MONTANA-DAKOTA
UTILITIES CO.
A Division of MDU Resources Group, Inc.

400 North Fourth Street
Bismarck, ND 58501
(701) 222-7900

May 10, 2017

Executive Secretary
North Dakota Public Service Commission
State Capitol Building
Bismarck, ND 58505-0480

Re: Case No. PU-17-___
Application to Amend the Certificate of Site Compatibility Permit No. 35 for the Thunder Spirit Wind Project.

Montana-Dakota Utilities Co., a Division of MDU Resources Group, Inc., (Montana-Dakota) herewith files an original and seven (7) copies of its request to amend the North Dakota Public Service Commission (Commission) Certificate of Site Compatibility Permit No. 35 (Permit No. 35) for the Thunder Spirit Wind project located in Adams County, North Dakota transferred to Montana-Dakota by the Commission's Order issued on December 16, 2105 in Case No. PU-15-592. An affidavit of Darcy Neigum in support of this request is attached hereto.

Montana-Dakota is requesting an amendment to Permit No. 35 to allow for the installation of up to 16 Nordex N117/3000 3.0MW wind turbines on previously approved turbine locations and a resulting increase in overall total generating capacity to 155.5MW. Work to install the additional 16 Nordex N117/3000 3.0MW wind turbines is expected to be completed by the end of 2018.

Background:
The original Certificate of Site Compatibility for the Thunder Spirit Wind project was filed under PU-11-601 by Thunder Spirit Wind, LLC. Montana-Dakota purchased the Thunder Spirit Wind project, including all expansion rights, from Thunder Spirit Wind, LLC on December 30, 2015.

On October 9, 2013, the Commission issued Permit No. 35 for the Thunder Spirit Wind project for the installation of up to 75 wind turbines and associated facilities totaling up to 150MW of generating capacity.

On May 30, 2014, Thunder Spirit Wind LLC filed with the Commission an application to amend Permit No. 35 using 43 Nordex N100/2500 2.5MW turbines totaling 107.5MW of generating capacity, utilizing 18 new turbine locations and shifting 25 originally approved turbine locations.

On August 14, 2014, the Commission issued its Supplemental Order and First Amended Certificate of Site Compatibility No. 35 for Thunder Spirit Wind, LLC to construct wind turbines in 43 proposed locations plus 31 previously-approved locations reserved for a possible installation of the remainder of the 150MW site certificate in the future. Thunder Spirit Wind, LLC was also required by the Commission's Supplemental Order issued on August 14, 2014 to file updated noise and shadow flicker impact studies for its final site plan prior to beginning construction on the remainder of its 150MW site certificate.

The Certificate for the Thunder Spirit Wind project was transferred to Montana-Dakota by the Commission's Order issued on December 16, 2015 in Case No. PU-15-592.

Permit Modification:
At this time, Montana-Dakota is seeking to install up to 16 Nordex N117/3000 3.0MW wind turbines with a 91 meter hub height and 116.8 meter rotor diameter, which fall within the original range of turbine configurations as submitted in the original application (Vestas V100 2.0MW turbines, Siemens SWT 2.3-108 2.3MW turbines and Acciona AW116/3000 3.0MW turbines with a hub height range of 80 to 92 meters and a rotor diameter range of 100 to 116 meters).

The turbines will be installed on previously approved turbine locations and there will be no changes to the project roads from previously approved design. The existing collector substation, step-up transformer, 230kV transmission line, and network interconnection facilities are already designed and constructed to handle the 150MW project size.

An updated original and final layout design is provided as Exhibit A. The layout design includes a total of 19 (16 proposed plus 3 alternate) sites for the additional turbines and the remaining 12 sites may be released from future development under Certificate of Site Compatibility No. 35. A Nordex N117/3000 Product Brochure is provided as Exhibit B.

The updated Sound Assessment Study provided as Exhibit C and the Updated Shadow Flicker Analysis provided as Exhibit D, show no additional impacts than previous studies and are within all permit requirements. The Nordex model N117/3000 wind turbines actually produce less noise than the wind turbines used for the first Thunder Spirit Wind project due to the turbines' larger size and newer technology.

The Original and Amended Certificate of Site Compatibility No. 35 for the Thunder Spirit Wind project allowed the installation of up to 75 wind turbines totaling up to 150MW of generating capacity. The MISO interconnection agreement for the Thunder Spirit Wind project is for 150MW of net generating capacity and the project collector substation, step-up transformer and interconnection facilities are sized for 150MW of energy flow from the project. Montana-Dakota is requesting the ability to install up to 155.5MW of gross (nameplate) generation under Certificate of Site Compatibility No. 35. The 155.5MW of gross (nameplate) generation matches the MISO interconnection and collector substation facilities. The total number of turbines for the Thunder Spirit Wind project would be up to 59 machines which is less than the originally contemplated 75 turbines. Installing larger turbines allows the use of fewer machines and allows for a smaller project footprint. If Thunder Spirt Wind had originally installed 150MW of turbines utilizing 2.5MW machines it would have required 60 turbine sites. At 155.5MW of gross generation (nameplate) the final project will only utilize 59 sites, adding additional MWs while reducing the overall footprint for the project site.

The 155.5MW of gross generation (nameplate) is measured at the base of the wind turbines while the MISO interconnection agreement controls the amount of energy or net generation added to the transmission system at the point of interconnection. The project has electric losses between the point of generation and point of interconnection due to (1) auxiliary turbine loads, (2), padmount transformer losses, (3) underground collector cabling losses, (4) step-up transformer losses, (5) station service at the collector substation losses, and (6) transmission line losses between the collector substation and point of interconnection. At full generation output for the final Thunder Spirit Wind project all of the electrical losses account for up to 5MW of energy lost between the point of generation and point of interconnection.

The 155.5MW of gross generation project size allows Montana-Dakota to utilize additional economies of scale with the final project design to match the MISO interconnection agreement and the larger turbine size allow for a smaller project footprint than originally proposed. The Commission has granted a similar request to install more generating nameplate MWs than the Certificate of Site Compatibility to Minnesota Power for their Bison Wind Project under PU-09-151 and Certificate of Site Compatibility Permit No. 15.

Montana-Dakota requests an expedited review and approval of this amendment request so that remaining turbine equipment can be ordered in the fall of 2017 to meet an end of 2018 in-service date.

Montana-Dakota requests the Commission provide a Notice of Opportunity to request a hearing to interested parties and, if no hearing is requested within twenty days, to waive the hearing in accordance with §49-22-13(4), N.D.C.C. and 69-02-04-01, N.D.A.C.

Please refer all inquiries regarding this filing to:

Ms. Tamie Aberle
Director of Regulatory Affairs

Montana-Dakota Utilities Co.
400 North Fourth Street
Bismarck, ND 58501
Tamie.aberle@mdu.com

Also, please send copies of all written inquiries, correspondence and pleadings to:

Karl Liepitz
Assistant General Counsel
MDU Resources Group, Inc.
P.O. Box 5650
Bismarck, ND 58506-5650
Karl.liepitz@mduresources.com

Montana-Dakota is including a check in the amount of $5,000.00. In the event the Commission determines an additional fee is required to cover anticipated expenses of processing the Application, Montana-Dakota shall remit such amount in accordance with North Dakota Century Code Section 49-22-22(1)(d).

Montana-Dakota respectfully requests that this filing be accepted as being in full compliance with the filing requirements of this Commission.

Please acknowledge receipt by stamping or initialing the duplicate copy of this letter attached hereto and returning the same in the enclosed self-addressed, stamped envelope.

Sincerely,

Tamie A. Aberle
Director of Regulatory Affairs

Attachments
Cc: Karl Liepitz
Darcy Neigum

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF NORTH DAKOTA

In the Matter of the Application of	)	
MONTANA-DAKOTA UTILITIES CO.,	)	
a Division of MDU Resources Group,	)	Case No. PU-17-____
Inc. to Amend the Certificate of Site	)	
Compatibility Permit No. 35 for the	)	
Thunder Spirit Wind Project	)	

AFFIDAVIT OF DARCY NEIGUM

STATE OF NORTH DAKOTA	)	
	)	:ss
COUNTY OF BURLEIGH	)	

1. I am the Director of Electric System Operations and Planning for Montana-Dakota Utilities Co., a Division of MDU Resources Group, Inc. (Montana-Dakota), 400 North 4th Street, Bismarck, ND 58501, and I make this affidavit on the basis of my own personal knowledge and belief as to the matters contained herein.

2. The information contained in this request to modify the Certificate of Site Compatibility for the Thunder Spirit Wind project under Energy Conversion Facility No. 35 (Certificate) originally dated October 9, 2013 with a First Amended dated August 14, 2014 in the above-referenced Docket is true and is based upon my knowledge.

3. I am responsible for overseeing the day-to-day operation of the Company's electric control center and System Operations & Planning Department which includes working with new generation development opportunities for the Company.

4. The purpose of my Affidavit is to provide evidence and support regarding Montana-Dakota's request to modify its Certificate for its Thunder Spirit Wind project located in Adams County.

5. Montana-Dakota acquired the Thunder Spirit Wind project and all future development rights from Thunder Spirit Wind, LLC on December 30, 2015.

6. The Certificate for the Thunder Spirit Wind project was transferred to Montana-Dakota by the North Dakota Public Service Commission (Commission) Order issued on December 16, 2015 in Case No. PU-15-592.

7. The Commission certified the Thunder Spirit Wind project "consisting of up to 75 wind turbines and associated facilities totaling up to 150MW generating capacity in Adams County, North Dakota."

8. Montana-Dakota is requesting two modifications to the Certificate which include: (1) the authority to utilize 3.0MW Nordex wind turbines, model N117/3000, with 91 meter hub heights and 116.8 meter diameter blades for the second phase of the project and (2) a resulting increase in overall total generating capacity to 155.5MW with a corresponding decrease by 16 in the total possible number of turbines for the Thunder Spirit Wind project to 59.

9. Provided as Exhibit A is an original and final proposed layout map for the initial Thunder Spirit Wind and expansion project.

10. The first phase of the Thunder Spirit Wind project, which commenced commercial operations December 30, 2015, consisted of 43, 2.5MW, wind turbine generators, a 34.5kV underground collector system, a 34.5 to 230kV project substation, a 230kV interconnection line and associated network transmission interconnection facilities, and an operation and maintenance building.

11. Montana-Dakota has contracted with Thunder Spirit Wind, LLC, a subsidiary of Allete Clean Energy (Allete), the original developer of the Thunder Spirit Wind project, to construct the second phase of the project.

12. Allete will be constructing the Thunder Spirit Wind expansion project under a Development Rights Agreement (DRA) with Montana-Dakota. Under the DRA, Montana-Dakota will make available to Allete certain project permits and agreements, including the Certificate, to permit Allete to construct the Thunder Spirit Wind expansion project on behalf of Montana-Dakota. Montana-Dakota will ultimately be responsible for all agreement obligations and permit rights and requirements with sufficient representations, indemnities, and warranties regarding Allete's work under the DRA. If Allete is the ultimate owner of the Thunder Spirit Wind expansion project, then on a trigger event under the DRA, Montana-Dakota will dually transfer, or share through separate agreements, sufficient agreements and permits necessary for Allete to own and operate the Thunder Spirit Wind expansion project. Montana-Dakota's rationale for deploying the larger turbine equipment is outlined below and supported in Exhibits B, C, and D.

13. The new turbine Nordex model N117/3000 feature 91 meter hub heights with 116.8 meter diameter blades which fall within the original range of turbine configurations (hub heights ranging from 80 to 92 meters and rotor diameters ranging from 100 to 116 meters) in the original Certificate. The new turbines deliver up to 20% more energy per turbine through larger blades and improved efficiency than the N100/2500 turbines installed during the first phase of Thunder Spirit Wind.

14. The Thunder Spirit Wind expansion project will be constructed on previously sited and approved locations utilizing approved access roads. There will be no changes to any previously approved locations or access roads and therefore no impacts with any exclusion or avoidance areas as defined under North Dakota law. Montana-Dakota is also requesting the release of 12 sites for construction consideration from the original Certificate, and 3 alternate turbine sites, once the expansion project is completed. Less turbines sites will be used for the final project design reducing the overall footprint for the Thunder Spirit Wind project.

15. Montana-Dakota is also requesting the ability to install up to 155.5MW of generating capability for the entire Thunder Spirit Wind project. The Midcontinent ISO (MISO) generating interconnection agreement allows for 150MW of net generation into the transmission system from the Thunder Spirit Wind project. The final Thunder Spirit Wind project is expected to have 5MW of energy losses between the turbine generating equipment and the point of interconnection. The larger project size will (1) be constructed on a smaller project footprint than originally permitted, (2) match the generating capacity under the MISO interconnection agreement, and (3) provide additional economies of scale to the expansion project.

16. Provided as Exhibit B is a copy of Nordex's informational brochure for the model N117/3000 machine.

17. The Sound Assessment Study conducted by Burns & MacDonnell (Exhibit C) for the entire Thunder Spirit Wind project showed no expected exceedances of any identified noise regulations due to the operation of any of the wind turbines proposed for the project. The newer and larger turbine equipment proposed for the expansion project actually produces less noise and overall impacts than the turbine equipment used for the original project.

18. The updated Shadow Flicker Analysis conducted by Burns & MacDonnel (Exhibit D) showed a quantity of 36 occupied residences within the project site for the entire Thunder Spirit Wind project with 13 residences experiencing shadow flicker over the course of the year. None of these residences experiences shadow flicker in excess of the baseline limitation of 30 hours per year of perceivable shadow flicker. The elimination of 12 turbine sites now and the 3 alternate turbine sites in the future from

the project layout will result in a decrease in total shadow flicker exposure within the original permitted project boundaries due to the use of larger project turbines.

By: ______________________

Darcy Neigum
Director of Electric System Operations and Planning

Subscribed and sworn to before me this 10 day of May, 2017.

CAITLIN STRAABE
Notary Public
State of North Dakota
My Commission Expires August 28, 2019

Caitlin Straabe, Notary Public
Burleigh County, North Dakota
My Commission Expires: 08/28/2019

OF COUNSEL:

Mr. Karl Liepitz
Associate General Counsel
MDU Resources Group, Inc.
P. O. Box 5650
Bismarck, ND 58506-5650

Exhibit A

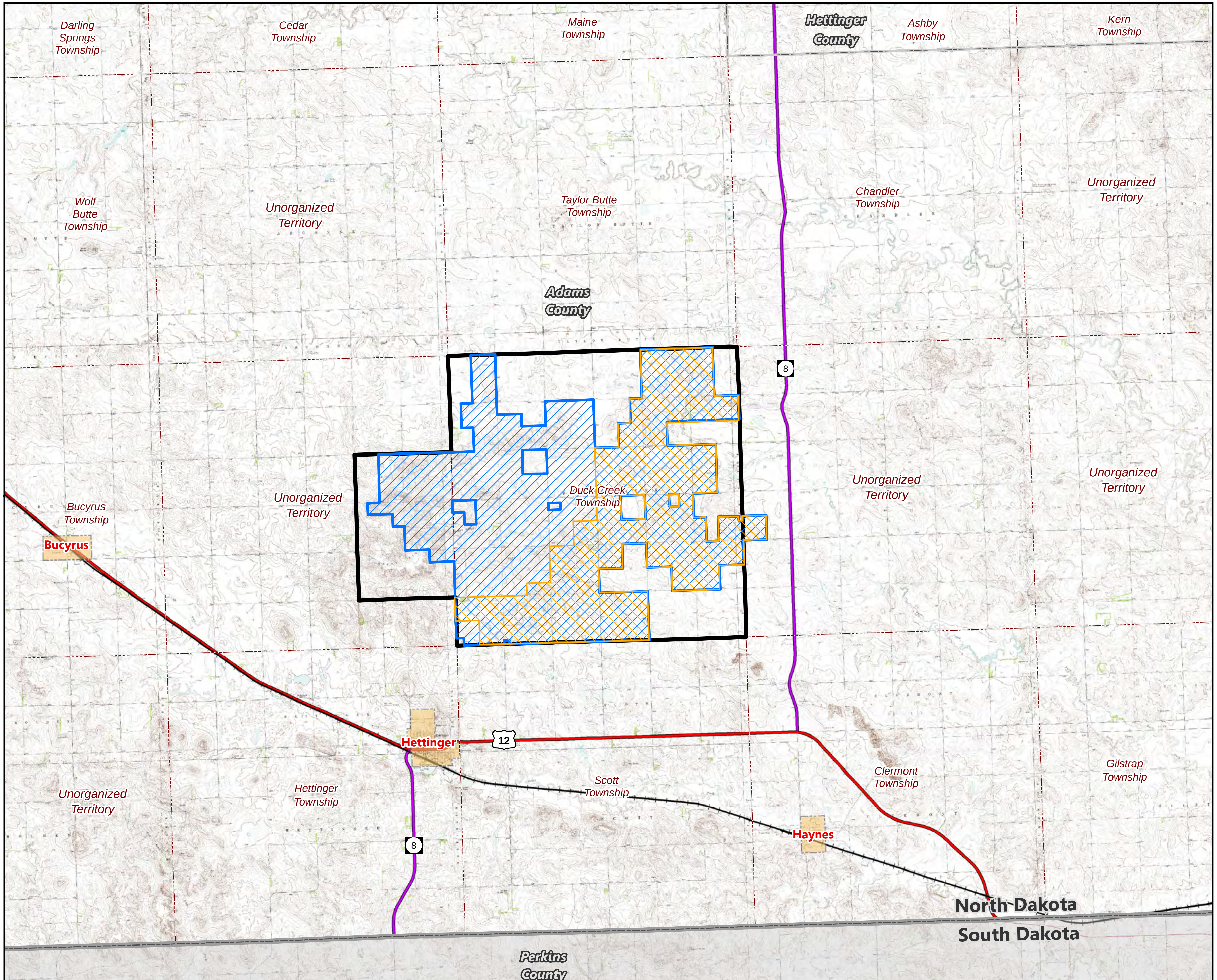
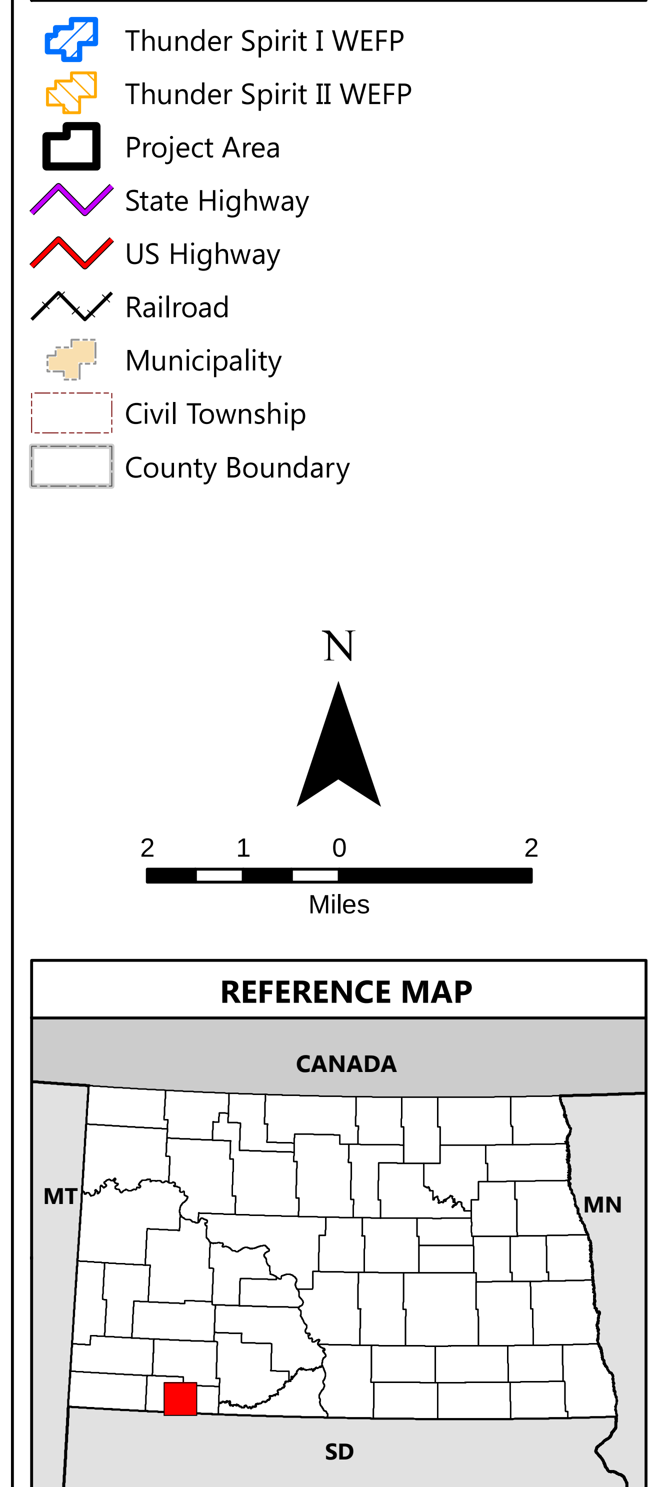


Figure 1

PROJECT LOCATION

Thunder Spirit II Wind Energy Project
Allete Clean Energy
Adams County, North Dakota

April 2017



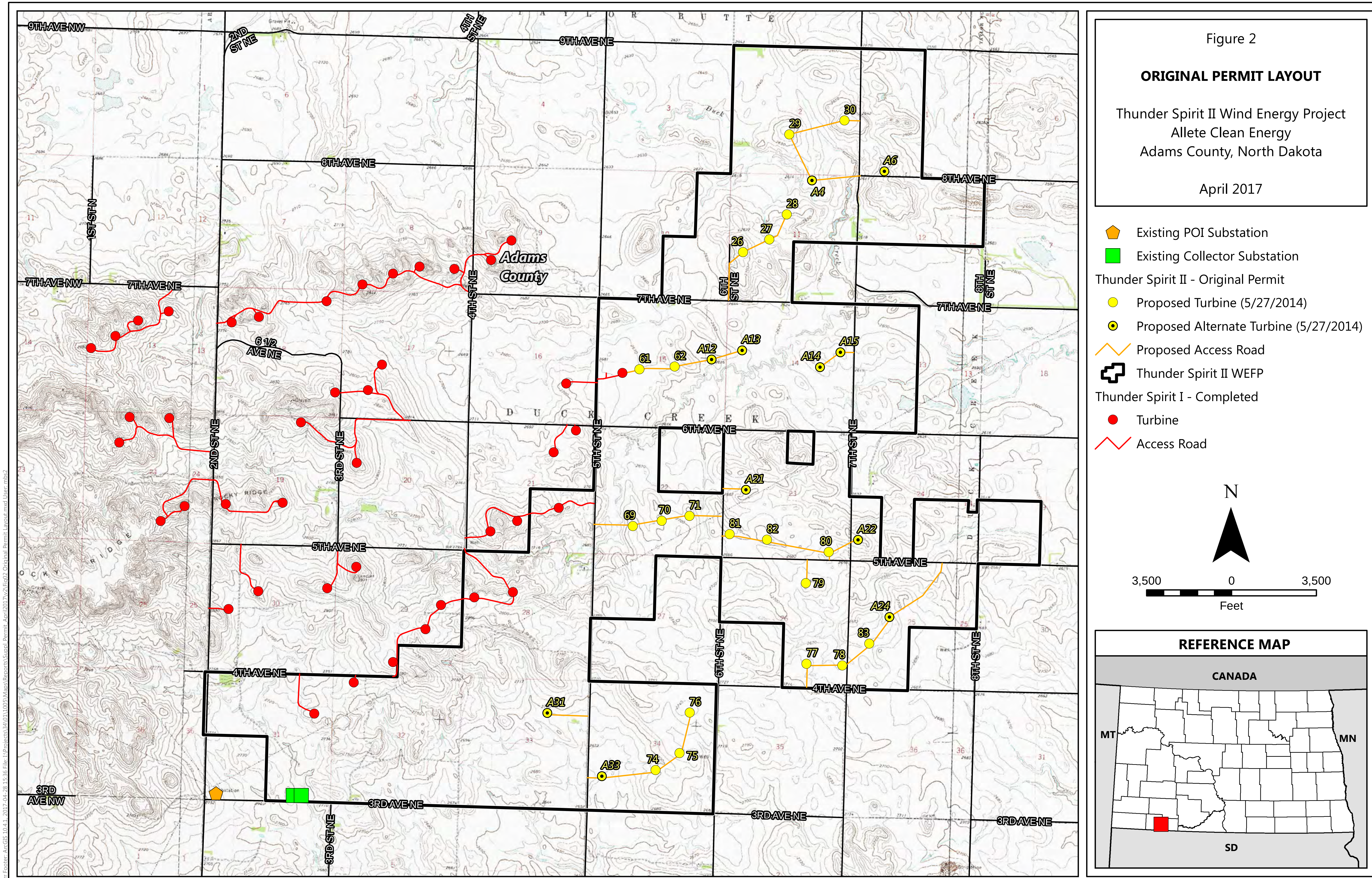


Figure 2

ORIGINAL PERMIT LAYOUT

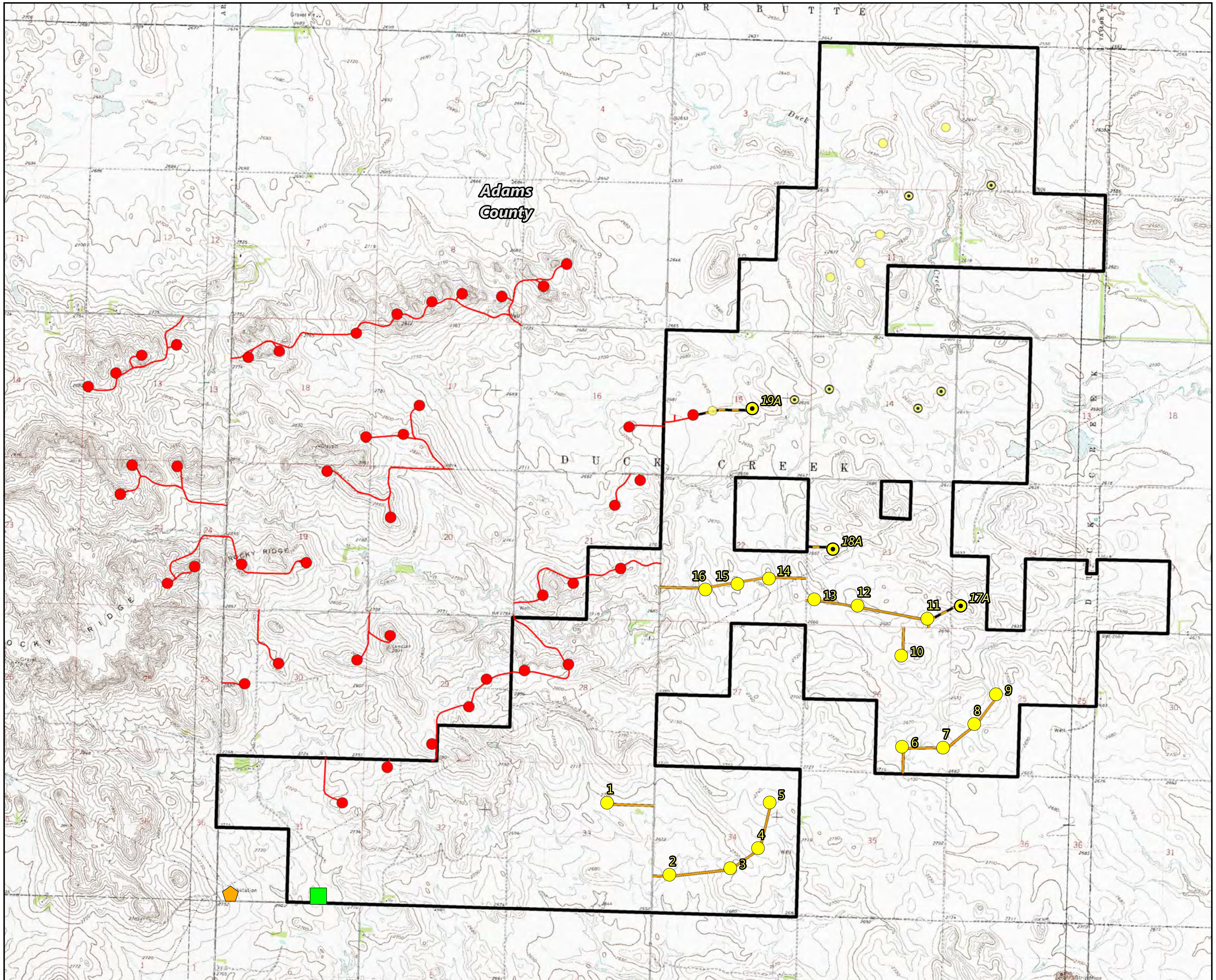
Thunder Spirit II Wind Energy Project
Allete Clean Energy
Adams County, North Dakota

April 2017

Figure 3

ORIGINAL PERMIT LAYOUT WITH FINAL PROPOSED LAYOUT

Thunder Spirit II Wind Energy Project
Allete Clean Energy
Adams County, North Dakota
April 2017

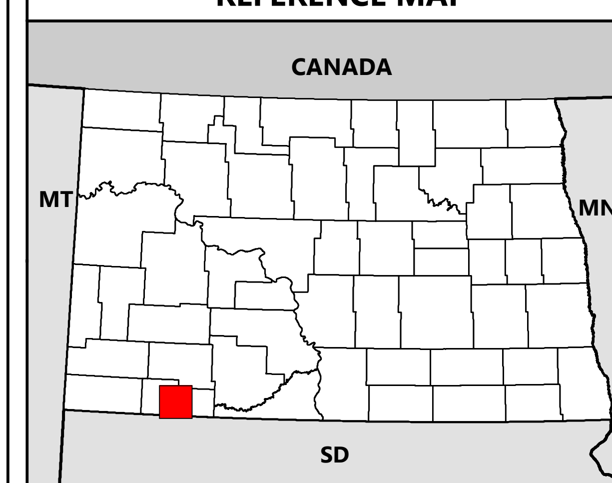


Existing POI Substation
Existing Collector Substation
Thunder Spirit II - Proposed
Proposed Turbine (3/29/2017)
Proposed Alternate Turbine (3/29/2017)
Proposed Access Road
Proposed Alternate Access Road
Thunder Spirit II - Original Permit
Proposed Turbine (5/27/2014)
Proposed Alternate Turbine (5/27/2014)
Thunder Spirit II WEFP
Thunder Spirit I - Completed
Turbine
Access Road

N

3,500 0 3,500
Feet

REFERENCE MAP



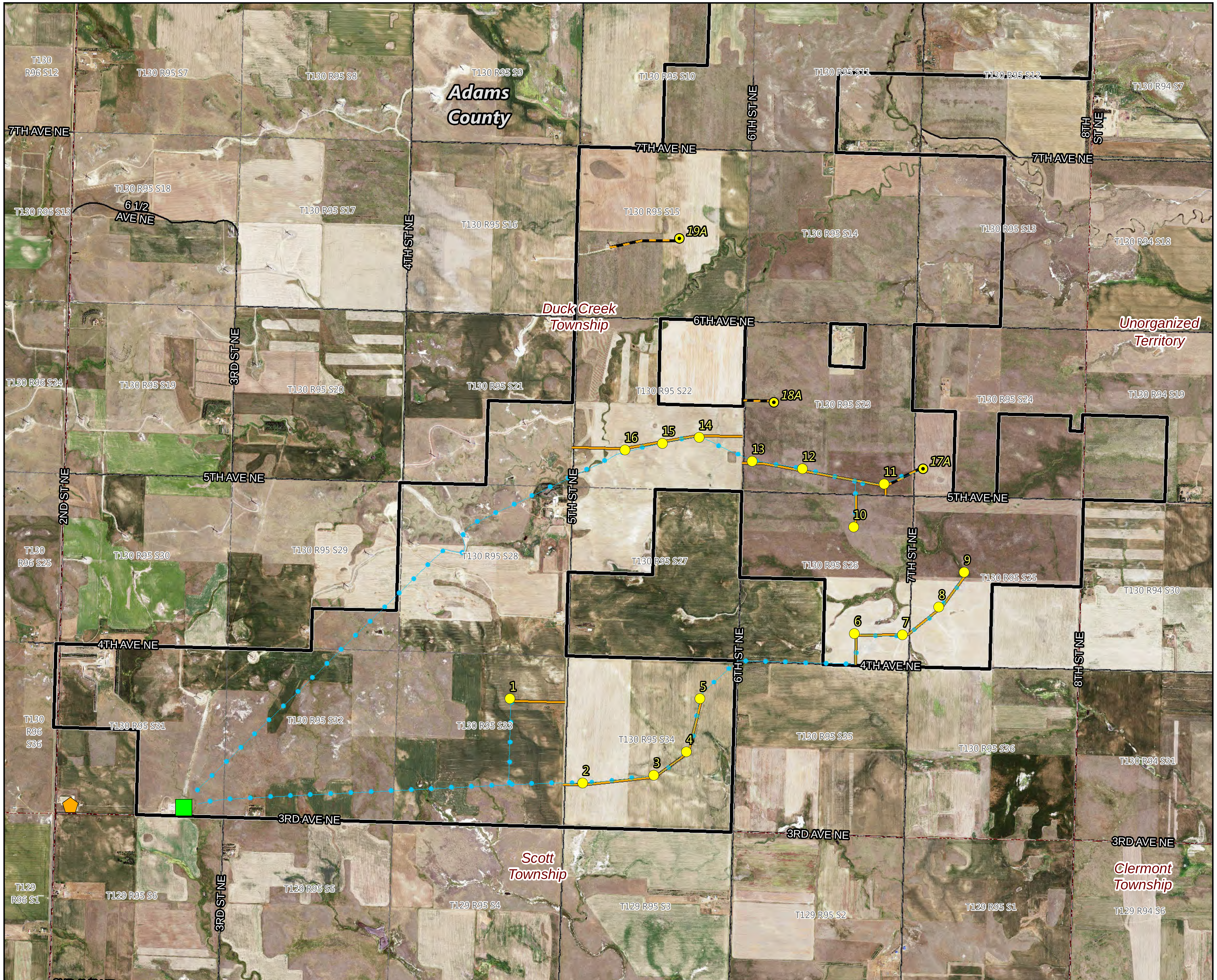


Figure 4

FINAL PROPOSED LAYOUT

Thunder Spirit II Wind Energy Project
Allete Clean Energy
Adams County, North Dakota

April 2017

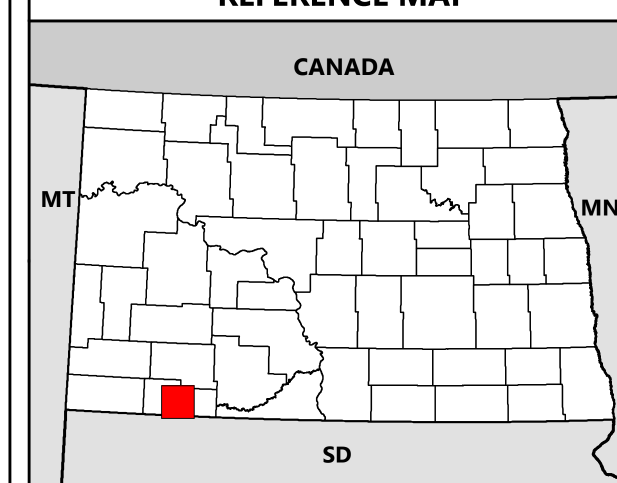
- Existing POI Substation
- Proposed Collector Substation
- Proposed Turbine (3/29/2017)
- Proposed Alternate Turbine (3/29/2017)
- Proposed Access Road
- Proposed Alternate Access Road
- Proposed Collection Line
- Thunder Spirit II WEFP
- Public Land Survey Section
- Civil Township

N

3,000 0 3,000

Feet

REFERENCE MAP



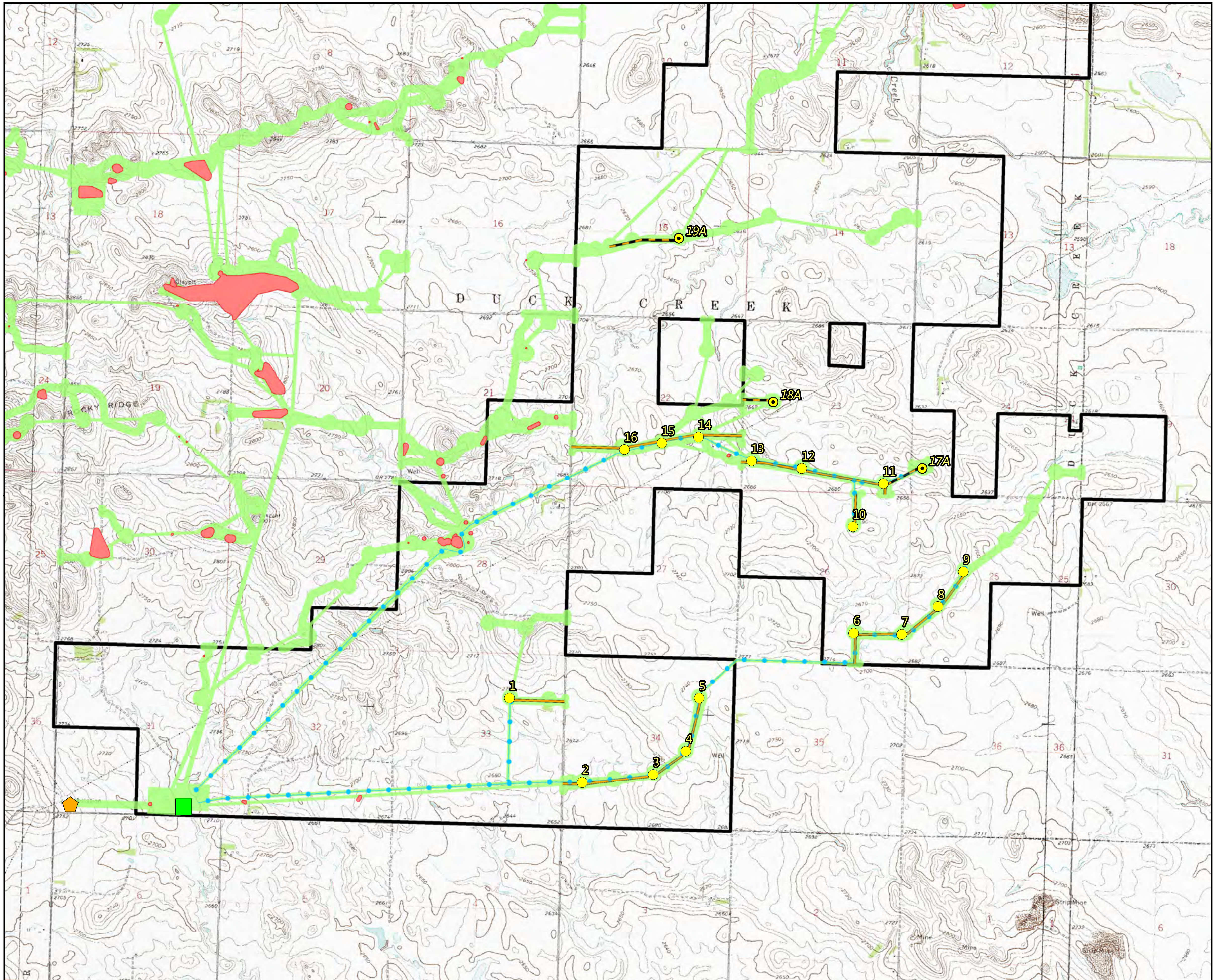


Figure 5

CULTURAL RESOURCES MAP

Thunder Spirit II Wind Energy Project
Allete Clean Energy
Adams County, North Dakota

April 2017

- Existing POI Substation
- Proposed Collector Substation
- Proposed Turbine (3/29/2017)
- Proposed Alternate Turbine (3/29/2017)
- Proposed Access Road
- Proposed Alternate Access Road
- Proposed Collection Line
- Cultural Resources Avoidance Buffer
- Survey Extents
- Thunder Spirit II WEFP

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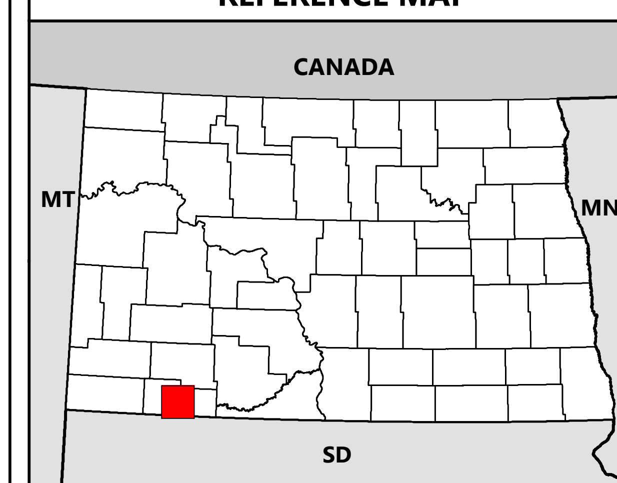
3,000 0 3,000

Feet

REFERENCE MAP



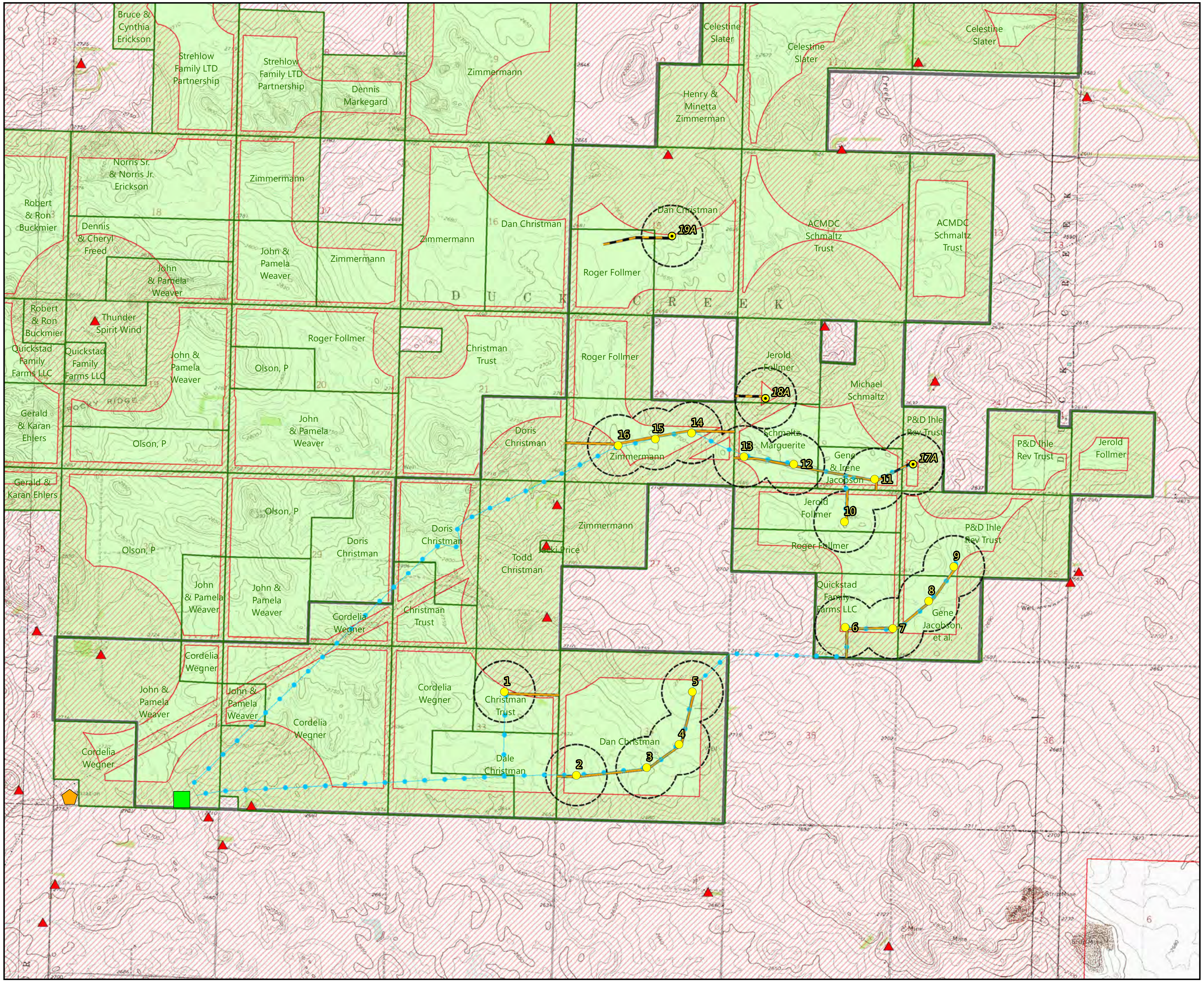


Figure 6

ADAMS COUNTY ZONING SETBACKS

Thunder Spirit II Wind Energy Project
Allete Clean Energy
Adams County, North Dakota

April 2017

- Existing POI Substation
- Proposed Collector Substation
- Proposed Turbine (3/29/2017)
- Proposed Alternate Turbine (3/29/2017)
- Proposed Access Road
- Proposed Alternate Access Road
- Proposed Collection Line
- Occupied Residence Location
- Adams County Zoning Setbacks
- Signed Landowner Parcel Outline
- Turbine Property Setback (292.5m)
- Thunder Spirit II WEFP

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3,000 0 3,000
Feet

REFERENCE MAP

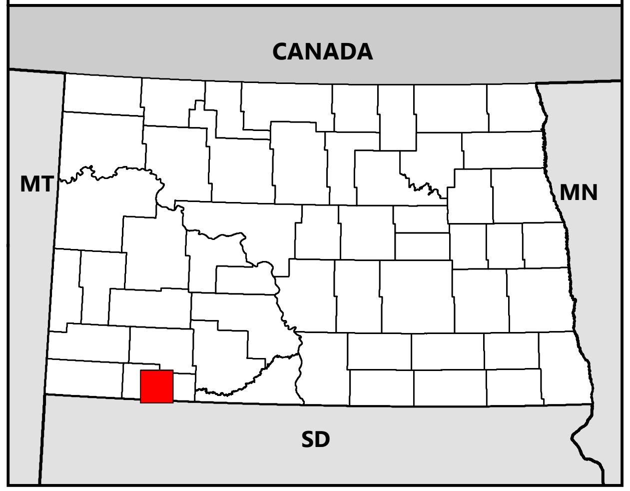


Exhibit B

DELTA GENERATION

PROVEN TECHNOLOGY – AT A NEW STAGE OF EVOLUTION

N100/3300
N117/3000
N131/3000

NORDEX
We've got the power.

CONTENTS

TECHNICAL DEVELOPMENT AT NORDEX
Experience keeps us one step ahead

As one of the pioneers in the modern use of wind energy, Nordex has been developing increasingly efficient wind turbines for use onshore since 1985. Since then, we have always remained true to proven principles, using tried-and-tested series engineering and giving top priority to the reliability of all system components.

In 2000, Nordex installed the first 2.5 megawatt series turbine in the world. Since then, the company has connected more than 4,000 machines from this platform to the grid at a wide range of locations around the world. We know what we're talking about when we claim that our wind turbine generators offer quality, mature technology and dependable performance, even in extreme locations.

With Delta Generation, we are now offering the fourth turbine generation of our proven multi-megawatt platform. Thanks to its larger rotors, greater nominal capacity and optimised technical systems, Delta Generation sets new standards for economic efficiency, reliability and service- and HSE-friendliness.

MATURE TECHNOLOGY
Proven concepts ensure a secure investment

With the new Delta Generation, Nordex customers benefit from the know-how we have gathered in the multi-megawatt range over many years. Mature technical solutions that have proven their worth thousands of times form a sound basis for the new generation.

Continuity: The electrical system

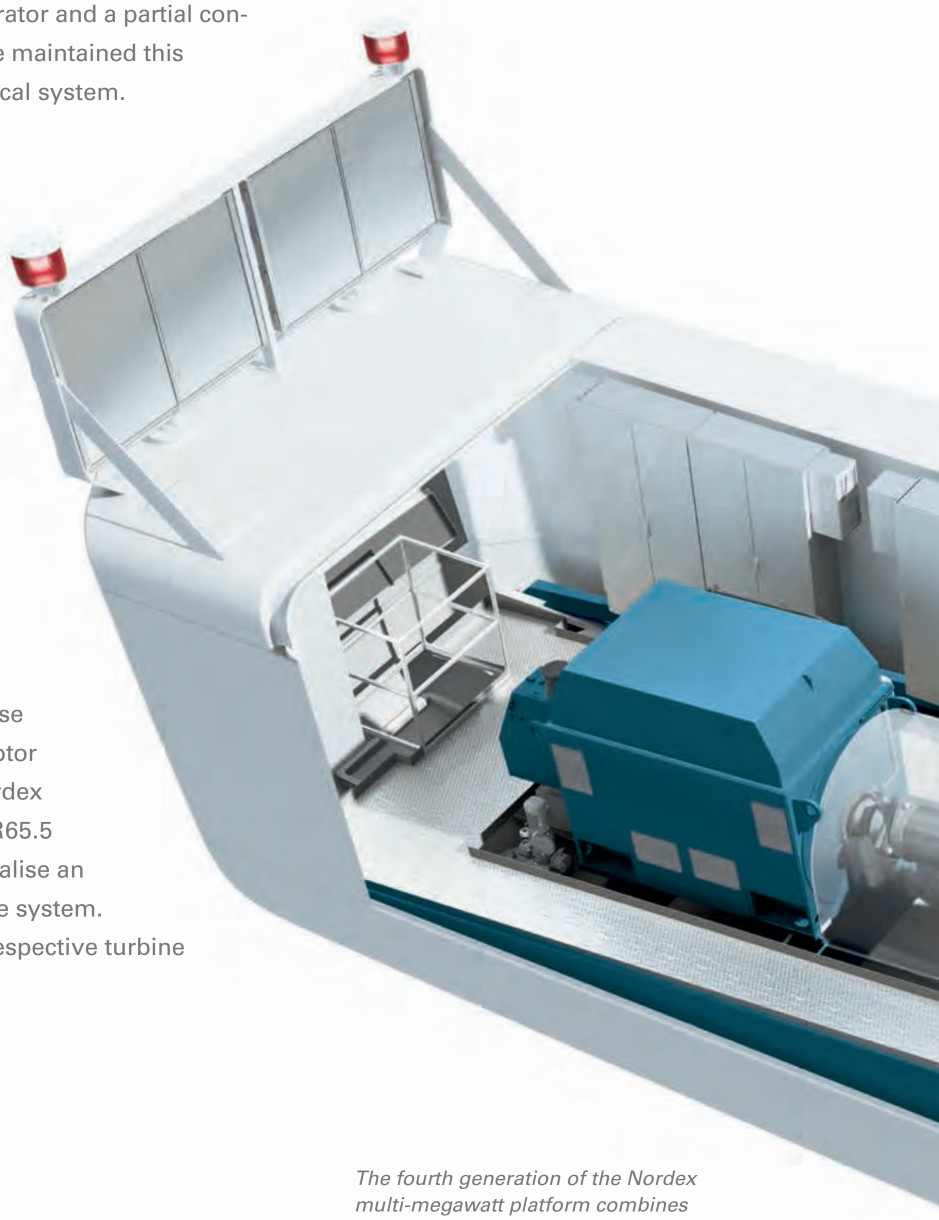
Even the first Nordex multi-megawatt turbine was equipped with a doubly fed asynchronous generator and a partial converter. With Delta Generation, we have maintained this proven and highly economical electrical system.

Tried-and-tested drive train concept

The drive train system is based on a modular drive train layout with a three-point suspension. We have used this system successfully from the outset. Together with our qualified suppliers, we work on continuously improving our drive train components. This delivers the output required while maintaining availability at a high level.

Proven rotor blade designs

The turbines of the new generation use proven aerodynamic designs for the rotor diameters of 100 and 117 metres. Nordex developed the NR50, NR58.5 and NR65.5 blades in-house. This allowed us to realise an optimal concept for the overall turbine system. The efficient rotor blades match the respective turbine technology perfectly.



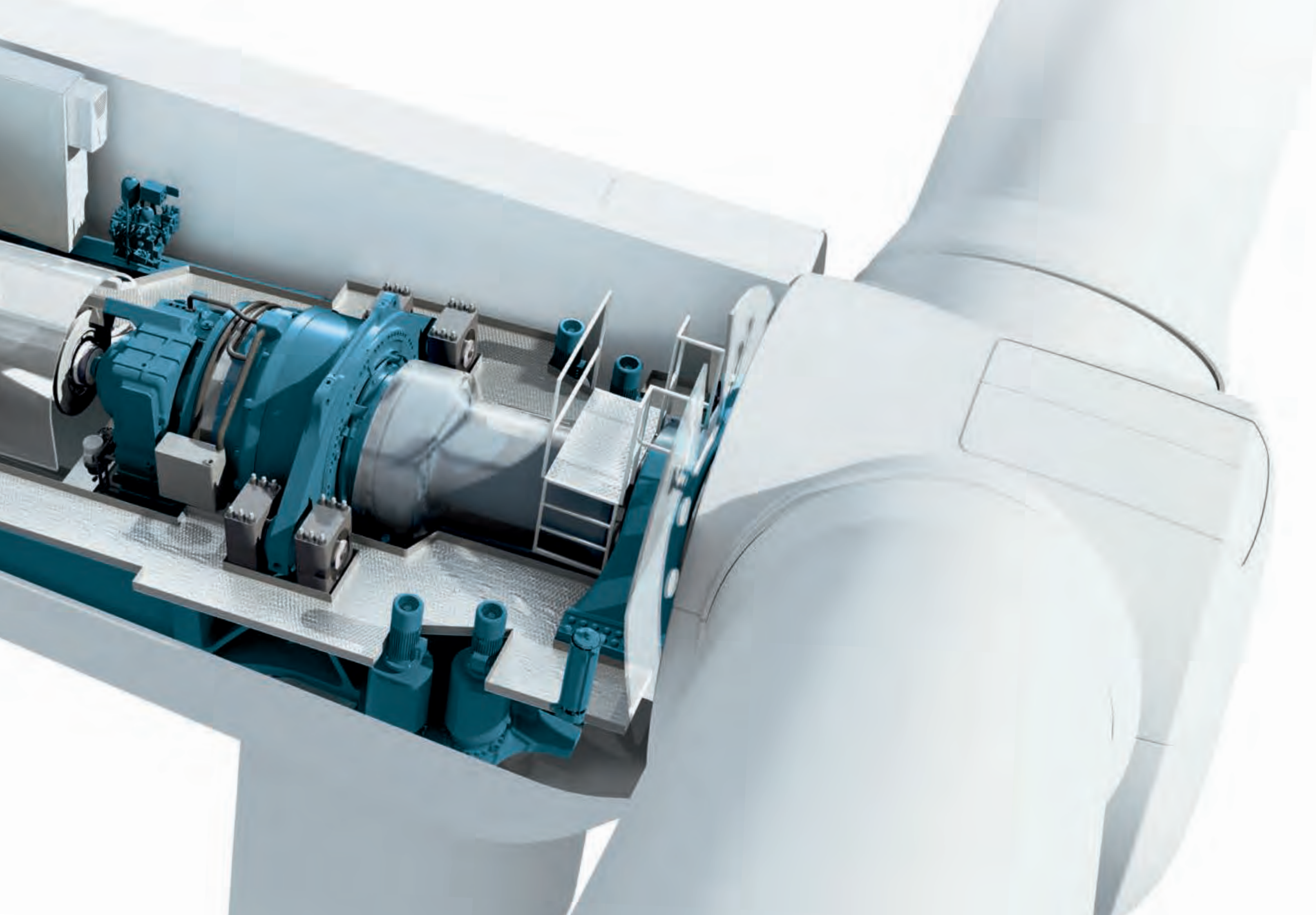
The fourth generation of the Nordex multi-megawatt platform combines proven, dependable technology with targeted improvements for enhanced performance.

Grid compatibility ensured

Like the previous generations, the turbines of Delta Generation meet the grid requirements of international markets. One of the most demanding grid connection directives in Europe is the German SDLWindV (Ordinance on System Services by Wind Energy Plants). Thanks to their fault-ride-through capability, our turbines are able to bridge voltage drops easily, thereby meeting all the requirements for the System Service Bonus (SDL Bonus). In addition, the Nordex Wind Farm Management System also allows the grid operator to directly control the active and reactive power of the wind farm in the grid.

Making the most of cold locations

During the winter, temperatures can be extreme at many sites offering a high wind yield. The tried-and-tested Nordex cold-climate package is designed to meet the challenges of these especially cold locations. Turbines in the cold-climate version (CCV) are able to operate down to an outside temperature of -30 degrees Celsius.



ECONOMIC EFFICIENCY
Higher yields reduce the cost of energy

In developing Delta Generation, we have met our main target – to cut the cost of energy. These Nordex multi-megawatt turbines deliver up to 31 per cent more yield from the sites, making Delta Generation turbines a particularly worthwhile investment.

Larger: Rotors

Nordex has designed the turbines to use a much larger rotor for each wind class. This produces higher yields. For example, the rotor diameter for machines for strong-wind locations was increased by ten metres compared to the previous model, resulting in a 23 per cent increase in swept area. The rotor for sites with moderate wind speeds is 17 metres larger: a 37 per cent increase in rotor sweep. With its 14 metre larger diameter, the rotor for light-wind sites offers a 25 per cent increase in swept area.

Stronger: Rated Output

With the N100/3300, Nordex has raised the rated output of the strong wind turbine by more than 30 per cent. The N117/3000 is designed for moderate wind speeds and has a 20 per cent higher rated output than the previous model. The increase in rated output amounts to 25 per cent for the N131/3000 light-wind turbine. This has a positive effect on the energy yields of the Delta turbines. In spite of the considerable increase in output, the sound power levels remain stable for each class. With the N131/3000, Nordex has further reduced the sound power level of the turbine for light-wind sites.

Higher: Towers

New and higher hub heights produce even greater yield increases and make siting possible, even in wooded areas or locations with complex topography. For the first time, Nordex is offering a tubular steel tower with a hub height of 100 metres for strong wind locations and one with a hub height of 120 metres for sites with moderate wind speeds.

Smarter: Anti-Icing Systems

Particularly in frost regions, ice forms on rotor blades in the winter months. Icing can reduce the efficiency of a wind turbine generator as well as lowering its availability. The proven Nordex anti-icing system heats the most aerodynamically important areas of the rotor blades and efficiently reduces icing levels. Nordex customers can rely on their turbines for dependable yields and maximum availability in cold regions.

QUALITY AND RELIABILITY
A focus on high availability

To ensure that our turbines perform reliably, we conduct exhaustive tests. We certify the quality of all components and manufacture in a modern line production. The average availability of all turbines covered by Nordex Service stands at 98 per cent. We ensure this high level of availability by consistently further developing the vital important systems. This contributes to a further reduction in the cost of energy.

Extreme tests for hardware and software

In the Nordex Test Centre, engineers test the components and systems of the new turbine generation under simulated wind and weather conditions. By subjecting them to strains in excess of the usual specifications, Nordex ensures that the design meets all criteria, delivering a high-quality, mature product for serial production.

Highest industrial standards

Nordex continues to meet high industrial standards, manufacturing the nacelle and hub modules in a continuous flow process. Many of the steps needed for assembly and commissioning are performed in the protected factory hall before the equipment is shipped to the site.

In the Nordex Test Centre engineers ensure the quality of components.

Advanced control infrastructure

Nordex has equipped the new turbine generation with the Profinet communication system. Its ethernet-based fieldbus transfers turbine data rapidly, reliably and by priority. All actuators and sensors in the turbine control systems, as well as the different module options, are directly integrated into the network. This ensures improved diagnostics and the reliability of the system.

Optimised drive train

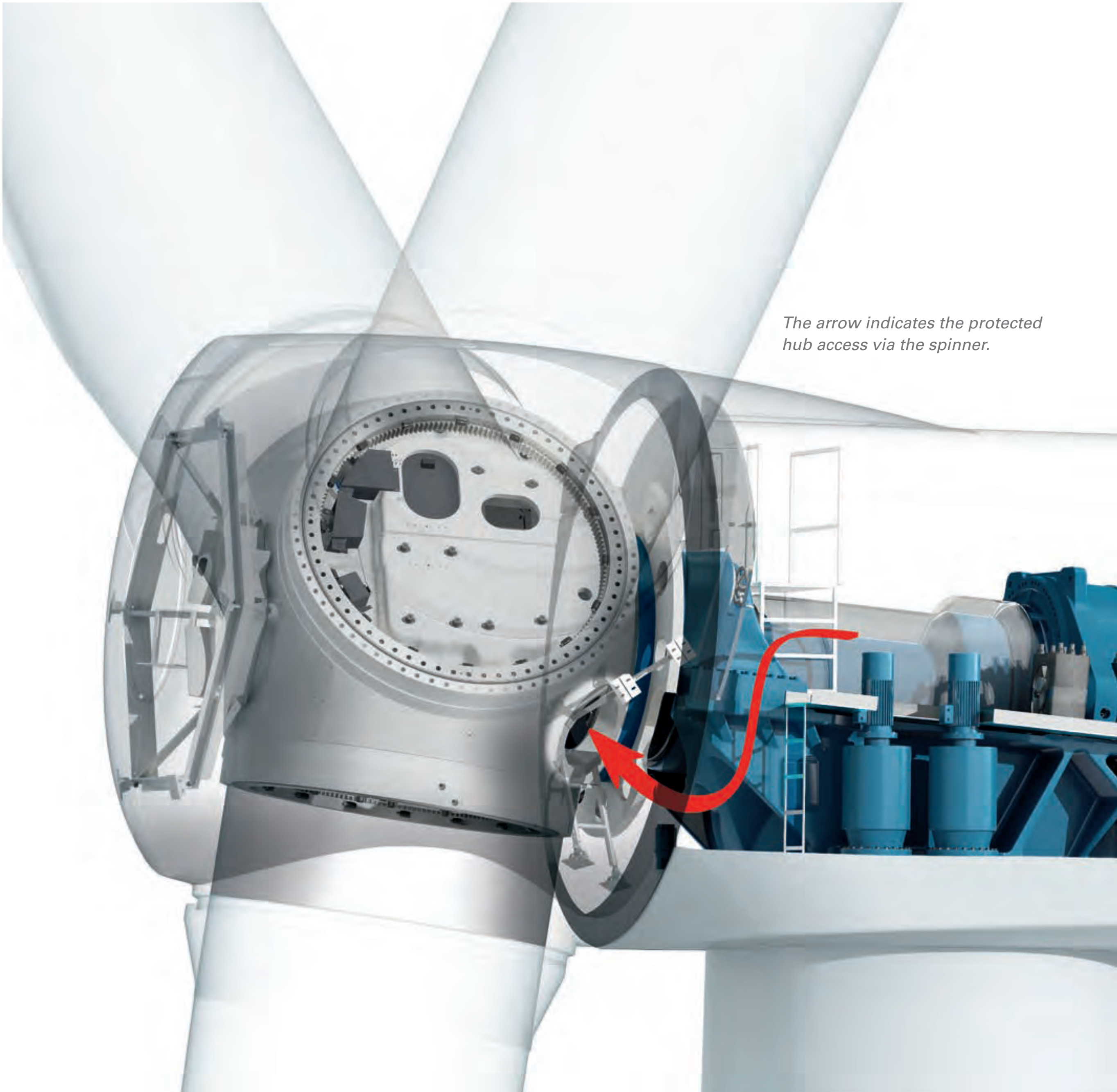
The drive train design of Delta Generation reduces the forces acting on the individual components, taking greater strain off the robust rotor bearing. Innovations in the cooling system of the drive train ensure constant temperatures over a wide operating range – with lower internal energy consumption.

SERVICE AND HSE
Fast and safe turbine O&M

Delta Generation is designed so that service operations can be conducted rapidly and safely. This reduces ongoing operational costs. We make no compromise when it comes to HSE – the turbines of the new generation meet the most stringent requirements.

Protected hub access

The new spinner, a complete housing for the rotor hub, provides rapid and protected access to the hub. This means that service work can be carried out in a wider range of wind and weather conditions. This is of particular advantage in cold regions – making it possible to reduce downtimes for service purposes.



The arrow indicates the protected hub access via the spinner.

Ergonomics and safety

When we were developing the new multi-megawatt generation, we gave high priority to designing the turbines as a particularly safe and spacious workplace. In case of an emergency, the platform also offers extended escape and rescue routes. All systems are easily accessible for maintenance. Nacelle components weighing less than one tonne can be reached with the onboard crane and, if necessary, can be exchanged without additional equipment.

Annual service interval

The technical design of Delta Generation allows for an annual service interval. Automatic lubrication of the bearings in the pitch system replaces manual processes. These bearings, as well as the main bearing and the generator bearings, are supplied automatically with lubricant, making them less susceptible to wear. This minimises the service requirements and reduces the O&M expenses.

Yaw n-1 concept

The yaw system runs with four drives in standard operation. However, should one drive break down, the turbine can continue to run temporarily on three drives, making it possible to plan any needed service work. This concept increases turbine availability and reduces service costs.

DELTA GENERATION IN THE FIELD
Tried-and-tested performance

In mid-2013, Nordex installed the first Delta Generation turbines for high and medium wind speeds in the Janneby wind farm in Germany. By now, the family has a new member – the light wind model N131/3000 has been installed and commissioned in the same wind farm.

Certification and field validation are running on schedule: all DIBt type approvals and the International IEC Design Evaluation Conformity Statements (DECS) have been obtained for the Delta Generation turbines. The IEC Type Certificate (TC) has been awarded for N100/3300 and N117/3000.

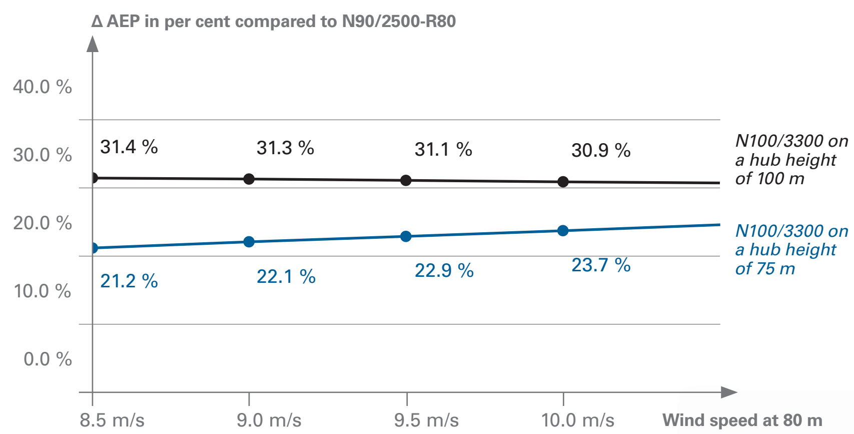
The principal measurement results for all types were recorded at the Janneby site. Particularly important: the sound power levels of the three turbines were confirmed by external measurements. The german unit certificates as well the power curves have already been issued for the N117/3000 and the N100/3300.


NORDEX

SOLUTION FOR STRONG WIND
High yields in rough climates

Wind sites with a rough environment call for mature, robust technology. With the turbines of Delta Generation, Nordex offers the proven 100-metre rotor, now also for IEC 1 locations. Thanks to the large rotor diameter and the higher rated output, the N100/3300 obtains much higher energy yields at sites with strong winds compared to the previous model. This turbine is available with hub heights of 75, 85 and 100 metres.

The N100/3300 generates between 21.2 and 31.4 per cent more AEP compared to the preceding IEC 1 model.



Calculation of AEP based on air density of 1.225 kg/m³, wind shear of 0.2 and Weibull shape parameter of k = 2.0

TECHNICAL DATA

	N100/3300
Operating data	
Rated power	3,300 kW
Cut-in wind speed	3.5 m/s
Cut-out wind speed	25 m/s
Rotor	
Diameter	99.8 m
Swept area	7,823 m²
Operating range rotational speed	9.0–16.1 rpm
Rated rotational speed	14.3 rpm
Tip speed	75 m/s
Speed control	Variable via microprocessor
Overspeed control	Pitch angle
Gearbox	
Type	3-stage gearbox (planetary-planetary-spur gear)
Generator	
Construction	Doubly-fed asynchronous generator
Cooling system	Liquid/air cooling
Voltage	660 V
Grid frequency	50/60 Hz
Brake system	
Main brake	Aerodynamic brake (Pitch)
Holding brake	Disk brake
Lightning protection	Fully compliant with IEC 61400-24
Tower	
Construction	Tubular steel tower
Hub height/Certification	75 m/IEC 1a, DIBt 3 85 m/IEC 1a 100 m/IEC 1a, DIBt 3

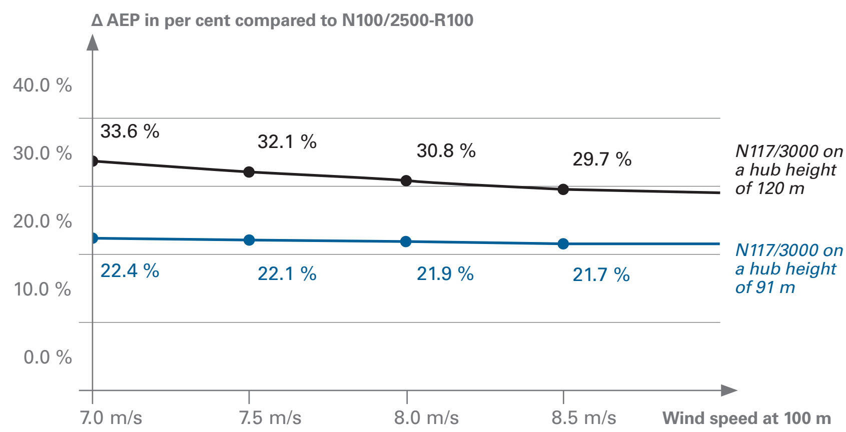
The powerful N100/3300 is the first choice for strong wind sites.

SOLUTION FOR MODERATE WIND
Economical at a wide range of sites

With the N117/3000, Nordex now offers an even more economical turbine for IEC 2 locations. The enlarged rotor sweep and higher rated output deliver much higher yields. The N117/3000 is available on tubular steel towers of 91 or 120 metres, as well as on a hybrid tower of 141 metres. Therefore, it is suitable for challenging sites as well.

To ensure high yields at sites in cold climates, Nordex equips the N117/3000 with the efficient anti-icing system as an option.

The N117/3000 generates between 21.7 and 33.6 per cent more AEP compared to the preceding IEC 2 model.



Calculation of AEP based on air density of 1.225 kg/m³, wind shear of 0.2 and Weibull shape parameter of k = 2.0

TECHNICAL DATA

	N117/3000	
Operating data		
Rated power	3,000 kW	
Cut-in wind speed	3.0 m/s	
Cut-out wind speed	25 m/s	
Rotor		
Diameter	116.8 m	
Swept area	10,715 m²	
Operating range rotational speed	7.9–14.1 rpm	
Rated rotational speed	12.6 rpm	
Tip speed	77 m/s	
Speed control	Variable via microprocessor	
Overspeed control	Pitch angle	
Gearbox		
Type	3-stage gearbox (planetary-planetary-spur gear)	
Generator		
Construction	Doubly-fed asynchronous generator	
Cooling system	Liquid/air cooling	
Voltage	660 V	
Grid frequency	50 / 60 Hz	
Brake system		
Main brake	Aerodynamic brake (Pitch)	
Holding brake	Disk brake	
Lightning protection	Fully compliant with IEC 61400-24	
Tower		
Construction	Tubular steel tower	Hybridtower
Hub height/Certification	91 m/IEC 2a, DIBt 3 120 m/IEC 2a, DIBt 2	141 m, DIBt 2

The N117/3000 – economical at a wide range of sites.

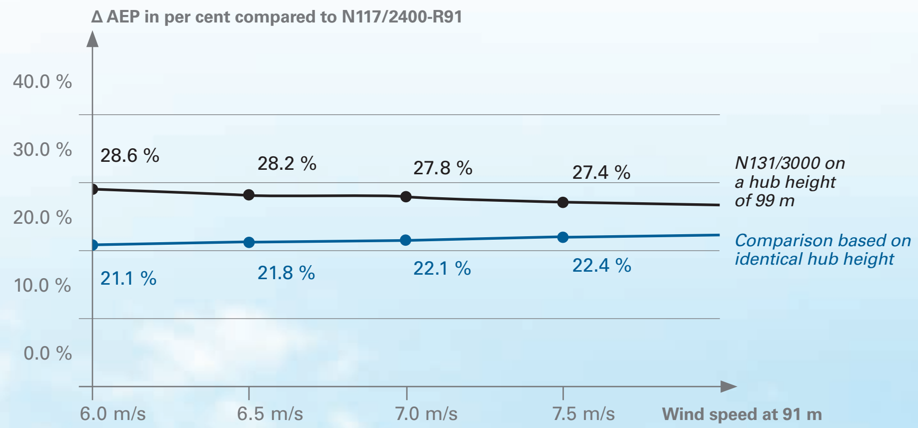
SOLUTION FOR LIGHT WIND
Maximum efficiency in the 3 MW segment

High yield even in regions with light wind: thanks to its enlarged rotor sweep and higher rated output, the N131/3000 generates a much higher yield at light-wind locations. The turbine is available on tubular steel towers with hub heights of 99 or 114 metres.

Nordex limits the sound power level of the light-wind turbine to max. 104.5 dB(A) – a crucial factor for optimising wind farms and facilitating permitting.

To ensure high yields at sites in cold climates, Nordex equips the N131/3000 with the efficient anti-icing system as an option.

The N131/3000 generates between 27.4 and 28.6 per cent more AEP compared to the preceding IEC3 model.



Calculation of AEP based on air density of 1.225 kg/m³, wind shear of 0.2 and Weibull shape parameter of k = 2.0

TECHNICAL DATA

	N131/3000
Operating data	
Rated power	3,000 kW
Cut-in wind speed	3.0 m/s
Cut-out wind speed	20 m/s
Rotor	
Diameter	131.0 m
Swept area	13,478 m²
Operating range rotational speed	6.5 – 11.6 rpm
Rated rotational speed	10.3 rpm
Tip speed	70.5 m/s
Speed control	Variable via microprocessor
Overspeed control	Pitch angle
Gearbox	
Type	3-stage gearbox (planetary-planetary-spur gear)
Generator	
Construction	Doubly-fed asynchronous generator
Cooling system	Liquid/air cooling
Voltage	660 V
Grid frequency	50 / 60 Hz
Brake system	
Main brake	Aerodynamic brake (Pitch)
Holding brake	Disk brake
Lightning protection	Fully compliant with IEC 61400-24
Tower	
Construction	Tubular steel tower
Hub height/Certification	99 m / IEC 3a, DIBt 2 114 m / IEC 3a, DIBt 2

Strong, efficient and quiet: the N131/3000.

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NORDEX
We've got the power.

Exhibit C

Sound Assessment Study

ALLETE Clean Energy

Thunder Spirit Wind Project
Project No. 98658

Revision 2
05/10/2017

Sound Assessment Study

prepared for

ALLETE Clean Energy
Thunder Spirit Wind Project
Adams County, North Dakota

Project No. 98658

Revision 2
05/10/2017

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
ACE	ALLETE Clean Energy
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
CadnaA	Computer Aided Design for Noise Abatement
dB	Decibel
dBA	A-weighted decibels
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
Hz	Hertz
ISO	International Organization for Standardization
L_{eq}	Equivalent-continuous sound level
L_x	Exceedance sound level
MW	Megawatt
Act	Noise Control Act of 1972
Project	Thunder Spirit Wind Project
Study	Acoustical sound assessment of the Thunder Spirit Wind Project
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

REVISION HISTORY

Rev	Issue Date	Release Notes
0	03-May-2017	Original Release
1	04-May-2017	Modified with additional project turbines and residences
2	10-May-2017	Issuance of final report

1.0 INTRODUCTION

1.1 Study Overview

Burns & McDonnell Engineering Company, Inc. ("Burns & McDonnell") was retained by ALLETE Clean Energy ("ACE") to conduct an acoustical sound assessment (the "Study") for Thunder Spirit Wind Project (the "Project"). The objective of the Study was to estimate the expected sound impacts caused by the Project wind turbines on neighboring occupied residences. No attempt was made in this Study to examine or opine on health effects related to sound impacts. There were several objectives in the Study, including:

- Identification of any applicable county, city, State, or Federal noise ordinances and other applicable sound guidelines.
- Estimation of the proposed operational sound levels from the Project layout using the three-dimensional sound modeling program called Computer Aided Design for Noise Abatement ("CadnaA").
- Determination if the Project can operate in compliance with the identified applicable regulatory standards.

1.2 Project Overview

The proposed Thunder Spirit Wind Project is located in Adams County, North Dakota, approximately 6 miles northeast of the city of Hettinger, North Dakota, and approximately 20 miles northwest of the city of Lemmon, South Dakota (the "Project Site"). The proposed Project will consist of 43 Nordex N100-2500 and 16 Nordex N117-3000 wind turbines with an aggregate nameplate capacity of approximately 155.5 megawatts ("MW"). Additionally, three (3) alternate locations for the Nordex N117-3000 wind turbine locations were included as part of the Study.

A map showing the general location and configuration of the Project is included in Appendix A.

The following sections describe the Study completed for the Project.

2.0 ACOUSTICAL TERMINOLOGY

The term "sound level" is often used to describe two different sound characteristics: sound power and sound pressure. Every source that produces sound has a sound power level. The sound power level is the acoustical energy emitted by a sound source and is an absolute number that is not affected by the surrounding environment. The acoustical energy produced by a source propagates through media as pressure fluctuations. These pressure fluctuations, also called sound pressure, are what human ears hear and microphones measure.

Sound is physically characterized by amplitude and frequency. The amplitude of sound is measured in decibels ("dB") as the logarithmic ratio of a sound pressure to a reference sound pressure (20 micro-Pascals). The reference sound pressure corresponds to the typical threshold of human hearing. To the average listener, a 3-dB change in a continuous broadband sound is generally considered "just barely perceptible"; a 5-dB change is generally considered "clearly noticeable"; and a 10-dB change is generally considered a doubling (or halving, if the sound is decreasing) of the apparent loudness.

Sound waves can occur at many different wavelengths, also known as the frequency. Frequency is measured in hertz ("Hz"), and is the number of wave cycles per second that occur. The typical human ear can hear frequencies ranging from approximately 20 to 20,000 Hz. Normally, the human ear is most sensitive to sounds in the middle frequencies (1,000 to 8,000 Hz) and is less sensitive to sounds in the lower and higher frequencies. As such, the A-weighting scale was developed to simulate the frequency response of the human ear to sounds at typical environmental levels. The A-weighting scale emphasizes sounds in the middle frequencies and de-emphasizes sounds in the low and high frequencies. Any sound level to which the A-weighting scale has been applied is expressed in A-weighted decibels ("dBA"). For reference, the A-weighted sound pressure level and subjective loudness associated with some common sound sources are listed in Table 2-1.

Table 2-1: Typical Sound Pressure Levels Associated with Common Sound Sources

Sound Pressure Level (dBA)	Subjective Evaluation	Environment	
		Outdoor	Indoor
140	Deafening	Jet aircraft at 75 feet	--
130	Threshold of pain	Jet aircraft during takeoff at a distance of 300 feet	--
120	Threshold of feeling	Elevated train	Hard rock band
110	--	Jet flyover at 1,000 feet	Inside propeller plane
100	Very loud	Power mower, motorcycle at 25 feet, auto horn at 10 feet, crowd sound at football game	--
90	--	Propeller plane flyover at 1,000 feet, noisy urban street	Full symphony or band, food blender, noisy factory
80	Moderately loud	Diesel truck (40 mph) at 50 feet	Inside auto at high speed, garbage disposal, dishwasher
70	Loud	B-757 cabin during flight	Close conversation, vacuum cleaner
60	Moderate	Air-conditioner condenser at 15 feet, near highway traffic	General office
50	Quiet	--	Private office
40	--	Farm field with light breeze, birdcalls	Soft stereo music in residence
30	Very quiet	Quiet residential neighborhood	Inside average residence (without TV and stereo)
20	--	Rustling leaves	Quiet theater, whisper
10	Just audible	--	Human breathing
0	Threshold of hearing	--	--
Source: Adapted from *Architectural Acoustics*, M. David Egan, 1988, and *Architectural Graphic Standards*, Ramsey and Sleeper, 1994.			

Sound in the environment is constantly fluctuating, as when a car drives by, a dog barks, or a plane passes overhead. Therefore, sound metrics have been developed to quantify fluctuating environmental sound levels. These metrics include the exceedance sound level. The exceedance sound level (“L_x”) is the sound level exceeded during “x” percent of the sampling period and is also referred to as a statistical sound level. The arithmetic average of the varying sound over a given time period is called the equivalent-continuous sound level (“L_{eq}”).

3.0 REGULATIONS

Federal, State, and county regulations were reviewed to determine the applicable overall sound level limits for the Project.

3.1 Federal

The Noise Control Act of 1972 (the “Act”) authorized the establishment of Federal noise emission standards. As required by the Act, the Environmental Protection Agency (“EPA”) established criteria for protecting the public health and wellbeing. However, these criteria do not constitute enforceable Federal regulations or standards. The EPA has since delegated regulatory authority to local entities. Therefore, no Federal noise regulations apply to this Project.

3.2 State

The North Dakota Administrative Code has detailed a numerical noise level for the evaluation of site suitability in Article 69-06-08-01: Energy conversion facility siting criteria.[1] Sub-article 4 states:

> *“A wind energy conversion facility site must not include a geographic area where, due to operation of the facility, the sound levels within one hundred feet of an inhabited residence or a community building will exceed fifty dBA. The sound level avoidance area criteria may be waived in writing by the owner of the occupied residence or the community building.”*

There are no other numerical noise limits indicated in the North Dakota rules or regulations that would apply to wind turbines such as those proposed here.

3.3 Local

The Adams County, North Dakota Zoning Ordinance prescribes numerical daytime and nighttime noise limits of 80 and 70 dBA, respectively.

3.1 Identified Design Criteria

Because there are differing numerical limits that both apply to this type of noise source, the more restrictive limit of 50 dBA will be used as the identified design criteria.

[1] http://www.legis.nd.gov/information/acdata/pdf/69-06-08.pdf

4.0 SOUND MODELING

4.1 Wind Turbine and Transformer Sound Characteristics

The sound commonly associated with a wind turbine is described as a rhythmic "whoosh" caused by aerodynamic processes. This sound is created as air flow interacts with the surface of rotor blades. As air flows over the rotor blade, turbulent eddies form in the surface boundary layer and wake of the blade. These eddies are where most of the "whooshing" sound is formed. Additional sound is generated from vortex shedding produced by the tip of the rotor blade. Air flowing past the rotor tip creates alternating low-pressure vortices on the downstream side of the tip causing sound generation to occur. Older wind turbines, built with rotors which operate downwind of the tower (downwind turbines), often have higher aerodynamic impulse sound levels. This is caused by the interaction between the aerodynamic lift created on the rotor blades and the turbulent wake vortices produced by the tower. Modern wind turbine rotors are mostly built to operate upwind of the tower (upwind turbines). Upwind wind turbines are not impacted by wake vortices generated by the tower and, therefore, overall sound levels can be as much as 10 dBA less for similarly sized turbines. The rhythmic fluctuations of the overall sound level are less perceivable farther from the turbine. Additionally, multiple turbines operating at the same time will create the whooshing sound at different times. These non-synchronized sounds will blend together to create a more constant sound to an observer at most distances from the turbines. Another phenomenon that reduces perceivable noise from turbines is the wind itself. Higher wind speed produces noise that tends to mask (or drown out) the sounds created by wind turbines.

Advancement in wind turbine technology has reduced pure tonal emissions of modern wind turbines. Manufacturers have reduced distinct tonal sounds by reshaping turbine blades and adjusting the angle at which air contacts the blade. Pitching technology allows the angle of the blade to adjust when the maximum rotational speed is achieved, which allows the turbine to maintain a constant rotational velocity. Therefore, sound emission levels remain constant as the velocity remains the same.

Wind turbines can create noise in other ways as well. Wind turbines have a nacelle where the mechanical portions of the turbine are housed. The current generation of wind turbines uses multiple techniques to reduce the noise from this portion of the turbine: vibration isolating mounts, special gears, and acoustic insulation. In general, all moving parts and the housing of the current generation wind turbines have been designed to minimize the noise they generate.

4.2 Model Inputs and Settings

Predicted sound levels were determined using industry-accepted sound modeling software. The program used to model the turbines was CadnaA, Version 2017, published by DataKustik, Ltd., Munich, Germany. The program takes into account scaled, three-dimensional air absorption, terrain, ground absorption, and ground reflection for each piece of noise-emitting equipment and predicts downwind sound pressure levels. The model calculates sound propagation based on International Organization for Standardization ("ISO") 9613-2:1996, General Method of Calculation. ISO 9613, and therefore CadnaA, assesses the sound pressure levels based on the octave-band center-frequency range from 31.5 to 8,000 Hz. Predicted compliance with the regulations for all turbines operating implies predicted compliance for any combination of the turbines operating.

4.2.1 Project Layout

The Project's proposed layout contains a total of 62 wind turbines including the proposed 59 project turbines, with 3 alternative locations. Predictive modeling was conducted using the proposed layout shown in Appendix A.

4.2.2 Terrain and Vegetation

Terrain and attenuation from ground absorption can have a significant impact on sound transmission. U.S. Geological Survey ("USGS") Digital Elevation Model ("DEM") contours were imported into the model to account for topographic variations around the Project. The contours were overlaid onto high-resolution, digital orthoimagery obtained from the U.S. Department of Agriculture ("USDA") to visually confirm proper contour positioning. The terrain around the proposed Project is mostly rural with few minor changes in elevation.

The land is primarily used for agricultural purposes. As such, vegetation is mostly low-lying with some small areas of trees. Therefore, all vegetation was excluded from the analysis to maintain conservativeness in the model. Ground attenuation is expected to be fairly high, due to the "soft ground" of the surrounding areas, but only half the available ground absorption was considered to be conservative.

4.2.3 Sound Propagation and Directivity

CadnaA calculates sound levels using ISO 9613 standards, which assume omni-directional downwind sound propagation and worst-case directivity factors. In other words, the model assumes that each turbine propagates its maximum sound level in all directions at all times. This will over-predict upwind sound levels, as well as the sound levels between two turbines.

4.2.4 Atmospheric Conditions

Atmospheric conditions were based on program defaults. Layers in the atmosphere often form where temperature increases with height (temperature inversions). Sound waves can reflect off of the temperature inversion layer and return to the surface of the earth. This process can increase sound levels at the surface, especially if the height of the inversion begins near the surface of the earth. Temperature inversions tend to occur mainly at night when winds are light or calm, usually when wind turbines are not operating. CadnaA calculates the downwind sound in a manner which is favorable for propagation (worst-case scenario) by assuming a well-developed, moderate ground-based temperature inversion such as can occur at night. Therefore, predicted sound levels tend to be higher than would likely occur.

The atmosphere does not flow smoothly and tends to have swirls and eddies, also known as turbulence. Turbulence is basically formed by two processes: thermal turbulence and mechanical turbulence. Thermal turbulence is caused by the interaction of heated air rapidly rising from the heated earth's surface with cooler air descending from the atmosphere. Mechanical turbulence is caused as moving air interacts with objects such as trees, buildings, and wind turbines. Turbulent eddies generated by wind turbines and other objects can cause sound waves to scatter, which in turn, provides sound attenuation between the wind turbine and the receiver. The acoustical model assumes laminar air flow, which minimizes sound attenuation that would occur in a realistic nonhomogeneous atmosphere. This assumption also causes the predicted sound levels to be higher than would likely occur.

4.2.5 Sound Emission Data

Acoustical modeling was conducted for the entirety of the Project. Wind turbine heights and acoustical emissions were input into the model. The wind turbine nacelles for the Nordex 100-2500 and N117-3000 models utilize towers with hub heights of 80 and 91 meters, respectively. The expected worst-case sound power levels for these turbine models were provided by ACE, and were based on various wind speeds at heights of 10 meters (32.8 feet) above grade. The sound data provided by ACE included octave band frequency data for the Nordex 117-3000 turbines, but not for the 100-2500 turbines. It was assumed that the frequency distribution of the 100-2500 turbines would be similar to the 117-3000 turbines. Therefore, the 117-3000 frequency distribution was used for both turbines, but the overall value was increased to replicate the Nordex 100-2500 maximum value provided in the documentation that ACE provided. The expected sound power levels of each turbine model are displayed in Table 4-1.

Table 4-1: Maximum Sound Power Levels

Equipment	dB at Octave Band Frequency (Hz)									Total Sound Power Level (dBA)
	31.5	63	125	250	500	1000	2000	4000	8000	
Nordex 100-2500	75.5	85.1	92	96.8	98.4	101.3	100.2	98.2	87.7	106.0
Nordex 117-3000	75.0	84.6	91.5	96.3	97.9	100.8	99.7	97.7	87.2	105.5

A point source located at the hub height of each proposed turbine location was used to model sound emissions from each of the wind turbines. This approach is appropriate for simulating wind turbine noise emissions due to the large distances between the turbines and the receivers as compared to the dimensions of the wind turbines. The sound levels shown in the table above were applied to every point source.

Appendix A displays the entire wind farm layout, including the neighboring residences. Each residence was modeled as a receiver at a height of 1.52 meters (5.0 feet) above ground level. Compliance with the regulation was assessed at the physical receiver.

The following assumptions were made to maintain the inherent conservativeness of the model and to estimate the worst-case modeled sound levels:

- Attenuation was not included for sound propagation through wooded areas, existing structures, and shielding, and
- Turbines were assumed to be operating at maximum power output (i.e., maximum sound levels) at all times to represent worst-case noise impacts from the Project as a whole in every direction.

4.3 Acoustical Modeling Results

Sound pressure levels were predicted for the identified receivers in the CadnaA noise modeling software using the manufacturer-specified sound power levels at each frequency and the assumptions listed above. CadnaA modeling results have been demonstrated in previous studies to conservatively approximate real-life measured noise from a source when extraneous noises are not present.

As previously mentioned, decibels are a logarithmic ratio of a sound pressure to a reference sound pressure. Therefore, they must be logarithmically added to determine a cumulative impact (i.e., logarithmically adding 50 dBA and 50 dBA results in 53 dBA). Logarithmically adding each of the individual turbine's impacts at each receiver provides an overall Project impact at each receiver. The maximum model-predicted sound pressure levels at each receiver (the logarithmic addition of sound levels from every turbine), as well as the limit, are included in Appendix B. These values represent only the noise emitted by the Project, and do not include any extraneous noises (traffic, etc.) that could be present during physical noise measurements. Extraneous sounds (grain dryers, traffic, etc.) are not included in these predictions and may make the overall sound level higher than the limits in some circumstances, but the turbines alone should not cause that to happen.

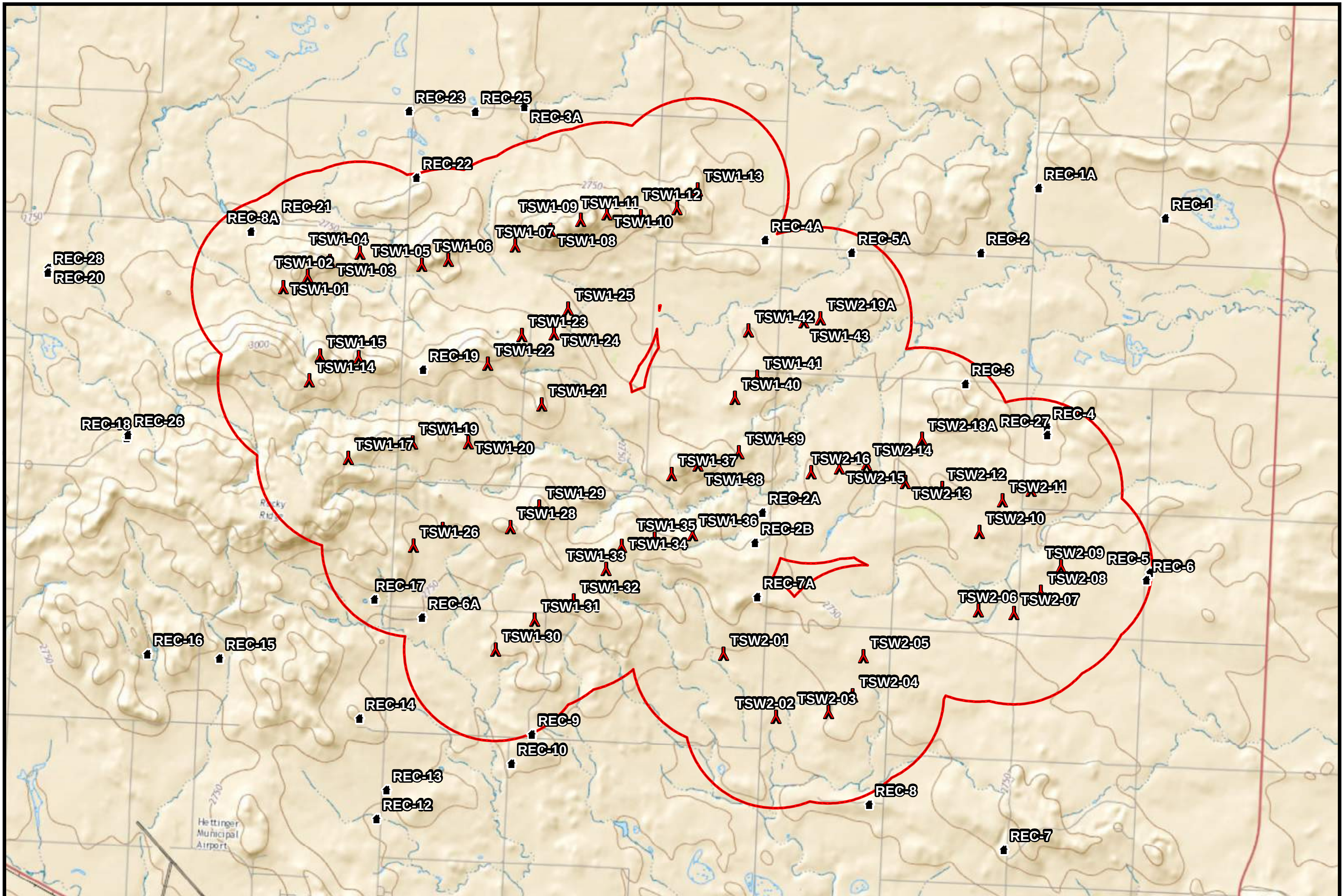
Appendix C contains graphical representation of the expected sound pressure levels generated by the simultaneous operation of all wind turbines proposed for the Project. The figure shows contours of sound levels in 5-dB increments overlaid onto a map to demonstrate how sound is expected to propagate. As can be seen in the figure, sound from the turbines will propagate in approximately circular contours of equal sound pressure from each turbine, and areas where two or more turbines interact are clearly visible.

5.0 CONCLUSION

Burns & McDonnell conducted a predictive acoustical sound assessment for the Thunder Sprit Wind Project. The Study included identification of applicable sound regulations and predictive modeling to estimate Project-related sound levels in the surrounding community. Sound pressure levels were predicted at occupied residences within and surrounding the Project area using manufacturer-specified sound power levels for each wind turbine. A number of conservative assumptions were applied to provide worst-case predicted sound pressure levels. Those results were then compared to the identified regulations.

There are no expected exceedances of the identified regulations due to operation of any of the wind turbines proposed for the Project at any residence.

APPENDIX A - PROJECT LAYOUT



LEGEND

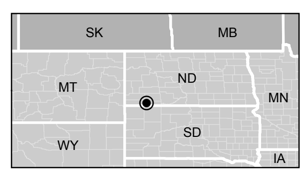
- Occupied Residence
- Wind Turbine
- Wind Turbine Buffer - 1170m

REFERENCE

0 0.75 1.5
MILES

0 0.8 1.6
KILOMETERS

N



THUNDER SPIRIT WIND PROJECT
Project Site Layout

LOCATION:	Adams County, North Dakota
CLIENT:	ALLETE Clean Energy
PROJ. NO.:	98658
CREATED:	05/04/2017

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Path: Z:\Clients\BTS\AlleteCleanE\98658_TSW2NoiseFlick\Studies\Business_Consult\Analysis\Shadow Flicker\08 - ArcMaps\TSW_WindPro_Shapefiles_20170504.mxd • Coordinate System: NAD 1983 UTM Zone 14N • Units: Meter

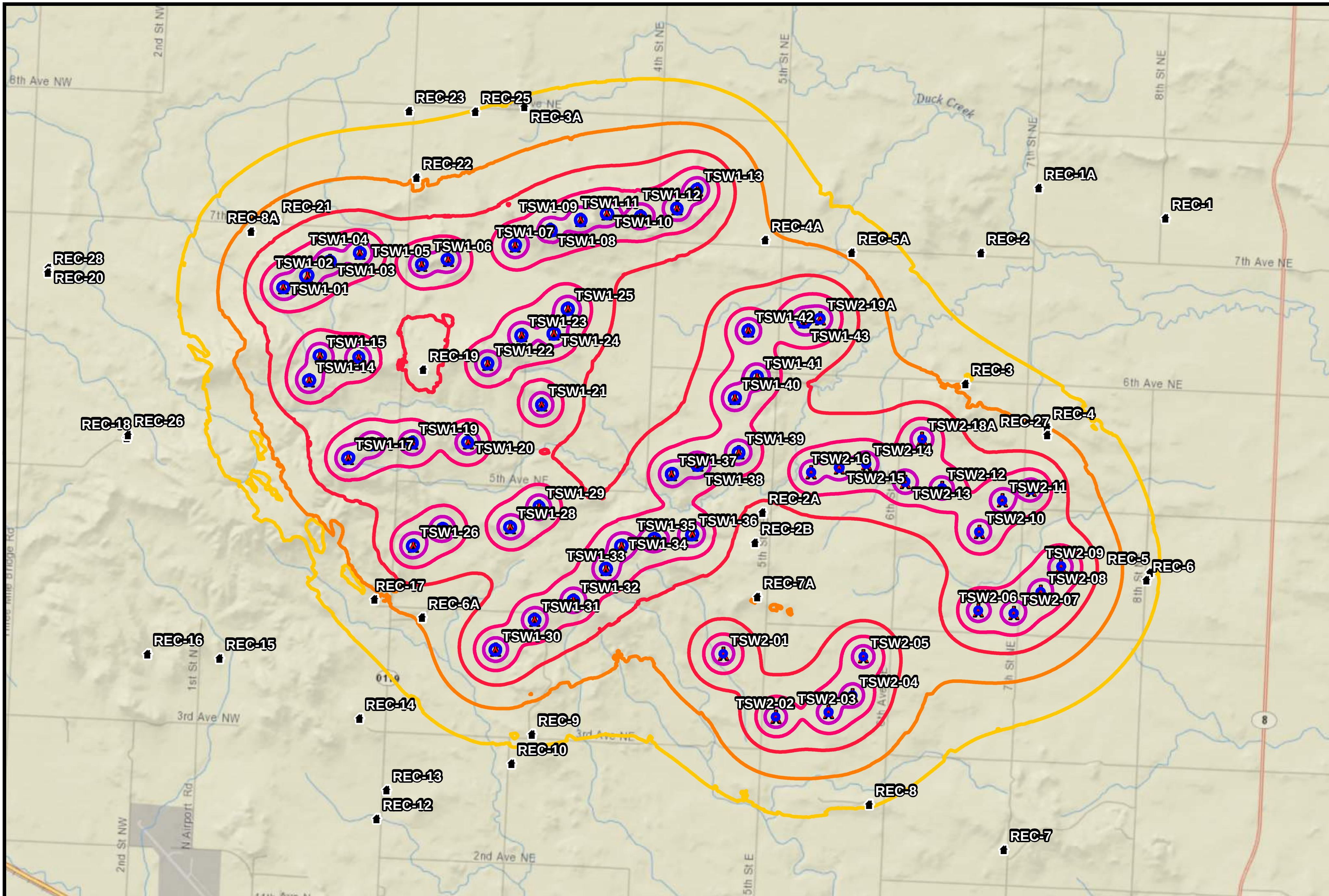
APPENDIX B - MODELED SOUND PRESSURE LEVELS

Table B-1: Receptor Coordinates and Sound Pressure Levels

Receptor Name	Easting [m]	Northing [m]	Predicted Level [dBA]	Sound Limit [dBA]
REC-01	229,736	5,110,565	14.7	50.0
REC-01A	228,112	5,110,954	20.1	50.0
REC-02	227,369	5,110,122	25.5	50.0
REC-02A	224,569	5,106,793	39.1	50.0
REC-02B	224,473	5,106,403	37.7	50.0
REC-03	227,171	5,108,443	34.2	50.0
REC-03A	221,516	5,111,996	30.9	50.0
REC-04	228,218	5,107,883	35.0	50.0
REC-04A	224,603	5,110,287	35.7	50.0
REC-05	229,538	5,106,023	31.2	50.0
REC-05A	225,715	5,110,125	34.1	50.0
REC-06	229,493	5,105,925	31.5	50.0
REC-06A	220,204	5,105,445	35.6	50.0
REC-07	227,664	5,102,467	20.8	50.0
REC-07A	224,502	5,105,709	36.1	50.0
REC-08	225,937	5,103,048	30.4	50.0
REC-08A	218,011	5,110,396	36.4	50.0
REC-09	221,611	5,103,948	31.3	50.0
REC-10	221,350	5,103,571	28.0	50.0
REC-12	219,620	5,102,864	20.5	50.0
REC-13	219,748	5,103,232	22.7	50.0
REC-14	219,401	5,104,150	25.3	50.0
REC-15	217,607	5,104,921	19.6	50.0
REC-16	216,682	5,104,977	13.1	50.0
REC-17	219,594	5,105,677	34.2	50.0
REC-18	216,416	5,107,750	23.0	50.0
REC-19	220,217	5,108,624	39.6	50.0
REC-20	215,411	5,109,929	19.7	50.0
REC-21	218,334	5,110,539	37.6	50.0
REC-22	220,131	5,111,089	34.7	50.0
REC-23	220,040	5,111,942	29.1	50.0
REC-24	220,856	5,113,563	21.7	50.0
REC-25	220,886	5,111,934	30.1	50.0
REC-26	216,433	5,107,788	23.1	50.0
REC-27	228,221	5,107,787	36.0	50.0
REC-28	215,405	5,109,871	19.7	50.0

Notes:
[1] All coordinates presented in UTM NAD83 Zone 14N (meters)
[2] Receptor locations provided by ACE via “TSW Houses.shp” on 5-03-2017

APPENDIX C - SOUND PRESSURE CONTOUR MAP



LEGEND

- Occupied Residence
- Wind Turbine

Sound Pressure Levels (dBA)

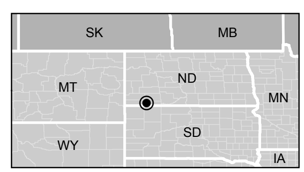
- 30
- 35
- 40
- 45
- 50
- 55

REFERENCE

0 0.75 1.5
MILES

0 0.8 1.6
KILOMETERS

N



THUNDER SPIRIT WIND PROJECT
Sound Pressure Level Contours

LOCATION:	Adams County, North Dakota
CLIENT:	ALLETE Clean Energy
PROJ. NO.:	98658
CREATED:	05/04/2017

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Path: Z:\Clients\BTS\AlleteClean\98658_TSW2NoiseFlick\Studies\Business_Consult\Analysis\Shadow Flicker\08 - ArcMaps\TSW_WindPro_Shapefiles_20170504.mxd • Coordinate System: NAD 1983 UTM Zone 14N • Units: Meter

CREATE AMAZING.

Burns & McDonnell World Headquarters
9400 Ward Parkway
Kansas City, MO 64114
O 816-333-9400
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Exhibit D

Shadow Flicker Analysis

ALLETE Clean Energy

Thunder Spirit Wind Project
Project No. 98658

Revision 2
05/10/2017

Shadow Flicker Analysis

prepared for

ALLETE Clean Energy
Thunder Spirit Wind Project
Adams County, North Dakota

Project No. 98658

Revision 2
05/10/2017

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
ACE	ALLETE Clean Energy
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
DEM	Digital Elevation Model
kg/m^3	Kilograms per cubic meter
m/s	Meters per second
MW	Megawatt
Project	Thunder Spirit Wind Project
Project Site	Location of Project in Adams County, North Dakota
Study	Shadow Flicker Analysis

REVISION HISTORY

Rev	Issue Date	Release Notes
0	03-May-2017	Original Release
1	04-May-2017	Modified with additional project turbines and residences
2	10-May-2017	Issuance of final report

1.0 INTRODUCTION

1.1 Study Overview

Burns & McDonnell Engineering Company, Inc. ("Burns & McDonnell") was retained by ALLETE Clean Energy ("ACE") to conduct a shadow flicker analysis (the "Study") for the proposed Thunder Spirit Wind Project (the "Project"). The objective of the Study was to estimate the annual frequency of shadow flicker on occupied residences caused by Project wind turbines. No attempt was made in this Study to examine or opine on health effects related to shadow flicker.

1.2 Project Overview

The proposed Thunder Spirit Wind Project is located in Adams County, North Dakota, approximately 6 miles northeast of the city of Hettinger, North Dakota, and approximately 20 miles northwest of the city of Lemmon, South Dakota (the "Project Site"). The proposed Project will consist of 43 Nordex N100-2500 and 16 Nordex N117-3000 wind turbines with an aggregate nameplate capacity of approximately 155.5 megawatts ("MW"). Additionally, three (3) alternate locations for the Nordex N117-3000 wind turbine locations were included as part of the Study.

A map showing the general location and configuration of the Project Site is included in Appendix A.

1.3 Shadow Flicker Overview

Shadow flicker occurs when wind turbine blades pass in front of the sun to create recurring shadows on an object. Such shadows occur only under very specific conditions, including sun position, wind direction, time of day, and other similar factors.

The intensity of shadow flicker varies significantly with distance, and as separation between a turbine and receptor increases, shadow flicker intensity correspondingly diminishes. Shadow flicker intensity for distances greater than 10 rotor diameters (i.e., a maximum distance of 1170 meters for the Project) is generally low and considered imperceptible. At such distances, shadow flicker most commonly occurs at sunrise or sunset, when cast shadows are sufficiently long.

Local ordinances stating the level of acceptable shadow flicker from the Project were not identified. However, Burns & McDonnell notes that a typical threshold identified in most ordinances throughout the country is a maximum of 30 hours per year of perceivable shadow flicker. This requirement was used as a baseline for this Study.

1.4 Site Visit

Burns & McDonnell did not visit the Project Site as part of this Study. The contents of this evaluation are based exclusively upon desktop analysis by Burns & McDonnell.

2.0 MODELING PARAMETERS AND INPUTS

2.1 Modeling Overview

Shadow flicker was modeled at the Project Site using WindPRO, an industry-leading software package for the design and planning of wind energy projects. This package models the sun's path with respect to every turbine location during every minute over a complete year. Any shadow flicker caused by each turbine is then aggregated for each receptor for the entire year.

The following sections are summaries of the inputs utilized in the WindPRO model for this Study.

2.2 Turbine Coordinates

Shadow flicker intensity is partially dependent upon the distance from a receptor to the turbine causing the shadow. The ACE-provided coordinates of each turbine are presented in Appendix B, and the location of each turbine is presented graphically in Appendix A.

2.3 Turbine Dimensions

The size of a wind turbine, including both hub height and rotor diameter, contributes to the length and width of the shadows that may be cast by that turbine. The Project will include 43 Nordex N100-2500 and 16 Nordex N117-3000 wind turbine generators with three (3) alternative locations for the Nordex N117-3000 turbine locations evaluated as part of the Study. The Nordex N100-2500 turbines was modeled with a rotor diameter of 100 meters and a hub height of 80 meters. Additionally, the Nordex N117-3000 was modeled with a rotor diameter of 117 meters and a hub height of 91 meters. These model parameters are shown in Appendix B.

2.4 Receptors

A quantity of 36 occupied residences were modeled at the Project Site. The ACE-provided coordinates of each receptor are presented in Appendix B, and the location of each receptor is presented graphically in Appendix A. Burns & McDonnell did not provide an independent verification of whether these receptors were occupied, however, the physical location of these receptors were identified by Burns & McDonnell using aerial imagery

Each receptor was modeled in "green house" mode within the WindPRO model. This conservative approach provides a worst-case estimate of the amount of time when shadow flicker could occur by modeling each receptor as having windows on all sides and effectively causing the home to be susceptible to flicker effects in all directions.

2.5 Terrain

The WindPRO model utilizes topography data to place turbines and receptors at the proper elevations. This information is also used by the model to consider any natural land features between a turbine and a receptor that may block shadows from being seen at a receptor.

Publically-available terrain data was downloaded from the National Elevation Dataset, a product of the United States Geological Survey. The 10-meter resolution digital elevation model ("DEM") was exported at 10-foot intervals for use in the WindPRO model. Elevations were assigned by Burns & McDonnell to each turbine and each receptor using this data.

2.6 Obstacles

Obstacles located between a receptor and a turbine, such as trees or buildings, may significantly reduce or eliminate the duration and/or intensity of shadow flicker. However, because Burns & McDonnell did not visit the Project Site as part of this Study and could not make in-person observations regarding the size or influence of obstacles, no attempt was made to model the presence of potential obstacles. This approach also provides the most conservative estimate of the amount of time when shadow flicker could occur.

2.7 Turbine Operation

Shadow flicker is contingent upon the movement of the turbine blades. Shadow flicker can only occur when the turbine is in operation (i.e., when the turbine blades are rotating). Moreover, shadow flicker is generally most notable when a turbine is facing a receptor, as this results in the widest-possible shadow being cast. To more accurately reflect the periods of operation of each Project wind turbine, on-site wind data provided by ACE and used to indicate the periods when the turbines are inactive due to wind speeds below the turbine cut-in speed or above the turbine cut-out speed, at which time the turbine rotor is not in motion and no shadow flicker will occur. Similar wind speeds were assumed for both hub heights.

Project Site-specific wind data was also utilized to model the actual orientation of the turbines relative to each receptor. The ACE-provided wind data included data collected by an on-site meteorological mast from February 2016 to April 2017. The provided data is shown in Appendix C.

Power curves for the Nordex N100-2500 and N117-3000 turbine were provided by ACE showing a cut-in speed of 3.0 meters per second ("m/s") and a cut-out speed of 25.0 m/s. These power curves were added to the WindPRO model to more accurately reflect the turbine's operational characteristics. The ACE-provided power curves are shown in Appendix E.

2.8 Flicker Relevance

At distances beyond 10 rotor diameters, shadow flicker effects are generally considered low, as shadows diffuse and become imperceptible. Thus, a distance of 1,170 meters was modeled based on the largest turbine model proposed as the maximum distance at which shadow flicker was considered relevant; turbines greater than this distance from a given receptor were not evaluated. The proximity of this buffer relative to each receptor is presented graphically in Appendix A.

2.9 Sun Angle

The sun's path with respect to each turbine location is calculated by the WindPRO model to determine the cast shadow paths during every minute over a complete year. However, at very low sun angles, the light must pass through more atmosphere and becomes too diffused to form a coherent shadow. Thus, a value of three (3) degrees was utilized for the height at which the sun would not cause noticeable flicker.

2.10 Sun Obstruction

The percentage of the turbine blade covering the sun disc is calculated by the WindPRO model to determine the size of shadow cast during every minute over a complete year. By default, the WindPRO model calculates shadow flicker only when at least 20 percent of the sun disc is covered by the turbine blades. When less than 20 percent of the sun disc is masked by the blades, the shadow will be too diffuse to cause a coherent shadow.

2.11 Environment

Shadow flicker is only caused when the sun is shining. Sunshine probability data (see Appendix D) was obtained by Burns & McDonnell from www.city-data.com. This data represents the percentage of hours each month that the sun is expected to be shining during daylight hours, with consideration given for cloud cover, rainy days, fog, or other similar occurrences that may diminish the potential occurrence or severity of shadow flicker.

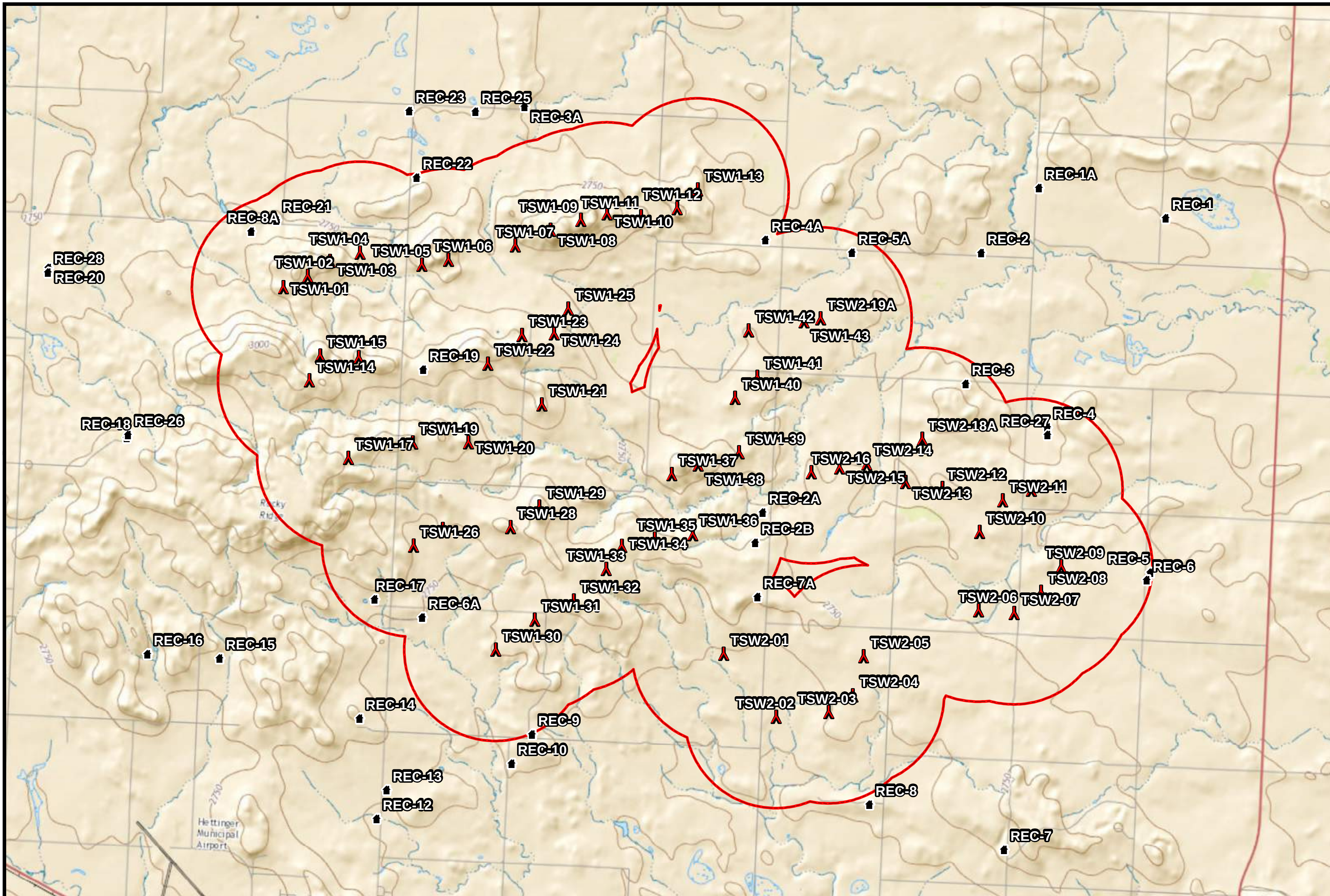
3.0 RESULTS

Using the inputs and parameters defined in Section 2.0, the WindPRO model was used to calculate shadow flicker for the receptors at the Project Site. Table F-1 and Table F-2 within Appendix F present estimated hours per year of shadow flicker by occupied residence, sorted by receptor name and total flicker time, respectively. Additionally, a map is provided in Appendix G which illustrates the shadow flicker vectors (in hours per year) caused by each Project turbine.

The following is a set of key observations from the results of the Study:

- 13 of the 36 known occupied residences were observed to experience shadow flicker over the course of a year. Refer to Table F-1 and Table F-2 within Appendix F for a complete listing of shadow flicker results.
- None of the known occupied residences experienced shadow flicker in excess of the baseline limitation of 30 hours per year of perceivable shadow flicker. Refer to Table F-1 and Table F-2 within Appendix F for a complete listing of shadow flicker results.
- The majority of observed shadow flicker on each residence occurs during early morning and/or late afternoon and evening hours (see Appendix H). Additionally, most observed shadow flicker occurs during spring and fall months.
- The Study was performed using a conservative modeling approach with Project Site-specific conditions. For example, the Study modeled each receptor as a “green house”, meaning each receptor was modeled as having windows on all sides and effectively causing the home to be susceptible to flicker effects in all directions. Further, the Project Site was modeled as if no obstacles were present, including trees or buildings, which may significantly reduce or eliminate the duration and/or intensity of shadow flicker at a receptor. Due to the conservative approach of the Study, the actual duration and intensity of shadow flicker experienced at each receptor is expected to be less than those reported in the Study.

APPENDIX A - PROJECT SITE LAYOUT



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LEGEND

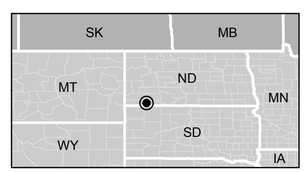
- Occupied Residence
- Wind Turbine
- Wind Turbine Buffer - 1170m

REFERENCE

0 0.75 1.5
MILES

0 0.8 1.6
KILOMETERS

N



THUNDER SPIRIT WIND PROJECT
Project Site Layout

LOCATION:	Adams County, North Dakota
CLIENT:	ALLETE Clean Energy
PROJ. NO.:	98658
CREATED:	05/04/2017

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APPENDIX B - INFRASTRUCTURE COORDINATES

Table B-1: Turbine Coordinates

Turbine ID	Easting [m]	Northing [m]	Hub Height [m]
TSW1-01	218,420	5,109,680	80
TSW1-02	218,730	5,109,825	80
TSW1-03	219,019	5,110,016	80
TSW1-04	219,404	5,110,123	80
TSW1-05	220,195	5,109,970	80
TSW1-06	220,538	5,110,034	80
TSW1-07	221,393	5,110,216	80
TSW1-08	221,848	5,110,417	80
TSW1-09	222,234	5,110,545	80
TSW1-10	222,569	5,110,627	80
TSW1-11	223,006	5,110,591	80
TSW1-12	223,468	5,110,693	80
TSW1-13	223,732	5,110,934	80
TSW1-14	218,754	5,108,487	80
TSW1-15	218,890	5,108,803	80
TSW1-16	219,389	5,108,781	80
TSW1-17	219,255	5,107,490	80
TSW1-18	219,560	5,107,670	80
TSW1-19	220,077	5,107,687	80
TSW1-20	220,792	5,107,690	80
TSW1-21	221,734	5,108,176	80
TSW1-22	221,042	5,108,698	80
TSW1-23	221,478	5,109,067	80
TSW1-24	221,891	5,109,088	80
TSW1-25	222,074	5,109,405	80
TSW1-26	220,088	5,106,368	80
TSW1-27	220,465	5,106,582	80
TSW1-28	221,333	5,106,604	80
TSW1-29	221,703	5,106,867	80
TSW1-30	221,142	5,105,032	80
TSW1-31	221,645	5,105,415	80
TSW1-32	222,142	5,105,662	80
TSW1-33	222,559	5,106,066	80
TSW1-34	222,760	5,106,367	80
TSW1-35	223,182	5,106,456	80

Turbine ID	Easting [m]	Northing [m]	Hub Height [m]
TSW1-36	223,668	5,106,514	80
TSW1-37	223,400	5,107,283	80
TSW1-38	223,737	5,107,405	80
TSW1-39	224,263	5,107,562	80
TSW1-40	224,213	5,108,261	80
TSW1-41	224,496	5,108,532	80
TSW1-42	224,385	5,109,125	80
TSW1-43	225,094	5,109,245	80
TSW2-01	224,064	5,104,979	91
TSW2-02	224,738	5,104,170	91
TSW2-03	225,411	5,104,231	91
TSW2-04	225,723	5,104,446	91
TSW2-05	225,860	5,104,947	91
TSW2-06	227,334	5,105,536	91
TSW2-07	227,788	5,105,501	91
TSW2-08	228,135	5,105,773	91
TSW2-09	228,394	5,106,100	91
TSW2-10	227,345	5,106,543	91
TSW2-11	227,641	5,106,946	91
TSW2-12	226,872	5,107,104	91
TSW2-13	226,396	5,107,183	91
TSW2-14	225,899	5,107,420	91
TSW2-15	225,551	5,107,368	91
TSW2-16	225,189	5,107,308	91
TSW2-17A	228,011	5,107,082	91
TSW2-18A	226,613	5,107,737	91
TSW2-19A	225,308	5,109,279	91

Notes:
[1] All coordinates provided in UTM NAD83 Zone 14N (meters)
[2] Coordinates provided by ACE via "98658_TSW2_WTG_20170329_16plus3Alt.shp" and “turbines.shp”

Table B-2: Receptor Coordinates

Receptor Name	Easting [m]	Northing [m]
REC-1	229,736	5,110,565
REC-1A	228,112	5,110,954
REC-2	227,369	5,110,122
REC-2A	224,569	5,106,793
REC-2B	224,473	5,106,403
REC-3	227,171	5,108,443
REC-3A	221,516	5,111,996
REC-4	228,218	5,107,883
REC-4A	224,603	5,110,287
REC-5	229,538	5,106,023
REC-5A	225,715	5,110,125
REC-6	229,492	5,105,925
REC-6A	220,204	5,105,445
REC-7	227,664	5,102,467
REC-7A	224,502	5,105,709
REC-8	225,937	5,103,048
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REC-9	221,611	5,103,948
REC-10	221,350	5,103,571
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REC-14	219,401	5,104,150
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REC-17	219,594	5,105,677
REC-18	216,415	5,107,750
REC-19	220,217	5,108,624
REC-20	215,411	5,109,929
REC-21	218,334	5,110,539
REC-22	220,131	5,111,089
REC-23	220,040	5,111,942
REC-24	220,856	5,113,563
REC-25	220,886	5,111,934
REC-26	216,433	5,107,788
REC-27	228,221	5,107,787
REC-28	215,405	5,109,871

Notes:
[1] All coordinates presented in UTM NAD83 Zone 14N (meters)
[2] Provided by ACE via "TSW Houses.shp" on 5-03-2017

APPENDIX C - ON-SITE FREQUENCY DISTRIBUTION

Table C-1: Onsite Frequency Distribution

Bin	Wind Direction [degrees]											
[m/s]	0	30	60	90	120	150	180	210	240	270	300	330
0	6.30	5.14	3.72	5.72	7.39	12.60	6.96	4.82	4.67	11.03	19.57	12.07
1	37.01	12.26	19.53	73.55	5.17	26.69	8.24	17.04	6.13	4.68	3.32	3.48
2	43.39	63.52	66.29	43.80	23.78	13.80	26.92	37.65	38.43	13.34	9.47	14.73
3	68.26	79.50	168.55	155.47	42.92	24.87	60.97	85.61	94.85	31.53	16.50	31.52
4	102.85	115.16	181.91	173.86	62.05	42.46	89.54	129.21	121.83	46.25	26.47	57.02
5	127.12	109.96	135.66	141.42	92.30	55.04	85.42	130.80	139.00	49.02	39.65	89.01
6	121.36	142.27	112.03	112.00	98.50	60.96	96.95	172.41	123.06	54.05	43.95	77.76
7	104.07	117.01	76.05	87.26	101.34	73.39	103.82	129.61	84.22	64.44	51.07	79.66
8	89.20	99.93	71.94	50.49	97.98	90.37	116.18	106.22	60.51	71.19	55.57	101.68
9	104.07	72.44	62.18	51.15	89.97	116.00	101.35	66.19	52.33	67.38	80.96	107.22
10	87.38	66.12	51.39	39.12	100.57	128.73	103.27	42.01	43.34	59.07	90.82	113.56
11	58.86	51.26	19.01	30.09	89.71	135.56	79.65	29.33	35.57	67.04	94.24	91.70
12	26.40	33.43	8.74	18.05	78.59	96.13	62.07	20.61	35.16	75.70	105.57	74.28
13	13.65	19.32	8.22	12.37	70.32	53.37	30.49	17.84	45.38	74.31	103.32	46.25
14	8.19	9.66	7.19	7.02	33.35	31.54	19.50	7.53	38.43	67.21	75.98	34.21
15	4.25	5.20	5.14	1.67	6.72	21.68	7.97	3.57	38.02	60.80	53.71	22.02
16	2.73	1.86	2.06	2.01	4.14	10.92	3.02	1.59	15.54	61.49	35.84	16.79
17	0.30	0.37	1.54	0.33	0.26	7.13	2.75	1.98	13.08	45.38	34.67	14.57
18	0.30	0.00	1.54	0.00	1.29	5.00	1.65	0.40	7.77	32.74	24.61	9.82
19	0.30	0.00	0.51	0.33	0.26	4.25	0.28	0.40	4.91	24.08	22.56	6.97
20	0.00	0.37	0.00	0.00	0.26	1.06	0.00	0.00	2.04	14.03	15.63	2.53
21	0.00	0.00	0.00	0.00	0.26	0.76	0.00	0.00	0.41	9.70	8.50	0.79
22	0.00	0.37	0.51	0.00	0.00	0.00	0.00	0.00	0.00	4.85	3.52	0.79
23	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.69	1.47	0.48
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	1.07	1.43
25	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.17	0.78	0.95
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.48
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.32
28	0.30	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00

Bin	Wind Direction [degrees]											
[m/s]	0	30	60	90	120	150	180	210	240	270	300	330
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes:

[1] All data provided by ACE via "MET data.xlsx"

[2] All data presented in milles for period from February 2016 to April 2017.

APPENDIX D - SUNSHINE PROBABILITY DATA

Figure D-1: Monthly Sunshine Probability for Hettinger, North Dakota

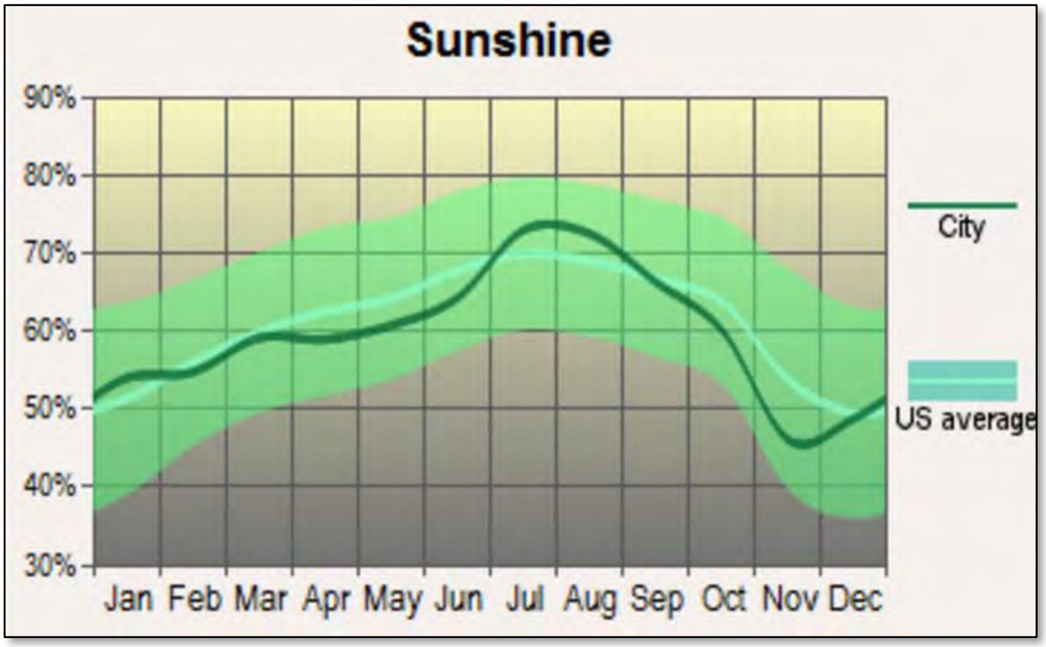


Table D-1: Monthly Sunshine Probability for Hettinger, North Dakota

Month	Avg Sunshine Probability
January	55%
February	56%
March	60%
April	59%
May	61%
June	65%
July	73%
August	72%
September	66%
October	60%
November	47%
December	49%

Notes:
[1] Data source: http://www.city-data.com/city/Hettinger-North-Dakota.html
[2] Data location: Hettinger, North Dakota
[3] Data in Table D-1 estimated from source data in Figure D-1

APPENDIX E - NORDEX POWER CURVES

Table E-1: Nordex N100-2500 and N117-3000 Power Curve Values

Wind Speed [m/s]	Nordex N100-2500 Power [kW]	Nordex N117-3000 Power [kW]
0.0	0	0
1.0	0	0
2.0	0	0
3.0	1	12
4.0	91	115
5.0	233	302
6.0	432	569
7.0	700	932
8.0	1,052	1,403
9.0	1,481	1,944
10.0	1,971	2,479
11.0	2,325	2,819
12.0	2,485	2,975
13.0	2,500	3,000
14.0	2,500	3,000
15.0	2,500	3,000
16.0	2,500	3,000
17.0	2,500	3,000
18.0	2,500	3,000
19.0	2,500	3,000
20.0	2,500	3,000
21.0	2,500	3,000
22.0	2,500	3,000
23.0	2,500	3,000
24.0	2,500	3,000
25.0	2,500	3,000

Notes:
[1] Power curve for air density of 1.125 kg/m^3 and normal turbulence intensity
[2] Provided by ACE via "F008_244_A12_EN_R01_Nordex+N117-3000.pdf" on 3-31-2017 and "F008_227_A05_EN_R02_N100-2500_PowerCurve.pdf" on 5-03-2017

APPENDIX F - FLICKER RESULTS BY RECEPTOR

Table F-1: Hours per Year of Shadow Flicker (Sorted by Receptor ID)

Receptor ID	Flicker [hr/yr]	Receptor ID	Flicker [hr/yr]	Receptor ID	Flicker [hr/yr]
REC-1	0:00	REC-6A	4:24	REC-17	0:28
REC-1A	0:00	REC-7	0:00	REC-18	0:00
REC-2	0:00	REC-7A	3:40	REC-19	16:05
REC-2A	14:38	REC-8	0:00	REC-20	0:00
REC-2B	7:58	REC-8A	11:18	REC-21	9:16
REC-3	0:00	REC-9	0:00	REC-22	1:33
REC-3A	0:00	REC-10	0:00	REC-23	0:00
REC-4	0:00	REC-12	0:00	REC-24	0:00
REC-4A	5:19	REC-13	0:00	REC-25	0:00
REC-5	4:32	REC-14	0:00	REC-26	0:00
REC-5A	1:36	REC-15	0:00	REC-27	0:00
REC-6	5:21	REC-16	0:00	REC-28	0:00

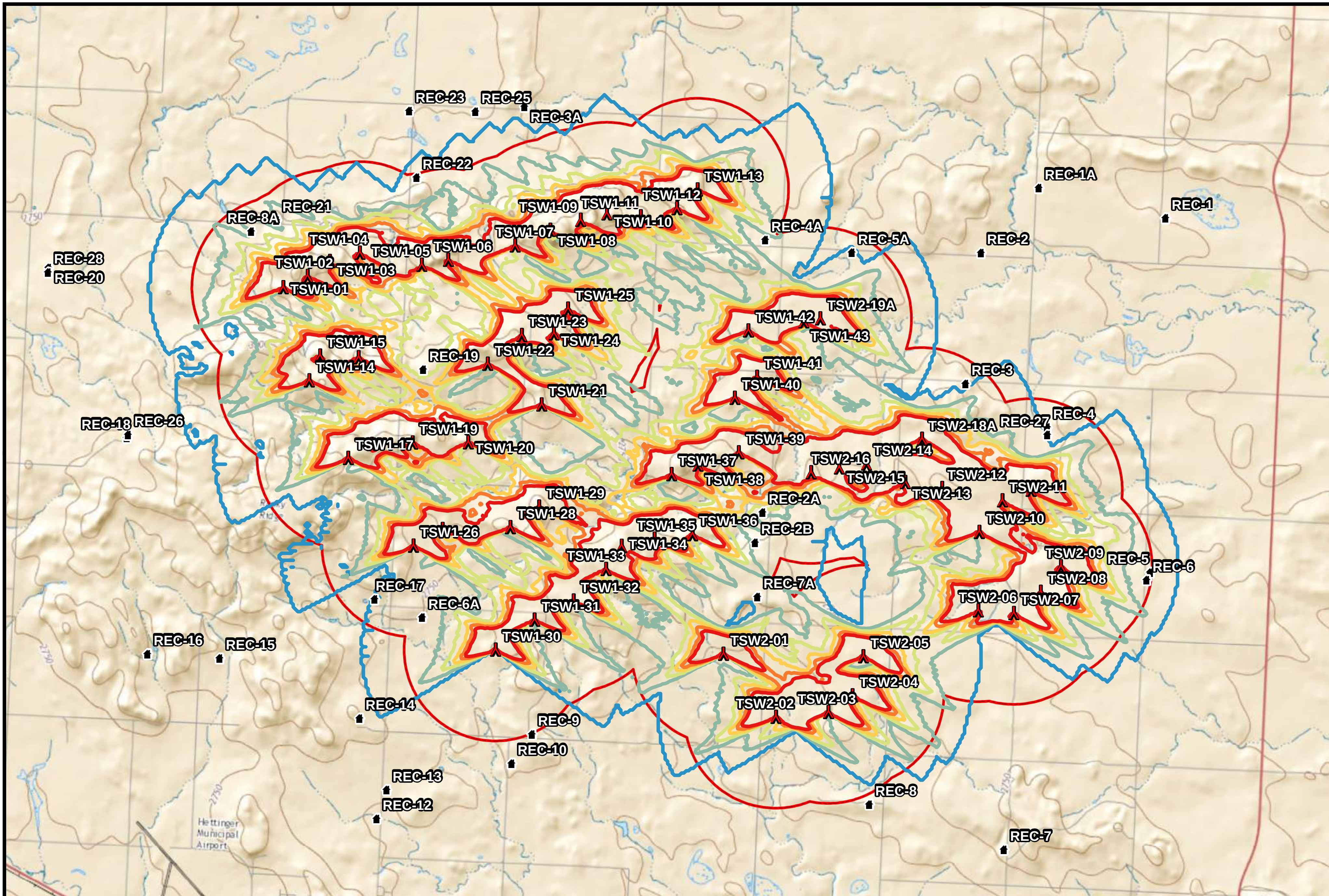
Notes:
[1] Receptor locations provided by ACE via “TSW Houses.shp” on 5-03-2017

Table F-2: Hours per Year of Shadow Flicker (Sorted by Flicker Duration)

Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]
REC-19	16:05	REC-17	0:28	REC-13	0:00
REC-2A	14:38	REC-1	0:00	REC-14	0:00
REC-8A	11:18	REC-1A	0:00	REC-15	0:00
REC-21	9:16	REC-2	0:00	REC-16	0:00
REC-2B	7:58	REC-3	0:00	REC-18	0:00
REC-4A	5:19	REC-3A	0:00	REC-20	0:00
REC-6	5:21	REC-4	0:00	REC-23	0:00
REC-5	4:32	REC-7	0:00	REC-24	0:00
REC-6A	4:24	REC-8	0:00	REC-25	0:00
REC-7A	3:40	REC-9	0:00	REC-26	0:00
REC-5A	1:36	REC-10	0:00	REC-27	0:00
REC-22	1:33	REC-12	0:00	REC-28	0:00

Notes:
[1] Receptor locations provided by ACE via "TSW Houses.shp" on 5-03-2017

APPENDIX G - SHADOW FLICKER DURATION MAP



LEGEND

- Occupied Residence
- Wind Turbine
- Wind Turbine Buffer - 1170m

Shadow Flicker Vectors [hours per year]

0 10 20 30 40 50

REFERENCE

0 0.75 1.5 MILES

0 0.8 1.6 KILOMETERS

N

SK MB MT ND MN WY SD IA

THUNDER SPIRIT WIND PROJECT
Shadow Flicker Duration Map

LOCATION:	Adams County, North Dakota
CLIENT:	ALLETE Clean Energy
PROJ. NO.:	98658
CREATED:	05/04/2017

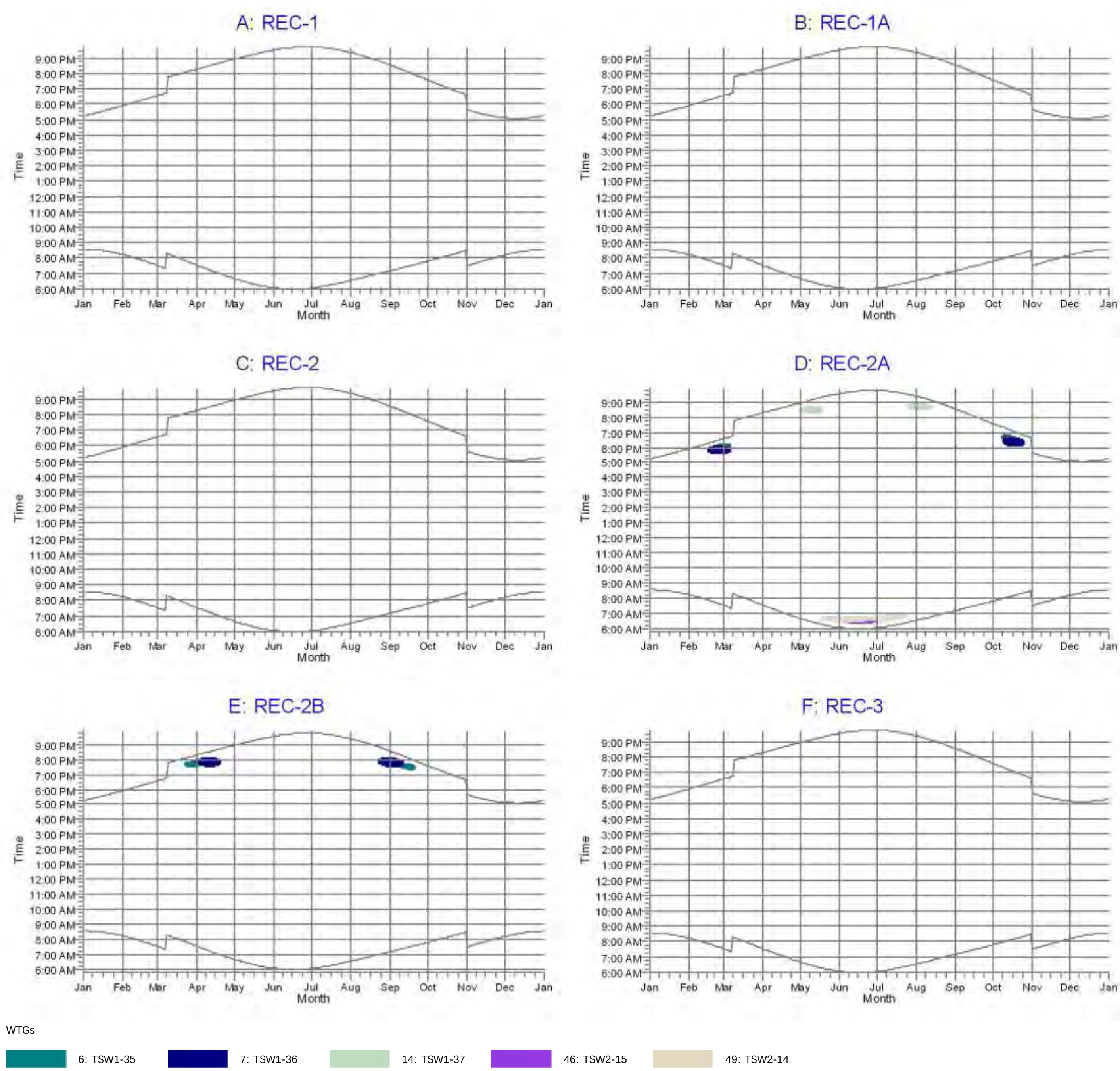
BURNS McDONNELL
www.burnsmcd.com

Path: Z:\Clients\BTS\AlleteCleanE\98658_TSW2NoiseFlick\Studies\Business_Consult\Analysis\Shadow Flicker\08 - ArcMaps\TSW_WindPro_Shapefiles_20170504.mxd • Coordinate System: NAD 1983 UTM Zone 14N • Units: Meter

APPENDIX H - SHADOW FLICKER CALENDAR

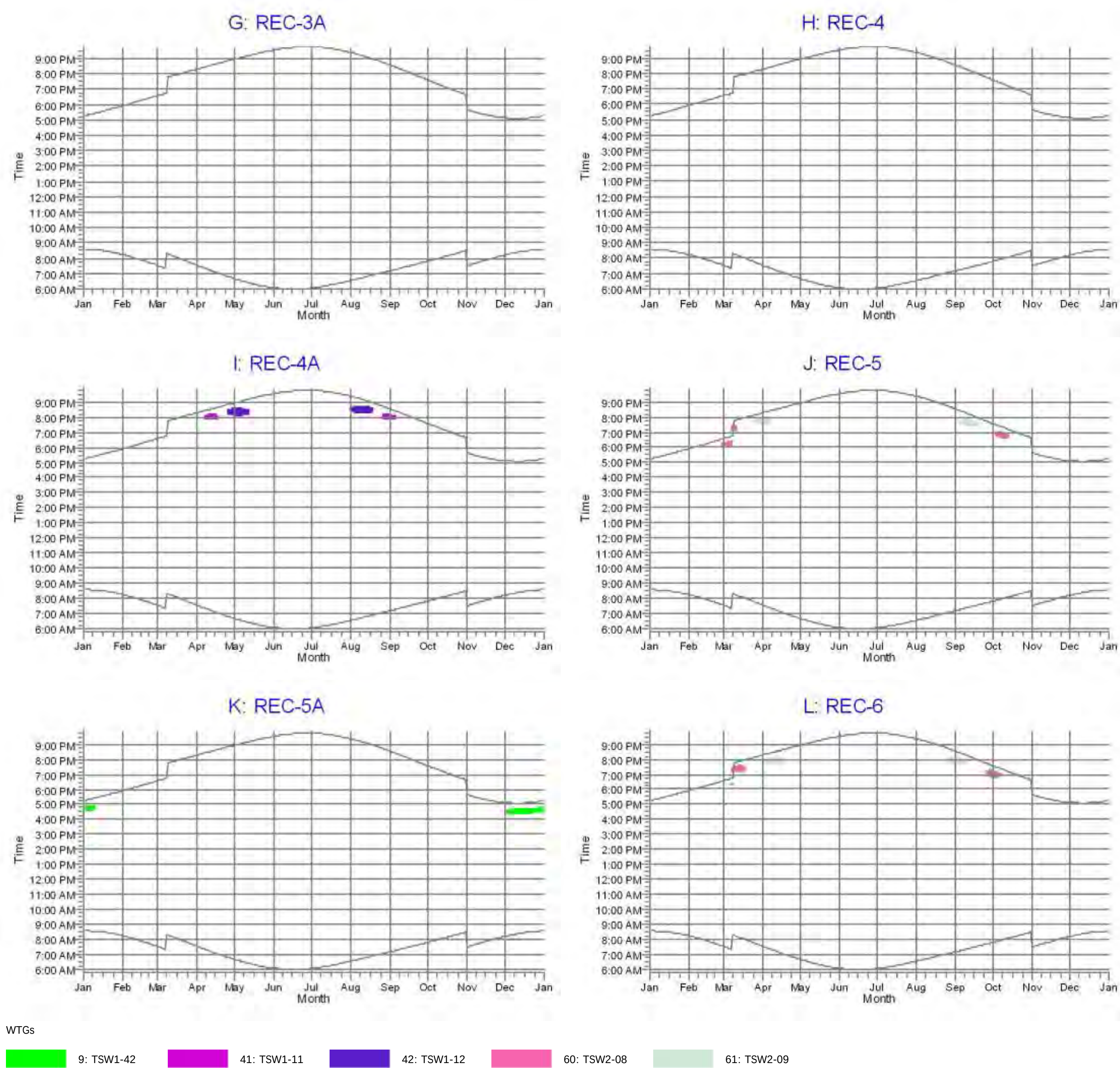
SHADOW - Calendar, graphical

Calculation: Thunder Spirit Wind Project - Shadow Flicker Analysis - 20170504



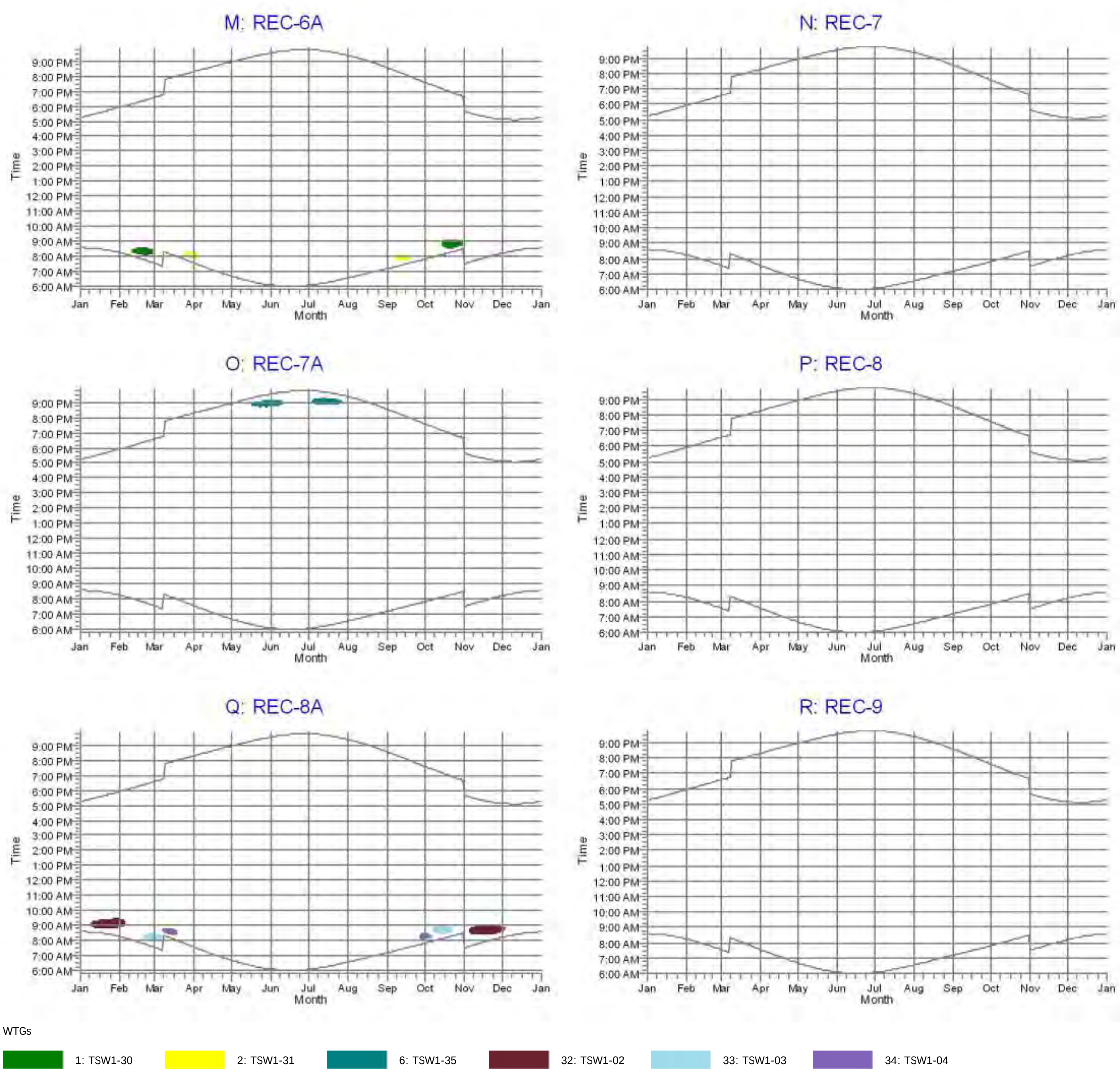
SHADOW - Calendar, graphical

Calculation: Thunder Spirit Wind Project - Shadow Flicker Analysis - 20170504



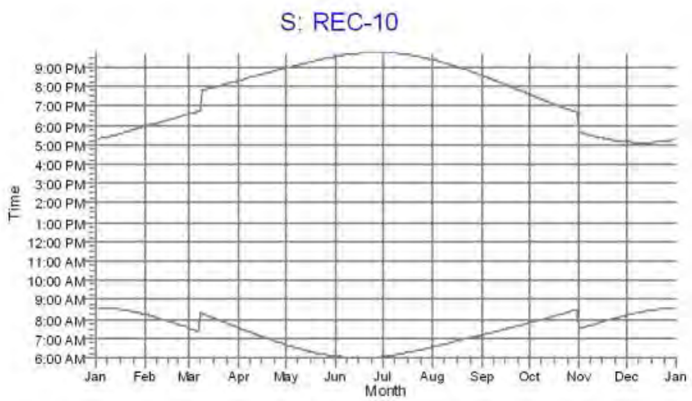
SHADOW - Calendar, graphical

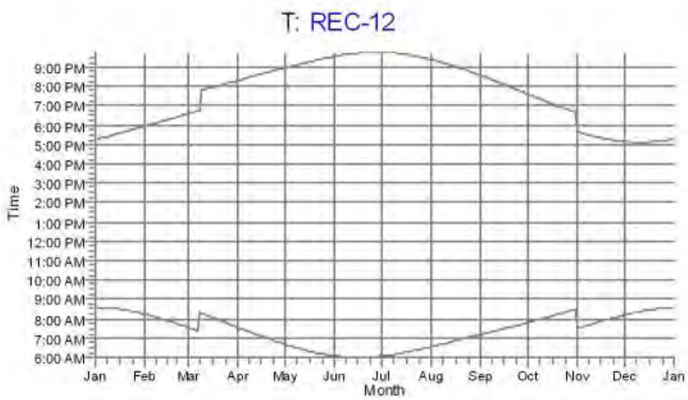
Calculation: Thunder Spirit Wind Project - Shadow Flicker Analysis - 20170504

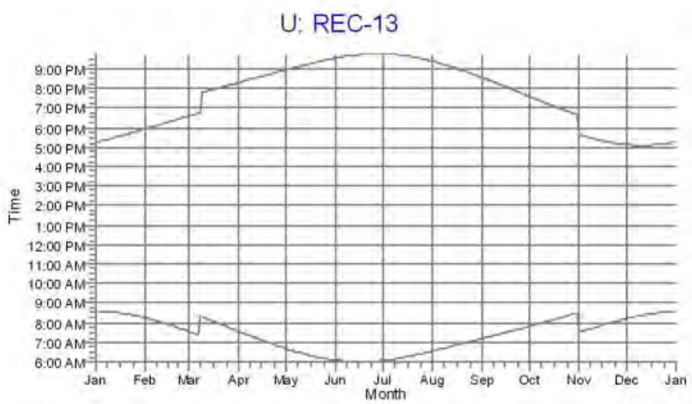


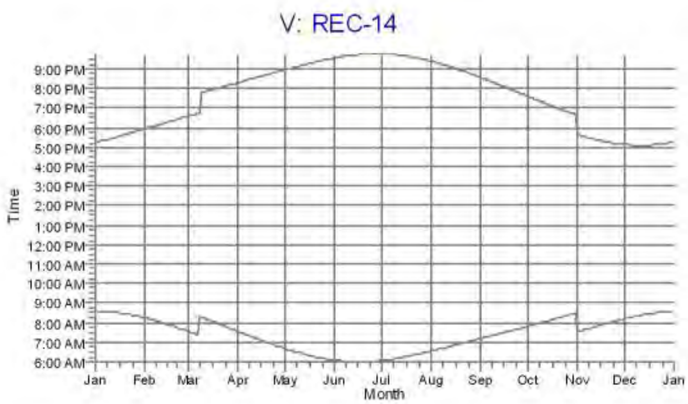
SHADOW - Calendar, graphical

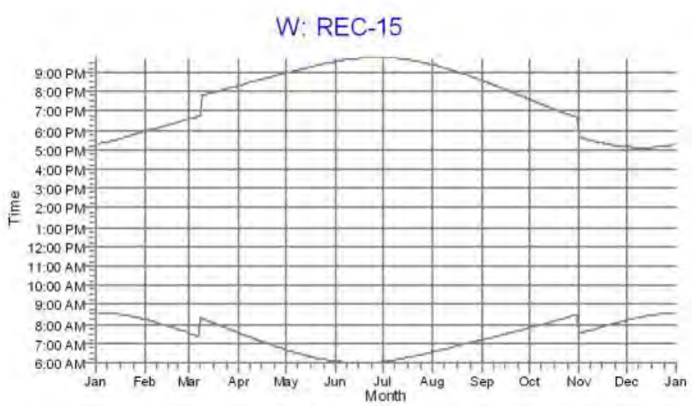
Calculation: Thunder Spirit Wind Project - Shadow Flicker Analysis - 20170504

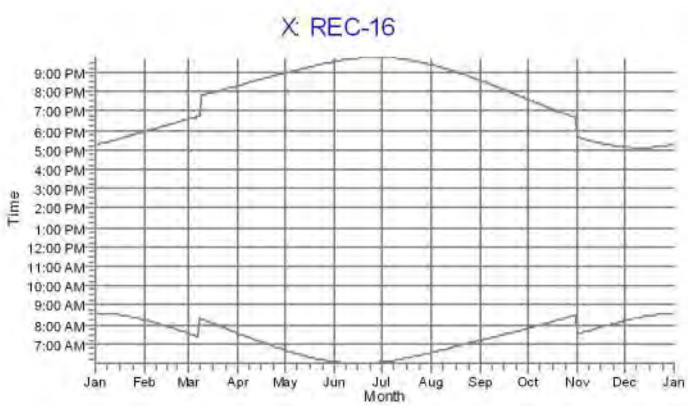








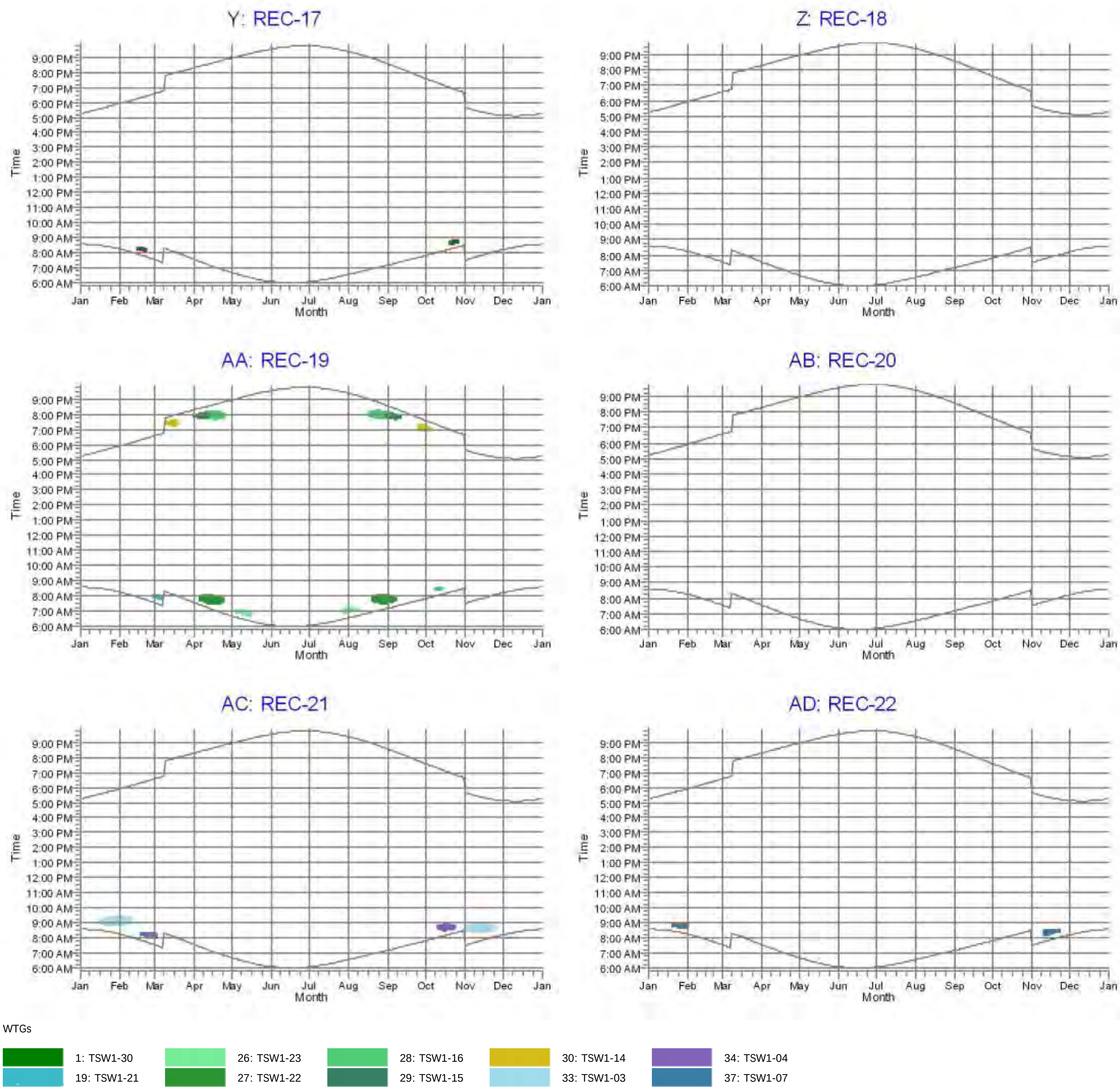




WTGs

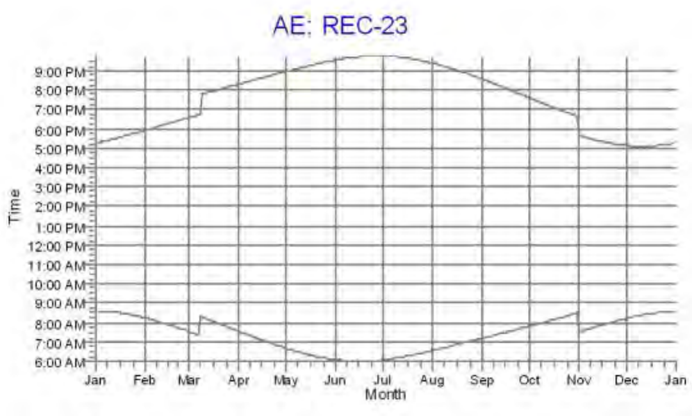
SHADOW - Calendar, graphical

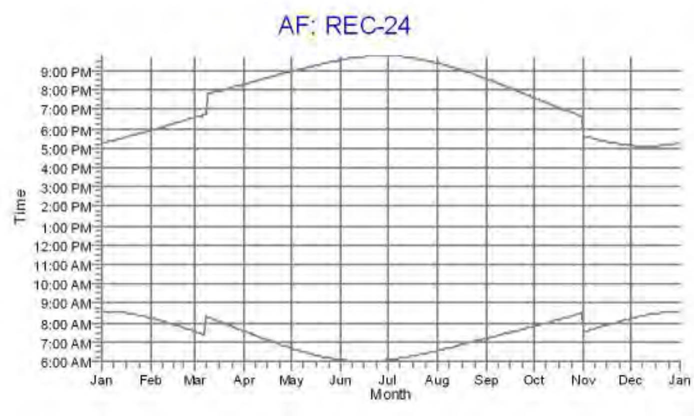
Calculation: Thunder Spirit Wind Project - Shadow Flicker Analysis - 20170504

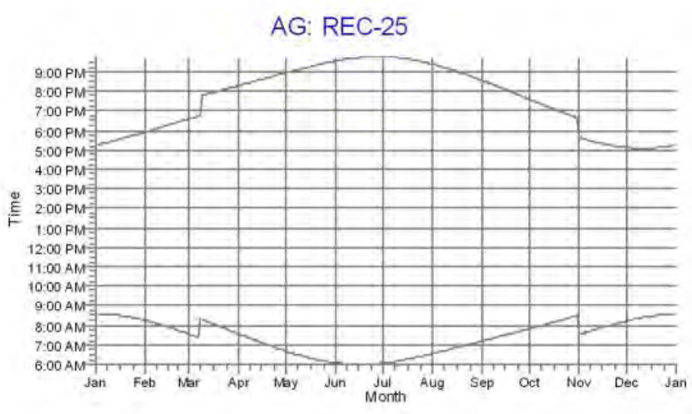


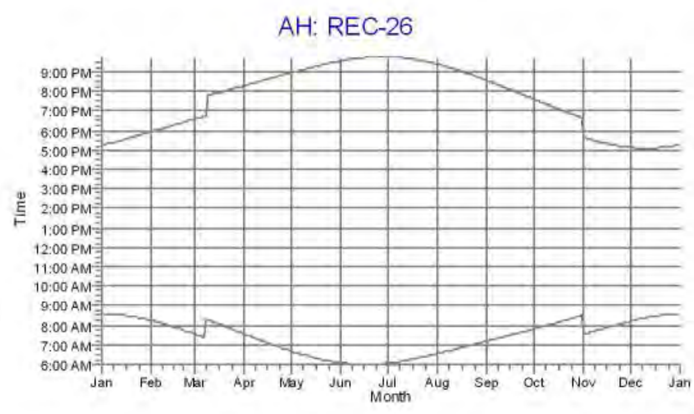
SHADOW - Calendar, graphical

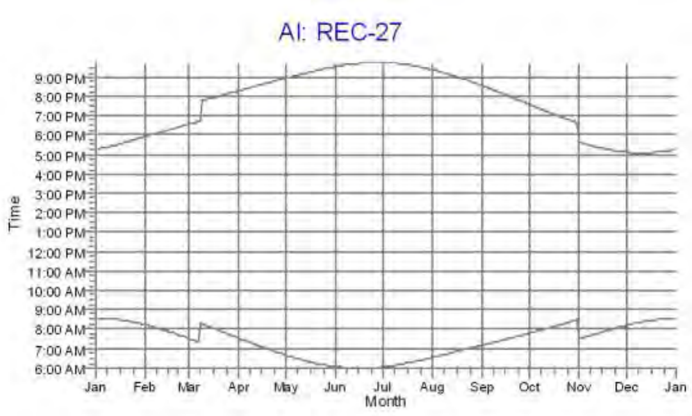
Calculation: Thunder Spirit Wind Project - Shadow Flicker Analysis - 20170504

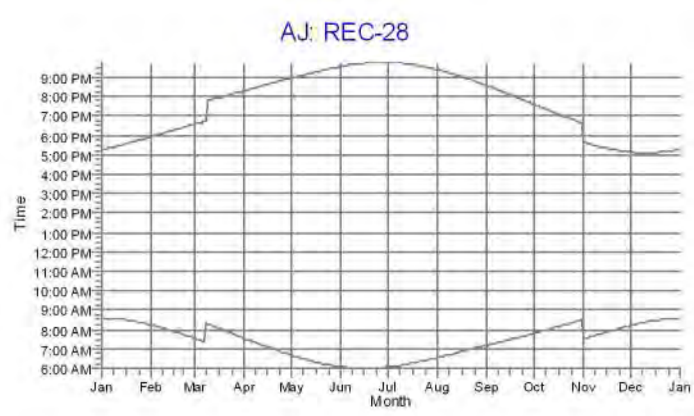












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