Regional Wind Energy Assessment Progress Report

June 1988- May 1989

Bonneville
POWER ADMINISTRATION

October 1989

OREGON STATE UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING
ENERGY RESOURCES RESEARCH LABORATORY

REPORT NO. BPA 89-33

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FINAL REPORT

Prepared by

J.E. Wade, R.W. Baker, and S.N. Walker

Submitted to the

Bonneville Power Administration
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Portland, Oregon

Contract No. DEAI79-86BP63406

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MASTER

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EXECUTIVE SUMMARY

The purpose of this report is to discuss the status of Bonneville Power Administrations wind monitoring program and the data collected from June 1988 through May 1989. The wind monitoring program has been on-going since 1976. The annual summary of this data provides BPA with a periodic status report on both the equipment and wind resource being measured.

There were nine active sites this year. Three sites were instrumented at more than one level. One site, Hampton Butte, apparently failed in November of 1988 and was removed in May of 1989. The data recovery rate for all nine sites over their entire period of record was 82%.

For each site, data are summarized for this past year in the body of the report. The statistics used to characterize the wind resource include: mean wind speed; peak gust; available energy; Weibull parameters; available energy; data recovery rate; and estimated turbine energy output for eight selected wind turbines. The appendices include summarized data for the entire period of record at these sites. These summaries provide the most important wind speed statistics required by potential wind developers.

A climatological analysis discussed the wind during the past year so that the representativeness of this period could be established. The winds during the past year were about average or slightly stronger than average at most sites except in the Columbia River Gorge. In the past, dry years have been associated with weaker winds. This past year (June 1988 through May 1989) June, August through November, and February were the extremely dry months. The Columbia Gorge sites had weaker winds during those months. The early spring drought reduced the coastal winds. In general, the worst drought occurred in the Fall when winds in the Pacific Northwest are typically weak.

The report also examines long-term variations in wind over the region. Among the conclusions are that there is considerable evidence that winds measured over the past twelve years in this region may about 10% weaker than the previous two to three decades. The results also suggest that energy estimates based on the last decade of wind measurements could be significantly

conservative. We found that estimates of past wind speeds that assume a Weibull distribution will provide energy estimates 10 to 25% lower than actual at many sites. This was particularly true in the Columbia River Gorge.

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1. INTRODUCTION

This report is a summary of wind statistics collected for the period June 1988 through May 1989. The data were gathered at nine locations throughout the Pacific Northwest as part of Bonneville Power Administration's Regional Wind Energy Assessment Program (Wind REAP) that has been continuing since 1976. The data collection sites are shown in Figure 1-1 and the status of the equipment is listed in Table 1-1. Hampton Butte equipment apparently failed in November 1988 and was removed in May of 1989. A propeller blade had come off the anemometer. No speeds above 20 mph were recorded after November 1988. A major equipment failure occurred at Cape Blanco in November of 1988. The data logger failed and was not replaced until January of 1989. The 80 ft speed and direction sensor was destroyed at Browning Depot in January. However, Browning has a redundant speed sensor at 80 ft so only direction data was lost. April data was lost at Browning due to a data logger failure. Miscellaneous data logger tape recorder problems were encountered at Goodnoe Hills, Kennewick, Upper Pyle and Pequop Summit. In some cases the person changing the tape failed to ensure the tape-record button was engaged. This resulted in losses of up to a month of data. In the case of Upper Pyle and Pequop these sites have had intermittent tape quality problems that may be related to sporadic magnetic interference. Kittitas, Pequop Summit and Upper Pyle anemometers were removed in the summer of 1989. Five anemometers will remain in service indefinitely. The permanent sites are: Cape Blanco; Browning; Kennewick; Goodnoe Hills; and Seven Mile Hill. However, this is the last annual report on winds collected at these sites.

The main objectives in this report are to:

- Summarize data collected during the past year.
- Document the status of each site any equipment problems and quality assurance.
- Discuss the relationship of this year's winds to those of previous years in the Pacific Northwest.
- Present analyses of wind characteristics at each site that will provide potential developers with necessary information to assess the quality and quantity of the wind resource.

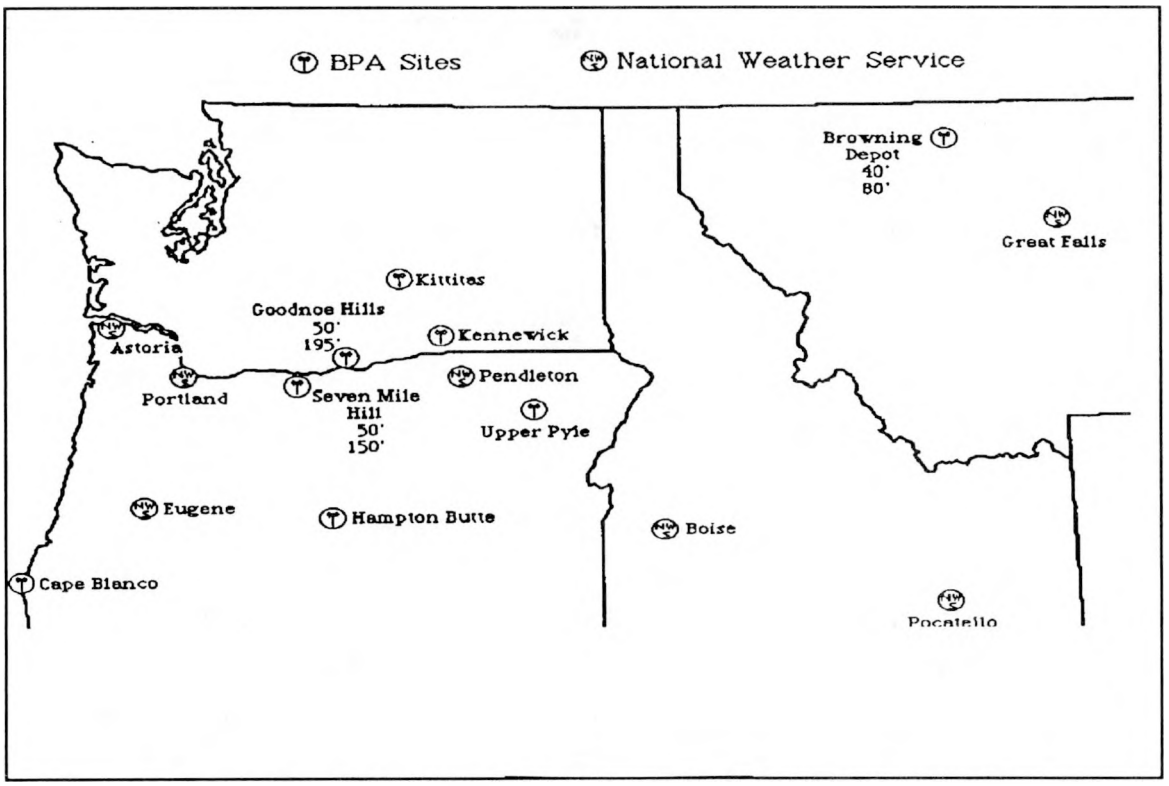


Figure 1-1. Map showing locations of Wind REAP sites and National Weather Service sites used in this report (see Table 1-1 for site names).

Table 1-1. Pacific Northwest wind energy site status.

UPDATE STATUS REPORT - 1989

MAP ID NAME	SITE NAME	PERIOD OF RECORD	PRESENT STATUS	
			ACTIVE	INACTIVE
	OREGON			
CBMW	Cape Blanco M/W	Oct. 1976 - Present	X	
HMBT	Hampton Butte	Oct. 1983 - Nov. 1988		X
SM50	Seven Mile Hill 50′	Oct. 1978 - Present	X	
SM150	Seven Mile Hill 150′	Oct. 1978 - Present	X	
UPPY	Upper Pyle	Mar. 1984 - May 1989		X
	WASHINGTON			
GH50	Goodnoe Hills 50′	May 1980 - Present	X	
GH150	Goodnoe Hills 195′	May 1980 - Present	X	
KENN	Kennewick	Jun. 1976 - Present	X	
KITT	Kittitas	Mar. 1980 - July 1989		X
	NEVADA			
PQSM	Pequop Summit	Apr. 1976 - May 1989		X
	MONTANA			
BD40	Browning Depot 40′	Oct. 1985 - Present	X	
BD80	Browning Depot 80′	Oct. 1985 - Present	X	

- Examine the long-term variation of the annual wind speeds at each of the nine sites.

Section 2 is a climatological discussion of the wind climate of the past year in the Pacific Northwest. The Wind REAP sites winds are compared with previous years and with the departures from "normal" of climate at the several nearby National Weather Service locations shown in Figure 1-1. In this report the term "normal" will refer to the National Weather Service definition, which is the previous 30-year period before this decade. The "normal" period is 1941-1970. In 1990 the normal period will advance to 1951-1980.

Section 3 is a discussion of wind characteristics and the status of data collection. There is a discussion and analysis of interannual variation of wind speed at each site. Supporting information presented in the appendices include analysis of all the data collected at each site.

Section 4 is an examination of the degree the past 12 years of wind data represent the true climatological mean. Surface and upper air wind data throughout the region are examined back to the late 1940s.

Section 5 is an analysis of the uncertainties in long-term energy predictions using actual and theoretical wind speed distributions. Also examined is the error between actual energy available at a wind energy site and that estimated using a theoretical wind speed distribution.

2. CLIMATOLOGICAL ANALYSIS

The climatological analysis has two purposes: 1) to determine the extent the winds during the past year deviated from winds in prior years, and 2) to evaluate the degree that the past year is typical. The value of this exercise is that it puts into chronological perspective the winds measured at the Wind REAP sites during the past year. In addition any significant trends in the wind caused by anemometer malfunction or changes in surface roughness are readily identified.

The approach used in this analysis is to calculate departures from the mean at four widely dispersed wind energy survey sites in the Pacific Northwest. These sites have in common a long record of wind measurement. To amplify the analysis we also examine departures from "normal" (1941-1970 mean) for eight National Weather Service (NWS) sites scattered throughout BPA's service territory.

2.1 Results

Table 2-1 presents mean wind speeds for the period June 1988 through May 1989 and departures from the long-term mean. Only months with above 80% data recovery are included. BPA and NWS site departures from the mean are also graphically presented in Figures 2-1 through 2-3. Figure 2-1 displays a bar graph of departure from the long-term mean of the winds at four Pacific Northwest wind survey sites. The winds were most often below the mean. Goodnoe Hills and Pequop Summit both had below average winds for the period June 1988 - May 1989. Goodnoe's winds were only slightly below average but Pequop's were much below average.

The winds at Pequop were adjusted by a factor of 1.29 for the period June 1986 through May 1987. The anemometer was replaced in May of 1987 and the correction was discontinued. Last year's winds were about average. This year, wind speeds were much below average. The anemometer was replaced with a newly calibrated anemometer in July of 1988. In May of 1989 the Pequop anemometer was removed and found to read 1 mph low at all speeds checked. The problem with correcting the data in this situation is: Where does one start? Was the degradation linear over time, or did it occur suddenly? In this case

Table 2-1. Mean speeds for the period June 1988 – May 1989 and the departures from the mean. The mean period for the National Weather Service data is 1941–1970.

STATION		WIND SPEEDS												
		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	ANNUAL
ASTORIA	41-70	8.3	8.5	8.0	7.5	7.5	8.8	9.3	9.4	8.9	8.9	8.7	8.5	8.5
(NWS)	88-89	9.7	10.7	9.6	9.1	8.1	10.3	8.6	9.3	9.8	10.0	9.1	8.1	9.4
	% DEP	16.9	25.9	20.0	21.3	8.0	17.0	(7.5)	(1.1)	10.1	12.4	4.6	(4.7)	9.9
EUGENE	41-70	7.4	8.0	7.5	7.4	6.5	7.4	7.9	8.1	8.0	8.6	7.7	7.4	7.7
(NWS)	88-89	6.7	8.6	8.5	7.4	6.4	10.2	8.6	9.0	6.9	9.0	8.2	6.9	8.0
	% DEP	(9.5)	7.5	13.3	.0	(1.5)	37.8	8.9	11.1	(13.8)	4.7	6.5	(6.8)	4.9
PORTLAND	41-70	6.9	7.4	7.0	6.4	6.1	8.7	9.8	9.8	8.8	8.2	7.3	6.9	7.8
(NWS)	88-89	7.4	8.0	7.7	6.8	6.0	9.7	9.1	9.1	8.3	12.1	10.2	8.2	8.6
	% DEP	7.2	8.1	10.0	6.3	(1.6)	11.5	(7.1)	(7.1)	(5.7)	47.6	39.7	18.8	10.0
PENDLETON	41-70	10.5	9.5	9.1	8.9	8.1	7.9	8.4	8.5	9.0	10.0	10.6	10.2	9.2
(NWS)	88-89	9.4	10.3	10.2	11.0	7.5	11.5	8.0	10.6	7.2	9.6	9.2	9.6	9.5
	% DEP	(10.5)	8.4	12.1	23.6	(7.4)	45.6	(4.8)	24.7	(20.0)	(4.0)	(13.2)	(5.9)	3.1
ELKO	41-70	6.7	6.2	6.0	5.5	5.2	5.1	5.1	5.4	5.9	6.7	7.2	6.9	6.0
(NWS)	88-89	7.5	6.2	6.1	5.5	4.5	5.7	5.1	3.6	4.5	7.0	6.5	6.6	5.7
	% DEP	11.9	.0	1.7	.0	(13.5)	11.8	.0	(33.3)	(23.7)	4.5	(9.7)	(4.3)	(4.3)
BOISE	41-70	9.1	8.5	8.2	8.3	8.5	8.5	8.4	8.3	9.2	10.2	10.2	9.6	8.9
(NWS)	88-89	8.7	7.7	7.2	7.4	6.2	8.9	6.4	7.1	5.8	9.4	8.4	9.0	7.7
	% DEP	(4.4)	(9.4)	(12.2)	(10.8)	(27.1)	4.7	(23.8)	(14.5)	(37.0)	(7.8)	(17.6)	(6.3)	(13.8)
POCATELLO	41-70	10.3	9.2	9.0	9.1	9.2	10.2	10.2	11.2	10.9	11.6	11.8	10.6	10.3
(NWS)	88-89	10.4	10.2	9.8	8.3	7.5	8.2	11.4	10.9	10.8	8.7	11.5	11.3	9.9
	% DEP	1.0	10.9	8.9	(8.8)	(18.5)	(19.6)	11.8	(2.7)	(.9)	(25.0)	(2.5)	6.6	(3.5)
GREAT FALLS	41-70	11.2	10.2	10.3	11.4	13.3	14.6	15.6	15.2	14.5	13.1	12.9	11.5	12.8
(NWS)	88-89	10.9	9.7	10.4	11.6	11.1	13.2	15.4	18.6	11.0	11.1	11.6	11.5	12.2
	% DEP	(2.7)	(4.9)	1.0	1.8	(16.5)	(9.6)	(1.3)	22.4	(24.1)	(15.3)	(10.1)	.0	(5.0)
CAPE BLANCO	76-86	18.5	20.0	16.2	16.7	17.4	20.4	20.0	20.5	24.1	20.5	18.0	17.7	19.2
	88-89	17.5	23.3	21.6	21.7	18.3				18.1		18.3	15.9	19.3
	% DEP	(5.4)	16.5	33.3	29.9	5.2				(24.9)		1.7	(10.2)	.9
GOODNOE HILLS	80-86	17.1	16.7	16.0	14.3	12.9	12.7	11.1	13.2	13.4	14.2	16.6	17.7	14.7
195'	88-89	16.0	17.3	15.3	14.3	11.2	16.5	11.6	16.2	10.0	12.6		15.8	14.3
	% DEP	(6.4)	3.6	(4.4)	.0	(13.1)	29.9	4.5	22.7	(25.4)	(11.3)		(4.8)	(2.7)
KENNEWICK	76-86	16.0	15.2	13.9	13.7	14.3	17.6	15.3	14.4	15.8	16.7	16.6	16.8	15.5
	88-89	16.0	15.4	13.9	13.2	13.7	25.6	15.0	23.7			15.8	14.4	16.7
	% DEP	.0	1.3	.0	(3.6)	(4.2)	45.5	(2.0)	64.6			(4.8)	(14.3)	7.4
PEQUOP SUMMIT	76-86	15.7	14.2	13.4	13.1	13.6	15.9	18.3	16.4	17.7	18.3	17.0	16.4	15.7
	88-89		10.7	9.4	10.6	9.0				12.6			12.1	10.7
	% DEP		(24.6)	(29.9)	(19.1)	(33.8)				(28.8)			(26.2)	(31.6)

IMPORTANT NOTES:
VALUES IN PARENTHESES REPRESENT NEGATIVE PERCENT DEPARTURES FROM NORMAL. AN ADJUSTMENT FACTOR OF 1.31 HAS BEEN APPLIED TO THE PENDLETON WIND DATA TO ACCOUNT FOR UNEXPLAINED LOW WIND SPEEDS. THE KENNEWICK ANEMOMETER DURING 9/87-5/89 IS 20 FT LOWER THAN IT WAS DURING 1976- 9/87 MONTH.

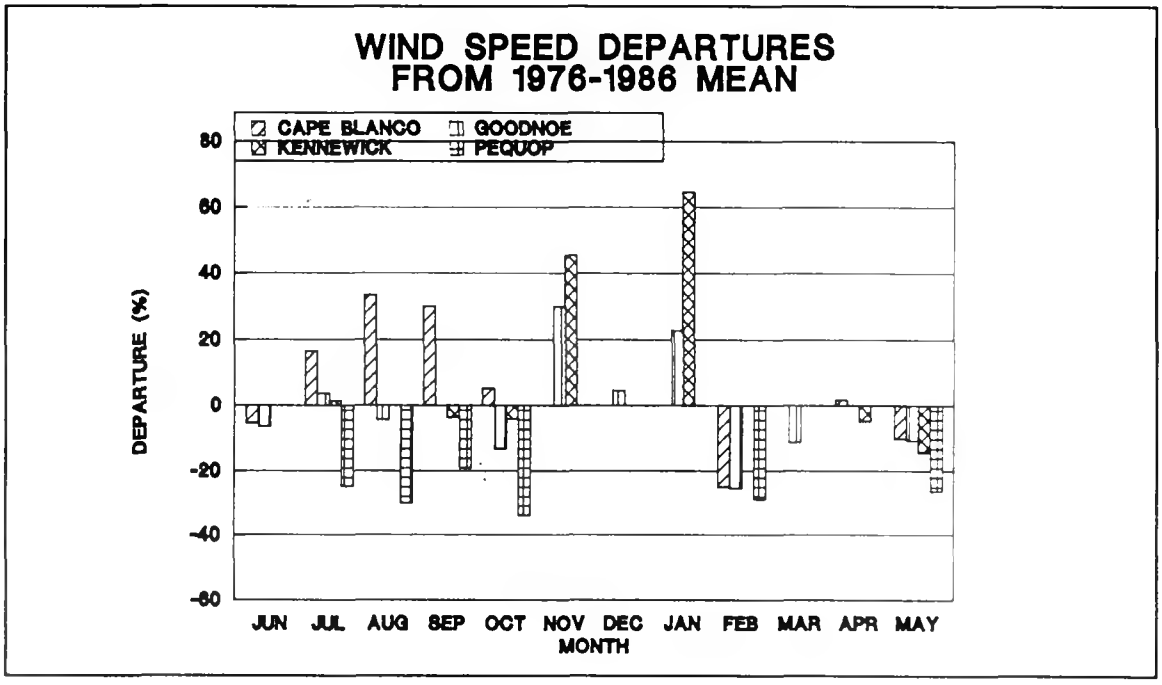


Figure 2-1. Wind speed departures from "mean" at four BPA wind sites for 1987-1988 data.

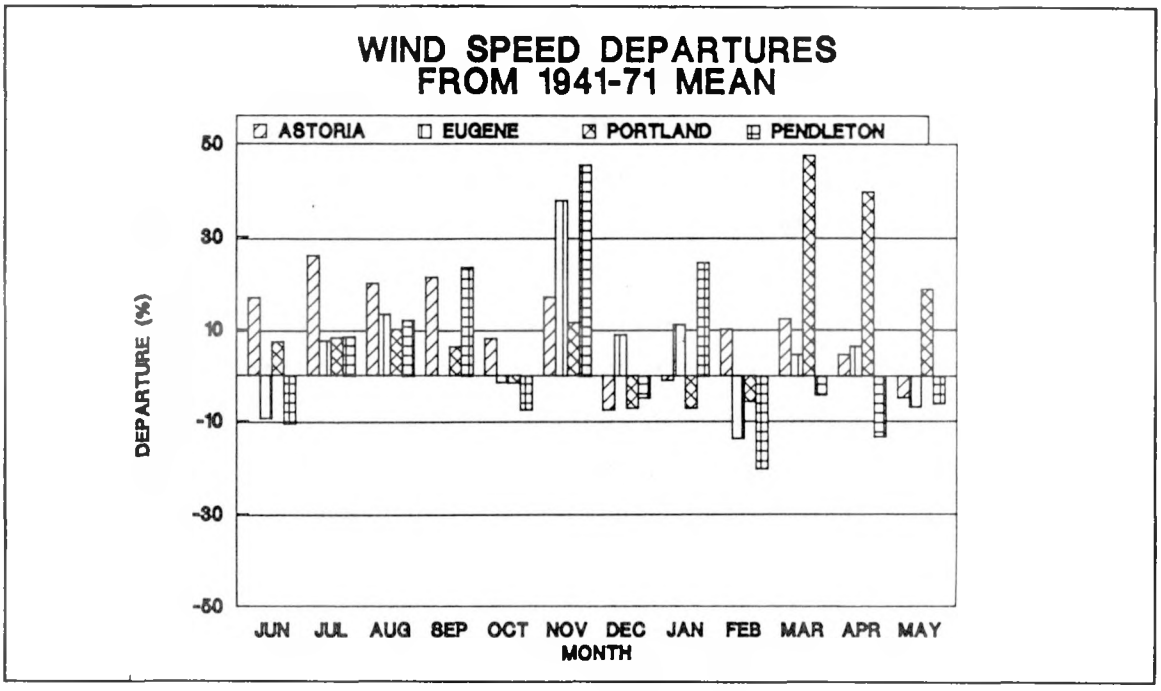


Figure 2-2. Wind speed departures from "normal" at four Oregon NWS sites for 1987-1988 data.

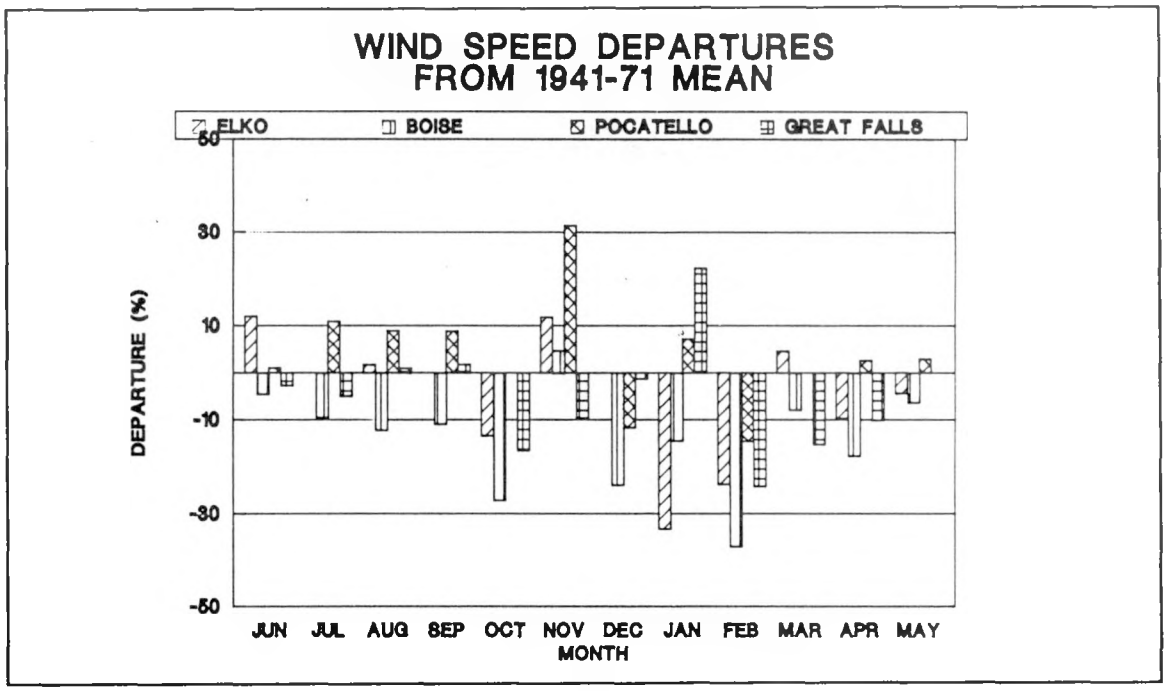


Figure 2-3. Wind speed departures from "normal" at four Regional NWS sites for 1987-1988 data.

the data has not been adjusted and a caution is attached to warn the user that some error is present in the data.

Among the National Weather Service sites, Elko, Boise and Pocatello all had below normal winds this past year. Boise's winds were significantly below normal. February was the month with the biggest negative departure of the winds. February was also extremely cold throughout the region. Only Astoria had above normal winds in February. Cold air pooled over the region particularly during the first week of the month. November had extraordinarily strong winds with few exceptions in this region. The month was wet and colder than normal. October was one of the driest Octobers in Pacific Northwest history. October had weaker than average winds at most locations in the region.

3. WIND SITE DATA SUMMARY

Wind data have been collected at high wind sites throughout the BPA area since 1976. In this section we will examine the statistics at each active wind energy survey site during the period 1 June 1988 through 31 May 1989.

This report presents all the most important wind statistics in tables for each site for the entire period of record in the appendices. The statistics summarized include: monthly mean speeds, number of observations since the site was instrumented, wind rose, speed and energy distributions and diurnal wind speed variations for each month. Overall data recovery for the nine sites active this year over their entire period of record was 84%.

A summary table in this section presents information on anemometer height, data recovery rate, peak hourly average wind speed, peak gust and time of occurrence, energy statistics, and the Weibull fit shape and scale parameters. The energy statistics are supplied for each site include estimated available energy, power density and estimated gross annual energy output for eight selected wind turbines at that site.

NOTE: These gross annual energy estimates should not be confused with the energy that could be produced at a site. The net power produced at a site would include losses because of turbine down time, array effects, electrical line losses, blade fouling, performance penalties, turbulence effects or any other factor that may alter machine performance.

3.1 Browning Depot

At the Browning Depot the mean wind speed averaged 16.4 mph at the 80 ft level for the 1988–89 period. Data recovery was 93% for the year. A maximum gust of 86 mph was measured in January (see Table 3–1). The shear coefficient between the 50 and 80 ft levels was 0.12. The CR–21 recorder failed in late March and was replaced in the beginning of May, 1989. The 80 ft level sensor was destroyed at the end of January 1989. A redundant speed sensor at 80 ft was used to complete the wind speed record through May of 1989.

Appendix A presents summarized statistics for Browning from October 1985 through May 1989. Data recovery over the entire period of record was 93%. A time series of monthly mean wind speeds at 80 ft is shown in Figure 3–1. The solid curve is three month running mean of the monthly data. The time series suggests lower wind speeds recently at Browning.

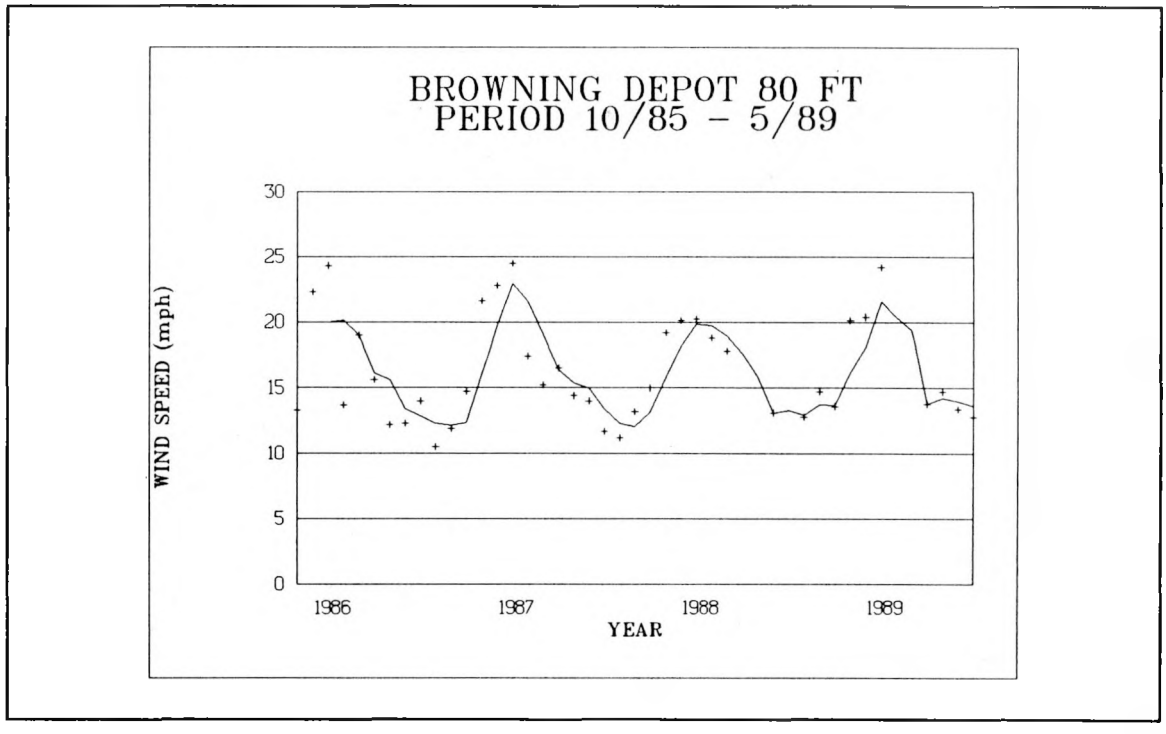


Figure 3–1. A Time Series of Wind Speeds at the 80 ft Level at the Browning Depot in Montana. The Solid Curve is a Three Month Running Means.

Table 3-1. Annual Summary Statistics for Browning Depot.

BROWNING DEPOT

Data Period: Jun. 1988 - May 1989 Site Elevation: 4500 ft

Wind Statistics

Anemometer Level:	40 ft	Data Recovery Rate:	78.3%
Average Speed:	15.2 mph	Power Density:	367 W/M**2
Available Energy:	3219 KWh/M**2	% Time (Speed 12.0-60.0):	58.6%
Maximum (1 hr Avg.):	63.5 mph	Maximum Gust:	85.5 mph
Date:	1/30 - 900	Date:	1/30 - 900
Shape Factor:	1.81	Scale Factor:	17.0 mph
Standard Deviation of Hourly Wind Speeds:			8.78
Anemometer Level:	80 ft	Data Recovery Rate:	78.4%
Average Speed:	16.4 mph	Power Density	469 W/M**2
Available Energy:	4105 KWh/M**2	% Time (Speed 12.0-60.0):	64.5%
Maximum (1 hr Avg.):	70.4 mph	Maximum Gust:	70.4 mph
Date:	1/30 - 1200	Date:	1/30 - 1200
Shape Factor:	1.81	Scale Factor:	18.5 mph
Standard Deviation of Hourly Wind Speeds:			9.52

Alpha Value (40 ft-80 ft):	0.118

Estimated Turbine Energy Output (Normalized to period of record)

Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	163076 kWh	337978 kWh	203463 kWh	608486 kWh
Capacity Factor*:	0.282	0.129	0.232	0.278
Efficiency Factor**:	0.202	0.267	0.240	0.222
Alpha Factor Used:	0.118	0.118	0.118	0.118

Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	963888 kWh	1590482 kWh	801104 kWh	696137 kWh
Capacity Factor*:	0.245	0.284	0.277	0.256
Efficiency Factor**:	0.217	0.228	0.229	0.216
Alpha Factor Used:	0.118	0.118	0.118	0.118

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.2 Cape Blanco

The anemometer sites at Cape Blanco was installed in October of 1976. The Cape Blanco site experienced poor data recovery (61%) this year due to numerous problems with the data logger and modem. A telephone modem has been used to retrieve the data since January 1988. Before January of 1988 data were collected only on cassette tape and strip charts prior to 1986. Statistical data for the microwave site are given in Table 3-2. The strongest hourly wind measured was 90 mph in November of 1988. The gust that accompanying gust was 110.5 mph.

The mean speed was 19.1 mph, which is close to average. Summarized statistics for Cape Blanco, since 1976, are presented in Appendix B. Data recovery over the entire period of record was 83%. Figure 3-2 presents a time series of monthly wind speeds. The wind speeds over the last four to five years are stronger than the winds experienced in the 70's and early 80's.

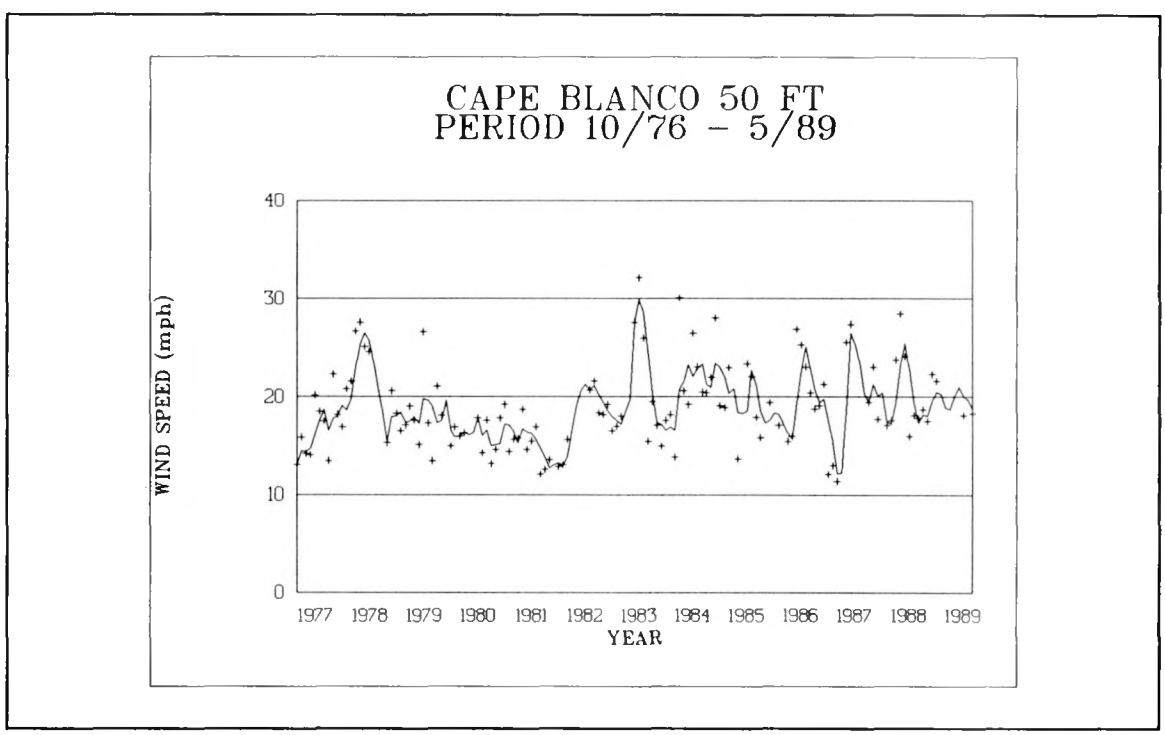


Figure 3-2. A Time Series of Monthly Wind Speeds at Cape Blanco at 50 ft. The solid line is a three month running mean.

Table 3-2. Annual Summary Statistics for Cape Blanco Microwave.

CAPE BLANCO M/W

Data Period: Jun. 1988 - May 1989 Site Elevation: 217 ft

Wind Statistics

Anemometer Level:	50 ft	Data Recovery Rate:	61.1%
Average Speed:	19.1 mph	Power Density:	816 W/M**2
Available Energy:	7145 KWh/M**2	% Time (Speed 12.0-60.0):	70.5%
Maximum (1 hr Avg.):	89.8 mph	Maximum Gust:	110.5 mph
Date:	11/2 - 1200	Date:	11/2 - 1200
Shape Factor:	1.80	Scale Factor:	21.5 mph
Standard Deviation of Hourly Wind Speeds:			11.13

Estimated Turbine Energy Output (Normalized to period of record)

Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	259169 kWh	630965 kWh	339732 kWh	891061 kWh
Capacity Factor*:	0.448	0.240	0.388	0.407
Efficiency Factor**:	0.180	0.254	0.208	0.202
Alpha Factor Used:	0.000	0.000	0.000	0.000

Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	1433116 kWh	2339266 kWh	1280568 kWh	1016892 kWh
Capacity Factor*:	0.364	0.417	0.443	0.374
Efficiency Factor**:	0.208	0.223	0.211	0.203
Alpha Factor Used:	0.000	0.000	0.000	0.000

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.3 Goodnoe Hills

Wind data have been collected at the BPA tower since May of 1980. During the past year data recovery was 90% at this location. The site statistics are presented in Table 3-3. A peak gust of 70 mph was measured at the 195 ft level of Goodnoe Hills tower in January of 1989. The mean speed measured at the site was 10.3 mph at the 50 ft level and 14.3 mph at the 195 ft level. The mean shear level is 0.24 which has increased from 0.21 in earlier studies (see BPA Report 85-19). The increase in shear may be attributed to an increase in roughness around the tower or a variation in the frequency of certain wind directions associated with high shear.

Wind statistics for Goodnoe Hills since the installation of the anemometer are presented in Appendix C. Overall data recovery for the entire collection period was 91%. Figure 3-3 presents a time series of monthly wind speeds for this site since 1980.

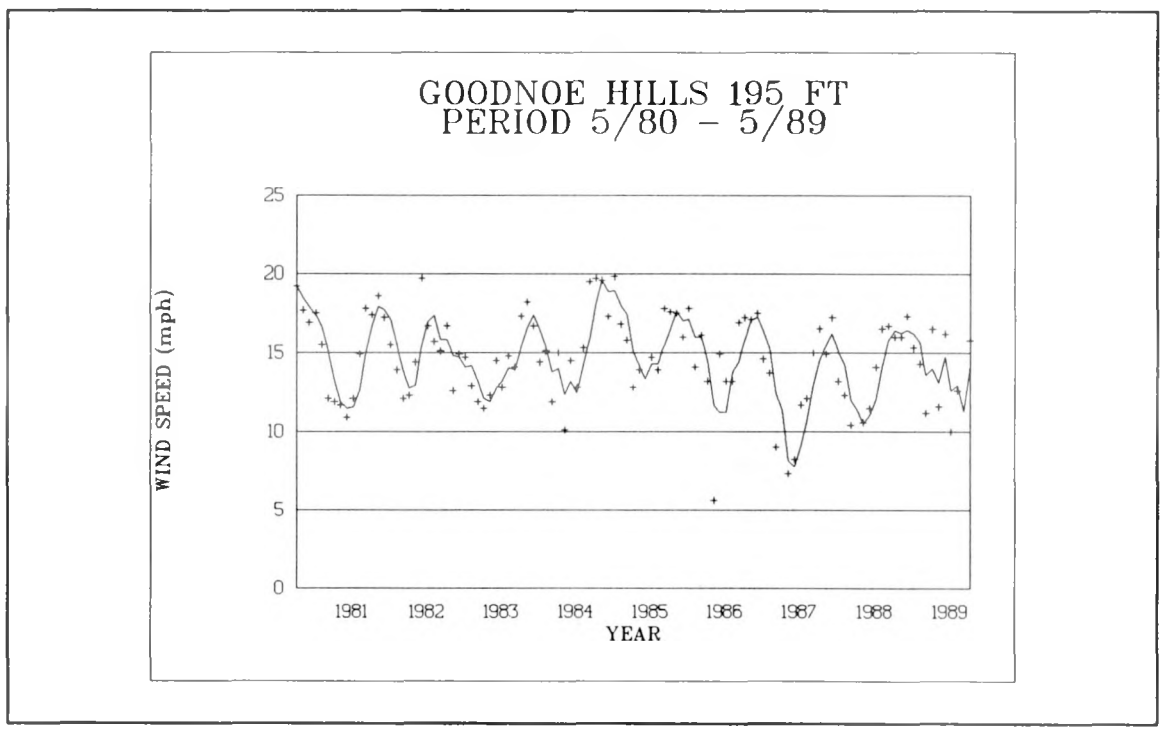


Figure 3-3. A Time Series of Monthly Mean Speeds at Goodnoe Hills 195 ft. The solid curve is a three-month running mean.

Table 3-3. Annual Summary Statistics for Goodnoe Hills.

GOODNOE HILLS TOWER			
Data Period: Jun. 1988 - May 1989		Site Elevation: 2540 ft	
Wind Statistics			
Anemometer Level:	50 ft	Data Recovery Rate:	89.7%
Average Speed:	10.3 mph	Power Density:	133 W/M**2
Available Energy:	1164 KWh/M**2	% Time (Speed 12.0-60.0):	38.7%
Maximum (1 hr Avg.):	43.4 mph	Maximum Gust:	64.1 mph
Date:	1/16 - 2000	Date:	1/16 - 2100
Shape Factor:	1.62	Scale Factor:	11.5 mph
Standard Deviation of Hourly Wind Speeds:			6.63
Anemometer Level:	195 ft	Data Recovery Rate:	89.8%
Average Speed:	14.3 mph	Power Density	346 W/M**2
Available Energy:	3027 KWh/M**2	% Time (Speed 12.0-60.0):	54.8%
Maximum (1 hr Avg.):	56.0 mph	Maximum Gust:	70.2 mph
Date:	1/16 - 1700	Date:	1/16 - 1700
Shape Factor:	1.62	Scale Factor:	15.9 mph
Standard Deviation of Hourly Wind Speeds:			9.13
Alpha Value (50 ft-195 ft):			0.238

Estimated Turbine Energy Output (Normalized to period of record)				
Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	91263 kWh	135879 kWh	92008 kWh	358448 kWh
Capacity Factor*:	0.158	0.052	0.105	0.164
Efficiency Factor**:	0.297	0.312	0.309	0.309
Alpha Factor Used:	0.238	0.238	0.238	0.238
Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	597637 kWh	964980 kWh	434230 kWh	406551 kWh
Capacity Factor*:	0.152	0.172	0.150	0.150
Efficiency Factor**:	0.308	0.307	0.319	0.289
Alpha Factor Used:	0.238	0.238	0.238	0.238

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.4 Hampton Butte

Data recovery at Hampton Butte was 98% this year, but the anemometer failed in late November. The mean wind speed for this incomplete year of wind data was 12.3 mph. The site experienced no gusts above 75 mph (see Table 3.4).

Wind statistics for this site are also presented in Appendix D. Data recovery for the entire period of record was 72%. Earlier much data were lost in the winter months because of inaccessibility problems. The installation of a data logger greatly improved data recovery over a strip chart recorder. Figure 3-4 shows a time series of wind data for Hampton Butte since the anemometer was installed in October of 1983.

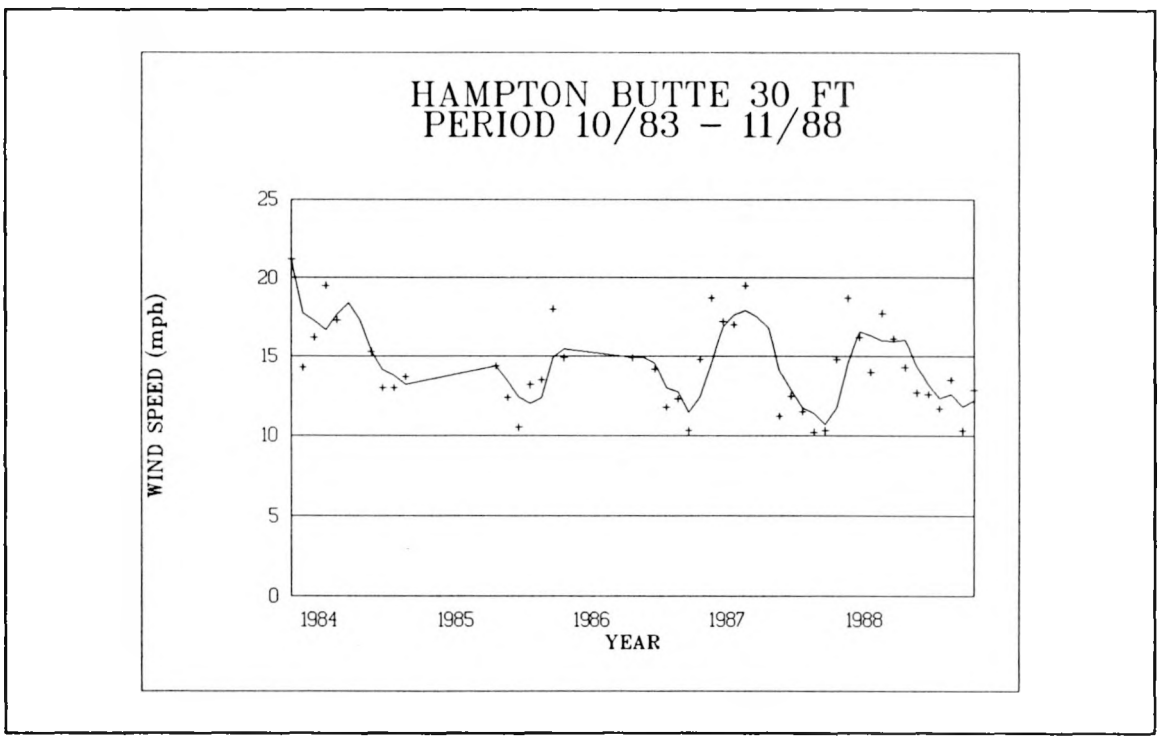


Figure 3-4. A Time Series of Monthly Mean Speeds at Hampton Butte. The solid line is a three month running mean.

Table 3-4. Annual Summary Statistics for Hampton Butte.

HAMPTON BUTTE			
Data Period: Jun. 1988 - May 1989		Site Elevation: 6343 ft	
Wind Statistics			
Anemometer Level:	30 ft	Data Recovery Rate:	98.1%
Average Speed:	12.3 mph	Power Density:	164 W/M**2
Available Energy:	719 KWh/M**2	% Time (Speed 12.0-60.0):	48.8%
Maximum (1 hr Avg.):	43.6 mph	Maximum Gust:	57.0 mph
Date:	11/22 - 1400	Date:	11/22 - 1700
Shape Factor:	1.95	Scale Factor:	13.9 mph
Standard Deviation of Hourly Wind Speeds:			6.63

Estimated Turbine Energy Output (Normalized to period of record)				
Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	52965 kWh	93639 kWh	61073 kWh	189695 kWh
Capacity Factor*:	0.183	0.071	0.139	0.173
Efficiency Factor**:	0.278	0.310	0.301	0.298
Alpha Factor Used:	0.100	0.100	0.100	0.100
Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	303953 kWh	478360 kWh	251382 kWh	209214 kWh
Capacity Factor*:	0.154	0.170	0.173	0.154
Efficiency Factor**:	0.297	0.298	0.306	0.281
Alpha Factor Used:	0.100	0.100	0.100	0.100

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.5 Kennewick

Data recovery was 79% at Kennewick 80 ft level this year. Problems in changing the cassette recorder tapes for CR-21 data logger resulted in lost data in February and March. The mean speed measured was 16.8 mph at 80 ft and the available energy was 6,710 kWh/m^2 for the period (see Table 3-5). Appendix E presents additional data summaries for this site. Kennewick has had 80% data recovery over the entire record of measurements.

Figure 3-5 presents a time series of monthly wind speeds at the Kennewick site since the anemometer was installed in June of 1976. The anemometer was lowered from 105 ft to 80 ft in September of 1987. The speeds at 80 ft are about 5% weaker for the prevailing wind directions based on a comparison of the winds at both levels during an overlapping period of measurement from July 1987 through September 1987.

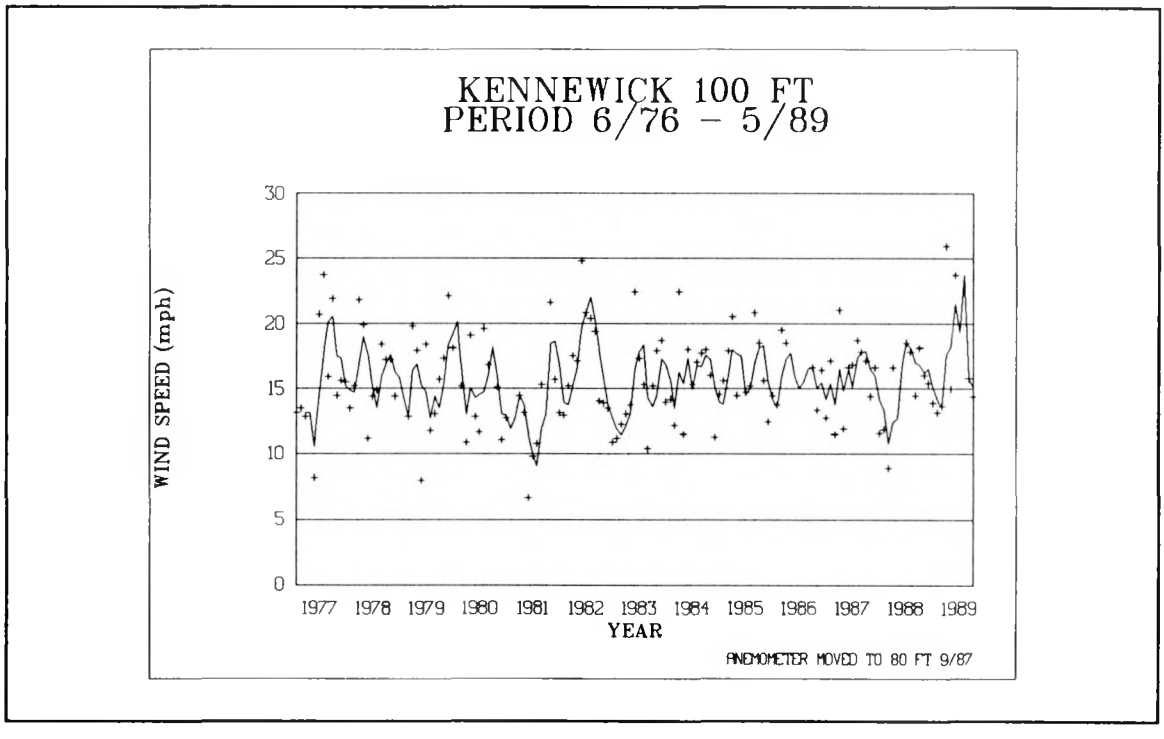


Figure 3-5. A Time Series of Monthly Mean Speeds at the Kennewick Site. The smooth line is the three-month running mean.

Table 3-5. Annual Summary Statistics for Kennewick 80 ft level.

KENNEWICK M/W			
Data Period: Jun. 1988 - May 1989		Site Elevation:	2200 ft
Wind Statistics			
Anemometer Level:	80 ft	Data Recovery Rate:	78.9%
Average Speed:	16.8 mph	Power Density:	766 W/M**2
Available Energy:	6710 KWh/M**2	% Time (Speed 12.0-60.0):	52.5%
Maximum (1 hr Avg.):	70.0 mph	Maximum Gust:	81.4 mph
Date:	1/18 - 0000	Date:	1/18 - 0000
Shape Factor:	1.35	Scale Factor:	18.3 mph
Standard Deviation of Hourly Wind Speeds:			12.71

Estimated Turbine Energy Output (Normalized to period of record)				
Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	182734 kWh	486765 kWh	225256 kWh	664923 kWh
Capacity Factor*:	0.316	0.185	0.257	0.304
Efficiency Factor**:	0.136	0.216	0.151	0.157
Alpha Factor Used:	0.030	0.030	0.030	0.030
Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	1072041 kWh	1687475 kWh	901745 kWh	761859 kWh
Capacity Factor*:	0.272	0.301	0.312	0.281
Efficiency Factor**:	0.161	0.165	0.158	0.157
Alpha Factor Used:	0.030	0.030	0.030	0.030

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.6 Kittitas Microwave

Data recovery at Kittitas was 84% during the past year and the measured mean annual wind speed was 12.9 mph. The winds this year were average for this site. Statistics for the site are presented in Table 3-6 and in Appendix F. Kittitas data recovery over the entire period of record was 93%.

A time series of wind speeds is presented for this site for the period March 1980 through May 1989. The anemometer was removed from August 1983 through December 1985.

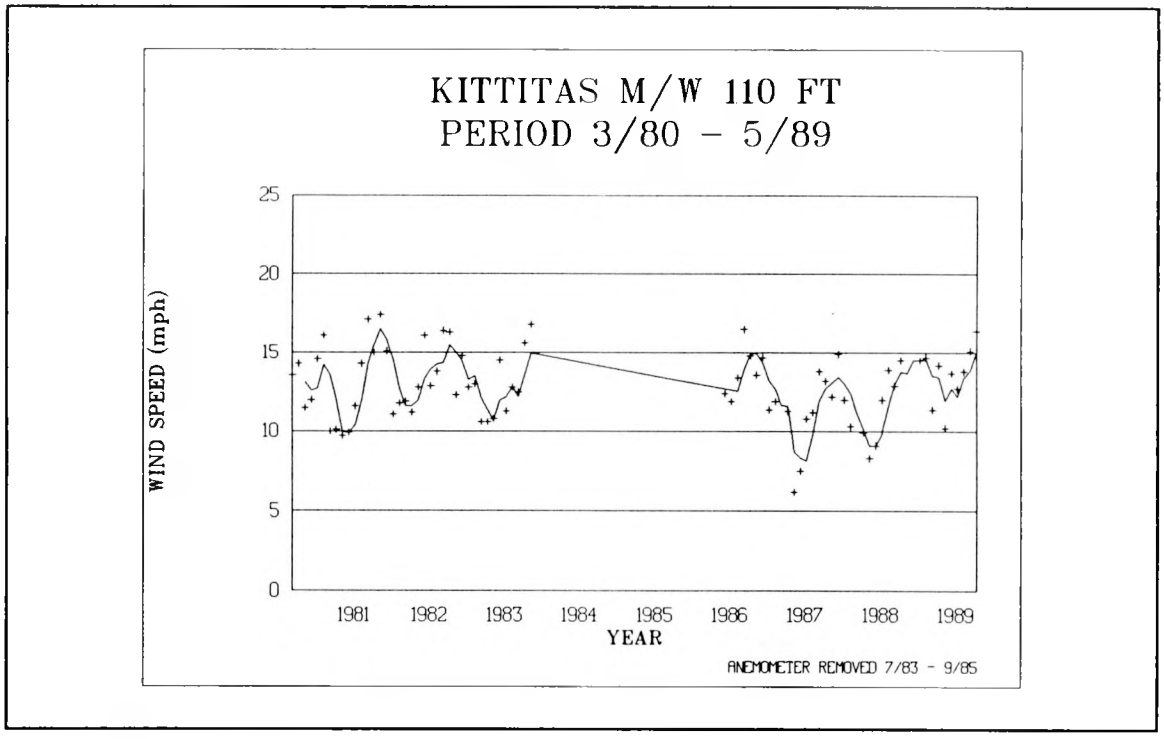


Figure 3-6. A Time Series of Monthly Mean Speeds at Kittitas Microwave. The solid curve is the three-month running mean.

Table 3-6. Annual Summary Statistics for Kittitas Microwave.

KITTITAS M/W

Data Period: Jun. 1988 - May 1989 Site Elevation: 2660 ft

Wind Statistics

Anemometer Level:	110 ft	Data Recovery Rate:	84.2%
Average Speed:	12.9 mph	Power Density:	305 W/M**2
Available Energy:	2668 KWh/M**2	% Time (Speed 12.0-60.0):	44.2%
Maximum (1 hr Avg.):	56.8 mph	Maximum Gust:	67.8 mph
Date:	1/17 - 400	Date:	1/17 - 500
Shape Factor:	1.47	Scale Factor:	14.2 mph
Standard Deviation of Hourly Wind Speeds:			9.00

Estimated Turbine Energy Output (Normalized to period of record)

Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	108857 kWh	218298 kWh	135488 kWh	404891 kWh
Capacity Factor*:	0.188	0.083	0.155	0.185
Efficiency Factor**:	0.228	0.287	0.266	0.253
Alpha Factor Used:	0.100	0.100	0.100	0.100

Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	641294 kWh	1023273 kWh	530078 kWh	461010 kWh
Capacity Factor*:	0.163	0.183	0.183	0.170
Efficiency Factor**:	0.249	0.254	0.257	0.247
Alpha Factor Used:	0.100	0.100	0.100	0.100

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.7 Pequop Summit

The Pequop Summit site had poor data recovery during the period (69%). The data tape recording system was the source of most of the problem. Several tapes were extremely difficult to read. Data recovery for the entire period of record was 72%. The statistics are presented in Table 3-7. The mean speed this past year was 11.7 mph compared to a long-term average of 15.2 mph. Summary statistics are in Appendix G. A time series of monthly mean speeds is presented in Figure 3-7.

When the anemometer was removed at this site in May of 1989 it calibrated out at 1 mph low at all speeds measured. The data over the past three months and perhaps earlier is thus suspect. The anemometer was calibrated prior to being installed in July of 1988.

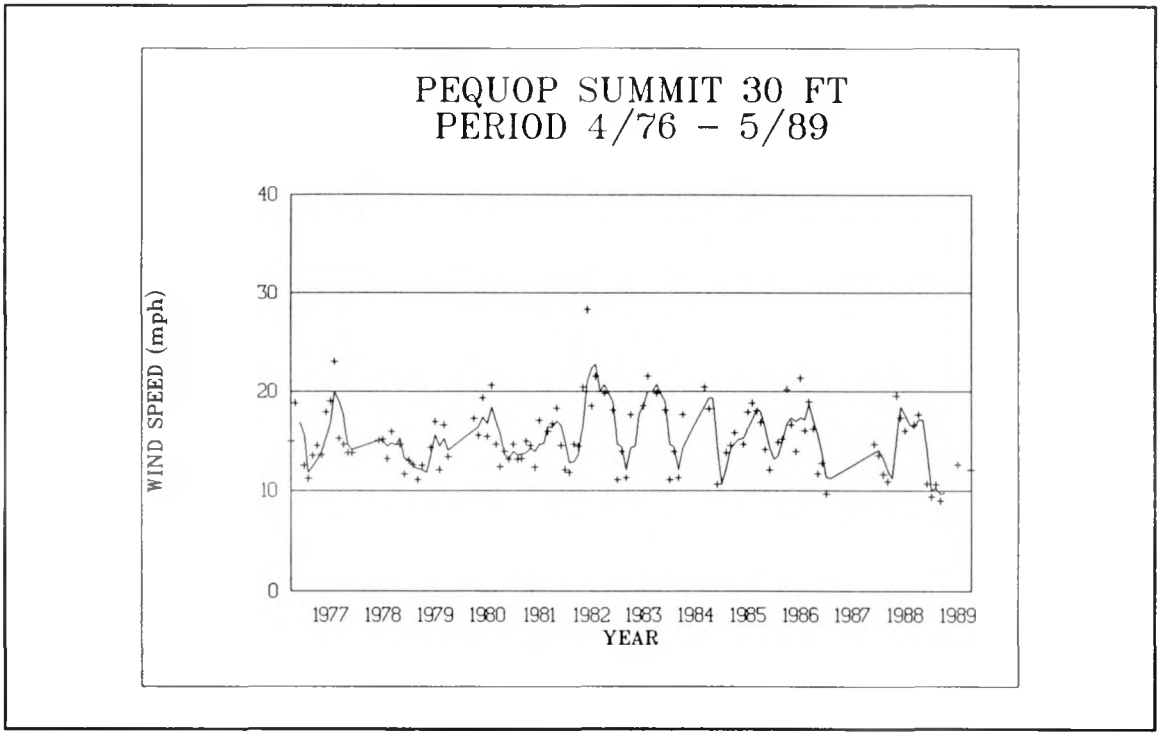


Figure 3-7. A Time Series of Monthly Mean Speeds at Pequop Summit. The solid line is the three-month running mean.

Table 3-7. Annual Summary Statistics for Pequop Summit.

PEQUOP SUMMIT			
Data Period: Jun. 1988 - May 1989		Site Elevation: 7538 ft	
Wind Statistics			
Anemometer Level:	30 ft	Data Recovery Rate:	69.3%
Average Speed:	11.7 mph	Power Density:	217 W/M**2
Available Energy:	1897 KWh/M**2	% Time (Speed 12.0-60.0):	40.0%
Maximum (1 hr Avg.):	55.9 mph	Maximum Gust:	150.5 mph
Date:	5/18 - 1700	Date:	1/16 - 1400
Shape Factor:	1.40	Scale Factor:	12.9 mph
Standard Deviation of Hourly Wind Speeds:			8.58

Estimated Turbine Energy Output (Normalized to period of record)

Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	86598 kWh	180445 kWh	114080 kWh	317026 kWh
Capacity Factor*:	0.150	0.069	0.130	0.145
Efficiency Factor**:	0.209	0.259	0.247	0.243
Alpha Factor Used:	0.030	0.030	0.030	0.030

Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	484126 kWh	772104 kWh	421054 kWh	354096 kWh
Capacity Factor*:	0.123	0.138	0.146	0.130
Efficiency Factor**:	0.235	0.244	0.239	0.237
Alpha Factor Used:	0.030	0.030	0.030	0.030

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.8 Seven Mile Hill Tower

Data have been collected at Seven Mile Hill, near The Dalles, Oregon, since 1978. The tower has two anemometer levels 50 and 150 ft. The 1988–89 statistics are presented in Table 3–8 and summarized for the entire period of record are presented in Appendix H. The data recovery for this past year was 92% and 90% over the entire period of record. The mean speed averaged 13.8 mph at 50 ft and 15.3 at 150 ft this year compared to a long-term average of 14.7 and 16.6 mph respectively. A time series of monthly mean speeds for the 150 ft level is shown in Figure 3–8.

This site exhibits decreasing wind speeds over the last 2.5 years as did Goodnoe Hills. The reason for this decease is unknown.

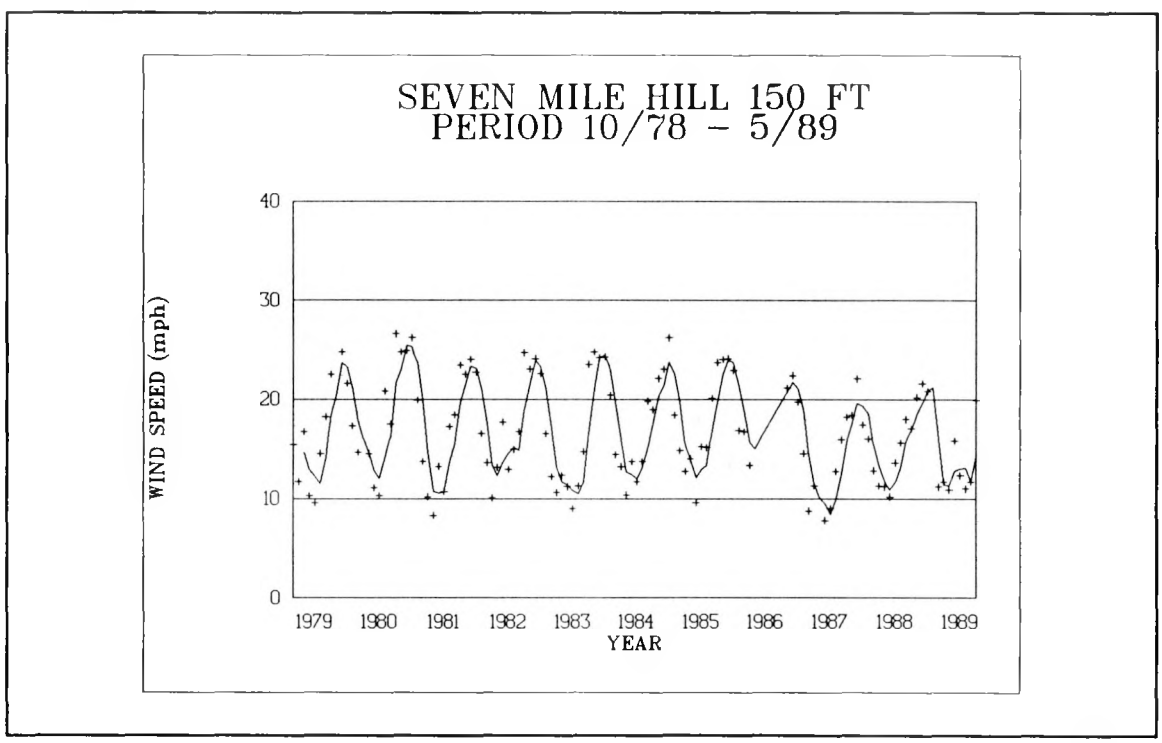


Figure 3–8. A Time Series of Monthly Mean Speeds at Seven Mile Hill 150 ft level. The solid line is the three-month running mean.

Table 3-8. Annual Summary Statistics for Seven Mile Hill Tower.

SEVEN MILE HILL TOWER			
Data Period: Jun. 1988 - May 1989		Site Elevation:	1880 ft
Wind Statistics			
Anemometer Level:	50 ft	Data Recovery Rate:	92.1%
Average Speed:	13.8 mph	Power Density:	350 W/M**2
Available Energy:	3065 KWh/M**2	% Time (Speed 12.0-60.0):	51.2%
Maximum (1 hr Avg.):	47.5 mph	Maximum Gust:	63.0 mph
Date:	7/31 - 1300	Date:	8/29 - 1800
Shape Factor:	1.51	Scale Factor:	15.3 mph
Standard Deviation of Hourly Wind Speeds:			9.41
Anemometer Level:	150 ft	Data Recovery Rate:	92.1%
Average Speed:	15.3 mph	Power Density	448 W/M**2
Available Energy:	3926 KWh/M**2	% Time (Speed 12.0-60.0):	56.9%
Maximum (1 hr Avg.):	55.6 mph	Maximum Gust:	75.6 mph
Date:	12/13 - 100	Date:	12/13 - 100
Shape Factor:	1.59	Scale Factor:	17.1 mph
Standard Deviation of Hourly Wind Speeds:			9.97
Alpha Value (50 ft-150 ft):			0.095

Estimated Turbine Energy Output (Normalized to period of record)				
Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	157906 kWh	323650 kWh	201791 kWh	575030 kWh
Capacity Factor*:	0.273	0.123	0.230	0.263
Efficiency Factor**:	0.244	0.313	0.292	0.266
Alpha Factor Used:	0.095	0.095	0.095	0.095
Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	917323 kWh	1513806 kWh	779326 kWh	660041 kWh
Capacity Factor*:	0.233	0.270	0.270	0.243
Efficiency Factor**:	0.265	0.279	0.279	0.262
Alpha Factor Used:	0.095	0.095	0.095	0.095

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

3.9 Upper Pyle Canyon

Upper Pyle Canyon has had a data recovery rate of 71% during this past year. The low data recovery problems are because of tape recorders problems that may be related to cold temperatures or magnetic interference.. The data recovery over the entire record is 66%. The wind speed and energy statistics are presented in Table 3-9 and in Appendix I. The mean speed at this site was 15.6 mph. The long-term mean is 14.1 mph for the period March 1984 through May 1989. Figure 3-9 shows the monthly wind speed variation at Upper Pyle.

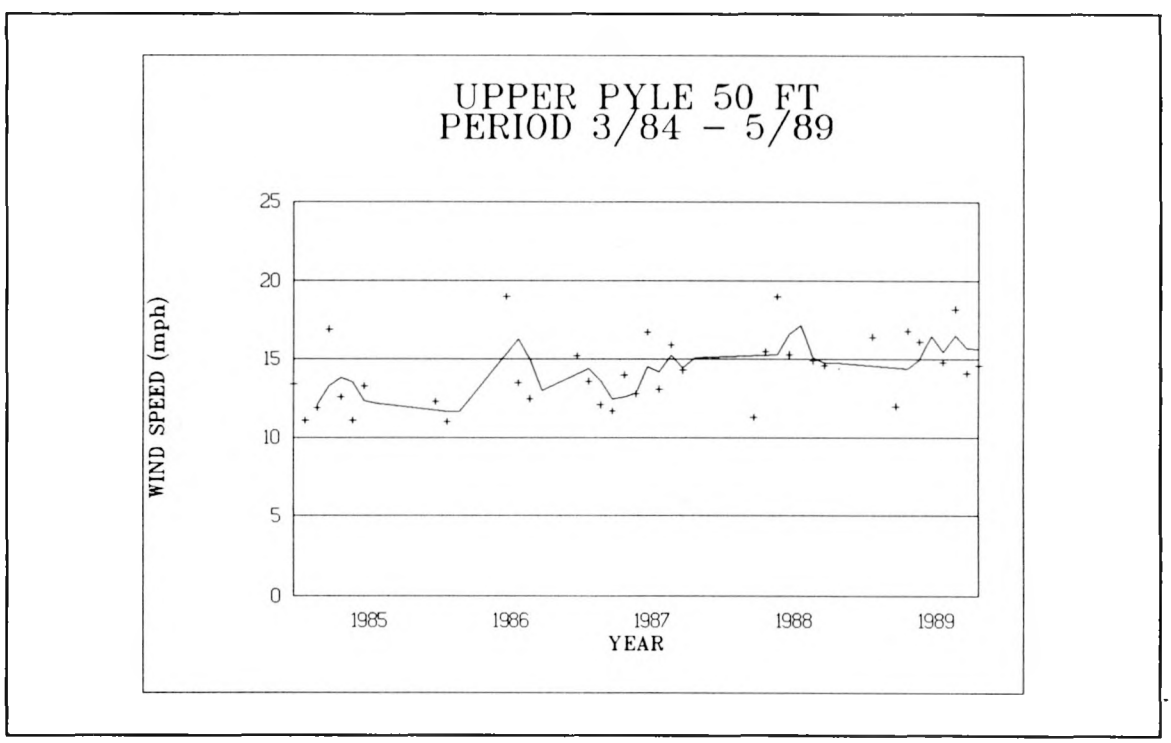


Figure 3-9. A Time Series of Monthly Mean Speeds at Upper Pyle Canyon at the 50 ft level. The solid line is the three month running mean.

Table 3-9. Annual Summary Statistics for Upper Pyle Canyon.

UPPER PYLE CANYON			
Data Period: Jun. 1988 - May 1989		Site Elevation: 3660 ft	
Wind Statistics			
Anemometer Level:	50 ft	Data Recovery Rate:	71.2%
Average Speed:	15.6 mph	Power Density:	419 W/M**2
Available Energy:	3670 KWh/M**2	% Time (Speed 12.0-60.0):	61.2%
Maximum (1 hr Avg.):	57.1 mph	Maximum Gust:	70.7 mph
Date:	1/13 - 100	Date:	1/13 - 300
Shape Factor:	1.75	Scale Factor:	17.5 mph
Standard Deviation of Hourly Wind Speeds:			9.34

Estimated Turbine Energy Output (Normalized to period of record)				
Turbine Type:	NORDTANK 65 KW	FLO-190 300 KW	USWP 56 100 KW	MITSUBISHI 250 KW
Hub Height:	75 ft	57 ft	60 ft	100 ft
Swept Area:	201 M**2	347 M**2	229 M**2	618 M**2
Est. Total Energy*:	170688 kWh	365025 kWh	213324 kWh	628369 kWh
Capacity Factor*:	0.295	0.139	0.244	0.287
Efficiency Factor**:	0.205	0.276	0.240	0.225
Alpha Factor Used:	0.100	0.100	0.100	0.100
Turbine Type:	BONUS 450 KW	WESTINGHOUSE 640 KW	HOWDEN 330 KW	HOLEC 310 KW
Hub Height:	110 ft	120 FT	80 FT	110 FT
Swept Area:	965 M**2	1471 M**2	851 M**2	701 M**2
Est. Total Energy*:	1002784 kWh	1638924 kWh	841442 kWh	719940 kWh
Capacity Factor*:	0.254	0.292	0.291	0.265
Efficiency Factor**:	0.223	0.233	0.234	0.221
Alpha Factor Used:	0.100	0.100	0.100	0.100

*Assuming 100% availability
Estimated monthly energy, kWh/(Available energy, kWh/M2)(Swept area, M**2)

4.0 LONG-TERM REGIONAL WIND VARIATION

4.1 Introduction

A widely accepted assumption among meteorologists and engineers in the wind energy assessment field is that there is little or no trend in annual wind speed data. However, the prospect of changing climate may render this assumption invalid. There has been little discussion in the scientific literature on wind climate and any expected impacts of global warming on local and regional wind strength and wind energy availability. This paper will examine the importance of wind climate change on wind energy availability and the need to consider climate change in the projections of the potential supply of wind energy.

A general approach used in wind prospecting is to measure wind characteristics on a site for at least one year. The assumption is that "on average, the climatic mean will be within ±10% of a single annual wind speed observation with about 90% uncertainty" (see Justus et al., 1979). This assumption was also verified in earlier work by Corotis (1977). The validity of this approach to wind resource characterization should be re-evaluated because of the possibility of changes in global and regional circulation patterns as the result of the "greenhouse effect."

Several recent papers have noted long-term deceasing trends in wind climate (see Alpert and Mandel, 1986; Palutikof et al., 1986; and Wade et al., 1986). Palutikof et al. (1986) found that in long record of winds at Southport, U.K., there was a 60% change in average wind power potential within a period of twenty years. They related the apparent trends in wind speeds to large-scale changes in atmospheric circulation. While Palutikof et al. (1986) found the changes in wind speed at Southport were gradual, they sited evidence that step jumps from a high wind speed decade to a low wind speed decade have occurred (Palutikof et al., 1986).

Wade et al. (1986) noted that the mean wind speed measured during the period 1976-83 were 16% weaker than the estimated 35-year mean at a site on

the Southern Oregon Coast. A 16% variation in wind speed could correspond to as much as a 50% variation in available wind energy.

In Israel, Alpert and Mandel (1986) described a systematic variation in diurnal variation of wind at three meteorological stations. They found a deceasing trend in diurnal wind variation over the past three decades. They note that the change in the wind speed characteristics suggest a change in mesoscale climate induced by agricultural development and settlement. Increasing irrigation in the 1960's led to increased soil moisture and changes in the albedo (absorption/reflection of sun's energy) and surface roughness due to more vegetation. These may have caused the decreased diurnal wind variation (a reverse desertification).

Wade et al. (1987) described upper level wind variations over the entire Pacific Northwest. They noted a consistent trend of below average wind speeds at all the Pacific Northwest upper air sites which were weaker from the period 1976 through 1982. These observations confirmed the earlier findings of Redmond (1985) (see also Wade et al., 1986) for western Oregon. The analysis in this paper will update the earlier investigations with data collected through 1987 for the entire Northwest.

4.2 Objectives

The objectives of this study were:

- to determine if the winds measured during the period 1976–87 represent the winds measured over a longer scale of time such as the life of a wind energy plant (20 to 30 years).
- to determine if longer climatic records of related climate variables (ie. surface and upper air wind data) can be used to infer wind climate history.

4.3 Method

The approach used in this study was to first examine surface wind climate data at long-term National Weather Service locations (see Figure 4-1). These sites were examined to determine if winds measured the 12-year period

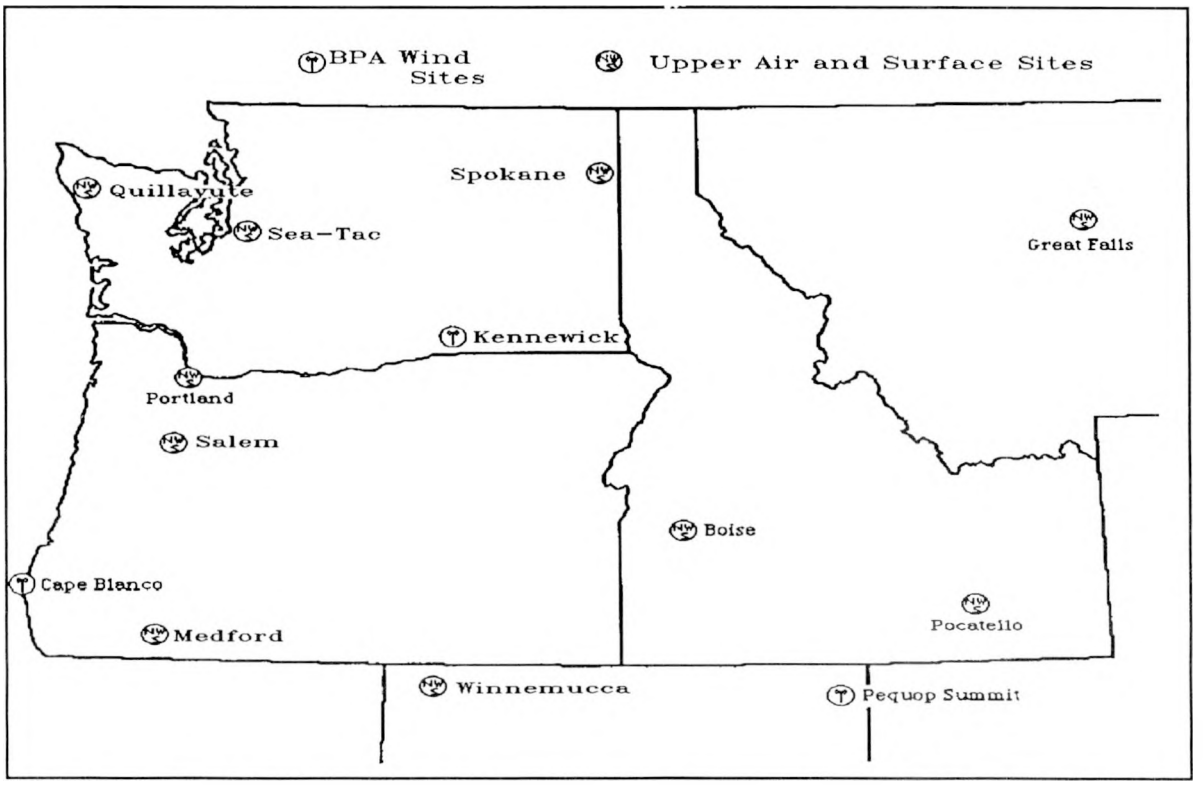


Figure 4-1. Wind data site locations in the Pacific Northwest.

1976-87 represent the mean for the entire period of record. Since the height that winds were measured has varied over the last 40 to 50 years, sites where the wind measurement height and location have varied little were used to determine the long-term wind history. The climate records were truncated in the late fifties to eliminate earlier data when anemometer heights varied widely. Many of the wind energy sites are at high elevations and poorly correlated with wind data collected at airport and urban locations. In response to this concern, upper air data were also examined for wind speed trends over the last thirty years. Use of upper air data avoids the problem of accounting for changes in instrument height and exposure. Upper air wind variations were examined at the seven Pacific Northwest upper air observing locations (see Figure 4-1).

The upper wind levels examined were for 850 mb (about 5000 ft above sea level), 700 mb (near 10,000 ft above sea level), and 500 mb (about 35,000 ft above sea level). Upper air data have been collected via balloon soundings twice a day for the past 40 years. The three levels above the surface are sufficiently high enough to avoid being influenced by local terrain irregularities and surface roughness.

To test for trends in the surface and upper air data, the means for the period 1976–87 were compared to means for the entire record prior to 1976. At most locations upper air data collection began in the late 1940's. The period 1976–87 represents the period over which wind data have been collected by Oregon State University for Bonneville Power Administration's Wind Resource Energy Assessment Program (Wind REAP).

A statistical model was developed to reconstruct a record for the winds before 1976 for three wind energy sites with data since 1976. The model was developed on data collected from 1976–1987 (dependent data set). At least four years from the recent wind record were excluded from the dependent data set to validate the model used to reconstruct the past wind record.

Monthly time series of wind data have a strong seasonal signal. To remove this seasonal signal, departures from the mean monthly speed were determined for both the predictor and predictand sites. The departures from the mean were next tested for evidence of any autocorrelation. No significant autocorrelation was noted (the first-order autocorrelation coefficients were less than .1). Regression relationships were developed between predictor and predictand departures from the mean monthly wind speed. The ratio of mean monthly wind speeds for both predictor and predictand site was computed and the standard deviation of the monthly departures from the mean too. Predictions of the mean monthly annual wind speed before 1976 and the interannual variation of wind speed were made using the relationship below and data for the predictor location before 1976. The predicted mean monthly wind speed for each month at the predictand location V_{mest} is given by:

$$V_{mest} = (mV'_{mref} + b)*\sigma V'_c/\sigma V'_{ref} + (mr*V_{mref}) \quad (1)$$

where m and b are the slope and intercept respectively of the regression relationship between the departures from the monthly means in the dependent data set for the predictor and predictand location; V'_{mref} is the monthly departure from normal for the predictor location; $\sigma V'_c$ is the standard deviation of the monthly departure from the mean in the dependent data set for the predictand site; $\sigma V'_{ref}$ is the standard deviation of the monthly departure from the mean in the dependent data set for the predictor site; mr is the ratio of the predictand to the predictor monthly mean speed for the month being pre-

dicted; V_{mref} is monthly mean speed for the predictor site for independent data set.

Annual mean speeds estimates for the predictand site were determined from the average of the predicted monthly mean speeds. The percent difference between the winds before 1976 and the winds from 1976 on was calculated to determine how representative the measurement period was compared to the past. As in the comparison above of surface and upper air data, the reference period is the winds before 1976.

The energy in the wind is given by the equation:

$$E = 1/2\rho AV^3 \qquad (2)$$

where E is the kinetic energy in the wind, ρ is the air density, A is the area swept by the turbine blades and V is the wind speed. Although energy is sensitive to changes in temperature and pressure in the density term, the most significant fact deduced from expression 1 is that wind energy is related to the cube of the wind speed. A 10% decrease in wind speed would result in over 30% less available energy.

To estimate the implication of long-term variations in wind speed to energy output it is necessary to determine the relationship of annual mean wind speed was to the distribution of wind speeds. The estimated distribution and the performance curve of the wind turbine can be used to predict the gross annual energy output for the selected wind turbine. Without a measured wind speed distribution, a commonly used fitted probability distribution is the Weibull, which is given by:

$$p(V) = (k/c)\ (V/c)^{k-1}\ \exp[-(V/c)^k]\ , \qquad (3)$$

where V is a wind speed; c is the scale factor and is related to the mean value of the wind speed V_{avg} by:

$$V_{avg} = c\Gamma(1+1/k)\ , \qquad (4)$$

where Γ is the gamma function and k is the shape factor, which is related to the variance (σ^2) of V_{avg} by:

$$\sigma_V^2 = c^2[\Gamma(1=2/k) - (\Gamma(1+1/k)^2] \quad . \qquad (5)$$

Three turbine performance curves were used to estimate annual energy output for a given wind speed. The three wind turbines rated at 100, 100 and 250 kW were used to determine the energy implications of variations in wind speeds over time. The two 100 kW turbines had different cut-in, rated and cut-out speeds. The difference between gross annual energy output before 1976 and since 1976 were calculated for each turbine and the differences were averaged to measure the likely difference in available energy.

4.4 Results

4.4.1 Wind Variations Since 1976 at Wind Energy Survey Sites

The variation of wind speed over the past twelve years is shown in Figure 4-2 for three sites with the longest records. Figure 4-2, an annual wind speed time series, reflects the wide variety of wind regimes within the region. Kennewick is in the Horse Heaven Hills at 2200 ft. The strongest winds occur in the spring and early summer and are from the south. Cape Blanco is located on the southern Oregon coast at 217 ft above sea level. The prevailing winds are from the north in the summer and from the south in the winter months. Spring and fall are transition seasons between the thermally driven coastal winds of the Summer and storm-driven winter winds. Pequop Summit is in northeast Nevada at 7538 ft elevation. Pequop's strongest winds occur in the winter and spring months and are predominantly from the west-northwest. The station history for each Wind REAP is resented in Table 4-1.

There is no consistent regional trend evident since 1976 in the annual wind speeds for the four Wind REAP sites with long data records. On a seasonal basis, years such as 1977 and 1981 were characteristically weak wind winters and 1982 and 1983 had generally stronger winter winds at most locations in the region. The summer season winds are less coherent, but 1978 and

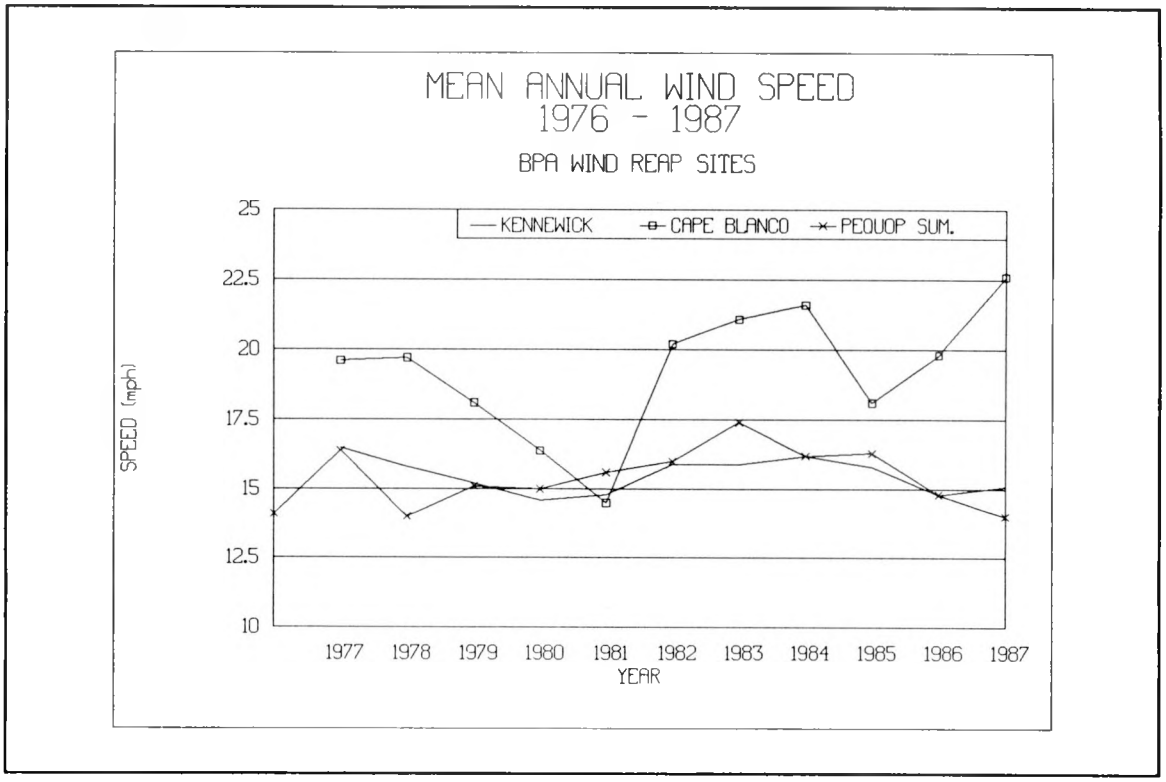


Figure 4-2. Wind variations at long-term wind data sites in the Pacific Northwest.

Table 4-1. Anemometer History for Wind Data Sites.

Site Name	Elevation (ft/m)	Anemometer Height (ft/m)	Period
Cape Blanco	217/66	50/15	8/10/76-Present
Kennewick M/W	2200/660	105/32	6/23/76-Present
Pequop Summit	7538/2261	30/9	4/27/76-4/16/89

1986 were weak wind summers at the four locations suggesting some regional response to changing circulation patterns.

4.4.2 Long-term Trends in Wind Speed in the Pacific Northwest

Seven long-term Pacific Northwest National Weather Service sites were examined for trends and annual wind speed variation at surface anemometer height (see Table 4-2). These locations were chosen because of they had few significant changes in anemometer height over a relatively long period. Five of the seven sites show a recent decrease in mean annual wind speed.

Surface wind data from the seven upper air sites are presented in Figure 4-3 and Table 4-3. These surface observations, taken twice a day, show evidence of a decrease in wind speeds from 1976-1987. Data are presented as departures from the mean before 1976. The solid line is the mean of the annual departures for the seven sites. Table 4-3 presents the percent departures from the mean for the 1976-87 period from the previous record. The discrepancies between the data in Tables 4-2 and 4-3 is partly because of differences in the length of the record and partly because the data in Table 4-3 represents only two observations a day at 0000 GMT and 1200 GMT. The means for the twice a day observations were consistently 2% lower than the means for 24 observations a day for the same time period.

The data in Tables 4-2 and 4-3 suggest that there have been weaker winds during the last 12 years than experienced previously. Since surface anemometer height at some of the stations has changed, some of the decrease may be due to better exposure of the anemometers before 1976. "Heat island effects" and increases in local roughness may also be accounting for some of the recent wind speed deceases evident in Tables 4-2 and 4-3. While it is possible to adjust wind data for changes in height, there is no assurance the adjustment will be correct. Changes in local exposure because of vegetation and buildings adds additional uncertainty that cannot be completely accounted for in the adjustments.

Table 4-2. The mean surface wind speed, standard deviation, and percent change from the period before 1976.

Period	Sea-Tac WA 60-87	Pocatello ID 60-87	Portland OR 63-87	Great Falls MT 59-87	Boise ID 58-87	Salem OR 60-87	Medford OR 60-87
Mean before 1976	8.5	10.0	8.1	11.9	8.5	7.2	4.7
Std Dev before 1976	.9	.6	.5	1.3	.7	.4	1.1
Mean 1976-1987	8.3	9.7	8.1	11.9	8.3	6.5	4.9
Std Dev 1976-1987	.2	.3	.5	.4	.2	.4	.2
Percent Change	-2	-3	0	0	-21	-10	-4

Sea-Tac: Moved 2800 ft SW of previous site from 1/1/60 to 12/2/69
Pocatello: Began recording at 20 ft 8/6/60
Portland: From 4/62 to 3/73 at 25 ft thereafter 20 ft
Great Falls: 23 ft from 8/59 to 11/64 22 ft thereafter
Boise: 20 ft from 8/58
Salem: 20 ft from 2/59
Medford: 20 ft from 5/59

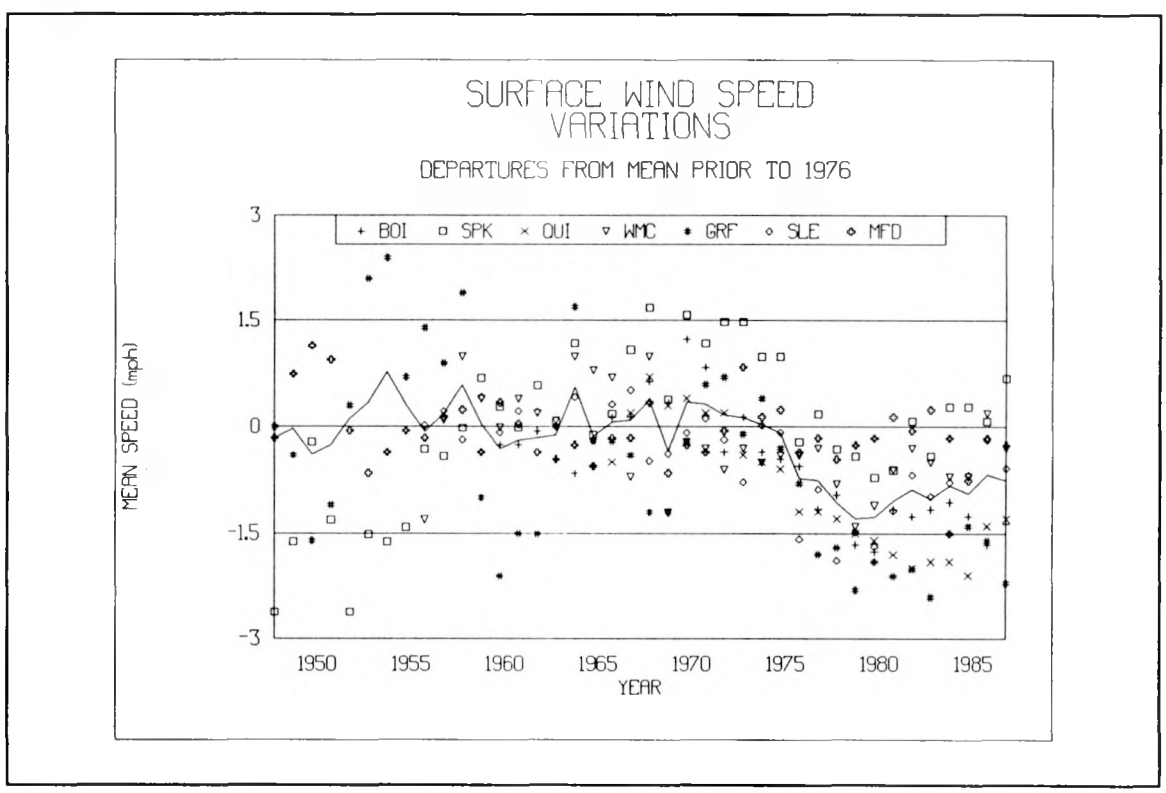


Figure 4-3. Surface wind variations at seven National Weather Service sites in the Pacific Northwest. The solid line is mean departure.

Table 4-3. The percent departure of the mean surface wind speed for the period 1976-87 from the previous record for seven upper air sites in the Pacific Northwest. The departure from the period 1966-1975 is given to show how the seven sites compared for the same periods of record.

Location	Period of Record	Before 1976	1966-1975
		Percent Departure	Percent Departure
Boise, ID	1960-1987	-13.5%	16%
Spokane, WA	1948-1987	-1%	12%
Quillayute, WA	1966-1987	-21%	21%
Winnemucca, NV	1956-1987	-7%	4%
Great Falls, MT	1948-1987	-14%	12%
Salem, OR	1956-1987	-14%	13%
Medford, OR	1948-1987	-4%	4%
Mean for Region		-10.6%	11.7%

The winds aloft provide wind speed measurements over time at constant height and pressure levels. Figure 4-4 shows the annual wind speeds for the seven National Weather Service upper air sites at the 850 millibar level. Figure 4-4 shows the same trend noticed in the surface data at all seven sites. This was evident at other pressure levels (see Figures 4-5 and 4-6). Annual wind speed variation was examined at the surface, 850 mb, 700 mb, and 500 mb. Table 4-4 gives the percent departures for the wind speeds for the 1976-87 period from the 1948-75 mean. At two upper air sites, Medford and Spokane, the strongest decrease in wind speeds recently was at 850 mb level.

At the 850 mb level the decrease in wind speed over the period 1976-87 was similar at all seven upper air sites in the Pacific Northwest (see Table 4-5). Five out of the last 12 years have had regional mean 850 mb wind speeds two standard deviations less than the mean for the previous record. Since many of the best potential wind energy development sites are at high elevations, the results below are of considerable interest. We would expect sites

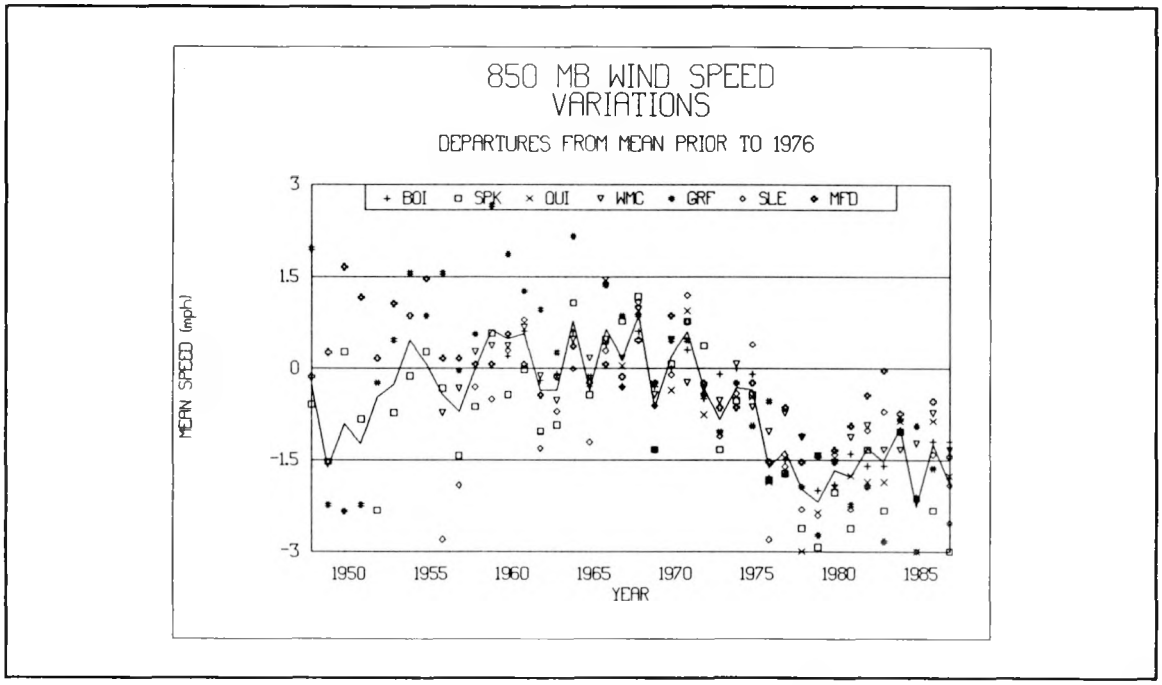


Figure 4-4. Annual variation of wind speed at the 850 mb level at seven Pacific Northwest locations. The winds are given as departures in mph from the mean before 1976.

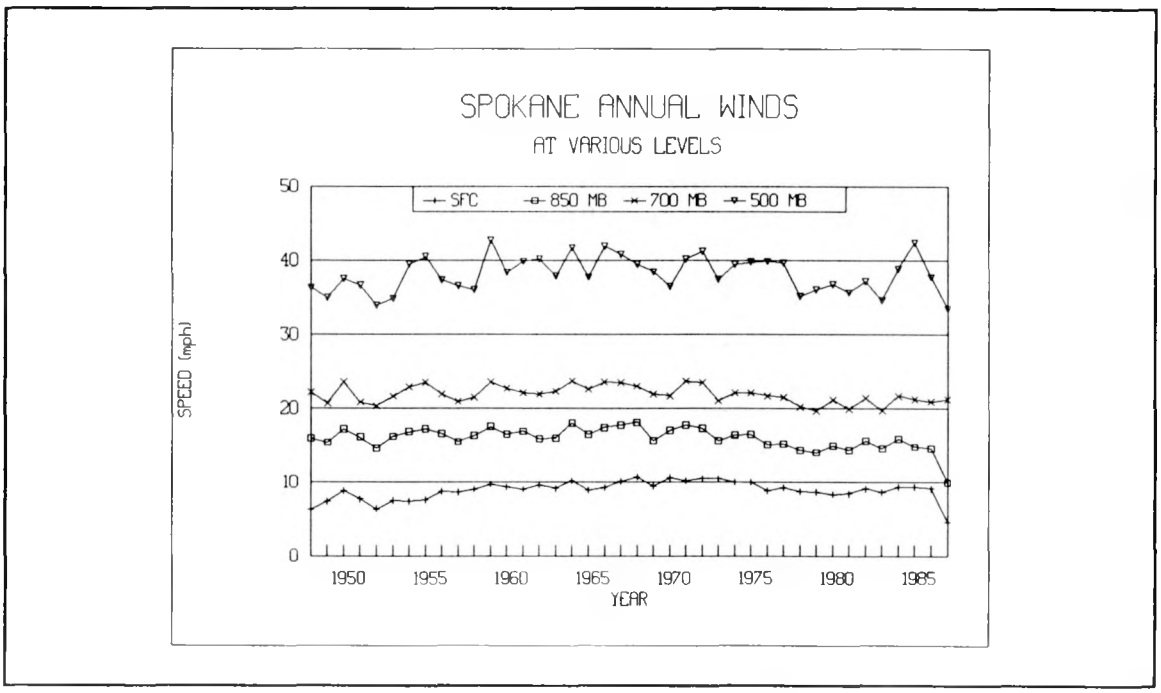


Figure 4-5. The annual variation of wind speed at Spokane, WA at four levels.

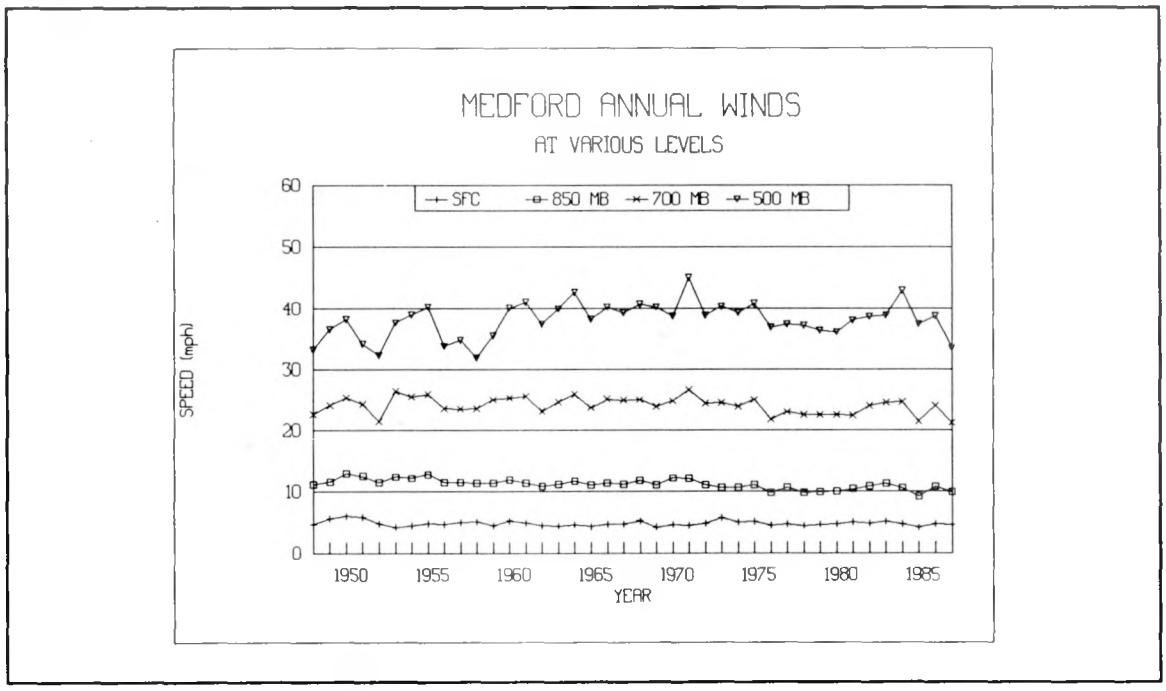


Figure 4-6. Annual wind speed variation at Medford, OR at four levels.

Table 4-4. The percent departure in wind speeds for the period 1976-87 from the mean for the period 1948-75.

Height	Spokane	Medford
Surface	1	4
850 mb (5000 ft)	13	11
700 mb (10,000 ft)	7	7
500 mb (35,000 ft)	3	2

Table 4-5. The percent departure increase in wind speeds for the period 1976-87 from the previous record at the 850 mb level at seven upper air sites in the Pacific Northwest.

Site	Before 1976	1966 - 1975
	Percent Departure	Percent Departure
Quillayute, WA	-10%	-10%
Spokane, WA	-11%	-13%
Boise, ID	-11%	-11%
Great Falls, MT	-11%	-9%
Salem, OR	-9%	-11%
Medford, OR	-11%	-9%
Winnemucca, NV	-11%	-11%

that are on well exposed ridgetops would be closely related to the winds measured in the free-air around 5,000 ft (1,500 m) above sea level.

The winter season showed the most evidence of recent weaker winds at all Pacific Northwest upper air sites. The season with the least evidence of weaker winds aloft recently is the summer season. Figures 4.7 and 4.8 show the long-term wind variation two upper air sites on a seasonal basis.

4.4.3 Reconstructing Wind Energy Potential Before 1976

Previously (Wade et al., 1986) had reconstructed a long-term history of the winds at the Cape Blanco wind survey site using data from nearby Coast Guard and North Bend FAA wind data. In the previous analysis a simple ratio of the annual mean wind speeds to was used predict the interannual variation before 1976. For this analysis we used the approach described in the methodology and only North Bend Airport data. Even though the closer Cape Blanco Coast Guard wind record was available for 1953-79, the data was of poor quality, varied in a number of observations, and had a less robust correlation to the Cape Blanco wind energy site. The period 1976-81 was used as the dependent data set and the predictions were verified on data for the period

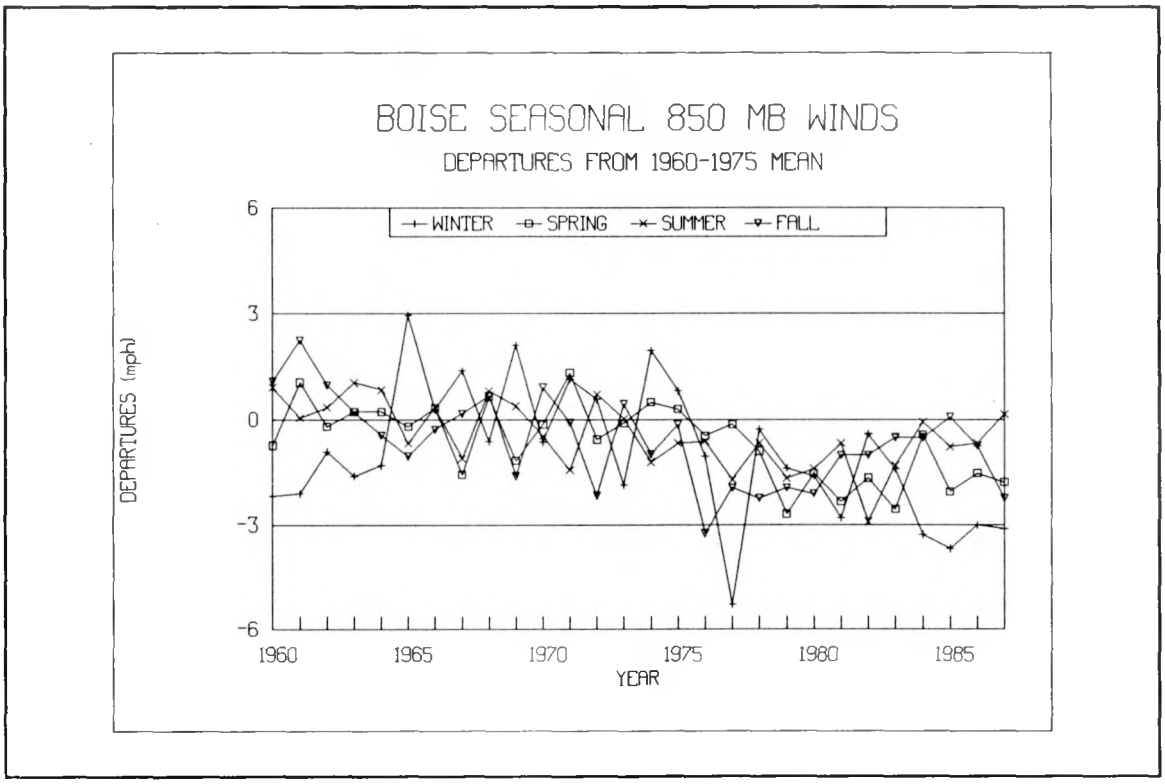


Figure 4-7. The seasonal variation of wind speed departures at Boise, ID. The departures are from the mean before 1976.

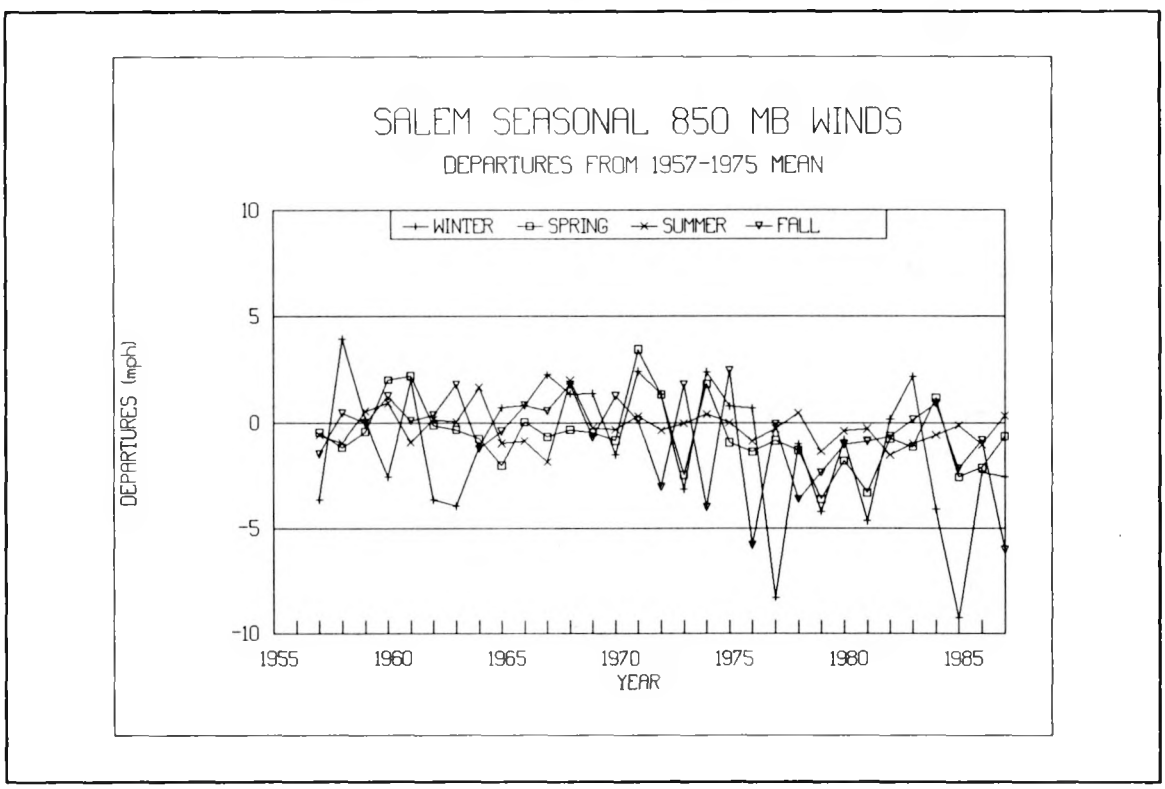


Figure 4-8. The seasonal variation of wind speed departures at Salem, OR. The departures are from the mean before 1976.

1982–87. Figure 4–9 shows a comparison of actual and predicted wind speeds at Cape Blanco for the period 1982–87 and the reconstructed annual wind speed record before 1976. The root mean square error of the prediction for 1982–87 was less than .5 m/s. Table 4–6 presents the statistics for the reconstruction of Cape Blanco winds before 1976. The wind speeds appear to be about 6.5% weaker recently at Cape Blanco than in the prior record of reconstructed winds from 1950–75. The period 1976 through 1981 had winds that were about 12% weaker than the estimated speeds for the period 1950–75.

The energy output for the most recent period at Cape Blanco is also lower by 6% which is similar to the wind speed deficit (see Table 4–6). Much of the stronger winds during the reconstructed period at Cape Blanco would have been outside the range used by the three wind turbines. Even though there was significant differences in their performance curves there was less than 3% difference in the amount of energy decrease noted since 1976 for the three turbines.

For Kennewick, winds were also estimated before 1976. The data used to reconstruct the Kennewick winds prior to 1976 were the 850 mb winds at Spokane. Table 4–6 presents the correlation between the predictor and predictand and the prediction error. Figure 4–10 shows the reconstructed winds compared to the measured winds. The data in Table 4–6 suggests that the wind speeds at Kennewick were stronger before 1976 by about 11% (±5%). The gross energy output of the three selected turbines would be 14% lower than what we estimate would have been available before 1976.

At Pequop Summit the wind speeds were estimated to be 14% stronger before 1976 than from 1976 through 1987. An average of 19% more energy would have been available for the three wind turbines used in the investigation. The predictor site was the Winnemucca 850 mb winds. Table 4–6 presents the correlation between the predictor and predictand and the prediction error. Figure 4–11 shows a reconstruction of Pequop Summit winds for the period 1948–75 and a comparison of measured and predicted winds for the period 1976–87.

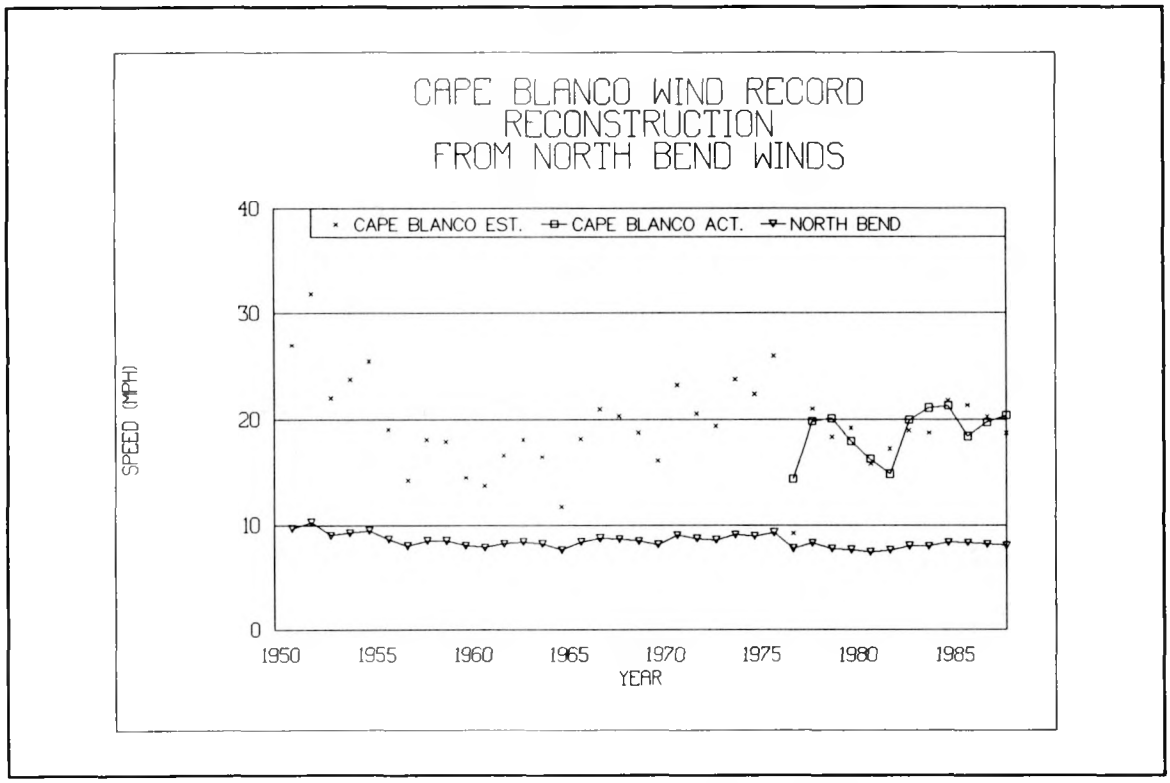


Figure 4-9. A Reconstruction of the Winds at Cape Blanco before 1976. The predicted wind speeds at Cape Blanco are compared to measured speeds from 1976-87 (solid line).

Table 4-6a. Statistics used in determining wind and energy availability before and after 1976 in the Pacific Northwest.

Site Name	Regression Statistics					Regression Verification				
	Vm mph	STDm mph	Rm	Slope	Constant	R	SE	Vpred mph	Vact mph	RMSE mph
Cape Blanco North Bend Dependent Period 1976-81 Verification Period 1982-1987	17.7 7.6	3.8 1.3	.32	2.72	.46	.68	2.56	20.0	20.2	1
Kennewick Spokane 850 mb Dependent Period 1976-81 Verification Period 1982-1987	15.2 14.4	3.5 3.7	1.08	.73	-.02	.66	2.48	15.6	15.6	.4
Pequop Summit Winnemucca 850 mb Dependent Period 1982-87 Verification Period 1976-81	14.9 9.4	1.4 2.5	1.8	.75	.26	.41	1.9	16.0	15.0	.7

Vm is the mean monthly speed; STDm is the standard duration of monthly speeds; Rm is the ratio of departures from normal of monthly speeds; R is the correlation coefficient; SE is the standard error of the estimate; Vpred is the predicted mean annual speed; Vact is the measure mean annual speed for the vertification data set; and RMSE is the root mean square error.

Table 4-6b. Comparison of Estimates of Winds Before 1976 to Those Measured Since 1976.

	V for 1976-87 mph	V for 1950-76 mph	Difference	Energy Difference
Cape Blanco North Bend	18.7 7.9	20.0 8.7	-6.5% ± 4.2 -9.2%	-6%
Kennewick Spokane 850 mb	15.4 14.6	17.3 16.7	-11% ± 4.9 -13%	-14%
Pequop Summit Winnemucca 850 mb	15.4 9.4	17.9 10.6	-14% ± 4.5 -11%	-19%

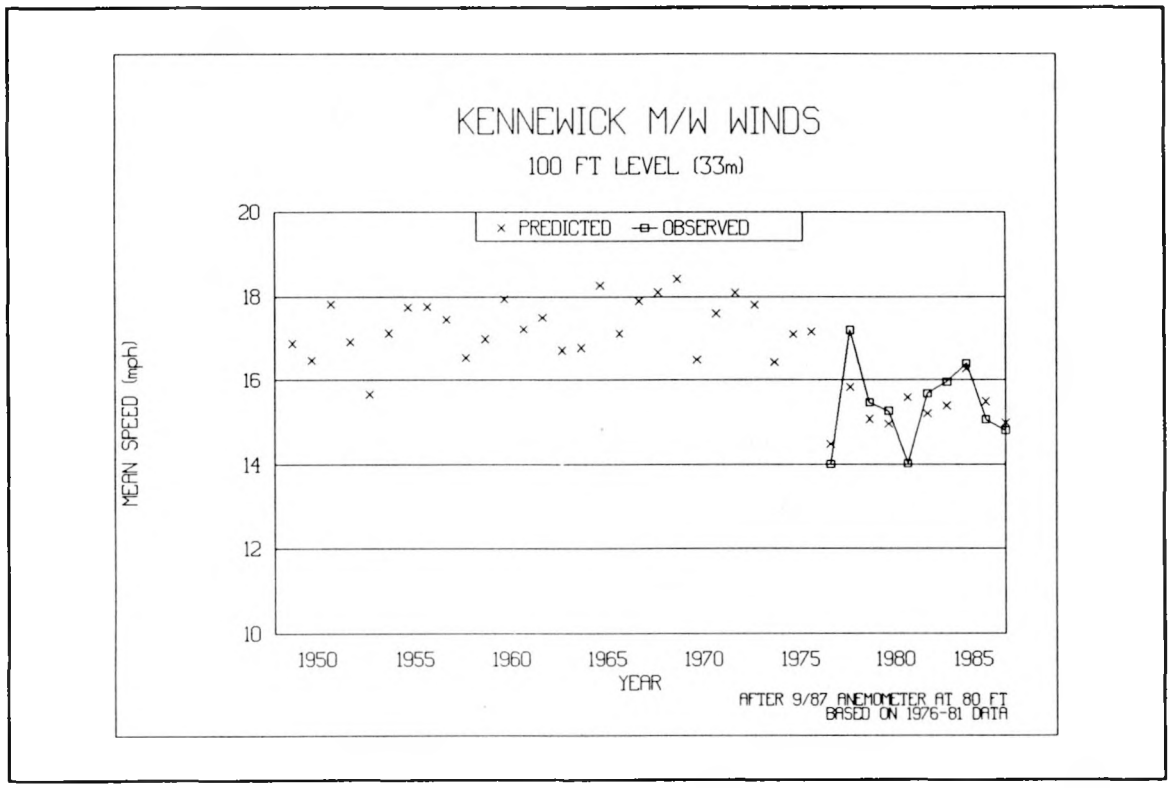


Figure 4-10. A reconstruction of the winds at Kennewick before 1976. The predicted wind speeds at Kennewick are compared to measured speeds from 1976-87 (solid line).

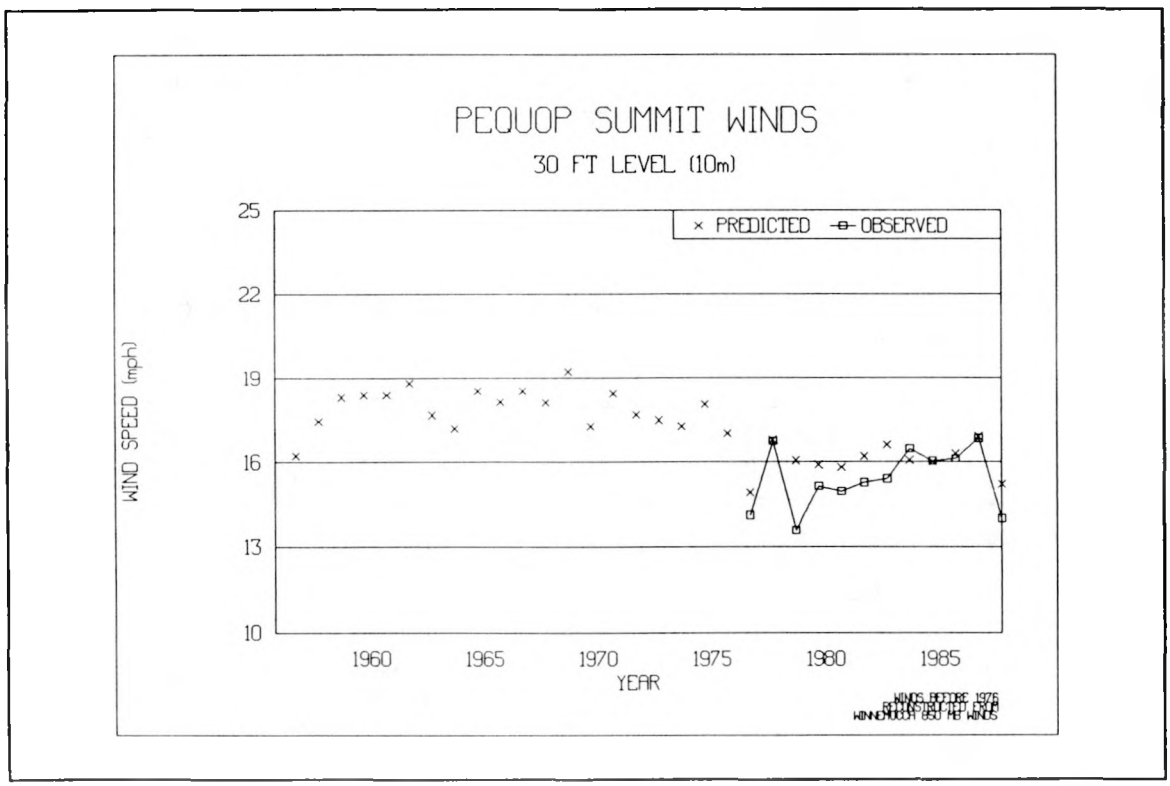


Figure 4-11. A reconstruction of the winds at Pequop Summit before 1976. The predicted wind speeds at Pequop Summit are compared to measured speeds from 1976-87 (solid line).

4.5 Summary

In wind energy assessment a "rule of thumb" is that, with a 90% confidence level, the winds measured for a year will be within ±10% of the long-term mean. An objective of the analyses in this section was to examine the adequacy of a 12-year wind record measured over the period 1976 through 1987. To determine the degree to which the winds were representative of an even longer mean, we compared winds measured at National Weather Service surface and upper air sites during the period 1976-87 to winds measured for at least two decades before that period. The results indicated that the winds during the recent period are about 10% weaker than those measured during the past. The results suggest that even a 12-year mean wind speed may not be within ±10% of the long-term mean (see Table 4-6b). The reason the winds are weaker is not examined in this study, but there are a number of possible explanations. A weakening of the jet stream due to greater warming recently at high latitudes relative to the amount of warming at low latitudes could be one cause of weaker winds. Another possibility may be the anomalous behavior of the pressure patterns in the tropical Pacific associated with El Niño. The pressure patterns in the tropical Pacific Ocean are known to exert influence on circulation patterns elsewhere. The anomalous behavior in the tropical Pacific began in 1976 and continued through 1987.

A second objective of this investigation was to try to estimate the wind speeds before 1976 at three long-term wind energy sites. The wind records were reconstructed using correlations between measured winds at those sites and nearby long-term upper air or surface wind data available from the National Climatic Data Center. The reconstructed winds before 1976 were 6 to 14% stronger than those measured after 1976. The energy implications of these results vary from site to site. For Cape Blanco, a strong wind site, the decrease in energy is nearly equal to the decrease in wind speed. At Kennewick and Pequop Summit the decrease in available energy was about 30 to 40%.

These results suggest that climate trends may affect assumptions about the interannual variation of wind speed. Even a decade or more of winds may not be adequate to estimate the mean wind speed within ±10%. A prudent

approach may be to examine climatological data at surface and upper air sites to determine if the winds in the region are representative of the longer record of winds. The results also suggest that climate change could significantly influence the amount of wind energy available. Changes in weather circulation patterns may result in stronger or weaker winds than expected. In the Pacific Northwest, many sites with winter wind resources depend on strong wind flow aloft. Any weakening of the jet stream or displacement of its position would have important implications for wind energy planning.

5. UNCERTAINTIES IN LONG-TERM ENERGY PREDICTIONS USING ACTUAL AND THEORETICAL WIND SPEED DISTRIBUTIONS

5.1 Introduction

Several years of hourly wind data have been collected at many windy sites in the Pacific Northwest. The wind data collected from three of the BPA wind monitoring locations (Cape Blanco, Seven Mile Hill, and Kennewick) will be discussed in this section. The data recovery rates over the 10- to 12-year data period have varied from 90% at Seven Mile Hill to 83% at Cape Blanco. Data have been analyzed through the year 1988 and all three sites are still in operation.

The long and mostly continuous data base at these three sites provides an opportunity to inspect the interannual as well as interseasonal variations in the mean speed, speed frequency distributions, and theoretical turbine energy production. The latter is computed by converting wind speed to power output using a turbine power curve and then analyzing the yearly or seasonal variations in the estimated turbine energy production. The power curve for a 250 kW machine was used to estimate energy production. The cut-in speed is 9 mph, the rated speed is 29 mph, and the cut-out speed is 54 mph.

Along with discussing the year-to-year variations in the mean annual speed (energy) and seasonal speeds (energy), the paper also addresses the relationship of changes in the mean annual wind speed to the changes in the estimated turbine energy production and a comparison of the turbine energy production using the actual and theoretical Weibull speed distributions.

5.2 Year-to-Year Variations in Mean Annual Wind Speed and Energy

At most wind energy sites or potential developments, a long period of continuous wind data on the order of 10 to 20 years duration or greater are

not available. However, information on the interannual and interseasonal variations in the strength of the wind is needed to predict likely turbine production variations (i.e., revenue variations). Work done previously by Corotis [1] and others on long periods of data from National Weather Service (NWS) locations has indicated relatively small variations in the mean annual wind speed. Corotis' research indicates that there is 90% confidence that the mean annual wind speed from a single year will be within ±10% of the true long-term mean speed. This assumption has been used by the wind industry. Unfortunately, the correlation between the wind speeds at NWS locations and high wind sites is poor so there is still a high degree of uncertainty in estimating interannual variations without a long period of site data to inspect. Although the 10 to 12 years of wind data collected at the three BPA sites does not represent a climatological long record (preferably 20 to 30 years), it does give an opportunity to investigate at the high wind sites interannual variations in wind speed and turbine energy production and discuss some of the reasons for the variations.

The yearly mean speeds and estimated turbine energy production at the three sites show different patterns with Cape Blanco having the largest variations and Kennewick the smallest. The annual statistics are listed in Table 5-1. For the 12 years of record, the mean speed at Kennewick was 15.6 mph and the maximum and minimum values were within ±10% of this mean speed. However, the highest turbine energy year was 19% above the 12-year mean value and the lowest energy year was 26% below the mean value.

For Seven Mile Hill, the highest mean speed year was only 10% above the long-term mean but the lowest speed year was 14% lower than the mean. Only one of the 10 years of record fell outside ±10% of the 10-year mean speed. With respect to turbine energy, the highest year was 17% above the mean and the lowest year 23% below the mean. At Cape Blanco, the largest variations occurred. The highest wind year at 22 mph exceeded the 12-year mean speed of 19.3 mph by 16% and the lowest wind year at 15 mph was 22% lower than the mean. The energy differences were +23% and -31%. The mean annual wind speeds for nine of the 12 years were outside the bounds of ±10% of the 12-year mean.

Table 5-1. Annual statistics for the three sites.

	Seven Mile Hill	Kennewick	Cape Blanco
Wind Speed (mph):			
Mean	16.8	15.7	19.3
Standard Deviation	1.3	0.7	2.0
High	18.4 (+10%)	16.8 (+7%)	22.4 (+16%)
Low	14.3 (-14%)	14.1 (-9%)	15.0 (-22%)
Years of Data	10	12	12
Estimated Turbine Energy (MWH):			
Mean	691.4	592.5	778.7
Standard Deviation	82.3	74.8	103.2
High	811.6 (+17%)	707.2 (+19%)	960.2 (+23%)
Low	532.0 (-23%)	438.6 (-26%)	538.3 (-31%)

Using the 10 to 12 years of data, an analysis was done to determine the long-term mean speed using the Student's T distribution statistics. For a 90% confidence limit the true mean speed lies between 15.2 and 15.9 mph at Kennewick, 15.9 and 17.5 mph at Seven Mile Hill, and 18.1 and 20.2 mph at Cape Blanco.

Large-scale synoptic weather patterns (fronts) and smaller meso-scale pressure patterns govern the strength of the wind at two of the three locations. The strong winds at the third location, Seven Mile Hill, are controlled by the meso-scale spring and summer Columbia River Gorge west flow and are not driven by fall and winter storms. The meso-scale flow pattern that sets up in the spring and summer over the Pacific Northwest creates persistent north winds along the coast and west winds through the Columbia River Gorge

that extend eastward to Kennewick. In contrast, the fall and winter strong winds are driven by large-scale fronts and strong winds aloft. With the jet stream aligned west southwest over the central Oregon coast, the winds at Cape Blanco persist at 30 mph or greater for days at a time. As the jet stream shifts to the north or south, the surface wind speeds can change dramatically. The winter winds at Kennewick, although not as strong as those at Cape Blanco, are also governed by storm movement. In years when storms have been frequent and winter wind speeds have been high at the Cape, the mean annual wind speeds has been high. In contrast, a winter with few storms relates to a year with lower than normal mean annual wind speed.

The annual turbine energy production at the sites is directly related to the shape of the site wind speed frequency distribution. The annual wind speed distributions for the three sites shown in Figure 5-1 indicate that each distribution has a different shape. The Kennewick distribution displays a definite single frequency peak at about 10.1 mph and the frequency drops off steadily for winds above 15.0 mph. In contrast, the distribution at Seven Mile Hill and Cape Blanco have a much broader shape and there are two relative frequency maximums at Seven Mile Hill (7.8 mph and 20.2 mph). At Cape Blanco there is a high frequency of winds above 40 mph.

Year-to-year variations in the wind speed frequency distributions at Seven Mile Hill are shown in Figure 5-2 for 1987, the lowest wind year, and 1985, one of the highest wind years recorded at the site. In 1987 the estimated energy production was 532 MWH ($\bar{v}$ = 14.3 mph) and in 1985 it was 769 MWH ($\bar{v}$ = 17.9 mph). Both distributions have a relatively similar shape (bi-modal maximum) but there was a much higher frequency of wind speeds above 25 mph in 1985 than in 1987.

Further analysis of wind speed versus energy production reveals that each site has a different relationship. Curves plotting mean annual wind speed and energy production are shown in Figure 5-3. A linear fit approximation was made to the data points. The most scatter in the data was at Kennewick and the least at Seven Mile Hill. The slope of the Kennewick curve indicates about a 25% change in the energy production with a 10% change in mean annual

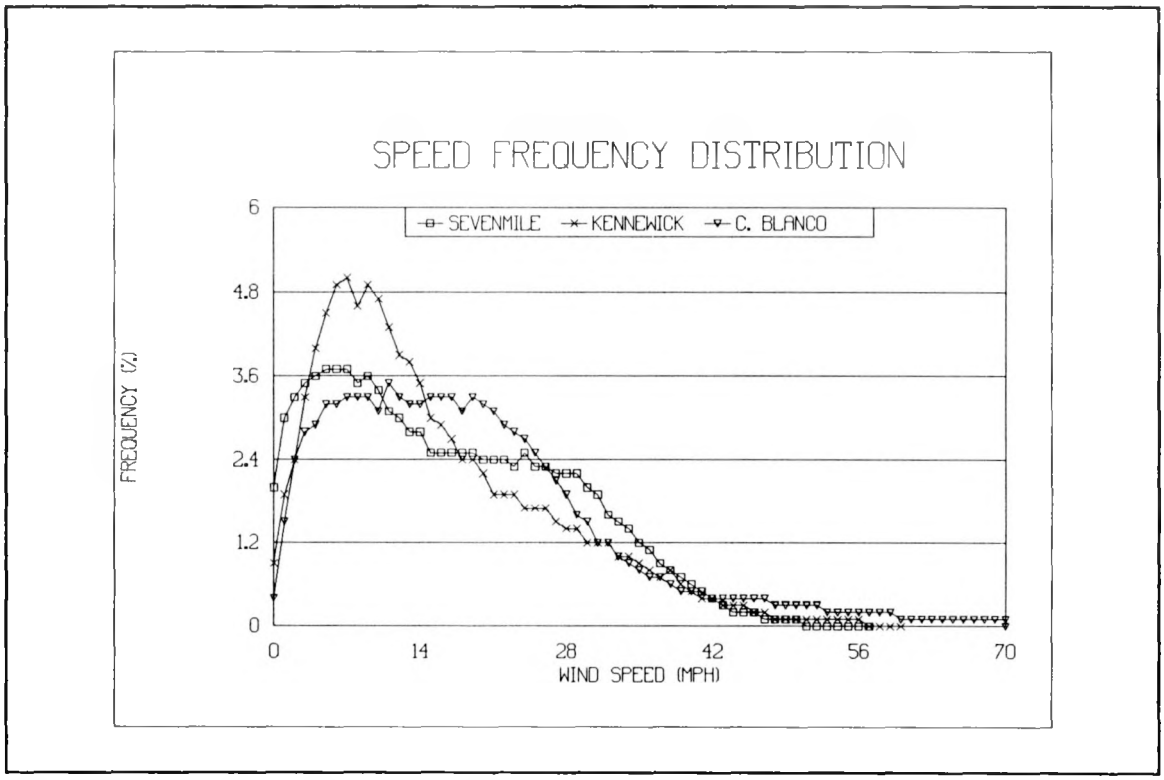


Figure 5-1. Speed frequency distributions (all data) for the three sites.

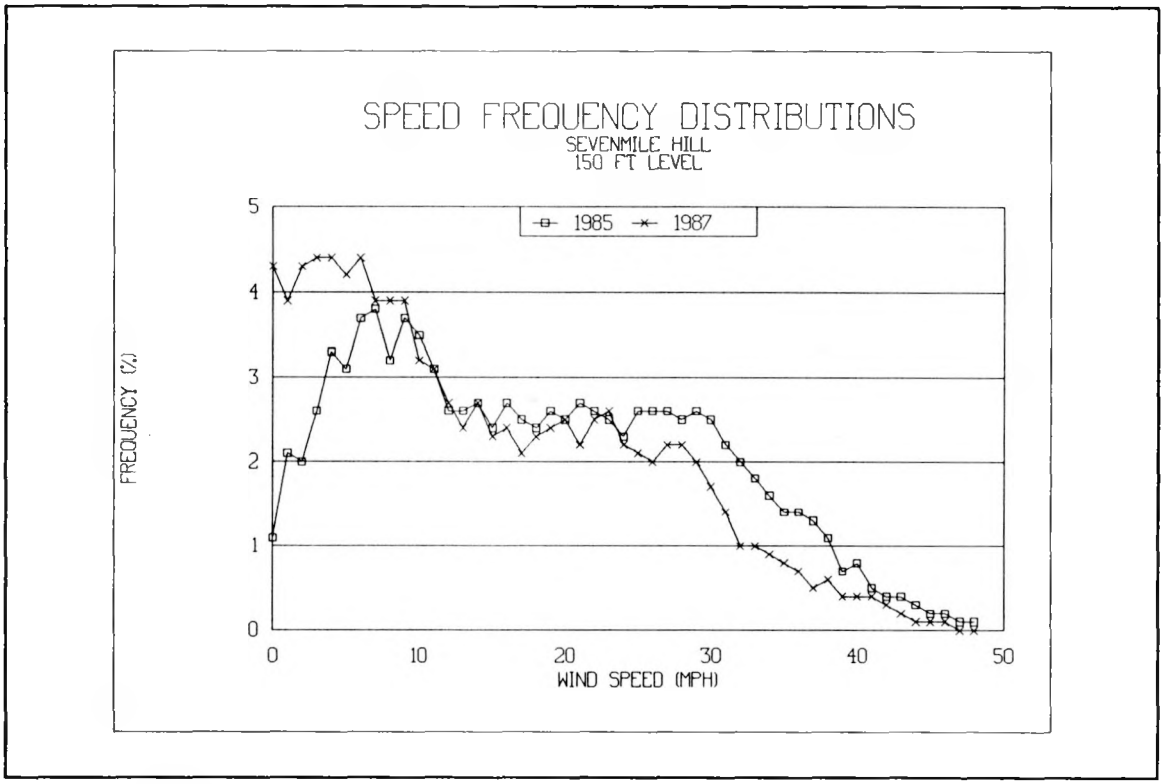


Figure 5-2. Interannual variations in the wind speed frequency distributions at Seven Mile Hill.

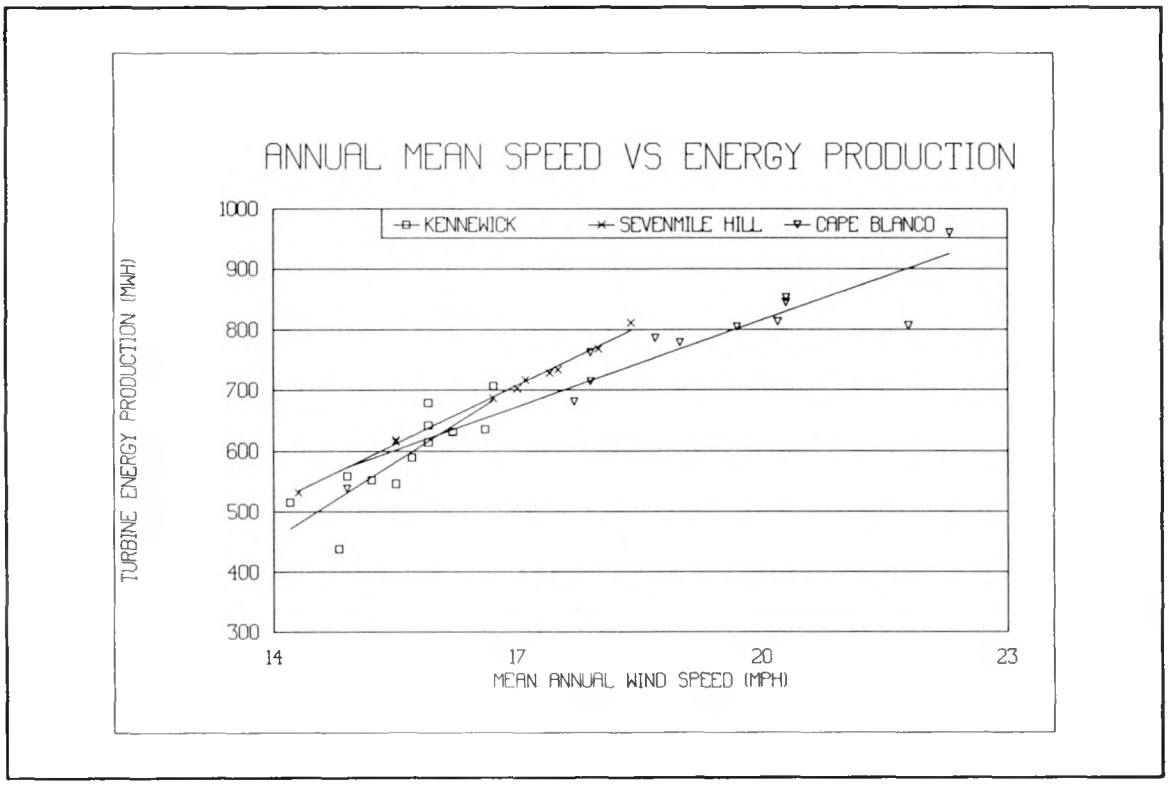


Figure 5-3. Mean annual wind speed versus estimated gross annual turbine energy production.

wind speed. At Seven Mile Hill there is about a 20% change in energy with a 10% change in mean speed, and at Cape Blanco there is only about a 13% change in energy for a 10% change in the mean speed. These variations are caused by the shape of the speed frequency distributions for a given turbine power curve. From cut-in to rated speed, the power curve varies with the cube of the wind speed (i.e., a 10% speed increase results in a 33% change in power output). In contrast, at speeds at rated power and above (29-54 mph) there is no power increase with speed increase. Thus, at a higher wind speed site the incremental change in energy with change in mean annual speed is less than at a lower wind speed site. This relationship is graphically depicted in Figure 5-4. At low mean annual wind speed sites the energy/speed relationship approaches 33%. And at the high speed sites the energy changes could be the same as the percent change in the wind speed. And if there were frequency wind speeds above cut-out, there could actually be less increase in energy with a given increase in mean annual speed (note the dotted curves). In this case a turbine with a higher cut-out speed should be considered. Thus, in

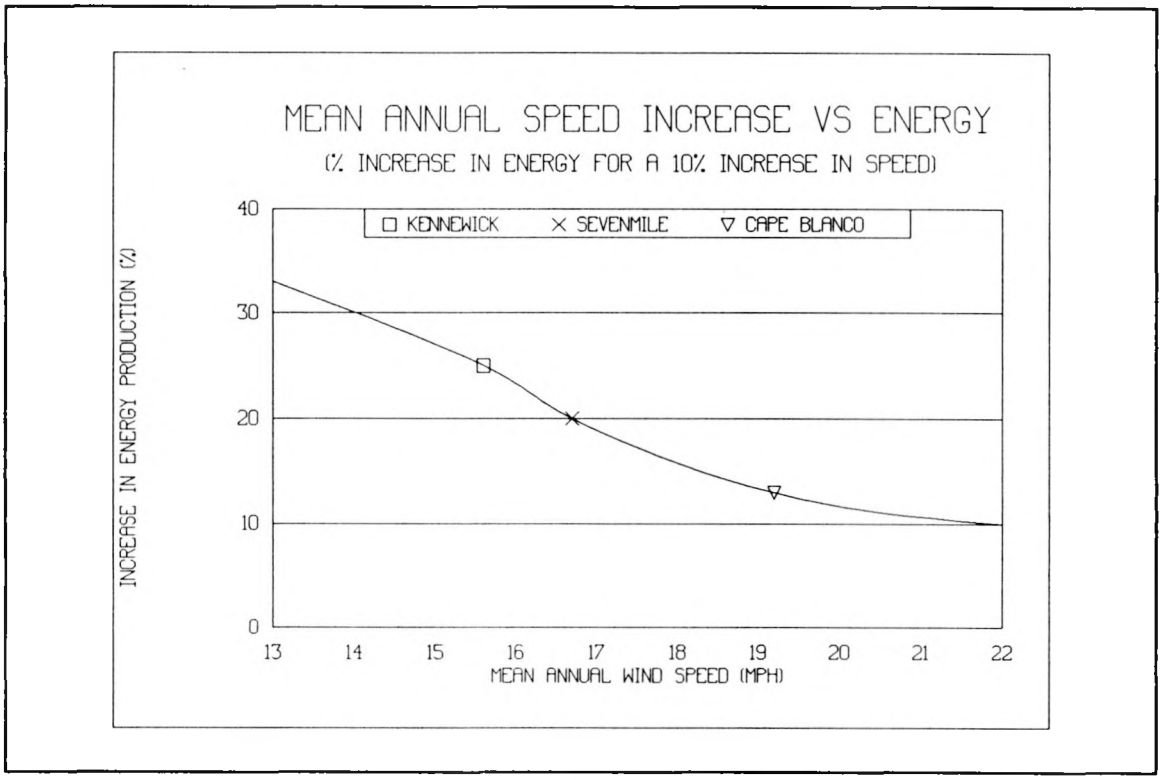


Figure 5-4. Turbine energy increase versus a 10% increase in mean annual wind speed.

evaluating the nergy production potential of sites with different wind speed frequency distributions some consideration should be given to selecting a machine whose performance curve best fits the distribution (i.e. tailor the machine for the site wind characteristics).

5.3 Interannual Variation in Seasonal Wind Speed and Energy

It is not uncommon for high wind areas to display distinct seasonal patterns in wind speed and direction. Two of the three California wind farm development areas, Altamont Pass and San Gorgonio Pass, have the strongest winds during the spring and summer months, an ideal match to load demand and on-peak/off-peak buyback rates. The Tehachapi area displays good spring and summer winds as well as frequent strong flow during the winter due to its higher elevation in the Tehachapi Mountains and its exposure to storm winds.

Of the three Northwest sites, only Seven Mile Hill displays a definite seasonal wind cycle as 70% of the estimated annual turbine energy is generated during the spring and summer months. The mean wind speed during the summer is 22.9 mph compared to 11.7 mph during the winter. On a yearly basis, winter winds at Seven Mile Hill, as well as at the two other locations, were the most variable. At Seven Mile this variability did not significantly impact the annual energy production since the strong wind season was in the spring and summer. However, at Kennewick and Cape Blanco the winter production is a significant contributor to the annual production. Also, at the latter two sites the energy production is distributed about evenly over the four seasons, although the seasonal mean speeds are not as uniform.

During the power producing spring and summer months at Seven Mile Hill the highest seasonal speed was 19% above the mean speed and the lowest was 15% below the mean value. With respect to turbine energy, the maximum value exceeded the mean by 30% and the minimum value was 22% lower than the mean.

At Kennewick the spring seasonal mean speed is about 0.9–1.6 mph higher than during the other seasons although the seasonal energy production values are about equal. The largest interseasonal variations occur during the winter as the maximum and minimum values approach ±50% of the mean. During the other three seasons the ranges have been ±30% of the mean values.

At Cape Blanco the highest seasonal mean speeds occurs during the winter (21.5 mph) and the other three seasons average about 18.6 mph. However, from an energy standpoint each season's contribution is about the same. The largest seasonal variations in energy have been recorded in the summer (about ±45%). Winter energy variations were about ±25% although winter mean speed variations were about ±30%.

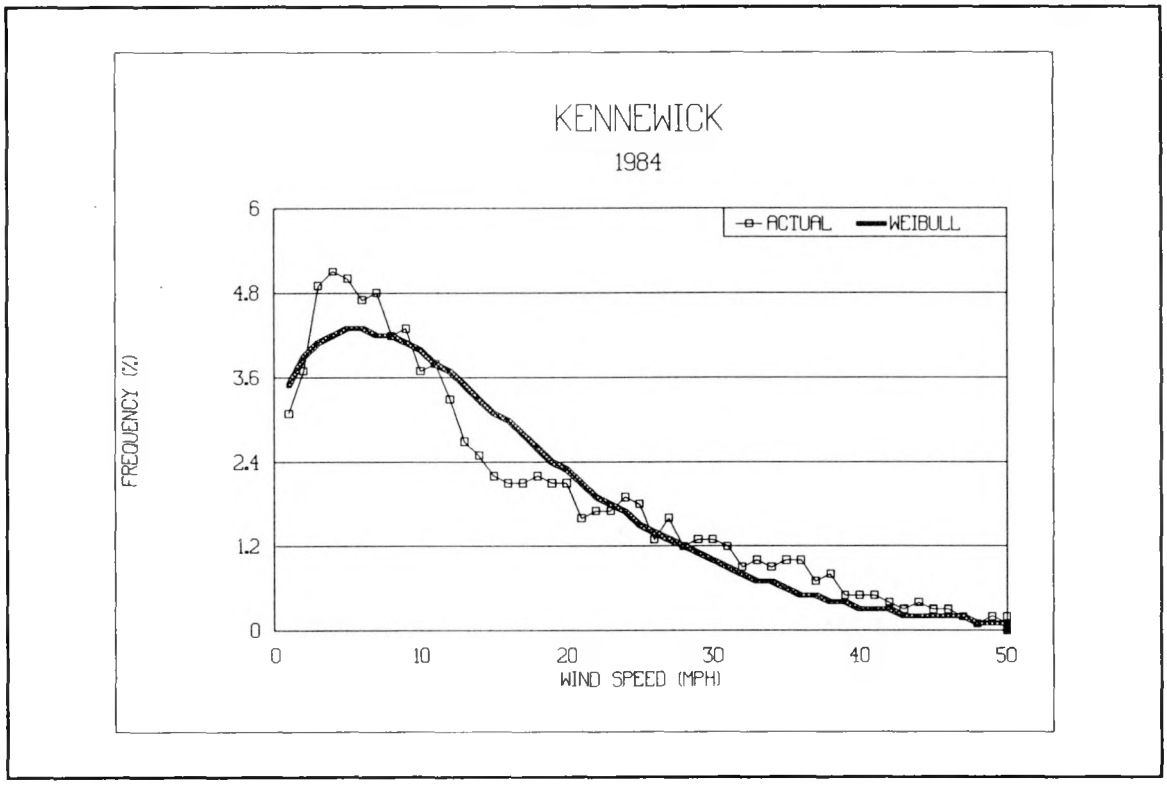
5.4 Comparison of Actual and Weibull Distribution Energy Estimates

The Weibull distribution has been commonly used to simulate the speed distribution when only the mean annual speed is known. The shape factor and scale factor must be estimated. If the shape factor is 2.0, the Weibull distribution becomes the Rayleigh distribution.

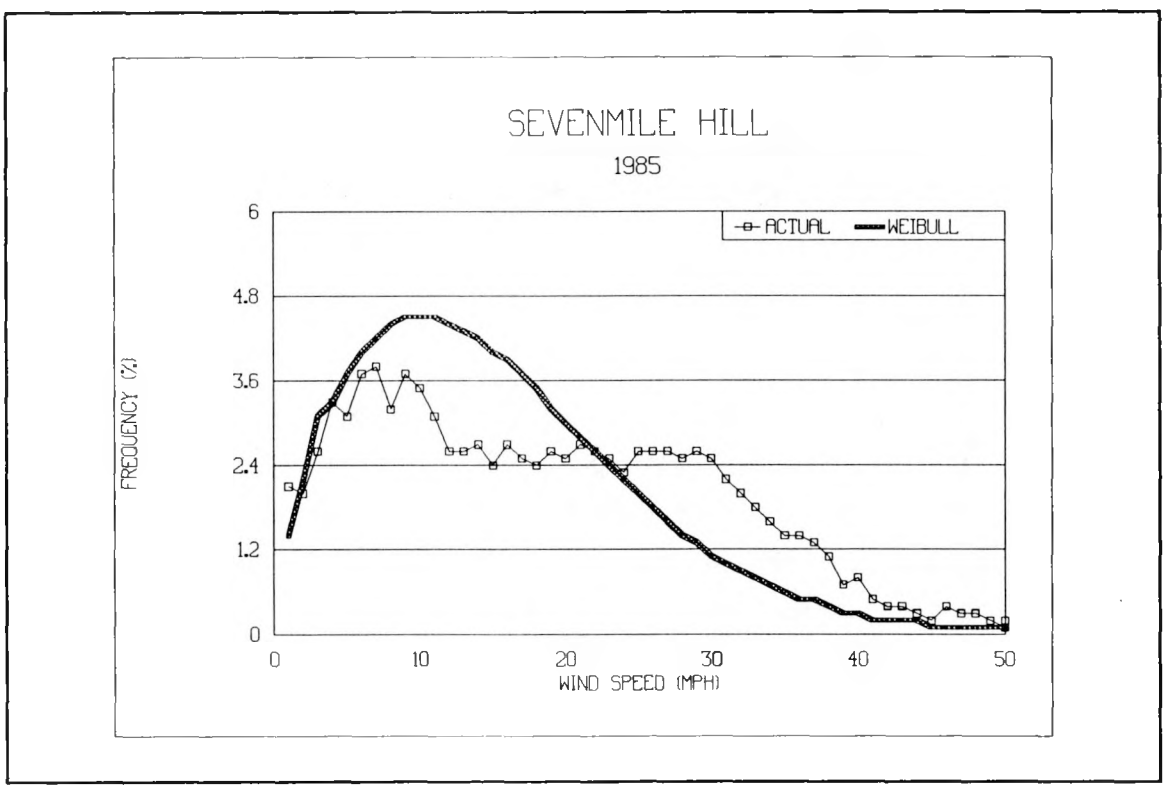
From the hourly data for each year, the annual energy production for a 250 KW machine was calculated using the actual speed frequency distribution and the Weibull distribution. The Weibull shape and scale factors were calculated for each year of data. The wind data were applied directly to the power curve with no adjustment for anemometer height differences to hub height (i.e., wind shear exponent = 0).

Energy differences (in %) between the Weibull and actual distribution for each year indicate that for the Seven Mile Hill data the Weibull estimates were considerably lower during most years (14–30%). At Kennewick the differences were less and varied between +9% and –18%. The closest agreement was at Cape Blanco where the annual differences varied from –3 to +6%.

Actual and Weibull speed distributions are shown in Figure 5–5 for Kennewick and Seven Mile Hill. In 1984 the turbine energy difference at Kennewick was –13%. As shown in Figure 5–5a, the Weibull distribution underestimated the frequency of speeds above 25 mph. This underestimation was even more pronounced at Seven Mile Hill (Figure 5–5b). The resulting turbine energy estimates were 29% apart, with the Weibull estimate being lower. This broad bi–modal distribution is difficult to model as opposed to the more uniform distribution like that at Cape Blanco.



(a)



(b)

Figure 5-5. Actual and Weibull speed frequency distributions for a) Kennewick 1984 and b) Seven Mile Hill.

5.5 Conclusions

The long record of hourly wind data at the three BPA wind monitoring sites (Cape Blanco, Seven Mile Hill, and Kennewick) provided an opportunity to investigate interannual and interseasonal variations in mean wind speed, the wind speed distribution, and, most importantly, the potential turbine energy production. Significant findings include:

- At Seven Mile Hill and Kennewick sites the mean annual wind speeds were within 10% of the long period mean 90% of the time. This is in agreement with Corotis' findings. At Cape Blanco only three of the 12 years fell within the ±10% bound. However, the annual maximum and minimum turbine energy values were typically 15 to 25% above or below the long period mean at all of the sites.
- Weibull distribution annual energy estimates were generally 10 to 25% lower than actual distribution estimates at Seven Mile Hill and Kennewick sites. At Cape Blanco there was fairly good agreement. The Weibull distribution consistently underestimated the frequency of speeds above 25 mph at the other two sites.
- Cape Blanco and Kennewick did not show definite seasonal cycles in energy production. However, at Seven Mile Hill 70% of the energy is produced during the spring and summer. The maximum and minimum seasonal energy values typically varied by 25 to 50% from the mean seasonal energy value.
- For sites with high mean annual wind speeds the % change in energy for a given turbine with a change in the mean annual wind speed from year to year is considerably less than at a lower wind speed site. At Cape Blanco ($\bar{v}$ = 19.3 mph) a 10% change in mean speed results in about a 13% change in turbine energy. In contrast, at Kennewick ($\bar{v}$ = 15.7 mph) a 10% change in mean speed results in about a 25% change in energy. This results is dependent on the choice of machine (i.e. power curve characteristics). If a machine was tailored to a given site's speed frequency distribution then these results would not apply.

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APPENDIX A

BROWNING DEPOT
SUMMARY STATISTICS
OCTOBER 1985 - MAY 1989

STATION - BROWNING DEPOT 40'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1985 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.5	13.4	22.3	1489	17.93	11.32
# OBS	0	0	0	0	0	0	0	0	0	64	719	706			
1986	22.2	12.9	17.8	14.7	11.5	11.2	12.7	9.6	11.0	13.2	20.1	21.2	8367	14.87	9.32
# OBS	730	668	671	658	688	664	721	730	688	733	720	696			
1987	23.1	15.9	14.2	15.4	13.3	12.9	10.9	9.7	11.8	13.7	18.2	19.0	8260	15.07	8.64
# OBS	739	665	650	715	744	720	744	368	720	742	710	743			
1988	19.5	18.1	17.1	0.0	13.9	12.2	12.3	11.9	13.7	12.8	18.8	19.0	7090	15.61	8.69
# OBS	702	629	729	0	352	591	424	744	711	744	720	744			
1989	22.9	0.0	20.8	12.4	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2184	16.38	10.29
# OBS	719	0	55	666	744	0	0	0	0	0	0	0			
AVG	21.9	15.6	16.5	14.2	12.9	12.1	10.3	10.5	12.2	13.4	17.6	20.3	27390	15.41	9.19
SD	1.7	2.6	2.7	1.6	1.0	0.9	1.0	1.3	1.4	3.7	2.9	1.6			

STATION - BROWNING DEPOT 80'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1985 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.2	13.3	22.3	1490	17.96	11.36
# OBS	0	0	0	0	0	0	0	0	0	64	720	706			
1986	24.3	13.7	19.0	15.6	12.2	12.3	14.0	10.5	11.9	14.7	21.6	22.8	8395	16.10	9.94
# OBS	738	667	696	655	686	665	717	731	690	737	720	693			
1987	24.5	17.4	15.2	16.5	14.4	14.0	11.7	11.2	13.2	15.0	19.2	20.1	8662	16.02	8.90
# OBS	737	667	676	715	744	720	744	744	720	742	710	743			
1988	20.2	18.8	17.8	0.0	14.8	13.1	12.9	12.8	14.7	13.6	20.1	20.4	7091	16.52	9.03
# OBS	702	629	729	0	352	591	424	744	712	744	720	744			
1989	24.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	718	24.22	13.10
# OBS	718	0	0	0	0	0	0	0	0	0	0	0			
AVG	23.3	16.6	17.4	16.1	13.6	13.2	13.1	11.5	13.3	14.6	18.5	21.4	26356	16.51	9.66
SD	2.1	2.6	2.0	0.7	1.4	0.9	1.1	1.2	1.4	3.9	3.6	1.3			

STATION - BROWNING DEPOT REDUNDANT 80'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 1/1989 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1989	25.7	0.0	22.8	13.8	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2184	18.26	11.37
# OBS	719	0	56	665	744	0	0	0	0	0	0	0			
AVG	25.7	0.0	22.8	13.8	14.7	0.0	11.4	0.0	0.0	0.0	0.0	0.0	2184	18.26	11.37
SD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

STATION - BROWNING DEPOT 40'
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1985 - 5/1989

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	21.0	20.8	20.7	21.4	21.1	22.4	22.6	22.5	22.3	22.1	23.0	23.5	23.1	23.4	22.1	21.5	21.6	22.1	21.8	22.1	22.0	21.5	20.8	21.1	21.9
FEB	15.7	15.9	15.6	15.5	15.3	15.0	14.9	15.2	15.6	16.2	17.1	16.6	17.4	16.8	15.9	14.8	14.8	15.2	15.4	14.8	15.2	14.9	15.1	15.0	15.6
MAR	14.8	14.9	16.2	16.9	16.7	17.0	17.0	17.4	17.7	18.0	18.5	18.8	17.9	17.8	16.7	15.9	15.7	15.4	15.4	16.0	15.3	15.7	15.4	15.8	16.5
APR	13.4	13.4	12.2	12.6	12.6	13.3	15.1	15.6	16.0	16.2	16.1	16.4	16.4	16.1	16.0	15.5	14.3	12.6	11.8	12.2	12.2	13.3	13.7	13.3	14.2
MAY	10.8	10.6	10.6	11.1	11.4	11.7	12.6	13.2	13.6	14.2	14.9	15.2	15.7	15.5	15.2	15.4	14.4	13.1	12.2	12.2	11.7	11.6	11.5	11.4	12.9
JUN	11.4	11.2	11.1	11.0	10.5	11.5	12.4	12.5	12.6	12.7	13.1	13.5	14.0	14.1	14.2	14.2	13.0	11.9	11.4	10.8	10.6	11.1	10.8	10.8	12.1
JUL	9.9	10.0	10.4	10.3	10.2	10.7	11.5	12.2	12.3	12.9	13.9	14.2	14.9	14.7	15.1	15.0	13.6	12.3	11.1	10.5	10.1	9.8	9.8	9.7	11.9
AUG	9.5	9.4	9.4	9.1	8.9	8.6	9.3	10.1	10.4	11.5	12.2	12.7	12.7	13.0	13.0	13.1	11.9	10.4	10.2	10.0	9.5	9.3	9.3	9.5	10.5
SEP	11.1	11.1	11.1	11.0	11.1	11.5	11.9	12.9	13.6	13.6	14.0	14.3	13.9	14.0	13.6	13.2	12.5	11.6	11.4	11.1	10.5	11.1	11.0	11.1	12.2
OCT	12.9	13.3	13.2	13.4	13.0	13.0	13.4	13.4	13.8	14.5	14.9	15.7	15.9	15.6	14.6	13.2	12.6	12.2	12.7	12.1	12.0	11.8	12.1	12.8	13.4
NOV	17.2	17.4	17.6	17.3	17.4	17.4	17.2	17.6	18.1	18.1	18.6	18.9	19.0	19.3	18.3	17.6	17.6	17.1	16.9	16.5	16.7	17.1	17.2	16.9	17.6
DEC	19.9	20.0	20.4	19.7	20.5	20.8	20.7	20.9	21.3	21.7	21.6	22.1	22.0	21.4	20.5	19.9	19.4	19.2	19.5	19.3	19.3	19.7	19.4	19.0	20.3
AUG SPD	14.5	14.5	14.6	14.6	14.6	14.9	15.4	15.8	16.1	16.4	16.9	17.3	17.3	17.2	16.6	16.1	15.5	14.9	14.6	14.5	14.2	14.4	14.3	14.4	15.4

STATION - BROWNING DEPOT 40'
WIND ROSE FOR ALL DATA - 25745 OBSERVATIONS
DATA PERIOD OF RECORD - 10/1985 - 5/1989

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	2.3	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	0.0	0.0	3.4	8.3
NNE	1.6	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	0.0	0.0	1.9	6.9
NE	1.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	7.0
ENE	1.4	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	0.0	0.0	1.6	6.4
E	1.9	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	0.0	2.1	6.3
ESE	1.5	0.4	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	2.1	8.2
SE	1.6	0.8	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	0.0	2.8	9.2
SSE	1.3	0.4	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	1.9	8.5
S	2.3	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	3.0	7.7
SSW	2.0	1.0	1.4	0.9	0.6	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	14.1
SW	3.3	2.9	4.3	4.9	3.8	3.3	2.5	2.1	1.4	0.9	0.5	0.3	0.2	0.1	0.1	0.0	0.1	30.7	20.0
WSW	4.6	2.7	2.9	3.0	2.5	2.0	1.6	1.0	0.8	0.6	0.4	0.2	0.2	0.1	0.0	0.0	0.1	22.7	18.1
W	4.0	1.1	1.3	1.3	1.0	0.7	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	14.0
WNW	1.5	0.3	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	0.0	2.1	7.6
NW	1.4	0.5	0.5	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	0.0	3.1	11.4
NNW	1.4	0.9	0.6	0.4	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	3.6	11.8
CALM TOTAL																		0.0	
%	33.3	12.8	12.6	11.2	8.5	6.7	5.0	3.6	2.5	1.5	1.0	0.5	0.4	0.1	0.1	0.1	0.1	100.0	15.2

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 - BROWNING DEPOT 40'
WIND SPEED FREQUENCY DISIRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 10/1985 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 15.4 MPH
NORMALIZED AVAILABLE ENERGY: 3440.8 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 27390

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	0	0.00	27390	100.00	0.0
1	184	0.67	27390	100.00	0.0
2	589	2.15	27206	99.33	0.1
3	866	3.16	26617	97.18	0.4
4	1082	3.95	25751	94.02	1.1
5	1161	4.24	24669	90.07	2.2
6	1144	4.18	23508	85.83	3.8
7	1093	3.99	22364	81.65	5.7
8	1082	3.95	21271	77.66	8.5
9	1084	3.96	20189	73.71	12.1
10	1199	4.38	19105	69.75	18.4
11	1141	4.17	17906	65.37	23.2
12	1145	4.18	16765	61.21	30.3
13	1149	4.19	15620	57.03	38.6
14	1165	4.25	14471	52.83	48.9
15	1128	4.12	13306	48.58	58.3
16	1121	4.09	12178	44.46	70.3
17	1040	3.80	11057	40.37	78.2
18	1028	3.75	10017	36.57	91.8
19	940	3.43	8989	32.82	98.7
20	841	3.07	8049	29.39	103.0
21	782	2.86	7208	26.32	110.9
22	693	2.53	6426	23.46	113.0
23	673	2.46	5733	20.93	125.4
24	620	2.26	5060	18.47	131.2
25	543	1.98	4440	16.21	129.9
26	492	1.80	3897	14.23	132.4
27	434	1.58	3405	12.43	130.8
28	429	1.57	2971	10.85	144.2
29	345	1.26	2542	9.28	128.8
30	312	1.14	2197	8.02	129.0
31	272	0.99	1885	6.88	124.0
32	266	0.97	1613	5.89	133.4
33	197	0.72	1347	4.92	108.4
34	210	0.77	1150	4.20	126.4
35	150	0.55	940	3.43	98.5
36	113	0.41	790	2.88	80.7
37	132	0.48	677	2.47	102.4
38	88	0.32	545	1.99	73.9
39	80	0.29	457	1.67	72.6
40	56	0.20	377	1.38	54.9
41	50	0.18	321	1.17	52.8
42	52	0.19	271	0.99	59.0
43	35	0.13	219	0.80	42.6
44	43	0.16	184	0.67	56.1
45	25	0.09	141	0.51	34.9
46	21	0.08	116	0.42	31.3
47	8	0.03	95	0.35	12.7
48	13	0.05	87	0.32	22.0
49	8	0.03	74	0.27	14.4
50	7	0.03	66	0.24	13.4
51	8	0.03	59	0.22	16.2
52	4	0.01	51	0.19	8.6
53	8	0.03	47	0.17	18.2
54	6	0.02	39	0.14	14.5
55	4	0.01	33	0.12	10.2
56	5	0.02	29	0.11	13.4
57	7	0.03	24	0.09	19.8
58	4	0.01	17	0.06	11.9
59	4	0.01	13	0.05	12.6
60	3	0.01	9	0.03	9.9
61	3	0.01	6	0.02	10.4
62	1	0.00	3	0.01	3.6
63	0	0.00	2	0.01	0.0
64	2	0.01	2	0.01	8.0

APPENDIX B

CAPE BLANCO MICROWAVE
SUMMARY STATISTICS
OCTOBER 1976 - MAY 1989

STATION - CAPE BLANCO 50'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1976 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.1	15.9	14.2	1996	14.48	11.01
# OBS	0	0	0	0	0	0	0	0	0	557	713	726			
1977	14.1	20.2	18.5	17.5	13.5	22.3	18.2	16.9	20.8	21.6	26.7	27.6	8418	19.64	12.77
# OBS	732	671	742	713	693	691	744	744	709	740	623	616			
1978	25.1	24.6	18.4	25.0	22.0	15.3	20.6	18.3	16.5	17.1	19.0	17.6	6677	19.67	12.71
# OBS	742	661	253	298	230	720	548	413	654	711	708	739			
1979	15.1	26.6	17.3	13.5	21.1	18.1	21.5	15.0	16.9	16.0	16.3	21.6	7712	18.12	12.67
# OBS	743	672	741	545	743	719	453	601	719	667	698	411			
1980	17.5	17.8	14.3	17.6	13.2	14.6	17.8	19.2	14.4	15.7	15.8	18.7	7993	16.38	10.65
# OBS	205	693	729	687	586	719	742	744	716	740	689	743			
1981	14.6	15.5	16.9	12.1	12.6	13.6	19.2	12.9	13.1	15.7	17.3	0.0	7199	14.53	9.99
# OBS	742	667	744	670	744	717	405	744	718	744	304	0			
1982	26.5	28.6	20.7	21.6	18.4	18.2	19.2	16.5	17.0	18.0	21.6	28.5	6582	20.24	13.48
# OBS	46	381	741	642	731	700	655	715	492	561	477	441			
1983	27.6	32.1	26.0	15.5	19.5	17.1	15.0	17.6	18.2	13.9	30.1	20.6	8464	21.11	15.42
# OBS	739	670	738	715	734	635	744	744	569	722	718	736			
1984	19.2	26.5	23.1	20.5	20.4	22.0	28.0	19.1	18.9	23.0	25.8	13.7	7698	21.62	14.02
# OBS	563	546	744	719	624	614	744	606	611	733	478	716			
1985	10.4	23.4	22.1	17.9	15.9	24.0	19.4	13.1	17.1	25.1	15.5	16.0	7176	18.13	12.53
# OBS	471	577	743	713	741	408	537	417	706	399	720	744			
1986	26.9	25.3	23.1	20.4	18.8	19.1	21.3	12.1	13.0	11.4	0.0	25.6	7474	19.85	13.57
# OBS	744	672	733	709	729	696	717	744	614	557	0	559			
1987	27.4	29.2	34.4	22.8	19.4	23.1	17.7	0.0	17.1	17.6	23.8	28.4	5227	22.60	14.94
# OBS	742	106	173	30	742	721	593	0	505	610	296	709			
1988	24.1	16.0	18.1	17.8	18.7	17.5	22.3	21.6	21.7	18.3	44.8	0.0	6315	19.84	11.91
# OBS	695	677	694	629	744	720	744	744	484	148	36	0			
1989	17.5	18.1	11.0	16.3	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2483	17.13	11.79
# OBS	494	557	86	602	744	0	0	0	0	0	0	0			
AVG	20.6	22.8	20.2	17.9	17.4	18.5	11.8	16.6	16.9	17.3	20.6	20.6	91414	19.07	13.08
SD	6.0	5.4	5.8	3.6	3.1	3.4	3.2	3.0	2.7	3.9	8.5	5.6			

STATION - CAPE BLANCO 50'
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1976 - 5/1989

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	19.9	19.8	19.7	19.5	19.2	19.3	19.4	19.3	19.8	20.2	21.0	22.0	22.2	22.1	22.3	22.3	21.9	21.4	20.9	20.7	20.3	20.2	20.5	20.2	20.6
FEB	22.9	23.0	23.3	22.9	22.3	22.2	21.9	22.6	22.4	22.4	23.0	23.4	23.8	23.7	23.7	23.6	23.2	22.5	22.2	22.2	22.1	22.0	22.3	22.5	22.8
MAR	19.1	18.8	18.6	18.7	18.6	18.0	17.9	18.4	19.4	20.6	21.6	22.3	22.0	22.1	22.1	22.0	22.2	22.0	21.4	20.8	19.9	19.2	19.2	19.4	20.2
APR	16.8	16.5	16.1	15.7	15.4	15.5	15.7	16.6	17.4	18.8	19.6	20.0	20.3	20.2	20.2	20.0	19.4	19.0	19.0	18.3	17.8	17.4	17.2	16.8	17.9
MAY	15.9	15.9	15.7	15.6	15.2	14.9	15.3	16.2	17.3	18.4	19.0	19.5	19.2	19.3	19.3	19.3	19.2	19.1	18.9	18.4	17.5	16.7	16.5	15.9	17.4
JUN	16.8	17.0	16.8	16.8	16.7	16.2	16.8	17.4	18.5	19.5	19.8	20.0	20.1	19.9	20.4	20.5	20.3	19.9	19.7	19.4	18.8	18.0	17.3	17.2	18.5
JUL	18.8	18.8	18.9	18.1	17.8	17.7	17.8	18.2	19.5	20.6	21.3	21.2	21.1	21.6	21.9	22.1	22.2	22.0	21.8	21.6	20.7	19.7	19.3	19.0	20.1
AUG	15.4	15.2	15.1	15.0	14.8	14.7	14.7	15.1	16.2	17.3	18.2	18.3	18.1	18.0	18.1	18.1	18.2	18.3	18.1	17.7	16.9	16.4	15.7	15.4	16.6
SEP	15.9	15.7	15.6	15.5	15.5	15.5	15.3	15.4	16.0	16.9	18.0	18.6	18.7	18.7	18.8	18.6	18.5	18.1	18.1	17.4	16.7	16.5	16.1	15.9	16.9
OCT	16.4	16.5	16.7	16.7	16.6	16.4	15.8	15.6	16.0	17.1	17.9	18.5	18.9	18.7	18.9	18.6	18.4	18.1	17.9	17.3	16.9	16.9	16.6	16.7	17.3
NOV	20.2	20.1	19.5	19.5	19.3	19.1	19.5	19.8	20.2	20.3	21.3	22.2	22.3	22.0	21.9	21.6	21.5	21.1	20.7	20.4	20.2	20.5	20.3	20.4	20.6
DEC	19.6	19.5	19.6	19.7	19.9	19.7	20.0	19.9	19.9	20.3	21.2	21.7	22.3	22.4	22.0	21.7	21.4	21.0	20.8	20.7	20.7	20.2	20.1	19.9	20.6
AVG SPD	18.1	18.0	17.9	17.8	17.6	17.4	17.5	17.8	18.5	19.4	20.1	20.6	20.7	20.7	20.8	20.7	20.5	20.2	19.9	19.5	19.0	18.6	18.4	18.2	19.1

STATION - CAPE BLANCO 50'
WIND ROSE FOR ALL DATA - 86914 OBSERVATIONS
DATA PERIOD OF RECORD - 10/1976 - 5/1989

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	3.1	1.7	1.9	2.2	2.7	2.5	2.1	1.5	0.8	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	19.2	18.9
NNE	3.3	2.1	2.5	3.1	3.2	3.0	2.3	1.2	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	21.7	18.2
NE	1.9	0.9	0.8	0.6	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	5.5	13.8
ENE	1.2	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	0.0	1.7	7.9
E	1.5	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	0.0	0.0	2.1	7.5
ESE	1.4	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	0.0	1.9	7.5
SE	1.7	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	0.0	0.0	0.0	2.3	7.7
SSE	2.6	1.1	0.9	0.6	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	7.0	15.1
S	3.1	1.5	1.6	1.7	1.8	1.7	1.7	1.6	1.5	1.3	1.1	1.1	1.0	0.9	0.7	0.6	2.1	24.8	28.8
SSW	1.3	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.1	5.2	20.8
SW	0.7	0.2	0.2	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	0.0	2.1	16.5
WSW	0.4	0.1	0.1	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	0.0	0.9	13.3
W	0.6	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	0.0	0.0	1.0	10.2
WNW	0.6	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	0.0	0.0	0.9	9.4
NW	0.5	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	0.0	0.0	0.0	0.9	10.2
NNW	1.0	0.3	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	2.1	11.4
CALM TOTAL																		0.6	
%	25.3	9.8	9.9	9.6	9.6	8.6	7.2	5.1	3.5	2.5	1.8	1.5	1.2	1.0	0.8	0.7	2.3	100.0	19.3

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 - CAPE BLANCO 50'
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 10/1976 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 19.1 MPH
NORMALIZED AVAILABLE ENERGY: 9272.7 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 91414

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR	SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	590	0.65	91414	100.00	0.0	46	331	0.36	4304	4.71	167.9
1	1375	1.50	90824	99.35	0.0	47	314	0.34	3973	4.35	169.9
2	2071	2.27	89449	97.85	0.1	48	280	0.31	3659	4.00	161.4
3	2426	2.65	87378	95.58	0.3	49	245	0.27	3379	3.70	150.2
4	2586	2.83	84952	92.93	0.9	50	241	0.26	3134	3.43	157.0
5	2772	3.03	82366	90.10	1.8	51	224	0.25	2893	3.16	154.8
6	2809	3.07	79594	87.07	3.2	52	237	0.26	2669	2.92	173.7
7	2959	3.24	76785	84.00	5.3	53	206	0.23	2432	2.66	159.8
8	2958	3.24	73826	80.76	7.9	54	189	0.21	2226	2.44	155.1
9	2915	3.19	70868	77.52	11.1	55	181	0.20	2037	2.23	156.9
10	2808	3.07	67953	74.34	14.6	56	168	0.18	1856	2.03	153.7
11	3066	3.35	65145	71.26	21.3	57	149	0.16	1688	1.85	143.8
12	2980	3.26	62079	67.91	26.8	58	147	0.16	1539	1.68	149.5
13	2916	3.19	59099	64.65	33.4	59	136	0.15	1392	1.52	145.6
14	2884	3.15	56183	61.46	41.2	60	132	0.14	1256	1.37	148.6
15	2896	3.17	53299	58.31	50.9	61	123	0.13	1124	1.23	145.5
16	2929	3.20	50403	55.14	62.5	62	108	0.12	1001	1.10	134.1
17	2921	3.20	47474	51.93	74.8	63	96	0.11	893	0.98	125.1
18	2819	3.08	44553	48.74	85.7	64	102	0.11	797	0.87	139.3
19	2909	3.18	41734	45.65	104.0	65	80	0.09	695	0.76	114.5
20	2884	3.15	38825	42.47	120.2	66	78	0.09	615	0.67	116.9
21	2783	3.04	35941	39.32	134.3	67	63	0.07	537	0.59	98.7
22	2719	2.97	33158	36.27	150.9	68	59	0.06	474	0.52	96.7
23	2599	2.84	30439	33.30	164.8	69	51	0.06	415	0.45	87.3
24	2537	2.78	27840	30.45	182.8	70	42	0.05	364	0.40	75.1
25	2282	2.50	25303	27.68	185.8	71	39	0.04	322	0.35	72.7
26	2202	2.41	23021	25.18	201.7	72	48	0.05	283	0.31	93.4
27	2025	2.22	20819	22.77	207.7	73	32	0.04	235	0.26	64.9
28	1824	2.00	18794	20.56	208.7	74	21	0.02	203	0.22	44.3
29	1570	1.72	16970	18.56	199.5	75	28	0.03	182	0.20	61.6
30	1405	1.54	15400	16.85	197.7	76	19	0.02	154	0.17	43.5
31	1210	1.32	13995	15.31	187.8	77	13	0.01	135	0.15	30.9
32	1100	1.20	12785	13.99	187.8	78	17	0.02	122	0.13	42.0
33	943	1.03	11685	12.78	176.6	79	12	0.01	105	0.11	30.8
34	867	0.95	10742	11.75	177.6	80	14	0.02	93	0.10	37.4
35	782	0.86	9875	10.80	174.7	81	9	0.01	79	0.09	24.9
36	673	0.74	9093	9.95	163.6	82	15	0.02	70	0.08	43.1
37	606	0.66	8420	9.21	160.0	83	10	0.01	55	0.06	29.8
38	564	0.62	7814	8.55	161.3	84	7	0.01	45	0.05	21.6
39	505	0.55	7250	7.93	156.1	85	3	0.00	38	0.04	9.6
40	493	0.54	6745	7.38	164.4	86	9	0.01	35	0.04	29.8
41	452	0.49	6252	6.84	162.3	87	6	0.01	26	0.03	20.6
42	435	0.48	5800	6.34	167.9	88	3	0.00	20	0.02	10.7
43	356	0.39	5365	5.87	147.5	89	3	0.00	17	0.02	11.0
44	385	0.42	5009	5.48	170.9	90	1	0.00	14	0.02	3.8
45	320	0.35	4624	5.06	152.0	91	1	0.00	13	0.01	3.9

APPENDIX C

GOODNOE HILLS
SUMMARY STATISTICS
MAY 1980 - MAY 1989

STATION - GOODNOE HILLS 50'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 5/1980 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1980	0.0	0.0	0.0	0.0	14.6	13.5	12.4	13.5	12.6	9.0	9.3	9.2	5529	11.71	6.36
# OBS	0	0	0	0	564	720	738	743	665	735	704	660			
1981	8.6	9.3	11.5	14.2	13.8	15.5	13.6	12.1	11.2	9.4	9.8	10.9	7973	11.67	6.41
# OBS	511	665	736	719	742	687	454	587	719	736	704	713			
1982	15.0	12.5	12.4	12.9	12.8	10.8	11.5	11.1	9.7	9.2	8.8	9.5	7632	11.21	6.53
# OBS	723	671	406	84	739	709	741	734	709	721	706	689			
1983	11.2	8.2	9.2	8.4	9.5	10.9	13.6	11.7	12.8	10.8	12.8	8.6	8114	10.63	5.71
# OBS	726	659	743	703	704	673	725	702	648	559	626	646			
1984	11.0	9.2	10.9	14.2	13.5	13.2	11.2	13.0	10.1	10.2	13.5	11.0	7960	11.65	6.64
# OBS	743	688	728	711	659	717	734	739	716	740	156	629			
1985	5.1	11.4	10.6	13.4	13.5	13.3	11.9	13.3	10.8	11.4	15.3	3.5	7041	10.90	6.65
# OBS	523	639	743	665	461	718	742	740	714	340	105	651			
1986	11.2	9.4	10.0	13.0	14.2	13.5	12.8	11.2	10.3	6.8	11.3	6.5	8516	10.95	6.87
# OBS	730	670	729	718	738	714	744	744	720	744	720	545			
1987	7.0	10.4	11.0	10.9	10.8	9.8	11.8	9.1	10.2	9.2	8.6	8.9	7811	9.90	6.54
# OBS	740	671	744	696	741	720	743	736	589	546	251	634			
1988	9.4	9.6	10.6	11.0	10.6	10.8	11.8	10.3	9.5	7.1	10.4	9.0	8613	10.02	6.61
# OBS	707	659	744	674	744	713	738	744	704	744	710	732			
1989	13.0	8.1	10.3	13.5	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2773	11.13	6.94
# OBS	708	671	742	85	567	0	0	0	0	0	0	0			
AVG	10.4	9.8	10.6	12.2	12.5	12.4	6.9	11.7	10.8	9.1	10.5	8.6	71962	10.93	6.54
SD	3.0	1.4	0.9	1.9	1.7	1.8	0.9	1.4	1.2	1.5	2.3	2.3			

STATION - GOODNOE HILLS 195'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 5/1980 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1980	0.0	0.0	0.0	0.0	19.2	17.7	16.9	17.5	15.5	12.1	11.9	11.7	5560	15.23	8.39
# OBS	0	0	0	0	565	720	741	743	659	708	710	714			
1981	10.9	12.1	14.9	17.8	17.4	18.6	17.2	15.5	13.9	12.1	12.3	14.4	7926	14.75	8.21
# OBS	520	661	738	688	742	688	456	540	720	742	718	713			
1982	19.7	16.7	15.7	15.1	16.7	12.6	14.9	14.7	12.9	11.9	11.5	12.3	8307	14.55	8.52
# OBS	716	585	638	708	741	626	733	735	704	715	707	699			
1983	14.5	12.8	14.8	14.1	17.3	18.2	16.7	14.4	15.1	11.9	15.0	10.1	8280	14.58	8.12
# OBS	729	651	707	675	697	655	724	707	674	659	700	702			
1984	14.5	12.8	15.3	19.5	19.7	19.6	17.3	19.8	16.8	15.8	12.8	13.9	8603	16.51	8.52
# OBS	743	675	743	719	744	718	744	740	621	706	716	734			
1985	6.7	14.7	13.9	17.8	17.6	17.5	16.0	17.6	14.1	16.1	13.2	5.6	7957	14.50	8.00
# OBS	499	667	743	665	461	719	742	744	719	737	688	573			
1986	14.9	13.2	13.2	16.9	17.2	17.1	17.5	14.6	13.7	9.0	9.3	7.3	7595	14.31	8.35
# OBS	694	663	722	712	738	712	744	744	717	601	124	522			
1987	8.2	11.7	12.1	15.0	16.5	14.9	17.2	13.2	12.3	10.4	10.5	10.6	7731	12.97	8.06
# OBS	686	644	733	720	743	719	742	738	575	546	151	634			
1988	11.5	14.1	16.5	16.7	16.0	16.0	17.3	15.3	14.3	11.2	16.5	11.6	8623	14.74	8.38
# OBS	708	658	744	674	744	713	738	744	704	744	709	743			
1989	16.2	10.0	12.6	17.1	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2773	13.67	9.35
# OBS	708	671	742	85	567	0	0	0	0	0	0	0			

STATION - GOODNOE HILLS 195'
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 5/1980 - 5/1989

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	13.8	13.6	13.3	13.2	13.1	13.4	13.4	13.4	13.2	12.6	12.5	12.6	12.4	12.3	12.9	13.3	13.6	14.0	13.9	14.0	14.2	14.0	13.7	13.5	13.3
FEB	13.3	13.6	13.7	13.3	13.4	13.6	13.7	13.0	12.2	11.8	11.7	12.0	12.3	12.9	13.0	13.3	13.5	13.7	13.7	13.5	13.3	13.1	13.0	13.0	13.1
MAR	15.1	15.0	14.9	15.0	14.7	14.2	14.0	12.7	12.3	12.1	12.3	13.0	13.5	13.8	14.3	14.3	14.5	15.2	16.0	15.7	15.4	15.4	15.2	15.0	14.3
APR	17.6	17.5	17.5	17.4	16.7	15.9	14.8	13.8	13.5	13.6	14.4	14.9	15.8	16.1	16.7	17.5	17.6	18.1	19.0	18.6	18.2	18.0	17.9	18.0	16.6
MAY	19.5	19.0	18.8	18.1	17.5	16.3	14.7	13.8	13.4	13.5	13.9	14.5	15.2	16.1	16.6	17.1	18.0	19.0	19.8	20.5	20.3	20.2	20.1	19.7	17.3
JUN	19.3	18.9	18.3	17.9	17.0	15.5	13.7	12.9	12.7	12.8	13.2	14.0	14.6	15.2	16.2	17.2	18.2	18.7	19.6	20.5	20.7	20.2	20.2	19.6	17.0
JUL	19.0	18.3	17.9	17.5	17.1	15.4	13.5	12.5	12.1	12.1	12.7	13.5	14.4	15.2	16.3	17.4	18.1	18.9	19.9	20.7	20.7	20.2	19.6	19.4	16.8
AUG	17.6	17.5	17.0	16.6	16.1	15.1	13.2	12.0	11.4	11.3	11.9	12.9	13.5	14.3	15.3	16.5	17.3	18.3	19.4	19.9	19.4	18.9	18.3	17.6	15.9
SEP	15.0	14.6	14.0	14.0	13.8	13.8	13.0	11.7	11.1	11.4	11.8	12.4	13.0	14.1	14.8	15.2	15.5	16.6	17.4	16.8	16.1	16.1	15.7	15.4	14.3
OCT	12.9	13.0	12.9	12.6	12.5	12.5	12.1	11.2	10.4	10.3	10.6	11.0	11.5	12.0	12.5	12.9	13.3	13.8	13.8	13.6	13.4	13.2	13.2	13.2	12.4
NOV	13.0	13.0	13.4	13.3	13.6	13.2	12.8	12.4	12.2	12.3	12.3	12.4	12.7	12.7	13.0	13.2	13.6	13.7	13.5	13.7	13.6	13.6	13.5	13.2	13.1
DEC	11.3	11.2	11.3	11.7	11.7	11.8	11.5	11.2	10.8	10.2	10.0	10.3	10.5	10.9	10.9	11.0	11.3	11.1	11.4	11.3	11.0	11.0	11.0	11.3	11.1
AVG SPD	15.7	15.5	15.3	15.1	14.8	14.3	13.4	12.5	12.1	12.0	12.3	12.8	13.3	13.8	14.4	14.9	15.4	16.0	16.5	16.7	16.5	16.2	16.0	15.8	14.7

STATION - GOODNOE HILLS 195'
WIND ROSE FOR ALL DATA - 71061 OBSERVATIONS
DATA PERIOD OF RECORD - 5/1980 - 5/1989

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	TOTAL %	MEAN SPEED (MPH)
N	0.6	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	0.0	0.8	6.6
NNE	0.6	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	0.0	0.0	1.4	12.3
NE	0.9	0.5	0.5	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	2.7	12.2
ENE	1.7	1.0	0.9	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	11.3
E	4.1	1.4	0.8	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	6.9	8.8
ESE	3.2	0.5	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	3.8	6.6
SE	2.6	0.5	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	3.3	6.8
SSE	2.7	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	0.0	0.0	3.1	6.2
S	3.2	0.3	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	3.9	6.9
SSW	1.6	0.3	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	2.7	9.7
SW	2.2	0.9	0.8	0.6	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	12.4
WSW	2.3	1.3	1.5	1.5	1.3	1.0	0.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	9.9	15.7
W	3.1	2.3	3.3	4.8	5.9	5.7	4.5	2.7	1.5	0.7	0.3	0.1	0.1	0.0	0.0	0.0	35.0	20.4
WNW	1.8	1.2	1.4	1.4	1.7	1.6	1.4	1.0	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	12.5	19.2
NW	1.1	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	1.9	9.8
NNW	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	0.0	0.5	6.6
CALM																	1.6	
TOTAL %	33.8	11.1	10.4	10.2	10.3	9.0	6.7	4.1	2.3	1.1	0.5	0.2	0.1	0.0	0.0	0.0	100.0	14.9

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 - GOODNOE HILLS 195'
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 5/1980 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 14.7 MPH
NORMALIZED AVAILABLE ENERGY: 3092.9 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 73353

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	1252	1.71	73353	100.00	0.0
1	1716	2.34	72101	98.29	0.0
2	1962	2.67	70385	95.95	0.1
3	2241	3.06	68423	93.28	0.4
4	2636	3.59	66182	90.22	1.0
5	2952	4.02	63546	86.63	2.2
6	3299	4.50	60594	82.61	4.3
7	3141	4.28	57295	78.11	6.5
8	3029	4.13	54154	73.83	9.4
9	3030	4.13	51125	69.70	13.4
10	2829	3.86	48095	65.57	17.1
11	2677	3.65	45266	61.71	21.6
12	2595	3.54	42589	58.06	27.2
13	2552	3.48	39994	54.52	34.0
14	2545	3.47	37442	51.04	42.3
15	2402	3.27	34897	47.57	49.1
16	2481	3.38	32495	44.30	61.6
17	2436	3.32	30014	40.92	72.6
18	2441	3.33	27578	37.60	86.3
19	2576	3.51	25137	34.27	107.1
20	2435	3.32	22561	30.76	118.1
21	2404	3.28	20126	27.44	135.0
22	2285	3.12	17722	24.16	147.5
23	2184	2.98	15437	21.04	161.1
24	2041	2.78	13253	18.07	171.0
25	1821	2.48	11212	15.28	172.5
26	1630	2.22	9391	12.80	173.7
27	1433	1.95	7761	10.58	171.0
28	1183	1.61	6328	8.63	157.4
29	1020	1.39	5145	7.01	150.8
30	878	1.20	4125	5.62	143.7
31	733	1.00	3247	4.43	132.4
32	525	0.72	2514	3.43	104.3
33	480	0.65	1989	2.71	104.6
34	361	0.49	1509	2.06	86.0
35	288	0.39	1148	1.57	74.9
36	210	0.29	860	1.17	59.4
37	153	0.21	650	0.89	47.0
38	114	0.16	497	0.68	37.9
39	91	0.12	383	0.52	32.7
40	73	0.10	292	0.40	28.3
41	41	0.06	219	0.30	17.1
42	50	0.07	178	0.24	22.5
43	29	0.04	128	0.17	14.0
44	11	0.01	99	0.13	5.7
45	19	0.03	88	0.12	10.5
46	13	0.02	69	0.09	7.7
47	10	0.01	56	0.08	6.3
48	5	0.01	46	0.06	3.4
49	6	0.01	41	0.06	4.3
50	8	0.01	35	0.05	6.1
51	5	0.01	27	0.04	4.0
52	4	0.01	22	0.03	3.4
53	0	0.00	18	0.02	0.0
54	5	0.01	18	0.02	4.8
55	1	0.00	13	0.02	1.0
56	3	0.00	12	0.02	3.2
57	2	0.00	9	0.01	2.2
58	1	0.00	7	0.01	1.2
59	0	0.00	6	0.01	0.0
60	1	0.00	6	0.01	1.3
61	0	0.00	5	0.01	0.0
62	1	0.00	5	0.01	1.4
63	0	0.00	4	0.01	0.0
64	1	0.00	4	0.01	1.6
65	1	0.00	3	0.00	1.7
66	0	0.00	2	0.00	0.0
67	0	0.00	2	0.00	0.0
68	0	0.00	2	0.00	0.0
69	1	0.00	2	0.00	2.0
70	1	0.00	1	0.00	2.1

APPENDIX D

HAMPTON BUTTE
SUMMARY STATISTICS
OCTOBER 1983 - NOVEMBER 1988

STATION - HAMPTON BUTTE 30'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1983 - 11/1988

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	21.2	14.3	1203	18.04	10.18
# OBS	0	0	0	0	0	0	0	0	0	140	600	463			
1984	16.2	19.5	17.3	0.0	17.7	15.3	13.0	13.0	13.7	18.4	0.0	0.0	5277	15.59	8.39
# OBS	672	693	651	0	282	700	688	719	715	157	0	0			
1985	0.0	0.0	0.0	16.3	14.4	12.4	10.5	13.2	13.5	18.0	14.9	19.7	4899	14.15	7.59
# OBS	0	0	0	191	697	693	672	678	583	598	531	256			
1986	0.0	0.0	15.9	14.9	14.9	12.8	14.2	11.8	12.3	12.5	17.6	14.3	5684	14.00	6.97
# OBS	0	0	246	467	607	494	590	695	650	598	685	652			
1987	17.2	17.0	19.5	0.0	14.2	11.2	12.5	11.5	10.2	10.3	14.8	18.7	7352	14.14	8.05
# OBS	683	658	589	0	290	720	744	744	721	744	719	740			
1988	16.2	14.0	17.7	16.1	14.3	12.7	12.6	11.7	13.5	10.3	12.9	0.0	7952	13.84	7.68
# OBS	742	696	744	720	744	720	741	724	700	724	697	0			
AVG	16.5	16.8	17.9	15.7	14.8	12.9	12.5	12.2	12.6	13.0	16.2	16.5	32367	14.42	7.92
SD	0.6	2.7	1.5	0.8	1.5	1.5	1.3	0.8	1.5	3.8	3.2	2.9			

STATION - HAMPTON BUTTE 30'
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1983 - 11/1988

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	16.9	16.4	16.2	16.1	16.3	16.2	16.5	16.3	15.9	16.0	15.7	16.4	16.9	16.5	16.6	16.8	16.7	17.0	17.3	17.1	17.0	16.5	16.4	16.7	16.5
FEB	17.6	17.7	17.3	17.1	17.4	17.2	16.6	16.2	15.7	16.0	15.6	15.9	16.3	16.1	16.4	16.4	16.4	16.9	17.4	17.6	17.6	17.7	17.4	17.2	16.8
MAR	17.6	17.2	17.3	17.1	16.8	16.5	15.9	15.6	16.0	16.2	16.9	17.9	18.5	19.1	19.5	19.7	19.4	19.4	19.5	19.3	19.4	18.5	17.9	17.6	17.9
APR	14.8	14.6	14.0	14.4	14.0	13.6	13.6	13.4	14.1	14.8	16.2	16.4	17.0	16.8	17.2	17.9	17.2	16.3	16.8	17.4	16.5	16.5	16.5	15.7	15.7
MAY	14.0	13.5	13.2	13.2	13.0	12.3	11.9	11.3	12.2	13.0	13.7	14.2	15.0	15.6	15.9	16.5	16.6	17.2	18.4	18.9	17.8	16.7	15.5	14.8	14.8
JUN	12.3	11.9	11.3	11.1	11.1	10.2	9.6	9.3	10.0	10.7	11.5	12.3	13.1	13.3	14.0	14.3	15.0	16.1	17.0	16.9	16.5	15.3	13.9	12.7	12.9
JUL	12.8	12.1	11.6	11.1	10.7	9.9	8.6	7.6	7.7	8.7	9.9	10.7	11.5	11.9	12.7	13.3	14.4	16.0	17.7	18.5	17.6	16.0	14.6	13.7	12.5
AUG	11.9	11.3	10.7	10.1	9.8	9.4	8.7	7.6	7.9	8.9	9.9	10.8	11.2	12.0	12.3	13.1	14.2	15.8	17.9	18.7	17.4	15.8	14.1	13.3	12.2
SEP	12.6	12.1	12.1	11.9	11.7	11.2	10.6	9.9	9.4	9.8	10.9	11.6	11.9	12.6	13.1	13.2	13.6	15.0	16.2	16.7	15.4	14.7	13.7	13.1	12.6
OCT	13.4	13.4	13.3	13.3	13.3	13.3	12.8	12.1	11.3	11.2	11.7	12.1	12.5	12.5	12.5	12.6	13.1	13.5	13.8	14.2	14.5	14.2	14.1	14.0	13.0
NOV	16.1	15.9	15.8	15.9	15.9	16.2	16.0	16.0	15.6	15.8	16.0	16.2	16.7	16.7	16.5	16.2	16.3	16.4	17.0	16.6	16.3	16.5	16.1	15.8	16.2
DEC	16.8	16.0	15.9	15.7	15.4	15.9	15.8	16.0	15.7	15.8	16.2	16.6	16.8	16.0	16.5	17.0	16.8	16.9	17.4	17.4	17.7	17.5	17.2	16.9	16.5
AVG SPD	14.3	14.0	13.6	13.5	13.3	13.0	12.5	12.0	12.1	12.5	13.2	13.8	14.3	14.5	14.9	15.1	15.5	16.2	17.1	17.4	16.9	16.1	15.3	14.8	14.4

STATION - HAMPTON BUTTE
WIND ROSE FOR ALL DATA - 31553 OBSERVATIONS
DATA PERIOD OF RECORD - 10/1983 - 11/1988

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	2.8	1.2	1.2	1.3	1.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	13.3
NNE	2.1	0.7	0.6	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	12.4
NE	3.0	0.4	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	4.0	7.9
ENE	2.0	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	0.0	2.8	8.7
E	1.6	0.5	0.4	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	3.5	11.7
ESE	1.1	0.6	0.5	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	13.5
SE	1.3	0.6	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	13.5
SSE	1.6	0.9	0.7	0.5	0.3	0.3	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	4.9	13.9
S	2.7	1.4	1.6	1.2	0.9	0.6	0.5	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	10.1	16.0
SSW	2.0	0.9	1.0	1.0	0.7	0.5	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	7.2	15.8
SW	1.8	0.8	1.0	0.9	0.6	0.5	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	15.5
WSW	2.2	1.1	1.2	1.2	1.0	0.8	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	15.5
W	3.1	1.6	1.5	1.1	0.8	0.7	0.4	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	9.9	14.6
WNW	1.6	1.1	1.2	1.1	1.0	0.8	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	16.4
NW	1.2	1.0	1.1	1.3	1.2	0.8	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	16.7
NNW	1.3	0.8	1.0	1.1	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	6.6	15.9
CALM																		0.8	
TOTAL %	32.4	14.0	14.0	12.9	10.1	7.0	4.2	2.5	1.3	0.7	0.5	0.2	0.1	0.1	0.0	0.0	0.0	100.0	14.4

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 - HAMPTON BUTTE 30'
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 10/1983 - 11/1988
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 14.4 MPH
NORMALIZED AVAILABLE ENERGY: 2396.4 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 32367

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	248	0.77	32367	100.00	0.0
1	363	1.12	32119	99.23	0.0
2	541	1.67	31756	98.11	0.1
3	749	2.31	31215	96.44	0.2
4	969	2.99	30466	94.13	0.8
5	1198	3.70	29497	91.13	1.8
6	1384	4.28	28299	87.43	3.7
7	1456	4.50	26915	83.16	6.1
8	1426	4.41	25459	78.66	8.9
9	1397	4.32	24033	74.25	12.5
10	1535	4.74	22636	69.94	18.8
11	1505	4.65	21101	65.19	24.5
12	1515	4.68	19596	60.54	32.1
13	1526	4.71	18081	55.86	41.1
14	1518	4.69	16555	51.15	51.0
15	1502	4.64	15037	46.46	62.1
16	1555	4.80	13535	41.82	78.0
17	1389	4.29	11980	37.01	83.6
18	1412	4.36	10591	32.72	100.9
19	1153	3.56	9179	28.36	96.9
20	1175	3.63	8026	24.80	115.1
21	1018	3.15	6851	21.17	115.5
22	959	2.96	5833	18.02	125.1
23	787	2.43	4874	15.06	117.3
24	705	2.18	4087	12.63	119.4
25	624	1.93	3382	10.45	119.4
26	478	1.48	2758	8.52	102.9
27	384	1.19	2280	7.04	92.6
28	337	1.04	1896	5.86	90.6
29	291	0.90	1559	4.82	86.9
30	230	0.71	1268	3.92	76.1
31	190	0.59	1038	3.21	69.3
32	160	0.49	848	2.62	64.2
33	107	0.33	688	2.13	47.1
34	85	0.26	581	1.80	40.9
35	70	0.22	496	1.53	36.8
36	70	0.22	426	1.32	40.0
37	59	0.18	356	1.10	36.6
38	56	0.17	297	0.92	37.6
39	45	0.14	241	0.74	32.7
40	41	0.13	196	0.61	32.1
41	34	0.11	155	0.48	28.7
42	18	0.06	121	0.37	16.3
43	18	0.06	103	0.32	17.5
44	15	0.05	85	0.26	15.7
45	13	0.04	70	0.22	14.5
46	12	0.04	57	0.18	14.3
47	12	0.04	45	0.14	15.3
48	9	0.03	33	0.10	12.2
49	7	0.02	24	0.07	10.1
50	4	0.01	17	0.05	6.1
51	3	0.01	13	0.04	4.9
52	3	0.01	10	0.03	5.2
53	2	0.01	7	0.02	3.6
54	2	0.01	5	0.02	3.9
55	0	0.00	3	0.01	0.0
56	1	0.00	3	0.01	2.2
57	2	0.01	2	0.01	4.5

APPENDIX E

KENNEWICK MICROWAVE
SUMMARY STATISTICS
JUNE 1976 - MAY 1989

STATION - KENNEWICK 80'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 9/1987 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.8	8.9	16.6	24.5	2384	13.19	11.20
# OBS	0	0	0	0	0	0	0	0	708	744	715	217			
1988	17.0	18.5	17.8	14.5	18.1	16.0	15.4	13.9	13.2	13.7	25.6	15.0	8010	16.53	11.92
# OBS	83	696	744	720	739	720	744	744	651	720	719	730			
1989	23.7	0.0	0.0	15.8	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1884	18.43	14.03
# OBS	728	0	0	608	548	0	0	0	0	0	0	0			
AVG	23.0	18.5	17.8	15.1	16.5	16.0	14.0	13.9	12.0	11.2	21.1	17.2	12278	16.18	12.24
SD	4.7	0.0	0.0	0.9	2.6	0.0	0.0	0.0	1.7	3.4	6.4	6.7			

STATION - KENNEWICK 100'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 6/1976 - 9/1987

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1976	0.0	0.0	0.0	0.0	0.0	15.4	0.0	15.9	13.2	13.5	12.9	13.2	3058	13.76	9.73
# OBS	0	0	0	0	0	180	0	480	633	735	720	310			
1977	8.2	20.7	23.7	15.9	21.9	14.5	15.6	15.5	13.5	15.2	21.8	19.9	7990	17.05	12.15
# OBS	645	515	744	718	384	582	744	744	720	739	720	735			
1978	11.2	14.4	14.9	18.4	17.2	17.2	14.4	11.5	15.8	12.9	19.8	17.9	7088	15.65	10.72
# OBS	565	671	744	710	700	672	738	227	94	734	491	742			
1979	8.0	18.4	11.8	13.1	15.7	17.3	22.1	18.1	13.5	15.2	10.9	19.1	7530	15.41	10.44
# OBS	563	493	744	706	743	688	682	709	390	615	556	641			
1980	12.9	11.7	19.6	16.8	16.0	15.1	11.1	12.8	0.0	10.7	14.5	13.2	6943	14.18	10.24
# OBS	689	693	744	705	430	718	699	511	0	399	719	636			
1981	6.7	9.8	10.8	15.3	0.0	21.6	15.7	13.2	13.0	15.2	17.5	17.1	7226	14.35	9.85
# OBS	494	643	702	514	0	630	743	649	696	742	720	693			
1982	24.8	20.8	20.4	19.4	14.1	13.9	13.5	10.9	11.2	12.3	13.1	13.8	8206	15.40	11.77
# OBS	532	644	638	715	690	719	740	697	693	719	700	719			
1983	22.4	17.3	15.3	10.4	15.2	17.9	18.7	14.0	14.2	12.2	22.4	11.5	8224	16.03	11.53
# OBS	741	637	727	716	708	709	626	637	694	698	718	613			
1984	18.0	15.3	17.0	17.7	18.0	16.0	11.3	14.6	15.6	17.9	20.5	14.5	8335	16.37	11.62
# OBS	729	664	744	720	663	719	740	556	699	695	689	717			
1985	5.3	14.7	15.2	20.8	18.5	15.6	12.5	14.5	13.8	19.5	18.5	11.9	7721	15.88	10.93
# OBS	162	671	737	721	744	720	744	744	721	661	721	375			
1986	0.0	0.0	0.0	12.6	16.6	13.4	16.4	12.8	17.1	11.5	21.0	11.9	5435	15.12	10.72
# OBS	0	0	0	24	694	649	670	685	648	744	720	601			
1987	16.6	16.8	18.7	17.8	17.1	14.4	16.6	11.6	11.9	0.0	0.0	0.0	6495	15.74	10.48
# OBS	729	669	743	720	744	720	744	729	697	0	0	0			
AVG	14.4	15.8	16.7	16.6	16.8	16.0	15.2	13.9	13.7	14.3	17.6	15.3	84251	15.54	11.01
SD	6.8	3.6	4.0	3.1	2.2	2.2	3.3	2.1	1.7	2.7	4.0	3.1			

STATION - KENNEWICK 80'
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 9/1987 - 5/1989

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	26.3	26.4	25.7	26.4	25.7	24.9	24.2	24.4	23.2	21.2	21.5	21.3	21.2	20.3	19.7	19.5	20.5	21.5	21.2	21.3	22.2	23.2	24.0	25.4	23.0
FEB	17.8	19.0	18.5	18.2	18.8	18.9	19.1	18.8	18.5	18.3	18.5	19.2	19.8	20.0	18.8	18.5	18.2	18.3	18.1	17.7	17.8	17.0	17.8	17.8	18.5
MAR	18.4	18.8	19.0	18.7	19.6	18.7	17.6	17.7	17.8	17.6	18.6	18.1	17.7	17.2	16.7	15.9	15.3	16.3	16.9	17.2	17.4	18.2	18.2	18.4	17.8
APR	15.4	15.5	15.5	15.3	14.7	15.6	15.3	14.9	14.3	15.2	16.3	16.4	15.9	15.6	15.6	14.6	14.7	14.6	14.5	14.5	14.3	14.7	14.6	14.7	15.1
MAY	17.7	16.4	17.2	17.2	16.5	17.1	16.4	16.4	15.4	15.4	15.3	15.4	15.6	14.5	14.6	15.5	16.5	16.3	16.9	17.6	17.4	18.1	18.3	18.3	16.5
JUN	15.6	15.8	15.8	15.9	15.3	15.0	15.1	15.4	15.7	15.7	16.0	16.3	16.1	16.5	16.3	16.8	16.4	16.1	16.1	16.5	15.9	16.4	16.8	16.4	16.0
JUL	16.3	16.2	15.4	15.8	16.3	16.4	15.6	15.8	16.2	15.8	15.2	14.5	14.0	13.7	14.3	15.2	15.5	14.9	15.2	14.1	15.4	15.3	15.6	16.1	15.4
AUG	12.9	12.5	13.2	14.2	15.3	15.2	13.8	13.8	14.2	13.7	13.7	13.9	13.9	14.0	14.1	13.8	14.0	13.9	14.2	14.3	14.8	14.7	13.2	13.3	13.9
SEP	11.1	11.8	11.9	12.4	12.9	13.3	13.6	13.4	13.1	11.9	11.7	11.5	11.8	11.7	12.2	12.2	11.7	11.4	11.3	11.0	11.7	11.4	11.3	10.9	12.0
OCT	10.6	11.3	11.7	12.2	12.4	12.5	12.5	12.6	12.2	11.8	11.9	11.4	11.0	11.1	10.8	10.9	10.6	10.2	10.3	10.0	9.8	10.3	10.7	10.9	11.2
NOV	21.1	20.8	21.1	21.1	20.8	21.1	21.0	20.5	20.1	20.2	20.6	21.1	21.5	21.4	21.2	20.5	20.9	20.8	21.2	21.8	22.1	22.3	22.2	21.7	21.1
DEC	17.9	17.9	17.3	16.8	16.8	17.7	18.2	17.3	17.5	16.6	16.4	16.3	15.8	15.5	15.5	16.3	17.2	17.5	16.7	18.3	18.2	18.1	18.3	18.4	17.2
AUG SPD	16.4	16.5	16.5	16.7	16.7	16.9	16.7	16.5	16.2	15.8	16.0	16.0	16.0	15.7	15.6	15.6	15.7	15.7	15.8	15.9	16.1	16.3	16.4	16.5	16.2

STATION - KENNEWICK 80'
WIND ROSE FOR ALL DATA - 12278 OBSERVATIONS
DATA PERIOD OF RECORD - 9/1987 - 5/1989

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	7.4	2.1	0.7	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	0.0	10.9	8.4
NNE	6.7	1.6	0.9	0.5	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	11.1	10.5
NE	2.7	0.5	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	0.0	3.7	7.9
ENE	1.8	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	0.0	2.3	7.2
E	1.3	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	0.0	0.0	1.6	6.8
ESE	0.6	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	0.7	6.4
SE	0.6	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	0.8	6.5
SSE	0.7	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	0.0	0.0	1.0	8.8
S	2.0	0.9	0.6	0.7	0.6	0.4	0.4	0.2	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6.2	15.3
SSW	3.5	1.8	2.2	2.3	2.3	2.6	2.2	2.4	1.8	1.4	1.1	0.8	0.5	0.2	0.1	0.2	0.2	25.4	23.1
SW	2.6	1.2	1.4	1.4	1.4	1.6	1.3	1.6	1.6	1.4	1.2	0.8	0.7	0.5	0.3	0.2	0.3	19.4	25.8
WSW	1.3	0.4	0.4	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3.3	15.1
W	1.5	0.2	0.2	0.0	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	2.1	8.2
WNW	1.0	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	0.0	0.0	1.4	7.8
NW	1.7	0.5	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	0.0	2.4	7.6
NNW	3.8	1.3	0.8	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	6.3	9.3
CALM																		1.5	
TOTAL %	40.7	11.3	7.9	6.2	5.4	5.3	4.4	4.5	3.7	3.1	2.4	1.7	1.3	0.7	0.4	0.4	0.5	100.0	16.2

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 - KENNEWICK 80'
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 9/1987 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 16.2 MPH
NORMALIZED AVAILABLE ENERGY: 5975.7 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 12278

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	181	1.47	12278	100.00	0.0
1	278	2.26	12097	98.53	0.0
2	346	2.82	11819	96.26	0.1
3	444	3.62	11473	93.44	0.4
4	516	4.20	11029	89.83	1.2
5	572	4.66	10513	85.62	2.6
6	620	5.05	9941	80.97	4.9
7	625	5.09	9321	75.92	7.8
8	626	5.10	8696	70.83	11.7
9	536	4.37	8070	65.73	14.3
10	541	4.41	7534	61.36	19.8
11	477	3.88	6993	56.96	23.2
12	430	3.50	6516	53.07	27.2
13	382	3.11	6086	49.57	30.7
14	347	2.83	5704	46.46	34.8
15	304	2.48	5357	43.63	37.5
16	277	2.26	5053	41.15	41.5
17	272	2.22	4776	38.90	48.9
18	251	2.04	4504	36.68	53.6
19	218	1.78	4253	34.64	54.7
20	226	1.84	4035	32.86	66.1
21	210	1.71	3809	31.02	71.2
22	207	1.69	3599	29.31	80.6
23	241	1.96	3392	27.63	107.3
24	207	1.69	3151	25.66	104.7
25	196	1.60	2944	23.98	112.0
26	180	1.47	2748	22.38	115.7
27	185	1.51	2568	20.92	133.2
28	172	1.40	2383	19.41	138.1
29	176	1.43	2211	18.01	157.0
30	191	1.56	2035	16.57	188.7
31	174	1.42	1844	15.02	189.7
32	149	1.21	1670	13.60	178.6
33	157	1.28	1521	12.39	206.4
34	151	1.23	1364	11.11	217.1
35	134	1.09	1213	9.88	210.2
36	110	0.90	1079	8.79	187.8
37	114	0.93	969	7.89	211.3
38	113	0.92	855	6.96	226.9
39	84	0.68	742	6.04	182.3
40	80	0.65	658	5.36	187.3
41	70	0.57	578	4.71	176.5
42	64	0.52	508	4.14	173.5
43	70	0.57	444	3.62	203.6
44	59	0.48	374	3.05	183.9
45	47	0.38	315	2.57	156.7
46	31	0.25	268	2.18	110.4
47	33	0.27	237	1.93	125.4
48	27	0.22	204	1.66	109.2
49	25	0.20	177	1.44	107.6
50	22	0.18	152	1.24	100.6
51	16	0.13	130	1.06	77.7
52	14	0.11	114	0.93	72.0
53	19	0.15	100	0.81	103.5
54	15	0.12	81	0.66	86.4
55	10	0.08	66	0.54	60.9
56	13	0.11	56	0.46	83.5
57	8	0.07	43	0.35	54.2
58	4	0.03	35	0.29	28.6
59	7	0.06	31	0.25	52.6
60	6	0.05	24	0.20	47.4
61	3	0.02	18	0.15	24.9
62	5	0.04	15	0.12	43.6
63	3	0.02	10	0.08	27.4
64	0	0.00	7	0.06	0.0
65	0	0.00	7	0.06	0.0
66	2	0.02	7	0.06	21.0
67	3	0.02	5	0.04	33.0
68	1	0.01	2	0.02	11.5
69	0	0.00	1	0.01	0.0
70	1	0.01	1	0.01	12.5

APPENDIX F

KITTITAS MICROWAVE
SUMMARY STATISTICS
MARCH 1980 - MAY 1989

STATION - KITTITAS M/W 110°
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 3/1980 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1980	0.0	0.0	16.3	13.6	14.3	11.5	12.0	14.6	16.1	10.0	10.1	9.7	5987	12.54	8.48
# OBS	0	0	156	719	665	625	394	586	720	709	718	695			
1981	9.9	11.6	14.3	17.1	15.0	17.4	15.1	11.1	11.8	11.9	11.2	12.8	8640	13.27	9.00
# OBS	697	651	741	744	744	656	743	743	719	743	720	739			
1982	16.1	12.9	13.8	16.4	16.3	12.3	14.8	12.8	13.0	10.6	10.6	10.8	8621	13.39	8.64
# OBS	734	658	741	708	738	718	741	744	719	687	715	718			
1983	14.5	11.3	12.8	12.5	15.6	16.8	15.9	0.0	0.0	0.0	0.0	0.0	4692	14.12	8.69
# OBS	721	666	744	714	744	682	421	0	0	0	0	0			
1984	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	0.00	0.00
# OBS	0	0	0	0	0	0	0	0	0	0	0	0			
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	466	6.50	6.55
# OBS	0	0	0	0	0	0	0	0	0	0	0	466			
1986	12.4	11.9	13.4	16.5	14.8	13.6	14.7	11.4	11.9	8.6	11.3	6.2	8000	12.54	8.48
# OBS	734	671	741	720	734	720	744	744	681	63	720	728			
1987	7.5	10.8	11.2	13.8	13.2	12.2	14.9	12.0	10.3	9.6	9.9	8.3	8356	11.19	8.63
# OBS	744	672	744	719	726	720	744	719	715	389	720	744			
1988	9.1	12.0	13.9	12.9	14.5	15.3	18.6	14.5	14.7	11.4	14.2	10.2	7626	13.21	9.81
# OBS	719	696	743	720	730	54	493	744	715	744	713	555			
1989	13.7	12.7	13.8	15.1	16.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2931	14.22	9.86
# OBS	391	672	737	664	467	0	0	0	0	0	0	0			
AVG	11.8	11.9	13.4	14.7	15.0	14.0	9.9	12.7	13.0	10.8	11.2	9.3	55319	12.85	8.95
SD	3.1	0.8	1.4	1.8	1.1	2.4	2.0	1.5	2.1	1.2	1.6	2.4			

STATION - KITTITAS M/W
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 3/1980 - 5/1989

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	11.9	12.1	11.5	11.5	11.4	10.9	11.2	10.8	11.2	11.6	11.6	11.8	12.3	12.7	13.3	12.9	12.3	12.1	11.7	11.5	11.4	11.3	11.6	11.7	11.8
FEB	11.3	11.7	11.9	11.1	11.0	11.5	11.6	11.7	11.3	12.0	12.4	12.8	13.0	13.4	13.6	13.2	12.3	11.8	11.5	11.4	11.4	11.2	11.1	10.8	11.9
MAR	12.3	12.1	12.1	12.0	11.7	11.8	11.7	12.1	13.0	13.8	13.9	14.0	14.6	15.0	15.5	16.4	16.1	14.9	13.7	13.4	13.2	12.6	12.6	12.5	13.4
APR	13.2	12.9	12.9	12.8	12.3	11.9	12.0	13.4	14.7	15.3	15.5	15.7	16.0	16.2	16.7	17.6	18.1	17.4	16.3	15.3	15.2	14.7	14.3	13.7	14.7
MAY	13.6	13.1	13.0	12.6	12.0	11.7	12.8	14.1	14.4	14.0	14.2	14.6	15.2	16.0	17.0	18.0	18.8	18.9	17.7	16.5	15.8	15.4	15.1	14.3	15.0
JUN	13.5	12.8	12.2	12.1	11.3	10.9	11.6	12.5	12.5	12.2	12.4	12.6	13.0	13.8	15.2	16.5	17.9	18.2	17.8	16.7	15.6	14.9	14.7	14.2	14.0
JUL	14.9	14.1	13.3	12.5	11.7	11.7	12.6	13.3	13.4	13.1	13.2	13.5	14.4	15.0	16.6	17.9	19.2	20.3	19.6	18.0	17.1	16.6	16.0	15.5	15.1
AUG	12.8	12.1	11.5	11.0	10.4	9.8	9.4	10.2	10.8	10.6	10.5	10.8	11.3	12.6	13.9	15.3	16.9	17.5	16.2	14.8	14.5	14.2	13.8	13.2	12.7
SEP	12.2	11.9	11.5	11.2	11.0	10.6	10.3	11.6	12.8	13.1	13.1	13.4	14.2	14.7	15.2	15.7	15.8	14.8	13.4	13.3	13.4	12.8	12.7	12.4	13.0
OCT	9.5	9.7	9.5	9.3	9.2	9.2	9.3	9.6	10.3	10.9	11.3	11.9	12.5	13.1	12.8	12.8	11.8	11.0	11.0	11.5	11.5	11.0	10.3	9.9	10.8
NOV	10.6	10.4	10.3	10.1	10.3	10.6	10.7	10.4	10.2	11.1	11.9	12.5	12.6	12.9	13.0	12.9	12.1	11.2	11.0	10.8	11.0	11.1	10.8	10.8	11.2
DEC	9.8	9.8	9.7	9.2	9.2	9.7	9.6	9.7	9.5	9.3	9.0	9.6	9.6	9.5	9.7	9.3	9.3	8.8	8.4	8.9	8.6	8.8	9.6	9.6	9.3
AVG SPD	12.2	12.0	11.7	11.4	11.1	11.0	11.2	11.7	12.2	12.4	12.6	12.9	13.3	13.8	14.5	15.0	15.2	14.9	14.2	13.6	13.3	13.0	12.8	12.5	12.8

STATION - KITTITAS M/W
WIND ROSE FOR ALL DATA - 44092 OBSERVATIONS
DATA PERIOD OF RECORD - 6/1980 - 5/1989

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	1.9	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	13.8
NNE	0.6	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	13.3
NE	0.5	0.1	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	0.0	0.0	1.5	13.7
ENE	1.0	0.8	0.8	0.7	0.6	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	15.5
E	4.3	2.5	1.7	0.8	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	11.7
ESE	3.8	1.2	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	5.6	8.2
SE	1.7	0.4	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	2.4	8.3
SSE	1.2	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	0.0	0.0	0.0	1.8	8.5
S	1.6	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	0.0	0.0	2.1	6.9
SSW	0.8	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	0.0	0.0	1.1	7.2
SW	0.9	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	12.7
WSW	1.9	0.4	0.2	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	3.2	9.9
W	9.0	3.2	2.0	1.3	0.8	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.1	10.4
WNW	8.9	3.6	3.4	3.2	2.6	2.2	1.5	1.1	0.9	0.6	0.3	0.2	0.1	0.1	0.0	0.0	0.0	28.8	15.7
NW	3.0	0.9	0.7	0.8	1.1	1.0	1.0	0.9	0.8	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	11.4	19.4
NNW	1.1	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	0.0	1.5	8.3
CALM																		1.4	
TOTAL %	43.0	14.8	10.6	8.3	6.5	5.1	3.7	2.7	2.2	1.4	0.8	0.4	0.2	0.1	0.0	0.0	0.0	100.0	13.1

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 - KITTITAS M/W 110
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 6/1980 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 12.8 MPH
NORMALIZED AVAILABLE ENERGY: 2624.6 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 53779

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	850	1.58	53779	100.00	0.0
1	1366	2.54	52929	98.42	0.0
2	1840	3.42	51563	95.88	0.1
3	2185	4.06	49723	92.46	0.5
4	2395	4.45	47538	88.40	1.3
5	2806	5.22	45143	83.94	2.9
6	3046	5.66	42337	78.72	5.4
7	3040	5.65	39291	73.06	8.6
8	3114	5.79	36251	67.41	13.1
9	2922	5.43	33137	61.62	17.6
10	2841	5.28	30215	56.18	23.4
11	2554	4.75	27374	50.90	28.0
12	2385	4.43	24820	46.15	34.0
13	2057	3.82	22435	41.72	37.2
14	1880	3.50	20378	37.89	42.5
15	1693	3.15	18498	34.40	47.1
16	1581	2.94	16805	31.25	53.4
17	1529	2.84	15224	28.31	61.9
18	1335	2.48	13695	25.47	64.1
19	1253	2.33	12360	22.98	70.8
20	1127	2.10	11107	20.65	74.3
21	1031	1.92	9980	18.56	78.7
22	1007	1.87	8949	16.64	88.3
23	882	1.64	7942	14.77	88.4
24	804	1.50	7060	13.13	91.6
25	728	1.35	6256	11.63	93.7
26	656	1.22	5528	10.28	95.0
27	588	1.09	4872	9.06	95.4
28	543	1.01	4284	7.97	98.2
29	471	0.88	3741	6.96	94.6
30	459	0.85	3270	6.08	102.1
31	404	0.75	2811	5.23	99.2
32	388	0.72	2407	4.48	104.8
33	327	0.61	2019	3.75	96.8
34	254	0.47	1692	3.15	82.3
35	253	0.47	1438	2.67	89.4
36	245	0.46	1185	2.20	94.2
37	192	0.36	940	1.75	80.1
38	158	0.29	748	1.39	71.4
39	112	0.21	590	1.10	54.7
40	102	0.19	478	0.89	53.8
41	83	0.15	376	0.70	47.1
42	62	0.12	293	0.54	37.8
43	50	0.09	231	0.43	32.8
44	31	0.06	181	0.34	21.8
45	30	0.06	150	0.28	22.5
46	27	0.05	120	0.22	21.7
47	17	0.03	93	0.17	14.5
48	17	0.03	76	0.14	15.5
49	15	0.03	59	0.11	14.5
50	9	0.02	44	0.08	9.3
51	9	0.02	35	0.07	9.8
52	6	0.01	26	0.05	7.0
53	1	0.00	20	0.04	1.2
54	6	0.01	19	0.04	7.8
55	2	0.00	13	0.02	2.7
56	2	0.00	11	0.02	2.9
57	1	0.00	9	0.02	1.5
58	2	0.00	8	0.01	3.2
59	1	0.00	6	0.01	1.7
60	2	0.00	5	0.01	3.6
61	0	0.00	3	0.01	0.0
62	1	0.00	3	0.01	2.0
63	0	0.00	2	0.00	0.0
64	1	0.00	2	0.00	2.2
65	0	0.00	1	0.00	0.0
66	0	0.00	1	0.00	0.0
67	0	0.00	1	0.00	0.0
68	0	0.00	1	0.00	0.0
69	0	0.00	1	0.00	0.0
70	1	0.00	1	0.00	2.8

APPENDIX G

PEQUOP SUMMIT
SUMMARY STATISTICS
APRIL 1976 - MAY 1989

STATION - PEQUOP SUMMIT 30'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 4/1976 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1976	0.0	0.0	0.0	10.1	14.9	18.8	13.3	12.5	11.2	13.5	14.5	13.6	5126	14.09	8.85
# OBS	0	0	0	74	718	710	205	576	718	663	720	742			
1977	17.9	19.0	23.0	15.2	14.6	13.8	13.8	16.4	9.8	0.0	0.0	0.0	5318	16.41	10.08
# OBS	741	631	738	719	743	720	493	182	351	0	0	0			
1978	15.0	15.1	13.2	15.9	17.0	14.6	11.7	13.0	12.6	11.1	12.5	22.0	7690	14.03	8.63
# OBS	561	672	744	717	484	718	741	743	576	730	719	365			
1979	14.3	16.9	12.1	16.6	13.4	14.2	0.0	0.0	0.0	16.7	17.2	15.5	5400	15.14	9.85
# OBS	744	519	560	720	743	478	0	0	0	184	717	735			
1980	19.3	15.4	20.6	14.6	12.4	13.9	13.1	14.6	13.1	13.2	14.9	14.5	8206	15.01	9.42
# OBS	743	694	743	546	738	719	744	734	720	744	715	366			
1981	12.3	17.0	21.9	15.9	16.7	18.3	14.5	12.1	11.8	14.6	14.4	20.4	8330	15.57	10.15
# OBS	700	666	369	720	743	720	744	743	719	743	720	743			
1982	25.2	16.2	0.0	0.0	0.0	16.9	12.6	12.8	13.5	0.0	22.5	22.0	3689	15.98	10.71
# OBS	158	513	0	0	0	157	740	742	607	0	34	738			
1983	28.3	18.5	21.5	24.7	19.8	13.0	18.1	11.1	13.9	11.3	17.6	23.9	6676	17.35	11.43
# OBS	258	636	732	155	710	273	733	742	720	666	720	331			
1984	20.2	20.0	18.0	20.4	18.2	17.4	10.6	13.2	13.8	14.5	15.8	19.6	5714	16.23	11.21
# OBS	149	448	155	529	690	434	640	422	719	552	613	363			
1985	14.6	17.9	18.8	18.0	16.8	14.1	12.1	14.5	14.8	15.1	20.2	16.6	7830	16.27	10.59
# OBS	737	605	718	701	663	505	565	452	709	721	715	739			
1986	13.9	21.3	16.0	18.9	16.2	11.7	12.7	9.7	9.0	0.0	0.0	0.0	5993	14.70	10.41
# OBS	739	653	742	711	739	710	703	719	277	0	0	0			
1987	0.0	0.0	0.0	0.0	0.0	14.0	14.6	13.5	11.6	10.9	0.0	19.5	3623	13.96	10.30
# OBS	0	0	0	0	0	356	693	694	702	576	0	602			
1988	17.3	16.0	20.8	16.6	17.6	11.1	10.7	9.4	10.6	9.0	17.3	0.0	6799	13.73	10.74
# OBS	596	672	386	720	744	427	744	744	715	744	307	0			
1989	12.4	12.6	15.4	15.5	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2392	13.38	10.14
# OBS	370	543	373	421	685	0	0	0	0	0	0	0			
AVG	16.2	17.1	18.3	16.9	15.7	14.8	10.1	12.4	12.4	12.7	16.0	18.4	82786	15.23	10.24
SD	5.0	2.4	3.7	3.5	2.4	2.4	2.0	2.0	1.8	2.4	3.0	3.5			

STATION - PEQUOP SUMMIT 30'
WIND ROSE FOR ALL DATA - 77996 OBSERVATIONS
DATA PERIOD OF RECORD - 4/1976 - 5/1989

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	1.3	0.8	0.9	0.7	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5.3	15.6
NNE	0.8	0.5	0.5	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	2.5	13.1
NE	0.8	0.3	0.2	0.1	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	1.7	12.5
ENE	0.9	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	0.0	0.0	1.6	12.7
E	1.9	0.4	0.3	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	2.9	9.5
ESE	1.7	0.4	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	2.5	8.9
SE	3.0	1.0	0.6	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	0.0	5.3	9.8
SSE	4.2	1.5	0.9	0.5	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	7.6	9.9
S	4.4	1.3	0.7	0.4	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	7.3	9.3
SSW	2.2	0.6	0.4	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	3.8	10.1
SW	1.8	0.6	0.6	0.5	0.4	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	13.0
WSW	1.5	0.7	0.7	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5.2	15.7
W	3.6	1.7	1.6	1.2	0.8	0.6	0.4	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	11.2	15.0
WNW	2.9	1.9	1.9	1.8	1.7	1.6	1.4	1.2	0.9	0.7	0.6	0.4	0.3	0.2	0.1	0.1	0.1	17.7	20.7
NW	1.7	1.4	1.7	1.9	1.9	1.7	1.3	1.1	0.9	0.6	0.4	0.3	0.2	0.1	0.1	0.0	0.0	15.3	21.4
NNW	0.7	0.5	0.6	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.1	0.0	0.1	4.8	21.0
CALM																		0.7	
TOTAL %	34.0	13.8	11.6	9.6	7.6	5.9	4.6	3.6	2.8	2.0	1.5	1.0	0.7	0.5	0.3	0.2	0.3	100.0	15.4

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 - PEQUOP SUMMIT 30'
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 4/1976 - 5/1989

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	16.7	16.3	15.9	16.2	16.1	16.4	15.7	15.5	15.5	16.0	16.5	16.9	16.9	16.9	16.7	16.4	16.3	16.1	15.8	16.3	16.1	15.9	16.1	16.6	16.2
FEB	16.5	16.3	16.3	16.4	16.5	16.5	15.8	16.0	16.7	16.9	17.9	18.9	19.2	19.2	18.5	18.6	18.0	17.6	17.5	16.4	16.4	16.4	16.4	16.2	17.1
MAR	17.0	17.0	16.9	16.9	16.6	16.5	16.7	17.6	18.2	18.9	20.3	20.5	20.7	21.0	21.2	20.5	19.5	18.5	18.0	18.0	17.6	17.1	17.1	17.0	18.3
APR	15.6	15.1	14.8	14.7	14.2	13.9	14.4	15.6	16.7	17.5	18.2	18.9	19.2	19.9	20.1	20.1	19.4	18.0	17.1	16.8	16.4	16.3	16.1	15.8	16.9
MAY	14.0	13.8	13.6	13.6	13.4	13.2	13.8	15.0	15.8	16.8	17.1	17.7	18.5	18.6	18.7	18.7	18.8	17.8	16.0	15.2	14.9	14.5	14.1	13.9	15.7
JUN	13.6	13.6	13.2	12.3	11.8	11.1	11.3	12.3	13.4	14.2	15.2	15.6	16.1	16.8	17.7	18.4	18.7	18.2	17.4	15.9	15.2	14.9	14.6	14.1	14.8
JUL	11.9	11.2	10.5	10.1	9.5	9.2	8.7	9.6	10.8	12.1	13.2	14.1	15.1	16.3	17.3	17.6	17.5	16.8	15.7	14.7	14.3	13.6	13.1	12.3	13.2
AUG	10.8	10.5	10.3	9.9	9.5	8.7	8.9	9.4	10.7	12.2	13.3	14.3	15.2	15.7	16.5	16.7	16.1	14.9	13.6	13.0	12.4	11.9	11.2	10.7	12.4
SEP	10.9	10.5	10.1	10.2	10.3	10.2	10.1	10.8	11.6	12.4	13.4	14.2	14.9	15.5	16.0	16.0	15.5	14.0	13.1	12.6	12.2	11.7	11.3	10.7	12.4
OCT	11.6	11.6	11.4	11.8	11.6	11.2	10.7	11.0	12.0	12.8	13.5	14.4	14.8	14.9	15.4	15.2	14.0	13.2	12.9	12.7	12.2	12.0	11.6	11.5	12.7
NOV	15.2	15.1	15.1	15.2	15.4	15.4	15.7	15.6	16.1	16.5	16.9	17.4	17.5	17.4	17.3	16.6	16.1	15.5	15.2	15.4	15.8	16.1	15.6	15.6	16.0
DEC	18.0	18.0	17.8	18.1	18.1	18.2	17.3	17.0	17.3	17.5	18.2	19.3	19.6	19.5	19.1	19.3	18.8	19.1	18.8	19.4	18.7	18.3	18.0	18.0	18.4
AVG SPD	14.2	13.9	13.7	13.6	13.4	13.2	13.1	13.6	14.4	15.2	16.0	16.7	17.3	17.6	17.8	17.8	17.4	16.6	15.9	15.4	15.1	14.8	14.5	14.2	15.2

STATION - PEQUOP SUMMIT 30'
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 4/1976 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 15.2 MPH
NORMALIZED AVAILABLE ENERGY: 3646.3 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 82786

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	640	0.77	82786	100.00	0.0
1	1147	1.39	82146	99.23	0.0
2	1663	2.01	80999	97.84	0.1
3	2238	2.70	79336	95.83	0.3
4	2950	3.56	77098	93.13	0.9
5	3463	4.18	74148	89.57	2.0
6	3953	4.77	70685	85.38	3.9
7	4167	5.03	66732	80.61	6.6
8	4201	5.07	62565	75.57	9.9
9	4282	5.17	58364	70.50	14.4
10	4079	4.93	54082	65.33	18.8
11	3731	4.51	50003	60.40	22.9
12	3553	4.29	46272	55.89	28.3
13	3385	4.09	42719	51.60	34.3
14	3099	3.74	39334	47.51	39.3
15	3070	3.71	36235	43.77	47.8
16	2843	3.43	33165	40.06	53.8
17	2538	3.07	30322	36.63	57.6
18	2503	3.02	27784	33.56	67.4
19	2296	2.77	25281	30.54	72.7
20	2025	2.45	22985	27.76	74.8
21	1890	2.28	20960	25.32	80.8
22	1763	2.13	19070	23.04	86.7
23	1609	1.94	17307	20.91	90.4
24	1452	1.75	15698	18.96	92.7
25	1386	1.67	14246	17.21	100.0
26	1247	1.51	12860	15.53	101.2
27	1113	1.34	11613	14.03	101.1
28	1055	1.27	10500	12.68	106.9
29	989	1.19	9445	11.41	111.3
30	883	1.07	8456	10.21	110.1
31	887	1.07	7573	9.15	122.0
32	786	0.95	6686	8.08	118.9
33	674	0.81	5900	7.13	111.8
34	625	0.75	5226	6.31	113.4
35	561	0.68	4601	5.56	111.0
36	467	0.56	4040	4.88	100.6
37	434	0.52	3573	4.32	101.5
38	404	0.49	3139	3.79	102.3
39	349	0.42	2735	3.30	95.6
40	297	0.36	2386	2.88	87.7
41	263	0.32	2089	2.52	83.7
42	232	0.28	1826	2.21	79.3
43	205	0.25	1594	1.93	75.2
44	198	0.24	1389	1.68	77.9
45	191	0.23	1191	1.44	80.3
46	148	0.18	1000	1.21	66.5
47	122	0.15	852	1.03	58.5
48	98	0.12	730	0.88	50.0
49	103	0.12	632	0.76	55.9
50	69	0.08	529	0.64	39.8
51	74	0.09	460	0.56	45.3
52	56	0.07	386	0.47	36.3
53	66	0.08	330	0.40	45.4
54	35	0.04	264	0.32	25.4
55	41	0.05	229	0.28	31.5
56	22	0.03	188	0.23	17.8
57	34	0.04	166	0.20	29.1
58	24	0.03	132	0.16	21.6
59	18	0.02	108	0.13	17.1
60	24	0.03	90	0.11	23.9
61	17	0.02	66	0.08	17.8
62	11	0.01	49	0.06	12.1
63	8	0.01	38	0.05	9.2
64	6	0.01	30	0.04	7.3
65	3	0.00	24	0.03	3.8
66	3	0.00	21	0.03	4.0
67	4	0.00	18	0.02	5.6
68	3	0.00	14	0.02	4.4
69	2	0.00	11	0.01	3.0
70	0	0.00	9	0.01	0.0
71	2	0.00	9	0.01	3.3
72	1	0.00	7	0.01	1.7
73	2	0.00	6	0.01	3.6
74	0	0.00	4	0.00	0.0
75	1	0.00	4	0.00	1.9
76	1	0.00	3	0.00	2.0
77	2	0.00	2	0.00	4.2

APPENDIX H

SEVEN MILE HILL 50 AND 150 FT LEVEL
SUMMARY STATISTICS
OCTOBER 1978 - MAY 1989

STATION - SEVEN MILE HILL 50'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1978 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	9.9	14.8	1749	12.26	9.38
# OBS	0	0	0	0	0	0	0	0	0	295	713	741			
1979	8.7	11.6	13.2	18.2	21.4	21.8	23.0	21.6	15.7	13.1	10.8	13.0	7840	15.85	10.42
# OBS	642	519	739	695	719	201	743	742	717	737	717	669			
1980	0.0	0.0	19.2	15.2	22.9	21.4	21.8	22.6	17.0	12.1	9.0	7.3	7209	16.85	10.22
# OBS	0	0	634	719	744	720	742	744	717	737	712	740			
1981	11.2	9.5	14.5	15.8	20.0	19.8	20.8	19.8	14.3	11.9	8.6	11.3	8578	14.91	9.61
# OBS	741	526	739	719	744	719	743	736	714	742	718	737			
1982	15.2	11.3	13.2	14.1	21.5	20.0	20.6	19.5	14.2	10.0	9.0	11.7	8363	15.15	9.58
# OBS	697	661	516	713	743	716	732	744	718	743	679	701			
1983	10.7	8.5	11.2	15.1	21.9	20.9	20.6	22.2	0.0	0.0	0.0	0.0	5501	16.17	10.26
# OBS	735	664	742	718	739	720	743	440	0	0	0	0			
1984	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	0.00	0.00
# OBS	0	0	0	0	0	0	0	0	0	0	0	0			
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	3.0	763	4.47	3.89
# OBS	0	0	0	0	0	0	0	0	0	0	545	218			
1986	0.0	0.0	0.0	16.7	17.9	19.8	21.1	18.2	13.6	8.1	10.5	6.4	5586	14.69	10.06
# OBS	0	0	0	476	744	720	369	715	720	744	720	378			
1987	8.4	8.9	12.1	15.3	17.5	17.6	21.3	16.8	15.3	10.8	8.8	8.7	8296	13.76	10.40
# OBS	306	672	744	720	744	720	734	744	721	744	709	738			
1988	8.0	11.4	13.9	16.3	15.4	18.6	20.0	19.3	14.9	9.6	9.8	8.9	8049	13.84	10.48
# OBS	743	667	729	718	732	720	741	744	189	615	709	742			
1989	12.5	10.1	10.9	12.5	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3610	12.88	7.99
# OBS	744	662	744	716	744	0	0	0	0	0	0	0			
AVG	10.9	10.2	13.4	15.4	19.6	19.8	8.0	19.9	15.0	10.9	9.2	10.2	65544	14.77	10.08
SD	2.6	1.3	2.6	1.6	2.5	1.4	0.9	2.0	1.1	1.6	1.7	3.6			

STATION - SEVEN MILE HILL 150'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1978 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	11.7	16.7	2109	14.59	10.13
# OBS	0	0	0	0	0	0	0	0	0	654	714	741			
1979	10.3	9.6	14.5	23.7	22.5	24.2	24.8	23.2	17.3	14.6	14.3	14.5	6027	16.50	11.34
# OBS	646	652	728	266	468	200	658	107	715	650	251	686			
1980	11.1	10.3	20.8	17.5	26.6	24.8	24.9	26.2	19.9	13.7	10.2	8.3	8732	17.93	11.95
# OBS	721	693	743	720	742	720	742	740	717	741	714	739			
1981	13.2	10.7	17.2	18.4	23.4	22.5	24.0	22.7	16.5	13.6	10.1	13.1	8717	17.17	11.29
# OBS	740	666	742	720	743	718	741	735	718	735	719	740			
1982	17.7	12.9	14.9	16.7	24.7	23.0	24.1	22.6	16.5	12.2	10.6	12.3	8660	17.39	11.14
# OBS	712	661	741	701	742	717	730	740	716	737	720	743			
1983	11.2	9.0	11.3	14.7	23.5	24.8	24.2	24.3	20.4	14.4	13.2	10.4	8670	16.89	11.70
# OBS	741	655	710	715	741	720	743	744	717	743	720	721			
1984	13.7	11.7	13.7	19.8	18.9	22.1	23.0	26.2	18.4	14.8	12.7	14.0	8709	17.46	11.20
# OBS	740	692	741	718	730	719	744	743	715	743	699	725			
1985	9.6	15.2	15.1	20.1	23.7	24.0	24.1	22.9	16.8	16.7	13.3	7.8	8014	18.21	11.23
# OBS	603	666	744	686	741	711	742	742	720	741	699	219			
1986	0.0	0.0	0.0	0.0	18.1	21.1	22.4	19.7	14.5	8.7	11.3	6.7	4504	14.75	10.96
# OBS	0	0	0	0	28	718	370	721	720	744	720	483			
1987	7.8	9.0	12.7	15.9	18.2	18.4	22.1	17.4	16.0	12.8	11.3	11.2	8505	14.59	10.84
# OBS	517	672	744	720	744	718	734	744	721	744	709	738			
1988	10.2	13.6	15.6	18.0	17.0	20.2	21.6	20.8	16.4	11.2	11.7	10.9	8049	15.63	10.72
# OBS	743	667	729	718	732	720	741	744	189	615	709	742			
1989	15.8	12.3	11.0	11.7	19.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3610	14.18	8.83
# OBS	744	662	744	716	744	0	0	0	0	0	0	0			
AVG	12.3	11.4	14.7	17.2	21.8	22.4	8.8	22.5	17.4	13.5	11.7	11.8	84306	16.59	11.21
SD	3.0	2.1	2.9	3.2	3.2	2.1	1.2	2.8	1.8	2.2	1.3	3.1			

STATION - SEVEN MILE HILL
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 10/1978 - 5/1989

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	12.1	12.2	12.4	12.1	11.7	11.5	11.4	11.2	11.4	11.5	11.6	11.8	11.9	12.6	13.5	13.8	13.4	12.9	12.6	12.8	12.6	12.8	12.3	12.2	12.3
FEB	11.4	11.2	10.9	10.8	10.9	10.8	10.8	10.5	10.3	10.2	10.8	11.2	11.7	12.2	12.4	12.9	13.1	12.8	12.6	12.1	11.5	11.3	11.0	11.2	11.4
MAR	14.1	13.8	13.4	13.4	13.3	13.2	12.8	12.6	12.4	12.7	13.6	14.2	15.4	16.2	16.8	17.0	16.9	16.9	16.6	15.9	15.7	15.6	15.1	14.8	14.7
APR	17.2	17.3	17.0	16.6	16.3	15.6	14.7	13.9	14.1	14.7	15.4	16.5	17.6	18.4	19.4	20.0	19.9	19.5	19.3	18.5	18.0	17.9	17.9	17.4	17.2
MAY	22.8	22.3	21.9	21.4	20.6	19.6	18.6	18.0	18.2	18.4	18.6	19.5	20.9	21.9	23.1	24.2	25.0	24.9	24.6	24.6	24.1	23.7	23.3	23.3	21.8
JUN	23.7	23.3	22.8	22.4	21.5	20.1	18.8	17.7	17.5	18.0	18.6	19.8	21.0	22.4	24.0	25.1	25.9	26.1	26.1	25.5	24.8	24.3	24.0	23.8	22.4
JUL	25.3	24.9	24.3	23.7	23.0	21.9	20.1	18.8	18.5	18.8	19.2	19.9	21.1	22.5	24.3	25.6	26.8	27.7	27.6	27.6	26.7	26.2	25.9	25.4	23.6
AUG	23.8	23.4	23.4	23.0	22.7	21.7	20.3	18.6	18.0	18.0	18.5	19.2	20.2	21.7	23.1	24.5	25.4	26.2	26.6	25.9	25.0	24.2	24.0	23.5	22.5
SEP	17.2	16.7	16.5	16.2	15.8	15.3	14.6	13.9	13.4	13.8	15.0	16.2	17.4	18.6	19.5	20.2	21.0	21.3	21.0	20.2	19.4	18.3	17.8	17.2	17.4
OCT	13.6	13.3	13.0	12.9	12.5	12.1	11.4	10.8	10.4	10.5	11.4	12.4	13.0	13.9	14.6	15.3	15.9	16.2	16.0	15.4	15.0	15.1	14.6	13.8	13.5
NOV	11.5	11.4	11.2	11.2	11.1	11.0	11.0	10.7	10.7	11.2	11.4	11.7	12.4	12.7	13.0	12.9	12.7	12.5	12.2	12.1	11.7	11.5	11.3	11.5	11.7
DEC	11.2	11.3	11.1	11.4	11.4	11.8	11.7	12.0	11.7	11.3	11.6	12.0	12.5	12.6	12.7	12.4	12.2	12.2	12.2	12.3	12.2	11.9	11.4	11.2	11.8
AVG SPD	16.8	16.7	16.4	16.1	15.8	15.3	14.6	14.0	13.8	14.0	14.6	15.3	16.2	17.1	18.0	18.6	18.9	19.0	18.8	18.4	18.0	17.6	17.3	17.0	16.6

STATION - SEVEN MILE HILL 150'
WIND ROSE FOR ALL DATA - 80239 OBSERVATIONS
DATA PERIOD OF RECORD - 10/1978 - 5/1989

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	0.6	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	0.6	4.6
NNE	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	0.0	0.3	5.5
NE	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	0.0	0.4	4.7
ENE	1.0	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	0.0	1.5	7.6
E	6.1	2.2	1.3	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	10.7	9.1
ESE	6.5	1.9	1.2	0.6	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	10.7	8.9
SE	3.4	0.5	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	4.3	6.7
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	1.7	4.6
S	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	1.0	4.3
SSW	0.5	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	0.5	4.9
SW	0.4	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	0.5	5.3
WSW	0.5	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	0.8	8.6
W	1.7	0.6	0.6	0.7	0.6	0.6	0.6	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.8	18.1
WNW	3.5	2.7	3.4	4.2	4.8	5.2	5.0	4.6	3.8	2.8	1.8	1.0	0.5	0.3	0.1	0.0	0.0	37.9	27.2
NW	2.3	1.1	1.1	1.3	1.3	1.2	1.2	1.1	0.8	0.6	0.4	0.3	0.1	0.1	0.0	0.0	0.0	13.0	20.8
NNW	1.2	0.1	0.1	0.1	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	1.8	9.2
CALM TOTAL																		1.8	
%	32.5	9.6	8.2	7.8	7.6	7.4	7.0	6.3	5.0	3.7	2.4	1.4	0.7	0.4	0.2	0.1	0.0	100.0	17.0

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 - SEVEN MILE HILL 150'
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 10/1978 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 16.6 MPH
NORMALIZED AVAILABLE ENERGY: 5224.4 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 84306

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	1653	1.96	84306	100.00	0.0
1	2505	2.97	82653	98.04	0.0
2	2814	3.34	80148	95.07	0.1
3	2972	3.53	77334	91.73	0.4
4	3081	3.65	74362	88.20	1.1
5	3145	3.73	71281	84.55	2.1
6	3197	3.79	68136	80.82	3.7
7	3107	3.69	64939	77.03	5.7
8	2971	3.52	61832	73.34	8.2
9	3020	3.58	58861	69.82	11.8
10	2932	3.48	55841	66.24	15.8
11	2629	3.12	52909	62.76	18.8
12	2574	3.05	50280	59.64	23.9
13	2385	2.83	47706	56.59	28.2
14	2341	2.78	45321	53.76	34.6
15	2139	2.54	42980	50.98	38.8
16	2163	2.57	40841	48.44	47.7
17	2113	2.51	38678	45.88	55.8
18	2141	2.54	36565	43.37	67.2
19	2094	2.48	34424	40.83	77.3
20	2040	2.42	32330	38.35	87.8
21	2056	2.44	30290	35.93	102.4
22	2084	2.47	28234	33.49	119.4
23	1964	2.33	26150	31.02	128.5
24	2073	2.46	24186	28.69	154.2
25	1935	2.30	22113	26.23	162.6
26	1890	2.24	20178	23.93	178.7
27	1849	2.19	18288	21.69	195.8
28	1790	2.12	16439	19.50	211.4
29	1760	2.09	14649	17.38	230.9
30	1609	1.91	12889	15.29	233.7
31	1510	1.79	11280	13.38	242.0
32	1319	1.56	9770	11.59	232.5
33	1230	1.46	8451	10.02	237.8
34	1131	1.34	7221	8.57	239.1
35	1004	1.19	6090	7.22	231.6
36	928	1.10	5086	6.03	232.9
37	741	0.88	4158	4.93	201.9
38	654	0.78	3417	4.05	193.1
39	527	0.63	2763	3.28	168.2
40	496	0.59	2236	2.65	170.8
41	386	0.46	1740	2.06	143.1
42	286	0.34	1354	1.61	114.0
43	217	0.26	1068	1.27	92.8
44	189	0.22	851	1.01	86.6
45	148	0.18	662	0.79	72.6
46	128	0.15	514	0.61	67.0
47	99	0.12	386	0.46	55.3
48	79	0.09	287	0.34	47.0
49	64	0.08	208	0.25	40.5
50	49	0.06	144	0.17	32.9
51	34	0.04	95	0.11	24.3
52	21	0.02	61	0.07	15.9
53	13	0.02	40	0.05	10.4
54	11	0.01	27	0.03	9.3
55	5	0.01	16	0.02	4.5
56	4	0.00	11	0.01	3.8
57	2	0.00	7	0.01	2.0
58	1	0.00	5	0.01	1.0
59	1	0.00	4	0.00	1.1
60	0	0.00	3	0.00	0.0
61	1	0.00	3	0.00	1.2
62	2	0.00	2	0.00	2.6

APPENDIX I

UPPER PYLE CANYON
SUMMARY STATISTICS
MARCH 1984 - MAY 1989

STATION - UPPER PYLE 50'
MONTHLY WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 3/1984 - 5/1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
1984	0.0	0.0	11.4	15.2	14.1	11.8	10.9	13.4	11.1	11.9	16.9	12.6	4925	13.01	7.50
# OBS	0	0	339	227	232	347	143	732	708	740	720	737			
1985	11.1	13.3	0.0	0.0	0.0	0.0	13.4	12.3	11.0	12.2	0.0	9.9	3691	11.82	7.03
# OBS	744	538	0	0	0	0	217	718	697	492	0	285			
1986	19.0	13.5	12.5	16.9	15.8	8.3	15.2	13.6	12.1	11.7	14.0	12.8	6946	13.96	9.25
# OBS	744	672	698	337	209	69	545	744	720	744	720	744			
1987	16.7	13.1	15.9	14.3	9.6	14.9	0.0	0.0	11.0	11.3	15.5	19.0	5706	14.78	9.78
# OBS	744	672	744	720	110	165	0	0	351	744	718	738			
1988	15.3	11.5	14.9	14.6	13.0	0.0	19.0	16.4	13.5	12.0	16.8	16.1	5836	14.95	8.73
# OBS	715	302	651	720	289	0	186	635	221	663	715	739			
1989	17.2	14.8	18.2	14.1	14.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3079	15.76	9.80
# OBS	465	540	724	720	630	0	0	0	0	0	0	0			
AVG	15.8	13.4	15.0	14.7	14.0	12.3	9.8	13.8	11.5	11.8	15.8	14.6	30183	14.07	8.88
SD	3.0	1.2	2.7	1.1	2.4	3.3	3.4	1.7	1.1	0.3	1.4	3.5			

STATION - UPPER PYLE 50'
DIURNAL WIND SPEEDS (MPH)
DATA PERIOD OF RECORD - 3/1984 - 5/1989

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	15.0	15.1	14.7	14.8	15.0	14.9	14.8	15.4	16.2	16.7	17.3	17.6	18.0	17.6	17.1	16.7	15.9	15.9	15.3	14.9	14.6	15.0	15.3	14.8	15.8
FEB	11.9	12.2	12.5	12.4	12.7	13.1	13.0	12.8	13.4	14.4	15.4	16.2	16.2	16.0	15.8	14.8	13.9	13.2	13.0	12.6	12.1	11.8	11.5	11.3	13.4
MAR	12.4	12.5	12.1	12.9	12.7	12.4	12.2	13.4	15.2	17.3	19.1	19.1	19.2	18.7	18.7	18.2	17.6	16.1	14.9	14.3	13.5	12.8	12.7	12.5	15.0
APR	12.2	11.7	11.5	11.7	11.3	11.3	12.0	13.9	15.5	17.5	18.0	18.3	18.0	17.6	18.0	18.2	17.6	16.6	15.5	14.6	13.8	13.1	12.4	12.4	14.7
MAY	11.6	10.6	10.0	10.0	10.7	10.6	11.6	13.0	14.4	16.5	16.7	16.9	17.7	18.0	18.0	17.8	17.9	17.5	14.9	12.9	12.3	12.4	12.6	12.1	14.0
JUN	10.1	9.8	10.2	11.0	12.3	12.7	13.1	14.0	14.1	13.9	13.2	13.5	14.4	12.8	12.8	14.2	15.1	12.8	11.2	11.3	11.3	10.2	10.3	9.9	12.3
JUL	13.5	13.7	12.8	13.2	13.9	14.0	15.0	15.7	15.0	14.9	14.1	13.3	13.1	14.0	15.5	17.2	19.2	19.0	17.0	15.7	15.2	14.2	13.9	13.6	14.9
AUG	13.3	12.9	13.1	12.3	11.6	10.8	11.7	12.5	13.3	13.6	13.6	13.0	13.4	14.1	15.1	16.2	17.0	16.9	15.8	15.4	14.6	14.8	13.9	13.1	13.8
SEP	9.9	10.0	10.0	9.8	9.3	8.9	8.8	10.1	10.9	12.4	13.3	14.2	13.4	13.9	13.5	13.4	13.4	12.5	12.4	12.2	12.0	11.0	10.3	10.4	11.5
OCT	9.8	9.6	9.1	9.1	9.1	9.2	9.2	9.9	11.2	13.2	14.9	15.9	16.4	16.4	16.1	15.1	13.3	12.2	11.4	10.7	10.5	10.5	10.3	9.9	11.8
NOV	14.1	14.4	14.5	15.1	15.2	15.0	14.7	15.5	16.2	17.3	18.4	19.3	19.3	18.6	17.9	16.3	15.1	14.4	14.6	14.8	14.8	14.5	14.5	14.6	15.8
DEC	14.2	14.7	14.0	14.5	14.3	14.5	14.6	15.1	15.2	15.7	16.1	16.7	16.8	16.2	15.6	14.9	13.8	13.3	13.4	13.2	13.0	13.4	13.8	13.9	14.6
AUG SPD	12.5	12.5	12.3	12.4	12.4	12.3	12.4	13.3	14.2	15.4	16.2	16.6	16.7	16.5	16.4	16.1	15.6	14.8	14.1	13.6	13.2	13.0	12.8	12.5	14.1

STATION - UPPER PYLE 50'
WIND ROSE FOR ALL DATA - 29082 OBSERVATIONS
DATA PERIOD OF RECORD - 3/1984 - 5/1989

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	6.0	4.1	4.9	4.6	3.3	2.0	0.9	0.6	0.5	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	27.6	15.8
NNE	6.2	2.1	2.1	1.5	1.0	0.7	0.5	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	12.9
NE	1.0	0.6	0.6	0.5	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	3.3	13.2
ENE	0.6	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	1.5	11.1
E	0.7	0.4	0.3	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	0.0	1.6	10.4
ESE	0.4	0.1	0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	14.3
SE	1.0	0.3	0.3	0.4	0.5	0.7	0.7	0.6	0.5	0.5	0.4	0.2	0.1	0.0	0.0	0.0	0.0	6.1	23.4
SSE	1.8	0.8	0.8	0.9	0.8	0.8	0.7	0.7	0.6	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	8.8	20.2
S	4.6	1.9	1.6	1.1	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	11.7
SSW	3.9	1.2	0.7	0.3	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	6.2	8.9
SW	3.0	0.7	0.3	0.1	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	4.4	9.2
WSW	0.9	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	0.0	0.0	0.0	1.3	8.1
W	0.8	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	0.0	1.4	9.1
WNW	0.6	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	0.0	1.1	9.6
NW	0.9	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	0.0	0.0	2.1	12.5
NNW	1.3	1.1	1.1	1.0	0.7	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	15.3
CALM																		1.8	
TOTAL %	35.6	14.3	13.7	11.3	7.8	5.5	3.7	2.8	2.1	1.4	0.9	0.5	0.3	0.2	0.1	0.0	0.0	100.0	14.2

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 - UPPER PYLE 50'
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY
DATA PERIOD OF RECORD - 3/1984 - 5/1989
NORMALIZATION PERIOD - ONE YEAR
AVERAGE WIND SPEED FOR PERIOD: 14.1 MPH
NORMALIZED AVAILABLE ENERGY: 2903.1 KWH/M**2/YEAR
TOTAL HOURS OBSERVED: 30183

SPD MPH	HOURS/ PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	NORMALIZED AVAIL. ENERGY KWH/M**2/YEAR
0	528	1.75	30183	100.00	0.0
1	635	2.10	29655	98.25	0.0
2	765	2.53	29020	96.15	0.1
3	948	3.14	28255	93.61	0.4
4	1051	3.48	27307	90.47	1.0
5	1157	3.83	26256	86.99	2.1
6	1137	3.77	25099	83.16	3.5
7	1208	4.00	23962	79.39	5.9
8	1339	4.44	22754	75.39	9.8
9	1432	4.74	21415	70.95	14.9
10	1454	4.82	19983	66.21	20.7
11	1426	4.72	18529	61.39	27.0
12	1477	4.89	17103	56.66	36.4
13	1447	4.79	15626	51.77	45.3
14	1408	4.66	14179	46.98	55.0
15	1384	4.59	12771	42.31	66.5
16	1279	4.24	11387	37.73	74.6
17	1132	3.75	10108	33.49	79.2
18	1067	3.54	8976	29.74	88.7
19	927	3.07	7909	26.20	90.6
20	833	2.76	6982	23.13	94.9
21	701	2.32	6149	20.37	92.5
22	673	2.23	5448	18.05	102.1
23	591	1.96	4775	15.82	102.4
24	502	1.66	4184	13.86	98.9
25	412	1.37	3682	12.20	91.7
26	401	1.33	3270	10.83	100.4
27	332	1.10	2869	9.51	93.1
28	290	0.96	2537	8.41	90.7
29	289	0.96	2247	7.44	100.4
30	265	0.88	1958	6.49	101.9
31	231	0.77	1693	5.61	98.0
32	223	0.74	1462	4.84	104.1
33	186	0.62	1239	4.10	95.2
34	151	0.50	1053	3.49	84.6
35	129	0.43	902	2.99	78.8
36	144	0.48	773	2.56	95.7
37	100	0.33	629	2.08	72.2
38	98	0.32	529	1.75	76.6
39	83	0.27	431	1.43	70.1
40	64	0.21	348	1.15	58.4
41	59	0.20	284	0.94	57.9
42	41	0.14	225	0.75	43.3
43	37	0.12	184	0.61	41.9
44	24	0.08	147	0.49	29.1
45	19	0.06	123	0.41	24.7
46	24	0.08	104	0.34	33.3
47	15	0.05	80	0.27	22.2
48	19	0.06	65	0.22	29.9
49	15	0.05	46	0.15	25.1
50	6	0.02	31	0.10	10.7
51	7	0.02	25	0.08	13.2
52	2	0.01	18	0.06	4.0
53	5	0.02	16	0.05	10.6
54	1	0.00	11	0.04	2.2
55	0	0.00	10	0.03	0.0
56	3	0.01	10	0.03	7.5
57	3	0.01	7	0.02	7.9
58	1	0.00	4	0.01	2.8
59	0	0.00	3	0.01	0.0
60	0	0.00	3	0.01	0.0
61	1	0.00	3	0.01	3.2
62	1	0.00	2	0.01	3.4
63	0	0.00	1	0.00	0.0
64	0	0.00	1	0.00	0.0
65	0	0.00	1	0.00	0.0
66	0	0.00	1	0.00	0.0
67	0	0.00	1	0.00	0.0
68	0	0.00	1	0.00	0.0
69	0	0.00	1	0.00	0.0
70	0	0.00	1	0.00	0.0
71	0	0.00	1	0.00	0.0
72	0	0.00	1	0.00	0.0
73	1	0.00	1	0.00	5.5