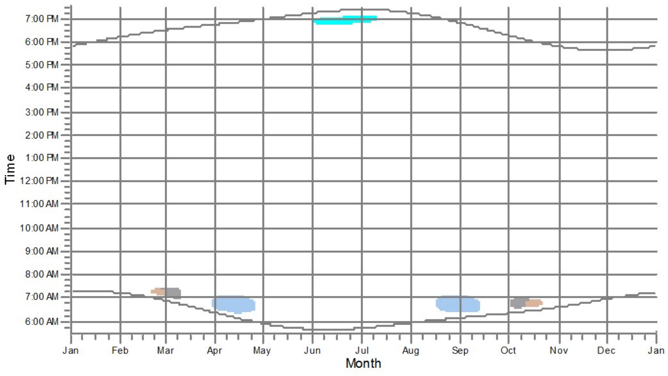
AS: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (45)



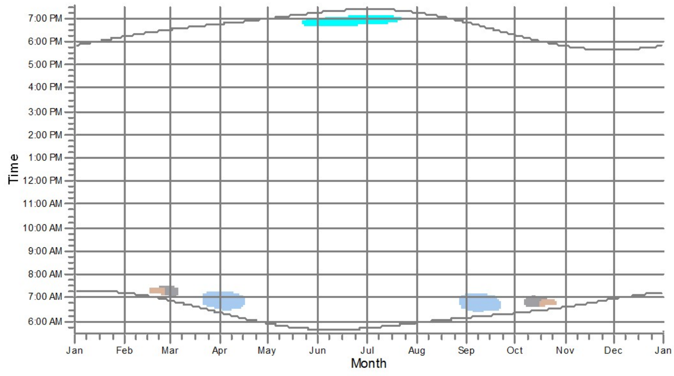
AT: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (46)



AU: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (47)



AV: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (48)



WTGs

13: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (13)
15: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (15)
16: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (16)
17: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (17)

Project:
GAWPL 50 MW

Description:
50 MW Wind Power Project of Gul Ahmed Wind Power Limited (GAWPL), Nooriabad, Sindh Province, Pakistan

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ERM India Private Limited
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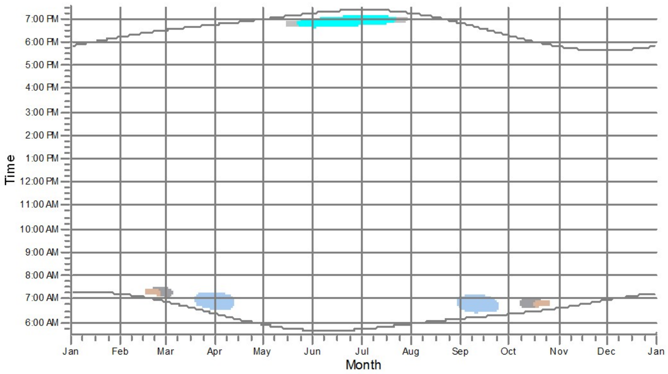
+91 124 4170300
Naval Chaudhary / naval.chaudhary@erm.com

Calculated:
8/10/2014 9:22 AM/2.9.269

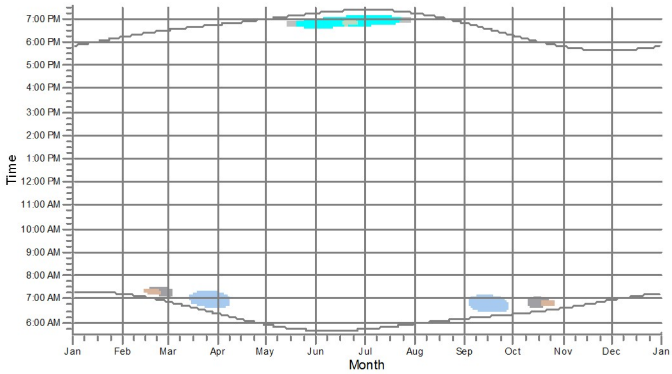
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

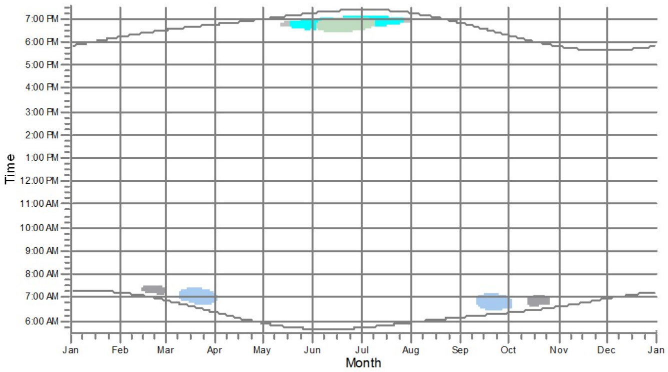
AW: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (49)



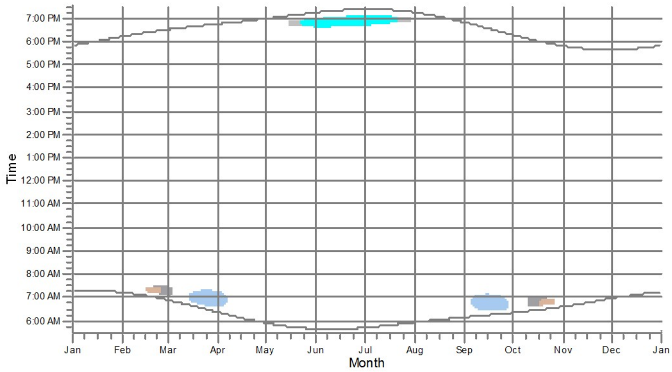
AX: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (50)



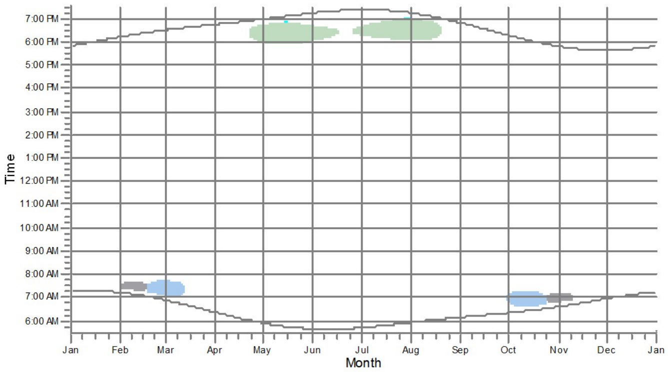
AY: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (51)



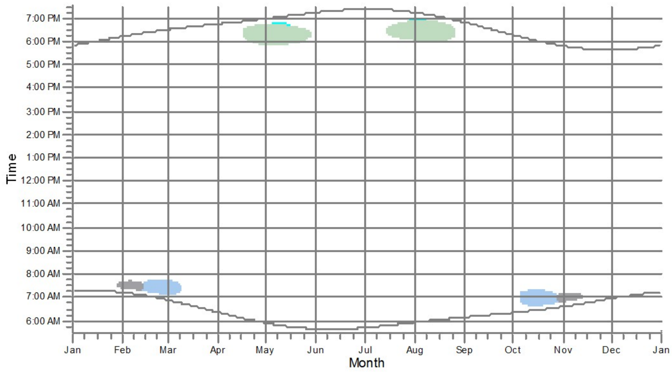
AZ: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (52)



BA: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (53)



BB: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (54)



WTGs

12: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (12)
13: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (13)
14: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (14)
15: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (15)
16: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (16)
17: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (17)

Project:
GAWPL 50 MW

Description:
50 MW Wind Power Project of Gul Ahmed Wind Power Limited (GAWPL), Nooriabad, Sindh Province, Pakistan

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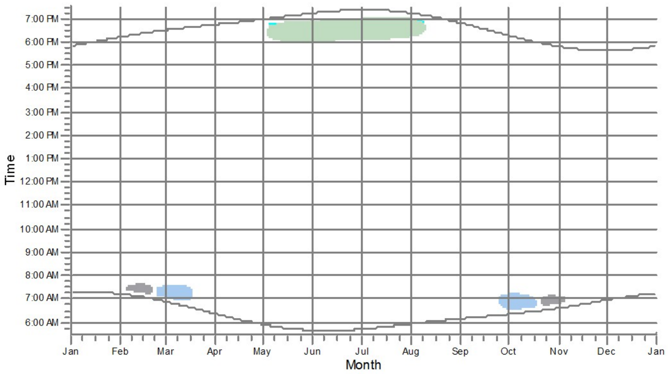
Naval Chaudhary / naval.chaudhary@erm.com

Calculated:
8/10/2014 9:22 AM/2.9.269

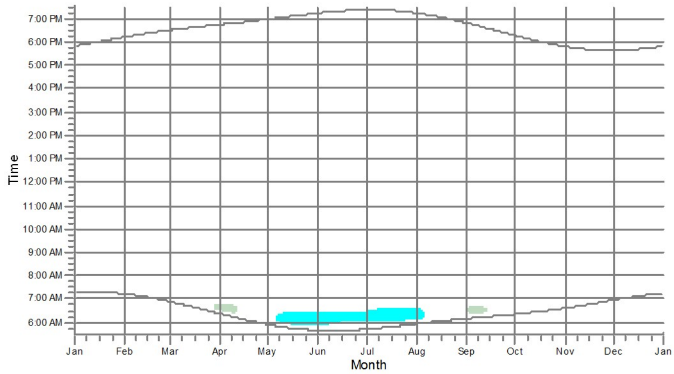
SHADOW - Calendar, graphical

Calculation: Real Case Scenario

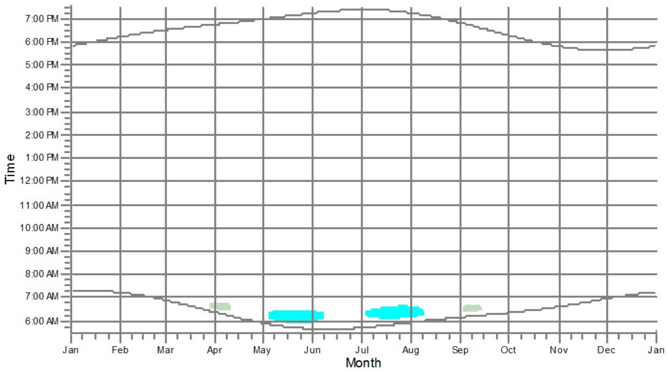
BC: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (55)



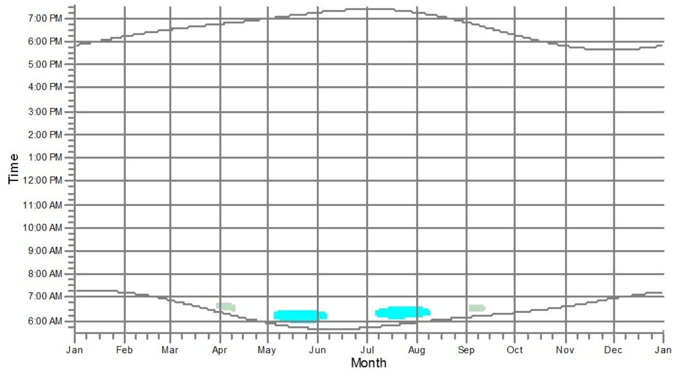
BD: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (56)



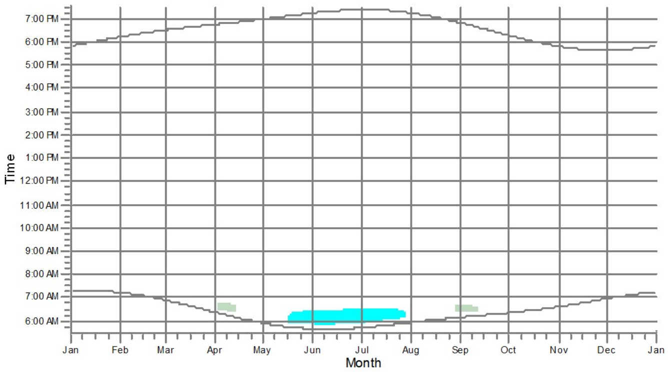
BE: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (57)



BF: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (58)



BG: Shadow Receptor: 0.9 × 1.2 Azimuth: 0.0° Slope: 90.0° (59)



WTGs

- 12: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (12)
- 13: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (13)
- 14: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (14)
- 15: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (15)
- 16: NORDEX N100 2500 99.8 !O! hub: 80.0 m (TOT: 129.9 m) (16)

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