Shadow Flicker Impact Analysis for the Campbell County Wind Project

Campbell County, South Dakota

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PREPARED FOR

Campbell County Wind Farm 2, LLC

PREPARED BY

Tetra Tech, Inc.

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
Hz	Hertz
MW	Megawatt
Tetra Tech	Tetra Tech, Inc.
the Project	Campbell County Wind 2 Project
Project Entity	Campbell County Wind Farm 2, LLC
UTM	Universal Transverse Mercator

1.0 OVERVIEW

Campbell County Wind Farm 2, LLC is proposing to construct and operate the Campbell County Wind Project (the Project) located in Campbell County, South Dakota. The Project is expected to have an approximate nominal 98.6-megawatt (MW) power output capacity after constructing approximately 29 wind turbines. RWE has contracted Tetra Tech, Inc. (Tetra Tech) to conduct a shadow flicker impact assessment. An analysis was conducted to evaluate the expected shadow flicker impacts resulting from the Project wind turbines.

2.0 PROJECT COMPONENTS

The Project will construct 29 wind turbines based on 33 potential turbine locations (including 29 primary and 4 alternate/secondary turbine locations). A wind turbine model that has been selected for the Project is the General Electric GE3.4-140 wind turbine. The turbine model has the following specifications:

- **GE3.4-140:** Three-blade 140-meter rotor diameter, with a hub height of 98 meters and generating capacity of 3.4 MW. The GE3.4-140 has an approximate nominal high rotor speed of 11.5 rotations per minute, which translates to a blade pass frequency of 0.58 hertz (Hz; 0.58 alternations per second).

The shadow flicker assessment has analyzed all 33 potential wind turbine locations (including 29 primary and 4 alternate/secondary wind turbine locations).

3.0 SHADOW FLICKER BACKGROUND

A wind turbine’s moving blades can cast a moving shadow on locations within a certain distance of a turbine. These moving shadows are called shadow flicker and can be a temporary phenomenon experienced at nearby residences or public gathering places. The impact area depends on the time of year and day (which determine the sun’s azimuth and altitude angles) and the wind turbine’s physical characteristics (height, rotor diameter, blade width, and orientation of the rotor blades). Shadow flicker occurs anytime the sun shines on the moving turbine blades but extends furthest during low angle sunlight conditions typical during sunrise and sunset, which are the periods when impacts to surrounding properties most often occur. However, when the sun angle gets very low (less than three degrees), sunlight passes through more atmosphere and becomes too diffused to form a coherent shadow. Shadow flicker will not occur when the sun is obscured by clouds or fog, at night, or when the source turbine(s) are not operating. In addition, shadow flicker only occurs when at least 20 percent of the sun’s disc is covered by the turbine blades.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance. In general, increasing proximity to turbines may make shadow flicker more noticeable, with the largest number of shadow flicker hours, along with greatest shadow flicker intensity, occurring nearest the wind turbines.

Shadow flicker frequency is related to the wind turbine’s rotor blade speed and the number of blades on the rotor. From a health perspective, the low flicker frequencies associated with wind turbines are harmless, and public concerns that flickering light from wind turbines can have negative health effects, such as triggering seizures in people with epilepsy are unfounded. Epilepsy Action (working name for the British Epilepsy Foundation) states that large turbines rotate at a rate that is unlikely to trigger seizures. Additionally, they provide a range of flicker rates, 3 to 60 Hz, that people with photosensitive epilepsy may be affected by. While some people are sensitive to rates as low as 3 Hz, light flicker between 16 and 25 Hz are most likely to trigger seizures (Epilepsy Action 2022). Since the proposed Project’s wind turbine blade pass frequency is approximately 0.64 Hz (less than one alternation per second), no negative health effects to individuals with photosensitive epilepsy are anticipated.

Shadow flicker impacts are not regulated in applicable state or federal law, and there is no permitting threshold with regard to hours per year of anticipated impacts to a receptor from a wind energy project. Due to the significant growth of the wind energy industry in recent years, some states have published model bylaws for local governments to adopt or modify at their own discretion which sometimes include guidance and recommendations for shadow flicker levels and mitigation. In lieu of specific regulations, a general precedent has been established in the industry both abroad and in the United States that fewer than 30 hours per year of shadow flicker impacts is acceptable to receptors in terms of nuisance.

4.0 WINDPRO SHADOW FLICKER ANALYSIS

An analysis of potential shadow flicker impacts from the Project was conducted using the WindPro software package. As described above, 29 primary wind turbine locations and 4 alternate/secondary wind turbine locations were evaluated.

The WindPro analysis was conducted to determine shadow flicker impacts under realistic impact conditions (actual expected shadow). This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at receptors surrounding the proposed Project turbines. It should be noted that this shadow flicker analysis was conducted with both the 29 primary and 4 alternate turbine locations modeled together, and therefore shadow flicker results for receptors that are impacted by both primary and alternate turbines are expected to be overestimated. The realistic impact condition scenario is based on the following:

- The elevation and position geometries of the wind turbines and surrounding receptors (potentially occupied residences). Elevations were determined using U.S. Geological Survey digital elevation model data. Positions geometries were determined using geographic information system and referenced to Universal Transverse Mercator (UTM) Zone 14 (NAD83).
- The position of the sun and the incident sunlight relative to the wind turbine and receptors on a minute-by-minute basis over the course of a year.
- Historical sunshine availability (percent of total hours available). Historical sunshine rates for the area (as summarized by the National Climatic Data Center [NOAA 2021] for nearby Bismarck, North Dakota) used in this analysis are provided in Table 1.
- Estimated wind turbine operations and orientation based on wind data (wind speed and direction) measured at meteorological towers located on the Project site.
- Receptors were input to WindPro as polygon shaped structures approximating the footprint of the house structure.

Table 1. Historical Sunshine Availability, Bismarck, North Dakota

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
54%	59%	61%	58%	64%	67%	75%	72%	67%	53%	42%	45%

WindPro incorporates terrain elevation contour information and the analysis accounts for terrain elevation differences. The sun's path with respect to each turbine location is calculated by the software to determine the cast shadow paths every minute over a full year. Sun angles less than 3 degrees above the horizon were excluded for the reasons identified in Section 3. Since shadow flicker is only an issue when at least 20 percent of the sun disc is covered by the blades, WindPro uses blade dimension data to calculate the maximum distance from the turbine where shadow flicker must be calculated. For the maximum proposed turbine dimensions, WindPro calculates a maximum distance of 1,905 meters. Beyond this distance, the turbine will not contribute to the shadow flicker impact. It should be noted that WindPro provides a conservative estimate of shadow flicker.

Obstacles such as trees, haze, and visual obstructions (window facing, coverings) are not accounted for despite the likelihood of their reducing or eliminating shadow flicker impacts to receptors.

A total of 34 residential structures were identified within and near the Project Area as occupied or potentially occupied residences and are considered potential shadow flicker receptors for the purpose of this analysis. A receptor in the model is defined as a one-meter squared area (approximate size of a typical window), that is one-meter (3.28 feet) above ground level. Approximate eye level is set at 1.5 meters (4.94 feet). Figure 1 shows the locations of all 34 identified residential structures, along with the 29 potential and 4 alternate turbine locations considered.

5.0 SHADOW FLICKER ANALYSIS RESULTS

As expected, WindPro predicts that shadow flicker impacts will be greatest at locations closer to the wind turbines. Figure 1 illustrates the WindPro predicted shadow flicker impact areas for the turbine model scenario, with the primary and alternate locations marked.

Table 2 presents the WindPro predicted shadow flicker impacts for the nine worst case impact receptors with expected shadow flicker impact greater than 30 hours per year. Just three (3) receptors have expected shadow flicker impact greater than 30 hours per year. All three of those receptors are participating in the project.

Table 3 summarizes the shadow flicker impact prediction statistics. The predicted shadow flicker impact for all 34 receptors is presented in Appendix B. The maximum predicted shadow flicker impact at any occupied residence receptor is 57 hours and 25 minute per year with both primary and alternate turbine locations considered. This is approximately 1.3 percent of the potential available daylight hours.

Table 2. WindPro Top Ten Worst Case Expected Shadow Flicker Impact Receptors

Receptor ID	Receptor Type	Expected Shadow Flicker Hours per Year [Hours:Minutes/Year]
483491	Participating Residence	57:25
502148	Participating Residence	50:32
1	Participating Residence	42:43
146792	Participating Residence	27:39
46497	Participating Residence	26:50
439768	Non-Participating Residence	8:26
433489	Participating Residence	6:18
165439	Non-Participating Residence	5:36
340463	Non-Participating Residence	4:24

Table 3. Statistical Summary of WindPro Expected Shadow Flicker Impacts – Number of Modeled Receptors

Cumulative Shadow Flicker Time (Expected)	Number of Modeled Receptors
Total	34
= 0 Hours	21
> 0 Hours ≤ 10 Hours	8
> 10 Hours ≤ 20 Hours	0
> 20 Hours ≤ 30 Hours	2
> 30 Hours	3

6.0 CONCLUSION

The analysis of potential shadow flicker impacts from the 29 primary and 4 alternate turbine locations on nearby receptors shows that three (3) receptor locations had modeled expected shadow flicker impacts greater than the threshold of 30 hours per year, with all three of those receptors participating in the project. It should also be noted, shadow flicker results for receptors that are impacted by both primary and alternate turbines are expected to be overestimated.

As stated in section 3, fewer than 30 hours per year of shadow flicker impacts is acceptable to receptors in terms of nuisance. This limit is typically applied to non-participating receptors. Since shadow flicker in less than 30 hours per year for all non-participating receptors curtailment is not needed.

7.0 REFERENCES

Epilepsy Action. February 2022. Information Web Page on Photosensitive Epilepsy. British Epilepsy Association. https://www.epilepsy.org.uk/info/seizure-triggers/photosensitive-epilepsy. Accessed July 2023.

National Oceanic and Atmospheric Administration (NOAA). 2021. Comparative Climatic Data for the United States Through 2020.

FIGURES

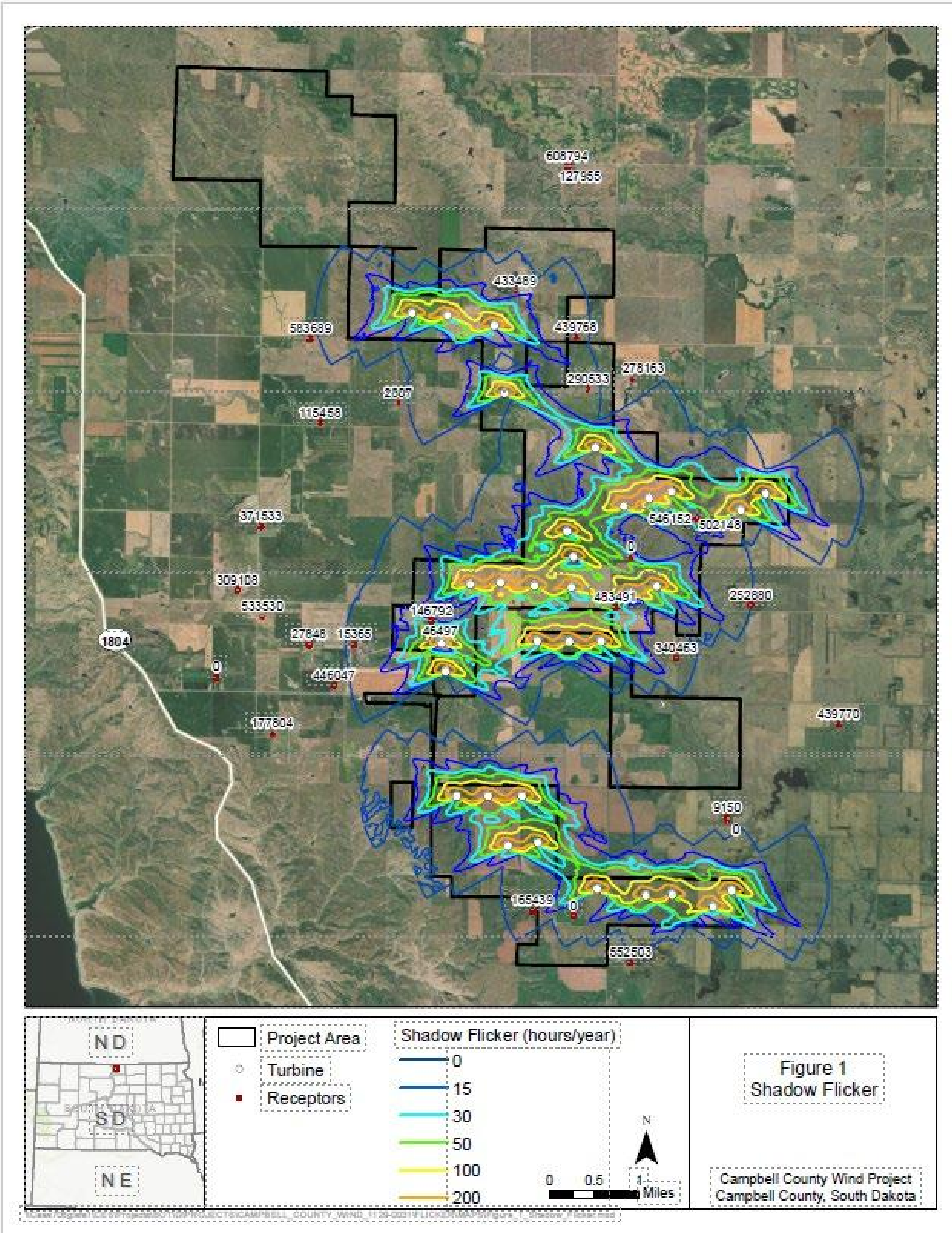

Figure 1. Expected Shadow Flicker Impact Areas

ATTACHMENT A. DETAILED SUMMARY OF WINDPRO SHADOW FLICKER ANALYSIS RESULTS

Table A-1. Detailed Summary of WindPro Shadow Flicker Analysis Results

Receptor ID	UTM-Easting (m)	UTM-Northing (m)	WindPro Predicted Expected Shadow Flicker [Hours:Minutes per Year]
483491	408880.96	5068970.96	57:25
502148	410293.47	5070602.88	50:32
1	409167.09	5069869.47	42:43
146792	405557.39	5068739.41	27:39
46497	405522.75	5068767.94	26:50
439768	408162.14	5073854.35	8:26
433489	407073.1	5074687.35	6:18
165439	407376.35	5063500.02	5:36
340463	409972.46	5068062.06	4:24
4	408119.72	5063420.22	3:48
15365	404166.08	5068308.12	3:13
252880	411321.32	5069020.31	3:07
290533	408386.06	5072922.22	2:43
2	401670.31	5067718.23	0:00
115458	403543.49	5072318.61	0:00
127955	408038.59	5076947.6	0:00
27848	403348.28	5068298.43	0:00
2807	404958.85	5072680.13	0:00
309108	402048.17	5069289.4	0:00
371533	402480.51	5070439.96	0:00
439770	412906.17	5066864.48	0:00
446047	403793.25	5067579.16	0:00
533530	402497.93	5068803.92	0:00
552503	409148.83	5062570.3	0:00
583689	403366.13	5073820.61	0:00
608794	408006.61	5076924.24	0:00
9150	410896.27	5065190.5	0:00
177804	402685.18	5066693.32	0:00
234167	405034.18	5060882.1	0:00
77604	406303.15	5061568.13	0:00
3	410901.71	5065128.79	0:00
2799	402622.73	5080106.42	0:00
278163	409183.8	5073093.24	0:00
290532	405470.45	5060900.32	0:00