

WIND DATA REPORT

Quincy, Quarry Hills

9/1/2006 – 11/30/2006

Prepared for

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NOTICE AND ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

Notice and Acknowledgements	1
Table of Contents	2
Table of Figures	3
Executive Summary	4
SECTION 1 - Station Location	5
SECTION 2 - Instrumentation and Equipment	6
SECTION 3 - Data Collection and Maintenance	6
SECTION 4 - Significant Meteorological Events	7
SECTION 5 - Data Recovery and Validation	7
Sensor Positions	7
Tower Effects on Measured Wind Speed	7
Data Validation	9
Test Definitions	9
Sensor Statistics	10
SECTION 6 - Data Summary	11
SECTION 7 - Graphs	11
Wind Speed Time Series	12
Wind Speed Distributions	13
Monthly Average Wind Speeds	13
Diurnal Average Wind Speeds	14
Turbulence Intensities	14
Wind Roses	15
APPENDIX A - Sensor Performance Report	16
Test Definitions	16
Sensor Statistics	16
APPENDIX B - Plot Data	18
Wind Speed Distribution Data	18
Monthly Average Wind Speed Data	18
Diurnal Average Wind Speed Data	19
Wind Rose Data	19

TABLE OF FIGURES

Figure 1 - Map showing the location of the Quincy Quarry Hills site	5
Figure 2 - Sensor Positions	7
Figure 3 - Difference in measured wind speeds.....	8
Figure 4 – Wind Speed Time Series September 2006 – November 2006	12
Figure 5 – Wind Speed Distribution September 2006 – November 2006	13
Figure 6 – Monthly Average Wind Speeds September 2006 – November 2006.....	13
Figure 7 – Diurnal Average Wind Speeds September 2006 – November 2006	14
Figure 8 – Turbulence Intensities September 2006 – November 2006	14
Figure 9 – Wind Roses September 2006 – November 2006.....	15

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.

The sensors at the Quincy Quarry Hills site were installed on August 10th 2006, and have been in continuous operation until the present. The data are from two anemometers and one wind vane at each of 101 meters (330 ft) and 67 meters (220 feet). These sensors are mounted on a triangular lattice tower, and were installed by the tower owner in a position different from that given in the instructions from the RERL. The proximity of the sensors to the tower is a source of some uncertainty in wind speed measurements, as the wind speed close to a lattice tower is affected significantly by the tower's presence.

This report covers wind data collected at the Quincy Quarry Hills Site from September 2006 through November 2006. During the months of September, October and November, 2006, the average wind speed measured at 101 meters was 6.86 m/s (15.35mph)¹ and the prevailing wind was from the west. The gross data recovery percentage (the actual percentage of expected data received) was 100% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 99.94%.

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 1 m/s = 2.237mph

SECTION 1 - Station Location

The Quincy Quarry Hills Site is Located near the Granite Links Golf Club in Quincy, Massachusetts, off Ricciuti Drive. The tower stands at 42.2470° north and 71.0483° west, corresponding to the WGS 84 datum. The tower base is at an elevation of 50 meters above sea level.

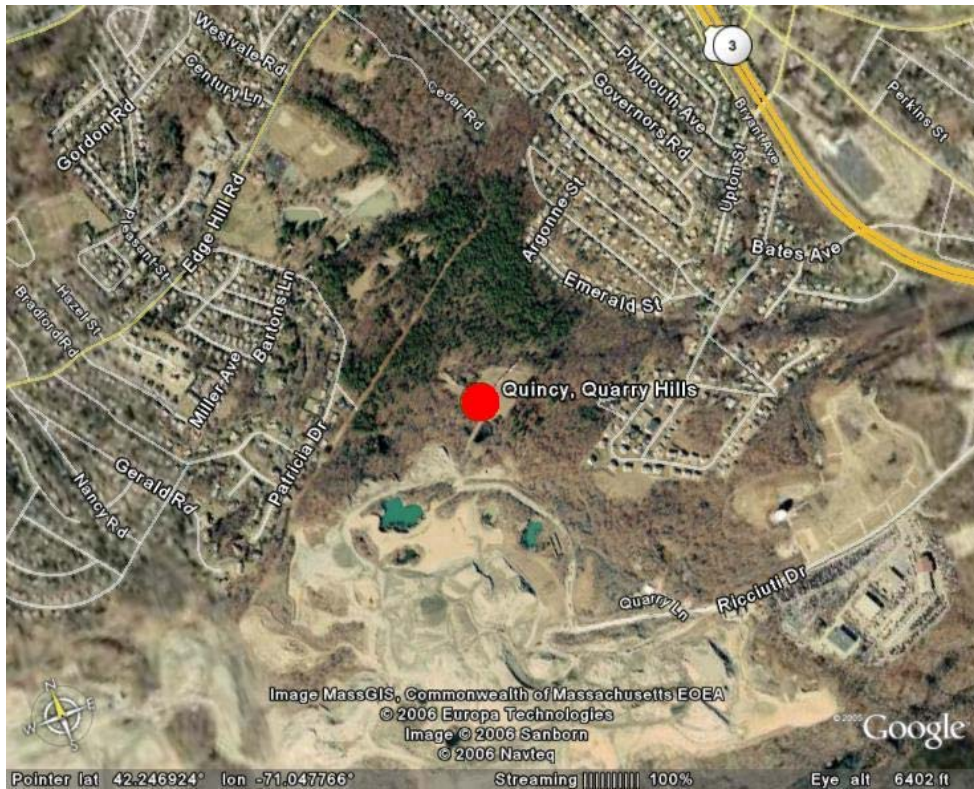


Figure 1 - Map showing the location of the Quincy Quarry Hills site

SECTION 2 - Instrumentation and Equipment

The Monitoring equipment at Quincy Quarry Hills is mounted on an existing triangular lattice tower owned by Industrial Communications. This equipment includes:

- Symphonie Data Logger
- Electrical enclosure box
- 4 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s). Two anemometers are located at 101 m (330 ft) and two at 67 m (220 ft).
- 2 - #200P Wind direction vanes. They are located at heights of 101m (330 ft.) and 67m (220 ft.).
- Shielded sensor wire

These sensor heights are approximate.

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

There were no notable interruptions in data during the period of this report and no maintenance operations were undertaken. However, because of the incorrect sensor installation (see Section 5 for details), plans are being made to remount the sensors in the next quarter.

Data Summary

Date	Mean Wind Speed	MaxWind Speed	Turbulence Intensity	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Turbulence Intensity	Prevailing Wind Direction	Wind Shear Coeff.
Height Units	101 m [m/s]	101 m [m/s]	101 m []	101 m [deg]	67 m [m/s]	67 m [m/s]	67 m []	67 m [deg]	Calc. B/t 101m & 67m
Sep-06	6.41	15.09	0.15	West	5.61	14.09	0.16	West	0.44
Oct-06	7.69	20.84	0.15	West	6.71	19.07	0.17	West	0.5
Nov-06	6.48	17.37	0.16	West	5.57	14.2	0.18	West	0.57
Sep '06 – Nov '06	6.86	20.84	0.15	West	5.96	19.07	0.17	West	0.5

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 $\pm 2\%$ or ± 0.2 m/s.

SECTION 4 - Significant Meteorological Events

There were no meteorological events, during the period from September through November, 2006, in Quincy, significant enough to affect monthly averages.

SECTION 5 - Data Recovery and Validation

Sensor Positions

The Quincy, Quarry Hills site has two anemometers and one wind vane at each of two heights: approximately 67 and 101 meters. These instruments are mounted north and south of the triangular lattice tower. The sensors mounted north of the tower are referred to as the A sensors, while those to the south are referred to as B sensors.

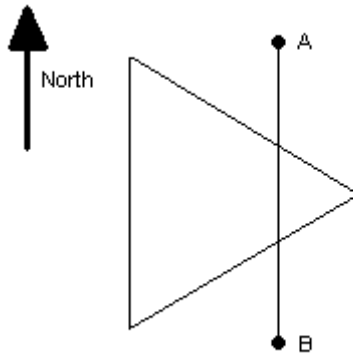


Figure 2 - Sensor Positions

Tower Effects on Measured Wind Speed

Since the sensors are mounted less than one tower-width from the tower (that is, the distance from the tower to the sensors is less than width of the tower), aerodynamic effects of the tower have a significant effect on the measured wind speeds. The measured wind speeds will be lower than free-stream velocity when an anemometer is in the wind shadow of the tower, and can be high when it is in an area where wind is accelerating around the tower.

Both of these effects and their magnitudes can be seen in the following graph for the difference in measured wind speeds between the A and B anemometers at 101 meters plotted against the measured wind direction.

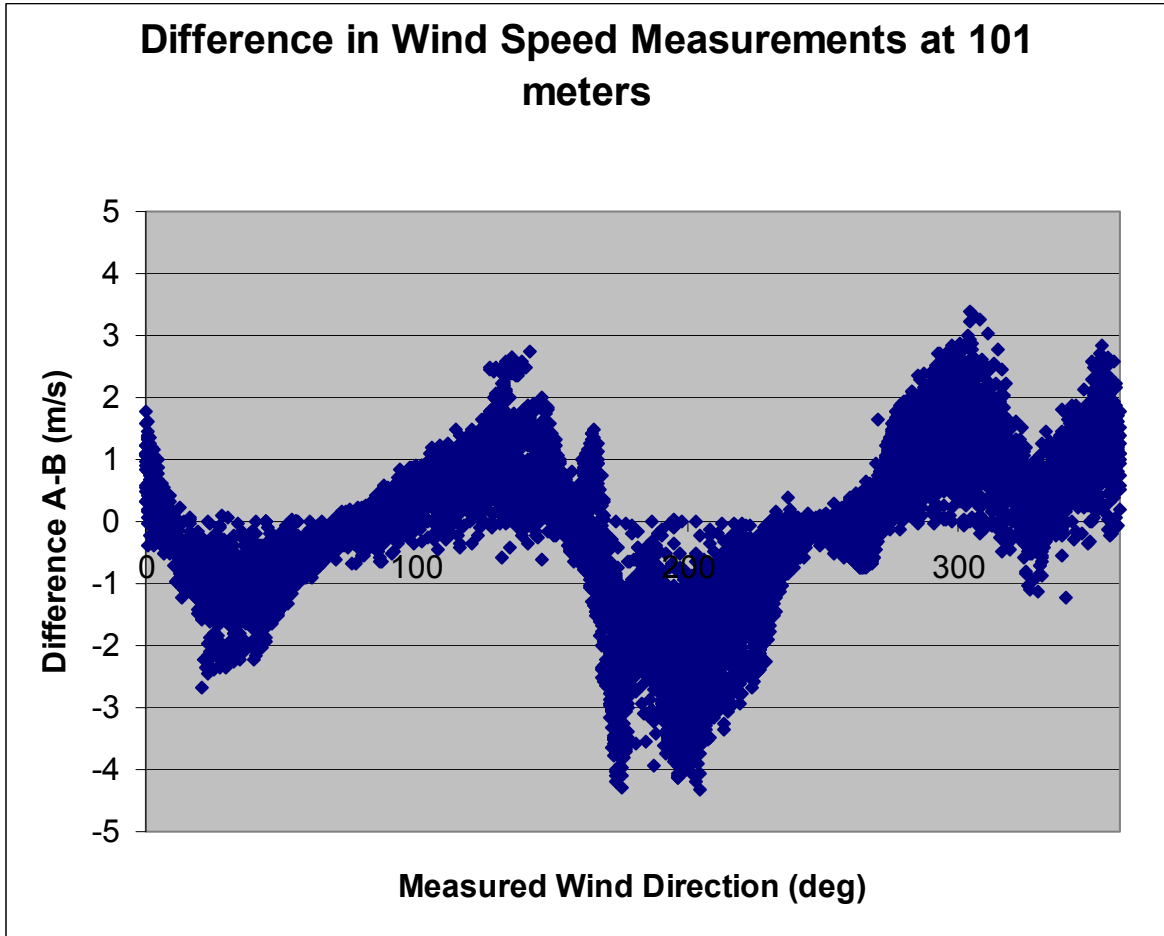


Figure 3 - Difference in measured wind speeds

A positive speed on this graph indicates a wind direction for which the A anemometer reads higher than the B anemometer. A negative speed indicates a direction for which the B anemometer reads higher. These discrepancies are due to a combination of the slow down in wind speed down wind of the tower and the speed up that can occur to either side.

With a tubular tower, and sensors placed far from it, it is preferable to choose the data from the anemometer that is reading higher, when two instruments disagree. An instrument in the tower shadow read significantly lower than the actual wind speed. Other speed-up and slow-down effects are generally minor and contribute to the uncertainty. This is the method that was also used in analyzing data from the Quincy Quarry Hills site as well, since it is the most effective method available with the information at our disposal. In the case of data from this tower, the wind speeds selected

by this method may be as much as 2 meters per second above the actual wind speed. Westerly wind directions could put both anemometers in the tower shadow, leading to readings notably below the actual wind speed.

Data 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 [%]	99.944

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.

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

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.

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

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. 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. There are two maxima of over 20 meters per second, in the second half of October. These data are presented in Figure 4.
- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. Wind speeds between 7 and 8 m/s are most common at this site occurring about 14% of the time. These data are presented in Figure 5.
- Monthly Average – A plot of the monthly average wind speed over a 3-month period. This graph shows the trends in the wind speed over the quarter. The month of October was appreciably windier than either September or November. These data are presented in Figure 6.
- Diurnal – A plot of the average wind speed for each hour of the day. On average, It was windiest between 8 pm and 6 am. These data are presented in Figure 7.
- 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. Turbulence intensities generally range from 0.1 to 0.4. The average turbulence intensity during this period was 0.16 at 101 meters. These data are presented in Figure 8.
- 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. This wind rose shows the prevailing wind direction to be west during this period. These data are presented in Figure 9.

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

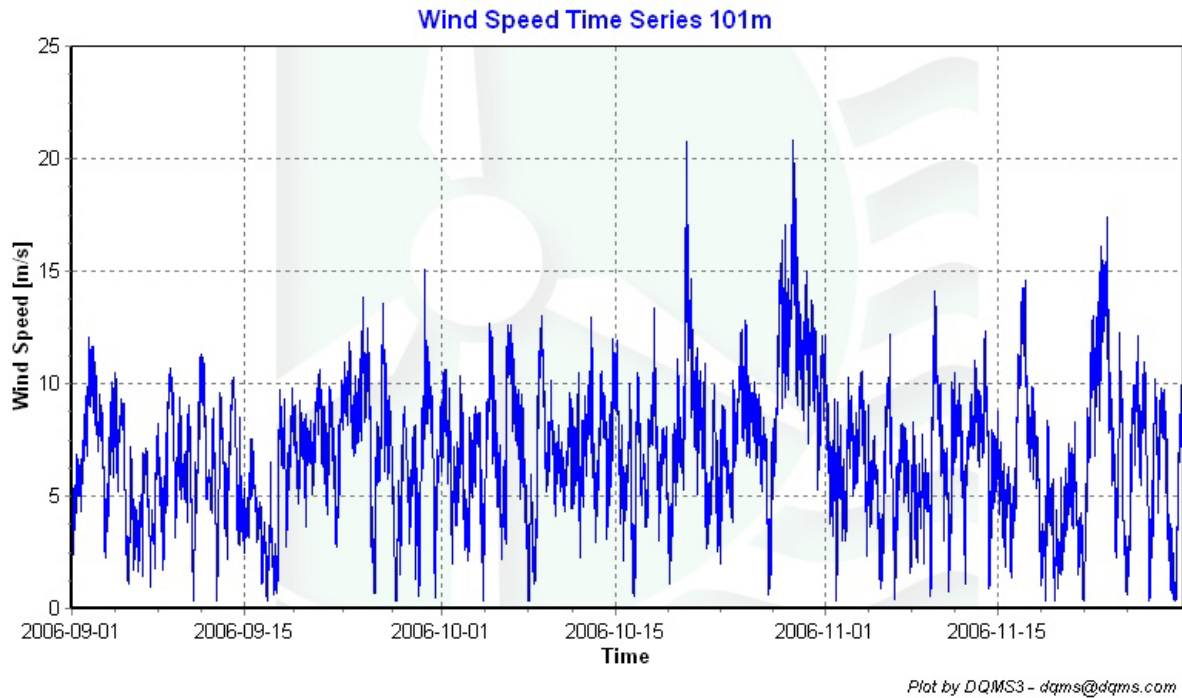


Figure 4 – Wind Speed Time Series September 2006 – November 2006

Wind Speed Distributions

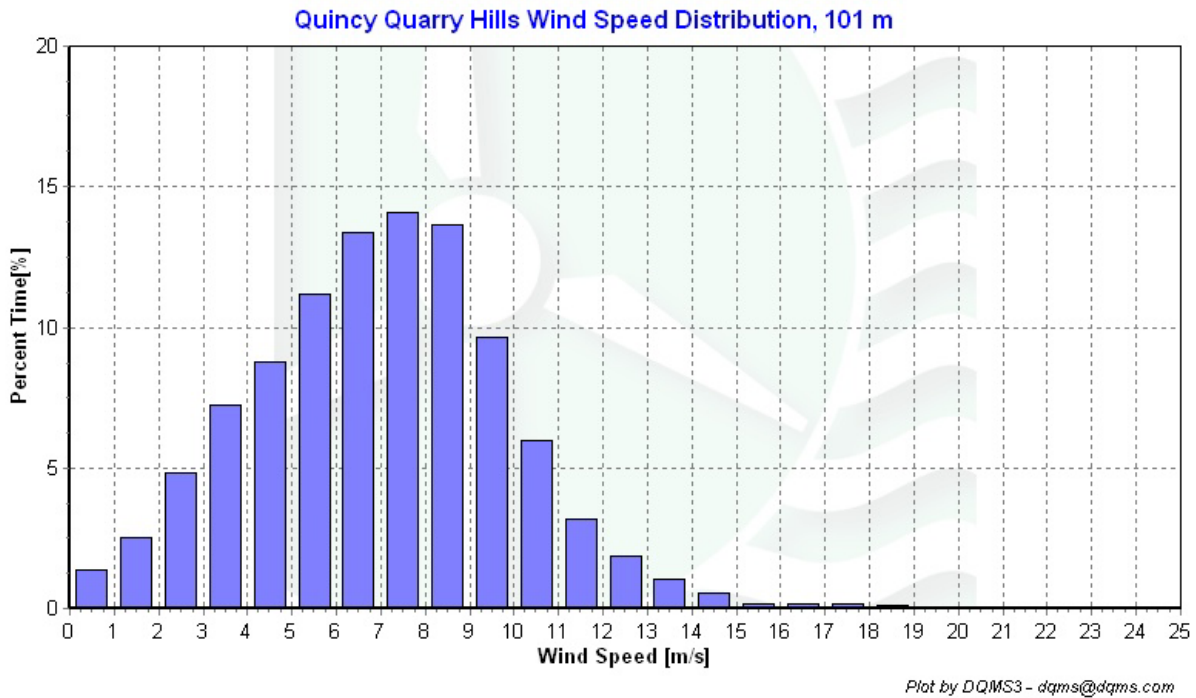


Figure 5 – Wind Speed Distribution September 2006 – November 2006

Monthly Average Wind Speeds

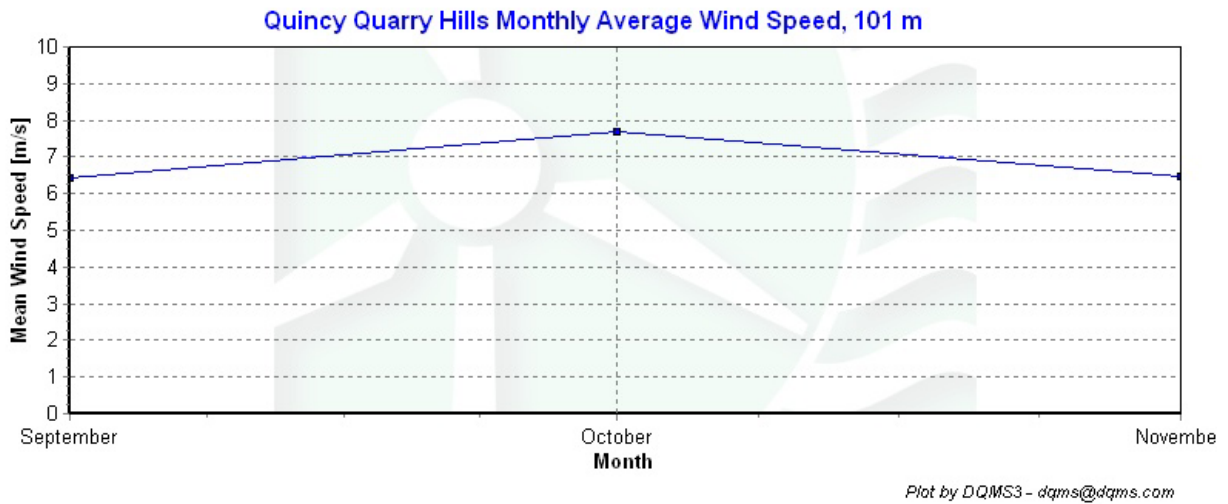


Figure 6 – Monthly Average Wind Speeds September 2006 – November 2006

Diurnal Average Wind Speeds

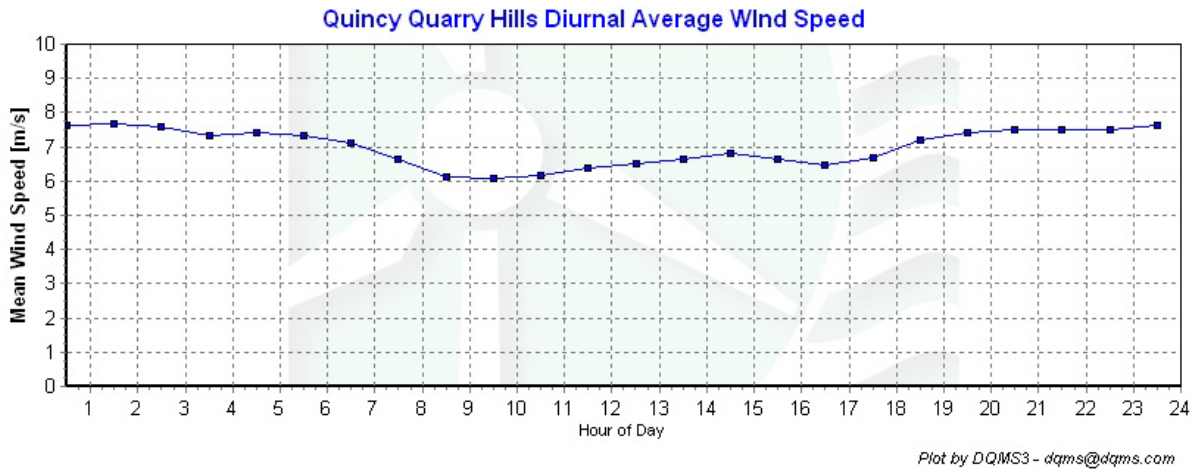


Figure 7 – Diurnal Average Wind Speeds September 2006 – November 2006

Turbulence Intensities

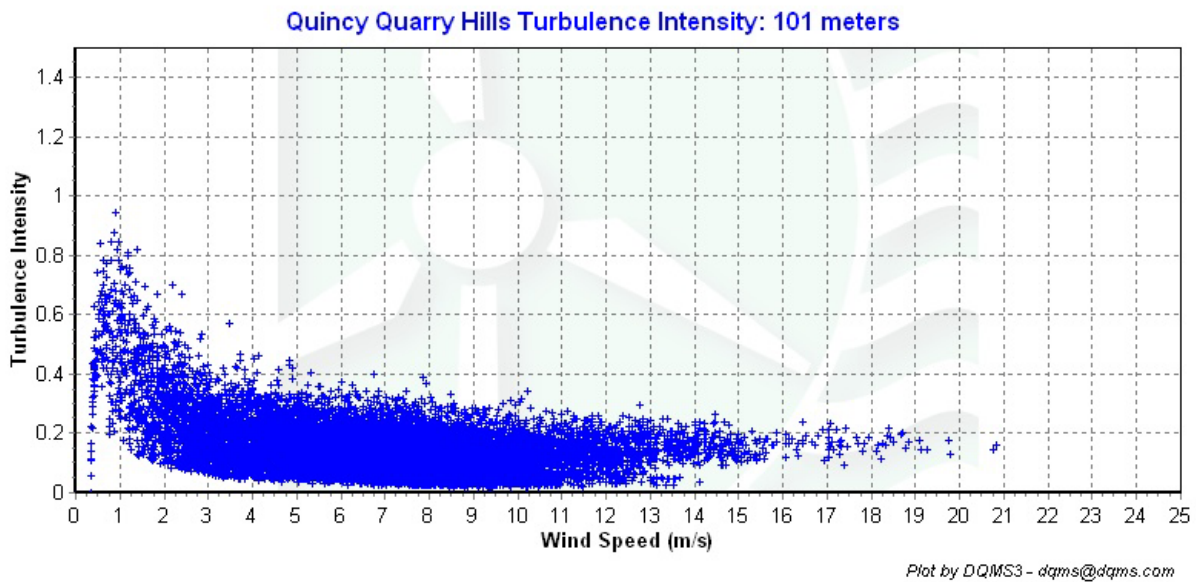
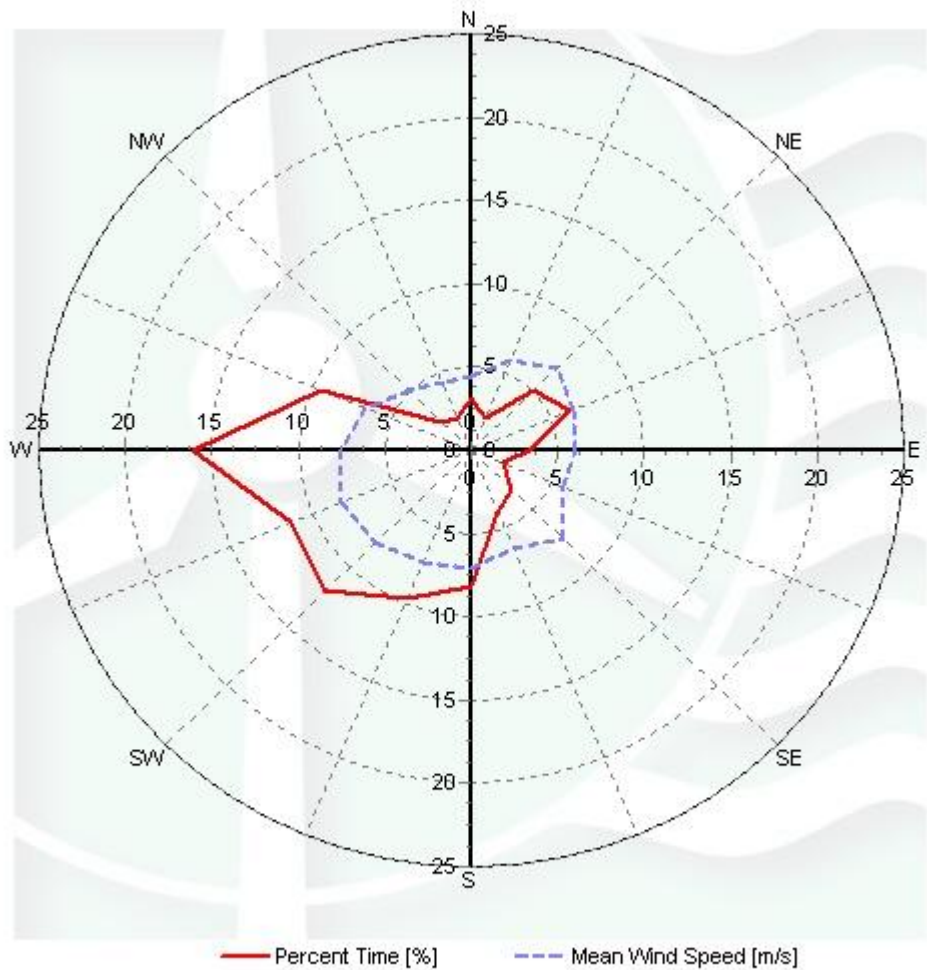


Figure 8 – Turbulence Intensities September 2006 – November 2006

Wind Roses

Quincy Quarry Hills Wind Rose, 101 m



Plot by DQMS3 - dqms@dqms.com

Figure 9 – Wind Roses September 2006 – November 2006

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	TestField3	CalcField1	CalcField2	CalcField3	TestType	Factor 1	Factor 2	Factor 3	Factor 4
1							TimeTest Insert				
4	Etmp2aDEGC						MinMax	-30	60		
5	EtmpSD2aDEGC						MinMax	-30	60		
10	Anem101aMS						MinMax	0	90		
11	Anem101bMS						MinMax	0	90		
12	Anem67aMS						MinMax	0	90		
13	Anem67bMS						MinMax	0	90		
20	AnemSD101aMS						MinMax	0	4		
21	AnemSD101bMS						MinMax	0	4		
22	AnemSD67aMS						MinMax	0	4		
23	AnemSD67bMS						MinMax	0	4		
30	Vane101aDEG						MinMax	0	359.9		
31	Vane67aDEG						MinMax	0	359.9		
50	Turb101zNONE						MinMax	0	2	0	0
51	Turb67zNONE						MinMax	0	2	0	0
60	Wshr0zNONE						MinMax	-100	100	0	0
70	Pwr101zWMS						MinMax	0	5000	0	0
71	Pwr67zWMS						MinMax	0	5000	0	0
200	VaneSD101aDEG	Anem101yMS					MinMaxT	0	100	100	10
201	VaneSD67aDEG	Anem67yMS					MinMaxDay	0	100	100	10
300	Anem101aMS	AnemSD101aMS	Vane101aDEG	VaneSD101aDEG	Etmp2aDEGC		Icing	0.5	1	2	
301	Anem101bMS	AnemSD101bMS	Vane101aDEG	VaneSD101aDEG	Etmp2aDEGC		Icing	0.5	1	2	
302	Anem67aMS	AnemSD67aMS	Vane67aDEG	VaneSD67aDEG	Etmp2aDEGC		Icing	0.5	1	2	
303	Anem67bMS	AnemSD67bMS	Vane67aDEG	VaneSD67aDEG	Etmp2aDEGC		Icing	0.5	1	2	

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	% Data Good
Etmp2aDEGC	13032	13032	100	0	0	100
EtmpSD2aDEGC	13032	13032	100	0	0	100
Anem101aMS	13032	13032	100	0.333	0.5	99.962
AnemSD101aMS	13032	13032	100	0.333	0.5	99.962
Anem101bMS	13032	13032	100	0.333	0.667	99.954
Anem67aMS	13032	13032	100	0.333	1.5	99.916
AnemSD67aMS	13032	13032	100	0.333	1.5	99.916

Anem67bMS	13032	13032	100	0.333	2	99.893
Vane101aDEG	13032	13032	100	0.167	0.667	99.962
VaneSD101aDEG	13032	13032	100	0.167	0.667	99.962
Vane67aDEG	13032	13032	100	0.167	2	99.9
VaneSD67aDEG	13032	13032	100	0.167	2	99.9
Anem101yMS	13032	13032	100	0.333	0.5	99.962
Anem67yMS	13032	13032	100	0	1.5	99.931
Total	182448	182448	100	3	14	99.944

APPENDIX B - Plot Data

Wind Speed Distribution Data

Wind Speed [m/s]	Percent [%]
0.5	1.39
1.5	2.5
2.5	4.82
3.5	7.26
4.5	8.78
5.5	11.2
6.5	13.35
7.5	14.09
8.5	13.62
9.5	9.66
10.5	5.95
11.5	3.17
12.5	1.88
13.5	1.02
14.5	0.56
15.5	0.19
16.5	0.16
17.5	0.19
18.5	0.13
19.5	0.06
20.5	0.02
21.5	0
22.5	0
23.5	0
24.5	0

Monthly Average Wind Speed Data

Date	Mean Wind Speed [m/s]
Sep-06	6.41
Oct-06	7.69
Nov-06	6.48

Diurnal Average Wind Speed Data

Hour of Day	Wind Speed [m/s]
0.5	7.64
1.5	7.66
2.5	7.6
3.5	7.34
4.5	7.41
5.5	7.32
6.5	7.11
7.5	6.66
8.5	6.1
9.5	6.06
10.5	6.17
11.5	6.39
12.5	6.51
13.5	6.65
14.5	6.8
15.5	6.63
16.5	6.48
17.5	6.67
18.5	7.18
19.5	7.39
20.5	7.49
21.5	7.52
22.5	7.48
23.5	7.62

Wind Rose Data

Wind Direction (deg)	Mean Wind Speed [m/s]	Percent of time [%]
0	4.48	3.12
22.5	5.82	2.05
45	7.04	5.03
67.5	6.34	6.17
90	5.97	3.35
112.5	5.7	2.02
135	7.51	3.33
157.5	6.37	3.99
180	7.07	8.21

202.5	7.28	9.61
225	7.86	11.89
247.5	8.1	11.3
270	7.51	16.09
292.5	6.62	9.35
315	5.14	2.42
337.5	4.38	2.07