OREGON ANEMOMETER LOAN PROGRAM

# *Wind Resource Evaluation: Black Cap Peak*

**Prepared By:**

**Energy Resources Research laboratory**

**Oregon State University**

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# *Wind Resource Evaluation*
# *Black Cap Peak*

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## *1.0 INTRODUCTION*

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. A discussion and summary is then presented in section 5.0. Generally, a discussion about the climatological significance is presented. In this case, three years of data are available and is believed to be sufficient to characterize the long-term mean.

## *2.0 SITE DESCRIPTION*

| | |
|---|---|
| **Site Name:** | **Black Cap Peak** |
| **Latitude:** | **42-12-22 (WGN 84)** |
| **Longitude:** | **120-19-23** |
| **Elevation:** | **6430 ft.** |
| **Tower Height:** | **65 feet (speed)** |
| **Site #** | **0616** |

| | |
|---|---|
| Types of Sensors: | NRG Maximum #40 wind speed<br>NRG 200 series2 wind vane |
| Instrumentation: | Single level mounted on top of existing wooden pole |
| County: | Lake |
| Installation Date: | Original - October 22, 2003<br>Re-instrumented – May 19, 2004 |
| Data Available to: | September , 2007 |

Data Collection Continuing

**Site Location:** Black Cap Peak is located just north-east of the town of Lakeview in south-central Oregon. The sensor in located on top of a ridge that boarders the city. Access to the site is by a dirt road that heads east from the center of the city. The tower is located on the top of the ridge several hundred yards east of the main communications facility. Access during winter months can be limited. The tower location is marked on the map included in Appendix A.

**Site Description:** The ridge that contains Black Cap Peak is oriented north-south and extends up sharply from the city of Lakeview and the basin below. The ridge is roughly 1800 feet above the elevation of the city. More peaks and ridges exist to the north and east and somewhat to the south. The immediate surroundings consist of small pines and junipers that show some limited signs of flagging. The area is dry, somewhat rocky and has excellent exposure to the south, west and around to north-northwest. A major communications facility is located on a knob in the ridge to the west. The area is also used by recreational hangliders during summer months.

**Project Description**: This project is sponsored by the office of the county commissioners of Lake County who are interested in evaluating the potential for wind to help in economic development. The site may be limited in size for a development area but the location should provide an ideal location for a long-term monitoring site.

**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 county personnel as permitted by the weather 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.

Several problems occurred at the Black Cap site. Because of the altitude and the exposure of the site, icing is a significant problems. The 20 meter tower installed in September 2003 appeared to suffer from icing and collapsed in January 2004. To keep the site active sensors were placed on a nearby wooden pole with the help of a crew from Surprise Valley Cooperative. This installation was done on May 19, 2004. In addition, several periods of icing were detected during winter months. In some cases, these have lasted for weeks. In January 2007 the direction sensor failed and had not been replaced by the time this report was prepared. 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.**

| | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Mean | % | Mean | % | Mean | % | Mean | % | Mean | % |
| JAN | | | 0.0 | 0.0 | 10.6 | 63.6 | 20.4 | 39.7 | 11.5 | 89.9 |
| FEB | | | 0.0 | 0.0 | 13.0 | 93.0 | 14.0 | 89.4 | 13.9 | 68.6 |
| MAR | | | 0.0 | 0.0 | 15.1 | 68.1 | 18.0 | 64.0 | 13.3 | 89.9 |
| APR | | | 0.0 | 0.0 | 13.3 | 92.9 | 14.0 | 82.9 | 12.9 | 97.8 |
| MAY | | | 0.0 | 0.0 | 14.0 | 97.7 | 13.4 | 100.0 | 12.7 | 100.0 |
| JUN | | | 12.8 | 25.0 | 11.9 | 100.0 | 12.1 | 100.0 | 12.6 | 100.0 |
| JUL | | | 11.6 | 100.0 | 11.8 | 100.0 | 12.0 | 100.0 | 12.7 | 94.9 |
| AUG | | | 12.4 | 100.0 | 11.6 | 100.0 | 12.0 | 100.0 | 13.4 | 100.0 |
| SEP | | | 11.3 | 100.0 | 10.5 | 100.0 | 10.9 | 100.0 | 12.0 | 81.5 |
| OCT | 12.3 | 30.4 | 13.2 | 83.7 | 12.6 | 100.0 | 10.4 | 100.0 | | |
| NOV | 14.2 | 74.6 | 11.4 | 94.9 | 14.0 | 82.4 | 19.9 | 79.9 | | |
| DEC | 20.0 | 50.3 | 15.5 | 89.2 | 18.0 | 78.2 | 16.8 | 78.6 | | |

## *3.0 WIND CHARACTERISTICS*

In the following sections, several characteristics of the winds at the Black Cap Peak 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 September 1, 2004 to August 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.

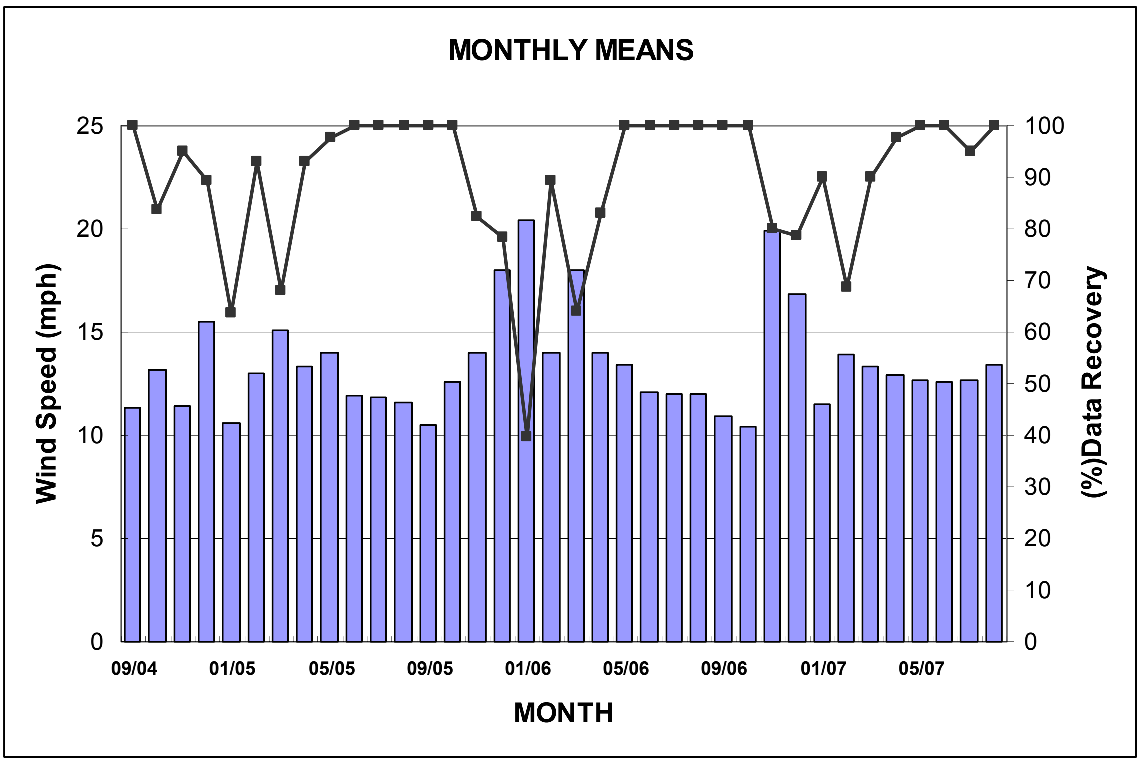


**Figure 3.1: Monthly Mean Wind Speed Values for the Black Cap Peak site.**

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

| | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|
| Month | Mean | % | Mean | % | Mean | % | Mean | % |
| JAN | | | 10.6 | 63.6 | 20.4 | 39.7 | 11.5 | 89.9 |
| FEB | | | 13.0 | 93.0 | 14.0 | 89.4 | 13.9 | 68.6 |
| MAR | | | 15.1 | 68.1 | 18.0 | 64.0 | 13.3 | 89.9 |
| APR | | | 13.3 | 92.9 | 14.0 | 82.9 | 12.9 | 97.8 |
| MAY | | | 14.0 | 97.7 | 13.4 | 100.0 | 12.7 | 100.0 |
| JUN | | | 11.9 | 100.0 | 12.1 | 100.0 | 12.6 | 100.0 |
| JUL | | | 11.8 | 100.0 | 12.0 | 100.0 | 12.7 | 94.9 |
| AUG | | | 11.6 | 100.0 | 12.0 | 100.0 | 13.4 | 100.0 |
| SEP | 11.3 | 100.0 | 10.5 | 100.0 | 10.9 | 100.0 | | |
| OCT | 13.2 | 83.7 | 12.6 | 100.0 | 10.4 | 100.0 | | |
| NOV | 11.4 | 94.9 | 14.0 | 82.4 | 19.9 | 79.9 | | |
| DEC | 15.5 | 89.2 | 18.0 | 78.2 | 16.8 | 78.6 | | |
| | | | | | | 3 year = | 13.2 | 89.4 |

**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.

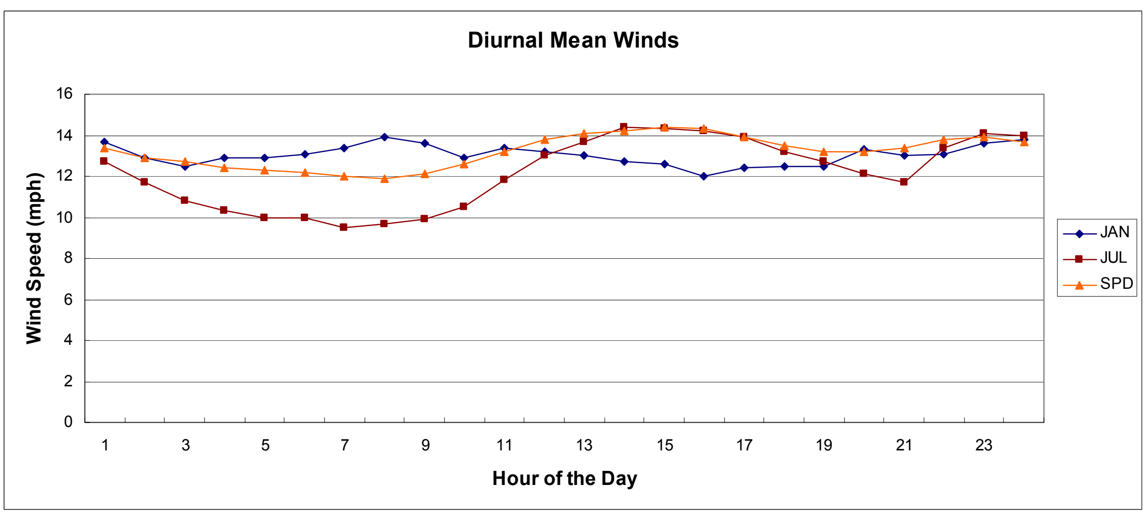


**Figure 3.2: Diurnal mean wind speed values for the Black Cap Peak site.**

**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.

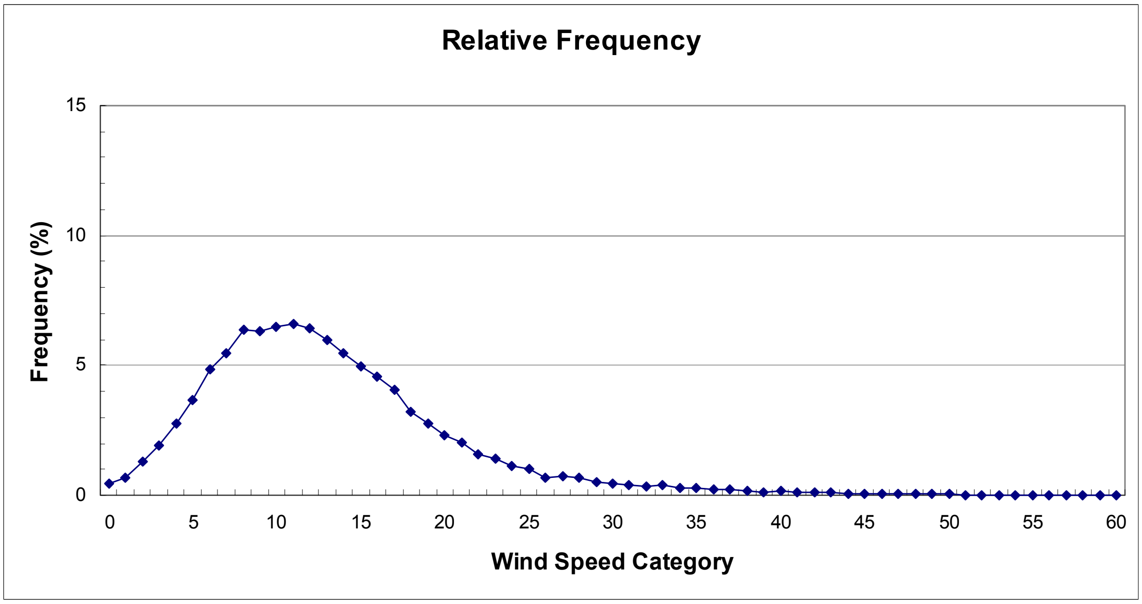


**Figure 3.3: Wind speed frequency distribution for the Black Cap Peak site.**

**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.

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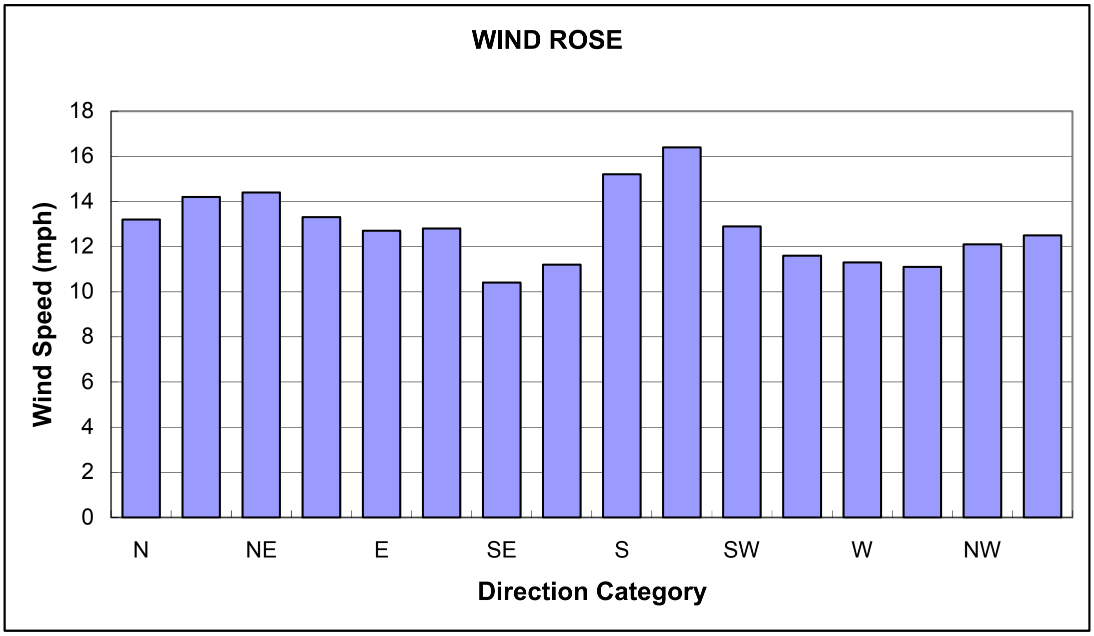


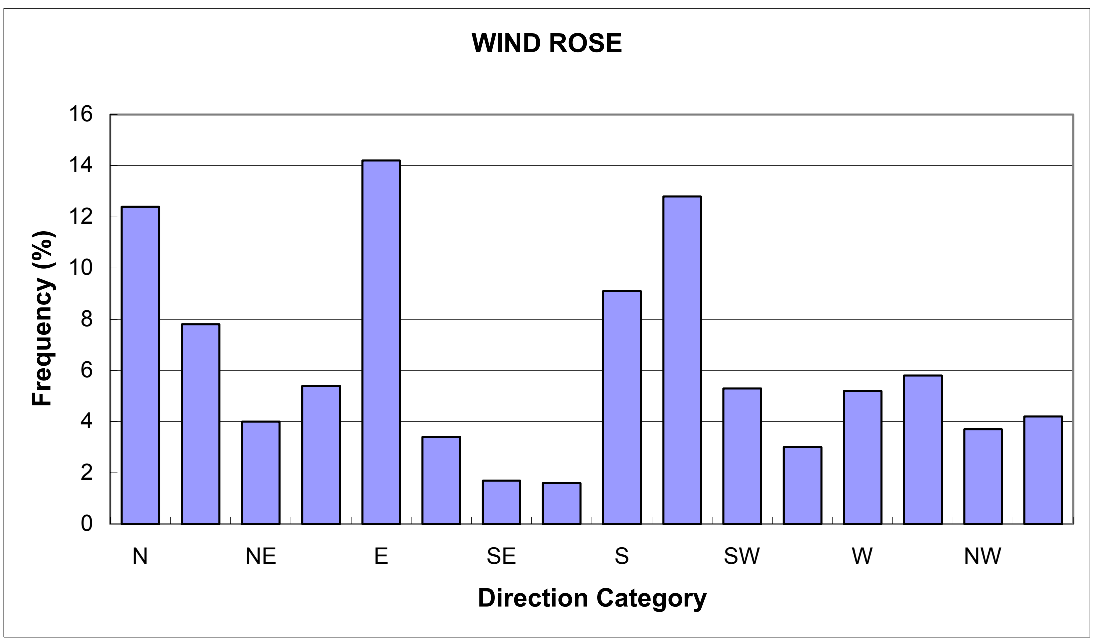




**Figure 3.4: a) Average wind speed (mph) and b) frequency (%) for each of 16 wind direction categories for the three-year analysis period.**

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.

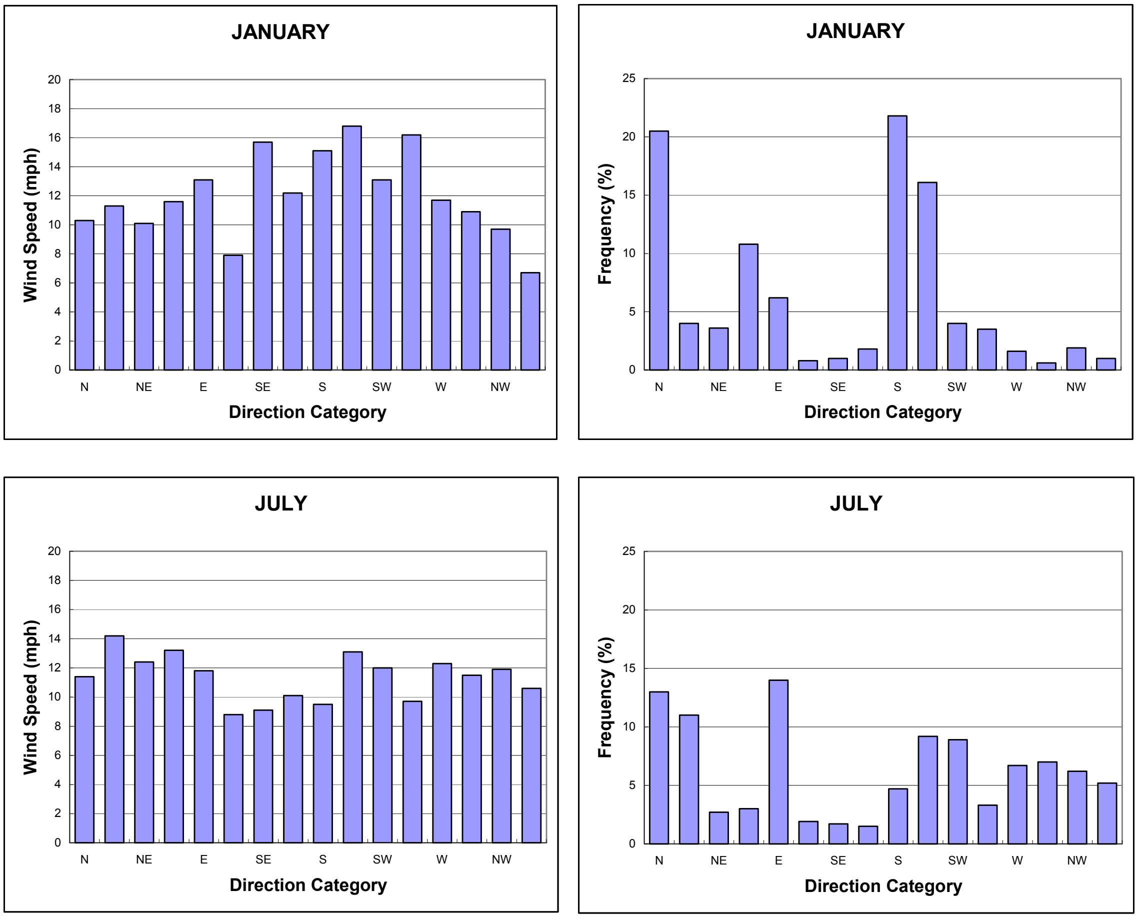



**Figure 3.5: Frequency (%) and average wind speed (mph) for each of 16 wind direction categories for a winter and summer month at the Black Cap Peak site.**

## *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.

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 years. The values range fro near 100 W/m**2 to nearly 600 W/m**2. This is largely a function of the amount of high winds observed at a site.

Table 4.1: Observed and computed power quantities at the Black Cap Peak site.

| Month | Mean (mph) | Std. (mph) | Recovery Rate(%) | Max 1-Hr (mph) | Time in Range (12-60 mph) | Power Den. W/m^2 |
|---|---|---|---|---|---|---|
| Sep-04 | 11.3 | 5.5 | 100.0 | 39.0 | 40.7 | 120 |
| Oct | 13.2 | 8.0 | 83.7 | 44.9 | 50.1 | 242 |
| Nov | 11.4 | 6.1 | 94.9 | 31.1 | 45.7 | 128 |
| Dec | 15.5 | 8.5 | 89.2 | 58.4 | 64.5 | 358 |
| Jan-05 | 10.6 | 5.7 | 63.6 | 39.2 | 40.4 | 105 |
| Feb | 13.0 | 6.0 | 93.0 | 35.4 | 55.4 | 165 |
| Mar | 15.1 | 9.3 | 68.1 | 47.1 | 54.0 | 374 |
| Apr | 13.3 | 7.9 | 92.9 | 48.0 | 51.7 | 233 |
| May | 14.0 | 7.0 | 97.7 | 44.5 | 55.3 | 231 |
| Jun | 11.9 | 6.1 | 100.0 | 40.4 | 41.3 | 148 |
| Jul | 11.8 | 5.7 | 100.0 | 30.0 | 43.8 | 129 |
| Aug | 11.6 | 4.6 | 100.0 | 27.5 | 43.4 | 104 |
| Sep | 10.5 | 5.3 | 100.0 | 27.6 | 34.9 | 96 |
| Oct | 12.6 | 8.1 | 100.0 | 53.9 | 40.9 | 240 |
| Nov | 14.0 | 7.5 | 82.4 | 48.5 | 57.2 | 258 |
| Dec | 18.0 | 11.1 | 78.2 | 49.9 | 65.1 | 608 |
| Jan-06 | 20.4 | 9.4 | 39.7 | 44.6 | 83.4 | 648 |
| Feb | 14.0 | 9.6 | 89.4 | 59.7 | 46.8 | 364 |
| Mar | 18.0 | 10.5 | 64.0 | 49.4 | 68.1 | 568 |
| Apr | 14.0 | 7.9 | 82.9 | 49.5 | 53.6 | 273 |
| May | 13.4 | 6.4 | 100.0 | 36.7 | 51.5 | 190 |
| Jun | 12.1 | 5.8 | 100.0 | 33.1 | 44.4 | 141 |
| Jul | 12.0 | 5.0 | 100.0 | 34.7 | 44.0 | 122 |
| Aug | 12.0 | 4.8 | 100.0 | 33.0 | 47.7 | 118 |
| Sep | 10.9 | 4.9 | 100.0 | 25.7 | 38.5 | 96 |
| Oct | 10.4 | 4.9 | 100.0 | 30.6 | 32.3 | 88 |
| Nov | 19.9 | 9.2 | 79.9 | 46.5 | 77.9 | 594 |
| Dec | 16.8 | 11.3 | 78.6 | 50.5 | 55.7 | 571 |
| Jan-07 | 11.5 | 6.7 | 89.9 | 40.3 | 43.8 | 157 |
| Feb | 13.9 | 8.5 | 68.6 | 45.3 | 49.0 | 285 |
| Mar | 13.3 | 6.5 | 89.9 | 41.8 | 51.3 | 195 |
| Apr | 12.9 | 6.3 | 97.8 | 37.8 | 50.9 | 173 |
| May | 12.7 | 5.4 | 100.0 | 33.3 | 49.6 | 150 |
| Jun | 12.6 | 6.2 | 100.0 | 31.0 | 51.4 | 161 |
| Jul | 12.7 | 5.2 | 94.9 | 31.2 | 53.8 | 141 |
| Aug | 13.4 | 5.8 | 100.0 | 29.9 | 56.3 | 172 |
| Ann1 | 12.7 | 6.9 | 90.2 | 58.4 | 48.7 | 191 |
| Ann2 | 13.7 | 8.0 | 86.3 | 59.7 | 50.6 | 267 |
| Ann3 | 13.2 | 7.2 | 91.8 | 50.5 | 50.4 | 218 |
| ANN | 13.2 | 7.4 | 89.4 | 59.7 | 49.9 | 225 |

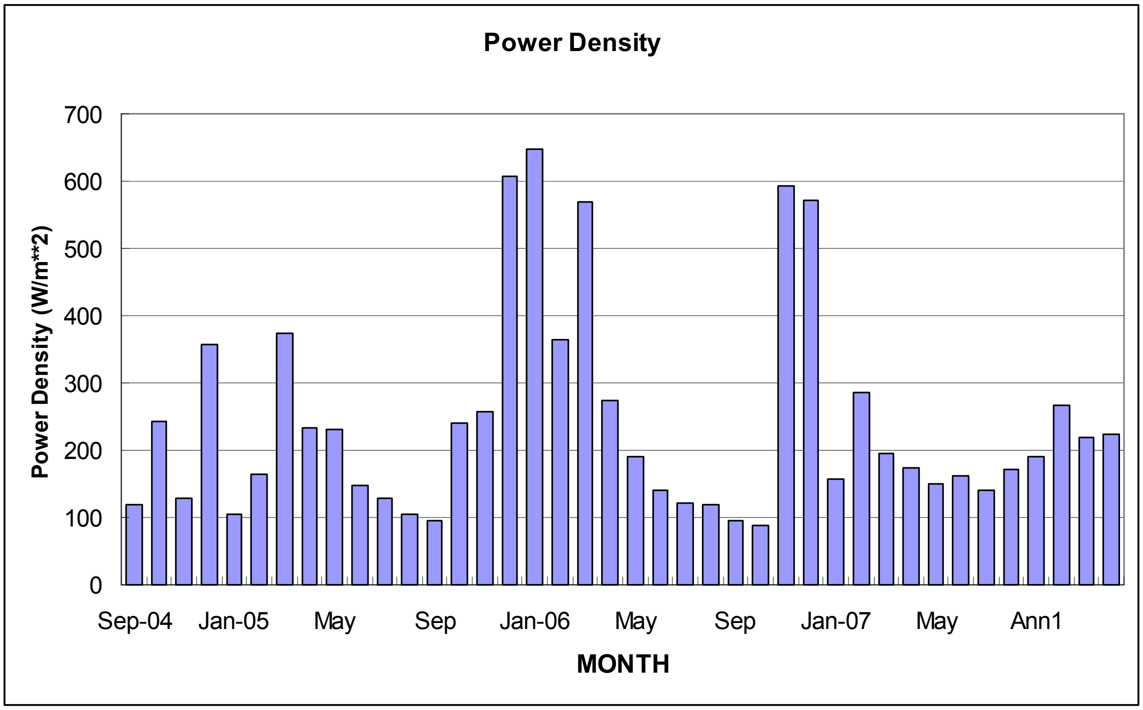


Figure 4.1: Monthly power density for the Black Cap Peak site.

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, gross energy capacity factors are shown for four different types of turbines. The gross 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 and does not account for losses from availability, electrical, etc. 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.

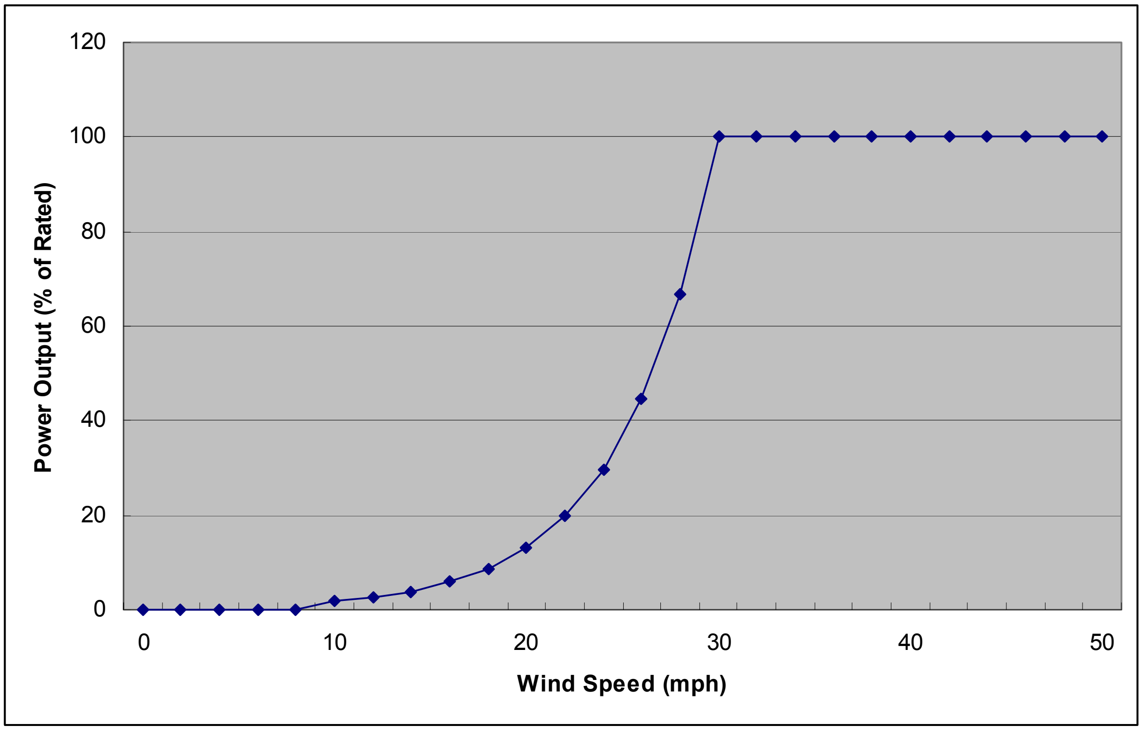



**Figure 4.2: Sample power curve for a theoretical turbine**

**Table 4.2: Gross Capacity factors computed for various wind turbines using the Black Cap Peak site and a shear coefficient of 0.143.**

| Turbine | Vestas 47 | Mit 250 | BWC Excel | GE Wind 70.5 |
|---|---|---|---|---|
| Size (kW) | 660 | 250 | 10 | 1500 |
| Hub Ht. (ft.) | 131 | 100 | 79 | 210 |
| Sep | 0.141 | 0.104 | 0.086 | 0.162 |
| Oct | 0.220 | 0.180 | 0.155 | 0.250 |
| Nov | 0.164 | 0.120 | 0.098 | 0.188 |
| Dec | 0.292 | 0.237 | 0.206 | 0.327 |
| Jan | 0.122 | 0.093 | 0.075 | 0.139 |
| Feb | 0.214 | 0.156 | 0.127 | 0.245 |
| Mar | 0.278 | 0.244 | 0.214 | 0.320 |
| Apr | 0.234 | 0.189 | 0.160 | 0.269 |
| May | 0.248 | 0.191 | 0.161 | 0.285 |
| Jun | 0.165 | 0.126 | 0.105 | 0.190 |
| Jul | 0.171 | 0.123 | 0.100 | 0.197 |
| Aug | 0.141 | 0.101 | 0.079 | 0.161 |
| Sep | 0.124 | 0.089 | 0.072 | 0.142 |
| Oct | 0.191 | 0.161 | 0.137 | 0.216 |
| Nov | 0.238 | 0.188 | 0.159 | 0.271 |
| Dec | 0.373 | 0.343 | 0.309 | 0.425 |
| Jan | 0.456 | 0.400 | 0.355 | 0.517 |
| Feb | 0.228 | 0.198 | 0.178 | 0.258 |
| Mar | 0.370 | 0.373 | 0.300 | 0.421 |
| Apr | 0.234 | 0.190 | 0.163 | 0.267 |
| May | 0.219 | 0.169 | 0.140 | 0.253 |
| Jun | 0.168 | 0.127 | 0.104 | 0.194 |
| Jul | 0.159 | 0.114 | 0.093 | 0.183 |
| Aug | 0.162 | 0.114 | 0.092 | 0.186 |
| Sep | 0.131 | 0.092 | 0.074 | 0.152 |
| Oct | 0.114 | 0.081 | 0.065 | 0.132 |
| Nov | 0.451 | 0.411 | 0.363 | 0.519 |
| Dec | 0.328 | 0.300 | 0.272 | 0.370 |
| Jan | 0.155 | 0.123 | 0.103 | 0.176 |
| Feb | 0.238 | 0.203 | 0.177 | 0.274 |
| Mar | 0.216 | 0.166 | 0.138 | 0.250 |
| Apr | 0.206 | 0.156 | 0.128 | 0.235 |
| May | 0.185 | 0.138 | 0.113 | 0.212 |
| Jun | 0.199 | 0.149 | 0.122 | 0.227 |
| Jul | 0.192 | 0.137 | 0.110 | 0.220 |
| Aug | 0.218 | 0.161 | 0.132 | 0.248 |
| Ann1 | 0.198 | 0.154 | 0.129 | 0.226 |
| Ann2 | 0.225 | 0.184 | 0.158 | 0.257 |
| Ann3 | 0.213 | 0.169 | 0.143 | 0.244 |
| ANN | 0.212 | 0.169 | 0.143 | 0.242 |

## *5.0 SUMMARY AND DISCUSSION*

There are a number of factors that might have an influence on the interpretation of the winds observed over at the Black Cap Peak 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 mountains and 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. The current sensor is also located on top of a wooden pole which may also have an influence on the observed winds.

In summary,

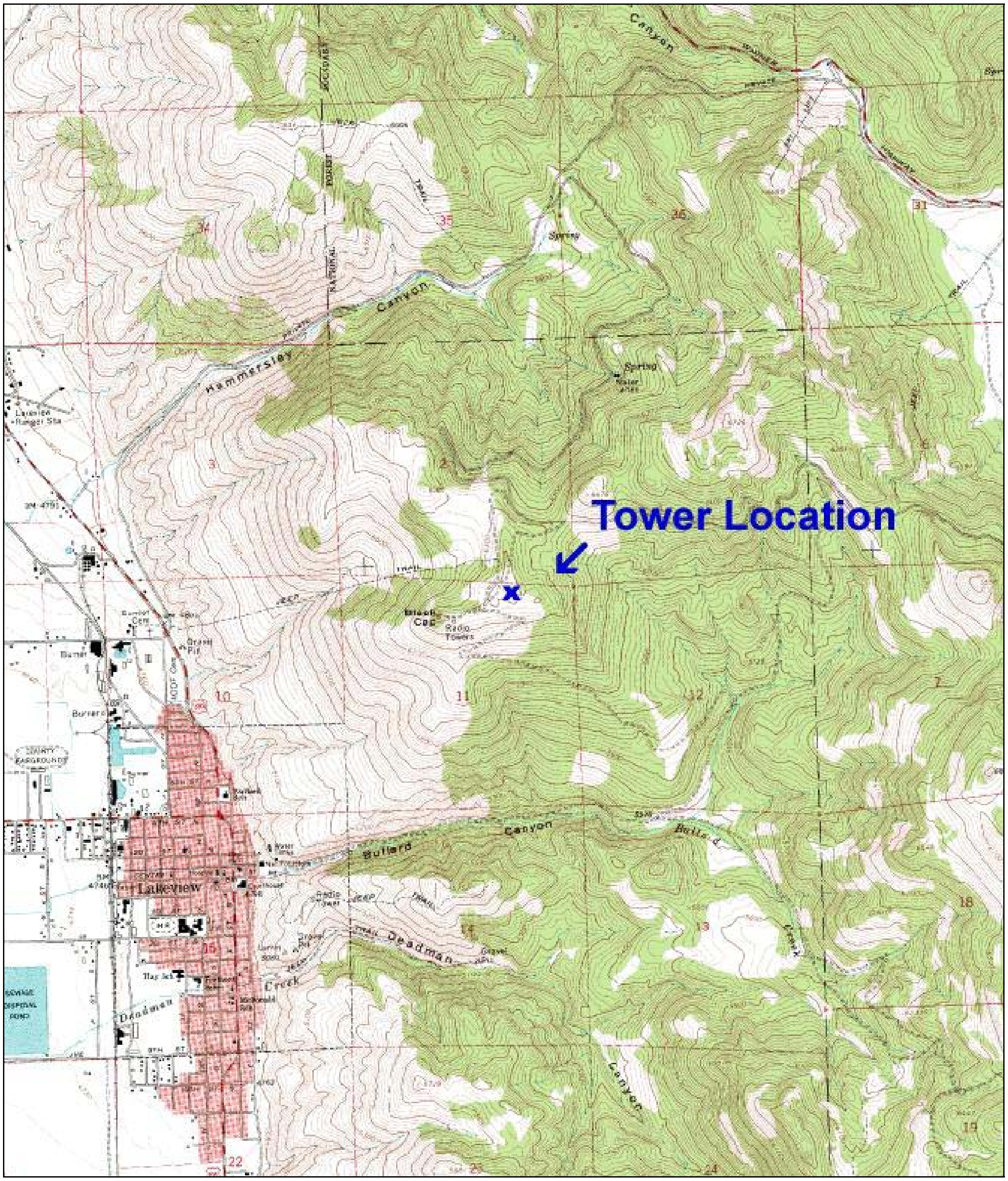
1) Data quality was good and a sufficient quantity of data was obtained to enable conditions to be characterized for a complete three year analysis period.

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) Because of the elevation and exposure the Black Cap Peak the influence of icing is observed frequently. The data have been adjusted here but there is some uncertainty in the wind conditions for several winter months.

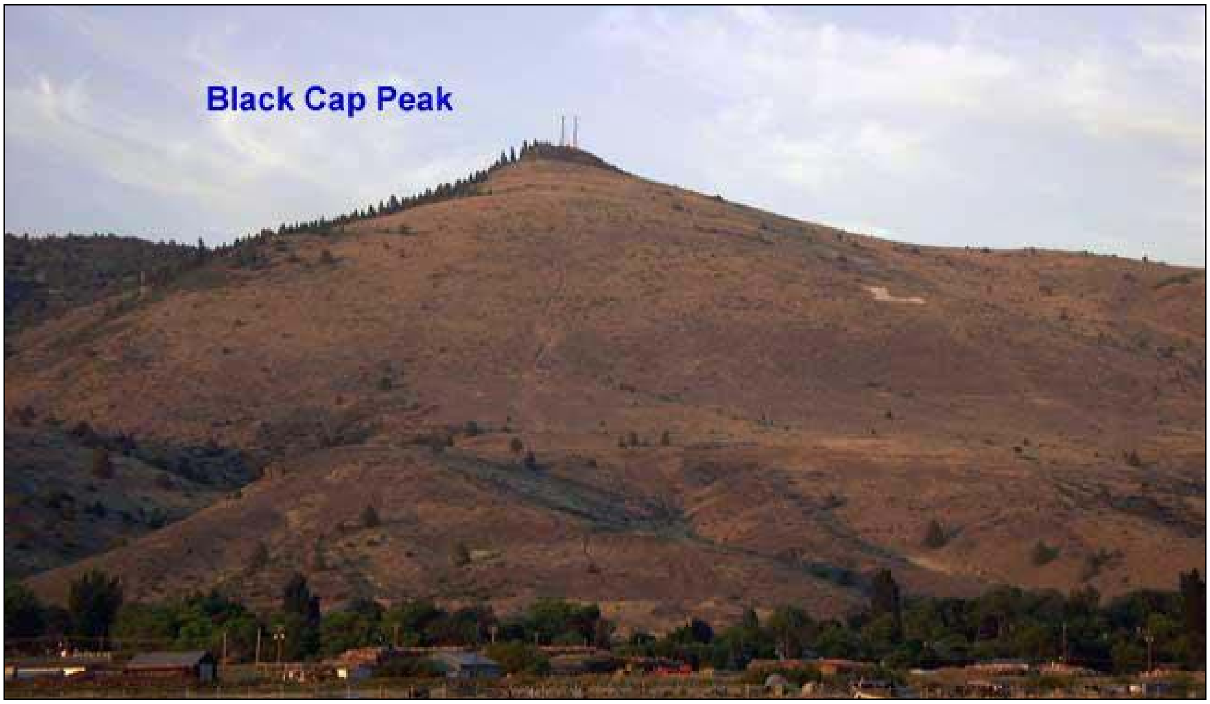
4) Gross capacity factors computed for the site using various assumptions are between 20.0% and 30.0% depending on the wind turbine type. These estimates were obtained using a standard shear coefficient of 0.143 and would likely be different if a better estimate of the site shear was known.

Appendix A:  Topographic map of the location of the Black Cap Peak site.



Appendix B:  Photograph of the wooden pole that the wind sensors were placed on.

Photograph of Black Cap Peak from just west of the City of Lakeview.



Appendix D: Miscellaneous analysis Tables.

**STATION – Black Cap Peak (site 616)**
**WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY**
**DATA PERIOD OF RECORD - 9/2004 - 8/2007**
**NORMALIZATION PERIOD - ONE YEAR**
**AVERAGE WIND SPEED FOR PERIOD: 13.2 MPH**
**NORMALIZED AVAILABLE ENERGY: 1974.4 KWH/M**2/YEAR**
**TOTAL HOURS OBSERVED: 23500**

| SPD MPH | HOURS/ PERIOD | RELFREQ | CUMHRS | CUMRELFREQ | NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR |
|---|---|---|---|---|---|
| 0 | 100 | 0.43 | 23500 | 100.00 | 0.0 |
| 1 | 159 | 0.68 | 23400 | 99.57 | 0.0 |
| 2 | 309 | 1.31 | 23241 | 98.90 | 0.0 |
| 3 | 450 | 1.91 | 22932 | 97.58 | 0.2 |
| 4 | 647 | 2.75 | 22482 | 95.67 | 0.7 |
| 5 | 861 | 3.66 | 21835 | 92.91 | 1.8 |
| 6 | 1138 | 4.84 | 20974 | 89.25 | 4.1 |
| 7 | 1288 | 5.48 | 19836 | 84.41 | 7.4 |
| 8 | 1497 | 6.37 | 18548 | 78.93 | 12.9 |
| 9 | 1485 | 6.32 | 17051 | 72.56 | 18.2 |
| 10 | 1529 | 6.51 | 15566 | 66.24 | 25.8 |
| 11 | 1548 | 6.59 | 14037 | 59.73 | 34.7 |
| 12 | 1507 | 6.41 | 12489 | 53.14 | 43.9 |
| 13 | 1400 | 5.96 | 10982 | 46.73 | 51.8 |
| 14 | 1285 | 5.47 | 9582 | 40.77 | 59.4 |
| 15 | 1163 | 4.95 | 8297 | 35.31 | 66.1 |
| 16 | 1067 | 4.54 | 7134 | 30.36 | 73.6 |
| 17 | 959 | 4.08 | 6067 | 25.82 | 79.4 |
| 18 | 750 | 3.19 | 5108 | 21.74 | 73.7 |
| 19 | 653 | 2.78 | 4358 | 18.54 | 75.4 |
| 20 | 546 | 2.32 | 3705 | 15.77 | 73.6 |
| 21 | 476 | 2.03 | 3159 | 13.44 | 74.2 |
| 22 | 367 | 1.56 | 2683 | 11.42 | 65.8 |
| 23 | 328 | 1.40 | 2316 | 9.86 | 67.2 |
| 24 | 262 | 1.11 | 1988 | 8.46 | 61.0 |
| 25 | 244 | 1.04 | 1726 | 7.34 | 64.2 |
| 26 | 162 | 0.69 | 1482 | 6.31 | 48.0 |
| 27 | 177 | 0.75 | 1320 | 5.62 | 58.7 |
| 28 | 153 | 0.65 | 1143 | 4.86 | 56.6 |
| 29 | 121 | 0.51 | 990 | 4.21 | 49.7 |
| 30 | 107 | 0.46 | 869 | 3.70 | 48.7 |
| 31 | 88 | 0.37 | 762 | 3.24 | 44.2 |
| 32 | 85 | 0.36 | 674 | 2.87 | 46.9 |
| 33 | 86 | 0.37 | 589 | 2.51 | 52.1 |
| 34 | 61 | 0.26 | 503 | 2.14 | 40.4 |
| 35 | 66 | 0.28 | 442 | 1.88 | 47.7 |
| 36 | 55 | 0.23 | 376 | 1.60 | 43.2 |
| 37 | 48 | 0.20 | 321 | 1.37 | 40.9 |
| 38 | 38 | 0.16 | 273 | 1.16 | 35.1 |
| 39 | 33 | 0.14 | 235 | 1.00 | 33.0 |
| 40 | 37 | 0.16 | 202 | 0.86 | 39.9 |
| 41 | 28 | 0.12 | 165 | 0.70 | 32.5 |
| 42 | 28 | 0.12 | 137 | 0.58 | 34.9 |
| 43 | 25 | 0.11 | 109 | 0.46 | 33.5 |
| 44 | 16 | 0.07 | 84 | 0.36 | 23.0 |
| 45 | 15 | 0.06 | 68 | 0.29 | 23.0 |
| 46 | 10 | 0.04 | 53 | 0.23 | 16.4 |
| 47 | 10 | 0.04 | 43 | 0.18 | 17.5 |
| 48 | 9 | 0.04 | 33 | 0.14 | 16.8 |
| 49 | 8 | 0.03 | 24 | 0.10 | 15.9 |
| 50 | 7 | 0.03 | 16 | 0.07 | 14.7 |
| 51 | 0 | 0.00 | 9 | 0.04 | 0.0 |
| 52 | 1 | 0.00 | 9 | 0.04 | 2.4 |
| 53 | 0 | 0.00 | 8 | 0.03 | 0.0 |
| 54 | 3 | 0.01 | 8 | 0.03 | 8.0 |
| 55 | 1 | 0.00 | 5 | 0.02 | 2.8 |
| 56 | 1 | 0.00 | 4 | 0.02 | 3.0 |
| 57 | 0 | 0.00 | 3 | 0.01 | 0.0 |
| 58 | 2 | 0.01 | 3 | 0.01 | 6.6 |
| 59 | 0 | 0.00 | 1 | 0.00 | 0.0 |
| 60 | 1 | 0.00 | 1 | 0.00 | 3.6 |

**STATION – Black Cap Peak (site 616)**
**MONTHLY WIND SPEEDS (MPH)**
**DATA PERIOD OF RECORD - 1/2003 - 9/2007**

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | # OBS | AVG | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.3 | 14.2 | 20.0 | 1137 | 15.74 | 8.67 |
| # OBS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 226 | 537 | 374 | | | |
| 2004 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.8 | 11.6 | 12.4 | 11.3 | 13.2 | 11.4 | 15.5 | 4358 | 12.54 | 6.59 |
| # OBS | 0 | 0 | 0 | 0 | 0 | 180 | 744 | 744 | 720 | 623 | 683 | 664 | | | |
| 2005 | 10.6 | 13.0 | 15.1 | 13.3 | 14.0 | 11.9 | 11.8 | 11.6 | 10.5 | 12.6 | 14.0 | 18.0 | 7848 | 12.93 | 7.40 |
| # OBS | 473 | 625 | 507 | 669 | 727 | 720 | 744 | 744 | 720 | 744 | 593 | 582 | | | |
| 2006 | 20.4 | 14.0 | 18.0 | 14.0 | 13.4 | 12.1 | 12.0 | 12.0 | 10.9 | 10.4 | 19.9 | 16.8 | 7545 | 13.88 | 8.05 |
| # OBS | 295 | 601 | 476 | 597 | 744 | 720 | 744 | 744 | 720 | 744 | 575 | 585 | | | |
| 2007 | 11.5 | 13.9 | 13.3 | 12.9 | 12.7 | 12.6 | 12.7 | 13.4 | 12.0 | 0.0 | 0.0 | 0.0 | 6004 | 12.76 | 6.23 |
| # OBS | 669 | 461 | 669 | 704 | 744 | 720 | 706 | 744 | 587 | 0 | 0 | 0 | | | |
| AVG | 13.0 | 13.6 | 15.2 | 13.3 | 13.4 | 12.3 | 12.0 | 12.3 | 11.1 | 12.0 | 14.7 | 17.3 | 26892 | 13.21 | 7.32 |
| SD | 5.4 | 0.6 | 2.4 | 0.6 | 0.6 | 0.4 | 0.5 | 0.8 | 0.6 | 1.2 | 3.6 | 1.9 | | | |

**STATION – Black Cap Peak (site 616)**
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 9/2004 - 8/2007

| MON | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 13.7 | 12.9 | 12.5 | 12.9 | 12.9 | 13.1 | 13.4 | 13.9 | 13.6 | 12.9 | 13.4 | 13.2 | 13.0 | 12.7 | 12.6 | 12.0 | 12.4 | 12.5 | 12.5 | 13.3 | 13.0 | 13.1 | 13.6 | 13.8 | 13.0 |
| FEB | 14.8 | 14.4 | 14.8 | 14.6 | 13.6 | 13.7 | 13.1 | 12.5 | 12.7 | 12.7 | 12.4 | 12.6 | 12.5 | 12.8 | 13.1 | 12.6 | 12.7 | 13.1 | 13.9 | 13.9 | 14.4 | 15.4 | 15.2 | 14.8 | 13.6 |
| MAR | 15.8 | 15.1 | 14.5 | 13.8 | 13.1 | 12.7 | 13.1 | 13.7 | 14.0 | 14.5 | 14.8 | 15.8 | 16.5 | 17.2 | 17.7 | 17.5 | 16.2 | 15.3 | 15.6 | 14.7 | 15.1 | 15.8 | 16.3 | 16.0 | 15.2 |
| APR | 13.1 | 13.0 | 13.2 | 12.9 | 12.4 | 12.1 | 12.1 | 12.3 | 13.1 | 13.7 | 14.1 | 14.3 | 15.1 | 15.2 | 15.3 | 15.2 | 14.5 | 13.2 | 12.3 | 12.3 | 12.6 | 12.7 | 12.8 | 12.3 | 13.3 |
| MAY | 13.1 | 12.8 | 12.7 | 12.6 | 12.9 | 12.5 | 12.4 | 12.2 | 12.5 | 13.3 | 14.0 | 14.8 | 15.4 | 14.9 | 14.7 | 14.6 | 13.9 | 13.6 | 13.1 | 12.6 | 13.1 | 13.2 | 13.1 | 12.9 | 13.4 |
| JUN | 11.8 | 10.9 | 10.3 | 9.9 | 10.4 | 10.2 | 10.0 | 9.7 | 9.8 | 10.8 | 12.2 | 13.2 | 13.8 | 14.0 | 14.6 | 14.4 | 14.5 | 14.1 | 13.0 | 12.9 | 13.1 | 13.3 | 13.5 | 12.7 | 12.2 |
| JUL | 12.7 | 11.7 | 10.8 | 10.3 | 10.0 | 10.0 | 9.5 | 9.7 | 9.9 | 10.5 | 11.8 | 13.0 | 13.7 | 14.4 | 14.3 | 14.2 | 13.9 | 13.2 | 12.7 | 12.1 | 11.7 | 13.4 | 14.1 | 14.0 | 12.1 |
| AUG | 12.7 | 11.9 | 11.3 | 11.1 | 10.8 | 10.3 | 9.8 | 9.9 | 10.3 | 10.9 | 12.0 | 12.8 | 13.1 | 13.8 | 13.6 | 14.0 | 14.1 | 13.3 | 12.3 | 12.5 | 13.4 | 13.9 | 14.0 | 13.7 | 12.3 |
| SEP | 10.3 | 10.0 | 9.7 | 9.1 | 9.5 | 9.8 | 9.1 | 9.1 | 9.6 | 10.4 | 11.4 | 12.5 | 13.1 | 13.0 | 13.3 | 12.9 | 11.9 | 10.8 | 10.4 | 10.9 | 11.6 | 11.6 | 11.0 | 10.6 | 10.9 |
| OCT | 12.2 | 12.2 | 12.1 | 11.7 | 11.8 | 11.7 | 11.1 | 11.0 | 11.3 | 11.9 | 12.3 | 12.5 | 12.6 | 12.9 | 12.6 | 12.1 | 11.5 | 11.1 | 11.5 | 12.0 | 12.1 | 12.4 | 12.6 | 12.5 | 12.0 |
| NOV | 15.3 | 15.3 | 14.8 | 14.8 | 14.5 | 14.5 | 14.6 | 14.0 | 14.3 | 14.3 | 14.4 | 14.5 | 14.7 | 14.6 | 14.8 | 15.4 | 15.2 | 15.4 | 16.0 | 15.9 | 15.5 | 15.1 | 14.9 | 14.7 | 14.9 |
| DEC | 16.5 | 16.2 | 17.4 | 17.4 | 17.2 | 17.8 | 18.0 | 17.5 | 17.0 | 16.5 | 16.3 | 16.4 | 16.1 | 15.7 | 15.8 | 16.9 | 16.9 | 16.6 | 15.9 | 16.6 | 16.8 | 16.3 | 16.9 | 17.4 | 16.7 |
| AVG SPD | 13.4 | 12.9 | 12.7 | 12.4 | 12.3 | 12.2 | 12.0 | 11.9 | 12.1 | 12.6 | 13.2 | 13.8 | 14.1 | 14.2 | 14.4 | 14.3 | 13.9 | 13.5 | 13.2 | 13.2 | 13.4 | 13.8 | 13.9 | 13.7 | 13.2 |

**STATION – Black Cap Peak (site 616)**
**WIND ROSE FOR ALL DATA - 18006 OBSERVATIONS**
**DATA PERIOD OF RECORD - 9/2004 - 8/2007**

SPEED CATEGORIES(MPH)

| DIR | 0 TO 10 | 10 TO 13 | 13 TO 16 | 16 TO 19 | 19 TO 22 | 22 TO 25 | 25 TO 28 | 28 TO 31 | 31 TO 34 | 34 TO 37 | 37 TO 40 | 40 TO 43 | 43 TO 46 | 46 TO 49 | 49 TO 52 | 52 TO 55 | >= 55 | TOTAL % | MEAN SPEED (MPH) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 4.8 | 2.6 | 1.8 | 1.2 | 0.5 | 0.4 | 0.3 | 0.3 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.4 | 13.2 |
| NNE | 2.4 | 1.4 | 1.4 | 1.1 | 0.6 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.8 | 14.2 |
| NE | 1.4 | 0.8 | 0.6 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 14.4 |
| ENE | 1.7 | 1.3 | 1.1 | 0.7 | 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 | 5.4 | 13.3 |
| E | 4.3 | 3.4 | 2.9 | 2.1 | 0.8 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.2 | 12.7 |
| ESE | 1.3 | 0.6 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.4 | 12.8 |
| SE | 0.9 | 0.3 | 0.2 | 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 | 1.7 | 10.4 |
| SSE | 0.8 | 0.3 | 0.2 | 0.1 | 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 | 1.6 | 11.2 |
| S | 3.2 | 1.5 | 1.3 | 0.9 | 0.5 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 9.1 | 15.2 |
| SSW | 3.0 | 2.2 | 1.8 | 1.6 | 1.2 | 1.0 | 0.7 | 0.5 | 0.4 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.8 | 16.4 |
| SW | 2.2 | 1.1 | 0.5 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.3 | 12.9 |
| WSW | 1.5 | 0.5 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 11.6 |
| W | 2.6 | 0.8 | 0.6 | 0.6 | 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 | 5.2 | 11.3 |
| WNW | 3.0 | 0.9 | 0.7 | 0.6 | 0.3 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.8 | 11.1 |
| NW | 1.8 | 0.6 | 0.5 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 | 12.1 |
| NNW | 2.0 | 0.7 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.2 | 12.5 |
| CALM | | | | | | | | | | | | | | | | | | 0.4 | |
| TOTAL % | 37.5 | 18.8 | 14.9 | 10.9 | 6.3 | 3.8 | 2.4 | 1.7 | 1.2 | 0.9 | 0.6 | 0.4 | 0.3 | 0.2 | 0.1 | 0.0 | 0.0 | 100.0 | 13.3 |

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 – Black Cap Peak (site 616)**
**ENERGY ROSE (TOTALS ARE NORMALIZED AVAILABLE ENERGY (KWH/M**2)**
**DATA PERIOD OF RECORD - 9/2004 - 8/2007**

| MON | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | TOTAL | OBS. | NORM. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 3.1 | 4.2 | 2.2 | 9.6 | 8.1 | 0.2 | 3.3 | 4.4 | 81.9 | 56.6 | 5.8 | 11.5 | 3.1 | 1.1 | 1.9 | 0.2 | 197.2 | 1198 | 744 |
| FEB | 12.5 | 3.3 | 12.7 | 32.5 | 44.4 | 6.3 | 0.1 | 2.2 | 9.6 | 17.8 | 3.6 | 16.6 | 11.1 | 5.5 | 4.0 | 5.9 | 188.1 | 1512 | 672 |
| MAR | 70.8 | 26.4 | 26.5 | 29.6 | 15.8 | 1.1 | 0.1 | 0.0 | 9.1 | 86.6 | 24.5 | 3.8 | 4.8 | 6.0 | 11.5 | 35.6 | 352.2 | 971 | 744 |
| APR | 12.5 | 8.5 | 3.7 | 3.5 | 10.9 | 3.4 | 0.4 | 0.6 | 11.1 | 45.5 | 16.1 | 5.7 | 6.2 | 12.1 | 38.4 | 6.9 | 185.5 | 1203 | 720 |
| MAY | 15.4 | 8.9 | 3.0 | 2.5 | 17.4 | 3.9 | 1.3 | 0.1 | 7.7 | 39.0 | 18.7 | 2.2 | 7.3 | 11.8 | 5.7 | 8.0 | 152.8 | 1425 | 744 |
| JUN | 13.0 | 14.1 | 2.5 | 2.8 | 5.1 | 0.7 | 1.9 | 0.3 | 4.2 | 26.2 | 6.8 | 1.2 | 6.8 | 5.1 | 5.6 | 6.6 | 103.1 | 1407 | 720 |
| JUL | 8.3 | 14.3 | 2.5 | 3.6 | 11.1 | 0.8 | 0.7 | 1.0 | 2.6 | 11.4 | 8.9 | 2.1 | 8.2 | 6.6 | 6.8 | 4.8 | 93.7 | 1457 | 744 |
| AUG | 8.6 | 11.5 | 3.6 | 4.0 | 11.9 | 2.2 | 1.8 | 2.2 | 4.6 | 10.4 | 4.2 | 1.8 | 4.9 | 6.5 | 1.6 | 2.1 | 82.0 | 1447 | 744 |
| SEP | 6.7 | 9.8 | 2.4 | 3.9 | 9.5 | 2.3 | 2.4 | 2.0 | 4.6 | 8.8 | 2.4 | 1.2 | 4.4 | 6.0 | 1.5 | 1.1 | 69.1 | 1391 | 720 |
| OCT | 4.4 | 5.5 | 1.6 | 2.1 | 10.9 | 0.8 | 2.0 | 2.2 | 23.6 | 56.8 | 8.9 | 1.2 | 2.5 | 2.6 | 1.9 | 1.0 | 128.2 | 1597 | 744 |
| NOV | 44.3 | 40.5 | 10.7 | 7.7 | 22.9 | 13.1 | 1.2 | 0.6 | 26.2 | 36.3 | 2.4 | 1.8 | 3.0 | 1.2 | 0.7 | 12.4 | 225.1 | 1785 | 720 |
| DEC | 7.6 | 38.8 | 55.8 | 12.3 | 20.4 | 12.9 | 1.3 | 4.1 | 151.3 | 64.8 | 6.3 | 0.8 | 0.9 | 5.6 | 1.1 | 5.6 | 389.5 | 1760 | 744 |
| TOT | 207.2 | 185.8 | 127.2 | 114.0 | 188.3 | 47.8 | 16.4 | 19.6 | 336.5 | 460.4 | 108.7 | 50.0 | 63.3 | 70.1 | 80.7 | 90.3 | 2166.4 | 17153 | 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.