CHALEUR VENTUS WIND ENERGY PROJECT

APPENDIX D - SHADOW FLICKER ASSESSMENT

CHALEUR VENTUS LIMITED PARTNERSHIP

CHALEUR VENTUS WIND ENERGY PROJECT

SHADOW FLICKER ASSESSMENT FOR 116 METRE HUB HEIGHT

CHALEUR VENTUS LIMITED PARTNERSHIP

September 2019

CHALEUR VENTUS WIND ENERGY PROJECT

SHADOW FLICKER ASSESSMENT FOR 116 METRE HUB HEIGHT

CHALEUR VENTUS LIMITED PARTNERSHIP

VERSION 1

WSP PROJECT NO.: 181-07802
DATE: SEPTEMBER 26, 2019

WSP
1 SPECTACLE LAKE DRIVE
DARTMOUTH, NS, CANADA B3B 1X7

T +1 902-935-9955
F +1 902-835-1645
WSP.COM

SIGNATURES

PREPARED BY

Alex Medd, E.I.T.
Specialist, Power

REVIEWED BY

Errol Halberg, P. Eng
Manager, Power

This report was prepared by WSP for the account of CHALEUR VENTUS LIMITED PARTNERSHIP, in accordance with the professional services agreement. The disclosure of any information contained in this report is the sole responsibility of the intended recipient. The material in it reflects WSP's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. WSP accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. This limitations statement is considered part of this report.

The original of the technology-based document sent herewith has been authenticated and will be retained by WSP for a minimum of ten years. Since the file transmitted is now out of WSP's control and its integrity can no longer be ensured, no guarantee may be given with regards to any modifications made to this document.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 EXECUTIVE SUMMARY

Impact of shadow flicker was quantified as total hours per year and maximum minutes per day. The SHADOW module of the WindPRO software package was used to model “worst-case” and “corrected-case” scenarios for the shadow flicker at 90 receptor locations within or near project boundaries. Shadow receptor locations were identified by WSP and are based on active residences within or near the Chaleur Ventus Wind Energy Project (Project). The receptors have been field validated.

Inputs to the model include terrain data, wind energy converter (WEC) specifications, geographic location of the Project (to determine the daily sun path), and on-site meteorological data. The shadow flicker modelled for the worst-case assumes that the sky is clear during all daylight hours, the turbine rotor is always perpendicular to the sun, and that the WEC blades are always rotating. In contrast, the shadow flicker modelled for the corrected-case reduces the hours of shadow flicker to account for the times when the sun is not shining, the turbine is not operating, or the orientation of the turbine (due to the direction of the wind) is not perpendicular to the sun. Public weather station data is used to determine the probability of bright sunshine and on-site meteorological data is used to estimate the periods of turbine operation and turbine orientation.

This analysis considers the 5 x Enercon E126 EP3 4.0 MW layout on 116 m towers.

The receptors with the highest shadow flicker impact from the project are listed in Table 1. New Brunswick does not have provincial standards specifying an acceptable limit of shadow flicker at a receptor.

It is important to consider that the modelling assumptions used in the shadow calculation are conservative and may result in an overestimation of the shadow flicker amounts. The model assumes receptors are susceptible to shadow flicker from all directions but this may not be the case. The actual size, location and orientation of the receptor’s windows relative to WEC locations may reduce the degree of flicker inside the dwellings. In addition, the presence of buildings, trees, and other obstacles are not considered by the model and may also reduce the effects of shadow flicker on these receptors.

Table 1 The Five Most Impacted Shadow Flicker Receptors by the 5 x E126 at 116 m Hub Height Turbine Layout

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	**Type**	**X**	**Y**	**Elevation**	**Annual**	**Max Daily**	**Annual**	**WEC**	**Month**
59	House	341658	5297042	14	69:13	0:47	25:13	T1	July
61	House	341582	5297007	14	55:35	0:42	20:17	T1	July
63	House	341635	5296917	14	41:11	0:43	15:22	T1	June
50	House	344604	5297809	10	41:30	0:36	13:22	T5	September
53	House	344710	5297634	10	38:56	0:32	12:39	T5	July

2 INTRODUCTION

This report provides a summary of the Shadow Flicker Assessment completed in support of the Project Registration Document that was submitted to the Sustainable Development, Planning and Impact Evaluation Branch, Department of Environment and Local Government in September of 2019.

The purpose of this report is to present the methods and results of the shadow flicker assessment for a hub height of 116 m. The impact of shadow flicker receptors is assessed for both the "corrected-case" and "worst-case" modelling scenarios.

2.1 PROJECT OVERVIEW

Chaleur Ventus Limited Partnership (CVLP) is proposing the development of the Project. The Project is located on privately owned land south of route 303 in Gloucester County, New Brunswick, and will have an aggregate electrical capacity of 20 megawatts (MW). The Project will consist of five WECs, access roads, collection system, substation, and associated temporary laydown areas required for construction. An approximate 9 kilometre (km) transmission line is proposed that runs south and southwest from the Project area to a proposed substation that will be located on Crown land approximately 2.8 km southeast of Saint-Leolin.

The Project is expected to consist of Enercon E-126 WECs with a nominal power of 4 MW. Each assembly will consist of the tower, hub, nacelle, rotor blades, and controller, with a total height of 179.5 to 194.5 m and is dependant on WEC availability from Enercon. The total WEC rotor diameter will be 127 m. It is anticipated that each WEC will be erected on a concrete foundation. The dimensions, depth, and type of foundation will depend on an evaluation of the local soil, surficial geology characteristics, wind forces at the location, and site-specific details of each location.

2.2 OVERVIEW OF SHADOW FLICKER

Shadow flicker occurs when the rotating blades of a turbine pass through the path between the sun and a receptor window when the sun is not obstructed by clouds. This phenomenon is dependent on weather conditions, site topography, and wind direction. The severity of shadow flicker will change both seasonally and hourly because of the daily and seasonal movements of the sun.

Shadow flicker can be calculated using the worst-case scenario or the corrected-case scenario. The worst-case, or "astronomical maximum" shadow flicker analysis, considers only the relative geographical location between WECs and receptors and assumes the sun is shining and the WEC rotor is spinning perpendicular to the path of the sunlight at all times. The corrected-case, or "meteorologically probable", shadow flicker analysis utilizes on-site wind data and expected sunshine probability statistics to account for periods when: the turbine is not operational; the orientation of the turbine is not perpendicular to the path of the sunlight; and the sunlight is not strong enough to cast a shadow.

The occurrence of shadow flicker within a residence occurs when the rotating blades of a turbine momentarily interrupt the sunlight shining into the window of a receptor. The occurrence of shadow flicker may be reduced by the following:

- Obstructions that block the sunlight from reaching the window during some or all the time that shadow flicker is occurring;
- The orientation of the WEC due to changing wind direction.

CVLP will track concerns related to shadow flicker throughout the Project. If the amount of shadow flicker is a concern, WEC curtailment for specific wind directions or times of day may be an effective mitigation technique. In addition, mitigation such as screening of receptors with vegetation, awnings, and/or structures, and/or adding shutters to receptors will be considered, as required.

New Brunswick does not have provincial standards specifying an acceptable limit of shadow flicker at a receptor. This is true for most Canadian jurisdictions.

2.3 SITE DESCRIPTION

The Project is located approximately 49 km east of Bathurst, New Brunswick and is heavily forested. For this analysis, 90 receptors were identified by WSP. Residence locations have been listed in Appendix B and are shown in Appendix E. The receptors have been field validated.

The shadow flicker assessment was completed for the 5 x Enercon E126 EP3 4 MW WEC layout on 116 m towers.

Locations of WECs are listed in Appendix D and are shown in Appendix E.

3 METHODS

3.1 SHADOW FLICKER ALGORITHM AND ASSUMPTIONS

The WindPRO SHADOW module was used to model the shadow flicker at the Project. WindPRO calculates the cumulative effect of shadowing from all WECs with a line of sight to each receptor. The worst-case results are evaluated on yearly and daily averaging periods; the corrected-case on a yearly averaging period.

The blade shadow gets gradually fainter as the distance from the WEC increases and at some distance from the WEC the edge of the turbine shadow will be hard to distinguish by the human eye. Within WindPRO, the maximum distance of shadow propagation may be calculated using the turbine blade width or may be set to a constant, usually ten times the turbine's rotor diameter[1]. A conservative constant distance of 2,000 m was selected for the analysis. Due to atmospheric diffusion and lower light levels, shadow flicker is ignored when the sun is lower than 3° above the horizon. The presented shadow flicker amounts are based only on total frequency of shadow flicker and do not distinguish the character of the shadow flicker.

WindPRO executes a site-specific simulation of the solar trajectory relative to the wind project for an entire year. The complete description and shadow flicker calculation algorithm of WindPRO is provided in Appendix A.

Both the worst-case and corrected-case shadow flicker modelling scenarios assume that receptors have windows oriented in every direction and are, as a result, susceptible to flicker from all directions. This is known as the "greenhouse mode" and represents a conservative estimate of the impact of shadow flicker. Obstacles such as trees or large structures, which could block some or all of the shadow flicker effect at a receptor, are not considered in the analysis thus making the shadow flicker additionally more conservative. Topography was included in the modelling; however, elevation changes smaller than the resolution of the sourced data may not have been captured[2] .

The calculations of modelled worst-case results assume the following:

- The sun is unobstructed by cloud cover for all daylight hours for the entire year.
- The WEC blades are always rotating.
- The turbine rotor is always perpendicular to the path between the sun and the receptor.

The calculation of modelled "corrected-case" shadow flicker incorporated the probability of sunshine (hours of bright sunshine per month). The sunshine hours for the Project were derived from the measurements from the

[1] Parsons Brinckerhoff, Update of UK Shadow Flicker Evidence Base, Department of Energy and Climate Change.
[2] CDSM (Elevation data) has a grid spacing of 8-23 m with a horizontal accuracy of 10 m. The vertical accuracy is 6 m.

Canadian Climate Station - Charlo located approximately 100 km west of the Project site. The monthly probabilities of sunshine used in the modelling are presented in Table 2[3].

Table 2 Average Daily Hours of Bright Sunshine for the Canadian Climate Station - Charlo

MONTH	BRIGHT SUNSHINE [HOURS/DAY]
January	3.80
February	4.71
March	5.03
April	5.73
May	7.07
June	8.23
July	8.22
August	7.84
September	5.68
October	4.25
November	2.83
December	3.16

Wind data for the Project was derived from the Wind Resource Assessment[4] for use in the shadow flicker analysis. WindPRO uses this data to determine the probability that the wind speed will be outside the operational range of the turbines. WindPRO assumes that the blades do not turn when the turbine is not operating and consequently that there will be no shadow flicker during those periods. The corrected case shadow flicker hours include a reduction of 1% from worst case shadow flicker hours to account for the time the turbine blades are not rotating due to the wind speed being out of the operational range of the turbine.

The yaw system of the wind turbine changes the orientation of the rotor according to the wind direction, thus the shadow cast by the rotating blades changes according to the wind direction. The wind rose representing the wind direction distribution at the Chaleur Ventus Wind Power Project is presented in Figure 1. Shadow flicker will have a maximum impact when the rotor is perpendicular to the path of the sun and a minimum impact when the rotor is parallel to a line between the sun and the receptor. Based on the wind rose and orientation of each turbine to each receptor, a yaw correction factor was estimated for each pair and this correction factor is presented in Appendix C. The yaw correction factor has only been estimated for turbine-receptor pairs with at least 1 minute of shadow flicker in a year.

[3] Environment Canada
http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=medicine&searchMethod=begins&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=2273&dispBack=1, accessed September 19, 2017.
[4] 'Naveco_ChaleurVentus_WRR_20190723_v3.pdf' WSP, 2019

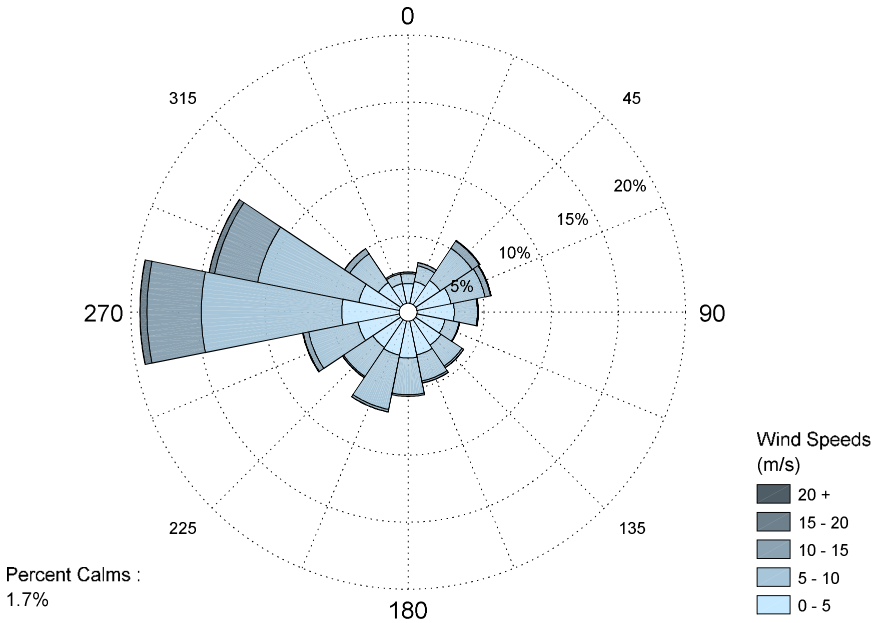


Figure 1 Wind Direction Distribution (Frequency %) at Chaleur Ventus Met Mast 1641 at 60 m

4 RESULTS

4.1 GREENHOUSE MODE SHADOW FLICKER RESULTS

The detailed results of the WindPRO shadow flicker model are presented in tabular form in Appendix B which includes the "corrected-case" annual hours, the “worst-case” annual hours, and the maximum daily minutes of shadow flicker for the “worst-case” scenario. Maps showing the iso-contour results for the “corrected-case” annual hours of shadow flicker have been included in Appendix E.

The results shown in Appendix B and Table 3 represent the predicted cumulative shadow flicker results from the Project. Only receptors experiencing more than 1 minute of shadow flicker originating from a WEC are presented in Table 3. The results also include the largest contributing wind turbine and month.

Table 3 Estimated Shadow Flicker for the E126 EP3 WEC at 116 m Hub Height on Impacted Shadow Receptors

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	TYPE	X	Y	ELEVATION	ANNUAL	MAX DAILY	ANNUAL	WEC	MONTH
1	House	343819	5299263	4	6:50	0:15	1:51	T3	January
4	House	342204	5299245	5	5:50	0:16	1:17	T5	January
5	House	343773	5299243	5	8:03	0:16	2:11	T3	January
7	House	342450	5299221	7	14:03	0:19	3:08	T5	December
8	House	342353	5299212	7	8:59	0:19	2:00	T5	January
11	House	343518	5299191	5	10:19	0:18	2:46	T3	December
17	House	342643	5299126	8	16:43	0:23	3:39	T5	December
18	House	341262	5299086	6	12:55	0:22	2:49	T3	December
19	House	342009	5299086	7	3:24	0:14	0:49	T5	February
21	House	341197	5299083	6	16:38	0:22	3:38	T3	December
22	House	342098	5299079	8	4:01	0:16	0:57	T5	February
23	House	343945	5299078	7	3:26	0:14	0:54	T3	January
24	House	341396	5299050	6	6:37	0:18	1:24	T3	December
27	House	343967	5299025	8	3:21	0:14	0:54	T3	November

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	TYPE	X	Y	ELEVATION	ANNUAL	MAX DAILY	ANNUAL	WEC	MONTH
28	House	343994	5299008	8	3:06	0:14	0:51	T3	February
29	House	343975	5298994	8	3:11	0:14	0:52	T3	February
30	House	343987	5298982	8	3:05	0:13	0:51	T3	February
32	House	344005	5298978	8	2:59	0:14	0:49	T3	February
33	House	340863	5298969	10	10:06	0:18	2:16	T3	December
34	House	344306	5298885	6	13:14	0:26	3:26	T5	December
35	House	344380	5298860	6	24:51	0:31	6:30	T5	December
36	House	344391	5298822	6	31:04	0:32	8:10	T5	December
37	House	344381	5298675	6	30:57	0:34	8:13	T5	January
38	House	340845	5298333	12	18:11	0:20	4:41	T3	February
39	House	340883	5298222	14	19:16	0:21	5:12	T3	February
40	House	340906	5298159	15	20:06	0:22	5:30	T3	February
41	House	340990	5298142	16	23:29	0:23	6:23	T3	February
42	House	341027	5298036	18	25:19	0:24	6:59	T3	September
43	House	341042	5297986	18	26:23	0:25	7:24	T3	April
44	House	344646	5297942	10	34:16	0:34	10:45	T6	March
45	House	344618	5297906	10	37:14	0:35	11:49	T6	August
46	House	340988	5297888	16	24:27	0:24	7:21	T3	August
47	House	344646	5297851	10	35:55	0:34	11:30	T6	August
48	House	344751	5297833	10	28:08	0:30	8:59	T6	September
49	House	341027	5297810	16	27:28	0:25	8:33	T3	August
50	House	344604	5297809	10	41:30	0:36	13:22	T5	September
51	House	341063	5297762	16	30:12	0:26	9:32	T3	August
52	House	344716	5297736	10	32:43	0:32	10:30	T5	September

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	TYPE	X	Y	ELEVATION	ANNUAL	MAX DAILY	ANNUAL	WEC	MONTH
53	House	344710	5297634	10	38:56	0:32	12:39	T5	July
54	House	344884	5297512	10	27:32	0:27	8:56	T5	July
55	House	344964	5297343	10	27:55	0:24	9:09	T5	June
56	House	344980	5297302	10	24:37	0:24	8:04	T5	June
57	House	344978	5297227	10	17:36	0:24	5:43	T6	May
58	House	345032	5297141	10	14:00	0:22	4:31	T6	July
59	House	341658	5297042	14	69:13	0:47	25:13	T1	July
60	House	345088	5297017	8	18:02	0:21	5:53	T6	June
61	House	341582	5297007	14	55:35	0:42	20:17	T1	July
62	House	345086	5296993	8	17:09	0:21	5:35	T6	June
63	House	341635	5296917	14	41:11	0:43	15:22	T1	June
65	House	343991	5296793	8	8:01	0:16	2:36	T1	August
68	House	344128	5296683	9	3:14	0:14	1:02	T1	August
69	House	343414	5296664	5	25:21	0:25	8:17	T1	July
77	House	343596	5296581	4	13:33	0:22	4:22	T1	July

A WINDPRO MODEL

The following information has been modified from section 4.2 of the WindPRO help files.

Introduction to Shadow

SHADOW is the WindPRO calculation module that calculates how often and in which intervals a specific area will be affected by shadows generated by one or more wind turbines. These calculations are expected case scenarios (i.e. calculations which are solely based on the probability of sunshine as calculated from the monthly maximum total duration of bright sunshine and the position of the turbine relative to the sun or the astronomical maximum shadow). Shadow flicker impact may occur when the blades of a wind turbine pass through the sun's rays seen from a specific spot (e.g. a window in an adjacent settlement). If the weather is overcast or calm, or if the wind direction forces the rotor plane of the wind turbine to stand parallel with the line between the sun and the receptor, the wind turbine will not produce shadow flicker impacts.

Apart from calculating the potential shadow flicker impact at a given receptor, a map rendering the iso-lines of the shadow flicker impact can be printed. This printout will render the amount of shadow flicker impact for any spot within the project area.

The time of the day for which shadow flicker impact is critical and the definition of a receptor for which shadow flicker impact is calculated are less rigidly defined by best practices and is often something which should be evaluated in each individual case.

As an example, a factory or office building would not be affected if all the shadow flicker impact occurred after business hours, whereas it would be more acceptable for private homes to experience shadow flicker impact during working hours, when the family members are at work/school.

Finally, the actual amount of shadow flicker impact as a fraction of the calculated potential risk will depend heavily on the geographic location in question. In areas with high rates of overcast weather the problem would obviously decrease, and during potential hours of shadow flicker impact in the summer the wind turbine may often be stationary due to lack of wind.

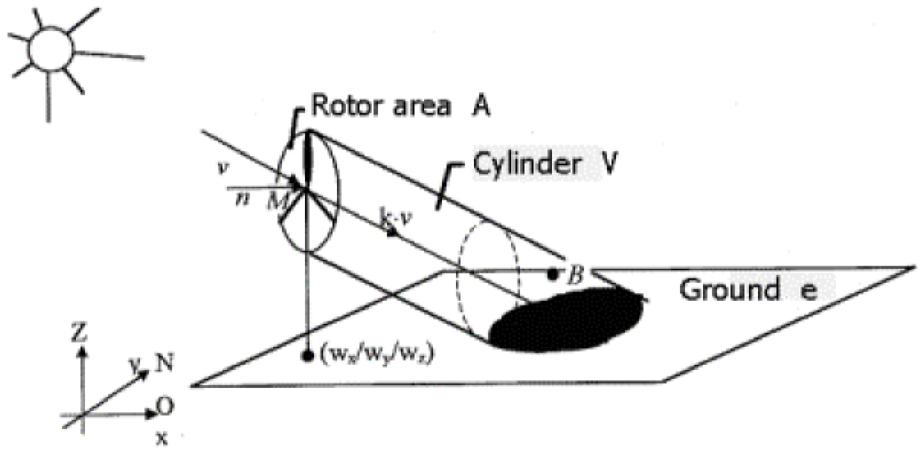
Statistics regarding the wind conditions and number of hours with clear sky can also be considered.

The wind direction reduction factor is calculated by WindPRO based on the geographic location of each receptor, turbine and the site-specific wind rose. A significant strength in the WindPRO system is the option of direct graphic on-screen input of wind turbines and receptors on a map.

The Shadow Calculation Method

The calculation of the potential shadow flicker impact at a given receptor is carried out simulating the situation. The position of the sun relative to the wind turbine rotor disk and the resulting shadow flicker is calculated in steps of 1 minute throughout a complete year. If the shadow flicker of the rotor disk (which in the calculation is assumed solid) at any time casts a shadow flicker reflection on the window, which has been defined as a receptor object, then this step will be registered as 1 minute of potential shadow flicker impact. The following information is required:

- The position of the wind turbines (x, y, z coordinates)
- The hub height and rotor diameter of the wind turbines
- The position of the receptor object (x, y, z coordinates)
- The size of the window and its orientation, both directional (relative to south) and tilt (angle of window plane to the horizontal).
- The geographic position (latitude and longitude) together with time zone and daylight-saving time information.
- A simulation model, which holds information about the earth's orbit and rotation relative to the sun.


Rotor area A
Cylinder V
v
n
M
k·v
B
Ground e
Z
y
N
O
x
(wx/wy/wz)

B SHADOW FLICKER RESULTS

5 x Enercon E126 EP3 4.0 MW at 116 m Hub Height Shadow Flicker Results

RECEPTOR		LOCATION NAD83, UTM ZONE 12			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	TYPE	X	Y	ELEVATION	ANNUAL	MAX DAILY	ANNUAL	TURBINE	MONTH
1	House	343819	5299263	4	6:50	0:15	1:51	T3	January
2	House	343886	5299251	4	0:00	0:00	0:00	-	-
3	House	342809	5299250	6	0:00	0:00	0:00	-	-
4	House	342204	5299245	5	5:50	0:16	1:17	T5	January
5	House	343773	5299243	5	8:03	0:16	2:11	T3	January
6	House	342704	5299242	5	0:00	0:00	0:00	-	-
7	House	342450	5299221	7	14:03	0:19	3:08	T5	December
8	House	342353	5299212	7	8:59	0:19	2:00	T5	January
9	House	343216	5299208	5	0:00	0:00	0:00	-	-
10	House	343928	5299203	5	0:00	0:00	0:00	-	-
11	House	343518	5299191	5	10:19	0:18	2:46	T3	December
12	House	343077	5299188	6	0:00	0:00	0:00	-	-
13	House	342899	5299170	6	0:00	0:00	0:00	-	-
14	House	341758	5299141	5	0:00	0:00	0:00	-	-
15	House	343950	5299136	6	0:00	0:00	0:00	-	-
16	House	341697	5299133	5	0:00	0:00	0:00	-	-
17	House	342643	5299126	8	16:43	0:23	3:39	T5	December
18	House	341262	5299086	6	12:55	0:22	2:49	T3	December
19	House	342009	5299086	7	3:24	0:14	0:49	T5	February
20	House	344186	5299085	6	0:00	0:00	0:00	-	-
21	House	341197	5299083	6	16:38	0:22	3:38	T3	December
22	House	342098	5299079	8	4:01	0:16	0:57	T5	February
23	House	343945	5299078	7	3:26	0:14	0:54	T3	January
24	House	341396	5299050	6	6:37	0:18	1:24	T3	December
25	House	341602	5299048	6	0:00	0:00	0:00	-	-
26	House	344258	5299040	6	0:00	0:00	0:00	-	-
27	House	343967	5299025	8	3:21	0:14	0:54	T3	November
28	House	343994	5299008	8	3:06	0:14	0:51	T3	February

29	House	343975	5298994	8	3:11	0:14	0:52	T3	February
30	House	343987	5298982	8	3:05	0:13	0:51	T3	February
31	House	344261	5298981	6	0:00	0:00	0:00	-	-
32	House	344005	5298978	8	2:59	0:14	0:49	T3	February
33	House	340863	5298969	10	10:06	0:18	2:16	T3	December
34	House	344306	5298885	6	13:14	0:26	3:26	T5	December
35	House	344380	5298860	6	24:51	0:31	6:30	T5	December
36	House	344391	5298822	6	31:04	0:32	8:10	T5	December
37	House	344381	5298675	6	30:57	0:34	8:13	T5	January
38	House	340845	5298333	12	18:11	0:20	4:41	T3	February
39	House	340883	5298222	14	19:16	0:21	5:12	T3	February
40	House	340906	5298159	15	20:06	0:22	5:30	T3	February
41	House	340990	5298142	16	23:29	0:23	6:23	T3	February
42	House	341027	5298036	18	25:19	0:24	6:59	T3	September
43	House	341042	5297986	18	26:23	0:25	7:24	T3	April
44	House	344646	5297942	10	34:16	0:34	10:45	T6	March
45	House	344618	5297906	10	37:14	0:35	11:49	T6	August
46	House	340988	5297888	16	24:27	0:24	7:21	T3	August
47	House	344646	5297851	10	35:55	0:34	11:30	T6	August
48	House	344751	5297833	10	28:08	0:30	8:59	T6	September
49	House	341027	5297810	16	27:28	0:25	8:33	T3	August
50	House	344604	5297809	10	41:30	0:36	13:22	T5	September
51	House	341063	5297762	16	30:12	0:26	9:32	T3	August
52	House	344716	5297736	10	32:43	0:32	10:30	T5	September
53	House	344710	5297634	10	38:56	0:32	12:39	T5	July
54	House	344884	5297512	10	27:32	0:27	8:56	T5	July
55	House	344964	5297343	10	27:55	0:24	9:09	T5	June
56	House	344980	5297302	10	24:37	0:24	8:04	T5	June
57	House	344978	5297227	10	17:36	0:24	5:43	T6	May
58	House	345032	5297141	10	14:00	0:22	4:31	T6	July
59	House	341658	5297042	14	69:13	0:47	25:13	T1	July
60	House	345088	5297017	8	18:02	0:21	5:53	T6	June

61	House	341582	5297007	14	55:35	0:42	20:17	T1	July
62	House	345086	5296993	8	17:09	0:21	5:35	T6	June
63	House	341635	5296917	14	41:11	0:43	15:22	T1	June
64	House	341773	5296866	12	0:00	0:00	0:00	-	-
65	House	343991	5296793	8	8:01	0:16	2:36	T1	August
66	House	342142	5296706	6	0:00	0:00	0:00	-	-
67	House	341945	5296697	9	0:00	0:00	0:00	-	-
68	House	344128	5296683	9	3:14	0:14	1:02	T1	August
69	House	343414	5296664	5	25:21	0:25	8:17	T1	July
70	House	344231	5296662	9	0:00	0:00	0:00	-	-
71	House	341926	5296660	9	0:00	0:00	0:00	-	-
72	House	341996	5296649	8	0:00	0:00	0:00	-	-
73	House	345038	5296617	8	0:00	0:00	0:00	-	-
74	House	341991	5296600	8	0:00	0:00	0:00	-	-
75	House	345098	5296598	8	0:00	0:00	0:00	-	-
76	House	345093	5296582	8	0:00	0:00	0:00	-	-
77	House	343596	5296581	4	13:33	0:22	4:22	T1	July
78	House	345034	5296573	8	0:00	0:00	0:00	-	-
79	House	342040	5296567	7	0:00	0:00	0:00	-	-
80	House	342077	5296559	7	0:00	0:00	0:00	-	-
81	House	345051	5296559	8	0:00	0:00	0:00	-	-
82	House	342149	5296509	6	0:00	0:00	0:00	-	-
83	House	342008	5296495	8	0:00	0:00	0:00	-	-
84	House	344973	5296445	8	0:00	0:00	0:00	-	-
85	House	342126	5296434	7	0:00	0:00	0:00	-	-
86	House	344735	5296371	5	0:00	0:00	0:00	-	-
87	House	342780	5296317	9	0:00	0:00	0:00	-	-
88	House	342745	5296317	9	0:00	0:00	0:00	-	-
89	House	342713	5296288	8	0:00	0:00	0:00	-	-
90	House	342644	5296277	7	0:00	0:00	0:00	-	-

C DIRECTION REDUCTION FACTORS FOR THE CORRECTED CASE

DIRECTION REDUCTION FACTORS – 5 x E126 EP3 4.0 MW layout

ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
T1																														
T2																														
T3	0.72				0.72						0.71							0.57			0.58		0.73	0.57			0.74	0.74	0.74	0.74
T5				0.61			0.59	0.60									0.58		0.64			0.64								
T6																														

ID	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
T1								0.61	0.62	0.63	0.62	0.63	0.64			0.65			0.66		0.66								0.73	
T2			0.57					0.65	0.66	0.66	0.66	0.67	0.67			0.68			0.69		0.70									
T3		0.74	0.63					0.69	0.70	0.71	0.71	0.72	0.73			0.73			0.73		0.73									
T5				0.69	0.69	0.70	0.72							0.69	0.68		0.67	0.67		0.67		0.67	0.66	0.65	0.64	0.64	0.63	0.62		
T6														0.73	0.73		0.73	0.73		0.73		0.72	0.70	0.68	0.67	0.66	0.66	0.65		0.64

ID	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
T1	0.73		0.74		0.67			0.67	0.65								0.65													
T2					0.66																									
T3																														
T5																														
T6		0.64																												

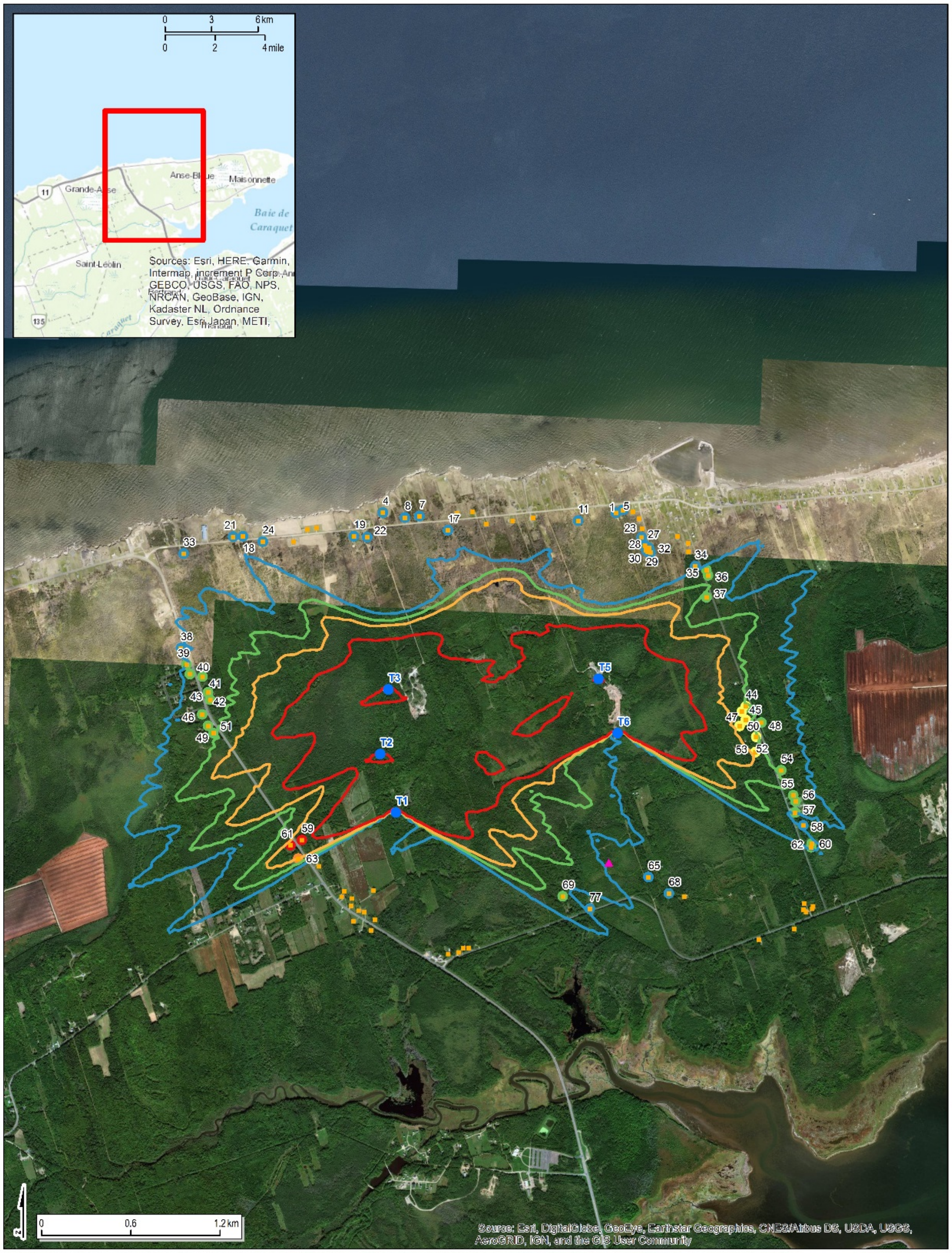
Appendix

D TURBINE LOCATIONS

TURBINE LOCATIONS – 5 X E126 EP3 4.0 MW LAYOUT

LABEL	EASTING UTM NAD83 Z20 (M)	NORTHING UTM NAD83 Z20 (M)	ELEVATION (M)
T1	342,292	5,297,227	13
T2	342,186	5,297,620	14
T3	342,241	5,298,055	12
T5	343,656	5,298,126	8
T6	343,783	5,297,761	7

E MAPS



Chaleur Ventus Wind Power Project
5 x E126 4.0 116 m HH Layout
Corrected Case Shadow Flicker Results

Legend

- Turbine Locations
- Validated Receptors
- Met Mast

Shadow Flicker Hours

- 5
- 10
- 15
- 30

Receptor Shadow Flicker Hours

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- >20

Version: 1
Datum: NAD 83
Projection: UTM Zone 20
Scale: 1:25,000

Prepared by: WSP
Author: A. Medd

In the preparation of this map, WSP has relied upon certain information provided by the client. While WSP has taken reasonable measures to present accurate information in the map, WSP does not warrant the reliability, accuracy, quality, currency, validity, or completeness of information found in the map. The locations shown are for informational purposes only and are not suitable for legal, surveying, or engineering purposes.

CHALEUR VENTUS WIND ENERGY PROJECT

SHADOW FLICKER ASSESSMENT FOR 132 METRE HUB HEIGHT

CHALEUR VENTUS LIMITED PARTNERSHIP

September 2019

CHALEUR VENTUS WIND ENERGY PROJECT

SHADOW FLICKER ASSESSMENT FOR 132 METRE HUB HEIGHT

CHALEUR VENTUS LIMITED PARTNERSHIP

VERSION 1

WSP PROJECT NO.: 181-07802
DATE: SEPTEMBER 26, 2019

WSP
1 SPECTACLE LAKE DRIVE
DARTMOUTH, NS, CANADA B3B 1X7

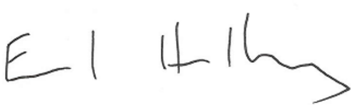
T +1 902-935-9955
F +1 902-835-1645
WSP.COM

SIGNATURES

PREPARED BY

Alex Medd, E.I.T.
Specialist, Power

REVIEWED BY



Errol Halberg, P. Eng
Manager, Power

This report was prepared by WSP for the account of CHALEUR VENTUS LIMITED PARTNERSHIP, in accordance with the professional services agreement. The disclosure of any information contained in this report is the sole responsibility of the intended recipient. The material in it reflects WSP's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. WSP accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. This limitations statement is considered part of this report.

The original of the technology-based document sent herewith has been authenticated and will be retained by WSP for a minimum of ten years. Since the file transmitted is now out of WSP's control and its integrity can no longer be ensured, no guarantee may be given with regards to any modifications made to this document.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 EXECUTIVE SUMMARY

Impact of shadow flicker was quantified as total hours per year and maximum minutes per day. The SHADOW module of the WindPRO software package was used to model "worst-case" and "corrected-case" scenarios for the shadow flicker at 90 receptor locations within or near project boundaries. Shadow receptor locations were identified by WSP and are based on active residences within or near the Chaleur Ventus Wind Energy Project (Project). The receptors have been field validated.

Inputs to the model include terrain data, wind energy converter (WEC) specifications, geographic location of the Project (to determine the daily sun path), and on-site meteorological data. The shadow flicker modelled for the worst-case assumes that the sky is clear during all daylight hours, the turbine rotor is always perpendicular to the sun, and that the WEC blades are always rotating. In contrast, the shadow flicker modelled for the corrected-case reduces the hours of shadow flicker to account for the times when the sun is not shining, the turbine is not operating, or the orientation of the turbine (due to the direction of the wind) is not perpendicular to the sun. Public weather station data is used to determine the probability of bright sunshine and on-site meteorological data is used to estimate the periods of turbine operation and turbine orientation.

This analysis considers the 5 x Enercon E126 EP3 4.0 MW layout on 132 metre (m) towers.

The receptors with the highest shadow flicker impact from the project are listed in Table 1. New Brunswick does not have provincial standards specifying an acceptable limit of shadow flicker at a receptor.

It is important to consider that the modelling assumptions used in the shadow calculation are conservative and may result in an overestimation of the shadow flicker amounts. The model assumes receptors are susceptible to shadow flicker from all directions but this may not be the case. The actual size, location and orientation of the receptor's windows relative to WEC locations may reduce the degree of flicker inside the dwellings. In addition, the presence of buildings, trees, and other obstacles are not considered by the model and may also reduce the effects of shadow flicker on these receptors.

Table 1 The Five Most Impacted Shadow Flicker Receptors by the 5 x E126 at 132 m Hub Height Turbine Layout

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	**Type**	**X**	**Y**	**Elevation**	**Annual**	**Max Daily**	**Annual**	**WEC**	**Month**
59	House	341658	5297042	14	69:17	0:46	25:23	T1	July
61	House	341582	5297007	14	58:12	0:41	21:22	T1	July
53	House	344710	5297634	10	44:26	0:32	14:37	T5	July
50	House	344604	5297809	10	42:44	0:36	13:50	T5	September
63	House	341635	5296917	14	32:55	0:40	12:22	T1	June

2 INTRODUCTION

This report provides a summary of the Shadow Flicker Assessment completed in support of the Project Registration Document that was submitted to the Sustainable Development, Planning and Impact Evaluation Branch, Department of Environment and Local Government in September of 2019.

The purpose of this report is to present the methods and results of the shadow flicker assessment for a hub height of 132 m. The impact of shadow flicker receptors is assessed for both the “corrected-case” and “worst-case” modelling scenarios.

2.1 PROJECT OVERVIEW

Chaleur Ventus Limited Partnership (CVLP) is proposing the development of the Project. The Project is located on privately owned land south of route 303 in Gloucester County, New Brunswick, and will have an aggregate electrical capacity of 20 megawatts (MW). The Project will consist of five WECs, access roads, collection system, substation, and associated temporary laydown areas required for construction. An approximate 9 kilometre (km) transmission line is proposed that runs south and southwest from the Project area to a proposed substation that will be located on Crown land approximately 2.8 km southeast of Saint-Leolin.

The Project is expected to consist of Enercon E-126 WECs with a nominal power of 4 MW. Each assembly will consist of the tower, hub, nacelle, rotor blades, and controller, with a total height of 179.5 to 194.5 m and is dependant on WEC availability from Enercon . The total WEC rotor diameter will be 127 m. It is anticipated that each WEC will be erected on a concrete foundation. The dimensions, depth, and type of foundation will depend on an evaluation of the local soil, surficial geology characteristics, wind forces at the location, and site-specific details of each location.

2.2 OVERVIEW OF SHADOW FLICKER

Shadow flicker occurs when the rotating blades of a turbine pass through the path between the sun and a receptor window when the sun is not obstructed by clouds. This phenomenon is dependent on weather conditions, site topography, and wind direction. The severity of shadow flicker will change both seasonally and hourly because of the daily and seasonal movements of the sun.

Shadow flicker can be calculated using the worst-case scenario or the corrected-case scenario. The worst-case, or “astronomical maximum” shadow flicker analysis, considers only the relative geographical location between WECs and receptors and assumes the sun is shining and the WEC rotor is spinning perpendicular to the path of the sunlight at all times. The corrected-case, or “meteorologically probable”, shadow flicker analysis utilizes on-site wind data and expected sunshine probability statistics to account for periods when: the turbine is not operational; the orientation of the turbine is not perpendicular to the path of the sunlight; and the sunlight is not strong enough to cast a shadow.

The occurrence of shadow flicker within a residence occurs when the rotating blades of a turbine momentarily interrupt the sunlight shining into the window of a receptor. The occurrence of shadow flicker may be reduced by the following:

- Obstructions that block the sunlight from reaching the window during some or all the time that shadow flicker is occurring;
- The orientation of the WEC due to changing wind direction.

CVLP will track concerns related to shadow flicker throughout the Project. If the amount of shadow flicker is a concern, WEC curtailment for specific wind directions or times of day may be an effective mitigation technique. In addition, mitigation such as screening of receptors with vegetation, awnings, and/or structures, and/or adding shutters to receptors will be considered, as required.

New Brunswick does not have provincial standards specifying an acceptable limit of shadow flicker at a receptor. This is true for most Canadian jurisdictions.

2.3 SITE DESCRIPTION

The Project is located approximately 49 km east of Bathurst, New Brunswick and is heavily forested. For this analysis, 90 receptors were identified by WSP. Residence locations have been listed in Appendix B and are shown in Appendix E. The receptors have been field validated.

The shadow flicker assessment was completed for the 5 x Enercon E126 EP3 4 MW WEC layout on 132 m towers.

Locations of WECs used for this study are listed in Appendix D and are shown in Appendix E.

3 METHODS

3.1 SHADOW FLICKER ALGORITHM AND ASSUMPTIONS

The WindPRO SHADOW module was used to model the shadow flicker at the Project. WindPRO calculates the cumulative effect of shadowing from all WECs with a line of sight to each receptor. The worst-case results are evaluated on yearly and daily averaging periods; the corrected-case on a yearly averaging period.

The blade shadow gets gradually fainter as the distance from the WEC increases and at some distance from the WEC the edge of the turbine shadow will be hard to distinguish by the human eye. Within WindPRO, the maximum distance of shadow propagation may be calculated using the turbine blade width or may be set to a constant, usually ten times the turbine's rotor diameter[1]. A conservative constant distance of 2,000 m was selected for the analysis. Due to atmospheric diffusion and lower light levels, shadow flicker is ignored when the sun is lower than 3° above the horizon. The presented shadow flicker amounts are based only on total frequency of shadow flicker and do not distinguish the character of the shadow flicker.

WindPRO executes a site-specific simulation of the solar trajectory relative to the wind project for an entire year. The complete description and shadow flicker calculation algorithm of WindPRO is provided in Appendix A.

Both the worst-case and corrected-case shadow flicker modelling scenarios assume that receptors have windows oriented in every direction and are, as a result, susceptible to flicker from all directions. This is known as the "greenhouse mode" and represents a conservative estimate of the impact of shadow flicker. Obstacles such as trees or large structures, which could block some or all of the shadow flicker effect at a receptor, are not considered in the analysis thus making the shadow flicker additionally more conservative. Topography was included in the modelling; however, elevation changes smaller than the resolution of the sourced data may not have been captured[2] .

The calculations of modelled worst-case results assume the following:

- The sun is unobstructed by cloud cover for all daylight hours for the entire year.
- The WEC blades are always rotating.
- The turbine rotor is always perpendicular to the path between the sun and the receptor.

The calculation of modelled "corrected-case" shadow flicker incorporated the probability of sunshine (hours of bright sunshine per month). The sunshine hours for the Project were derived from the measurements from the

---

[1] Parsons Brinckerhoff, Update of UK Shadow Flicker Evidence Base, Department of Energy and Climate Change.
[2] CDSM (Elevation data) has a grid spacing of 8-23 m with a horizontal accuracy of 10 m. The vertical accuracy is 6 m.

Canadian Climate Station - Charlo located approximately 100 km west of the Project site. The monthly probabilities of sunshine used in the modelling are presented in Table 2[3].

Table 2 Average Daily Hours of Bright Sunshine for the Canadian Climate Station - Charlo

MONTH	BRIGHT SUNSHINE [HOURS/DAY]
January	3.80
February	4.71
March	5.03
April	5.73
May	7.07
June	8.23
July	8.22
August	7.84
September	5.68
October	4.25
November	2.83
December	3.16

Wind data for the Project was derived from the Wind Resource Assessment[4] for use in the shadow flicker analysis. WindPRO uses this data to determine the probability that the wind speed will be outside the operational range of the turbines. WindPRO assumes that the blades do not turn when the turbine is not operating and consequently that there will be no shadow flicker during those periods. The corrected case shadow flicker hours include a reduction of 1% from worst case shadow flicker hours to account for the time the turbine blades are not rotating due to the wind speed being out of the operational range of the turbine.

The yaw system of the wind turbine changes the orientation of the rotor according to the wind direction, thus the shadow cast by the rotating blades changes according to the wind direction. The wind rose representing the wind direction distribution at the Chaleur Ventus Wind Power Project is presented in Figure 1. Shadow flicker will have a maximum impact when the rotor is perpendicular to the path of the sun and a minimum impact when the rotor is parallel to a line between the sun and the receptor. Based on the wind rose and orientation of each turbine to each receptor, a yaw correction factor was estimated for each pair and this correction factor is presented in Appendix C. The yaw correction factor has only been estimated for turbine-receptor pairs with at least 1 minute of shadow flicker in a year.

[3] Environment Canada http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=medicine&searchMethod=begins&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=2273&dispBack=1, accessed September 19, 2017.
[4] 'Naveco_ChaleurVentus_WRR_20190723_v3.pdf' WSP, 2019

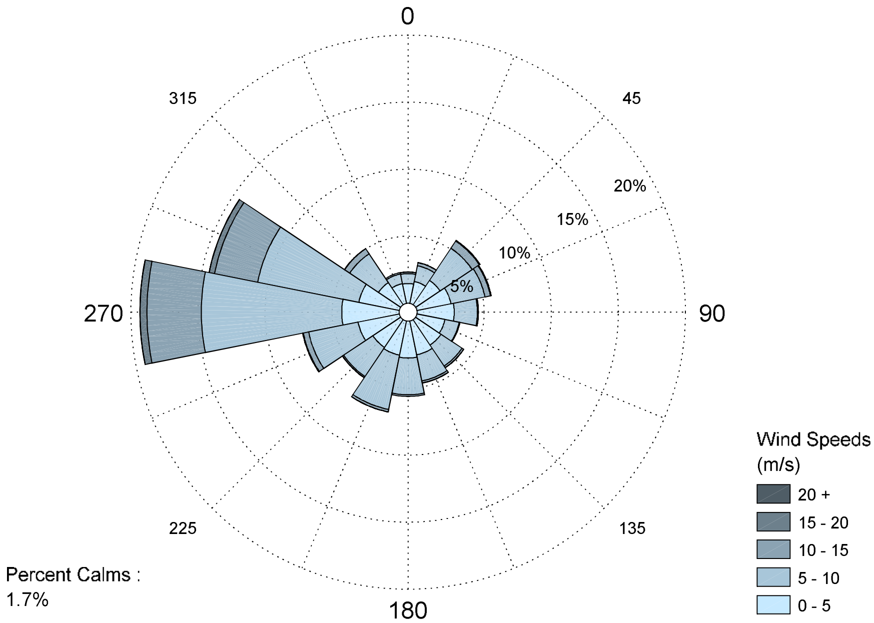


Figure 1 Wind Direction Distribution (Frequency %) at Chaleur Ventus Met Mast 1641 at 60 m

4 RESULTS

4.1 GREENHOUSE MODE SHADOW FLICKER RESULTS

The detailed results of the WindPRO shadow flicker model are presented in tabular form in Appendix B which includes the "corrected-case" annual hours, the “worst-case” annual hours, and the maximum daily minutes of shadow flicker for the “worst-case” scenario. Maps showing the iso-contour results for the “corrected-case” annual hours of shadow flicker have been included in Appendix E.

The results shown in Appendix B and Table 3 represent the predicted cumulative shadow flicker results from the Project. Only receptors experiencing more than 1 minute of shadow flicker originating from a WEC are presented in Table 3. The results also include the largest contributing wind turbine and month.

Table 3 Estimated Shadow Flicker for the E126 EP3 WEC at 132 m Hub Height on Impacted Shadow Receptors

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	TYPE	X	Y	ELEVATION	ANNUAL	MAX DAILY	ANNUAL	WEC	MONTH
1	House	343819	5299263	4	7:47	0:15	2:06	T3	January
4	House	342204	5299245	5	6:46	0:17	1:30	T5	January
5	House	343773	5299243	5	9:14	0:16	2:30	T3	January
6	House	342704	5299242	5	3:47	0:13	0:48	T5	December
7	House	342450	5299221	7	15:49	0:20	3:32	T5	December
8	House	342353	5299212	7	10:05	0:19	2:15	T5	January
11	House	343518	5299191	5	12:31	0:19	3:22	T3	December
17	House	342643	5299126	8	18:53	0:23	4:07	T5	December
18	House	341262	5299086	6	15:50	0:23	3:27	T3	December
19	House	342009	5299086	7	4:06	0:16	1:00	T5	February
21	House	341197	5299083	6	18:37	0:22	4:04	T3	December
22	House	342098	5299079	8	4:55	0:17	1:10	T5	February
23	House	343945	5299078	7	4:22	0:16	1:10	T3	November
24	House	341396	5299050	6	10:54	0:21	2:21	T3	December
27	House	343967	5299025	8	4:03	0:15	1:06	T3	February
28	House	343994	5299008	8	3:47	0:15	1:02	T3	February
29	House	343975	5298994	8	3:54	0:15	1:04	T3	February
30	House	343987	5298982	8	3:49	0:15	1:03	T3	February
32	House	344005	5298978	8	3:42	0:15	1:01	T3	February

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	TYPE	X	Y	ELEVATION	ANNUAL	MAX DAILY	ANNUAL	WEC	MONTH
33	House	340863	5298969	10	13:22	0:19	3:00	T3	December
34	House	344306	5298885	6	19:25	0:30	5:05	T5	December
35	House	344380	5298860	6	28:53	0:31	7:33	T5	December
36	House	344391	5298822	6	33:45	0:31	8:52	T5	December
37	House	344381	5298675	6	27:39	0:34	7:19	T5	November
38	House	340845	5298333	12	20:43	0:21	5:21	T3	February
39	House	340883	5298222	14	21:41	0:22	5:52	T3	February
40	House	340906	5298159	15	22:32	0:22	6:10	T3	February
41	House	340990	5298142	16	26:07	0:24	7:07	T3	February
42	House	341027	5298036	18	27:50	0:25	7:42	T3	September
43	House	341042	5297986	18	28:53	0:25	8:10	T3	April
44	House	344646	5297942	10	34:32	0:33	10:58	T6	August
45	House	344618	5297906	10	37:22	0:34	11:59	T6	August
46	House	340988	5297888	16	27:02	0:24	8:12	T3	August
47	House	344646	5297851	10	36:46	0:34	11:52	T6	August
48	House	344751	5297833	10	29:13	0:30	9:23	T6	August
49	House	341027	5297810	16	29:52	0:25	9:21	T3	August
50	House	344604	5297809	10	42:44	0:36	13:50	T5	September
51	House	341063	5297762	16	32:39	0:26	10:22	T3	August
52	House	344716	5297736	10	34:28	0:32	11:09	T5	May
53	House	344710	5297634	10	44:26	0:32	14:37	T5	July
54	House	344884	5297512	10	31:48	0:27	10:24	T5	July
55	House	344964	5297343	10	29:49	0:24	9:48	T5	June
56	House	344980	5297302	10	26:51	0:24	8:50	T6	June
57	House	344978	5297227	10	19:31	0:24	6:21	T6	May
58	House	345032	5297141	10	16:42	0:23	5:26	T6	July
59	House	341658	5297042	14	69:17	0:46	25:23	T1	July
60	House	345088	5297017	8	19:25	0:22	6:21	T6	June
61	House	341582	5297007	14	58:12	0:41	21:22	T1	July

RECEPTOR		LOCATION NAD83, UTM ZONE 20			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	TYPE	X	Y	ELEVATION	ANNUAL	MAX DAILY	ANNUAL	WEC	MONTH
62	House	345086	5296993	8	17:51	0:21	5:50	T6	June
63	House	341635	5296917	14	32:55	0:40	12:22	T1	June
65	House	343991	5296793	8	9:45	0:17	3:10	T1	August
68	House	344128	5296683	9	3:58	0:16	1:16	T1	August
69	House	343414	5296664	5	27:01	0:25	8:54	T1	July
77	House	343596	5296581	4	16:12	0:22	5:16	T1	July

A WINDPRO MODEL

The following information has been modified from section 4.2 of the WindPRO help files.

Introduction to Shadow

SHADOW is the WindPRO calculation module that calculates how often and in which intervals a specific area will be affected by shadows generated by one or more wind turbines. These calculations are expected case scenarios (i.e. calculations which are solely based on the probability of sunshine as calculated from the monthly maximum total duration of bright sunshine and the position of the turbine relative to the sun or the astronomical maximum shadow). Shadow flicker impact may occur when the blades of a wind turbine pass through the sun's rays seen from a specific spot (e.g. a window in an adjacent settlement). If the weather is overcast or calm, or if the wind direction forces the rotor plane of the wind turbine to stand parallel with the line between the sun and the receptor, the wind turbine will not produce shadow flicker impacts.

Apart from calculating the potential shadow flicker impact at a given receptor, a map rendering the iso-lines of the shadow flicker impact can be printed. This printout will render the amount of shadow flicker impact for any spot within the project area.

The time of the day for which shadow flicker impact is critical and the definition of a receptor for which shadow flicker impact is calculated are less rigidly defined by best practices and is often something which should be evaluated in each individual case.

As an example, a factory or office building would not be affected if all the shadow flicker impact occurred after business hours, whereas it would be more acceptable for private homes to experience shadow flicker impact during working hours, when the family members are at work/school.

Finally, the actual amount of shadow flicker impact as a fraction of the calculated potential risk will depend heavily on the geographic location in question. In areas with high rates of overcast weather the problem would obviously decrease, and during potential hours of shadow flicker impact in the summer the wind turbine may often be stationary due to lack of wind.

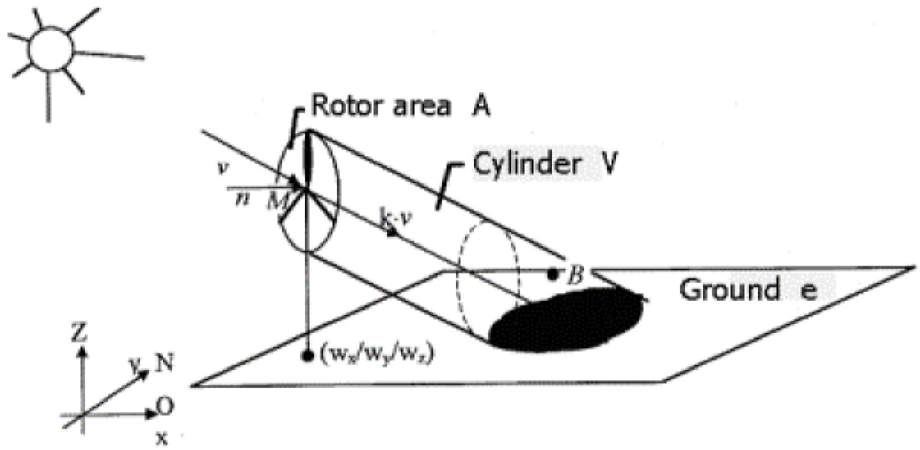
Statistics regarding the wind conditions and number of hours with clear sky can also be considered.

The wind direction reduction factor is calculated by WindPRO based on the geographic location of each receptor, turbine and the site-specific wind rose. A significant strength in the WindPRO system is the option of direct graphic on-screen input of wind turbines and receptors on a map.

The Shadow Calculation Method

The calculation of the potential shadow flicker impact at a given receptor is carried out simulating the situation. The position of the sun relative to the wind turbine rotor disk and the resulting shadow flicker is calculated in steps of 1 minute throughout a complete year. If the shadow flicker of the rotor disk (which in the calculation is assumed solid) at any time casts a shadow flicker reflection on the window, which has been defined as a receptor object, then this step will be registered as 1 minute of potential shadow flicker impact. The following information is required:

- The position of the wind turbines (x, y, z coordinates)
- The hub height and rotor diameter of the wind turbines
- The position of the receptor object (x, y, z coordinates)
- The size of the window and its orientation, both directional (relative to south) and tilt (angle of window plane to the horizontal).
- The geographic position (latitude and longitude) together with time zone and daylight-saving time information.
- A simulation model, which holds information about the earth's orbit and rotation relative to the sun.



Rotor area A
Cylinder V
v
n
M
k·v
B
Ground e
(w_x/w_y/w_z)
Z
y N
O
x

B SHADOW FLICKER RESULTS

5 x Enercon E126 EP3 4.0 MW at 132 m Hub Height Shadow Flicker Results

RECEPTOR		LOCATION NAD83, UTM ZONE 12			WORST CASE [HH:MM]		CORRECTED CASE [HH:MM]	LARGEST CONTRIBUTION	
ID	**Type**	**X**	**Y**	**Elevation**	**Annual**	**Max Daily**	**Annual**	**Turbine**	**Month**
1	House	343819	5299263	4	7:47	0:15	2:06	T3	January
2	House	343886	5299251	4	0:00	0:00	0:00	-	-
3	House	342809	5299250	6	0:00	0:00	0:00	-	-
4	House	342204	5299245	5	6:46	0:17	1:30	T5	January
5	House	343773	5299243	5	9:14	0:16	2:30	T3	January
6	House	342704	5299242	5	3:47	0:13	0:48	T5	December
7	House	342450	5299221	7	15:49	0:20	3:32	T5	December
8	House	342353	5299212	7	10:05	0:19	2:15	T5	January
9	House	343216	5299208	5	0:00	0:00	0:00	-	-
10	House	343928	5299203	5	0:00	0:00	0:00	-	-
11	House	343518	5299191	5	12:31	0:19	3:22	T3	December
12	House	343077	5299188	6	0:00	0:00	0:00	-	-
13	House	342899	5299170	6	0:00	0:00	0:00	-	-
14	House	341758	5299141	5	0:00	0:00	0:00	-	-
15	House	343950	5299136	6	0:00	0:00	0:00	-	-
16	House	341697	5299133	5	0:00	0:00	0:00	-	-
17	House	342643	5299126	8	18:53	0:23	4:07	T5	December
18	House	341262	5299086	6	15:50	0:23	3:27	T3	December
19	House	342009	5299086	7	4:06	0:16	1:00	T5	February
20	House	344186	5299085	6	0:00	0:00	0:00	-	-
21	House	341197	5299083	6	18:37	0:22	4:04	T3	December
22	House	342098	5299079	8	4:55	0:17	1:10	T5	February
23	House	343945	5299078	7	4:22	0:16	1:10	T3	November
24	House	341396	5299050	6	10:54	0:21	2:21	T3	December
25	House	341602	5299048	6	0:00	0:00	0:00	-	-
26	House	344258	5299040	6	0:00	0:00	0:00	-	-
27	House	343967	5299025	8	4:03	0:15	1:06	T3	February
28	House	343994	5299008	8	3:47	0:15	1:02	T3	February

29	House	343975	5298994	8	3:54	0:15	1:04	T3	February
30	House	343987	5298982	8	3:49	0:15	1:03	T3	February
31	House	344261	5298981	6	0:00	0:00	0:00	-	-
32	House	344005	5298978	8	3:42	0:15	1:01	T3	February
33	House	340863	5298969	10	13:22	0:19	3:00	T3	December
34	House	344306	5298885	6	19:25	0:30	5:05	T5	December
35	House	344380	5298860	6	28:53	0:31	7:33	T5	December
36	House	344391	5298822	6	33:45	0:31	8:52	T5	December
37	House	344381	5298675	6	27:39	0:34	7:19	T5	November
38	House	340845	5298333	12	20:43	0:21	5:21	T3	February
39	House	340883	5298222	14	21:41	0:22	5:52	T3	February
40	House	340906	5298159	15	22:32	0:22	6:10	T3	February
41	House	340990	5298142	16	26:07	0:24	7:07	T3	February
42	House	341027	5298036	18	27:50	0:25	7:42	T3	September
43	House	341042	5297986	18	28:53	0:25	8:10	T3	April
44	House	344646	5297942	10	34:32	0:33	10:58	T6	August
45	House	344618	5297906	10	37:22	0:34	11:59	T6	August
46	House	340988	5297888	16	27:02	0:24	8:12	T3	August
47	House	344646	5297851	10	36:46	0:34	11:52	T6	August
48	House	344751	5297833	10	29:13	0:30	9:23	T6	August
49	House	341027	5297810	16	29:52	0:25	9:21	T3	August
50	House	344604	5297809	10	42:44	0:36	13:50	T5	September
51	House	341063	5297762	16	32:39	0:26	10:22	T3	August
52	House	344716	5297736	10	34:28	0:32	11:09	T5	May
53	House	344710	5297634	10	44:26	0:32	14:37	T5	July
54	House	344884	5297512	10	31:48	0:27	10:24	T5	July
55	House	344964	5297343	10	29:49	0:24	9:48	T5	June
56	House	344980	5297302	10	26:51	0:24	8:50	T6	June
57	House	344978	5297227	10	19:31	0:24	6:21	T6	May
58	House	345032	5297141	10	16:42	0:23	5:26	T6	July
59	House	341658	5297042	14	69:17	0:46	25:23	T1	July
60	House	345088	5297017	8	19:25	0:22	6:21	T6	June

61	House	341582	5297007	14	58:12	0:41	21:22	T1	July
62	House	345086	5296993	8	17:51	0:21	5:50	T6	June
63	House	341635	5296917	14	32:55	0:40	12:22	T1	June
64	House	341773	5296866	12	0:00	0:00	0:00	-	-
65	House	343991	5296793	8	9:45	0:17	3:10	T1	August
66	House	342142	5296706	6	0:00	0:00	0:00	-	-
67	House	341945	5296697	9	0:00	0:00	0:00	-	-
68	House	344128	5296683	9	3:58	0:16	1:16	T1	August
69	House	343414	5296664	5	27:01	0:25	8:54	T1	July
70	House	344231	5296662	9	0:00	0:00	0:00	-	-
71	House	341926	5296660	9	0:00	0:00	0:00	-	-
72	House	341996	5296649	8	0:00	0:00	0:00	-	-
73	House	345038	5296617	8	0:00	0:00	0:00	-	-
74	House	341991	5296600	8	0:00	0:00	0:00	-	-
75	House	345098	5296598	8	0:00	0:00	0:00	-	-
76	House	345093	5296582	8	0:00	0:00	0:00	-	-
77	House	343596	5296581	4	16:12	0:22	5:16	T1	July
78	House	345034	5296573	8	0:00	0:00	0:00	-	-
79	House	342040	5296567	7	0:00	0:00	0:00	-	-
80	House	342077	5296559	7	0:00	0:00	0:00	-	-
81	House	345051	5296559	8	0:00	0:00	0:00	-	-
82	House	342149	5296509	6	0:00	0:00	0:00	-	-
83	House	342008	5296495	8	0:00	0:00	0:00	-	-
84	House	344973	5296445	8	0:00	0:00	0:00	-	-
85	House	342126	5296434	7	0:00	0:00	0:00	-	-
86	House	344735	5296371	5	0:00	0:00	0:00	-	-
87	House	342780	5296317	9	0:00	0:00	0:00	-	-
88	House	342745	5296317	9	0:00	0:00	0:00	-	-
89	House	342713	5296288	8	0:00	0:00	0:00	-	-
90	House	342644	5296277	7	0:00	0:00	0:00	-	-

C DIRECTION REDUCTION FACTORS FOR THE CORRECTED CASE

DIRECTION REDUCTION FACTORS – 5 x E126 EP3 4.0 MW layout

ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
T1																														
T2																														
T3	0.72				0.72						0.71							0.57			0.58		0.73	0.57			0.74	0.74	0.74	0.74
T5				0.61			0.59	0.60									0.58		0.64			0.64								
T6																														

ID	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
T1								0.61	0.62	0.63	0.62	0.63	0.64			0.65			0.66		0.66								0.73	
T2			0.57					0.65	0.66	0.66	0.66	0.67	0.67			0.68			0.69		0.70									
T3		0.74	0.63					0.69	0.70	0.71	0.71	0.72	0.73			0.73			0.73		0.73									
T5				0.69	0.69	0.70	0.72							0.69	0.68		0.67	0.67		0.67		0.67	0.66	0.65	0.64	0.64	0.63	0.62		
T6														0.73	0.73		0.73	0.73		0.73		0.72	0.70	0.68	0.67	0.66	0.66	0.65		0.64

ID	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
T1	0.73		0.74		0.67			0.67	0.65								0.65													
T2					0.66																									
T3																														
T5																														
T6		0.64																												

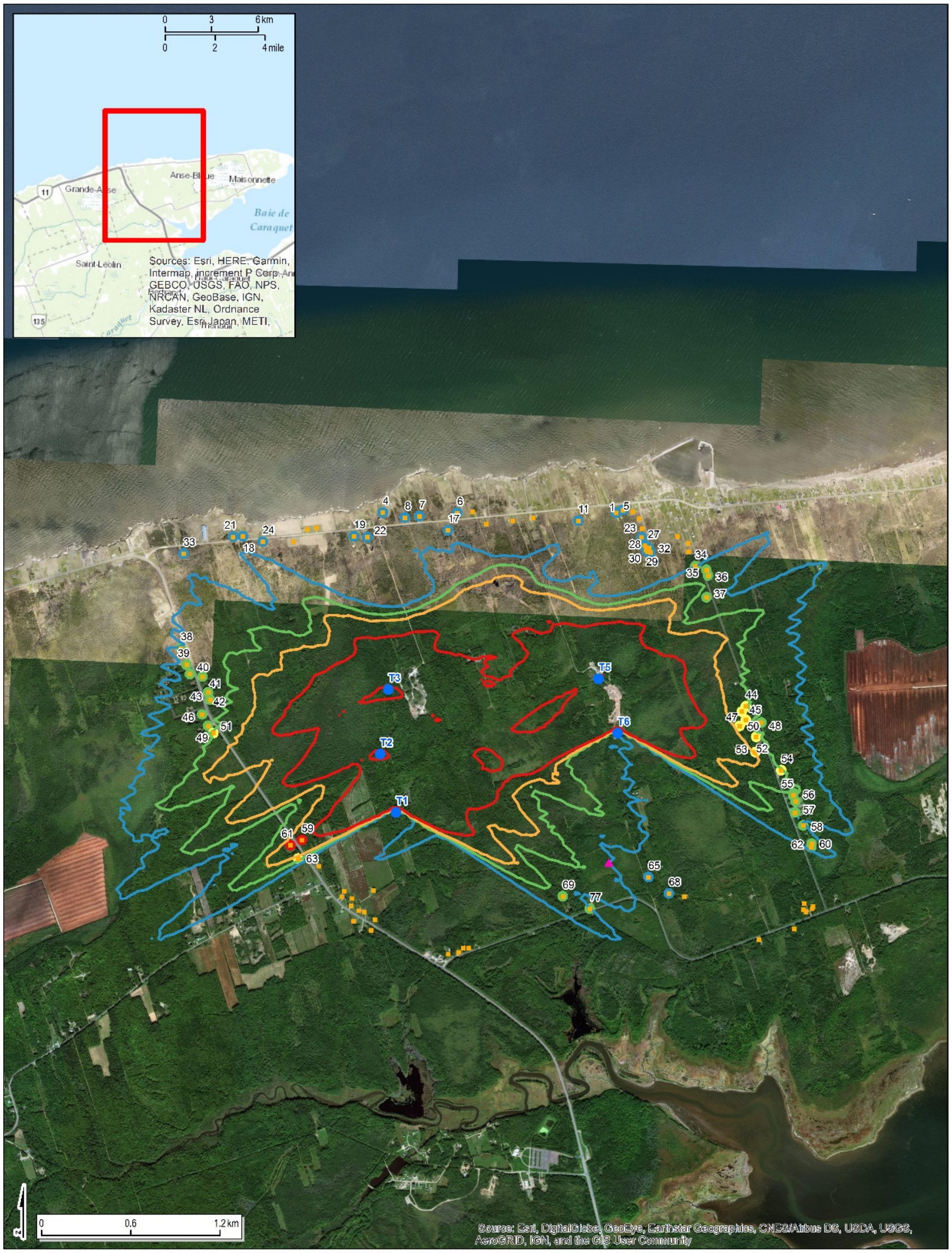
Appendix

D TURBINE LOCATIONS

TURBINE LOCATIONS – 5 X E126 EP3 4.0 MW LAYOUT

LABEL	EASTING UTM NAD83 Z20 (M)	NORTHING UTM NAD83 Z20 (M)	ELEVATION (M)
T1	342,292	5,297,227	13
T2	342,186	5,297,620	14
T3	342,241	5,298,055	12
T5	343,656	5,298,126	8
T6	343,783	5,297,761	7

E MAPS



Chaleur Ventus Wind Power Project

5 x E126 4.0 132 m HH Layout

Corrected Case Shadow Flicker Results

Legend

- Turbine Locations
- Validated Receptors
- Met Mast

Shadow Flicker Hours

- 5
- 10
- 15
- 30

Hours

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- >20

Version: 1
Datum: NAD 83
Projection: UTM Zone 20
Scale: 1:25,000

Prepared by: WSP
Author: A. Medd

In the preparation of this map, WSP has relied upon certain information provided by the client. While WSP has taken reasonable measures to present accurate information in the map, WSP does not warrant the reliability, accuracy, quality, currency, validity, or completeness of information found in the map. The locations shown are for informational purposes only and are not suitable for legal, surveying, or engineering purposes.