WIND DATA REPORT

Thompson Island

September 1, 2004 – November 30, 2004

Prepared for

Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

by

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January 7, 2005
NOTICE AND ACKNOWLEDGEMENTS

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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 preformed by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst.

Wind monitoring equipment was first installed at Thompson Island in 1998. Due to planned construction by the Outward Bound School on the island, the monitoring tower was relocated in November 2001 from a central, inland site, to the current site, which is closer to the western shoreline, 4 m (13 ft) above sea level. Anemometers and wind direction vanes are installed at 25 and 40 m (82 and 131 ft) above the tower base. A temperature sensor and a solar sensor (pyronometer) are installed near the base.

This report describes the wind data collected at Thompson Island during the fall of 2004, September – November. On June 30, 2004, the data logger stopped collecting data, possibly due to a nearby lightening strike. In early November the logger and sensors were replaced and tower operation was restarted on November 10, 2004. Therefore, the only data summarized in this report are from November 10 to November 30.

With the tower out of commission for all of September and October and for the first 10 days of November, this report can not give summary statistics for any of those months or for the quarter as a whole. With more than 10% of the data missing for each month and for the quarter, any summary statistics would not be comparable to previous or future months or quarters.

For the quarter, the gross data recovery percentage (the actual percentage of expected data received) was 22.550% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 22.002%. Both of these percentages are low due to the loss of data as described above. The difference between these two numbers is due to an icing event on November 13.

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:


* 1 m/s = 2.25 mph.
SECTION 1 - Station Location

Thompson Island is located in Boston Harbor, approx 2 ½ miles south of Logan Airport. It is home to the Outward Bound School of Boston. The 40 m (131 ft) monitoring tower is located at 42° 18' - 54.1" North, 071° 00' - 44.7" West (see Figure 1). The location is near the western shore of the island, located on a small bluff, 4 m (13 ft) above sea level.

Figure 1 - Site location on Thompson Island
SECTION 2 - Instrumentation and Equipment

The 40 m (131 ft) monitoring tower and associated equipment are supplied by NRG systems, with the exceptions of custom made anemometer booms, temperature sensor, and the FAA-approved L-810 warning light. The wind speed and direction were measured at both 25 and 40 m (82 and 131 ft) height. The monitoring equipment (Figure 2) consists of the following items:

- Model 9300 Cellogger®, serial # 0568
- Electrical enclosure box with 5 watt PV panel
- Yagi directional antenna and mount
- NRG 40m tower, 4.5” diameter model  
- 4 – #40 Anemometers, standard calibration (Slope 0.765, Offset 0.350)
- 2 - #200P Wind direction vanes (Slope 1.0, Offset 0.0)  
- 1 – Li-Cor Solar sensor (Slope 70.9, Offset 0.0)
- 1- Custom temp sensor (Slope 0.1356, Offset -17.78)
- 2 – Sensor booms, 54” length at 25 m
- 2 - Sensor booms, 44” length at 40 m
- 2 – ‘Z’ masts, for vane mount
- Lightning rod and grounding cable
- Shielded sensor wire

Figure 2 - Monitoring Station/Data Equipment at Thompson Island
The NRG 9300 system logger is equipped with a built-in cell phone so that the data can be transmitted weekly to a PC, located at the University of Massachusetts/Amherst. The logger samples wind speed and direction once every second. 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 quality assurance (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:

- The monitoring tower did not operate from June 30 until November 10, 2004. A suspected nearby lightning strike caused the data logger and sensors to malfunction. On November 10, the sensors and logger were replaced and the tower was put back into operation.

Data Statistics Summary

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* At least 10% of the data were missing for each month and for the quarter. Therefore, summary statistics have not been calculated.

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.
SECTION 4 - Significant Meteorological Events

Fall of 2004 experienced, on average, normal winds and precipitation, though September was a wetter than normal month. There are no major wind events shown in the wind speed time series.

During the fall of 2004 several hurricanes affected weather on the east coast of the US, though none of these storms produced abnormally strong winds in eastern Massachusetts. The winds of Hurricanes Karl and Jeanne did produce high surf along the Massachusetts coast, but the storm was too far from shore for their winds to be felt.


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 QA controls are given below under Test Definitions and Sensor Statistics. 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. See Section 3 above for an explanation of the low percentages reported here.

<table>
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<th>Gross Data Recovered [%]</th>
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<td>Net Data Recovered [%]</td>
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**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.

\[
(\text{TF1} < \text{F1}) \\
\text{or } (\text{TF2} < \text{F4} \text{ and } \text{TF1} > \text{F2}) \\
\text{or } (\text{TF2} \geq \text{F4} \text{ and } \text{TF1} > \text{F3})
\]

**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 speed (TF2) is less than or equal to Factor 1 (F1), the wind direction standard deviation (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).

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

**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.

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

**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 September 2004. The following graphs are included:

- **Time Series** – 10-minute average wind speeds are plotted against time. Data before November 10 were missing because the tower was not of operating. The wind speed time series is shown in Figure 3.

- **Wind Speed Distribution** – There were not enough data for the quarter to calculate values for this plot. The wind speed distribution is shown in Figure 4.

- **Monthly Average** – A plot of the monthly average wind speed over the 12 month period ending November 2004. December 2003 - February 2004 and July - November 2004 are not shown because more than 10% of the data in each of those months was either missing or invalid. The monthly average plot is shown in Figure 5.

- **Diurnal** – There were not enough data for the quarter to calculate values for this plot. The diurnal wind speeds are shown in 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. In the graph, the turbulence intensity bottoms out around 5 m/s (11.3 mph), which is typical for this site. The turbulence intensity plot is shown in Figure 7.
• Wind Rose – There were not enough data for the quarter to calculate values for this plot. The wind rose is shown in Figure 8.
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 3 - Wind Speed Time Series, September 2004 – November 2004

Wind Speed Distribution

Figure 4 - Wind Speed Distribution, September 2004 – November 2004
Monthly Average Wind Speeds

Thompson Island Monthly Average Wind Speed, 40 m

Figure 5 - Monthly average wind speed

Diurnal Average Wind Speeds

Data Not Available

Figure 6 - Diurnal Wind Speed, September 2004 – November 2004
Turbulence Intensities

Thompson Island Turbulence Intensity, 40 m

Figure 7 - Turbulence Intensity vs Wind Speed, November 10 – 30, 2004

Wind Roses

Data Not Available

Figure 8 - Wind Rose, September 2004 – November 2004
## Test Definitions

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### APPENDIX B - Plot Data

#### Wind Speed Distribution Data

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Table 1 - Wind Speed Distribution
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**Table 2 - Wind Speed Averages**

Note: Dashes (-) indicate months for which more than 10% of the data were missing or invalid. No statistics are reported for these months.
### Diurnal Average Wind Speed Data

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