

OREGON ANEMOMETER LOAN PROGRAM

# *Wind Resource Evaluation: South Salem Hills*



Prepared By:  
**Energy Resources Research laboratory**  
**Oregon State University**

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# *Wind Resource Evaluation: South Salem Hills*

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## ***1.0 INTRODUCTION***

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The Oregon anemometer loan program was established in the fall of 2002 in order to assist landowners in the state evaluate the wind energy potential of their property. The program is funded by a grant from the Energy Trust of Oregon and is administered by the Energy Resources Research Laboratory at Oregon State University. The program involves several steps, beginning with a preliminary evaluation of the site. If estimates of the site show promise then a monitoring system is installed for a fixed duration (typically one year). The site is monitored regularly and the data processed and checked at regular intervals. Upon completion of the first year, the collected wind data is summarized and a report is prepared evaluating the wind data and the wind resource of the location.

This report represents the final portion of the project and is designed to give the landowner the information necessary to make an informed choice about the role wind energy might play in their property. The report is separated in to sections with section 2.0 devoted to a description of the site, its location and the type of terrain found there. Section 3.0 includes a summary of the wind data collected during the study period including data quality checks and a characterization of the measured winds. In section 4.0 the wind data is analyzed to determine the amount of power production that might be expected from the site and to examine characteristics that might influence these estimates. This is followed in section 5.0 in which wind data from a nearby site is summarized and used to place the current study period in climatological context. A discussion and summary is then presented in section 6.0

## 2.0 *SITE DESCRIPTION*

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**Site Name:** South Salem Hills  
**Latitude:** 44-51-51 (WGN 84)  
**Longitude:** 123-05-47  
**Elevation:** 845 ft.  
**Tower Height:** 65 feet (speed)  
**Site #** 0633

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**Types of Sensors:** NRG Maximum #40 wind speed  
NRG 200 series2 wind vane  
**Instrumentation:** Single level mounted with booms off exiting turbine tower

**County:** Marion  
**Installation Date:** February 20, 2006  
**Data Available to:** August 26, 2007

**Site Location:** The site is located on residential property in a semi-rural area know as the South Salem Hills. The Hills are a prominent feature in the center of the Willamette Valley and rise roughly 600 feet above the Valley floor. There is a sharp drop along the southern and western slopes and a more gradual drop to the north. The area consists of rolling hills with small farms many bordered by tall trees. The instrument location is near the top of the Hills and somewhat north of the southern slope. The immediate area is relatively clear and unobstructed. The tower location is marked on the map included in Appendix A.

**Project Description:** This project was initiated by the Energy Trust of Oregon and was originally designed to help evaluate an operating wind turbine at the site. The wind sensors were placed on booms on the existing tower to help obtain field measurements and compare turbine performance with measured winds. Since the instruments were installed however, this particular type of turbine is no longer available in the United States.

**Data Collection and Processing:** NRG equipment was used at this site including #40 anemometers and a Wind Explorer data logger. Data plugs were swapped out on roughly a monthly basis by a nearby land owner and sent to the ERRL. Raw NRG files were read and downloaded from the data cards and used to generate monthly files of ten minute averages. These files were then converted to hourly averages and converted to an internal ERRL format to accommodate data checking and to perform analysis using existing programs. Data were plotted and scanned manually to detect problems and to flag periods of suspected icing.

For the South Salem Hills site several icing periods were identified and removed from the records. These were confined to the months of November and December

2006 and January 2007. The monthly means and recovery rates for the whole period can be found in Table 1.

**Table 2.1: Monthly mean and data recovery rates for the entire monitoring period.**

Month	Site 0633	
	Mean (mph)	Rec. (%)
FEB	9.1	30.5
MAR	10.2	100.0
APR	8.4	100.0
MAY	8.2	100.0
JUN	8.5	100.0
JUL	8.3	100.0
AUG	8.1	100.0
SEP	7.5	100.0
OCT	6.9	100.0
NOV	12.3	93.2
DEC	6.1	77.7
JAN	7.9	98.0
FEB	10.6	100.0
MAR	9.0	100.0
APR	8.1	100.0
MAY	8.2	100.0
JUN	7.9	100.0
JUL	8.2	100.0
AUG	8.0	83.9
MEAN	8.5	89.3

### 3.0 WIND CHARACTERISTICS

In the following sections, several characteristics of the winds at the South Salem site are examined and discussed. The goals are to evaluate the characteristics that can help explain the physical processes at work at the site and to highlight the characteristics that are important to assessing the wind energy potential. These evaluations are done using hourly averaged means that have been constructed using the 10 minute means recorded at the site. This is done so that existing analysis programs can be used and is not expected to have any appreciable influence on the interpretation of data. These evaluations are confined to a single annual period. This is done so that the results are not biased by the addition of data from only a particular season or a portion of a year. *The period analyzed here is for April 1, 2006 to March 31 2007.*

**Monthly Means and Data Recovery:** Monthly means are constructed and used to determine the overall strength of the winds during different periods of the year.

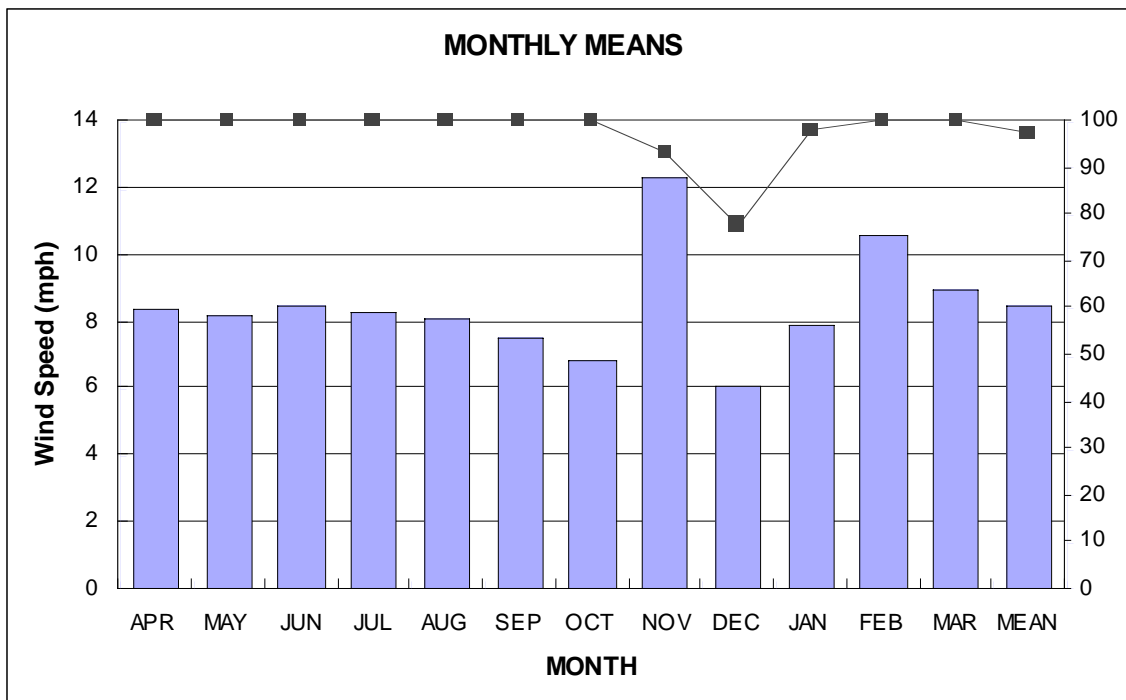
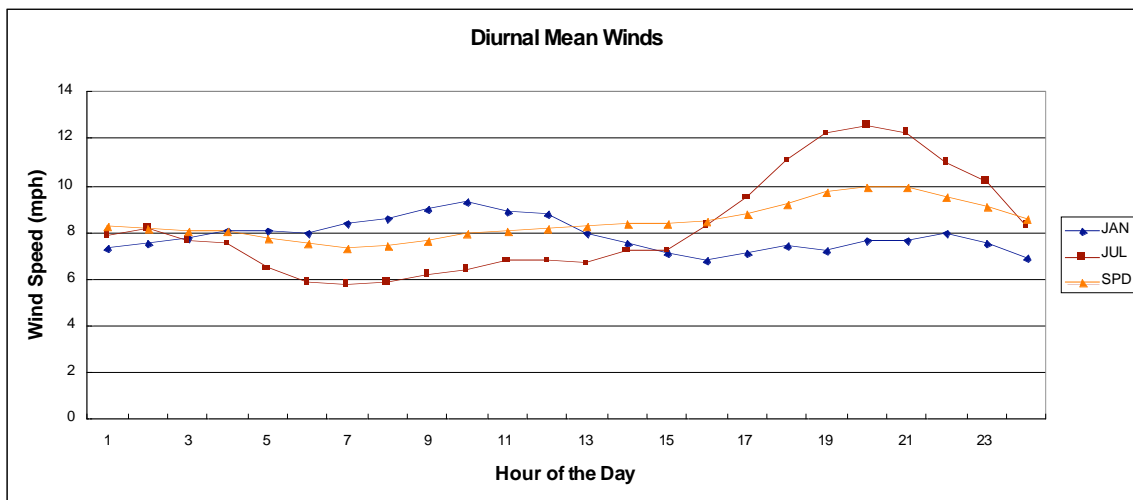


Figure 3.1: Monthly Mean Wind Speed Values for the South Salem Hills site.

**Table 3.1: Monthly mean and data recovery rates for the annual study period.**

Month	Site 0633	
	Mean (mph)	Rec. (%)
APR	8.4	100.0
MAY	8.2	100.0
JUN	8.5	100.0
JUL	8.3	100.0
AUG	8.1	100.0
SEP	7.5	100.0
OCT	6.9	100.0
NOV	12.3	93.2
DEC	6.1	77.7
JAN	7.9	98.0
FEB	10.6	100.0
MAR	9.0	100.0
MEAN	8.5	97.4

**Diurnal Means:** The diurnal pattern of winds is an important characteristic for many wind sites and helps illuminate the mechanisms responsible for the winds. In general, a diurnal pattern is associated with a site at which strong thermal influences play a role. These are normally accentuated during the summer months when the daily heating cycle is at its greatest. Diurnal variations can also provide an indication of dependable and predictable winds at a site.



**Figure 3.2: Diurnal mean wind speed values for the South Salem Hills site.**

**Frequency Distribution:** How the wind speed at a site is distributed over various wind speed categories is an important indication of the wind resource potential of a site. An ideal site would have winds that blow at a high rate for long periods. This is not normally the case, however, and wind records from a site show a skewed distribution with a higher frequency of winds at lower speeds.

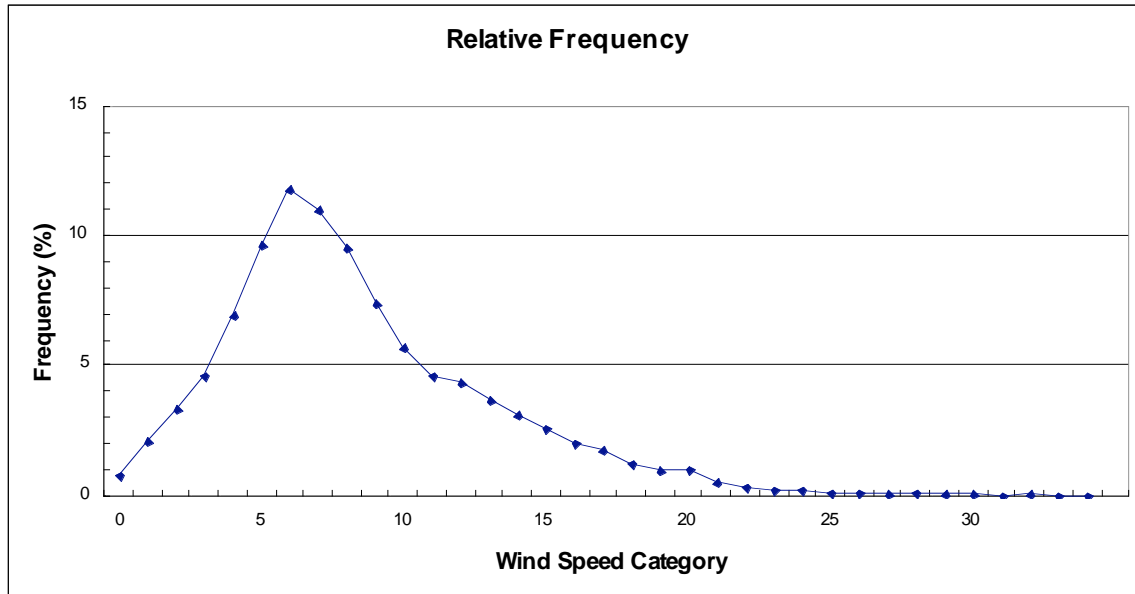
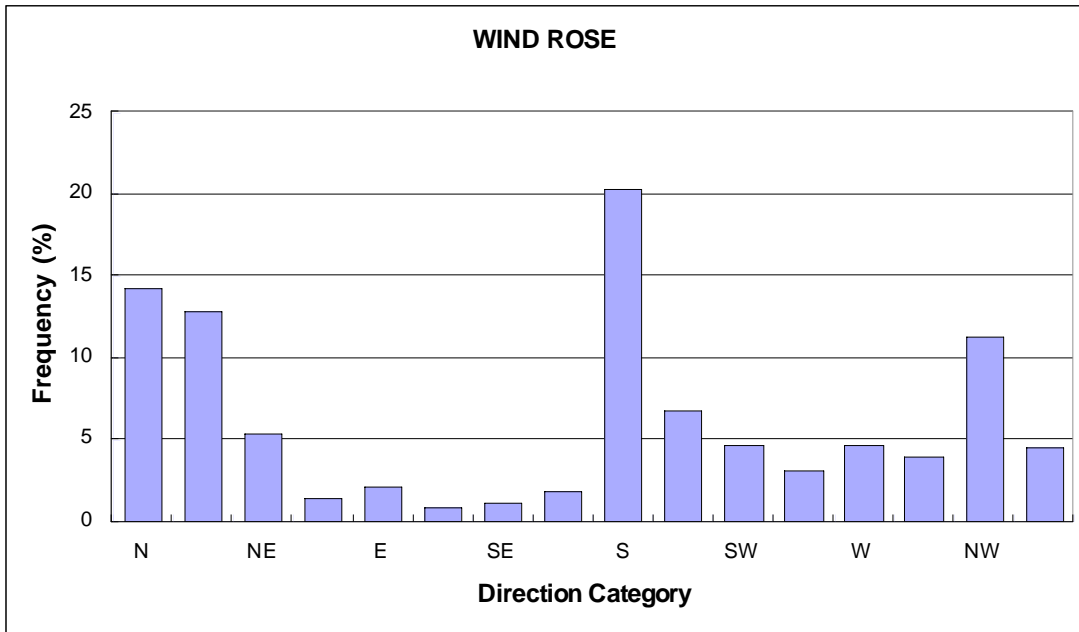
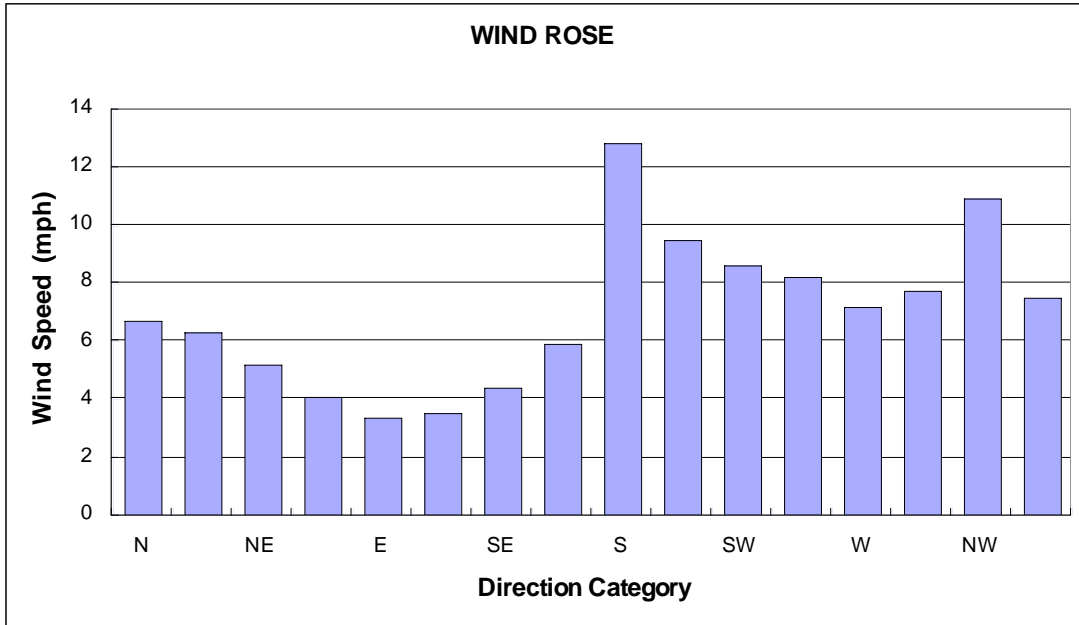


Figure 3.3: Wind speed frequency distribution for the South Salem Hills site.

**Wind Rose:** How the wind varies with direction is also important to understanding the physical processes that contribute to the local winds at a site and eventually in designing a wind facility. A wind rose is often used to display this information and show the frequency with which the wind occurs in different direction categories. A similar plot can be used to show the strength of the wind from each of the direction categories.



**Figure 3.4:** a) Average wind speed (mph) and b) frequency (%) for each of 16 wind direction categories for the annual analysis period.

In order understand better the winds at the site during different times of year; similar plots have been constructed using data from the individual months for the winter and summer. These can be seen in figures 3.5a-d and show any differences between the two periods.

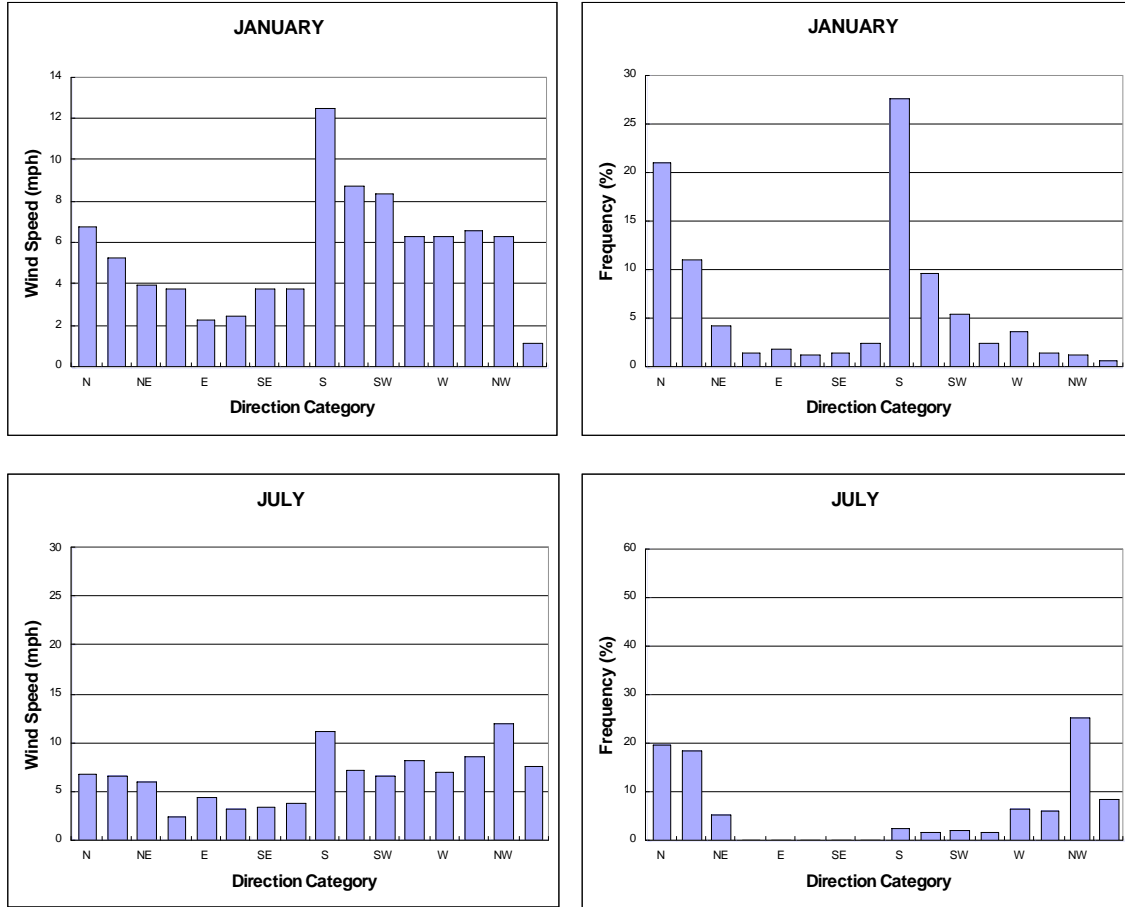


Figure 3.5: Frequency (%) and average wind speed (mph) for each of 16 wind direction categories for a winter and summer month at the South Salem Hills site.

#### 4.0 *SITE POWER CHARACTERISTICS*

In order to evaluate the wind power potential at this site a number of quantities were computed using the collected wind data. As with the wind characteristics, hourly wind data was used to complete this work. The power density calculation requires air density. This is estimated assuming a standard atmosphere and the site elevation. The computed quantities include the mean and standard deviation of the hourly values, the recovery rate, the maximum one hour average, the wind power density and the frequency that the wind was observed within a wind speed range (12 mph to 60 mph). These quantities are shown in Table 4.1 and reveal a number of things about the potential for generating energy at the site.

**Table 4.1: Observed and computed power quantities at the South Salem Hills site.**

Month	Mean	Std.	Recovery	Max 1-Hr	Time in Range	Power Den.
	(mph)	(mph)	Rate(%)	(mph)	(12-60 mph)	W/m <sup>2</sup>
Apr	8.4	4.0	100.0	23.5	19.0	56
May	8.2	3.3	100.0	19.8	13.8	45
Jun	8.5	3.4	100.0	20.1	15.0	50
Jul	8.3	3.7	100.0	20.3	17.6	51
Aug	8.1	3.5	100.0	20.8	14.4	46
Sep	7.5	3.2	100.0	19.9	10.1	37
Oct	6.9	3.7	100.0	24.4	9.8	36
Nov	12.3	6.6	93.2	32.6	53.4	186
Dec	6.1	5.7	77.7	33.6	15.1	62
Jan	7.9	5.4	98.0	26.3	17.1	72
Feb	10.6	5.9	100.0	32.1	37.2	131
Mar	9.0	4.7	100.0	25.3	25.9	74
ANN	8.5	4.8	97.4	33.6	20.5	69

To examine the overall amount of energy contained in the wind, the power density is very useful. It represents the amount of energy that would be available to a unit area each hour. The monthly mean values are shown in figure 4.1 and highlight the difference between the seasons and the different sites. The monthly power density for November was over 180 W/m<sup>2</sup> while the summer months were below 100 W/m<sup>2</sup>. This is largely a function of the amount of high winds observed at a site.

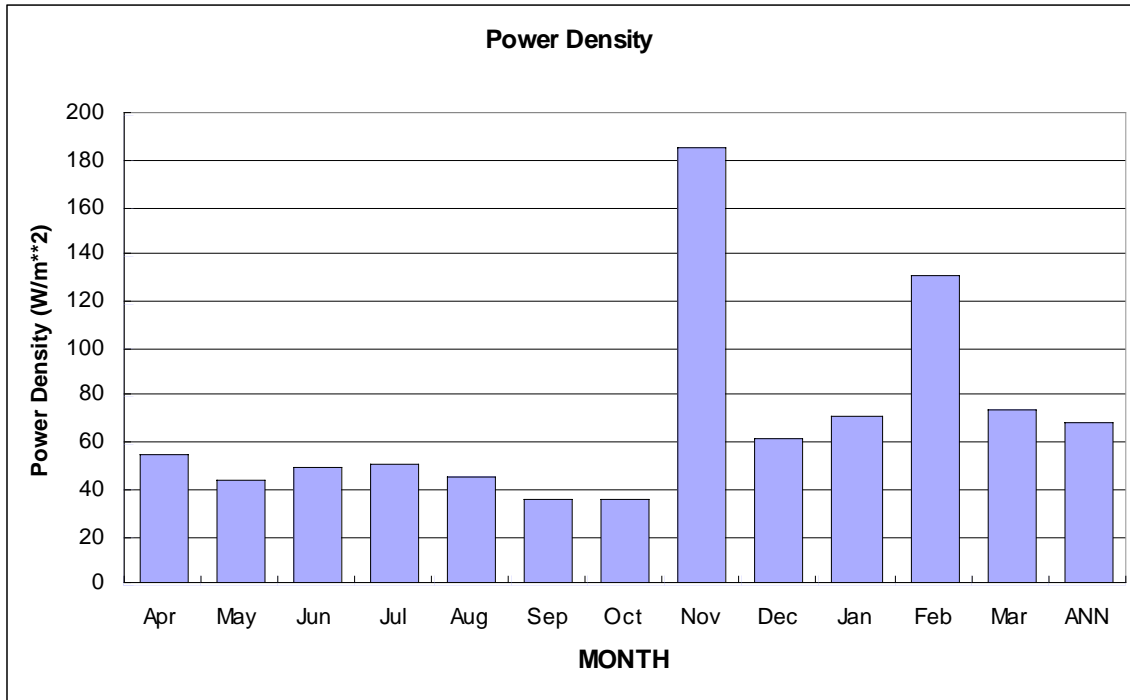


Figure 4.1: Monthly power density for the South Salem Hills site.

In addition to evaluating these basic power characteristics it is possible to estimate how specific wind turbines might interact with the winds at a particular site. Using the collected wind data and the characteristics of a particular wind turbine it is possible to estimate the amount of power it could produce. This is done by comparing the wind data with a power curve for a specific wind turbine. A power curve is simply the curve that shows the relationship between the wind speed and the amount of power a turbine can produce. An example is provided in Figure 4.2. There are several portions of the curve that are important. At low wind speeds, below the cut-in speed, no energy is produced. Any turbine has a lower threshold below which it won't operate. This is in part because there is little energy available at these levels. In the middle is a ramp up zone where even a small increase in wind speed results in a larger increase in power. At some point, depending on the type of turbine, the amount of power that is generated reaches the rated limit of the generator (rated capacity). The blades are then pitched to spill energy and protect the generator. At the upper end, energy production will stop if the winds reach a cut-out speed. This is the speed at which a turbine is shut down to protect the structural integrity of the turbine.

In Table 4.2, energy capacity factors are shown for four different types of turbines. The capacity factor is the ratio of the amount of energy produce to the amount of energy that could be produced if a turbine ran at its rated capacity all the time. The rated capacity is effectively a theoretical maximum and capacity factors generally range from 0.0 to 0.40.

It's difficult to compare these because of the different turbine characteristics but they are given to provide a range of values that might be expected from this site. In computing these values, it is necessary to adjust the observed data which is measured at 65 feet to the hub height of the particular turbine. In this case this is done using a standard assumption that the wind follows a typical power law profile. Unfortunately, the shear coefficient is not know and must be estimated. A standard value of 0.143 is used here.

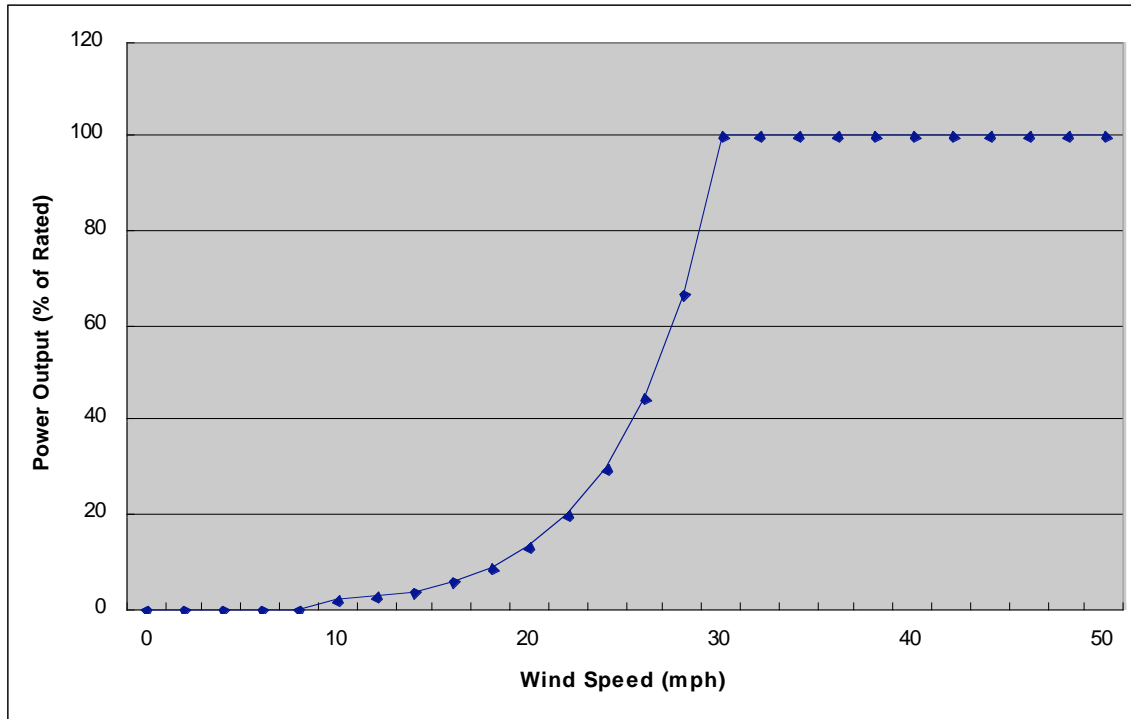


Figure 4.2: Sample power curve for a theoretical turbine

The capacity factors in Table 4.3 support the conclusions of the previous sections and indicate that although a few months show some signs of a moderate wind resource the site in general is low for much of the year.

**Table 4.2: Capacity factors computed for various wind turbines using the South Salem Hills site and a shear coefficient of 0.143.**

<b>Turbine</b>	<b>Vestas 47</b>	<b>Mit 250</b>	<b>BWC Excel</b>	<b>GE Wind 70.5</b>
<b>Size (kW)</b>	660	250	10	1500
<b>Hub Ht. (ft.)</b>	131	100	79	210
<b>Apr</b>	0.071	0.050	0.040	0.085
<b>May</b>	0.053	0.037	0.029	0.064
<b>Jun</b>	0.059	0.042	0.033	0.073
<b>Jul</b>	0.063	0.044	0.035	0.074
<b>Aug</b>	0.055	0.039	0.031	0.067
<b>Sep</b>	0.040	0.029	0.023	0.050
<b>Oct</b>	0.039	0.028	0.023	0.048
<b>Nov</b>	0.251	0.183	0.150	0.285
<b>Dec</b>	0.064	0.050	0.042	0.072
<b>Jan</b>	0.090	0.065	0.054	0.105
<b>Feb</b>	0.171	0.124	0.102	0.196
<b>Mar</b>	0.102	0.072	0.057	0.118
<b>ANN</b>	0.086	0.062	0.050	0.100

## ***5.0 CLIMATOLOGICAL ANALYSIS***

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Measurements taken over a single one-year period can provide a good estimation of the winds and wind energy potential of a site. However, this is a fairly limited period and is only meaningful if we can place the period into a larger climatological context. The South Salem Hills site is relatively close to a long-term NWS site which should provide the necessary climatological information.

Salem McNary Field has been a NWS station since the 1920's. The site is located several miles NE and at a lower elevation but should provide a reasonable representation of the conditions over this annual study period. Monthly mean wind speed values were obtained from the NCDC archives in the form of "Local Climatological Data" bulletins that are issued monthly.

The long-term monthly means and monthly means for the current study period for each of these sites are shown in Table 5.1. Also shown are the monthly departures. Overall, wind conditions for the analysis period appeared to be below normal by 4.5 %. For this period, the only month with a strong positive departure was November (31.5%). The departures for all other months were either small or negative. This suggests that the winds during the analysis period may be underestimating the long-term conditions at the South Salem Hills site. In fact this was observed at other sites in the region. The low winds in the winter months suggest that the usual southerly winds were lighter than normal (fewer storms). In a more typical winter there would likely be a greater frequency of southerly winds. However, the wind resource overall is low and would not be expected to increase substantially during a more typical year.

Table 5.1: Monthly mean and departures for long-term National Weather Service Station in Salem

<b>Salem McNary Field</b>			
<b>Latitude: 44.90N</b>		<b>Elevation: 205'</b>	
<b>Longitude 122.98W</b>			
<b>Month</b>	<b>Normal (mph) 1971-2000</b>	<b>Mean (mph) 2006-2007</b>	<b>Departure (%)</b>
<b>Apr</b>	<b>7.0</b>	<b>6.4</b>	<b>-8.6</b>
<b>May</b>	<b>6.6</b>	<b>6.1</b>	<b>-7.6</b>
<b>Jun</b>	<b>6.7</b>	<b>6.6</b>	<b>-1.5</b>
<b>Jul</b>	<b>6.7</b>	<b>6.6</b>	<b>-1.5</b>
<b>Aug</b>	<b>6.2</b>	<b>6.3</b>	<b>1.6</b>
<b>Sep</b>	<b>5.7</b>	<b>5.3</b>	<b>-7.0</b>
<b>Oct</b>	<b>5.8</b>	<b>4.8</b>	<b>-17.2</b>
<b>Nov</b>	<b>7.3</b>	<b>9.6</b>	<b>31.5</b>
<b>Dec</b>	<b>7.2</b>	<b>5.8</b>	<b>-19.4</b>
<b>Jan</b>	<b>7.3</b>	<b>5.9</b>	<b>-19.2</b>
<b>Feb</b>	<b>7.2</b>	<b>7.7</b>	<b>6.9</b>
<b>Mar</b>	<b>7.3</b>	<b>6.8</b>	<b>-6.8</b>
<b>ANN</b>	<b>6.8</b>	<b>6.5</b>	<b>-4.5</b>

## ***6.0 SUMMARY AND DISCUSSION***

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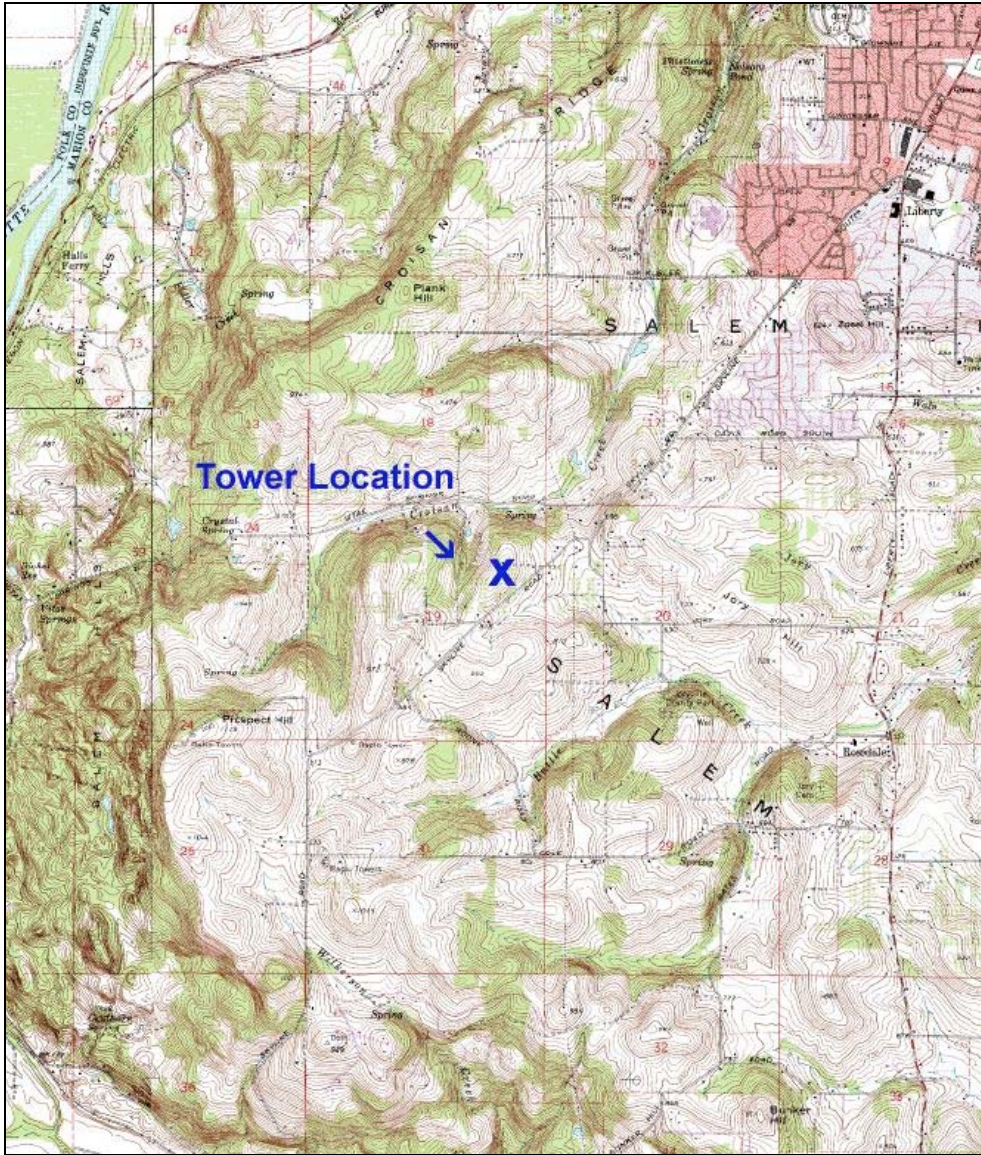
There are a number of factors that might have an influence on the interpretation of the winds observed over this annual study period at the South Salem Hills site. First, measurements were taken from only one location and it is possible that other locations in the immediate area might provide better exposure to the prevailing winds. The location of the tower was dictated by the constraints of the property boundaries and the terrain.

A second factor that is important to consider is that observations were collected at only one height. Flow over and around the coastlines and coastal hills can be very complex and difficult to estimate. These types of flows are influenced by many factors including the density of the air and the exact shape and orientation of the local terrain. Observations taken at a different height above ground would most likely show some differences that might be important to a determination of economic feasibility.

In summary,

- 1) Data Quality was good and sufficient a sufficient quantity of data was obtained to enable conditions to be characterized for a complete annual analysis period.
- 2) During the summer winds generally come from the N and NW. During winter months winds come from the southerly directions. The strongest energy producing winds come from the South.
- 3) Comparisons with a nearby site where a longer history of observations are available suggest that the annual study period (April 2006-March 2007) was below the long-term mean by about 4.5 %.
- 4) Gross capacity factors computed for the site using various assumptions are between 5.0% and 10.0% depending on the wind turbine type. This suggests the wind resource at the site and in the area in general is fairly low.

Appendix A: Topographic map of the location of the South Salem Hills tower site.



Appendix B: Photograph of the wind turbine and tower the wind sensors were placed on and of the surrounding area.





Appendix C: Site Visit Records and wind gust during period prior to visit.

Changes Made					
Date:	Plug	Battery	Time	Gust (mph)	Comment
02/20/2006					Site Installed
05/05/2006	Y			50	
07/04/2006	Y	Y		62	
04/14/2006	Y	Y	Y	39	
08/29/2006	Y		Y	31	
12/16/2006	Y			66	
05/30/2007	Y		Y	50	
10/11/2007	Y			35	Site Removed (est. date)
					(Battery was dead upon retrieval)

Appendix D: Miscellaneous analysis Tables.

STATION SOUTH SALEM HILLS (SITE 0633)  
 WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY  
 DATA PERIOD OF RECORD - 4/2006 - 3/2007  
 NORMALIZATION PERIOD - ONE YEAR  
 AVERAGE WIND SPEED FOR PERIOD: 8.5 MPH  
 NORMALIZED AVAILABLE ENERGY: 609.4 KWH/M\*\*2/YEAR  
 TOTAL HOURS OBSERVED: 8530

MPH	PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	KWH/M**2/YEAR
0	66	0.77	8530	100.00	0.0
1	176	2.06	8464	99.23	0.0
2	286	3.35	8288	97.16	0.1
3	396	4.64	8002	93.81	0.6
4	592	6.94	7606	89.17	2.1
5	822	9.64	7014	82.23	5.6
6	1004	11.77	6192	72.59	11.9
7	936	10.97	5188	60.82	17.6
8	813	9.53	4252	49.85	22.8
9	630	7.39	3439	40.32	25.2
10	487	5.71	2809	32.93	26.7
11	393	4.61	2322	27.22	28.7
12	371	4.35	1929	22.61	35.1
13	314	3.68	1558	18.26	37.8
14	263	3.08	1244	14.58	39.6
15	219	2.57	981	11.50	40.5
16	174	2.04	762	8.93	39.1
17	147	1.72	588	6.89	39.6
18	107	1.25	441	5.17	34.2
19	84	0.98	334	3.92	31.6
20	85	1.00	250	2.93	37.3
21	41	0.48	165	1.93	20.8
22	31	0.36	124	1.45	18.1
23	20	0.23	93	1.09	13.3
24	20	0.23	73	0.86	15.2
25	11	0.13	53	0.62	9.4
26	10	0.12	42	0.49	9.6
27	5	0.06	32	0.38	5.4
28	8	0.09	27	0.32	9.6
29	4	0.05	19	0.22	5.3
30	3	0.04	15	0.18	4.4
31	2	0.02	12	0.14	3.3
32	7	0.08	10	0.12	12.6
33	2	0.02	3	0.04	3.9
34	1	0.01	1	0.01	2.2

**STATION SOUTH SALEM HILLS (SITE 0633)**

MONTHLY WIND SPEEDS (MPH)

DATA PERIOD OF RECORD - 1/2006 - 8/2007

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG
2006	0.0	9.1	10.2	8.4	8.2	8.5	8.3	8.1	7.5	6.9	12.3	6.1	7334	8.47
# OBS	0	205	744	720	744	720	744	744	720	744	671	578		
2007	7.9	10.6	9.0	8.1	8.2	7.9	8.2	8.0	0.0	0.0	0.0	0.0	5697	8.48
# OBS	729	672	744	720	744	720	744	624	0	0	0	0		
AVG	7.9	10.2	9.6	8.2	8.2	8.2	8.2	8.1	7.5	6.9	12.3	6.1	13031	8.48
SD	0.0	1.1	0.8	0.2	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0		

**STATION SOUTH SALEM HILLS (SITE 0633)**

DIURNAL WIND SPEEDS (MPH)

DATA PERIOD OF RECORD - 4/2006 - 3/2007

	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	AVG SPD	
MON	7.3	7.5	7.8	8.1	8.1	8.0	8.4	8.6	9.0	9.3	8.9	8.8	8.0	7.5	7.1	6.8	7.1	7.4	7.2	7.7	7.7	7.7	8.0	7.5	6.9	7.9
JAN	10.6	10.7	10.7	11.8	12.1	11.8	11.8	11.6	11.1	10.7	10.3	10.3	10.3	9.8	10.1	10.0	10.1	9.7	10.2	10.2	9.6	10.1	10.4	10.4	10.4	10.6
FEB	9.8	9.1	9.1	8.8	8.0	8.1	8.1	7.6	8.0	8.6	8.9	8.7	9.0	9.5	9.6	9.7	9.3	9.3	9.7	9.6	9.7	9.6	9.5	9.3	9.3	9.0
MAR	7.9	8.0	8.1	7.8	7.8	7.4	7.3	7.5	8.0	8.3	8.6	8.8	9.2	9.0	9.3	9.3	8.9	8.5	8.8	10.0	8.8	7.9	8.2	7.9	8.4	8.4
APR	8.0	7.8	8.2	7.7	7.1	6.6	6.7	7.0	7.1	7.6	8.2	8.3	8.9	8.8	8.3	8.2	8.5	8.8	9.5	9.8	10.1	9.3	8.1	7.5	8.2	8.2
MAY	8.5	8.0	7.2	7.4	7.0	6.3	6.1	6.4	7.0	7.2	7.4	7.7	8.3	8.8	9.0	8.9	9.1	9.4	10.0	10.6	11.5	11.2	10.7	9.3	8.5	8.5
JUN	7.9	8.2	7.7	7.5	6.5	5.9	5.8	5.9	6.2	6.4	6.8	6.8	6.7	7.2	7.2	8.3	9.5	11.1	12.2	12.6	12.3	11.0	10.2	8.3	8.3	8.3
JUL	8.7	7.6	7.5	7.0	6.3	5.5	5.1	5.4	5.8	6.3	6.6	6.7	7.0	7.2	7.9	8.4	9.2	10.5	12.2	12.2	11.3	11.1	9.8	9.3	8.1	8.1
AUG	7.8	7.3	7.1	6.6	6.5	6.2	5.2	5.7	6.0	6.4	6.9	7.1	7.3	7.5	7.6	7.8	8.6	9.6	10.2	10.1	9.3	8.3	8.1	7.8	7.5	7.5
SEP	6.6	6.4	6.5	6.9	6.3	6.4	6.2	6.0	6.2	6.5	6.8	6.8	6.6	6.5	6.3	6.3	7.0	7.7	7.8	7.8	8.2	7.7	7.7	7.4	6.9	6.9
OCT	11.8	12.1	11.7	12.2	12.6	12.7	12.5	12.4	13.0	13.3	13.5	13.4	12.7	12.3	12.5	11.9	11.0	11.1	11.8	12.1	12.1	11.6	12.2	11.8	12.3	12.3
NOV	5.1	5.5	5.9	5.8	5.5	5.4	5.6	5.6	5.7	5.3	4.8	4.9	6.1	6.8	6.4	6.1	6.7	7.0	6.4	7.5	7.6	7.2	7.0	6.8	6.1	6.1
DEC	8.3	8.2	8.1	8.1	7.8	7.5	7.3	7.4	7.7	8.0	8.1	8.2	8.3	8.4	8.4	8.5	8.8	9.2	9.7	10.0	9.9	9.5	9.1	8.6	8.5	8.5

STATION SOUTH SALEM HILLS (SITE 0633)  
WIND ROSE FOR ALL DATA - 8530 OBSERVATIONS  
DATA PERIOD OF RECORD - 4/2006 - 3/2007

DIR	SPEED CATEGORIES (MPH)																TOTAL %	MEAN SPEED (MPH)	
	0	10	13	16	19	22	25	28	31	34	37	40	43	46	49	52			>=
N	13.5	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	6.7
NNE	12.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	6.3
NE	5.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	5.2
ENE	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	4.1
E	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	3.4
ESE	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.5
SE	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	4.4
SSE	1.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	5.9
S	6.6	4.4	3.7	2.7	1.7	0.7	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	12.8
SSW	3.8	1.7	0.9	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	9.5
SW	3.1	1.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	8.6
WSW	2.1	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	8.2
W	3.8	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	7.2
WNW	3.2	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	7.7
NW	4.8	2.3	2.6	1.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3	10.9
NNW	3.4	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	7.5
CALM																			0.8
TOTAL	70.0	13.7	8.4	4.5	2.1	0.8	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	8.5

NOTE: MEAN SPEED OF THE TOTAL IN A WIND ROSE MAY DIFFER FROM THE SPEED FREQUENCY DISTRIBUTION FOR A GIVEN PERIOD DUE TO DATA SELECTION. SPEED FREQUENCY DISTRIBUTIONS REQUIRE ONLY A WIND SPEED OBSERVATION BE PRESENT. WIND ROSES, ON THE OTHER HAND, REQUIRE BOTH SPEED AND DIRECTION BE PRESENT FOR EACH OBSERVATION.

STATION SOUTH SALEM HILLS (SITE 0633)  
 ENERGY ROSE (TOTALS ARE NORMALIZED AVAILABLE ENERGY (KWH/M\*\*2)  
 DATA PERIOD OF RECORD - 4/2006 - 3/2007

MON	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	OBS.	NORM.
JAN	3.5	0.9	0.2	0.1	0.0	0.0	0.0	0.1	41.6	4.8	2.1	0.4	0.5	0.3	0.4	0.0	55.1	716	744
FEB	0.5	0.8	0.2	0.1	0.0	0.1	0.1	0.6	72.7	8.3	2.9	1.2	0.7	0.1	0.1	0.0	88.4	669	672
MAR	0.3	0.3	0.3	0.1	0.1	0.0	0.1	0.4	36.1	5.4	3.2	2.3	1.3	0.8	4.8	0.2	55.7	741	744
APR	2.4	1.4	1.0	0.2	0.2	0.2	0.2	0.5	16.4	2.4	1.5	2.6	1.9	1.6	6.3	1.3	40.1	720	720
MAY	3.0	2.2	0.9	0.0	0.0	0.0	0.1	0.1	9.1	1.8	1.4	1.4	1.6	1.4	8.5	1.8	33.4	743	744
JUN	3.6	1.8	0.4	0.0	0.0	0.0	0.0	0.1	3.1	1.6	0.9	2.2	1.5	0.6	17.3	3.0	35.9	719	720
JUL	2.8	2.4	0.6	0.0	0.0	0.0	0.0	0.0	1.9	0.4	0.4	0.5	1.4	2.3	23.1	2.2	38.0	744	744
AUG	4.0	3.1	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.2	1.4	1.3	20.9	3.2	34.9	744	744
SEP	2.7	2.0	0.8	0.1	0.0	0.0	0.0	0.0	5.7	1.3	0.9	0.6	1.0	1.3	9.1	1.3	26.9	719	720
OCT	2.3	3.5	0.7	0.1	0.0	0.0	0.0	0.0	10.3	1.4	0.7	0.1	0.5	0.9	5.3	0.6	26.6	742	744
NOV	0.3	0.1	0.0	0.0	0.0	0.0	0.0	1.3	114.1	13.7	5.0	0.9	0.6	0.3	0.5	0.0	137.0	660	720
DEC	0.4	0.3	0.1	0.0	0.4	0.1	0.2	1.9	20.6	6.0	11.9	1.5	0.8	1.0	3.3	0.1	48.8	543	744
TOT	25.9	18.7	5.5	0.7	0.9	0.5	0.9	5.1	331.8	47.4	30.9	14.0	13.2	12.0	99.5	13.8	620.9	8460	8760

NOTE: AVAILABLE ENERGY IN AN ENERGY ROSE MAY DIFFER FROM THE SPEED FREQUENCY DISTRIBUTION FOR A GIVEN PERIOD DUE TO DATA SELECTION. SPEED FREQUENCY DISTRIBUTIONS REQUIRE ONLY A WIND SPEED OBSERVATION BE PRESENT. ENERGY ROSES, ON THE OTHER HAND, REQUIRE BOTH SPEED AND DIRECTION BE PRESENT FOR EACH OBSERVATION.