WIND DATA REPORT

Quincy DPW, MA

September 1st 2006 to November 30th 2006

Prepared for

Massachusetts Technology Collaborative
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by

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NOTICE AND ACKNOWLEDGEMENTS

This report was prepared by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst in the course of performing work sponsored by the Renewable Energy Trust (RET), as administered by the Massachusetts Technology Collaborative (MTC), pursuant to work order number 05-1. The opinions expressed in this report do not necessarily reflect those of MTC or the Commonwealth of Massachusetts, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it.

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EXECUTIVE SUMMARY

All the work presented in this Wind Data Report including installation and decommissioning of the meteorological tower and instrumentation, and the data analysis and reporting was preformed by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst.

This report covers wind data measured at the Town of Quincy Department of Public Works (DPW). Two anemometers and one direction vane were installed at 40 m (131.2 ft) and 50 m (164.1 ft) on the communications tower on August 10, 2006. One anemometer and one vane were installed at 25 m (82.0 ft).

The season covered by this report is September 1, 2006-November 30, 2006. The quarterly mean recorded wind speed at 50 m was 4.86 m/s (10.87 mph)* and the prevailing direction was from the southwest. The gross data recovery percentage (the actual percentage of data received) for the quarter was 100% and the net data recovery (the percentage of expected data which was received and passed all quality assurance tests) was 76.9%. The majority of data which did not pass quality tests was due to a faulty temperature sensor and a faulty direction vane.

Additional information about interpreting the data presented in this report can be found in the Fact Sheet, "Interpreting Your Wind Resource Data," produced by RERL and the Massachusetts Technology Collaborative (MTC). This document is found through the RERL website:

http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_6_Wind_resource_interpretation.pdf

* 1 m/s = 2.237 mph.

SECTION 1 - Station Location

The communications tower is located at the Quincy DPW. The tower base is located at 42.25560 deg N, 70.99608 deg W (WGS84/NAD83) (Figure 1). The cross indicates the approximate location of the tower.

Figure 1- Quincy DPW

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 50 m (164 ft) lattice tower used by the Quincy police department. The wind monitoring equipment comes from NRG systems, and consists of the following items:

- Symphonie Data Logger
- 5 - #40 Anemometers, standard calibration (Slope – 0.765 m/s, Offset – 0.350 m/s). One anemometer is located at 25 m (82 ft). Two anemometers are located at 40 m (131 ft) and two at 50 m (164 ft).

- 3 - #200P Wind direction vanes. The vanes are located at 25 m (82 ft), 40 m (131 ft), and 50 m (164 ft).

- 1 - #110S Temperature sensor located at 2 m (6.5 ft).

The data from the Symphonie logger is mailed to the University of Massachusetts , Amherst on a regular basis. The logger samples wind speed and direction once every two seconds. These samples are combined into 10-minute averages and are put into a binary file along with the standard deviation for each 10-minute interval. The binary files are converted to ASCII text files using the NRG software BaseStation®. These text files are then imported into a database software program where they are subjected to quality assurance tests prior to data usage.

SECTION 3 - Data Collection and Maintenance

The following maintenance/equipment problems occurred during the report period:

- The 25 meter direction vane was recording values of zero exclusively (indicating zero electrical resistance through the vane).
- The temperature sensor was recording unrealistically low temperatures.

Data Statistics Summary

Date	Mean Wind Speed	Max Wind Speed	Turbulence Intensity	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Turbulence Intensity	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Turbulence Intensity	Prevailing Wind Direction	Wind Shear Coeff
Height units	50 m, [m/s]	50 m, [m/s]	50m [ ]	50 m [ ]	40 m [m/s]	40m [m/s]	40 m [ ]	40 m [ ]	25m [m/s]	25 m [m/s]	25 m [ ]	25 m [ ]	Calc b/t 50 & 40m, [ ]
Sept 2006	4.51	11.5	0.19	W	4.12	11.1	0.23	W	3.53	10.3	0.26	-	0.41
Oct 2006	5.27	15.8	0.19	W	4.83	14.9	0.22	NW	4.18	14.0	0.24	-	0.39
Nov 2006	4.78	15.3	0.20	SSW	4.31	14.3	0.23	SW	3.67	12.6	0.26	-	0.46
Sept 2006- Nov 2006	4.86	15.8	0.19	SSW	4.43	14.9	0.23	SW	3.8	14.0	0.25	-	0.42

Wind data statistics in the table are representative of the 76.9% of expected data for the quarter that passed quality assurance tests. The prevailing wind direction at 25 m is not available due to a faulty wind direction vane.

No measurement of wind speed can be perfectly accurate. Errors occur due to anemometer manufacturing variability, anemometer calibration errors, the response of anemometers to turbulence and vertical air flow and due to air flows caused by the anemometer mounting system. Every effort is made to reduce the sources of these errors. Nevertheless, the values reported in this report have an expected uncertainty of about ± 2% or ± 0.2 m/s, whichever is greater.

When data at multiple heights are available, shear coefficients, α, have been determined. They can be used in the following formula to estimate the average wind speed, $U(z)$, at height z, when the average wind speed, $U(z_r)$, at height z_r is known:

$$U(z) = U(z_r)\left(\frac{z}{z_r}\right)^{\alpha}$$

The change in wind speed with height is a very complicated relationship related to atmospheric conditions, wind speed, wind direction, time of day and time of year. This formula may not provide the correct answer at any given site. Nevertheless the calculated shear coefficient, based on measurements at two heights, can be used to characterize the degree of increase in wind speed with height at a site.

SECTION 4 - Significant Meteorological Events

There were no extreme metrological events during this data collection period. The highest recorded wind speed was 15.8 m/s (35.3 mph).

SECTION 5 - Data Recovery and Validation

All raw wind data are subjected to a series of tests and filters to weed out data that are faulty or corrupted. Definitions of these quality assurance (QA) controls are given below under Test Definitions and Sensor Statistics. These control filters were designed to automate the quality control process and used many of the previous hand-worked data sets made at UMass to affect a suitable emulation. The gross percentage of data recovered (ratio of the number of raw data points received to data points expected) and net percentage (ratio of raw data points which passed all QA control tests to data points expected) are shown below.

Gross Data Recovered [%]	100
Net Data Recovered [%]	76.9

Test Definitions

All raw data were subjected to a series of validation tests, as described below. The sensors tested and the parameters specific to each sensor are given in the Sensor Performance Report which is included in APPENDIX A. Data which were flagged as invalid were not included in the statistics presented in this report.

MinMax Test: All sensors are expected to report data values within a range specified by the sensor and logger manufacturers. If a value falls outside this range, it is flagged as invalid. A data value from the sensor listed in Test Field 1 (TF1) is flagged if it is less than Factor 1 (F1) or greater than Factor 2. This test has been applied to the following sensors (as applicable): wind speed, wind speed standard deviation, wind direction, temperature, and solar insolation.

$$F1 > TF1 > F2$$

MinMaxT Test: This is a MinMax test for wind direction standard deviation with different ranges applied for high and low wind speeds. A wind direction standard deviation data value (TF1) is flagged either if it is less than Factor 1, if the wind speed (TF2) is less than Factor 4 and the wind direction standard deviation is greater than Factor 2, or if the wind speed is greater than or equal to Factor 4 and the wind direction standard deviation is greater than Factor 3.

$$(TF1 < F1)$$
$$\text{or } (TF2 < F4 \text{ and } TF1 > F2)$$
$$\text{or } (TF2 \geq F4 \text{ and } TF1 > F3)$$

Icing Test:[*] An icing event occurs when ice collects on a sensor and degrades its performance. Icing events are characterized by the simultaneous measurements of near-zero standard deviation of wind direction, non-zero wind speed, and near- or below-freezing temperatures. Wind speed, wind speed standard deviation, wind direction, and wind direction standard deviation data values are flagged if the wind direction standard deviation (CF1) is less than or equal to Factor 1 (F1), the wind speed (TF1) is greater than Factor 2 (F2), and the temperature (CF2) is less than Factor 3 (F3). To exit an icing event, the wind direction standard deviation must be greater than Factor 4 (F4).

$$CF1 \leq F1 \text{ and } TF1 > F2 \text{ and } CF2 < F3$$

CompareSensors Test: Where primary and redundant sensors are used, it is possible to determine when one of the sensors is not performing properly. For anemometers, poor performance is characterized by low data values. Therefore, if one sensor of the pair reports values significantly below the other, the low values are flagged. At low wind speeds (Test Fields 1 and 2 less than or equal to Factor 3) wind speed data are flagged if the absolute difference between the two wind speeds is greater than Factor 1. At high wind speeds (Test Fields 1 or 2 greater than Factor 3) wind speed data are flagged if the absolute value of the ratio of the two wind speeds is greater is greater than Factor 2.

$$[\ TF1 \leq F3 \text{ and } TF2 \leq F3 \text{ and } \mathrm{abs}(TF1 - TF2) > F1\ ]$$
$$\text{or } [\ (TF1 > F3 \text{ or } TF2 > F3) \text{ and } (\mathrm{abs}(1 - TF1 / TF2) > F2 \text{ or } \mathrm{abs}(1 - TF2 / TF1) > F2)\ ]$$

Sensor Statistics

Expected Data Points: the total number of sample intervals between the start and end dates (inclusive).

Actual Data Points: the total number of data points recorded between the start and end dates.

% Data Recovered: the ratio of actual and expected data points (this is the *gross data recovered percentage*).

Hours Out of Range: total number of hours for which data were flagged according to MinMax and MinMaxT tests. These tests flag data which fall outside of an expected range.

[*] Icing tests were not run for this period due to a faulty temperature sensor.

Hours of Icing: total number of hours for which data were flagged according to Icing tests. This test uses the standard deviation of wind direction, air temperature, and wind speed to determine when sensor icing has occurred.

Hours of Fault: total number of hours for which data were flagged according to CompareSensors tests. These tests compare two sensors (e.g. primary and redundant anemometers installed at the same height) and flag data points where one sensor differs significantly from the other.

% Data Good: the filter results are subtracted from the gross data recovery percentage to yield the *net data recovered percentage*.

SECTION 6 - Data Summary

This report contains several types of wind data graphs. Unless otherwise noted, each graph represents data from 1 quarter (3 months). The following graphs are included:

- Time Series – 10-minute averaged wind speeds at 50 m are plotted against time. The time series, shown in figure 2, indicates that the highest wind speed of about 15.8 m/s, occurred towards the end of October.

- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind at 50 m is at a given wind speed. Figure 3 shows that the most frequently occurring wind speeds were between 4 and 5 m/s.

- Diurnal Average Wind Speeds – A plot of the average wind speed at 50 m for each hour of the day. The diurnal plot, shown in Figure 4, indicates that the average wind speeds remain relatively constant throughout the day with a slight increase between the 12^{th} and 16^{th} hours (12 pm – 4 pm).

- Turbulence Intensity – A plot of turbulence intensity as a function of wind speed at 50 m. Turbulence Intensity is calculated as the standard deviation of the wind speed divided by the wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. A plot of turbulence intensity, shown in Figure 5, shows a decrease of turbulence intensity with increasing wind velocities. The average turbulence intensity for August is 0.19.

- Wind Rose – A plot, by compass direction showing the percentage of time that the wind comes from a given direction and the average wind speed in that direction at 50 m. The plot, shown in Figure 6, shows prevailing winds and greatest wind speeds from the west and the south-southwest, respectively.

SECTION 7- Graphs

Data for the wind speed histograms, monthly and diurnal average plots, and wind roses are included in APPENDIX B.

Wind Speed Time Series

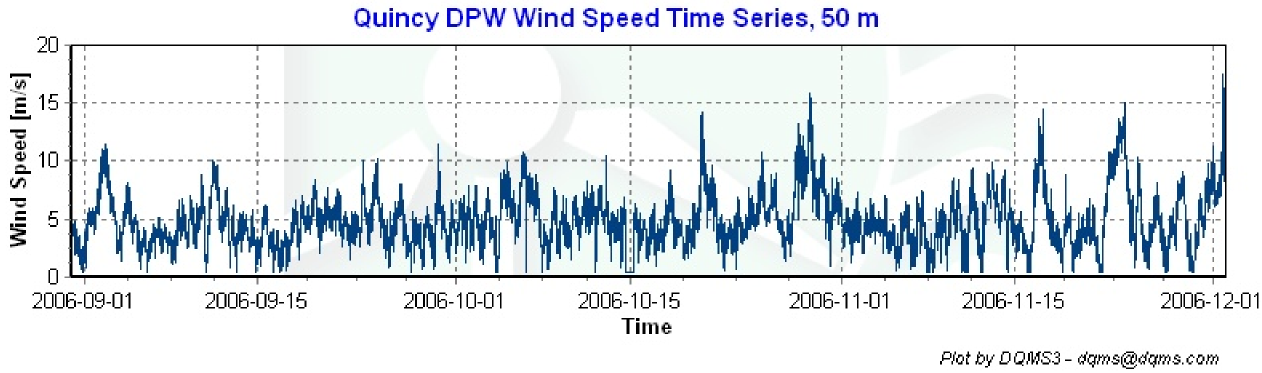

Figure 2 – Wind Speed Time Series, September 1, 2006 – November 30, 2006.

Wind Speed Distributions

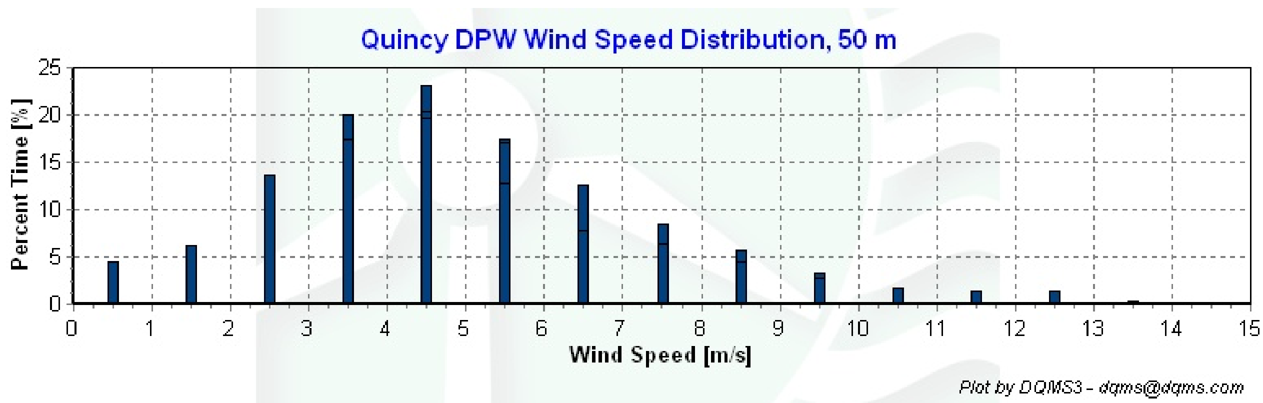

Figure 3 – Wind Speed Distribution, September 1, 2006 – November 30, 2006.

Diurnal Average Wind Speeds

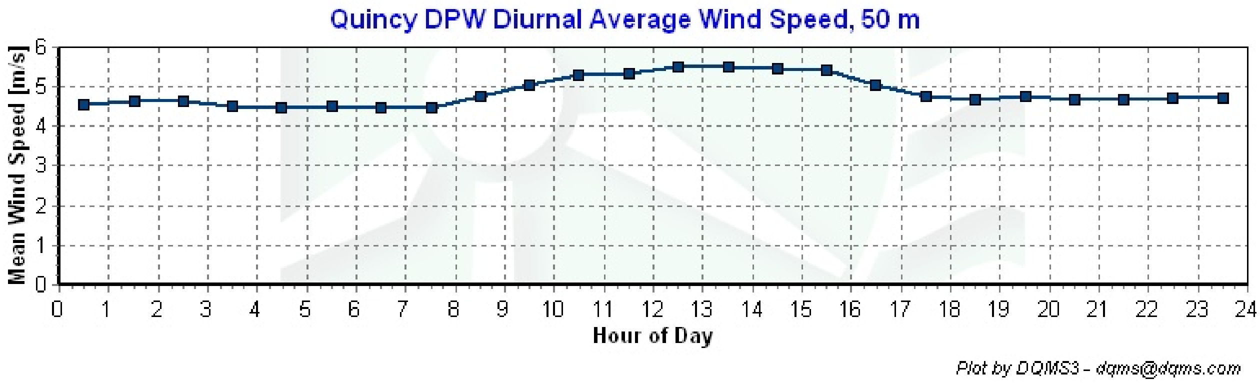

Figure 4 – Diurnal Average Wind Speeds, September 1, 2006 – November 30, 2006.

Turbulence Intensities

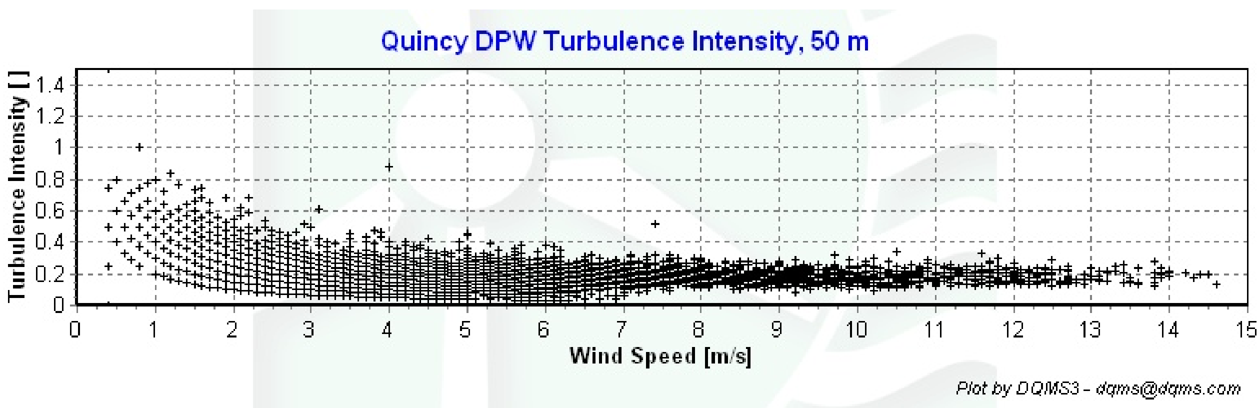

Figure 5 – Turbulence Intensity vs. Wind Speed, September 1, 2006 – November 30, 2006.

Wind Roses

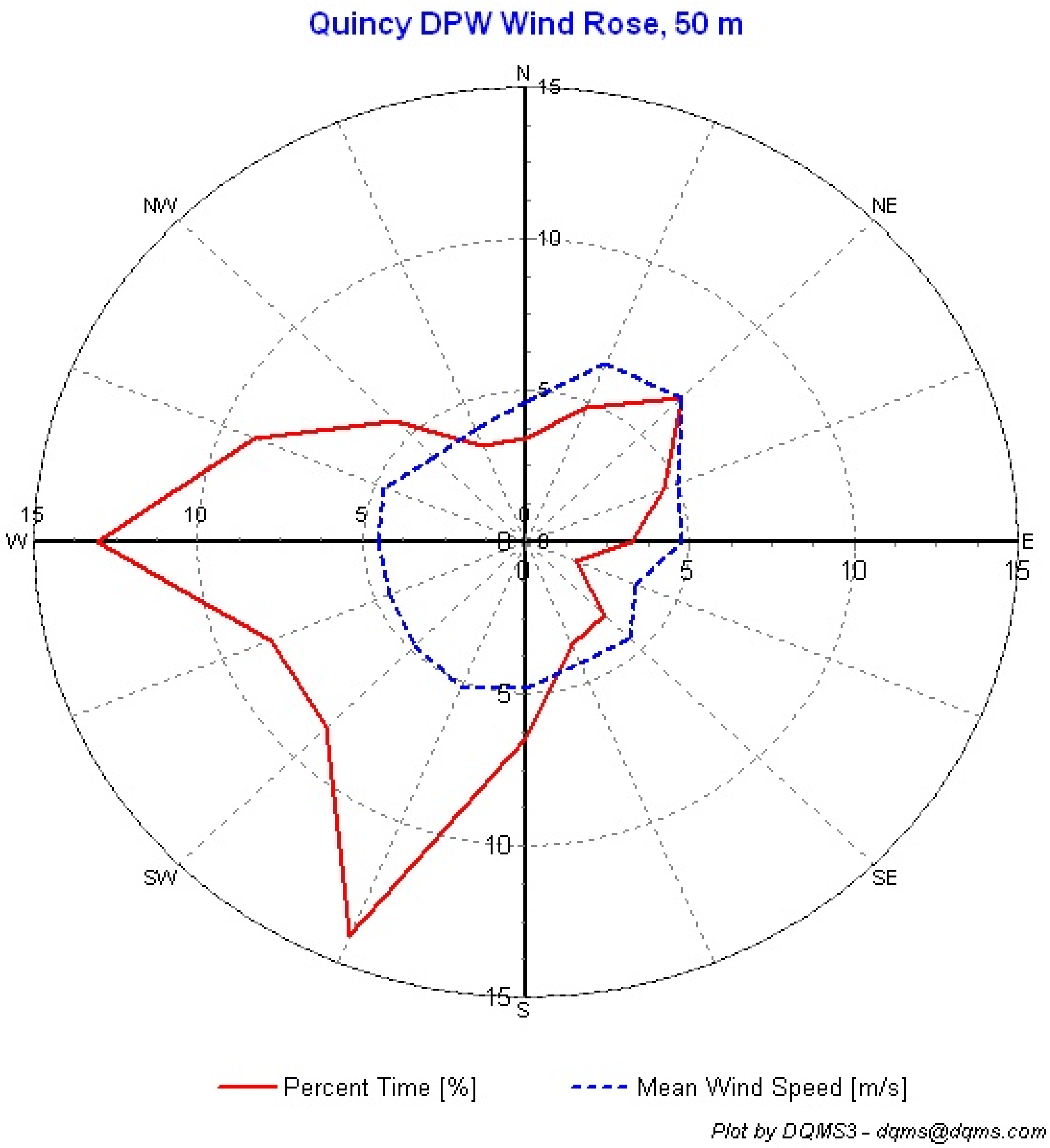

Figure 6 – Wind Rose, September 1, 2006 – November 30, 2006.

APPENDIX A - Sensor Performance Report

Test Definitions

TestOrder	TestField1	TestField2	Test Field3	TestType	Factor1	Factor2	Factor3	Factor4
1				TimeTest Insert	0	0	0	0
4	Etmp2aDEGC			MinMax	-30	40	0	0
5	EtmpSD2aDEGC			MinMax	0	4	0	0
6	Etmx2aDEGC			MinMax	-30	40	0	0
7	Etmn2aDEGC			MinMax	-30	40	0	0
10	Anem50aMS			MinMax	0	90	0	0
11	Anem50bMS			MinMax	0	90	0	0
12	Anem40aMS			MinMax	0	90	0	0
13	Anem40bMS			MinMax	0	90	0	0
14	Anem25aMS			MinMax	0	90	0	0
20	AnemSD50aMS			MinMax	0	4	0	0
22	AnemSD50bMS			MinMax	0	4	0	0
23	AnemSD40aMS			MinMax	0	4	0	0
24	AnemSD40bMS			MinMax	0	4	0	0
25	AnemSD25aMS			MinMax	0	4	0	0
30	Vane50aDEG			MinMax	0	359.9	0	0
31	Vane40aDEG			MinMax	0	359.9	0	0
32	Vane25aDEG			MinMax	0	359.9	0	0
50	Turb50zNONE			MinMax	0	2	0	0
51	Turb40zNONE			MinMax	0	2	0	0
52	Turb25zNONE			MinMax	0	2	0	0
60	Wshr0zNONE			MinMax	-100	100	0	0
70	Amax50aMS			MinMax	0	90	0	0
71	Amin50aMS			MinMax	0	90	0	0
72	Amax50bMS			MinMax	0	90	0	0
73	Amin50bMS			MinMax	0	90	0	0
74	Amax40aMS			MinMax	0	90	0	0
75	Amin40aMS			MinMax	0	90	0	0
76	Amax40bMS			MinMax	0	90	0	0
77	Amin40bMS			MinMax	0	90	0	0
78	Amax25aMS			MinMax	0	90	0	0
79	Amin25aMS			MinMax	0	90	0	0
80	Vmax50aDEG			MinMax	0	359.9	0	0
81	Vmin50aDEG			MinMax	0	359.9	0	0
82	Vmax40aDEG			MinMax	0	359.9	0	0
83	Vmin40aDEG			MinMax	0	359.9	0	0
84	Vmax25aDEG			MinMax	0	359.9	0	0

85	Vmin25aDEG			MinMax	0	359.9	0	0
200	VaneSD50aDEG	Anem50aMS		MinMaxT	0	100	100	10
201	VaneSD50aDEG	Anem50bMS		MinMaxT	0	100	100	10
202	VaneSD40aDEG	Amax40aMS		MinMaxT	0	100	100	10
203	VaneSD40aDEG	Anem40bMS		MinMaxT	0	100	100	10
204	VaneSD25aDEG	Anem25aMS		MinMaxT	0	100	100	10
400	Anem50aMS	Anem50bMS		CompareSensors	1	0.25	3	0
401	Anem40aMS	Anem40bMS		CompareSensors	1	0.25	3	0
500	Pwrd50zWMC			MinMax	0	447970	0	0
501	Pwrd40zWMC			MinMax	0	447970	0	0
502	Pwrd25zWMC			MinMax	0	447970	0	0

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Fault	% Data Good
Anem50aMS	13105	13105	100	0.167	0.167	99.985
AnemSD50aMS	13105	13105	100	0.167	0.167	99.985
Anem50bMS	13105	13105	100	0	62.333	97.146
AnemSD50bMS	13105	13105	100	0	62.333	97.146
Anem40aMS	13105	13105	100	0.167	0.5	99.969
AnemSD40aMS	13105	13105	100	0.167	0.5	99.969
Anem40bMS	13105	13105	100	0	271.167	87.585
AnemSD40bMS	13105	13105	100	0	271.167	87.585
Anem25aMS	13105	13105	100	0	0	100
AnemSD25aMS	13105	13105	100	0	0	100
Vane50aDEG	13105	13105	100	0.167	0	99.992
VaneSD50aDEG	13105	13105	100	0.167	0	99.992
Vane40aDEG	13105	13105	100	0.167	0	99.992
VaneSD40aDEG	13105	13105	100	0.167	0	99.992
Vane25aDEG	13105	13105	100	2184.167	0	0
VaneSD25aDEG	13105	13105	100	2184.167	0	0
Etmp2aDEGC	13105	13105	100	2184.167	0	0
EtmpSD2aDEGC	13105	13105	100	2184.167	0	0
Total	471780	471780	100	17474.667	668.333	76.926

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	3
1.5	4.79
2.5	11.31
3.5	17.73
4.5	21.02
5.5	15.75
6.5	9.81
7.5	6.5
8.5	4.22
9.5	2.75
10.5	1.33
11.5	0.85
12.5	0.61
13.5	0.25
14.5	0.06
15.5	0.02
16.5	0
17.5	0
18.5	0
19.5	0
20.5	0
21.5	0
22.5	0
23.5	0
24.5	0

Table 1- Wind Speed Distribution, 50 m, September 1, 2006 – November 30, 2006.

<u>Diurnal Average Wind Speed Data</u>

Hour of Day	Average Wind Speed [m/s]
0.5	4.54
1.5	4.63
2.5	4.63
3.5	4.5
4.5	4.49
5.5	4.5
6.5	4.48
7.5	4.49
8.5	4.78
9.5	5.04
10.5	5.28
11.5	5.32
12.5	5.52
13.5	5.49
14.5	5.44
15.5	5.42
16.5	5.05
17.5	4.76
18.5	4.67
19.5	4.76
20.5	4.68
21.5	4.69
22.5	4.7
23.5	4.7

Table 2- Diurnal Average Wind Speeds, 50 m, September 1, 2006 – November 30, 2006.

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	3.43	4.62
NNE	4.76	6.35
NE	6.72	6.68
ENE	4.57	5
E	3.22	4.73
ESE	1.66	3.64
SE	3.37	4.5
SSE	3.62	4.34
S	6.49	4.81
SSW	14.01	5.13
SWE	8.59	4.82
WSW	8.46	4.49
W	13.07	4.52
WNW	8.94	4.7
NW	5.62	3.94
NNW	3.46	4.03

Table 3- Wind Rose, Time Percentage, and Mean Wind Speed by Direction, 50 m, September 1, 2006 – November 30, 2006