Shadow Flicker Report

Buckeye II Wind Farm
Champaign County, Ohio

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1.0 PROJECT OVERVIEW

Champaign Wind, LLC (the Applicant), a wholly owned subsidiary of EverPower Wind Holdings, Inc., is proposing to develop a wind-powered electric generating facility in Champaign County, Ohio (Figure 1). The Buckeye II Wind Farm (the Facility) is anticipated to include 56 wind turbines (Figure 2) with a maximum rated power output of 2.5 megawatts (MW) each, for a total generating capacity of 140 MW. While the exact turbine model to be used at the Facility has not yet been determined, this report assumes use of the GE 2.5-103. This model was selected because, among the turbines under consideration, the GE 2.5-103 represents a worst-case analysis with respect to shadow flicker. The Facility is also anticipated to include a system of gravel-surfaced turbine access/service roads, electrical collection lines, up to four permanent meteorological towers, and a substation and switchyard to allow connection to the power grid.

The Facility will be sited on privately-owned leased land in the eastern portion of Champaign County, east of the City of Urbana. The Facility is generally bounded by State Route 814 to the west, State Route 559 to the east, Urbana Woodstock Pike to the north, and State Route 4 to the south. U.S. Route 36 passes through the center of the site. Land use in the vicinity of the Facility includes agriculture, sparse woodlots, areas of successional shrubland, and wetlands, with elevations in the range of 1,100 to 1,300 feet above mean sea level (amsl). The Facility is located in an area that is primarily undeveloped, with farms and rural residences interspersed along area roadways. More concentrated development occurs in the nearby City of Urbana and in the Villages of Mechanicsburg and North Lewisburg.

On behalf of the Applicant, **edr** Companies (**edr**) has prepared this report in satisfaction of the requirements set forth in Section 4906-17-08(A)(6) of the Ohio Administrative Code (OAC).

2.0 INTRODUCTION

Shadow flicker refers to the moving shadows that an operating wind turbine casts over an identified receptor at times of the day when the turbine rotor is between the sun and a receptor's position. Shadow flicker is most pronounced in northern latitudes during winter months because of the lower angle of the sun in the winter sky. However, it is possible to encounter shadow flicker anywhere for brief periods before sunset and after sunrise (U.S. Department of the Interior, 2005). During intervals of sunshine, wind turbine generators will cast a shadow on surrounding areas as the rotor blades pass in front of the sun, causing a flickering effect while the rotor is in motion. Shadow flicker does not occur when fog or clouds obscure the sun, or when turbines are not operating.

The distance between a wind turbine and a potential shadow flicker receptor affects the intensity of the shadows cast by the blades, and therefore the intensity of flickering. Shadows cast close to a turbine will be more intense, distinct, and focused. This is because a greater proportion of the sun's disc is intermittently blocked by the turbine (BERR, 2009). Obstacles such as terrain, vegetation, and/or buildings occurring between receptors and wind turbines may significantly reduce or eliminate shadow flicker effects. At distances beyond 10 rotor diameters (approximately 1,030 meters in this case), shadow flicker effects are essentially undetectable (BERR, 2009; DECC, 2011).

Shadow flicker is not considered a health-related issue, as blade pass frequencies for modern commercial-scale wind turbines are so low they are considered harmless. According to the British Epilepsy Association (2007), approximately five percent of individuals with epilepsy have sensitivity to light, and most people with photosensitive epilepsy are sensitive to flickering around 16-25 Hz (Hertz or Hz = 1 flash per second), although some people may be sensitive to rates as low as 3 Hz and as high as 60 Hz. Modern wind turbines are usually built to operate at a frequency of 1 Hz or less. There is no evidence that wind turbines operating at this frequency can trigger seizures (British Epilepsy Association, 2007). Therefore, the primary concern with shadow flicker is the annoyance it could cause for adjacent receptors (i.e., within a distance equivalent to approximately 10 rotor diameters).

The location and duration of shadow flicker can be predicted using computer modeling programs and input data regarding turbine characteristics and weather conditions. A "worst-case" shadow flicker scenario could be predicted based on the assumptions that there are no clouds or fog, wind conditions allow continuous turbine operation, the turbine rotor is continuously perpendicular to the sun, and the turbine rotor is always positioned between the receptor and the sun. However, this worst case is not what would actually occur, as turbines are not in continuous operation, are not always aligned perpendicular to the sun, and are not always positioned between the receptor and the sun. In addition, sunlight intensity and duration vary daily and seasonally, and obstacles that block shadows (terrain, vegetation, and buildings) exist in the landscape.

The shadow flicker analysis conducted for the Buckeye II Wind Farm was based on the conservative assumption that turbines are in continuous operation during daylight hours. Local sunshine and wind data were used to more accurately predict rotor alignment and the percent of daylight hours when shadows are most likely to be cast. The analysis evaluated the potential impact of the GE 2.5-103 turbine model, which has a rotor diameter of 103 meters and a tower/hub height of 98.5 meters.

3.0 METHODS

This report has been prepared to satisfy the requirements set forth in OAC Section 4906-17-08 (A)(6), which requires the Applicant to evaluate and describe the potential impacts from shadow flicker at adjacent residences and primary roads, including plans to minimize potential impacts if warranted. In order to satisfy this requirement, **edr** conducted a shadow flicker modeling analysis for the proposed Buckeye II Wind Farm using WindPRO version 2.7.490 software (WindPRO), and associated shadow module, which is a widely accepted modeling software package developed specifically for the design and evaluation of wind power projects. Input variables and assumptions used for shadow flicker modeling calculations for the proposed Facility include:

- Latitude and longitude coordinates of 56 proposed wind turbine sites (provided by the Applicant).
- Latitude and longitude coordinates for 880 structures/receptors within approximately 1,100 meters of the Facility, which includes participating and non-participating residential (homes) and non-residential (barns, sheds, etc.) structures (provided by the Applicant).
- USGS 1:24,000 topographic mapping and USGS digital elevation model (DEM) data.
- The rotor diameter and hub height for the GE 2.5-103 wind turbine.
- Annual wind rose data provided by the Applicant, which is depicted in Table A1 of Attachment A (to determine the approximate directional frequency of rotor orientation throughout the year).
- The average monthly percent of available sunshine values, obtained from NOAA "Comparative Climatic Data for the United States through 2009" (see Table A2 of Attachment A).
- No allowance was made for wind being below or above generation speeds. Blades are assumed to be moving during all daylight hours when the sun's elevation is more than 3 degrees above the horizon (due to the scattering effect of the atmosphere on low angle sunlight).
- It is assumed that there is no shadow impact when the sun's elevation is less than 3 degrees above the horizon (due to the scattering effect of the atmosphere on low angle sunlight).
- It is assumed that there is no shadow impact when less than 20 percent of the sun is masked by the rotor blades because this is not enough masking to create a detectable shadow.
- The possible screening effect of trees and buildings adjacent to the structures was not taken into consideration in the initial phase of the analysis. In addition, the number and/or orientation of windows in residential structures were not taken into consideration in the analysis.

Shadow flicker effects on receptors are expressed in terms of predicted annual cumulative duration (hours per year). Shadow isolines (i.e., contours indicating total number of hours of shadow per average year) were calculated for the GE 2.5-103 turbine based on the data and assumptions outlined above, using a 10-meter by 10-meter grid from the

USGS DEM. These isolines define the theoretical number of hours per year that shadow flicker would occur at any given location within a conservative 1,100-meter radius of all proposed turbines (see Figure 3). As mentioned previously, shadow intensity diminishes as the distance between turbines and receptors increases, and at distances beyond 10 rotor diameters shadow flicker effects are essentially undetectable (BERR, 2009).

The model calculations include the cumulative sum of shadow hours for all Facility turbines. This omni-directional approach reports total shadow flicker results at a receptor regardless of the presence or orientation of windows at that particular residence (i.e., it assumes shadows from all directions can be perceived at a residence, which may or may not be true). A receptor in the model is defined as a one square meter area, one meter above ground level; actual structure dimensions are not taken into consideration. Therefore, the analysis presented herein is expected to be a conservative projection of the shadow flicker effects of the proposed Buckeye II Wind Farm.

4.0 RESULTS

Output from the model includes the following information:

- Calculated shadow flicker duration (hours per year) at each structure (receptor) within 1,100 meters of the Facility.
- Tabulated and plotted time of day that structures are predicted to receive shadow flicker.
- Shadow isolines, which were used to create a map showing turbine locations, structures, and projected shadow flicker duration (hours per year; see Figure 3).

All of these data are presented in the overview reports and calendars included in Attachment C.

A summary of the projected shadow flicker at each of the 880 structures located within 1,100 meters of a proposed turbine site is presented below:

- 344 (39%) will experience no shadow flicker,
- 282 (32%) may be affected >0 to 10 hours/year,
- 133 (15%) may be affected 10 to 20 hours/year,
- 71 (8%) may be affected 20 to 30 hours/year,
- 50 (6%) may be affected by more than 30 hours/year.

5.0 DISCUSSION

As previously indicated, Section 4906-17-08(A)(6) of the OAC requires the Applicant to "evaluate and describe the potential impact from shadow flicker at adjacent residential structures and primary roads…" With respect to primary roads, Figure 3 depicts the expected shadow flicker at all areas (including roads) in the vicinity of the proposed Facility. However, the model results generated by WindPRO assume a stationary object that remains fixed 24 hours/day, 365 days/year. Therefore, because primary road users are mobile (typically in a motorized vehicle traveling at a relatively high speed), any Facility-related shadow flicker experienced by such users would be a small fraction of that experienced by a stationary object. Furthermore, most vehicle operators and passengers are accustomed to shadow flicker while driving, since shadows cast from nearby objects (e.g., trees, roadside/overhead signage, etc.) will "flicker" across the windows of a moving vehicle during the appropriate conditions.

Attachment B provides a summary of the predicted shadow flicker at each structure calculated to experience more than 10 hours of shadow flicker per year. The times of day and duration of shadow flicker experienced by each structure will vary throughout the calendar year based on the position of the sun in the sky and the direction of prevailing winds. See Attachment C for detailed calendars that illustrate the specific times of year and day that each structure may experience shadow flicker.

With respect to regulatory thresholds, no national, state, county, or local standards exist for allowable frequency or duration of shadow flicker from wind turbines at the proposed Facility site. In general, quantified limits on shadow flicker are uncommon in the United States as studies have not shown it to be a significant issue (USDOE, 2008; NRC, 2007). However, standards developed by some states and countries provide guidance in this regard. The Ohio Power Siting Board has used 30 annual hours of shadow flicker as a threshold of acceptability in reviewing and approving commercial wind power projects (OPSB, 2008, 2009a, 2009b, 2009c, 2009d). International guidelines from Europe have suggested 30 hours of shadow flicker per year as the threshold of significant impact, or the point at which shadow flicker is commonly perceived as an annoyance (DECC, 2011). Additionally, guidelines for wind power development in the State of Victoria, Australia specify that shadow flicker may not exceed 30 hours per year at any dwelling in the surrounding area (Sustainable Energy Authority Victoria, 2009). Accordingly, a threshold of 30 shadow flicker hours per year was applied to the analysis of the proposed Buckeye II Wind Farm to identify any potentially significant impacts on area residences.

The model results indicate that a total of 50 structures are predicted to exceed the 30-hour threshold. However, many of these structures are project participants, while others are in fact non-residential structures (e.g., barns, sheds). Therefore, based on the initial analysis, only 11 non-participating residential structures are predicted to exceed the 30-hour threshold. It should be noted that of these 11 structures, seven are classified by the Applicant as

"pending", indicating the respective landowner is anticipated to become a project participant. However, to assure a worst-case analysis, pending structures are included in the subsequent evaluation and discussion. Details regarding the anticipated shadow flicker at each of these structures are summarized below in Table 1.

Table 1. Structures Exceeding 30 Hours of Shadow Flicker per Year (Initial Analysis)

Structure ID	Project Status	Predicted Shadow Flicker (hh:mm/year)	Turbines Contributing Shadow Flicker	Approximate Times of Day Structure Potentially Affected by Flicker[1]
342	Non-participating	32:19	131, 90, 86, 80, 79	6:30AM-10:00AM 7:00PM-7:45PM
411	Non-participating	36:53	118, 119, 113	7:00AM-9:00AM
662	Pending	57:11	108, 83, 82, 107	7:45AM-8:30AM 3:00PM-8:00PM
719	Pending	32:59	107, 81, 106, 105	7:30AM-10:00AM 4:00PM-4:30PM
725	Pending	35:03	106, 105	8:00AM-10:00AM
789	Pending	39:26	105, 116, 77, 76	6:30AM-8:30AM 4:00PM-5:30PM
799	Pending	54:27	72, 116, 117, 74	8:30AM-10:00AM 4:30PM-8:30PM
833	Non-participating	31:46	117, 74, 73	3:00PM-8:15PM
3431	Non-participating	32:35	129, 100	7:00AM-9:00AM
6538	Pending	31:42	130	6:30AM-8:00AM
10308	Pending	38:33	131, 86, 98, 85	7:30AM – 8:30AM 6:30PM – 8:45PM

Although shadow flicker at these structures exceeds the normal 30-hour per year threshold, these calculations do not take into account the actual location and orientation of windows, or the screening effects associated with existing site-specific conditions such as vegetation and/or buildings. To more accurately predict the amount of shadow flicker a particular receptor will receive, such site-specific obstacles can be included in the WindPro model. Therefore, the following steps were undertaken to refine the shadow flicker analysis of the Buckeye II Wind Farm:

[1] The times of day presented in Table 1 represent the range of times during which each structure could potentially experience shadow flicker throughout the year; however, no structures will experience shadow flicker every day during all those hours. See Attachments C and E for detailed calendars that illustrate the specific times of year and day that each structure may experience shadow flicker.

1. Site reconnaissance was performed on April 19, 2012 at each of the non-participating residential receptors predicted to receive greater than 30 hours of shadow flicker per year under the worst case analysis, as described above (see Attachment D for Obstacle Analysis Data Sheets). Photos were taken to document any obstacles that may block a receptor from receiving shadow flicker.
2. The photos were then compared to orthoimagery (geometrically corrected aerial photographs) of the site to determine the actual location of each obstacle with respect to nearby receptors and the wind turbines.
3. The orthoimagery was then imported into the WindPro program and overlaid on the Facility site (all maps are geo-referenced).
4. Using digitizing tools in WindPro, rectangles were drawn on the site to represent different types of obstacles. Each rectangle was assigned a width, length, and height to reflect the dimensions of the obstacle. The width and length of obstacles were determined from the orthoimagery, while the heights were determined by observations in the field or from the photographs taken on site. Ten progressively more dense levels of porosity can also be assigned to each obstacle. Small porosity factors (.1, .2, etc.) were assigned to dense obstacles (like buildings and dense forest cover) while higher porosity factors were assigned to obstacles with much less density (such as trees with large spaces between them). Each obstacle was automatically assigned its correct elevation according to its position in the contour height object in WindPro.
5. Once all the obstacles were drawn (digitized) in the model, WindPro used the properties of the objects to determine how they mitigate the impact of shadow flicker on the surrounding receptors.

Results of the revised shadow flicker analysis that considers the screening effects of obstacles are provided in Attachment E and summarized below in Table 2.

Table 2. Structures Exceeding 30 Hours of Shadow Flicker per Year (Obstacle Analysis)

Structure ID	Project Status	Predicted Shadow Flicker (hh:mm/year)		Turbines Contributing Shadow Flicker
		Without Obstacles	With Obstacles	
342	Non-Participating	32:19	32:19	131, 90, 86, 80, 79
411	Non-Participating	36:53	36:53	118, 119, 113
662	Pending	57:11	57:11	108, 83, 82, 107
719	Pending	32:59	32:59	107, 81, 106, 105
725	Pending	35:03	35:03	106, 105
789	Pending	39:26	19:20	105, 116, 77, 76
799	Pending	54:27	47:47	72, 116, 117, 74
833	Non-Participating	31:46	12:30	117, 74, 73
3431	Non-Participating	32:35	32:35	129, 100
6538	Pending	31:42	31:42	130
10308	Pending	38:33	18:33	131, 86, 98, 85

As shown in Table 2, consideration of obstacles in the shadow flicker analysis reduced the anticipated shadow flicker for four of the analyzed structures, three of which no longer exceed the 30-hour threshold. However, three non-participating structures and four pending structures remain in excess of this threshold. As mentioned previously, final selection of the turbine make/model for the Buckeye II Wind Farm has not been made so this analysis evaluates the worst-case turbine model under consideration. If the final turbine selection is different than the turbine model used in this analysis, another computer model analysis will be conducted to quantify any potential reductions in anticipated shadow flicker. If any non-participating receptors remain in excess of 30 hours per year of anticipated shadow flicker, additional mitigation measures may include curtailment of operation during select times and/or screening (such as vegetative planting or window treatments).

6.0 CUMULATIVE ANALYSIS

edr conducted a cumulative shadow flicker impact evaluation to analyze the potential impacts that may occur if both Buckeye I and Buckeye II Wind Farms become operational. A total of 458 structures are within 1,100 meters of turbines from both wind farms, and these structures were evaluated to determine potential cumulative shadow flicker impacts. The analysis was run using the Nordex N100 turbine model for Buckeye I and the GE 2.5-103 turbine model for Buckeye II.

A summary of model results from the cumulative analysis are as follows:

- 70 (15%) will experience no shadow flicker,
- 202 (44%) may be affected >0-10 hours/year,
- 90 (20%) may be affected 10-20 hours/year,
- 59 (13%) may be affected 20-30 hours/year,
- 37 (8%) may be affected more than 30 hours/year.

The threshold of 30 hours of shadow flicker per year was used in this cumulative analysis to evaluate potential shadow flicker impacts to area residences from both proposed Facilities (see Section 5.0 of this report for additional detail regarding this threshold). As indicated above, 37 structures are predicted to exceed that threshold as a result of the Buckeye I and II cumulative shadow flicker analysis. However, many of these structures are project participants, while others are in fact non-residential structures (e.g., barns, sheds). Therefore, based on the initial analysis, only 11 non-participating or pending structures are predicted to exceed the 30-hour threshold for cumulative impacts. As previously indicated, any structure classified by the Applicant as “pending” is included in the subsequent evaluation and discussion to assure a worst-case analysis.

Two of the non-participating or pending structures that will receive more than 30 hours per year of shadow flicker from Buckeye II (662 and 3431) would receive further shadow flicker impacts from the concurrent operation of both Buckeye I and Buckeye II Facilities. An additional nine structures that will not receive more than 30 hours per year of shadow flicker from Buckeye II would exceed the 30 hour per year threshold when cumulative impacts from both Facilities are considered. Cumulative shadow flicker impacts that exceed 30 hours per year are summarized below in Table 3 for each of the 11 non-participating or pending structures that would receive shadow flicker from both the Buckeye I and Buckeye II Facilities. Also refer to Attachment F, which contains graphical calendars produced by WindPRO that illustrate the times of day and year when structures are anticipated to receive shadow flicker effects.

Table 3. Cumulative Analysis: Structures Exceeding 30 Hours of Shadow Flicker per Year (Initial Analysis)

Structure ID	Project Status	Predicted Shadow Flicker (hh:mm/year)	Turbines Contributing Shadow Flicker		Approximate Times of Day Receptor Potentially Affected by Flicker[2]
			Buckeye I	Buckeye II	
662	Pending	63:47	32	82, 83, 107, 108	7:00AM – 9:00AM 4:00PM – 8:30PM
747	Non-Participating	31:27	18, 21, 22	129	7:00AM – 9:30AM 5:30PM – 8:30PM
750	Non-Participating	30:36	18, 21, 22,	129	6:30AM – 9:00AM 6:00PM – 8:30PM
812	Non-Participating	30:48	16, 18	100, 126	7:30AM – 9:30AM 4:30PM – 8:30PM
3426	Non-Participating	35:03	18, 21, 22	129	7:00AM – 9:00AM 5:30PM – 8:30PM
3431	Non-Participating	36:37	18	100, 129	7:00AM – 9:00AM 6:00PM – 7:30PM
8224	Non-Participating	34:15	49	118, 119	7:00AM – 8:30AM 4:00PM – 5:00PM
8226	Non-Participating	33:50	49	118, 119	7:00AM – 8:30AM 4:00PM – 5:00PM
8343	Non-Participating	33:59	15, 16	100, 126	6:30AM – 9:30AM 7:00PM – 8:00PM
10056	Non-Participating	36:10	32, 39	83, 108	7:00AM – 9:30AM 4:00PM – 6:30PM
10168	Non-Participating	38:22	22	127	2:30PM – 8:30PM

As previously mentioned, these calculations do not take into account the actual location and orientation of windows, or the screening effects associated with existing site-specific conditions such as vegetation and/or buildings. However, the methodology described in Section 5.0 for incorporating site-specific obstacles into the WindPro analysis, based on the site investigation conducted by **edr** on April 19, 2012, was also applied to the cumulative shadow flicker analysis (see Attachment D for Obstacle Analysis Data Sheets).

Results of the revised shadow flicker analysis that considers the screening effects of obstacles are provided in Attachment G and summarized below in Table 4.

[2] The times of day presented in Table 3 represent the range of times during which each structure could potentially experience shadow flicker throughout the year; however, no structures will experience shadow flicker every day during all those hours. See Attachments F and G for detailed calendars that illustrate the specific times of year and day that each structure may experience shadow flicker.

Table 4. Cumulative Analysis: Structures Exceeding 30 hours of Shadow Flicker per Year (Obstacle Analysis)

Structure ID	Project Status	Predicted Shadow Flicker (hh:mm/year)		Turbines Contributing Shadow Flicker
		Without Obstacles	With Obstacles	
662	Pending	63:47	63:47	32, 108, 83, 82, 107
747	Non-Participating	31:27	18:36	22, 21, 129, 18
750	Non-Participating	39:13	30:36	22, 21, 129, 18
812	Non-Participating	30:48	0:00	18, 100, 126, 16
3426	Non-Participating	35:03	20:55	22, 21, 18, 129
3431	Non-Participating	36:37	36:37	129, 18, 100
8224	Non-Participating	34:15	22:50	49, 118, 119
8226	Non-Participating	33:50	33:50	49, 118, 119
8343	Non-Participating	33:59	33:59	100, 126, 16, 15
10056	Non-Participating	36:10	36:10	39, 32, 108, 83
10168	Non-Participating	38:22	38:22	127, 22

As shown in Table 4, consideration of obstacles in the shadow flicker analysis reduced the anticipated cumulative shadow flicker for five of the analyzed structures, four of which no longer exceed the 30-hour threshold. However, six non-participating structures and one pending structure remain in excess of this threshold. As mentioned previously, final selection of the turbine make/model for the Buckeye II Wind Farm has not been made so this analysis evaluates the worst-case turbine model under consideration. If the final turbine selection is different than the turbine model used in this analysis, another computer model analysis will be conducted to quantify any potential reductions in anticipated shadow flicker. If any non-participating receptors remain in excess of 30 hours per year of anticipated cumulative shadow flicker, additional mitigation measures may include curtailment of operation during select times and/or screening (such as vegetative planting or window treatments).

7.0 REFERENCES

British Epilepsy Association. 2012. *Photosensitive Epilepsy* [website]. Available at: http://www.epilepsy.org.uk/info/photosensitive-epilepsy (Accessed March 6, 2012). Epilepsy Action, Yeadon Leeds, UK.

Business Enterprise & Regulatory Reform (BERR). 2009. *Onshore Wind: Shadow Flicker* [website]. Available at: http://www.berr.gov.uk/whatwedo/energy/sources/renewables/planning/ onshore-wind/shadow-flicker (Accessed January 27, 2009). United Kingdom Department for Business Enterprise and Regulatory Reform.

Department of Energy and Climate Change (DECC). 2011. *Update of UK Shadow Flicker Evidence Base: Final Report.* Parsons Brinckerhoff, London, UK, p. 5.

National Research Council (NRC). 2007. *Environmental Impacts of Wind Energy Projects*. Committee on Environmental Impacts on Wind Energy Projects. The National Academies Press, Washington, D.C., pp. 160-162.

North Carolina Wind Working Group (NCWWG). 2008. *Model wind ordinance for wind energy facilities in North Carolina*. http://www.dsireusa.org/documents/Incentives/NC18R.pdf (Accessed March 1, 2012).

Ohio Power Siting Board (OPSB), 2008. *Opinion, Order, and Certificate in the Matter of Buckeye Wind, LLC.* Case No. 08-666-EL-BGN. Conclusions and Conditions Section (31), p. 89.

Ohio Power Siting Board (OPSB), 2009a. *Opinion, Order, and Certificate in the Matter of JW Great Lakes Wind, LLC.* Case No. 09-277-EL-BGN. Stipulation's Recommended Conditions, Section (23), p. 22.

Ohio Power Siting Board (OPSB), 2009b. *Opinion, Order, and Certificate in the Matter of Harden Wind Energy, LLC.* Case No. 09-479-EL-BGN. Summary of the Evidence, Section D (2) and Stipulation's Recommended Conditions, Sections (34) and (35), pp. 16 & 28.

Ohio Power Siting Board (OPSB), 2009c. *Opinion, Order, and Certificate in the Matter of Paulding Wind Farm, LLC.* Case No. 09-980-EL-BGN. Summary of the Evidence Section D (3) and Stipulation's Recommended Conditions, Section (39), pp. 17 & 31.

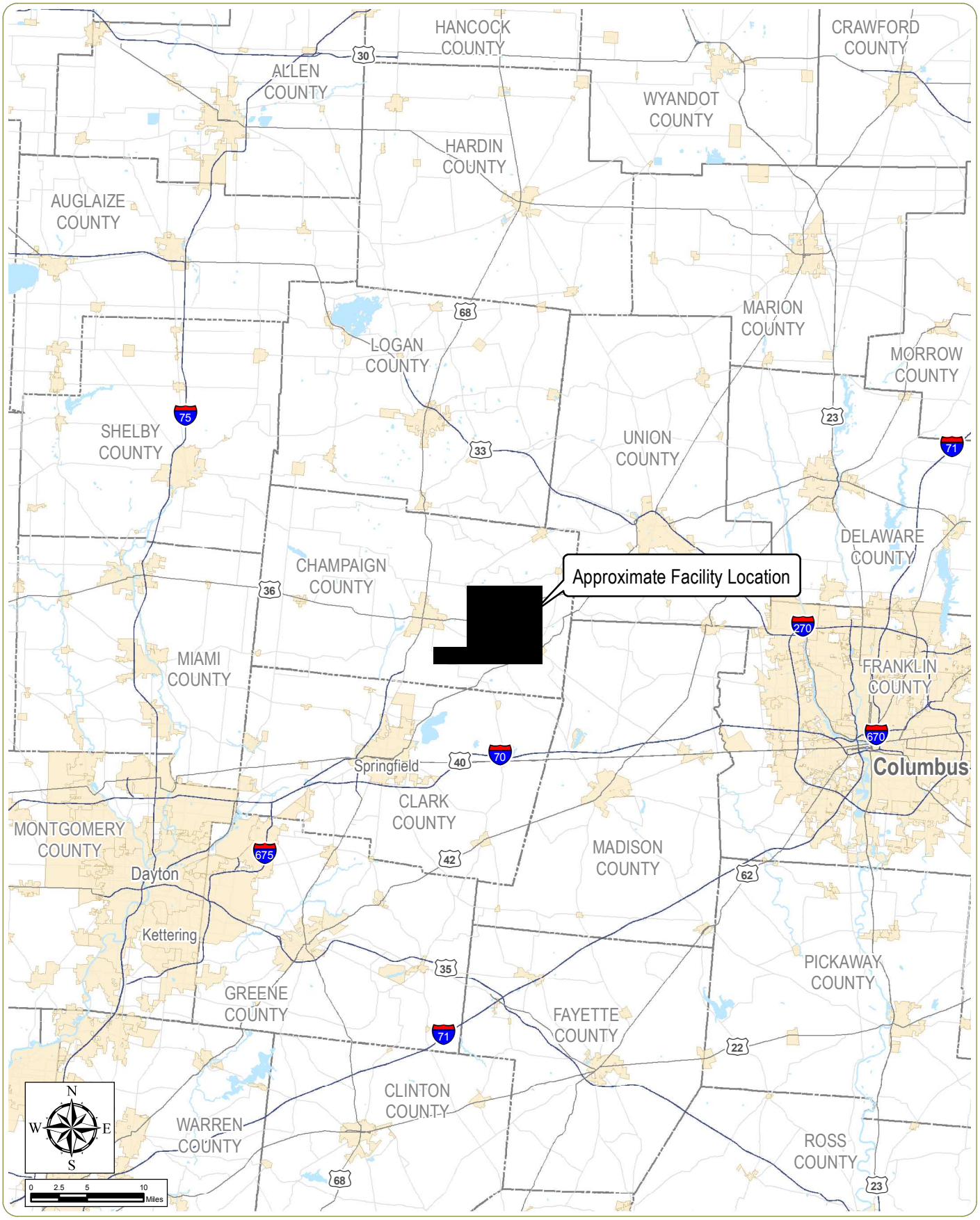
Ohio Power Siting Board (OPSB), 2009d. *Opinion, Order, and Certificate in the Matter of Heartland Wind, LLC.* Case No. 09-1066-EL-BGN. Summary of the Evidence Section D (3), p. 16.

Sustainable Energy Authority Victoria. 2009. *Policy Planning and Guidelines for Development of Wind Energy Facilities in Victoria.* Sustainable Energy Authority Victoria, Melbourne Victoria, Australia.

U.S. Department of Energy (USDOE) National Renewable Energy Laboratory. 2008. *An Overview of Existing Wind Energy Ordinances*. Available at: http://www.windpoweringamerica.gov/pdfs/policy/2008/ordinances_overview.pdf (Accessed March 6, 2012).

U.S. Department of the Interior. 2005. *Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western United States.* Bureau of Land Management, Appendix D: Wind Energy Technology Overview.

Figures



Buckeye II Wind Farm

Goshen, Rush, Salem, Union, Urbana, and Wayne Townships - Champaign County, Ohio

Shadow Flicker Report

Figure 1: Regional Facility Location

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Notes: Base Map: ESRI StreetMap North America, 2008.

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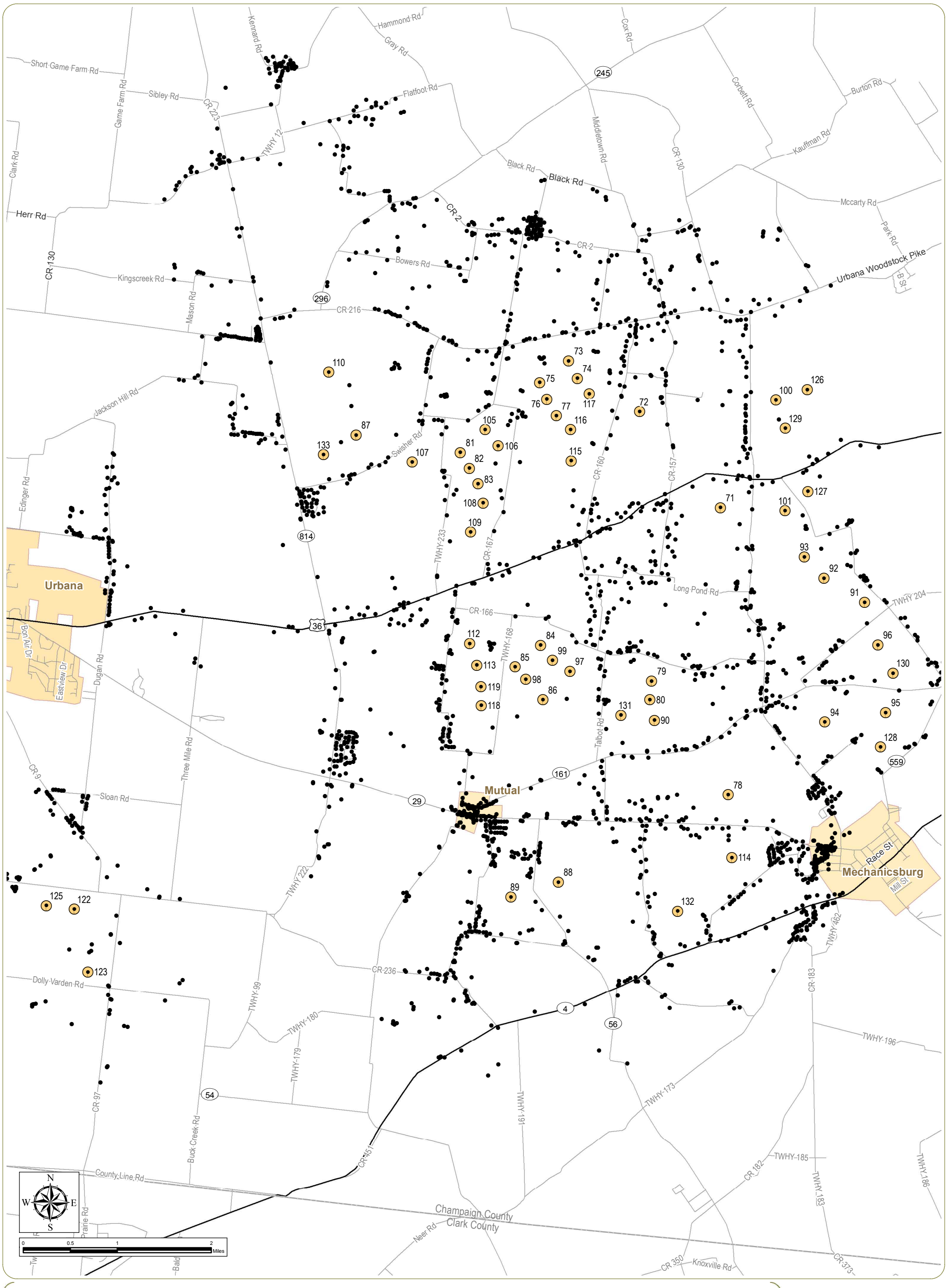

Buckeye II Wind Farm

Goshen, Rush, Salem, Union, Urbana, and
Wayne Townships - Champaign County, Ohio

Shadow Flicker Report
Figure 2: Proposed Turbine Layout

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Notes: Base Map: ESRI StreetMap North America, 2008.

• Receptor/Structure
⊙ Wind Turbine

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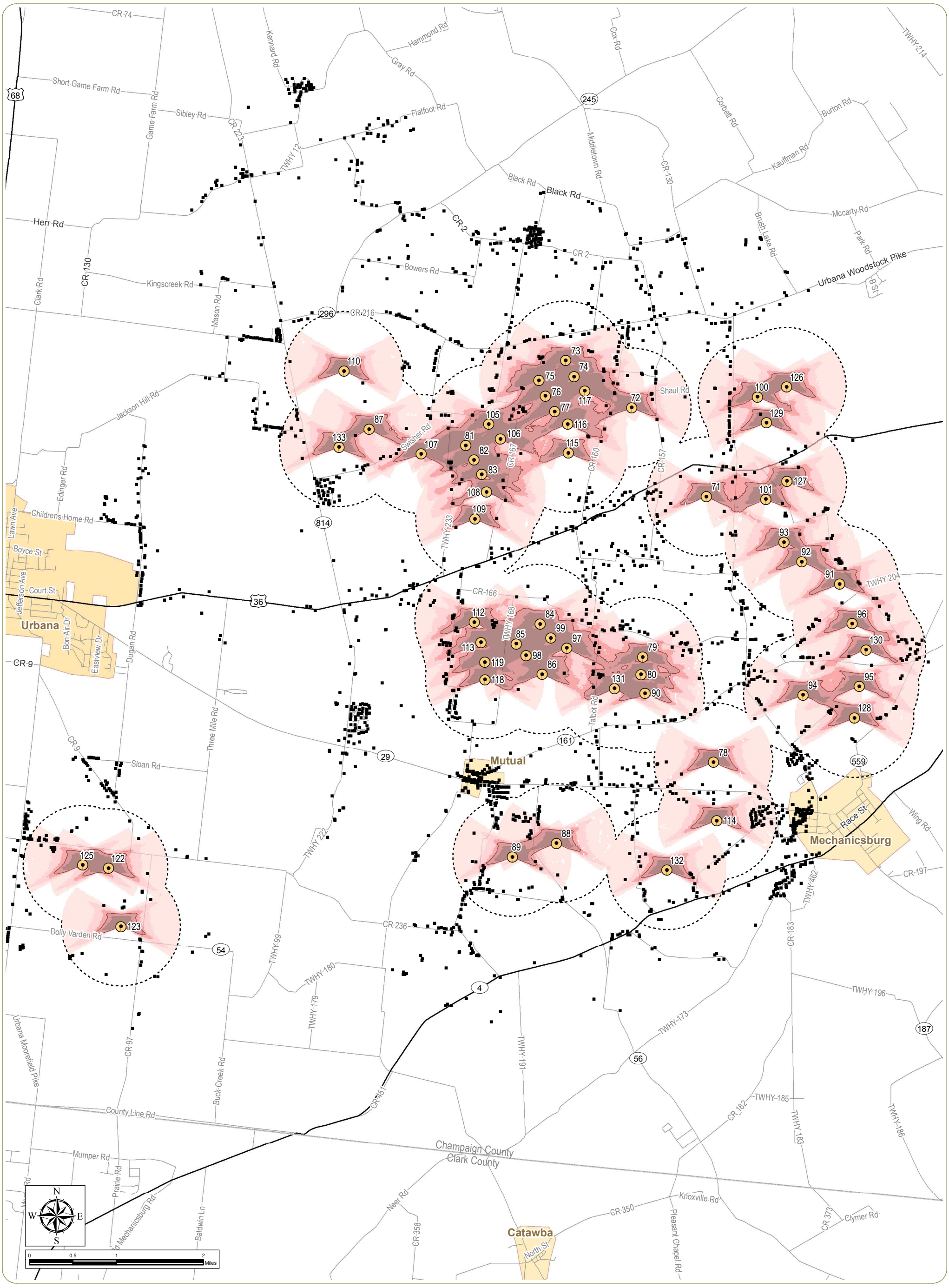

Buckeye II Wind Farm

Goshen, Rush, Salem, Union, Urbana, and Wayne Townships - Champaign County, Ohio

Shadow Flicker Report
Figure 3: Projected Shadow Flicker Map

May 2012

Notes: Base Map: ESRI StreetMap North America, 2008.

- Receptor/Structure
- Wind Turbine
- 30 hours per year contour
- 1100-Meter Radius

Projected Shadow Flicker

- >0 - 9 hours per year
- 10 - 19 hours per year
- 20 - 29 hours per year
- 30 - 49 hours per year
- >50 hours per year

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Attachment A

Wind Rose and Sunshine Data

Table A1. Wind Rose Data

Sector	N	NNE	NE	ENE	E	ESE	SE	SSE
Frequency	3.20	3.50	5.50	4.80	5.40	4.40	4.70	4.40
Hours of Operation	280	307	482	420	473	385	412	385

Sector	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Frequency	6.80	9.10	9.50	8.30	9.80	8.50	7.20	4.90	100.00
Hours of Operation	596	797	832	727	858	745	631	430	8,760

Source: Wind rose data provided by Champaign Wind LLC.

Table A2. Sunshine Probability Data

Month	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Sunshine Probability	0.36	0.42	0.44	0.51	0.56	0.6	0.6	0.6	0.61	0.56	0.37	0.5

Source: NOAA Comparative Climatic Data for the United States – Columbus Ohio Weather Station.

Attachment B

Summary of Structures Modeled to Receive more than 10 Hours of Shadow Flicker per Year

Summary of Structures Modeled to Receive more than 10 Hours of Shadow Flicker per Year

Structure ID	Predicted Shadow Flicker		
	Shadow Days per Year	Maximum Hours per Day (hh:mm/day)	Annual Total Duration (hh:mm/year)
9736	68	0:39	10:00
10045	90	0:31	10:00
8229	73	0:32	10:05
6545	83	0:32	10:09
6919	94	0:37	10:12
624	88	0:29	10:14
10104	56	0:42	10:17
3269	87	0:29	10:18
9607	56	0:44	10:20
3248	94	0:31	10:22
378	74	0:33	10:23
6923	66	0:48	10:23
3271	82	0:33	10:26
6543	81	0:33	10:27
3346	59	0:36	10:28
3272	94	0:31	10:32
246	70	0:28	10:40
3056	54	0:36	10:41
747	61	0:35	10:44
850	92	0:36	10:44
6922	80	0:43	10:45
820	102	0:26	10:46
3095	58	0:45	10:46
3349	79	0:26	10:54
717	80	0:35	10:55
10062	75	0:36	10:55
4566	63	0:45	10:57
3247	87	0:32	11:00
6143	82	0:35	11:02
6569	84	0:30	11:05
3093	64	0:47	11:07
6921	86	0:42	11:14
6558	102	0:32	11:17
6925	69	0:51	11:17
376	93	0:32	11:21
8334	93	0:38	11:25
6926	61	0:56	11:27
6145	85	0:34	11:29

Structure ID	Predicted Shadow Flicker		
	Shadow Days per Year	Maximum Hours per Day (hh:mm/day)	Annual Total Duration (hh:mm/year)
6918	100	0:39	11:29
375	105	0:28	11:31
392	96	0:35	11:31
826	59	0:45	11:32
623	87	0:33	11:33
6924	74	0:50	11:34
10047	108	0:31	11:36
8228	80	0:33	11:37
3092	61	0:47	11:40
416	110	0:33	11:49
6165	101	0:39	11:51
6144	86	0:35	11:54
629	117	0:31	11:55
5.1	102	0:29	12:00
111	92	0:38	12:00
6553	120	0:31	12:00
374	111	0:29	12:08
373	104	0:29	12:10
6181	62	0:48	12:12
377	95	0:33	12:18
6147	92	0:35	12:19
10041	53	0:57	12:22
390	66	0:51	12:23
336	69	0:38	12:28
9443	95	0:35	12:29
3244	86	0:37	12:31
3444	95	0:26	12:31
6542	92	0:35	12:42
3426	75	0:35	12:46
3425	69	0:33	12:48
389	104	0:34	12:52
9608	62	0:48	12:58
672	63	0:53	13:04
6179	64	0:49	13:07
6178	63	0:50	13:12
3238	68	0:50	13:28
6150	93	0:38	13:31
3391	92	0:42	13:51
6180	65	0:50	13:51

Structure ID	Predicted Shadow Flicker		
	Shadow Days per Year	Maximum Hours per Day (hh:mm/day)	Annual Total Duration (hh:mm/year)
10111	107	0:38	14:00
6142	94	0:38	14:07
851	113	0:38	14:14
3443	101	0:27	14:15
6564	64	0:48	14:21
418	122	0:34	14:25
8343	114	0:40	14:30
8090	67	0:43	14:39
6540	100	0:38	14:40
3270	115	0:33	14:43
575	55	0:49	14:44
415	118	0:37	14:49
3347	91	0:32	14:50
622	102	0:37	14:58
3096	92	0:43	15:03
394	128	0:57	15:09
388	142	0:46	15:18
6177	67	0:53	15:19
6565	66	0:49	15:22
414	102	0:39	15:30
10042	62	1:04	15:33
6544	107	0:38	15:43
824	127	0:32	16:01
417	144	0:31	16:13
4666	103	0:41	16:13
3055	67	0:43	16:17
245	82	0:34	16:20
6559	136	0:36	16:36
3402	100	0:35	16:40
828	110	0:48	16:41
714	70	0:55	16:49
3094	86	0:54	16:54
6534	128	0:41	17:14
6533	84	0:38	17:21
736	104	0:37	17:23
6532	128	0:34	17:28
6171	122	0:32	17:37
656	136	0:42	17:38
413	112	0:42	17:49

Structure ID	Predicted Shadow Flicker		
	Shadow Days per Year	Maximum Hours per Day (hh:mm/day)	Annual Total Duration (hh:mm/year)
335	105	0:39	17:52
8227	104	0:33	17:58
421	143	0:34	18:04
750	92	0:35	18:16
9609	112	0:50	18:17
812	102	0:52	18:18
807	76	0:56	18:21
8225	120	0:34	18:28
6151	94	1:02	18:39
741	75	0:49	18:49
408	161	0:39	18:53
6172	132	0:33	19:01
6560	133	0:37	19:03
6141	110	0:47	19:06
827	129	0:51	19:49
10043	73	1:08	19:57
419	145	0:37	19:58
7816	114	0:44	20:03
6566	77	0:55	20:05
407	103	0:46	20:06
333	82	0:42	20:12
734	92	0:53	20:15
617	122	0:42	20:17
8088	87	0:52	20:20
8215	84	0:41	20:30
3241	123	0:52	20:31
8226	130	0:32	20:34
3442	127	0:45	20:35
3054	78	0:46	20:40
579	78	0:58	20:55
729	124	0:45	21:02
834	136	0:42	21:10
10163	110	1:18	21:10
730	126	0:41	21:11
3186	91	0:41	21:13
10311	183	0:48	21:14
8216	89	0:41	21:15
733	103	0:52	21:22
8086	86	0:54	21:35

Structure ID	Predicted Shadow Flicker		
	Shadow Days per Year	Maximum Hours per Day (hh:mm/day)	Annual Total Duration (hh:mm/year)
8217	78	0:49	21:38
412	145	0:42	21:48
3441	120	0:56	21:48
10202	143	0:45	21:50
8087	89	0:53	21:51
806	120	0:54	21:56
811	143	0:46	22:06
396	172	0:39	22:20
728	122	0:51	22:20
3430	112	0:44	22:20
6140	130	0:52	22:40
468	115	0:59	22:45
8224	138	0:34	22:50
8383	172	0:38	23:01
844	175	0:47	23:20
10056	112	0:45	23:25
8370	119	0:55	23:46
3240	142	1:09	23:49
471	127	0:55	23:51
732	181	0:35	23:51
4519	94	0:55	23:57
3424	119	0:57	24:12
6176	121	0:53	24:14
800	173	0:39	24:28
397	161	0:48	24:30
3239	168	1:07	24:36
6153	86	1:01	24:40
797	138	0:50	24:41
3053	104	0:44	25:25
3432	131	1:05	25:34
845	185	0:48	25:45
3097	126	0:51	26:04
658	89	1:08	27:10
8335	121	1:16	27:25
6152	88	1:07	27:38
832	161	0:42	27:41
10168	94	1:15	27:44
8089	114	0:49	27:48
846	186	0:51	28:00

Structure ID	Predicted Shadow Flicker		
	Shadow Days per Year	Maximum Hours per Day (hh:mm/day)	Annual Total Duration (hh:mm/year)
10164	117	1:24	28:04
395	226	0:59	28:21
8384	177	0:43	28:24
469	143	0:58	28:30
391	216	0:51	28:49
10110	143	0:53	28:51
847	181	0:54	29:02
6139	99	1:11	29:15
470	154	0:56	29:45
726	195	0:52	29:53
410	197	0:41	31:13
6538	82	1:10	31:42
833	176	0:48	31:46
794	218	0:53	32:15
342	209	0:57	32:19
727	184	1:12	32:23
3431	160	0:47	32:35
719	171	1:19	32:59
573	186	0:49	34:06
341	227	0:50	34:49
725	172	1:08	35:03
581	167	1:02	35:44
9758	138	1:09	36:35
411	223	0:41	36:53
6175	203	1:02	37:15
10308	188	0:57	38:33
849	227	0:57	38:43
795	223	0:48	38:45
3417	157	1:07	38:48
7825	195	0:51	38:56
789	238	0:46	39:26
406	152	1:08	42:14
402	160	1:33	44:05
343	224	1:25	44:42
400	173	1:23	45:43
401	190	1:24	46:11
739	178	1:02	47:27
793	256	1:00	48:39
10055	167	1:04	49:32

Structure ID	Predicted Shadow Flicker		
	Shadow Days per Year	Maximum Hours per Day (hh:mm/day)	Annual Total Duration (hh:mm/year)
340	271	1:01	50:37
616	122	1:16	50:49
344	241	1:15	52:02
339	265	1:08	53:13
8386	263	1:00	53:20
799	261	1:23	54:27
348	263	1:12	55:04
662	200	1:37	57:11
10206	265	1:22	57:45
403	217	1:17	60:34
8353	261	1:37	62:32
8355	268	1:28	62:43
8354	260	1:36	63:42
8351	265	1:32	64:24
8352	262	1:35	64:28
8356	267	1:30	64:47
10280	260	1:35	67:03
3380	248	1:05	69:39
3429	171	1:56	72:10
404	289	1:40	78:38
405	302	1:43	93:40