Appendix L

Shadow Flicker Report

SHADOW FLICKER ANALYSIS
Ostrander Point Wind Energy Park, Ontario

Prepared for
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

This report presents the results of a shadow flicker analysis for the Ostrander Point Wind Energy Park. The Project is located along the coastline of Lake Ontario, approximately 15 km southeast of the community of Picton.

This report includes an explanation of shadow flicker, the methodology used, results of the analysis including a map illustrating shadow flicker zones, and concluding comments.

2 SHADOW FLICKER BACKGROUND

2.1 Definition

Shadow flicker is defined as the alternating light intensity produced by a wind turbine as the rotating blade casts shadows on the ground and stationary objects, such as the window of a residence. No flicker will occur when the turbine is not rotating or when the sun is obscured by clouds or fog. A larger turbine rotor diameter will cast a larger shadow, meaning a larger area will be prone to incidences of shadow flicker.

The two key factors related to shadow flicker occurrence (measured in number of hours per year or minutes per day) are i) the spatial relationships between a wind turbine and the receptor and ii) the wind direction. These factors are discussed below.

2.1.1 Spatial Relationships

At distances of greater than approximately 500 m between a turbine and a receptor, shadow flicker generally occurs only at sunrise or sunset when the cast shadows are extremely long. It is generally considered that 900 m is the limit beyond which shadow flicker becomes insignificant or non-existent. **Erreur ! Source du renvoi introuvable.** shows an approximation of the shadow cast by a turbine at various times during the day, where the red shading represents the area where shadow flicker may occur.

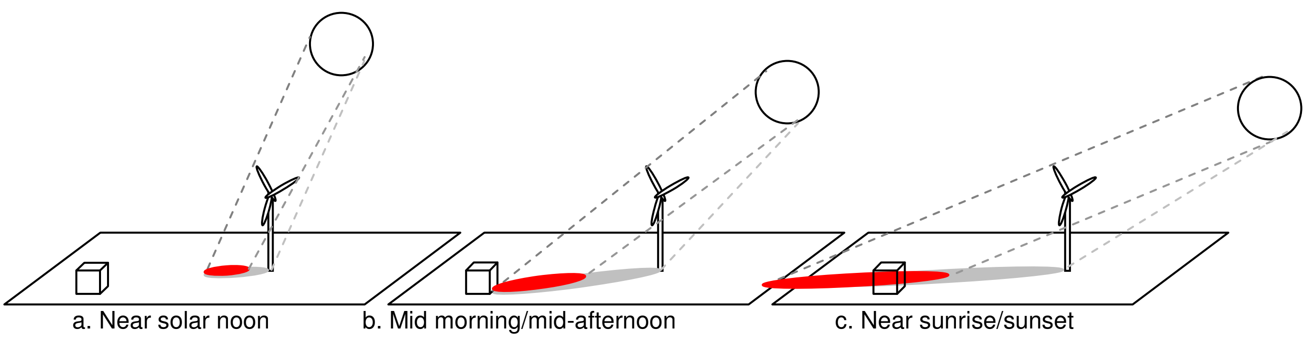


Figure 2-1: Shadow-prone Area as a Function of Time of Day

Buildings to the north or south of wind turbines are less likely to receive shadow flicker than those to the east or west because shadows cast in the northerly and southerly directions are very short.

2.1.2 Wind Direction

The angle between the sun and the rotor plane also plays a determining role for both shadow flicker occurrence and intensity. The rotor plane is determined by the direction of the wind: because the turbine rotor continuously yaws to face the wind, the rotor plane will always be perpendicular to the wind direction. Shadow flicker will be most pronounced when the rotor plane is perpendicular to the sun-receptor line of sight.

3 METHODOLOGY

Shadow flicker was calculated using the industry-standard simulation software WindFarm, a tool which has been successfully applied to a number of similar studies around the world. The WindFarm model uses a worst case scenario when reporting shadow flicker results. The model assumes that:

1. The sun will always be shining during daylight hours, with no cloud cover or fog.
2. The wind will blow continuously throughout the day and always above cut-in speed, i.e. the turbine will always be rotating.
3. The wind will always be blowing from a direction such that the turbine rotor is aligned with the sun/receptor line. In other words, the rotor will yaw in parallel with the sun such that the rotor blades are always perpendicular to the sun-receptor view line.

To this "astronomical worse-case scenario" model, Helimax factors in a realistic percentage of cloud cover for the area, taken from the closest Environment Canada meteorological station. For the Ostrander Project, the Environment Canada station in Trenton, Ontario, was used to estimate the cloud cover. Low visibility weather conditions will result in lower shadow flicker intensity. Furthermore, it should be noted that meteorological conditions such as clear skies and wind are often mutually exclusive.

It is important to note that even when cloud cover is taken into account, the results are still considered "worse-case" as:

- It is assumed that the rotor is always spinning.
- It is assumed that the rotor is always perpendicular to the sun/receptor line of sight.
- The model does not take into account probable screening. Obstacles such as trees or buildings located between the receptor and the wind turbine will reduce or eliminate the occurrence and/or intensity of the shadow flicker.
- The model assumes that each point of reception is covered by windows. This is modelled by actually considering the dwelling as a flat window at 1.5 m above ground level. Thus all periods when flicker "hits" the window are counted.
- Only two cases – possibility of flicker or no possibility of flicker – are considered by the WindFarm model. There is no parameter that speaks for the distinctiveness of the shadow when, actually, the longer a shadow is, the less visible it becomes (i.e. the finite definition of the shadow's form, and its darkness).
- When a turbine is located close enough to a receptor such that the blades cover most of the sun's disc (as seen by the receptor), the flicker intensity will be high. Shadow flicker intensity will diminish at greater distances as the blades will cover a smaller portion of the sun's disc.
- Beyond a certain distance from a turbine (somewhere in the range of 500 m to 1000 m or more), the rotor will no longer appear to be "chopping the light", but rather the turbine will resemble a stationary object with the sun behind it.

3.1 Presentation of Results

Results are presented in hours/year and minutes/day.

For the yearly values, the model calculates the total number of hours of flicker at each dwelling. For the daily values, the model calculates the number of minutes of flicker for each day of the year, and singles out the day with the maximum number of minutes; this value is presented for each dwelling.

3.2 Model Inputs

The following tables summarize the various inputs to the model.

Table 3-1 : Model Inputs

Input	Details
Hub Height	78 m
Rotor Diameter	82 m
Total Height	119 m
Number of turbines	12
Study Area	Turbine Array footprint, with an additional 1500 m
Points of Reception	8

Table 3-2 : Cloud Cover

Input	Details
EC Station	Trenton Ontario
Cloud amount: 3 to 7 tenths	20.5%
Cloud amount: 8 to 10 tenths	52.7%
Percentage of Cloud cover considered for Project (50% of 3 to 7 tenths, 100% of 8 to 10 tenths)	63.0%

Table 3-3 : Turbine Coordinates (UTM18-NAD 83)[1]

ID	Easting [m]	Northing [m]
1	338274	4862699
2	338480	4862496
3	338681	4862291
4	338873	4862085
5	338736	4863021
6	339017	4862739
7	339293	4862469
8	339238	4863294
9	339483	4863072
10	339729	4862811
11	339240	4863706
12	340169	4862885

[1] As per layout L11-554OSTRAND(GP22501)-T01-20081126-SD.WLX

4 RESULTS

The following table presents the complete results of the shadow flicker analysis, and shows that potential maximum flicker occurrence, calculated with the methodology presented above, will not exceed 30 hours per year or 30 minutes per day at any receptor. Although there are no specific by-laws or legislature in effect on permissible levels of shadow flicker prescribed by Prince Edward County or the Province of Ontario, a maximum of 30 hours per year has been used as a guideline in other jurisdictions (Europe, Essex County, etc.). The highest values are found at Point of Reception 1 where it was calculated that 13.7 hours/year of flicker would occur, and a maximum of 25.2 minutes of flicker on any given day.

It should be noted that these values remain conservative, as the model assumes that the rotor is always perpendicular to the sun/receptor line of sight; the model also assumes no screening from trees or buildings. The map presented below illustrates the simulated flicker zones.

Table 4-1 : Shadow Flicker Maximum Occurrence at all Points of Reception in Study Area

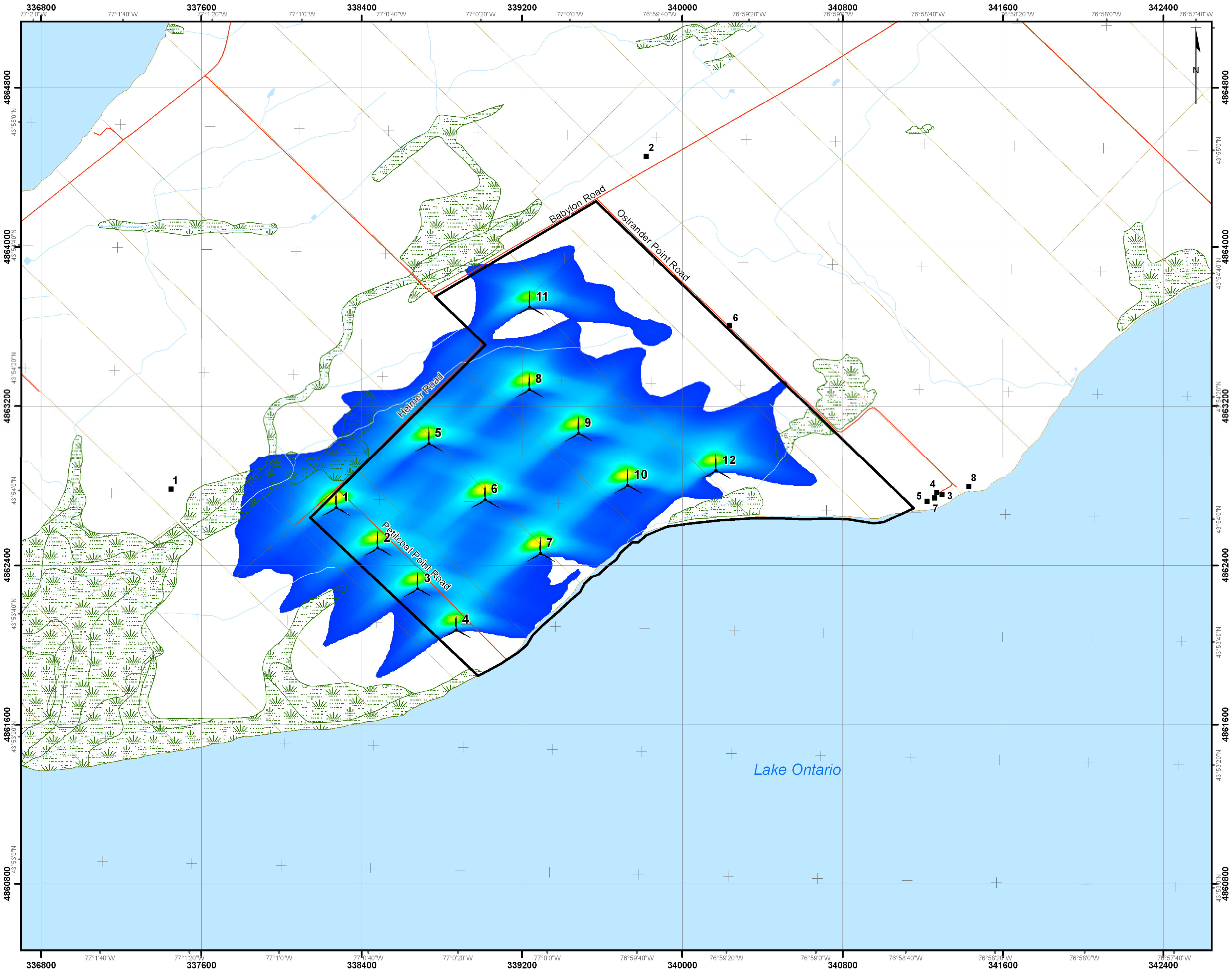
Point of Reception (PoR) ID	UTM coordinates		Results at PoR	
	Easting [m]	Northing [m]	[hrs/yr]	[maximum mins/day]
1	337449	4862785	13.7	25.2
2	339821	4864457	5.8	23.4
3	341297	4862757	2.9	19.2
4	341271	4862768	3.0	19.8
5	341222	4862724	5.4	20.4
6	340236	4863608	12.9	23.4
7	341260	4862741	3.2	20.4
8	341431	4862798	2.3	17.4

5 CONCLUSION

This shadow flicker analysis was performed on a study area of 1.5 km around every wind turbine, which comprised a total of 8 points of reception. Shadow flicker occurrence was modeled based on industry standards and a sophisticated program capable of calculating number of hours/year and minutes/day of shadow flicker.

According to this analysis, the highest values were found at Point of Reception 1 where it was calculated that 13.7 hours/year of flicker would occur, and a maximum of 25.2 minutes of flicker on any given day. It is important to note as well that the calculated values presented in the previous section are considered conservative, given the conservative nature of the assumptions used in this modeling exercise. While there is no regulation on permissible flicker in Prince Edward County, potential shadow flicker occurrence, at all points of reception around this wind farm project, are considered low and at acceptable levels.

APPENDIX A SHADOW FLICKER MAP



Legend

- Primary Study Area
- Wind Turbine (12)
- Point of Reception (Dwelling)
- Road
- Lot
- Watercourse
- Wetland
- Waterbody

Shadow Flicker [hour/year]

30

315

Worst-case scenario calculations based on the following assumptions :
i. Turbine rotor is always perpendicular to the sun-house line-of-sight
ii. Turbines are always spinning
iii. No screening from trees

0 0.2 0.4 0.8 kilometres

GILEAD POWER CORP.

Ostrander Wind Project

SHADOW FLICKER

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Projection: UTM Zone 18, NAD83
Sources: OMNR and Geobase.