WIND DATA REPORT

Presque Isle

March 1, 2005 – May 31, 2005

Prepared for
United States Department of Energy
And the University of Maine at Presque Isle
181 Main Street
Presque Isle, ME 04769

by

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TABLE OF CONTENTS

TABLE OF FIGURES

EXECUTIVE SUMMARY

The Renewable Energy Research Laboratory (RERL) and the University of Maine, Presque Isle (UMPI) installed wind monitoring equipment at the UMPI campus on November 21, 2004. Anemometers and wind direction vanes are installed at 10 m, 30 m, and 39 m above the tower base. Data stored on memory chips are received via mail once per month. This wind resource assessment project is made possible with funding assistance from the United States Department of Energy (DOE).

This is the second quarterly wind data report since the tower installation and covers data collected over the period of March 1, 2005 until May 31, 2005. At 39 m, the mean recorded wind speed was 4.60 m/s (10.3 mph)* and the prevailing wind direction was from the North. The average wind shear power-law factor is 0.38, and is calculated from data from the 39 m and 30 m anemometers. The average turbulence intensity at 39 m was 0.21, well within the normal values recorded by the RERL at wind monitoring sites it maintains in Massachusetts.

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 95.5%. The net data recovered is good, but lower than the gross recovery, primarily due to icing of the sensors.

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) at:
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 Presque Isle station is located on the campus of UMPI in Presque Isle, Maine on the edge of an athletic field to the southwest of the main group of buildings. The site is indicated on a topographical map in Figure 1. The Northern Maine Regional Airport (callsign: KPQI) is approximately 3km to the northwest. The tower base coordinates (using the NAD27 datum) are 46.669N Latitude and -68.021E Longitude.

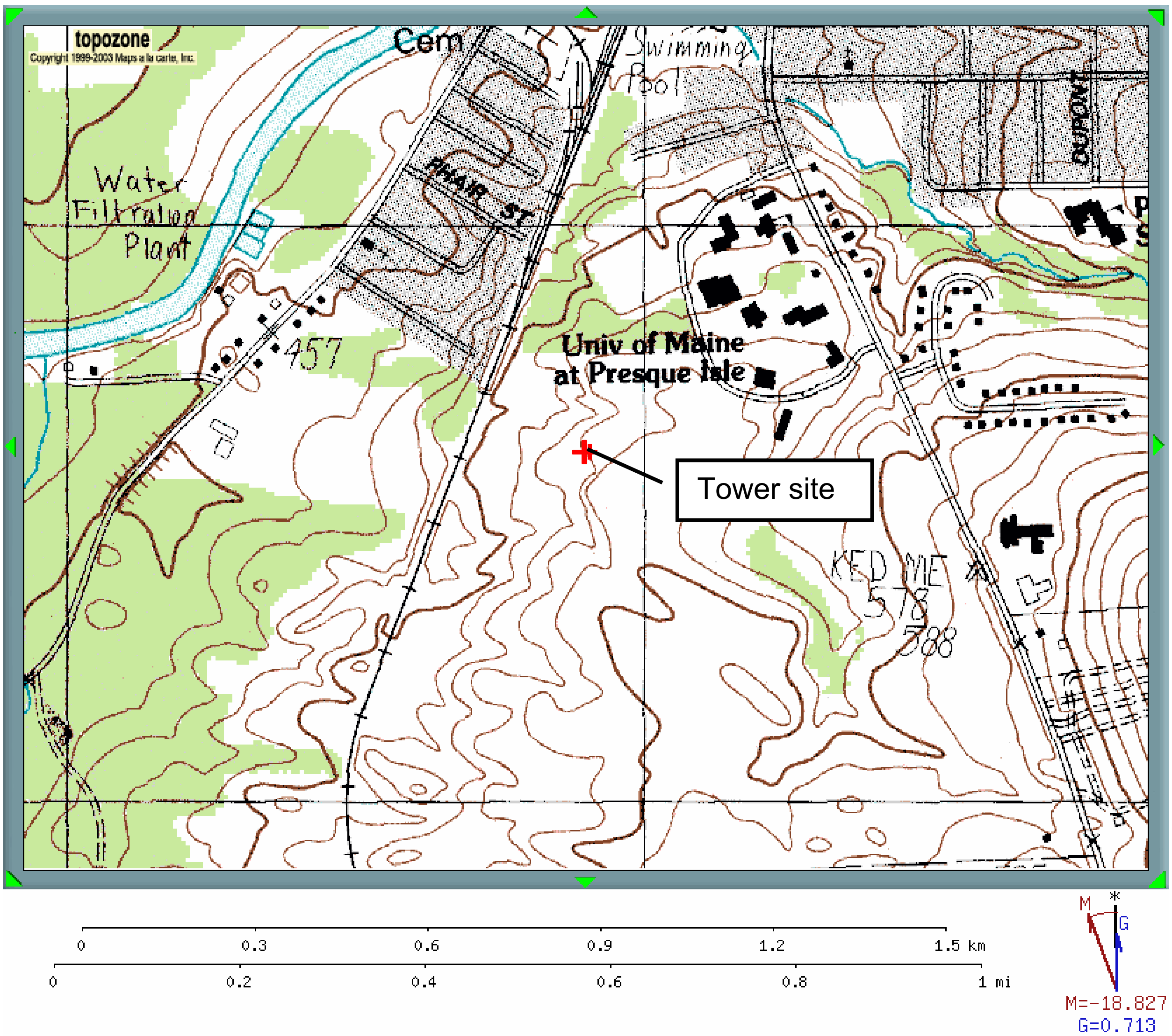

Figure 1 – Map of Presque Isle site.

Source: www.topozone.com.

SECTION 2 - Instrumentation and Equipment

Wind monitoring equipment is mounted on a standard WindMast™ 40-meter tall, 6in diameter, tilt-up guyed tower purchased from Second Wind Inc. Figure 2 shows a picture of the completed installation. Anchors for the tower were placed by UMPI according to RERL instructions. FAA approval (required due to the proximity to the nearby airport) was granted with no tower modifications or lighting requirements. Wind vanes and anemometers are located at three heights on the tower: 10 m, 30 m, and 39 m. Redundant anemometers exist at 30 m and 39 m. The installed equipment and models are as follows:

- Symphonie Data Logger
- 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

Figure 2 – 50 m data tower in Presque Isle soon after installation.

SECTION 3 - Data Collection and Maintenance

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.

There have been no data collection nor maintenance issues as yet. Sensor data is measured with a frequency of 0.5 Hz, averaged over ten-minute periods, and stored on a removable memory card to be periodically sent via mail to the RERL for processing and reporting.

Data Statistics Summary

	Anemometer 39m			Anemometer 30m			Anemometer 10m		10m to 39m	Vane 39m	Vane 30m	Vane 10m
Date	Mean [m/s]	Max [m/s]	Turb. Int. [ ]	Mean [m/s]	Max [m/s]	Turb. Int [ ]	Mean [m/s]	Max [m/s]	Shear [ ]	Prev. Dir	Prev. Dir	Prev. Dir
Mar 2005	4.1	11.2	0.2	4.13	11.6	0.22	2.98	8.6	0.39	N	N	N
Apr 2005	5.2	14.9	0.2	4.8	14	0.21	3.64	10.9	0.34	N	N	N
May 2005	4.49	14.7	0.22	4.17	13.4	0.24	3.25	10.4	0.41	ENE	ENE	ENE
Quarter	4.59	14.9	0.21	4.37	14	0.22	5.57	19.9	0.38	N	N	N

SECTION 4- Significant Meteorological Events

This quarter had very close to normal seasonal averages for temperatures. March had a significantly higher amount of precipitation than average—as a mixture of snow, ice, and rain; April and May also had higher than normal amounts of precipitation—mostly in the form of rain. No exceptional wind events occurred during the quarter.

Source: http://www.erh.noaa.gov/box/MonthlyClimate2.shtml

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 [%]	95.468

The gross data recovery percentage (the actual percentage of expected data received) was excellent: 100%, and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 95.5%. The net data recovered is good, but lower than the gross recovery, primarily due to icing of the sensors, during a few periods (e.g. March 8-10).

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.

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

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 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 the following types of wind data graphs:

- Time Series – 10-minute average wind speeds are plotted against time (Figure 3). The icing event over March 8-10 is clearly visible in the figure.

- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. The distribution peak occurs between 4 and 5 m/s (Figure 4).

- Monthly Average – A plot of the monthly average wind speed at 39 m. For this quarter, the averages are near 4.5 m/s. (Figure 5)

- Diurnal – A plot of the average wind speed for each hour of the day. This site has a peak wind speed in the early afternoon and a slight decrease in wind speeds in the early morning hours (Figure 6).

- 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. The average turbulence intensity was 0.21 at 39 m. This is a typical value (Figure 7).

- 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 graph shows prevailing wind directions from the N and SSE, and shows that the mean wind speeds are, in general, fairly constant about the compass rose (Figure 8).

SECTION 7 - Graphs

Data for the wind speed histograms, diurnal average plots, and wind rose are included in APPENDIX B.

Wind Speed Time Series

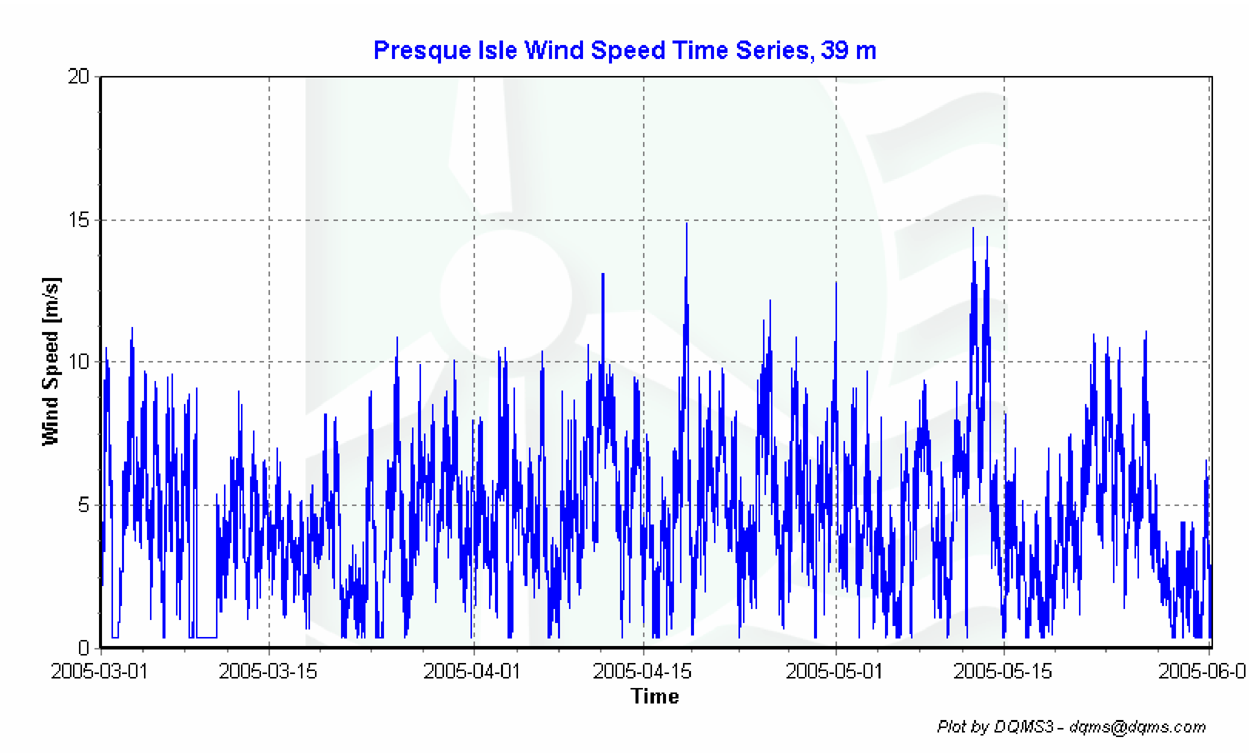

Figure 3 – Wind Speed Time Series, March 1, 2005 – May 31, 2005

Wind Speed Distributions

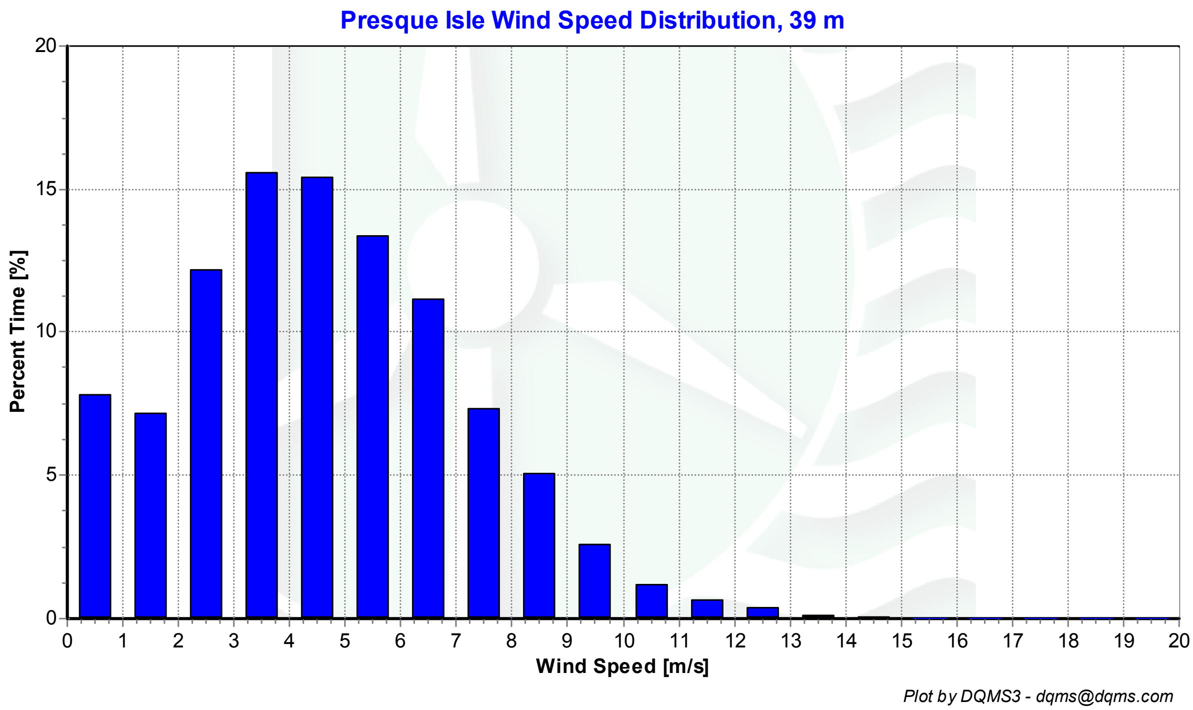

Figure 4 – Wind Speed Distribution, March 1, 2005 – May 31, 2005

Monthly Average Wind Speed

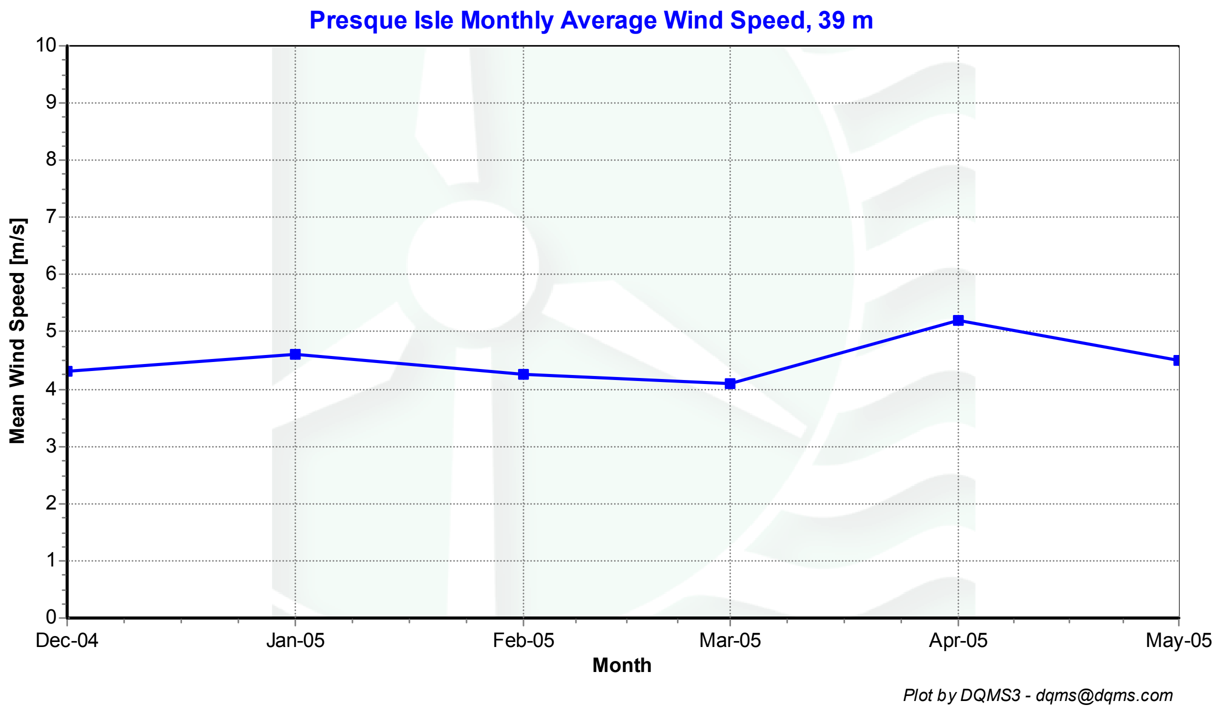

Figure 5 -- Monthly Average Wind Speed, December 1, 2004– May 31, 2005

Diurnal Average Wind Speeds

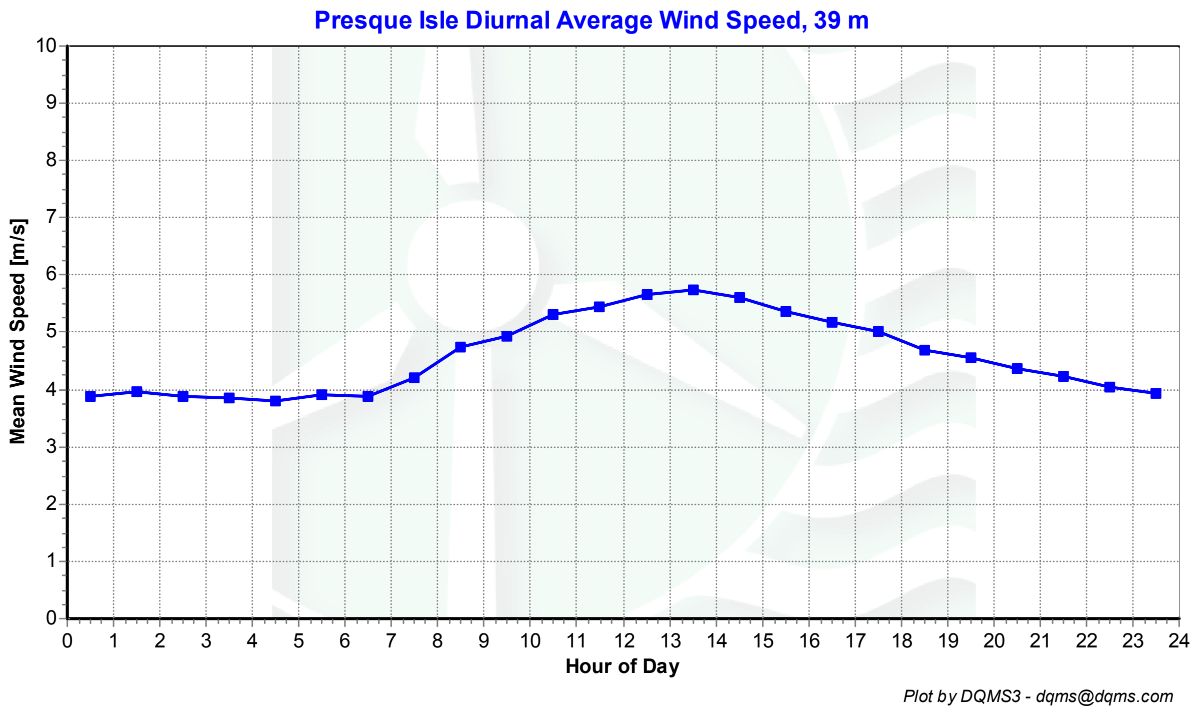

Figure 6 – Diurnal Wind Speed, March 1, 2005 – May 31, 2005

Turbulence Intensities

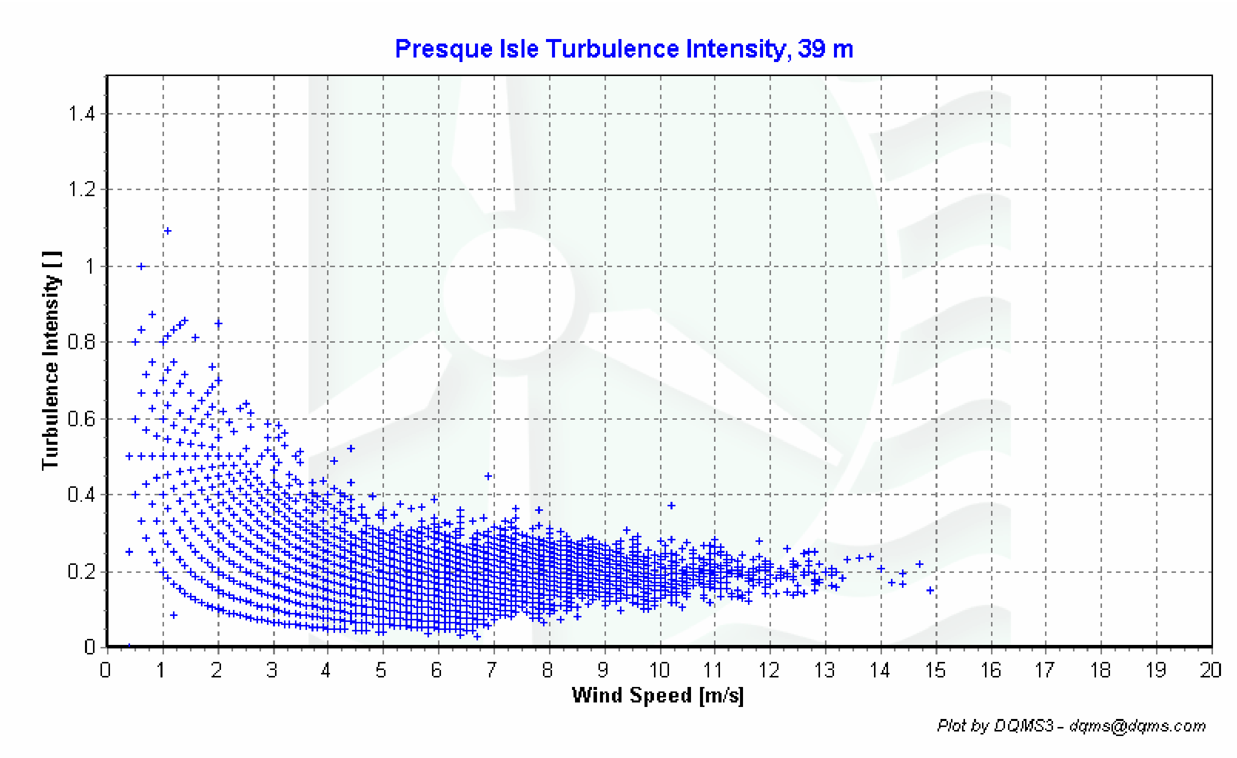

Figure 7 – Turbulence Intensity vs Wind Speed, March 1, 2005 – May 31, 2005

<u>**Wind Roses**</u>

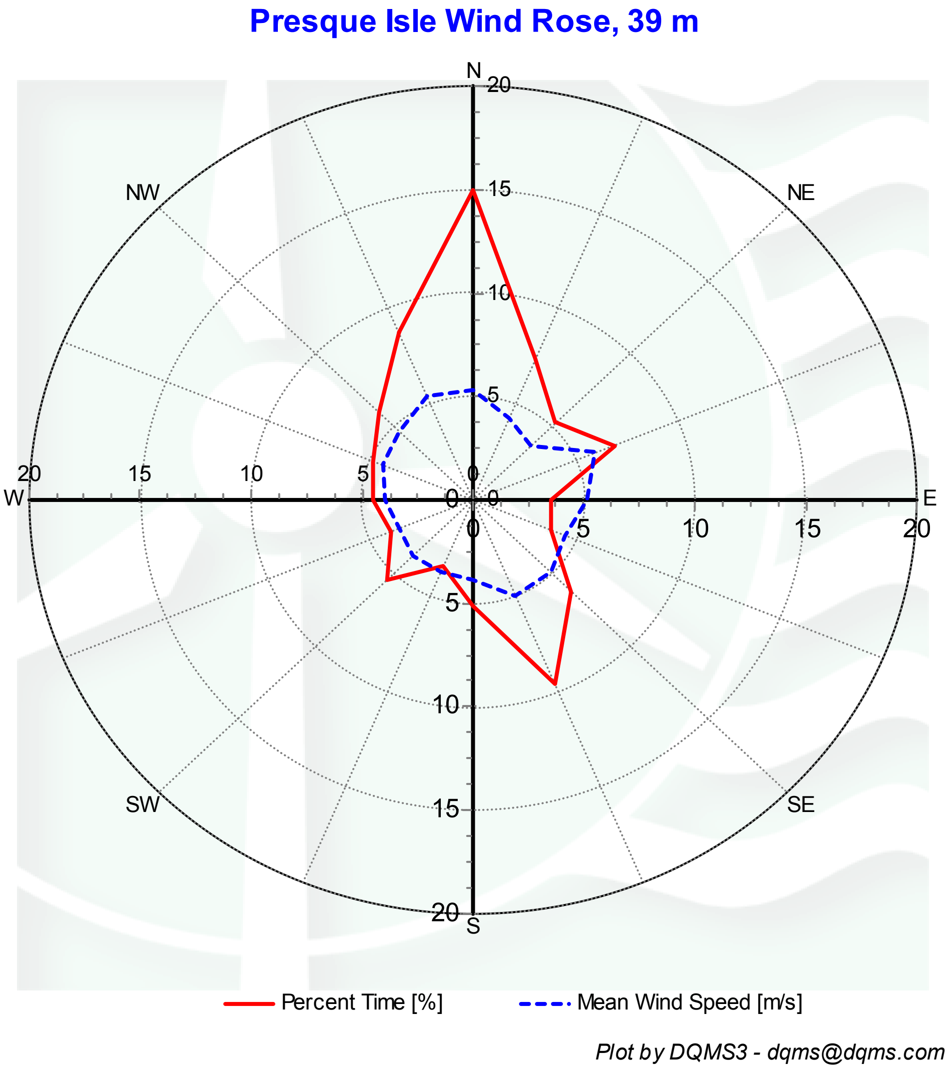

Figure 8 – Wind Rose, March 1, 2005 – May 31, 2005

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	Test Field1	Test Field2	Test Field3	Calc Field1	Calc Field2	Calc Field3	Test Type	Factor 1	Factor 2	Factor 3	Factor 4
1							TimeTest Insert	0	0	0	0
2	Etmp2aDEGC						MinMax	-30	60	0	0
3	Etmx2aDEGC						MinMax	-30	60	0	0
4	Etmn2aDEGC						MinMax	-30	60	0	0
5	EtmpSD2aDEGC						MinMax	-30	60	0	0
10	Anem39aMS						MinMax	0	90	0	0
11	Anem39bMS						MinMax	0	90	0	0
12	Anem30aMS						MinMax	0	90	0	0
13	Anem30bMS						MinMax	0	90	0	0
14	Anem10aMS						MinMax	0	90	0	0
15	Anem39yMS						MinMax	0	90	0	0
16	Anem30yMS						MinMax	0	90	0	0
20	AnemSD39aMS						MinMax	0	4	0	0
21	AnemSD39bMS						MinMax	0	4	0	0
22	AnemSD30aMS						MinMax	0	4	0	0
23	AnemSD30bMS						MinMax	0	4	0	0
24	AnemSD10aMS						MinMax	0	4	0	0
25	AnemSD39yMS						MinMax	0	4	0	0
26	AnemSD30yMS						MinMax	0	4	0	0
30	Vane39aDEG						MinMax	0	359.9	0	0
31	Vane30aDEG						MinMax	0	359.9	0	0
32	Vane10aDEG						MinMax	0	359.9	0	0
50	Turb39zNONE						MinMax	0	2	0	0
51	Turb30zNONE						MinMax	0	2	0	0
60	Wshr0zNONE						MinMax	-100	100	0	0
70	Pwrd39zWMS						MinMax	0	5000	0	0
71	Pwrd30zWMS						MinMax	0	5000	0	0
200	VaneSD39aDEG	Anem30yMS					MinMaxT	0	100	100	10
201	VaneSD30aDEG	Anem30yMS					MinMaxT	0	100	100	10
202	VaneSD10aDEG	Anem10aMS					MinMax	0	100	100	10
300	Anem39aMS	AnemSD39aMS	Vane39aDEG	VaneSD39aDEG	Etmp2aDEGC		Icing	1.1	1	2	10
301	Anem39bMS	AnemSD39bMS	Vane39aDEG	VaneSD39aDEG	Etmp2aDEGC		Icing	1.1	1	2	10
302	Anem30aMS	AnemSD30aMS	Vane30aDEG	VaneSD30aDEG	Etmp2aDEGC		Icing	1.1	1	2	10
303	Anem30bMS	AnemSD30bMS	Vane30aDEG	VaneSD30aDEG	Etmp2aDEGC		Icing	1.1	1	2	10
304	Anem10aMS	AnemSD10aMS	Vane10aDEG	VaneSD10aDEG	Etmp2aDEGC		Icing	1.1	1	2	10
400	Anem39aMS	Anem39bMS					CompareSensors	1	0.25	3	0
500	Anem30aMS	Anem30bMS					CompareSensors	1	0.25	3	0
501	Amin39aMS						MinMax	0	90	0	0
502	Amax39bMS						MinMax	0	90	0	0
503	Amax30aMS						MinMax	0	90	0	0
504	Amax30bMS						MinMax	0	90	0	0

510	Amax10aMS	MinMax	0	90	0	0
511	Amin39aMS	MinMax	0	90	0	0
512	Amin39bMS	MinMax	0	90	0	0
513	Amin30aMS	MinMax	0	90	0	0
514	Amin30bMS	MinMax	0	90	0	0
520	Amin10aMS	MinMax	0	90	0	0
521	Vmax39aDEG	MinMax	0	359.9	0	0
522	Vmax30aDEG	MinMax	0	359.9	0	0
530	Vmax10aDEG	MinMax	0	359.9	0	0
531	Vmin39aDEG	MinMax	0	359.9	0	0
532	Vmin30aDEG	MinMax	0	359.9	0	0

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Etmp2aDEGC	13105	13105	100	0	0	0	100
EtmpSD2aDEGC	13105	13105	100	0	0	0	100
Anem39aMS	13105	13105	100	0	57	70.667	94.155
AnemSD39aMS	13105	13105	100	0	57	70.667	94.155
Anem39bMS	13105	13105	100	0	112.667	4.833	94.62
AnemSD39bMS	13105	13105	100	0	112.667	4.833	94.62
Anem30aMS	13105	13105	100	0	131.667	4.167	93.781
AnemSD30aMS	13105	13105	100	0	131.667	4.167	93.781
Anem30bMS	13105	13105	100	0	137	0.5	93.705
AnemSD30bMS	13105	13105	100	0	137	0.5	93.705
Anem10aMS	13105	13105	100	0	60.167	0	97.245
AnemSD10aMS	13105	13105	100	0	60.167	0	97.245
Vane39aDEG	13105	13105	100	0.5	112.667	0	94.819
VaneSD39aDEG	13105	13105	100	0.5	112.667	0	94.819
Vane30aDEG	13105	13105	100	0.667	137.333	0	93.682
VaneSD30aDEG	13105	13105	100	0.667	137.333	0	93.682
Vane10aDEG	13105	13105	100	0.833	60.167	0	97.207
VaneSD10aDEG	13105	13105	100	0.833	60.167	0	97.207
Total	235890	235890	100	4	1617.333	160.333	95.468

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent
0.5	7.8
1.5	7.15
2.5	12.18
3.5	15.59
4.5	15.41
5.5	13.38
6.5	11.17
7.5	7.32
8.5	5.07
9.5	2.57
10.5	1.16
11.5	0.67
12.5	0.38
13.5	0.1
14.5	0.05
15.5	0
16.5	0
17.5	0
18.5	0
19.5	0
20.5	0

Table B1: Wind Speed Distribution

Diurnal Average Wind Speed Data

Hour of Day	Wind Speed [m/s]
0	3.87
1	3.97
2	3.88
3	3.87
4	3.79
5	3.9
6	3.87
7	4.2
8	4.75
9	4.94
10	5.3
11	5.43
12	5.66
13	5.74
14	5.6
15	5.36
16	5.18
17	5.01
18	4.7
19	4.56
20	4.37
21	4.24
22	4.05
23	3.93

Table B3: Diurnal Wind Speed

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	15.1	5.28
NNE	7.64	4.35
NE	4.58	4.15
ENE	7.14	5.94
E	3.6	5.09
ESE	3.93	4.44
SE	6.37	4.95
SSE	9.49	5.11
S	4.84	4.07
SSW	3.3	3.83
SW	5.34	3.86
WSW	3.87	3.7
W	4.56	4.03
WNW	4.93	4.46
NW	6.21	4.72
NNW	9.09	5.48

Table B4: Wind Rose Time Percentage and Mean Wind Speed