Shadow Flicker Assessment

Emmons-Logan Wind Energy Center
Emmons-Logan Wind, LLC
Emmons County and Logan Counties, North Dakota

Prepared for:

Emmons-Logan Wind, LLC
700 Universe Boulevard
Juno Beach, FL 33408

Prepared by:

AECOM
1000 East Calgary Avenue, Suite 1
Bismarck, North Dakota 58503

November 2018

This page intentionally left blank.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Emmons-Logan Wind, LLC (Emmons-Logan Wind), a wholly owned, indirect subsidiary of NextEra Energy Resources, LLC (NEER), has submitted an Application for a Certificate of Site Compatibility (Certificate) to construct and operate the Emmons-Logan Wind Energy Center (Project) in Emmons and Logan Counties, in south-central North Dakota. Emmons-Logan Wind signed a 25-year power purchase agreement (PPA) with Great River Energy (GRE) for the Project. Pursuant to this PPA, GRE will purchase all of the electrical output generated by the Project for 25 years.

The Project will have a nameplate capacity of approximately 298.1 megawatts (MW), consisting of up to 123 wind turbines using both GE 2.5 MW and GE 1.715 MW utility-grade wind turbines. In addition to the 123 primary turbines, up to six alternative turbine locations have also been considered. The alternate turbine locations are proposed to provide siting flexibility based on on-going studies, landowner preferences, and issues identified during construction. Only 123 turbines will be constructed. AECOM has conducted the following shadow flicker analysis for the Project to support Emmons-Logan Wind's application for a Certificate under the North Dakota Public Service Commission (Commission).

2.0 PROJECT COMPONENTS

The Project will consist of up to 123 wind turbines (**Figure 1**). The wind turbine technology proposed for this Project is 3-bladed, upwind, horizontal-axis wind turbines that are state of the art technology. Each GE 2.5 MW utility-grade wind turbine will have a 90-meter (295 feet) hub height and a 116-meter (380.5 foot) rotor diameter with a swept area of 10,568 m^2. The GE 1.715 MW turbine has an 80-meter hub height, and a 103-meter (338 foot) rotor diameter with a swept area of 8,332 m^2. Both turbines begin operation in wind speeds of 3.0 meters per second, or 6.7 miles per hour, and are designed to operate in wind speeds of up to 20 meters per second (45 miles per hour). The coordinates for the 129 (123 proposed and six alternate) turbine locations are listed in **Table 1**. Twelve turbines are proposed as the GE 1.715 MW model and the rest of the turbines are proposed as the GE 2.5 MW model.

3.0 SHADOW FLICKER BACKGROUND

Shadow flicker is a temporary condition resulting from the sun casting intermittent shadows from the rotating blades of a wind turbine onto a sensitive receptor such as a window in a building. The flicker is due to alternating light intensity between the direct beam of sunlight and the shadow from the turbine blades. For shadow flicker to occur, the following criteria must be met:

1. The sun must be shining and not obscured by any cloud cover.

2. The wind turbine blades must be between the sun and the shadow receptor. The wind turbine must be facing directly towards (or away from) the sun such that the rotational plane of the blades is perpendicular to the azimuth of incident sun rays. For this to occur, the wind direction would have to perpetually be parallel to the azimuth of the incident sun rays throughout the day.

3. The line of sight between the turbine and the shadow receptor must be clear. Light impermeable obstacles, such as trees, buildings or other structures, will prevent or reduce shadow flicker from occurring at the receptor. Terrain can also affect the exposure at a receptor.

4. The receptor has to be close enough to the turbine to be in the shadow. The shadow from a turbine extends furthest when the sun is low in the sky (sunrise and sunset) such that receptors to the east or west of a turbine will be exposed more than receptors to the north and south of a turbine.

5. The turbine is operational and not stationary due to a lack of wind or maintenance activities.

The frequency of shadow flicker is dependent on the wind turbine's rotor blade speed and the number of blades on the rotor. 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.

Although shadow flicker does not impact health it can be a nuisance to neighboring properties if not kept to a reasonable number of hours a year (Knopper et al., 2014). There have been public concerns that flickering light from wind turbines could trigger seizures in people with epilepsy, but these concerns are unfounded. The UK Epilepsy Society states that turbine blades would need to rotate at speeds greater than 3 Hertz (flashes per second) to potentially cause seizures in persons with photosensitive epilepsy (Epilepsy Society 2016); however, turbines on commercial wind farms rotate at speeds of 2 Hertz or less. The GE 2.5 wind turbines for this Project have a maximum rotational speed of 15.7 revolutions per minute (rpm), which corresponds to a shadow flicker frequency of 0.26 Hertz. The GE 1.715 wind turbines for this Project have a maximum rotational speed of 17 rpm, which corresponds to a shadow flicker frequency of 0.28 Hertz. Therefore, the Project turbines will result in a flash frequency well below that which would cause photosensitive epileptic seizures.

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. However, a widely used industry standard of 30 hours per year has been used for this shadow flicker impact analysis. The Commission requires effects from the impact upon light-sensitive land uses to be managed and maintained at an acceptable minimum.[1] The Commission has recognized the 30 hour per year standard and historically evaluates shadow flicker impacts pursuant to this standard.

4.0 SHADOW FLICKER ANALYSIS

The shadow flicker analysis for the Project was completed using the WindPRO Version 3.2 modelling software. As discussed above, the Project will install up to 123 wind turbines. The 123 proposed locations as well as six alternate locations have been assessed in two scenarios:

- Scenario A: 123 wind turbines (proposed locations only)
- Scenario B: 129 wind turbines (proposed and alternate locations)

WindPRO considers the terrain features determined by U.S. Geological Survey (USGS) Digital Elevation Model (DEM) data, receptor, and turbine locations in the modelling analysis. It is generally accepted that shadow flicker from wind turbines does not occur beyond a certain distance from a wind turbine (Department of Energy and Climate Change 2011). The *Update of UK Shadow Flicker Evidence Base* by Parsons Brinckerhoff, on behalf of the Department of Energy and Climate Change, states this distance is equivalent to 10 rotor diameters. AECOM calculated a maximum distance of 3,805 feet (380.5 foot rotor diameter times 10) for all turbines, which is conservative for the 338 foot rotor diameter turbines. WindPRO also assumes the sun is shining during all daytime hours and that the turbines are always operating. This method produces a theoretical worst case astronomical prediction at each receptor. Thirty years of hourly meteorological data generated at hub height for the Project Area shows that the wind blows predominantly from the northwest or south and that receptors to the east or west of a turbine are less likely to experience shadow flicker. The meteorological data also shows that up to seven

[1] N.D. Admin. Code § 69-06-08-01(5)(c)(3).

percent of the hours when flicker is likely to occur, the wind speed would be less than the cut-in speed of the turbine and the blades would not be rotating.

WindPRO was run in "greenhouse mode" such that the wind turbine blades are always perpendicular to the receptor with a direct line of sight where the window is one meter by one meter and the height above ground to the middle of the window is 1.5 meters to determine the maximum exposure. The amount of bright sunshine can also affect the frequency and duration of exposure to shadow flicker. **Table 2** summarizes the percentage of bright sunshine (classified as zero or few clouds) at Jamestown Airport, North Dakota, and Bismarck, North Dakota based on 30-year climatological data (1983 – 2012) from the National Climatic Data Center (NCDC 2017). The average between the two airports during daytime hours is 43.6% bright sunshine. This factor was used to adjust the number of hours when shadow flicker occurs on an annual basis.

The analysis is inherently conservative by assuming 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. Adding to the analysis' conservatism, both the primary and alternate turbines (for a total of 129 turbines) are modeled cumulatively for Scenario B, even though Emmons-Logan Wind will only construct no more than 123 turbines.

A total of 95 structures were identified within and near the Project Area. The receptors in this analysis have been classified into two different categories, participating and non-participating. Determination of habitation for existing structures was limited to public information and roadside surveys. For purposes of conservatism in this analysis, all structures located on non-participating land that were identified as capable of habitation were considered active residential structures. Receptors that were identified as participating in the Project are associated with the wind farm development via a legal agreement with the owner of the subject property to allow for the installation and operation of wind turbines or related equipment.

5.0 SHADOW FLICKER ANALYSIS RESULTS

The shadow flicker analysis accounts for the placement of turbines, receptors, and sun angle such that the time when the turbine is in between the sun and the receptor is included in the total hours per year that shadow flicker could occur. However, this is a conservative analysis that does not account for maintenance time, wind speeds less than three meters per second when the turbines will not operate, light permeable obstacles such as trees and other structures, or that the turbine will rarely be directly facing the sun, which will shorten the shadow from the turbine blades. It was assumed that the receptor is always perpendicular (facing) to the turbine and a window measuring one meter by one meter at each receptor is located 1.5 meters high off the ground.

5.1 Scenario A Results

The results of the Scenario A analysis are summarized in **Table 3** and **Table 4** and shown on **Figure 2**. The maximum shadow flicker per year at an occupied receptor is 48 hours per year. It is based on annual percentage of sunshine in **Table 2** and estimated hours during which the wind speed would be less than the cut-in speed of 3 meters per second or the turbine is down for maintenance. This analysis is conservative as it assumes that there is a window facing the turbine at all times ("greenhouse mode"). Even using this conservative analysis, only seven receptors were predicted to have shadow flicker values of 30 hours or greater each year.

5.2 Scenario B Results

The results of the Scenario B analysis are summarized in **Table 5** and **Table 6** and shown on **Figure 3**. Similar to Scenario A, the maximum shadow flicker per year at an occupied receptor is 48 hours per

year. It is based on annual percentage of sunshine in **Table 2** and estimated hours during which the wind speed would be less than the cut-in speed of three meter per second or the turbine is down for maintenance. This analysis is conservative as it assumes that there is a window facing the turbine at all times ("greenhouse mode"). Even using this conservative analysis, only seven receptors were predicted to have shadow flicker values of 30 hours or greater each year.

6.0 CONCLUSIONS

As expected, the analysis predicts that shadow flicker impacts will be greatest at locations nearer to the wind turbines. Emmons-Logan Wind has used a minimum internal setback of 1,400-feet from all participating receptors, and a minimum setback of three times the turbine height at non-participating receptors, per North Dakota Administrative Code (NDAC) Section 69-06-08-01(2). 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 well within acceptable ranges for avoiding nuisance conditions. The predicted shadow flicker impacts are less than the Commission-recognized 30 hours per year industry standard at all but seven occupied residences; these residences are owned by landowners that are participating in the Project and have signed waivers of the exceedances.

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 that may block sunlight. In reality, the windows of some houses will not face the sun directly for the key shadow flicker impact times. Adding to the analysis' conservatism, both the primary and alternate turbines were modeled cumulatively in Scenario B. Emmons-Logan Wind will only construct up to 123 turbines, which is fewer wind turbines than were included in the Scenario B modeled results.

7.0 LITERATURE CITED

Department of Energy and Climate Change. 2011. Update of UK Shadow Flicker Evidence Base. Accessed June 20, 2018. Available online at: https://www.gov.uk/government/publications/update-of-uk-shadow-flicker-evidence-base

Epilepsy Society. 2016. Wind Turbines and Photosensitive Epilepsy. Accessed June 20, 2018. Available online at: https://www.epilepsysociety.org.uk/wind-turbines-and-photosensitive-epilepsy#.WU1pn1UrLcs

Knopper, L.D., Ollson, C.A., McCallum, L.C., Aslund, M.L., Berger, R.G, Souweine, K., and McDaniel, M. 2014. Wind Turbines and Human Health. Frontiers in Public Health. Vol. 2, Art. 63. Accessed June 20, 2018. Available online at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4063257/

NCDC (National Climatic Data Center). 2018. Local Climate Station Summaries. Accessed May 18, 2018. Available online at: https://www7.ncdc.noaa.gov/CDO/cdoselect.cmd?datasetabbv=SUMMARIES&countryabbv=&georegionabbv=&resolution=0

Tables

Table 1. Wind Turbine Locations

Turbine ID	UTM Coordinates		Turbine ID	UTM Coordinates		Turbine ID	UTM Coordinates	
	X	Y		X	Y		X	Y
1	410814	5137756	44	420159	5141194	87	425180	5133454
2	411488	5137861	45	420521	5141305	88	425561	5133688
3	411978	5138547	46	420317	5139212	89	425949	5133807
4	412294	5138850	47	420763	5139279	90	426413	5134389
5	413662	5140037	48(1)	421037	5139565	91	426691	5134642
6(1)	413977	5140328	49	421187	5139961	92	427236	5134611
7(1)	414311	5140477	50	419221	5133651	93	427482	5134959
8(1)	415230	5140465	51	418370	5134473	94	427238	5135935
9	412281	5136466	52	418369	5135053	95	427403	5136341
10	412952	5137228	53	418752	5135202	96	427651	5136750
11	413797	5137704	54	419047	5135466	97	428132	5136851
12	414297	5137697	55	419446	5135533	98	428494	5137040
13	414368	5138609	56	420708	5135159	99	428893	5137678
14	414772	5138791	57	421068	5135326	100	429244	5137931
15	415186	5138865	58	419990	5136109	101	428130	5135909
16	415543	5139325	59	420117	5136584	102(1)	428511	5135985
17	415877	5139647	60	420237	5137072	103(1)	428867	5136106
18	416314	5139632	61	420667	5137198	104	429222	5136288
19	413789	5136264	62	421915	5137649	105	429690	5136519
20	414038	5136591	63	422403	5137737	106	429776	5137029
21	414359	5136829	64	422713	5137958	107	429953	5137526
22	414678	5137021	65	423237	5137090	108	429965	5138112
23	415509	5136515	66	423673	5137092	109	430145	5138519
24	416094	5137750	67	424048	5137609	110	430245	5139109
25(1)	416351	5138075	68	424384	5137865	111	430589	5139316
26	417022	5137695	69	424863	5136137	112	430911	5139488
27	417500	5137631	70	425302	5136027	113	431442	5139787
28	417840	5137861	71	425916	5136015	114	431622	5140172
29(1)	412735	5134898	72	426604	5141449	115	428803	5134241
30(1)	413008	5135201	73	427019	5141498	116	428953	5134741
31(1)	413563	5135322	74	427535	5141399	117	429203	5135091
32(1)	413964	5135290	75	428574	5140966	118	429771	5134963
33(1)	414307	5135589	76	428564	5141551	119	430126	5135083
34	412689	5133704	77	428827	5141888	120	430482	5135236
35	413019	5133855	78	428194	5139487	121	430815	5135392
36	413531	5133738	79	428442	5139817	122	431437	5135309
37	413876	5133919	80	428837	5139911	123	431828	5135375
38	415275	5134415	81	423166	5131801	Alt1	432129	5135798
39	415633	5134815	82	423268	5132267	Alt2	432479	5135896
40	419209	5139209	83	423574	5132655	Alt3	414708	5135621
41	419498	5139476	84	423929	5132776	Alt4	429238	5140114
42	419572	5140052	85	424286	5133005	Alt5	429774	5140186
43	419573	5140822	86	424882	5133081	Alt6	429289	5141487

(1) GE 1.715 MW turbines. All others are GE 2.5 MW turbines.

Table 2. Percent of Bright Sunshine at Nearby Airports

Hour	% Bright Sunshine (Jamestown, ND)	% Bright Sunshine (Aberdeen, SD)	% Bright Sunshine (Average)
0	0.0	0.0	0.0
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	0.0
6	49.6	55.2	52.4
7	49.2	49.1	49.2
8	49.1	47.5	48.3
9	48.0	46.9	47.5
10	46.6	46.5	46.6
11	44.9	44.1	44.5
12	43.4	47.3	45.4
13	41.7	41.2	41.5
14	40.1	40.4	40.3
15	39.7	39.6	39.7
16	40.2	40.1	40.2
17	40.4	40.7	40.6
18	40.6	47.5	44.1
19	39.7	40.7	40.2
20	0.0	0.0	0.0
21	0.0	0.0	0.0
22	0.0	0.0	0.0
23	0.0	0.0	0.0
Daytime Hours (0600-1900)	**43.8**	**44.8**	**44.3**

Table 3. Scenario A Statistical Summary of Predicted Shadow Flicker at Occupied/Possibly Occupied Receptors

Total Shadow Flicker Time (expected)	Number of Receptors
Total	95
= 0 Hours	66
> 0 Hours < 10 Hours	5
> 10 Hours < 20 Hours	9
> 20 Hours < 30 Hours	6
> 30 Hours	7

Table 4. Scenario A Results by Modeled Receptor

Receiver ID	Participating Landowner?	Nearest Turbine ID	Distance to Nearest Turbine (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Shadow Flicker Hours/Year
ARCH1a	No	5	9659	411748	5142273	0
ARCH1b	No	5	9829	411681	5142284	0
ARCH3	No	8	7766	414922	5142811	0
ARCH4a	No	43	5430	418970	5142363	0
ARCH4b	No	43	5522	418976	5142395	0
ARCH7	No	73	2287	426874	5142180	0
ARCH9a	Yes	74	2274	427858	5142012	20
ARCH9b	Yes	74	1900	427845	5141887	21
ARCH10	Yes	77	3602	429319	5142869	0
ARCH11	No	77	3894	429934	5142318	0
ARCH12	No	114	5482	432773	5141382	0
ARCH14	Yes	4	8917	410443	5140839	0
ARCH15	Yes	75	1860	428022	5140842	22
ARCH16a	Yes	80	1683	428633	5140382	0
ARCH16b	Yes	80	1581	428774	5140389	0
ARCH17	Yes	49	5584	422884	5139836	0
ARCH18	Yes	1	5925	410039	5139386	0
ARCH19	No	4	2152	411861	5139343	17
ARCH20a	Yes	109	2064	429635	5138886	48
ARCH20b	Yes	110	2142	429592	5139083	30
ARCH21	No	113	5318	432803	5138909	0
ARCH22	No	114	11289	434822	5138912	0
ARCH24	Yes	113	4373	432380	5138841	0
ARCH25	Yes	110	1634	430597	5138756	29
ARCH28	Yes	13	2011	413756	5138574	18
ARCH29	Yes	1	1545	410988	5138194	27
ARCH30a	No	1	3225	410075	5138403	12
ARCH30b	No	1	3291	410068	5138425	11
ARCH31	Yes	10	2372	412313	5137566	18
ARCH33	Yes	68	2533	424685	5137154	4
ARCH34	Yes	123	3750	431973	5136509	0
ARCH35	Yes	61	1722	420653	5136674	30
ARCH36a	No	23	3245	416487	5136666	4
ARCH36b	No	23	3251	416500	5136699	4
ARCH37	Yes	24	1883	415694	5137337	4
ARCH38	Yes	11	1742	413943	5137194	42

Receiver ID	Participating Landowner?	Nearest Turbine ID	Distance to Nearest Turbine (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Shadow Flicker Hours/Year
ARCH39	Yes	10	2369	413090	5136520	21
ARCH42	Yes	57	2812	421759	5135832	13
ARCH45	Yes	123	4800	433280	5135553	0
ARCH46	Yes	123	3225	432802	5135504	5
ARCH47	Yes	121	1496	430992	5134971	40
ARCH48	Yes	117	1804	429531	5135533	39
ARCH49a	Yes	87	4564	424296	5134528	0
ARCH49b	Yes	87	4757	424324	5134624	0
ARCH51	Yes	55	2349	419802	5134912	11
ARCH52	Yes	9	2913	411640	5135851	0
ARCH53	No	29	8432	410166	5134921	0
ARCH54	Yes	38	1663	414773	5134478	35
ARCH55	Yes	92	1663	427252	5134105	9
ARCH57	Yes	123	7369	432556	5133251	0
ARCH59	Yes	85	2490	423789	5133578	11
ARCH60	Yes	83	5413	422205	5133575	0
ARCH61a	Yes	56	3540	420718	5134080	0
ARCH62	No	34	3573	411735	5134229	5
ARCH64	Yes	86	1654	425154	5132657	10
ARCH66	No	122	9744	431631	5132346	0
ARCH68	No	34	9495	410162	5132295	0
ARCH69	No	34	10423	409972	5132060	0
ARCH70	Yes	115	11585	429825	5130862	0
ARCH72	Yes	34	10469	412251	5130545	0
ARCH73	Yes	37	13107	415645	5130338	0
ARCH74	Yes	115	13383	428480	5130176	0
ARCH75	Yes	115	14347	429070	5129877	0
ARCH76a	Yes	81	11791	425726	5129279	0
ARCH76b	Yes	81	11942	425766	5129255	0
ARCH76c	Yes	81	11719	425673	5129258	0
ARCH77a	No	81	11063	425349	5129233	0
ARCH77b	No	81	10984	425314	5129234	0
ARCH77c	No	81	11165	425393	5129229	0
ARCH77d	No	81	11296	425391	5129175	0
ARCH79a	Yes	81	8054	422894	5129362	0
ARCH79b	Yes	81	8209	422880	5129316	0
ARCH79c	Yes	81	7651	422886	5129487	0

Receiver ID	Participating Landowner?	Nearest Turbine ID	Distance to Nearest Turbine (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Shadow Flicker Hours/Year
ARCH80	No	50	13783	418813	5129471	0
ARCH81	No	38	15958	416269	5129655	0
ARCH83	Yes	81	10820	424451	5128764	0
ARCH84	No	34	7277	411554	5131800	0
ARCH107	No	1	11742	407590	5136204	0
ARCH108	No	5	12064	410981	5142552	0
ARCH111a	No	45	10656	422531	5143856	0
ARCH111b	No	45	10614	422512	5143854	0
ARCH111c	No	45	10640	422510	5143865	0
ARCH111d	No	45	10761	422528	5143898	0
ARCH112	No	72	11860	423893	5143839	0
ARCH115	Yes	72	10174	424647	5143854	0
ARCH117	Yes	72	9616	426457	5144375	0
ARCH119	No	77	9665	427937	5144695	0
ARCH120a	No	77	8668	429651	5144397	0
ARCH120b	No	77	9003	429656	5144503	0
ARCH120c	No	77	9167	429659	5144554	0
ARCH121a	No	77	8579	430675	5143737	0
ARCH121b	No	77	8652	430715	5143728	0
ARCH122	No	77	8461	430727	5143631	0
ARCH123	Yes	81	10056	424917	5129298	0
ARCH126	Yes	34	12142	412953	5130014	0

Table 5. Scenario B Results by Modeled Receptor

Receiver ID	Participating Landowner?	Nearest Turbine ID	Distance to Nearest Turbine (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Shadow Flicker Hours/Year
ARCH1a	No	5	9659	411748	5142273	0
ARCH1b	No	5	9829	411681	5142284	0
ARCH3	No	8	7766	414922	5142811	0
ARCH4a	No	43	5430	418970	5142363	0
ARCH4b	No	43	5522	418976	5142395	0
ARCH7	No	73	2287	426874	5142180	0
ARCH9a	Yes	74	2274	427858	5142012	20
ARCH9b	Yes	74	1900	427845	5141887	21
ARCH10	Yes	77	3602	429319	5142869	0

Receiver ID	Participating Landowner?	Nearest Turbine ID	Distance to Nearest Turbine (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Shadow Flicker Hours/Year
ARCH11	No	Alt6	3449	429934	5142318	0
ARCH12	No	114	5482	432773	5141382	0
ARCH14	Yes	4	8917	410443	5140839	0
ARCH15	Yes	75	1860	428022	5140842	22
ARCH16a	Yes	80	1683	428633	5140382	14
ARCH16b	Yes	80	1581	428774	5140389	24
ARCH17	Yes	49	5584	422884	5139836	0
ARCH18	Yes	1	5925	410039	5139386	0
ARCH19	No	4	2152	411861	5139343	17
ARCH20a	Yes	109	2064	429635	5138886	48
ARCH20b	Yes	110	2142	429592	5139083	30
ARCH21	No	113	5318	432803	5138909	0
ARCH22	No	114	11289	434822	5138912	0
ARCH24	Yes	113	4373	432380	5138841	0
ARCH25	Yes	110	1634	430597	5138756	29
ARCH28	Yes	13	2011	413756	5138574	18
ARCH29	Yes	1	1545	410988	5138194	27
ARCH30a	No	1	3225	410075	5138403	12
ARCH30b	No	1	3291	410068	5138425	11
ARCH31	Yes	10	2372	412313	5137566	18
ARCH33	Yes	68	2533	424685	5137154	4
ARCH34	Yes	Alt1	2385	431973	5136509	5
ARCH35	Yes	61	1722	420653	5136674	30
ARCH36a	No	23	3245	416487	5136666	4
ARCH36b	No	23	3251	416500	5136699	4
ARCH37	Yes	24	1883	415694	5137337	4
ARCH38	Yes	11	1742	413943	5137194	42
ARCH39	Yes	10	2369	413090	5136520	21
ARCH42	Yes	57	2812	421759	5135832	13
ARCH45	Yes	Alt2	2856	433280	5135553	13
ARCH46	Yes	Alt2	1667	432802	5135504	26
ARCH47	Yes	121	1496	430992	5134971	40
ARCH48	Yes	117	1804	429531	5135533	39
ARCH49a	Yes	87	4564	424296	5134528	0
ARCH49b	Yes	87	4757	424324	5134624	0
ARCH51	Yes	55	2349	419802	5134912	11
ARCH52	Yes	9	2913	411640	5135851	0

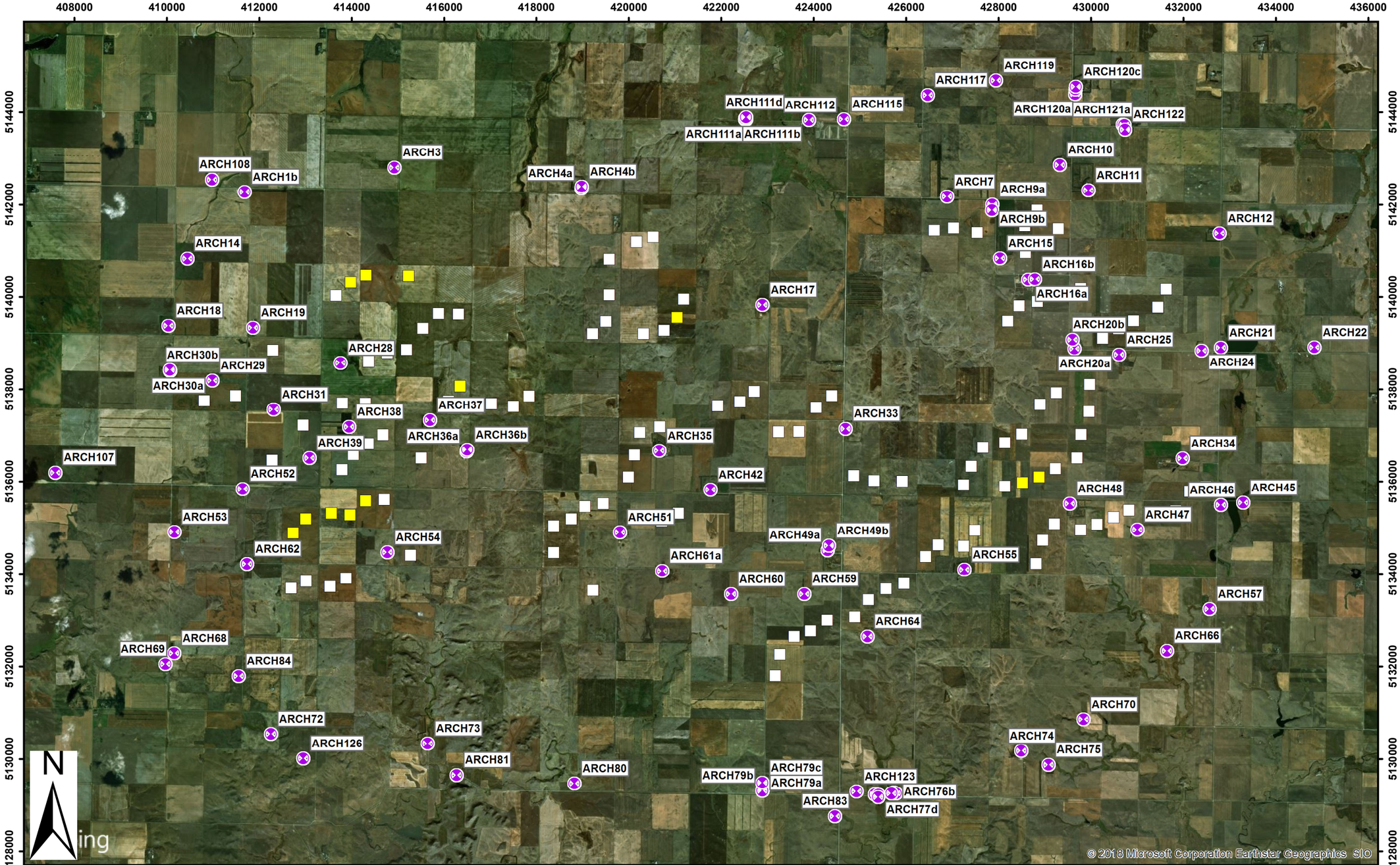
Receiver ID	Participating Landowner?	Nearest Turbine ID	Distance to Nearest Turbine (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Shadow Flicker Hours/Year
ARCH53	No	29	8432	410166	5134921	0
ARCH54	Yes	38	1663	414773	5134478	35
ARCH55	Yes	92	1663	427252	5134105	9
ARCH57	Yes	123	7369	432556	5133251	0
ARCH59	Yes	85	2490	423789	5133578	11
ARCH60	Yes	83	5413	422205	5133575	0
ARCH61a	Yes	56	3540	420718	5134080	0
ARCH62	No	34	3573	411735	5134229	5
ARCH64	Yes	86	1654	425154	5132657	10
ARCH66	No	122	9744	431631	5132346	0
ARCH68	No	34	9495	410162	5132295	0
ARCH69	No	34	10423	409972	5132060	0
ARCH70	Yes	115	11585	429825	5130862	0
ARCH72	Yes	34	10469	412251	5130545	0
ARCH73	Yes	37	13107	415645	5130338	0
ARCH74	Yes	115	13383	428480	5130176	0
ARCH75	Yes	115	14347	429070	5129877	0
ARCH76a	Yes	81	11791	425726	5129279	0
ARCH76b	Yes	81	11942	425766	5129255	0
ARCH76c	Yes	81	11719	425673	5129258	0
ARCH77a	No	81	11063	425349	5129233	0
ARCH77b	No	81	10984	425314	5129234	0
ARCH77c	No	81	11165	425393	5129229	0
ARCH77d	No	81	11296	425391	5129175	0
ARCH79a	Yes	81	8054	422894	5129362	0
ARCH79b	Yes	81	8209	422880	5129316	0
ARCH79c	Yes	81	7651	422886	5129487	0
ARCH80	No	50	13783	418813	5129471	0
ARCH81	No	38	15958	416269	5129655	0
ARCH83	Yes	81	10820	424451	5128764	0
ARCH84	No	34	7277	411554	5131800	0
ARCH107	No	1	11742	407590	5136204	0
ARCH108	No	5	12064	410981	5142552	0
ARCH111a	No	45	10656	422531	5143856	0
ARCH111b	No	45	10614	422512	5143854	0
ARCH111c	No	45	10640	422510	5143865	0
ARCH111d	No	45	10761	422528	5143898	0

Receiver ID	Participating Landowner?	Nearest Turbine ID	Distance to Nearest Turbine (feet)	Receptor Coordinates (UTM Zone 14, NAD 83) Easting (m)	Northing (m)	Predicted Shadow Flicker Hours/Year
ARCH112	No	72	11860	423893	5143839	0
ARCH115	Yes	72	10174	424647	5143854	0
ARCH117	Yes	72	9616	426457	5144375	0
ARCH119	No	77	9665	427937	5144695	0
ARCH120a	No	77	8668	429651	5144397	0
ARCH120b	No	77	9003	429656	5144503	0
ARCH120c	No	77	9167	429659	5144554	0
ARCH121a	No	77	8579	430675	5143737	0
ARCH121b	No	77	8652	430715	5143728	0
ARCH122	No	77	8461	430727	5143631	0
ARCH123	Yes	81	10056	424917	5129298	0
ARCH126	Yes	34	12142	412953	5130014	0

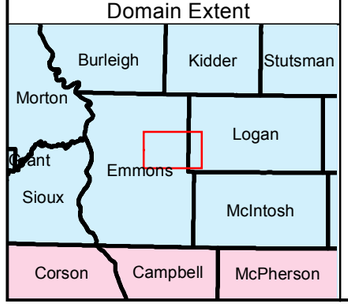
Table 6. Scenario B Statistical Summary of Predicted Shadow Flicker at Occupied/Possibly Occupied Receptors

Total Shadow Flicker Time (expected)	Number of Receptors
Total	95
= 0 Hours	62
> 0 Hours < 10 Hours	6
> 10 Hours < 20 Hours	12
> 20 Hours < 30 Hours	8
> 30 Hours	7

Figures



Domain Extent



Legend

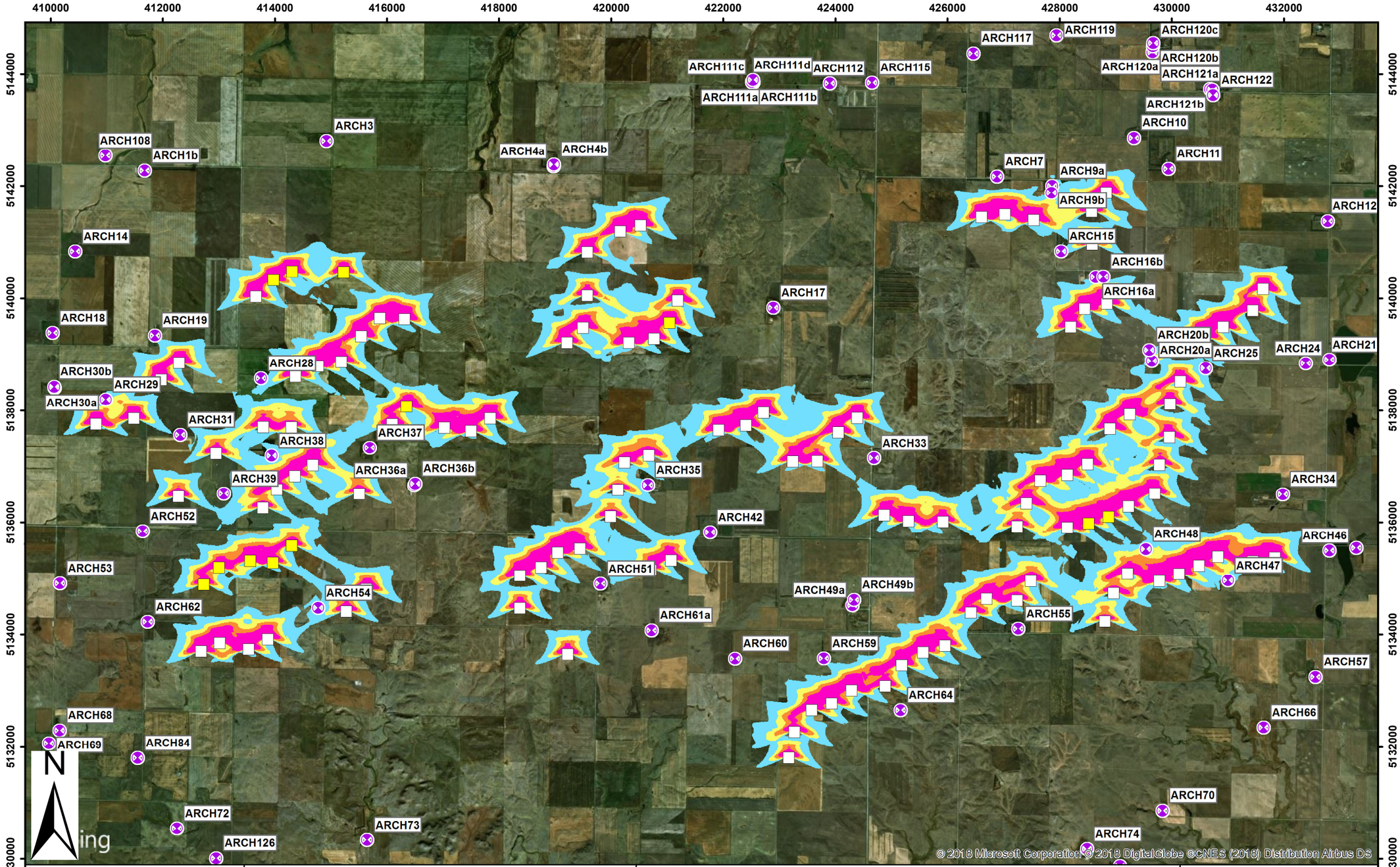
- Turbine (1.715 MW)
- Turbine (2.5 MW)
- Occupied / Possibly Occupied Receptor

Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

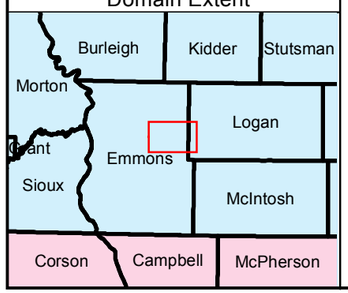
Figure 1
Wind Turbine and Occupied/Possibly Occupied Receptor Locations

AECOM

Scale 0 1.25 2.5 5 7.5 10 Kilometers



Domain Extent



Legend

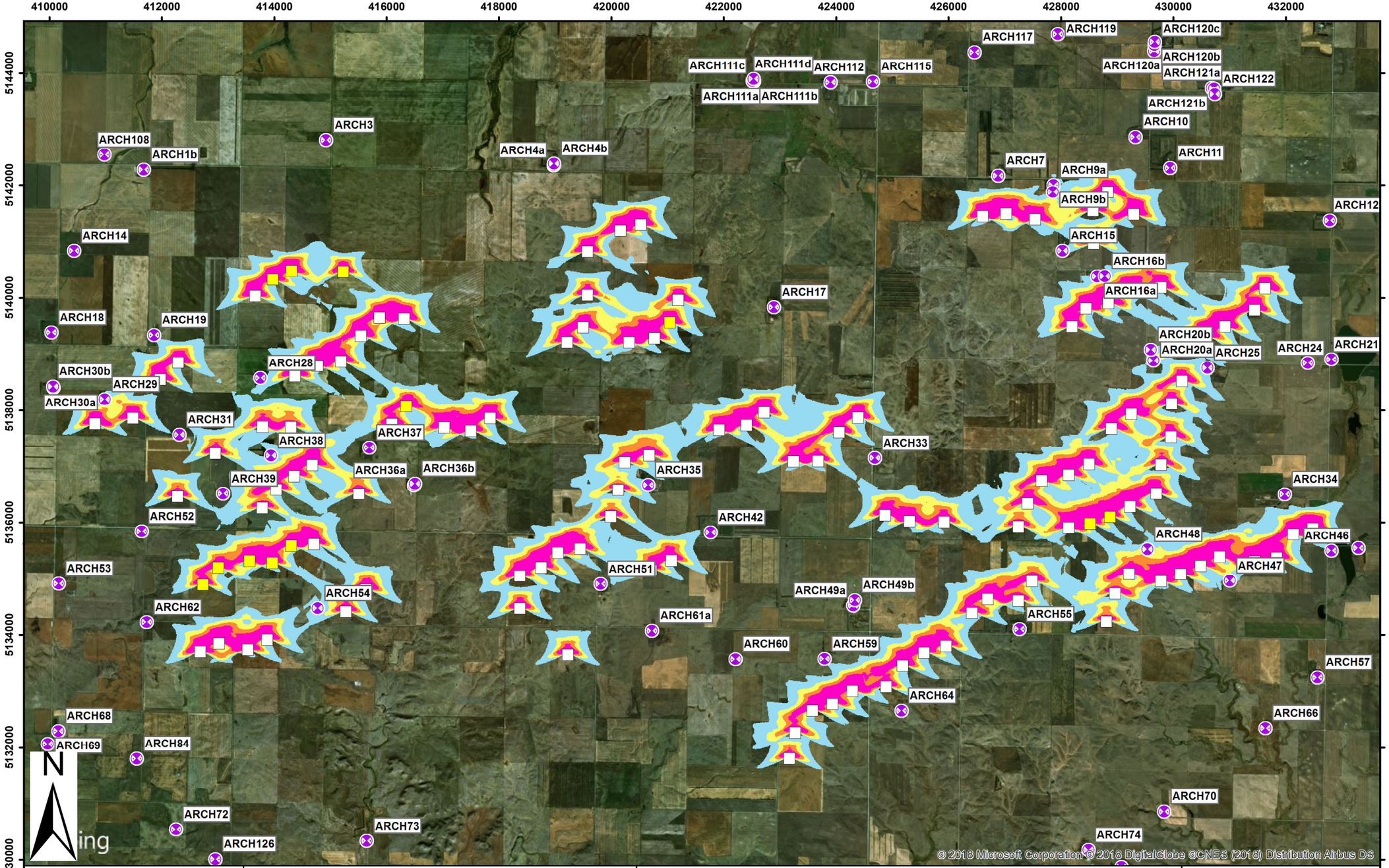
- 1.715 MW Turbines
- 2.5 MW Turbines
- Occupied / Possibly Occupied Receptor
- 30 - 60 Hours
- 60 - 90 Hours
- 90 - 120 Hours
- > 120 Hours

Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

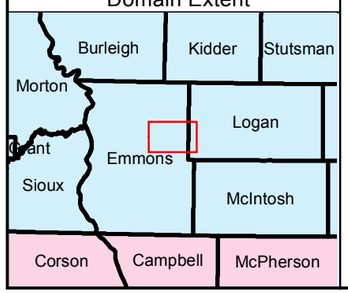
Figure 2
Without Alternates
Predicted Shadow Flicker

AECOM

Scale 0 1 2 4 6 8 Kilometers



Domain Extent



Legend

- Turbine (1.715 MW)
- Turbine (2.5 MW)
- Occupied / Possibly Occupied Receptor
- 30 - 60 Hours
- 60 - 90 Hours
- 90 - 120 Hours
- > 120 Hours

Emmons-Logan Wind Energy Center
Emmons and Logan Counties, ND

Figure 3
With Alternates
Predicted Shadow Flicker

AECOM

Scale 0 1 2 4 6 8 Kilometers