26.0 SHADOW FLICKER

26.1 SHADOW FLICKER ASSESSMENT

Stantec conducted an analysis of the likely shadow flicker impacts of the Bingham Wind Project (project) using the candidate turbine with the greatest potential impact (Exhibit 26A). This assessment considered 63 Vestas V-112 3.0-megawatt turbines, with a maximum height of 150 meters (492 feet) and a rotor diameter of 112 meters (367 feet).

Based on the results of the assessment of shadow flicker levels from the project, it was determined that there is one identified receptor that will potentially receive shadow flicker for 2 hours 55 minutes per year. Therefore, there are no receptors where flicker impacts are expected to exceed the Maine Department of Environmental Protection guideline of 30 hours per year, under most conservative conditions. The model used did not adjust for weather conditions and wind direction, which would substantially decrease modeled impacts.

Exhibit 26A: Shadow Flicker Assessment

Memo

To:	Dale Knapp Stantec Consulting Topsham, ME	From:	Theo Kindermans Stantec Planning and Landscape Architecture, PC Boston, MA
File:	Bingham Wind Project	Date:	April 1, 2013

Stantec

Reference: **Shadow Flicker Modeling**
Bingham Wind Project, Somerset and Piscataquis Counties, Maine

Introduction

This memorandum provides a brief explanation of the shadow flicker phenomenon, the modeling approach employed for the Bingham Wind Project in Somerset and Piscataquis Counties, ME, and relevant explanations and results. The site layout was provided by Stantec Consulting located in Topsham, ME. The layout shows a total of 63 turbine locations; for modeling purposes the turbine with the greatest potential impact was analyzed. Turbines are presumed to be Vestas V112-3.0 MW, with a 94-meter high hub and a 112-meter diameter rotor, and a total maximum height of approximately 150 meters.

Shadow Flicker Background

Shadow flicker from wind turbines results from brief reductions in light intensities caused by the rotating blades of the turbine casting shadows on receptors on the ground and stationary objects such as a window at a residence. When the sun is obscured by clouds or storms, or when the turbine is not operating, no shadows will be cast.

Shadow flicker can occur on project area receptors when wind turbines are located near the receptor and when the turbine blades interfere with the angle of the sunlight. The most typical effect is the visibility of an intermittent light reduction on the receptor facing the wind turbine and subject to the shadow-flicker. Obstacles such as terrain, trees, or buildings between the wind turbine and a potential shadow-flicker receptor significantly reduce or eliminate shadow flicker effects. No shadow flicker is present when the rotor of the turbine is perpendicular to the receptor.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensities diminish with increased distance from turbine to receptor and with lower visibility weather or atmospheric conditions such as haze or fog. Closer to a turbine, the shadow will appear to be darker and wider as the rotors will block out a larger portion of sunrays. The shadow line will also be more defined. Further from the turbine, the shadow will be less intense or lighter, and less distinct.

The spatial relationship between a wind turbine and a receptor, as well as wind direction, are key factors related to the amount of time any location might experience shadow flicker. Shadow flicker time is most commonly expressed in number of hours per year. Shadow flicker is most pronounced at distances from the turbine of less than 1,000 feet and during sunrise and sunset when the sun's angle is lower and the resulting shadows are longer. The phenomenon is more prevalent in the winter than in the summer due to the sun's lower position on the horizon in winter months in North America (NAS, 2007)[1].

[1] National Academies of Sciences, Environmental Impacts of Wind Energy Projects, Washington, 2007

The analysis provided in this report does not evaluate the flicker intensity, but rather focuses on the total amount of time (hours and minutes per year) that shadow flicker can potentially occur at receptors regardless if the shadow flicker is barely noticeable or clearly distinct. As a result, it is likely that receptors will experience less shadow flicker impact than modeled and reported, especially those that are farther away from the turbines. It is likely that marginally affected receptors may not be able to identify shadow flicker at all as the shadows become more diffuse with increased distance.

The speed of the rotor and the number of blades determine the frequency of the flicker of the shadow. The shadow-flicker results in this memo are based on Vestas 3-blade model V112 3.0 MW, with a turbine hub height of 94 meters and a rotor diameter of 112 meters. The maximum rotor speed of 17.7 revolutions per minute translates to a blade frequency of 0.89 Hz (less than 1 alternation per second, or one light interruption every 1.12 seconds).

Modeling Approach

For the shadow flicker modeling, Stantec utilized a module of the WindPRO software. The computer model simulates the path of the sun over the course of the year and assesses at regular intervals the potential shadow flicker across a given receptor. The color-coded map produced by the computer model is a conservative estimate of the number of hours per year that shadows could be cast by the rotation of the turbine blades. This report presents a flicker analysis for this worst case condition. It assumes that:

-the sun is always shining from sunrise to sunset;

-the rotor plane is always perpendicular to the line from the turbine to the sun;

-the turbine is always operating; and

-there is no topographic or vegetative buffer between the receptor and the turbine.

Furthermore, the analysis assumes windows are situated in direct alignment with the turbine-to-sun line of sight. Even when windows are so aligned, the analysis does not account for the difference between windows in rooms with primary use and enjoyment (e.g. living rooms) and other less frequently occupied or un-occupied rooms or garages.

The worst case shadow-flicker model uses the following inputs:

- Turbine locations;
- Shadow flicker receptor (residence or camp) locations (coordinates);
- USGS 1:24,000 topographic and USGS DEM (height contours);
- Turbine rotor diameter; and
- Turbine hub height.

The model calculates detailed shadow flicker results for each receptor location and the amount of shadow-flicker (hours and minutes per year) surrounding the project. A receptor in the model is defined as a 1 square meter area that is 1 meter above ground level, approximating a window. This omni-directional approach produces shadow-flicker results at a receptor regardless of the direction of windows and provides similar results as a model with windows on various sides of the receptor.

The sun’s path with respect to each turbine location is calculated by the software to determine the cast shadow paths every minute, daily over one full year.

Output from the model includes the following information:

- Calculated shadow-flicker time at selected receptors;
- Tabulated and plotted time of day with shadow flicker at receptors;
- Tabulated time of impact from each turbine at a receptor; and
- Map showing turbine locations, selected shadow-flicker receptors and color-coded contour lines indicating projected shadow-flicker time (hours per year).

Analysis

As previously stated, the shadow-flicker model assumptions applied to this project are very conservative and as such, the results are expected to over-predict impacts. Additionally, many of the modeled shadow flicker hours are expected to be of very low intensity.

Of the modeled 149 receptors assessed and analyzed, only 1 potentially receives shadow flicker. All other modeled receptors do not show any impact of shadow flicker in the worst case scenario modeled.

The statistics of the potentially impacted receptors are outlined in the table below:

Flicker Receptor	Total shadow flicker time per year (hours:minutes) worst case	Distance to nearest wind turbine with impact (feet)
A	2:55	2,200

Standards

Maine statute provides that projects such as the Bingham Wind Project are subject to a requirement that they "… be designed and sited to avoid undue adverse shadow flicker effects." (38 M.R.S.A. § 484(10)). Maine has not set any specific regulatory limits on exposure to shadow flicker. However, in previous regulatory decisions, a general standard of 30 hours of expected shadow flicker per year has been cited (see Oakfield Wind Project, Rollins Wind Project, and Record Hill Wind Project).

The sun has to be at a very shallow angle to produce calculated shadow flicker beyond 1,000 feet. The impacted receptor at the Bingham Wind Project is far beyond this distance at 2,200 feet. As such, the intensity of the shadow is greatly reduced, diffusing the contrast between light and shadow.

The analysis above does not take into account any vegetation between the turbines and the receptors. However, the actual project and surrounding area is densely wooded. The likelihood that vegetation in this heavily wooded area will block the changes in light intensity is great.

Conclusion

The calculated shadow flicker effect on the listed receptors is expected to be well below the range of Maine's previously accepted guidelines of less than 30 hours per year. Furthermore, the area between the receptor sites and the turbine is heavily wooded. It is Stantec's opinion that potentially calculated shadow flicker will not pose an unreasonable adverse impact on the receptors identified in this report.

Bingham Wind Project - Vestas V112
Bingham, Maine

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Stantec
Stantec
Planning and Landscape Architecture, PC
141 Portland Street
Boston, MA 02114

Shadow Flicker Study

March 2013

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