EXHIBIT C

Shadow Flicker Impact Analysis for the New Frontier Wind Energy Project McHenry County, North Dakota

Prepared for

Capital Power

Prepared by

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Updated May 2018
Updated August 2018
Updated October 2018

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Acronyms and Abbreviations

Capital Power	Capital Power Corporation
Hz	Hertz
Meadowlark	Meadowlark Wind I LLC
NCDC	National Climatic Data Center
Project	New Frontier Wind Energy Project
PSC	North Dakota Public Service Commission
PSC Order	Order on Continuing Suitability PU-11-69
rpm	rotations per minute
UTM	Universal Transverse Mercator

1.0 OVERVIEW

On April 26, 2012, the North Dakota Public Service Commission (PSC) issued Certificate of Site Compatibility Number 29 to Meadowlark Wind I LLC (Meadowlark) for the New Frontier Wind Energy Project (Project) in McHenry County, North Dakota (Figure 1). In December 2014, Capital Power Investments LLC, a subsidiary of Capital Power Corporation (Capital Power), completed the acquisition of Element Power US, LLC, which included Meadowlark and the Project. In February 2016, Capital Power contracted Tetra Tech to conduct the following shadow flicker analysis for the Project, to support the Certification of Continuing Suitability Application for the Project. On May 10, 2017, the PSC issued to Meadowlark the Order on Continuing Suitability PU-11-69 (PSC Order) for the Project. The shadow flicker analysis was updated in January 2018 to assess the Project's final selected turbine model and array layout and updated again in May 2018, August 2018, and October 2018 to address minor turbine location adjustments, per the PSC Order Paragraph No. 8:

> *In the event Project modifications occur that are not covered by its current shadow flicker analysis, Meadowlark shall conduct a shadow flicker analysis and file a report with the Commission to ensure that the Project complies with the commitment in Order Paragraph No. 4(d) [Meadowlark shall site Project turbines so as to meet a shadow flicker goal of 30 hours per year or less at each currently occupied residence, considering site-specific conditions, unless a written acknowledgment is obtained from the landowner.]*.

2.0 PROJECT COMPONENTS

The Project will consist of up to 29 wind turbines. The turbine model selected for the Project is the Vestas V126-3.45 and has the following specifications:

- **Vestas V126-3.45:** Three-blade 126 m rotor diameter, with a hub height of 87 meters and generating capacity of 3.45 megawatts. The V126-3.45 has a normal high rotor speed of 12.8 rotations per minute (rpm), which translates to a blade pass frequency of 0.64 hertz (Hz; 0.64 alternations per second).

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 impact to surrounding properties generally occurs during low angle sunlight conditions, typically during sunrise and sunset times of the day.

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 is only an issue 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. Shadow flicker intensity for receptor-to-turbine distances beyond 2,500 meters (8,202 feet) is very low and generally considered imperceptible. 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 standpoint, 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 there is no evidence that wind turbines can cause seizures (Epilepsy Action 2008). However, they recommend that wind turbine flicker frequency be limited to three Hz (for comparison, strobe lights used in discos have frequencies which range from about three Hz to 10 Hz (one Hz = one flash per second)). Since the proposed Project's wind turbine blade pass frequency is approximately 0.87 Hz (less than one alternation per second), no negative health effects to individuals with photosensitive epilepsy are anticipated.

As stated in Section 1, PSC Order Paragraph 8 requires that the project site the wind turbines so as to meet a shadow flicker goal of 30 hours per year or less at each currently occupied residence. Therefore, the 30 hours per year threshold has been used in this shadow flicker analysis.

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, the Project will install up to 29 wind turbines.

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 Project turbines. 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 2015] for nearby Bismarck, North Dakota) used in this analysis are as follows:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
54%	52%	61%	58%	64%	67%	75%	72%	67%	53%	42%	45%

- Estimated wind turbine operations and orientation based on wind data (wind speed and direction) measured at meteorological towers located on the Project site.
- Receptor viewpoints (i.e., house windows) are assumed to always be directly facing turbine to sun line of sight ("greenhouse mode").

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 earlier 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 width dimension data to calculate the maximum distance from the turbine where shadow flicker must be calculated. Beyond this distance, the turbine will not contribute to the shadow flicker impact. It should be noted however, that WindPro provides a conservative estimate of shadow flicker as 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 47 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), 3.28 feet (one meter) above ground level. Approximate eye level is set at 4.94 feet (1.5 meters). Figure 1 shows the locations of all 47 identified residential structures, along with the 29 potential 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 2 illustrate the WindPro predicted shadow flicker impact areas for each of the turbine model scenarios.

Table 1 presents the WindPro predicted shadow flicker impacts for the top ten worst case impacts receptors. Table 2 summarizes the shadow flicker impact prediction statistics. The predicted shadow flicker for all 47 receptors is presented in Appendix A. Because the Project is using a minimum turbine siting setback requirement of 1,400 feet to occupied residences as required by the PSC Order for the Project, the most sensitive receptors are generally not located in the high potential shadow flicker impact zones. The maximum predicted shadow flicker impact at any occupied residence receptor is 70 hours and 33 minutes per year (Receptor 12). This is approximately 1.58 percent of the potential available daylight hours. There are four occupied receptors (Receptors 2, 3, 12, and 44) with shadow flicker impacts greater than 30 hours per year. All of these residences are owned by landowners that are participating in the Project. The analysis results indicate substantial reduction of shadow flicker impact from what was presented in the November 2016 shadow flicker analysis report. This improvement is the result of the smaller number of wind turbines proposed in the current project design.

Table 1. WindPro Top Ten Expected Shadow Flicker Impacts

Receptor ID	Receptor Type	Receptor Project Participation Status	Expected Shadow Flicker Hours per Year (Hours/Year)
			Vestas V126-3.45
12	Resident	Participant	70.55
3	Resident	Participant	61.67
2	Resident	Participant	42.85
44	Resident	Participant	31.02
1	Resident	Participant	25.12
13	Resident	Participant	22.68
14	Resident	Participant	21.62
5	Resident	Participant	19.90
7	Resident	Participant	13.45
6	Resident	Participant	10.87

Table 2. Statistical Summary of WindPro Expected Shadow Flicker Impacts – Number of Modeled Receptors

Cumulative Shadow Flicker Time (Expected)	Vestas V126-3.45
Total	47
= 0 Hours	31
> 0 Hours < 10 Hours	6
≥ 10 Hours < 20 Hours	3
≥ 20 Hours < 30 Hours	3
≥ 30 Hours	4

6.0 CONCLUSION

The analysis of potential shadow flicker impacts from the Project on nearby receptors shows that shadow flicker impacts within the area of study are expected to be minor and within acceptable ranges for avoiding nuisance conditions. There are four occupied receptors with shadow flicker impacts greater than 30 hours per year, however all of these residences are owned by landowners that are participating in the Project. Meadowlark has communicated this information to the landowners, and the landowners have executed written acknowledgments, copies of which are provided in Appendix D of the New Frontier Wind Energy Project Certification of Continuing Suitability Filing dated November 2016. The Project continues to comply with the PSC Order Paragraphs 4(d) and 8. Shadow flicker is not expected to be a significant environmental impact.

The analysis was deliberately conservative and actual shadow flicker is expected to occur for less than the modeled durations. The analysis assumes that the receptors all have a direct in-line view of the incoming shadow flicker sunlight and does not account for trees or other obstructions which may block sunlight. In reality, the windows of many houses will not face the sun directly for the key shadow flicker impact times.

7.0 REFERENCES

Epilepsy Action. 2008. Information Web Page on Photosensitive Epilepsy. British Epilepsy Association. http://www.epilepsy.org.uk/info/photo_other.html. Accessed November 2015.

NOAA (National Oceanic and Atmospheric Administration). 2015. Comparative Climatic Data for the United States Through 2015.

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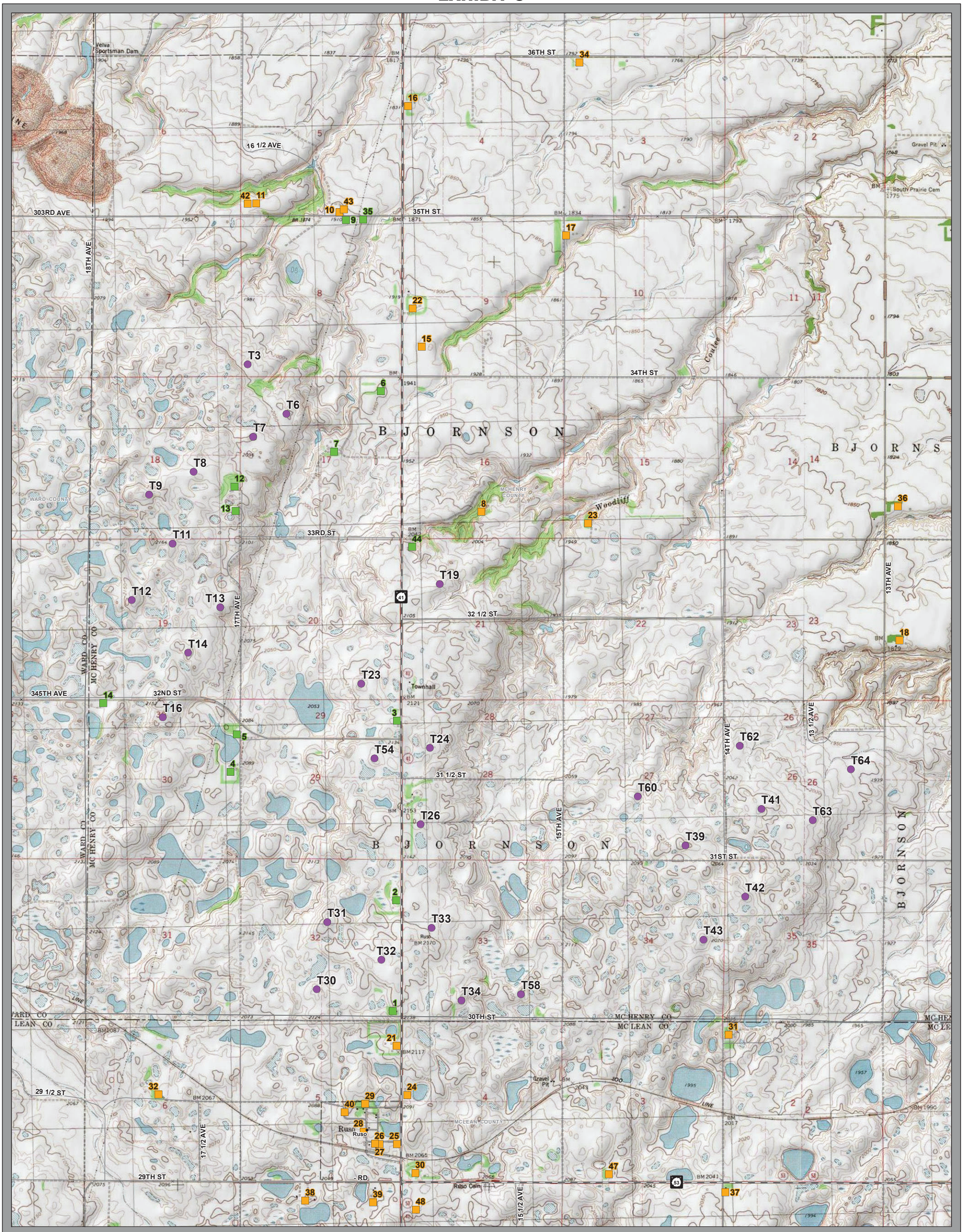

NEW FRONTIER WIND ENERGY PROJECT

Figure 1: Turbine and Receptor Locations

- Turbine
- Participant Receptor
- Non-Participant Receptor

0 0.25 0.5 Miles

Scale is 1:18,000 when printed at 22x34"

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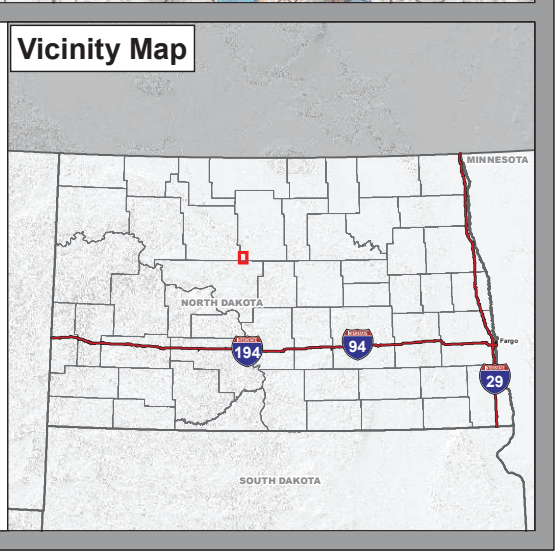

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Figure 2: Expected Shadow Flicker Impact Areas
Vestas V126 Array

0 0.25 0.5 Miles

Scale is 1:24,000 when printed at 22x34"

- Vestas V126 Turbine Array
- Participant Receptor
- Non-Participant Receptor

Shadow Flicker (hours per year)

- 0 - 15
- >15 - 30
- >30 - 50
- >50 - 100
- >100 - 200
- >200

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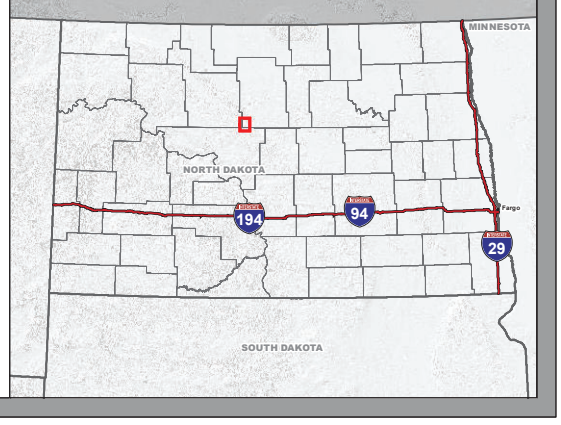
Vicinity Map



Attachment A:
Detailed Summary of WindPro Shadow Flicker Analysis Results

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Detailed Summary of WindPro Shadow Flicker Analysis Results – Vestas V126-3.45

Capital Power New Frontier Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted Expected Shadow Flicker (Hours per Year)	Status	Participation Status
1	355605.40	5301329.12	25.12	Resident	Participant
2	355661.04	5302441.06	42.85	Resident	Participant
3	355701.95	5304237.91	61.67	Resident	Participant
4	354027.18	5303758.70	2.22	Resident	Participant
5	354097.00	5304133.53	19.90	Resident	Participant
6	355606.23	5307543.03	10.87	Resident	Participant
7	355126.06	5306944.55	13.45	Resident	Participant
8	356588.12	5306314.94	0.60	Resident	Non-Participant
9	355289.86	5309264.74	0.00	Resident	Participant
10	355228.99	5309342.92	0.00	Resident	Non-Participant
11	354396.88	5309448.87	0.00	Resident	Non-Participant
12	354123.00	5306615.00	70.55	Resident	Participant
13	354128.83	5306369.78	22.68	Resident	Participant
14	352764.09	5304471.09	21.62	Resident	Participant
15	356023.92	5307978.07	1.95	Missile Site	Non-Participant
16	355934.85	5310391.99	0.00	Resident	Non-Participant
17	357492.91	5309064.75	0.00	Resident	Non-Participant
18	360751.46	5304943.70	0.00	Resident	Non-Participant
19	348671.06	5304721.90	0.00	Resident	Non-Participant
20	348189.46	5304542.92	0.00	Resident	Non-Participant
21	355635.43	5300982.28	3.30	Resident	Non-Participant
22	355939.73	5308365.07	3.72	Resident	Non-Participant
23	357655.42	5306177.53	1.67	Resident	Non-Participant
24	355731.47	5300485.94	0.00	Resident	Non-Participant
25	355618.73	5299997.13	0.00	Resident	Non-Participant
26	355445.39	5300001.72	0.00	Resident	Non-Participant
27	355400.62	5300005.16	0.00	Resident	Non-Participant
28	355289.26	5300129.61	0.00	Resident	Non-Participant
29	355309.24	5300408.57	0.00	Resident	Non-Participant
30	355798.51	5299703.70	0.00	Resident	Non-Participant
31	358962.39	5301029.91	0.00	Resident	Non-Participant
32	353241.16	5300542.53	0.00	Resident	Non-Participant
33	355840.17	5311882.33	0.00	Resident	Non-Participant
34	357660.51	5310795.29	0.00	Resident	Non-Participant
35	355462.08	5309266.00	0.00	Resident	Participant
36	360761.37	5306287.05	0.00	Resident	Non-Participant
37	358897.97	5299450.61	0.00	Resident	Non-Participant
38	354691.97	5299450.42	0.00	Resident	Non-Participant
39	355368.25	5299419.73	0.00	Resident	Non-Participant
40	355103.66	5300326.72	0.00	Resident	Non-Participant
41	352663.41	5299129.48	0.00	Resident	Non-Participant
42	354311.50	5309444.28	0.00	Resident	Non-Participant
43	355272.03	5309369.84	0.00	Resident	Non-Participant
44	355889.74	5305977.17	31.02	Resident	Participant
45	361732.60	5299729.17	0.00	Resident	Non-Participant
46	362417.60	5300028.31	0.00	Resident	Non-Participant
47	357737.12	5299653.55	0.00	Resident	Non-Participant

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