Environment

Goshen Wind, Inc.

Goshen Wind Energy Centre – Revised Shadow Flicker Assessment Report

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1. Introduction

AECOM was retained by Goshen Wind Inc., a wholly owned subsidiary of NextEra Energy Canada, ULC (NextEra) to prepare a Shadow Flicker Assessment Report for the proposed Goshen Wind Energy Centre. Shadow flicker is a temporary condition resulting from the sun casting intermittent shadows from the rotating blades of a wind turbine onto a Point of Reception (receptor) such as a window in a building. See **Appendix C** for the full definition of a Point of Reception and a Shadow Flicker Source. 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:

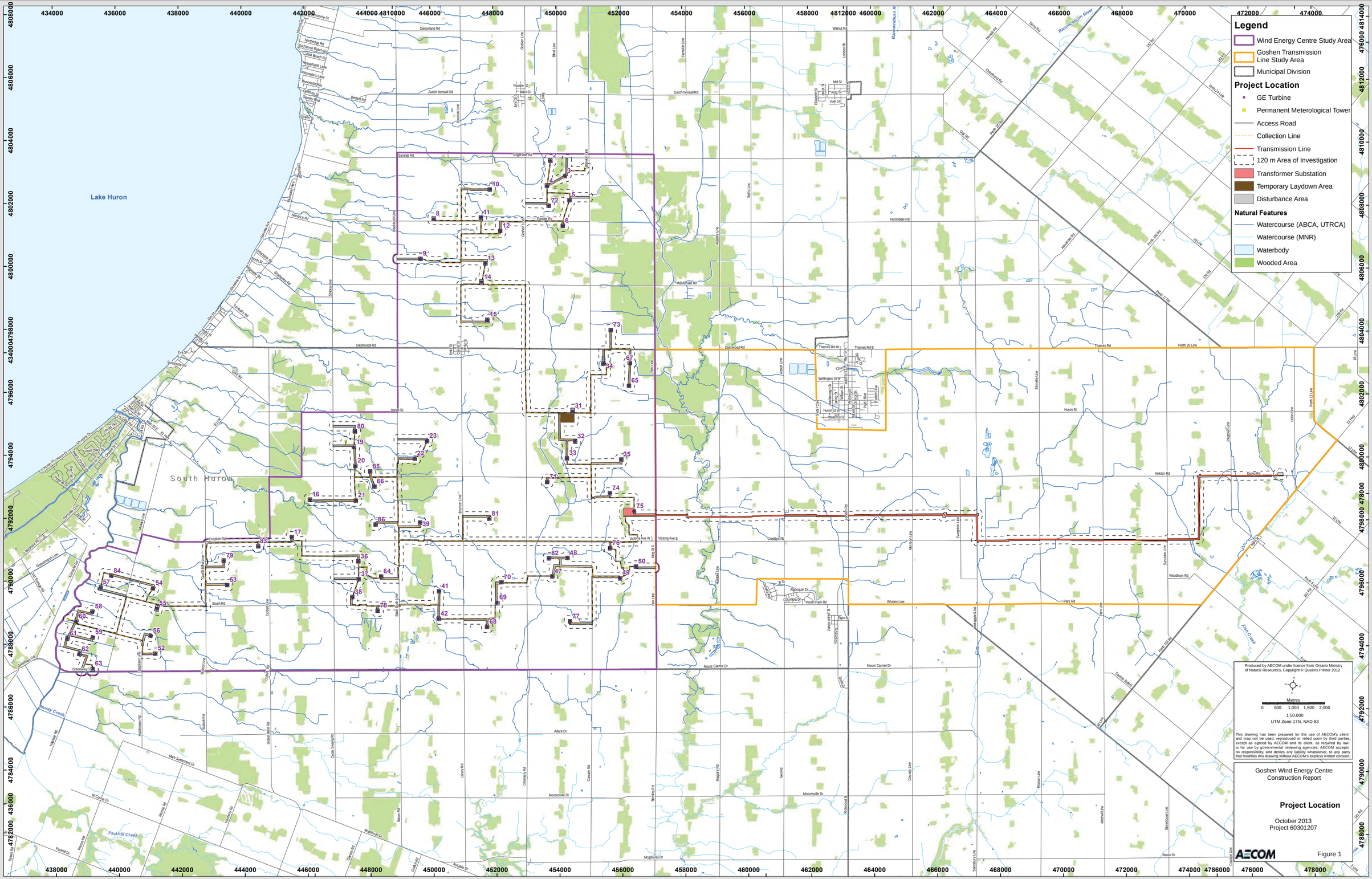
- The sun must be shining and unobscured by any cloud cover.
- The wind turbine must be between the sun and the shadow receptor.
- The wind turbine must be facing directly towards (or away from) the sun such that the rotational plane of the blades is perpendicular to the azimuth of incident sun rays. For this to occur, the wind direction would have to perpetually be parallel to the azimuth of the incident sun rays throughout the day.
- 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.
- The receptor has to be close enough to the turbine to be in the shadow.
- The turbine is operational and not stationary due to a lack of wind or maintenance activities.

2. Project Location and Study Area

Approval is being sought for up to 69 GE 1.6-100 Wind Turbine generator locations and pad mounted step-up transformers and one GE 1.56-100 Wind Turbine generator location and pad mounted step-up transformer (however, only 63 turbines will be constructed).

The proposed Project is located in the Municipality of Bluewater and the Municipality of South Huron in Huron County, Ontario. The Project Study Area consists of the areas being studied for the wind farm components (Wind Energy Centre Study Area), as well as for the interconnection route (i.e., the area being studied for transmission lines to connect the Project to the electrical grid) (Transmission Line Study Area). The Wind Energy Centre Study Area is generally bounded by Klondyke Road to the west, Rogerville Road to the north, Parr Line to the east, and Mount Carmel Drive to the south, in the Municipalities of Bluewater and South Huron. The Transmission Line Study Area is located to the east of the Wind Energy Centre Study Area, and is generally bounded by Parr Line to the west, Thames Road to the north, Perth 164 Road to the east, and Park Road to the south, extending into the Municipality of South Huron.

The location of the Project Study Area was defined early in the planning process for the proposed wind energy facility, based on the availability of wind resources, approximate area required for the proposed project, and availability of existing infrastructure for connection to the electrical grid. The Project Study Area was used to facilitate information collection. The Project Location, including the Wind Energy Centre and Transmission Line Study Areas, is provided in **Figure 1**.



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3. Shadow Flicker Sources

The wind turbine technology proposed for the Project is the GE 1.6-100 Wind Turbine and GE 1.56-100 Wind Turbine (one turbine only). These are 3-bladed, upwind, horizontal-axis wind turbines that are state of the art technology. The turbines have a 100 metre (m) rotor diameter with a swept area of 7,854 m; each blade is connected to the main shaft via the hub. Both turbine models have a hub height of 80 m. The GE 1.6-100 Wind Turbine is designed to operate between 9.75 and 15.33 revolutions per minute (rpm), while the GE 1.56-100 Wind Turbine is designed to operate between 9.75 and 16.2 rpm. The turbines have a cut-in speed of 3 metres per second (m/s) and a cut-out speed of 13 m/s. The coordinates for the 70 turbines are listed in **Table 1**.

Table 1. Wind Turbine Locations

Identifier	UTM Coordinates	
	X	Y
2	450520	4805782
3	451051	4805361
4	450524	4804972
5	451300	4804616
6	451203	4803770
8	447071	4803417
9	446830	4802090
10	448722	4804602
11	448568	4803670
12	449241	4803328
13	448911	4802237
14	448875	4801624
15	449226	4800450
16	444383	4793947
17	443972	4792675
19	445549	4795811
20	445679	4795219
21	445847	4794126
22	447530	4795721
23	447843	4796331
31	452335	4797930
32	452553	4796971
33	452366	4796399
34	453108	4799573

Identifier	UTM Coordinates	
	X	Y
35	454089	4796605
36	446196	4792203
37	446287	4791638
38	446167	4791042
39	447984	4793710
41	448895	4791606
42	448990	4790737
47	452425	4792588
48	452825	4793244
49	454586	4792838
50	455040	4793271
52	440156	4788373
53	442135	4790871
54	439792	4790436
55	440005	4789811
56	439925	4788922
57	438121	4790232
58	437973	4789428
59	438098	4788616
60	437501	4789050
61	437294	4788459
62	437743	4788017
63	438227	4787615
64	446988	4791822

Identifier	UTM Coordinates	
	X	Y
65	454014	4798992
66	446376	4794650
67	453955	4799707
68	450577	4790696
69	450788	4791504
70	450838	4792170
71	451847	4795562
72	450670	4804345
73	453192	4800669
74	453886	4795484
75	454731	4795014
76	454137	4793736
77	453186	4791237
78	447027	4790721
79	441914	4791634
80	445510	4796315
81	450167	4794140
82	452242	4793145
83	442950	4792234
84	438410	4790647
85	446173	4795111
86	446578	4793447

The exposure time and amount of shadow flicker at each receptor can vary according to the following factors:

- The sun must be shining and not obscured by cloud cover.
- The turbine must be between the sun and the receptor and be facing directly towards (or away from) the sun such that the rotation of the blades is perpendicular to the sun rays. 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.
- The turbine must be close enough to the receptor to cause shadow flicker and be operational (not stationary due to lack of wind or maintenance activities).
- Terrain, other buildings and vegetation can affect the exposure at a receptor such that if there are trees between the turbine and a receptor, shadow flicker will not occur at the receptor.

The orientation of windows at each receptor location will determine what rooms at each receptor would be exposed to shadow flicker. AECOM did not catalogue the number or orientation of windows at each receptor; instead each

receptor is assumed to have eight windows every 45 degrees to capture all angles for exposure. The amount of bright sunshine can also affect the frequency and duration of exposure to shadow flicker. **Table 2** summarizes the percent of bright sunshine at the London International Airport based on monthly climatological data.

Table 2. Percent of Bright Sunshine at London International Airport, Ontario

Month	% Bright Sunshine
January	22.6
February	30.9
March	32.4
April	40.4
May	48.6
June	53.0
July	56.3
August	51.4
September	43.3
October	37.4
November	23.8
December	18.6
Annual Average	**38.2**

4. Points of Reception

The receptors have been classified into four (4) different categories which are outlined in **Table 3** below. There are 3,394 receptors in the area of Goshen Wind Energy Centre.

Table 3. Receptor Classifications

Class	Number of Points of Reception	Description
NPR	2,618	Non-participating
PR	197	Participating
VNPR	519	Vacant Lot Non-participating
VPR	60	Vacant Lot Participating

Participating receptors (PR and VPR) are associated with the Wind Energy Centre via legal agreements with the owners of subject properties to allow for the installation and operation of wind turbines or related equipment.

5. Detailed Shadow Flicker Impact Assessment

The shadow flicker analysis for the Goshen Wind Energy Centre was completed using the *WindFarm* modelling software. *WindFarm* considers the hourly meteorological data, terrain features, receptor, and turbine locations in the modelling analysis. The wind speed distribution is shown in **Figure 2** and the wind rose for the onsite meteorological station is shown in **Figure 3**. It is generally accepted that shadow flicker from wind turbines does not occur beyond a certain distance from a wind turbine. The *Update of UK Shadow Flicker Evidence Base* by Parsons Brinckerhoff on behalf of the Department of Energy and Climate Change considers this distance to be equivalent to 10 rotor diameters. AECOM conservatively calculated using a maximum distance of 1,300 metres (80 metre hub height plus 50 metre blade multiplied by 10). WindFarm 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. **Table 4** provides a summary of receptors within 1,300 m of turbine locations. The distance limitation reduced the number of receptors in the analysis to 2,326. Receptor locations are shown in **Figure 4**.

Figure 2. Wind Speed Distribution

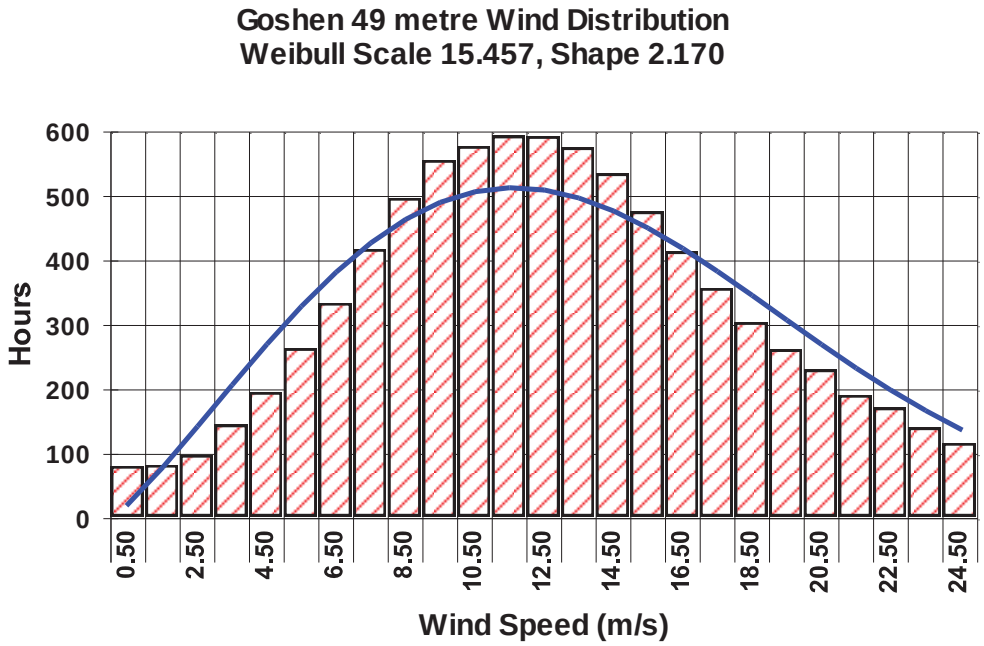

Table 4. Receptors within 1,300 m of Turbine Locations

Class	Number of Receptors	Description
NPR	1,719	Non-participating
PR	197	Participating
VNPR	350	Vacant Lot Non-participating
VPR	60	Vacant Lot Participating

6. Results

The Shadow Flicker Impact Summary, **Table 5**, presents the worst case astronomical results of the shadow flicker modelling and the corrected hours per year based on the annual percentage of sunshine shown in **Table 2**. **Figure 5** shows the contours that represent the astronomical (calculated based the time of sunrise and sunset at the Energy Centre's location) maximum number of hours per year that shadow flicker occurs in the modelling domain. **Appendix A** includes shadow time graphs for each receptor location and **Appendix B** lists the specific start and end times of each exposure.

The worst case maximum shadow flicker per day is 1.45 hours and the worst case maximum shadow flicker per year is 130.9 hours (corrected to 50.0 hours per year based on annual percentage of sunshine) at a Vacant Lot Participating receptor (VPR). All receptors with zero shadow flicker are not included in the Shadow Flicker Impact Summary (**Table 5**). The 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 minutes per day and hours per year that shadow flicker could occur. However, this is a conservative analysis that does not account for maintenance time, winds less than 3 m/s 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.

Potentially affected receptors should be monitored. If excessive shadow flicker is found to occur, vegetation can be planted, window shutters installed or other measures can be considered to mitigate effects.

Figure 3. Wind Rose for Onsite Meteorological Station

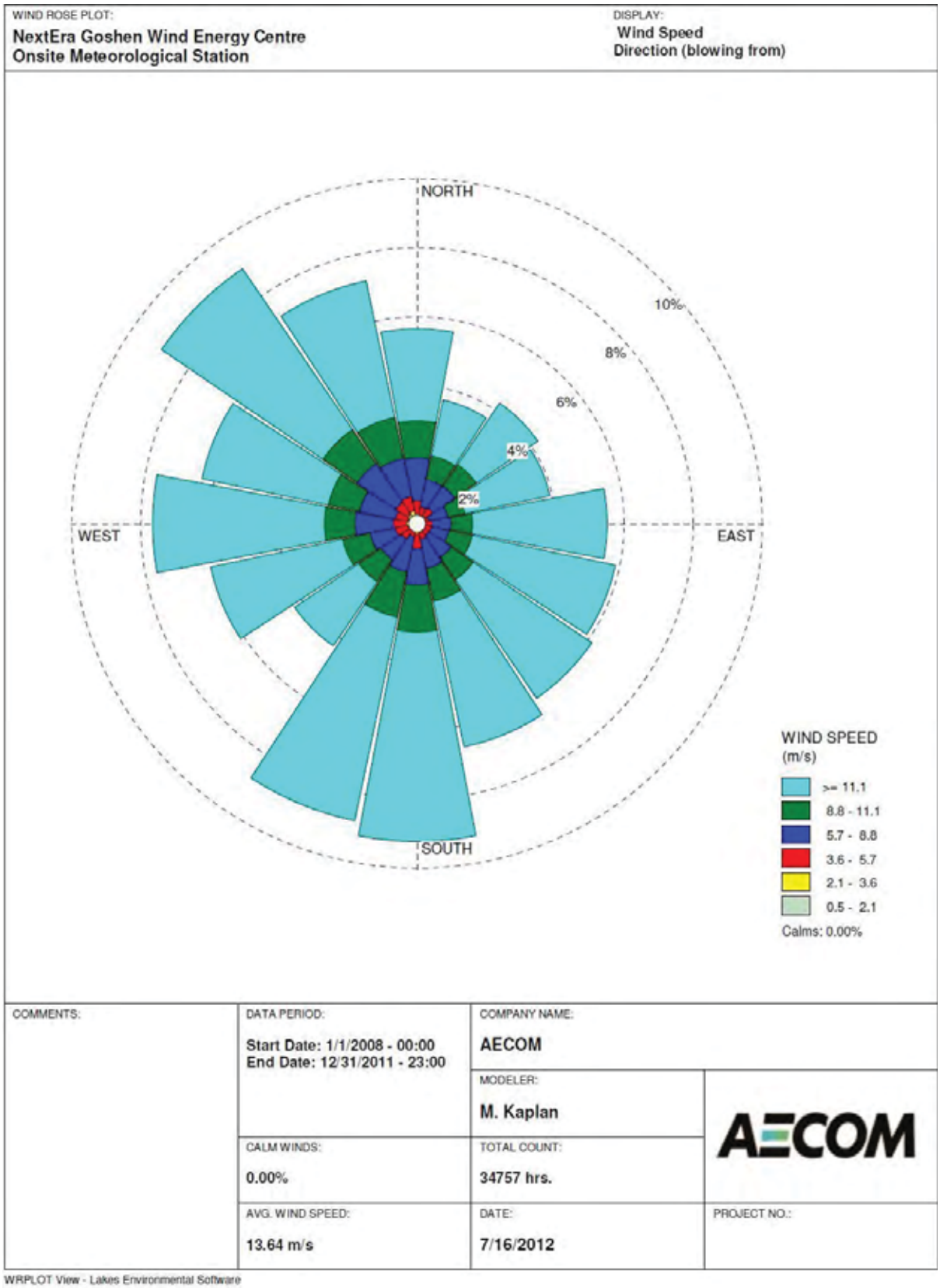

Figure 4. Modeled Receptor Locations