WIND DATA REPORT

Orleans

December, 2003 – February 29, 2004

Prepared for

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by

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EXECUTIVE SUMMARY

This wind measurement station is installed at the town watershed in Orleans, MA. Installed on October 27 of 2003, the station is in continuous operation to this day. The two sets of two anemometers and one wind vane are mounted at 50 m (164.0 ft) and 40 m (131.2 ft), an additional vane and anemometer are mounted at 20 m (65.6 ft).

During the period covered by this report, December 2003 – February 2004, the mean recorded wind speed at 50 meters was 6.83 m/s (15.3 mph); the prevailing wind direction at 40 meters was WNW. The gross data recovery percentage (the actual percentage of expected data received) was 100.00% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 98.477%.

SECTION 1 - Station Location

The Orleans site is located on the town watershed in Orleans, MA. The tower is on a cleared hilltop, surrounded by trees. The location of the tower base is at 41.7584° North, 69.9933° West.

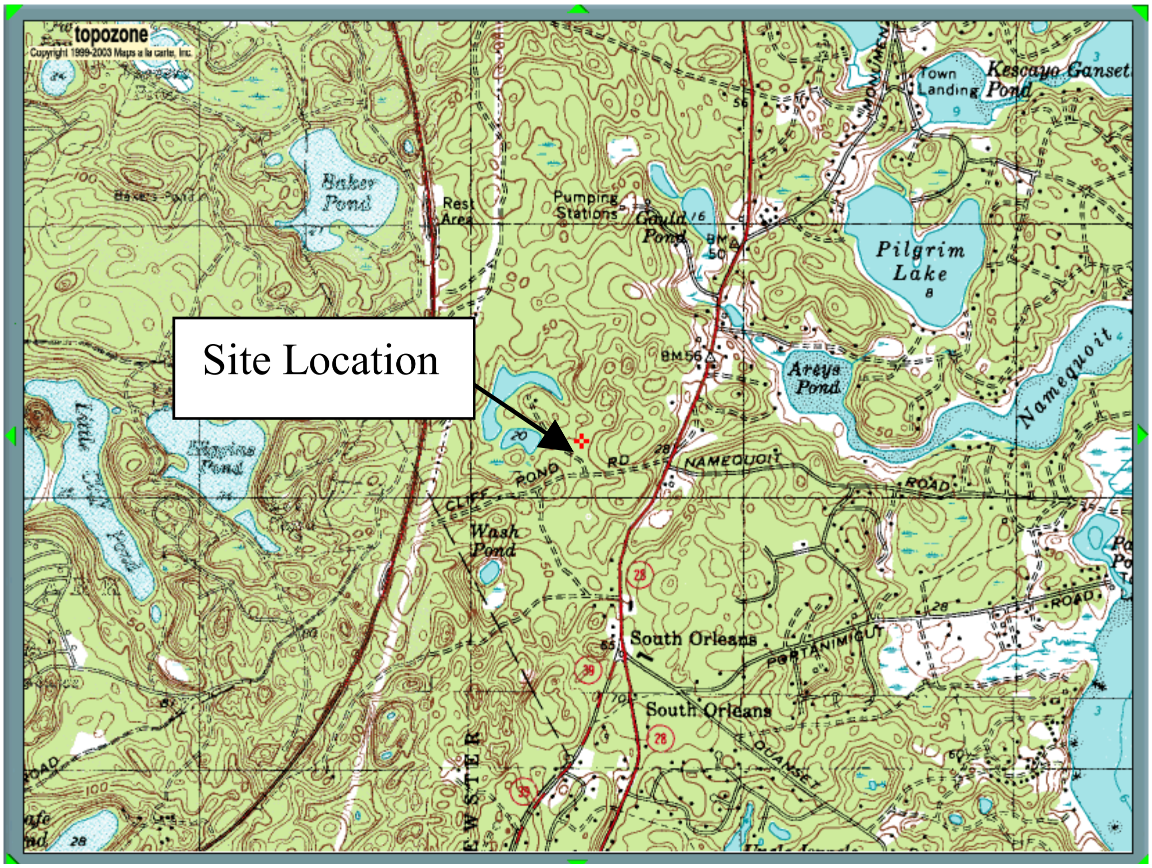

Figure 1 - Site location at Orleans site.

Source: www.topozone.com.

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 50 m 2nd Wind tower. All the remaining 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 – 0.350 m/s)
- 3 - #200P Wind direction vanes
- 5 – Sensor booms, 54” length
- Lightning rod and grounding cable
- Shielded sensor wire

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 this quarter.

Data Statistics Summary

Date	Mean Wind Speed 50 m, [m/s]	Max Wind Speed 50 m, [m/s]	Turbulence Intensity 50 m, [ ]	Prevailing Wind Direction 40 m, [ ]
December 2003	7.47	17.3	0.2	NW
January 2004	6.95	14.4	0.2	WNW
February 2004	6.02	14.5	0.15	NW
Dec, 2003 – Feb 22, 2004	**6.83**	**17.3**	**0.2**	**WNW**

SECTION 4 - Significant Meteorological Events

A low pressure area formed over the southeastern states on December 5. At the same time, a large arctic high became established over eastern Canada. The storm tracked off the Virginia coastline on December 6, then took a track along the eastern seaboard as a classic nor'easter. The storm interacted with the strong high in eastern Canada, which caused it to move very slowly. It took over a day for the storm to move northeast of Cape Cod, which was not until late December 7. The result was the first major snowstorm of the early winter season across the Berkshires. Nine to 18 inches fell across the Berkshires with Dalton receiving 17 inches.

A low pressure area formed in the Gulf States early on December 14. This storm hugged the coast line as it tracked northward to become the second nor'easter of the winter season. This storm moved a little quicker than its predecessor. In addition, enough warm air moved in aloft to change the snow to sleet and freezing rain, thus reducing snow fall accumulations, especially in southern sections of the county. By the time the storm moved off the New England coastline, 5 to 10 inches of snow had accumulated in Berkshire County. The city of West Otis received 10.5 inches, the most reported in the county. (http://www4.ncdc.noaa.gov)

January began with a week of warm temperatures and rainy days. The entire Northeast was at least 2 degrees above normal from the 1st to the 7th of January, with the majority of the region between 8 and 12 degrees warmer than average during this period. Beginning on the 7th, the continental weather pattern changed drastically and January ended up the 11th coldest on record in the Northeast. Wave after wave of arctic air sank into the region from Canada setting many minimum temperature records at observation sites all over the Northeast. Cold snaps occurred from January 9-11, 13-16, and 24-26 causing pipe bursts across the region and prompting school closures even in the winter-hardy northern New England states. The entire region was more than 4 degrees below normal. Massachusetts recorded the coldest January in that state (16.4 degrees) since records began in 1895, surpassing the old record of 16.7 degrees that had stood since 1981. New York, Rhode Island, and Connecticut all fell more than 7 degrees below their respective normals setting January 2004 among the ten coldest on record in each state. The region as a whole was 5.7 degrees below normal and, at 17.3 degrees, was the coldest month since 1994 and 0.8 degrees colder than last January.

When the region changed from warm to cold after the first week in January, it also went from wet to extremely dry. Many observation sites, especially in the northern half of the region, measured less than a quarter inch of rain/melted snow after the first week. All six New England states were more than 2 inches below the normal amount. Maine, New Hampshire and Vermont averaged only about an inch of precipitation (rain plus the liquid equivalent of snow) making this January one of the five driest on record in those states.. The near continuous fresh snow pack contributed to temperature departures in the 14 to 16 degree below normal range in these areas during the latter part of the month. Overall the Northeast fell more than 1 inch short of its January precipitation total but amazingly this was the wettest January since 2000. The lack of rain and snow this month puts an end to an 8-month streak of wet weather here in the Northeast.

The Northeast was very close to normal in terms of temperature this February. While southern portions of the region were at or slightly below normal this month, the New

England states saw a more significant positive temperature departure. Overall, the land-area weighted regional average was 26.0 degrees, or 0.5 degrees above normal. While not a very impressive temperature departure, this month was 4.5 degrees warmer than February 2003. All six New England states were above normal, and all of these except Vermont were more than 1 degree above normal. The general weather pattern this February brought storm systems northward over the Appalachains rather than over the coast, keeping New England on the warm side of the storms. This western storm trend also prevented any deep or prolonged cold snaps from taking hold in the northern states which could potentially have dropped the average temperatures down a notch. New Jersey was the only other state above normal this month, and the remaining 5 states were all within 0.5 degrees of their respective averages. Whether warmer or colder than normal, February temperatures in all 12 states were a welcome change after a bitterly cold January. Many states in the region saw a temperature increase of over 10 degrees from last month to this month. In fact, the region as a whole was 8.7 degrees warmer in February than in January.

One trend that did continue from January was the lack of precipitation across the Northeast (rain and water equivalent of snow). The region's measure of 1.97 inches makes February 2004 the driest since 1991. Rain and snow from two storms early in the month was followed by 20 days of no significant precipitation. High pressure was dominant during this time and the majority of the region received less than 1/2 an inch of rain/melted snow. Large portions of the region didn't see even a quarter of an inch after the 8th of February. This dry period was more extreme in the region's southern states, but early rains in that area seemed to cover for the future lack. Northern states were the most dry overall. Of six states in the region falling more than an inch short of their normal amounts, five were in New England (the sixth was Delaware). New Hampshire and Vermont both totaled less than an inch and a half on the month which was enough to put 2004 among the ten driest on record for both states. West Virginia was the most wet state in the region at 2.98 inches but still failed to reach its average value (precipitation departure: -.13 inches). This February was the first month since January 2003 in which all 12 states in the Northeast were on the dry side of their respective normals. A precipitation total of 1.97 inches is the lowest of any month since November 2001. (http://met-www.cit.cornell.edu/climate/Impacts.html)

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 [%]	100.00
Net Data Recovered [%]	98.477

The high Gross Data Recovery Percentage is an indication that the logger was recording and transmitting properly, the number is not 100% because these results reflect an incomplete quarter. The lower Net Data Recovery Percentage is a result of the 50 m vane failing.

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 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.

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

To exit an icing event, the wind direction standard deviation must be greater than Factor 4.

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. It should be noted that, while this test is tuned to detect sensor icing events, it is possible for the conditions that are representative of icing to occur at other times. The error due to this possibility is considered to be insignificant.

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 maximum percentage 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 November 2003 – Feb 2004.

- Diurnal – A plot of the average wind speed for each hour of the day. This graph shows a two peak wind speeds. One peak between 11 AM and 12 PM and another between 8 PM and 9PM.

- 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. The winter wind rose shows a prevailing WNW wind direction at the 40 m height. The highest average wind speed at the 50 m height was recorded from the WNW.

- Wind Direction Comparison – A plot of time series wind direction at 40m and 50m for a period when both sensors were working. This plot is to validate using the 40m direction data with the 50m speed data.

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

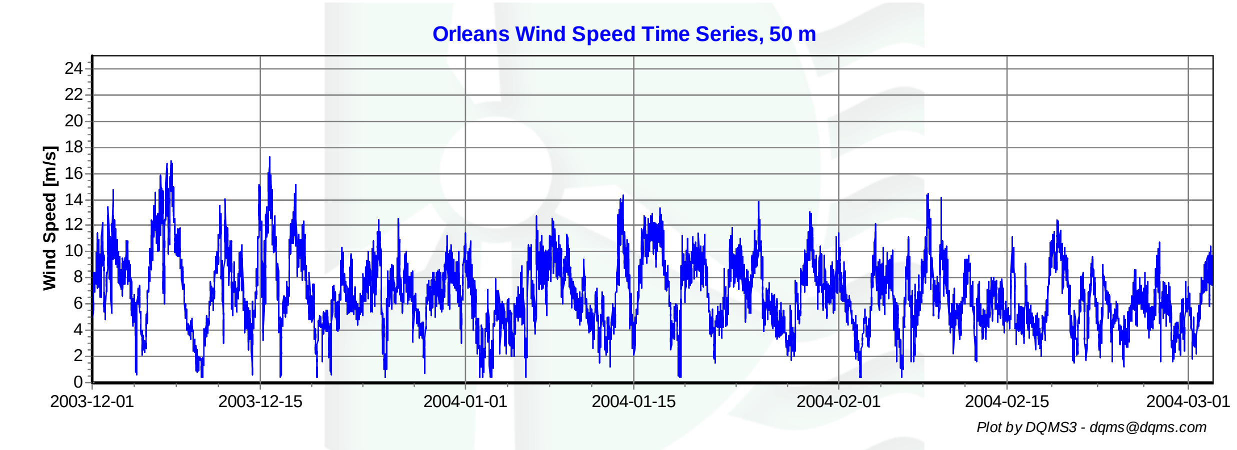

Figure 2 - Wind Speed Time Series, December 2003 – February, 2004

Wind Speed Distributions

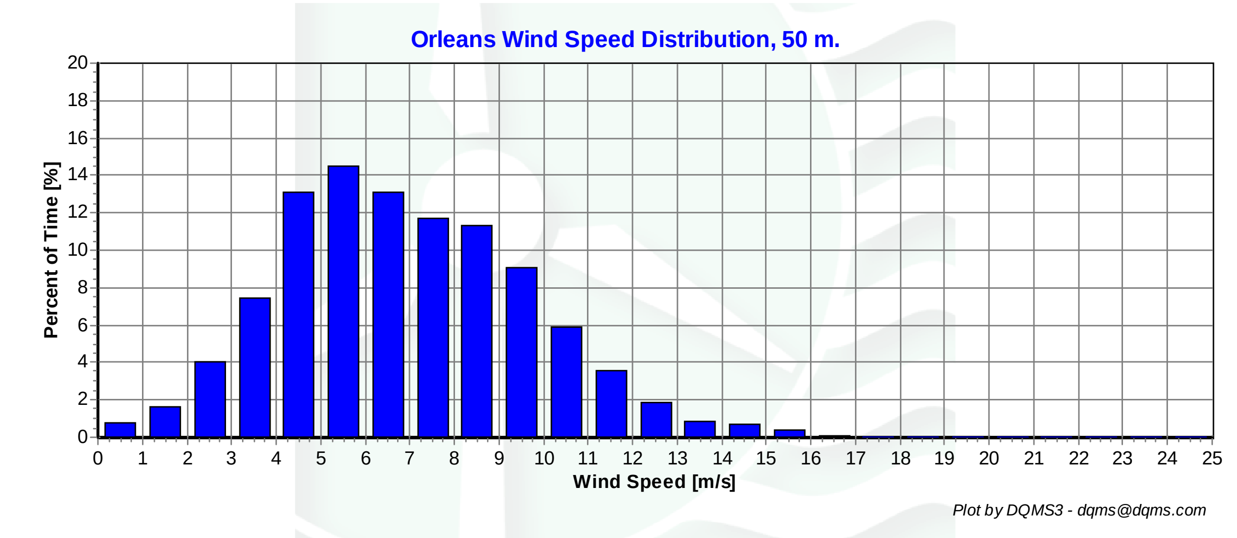

Figure 3 - Wind Speed Distribution, December 2003 – February 2004

Monthly Average Wind Speeds

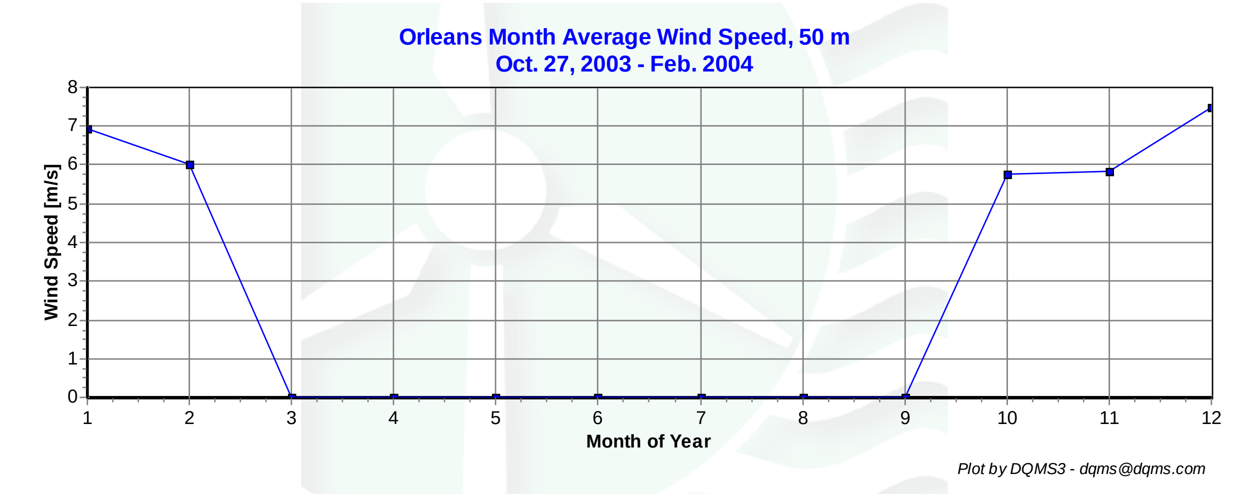

Figure 4 - Monthly average wind speed

Diurnal Average Wind Speeds

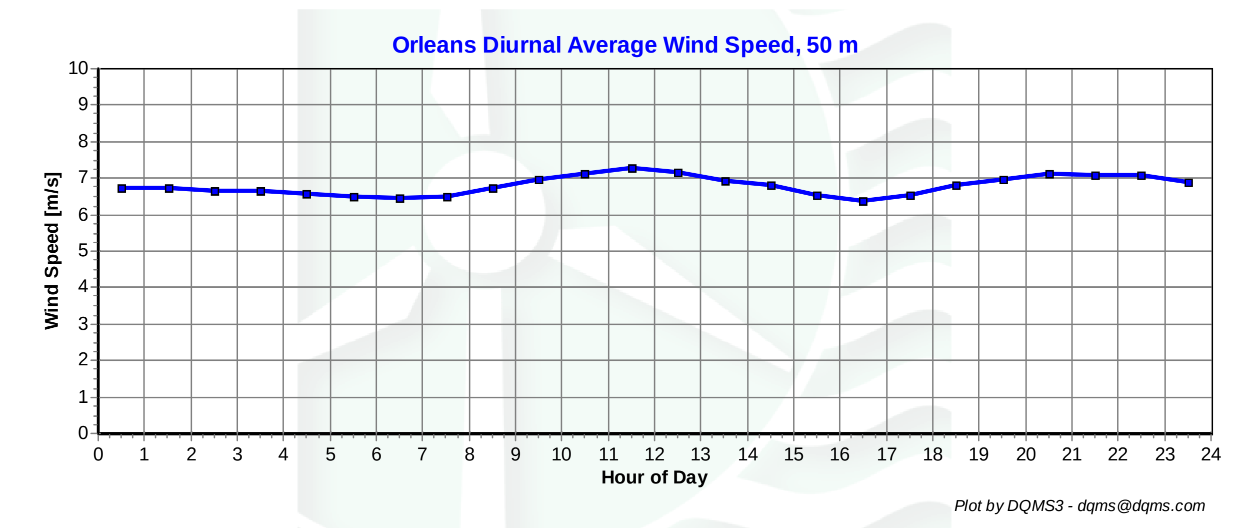

Figure 5 - Diurnal Wind Speed, December 2003 – February 2004

Turbulence Intensities

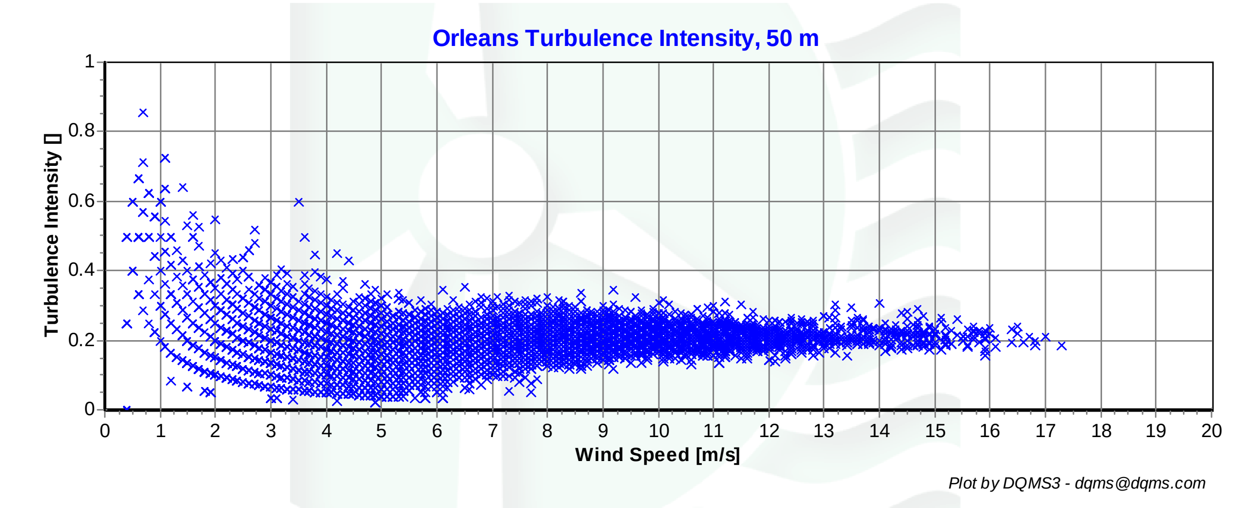

Figure 6 - Turbulence Intensity vs. Wind Speed, December, 2003 – February 2004

Wind Direction Comparison

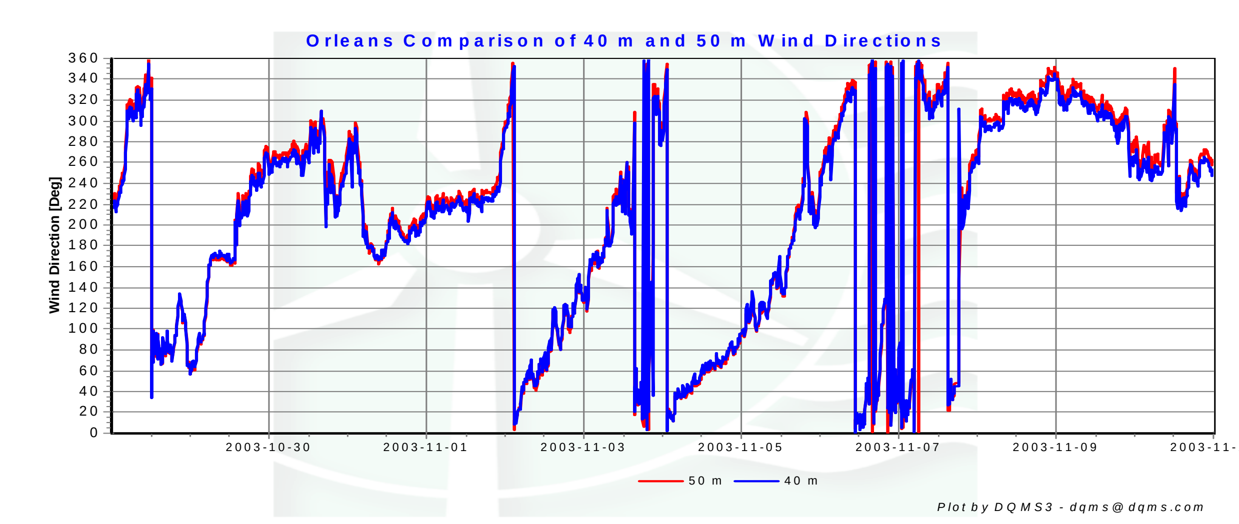

Figure 7- Comparison of Wind Direction at Different Heights

Wind Roses

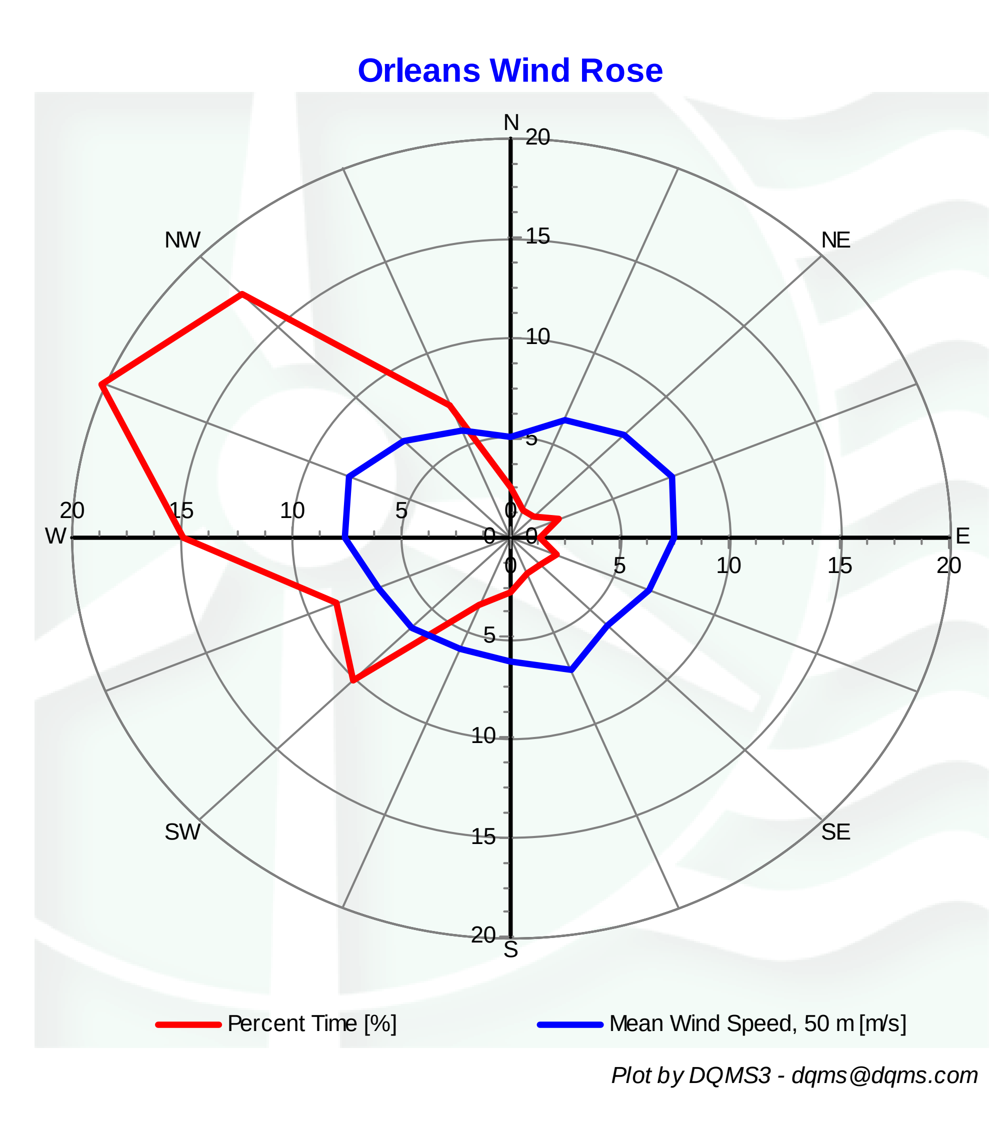

Figure 8 - Wind Rose, December 2003-February 2004

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	TestField3	CalcField1	CalcField2	TestType	Factor1	Factor2	Factor3	Factor4
1						TimeTest Insert				
2	Etmp2aDEGC					MinMax	-30	60		
3	Etmx2aDEGC					MinMax	-30	60		
4	Etmn2aDEGC					MinMax	-30	60		
5	EtmpSD2aDEGC					MinMax	-30	60		
10	Anem50aMS					MinMax	0	90		
11	Anem50bMS					MinMax	0	90		
12	Anem40aMS					MinMax	0	90		
13	Anem40bMS					MinMax	0	90		
14	Anem20aMS					MinMax	0	90		
15	Anem50yMS					MinMax	0	90		
16	Anem40yMS					MinMax	0	90		
20	AnemSD50aMS					MinMax	0	4		
21	AnemSD50bMS					MinMax	0	4		
22	AnemSD40aMS					MinMax	0	4		
23	AnemSD40bMS					MinMax	0	4		
24	AnemSD20aMS					MinMax	0	4		
25	AnemSD50yMS					MinMax	0	4		
26	AnemSD40yMS					MinMax	0	4		
30	Vane50aDEG					MinMax	0	359.9		
31	Vane40aDEG					MinMax	0	359.9		
32	Vane20aDEG					MinMax	0	359.9		
50	Turb50zNONE					MinMax	0	2		
51	Turb40zNONE					MinMax	0	2		
60	Wshr0zNONE					MinMax	-100	100		
70	Pwrd50zWMS					MinMax	0	5000		
71	Pwrd40zWMS					MinMax	0	5000		
200	VaneSD50aDEG	Anem50yMS				MinMaxT	0	100	100	10
201	VaneSD40aDEG	Anem40yMS				MinMaxT	0	100	100	10
202	VaneSD20aDEG	Anem20aMS				MinMax	0	100	100	10
300	Anem50aMS	AnemSD50aMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
301	Anem50bMS	AnemSD50bMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
302	Anem40aMS	AnemSD40aMS	Vane40aDEG	VaneSD40aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
303	Anem40bMS	AnemSD40bMS	Vane40aDEG	VaneSD40aDEG	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	Anem40aMS	Anem40bMS				CompareSensors	1	0.25	3	0
500	Amax50aMS					MinMax	0	90		
501	Amax50bMS					MinMax	0	90		
502	Amax40aMS					MinMax	0	90		
503	Amax40bMS					MinMax	0	90		
504	Amax20aMS					MinMax	0	90		
510	Amin50aMS					MinMax	0	90		
511	Amin50bMS					MinMax	0	90		
512	Amin40aMS					MinMax	0	90		
513	Amin40bMS					MinMax	0	90		
514	Amin20aMS					MinMax	0	90		
520	Vmax50aDEG					MinMax	0	359.9		
521	Vmax40aDEG					MinMax	0	359.9		
522	Vmax20aDEG					MinMax	0	359.9		
530	Vmin50aDEG					MinMax	0	359.9		
531	Vmin40aDEG					MinMax	0	359.9		
532	Vmin20aDEG					MinMax	0	359.9		

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Anem50aMS	13105	13105	100	0.667	79.167	3.5	96.185
AnemSD50aMS	13105	13105	100	0.667	79.167	3.5	96.185
Amax50aMS	13105	13105	100	0	0	0	100
Amin50aMS	13105	13105	100	0	0	0	100
Anem50bMS	13105	13105	100	0.833	75	1.833	96.444
AnemSD50bMS	13105	13105	100	0.833	75	1.833	96.444
Amax50bMS	13105	13105	100	0	0	0	100
Amin50bMS	13105	13105	100	0	0	0	100
Anem40aMS	13105	13105	100	0.333	76.667	5.5	96.223
AnemSD40aMS	13105	13105	100	0.333	76.667	5.5	96.223
Amax40aMS	13105	13105	100	0	0	0	100
Amin40aMS	13105	13105	100	0	0	0	100
Anem40bMS	13105	13105	100	0.5	73.333	11.333	96.101
AnemSD40bMS	13105	13105	100	0.5	73.333	11.333	96.101
Amax40bMS	13105	13105	100	0	0	0	100
Amin40bMS	13105	13105	100	0	0	0	100
Anem20aMS	13105	13105	100	0	55.167	0	97.474
AnemSD20aMS	13105	13105	100	0	55.167	0	97.474
Amax20aMS	13105	13105	100	0	0	0	100
Amin20aMS	13105	13105	100	0	0	0	100
Vane50aDEG	13105	13105	100	0	79.667	0.167	96.345
VaneSD50aDEG	13105	13105	100	0	79.667	0.167	96.345
Vmax50aDEG	13105	13105	100	0	0	0.167	99.992
Vmin50aDEG	13105	13105	100	0	0	0.167	99.992
Vane40aDEG	13105	13105	100	0.167	79.667	0	96.345
VaneSD40aDEG	13105	13105	100	0.167	79.667	0	96.345
Vmax40aDEG	13105	13105	100	0	0	0	100
Vmin40aDEG	13105	13105	100	0	0	0	100

Vane20aDEG	13105	13105	100	0	55.167	0	97.474
VaneSD20aDEG	13105	13105	100	0.167	55.167	0	97.467
Vmax20aDEG	13105	13105	100	0	0	0	100
Vmin20aDEG	13105	13105	100	0	0	0	100
Etmp2aDEGC	13105	13105	100	0	0	0	100
EtmpSD2aDEGC	13105	13105	100	0	0	0	100
Etmx2aDEGC	13105	13105	100	0	0	0	100
Etmn2aDEGC	13105	13105	100	0	0	0	100
Total	**471780**	**471780**	**100**	**5.167**	**1147.667**	**45**	**98.477**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	0.78
1.5	1.66
2.5	4.07
3.5	7.42
4.5	13.09
5.5	14.51
6.5	13.11
7.5	11.7
8.5	11.34
9.5	9.07
10.5	5.86
11.5	3.53
12.5	1.85
13.5	0.82
14.5	0.69
15.5	0.39
16.5	0.09
17.5	0.02
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]
2004 Jan	6.95
Feb	6.02
Mar	0
Apr	0
May	0
Jun	0
Jul	0
Aug	0
Sept	0
2003 Oct	0
Nov	5.84
Dec	7.47

Table 2 - Wind Speed Averages

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0	6.74
1	6.73
2	6.65
3	6.64
4	6.57
5	6.51
6	6.47
7	6.51
8	6.74
9	6.97
10	7.14
11	7.27
12	7.17
13	6.92
14	6.82
15	6.54
16	6.36
17	6.54
18	6.8
19	6.98
20	7.12
21	7.08
22	7.08
23	6.88

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%], 40 m	Mean Wind Speed [m/s], 50 m
N	2.51	5.03
NNE	1.53	6.4
NE	1.54	7.31
ENE	2.41	7.94
E	1.32	7.5
ESE	2.26	6.79
SE	1.87	6.18
SSE	1.91	7.17
S	2.7	6.19
SSW	3.64	6
SW	10.19	6.34
WSW	8.64	6.52
W	14.89	7.52
WNW	20.17	7.93
NW	17.27	6.92
NNW	7.14	5.84

Table 4 - Wind Rose, Time Percentage and Mean Wind Speed by Direction, December 2003-February 2004