REPORT

Buffalo Atlee Wind Power Projects - Shadow Flicker Assessment

Capstone Infrastructure Corporation on behalf of Buffalo Atlee 1 Wind LP, Buffalo Atlee 2 Wind LP, and Buffalo Atlee 3 Wind LP

Submitted to:

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Distribution List

1 electronic copy – Capstone Infrastructure Corporation

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1.0 INTRODUCTION

Capstone Infrastructure Corporation (Capstone) and Sawridge First Nation, through their subsidiaries Buffalo Atlee 1 Wind LP, Buffalo Atlee 2 Wind LP, and Buffalo Atlee 3 Wind LP, are developing the Buffalo Atlee 1, 2, and 3 Wind Power Projects east and southeast of the Hamlet of Jenner, Alberta, in Special Areas No. 2. The three Buffalo Atlee Projects will hereafter be referred to collectively as “the Project”.

The Project will consist of eleven Siemens Gamesa SG 4.5-145 wind turbines. The total installed nominal capacity of the Project will be 48.30 megawatts (MW): 17.25 MW from Buffalo Atlee 1, 13.80 MW from Buffalo Atlee 2, and 17.25 MW from Buffalo Atlee 3.

Capstone retained Golder Associates Ltd. (Golder) to assess shadow flicker resulting from the Project wind turbines. The results of the Project shadow flicker assessment are presented in this report. This report is structured as follows:

- Section 1 provides a brief introduction
- Section 2 presents a description of the Project wind turbines
- Section 3 outlines the assessment approach, including a description of:
  - assessment cases
  - shadow flicker receptors
  - assessment criteria
  - shadow flicker modelling methods
- Section 4 presents results for each assessment case
- Section 5 discusses the results of the shadow flicker assessment
- Section 6 provides a brief conclusion

2.0 PROJECT DESCRIPTION

The Project will consist of eleven Siemens Gamesa SG 4.5-145 wind turbines. The Project wind turbines will consist of three-blade rotors and tubular towers that will operate at a hub height of 127.5 metres (m) and a rotor diameter of 145 m, totalling 200 m above ground level.

Table 1 presents the location of Project wind turbines. A map showing the locations of Project wind turbines is presented in Section 3.2 of this report (see Figure 1).

Table 1: Project Wind Turbines

Project Phase	Turbine Identification Code	Universal Transverse Mercator Coordinates [NAD83, Zone 12]	
		Easting [m]	Northing [m]
Buffalo Atlee 1	BA1_T1	497102	5621225
	BA1_T2	497071	5620759
	BA1_T3	497608	5620272
	BA1_T4	497028	5620141
Buffalo Atlee 2	BA2_T1	491659	5618204
	BA2_T2	492341	5617440
	BA2_T3	492205	5617009
Buffalo Atlee 3	BA3_T1	495426	5619890
	BA3_T2	495586	5619388
	BA3_T3	496402	5619369
	BA3_T4	496556	5619899

3.0 ASSESSMENT APPROACH

3.1 Assessment Cases

Shadow flicker occurs when the spinning rotor of a wind turbine is located between the sun and a receptor point (e.g., an occupied dwelling). As the turbine blades alternately block sunlight and allow sunlight to shine through, the shadow at the receptor point may be observed to flicker under certain environmental conditions. For shadow flicker to occur, the sun must be shining, the sun must be low enough in the sky that the shadow of the wind turbine falls across the receptor point, the wind turbine must be active (i.e., the rotor must be spinning), and the turbine rotor must be oriented such that the blades are not parallel to the line joining the sun and receptor point. The shadow flicker assessment for the Project considered two assessment cases representing two different sets of environmental conditions.

"Worst Case" assumes that the sun is always shining during daylight hours (i.e., there are no cloudy periods), all Project wind turbines are always active (i.e., rotors spinning), and all Project wind turbines are always oriented with their rotors perpendicular to the line joining the sun and all receptor points. "Worst Case" is highly conservative (i.e., likely to overestimate potential shadow flicker effects) because the sun is not always shining, and Project wind turbines are not always active. In addition, the orientation of Project wind turbines will change continuously based on wind direction, so turbine rotors are not always oriented perpendicular to the line joining the sun and receptor points.

"Expected Case" makes use of statistical weather data to reduce some of the conservatism inherent in the "Worst Case" assessment. In particular, "Expected Case" uses statistical weather data to estimate the probability of sunshine for each month of the year. In addition, "Expected Case" uses statistical weather data to estimate the probability of different wind directions, and hence turbine orientations. Even with the use of statistical weather data, "Expected Case" is still a conservative evaluation of potential shadow flicker effects because it assumes that Project wind turbines are always active (i.e., turbine rotors are always spinning), which is not the case.

3.2 Receptors

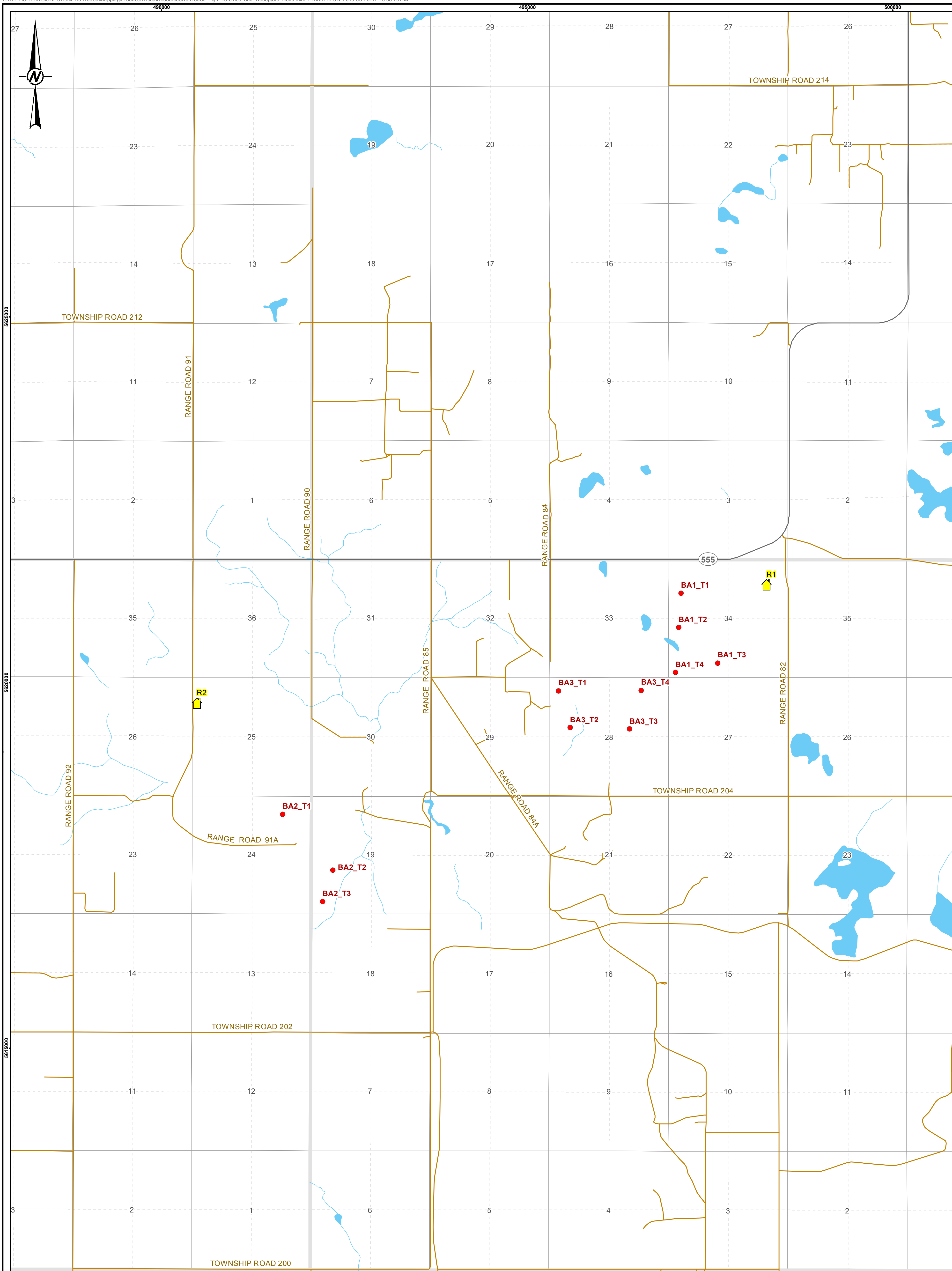
Two receptors were considered in the Project shadow flicker assessment. In particular, the Project shadow flicker assessment considered all occupied dwellings located within a two-kilometre (km) buffer around the Project wind turbines. The receptor points considered in the Project shadow flicker assessment were the same as the receptors considered in the noise impact assessment prepared for the Project (Golder 2019).

When assessing potential shadow flicker effects, each receptor point was assumed to be sensitive to shadow flicker in any direction. In other words, each receptor point was assumed to have windows facing in all directions. This approach is often referred to as greenhouse mode modelling. Greenhouse mode modelling is conservative, since receptors may not actually have windows facing in all directions. In addition, trees, outbuildings, and other local structures can screen shadow flicker effects. These local shadow screens were not considered when modelling receptors, which adds further conservatism to the shadow flicker assessment.

Table 2 presents locations for the two receptors considered in the Project shadow flicker assessment. For each receptor, Table 2 also identifies and provides the distance to the closest Project wind turbine. Figure 1 presents a map showing the locations the Project wind turbines and the shadow flicker receptors.

Table 2: Shadow Flicker Receptors

Receptor Identification Code	Universal Transverse Mercator Coordinates [NAD83, Zone 12]		Receptor Description	Closest Wind Turbine	Distance to Closest Wind Turbine [m]
	Easting [m]	Northing [m]			
R1	498270	5621337	occupied dwelling	BA1_T1	1,173
R2	490484	5619719	occupied dwelling	BA2_T1	1,917



LEGEND

- TURBINE
- DWELLING RECEPTOR
- SECONDARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY

0 1,000 2,000

1:50,000 METRES

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
CAPSTONE

PROJECT
BUFFALO ATLEE

TITLE
WIND TURBINES AND RECEPTORS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-08-26
DESIGNED	VY
PREPARED	AL
REVIEWED	VY
APPROVED	AF

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3.3 Assessment Criteria

There are no federal or provincial guidelines or regulations that specify limits or criteria for assessing shadow flicker effects for facilities in Alberta or elsewhere in Canada. In the absence of federal or provincial guidance, the Project shadow flicker assessment compared the predicted shadow flicker from the Project to widely-used guidelines (Koppen et al. 2017; LUNG 2017), which recommend that exposure to shadow flicker be limited to a maximum of 30 hours per year and a maximum of 30 minutes per day.

3.4 Modelling Methods

Project shadow flicker effects were modelled using WindPro v2.7, a commercial software tool developed and distributed by EMD International A/S. Separate WindPro models were created for the “Worst Case” and the “Expected Case”.

Inputs to the WindPro models for both assessment cases included location, hub height, and rotor diameter for the Project wind turbines, location of shadow flicker receptors, and terrain elevation contours at 5 m intervals. Additional inputs to the WindPro model for the “Expected Case” included statistical data about monthly sunshine and long-term wind direction in the Project study area.

Table 3 presents the statistical sunshine data used in the WindPro model for the “Expected Case”. This statistical sunshine data was obtained from a meteorological station located in Suffield, Alberta, which is approximately 50 km south-southwest of the Project. Table 4 presents statistical wind direction data used in the WindPro model for the “Expected Case”. This statistical wind direction data is based on extrapolated, long-term adjusted data from the Project meteorological tower.

Table 3: Statistical Sunshine Data Used to Model the "Expected Case"

Month	Average Daily Sunshine Hours
January	3.34
February	4.39
March	5.56
April	7.26
May	8.85
June	9.92
July	10.59
August	9.78
September	6.62
October	5.84
November	4.03
December	2.92

Table 4: Statistical Wind Direction Data Used to Model the "Expected Case"

Wind Direction [degrees relative to North]	Hours Per Year
0 – North	447
30	429
60	499
90 – East	701
120	701
150	701
180 – South	832
210	929
240	867
270 – West	876
300	946
330	832
Total	***8,760***

The WindPro models predicted shadow flicker effects at each of the receptors listed in Table 2 based on the daily and yearly path of the sun through the sky at the Project latitude. In the “Worst Case”, the WindPro model assumed that the sun was always shining, the wind turbines were always active, and the turbine rotors were always oriented perpendicular to the line joining the sun and each receptor point. In the “Expected Case”, the WindPro model adjusted the predictions to account for statistical monthly sunshine data and to account for turbine orientation based on statistical wind direction data. In both the “Worst Case” and the “Expected Case”, each receptor point was modelled in greenhouse mode (i.e., sensitive to shadow flicker in every direction). Modelling for both the “Worst Case” and the “Expected Case” considered screening by terrain features (e.g., hills and valleys), but neither assessment case considered screening effects from trees, outbuildings, or other local structures.

4.0 RESULTS

Table 5 presents shadow flicker modelling results for the “Worst Case” and the “Expected Case”. Shadow flicker results are presented for each of the receptors identified in Table 2. For the “Worst Case”, results are presented in the form of total hours of shadow flicker per year, number of days per year with shadow flicker, and maximum minutes of shadow flicker on a single day. For the “Expected Case”, results are presented in the form of total hours of shadow flicker per year. Note that daily results are not available for the “Expected Case” because the modelling algorithm is based on monthly sunshine statistics and long-term wind direction data. Figure 2 presents a contour map of modelling results in the form of total hours of shadow flicker per year for the “Expected Case”.

Table 5: Shadow Flicker Modelling Results

Receptor Identification Code	“Worst Case”			“Expected Case”
	Total Hours of Shadow Flicker Per Year	Number of Days Per Year with Shadow Flicker	Maximum Minutes of Shadow Flicker on a Single Day	Total Hours of Shadow Flicker Per Year
R1	38.4	130	29	11.2
R2	0.0	0	0	0.0

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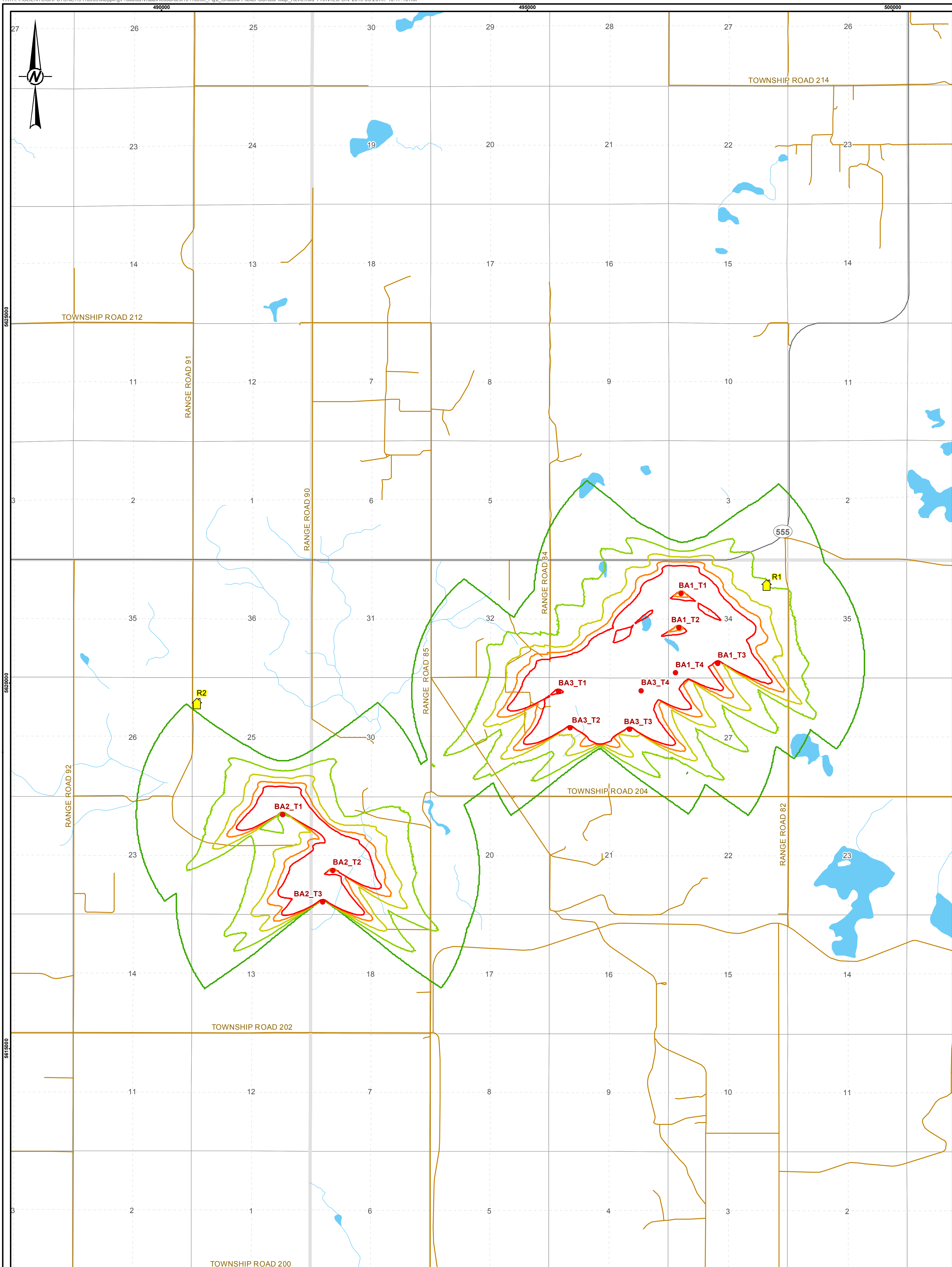

LEGEND

- TURBINE
- DWELLING RECEPTOR

SHADOW FLICKER [HOURS/YEAR]

- ~0
- 10
- 20
- 30
- 40

- SECONDARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY

0 1,000 2,000

1:50,000 METRES

NOTE(S)

1. LOCATIONS OUTSIDE THE "~0" CONTOUR LINE WILL EXPERIENCE NO SHADOW FLICKER AS A RESULT OF THE PROJECT

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
CAPSTONE

PROJECT
BUFFALO ATLEE

TITLE
SHADOW FLICKER CONTOUR MAP – STATISTICAL SUNSHINE AND WIND DIRECTION ("EXPECTED CASE")

CONSULTANT

GOLDER

YYYY-MM-DD	2019-08-26
DESIGNED	VY
PREPARED	AL
REVIEWED	VY
APPROVED	AF

PROJECT NO.	CONTROL	REV.	FIGURE
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5.0 DISCUSSION

The results presented in Table 5 indicate that receptor R2 will experience no shadow flicker as a result of the Project wind turbines but receptor R1 will experience some shadow flicker. In the “Worst Case”, which assumes the sun is always shining and turbines are always operating with rotors perpendicular to the line joining the sun and receptor points, modelling predicts that receptor R1 will experience more than 30 hours of shadow flicker per year but will not experience more than 30 minutes of shadow flicker on any day.

The modelling assumptions used in the “Worst Case” are unrealistic and highly conservative (i.e., tending to overestimate potential shadow flicker effects). The “Expected Case” predicts potential shadow flicker effects under more realistic, but still conservative, environmental conditions. The “Expected Case” makes use of statistical sunshine data (rather than assuming the sun is always shining) and statistical wind direction data (rather than assuming turbine rotors are always perpendicular to the line joining the sun and receptor points). The “Expected Case” is still a conservative treatment of potential shadow flicker effects, however, since the “Expected Case” assumes the Project turbines are always active (i.e., rotors always spinning), assumes that receptors are sensitive to shadow flicker in all directions (i.e., greenhouse mode), and does not account for screening by trees, outbuildings, or other local structures.

Modelling for the “Expected Case” predicts that receptor R1 will experience less than 30 hours of shadow flicker per year. Furthermore, satellite photographs of receptor R1 show vegetation and outbuildings south and southwest of the occupied dwelling, which may provide partial line-of-sight screening for the Project turbines that potentially contribute shadow flicker at this receptor (i.e., BA1_T1, BA1_T2, and BA1_T4).

6.0 CONCLUSION

A shadow flicker assessment was completed for the Buffalo Atlee 1, 2, and 3 Wind Power Projects. The shadow flicker assessment evaluated two conservative modelling scenarios: “Worst Case” and “Expected Case”. The shadow flicker assessment considered potential effects at both occupied dwellings located within 2 km of the Project wind turbines: R1 and R2.

The “Worst Case” assessment assumed the sun is always shining during daylight hours (i.e., there are no cloudy periods), all Project wind turbines are always active (i.e., rotors spinning), and all Project wind turbines are always oriented with their rotors perpendicular to the line joining the sun and all receptor points. The “Expected Case” assessment used statistical weather data to estimate the probability of sunshine for each month of the year and to estimate the probability of different wind directions, and hence turbine orientations. Both assessment cases assumed that receptors are sensitive to shadow flicker in any direction (i.e., greenhouse mode) and neither assessment case accounted for the screening of shadow flicker by vegetation, outbuildings, or other structures.

In the “Worst Case” assessment, one receptor (R1) is predicted to experience shadow flicker in excess of the 30 hours per year guideline level (Koppen et al. 2017; LUNG 2017). In the “Worst Case” assessment none of the receptors are predicted to experience shadow flicker in excess of the 30 minutes per day guideline level (Koppen et al. 2017; LUNG 2017).

In the “Expected Case” assessment, none of the receptors are predicted to experience more than 30 hours per year of shadow flicker. In the “Expected Case” assessment, a maximum of 11.2 hours per year of shadow flicker is predicted for receptor R1. However, actual shadow flicker experienced by R1 is likely to be reduced by the presence of vegetation and outbuildings, which may provide partial screening for the Project turbines during those hours when the sun is low enough to create long shadows.

In conclusion, the present assessment demonstrates there is minimal potential for shadow flicker effects from the Project. In particular, the assessment concludes that receptor R2 will not experience any shadow flicker as a result of the Project and that shadow flicker at R1 will be less than 30 hours per year and less than 30 minutes per day.

Signature Page

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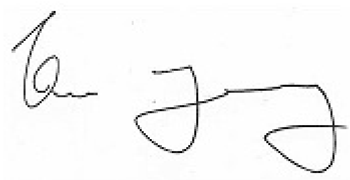

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https://golderassociates.sharepoint.com/sites/103641/deliverables/shadow flicker assessment/buffaloatlee shadowflickerassessment final.docx

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LUNG (Das Landesamt für Umwelt, Naturschutz und Geologie [Land Office for Environment, Nature Conservation and Geology]). 2017. *Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergianlagen* [*Instructions for the Determination and Assessment of the Optical Emissions of Wind Turbine Installations*]. Website: *https://www.lung.mv-regierung.de/dateien/wea_schattenwurf_hinweise.pdf.* Accessed September 18, 2017.

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