WIND DATA REPORT

Quincy DPW, MA

March 1st 2007 to May 31st 2007

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). 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.

TABLE OF CONTENTS

TABLE OF FIGURES

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 performed 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 March 1, 2007-May 31, 2007. The quarterly mean recorded wind speed at 50 m was 5.74 m/s (12.84 mph)* and the prevailing direction was from the south-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 88.3%. The majority of data which did not pass quality tests is due to 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 Summary

A summary of the wind speeds and wind directions measured during the reporting period is included in Table 1. Table 1 includes the mean wind speeds measured at each measurement height, the maximum instantaneous wind speed measured at each measurement height and the prevailing wind direction measured at each measurement height. These values are provided for each month of the reporting period and for the whole reporting period.

Table 1. Wind Speed and Direction Data Summary

Date	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction
Height Units	**50 m [m/s]**	**50 m [m/s]**	**50 m [m/s]**	**40 m [m/s]**	**40 m [m/s]**	**40 m [m/s]**	**25 m [m/s]**	**25 m [m/s]**	**25 m [m/s]**
Mar 2007	6.48	16.4	SSW	6.10	15.8	WSW	5.41	14.3	-
April 2007	5.77	17.9	W	5.44	17.2	NW	4.73	15.5	-
May 2007	4.98	12.4	SSW	4.65	11.9	WSW	4.07	10.5	-
Mar 2007 - May 2007	**5.74**	**17.9**	**SSW**	**5.39**	**17.2**	**WSW**	**4.73**	**15.5**	**-**

Wind data statistics in the table are representative of the 88.3% of expected data for the quarter that passed quality assurance tests. This lower percentage of accepted data is due to the prevailing wind direction at 25 m not being available because of a faulty wind direction vane.

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No measurement of wind speed or direction can be perfectly accurate. Wind speed measurement 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. Wind direction measurement errors occur due to sensor measurement uncertainty, tower effects, boom alignment measurement errors and twisting of pipe sections during the raising of a pipe tower. Efforts are also made to reduce these errors, but the reported wind directions are estimated to have an uncertainty of +/- 5 degrees.

A summary of the turbulence intensity and mean wind shear measured at each measurement height during the reporting period is included in Table 2. These values are provided for each month of the reporting period and for the whole reporting period. Turbulence Intensity is calculated by dividing the standard deviation of the wind speed by the mean wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. Turbulence intensity varies with wind speed. The average turbulence intensity presented in Table 2 is the mean turbulence intensity when the wind speed at the highest measurement height is between 10 and 11 m/s.

Shear coefficients provide a measure of the change in wind speed with height. 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 will not always 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.

The mean wind shear coefficient that is provided here is calculated based on the mean wind speeds in Table 1, where z_{high} and z_{high} are the heights of the higher and lower mean wind speeds used in the calculation and $U(z_{low})$ and $U(z_{low})$ are the mean wind speeds at the two heights.

$$\alpha = \log\left(\frac{U(z_{high})}{U(z_{low})}\right) \Big/ \log\left(\frac{z_{high}}{z_{low}}\right)$$

Table 2. Shear and Turbulence Intensity Data Summary

Date	Turbulence Intensity at 10 m/s	Turbulence Intensity at 10 m/s	Turbulence Intensity at 10 m/s	Mean Wind Shear Coefficient, α
Height Units	50 m [-]	40 m [-]	25 m [-]	Between 50 m and 40 m [-]
Mar 2007	0.20	0.22	0.23	0.27
April 2007	0.19	0.20	0.21	0.26
May 2007	0.17	0.18	0.17	0.31
Mar 2007 -May 2007	**0.19**	**0.20**	**0.20**	**0.28**

SECTION 4- Graphs

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 average wind speeds are plotted against time.
- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed.
- Monthly Average – A plot of the monthly average wind speed over a 12-month period. This graph shows the trends in the wind speed over the year.
- Diurnal – A plot of the average wind speed for each hour of the day.
- Turbulence Intensity – A plot of turbulence intensity as a function of wind speed. 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.
- 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.

Figure 2, the average wind speed time series, shows that the highest speed of 17.9 m/s occurred in the middle of April. The wind speed distribution, shown in figure 3, indicates that the most frequently occurring wind speeds were between 4 and 5 m/s. The monthly average wind speeds, shown in figure 4, shows that the monthly average wind speeds have peaked in March. Figure 5 shows that the average wind speeds remain relatively constant throughout the day with a slight increase in the middle of the afternoon. The plot of turbulence intensity, shown in figure 6, shows a decrease in turbulence intensity with an increase in wind velocity. The wind rose, shown in figure 7, shows that the prevailing winds and highest wind speeds both occur from the south-southwest.

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

Wind Speed Time Series

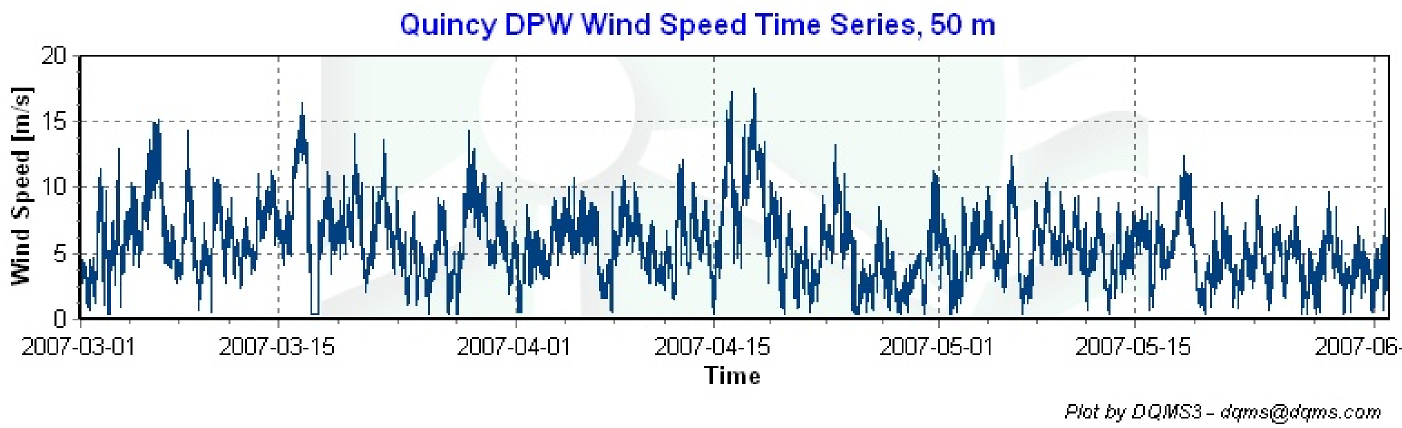

Figure 2– Wind Speed Time Series, March 1, 2007 – May 31, 2007.

Wind Speed Distributions

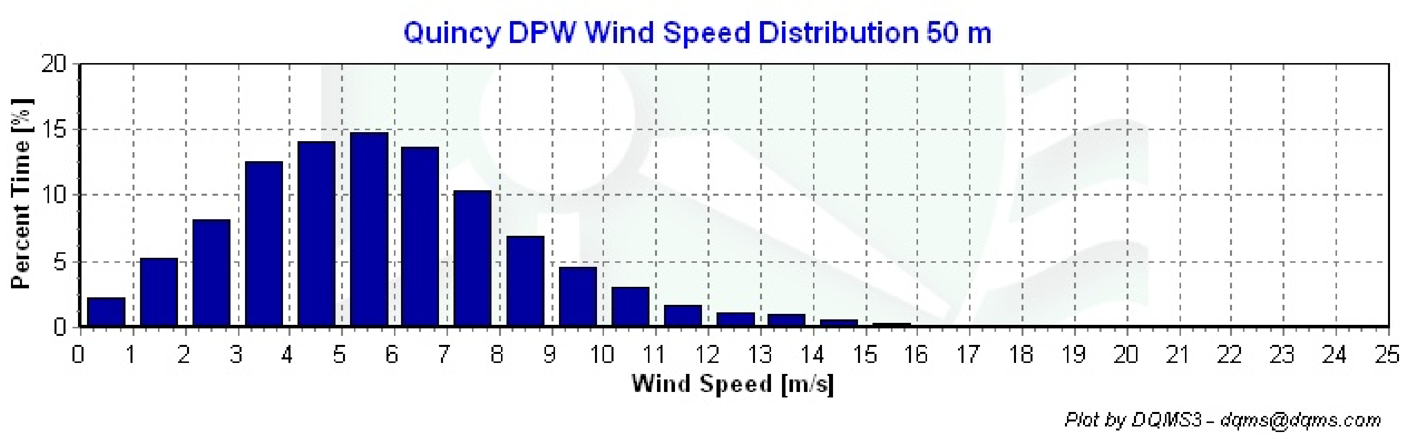

Figure 3– Wind Speed Distribution, March 1, 2007 – May 31, 2007.

Monthly Average Wind Speeds

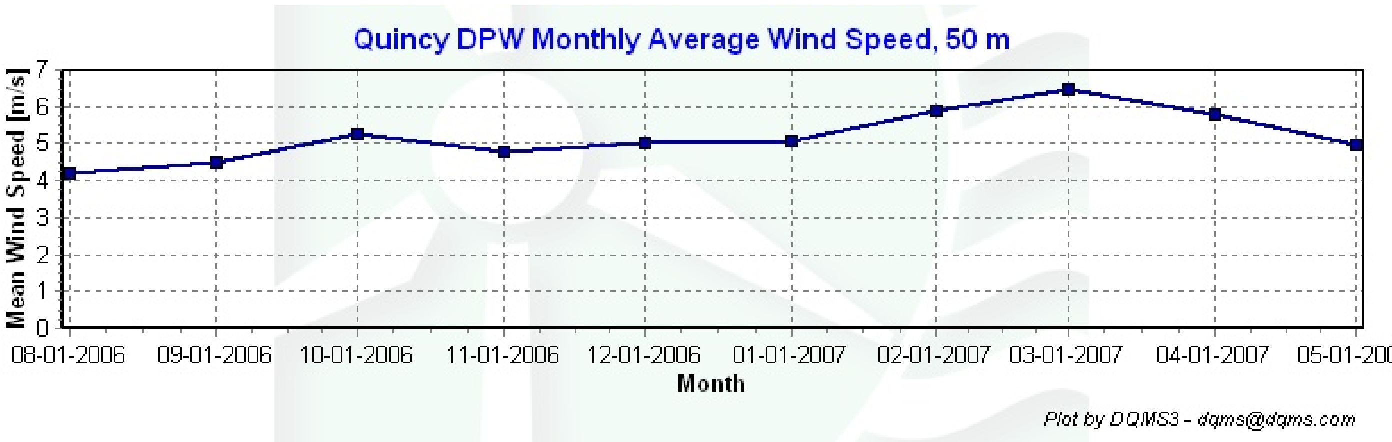

Figure 4– Monthly Average Wind Speeds, August 2006 – May 2007.

Diurnal Average Wind Speeds

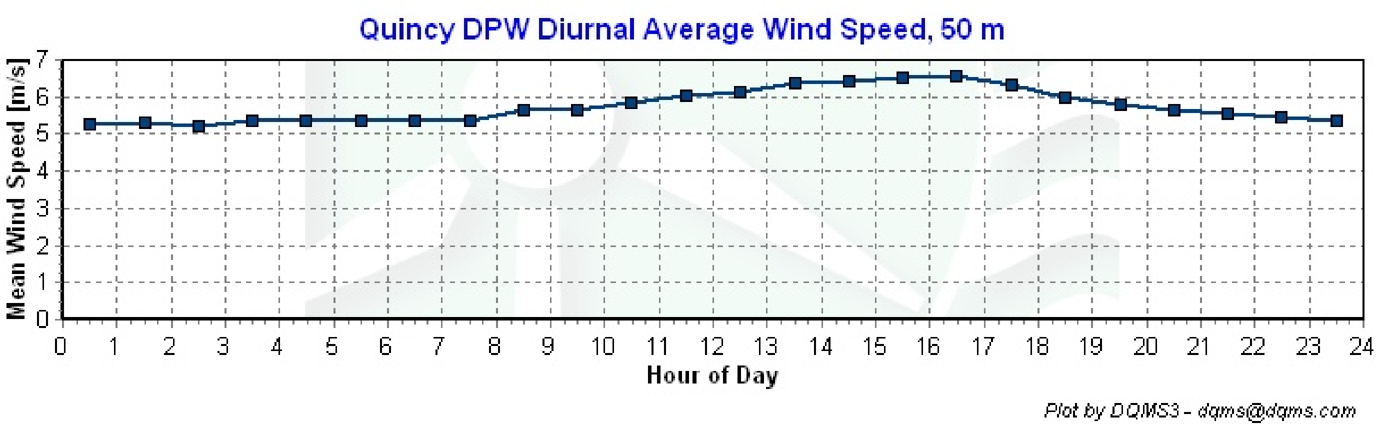

Figure 5– Diurnal Average Wind Speeds, March 1, 2007 – May 31, 2007.

Turbulence Intensities

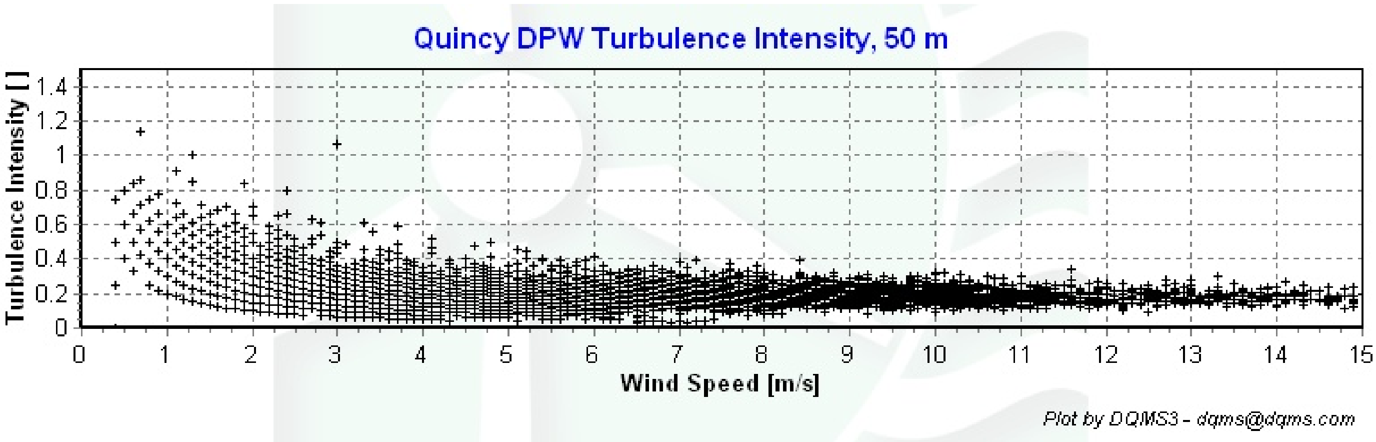

Figure 6– Turbulence Intensity vs. Wind Speed, March 1, 2007 – May 31, 2007.

Wind Roses

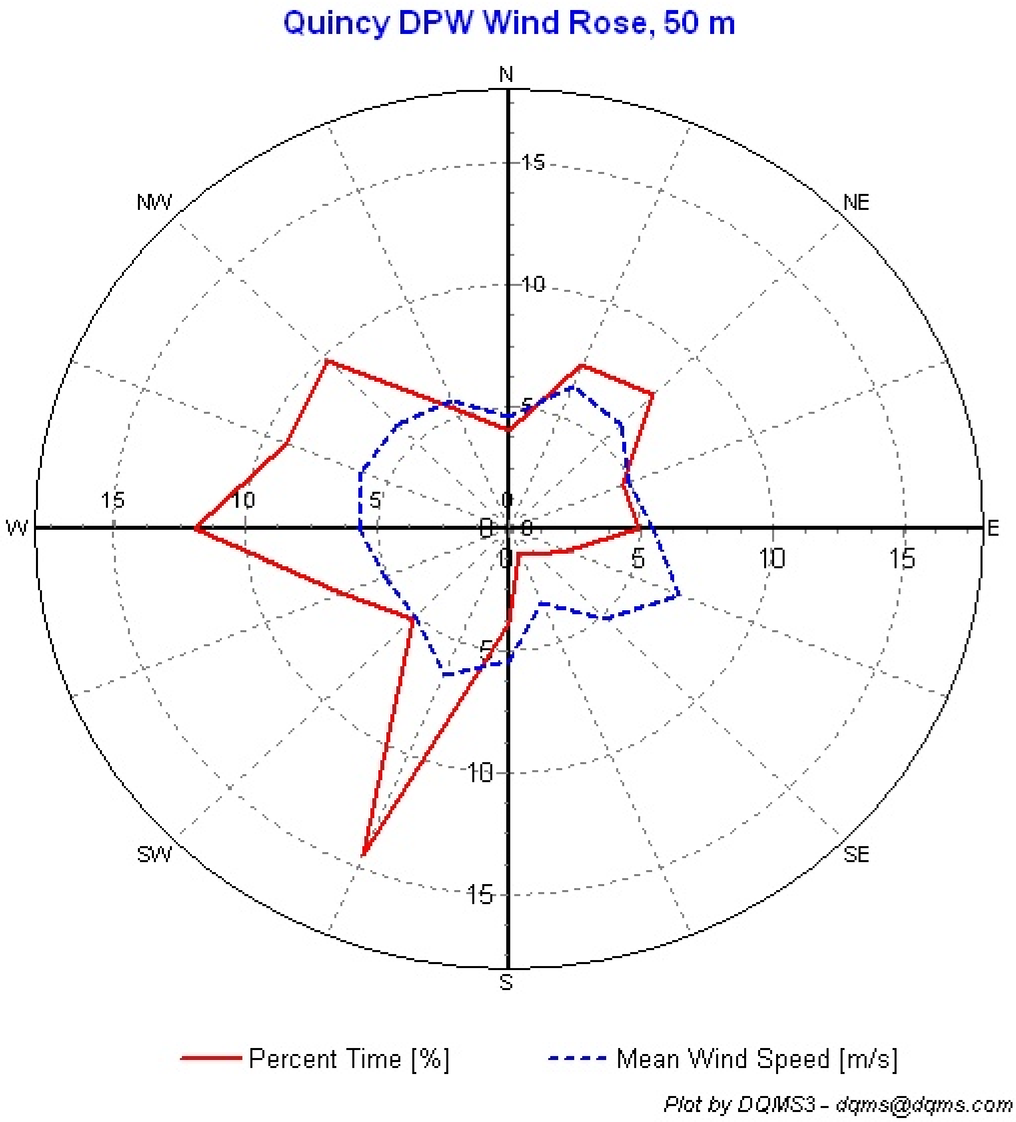

Figure 7– Wind Rose, March 1, 2007 – May 31, 2007.

SECTION 5 - Significant Meteorological Events

There were no extreme metrological events during this data collection period. The highest recorded wind speed was 17.9 m/s (40.0 mph).

SECTION 6 - 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).

SECTION 7 - 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 [%]	88.3

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.

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

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.

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

Sensor Statistics

A summary of the results of the data collection and filtering are given in the Sensor Performance Report which is included in APPENDIX A. The following categories of information, tabulated for each sensor, are included in that report.

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.

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*.

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

Continued: Test definitions

TestOrder	TestField1	TestField2	Test Field3	TestType	Factor1	Factor2	Factor3	Factor4
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	13249	13249	100	0.167	0	99.992
AnemSD50aMS	13249	13249	100	0.167	0	99.992
Amax50aMS	13249	13249	100	0	0	100
Amin50aMS	13249	13249	100	0	0	100
Anem50bMS	13249	13249	100	0	61.333	97.222
AnemSD50bMS	13249	13249	100	0	61.333	97.222
Amax50bMS	13249	13249	100	0	0	100
Amin50bMS	13249	13249	100	0	0	100
Anem40aMS	13249	13249	100	0	0.333	99.985
AnemSD40aMS	13249	13249	100	0	0.333	99.985
Amax40aMS	13249	13249	100	0	0	100
Amin40aMS	13249	13249	100	0	0	100
Anem40bMS	13249	13249	100	0.167	152.833	93.071
AnemSD40bMS	13249	13249	100	0.167	152.833	93.071
Amax40bMS	13249	13249	100	0	0	100
Amin40bMS	13249	13249	100	0	0	100
Anem25aMS	13249	13249	100	0	0	100
AnemSD25aMS	13249	13249	100	0	0	100
Amax25aMS	13249	13249	100	0	0	100
Amin25aMS	13249	13249	100	0	0	100
Vane50aDEG	13249	13249	100	0.333	0	99.985
VaneSD50aDEG	13249	13249	100	0.333	0	99.985
Vmax50aDEG	13249	13249	100	0	0	100
Vmin50aDEG	13249	13249	100	0	0	100
Vane40aDEG	13249	13249	100	1.333	0	99.94
VaneSD40aDEG	13249	13249	100	1.333	0	99.94
Vmax40aDEG	13249	13249	100	0	0	100
Vmin40aDEG	13249	13249	100	0	0	100
Vane25aDEG	13249	13249	100	2208.167	0	0
VaneSD25aDEG	13249	13249	100	2208.167	0	0
Vmax25aDEG	13249	13249	100	2208.167	0	0
Vmin25aDEG	13249	13249	100	2208.167	0	0
Etmp2aDEGC	13249	13249	100	0	0	100
EtmpSD2aDEGC	13249	13249	100	0	0	100
Etmx2aDEGC	13249	13249	100	0	0	100
Etmn2aDEGC	13249	13249	100	0	0	100
Total	476964	476964	100	8836.667	429	88.344

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
anem50yms	Percent
0.5	2.14
1.5	5.19
2.5	8.14
3.5	12.51
4.5	14.01
5.5	14.71
6.5	13.66
7.5	10.38
8.5	6.89
9.5	4.56
10.5	3.04
11.5	1.61
12.5	1.11
13.5	1.03
14.5	0.57
15.5	0.28
16.5	0.11
17.5	0.06
18.5	0
19.5	0
20.5	0
21.5	0
22.5	0
23.5	0

Table 1- Wind Speed Distribution, 50 m, March 1, 2007 – May 31, 2007.

Monthly Average Wind Speed Data

Month	Monthly Average Speed [m/s]
08-2006	4.19
09-2006	4.51
10-2006	5.27
11-2006	4.78
12-2006	5.02
01-2007	5.06
02-2007	5.89
03-2007	6.48
04-2007	5.77
05-2007	4.98

Table 2- Monthly average wind speed, 50 m, August 2006 – May 2007.

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0.5	5.26
1.5	5.31
2.5	5.2
3.5	5.35
4.5	5.35
5.5	5.34
6.5	5.36
7.5	5.38
8.5	5.64
9.5	5.64
10.5	5.83
11.5	6.03
12.5	6.13
13.5	6.39
14.5	6.41
15.5	6.49
16.5	6.57
17.5	6.31
18.5	5.96
19.5	5.79
20.5	5.67
21.5	5.57
22.5	5.47
23.5	5.36

Table 3- Diurnal Average Wind Speeds, 50 m, March 1, 2007 – May 31, 2007.

Wind Rose Data

Direction	Percent of time [%]	Mean Wind Speed [m/s]
N	4.01	4.61
NNE	7.23	6.3
NE	7.71	5.97
ENE	4.66	4.95
E	4.95	5.49
ESE	2.39	6.98
SE	1.5	5.15
SSE	1.06	3.24
S	3.81	5.37
SSW	14.43	6.43
SWE	5.19	5.05
WSW	6.92	5.12
W	11.93	5.66
WNW	9.16	6.06
NW	9.75	5.98
NNW	5.31	5.67

Table 4- Wind Rose, Time Percentage, and Mean Wind Speed by Direction, 50 m, March 1, 2007 – May 31, 2007.