WIND DATA REPORT

Mattapoisett, Massachusetts

September 1, 2006 – November 30, 2006

Prepared for

Massachusetts Technology Collaborative
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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.

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EXECUTIVE SUMMARY

All of 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 a meteorological tower installed near the South Shore Marshes Wildlife Management Area in the town of Mattapoisett, MA. Installed on January 20th, 2006, the wind monitoring station has been in continuous operation to this day. Two sets of two anemometers and one wind vane are mounted at 49 m (160.8 ft) and 38 m (124.7 ft), and an additional anemometer and vane are mounted at 20 m (65.6 ft). Reports are made on a quarterly basis; and this report is the fourth such report for Mattapoisett.

The season covered by this report is September 2006 – November 2006 (Fall quarter). Due to a high percentage of missing data (64.5%), statistics for this quarter cannot be determined. The cause of the missing data appears to be due to a battery failure in the logger. The battery has been replaced.

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

SECTION 1 - Station Location

The Mattapoisett site is located near the South Shore Marshes Wildlife Management Area in Mattapoisett, MA as shown in Figure 1. The latitude and Longitude are 41° 38.11'N and 70° 50.55'W, respectively, using the NAD 83 datum.

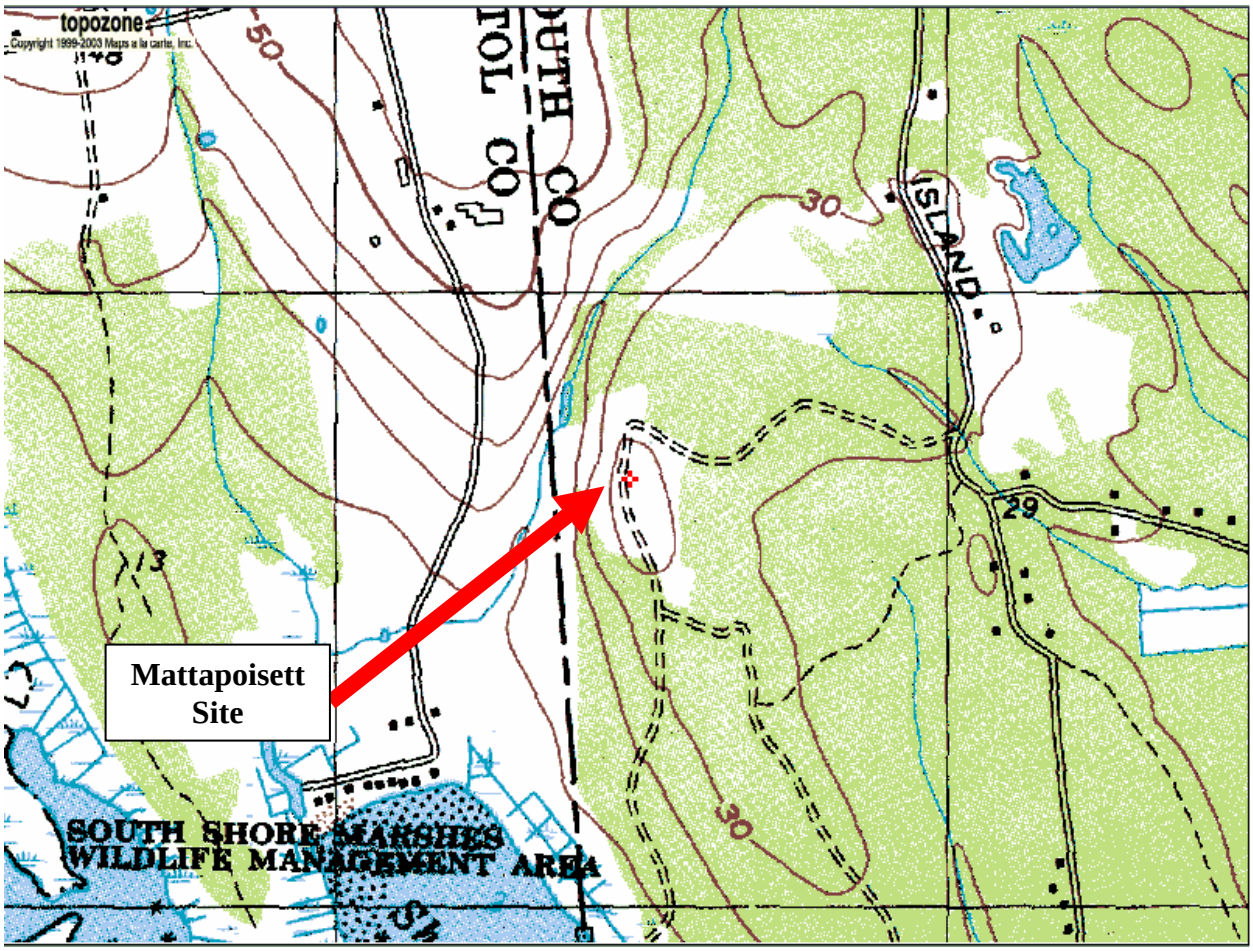

Figure 1 Topographic Map Showing Mattapoisett Site Location--Source Topozone.com

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 49 m (164.0 ft) NRG tower. All other monitoring equipment comes from NRG Systems, and consists of the following items:

- Symphonie Data Logger
- Electrical enclosure box
- 5 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.349 m/s). Two anemometers are located at 49 m (160.8 ft), two at 38 m (124.7 ft) and one at a height of 20 m (65.6 ft).
- 3 - #200P Wind direction vanes. They are located at heights of 49 m (160.8 ft), 38 m (124.7 ft) and 20 m (65.6 ft) each.
- 5 – Sensor booms, 54" length
- Lightning rod and grounding cable
- Shielded sensor wire

The data from the Symphonie logger is mailed to the Renewable Energy Research Laboratory at the University of Massachusetts, Amherst on a regular basis. The logger samples wind speed and direction once every two seconds. These data 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 quality assurance (QA) tests prior to using the data.

SECTION 3 - Data Collection and Maintenance

One maintenance/equipment problem occurred during the report period which caused of the large amount of missing data. No data was received on the data cards after October 3, 2006. The problem appears to be due to a battery failure. The battery has been replaced.

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 Coefficient
Height units	**49 m, [m/s]**	**49 m, [m/s]**	**49 m, [ ]**	**49 m, [ ]**	**38 m, [m/s]**	**38 m, [m/s]**	**38 m, [ ]**	**38 m, [ ]**	**20 m, [m/s]**	**20 m, [m/s]**	**20 m, [ ]**	**20 m, [ ]**	**49m - 38m []**
September 2006	5.02	13.9	0.16	SW	4.55	13	0.18	SSW	3.1	8.6	0.29	SW	0.36
October 2006	--	--	--	--	--	--	--	--	--	--	--	--	--
November 2006	--	--	--	--	--	--	--	--	--	--	--	--	--
September '06 – November '06	--	--	--	--	--	--	--	--	--	--	--	--	--

Wind data statistics in the table are reported when more than 90% of the data during the reporting period are valid.

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 airflow and due to airflows 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—in this case from the anemometry located at 49 m and 38 m. 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

The Fall of 2006 had no major meteorological events that would have caused notable fluctuations in wind speed measurements. Mattapoisett experienced a small storm in late October; however we were unable to achieve data during this time.

Source:
http://www.wunderground.com/history/airport/KEWB/2006/6/1/CustomHistory.html?dayend=31&monthend=8&yearend=2006&req_city=NA&req_state=NA&req_statename=NA

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 [%]	35.62%
Net Data Recovered [%]	35.55%

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 that 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 insulation.

$$F1 > TF1 > F2$$

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.

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

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 that 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. Unless otherwise noted, each graph represents data for the month of September in 2006. The following graphs are included:

- Time Series – 10-minute average wind speeds are plotted against time for roughly one month of the Fall quarter data (i.e. September 1, 2006 - October 3, 2006) in Figure 2. This plot presents data at 49 meters.

- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. Figure 3 shows that the wind speeds ranged between 4 and 6 m/s (8.95 and 13.42 mph) more than 40% of the time. The wind speed was between 4 and 5 m/s (8.95 and 11.18 mph) roughly 20% of the time as well as between 5 and 6 m/s (11.18 and 13.42 mph). This plot presents data at 49 meters and is drawn from the month of September in the Fall quarter dataset.

- Monthly Average Wind Speeds – This plot shows the trends in the mean monthly wind speed at a height of 49 m. This graph shows the trends in the wind speed over the year. The monthly average wind speed plot is shown in Figure 4. As can be seen in the figure, to date, the monthly average wind speed is roughly between 5 m/s and 5.5 m/s (11.18 mph and 12.30 mph).

- Diurnal – A plot of the average wind speed for each hour of the day. Figure 5 shows that the hourly average varied between 4.5m/s and 6 m/s (10.06 mph and 15.66 mph), with the highest average speeds in the early afternoon. This plot presents data at 49 meters and is drawn from the month of September in the Fall quarter dataset.

- 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. In general, turbulence intensities range from 0.1 to 0.4. Figure 6 presents data at 49 meters and is drawn from the month of September in the Fall quarter dataset.

- 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 7 shows the prevailing direction ranges from the south-southwest and southwest. The wind blew from the SSW 11.13% and the SW 12.01% of the time with a mean wind speed of 5.93 m/s and 6.01 m/s (13.26mph and13.44mph), respectively. This plot presents data at 49 meters and is drawn from the month of September in the Fall quarter dataset.

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

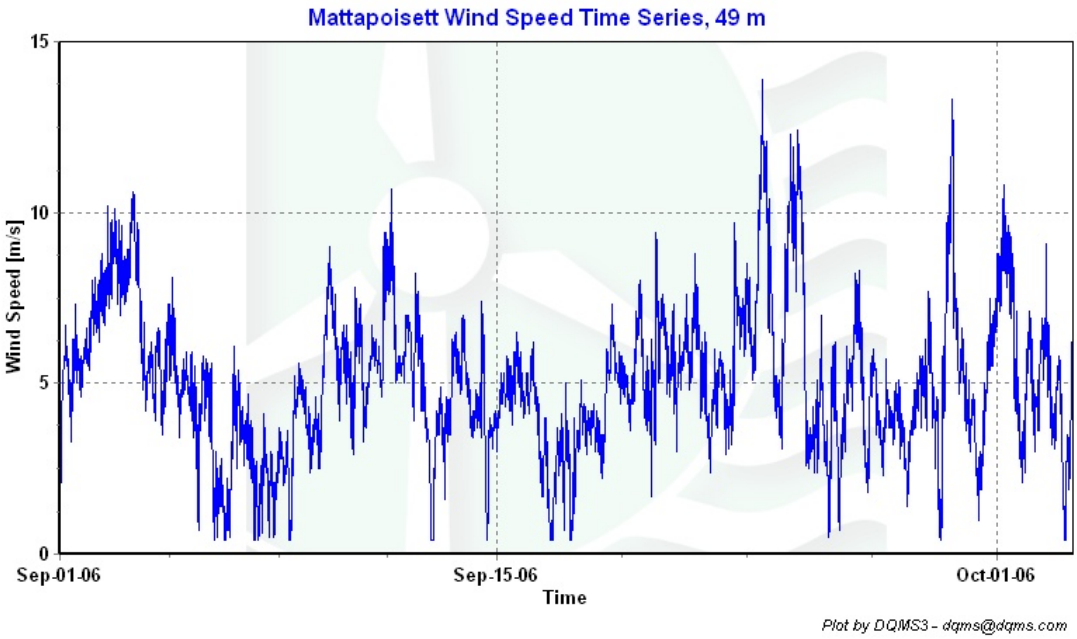

Figure 2 – Wind Speed Time Series, September 1, 2006-October 3, 2006

Wind Speed Distributions

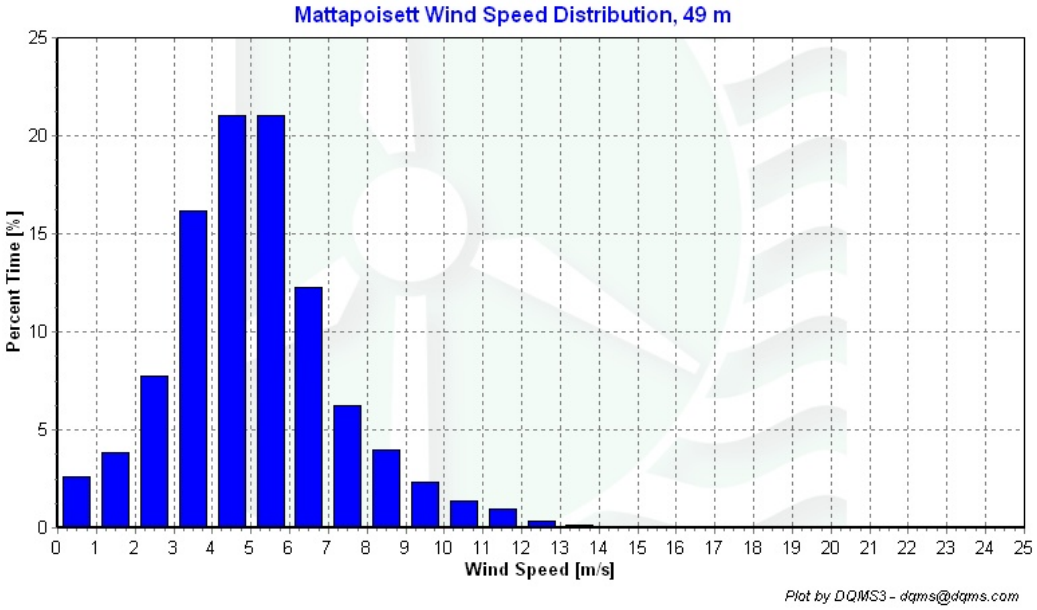

Figure 3 – Wind Speed Distribution, September, 2006

Monthly Average Wind Speeds

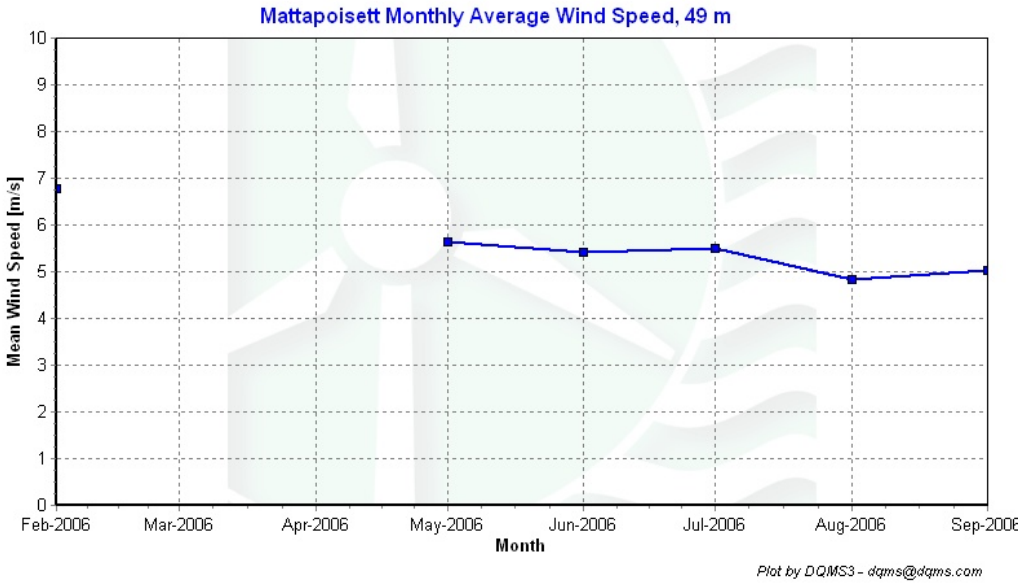

Figure 4 – Monthly Average Wind Speed

Diurnal Average Wind Speeds

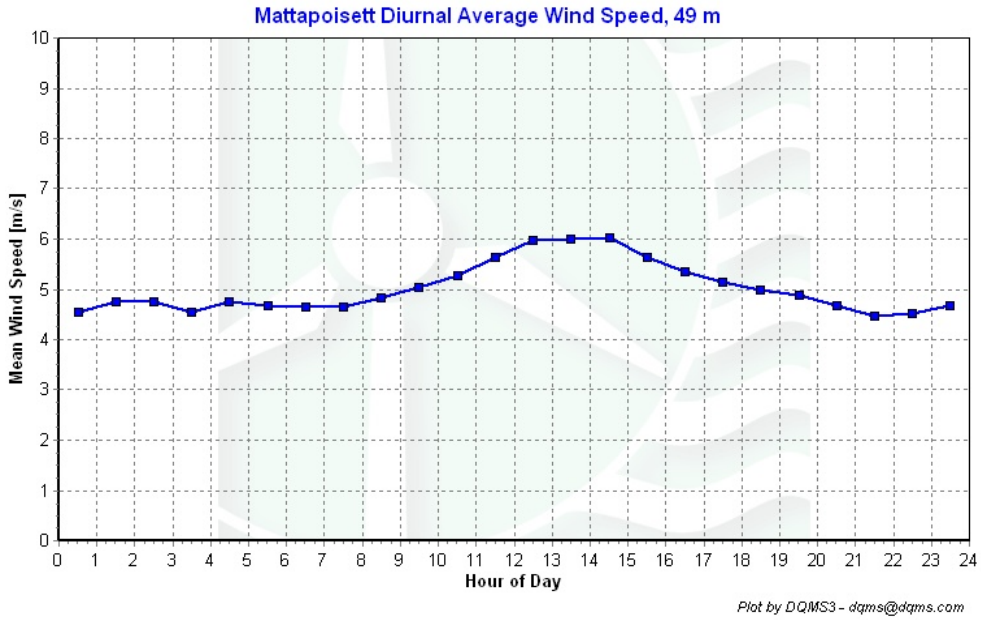

Figure 5 – Diurnal Average Wind Speed, September, 2006

Turbulence Intensities

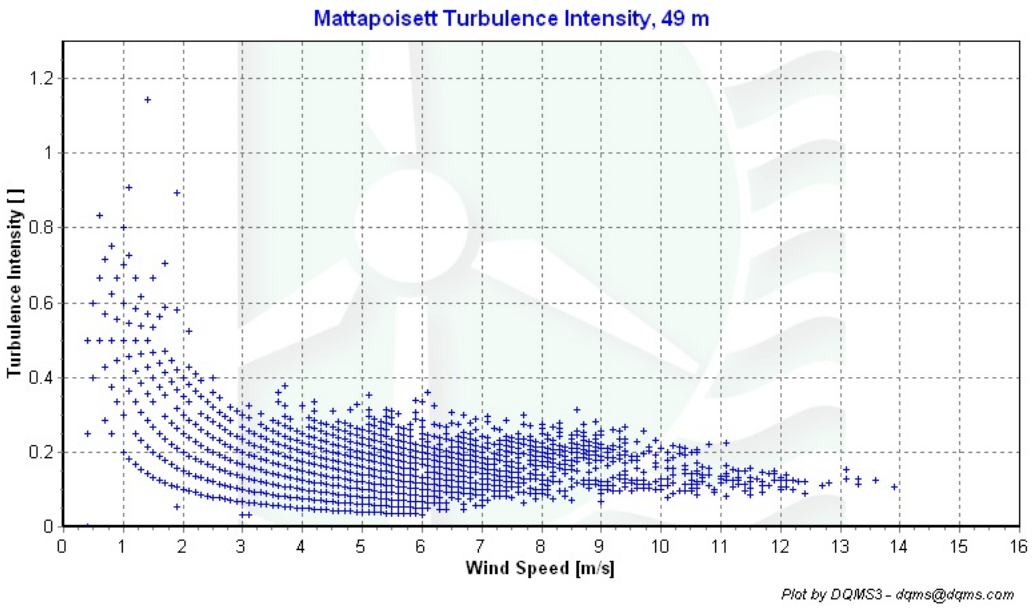

Figure 6 – Turbulence Intensity, September, 2006

Wind Roses

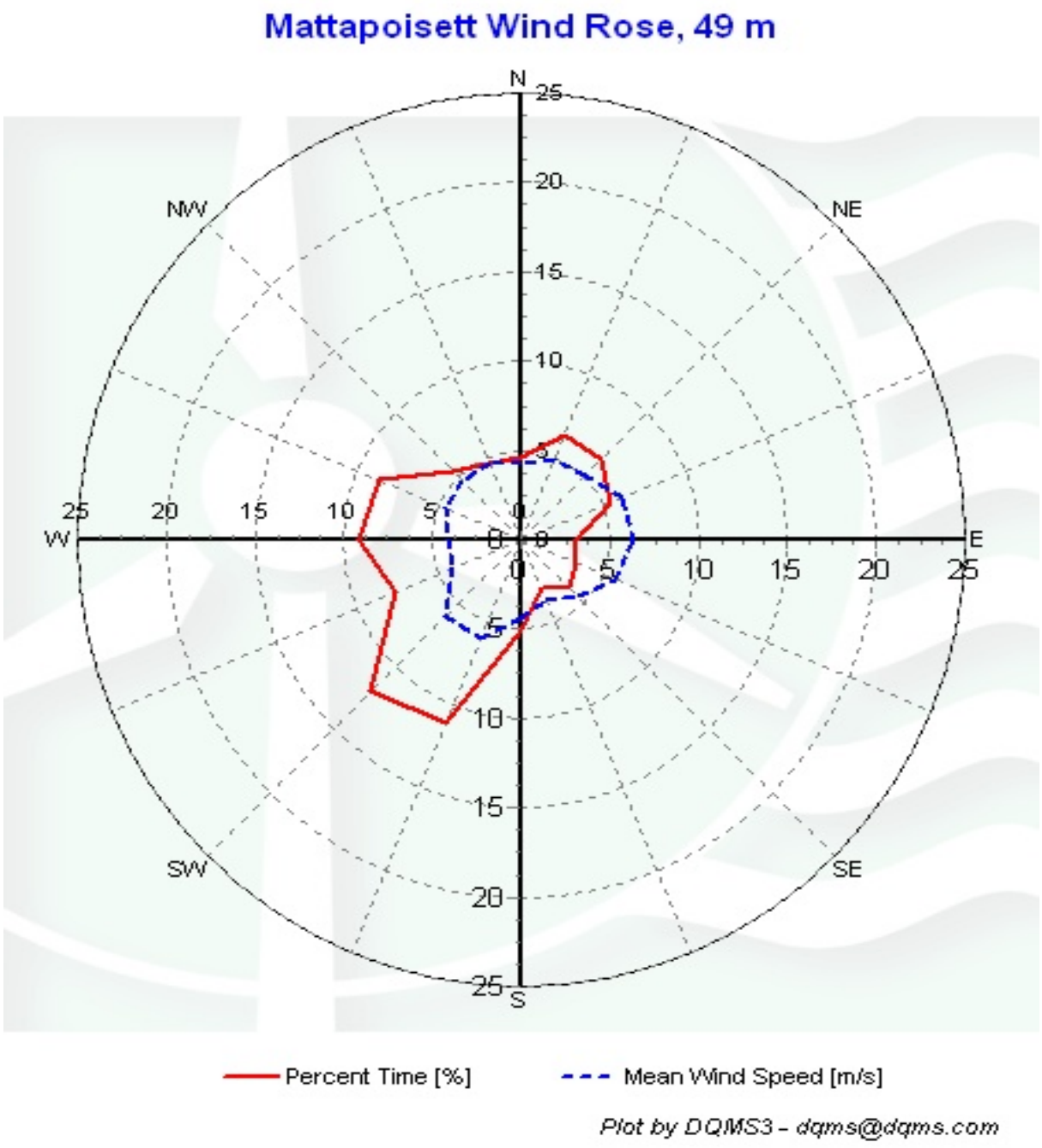

Figure 7 – Wind Rose, September, 2006

APPENDIX A - Sensor Performance Report

Test Definitions

TestOrder	TestField 1	TestField 2	TestField 3	CalcField 1	CalcField 2	CalcField 3	TestType	Factor1	Factor2	Factor3	Factor4
1							TimeTest Insert	0	0	0	0
2	Etmp2aD EGC						MinMax	-30	60	0	0
3	Etmx2aD EGC						MinMax	-30	60	0	0
4	Etmn2aD EGC						MinMax	-30	60	0	0
5	EtmpSD2 aDEGC						MinMax	-30	60	0	0
10	Anem50a MS						MinMax	0	90	0	0
11	Anem50b MS						MinMax	0	90	0	0
12	Anem38a MS						MinMax	0	90	0	0
13	Anem38b MS						MinMax	0	90	0	0
14	Anem20a MS						MinMax	0	90	0	0
20	AnemSD 50aMS						MinMax	0	4	0	0
21	AnemSD 50bMS						MinMax	0	4	0	0
22	AnemSD 38aMS						MinMax	0	4	0	0
23	AnemSD 38bMS						MinMax	0	4	0	0
24	AnemSD 20aMS						MinMax	0	4	0	0
30	Vane50a DEG						MinMax	0	359.9	0	0
31	Vane38a DEG						MinMax	0	359.9	0	0
32	Vane20a DEG						MinMax	0	359.9	0	0
50	Turb50zN ONE						MinMax	0	2	0	0
51	Turb38zN ONE						MinMax	0	2	0	0
52	Turb20zN ONE						MinMax	0	2	0	0
60	Wshr0zN ONE						MinMax	-100	100	0	0
200	VaneSD5 0aDEG	Anem50y MS					MinMaxT	0	100	100	10
201	VaneSD3 8aDEG	Anem38y MS					MinMaxT	0	100	100	10
202	VaneSD2 0aDEG	Anem20a MS					MinMaxT	0	100	100	10
300	Anem50a MS	AnemSD 50aMS	Vane50a DEG	VaneSD5 0aDEG	Etmp2aD EGC		Icing	0.5	1	2	10
301	Anem50b MS	AnemSD 50bMS	Vane50a DEG	VaneSD5 0aDEG	Etmp2aD EGC		Icing	0.5	1	2	10
302	Anem38a MS	AnemSD 38aMS	Vane38a DEG	VaneSD3 8aDEG	Etmp2aD EGC		Icing	0.5	1	2	10

303	Anem38bMS	AnemSD38bMS	Vane38aDEG	VaneSD38aDEG	Etmp2aDEGC		Icing	0.5	1	2	10
304	Anem20aMS	AnemSD20aMS	Vane20aDEG	VaneSD20aDEG	Etmp2aDEGC		Icing	0.5	1	2	10
400	Anem50aMS	Anem50bMS					CompareSensors	1	0.25	3	0
401	Anem38aMS	Anem38bMS					CompareSensors	1	0.25	3	0
500	Amax50aMS						MinMax	0	90	0	0
501	Amax50bMS						MinMax	0	90	0	0
502	Amax38aMS						MinMax	0	90	0	0
503	Amax38bMS						MinMax	0	90	0	0
504	Amax20aMS						MinMax	0	90	0	0
510	Amin50aMS						MinMax	0	90	0	0
511	Amin50bMS						MinMax	0	90	0	0
512	Amin38aMS						MinMax	0	90	0	0
513	Amin38bMS						MinMax	0	90	0	0
514	Amin20aMS						MinMax	0	90	0	0
520	Vmax50aDEG						MinMax	0	359.9	0	0
521	Vmax38aDEG						MinMax	0	359.9	0	0
522	Vmax20aDEG						MinMax	0	359.9	0	0
530	Vmin50aDEG						MinMax	0	359.9	0	0
531	Vmin38aDEG						MinMax	0	359.9	0	0
532	Vmin20aDEG						MinMax	0	359.9	0	0

Sensor Statistics

Sensors	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Anem50aMS	13105	4668	35.62	0	0	1.167	35.567
AnemSD50aMS	13105	4668	35.62	0	0	1.167	35.567
Anem50bMS	13105	4668	35.62	0	0	14.333	34.964
AnemSD50bMS	13105	4668	35.62	0	0	14.333	34.964
Anem50yMS	13105	4668	35.62	0	0	0	35.62
AnemSD50yMS	13105	4668	35.62	0	0	0	35.62
Anem38aMS	13105	4668	35.62	0	0	0.667	35.589
AnemSD38aMS	13105	4668	35.62	0	0	0.667	35.589
Anem38bMS	13105	4668	35.62	0	0	0.333	35.605
AnemSD38bMS	13105	4668	35.62	0	0	0.333	35.605
Anem38yMS	13105	4668	35.62	0	0	0	35.62
AnemSD38yMS	13105	4668	35.62	0	0	0	35.62
Anem20aMS	13105	4668	35.62	0	0	0	35.62
AnemSD20aMS	13105	4668	35.62	0	0	0	35.62
Vane50aDEG	13105	4668	35.62	0	0	0	35.62
VaneSD50aDEG	13105	4668	35.62	0	0	0	35.62
Vane38aDEG	13105	4668	35.62	0	0	0	35.62
VaneSD38aDEG	13105	4668	35.62	0	0	0	35.62
Vane20aDEG	13105	4668	35.62	0.5	0	0	35.597
VaneSD20aDEG	13105	4668	35.62	0.5	0	0	35.597
Etmp2aDEGC	13105	4668	35.62	0	0	0	35.62
EtmpSD2aDEGC	13105	4668	35.62	0	0	0	35.62
Total	**288310**	**102696**	**35.62**	**1**	**0**	**33**	**35.549**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	2.59
1.5	3.84
2.5	7.75
3.5	16.16
4.5	21.04
5.5	21
6.5	12.27
7.5	6.23
8.5	4
9.5	2.36
10.5	1.34
11.5	0.93
12.5	0.35
13.5	0.14
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

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]
Feb-06	6.78
Mar-06	5.66
April-06	--
May-06	5.62
June-06	5.42
July-06	5.50
Aug-06	4.84
Sept-06	5.02

Table 2 - Wind Speed Averages, 49m

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0.5	4.55
1.5	4.76
2.5	4.75
3.5	4.54
4.5	4.74
5.5	4.68
6.5	4.66
7.5	4.65
8.5	4.84
9.5	5.03
10.5	5.28
11.5	5.64
12.5	5.99
13.5	5.99
14.5	6.03
15.5	5.64
16.5	5.35
17.5	5.15
18.5	5.00
19.5	4.88
20.5	4.67
21.5	4.48
22.5	4.52
23.5	4.68

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%], 49 m	Mean Wind Speed [m/s], 49 m
N	4.63	4.24
NNE	6.37	4.87
NE	6.44	5.12
ENE	5.44	6.12
E	3.1	6.29
ESE	3.36	5.76
SE	3.84	4.52
SSE	2.99	3.64
S	5.07	4.42
SSW	11.13	5.93
SW	12.01	6.01
WSW	7.69	4.18
W	9.14	4.17
WNW	8.7	4.63
NW	5.42	4.65
NNW	4.68	4.68

Table 4 - Wind Rose, Time Percentage and Mean Wind Speed by Direction