REPORT

Mirny (Kazakhstan) 1GW Wind Farm Project

Appendix A - Noise and Flickering Modelling Report

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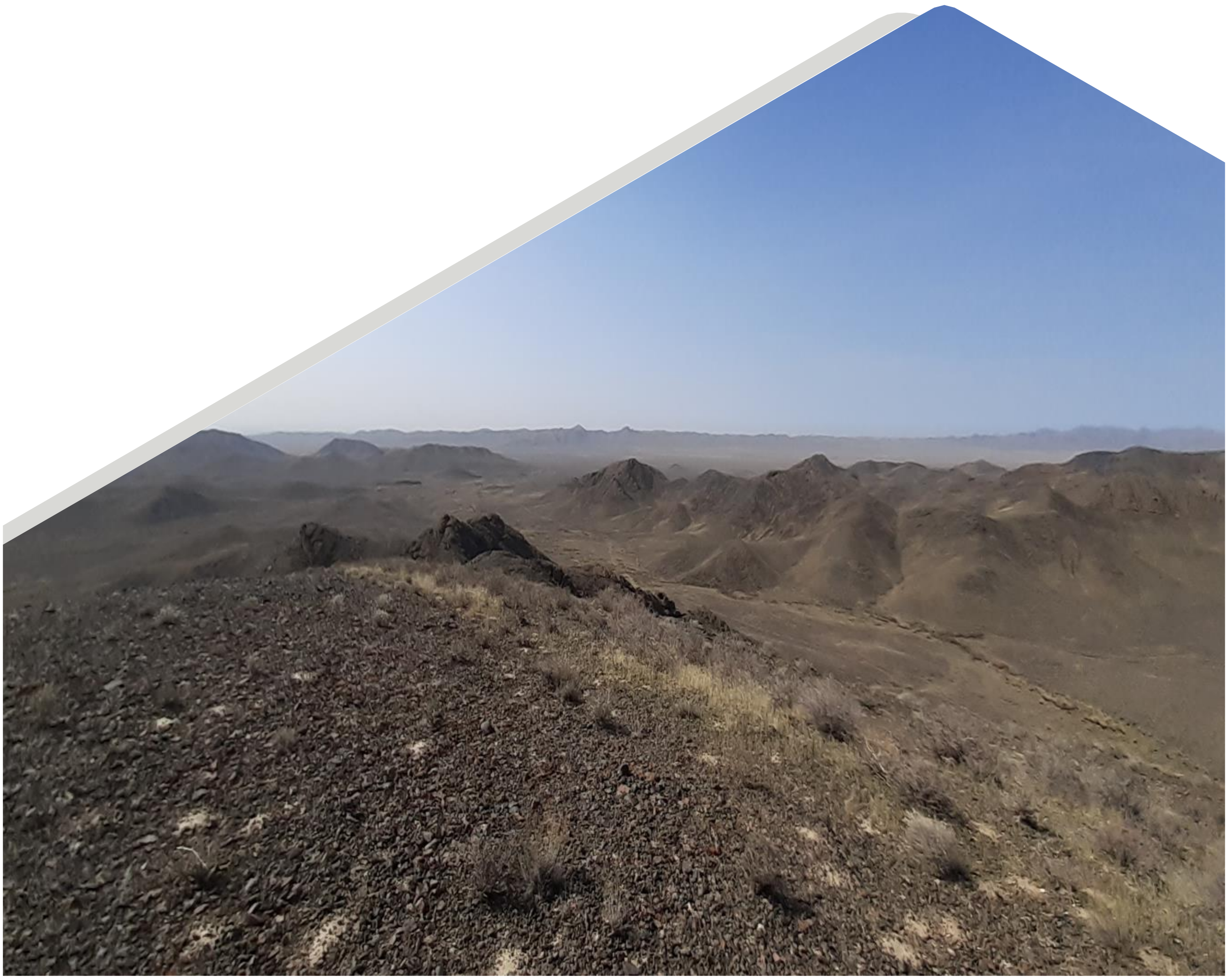

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1.0 NOISE MODELLING STUDIES

Wind turbines produce noise through a number of different mechanisms, which can be roughly grouped into mechanical and aerodynamic sources. The major mechanical components include the gearbox, generator, and yaw motors, each of which produce their own characteristic sounds. Other mechanical systems, such as fans and hydraulic motors, can also contribute to the overall acoustic emissions. Mechanical noise is radiated by the surface of the turbine and by openings in the nacelle housing. The interaction of air and the turbine blades produces aerodynamic noise through a variety of processes as air passes over and past the blades.[1]

During the investigation of potential noise impacts originated from the operation of WTGs, baseline noise levels in the Project AoI and the nearest sensitive receptors to the Project site have been taken into consideration. As detailed below, the main approach for impact analysis is based on the calculations, modelling and predictions of noise impacts during the operation of WTGs. A noise modelling software "windPRO 4.1"[2] was applied to determine the predicted noise levels that would potentially occur during the operation of WTGs and BESS.

1.1 Regulatory Framework

1.1.1 National Regulatory Requirements

The Code of Practice of the Republic of Kazakhstan 4.04-112-2014 "Design of Wind Power Plants" contains specific requirements regarding the design of WPPs. Accordingly, the predicted noise level in the settlement should not exceed the permissible levels established by sanitary norms for allowable noise in residential and public buildings and residential areas.

According to Construction norms and regulations 11-12-77 "Protection from noise" and in accordance with order No. 136 of the acting Minister of Healthcare of the Republic of Kazakhstan dated March 24th, 2005, maximum permissible noise level at the industrial area is 70 dB (for residential areas the limit is lower and it varies from 45-55 dB between day and night).

Maximum permissible noise level is accepted for the territories adjacent to dwelling houses, rest areas of districts, and group of dwelling houses, kindergarten areas, school areas, taking into account the following corrections:

- For noise created by transport means – 10 dB;
- For existing housing development – 5 dB;
- For the daytime from 7 a.m. till 11 p.m. – 10 dB.

1.1.2 International Standards

Following standards and best practices have been taken into account for the noise impact assessment:

- WBG's EHS Guidelines for Wind Energy.
- IFC General EHS Guidelines: Environmental - Noise Management.
- Energy Technical Support Unit ("ETSU") R-97: The Assessment and Rating of Noise from Wind Farms.

[1] World Bank Group. (2015). Environmental, Health, and Safety Guidelines for Wind Energy.

[2] https://www.emd-international.com/windpro/

- Institute of Acoustics ("IoA"): A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise.

According to the WBG EHS Guidelines for Wind Energy, noise impact should be assessed in accordance with the following principles:

- Receptors should be chosen according to their environmental sensitivity (human, livestock, or wildlife).
- Preliminary modelling should be carried out to determine whether more detailed investigation is warranted. The preliminary modelling can be as simple as assuming hemispherical propagation (i.e., the radiation of sound, in all directions, from a source point). Preliminary modelling should focus on sensitive receptors within 2,000 meters ("m") of any of the turbines in a wind energy facility.
- If the preliminary model suggests that turbine noise at all sensitive receptors is likely to be below an LA90 of 35 dB (A) at a wind speed of 10 meters/second ("m/s") at 10 m height during day and night times, then this preliminary modelling is likely to be sufficient to assess noise impact; otherwise it is recommended that more detailed modelling be carried out, which may include background ambient noise measurements.
- All modelling should take account of the cumulative noise from all wind energy facilities in the vicinity having the potential to increase noise levels.
- If noise criteria based on ambient noise are to be used, it is necessary to measure the background noise in the absence of any wind turbines. This should be done at one or more noise-sensitive receptors. Often the critical receptors will be those closest to the wind energy facility, but if the nearest receptor is also close to other significant noise sources, an alternative receptor may need to be chosen.

The above given principles are also referenced from the ETSU-R-97: The Assessment and Rating of Noise from Wind Farms and IOA: A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise.

On the other hand, WBG EHS Guidelines for Wind Energy do not provide ambient noise limit values apart from the screening limit. With this regard, following ambient noise limit values set within the IFC General EHS Guidelines: Environmental - Noise Management have been adopted.

Table 1: Ambient Noise Limit Values per IFC General EHS Guidelines: Environmental - Noise Management

Receptor	One Hour L_{Aeq} (decibel ampere – "dBA")	
	Daytime (07:00-22:00)	Nighttime (22:00-07:00)
Residential; institutional; educational	55	45
Industrial; commercial	70	70

According to the recommendations of the IFC General EHS Guidelines, when host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. Based on that, the Project adopts as Project Standards the IFC noise limit values of 55 dBA and 45 dBA for, respectively, the daytime and nighttime. According to the same standards, in case baseline noise values already exceed IFC noise limits, IFC limits and the Project standards indicate that a maximum of 3 dBA increase in background noise levels is allowed.

1.2 Noise Baseline Summary

The Project site, which is considered to include the Project AoI for noise, is uninhabited and there are no anthropogenic sources of noise or wind energy facilities in the vicinity having the potential to increase noise levels. Based on that, three background noise measurement points were determined within the Project site, evenly covering the whole perimeter. On July 9th, 2024, background noise levels were measured by an accredited laboratory at each location.

The noise measurement results are in compliance with both the IFC noise standards and Kazakh regulatory noise limit values.

For the worst-case scenario simulation, the highest baseline noise level of 43.8 dBA measured at location N3 was taken into consideration in the noise impact analysis (i.e. baseline noise levels + Project predicted noise levels for operation phase).

1.3 Noise Modelling Methodology

Apart from the WTGs, no significant noise impact is expected from the other infrastructure part of the Project (BESS, OHTL, offices, substation, etc.) since these components primarily involve stationary equipment or infrastructure that typically operate with low noise emissions compared to the WTGs.

Based on that, in order to predict noise levels that would potentially occur during the operation of WTGs, the wind PRO 4.1 noise modelling software made use of the ISO 9613-2:2024 "Acoustics – Attenuation of sound during propagation outdoors – Part 2: Engineering method for the prediction of sound pressure levels outdoors", which was embedded in it.

ISO 9613-2:2024 provides an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level under meteorological conditions favourable to propagation from sources of known sound emission.

The method predicts the sound pressure level at each receptor through subtracting attenuation factors from the source sound power level, as given below:

$$Sound\ Pressure\ Level = L_{wA} + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

Where:

L_{WA}: Sound pressure level at WTG

D: Directivity correction factor

A_{geo}: Attenuation due to geometrical divergence

A_{atm}: Attenuation due to atmospheric absorption

A_{gr}: Attenuation due to ground effect

A_{bar}: Attenuation due to a barrier

A_{misc}: Attenuation due to miscellaneous other effects (e.g. vegetation, industrial site, houses)

For the purpose of displaying the worst-case scenario, the following assumptions are made within the ISO 9613-2:2024:

- The wind speed that corresponds to the highest noise value was selected, as generated noise levels will vary with the wind speed. The technical specifications of the WTGs were used for this purpose as provided by the Client.
- Sound power levels of the turbines were considered using the L_{Aeq} value rather than L_{A90} value, since L_{Aeq} is higher than L_{A90} because it accounts for the entire range of noise levels, including louder events. This allowed calculating the maximum noise impacts.
- Wind direction was set to place all receptors downwind of all wind turbines.
- Atmospheric conditions of humidity and temperature were set as 70% and 10°C, respectively.[3]
- Receiver height was set to 4.0 m.[4]
- A_{bar} and A_{misc} attenuation factors were not taken into account.

The technical specifications of Envision EN182-6.5 and Sany SI19577 type WTGs were provided by the Client; they are presented in Table 2.

Table 2: Technical Specifications of Envision EN182-6.5 and Sany SI19577 type WTGs

Technical Specifications	Envision EN182-6.5	Sany SI19577
Number of Turbines	124	26
Rated Power (MW)	6.5	7.7
Rotor Diameter (m)	181.1	195.0
Hub Height (m)	110.0	120.0
Maximum Sound Power Level (dBA)	114.2	110.8

1.4 Noise Modelling Results

The model was run and results added to the baseline noise measurements for the study area (which is included in the Project site). The predicted noise levels resulting from the model, the baseline noise levels, the cumulated effect of baseline + predicted noise levels at the sensitive receptors, and the comparison of the results with the Project Standards (IFC noise limit values for the daytime and nighttime of 55 dBA and 45 dBA, respectively) are presented in Table 3.

[3] Institute of Acoustics. (2013). A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise

[4] Institute of Acoustics. (2013). A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise

Table 3: Modelled Noise Levels at the Nearest Sensitive Receptors due to the Operation of WTGs

Measurement Point	Measurement Location			Modelled Noise Level (originated from Project activities) (dBA)		Baseline Noise Levels (dBA)		Modelled Noise Level + Baseline Ambient Noise Level (dBA)		Difference Between Ambient and Modelled Noise Levels (dBA)	
	Village	Receptor Type	Distance to the Nearest WTG (km)	Day (07-22)	Night (22-07)	Day (07-22)	Night (22-07)	Day (07-22)	Night (22-07)	Day (07-22)	Night (22-07)
Kiyakhty	Kiyakhty	Residential	21.5	16.0	16.0	43.8	43.8	43.8	43.8	0.0	0.0
Sholpan	Sholpan	Residential	19.3	17.8	17.8	43.8	43.8	43.8	43.8	0.0	0.0
Project Standards [1,2]	Industrial; commercial areas			**70**	**70**	**70**	**70**	**70**	**70**	**3**	**3**
	Residential; institutional; educational areas			**55**	**45**	**55**	**45**	**55**	**45**	**3**	**3**

Notes:
[1] IFC Environmental, Health, and Safety ("EHS") Guidelines General EHS Guidelines: Environmental - Noise Management;
[2] IFC Guidelines provide noise standards for two-time intervals in 24 hours: day (07:00 to 22:00), and night (22:00 to 07:00).

Based on the modelling results, calculated cumulative noise levels at the nearest sensitive receptors are in compliance with the Project noise standards (the assessment considered livestock and wildlife, but on these no significant impact is expected considering they are moving and not stationary close the Project).

The grid noise map presenting the highest noise levels due to the operation of WTGs, is illustrated in the Figure 1 below.

Regarding the BESS it is noted that, although technical details are still missing, the sound power levels for the worst-case scenario can be assumed around 70 dBA. Based on that, in accordance with the Inverse Square Law for Sound, it is expected that this 70 dBA soundpower level of the source (i.e., BESS) will drop down to 30 dBA around 100 meters distance from the source. So, taking into account that BESS will be located approximately at the center of the WPPs and according to the modelling results, noise levels are expected to be between the range of 41 – 48 dBA up until around 1.8 km away from the BESS location (where the contribution of the BESS noise will be negligible). Additionally, the nearest sensitive receptor is located 19.3 km away from the Project Area. Taking into account these conditions, the inclusion of BESS will not create any significant change in this modelling results.

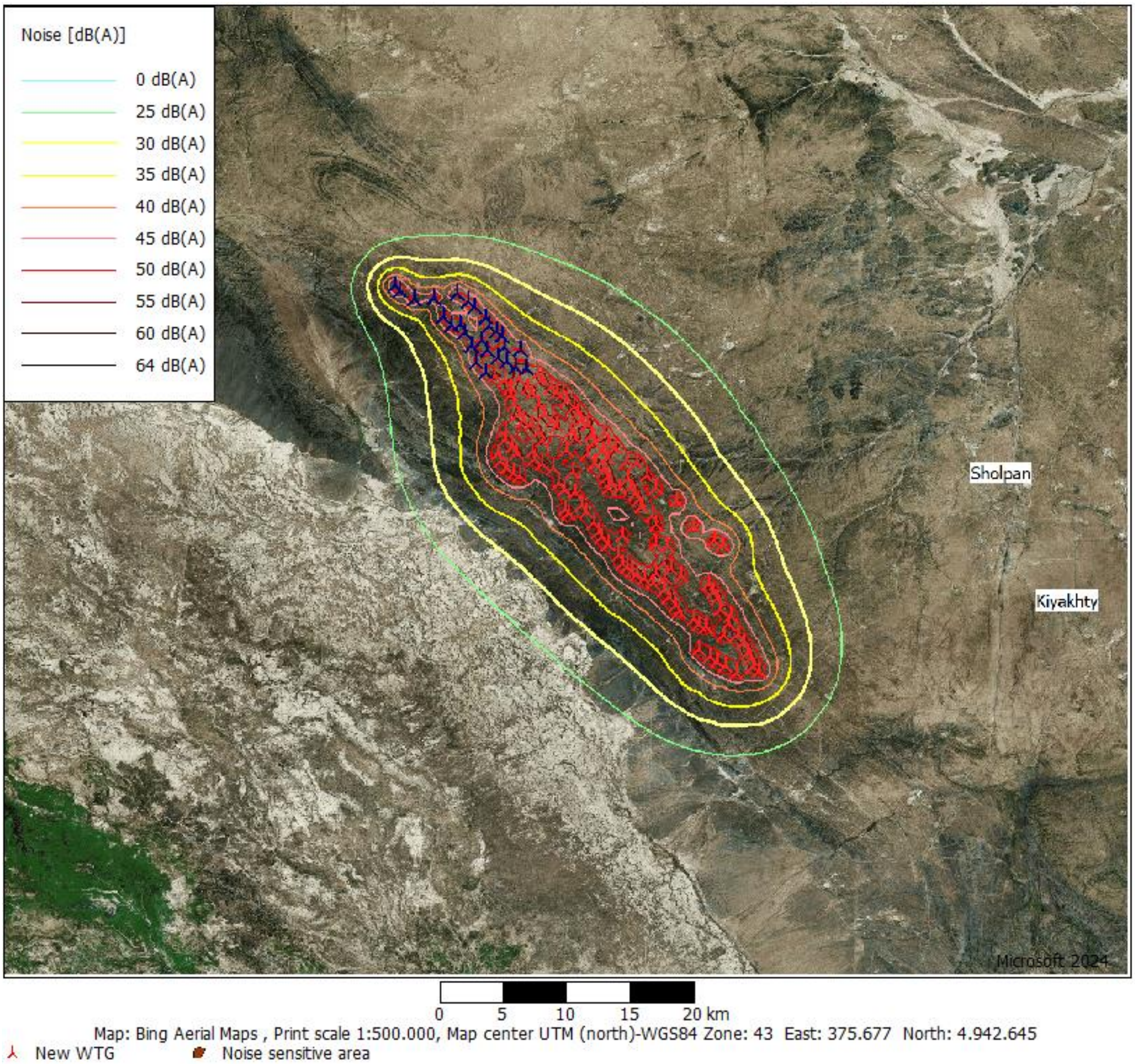

Figure 1: Grid Noise Map Presenting the Highest Noise Levels due to the Operation of WTGs[5]

[5] Sholpan is shown on the figure instead of Mirny as the former is closer to the Project site and therefore a more significant receptor.

2.0 SHADOW FLICKER MODELLING STUDIES

Shadow flicker occurs when the sun passes behind the wind turbine and casts a shadow. As the rotor blades rotate, shadows pass over the same point causing an effect termed shadow flicker. Shadow flicker may become a problem when potentially sensitive receptors (e.g., residential properties, workplaces, learning and/or health care spaces/facilities) are located nearby, or have a specific orientation to the wind energy facility.[6]

During the assessment of shadow flicker impacts originated from the operation of WTGs, the nearest sensitive receptors to the turbines, have been taken into consideration. As detailed below, the impact assessment is based on the calculations, modelling and predictions of shadow flicker impacts during the operation of WTGs. A shadow flicker modelling software "windPRO 4.1"[7] was applied to determine the predicted shadow flicker effects that would potentially occur during the operation of WTGs.

2.1 Regulatory Framework

The following international standards and best practices have taken into account for the shadow flicker impact prediction and assessment:

- WBG EHS Guidelines for Wind Energy.
- Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen[8]

According to the WBG EHS Guidelines for Wind Energy, shadow flicker impact should be assessed in accordance with the following principles:

- Where there are nearby receptors, commercially available software can be used to model shadow flicker in order to identify the distance to which potential shadow flicker effects may extend. The same software can typically also be used to predict the duration and timing of shadow flicker occurrence under real weather conditions at specific receptors located within the zone of potential shadow flicker impact.
- If it is not possible to locate the wind energy facility/turbines such that neighbouring receptors experience no shadow flicker effects, it is recommended to adopt a worst-case scenario with the predicted duration of shadow flicker effects experienced at a sensitive receptor not exceeding 30 hours per year and 30 minutes per day on the worst affected day.

The above given principles are also referenced from the German Guidelines - Determination and Assessment of Optical Emissions from Wind Energy Systems.

According to the above given standards, the Project Standards will be the limit values of 30 hours per year and 30 minutes per day.

2.2 Shadow Flicker Modelling Methodology

To assess compliance with the recommended limits, WBG EHS Guidelines for Wind Energy indicate that shadow flicker impact should be modelled and predicted based on an astronomical worst-case scenario, which is defined as follows:

[6] World Bank Group. (2015). Environmental, Health, and Safety Guidelines for Wind Energy.

[7] https://www.emd-international.com/windpro/

[8] Several countries have guidelines or standards, most of which use the same thresholds as or reference the German Guidelines for the "Determination and Assessment of Optical Emissions from Wind Energy Systems", for the evaluation of Shadow Flicker.

- There is continual sunshine and permanently cloudless skies from sunrise to sunset.
- There is sufficient wind for continually rotating turbine blades.
- Rotor is perpendicular to the incident direction of the sunlight.
- Sun angles less than 3 degrees above the horizon level are disregarded (due to likelihood for vegetation and building screening).
- Distances between the rotor plane and the tower axis are negligible.
- Light refraction in the atmosphere is not considered.

Based on that, the shadow flicker modelling software “windPRO 4.1”[9] has been adopted to predict the shadow flickering effects for the worst-case scenario; the following assumptions apply:

- Calculations were only conducted when more than 20% of sun is covered by the blade.
- Minimum sun height over horizon for influence was set as 3 degrees.
- Day step and time step for calculations were set as 1 day and 1 minute, respectively.
- The calculated times are "worst case" given by the following assumptions:
  - The sun is shining all the day, from sunrise to sunset.
  - The rotor plane is always perpendicular to the line from the WTG to the sun.
  - The WTG is always operating.
- A Zones of Visual Influence (“ZVI”) calculation is performed before flicker calculation so non-visible WTG do not contribute to calculated flicker values.
- A WTG will be visible if it is visible from any part of the receiver window.
- The widths, heights and above ground elevations of the receiver windows were assumed as 2 m, 1.5 m and 1 m, respectively.

2.3 Shadow Flicker Modelling Results

The shadow flicker effects were modelled for the nearest sensitive receptors. The results were compared with the WBG EHS Guidelines for Wind Energy limit values adopted as Project Standards; these are presented in Table 4.

Table 4: Modelled Shadow Flicker Durations at the Nearest Sensitive Receptors due to the Operation of WTGs

Receptor	Receptor Location			Modelled Shadow Flicker Durations (originated from Project activities)	
				WBG[1]	
	Village	Receptor Type	Distance to the Nearest WTG (km)	Shadow Hours per Year (h/year)	Maximum Shadow Minutes per Day (minutes/day)
Kiyakhty	Kiyakhty	Residential	21.5	0:00	0:00

[9] https://www.emd-international.com/windpro/

Receptor	Receptor Location			Modelled Shadow Flicker Durations (originated from Project activities)	
				WBG[1]	
	Village	Receptor Type	Distance to the Nearest WTG (km)	Shadow Hours per Year (h/year)	Maximum Shadow Minutes per Day (minutes/day)
Sholpan	Sholpan	Industrial	19.0	0:00	0:00
WBG Shadow Flicker Standards[1,]	Shadow Hours per Year			**30:00**	**-**
	Shadow Minutes per Day			**-**	**00:30**

Notes:
[1] World Bank Group. (2015). Environmental, Health, and Safety Guidelines for Wind Energy.

Based on the modelling results, the shadow flicker effects at the nearest sensitive receptors are in compliance with the Project Standards.

The shadow flicker effect distribution maps generated for the astronomical worst-case scenarios in terms of hours per year and minutes per day on the worst affected day, are given in Figure 2 and Figure 3, respectively.

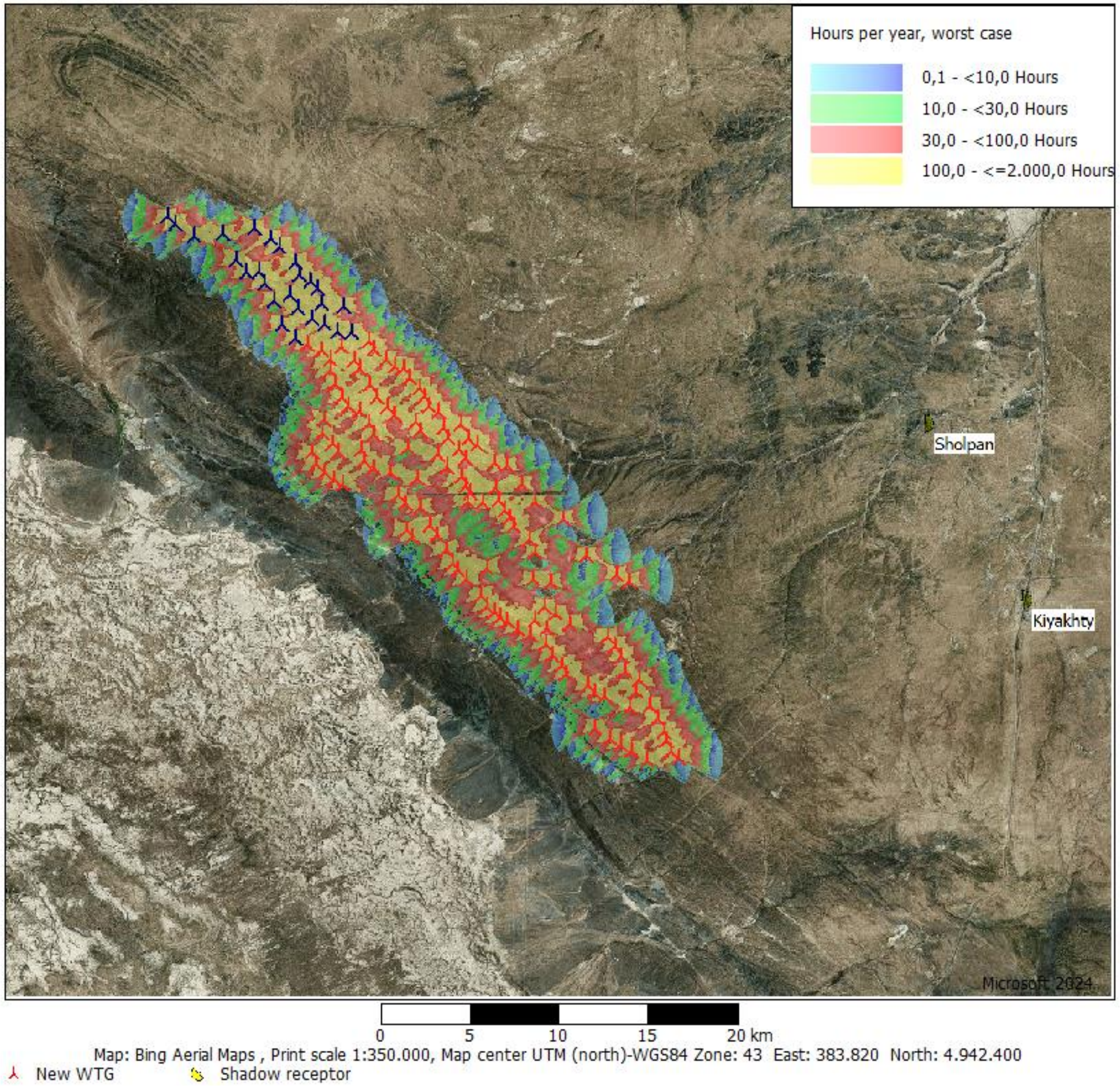

Figure 2: Shadow Flicker Effect Distribution Map Presenting the Astronomical Worst-Case Scenario in Terms of Hours per Year

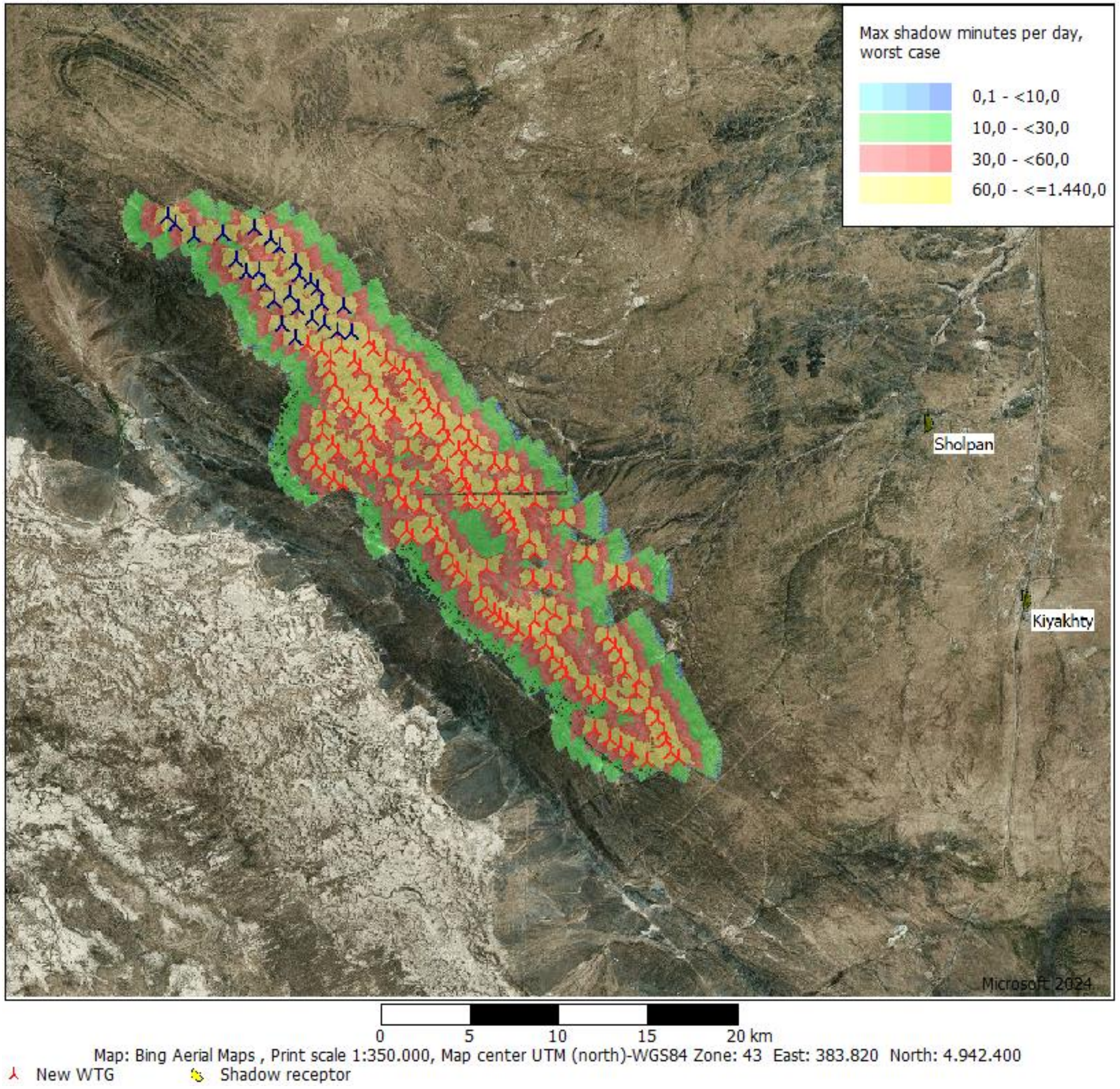

Figure 3: Shadow Flicker Effect Distribution Map Presenting the Astronomical Worst-Case Scenario in Terms of Minutes per Day on the Worst Affected Day

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