SECTION 26.
SHADOW FLICKER

26.1 SHADOW FLICKER ASSESSMENT

Stantec conducted an analysis of the likely shadow flicker impacts from the proposed turbines for the Number Nine Wind Farm (Project) (Exhibit 26-A). The Turbine Area will include 119 turbines. The Project designs depict 129 turbine locations and the shadow flicker assessment assumes that all 129 turbines are operating; however the Applicant will ultimately select 119 of these turbine sites for construction. The turbines will be Gamesa G114 models, with a hub height of 93 meters, rotor diameter of 114 meters, and maximum height of 150 meters (492 feet) with the blade fully extended.

The shadow flicker model utilized WindPro software and evaluated the likely worst-case and meteorologically adjusted shadow flicker for 129 potential turbine locations. Meteorological (met) data was incorporated from a temporary met tower at the Project to refine the model to include anticipated hours of sunshine.

Although Maine has no regulatory limit for shadow flicker exposure, the Maine Department of Environmental Protection (MDEP) has identified the industry-applied limit of 30 hours of shadow flicker per year for recent wind projects.

As described in Section 2 of the application, the Applicant is party to leases with timberland landowners on whose lands (Wind Parcels) it will construct and operate the Project, including but not limited to the installation and operation of wind turbines on these Wind Parcels in the Turbine Area. The Applicant is also party to easements with those timberland landowners. There are recreational leases granted by the timberland landowners within the bounds of the Wind Parcels and there are dwellings and/or camps, mostly seasonal, located on certain of those recreational lease sites.

The closest dwelling outside of these Wind Parcels is approximately 2,260 feet from a turbine. There are several recreational leases granted by the timberland landowners within the bounds of the Wind Parcels and there are dwellings and/or camps, mostly seasonal, located on certain of those recreational lease sites. Those recreational lease sites are generally depicted in Exhibit 28-A, Figure 3-2 and are further identified in Exhibit 28-A, Table 2.

The limits do not apply to shadow flicker received within the Project boundary or Wind Parcels which are subject to a shadow flicker easement. A landowner may grant a shadow flicker easement that exempts the Project from limits for the parcel of land and term covered by the

easement. The Wind Parcels for the Turbine Area include such shadow flicker easements, as described in Exhibit 28-A, Table 2.

There is no shadow flicker expected at dwellings outside of the Wind Parcels.

EXHIBIT 26-A SHADOW FLICKER ASSESSMENT

Shadow Flicker Assessment

Number Nine Wind Farm
Aroostook County, Maine

Prepared for:
Number Nine Wind Farm LLC

Prepared by:
Stantec Consulting Services Inc.

April 2015

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Number Nine Wind Farm LLC (the Applicant) has proposed construction of the Number Nine Wind Farm (Project), a grid-scale wind energy facility in Aroostook County, Maine. The Project will include up to 119 Gamesa G114 turbines to be located on 129 permitted sites in T10 R3 WELS; E Township; T9 R3 WELS; TD R2 WELS; T8 R3 WELS; and Saint Croix Township, Maine. The G114 turbines will be one of two types, 2.0 MW (megawatts) or 2.1 MW, resulting in a total rated generating capacity of approximately 250 MW of electricity. Other Project components include an Operations and Maintenance (O&M) building, access roads, a collector system and substation, and generator lead line.

Stantec Consulting Services Inc. (Stantec) assessed shadow flicker levels expected to result from operation of the Project. This report provides a brief explanation of the shadow flicker phenomenon, the modeling approach employed for the Project and relevant explanations and results. The layout shows a total of 129 turbine locations; for modeling purposes, all 129 locations were included although only 119 turbines will be constructed. Turbines are presumed to be Gamesa turbines, with a 93-meter high hub and a 114-meter diameter rotor, and a total maximum height of approximately 150 meters.

2.0 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 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].

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 Gamesa 3-blade model, with a turbine hub height of 93 meters and a rotor diameter of 114 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).

3.0 PROJECT DESCRIPTION

Number Nine Wind Farm will consist of 119 wind turbines to be constructed on 129 proposed turbine sites located in T10 R3 WELS; E Township; T9 R3 WELS; TD R2 WELS; T8 R3 WELS; and Saint Croix Township, Maine, resulting in a total rated generating capacity of approximately 250 megawatts (MW) of electricity. For purposes of permitting and the shadow flicker assessment, all proposed turbine sites are evaluated as if 129 turbines were operating simultaneously on all proposed turbine sites although a maximum of 119 turbines are planned for construction.

An operations and maintenance building and collector substation will be constructed in T9 R3. The collector substation will consist of a step up transformer, synchronous condenser and associated switchgear. Two segments of a 345 kV Generator Lead Line, from T9 R3 to Houlton, and from Houlton to Haynesville, will deliver power to the grid. Other project features include: upgrades to existing road and new roads to access the turbines and crane paths; up to four permanent and four temporary meteorological (met) towers; and overhead and underground electrical collector lines among the turbines.

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

NUMBER NINE WIND FARM
SHADOW FLICKER ASSESSMENT

April 2015

The proposed wind turbines are one of two Gamesa G114 models with a rated capacity of either 2.0 or 2.1 MW, hub height of 93 meters, rotor diameter of 114 meters, and maximum height of 150 meters (492 feet) with the blade fully extended. The wind turbines will be constructed on ridges and hills across several unorganized townships in the vicinity of Number Nine Lake, including Hedgehog Mountain, Hovey Mountain, Meduxnekeag Mountain, Collins Ridge, Nineteen Mountain, Burnt Land Ridge and unnamed hills and ridges west of U.S. Route 1. Figure 3-1 provides a topographic map of the proposed turbine locations.

The Applicant has lease agreements which allow construction and operation of the Project including proposed turbines and met towers, O&M Building, collection lines, substation and electrical generator lead line. Surrounding land uses consist mostly of undeveloped forestry land, with limited rural residential and seasonal properties such as hunting and lakeside camps. Several residential and seasonal properties in the vicinity of the Project are located along the shores of Number Nine Lake and Presque Isle Lake in T9 R3 WELS. The closest dwelling not located within the Project lease area is approximately 2,260 feet from a turbine.

The Applicant is party to leases, easements and other agreements which allow for construction and operation of the Project, including proposed turbines and met towers, O&M building, substation, collection lines and electrical generator lead line. Specifically, the Applicant is party to leases ("Wind Lease") with those landowners ("Wind Lessor" or "timberland landowners") on whose lands it will construct and operate the Project, including but not limited to the installation and operation of wind turbines at the proposed locations on these lands ("Wind Lease Parcel"). There are recreational leases granted by the timberland landowners within the bounds of the Wind Lease Parcels, and there are dwellings and/or camps, mostly seasonal, located on certain of those recreational lease sites. These recreational lease dwellings are subject to a shadow flicker easement. Additional details concerning the Applicant's Wind Leases and shadow flicker easements in relation to applicable standards can be found in Section 5.0.

Figure 3-2 consists of three sheets (north, center, and south) that provides mapping of the proposed wind turbine locations along with parcel and land use information including topographic contours of the study area and dwellings within the study area. Figure 3-2 also depicts by hatching the Wind Lease Parcels that are under a lease or easement agreements for construction and operation of the Project.

Number Nine Wind Farm

Project Turbine Location Map

NUMBER NINE
WIND FARM

Legend

- Turbines

Figure 3-1. Project Turbine Location Map

Author - Jon Dove
Date: 3/20/2015
Version -1

Datum -

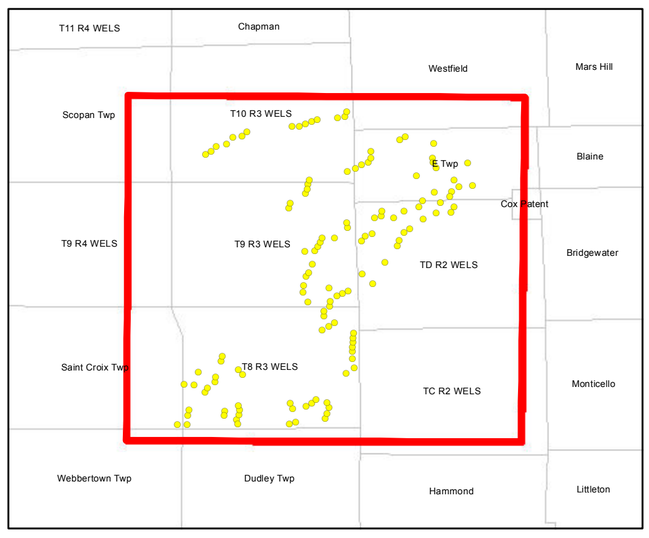
Projection -
NAD 83 State Plane ME E 1801 FT

Data Sources -ESRI, EDPR, MEGIS

Notes -

1:40,354

Miles
0 1.5 3



Number Nine Wind Farm

NUMBER NINE WIND FARM

Figure 3-2 (1 of 3)
Land Uses, Topography,
& Proposed Wind Turbines

Legend

- Wind Turbine
- Dwelling
- Recreational Lease Dwelling
- Recreational Lease Dwelling will shift at least 1,500ft away from Wind Turbine
- Project Lease Parcel
- Project Easement Parcel

N
W E
S

Date: 4/2/2015

Projection -
NAD 83 State Plane ME E 1801 FT

1:47,151

Data Sources -ESRI, EDPR, MEGIS

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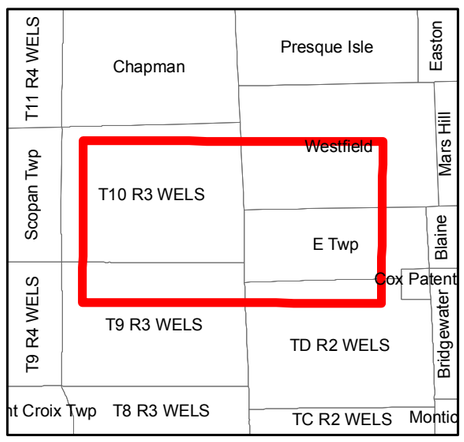


Number Nine Wind Farm

NUMBER NINE WIND FARM

Figure 3-2 (2 of 3)
Land Uses, Topography, & Proposed Wind Turbines

Legend

- Wind Turbine
- Dwelling
- Recreational Lease Dwelling
- Project Lease Parcel
- Project Easement Parcel

N
W E
S

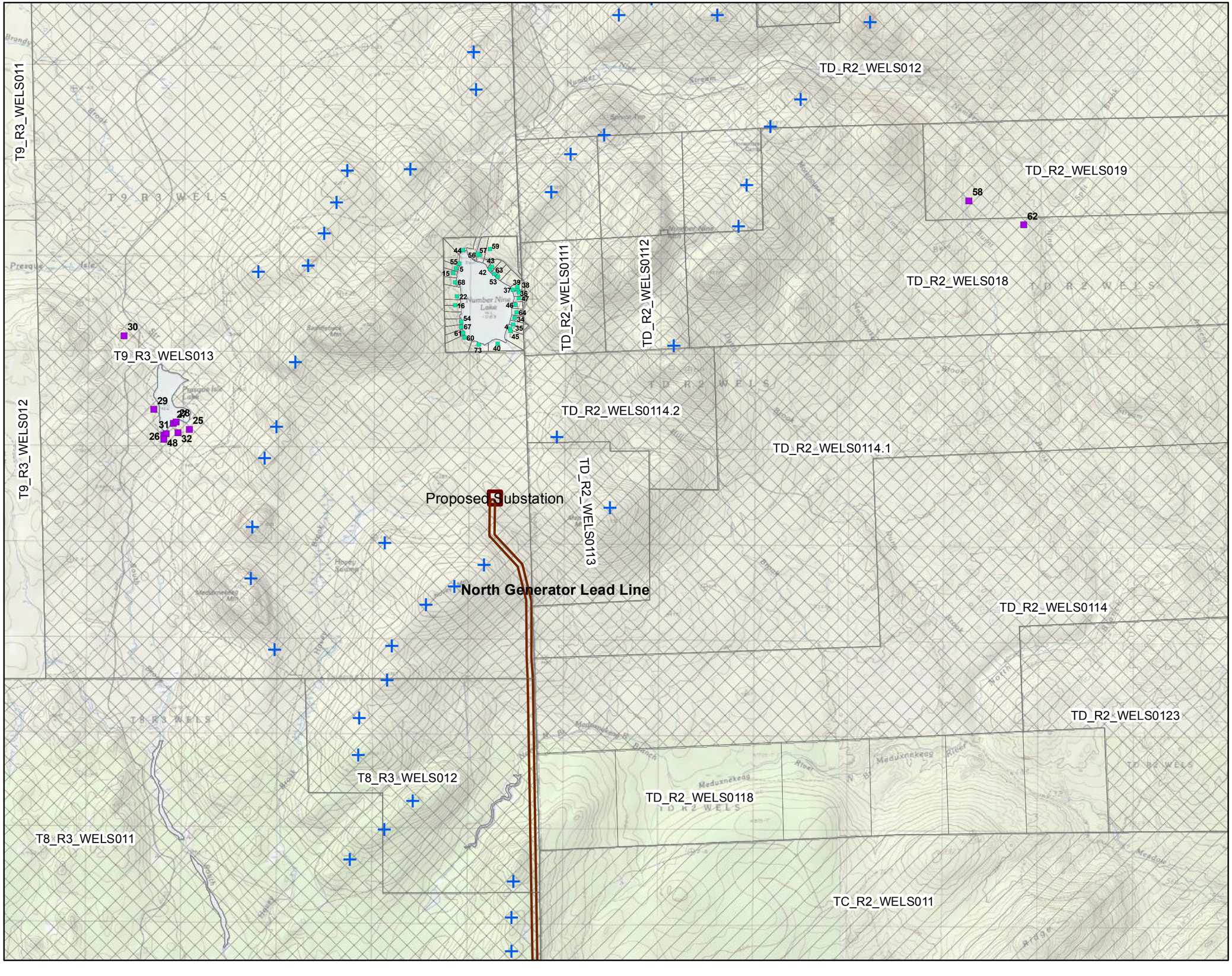
Date: 3/31/2015

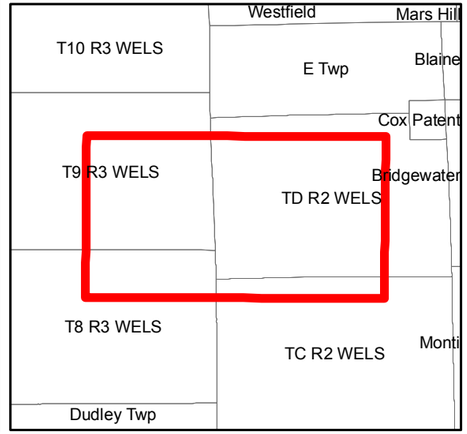
Projection -
NAD 83 State Plane ME E 1801 FT

1:37,188

Data Sources -ESRI, EDPR, MEGIS

0 1,750 3,500 7,000 Feet





Number Nine Wind Farm

NUMBER NINE WIND FARM

Figure 3-2 (3 of 3)
Land Uses, Topography,
& Proposed Wind Turbines

Legend

- Wind Turbine
- Dwelling
- Recreational Lease Dwelling
- Recreational Lease Dwelling will shift at least 1,500ft away from Wind Turbine
- Project Lease Parcel
- Project Easement Parcel

N
W E
S

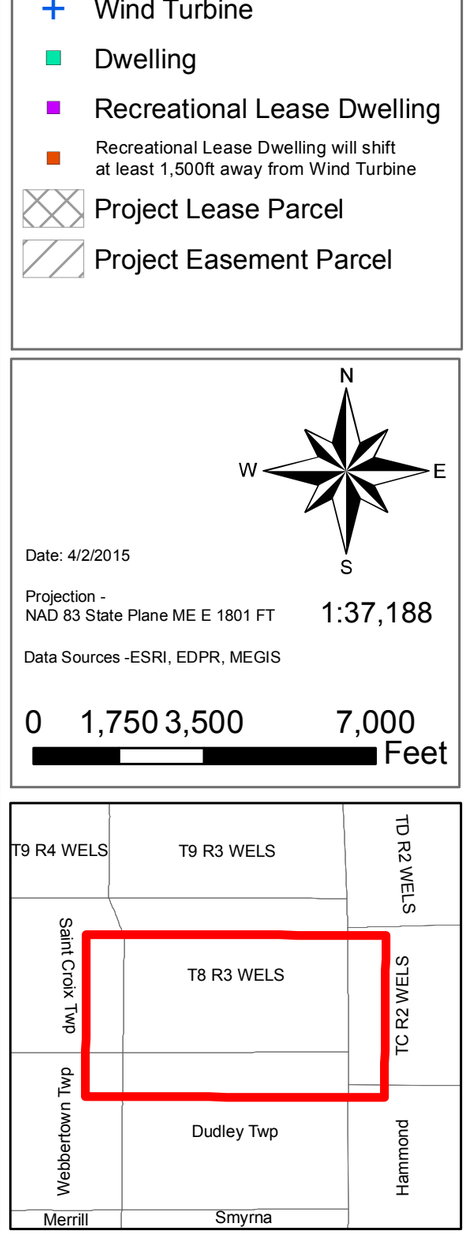
Date: 4/2/2015

Projection -
NAD 83 State Plane ME E 1801 FT

1:37,188

Data Sources -ESRI, EDPR, MEGIS

0 1,750 3,500 7,000 Feet



Saint_Croix_Twp012
T8_R3_WELS011
Saint_Croix_Twp014
Webbertown_Twp011
Dudley_Twp011
TC_R2_WELS011
Hammond031
North Generator Lead Line
20
24
21
66
41
52
51
23

4.0 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 and also includes a meteorologically adjusted condition that describes the expected values.

The worst case condition 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 meteorologically adjusted model uses the same inputs as the worst case model and also incorporates meteorological data. The meteorologically adjusted model provides an evaluation that is reflective of typical conditions at the Project.

The data used is local meteorological information on wind speed and direction, and cloud cover. Other model inputs remained the same. The data came from the following sources:

- Wind speeds and direction frequency distributions were acquired from a meteorological tower within the Project,
- Sunshine hours, the time between sunrise and sundown for the area, was obtained from monthly reference data for the annual number of sunny or partly sunny days experienced at the airport in Caribou, ME (the closest reporting station for cloudiness data for the National Oceanic and Atmospheric Administration).

The turbine run-time and direction (seen from the receptor) are calculated from the site's long-term wind speed and direction distribution, while the actual sunshine hours add the probability of sunshine during any given period. This calculation more accurately reflects the expected shadow-flicker time in the meteorologically adjusted model.

In both scenarios, it is assumed that no trees or other obstacles are placed between the turbine and the receptor. Inclusion of vegetation or obstructions would further minimize the effects of shadow-flicker.

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).

5.0 ANALYSIS

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

Maine statute provides that projects such as the Number Nine 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 Bingham Wind Project, Hancock Wind Project, 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 nearest dwellings outside the Project Lease Parcels are far beyond this distance at

2,260 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.

The Maine DEP limits do not apply to shadow flicker received within the project boundary or Wind Lease Parcels, which are subject to a shadow flicker easement. A landowner may grant a shadow flicker easement that exempts the project from Maine DEP limits for the specific development, parcel of land and term covered by the easement.

In particular, the Wind Leases grant to Number Nine Wind Farm LLC the following:

> "A nonexclusive easement for ... shadow flicker (sometimes hereafter "flicker"), ... and any other effects attributable to any Project or Operations located on the Property or on adjacent properties over and across the Property and any other property owned by Landowner adjacent to or in the vicinity of the Property (collectively, for purposes of this section, "Servient Land"), including but not limited to (a) the right to have shadow flicker generated from the Project or Operations impact the Servient Land and exceed otherwise applicable federal, state or local maximum shadow flicker level limits applicable to locations on the Servient Land ..."

Prior to the renewal date of each recreational lease within a Wind Lease Parcel and affected by a shadow flicker easement, the timberland landowner has provided or will provide written notice to each such recreational tenant a) of the existence of such shadow flicker easements and b) that such recreational leases, recreational tenant a) of the existence of such shadow flicker easements and b) that such recreational leases, automatically upon renewal, are amended to be expressly subject to the same.

The predicted shadow flicker levels of the Project at the receptor points are shown on Figure 5-1 and 5-2. A summary of the predicted shadow flicker levels at these receptor points is provided in Table 1. Distances from each receptor point to the nearest proposed turbine and the difference between the predicted worst-case and expected-case shadow flicker levels are also shown for each receptor point.

Table 1. Predicted Shadow Flicker Levels from Wind Turbine Operations.

Receptor Point	Description	Distance (feet)	Predicted Shadow Flicker Level (hours per year)	
			Worst Case	Expected Case
70	Dwelling - Westfield	5,433	*00:00*	*00:00*
71	Dwelling - Westfield	4,505	*00:00*	*00:00*
59	Dwelling – T9 R3 WELS	2,802	*00:00*	*00:00*
65	Dwelling – T9 R3 WELS	3,619	*00:00*	*00:00*
52	Dwelling – Dudley	3,173	*00:00*	*00:00*
23	Dwelling – Dudley	5,427	*00:00*	*00:00*

The results in Table 5-1 indicate that the predicted shadow flicker levels will not exceed 30 hours per year. Of the modeled receptors assessed and analyzed, no receptors beyond the Wind Lease Parcels receive shadow flicker.

Legend

- Receptors
- Wind Turbines

Max. Potential Shadow Flicker Hours Per Year (Worst Case Study)

- 0-10
- 10-25
- 25-50
- 50-100
- 100-200
- >=200
- Approximate Parcel Boundary

N

0 2,500 5,000 10,000 15,000 20,000 Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Number Nine Wind Project
Aroostook County, Maine

Created by: ZYY
Filename: V:\2108\active\195600919\design\flicker study\North Maine\24x36-worst case -2015-4-3.mxd

Stantec
Planning and Landscape Architecture, PC
226 Causeway Street
Boston, MA 02114

Worst Case Shadow Flicker Study

April 2, 2015

Data Source: Aerial from ESRI

Legend

- Receptors
- Wind Turbines

Max. Potential Shadow Flicker Hours Per Year (Meteorological Adjustment)

- 0-10
- 10-25
- 25-50
- 50-100
- 100-200
- >=200
- Approximate Parcel Boundary

N

0 2,500 5,000 10,000 15,000 20,000 Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Number Nine Wind Project
Aroostook County, Maine

Created by: ZYY
Filename: V:\2108\active\195600919\design\flicker study\North Maine\24x36-meteorological-2015-3-31.mxd

Stantec
Planning and Landscape Architecture, PC
226 Causeway Street
Boston, MA 02114

Meteorologically Adjusted Shadow Flicker Study

April 2, 2015

Data Source: Aerial from ESRI

Table 2 provides a list of recreational lease dwellings where the predicted shadow flicker level exceeds the general standard of 30 hours of expected shadow flicker per year. These dwellings are not regulated protected locations as they are located on Wind Lease Parcels and are subject to a shadow flicker easement. Of the 17 dwellings listed, the Applicant plans to relocate six dwellings so that they will be at least 1500 feet from any proposed wind turbine site.

Table 2. Recreational Lease Dwellings within Project Lease Areas where Predicted Shadow Flicker Levels Exceed 30 Hours per Year.

Dwelling ID[A]	Dwelling Relocation[B]	Easement	Map Coordinates		Landowner for Wind Lease Parcel
			Latitude	Longitude	
1	No	Yes	46° 28' 38.112" N	68° 1' 54.926" W	Griswold Trust
65	No	Yes	46° 28' 38.430" N	68° 1' 55.263" W	Griswold Trust
7	Yes	Yes	46° 31' 15.957" N	68° 3' 2.016" W	Prentiss and Carlisle
8	No	Yes	46° 30' 43.879" N	68° 3' 47.333" W	Prentiss and Carlisle
9	Yes	Yes	46° 29' 43.547" N	68° 7' 50.594" W	Prentiss and Carlisle
11	Yes	Yes	46° 30' 41.334" N	68° 4' 21.854" W	Prentiss and Carlisle
12	No	Yes	46° 30' 51.818" N	68° 3' 44.988" W	Prentiss and Carlisle
13	Yes	Yes	46° 30' 32.569" N	68° 5' 31.036" W	Prentiss and Carlisle
17	No	Yes	46° 31' 16.879" N	68° 3' 46.887" W	Prentiss and Carlisle
21	Yes	Yes	46° 17' 53.202" N	68° 9' 54.713" W	Lakeville Shores, Inc.
24	No	Yes	46° 18' 20.120" N	68° 6' 39.208" W	Lakeville Shores, Inc.
66	No	Yes	46° 17' 41.298" N	68° 6' 56.257" W	Lakeville Shores, Inc.
2	Yes	Yes	46° 29' 4.297" N	67° 57' 53.026" W	R.A. Crawford & Son Land & Timber, Inc.
25	No	Yes	46° 24' 15.907" N	68° 5' 16.512" W	R.A. Crawford & Son Land & Timber, Inc.
27	No	Yes	46° 24' 18.110" N	68° 5' 24.471" W	R.A. Crawford & Son Land & Timber, Inc.
28	No	Yes	46° 24' 18.547" N	68° 5' 23.064" W	R.A. Crawford & Son Land & Timber, Inc.
32	No	Yes	46° 24' 14.937" N	68° 5' 22.132" W	R.A. Crawford & Son Land & Timber, Inc.

[A] Refer to Figure 3-2 for Dwelling Location Map
[B] If Yes, Dwelling will shift at least 1,500 feet away from Wind Turbine

6.0 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 turbines 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.