WIND DATA REPORT

Camden Hills Regional High School, ME

March 1st 2006 to May 31th 2006

Prepared for

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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 preformed by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst.

This report covers wind data measured at the Camden Hills Regional High School site in Maine, which was installed on February 1, 2006. Two anemometers and one wind vane are mounted at 39 m (127.9 ft) and 30 m (98.4 ft).

The season covered by this report is March 1, 2006 – May 31, 2006. The quarterly mean recorded wind speed at 39 m was 4.2 m/s (9.4 mph)* and the prevailing direction was from the north. The gross data recovery percentage (the actual percentage of expected data received) for the quarter was 100 % and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) for the quarter was 99.6%.

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 station is located at the Camden Hills Regional High School. The tower base is located at 44.190° N, -69.100° W (WGS84/ NAD83) (Figure 1). The red cross indicates the approximate location of the tower.

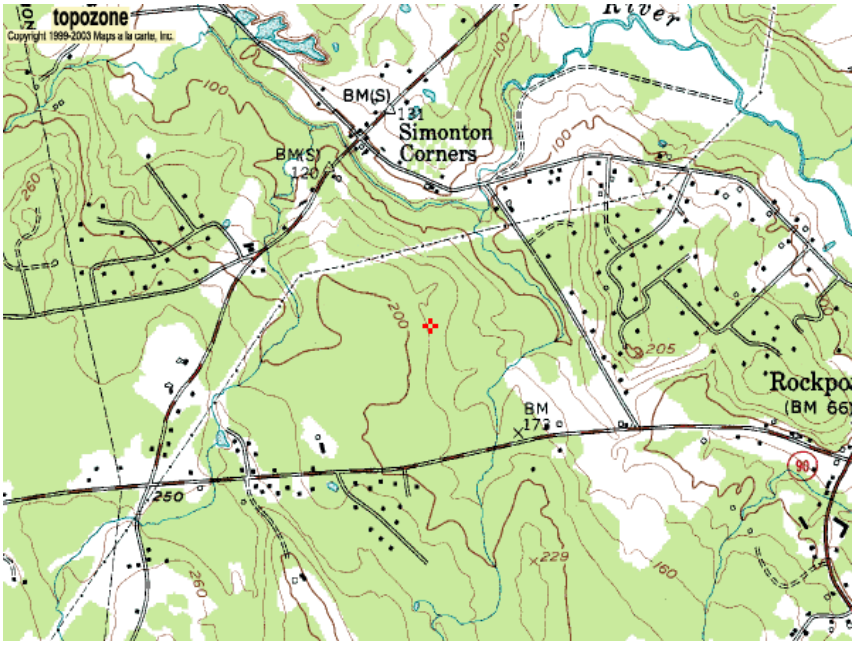

Figure 1 – Camden Hills Regional High School Site Location

Source: www.topozone.com.

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 40 m (131.2 ft) meteorological tower. All the remaining monitoring equipment comes from NRG Systems, and consists of the following items:

- Symphonie Data Logger
- 4 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s). Two anemometers are located at 39 m (127.9 ft), and two at 30 m (98.4 ft).
- 2 - #200P Wind direction vanes. They are located at heights of 39 m (127.9 ft) and 30 m (98.4 ft).

- 4 – Sensor booms, 12’ length
- Lightning rod and grounding cable

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 are then combined into 10-minute averages, and along with the standard deviation for those 10-minute periods, are put into a binary file. These 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 QA tests prior to using the data.

SECTION 3- Data Collection and Maintenance

The following maintenance/equipment problems occurred during the report period, and the following corrective actions taken:

No maintenance work was done in this quarter.

Data Statistics Summary

Date	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction	Turbulence Intensity	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction	Turbulence Intensity	Wind Shear Coefficient
Heights, units	**39 m, [m/s]**	**39 m, [m/s]**	**39 m, [ ]**	**39 m, [ ]**	**30 m, [m/s]**	**30 m, [m/s]**	**30 m, [ ]**	**30 m, [ ]**	**39 m, 30 m, [ ]**
06-Mar	4.41	13.5	N	0.28	3.93	11.3	N	0.31	0.59
06-Apr	3.86	10.2	E	0.28	3.43	9.3	E	0.31	0.65
06-May	3.05	9.0	SE	0.31	2.73	7.7	SE	0.33	0.56
Mar 06 – May 06	**4.18**	**13.5**	**N**	**0.28**	**3.72**	**11.3**	**NNW**	**0.31**	**0.62**

Wind data statistics in the table are reported when more than 90% of the data during the reporting period are valid. In cases when a larger amount of data are missing, the percent of the available data that are used to determine the data statistics is noted.

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 in the three months covered by this report. The highest wind speeds in February are less than 14 m/s as shown by the time series graph.

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. The net data recovered is approximately 0.4% less than the gross data recovered. This is due to icing of the sensors, which causes some of the data points to fail the quality control tests.

Gross Data Recovered [%]	100
Net Data Recovered [%]	99.6

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.

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

Sensor Statistics

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*.

SECTION 6 - Data Summary

This report contains several types of wind data graphs. All graphs contain data from the month of February. The following graphs are included:

- Time Series – 10-minute average wind speeds at a height of 39 m are plotted against time. The wind speed time series is shown in Figure 2.

- Wind Speed Distribution –A histogram plot giving the percentage of time that the wind is at a given wind speed at a height of 39 m. The wind blows most frequently between 4 m/s and 5 m/s, for approximately 19.5% of the time. The wind speed distribution is shown in Figure 3.

- Monthly Averages - A plot of the monthly average wind speed at a height of 39 m from February 2005 - May 2006. This graph shows the trends in the wind speed over the year. The monthly average wind speed plot is shown in Figure 4.

- Diurnal –A plot of the average wind speed for each hour of the day at a height of 39 m. The wind speeds are highest between 12 pm and 1 pm, and lowest between 4 am and 5 am. The diurnal variation plot is shown in Figure 4.

- Turbulence Intensity –A plot of turbulence intensity as a function of wind speed at a height of 39 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. In general, turbulence intensities range from 0.1 to 0.4; for Camden, the average turbulence intensity was 0.28. The turbulence intensity plot is shown in Figure 5.

- 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 a height of 39 m. This wind rose shows the prevailing direction from the north, and wind speeds are greatest from the north-northeast. The wind rose plot is shown in Figure 6.

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

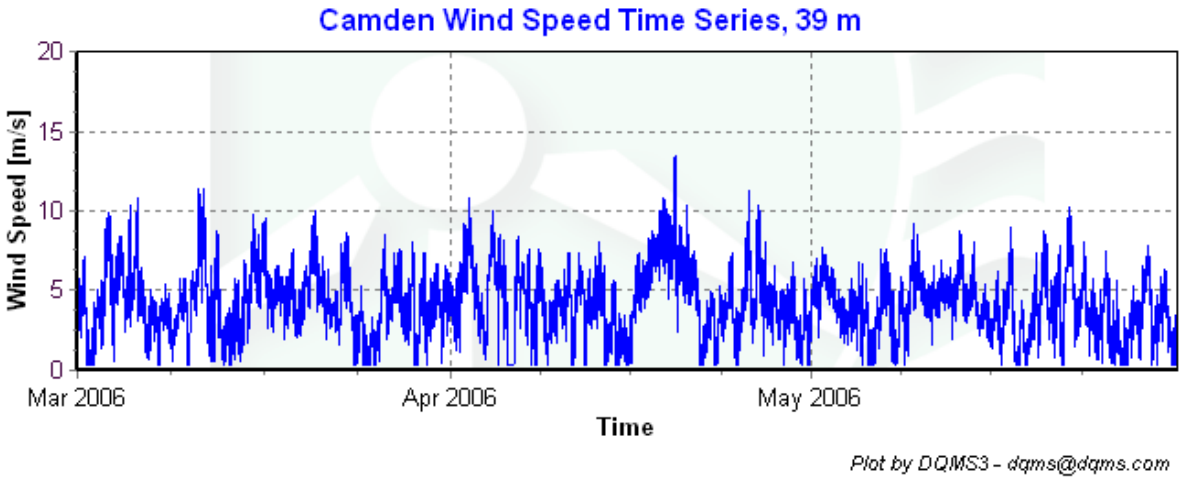

Figure 2 - Wind Speed Time Series, March 1, 2006 - May 31, 2006.

Wind Speed Distributions

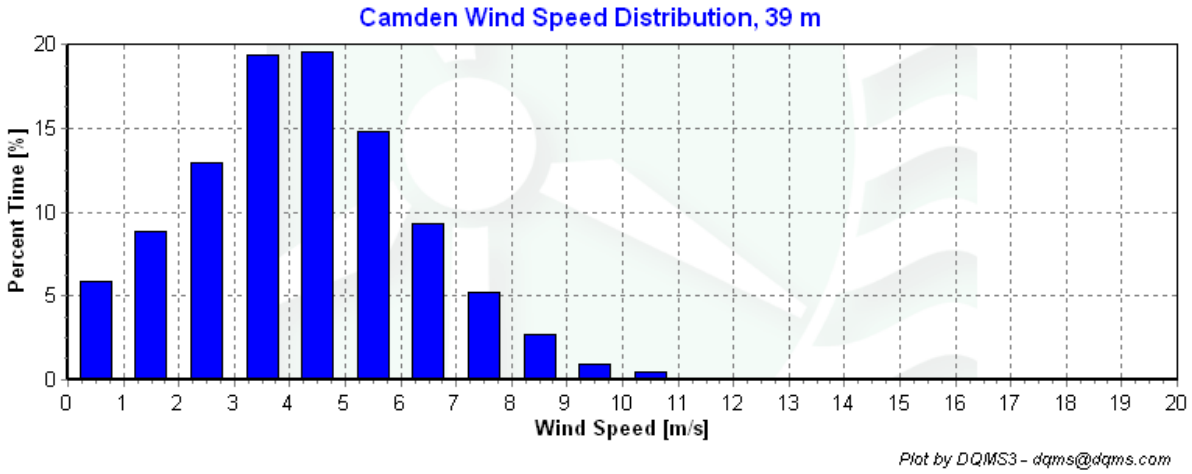

Figure 3 - Wind Speed Distribution, March 1, 2006 - May 31, 2006.

Monthly Average Wind Speeds

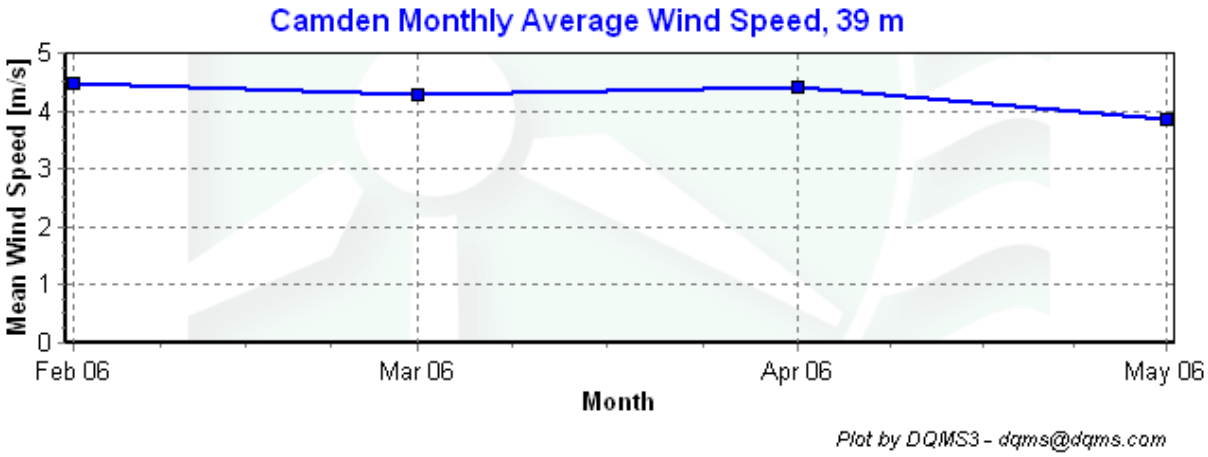

Figure 4 – Monthly Average Wind Speed, March 1, 2006 - May 31, 2006

Diurnal Average Wind Speeds

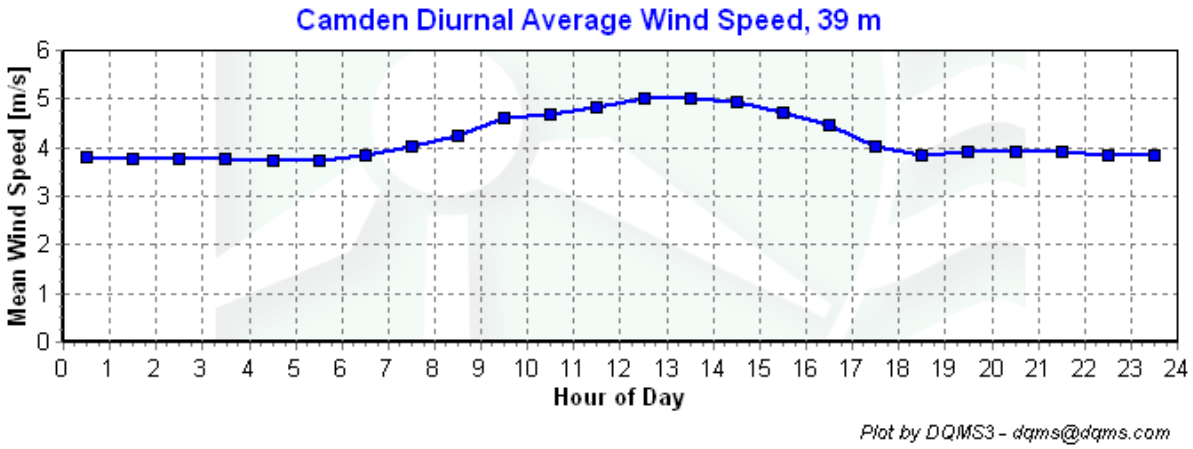

Figure 5 - Diurnal Wind Speed, March 1, 2006 - May 31, 2006.

Turbulence Intensities

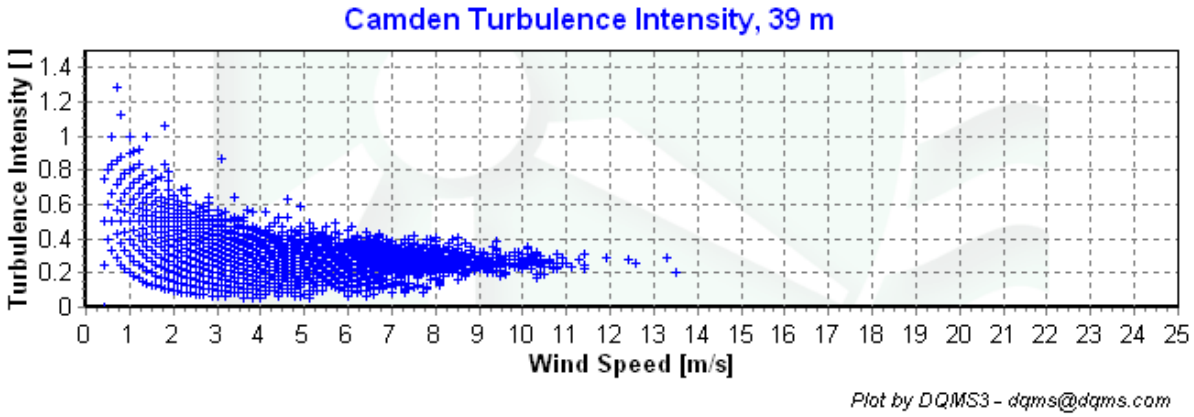

Figure 6 - Turbulence Intensity vs. Wind Speed, March 1, 2006 - May 31, 2006.

Wind Rose

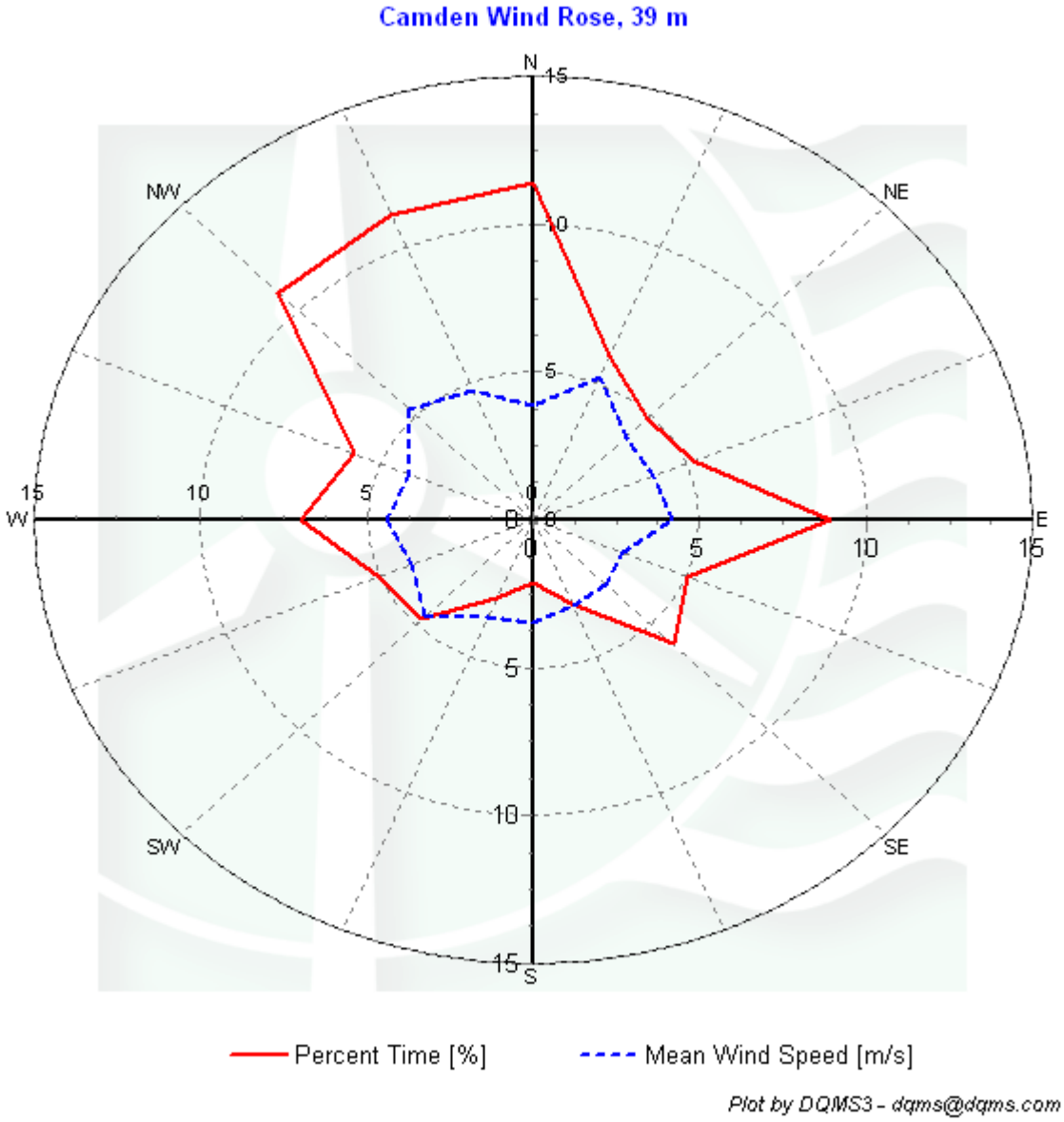

Figure 7 - Wind Rose, March 1, 2006 - May 31, 2006.

APPENDIX A – Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	Test Field3	Calc Field1	Calc Field2	Calc Field3	TestType	Factor1	Factor2	Factor3	Factor4
1							TimeTest Insert				
4	Etmp2adegc						MinMax	-30	60	0	0
5	EtmpSD2adegc						MinMax	-30	60	0	0
10	Anem39ams						MinMax	0	90		
11	Anem39bms						MinMax	0	90		
12	Anem30ams						MinMax	0	90		
13	Anem30bms						MinMax	0	90		
14	Anem39yms						MinMax	0	90		
15	Anem30yms						MinMax	0	90		
20	AnemSD39ams						MinMax	0	4		
21	AnemSD39bms						MinMax	0	4		
22	AnemSD30ams						MinMax	0	4		
23	AnemSD30bms						MinMax	0	4		
24	AnemSD39yms						MinMax	0	4		
25	AnemSD30yms						MinMax	0	4		
30	Vane39adeg						MinMax	0	359.9		
31	Vane30adeg						MinMax	0	359.9		
50	Turb39zNONE						MinMax	0	2		
51	Turb30zNONE						MinMax	0	2		
60	Wshr0zNONE						MinMax	-100	100		
70	Pwrd39zWMS						MinMax	0	5000		
71	Pwrd30zWMS						MinMax	0	5000		
200	VaneSD39adeg	Anem39yms					MinMaxT	0	100	100	10
201	VaneSD30adeg	Anem30yms					MinMaxT	0	100	100	10
300	Anem39ams	AnemSD39ams	Vane39adeg	VaneSD39adeg	Etmp2adegc		Icing	0.5	1	2	10
301	Anem39bms	AnemSD39bms	Vane39adeg	VaneSD39adeg	Etmp2adegc		Icing	0.5	1	2	10
302	Anem30ams	AnemSD30ams	Vane30adeg	VaneSD30adeg	Etmp2adegc		Icing	0.5	1	2	10
303	Anem30bms	AnemSD30bms	Vane30adeg	VaneSD30adeg	Etmp2adegc		Icing	0.5	1	2	10
400	Anem39ams	Anem39bms					CompareSensors	1	0.25	3	0
401	Anem30ams	Anem30bms					CompareSensors	1	0.25	3	0

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Anem39ams	13248	13248	100	0	4.667	1	99.743
AnemSD39ams	13248	13248	100	0	4.667	1	99.743
Anem39bms	13248	13248	100	0	6.167	8.667	99.328
AnemSD39bms	13248	13248	100	0	6.167	8.667	99.328
Anem30ams	13248	13248	100	0	10.667	0.333	99.502
AnemSD30ams	13248	13248	100	0	10.667	0.333	99.502
Anem30bms	13248	13248	100	0	2.833	14.833	99.2
AnemSD30bms	13248	13248	100	0	2.833	14.833	99.2
Vane39adeg	13248	13248	100	0.5	6.167	0	99.698
VaneSD39adeg	13248	13248	100	0.5	6.167	0	99.698
Vane30adeg	13248	13248	100	1.5	10.667	0	99.449
VaneSD30adeg	13248	13248	100	1.5	10.667	0	99.449
Etmp2adegc	13248	13248	100	0	0	0	100
EtmpSD2adegc	13248	13248	100	0	0	0	100
Total	**185472**	**185472**	**100**	**4**	**82.333**	**49.667**	**99.56**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	5.85
1.5	8.85
2.5	12.95
3.5	19.39
4.5	19.52
5.5	14.75
6.5	9.28
7.5	5.2
8.5	2.71
9.5	0.98
10.5	0.45
11.5	0.05
12.5	0.02
13.5	0.02
14.5	0
15.5	0
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, 39 m, March 1, 2006 - May 31, 2006.

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0.5	3.79
1.5	3.77
2.5	3.78
3.5	3.78
4.5	3.74
5.5	3.74
6.5	3.85
7.5	4.01
8.5	4.25
9.5	4.61

10.5	4.69
11.5	4.85
12.5	5.03
13.5	5
14.5	4.92
15.5	4.72
16.5	4.48
17.5	4.03
18.5	3.83
19.5	3.91
20.5	3.91
21.5	3.92
22.5	3.84
23.5	3.86

Table 2 - Diurnal Average Wind Speeds, 39 m, March 1, 2006 - May 31, 2006.

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]
Feb-06	4.28
Mar-06	4.41
Apr-06	3.86
May-06	3.05

Table 3 - Monthly Average Wind Speeds, 39 m, February 1, 2006 - May 31, 2006.

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	11.42	3.84
NNE	6.02	5.21
NE	4.83	3.94
ENE	5.22	3.9
E	8.96	4.16
ESE	5.01	2.94
SE	5.96	3.07
SSE	3.05	3.12
S	2.1	3.49
SSW	2.85	3.52
SW	4.75	4.59
WSW	5	3.95
W	7.01	4.41
WNW	5.81	4.05
NW	10.85	5.28
NNW	11.16	4.76

Table 4 - Wind Rose, Time Percentage and Mean Wind Speed by Direction, 39 m, March 1, 2006 - May 31, 2006.