WIND DATA REPORT

Ipswich

December 1,2003 – February 29,2004

Prepared for

Town of Ipswich
Massachusetts

by

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April 15, 2004

Report template version 1.1

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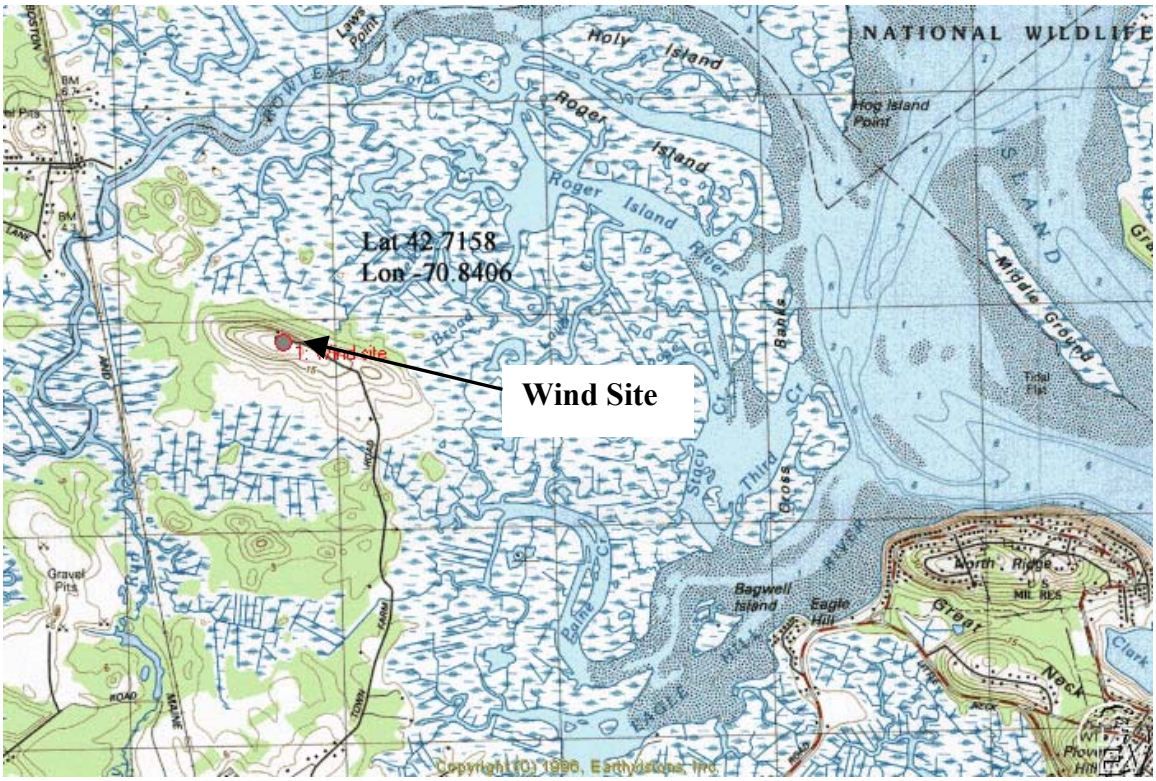
EXECUTIVE SUMMARY

Wind monitoring at Ipswich commenced on July 7, 2003. Wind speed and direction monitoring are being done at three heights 39m, 30m and 10m. This report is for the quarter from December 2003 through February 2004. Data collection for the period has been good with 97.2% of the data points passing the quality assurance controls. This is lower than the data collection from the previous quarter of 99.9%, due primarily to icing of the sensors. Average wind speed for the winter quarter is 5.99 m/s at 39m with NNW being the predominant wind direction. An increase in wind speed is observed as we move from fall to winter. For the fall quarter, average wind speed was observed to be 4.58 m/s.

SECTION 1 - Station Location

Ipswich, is one of the oldest towns in the United States, located on the North Shore of Massachusetts, approximately 28 miles north of Boston. The town is 33 square miles and has a landscape that includes marshes, dunes and beaches, upland, forests, fields, and farmland [1]. The monitoring tower is installed at the town transfer station (old landfill) on a small hill with salt marshes to the west and some trees to the north. The site is located at 42°42'58''N and 70°50'30''W. The figure below shows the site location.



SECTION 2 - Instrumentation and Equipment

The monitoring at the site is being done at three heights, 39m, 30m and 10m. The table below gives the description of the sensors and data collection equipment along with the number installed.

Description	39 m	30 m	10 m	Base
Maximum #40 Anemometer	2	2	1	-
NRG 200P Wind Vane	1	1	1	-
NRG 11Stemperature Sensor	-	-	-	1
Datalogger Type: 9300 Cellogger	-	-	-	1

SECTION 3 - Data Collection and Maintenance

Data collection during this period was good, with the redundant wind speed sensor installed to cover for the primary ones if they failed. The data is summarized below.

Date	Mean Wind Speed [m/s]	Max Wind Speed [m/s]	Turbulence Intensity [ ]	Prevailing Wind Direction [ ]
Dec 2003	6.76	22.26	0.18	NNW
Jan 2004	5.81	15.43	0.21	NNW
Feb 2004	5.35	14.03	0.19	NNW
Dec 03 – Feb 04	**5.99**	**22.26**	**0.19**	**NNW**

SECTION 4 - Significant Meteorological Events

There was one significant meteorological event during this period. A major winter storm brought heavy snow and strong winds to Southern New England on December 5 and 6, dumping 1 to 3 feet of snow. A peak gust of 26 m/s was reported at Provincetown during the height of the storm. At the Ipswich site, average wind speeds over 20 m/s were recorded.

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 [%]	99.983
Net Data Recovered [%]	97.169

Test Definitions

All raw data were subjected to a series of validation tests, as described below. The sensors tested and the parameters specific for 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.

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

Icing Test: An icing event is 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, the wind speed (TF1) is greater than Factor 2, and the temperature (CF2) is less than Factor 3.

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

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.

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

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.
- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. The most likely wind speed for winter is between 5 and 6 m/s.
- Monthly Average – A plot of the monthly average wind speed over a 12-month period. This graph shows the trends in the wind speed from August 2003 to March 2004. The meteorological tower was installed in July, therefore the average for July is not plotted. The wind speed remains fairly uniform from August to September. There is a rise in wind speed thereafter, with a maximum wind speed reported for December of 6.76 m/s. This is similar to the trend observed throughout New England, with the highest wind speeds reported in

winter. January to March also sees fairly uniform wind speed between 5 and 6 m/s.

- Diurnal – A plot of the average wind speed for each hour of the day. For winter, the wind speed tends to peak in the middle of the day, with highest wind speeds for the day reported between 1:00 PM and 3:00 PM. Lowest wind speeds are reported during morning between 7:00 AM and 8:00 AM.

- 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 intensity is frequently in the range of 0.1 to 0.4. For this site turbulence intensity for the quarter 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. For winter most of the time wind is blowing from the NW – NNW direction. This is also true for most of the sites that UMass has monitored.

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

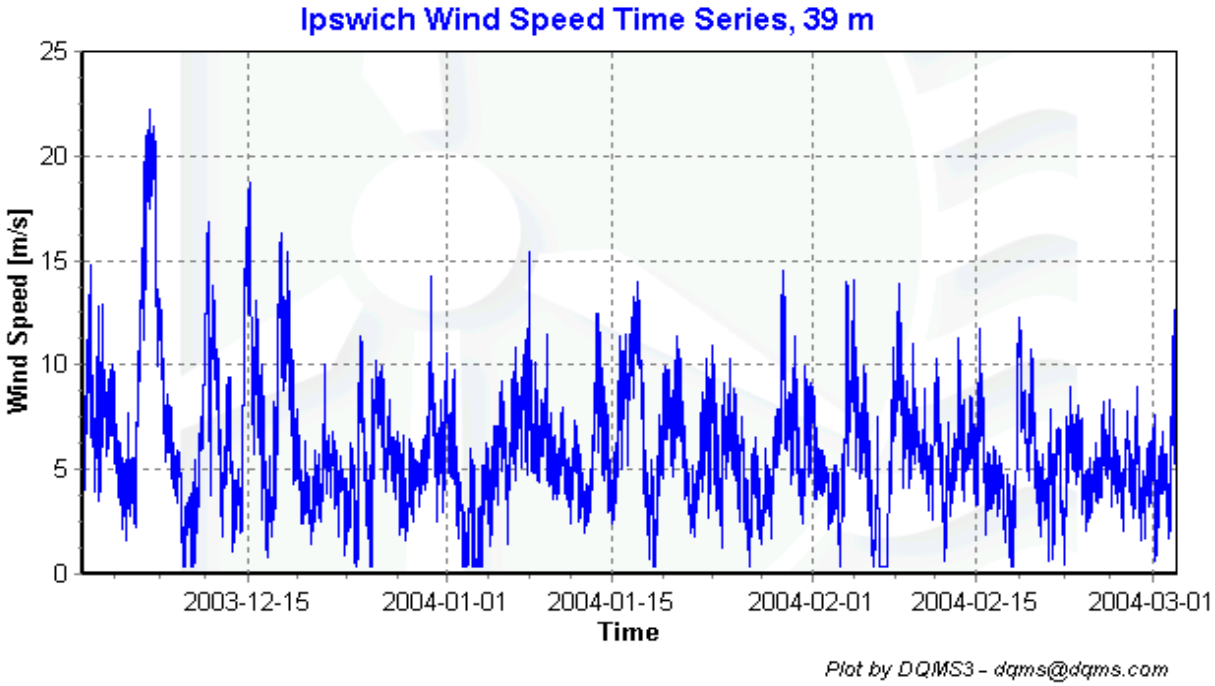


Figure 1 – Wind Speed Time Series, December 2003 – February 2004

Wind Speed Distributions

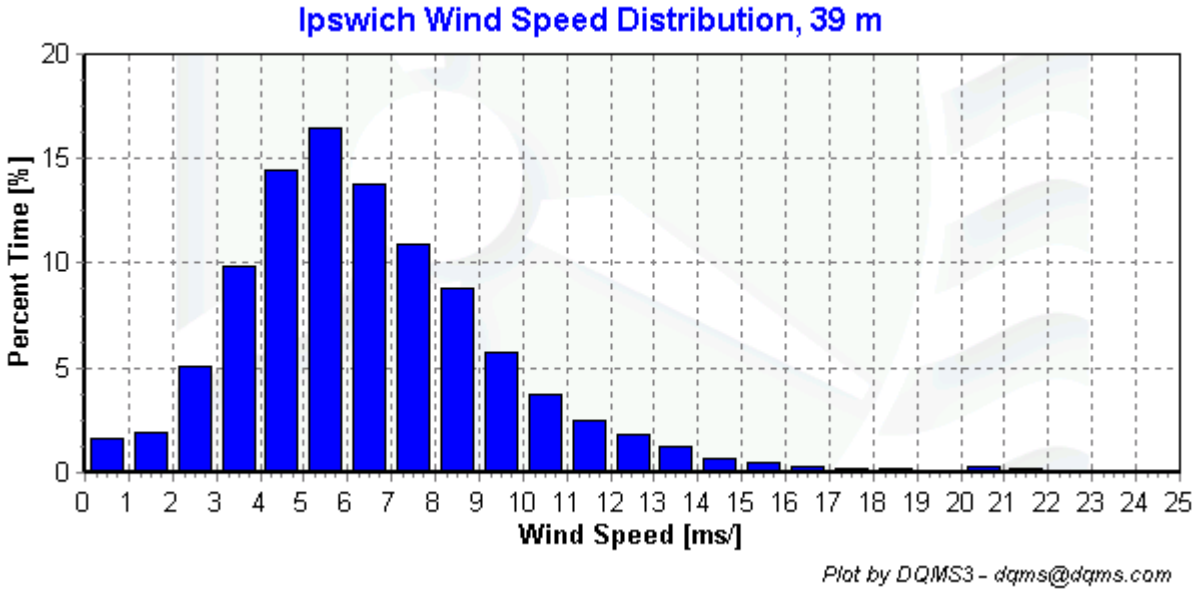


Figure 2 – Wind Speed Distribution, December 2003 – February 2004

Monthly Average Wind Speeds

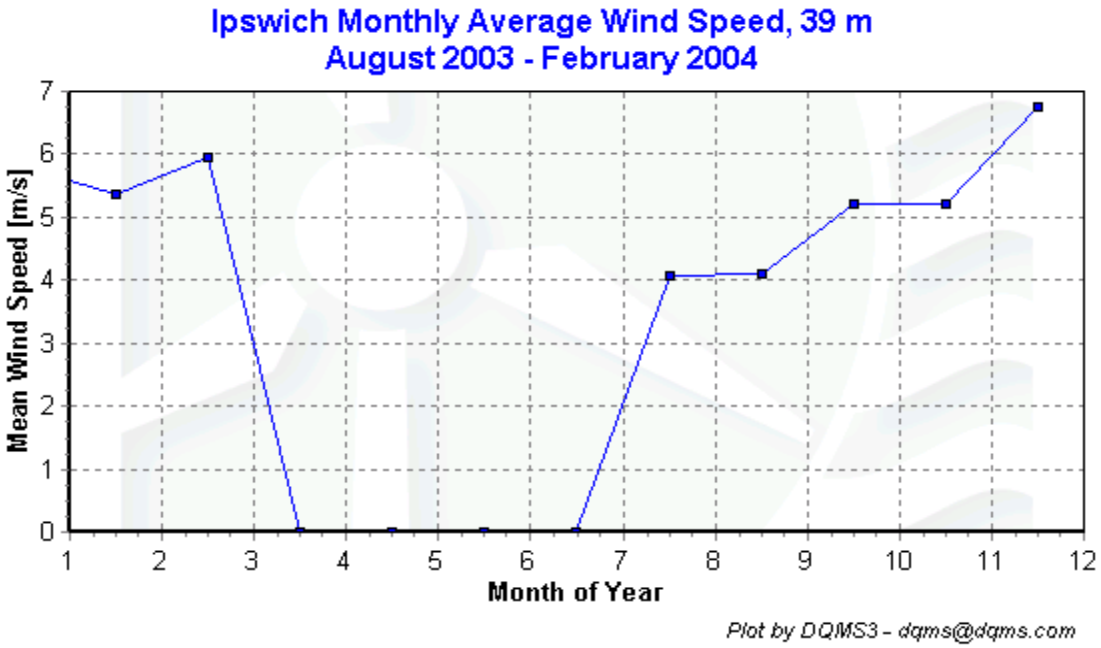


Figure 3 – Monthly Average Wind Speeds

Diurnal Average Wind Speeds

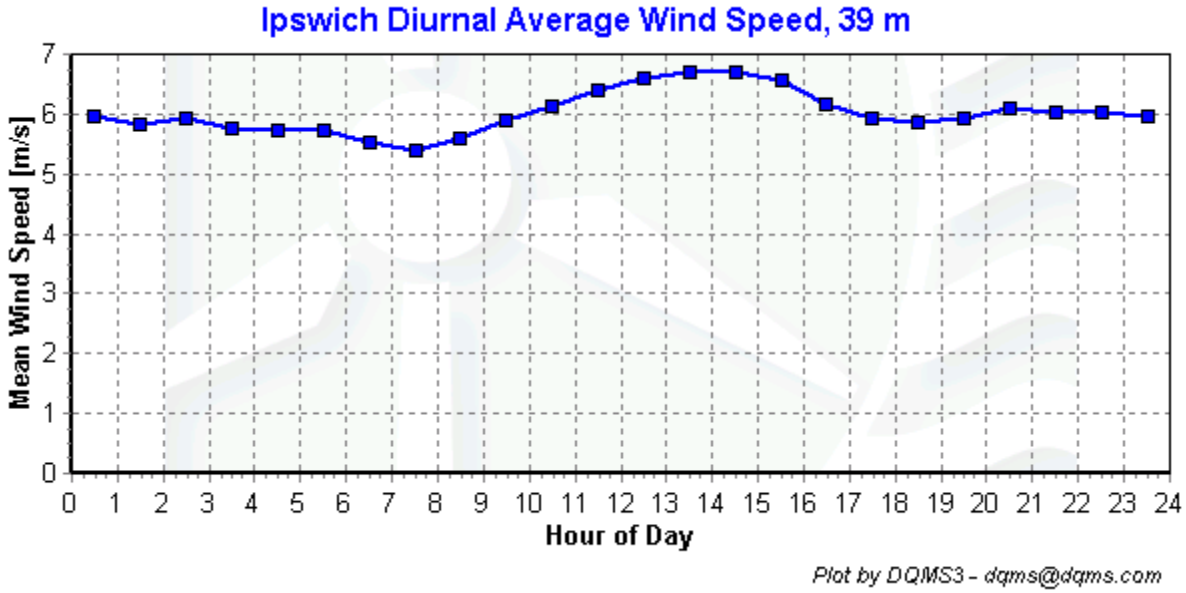


Figure 4 – Diurnal Wind Speed, December 2003 – February 2004

Turbulence Intensities

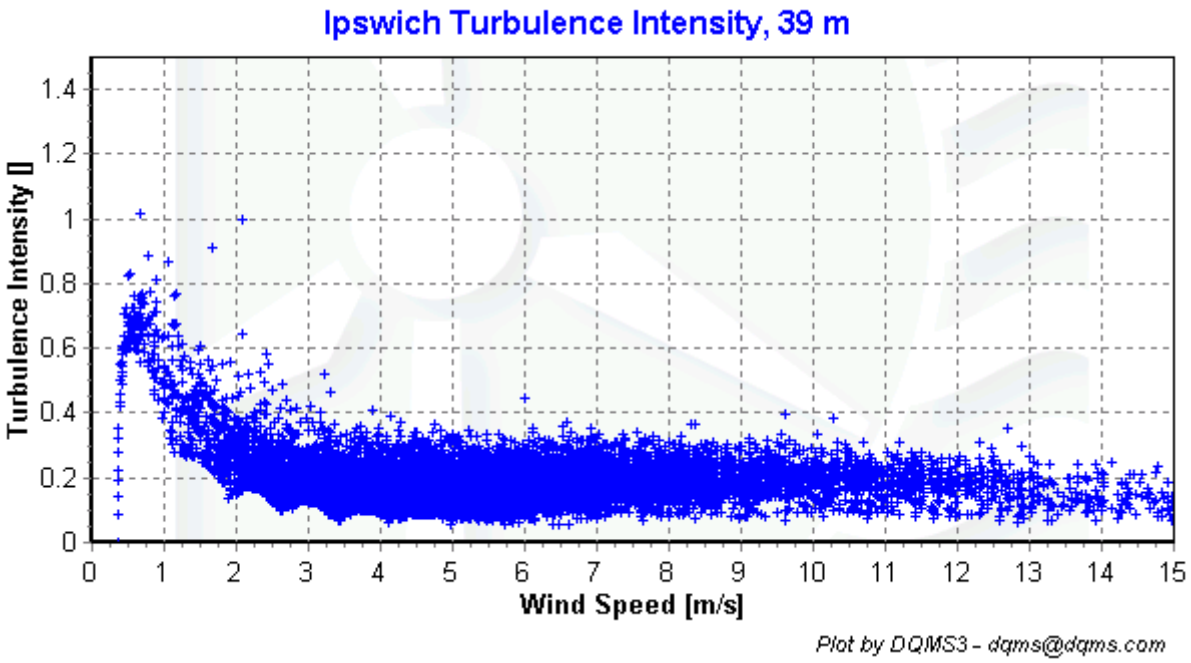


Figure 5 – Turbulence Intensity vs Wind Speed, December 2003 – February 2004

Wind Roses

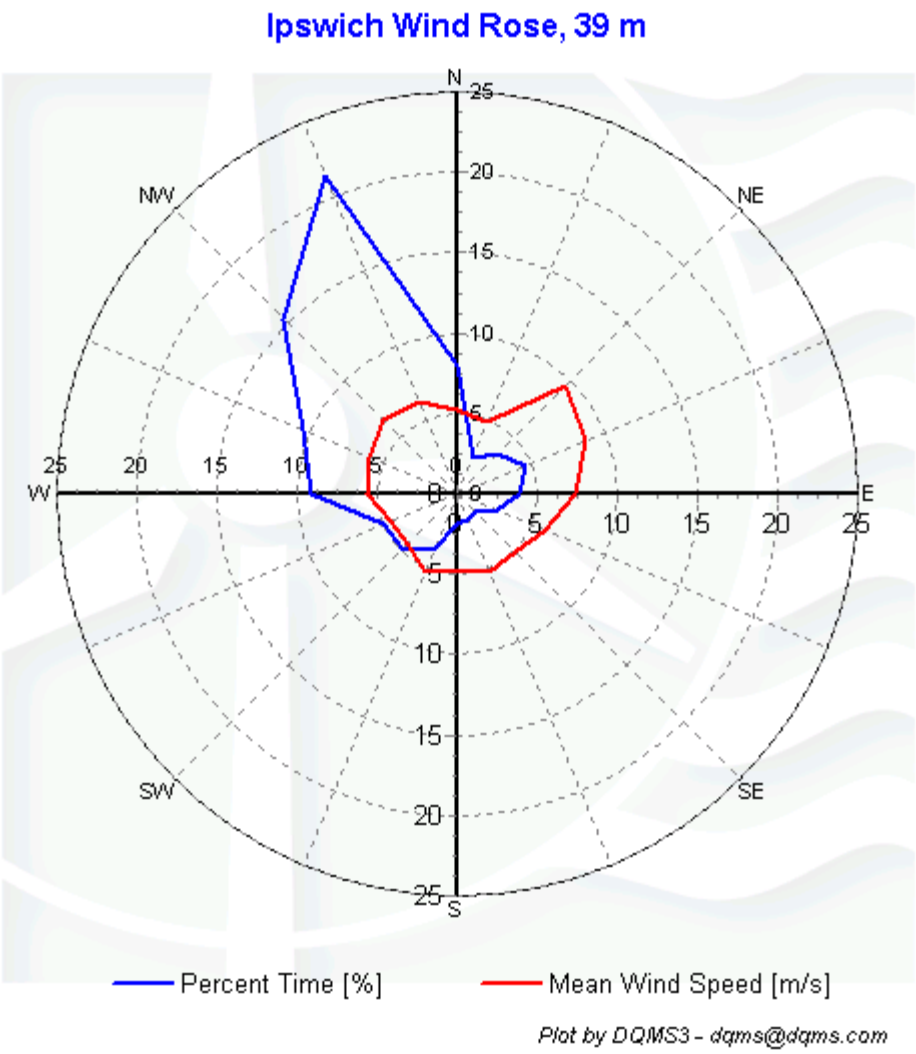


Figure 6 - Wind Rose, December 2003 – February 2004

APPENDIX A – Sensor Performance Report

Test Definitions

Test Order	Test Field1	Test Field2	Test Field3	Calc Field1	Calc Field2	Calc Field3	TestType	Factor 1	Factor 2	Factor 3	Factor 4
1							TimeTest Insert				
2	Itmp2aDEGC						MinMax	-30	60		
3	Batt2aVDC						MinMax	10.5	15		
10	Anem39aMS						MinMax	0	90		
11	Anem39bbMS						MinMax	0	90		
12	Anem30aMS						MinMax	0	90		
13	Anem30bMS						MinMax	0	90		
14	Anem10aMS						MinMax	0	90		
15	Anem39yMS						MinMax	0	90		
16	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	AnemSD10aMS						MinMax	0	4		
25	AnemSD39yMS						MiinMax	0	4		
26	AnemSD30yMS						MinMax	0	4		
30	Vane39aDEG						MiinMax	0	359.9		
31	Vane30aDEG						MinMax	0	359.9		
32	Vane10aDEG						MinMax	0	359.9		
50	Turb39zNONE						MinMax	0	2		
51	Turb30zNONE						MinMax	0	2		
52	Turb10zNONE						MinMax	0	2		
60	Wshr0zNONE						MinMax	-100	100		
200	VaneSD39aDEG	Anem39yMS					MinMaxT	0	100	100	10
201	VaneSD30aDEG	Anem30yMS					MinMaxT	0	100	100	10
202	VaneSD10aDEG	Anem10aMS					MinMaxT	0	100	100	10
300	Anem39aMS	AnemSD39aMS	Vane39aDEG	VaneSD39aDEG	Itmp2aDEGC		Icing	0.5	1	2	
301	Anem39bMS	AnemSD39bMS	Vane39aDEG	VaneSD39aDEG	Itmp2aDEGC		Icing	0.5	1	2	
302	Anem30aMS	AnemSD30aMS	Vane30aDEG	VaneSD30aDEG	Itmp2aDEGC		Icing	0.5	1	2	
303	Anem30bMS	AnemSD30bMS	Vane30aDEG	VaneSD30aDEG	Itmp2aDEGC		Icing	0.5	1	2	
304	Anem10aMS	AnemSD10aMS	Vane10aDEG	VaneSD10aDEG	Itmp2aDEGC		Icing	0.5	1	2	
400	Anem39aMS	Anem39bMS					CompareSensor	1	0.25	3	0
401	Anem30aMS	Anem30bMS					CompareSensor	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
Itmp2aDEGC	13104	13102	99.985	0.000	0.000	0.0	99.985
Batt2aVDC	13104	13102	99.985	0.000	0.000	0.0	99.985
Anem39aMS	13104	13102	99.985	0.167	68.000	19.0	95.994
AnemSD39aMS	13104	13102	99.985	0.167	68.000	19.0	95.994
Anem39bMS	13104	13102	99.985	0.167	88.500	0.0	95.925
AnemSD39bMS	13104	13102	99.985	0.167	88.500	0.0	95.925
Anem30aMS	13104	13102	99.985	0.167	88.667	4.5	95.711
AnemSD30aMS	13104	13102	99.985	0.167	88.667	4.5	95.711
Anem30bMS	13104	13102	99.985	0.167	95.500	0.0	95.604
AnemSD30bMS	13104	13102	99.985	0.167	95.500	0.0	95.604
Anem10aMS	13104	13101	99.977	0.000	60.333	0.0	97.215
AnemSD10aMS	13104	13101	99.977	0.000	60.333	0.0	97.215
Vane39aDEG	13104	13102	99.985	0.500	88.500	0.0	95.910
VaneSD39aDEG	13104	13102	99.985	0.500	88.500	0.0	95.910
Vane30aDEG	13104	13102	99.985	0.167	96.000	0.0	95.582
VaneSD30aDEG	13104	13102	99.985	0.167	96.000	0.0	95.582
Vane10aDEG	13104	13101	99.977	5.333	60.333	0.0	96.970
VaneSD10aDEG	13104	13101	99.977	5.333	60.333	0.0	96.970
Anem39yMS	13104	13102	99.985	0.000	0.000	0.0	99.985
Anem30yMS	13104	13102	99.985	0.000	0.000	0.0	99.985
AnemSD39yMS	13104	13102	99.985	0.167	0.000	0.0	99.977
AnemSD30yMS	13104	13102	99.985	0.167	0.000	0.0	99.977
Total	288288	288240	99.983	13.667	1291.667	47.0	97.169

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	December 2003 – February 2004 [%]
0.5	1.63
1.5	1.89
2.5	5.03
3.5	9.88
4.5	14.50
5.5	16.44
6.5	13.77
7.5	10.87
8.5	8.77
9.5	5.70
10.5	3.77
11.5	2.44
12.5	1.78
13.5	1.22
14.5	0.70
15.5	0.43
16.5	0.28
17.5	0.16
18.5	0.18
19.5	0.14
20.5	0.24
21.5	0.18
22.5	0.02
23.5	0.00
24.5	0.00

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]
2003 Aug	4.08
Sept	4.11
Oct	5.21
Nov	5.20
Dec	6.76
2004 Jan	5.81
Feb	5.35
Aug 2003 – Feb 2004	**5.22**

Diurnal Average Wind Speed Data

Hour of Day	December 2003 - February 2004 [m/s]
0	5.96
1	5.84
2	5.93
3	5.75
4	5.72
5	5.73
6	5.52
7	5.4
8	5.61
9	5.91
10	6.14
11	6.39
12	6.59
13	6.69
14	6.71
15	6.55
16	6.18
17	5.94
18	5.88
19	5.92
20	6.08
21	6.01
22	6.02
23	5.95

Wind Rose Data

	December 2003 to February 2004	
Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	7.93	5.21
NNE	2.46	4.79
NE	3.50	9.48
ENE	4.54	8.69
E	3.91	7.34
ESE	2.73	6.01
SE	1.61	5.08
SSE	1.77	5.27
S	1.85	4.86
SSW	3.57	5.27
SW	4.85	4.42
WSW	4.97	4.51
W	9.17	5.58
WNW	10.37	5.98
NW	15.35	6.48
NNW	21.41	6.22