Sonic Detection and Ranging (SODAR) Data Collection and Evaluation Report

Natural Resource Partners L.P.

Town Creek Knob, Fayette County, West Virginia

(Data Evaluation Period: April 18, 2012 to January 7, 2013)

Compiled by:

Marshall University Center for Environmental, Geotechnical and Applied Sciences (CEGAS)

With Assistance from:

Marshall University Center for Business and Economic Research (CBER)

Under Direction of:

West Virginia Division of Energy

Funded by:

Appalachian Regional Commission

West Virginia Division of Energy

March, 2013

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1.0 Introduction

Marshall University's Center for Environmental, Geotechnical and Applied Sciences (CEGAS) has partnered with the West Virginia Division of Energy to perform initial screening and wind resource data collection to assess wind energy development opportunities at selected surface mine properties in West Virginia using Sonic Detection and Ranging (SODAR) technologies. This report has been compiled with assistance from Marshall University's Center for Business and Economic Research (CBER), with funding for this study provided under joint partnership from the Appalachian Regional Commission and the West Virginia Division of Energy.

1.1 Project Location and Site Conditions

The site is located at the Natural Resource Partners L.P. surface mine site, located in the Town Creek Knob area of Fayette County, approximately 3.5 miles northwest of the community of Pax, WV and the WV Turnpike (Interstate 64 and 77). The area was accessed using Paint Creek Road to County Route 23/3, then using a mining haul road. The site includes several hundred acres or reclaimed surface mine lands. The SODAR was placed on a reclaimed ridgeline at Latitude 37.94203, Longitude -81.29405, at an elevation of 2835 feet (864 meters) above mean sea level. This area is along a network of ridgelines, part of large reclaimed surface mine area, with active surface mine operations located generally south. A general site location map is provided in Appendix A.

The immediately surrounding area consists of reclaimed surface mine property. Minimal ground vegetation is present, and much of the immediate area is in the early stages of reclamation. Minimal traffic and/or related noise from surface mine operations that would affect SODAR data collection. Several commercial radio towers are located eight tenths of mile to the west of the site on Lick Knob. The area is also used by a hunting club during designated hunting seasons.

1.2 Data Collection Description

Wind resource data was collected using a Triton™ Sonic Wind Profiler, manufactured by SecondWind, utilizing SODAR technology. Data collection occurred during the period of April 18, 2012 to January 7, 2013. Photos showing the Triton unit and surrounding area are included in Appendix A.

The Triton™ unit was set up per SecondWind recommendations, including leveling of the unit to within operating condition (within 3 degrees of level), and proper directional orientation of the unit using Global Positioning System and magnetic compass equipment. The Triton™ unit is oriented properly when the south sound beam is positioned to within a few degrees of South. A

Site Information Form and Checklist, as provided by SecondWind, was completed during initial setup, which records site conditions, including nearby surface features, site noise, and unit operation parameter checks. A copy of the Site Information Form and Checklist is included in Appendix A.

1.3 SODAR Configuration

The Triton™ Sonic Wind Profiler utilizes a hexagonal 36-speaker array to transmit high frequency acoustic pulses, or "chirps", and measures how they scatter and return to the unit. Sources of scattering are irregularities in wind velocities, air temperature and density, causing acoustic refractive index changes. By measuring the Doppler shifted frequency of the returned signal or echo, the SODAR determines wind speed and direction at various altitudes. Additional information on Triton™ Sonic Wind Profiler's operational details is available at: www.secondwind.com.

The SODAR unit saves records on 10-minute intervals. Each record includes data from 10 heights, ranging from 40 meters to 200 meters above ground surface. Data collected includes wind direction, horizontal and vertical wind speeds, turbulence, and general weather parameters, including temperature and barometric pressure.

2.0 SODAR Data Filtering and Performance

Using guidelines provided by Second Wind, SODAR data was filtered to remove low-quality data before analysis was performed. For this study, a 90% wind speed quality factor, as recommended by Second Wind, was used. During the time frame for this study, the SODAR unit operated continuously.

3.0 Results and Data Comparisons

All data collected during the study was exported into *Windographer*™ software for data analysis. *Windographer*™ is a wind data analysis program that reads data files directly from SODAR wind profilers and performs a number of calculations, including wind shear, turbulence intensity, extreme wind speeds, and wind turbine energy production. *Windographer*™ software version 2.4.8 was used for data analysis. Cumulative wind speed mean averages at various elevations above the ground surface during the study period ranged from 4.57 meters per second (m/s) at 40 meters, increasing fairly consistently to 7.41 m/s at 200 meters. Wind direction was predominantly from the west-southwest. Table 1 provides a summary of wind speed, wind

direction, vertical wind speed, and power density estimates at specified elevations from 40 to 200 meters above existing ground surface:

TABLE 1: Wind Speed, Wind Direction, Vertical Wind and Power Density Summary

Elevation Above Ground Surface (872 m)	Wind Speed (m/s, mean)	Wind Direction (degrees, mean)	Vertical Wind Speed (m/s, mean)	Power Density (W/m^2, mean)
40 Meters	4.57	240.2	-0.214	109
50 Meters	4.85	239.9	-0.228	125
60 Meters	5.03	239.6	-0.241	135
80 Meters	5.37	238.5	-0.253	158
100 Meters	5.70	236.8	-0.257	184
120 Meters	5.97	235.3	-0.250	206
140 Meters	6.29	233.5	-0.235	236
160 Meters	6.67	233.8	-0.225	276
180 Meters	7.03	235.0	-0.210	318
200 Meters	7.41	237.6	-0.207	371

Appendix B contains a Data Summary Report which includes wind frequency, mean wind speed, and total wind energy rose diagrams, plus project period wind speed and diurnal wind speed profiles. Complete SODAR field data collected is available upon request to the West Virginia Division of Energy.

3.1 Data Comparison to Estimated Wind Speeds

Data collected from the SODAR unit has been compared to available wind data evaluations for similar time periods to assess whether actual data obtained is representative of "normal" expected wind conditions, or were unusual wind conditions recorded during the period. Three data sets were evaluated for this comparison.

3.1.1 AWS Truewind Monthly Wind Speed Estimates

AWS Truewind™ has formulated estimated average monthly wind speeds at 80 meters above ground surface for the U.S. As part of data collection efforts, CEGAS obtained this information for site-specific evaluation and comparison. According to AWS Truewind™, this data has been compiled based on a distribution of the annual wind speed by month, using various public and authorized private data sources, including data from over 1,400 wind monitoring stations in the U.S. and Canada. AWS Truewind™ states that "values have been determined objectively to be within 0.35 meters per second of the true speed at over 68% of points used". For the Town Creek Knob site, monthly data comparisons between AWS Truepower™ and actual SODAR data have been compared for the period of May 2012 through December 2012, and are provided in Table 2.

Table 2: AWS Truewind and SODAR Comparisons

Month	AWS Truewind Estimate (meters per second)	SODAR Recorded Wind Speed (meters per second)
May 2012	5.25	4.67
June 2012	4.50	5.19
July 2012	4.27	5.12
August 2012	4.31	4.46
September 2012	4.84	5.12
October 2012	5.26	5.51
November 2012	5.73	5.63
December 2012	6.20	7.45

As the data reflects, both data sets are generally comparable, most months are within 0.85 meters per second (m/s). SODAR results indicating more than 0.85 m/s above expected results were recorded in December, 2012.

3.1.2 AWS Truepower™ Annual Wind Speed Estimates

AWS Truepower™ issues Quarterly reports for the U.S. on wind speeds compared to long-term averages. This data is based on computer simulation of weather conditions dating back to 1997. For the period that most closely parallels the SODAR data collection time period (Second Quarter 2012 through fourth Quarter 2012), wind speeds for the Eastern United States were

estimated at 5% to 15% below normal wind speeds. Fourth quarter data was not available at the time of the writing of this report. Complete details can be found at www.awstruepower.com. The SODAR wind speed data collected during this similar timeframe did not follow the AWS quarterly report trend. This could be attributed to not having the fourth quarter data, as well as, the geographic area covered by the AWS report.

3.2 Data Comparison to Regional Airport Wind Speeds

In addition to wind speed data comparisons previously presented, data from the SODAR was also compared to two regional airports to analyze wind speed variations and trends. The Charleston Yeager Airport (CRW) is located approximately 33 miles north-northwest of the Town Creek Knob site, and the Raleigh County Memorial Airport (BKW) in Beckley is located approximately 14 miles to the southeast. A general site map showing the two airports in relation to the project site is included in Appendix C. A 10-month time period was used (April 18, 2012 through December, 2012) for this comparison, in addition to other historical time periods.

3.2.1 Site Elevation Comparisons

The approximate elevation of each location and the distance from the Town Creek Knob site is provided in Table 3.

Table 3 Airport and SODAR Elevations

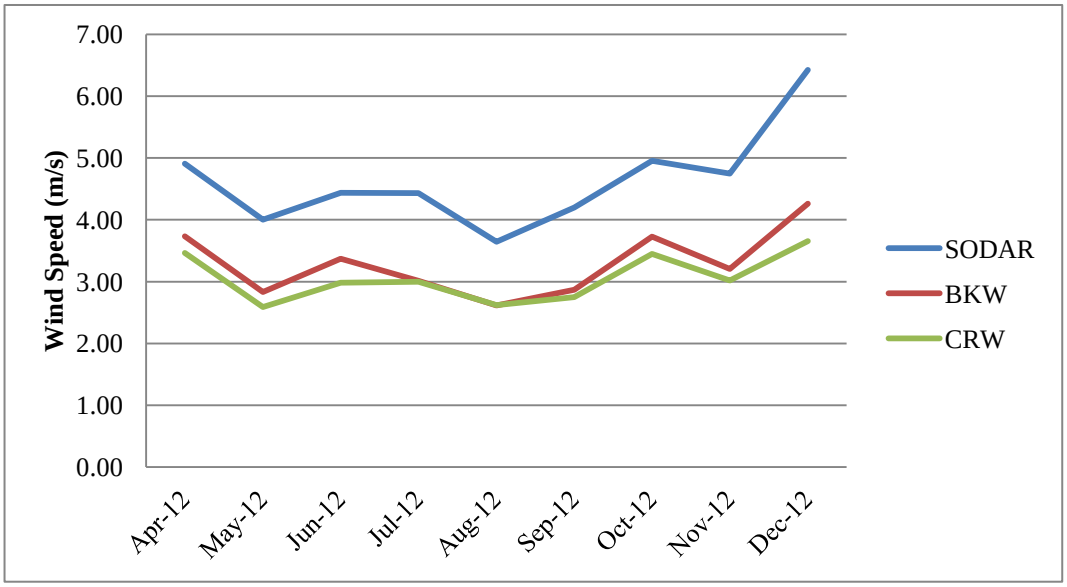
Location	Elevation	Distance
BKW	758 m	14 miles
CRW	287 m	33 miles
SODAR	864 m	

The height differences of wind speed measurement devices for each location also vary. Without taking elevation into consideration, the SODAR unit measures wind speeds at multiple heights. For the purpose of this comparison, only the 40 m wind speed readings will be used. The altitudes of the airport anemometers are unknown, but are unlikely to be higher than 10 or 20 meters.

3.2.2 Wind Speed Comparison: Nine-Month Trend

Average monthly wind speeds from April 18, 2012 to December 31, 2012, recorded by the SODAR unit were compared to average monthly wind speeds recorded at each airport location for the same time period. A basic correlation of monthly average wind speed for the SODAR at 40m and each of the two airports provides fairly strong trends. The SODAR and BKW have a correlation of 0.94 for the time period, and the SODAR and CRW have a 0.89 correlation. A graphical representation of this trend is provided in Figure 1.

Figure 1 Average Monthly Wind Speeds: April 2012 through December 2012



As is evidenced in Figure 1, average monthly wind speeds varied month-to-month as well as by wind speed recording location. The largest difference in wind speeds occurred in December 2012 (approximately 2.77 m/s difference between the readings of the SODAR unit and those of Yeager Airport). The smallest difference occurred in August 2012 (approximately 1.02 m/s difference between the readings of the SODAR unit and those of Yeager Airport). Overall, the general trend of wind speed fluctuations over the nine-month time period was consisted in each location.

3.2.3 Wind Speed Comparison: Quarterly Trend

Quarterly tend data is helpful in analyzing wind speeds over a period of time by dividing the year into four segments. For this comparison, average quarterly wind speed data from BKW and CRW airports is mapped over a three-year (12-quarter) time period beginning in Quarter 1 2010. For three quarters as applicable—Quarters 2, 3 and 4 2012—the average quarterly wind speed recorded by the SODAR unit is also included. For reference, Quarter 1 of any given year corresponds to the months of January, February and March. Subsequent quarters follow in like sequence. Figure 2 provides graphical representation of this relationship.

Figure 2 Average Quarterly Wind Speeds: Q1 2010 to Q4 2012

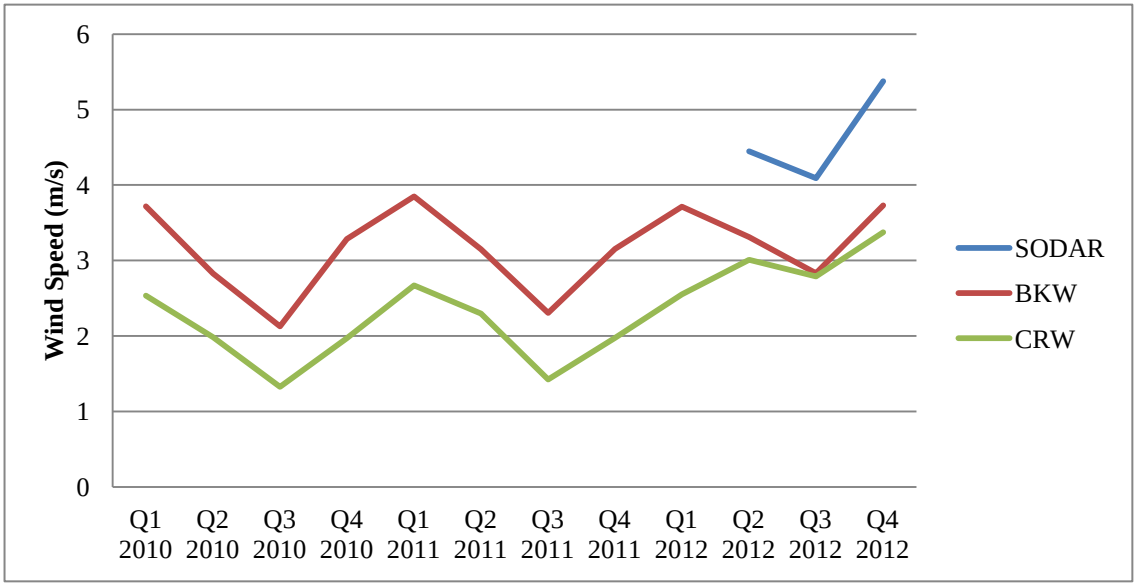
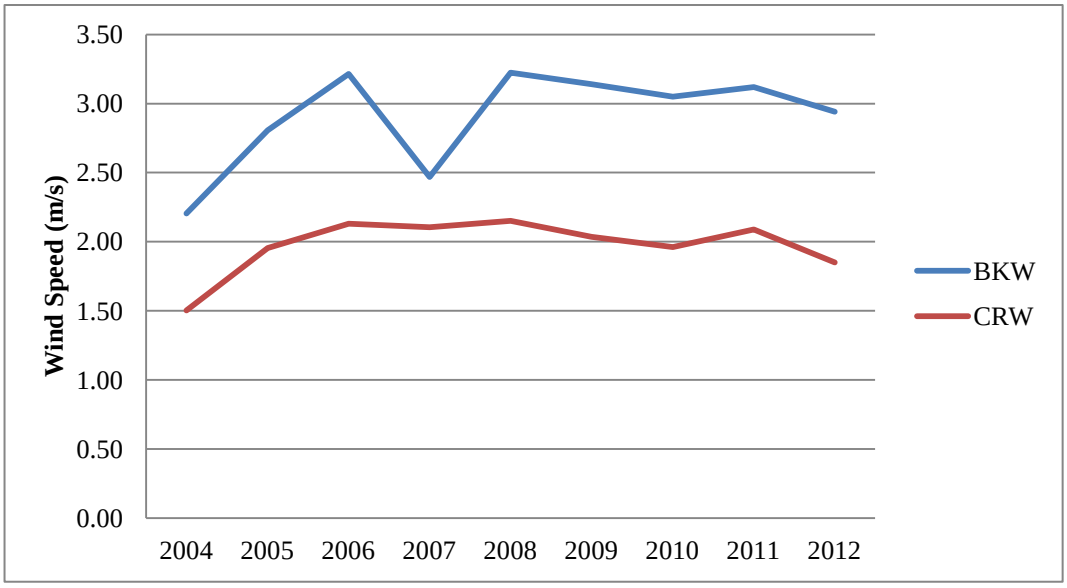


Figure 2 demonstrates a common trend between wind speed data recorded by the Raleigh County Memorial and Yeager airports over the time period. For available data in the last three quarters of 2012, the SODAR wind speeds recorded follow the same trend as well. Wind speed data for each of the third quarters—the quarter with the smallest average recorded wind speed—in this time period exhibits a slight increase from Quarter 3 2010 to Quarter 3 2012.

3.2.4 Wind Speed Comparison: 9-Year Trend

For further comparison, the trend of average annual wind speeds was also evaluated. Annual wind speeds are provided for years 2004 through 2012 for both the Raleigh Memorial Airport and the Yeager Airport. Results are provided in Figure 3.

Figure 3 Airport Average Annual Wind Speeds: 2004 through 2012



The graphical representation in Figure 3 demonstrates more wind speed variation in the Beckley area than in Charleston, the most dramatic occurring in 2007. Both airports reported a decrease in average annual wind speed from 2011 to 2012 preceded by an increase from 2010 to 2011. Wind speed recordings from both airports reported the highest average annual wind speeds for the data set in 2008. Wind speeds recorded in 2004 reported the lowest average annual wind speeds for the data set examined at both airports.

4.0 Findings Calculated to Specific Wind Turbine Energy Output

Three wind turbines were selected for comparison of energy output based on the findings from this data collection period. The three units selected are generally representative of small, medium, and large-scale wind turbines that may be utilized for small to large-scale wind power generation. Each turbine was selected with an appropriate hub height and energy output calculated using *Windographer*™ software. Table 4 summarizes turbine properties and associated energy output and related information:

Table 4: Wind Turbine Energy Output Comparisons

Wind Turbine Model Number	Rated Power (kW)	Hub Height (meters)	Hub Height Wind Speed (m/s)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Endurance G-3120	35	42.7	4.57	53,947	17.6
Vestas V52	850	74	5.37	838,691	11.3
GE 2.5xl	2,500	75	5.37	2,763,211	12.6

Complete wind turbine comparison summaries are provided in Appendix D.

5.0 Comparison to Kayford Mountain Study

One of the main purposes for conducting the study at the Town Creek Knob site was to compare data with a study completed at the Kayford Mountain area between March, 2011 and April, 2012. A complete report was completed for the Kayford Mountain site in August, 2012. These two sites are approximately 3.4 miles apart. Table 5 shows a comparison of monthly wind speeds.

Table 5: Monthly Data Comparison between Kayford Mountain and Town Creek Knob

Month	Kayford Mountain (2011)	Town Creek Knob (2012)
May	5.3	4.7
June	5.1	5.2
July	4.3	5.1
August	5.2	4.5
September	5.7	5.1
October	6.0	5.5
November	7.0	5.6
December	6.7	7.5

Due to the one year difference in data collection, the data cannot be analyzed beyond observing general trends. With this restriction, both sites show similar characteristics and wind speeds.

6.0 Conclusions and Recommendations

Wind resource data was collected from the Natural Resource Partners L.P. surface mine site in the Town Creek Knob area of Fayette County from April 18th, 2012 through January 7th, 2013. As expected, summer months experienced the lowest wind speeds recorded, while late fall, winter and early spring months experienced the highest wind speeds. The data compiled has been compared to applicable regional and national datasets and appears to be representative of what would generally be considered "normal" expected wind speeds, wind direction and related factors for this particular location. The collected data did not correspond with AWS Truepower™ Annual Wind Speed Estimates. This may be attributed to not having fourth quarter data available at the time of this report, as well as, the geographic area covered by the report. At the Town Creek Knob site, recorded wind resource data and associated net capacity factors suggest levels are somewhat below but approaching existing commercial wind energy development standards. The data collected at the Town Creek Knob site was compared to a previous study at Kayford Mountain. These two sites showed similar characteristics and wind speeds. With recent and on-going advancements in the wind energy industry, including increased turbine and blade efficiencies and the use of higher turbine tower heights, wind resources in the Town Creek Knob area may likely be considered for future potential wind energy development.

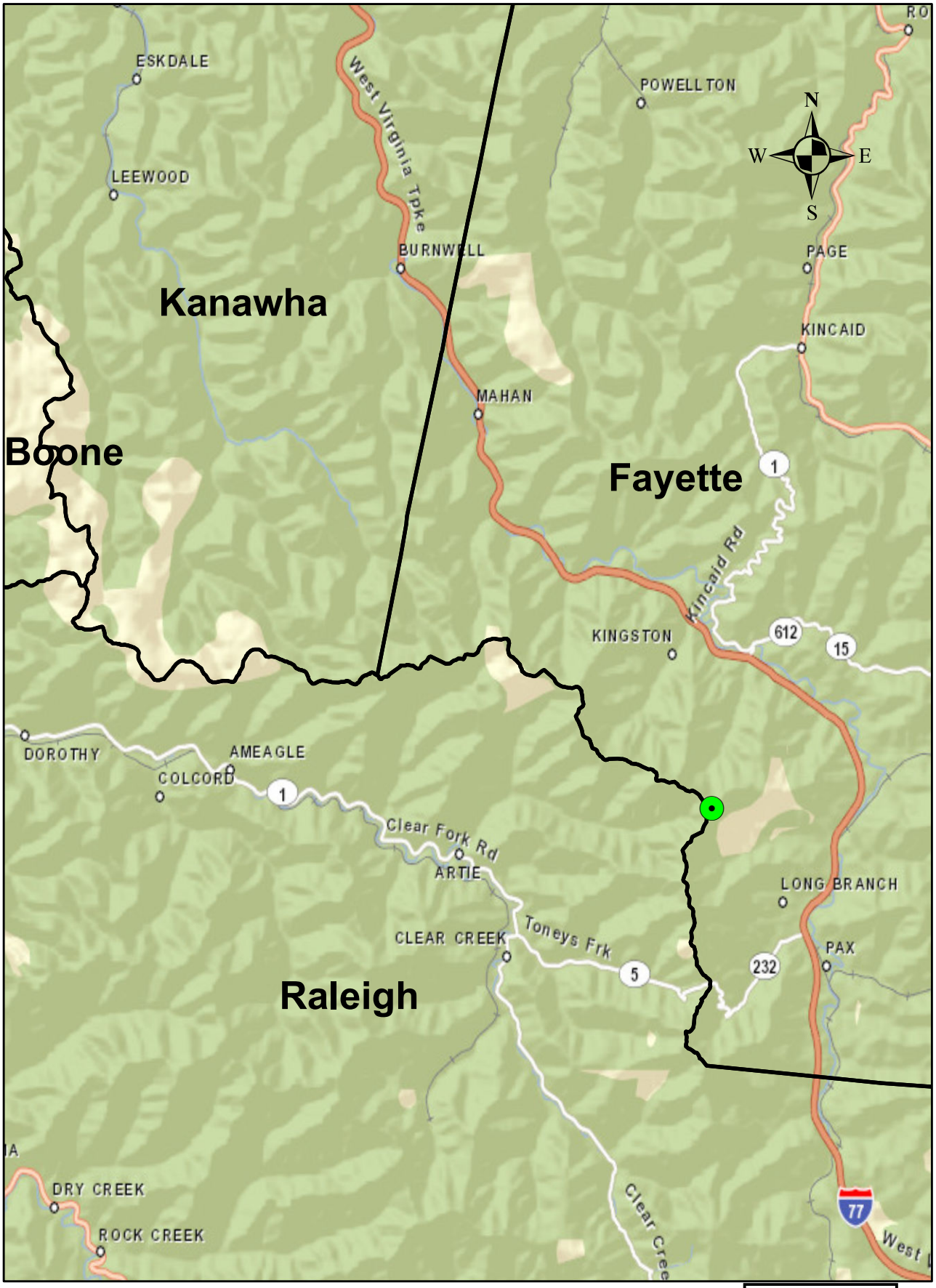
APPENDIX A

Site Location Map

Site Photos

SecondWind™ Site Information Form and Checklist

Town Creek Knob SODAR Site Map



1 0.5 0 1 Miles

Legend

- SODAR Location
- County Boundary

Top View: SODAR unit looking Northeast toward reclaimed surface mine land

Bottom View: SODAR unit looking Northwest toward Lick Knob

Top View: Close-up View of SODAR unit looking West with Utility Trailer and Security Fence

Bottom View: SODAR unit looking West prior to removal from site

SECONDWIND

TRITON
SONIC WIND PROFILER

Site Information Form & Checklist

1. Triton Information				
Triton Site Name:	Town Creek Knob (NRP Property), near Pax, WV			
Triton Owner:	Marshall University - CEGAS			
Install Date:				18-Apr
Triton Serial #:				258
Triton Model:	Circle/Highlight:	STD	HP	HR
Personnel Present:	J. wolfe, D. Jarvis, G. Carico			

2. Site Information	
Surrounding Site Description (i.e. Windfarm, Forest, Field etc.)	Reclaimed Surface Mine Property
Road Access Description (i.e. 4WD required)	Gravel Road
Gate Key Location/Security Details	Notify NRP and Mossy Hunting Club when on site (Dale Burnside, 304/640-6731)
Front Door Lock Details (Combo or Key Location)	Keyed Lock on SODAR and gate
Property Management Contacts	Joe Newlon, NRP, 304/522-5757 (cell 304/633-1779)

3. Fixed Object Vista Table				
Description of Object	**Azimuth (Deg)**	**Distance (m)**	**Height of Object (m)**	**Relative Elevation to Triton (m)**
No tall objects in area				
small trees NW of site	nw	scattered	up to 4 meterstall	
Towers located NW of site	nw	300 meters	up to 50 meters	
higher peak east of site	east	300 meters		

4. Installation Checklist			
Item	✓	Unit	Value
Mechanical Inspection		List Damage/Defects	No Damage
Exterior Warning Sign Cover Removed (Heater Only)		none	ok
Triton Properly Oriented		Record Azimuth of B-Beam (deg mag)	OK (B-beam oriented south)
Triton Secured		Method (i.e. earth anchors, trailer, snow platform, etc.)	on Trailor, fenced
Batteries Charged (>12.7V)		Record voltage level, V - DC	batteries charging
Solar Panels Installed, Connected		# of Panels	2
Solar Panels Charging		V - DC	OK
Antifreeze Fluid Level (Heater Only)		none	OK
Propane Tanks installed		Tank capacity and level	tanks removed
Propane Leak Test (Heater Only)		none	na
Operator Panel: GPS		Red/Green/Rapid/Off	green
Operator Panel: SENSORS		Red/Green/Rapid/Off	green
Operator Panel: SUPPLIES		Red/Green/Rapid/Off	green
Operator Panel: SD CARD		Red/Green/Rapid/Off	green
Operator Panel: HEATER		Off/NA	na
Operator Panel: NOTA (self-test)		Red/Green/Rapid/Off/NA	green
Operator Panel: ARRAY		Red/Green/Rapid/Off	green
Operator Panel: SODAR		Red/Green/Rapid/Off	green
Operator Panel: SNR		Red/Green/Rapid/Off	green
Operator Panel: INTERNET		Red/Green/Rapid/Off	green
Operator Panel: TSP		Red/Green/Rapid/Off	green
Operator Panel: SKYSERVE		Red/Green/Rapid/Off	green
Take Photos or Videos		Pictures of 360deg site and Anchored Triton	yes
Ambient Noise Level		dB	minimal
Ambient Noise Description		(i.e. Birds, Crickets, Highway)	occasional vehicle travel
Triton Information (1) Section Complete		none	
Site Information (2) Section Complete		none	
Fixed Obstacle Vista Table (3) Complete		none	

Installer's Signature: _____ Date: 4 18 12

Installer's Name (print): G. Carico, J. Wolfe, D. Jarvis

Installer's ID #: _____

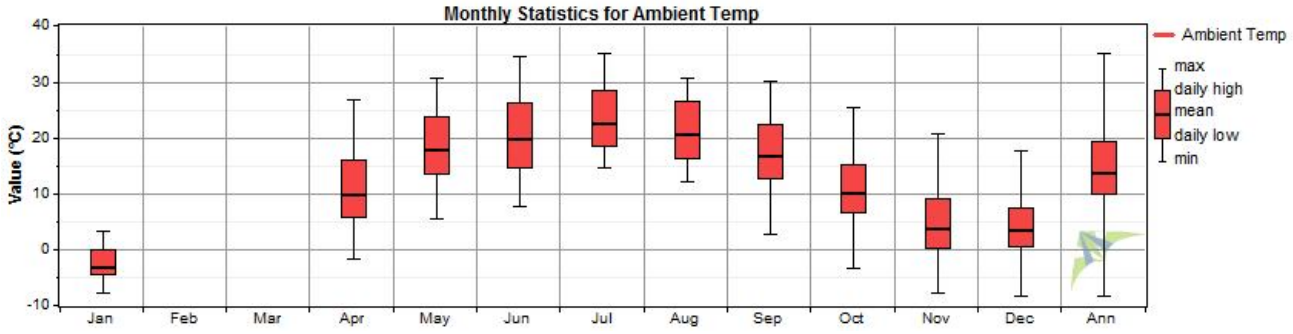
APPENDIX B

Windographer™ Summary Report

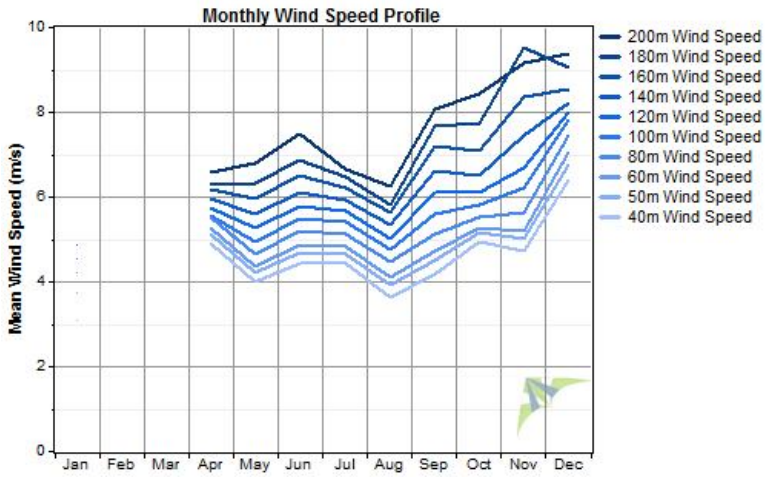
Data Set Properties

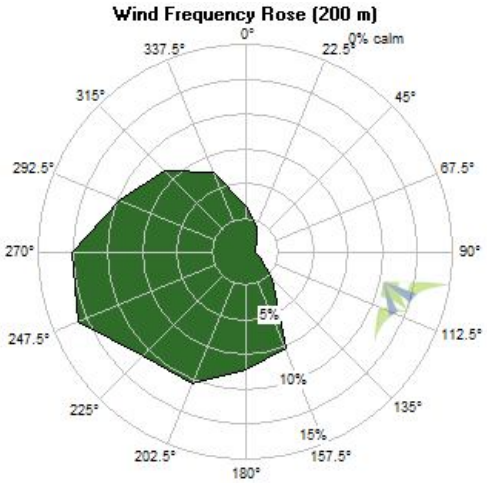
Report Created: 1/17/2013 10:01 using Windographer 2.4.8
Filter Settings: <Unflagged data>

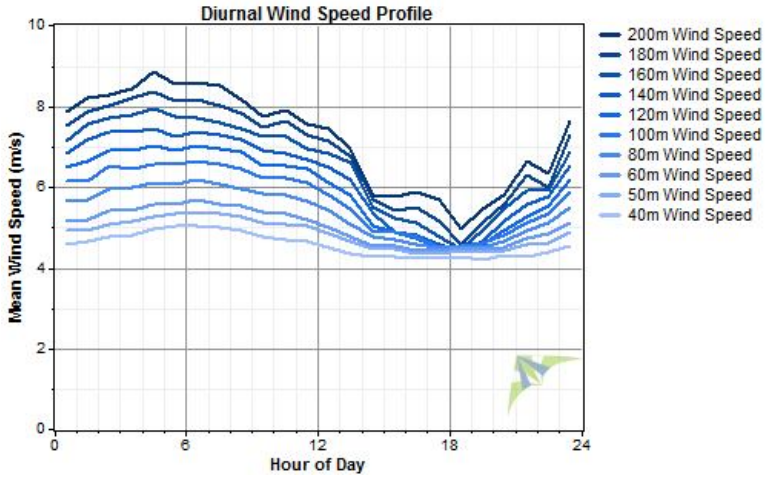
Variable	Value
Latitude	N 37.942030
Longitude	W 81.294050
Elevation	864 m
Start date	4/18/2012 00:00
End date	1/7/2013 00:10
Duration	8.7 months
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	13.8 °C
Mean pressure	921.3 mbar
Mean air density	1.120 kg/m³
Power density at 50m	119 W/m²
Wind power class	1 (Poor)
Power law exponent	0.229
Surface roughness	1.2 m
Roughness class	4.07
Roughness description	Suburban

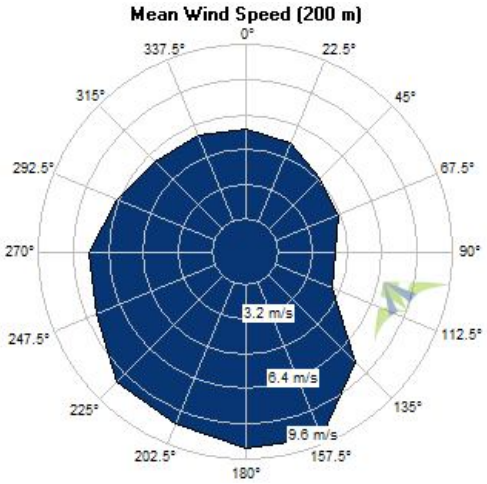


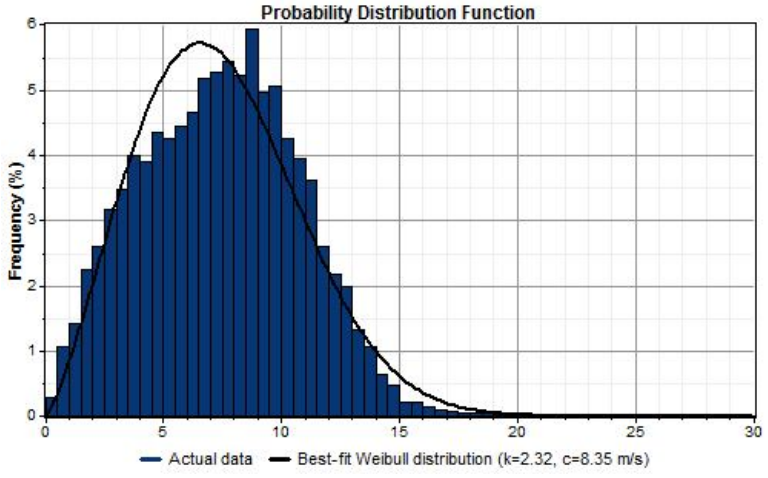
Wind Speed and Direction

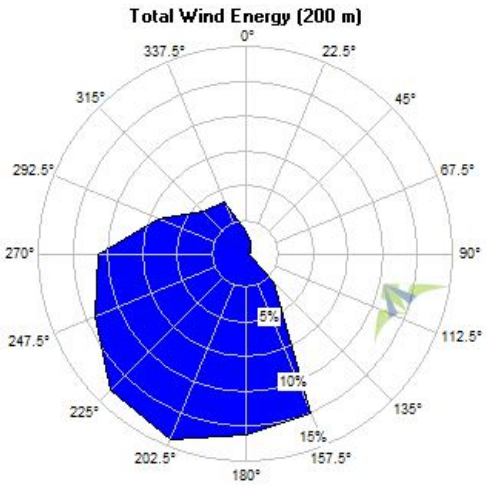




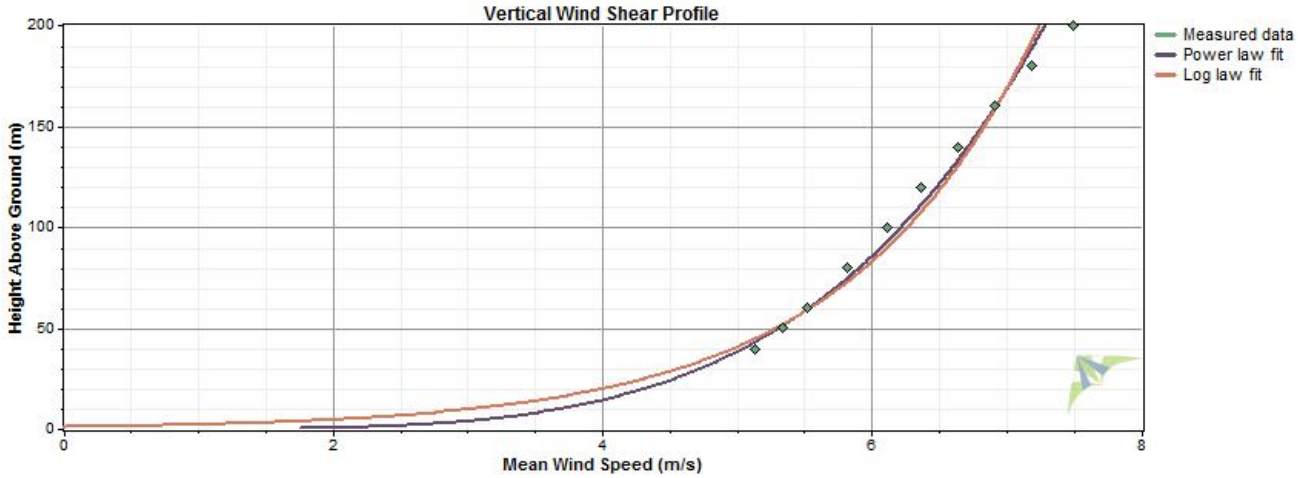


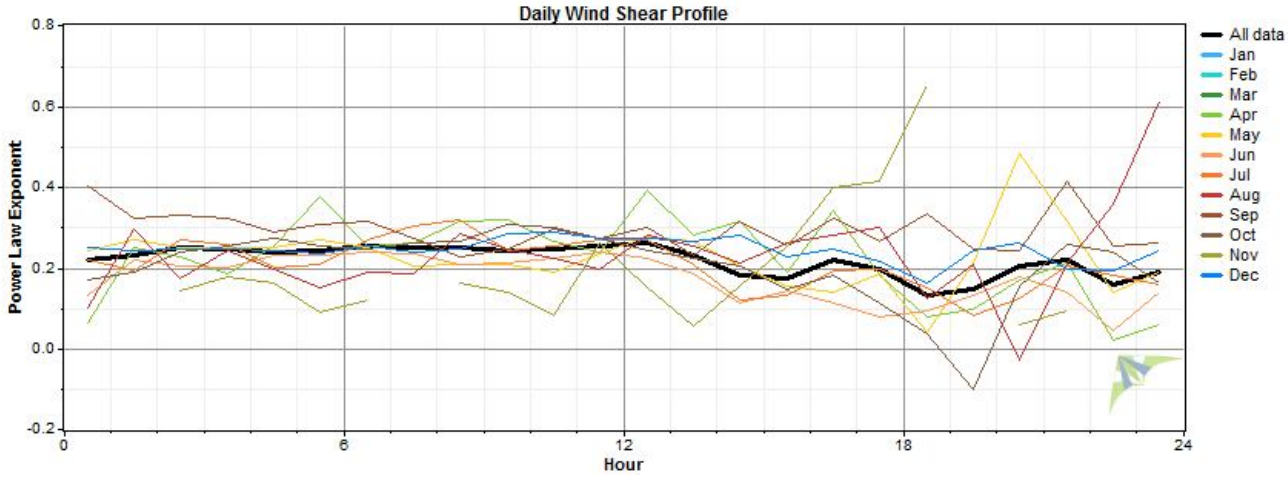






Wind Shear


Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
Mean Wind Speed (m/s)
0
50
100
150
200
0
2
4
6
8


Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
Hour
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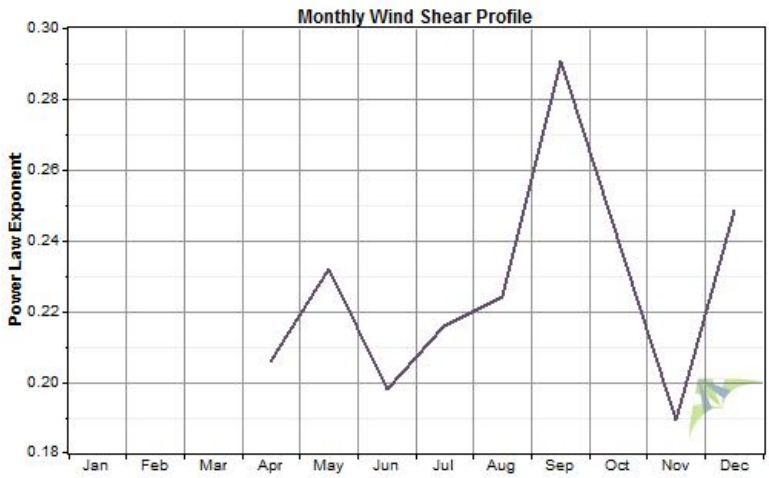
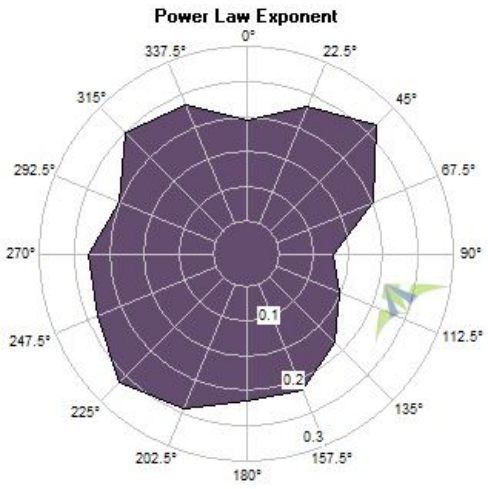
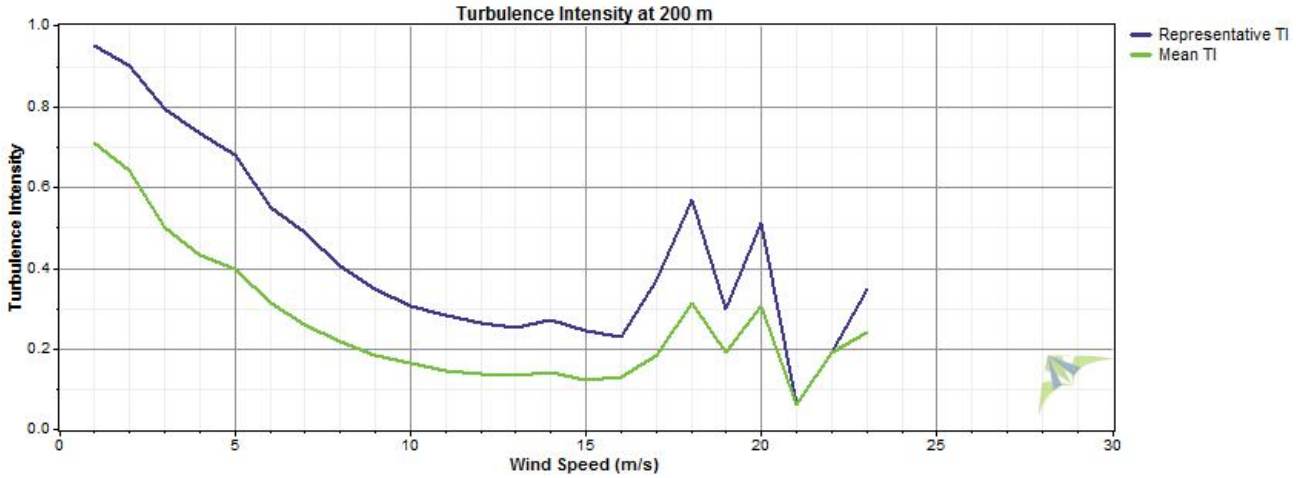
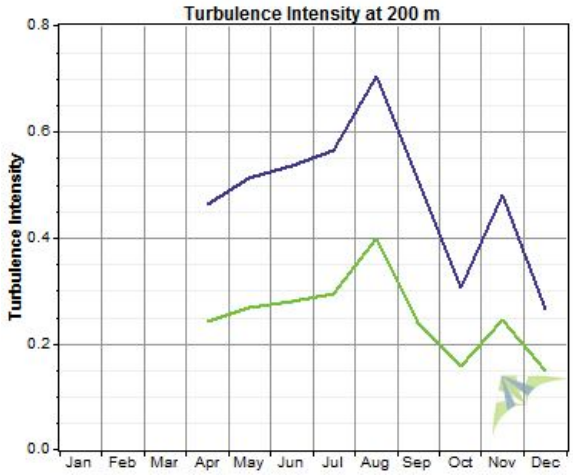
0.0
0.2
0.4
0.6
0.8
0
6
12
18
24

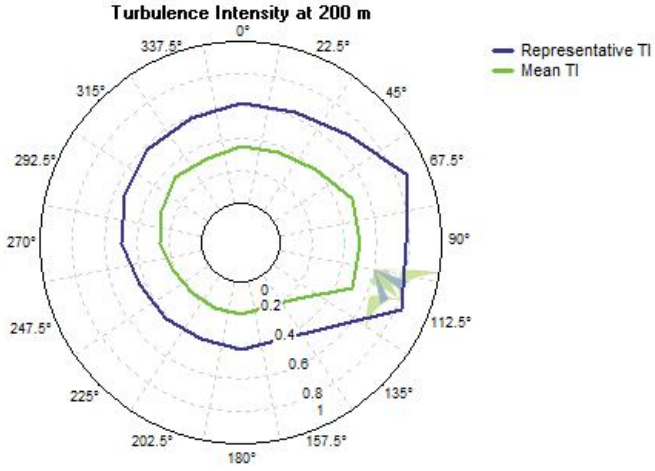

Monthly Wind Shear Profile
Power Law Exponent
0.18
0.20
0.22
0.24
0.26
0.28
0.30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

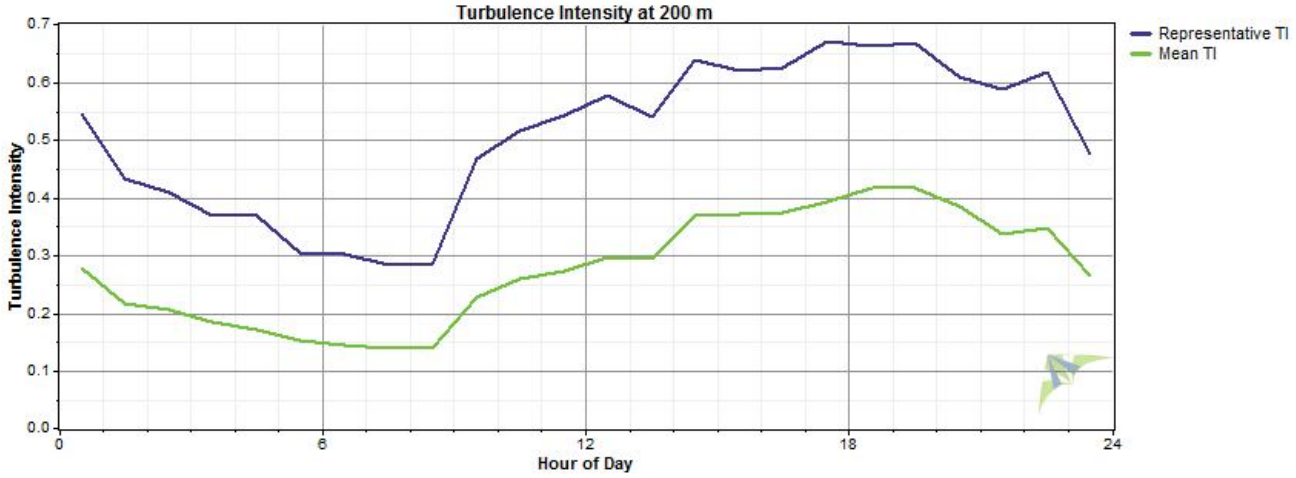

Power Law Exponent
0°
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
202.5°
225°
247.5°
270°
292.5°
315°
337.5°
0.1
0.2
0.3

Turbulence Intensity









Data Column Properties

Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	40m Wind Direction	°	40 m	38,017	36,902	97.07	240.2	0.0	360.0	88.6
2	40m Wind Speed	m/s	40 m	38,017	36,902	97.07	4.57	0.01	21.14	2.43
3	40m Wind Vert	m/s		38,017	36,902	97.07	-0.214	-8.940	2.050	0.847
4	Quality (Station Height 40m)	%		38,017	36,902	97.07	97.8	85.0	100.0	2.1
5	50m Wind Direction	°	50 m	38,017	35,757	94.06	239.9	0.0	360.0	88.1
6	50m Wind Speed	m/s	50 m	38,017	35,757	94.06	4.85	0.01	23.04	2.49
7	50m Wind Vert	m/s		38,017	35,757	94.06	-0.228	-9.030	3.280	0.874
8	Quality (Station Height 50m)	%		38,017	35,757	94.06	97.7	85.0	100.0	2.1
9	60m Wind Direction	°	60 m	38,017	34,782	91.49	239.6	0.0	360.0	87.8
10	60m Wind Speed	m/s	60 m	38,017	34,782	91.49	5.03	0.03	20.24	2.53
11	60m Wind Vert	m/s		38,017	34,782	91.49	-0.241	-9.000	4.150	0.897
12	Quality (Station Height 60m)	%		38,017	34,782	91.49	97.3	85.0	100.0	2.5
13	80m Wind Direction	°	80 m	38,017	31,970	84.09	238.5	0.0	360.0	86.2
14	80m Wind Speed	m/s	80 m	38,017	31,970	84.09	5.37	0.02	21.15	2.62
15	80m Wind Vert	m/s		38,017	31,970	84.09	-0.253	-8.960	4.630	0.945
16	Quality (Station Height 80m)	%		38,017	31,970	84.09	96.5	85.0	100.0	3.0
17	100m Wind Direction	°	100 m	38,017	27,853	73.26	236.8	0.0	360.0	84.4
18	100m Wind Speed	m/s	100 m	38,017	27,853	73.26	5.70	0.06	26.55	2.73
19	100m Wind Vert	m/s		38,017	27,853	73.26	-0.257	-8.760	4.060	0.983
20	Quality (Station Height 100m)	%		38,017	27,853	73.26	95.6	85.0	100.0	3.4
21	120m Wind Direction	°	120 m	38,017	23,416	61.59	235.3	0.0	360.0	82.6
22	120m Wind Speed	m/s	120 m	38,017	23,416	61.59	5.97	0.06	20.67	2.84
23	120m Wind Vert	m/s		38,017	23,416	61.59	-0.250	-8.810	4.750	0.999
24	Quality (Station Height 120m)	%		38,017	23,416	61.59	94.9	85.0	100.0	3.7
25	140m Wind Direction	°	140 m	38,017	18,925	49.78	233.5	0.0	360.0	81.1
26	140m Wind Speed	m/s	140 m	38,017	18,925	49.78	6.29	0.06	23.24	2.96
27	140m Wind Vert	m/s		38,017	18,925	49.78	-0.235	-8.780	4.090	0.986
28	Quality (Station Height 140m)	%		38,017	18,925	49.78	94.3	85.0	100.0	3.8
29	160m Wind Direction	°	160 m	38,017	14,987	39.42	233.8	0.1	360.0	79.8
30	160m Wind Speed	m/s	160 m	38,017	14,987	39.42	6.67	0.05	28.88	3.09
31	160m Wind Vert	m/s		38,017	14,987	39.42	-0.225	-8.550	6.000	0.958
32	Quality (Station Height 160m)	%		38,017	14,987	39.42	93.8	85.0	100.0	3.8
33	180m Wind Direction	°	180 m	38,017	11,566	30.42	235.0	0.0	359.8	78.1
34	180m Wind Speed	m/s	180 m	38,017	11,566	30.42	7.03	0.01	25.68	3.21
35	180m Wind Vert	m/s		38,017	11,566	30.42	-0.210	-8.510	5.210	0.929
36	Quality (Station Height 180m)	%		38,017	11,566	30.42	93.2	85.0	100.0	3.9
37	200m Wind Direction	°	200 m	38,017	8,749	23.01	237.6	0.0	359.8	76.3
38	200m Wind Speed	m/s	200 m	38,017	8,749	23.01	7.41	0.07	28.51	3.37
39	200m Wind Vert	m/s		38,017	8,749	23.01	-0.207	-7.860	6.180	0.912
40	Quality (Station Height 200m)	%		38,017	8,749	23.01	92.7	85.0	100.0	3.9
41	40m Wind Turbulence	m/s	40 m	38,017	26,063	68.56	0.162	0.040	1.340	0.111
42	50m Wind Turbulence	m/s	50 m	38,017	26,836	70.59	0.169	0.030	1.400	0.121
43	60m Wind Turbulence	m/s	60 m	38,017	26,817	70.54	0.179	0.030	1.270	0.130
44	80m Wind Turbulence	m/s	80 m	38,017	25,498	67.07	0.202	0.030	1.330	0.148
45	100m Wind Turbulence	m/s	100 m	38,017	22,777	59.91	0.220	0.030	1.380	0.161
46	120m Wind Turbulence	m/s	120 m	38,017	19,337	50.86	0.235	0.030	1.540	0.175
47	140m Wind Turbulence	m/s	140 m	38,017	15,891	41.80	0.242	0.030	1.350	0.184
48	160m Wind Turbulence	m/s	160 m	38,017	12,835	33.76	0.246	0.030	1.540	0.188
49	180m Wind Turbulence	m/s	180 m	38,017	10,013	26.34	0.252	0.030	1.540	0.194
50	200m Wind Turbulence	m/s	200 m	38,017	7,684	20.21	0.254	0.030	1.400	0.197
51	Turbu. Quality (Station Height 40m)	%		38,017	26,063	68.56	97.4	85.0	100.0	3.2
52	Turbu. Quality (Station Height 50m)	%		38,017	26,836	70.59	97.3	85.0	100.0	3.1

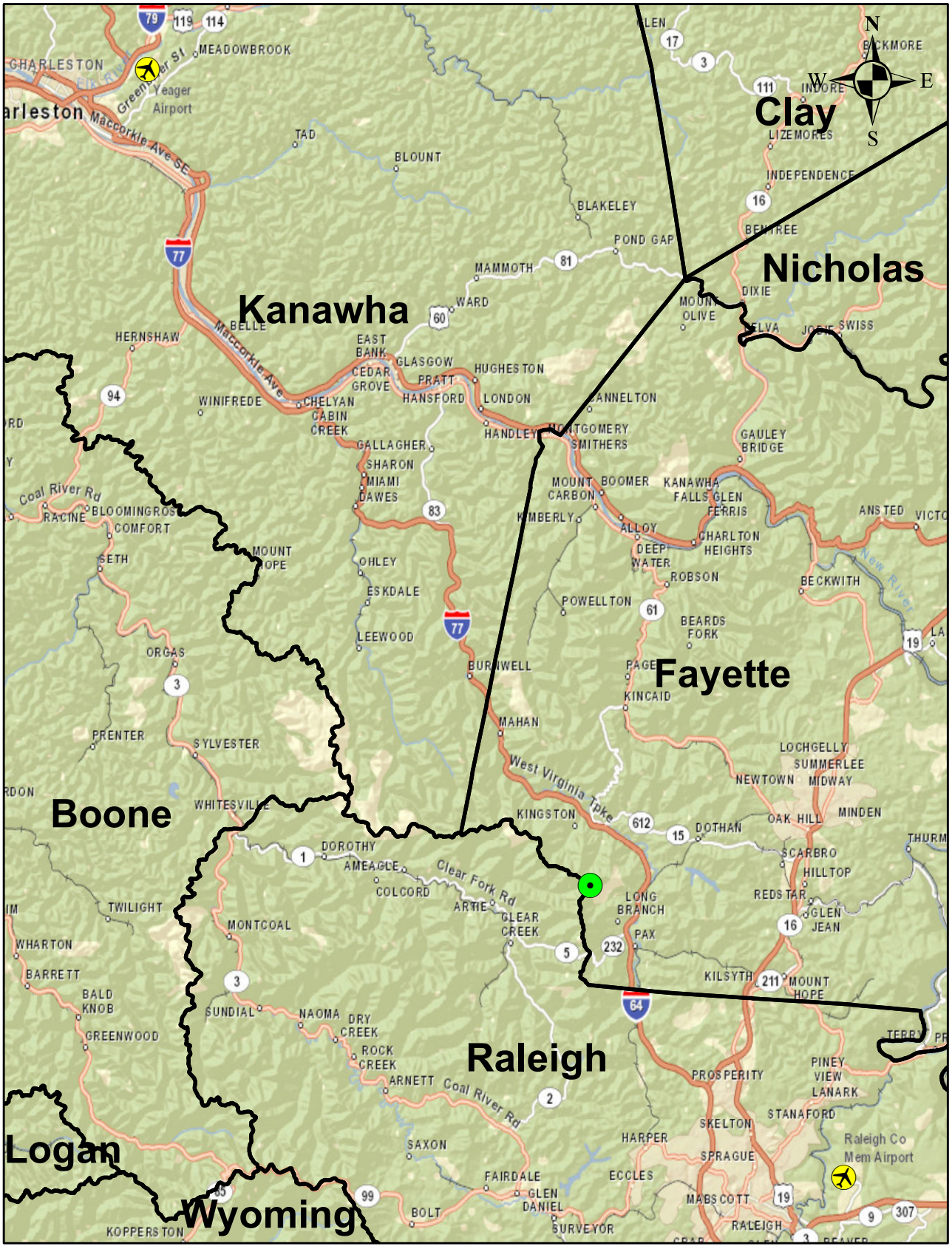
Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	Turbu. Quality (Station Height 60m)	%		38,017	26,817	70.54	97.0	85.0	100.0	3.2
54	Turbu. Quality (Station Height 80m)	%		38,017	25,498	67.07	96.3	85.0	100.0	3.4
55	Turbu. Quality (Station Height 100m)	%		38,017	22,777	59.91	95.5	85.0	100.0	3.7
56	Turbu. Quality (Station Height 120m)	%		38,017	19,337	50.86	94.8	85.0	100.0	3.9
57	Turbu. Quality (Station Height 140m)	%		38,017	15,891	41.80	94.3	85.0	100.0	4.0
58	Turbu. Quality (Station Height 160m)	%		38,017	12,835	33.76	93.8	85.0	100.0	4.0
59	Turbu. Quality (Station Height 180m)	%		38,017	10,013	26.34	93.2	85.0	100.0	4.0
60	Turbu. Quality (Station Height 200m)	%		38,017	7,684	20.21	92.7	85.0	100.0	3.9
61	Ambient Temp	°C		38,017	37,893	99.67	13.80	-8.40	35.00	9.08
62	Barometric Pressure	mbar		38,017	37,893	99.67	921.3	896.2	968.6	5.2
63	Azimuth	Â°		38,017	37,893	99.67	0	0	0	0
64	TiltY	Â°		38,017	37,893	99.67	-0.179	-2.200	0.600	0.293
65	TiltX	Â°		38,017	37,893	99.67	-0.302	-1.800	0.200	0.178
66	Humidity	%		38,017	37,893	99.67	69.6	0.0	255.0	26.0
67	Noise Level-A	dB		38,017	37,893	99.67	13.21	5.00	17.10	1.54
68	Noise Level-B	dB		38,017	37,893	99.67	13.17	5.00	17.10	1.54
69	Noise Level-C	dB		38,017	37,893	99.67	13.29	5.00	17.00	1.55
70	CPU Power	W		38,017	37,893	99.67	1.08	0.90	1.40	0.08
71	Speaker Power	W		38,017	37,893	99.67	4.37	0.00	22.80	3.02
72	PWM Power	W		38,017	37,893	99.67	1.104	0.700	2.300	0.200
73	Core Power	W		38,017	37,893	99.67	3.618	3.200	4.300	0.169
74	Modem Power	W		38,017	37,893	99.67	0.464	0.000	1.700	0.284
75	Solar Power	W		38,017	37,893	99.67	0	0	0	0
76	Internal Temp	Â°C		38,017	37,893	99.67	17.85	-7.20	48.00	11.23
77	Mirror Temp	Â°C		38,017	37,893	99.67	17.24	-8.50	57.90	12.59
78	CPU Temp	Â°C		38,017	37,893	99.67	0	0	0	0
79	Heater Temp	Â°C		38,017	37,893	99.67	0	0	0	0
80	VibrationY	g		38,017	37,893	99.67	0	0	0	0
81	VibrationX	g		38,017	37,893	99.67	0	0	0	0
82	Battery	V		38,017	37,893	99.67	12.92	11.40	15.30	0.79
83	Beep Volume	dB		38,017	37,893	99.67	90.2	0.0	100.0	29.8
84	40m BeamNumA			38,017	37,893	99.67	81.45	3.00	97.00	11.07
85	40m BeamNumB			38,017	37,893	99.67	80.14	1.00	90.00	9.79
86	40m BeamNumC			38,017	37,893	99.67	78.87	0.00	90.00	12.91
87	40m Confidence Function	Number		38,017	37,893	99.67	6	6	6	0
88	40m Confidence-A	%		38,017	37,893	99.67	86.9	0.0	100.0	16.5
89	40m Confidence-B	%		38,017	37,893	99.67	89.2	0.0	100.0	13.7
90	40m Confidence-C	%		38,017	37,893	99.67	87.0	0.0	100.0	18.4
91	40m Echo Suppression	kPa		38,017	37,893	99.67	4	4	4	0
92	40m Number of Shots-A	Count		38,017	37,893	99.67	90.13	35.00	97.00	1.68
93	40m Number of Shots-B	Count		38,017	37,893	99.67	86.89	35.00	91.00	2.37
94	40m Number of Shots-C	Count		38,017	37,893	99.67	86.92	35.00	90.00	2.38
95	40m Peak Detection	m/s		38,017	37,893	99.67	1	1	1	0
96	40m Range Gate	Number		38,017	37,893	99.67	3	3	3	0
97	40m Signal Level-A	dB		38,017	37,893	99.67	16.90	14.00	21.10	0.88
98	40m Signal Level-B	dB		38,017	37,893	99.67	16.88	13.80	20.60	0.82
99	40m Signal Level-C	dB		38,017	37,893	99.67	16.89	13.60	21.00	0.90
100	40m SNR-A	dB		38,017	37,893	99.67	15.85	0.90	22.80	3.40
101	40m SNR-B	dB		38,017	37,893	99.67	16.23	1.40	23.20	3.19
102	40m SNR-C	dB		38,017	37,893	99.67	15.96	1.40	23.20	3.56
103	40m Suppressed Echoes-A	Count		38,017	37,893	99.67	35.56	0.00	93.00	15.10
104	40m Suppressed Echoes-B	Count		38,017	37,893	99.67	39.75	0.00	89.00	17.43
105	40m Suppressed Echoes-C	Count		38,017	37,893	99.67	34.31	0.00	89.00	15.85
106	40m Valid Spectra-A	Count		38,017	37,893	99.67	81.45	3.00	97.00	11.07

Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
107	40m Valid Spectra-B	Count		38,017	37,893	99.67	80.14	1.00	90.00	9.79
108	40m Valid Spectra-C	Count		38,017	37,893	99.67	78.87	0.00	90.00	12.91
109	Air Density	kg/m³		38,017	38,017	100.00	1.120	1.040	1.220	0.035
110	200m Wind Speed WPD	W/m²		38,017	8,749	23.01	371	0	12,459	467
111	180m Wind Speed WPD	W/m²		38,017	11,566	30.42	318	0	9,008	385
112	160m Wind Speed WPD	W/m²		38,017	14,987	39.42	276	0	12,950	355
113	140m Wind Speed WPD	W/m²		38,017	18,925	49.78	236	0	6,922	315
114	120m Wind Speed WPD	W/m²		38,017	23,416	61.59	206	0	4,860	294
115	100m Wind Speed WPD	W/m²		38,017	27,853	73.26	184	0	10,062	300
116	80m Wind Speed WPD	W/m²		38,017	31,970	84.09	158	0	5,196	276
117	60m Wind Speed WPD	W/m²		38,017	34,782	91.49	135	0	4,781	258
118	50m Wind Speed WPD	W/m²		38,017	35,757	94.06	125	0	6,998	261
119	40m Wind Speed WPD	W/m²		38,017	36,902	97.07	109	0	5,012	230

APPENDIX C

General Site Map of SODAR and Regional Airports

Town Creek Knob SODAR Site Map



APPENDIX D

Wind Turbine Energy Output Summaries

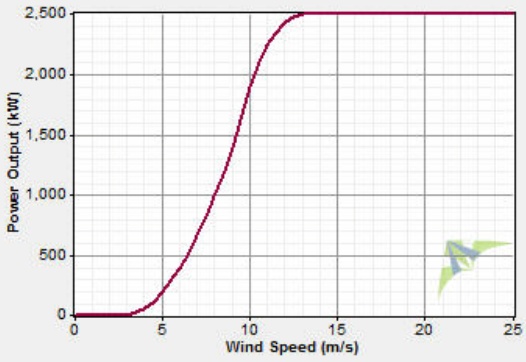
Wind Turbine Output

This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height, then click Calculate Output.

Wind turbine: GE 2.5xl | Details... | Edit... | New... | Delete... | Compare...

Properties

Manufacturer:	GE Wind
Website:	www.gepower.com
Rotor diameter:	100 m
Rated power:	2,500 kW
Power regulation:	Pitch control



Hub height

- (•) 75 m
- ( ) 85 m
- ( ) 100 m
- ( ) Other 70 m

Losses

Downtime losses (%)	6
Array losses (%)	5
Icing/soiling losses (%)	4
Other losses (%)	4
Overall loss factor (%)	17.70

Calculate Output

(•) Monthly details
( ) Turbine comparison

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	582	3.64	44.33	0.17	163.5	121,646	6.5
Feb	0	n/a	n/a	n/a	n/a	n/a	n/a
Mar	0	n/a	n/a	n/a	n/a	n/a	n/a
Apr	1,723	5.47	16.83	0.23	336.8	242,517	13.5
May	4,462	4.52	30.41	0.02	204.2	151,946	8.2
Jun	4,315	4.96	23.94	0.05	267.0	192,261	10.7
Jul	4,438	4.96	20.46	0.05	243.0	180,764	9.7
Aug	4,388	4.29	30.63	0.21	158.8	118,114	6.4
Sep	4,280	4.96	22.71	0.26	260.4	187,456	10.4
Oct	4,317	5.56	21.10	1.30	395.2	293,994	15.8
Nov	4,273	5.35	17.79	0.77	347.6	250,259	13.9
Dec	4,157	7.24	9.41	7.75	681.1	506,731	27.2
Overall	36,935	5.20	22.27	1.19	315.4	2,763,211	12.6

Help | Cancel | Add Turbine Output Time Series To Data Set & Close

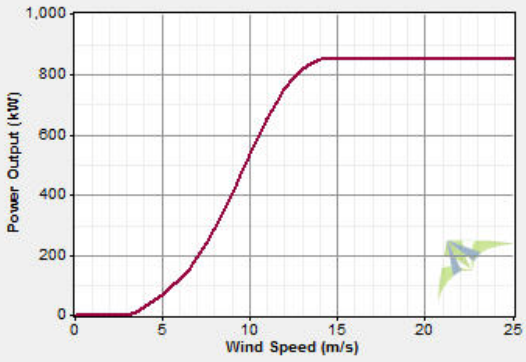
Wind Turbine Output

This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height, then click Calculate Output.

Wind turbine: Vestas V52 - 850 kW | Details... | Edit... | New... | Delete... | Compare...

Properties

Manufacturer:	Vestas Wind Systems A/S
Website:	www.vestas.com
Rotor diameter:	52 m
Rated power:	850 kW
Power regulation:	Pitch control



Hub height

- 40 m
- 44 m
- 49 m
- 55 m
- 60 m
- 65 m
- 74 m
- 86 m
- Other: 70 m

Losses

Downtime losses (%)	6
Array losses (%)	5
Icing/soiling losses (%)	4
Other losses (%)	4
Overall loss factor (%)	17.70

Calculate Output

- Monthly details
- Turbine comparison

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	582	3.62	44.50	0.00	50.1	37,271	5.9
Feb	0	n/a	n/a	n/a	n/a	n/a	n/a
Mar	0	n/a	n/a	n/a	n/a	n/a	n/a
Apr	1,723	5.45	16.83	0.12	101.1	72,820	11.9
May	4,462	4.50	30.57	0.00	62.2	46,262	7.3
Jun	4,315	4.94	24.17	0.02	80.6	58,002	9.5
Jul	4,438	4.95	20.57	0.05	74.1	55,126	8.7
Aug	4,388	4.27	30.88	0.05	49.6	36,875	5.8
Sep	4,280	4.93	22.99	0.12	78.6	56,593	9.2
Oct	4,317	5.55	21.24	0.53	118.7	88,319	14.0
Nov	4,273	5.34	17.97	0.14	105.3	75,823	12.4
Dec	4,157	7.22	9.50	4.59	207.5	154,375	24.4
Overall	36,935	5.18	22.44	0.63	95.7	838,691	11.3

Help | Cancel | Add Turbine Output Time Series To Data Set & Close

Wind Turbine Output

This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height, then click Calculate Output.

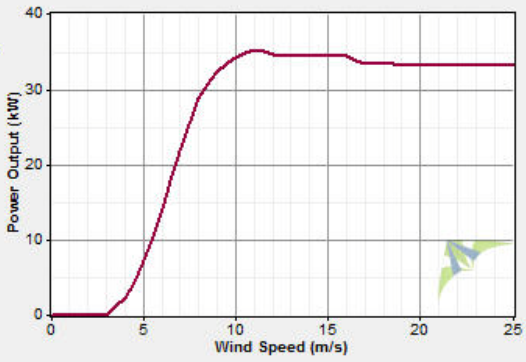
Wind turbine: Endurance G-3120 | Details... | Edit... | New... | Delete... | Compare...

Properties

Manufacturer:	Endurance Wind Power
Website:	www.endurancewindpower.c
Rotor diameter:	19.2 m
Rated power:	35 kW
Power regulation:	Stall control

Losses

Downtime losses (%)	6
Array losses (%)	5
Icing/soiling losses (%)	4
Other losses (%)	4
Overall loss factor (%)	17.70



Hub height

- 30.5 m
- 42.7 m
- Other 70 m

Calculate Output

- Monthly details
- Turbine comparison

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	582	3.10	50.86	0.00	3.0	2,245	8.6
Feb	0	n/a	n/a	n/a	n/a	n/a	n/a
Mar	0	n/a	n/a	n/a	n/a	n/a	n/a
Apr	1,723	4.89	20.84	0.00	7.3	5,268	20.9
May	4,462	3.95	38.61	0.00	4.3	3,236	12.4
Jun	4,315	4.38	29.99	0.00	5.7	4,120	16.3
Jul	4,438	4.38	26.45	0.00	5.3	3,916	15.0
Aug	4,388	3.59	40.31	0.00	2.9	2,187	8.4
Sep	4,280	4.16	32.52	0.00	4.8	3,461	13.7
Oct	4,317	4.92	26.43	0.00	7.7	5,716	22.0
Nov	4,273	4.72	25.91	0.00	6.8	4,878	19.4
Dec	4,157	6.40	12.73	0.00	12.0	8,957	34.4
Overall	36,935	4.54	29.20	0.00	6.2	53,947	17.6

Help | Cancel | Add Turbine Output Time Series To Data Set & Close