Sandia National Laboratories

New Mexico Wind Resource Assessment

Lee Ranch

Data Summary and Transmittal for

September – December 2002

&

Annual Analysis for

January – December 2002

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SECTION I: PROJECT BACKGROUND

Sandia National Laboratories (SNL) in Albuquerque, New Mexico, hired Global Energy Concepts (GEC) to conduct a two-year wind monitoring program at one previously selected site. The wind resource assessment study includes eight quarterly reports and one final report. Each report provides a general summary of the data collected during the reporting period. Raw and processed data along with reports are submitted to SNL for archiving and distribution.

The Quarter 4 – 2000 report was the first of the eight quarterly reports and covered the period from installation, October 17, 2000, through December 31, 2000. Due to communications problems at the site, SNL requested a shift in the reporting periods. The second quarterly report covered the period from December 1, 2000, through February 23, 2001. The third report covered the period from February 24 through May 31, 2001. The fourth quarterly report covered the period from June 1 through August 31, 2001. Due to delays in data collection and low data recovery, the fifth and sixth quarters of the monitoring program, for the period of September 1, 2001, through February 28, 2002, were reported together. The seventh report covered the period of March 1 through May 31, 2002. The eighth report covered the period of June 1 through August 31, 2002.

This report covers the period of September 1 through December 31, 2002, and also summarizes the annual period of January 1 through December 31, 2002.

The site is located in the San Mateo Mountains, at 35º 18' 45" N – 107º 25' 51" W with an elevation of 2,578 m (8,458 ft). The site was commissioned on October 17, 2000. Figure 1 provides a map indicating the general site location.

Figure 1. Location of Lee Ranch Wind Monitoring Station

EQUIPMENT

The Lee Ranch monitoring station is equipped with four calibrated wind speed sensors, two wind direction sensors, one temperature sensor, and a cellular data logger with a solar panel and battery. The station measures wind speed at 10, 25, and 40 m and wind direction at 25 and 40 m. There is a redundant wind speed sensor at 40 m and the temperature sensor is located at 3 m.

DATA COLLECTION

Nearby high voltage wires appear to interfere with the cellular signal, causing calls to be cut short and data to be distorted. In order to ensure data recovery, GEC arranged to have the data collected manually by Hank Wood, one of the landowner's ranch hands. Mr. Wood began manually changing the data cards on July 15, 2001, and is scheduled to change the cards twice a month.

DATA PROCESSING

All data are reviewed for accuracy and invalid data are removed to create a validated data set. Data are considered invalid if they do not represent the actual wind conditions at the site. Typical causes of invalid data include sensor icing, tower shadow, and equipment damage due to lightning, electrostatic discharge, failed components, or vandalism.

Missing and removed wind speed data at the 40-m level are replaced to create a corrected data set. Data are replaced using the following methods in the order presented. In the case where only a few hours are missing, the average of the hour before and the hour after the outage is used to replace the invalid data. When a longer period of data is affected and another wind speed sensor is operating at the site, the data are filled in based on a correlation between the sensors. When all sensors are affected by the outage, the standard methodology for data replacement is to develop a correlation to a nearby reference site that has data concurrent with the affected hours. However, GEC has not been able to establish a correlation between the Lee Ranch and any nearby reference sites. Some missing or erroneous data have been replaced with the average diurnal values of valid data from the same site in the same month. This data replacement is only used if the data recovery for the month is greater than 90%. Consequently, some data have not yet been replaced. Details on the data replacement methods used for invalid data are provided in the Data Adjustment Table that is included in the appendix of this report. Now that the two-year monitoring program has concluded, GEC has compiled an annual data set.

SECTION II: DATA SUMMARY FOR SEPTEMBER – DECEMBER 2002

This section summarizes the data collected from September through December 2002.

DATA RECOVERY

Table 1 provides the recovery rates for wind speed data collected at 10, 25, and 40 m. The "Hours Lost" column indicates the number of hourly data points that were missing or removed during the data validation process for each monitoring height. For example, if at the 40-m level, data were removed from 12:00 – 2:00, this would be considered three hourly data points. The remaining data are expressed as a percentage of total sensor hours in the period on the "Recovery Rate" column. The recovery rate at all sensor levels for the period of September through December is 99.7%.

Table 1. Wind Speed Data Recovery – September to December 2002

Month	Total Hours In Period	Hours Lost			Recovery Rate	
		10m	25m	40m	All Heights	40m Level
September	720	0	0	0	100.0%	100.0%
October	744	4	4	6	99.4%	99.2%
November	720	3	3	3	99.6%	99.6%
December	744	0	0	0	100.0%	100.0%
Sep - Dec	**2928**	**7**	**7**	**9**	**99.7%**	**99.7%**
Year to Date	**8760**	**36**	**37**	**39**	**99.6%**	**99.6%**

WIND DATA SUMMARY

The average wind speeds for September through December 2002 are summarized in Table 2 and illustrated in Figure 2. The averages for the 40-m level are based on the corrected hourly data set.

Table 2. Monthly Average Wind Speeds – September to December 2002

	10M		25M		40M	
	m/s	mph	m/s	mph	m/s	mph
September	4.0	8.9	4.9	10.9	5.6	12.4
October	3.7	8.2	4.7	10.4	5.3	11.8
November	5.2	11.6	6.2	13.9	7.0	15.6
December	5.4	12.1	6.3	14.0	7.0	15.8
Sep - Dec	4.6	10.2	5.5	12.3	6.2	13.9
YTD Avg	5.1	11.3	6.1	13.5	6.8	15.1

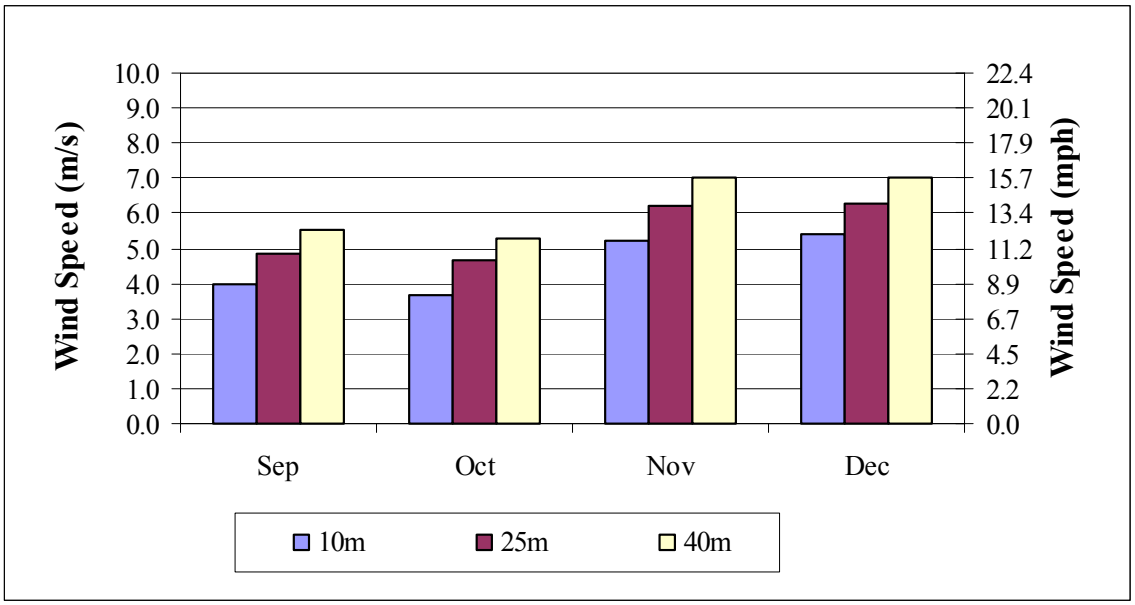


Figure 2. Monthly Wind Speeds – September to December 2002

The average diurnal wind speeds are shown in Figure 3. As shown in the figure, the wind speeds are highest during the afternoon from 12:00 p.m. to 4:00 p.m.

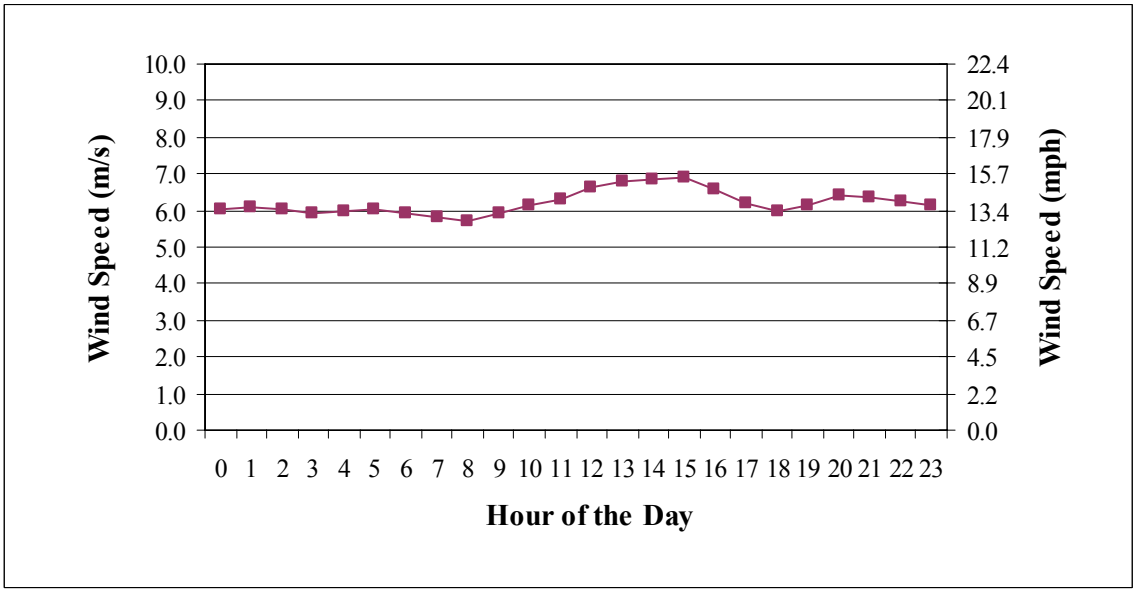


Figure 3. Diurnal Wind Speed Pattern – September to December 2002

Monthly wind rose graphs for Lee Ranch are provided in the appendix. The graphs illustrate prevailing wind directions and also provide turbulence intensity by wind direction sector. The graphs consist of two bars in each of the 16 wind direction sectors that represent the percent of total time and the percent of

total wind energy. During this period the predominant wind energy direction at the site was from the west-northwest.

Turbulence intensity (TI) is a relative indicator of turbulence and not an absolute value. According to the American Wind Energy Association, moderate turbulence intensity is considered to be between 0.10 and 0.25. The average turbulence intensity at 40 m is provided in Table 3. The TI value shown is from the predominant wind direction only. TI values for all direction sectors are provided in the monthly wind rose graphs included in the appendix. Lee Ranch experiences turbulence intensities at the low end of the moderate range; therefore, the TI values to date indicate no concerns for wind energy development at this location.

Wind shear exponent values are also provided in Table 3. The wind shear exponent represents the degree to which wind speed increases with height. For the purposes of this report, the wind shear exponent was calculated for the 25-to-40-m height. The theoretically derived value for wind shear over smooth, flat terrain is 0.14. During this period the wind shear exponent in operable winds (winds above 4 m/s) was 0.26. During wind project development, wind shear is used when determining an appropriate wind turbine hub height.

Table 3. Turbulence Intensity and Wind Shear Summary – September to December 2002

Month	Average TI (Predominant Direction)	Average Wind Shear Exponent (25m - 40m)
September	0.12	0.27
October	0.12	0.25
November	0.10	0.26
December	0.10	0.25
Sep - Dec	**0.11**	**0.26**
Year to Date	**0.11**	**0.24**

The Appendix contains the following reports:

- Site and Sensor Information Table
- Data Validation Table
- Summary Table for Monthly and Diurnal Wind Speeds
- Frequency Distribution Table
- Summary Reports (for each month)
- Wind Rose Graphs (for each month)

The forms and reports in the appendix are consistent with the reporting procedures developed for the Utility Wind Resource Assessment Program (UWRAP). Electronic copies of the raw hourly averaged data, hourly averaged validated data, and corrected hourly data files have been submitted to SNL.

SECTION III: ANNUAL DATA ANALYSIS - 2002

The Lee Ranch monitoring program has been in operation since October 17, 2000. During the first year of operation, the project experienced several periods of low data recovery. The majority of data loss was due to data transmission problems. In July 2001, a manual data collection program was initiated for the monitoring program. Data recovery was very high during the 2002 calendar year with a recovery rate of 99.6%. A 12-month period of continuous data with high data recovery is preferable for performing an annual analysis. Therefore, the 2002 data were selected for the annual data analysis.

To determine the long-term representativeness of the 2002 data, GEC compared the monthly wind speeds for 2002 recorded at the Albuquerque International Airport to the long-term monthly wind speeds at the airport. Figure 4 illustrates the monthly wind speed patterns at the Lee Ranch and the airport for 2002, as well as the long-term monthly wind speeds at the airport. The long-term wind speeds for the airport are based on a six-year period. Although the Lee Ranch wind speed and the airport wind speed are not closely correlated they probably experience similar interannual variations. Table 4 provides a comparison of the 2002 monthly wind speeds to the six-year monthly averages at the airport. Although there is some monthly variation between 2002 and the long-term, the annual averages are the same and, as shown in Figure 4, the seasonal patterns are similar. Based on this relationship, the data collected at Lee Ranch during 2002 is expected to be fairly representative of the long-term wind resource.

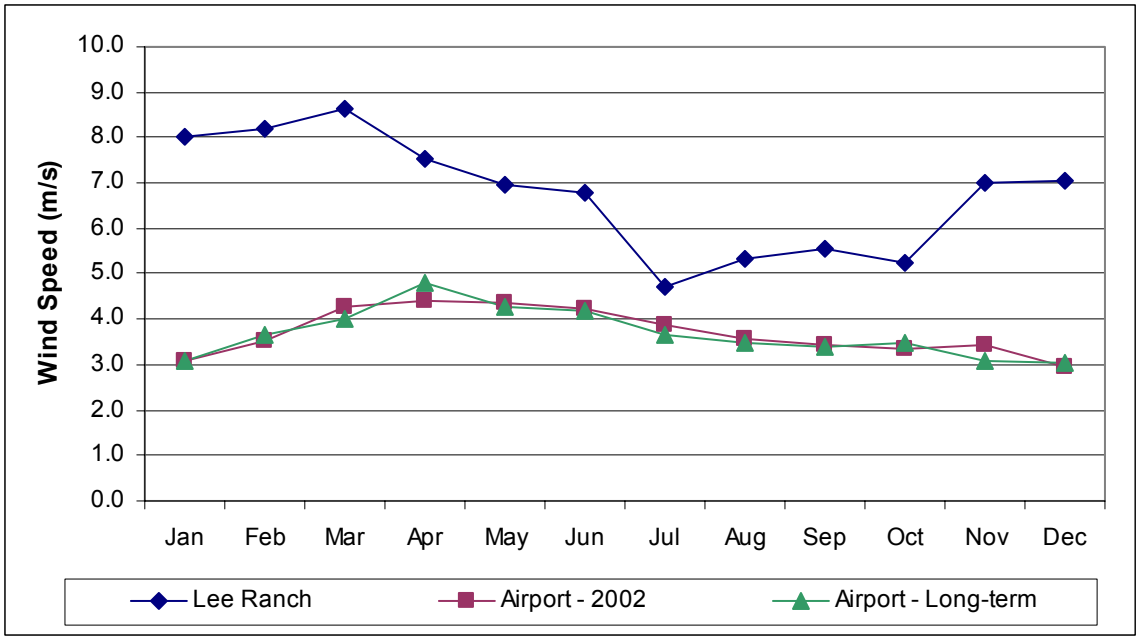


Figure 4. Albuquerque Airport Wind Speed Comparison

Table 4. Albuquerque International Airport Monthly Wind Speeds

	Albuquerque Airport	
	2002	**Long-Term**
January	3.1	3.1
February	3.5	3.6
March	4.3	4.0
April	4.4	4.8
May	4.4	4.3
June	4.2	4.2
July	3.9	3.6
August	3.6	3.5
September	3.4	3.4
October	3.4	3.5
November	3.4	3.1
December	3.0	3.1
Annual	**3.7**	**3.7**

DATA RECOVERY

Table 5 provides the monthly recovery rates for wind speed data collected at 10, 25, and 40 m. February experienced the lowest recovery rate due entirely to icing. The average recovery rate at the 40-m level for 2002 is 99.6%. All data loss was due to icing.

Table 5. Wind Speed Data Recovery – 2002

	Total Hours	Hours Lost			Recovery Rate	
Month	**In Period**	**10m**	**25m**	**40m**	**All Heights**	**40m Level**
January	744	6	7	7	99.1%	99.1%
February	720	23	23	23	96.8%	96.8%
March	744	0	0	0	100.0%	100.0%
April	720	0	0	0	100.0%	100.0%
May	744	0	0	0	100.0%	100.0%
June	720	0	0	0	100.0%	100.0%
July	744	0	0	0	100.0%	100.0%
August	744	0	0	0	100.0%	100.0%
September	720	0	0	0	100.0%	100.0%
October	744	4	4	6	99.4%	99.2%
November	720	3	3	3	99.6%	99.6%
December	744	0	0	0	100.0%	100.0%
Annual	**8760**	**36**	**37**	**39**	**99.6%**	**99.6%**

WIND SPEED

Monthly wind speeds for all levels are summarized in Table 6 and illustrated in Figure 5. As shown in Figure 5, the wind speeds were highest during January through March and lowest July through October.

Table 6. Monthly Wind Speeds – 2002

	10M		25M		40M	
	m/s	**mph**	**m/s**	**mph**	**m/s**	**mph**
January	6.0	13.5	7.2	16.1	8.0	18.0
February	6.1	13.7	7.3	16.4	8.2	18.4
March	6.7	15.0	7.8	17.5	8.6	19.3
April	5.8	13.0	6.8	15.2	7.5	16.8
May	5.4	12.0	6.3	14.2	7.0	15.6
June	5.2	11.6	6.1	13.7	6.8	15.2
July	3.4	7.7	4.3	9.6	4.7	10.6
August	3.8	8.4	4.7	10.5	5.3	11.9
September	4.0	8.9	4.9	10.9	5.6	12.4
October	3.7	8.2	4.7	10.4	5.3	11.8
November	5.2	11.6	6.2	13.9	7.0	15.6
December	5.4	12.1	6.3	14.0	7.0	15.8
Annual	**5.1**	**11.3**	**6.1**	**13.5**	**6.8**	**15.1**

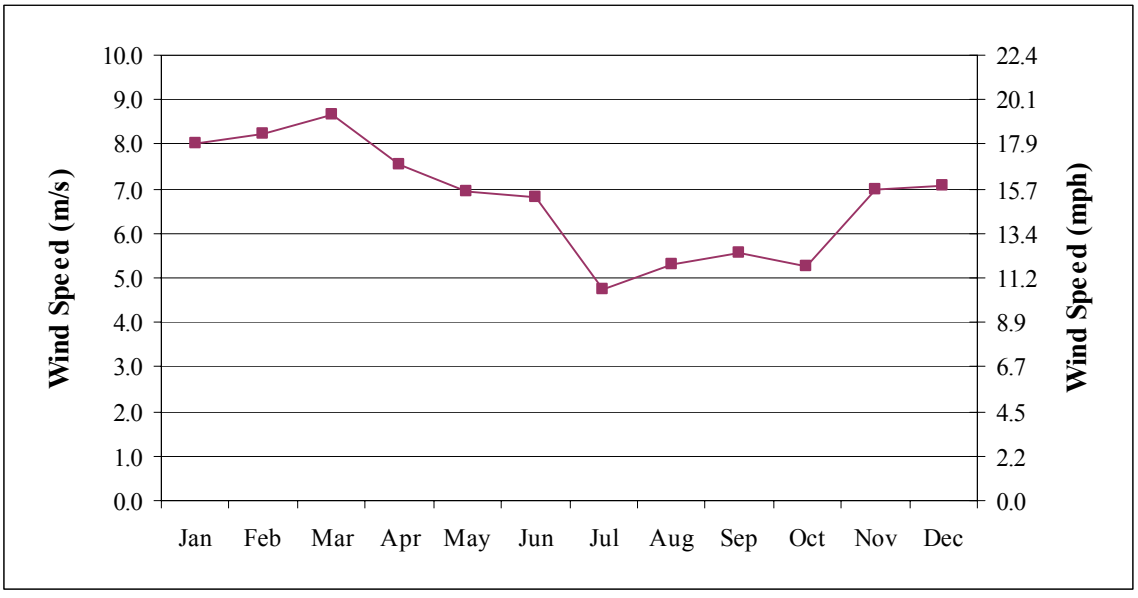


Figure 5. 40-m Monthly Wind Speed

The annual diurnal wind speed pattern is shown in Figure 6. On an annual basis, the wind speeds were highest midday from 12:00 – 17:00. The monthly diurnal wind speeds provided in Figure 7 illustrate the variation of the diurnal pattern from season to season.

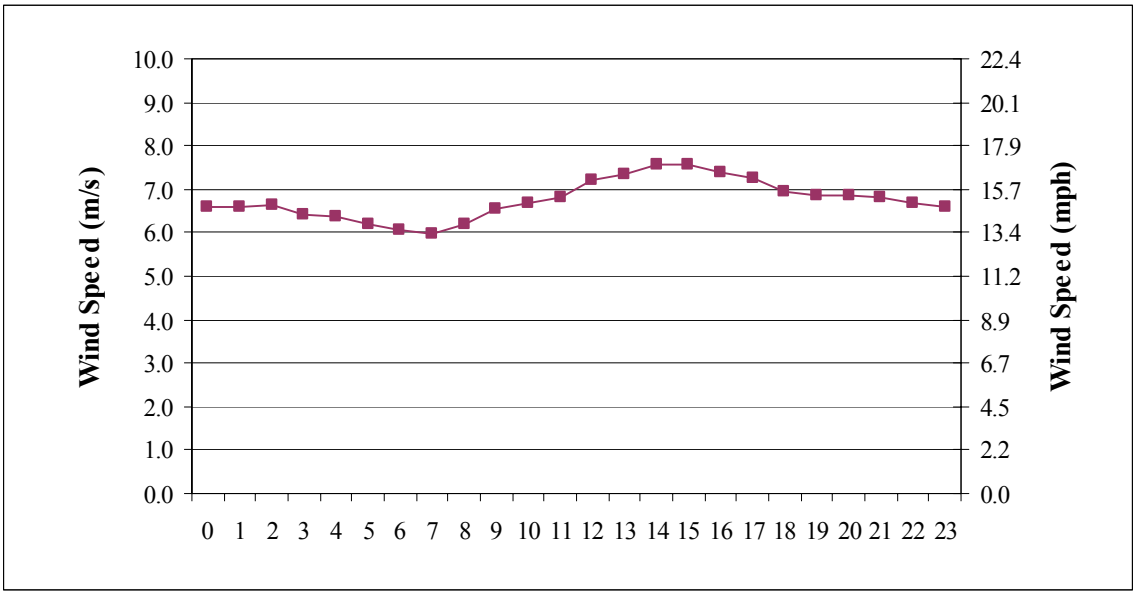


Figure 6. Annual 40-m Diurnal Wind Speed

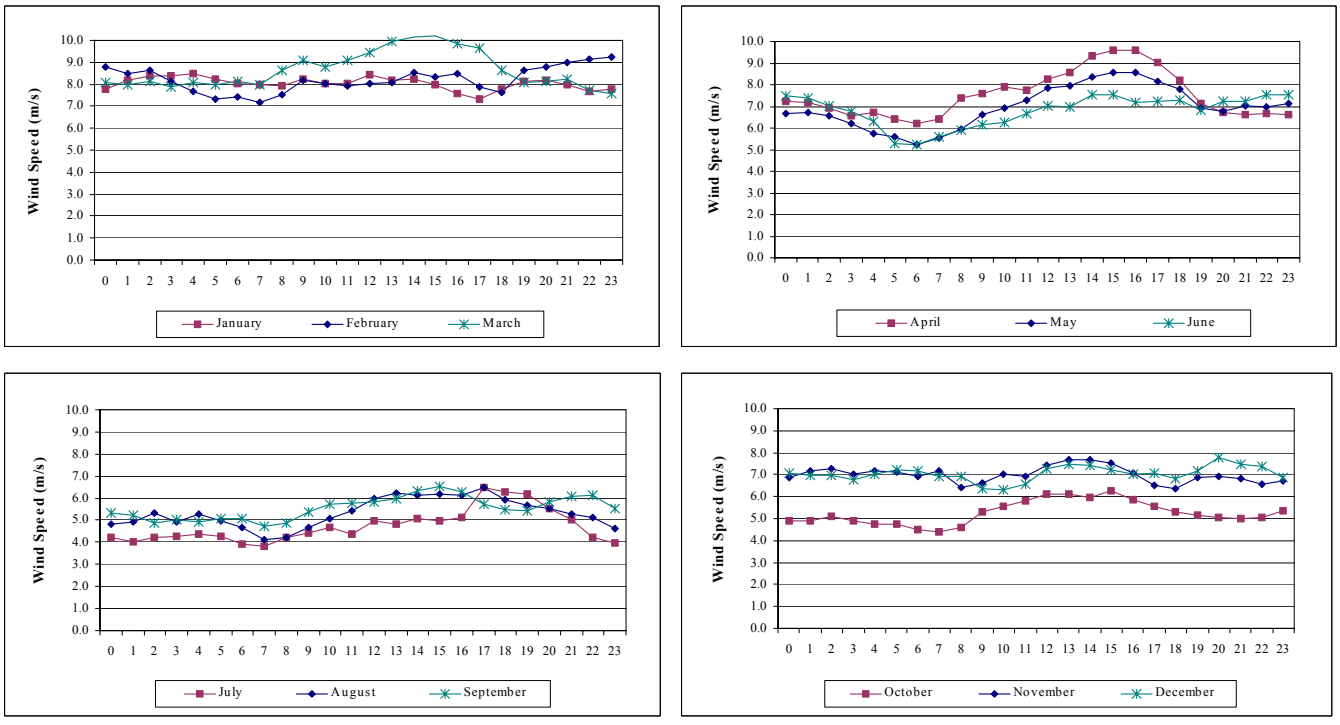


Figure 7. 40-m Monthly Diurnal Wind Speed

WIND DIRECTION

Figure 8 shows the annual wind rose for Lee Ranch. This graph illustrates the percent time and percent energy in each direction sector for data collected from January through December 2002. The predominant wind direction is west-northwest.

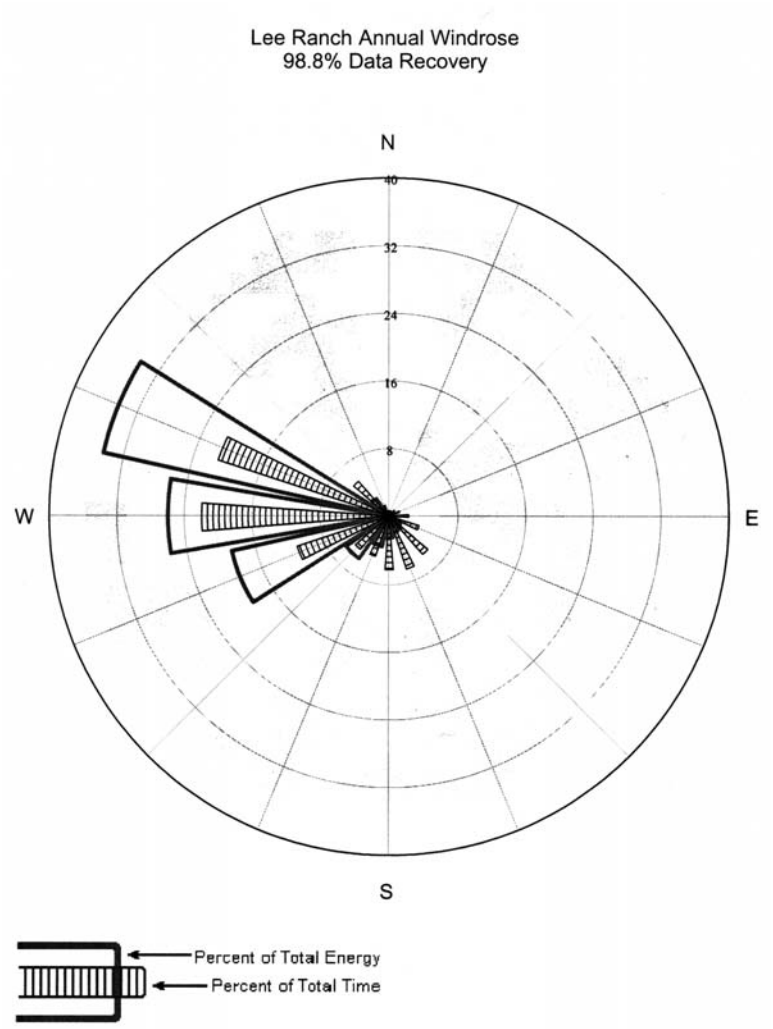


Figure 8. Annual Wind Rose

Monthly wind rose graphs are provided in the appendices of each quarterly report. September – December 2002 monthly wind rose graphs are provided in the appendix of this report. Similar to the annual wind rose in Figure 8, the monthly wind roses consist of two bars in each of the 16 wind direction sectors that represent the percent of total time and the percent of total wind energy. The monthly wind roses illustrate prevailing wind directions and also provide turbulence intensity by wind direction sector.

WIND SHEAR AND TURBULENCE INTENSITY

The average turbulence intensity at 40 m is provided in Table 7. The TI value shown is from the predominant wind direction only. TI values for all direction sectors are provided in the monthly wind rose graphs included in the appendix. Lee Ranch experiences turbulence intensities at the low end of the moderate range; therefore, the TI values to date indicate no concerns for wind energy development at this location.

Wind shear exponent values are also provided in Table 7. For the purposes of this report, the wind shear exponent was calculated for the 25-40 m height. During this period the wind shear exponent in operable winds (winds above 4 m/s) was 0.24.

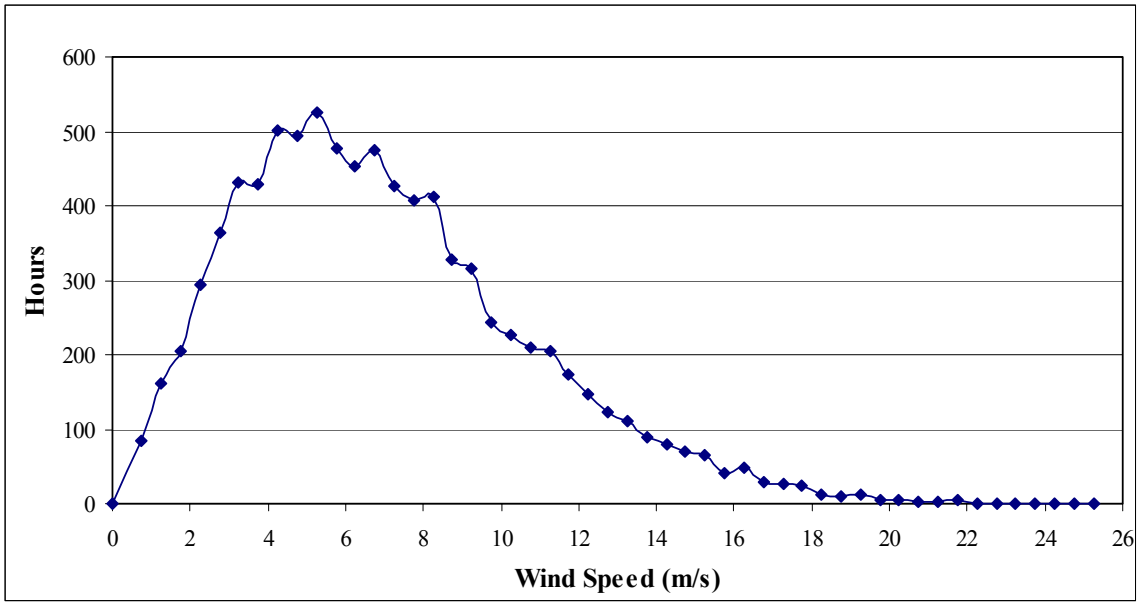
Table 7. Turbulence Intensity and Wind Shear Summary – 2002

	Average TI (Predominant Direction)	Average Wind Shear Exponent* (25m - 40m)
January	0.09	0.24
February	0.09	0.25
March	0.11	0.22
April	0.14	0.22
May	0.12	0.20
June	0.12	0.21
July	0.13	0.23
August	0.11	0.26
September	0.12	0.27
October	0.12	0.25
November	0.10	0.26
December	0.10	0.25
Annual	**0.11**	**0.24**

* for wind speeds greater than 4 m/s

FREQUENCY DISTRIBUTION

Figure 9 presents the annual wind speed frequency distribution at Lee Ranch for 2002 in graphical and tabular form. This frequency distribution is based on corrected 40-m wind speed data. Monthly frequency distributions are provided in the appendices of each quarterly report.



Bin Center	Hours	Bin Center	Hours	Bin Center	Hours
0.0	0	8.5	327	17.0	27
0.5	84	9.0	316	17.5	24
1.0	162	9.5	243	18.0	12
1.5	206	10.0	227	18.5	9
2.0	293	10.5	210	19.0	13
2.5	364	11.0	206	19.5	6
3.0	432	11.5	173	20.0	6
3.5	428	12.0	148	20.5	2
4.0	501	12.5	124	21.0	2
4.5	495	13.0	110	21.5	4
5.0	526	13.5	90	22.0	1
5.5	478	14.0	80	22.5	0
6.0	454	14.5	70	23.0	0
6.5	475	15.0	65	23.5	0
7.0	427	15.5	41	24.0	1
7.5	407	16.0	48	24.5	1
8.0	413	16.5	29	25.0+	0
				Annual Hours	**8,760**

Figure 9. 40-m Wind Speed Frequency Distributions

APPENDIX

SITE 701 – LEE RANCH