Quinhagak, Alaska Wind Resource Report

Report prepared by: Douglas Vaught, V3 Energy LLC, Eagle River, AK
Date of report: November 21, 2006

Photo: Doug Vaught

Quinhagak Meteorological Tower Data Synopsis

Wind power class (measured to date)	Class 3 – Fair
Channel 1 average wind speed	6.41 m/s (at 30 meters)
Maximum wind speed (10 min. avg)	27.2 m/s
Mean wind power density (50 meters)	340 W/m^2
Roughness Class	2.14 (few trees)
Power law exponent	0.188 (moderate wind shear)
Data start date	October 23, 2005
Most recent data date	October 17, 2006

Community Profile

Location:

Quinhagak is on the Kanektok River on the east shore of Kuskokwim Bay, less than a mile from the Bering Sea coast. It lies 71 miles southwest of Bethel at approximately 59.748890° North Latitude and

161.915830° West Longitude. (Sec. 17, T005S, R074W, Seward Meridian.) Quinhagak is located in the Bethel Recording District. The area encompasses 4.7 sq. miles of land and 0.6 sq. miles of water.

History:
The Yup'ik name is Kuinerraq, meaning "new river channel." Quinhagak is a long-established village whose origin has been dated to 1,000 A.D. It was the first village on the lower Kuskokwim to have sustained contact with whites. Gavril Sarichev reported the village on a map in 1826. After the purchase of Alaska in 1867, the Alaska Commercial Co. sent annual supply ships to Quinhagak with goods for Kuskokwim River trading posts. Supplies were lightered to shore from the ship, and stored in a building on Warehouse Creek. A Moravian Mission was built in 1893. There were many non-Natives in the village at that time; most waiting for boats to go upriver. In 1904 a mission store opened, followed by a post office in 1905 and a school in 1909. Between 1906 and 1909, over 2,000 reindeer were brought in to the Quinhagak area. They were managed for a time by the Native-owned Kuskokwim Reindeer Company, but the herd had scattered by the 1950s. In 1915 the Kuskokwim River was charted, so goods were barged directly upriver to Bethel. In 1928, the first electric plant opened; the first mail plane arrived in 1934. The City was incorporated in 1975.

Culture:
The community is primarily Yup'ik Eskimos who fish commercially and are active in subsistence food gathering. The sale, importation or possession of alcohol is banned in the village.

Economy:
Most of the employment is with the school, government services or commercial fishing. Trapping, basket weaving, skin sewing and ivory carving also provide income. Subsistence remains an important part of the livelihood; seal and salmon are staples of the diet. Eighty-three residents hold commercial fishing permits for salmon net and herring roe fisheries. Coastal Villages Seafood LLC processes halibut and salmon in Quinhagak.

Facilities:
All services are provided by the Native Village of Kwinhagak, under agreement with the City. Water is derived from a well near the Kanektok River. The water treatment plant, storage tank, and waterline were relocated in 1997 as part of a new flush/haul system for the community. Forty homes are now served by the new system, with water delivery and tank haul. An old BIA building has been renovated as a new washeteria and health clinic. The school and washeteria are connected directly to the water plant. Eighty-nine households still haul water and use honeybuckets, and funds are being appropriated to expand the flush/haul system. Major improvements continue.

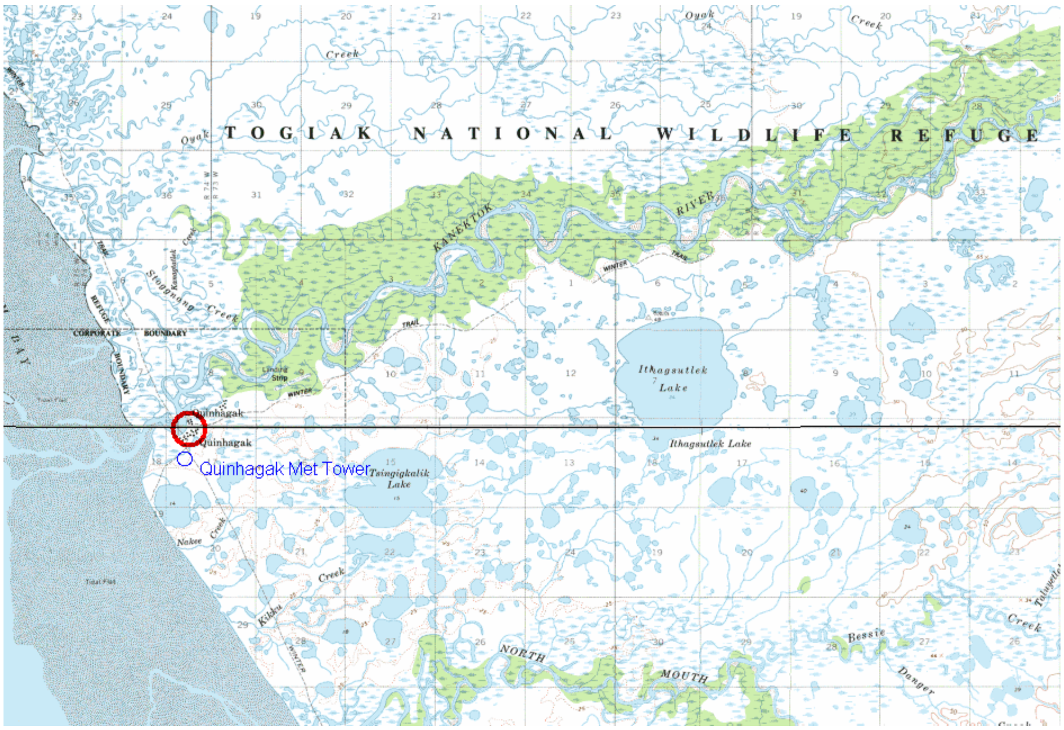
Transportation:
Quinhagak relies heavily on air transportation for passenger mail and cargo service. A State-owned 2,600' long by 60' wide gravel airstrip is available. A longer runway is nearly complete, which will enable direct flights to Anchorage. Float planes land on the Kanektok River. A harbor and dock were recently completed. Barges deliver heavy goods at least twice a year. Boats, ATVs, snow machines, and some vehicles are used for local transportation. Winter trails are marked to Eek and Goodnews Bay.

Climate:
Quinhagak is located in a marine climate. Precipitation averages 22 inches, with 43 inches of snowfall annually. Summer temperatures average 41 to 57 degrees F, winter temperatures average 6 to 24 F. Extremes have been measured from 82 to -34 F.

(Above information from State of Alaska Department of Commerce, Community, and Economic Development website, http://www.dced.state.ak.us/)

Meteorological Tower Site Information

Site number	0022
Site Description	Quinhagak – Alaska Village Electric Coop, Inc. (AVEC)
Latitude/longitude	N 059° 44.646'; W 161° 55.030'
Site elevation	3 meters
Datalogger type	NRG Symphonie
Tower type	NRG 30-meter tall tower, 152 mm (6-in) diameter



Met Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.765	0.35	NE
2	NRG #40 anemometer	30 m (B)	0.765	0.35	SW
3	NRG #40 anemometer	20 m	0.765	0.35	SW
7	NRG #200P wind vane	25 m	0.351	220	NE
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Data Quality Control Summary

Data was filtered to remove presumed icing events that yield false zero wind speed data. Data that met the following criteria were filtered: wind speed < 1 m/s, wind speed standard deviation = 0, and temperature < 3 °C. Other obvious icing data was removed even if it did not meet the above criteria. A strange offset failure in the temperature sensor and/or data logger occurred on July 7. Subsequent temperature data was corrected with an estimated offset. After removal of icing event data, a gap fill routine was run to derive a complete data set for subsequent analysis.

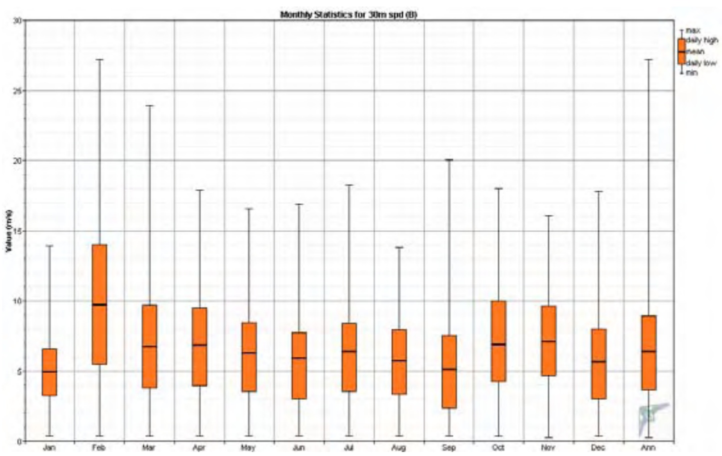
Year	Month	Ch 1 anem Records	Ch 1 anem Recovery Rate (%)	Ch 2 anem Records	Ch 2 anem Recovery Rate (%)	Ch 3 anem Records	Ch 3 anem Recovery Rate (%)
2005	Oct	1,234	100.0	1,234	100.0	1,234	100.0
2005	Nov	3,435	79.5	3,854	89.2	3,852	89.2
2005	Dec	4,148	92.9	3,985	89.3	4,464	100.0
2006	Jan	4,464	100.0	4,464	100.0	4,464	100.0
2006	Feb	4,032	100.0	4,032	100.0	4,032	100.0
2006	Mar	4,464	100.0	4,464	100.0	4,464	100.0
2006	Apr	4,320	100.0	4,320	100.0	4,320	100.0
2006	May	4,464	100.0	4,464	100.0	4,464	100.0
2006	Jun	4,320	100.0	4,320	100.0	4,320	100.0
2006	Jul	4,464	100.0	4,464	100.0	4,464	100.0
2006	Aug	4,464	100.0	4,464	100.0	4,464	100.0
2006	Sep	4,320	100.0	4,320	100.0	4,320	100.0
2006	Oct	2,376	100.0	2,376	100.0	2,376	100.0
All data		50,505	97.4	50,761	97.9	51,238	98.8

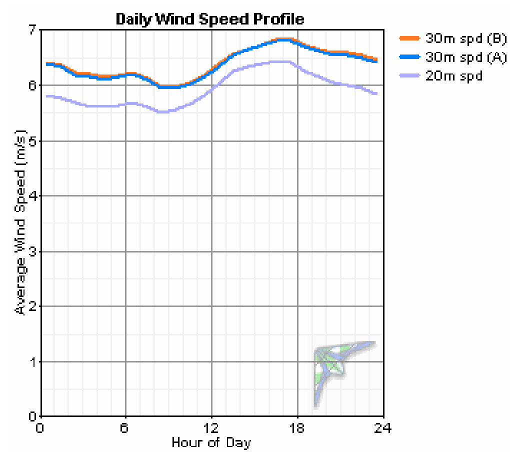
Year	Month	Ch 7 vane Records	Ch 7 vane Recovery Rate (%)	Ch 9 temp Records	Ch 9 temp Recovery Rate (%)
2005	Oct	1,240	100.0	1,239	100.0
2005	Nov	3,394	78.6	4,320	100.0
2005	Dec	3,374	75.6	4,464	100.0
2006	Jan	4,464	100.0	4,464	100.0
2006	Feb	3,699	91.7	4,032	100.0
2006	Mar	4,464	100.0	4,464	100.0
2006	Apr	3,907	90.4	4,320	100.0
2006	May	4,464	100.0	4,464	100.0
2006	Jun	4,320	100.0	4,320	100.0
2006	Jul	4,464	100.0	4,464	100.0
2006	Aug	4,464	100.0	4,464	100.0
2006	Sep	4,320	100.0	4,320	100.0
2006	Oct	2,376	100.0	2,376	100.0
All data		48,950	94.4	51,711	99.8

Measured Wind Speeds

The Channel 1 (30-meter [A]) anemometer wind speed average for the reporting period is 6.37 m/s. The Channel 2 (30-meter [B]) anemometer wind speed average is 6.41 m/s and the Channel 3 (20-meter) anemometer wind speed average for the reporting period is 5.92 m/s. The daily wind speed profile indicates that the lowest winds of the day occur in the morning at about 3 a.m. to 9 a.m. and the highest winds of the day occur in the afternoon and early evening hours of about 1 p.m. to 8 p.m.

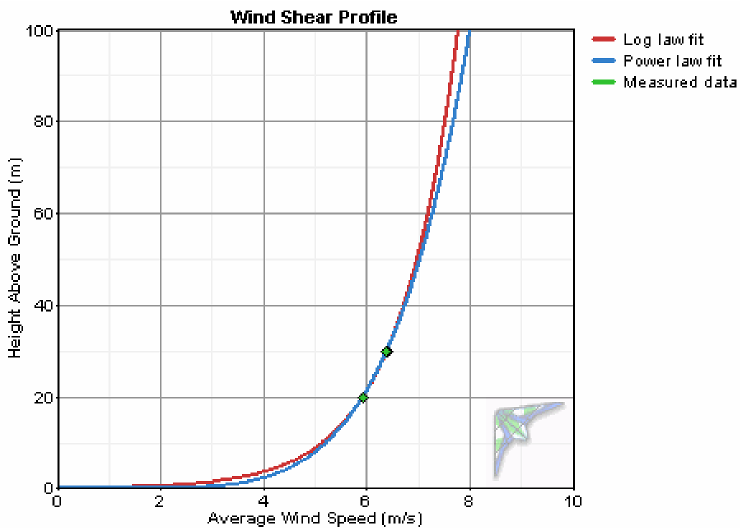
		30 m (B) anemeter					30 m (A) anem.		20 m anemometer	
Year	Month	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)	Mean (m/s)	Max (m/s)
2005	Oct	5.61	16.1	2.81	2.09	6.33	5.67	16.1	5.33	14.8
2005	Nov	7.10	16.1	3.33	2.25	8.01	7.09	16.1	6.59	15.4
2005	Dec	5.69	17.8	2.39	2.50	6.40	5.72	17.5	5.08	16.9
2006	Jan	4.95	13.9	2.49	2.10	5.60	4.91	13.8	4.74	13.9
2006	Feb	9.70	27.2	4.79	2.12	10.94	9.58	27.0	9.01	25.5
2006	Mar	6.74	23.9	3.83	1.81	7.57	6.74	23.7	6.33	23.0
2006	Apr	6.84	17.9	3.23	2.24	7.73	6.84	17.8	6.40	17.3
2006	May	6.26	16.6	2.94	2.25	7.07	6.26	16.8	5.79	16.1
2006	Jun	5.90	16.9	2.78	2.26	6.67	5.92	16.7	5.56	15.8
2006	Jul	6.39	18.3	2.89	2.33	7.20	6.28	16.2	5.83	15.6
2006	Aug	5.70	13.8	2.81	2.15	6.45	5.56	13.8	5.16	13.2
2006	Sep	5.10	20.1	2.95	1.84	5.76	5.08	20.1	4.56	18.9
2006	Oct	7.62	18.0	3.99	1.97	8.58	7.58	17.9	6.97	16.9
All data		**6.41**	27.2	3.43	1.96	7.23	**6.37**	27.0	**5.92**	25.5

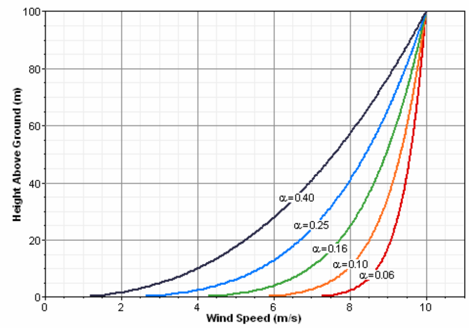


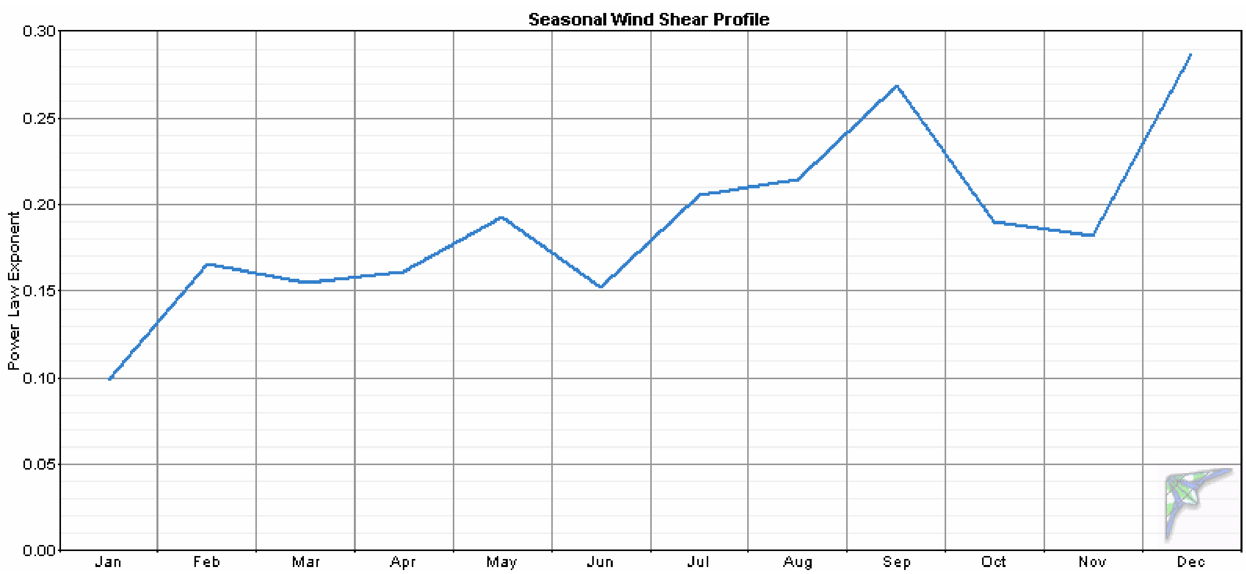


Wind Shear Profile

The power law exponent was calculated at 0.188, indicating moderate wind shear at the Quinhagak met tower test site. The practical application of this data is that there is an advantage of increased power production with increased turbine tower height. A tower height/energy production cost tradeoff study is recommended. Note that some of the observed shear may be due to the presence of tanks and other structures near the met tower test site and would not be indicative of general wind shear conditions in the Quinhagak area.

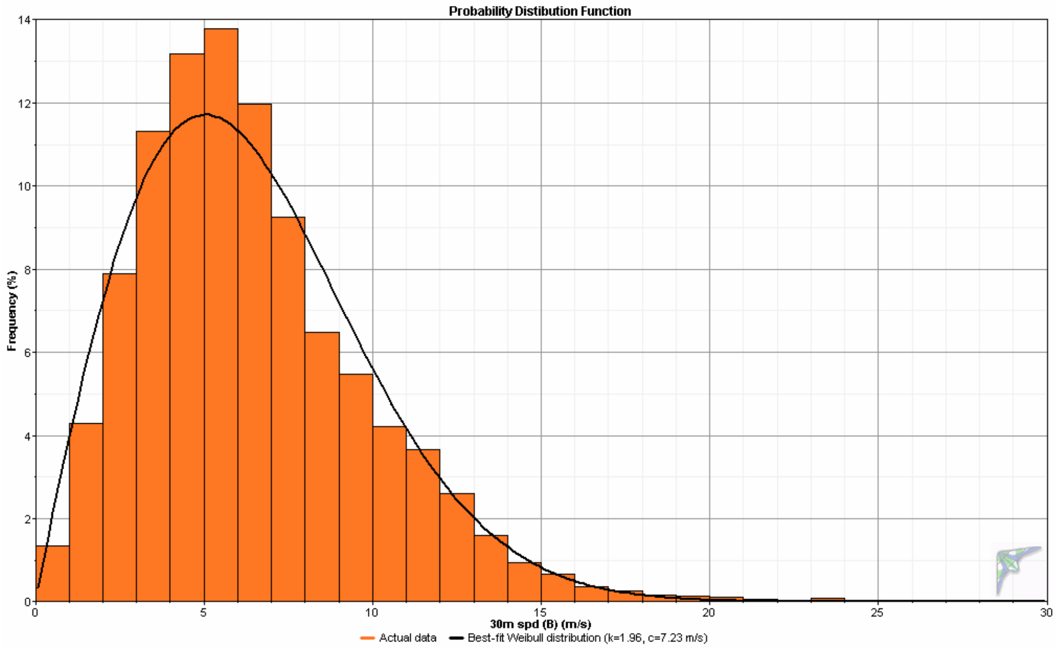






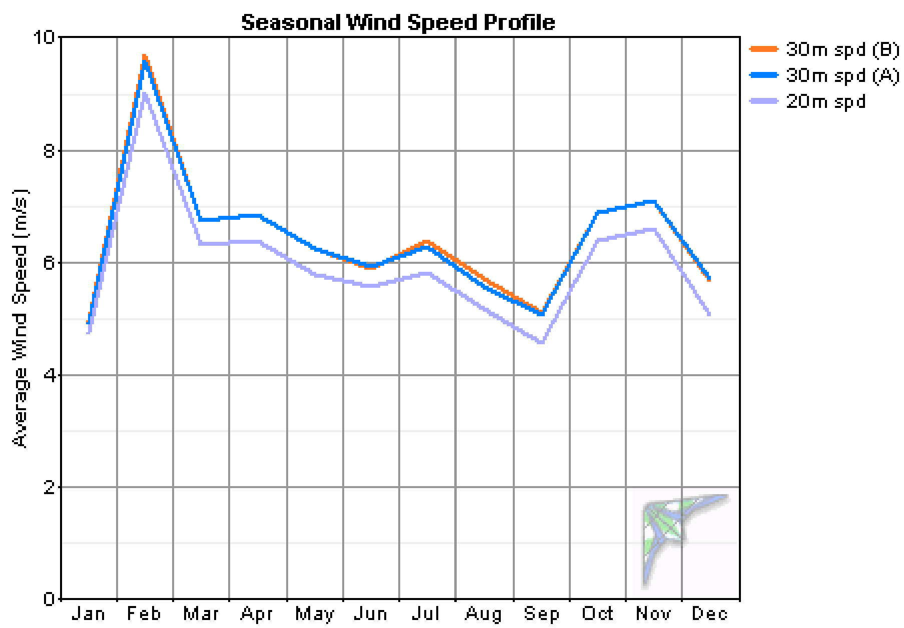
Probability Distribution Function

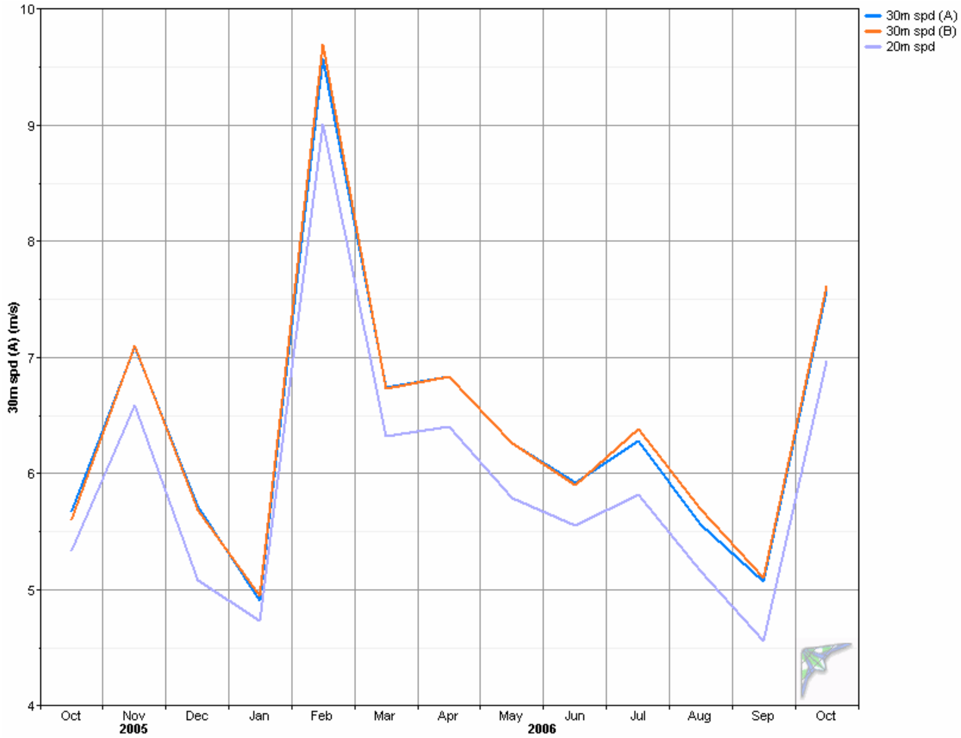
The graphed probability distribution function provides a visual indication of measured wind speeds in one meter per second "bins." Note that most wind turbines do not begin to generate power until the wind speed at hub height reached 4 m/s; using this criteria, 28% of Quinhagak's winds are calm (less than 4 m/s). The black line in the graph is a best fit Weibull approximation of the wind speed distribution. At the 30 meter level, the Weibull parameters are k = 1.96 (indicates a relatively narrow distribution of wind speeds) and c = 7.23 m/s (scale factor for the Weibull distribution).

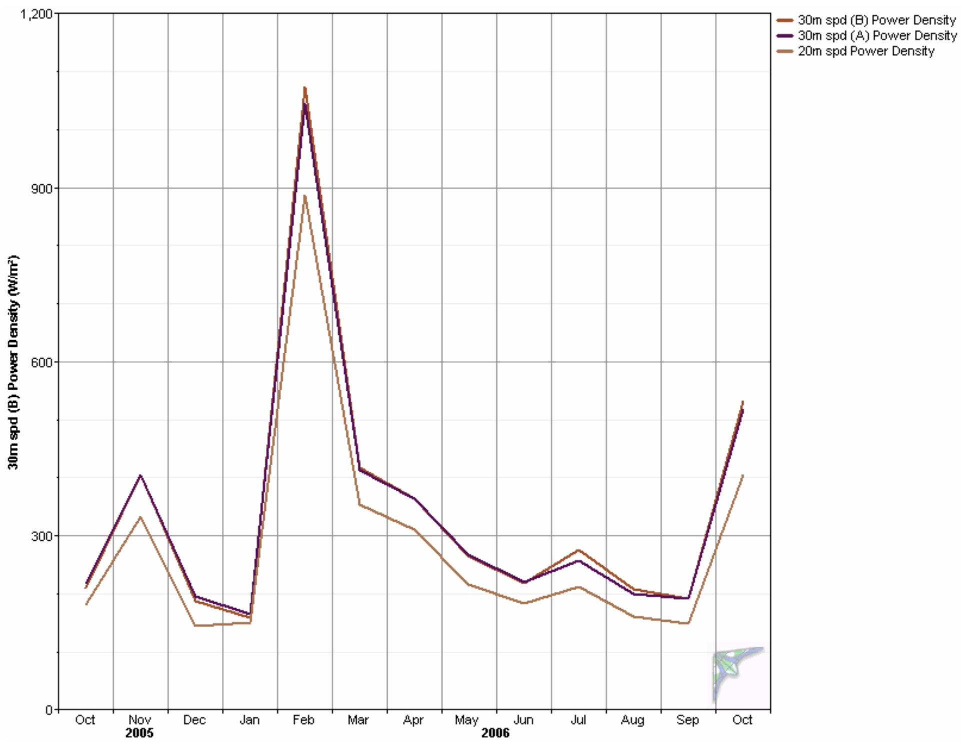


Time Series of Wind Speed Monthly Averages

The average wind speed at 30 meters for the measurement period is 6.41 m/s. Typically, the highest wind speeds occur during the winter months of October through March with the lowest winds during the summer months of May through September. The unusually low winds measured in January 2006 were due to a persistent high pressure system over Alaska that month that yielded calm winds and extremely cold weather Statewide. January 2006 was then followed by an extremely windy February.



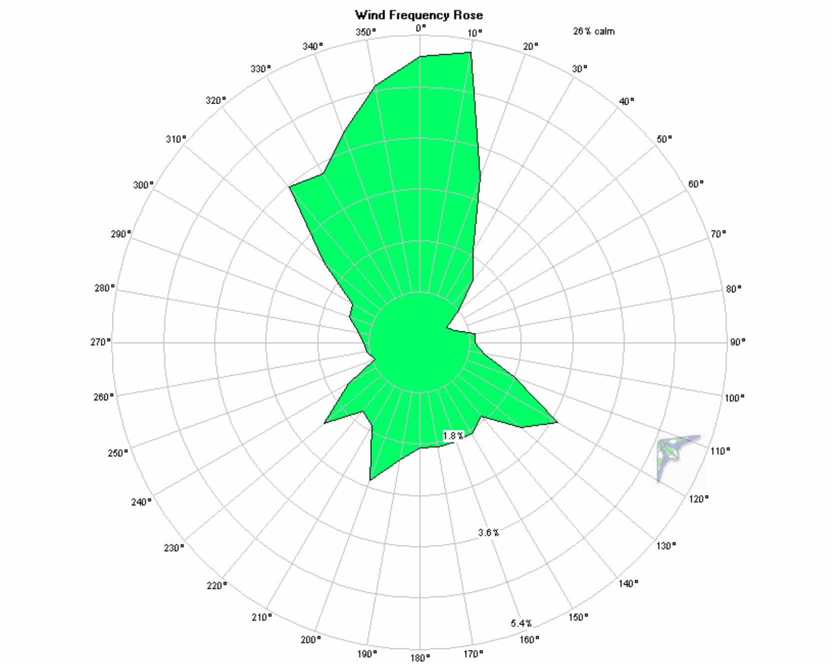




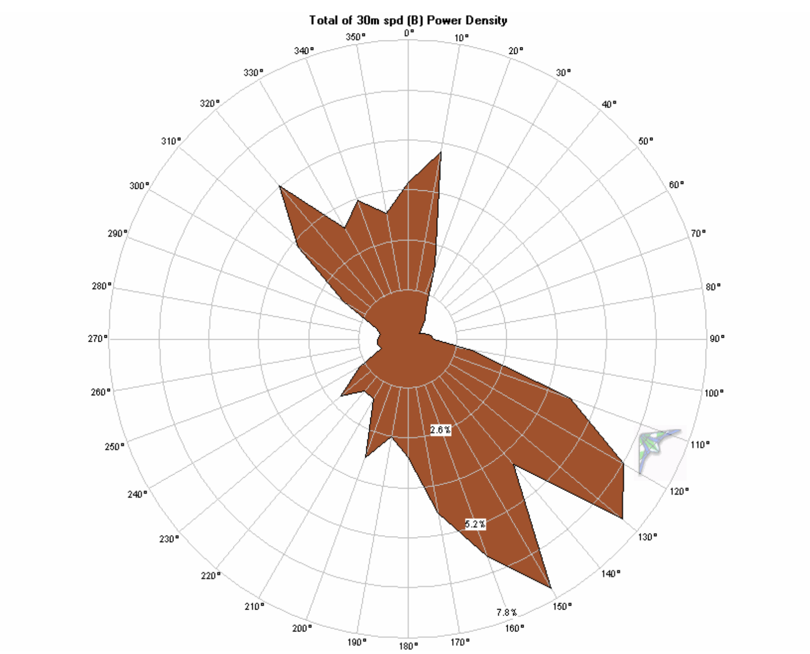
Wind Roses

Quinhagak winds are directional from the north and south with a lesser south to southeast wind component. Interestingly though, the power producing winds (second wind rose below) are more strongly oriented southeast and to a lesser extent northwest. The practical use of this information is that wind turbines should be located with due consideration for clear zones to the northwest, north, and southeast to minimize wind shear and turbulence. Several turbines could be located relatively close together along an alignment perpendicular to the northwest-southeast power wind directions.

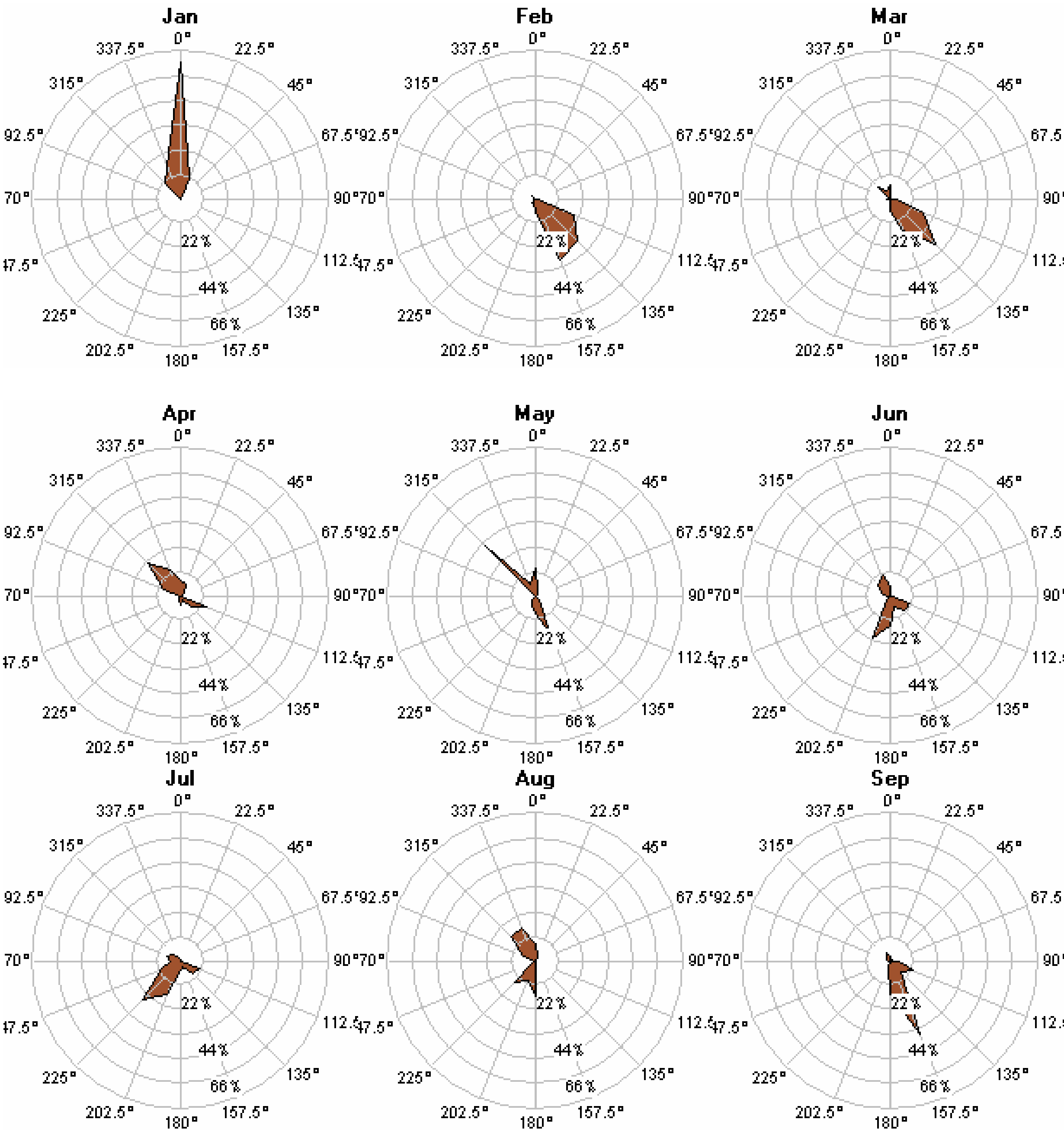
Wind frequency rose (25 meters)

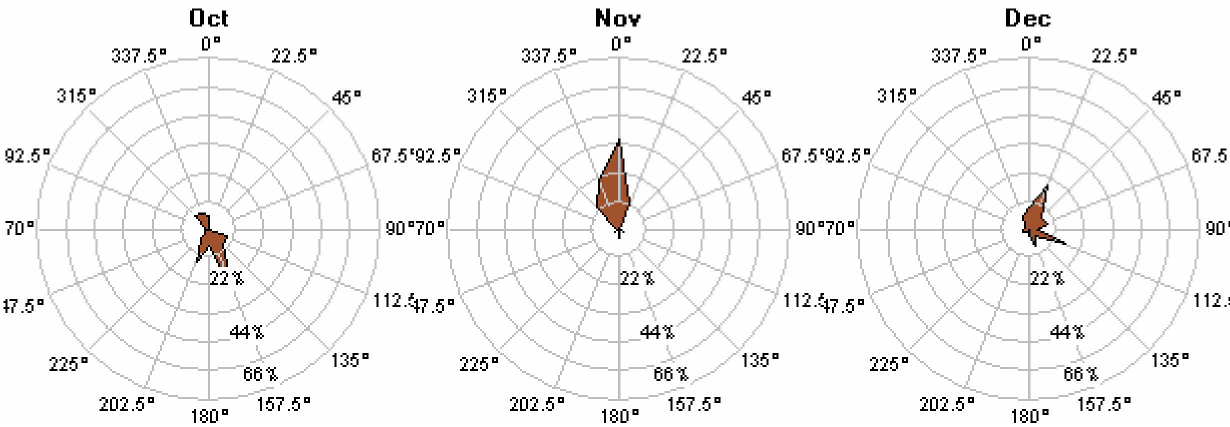


Wind power density rose (25 meters)



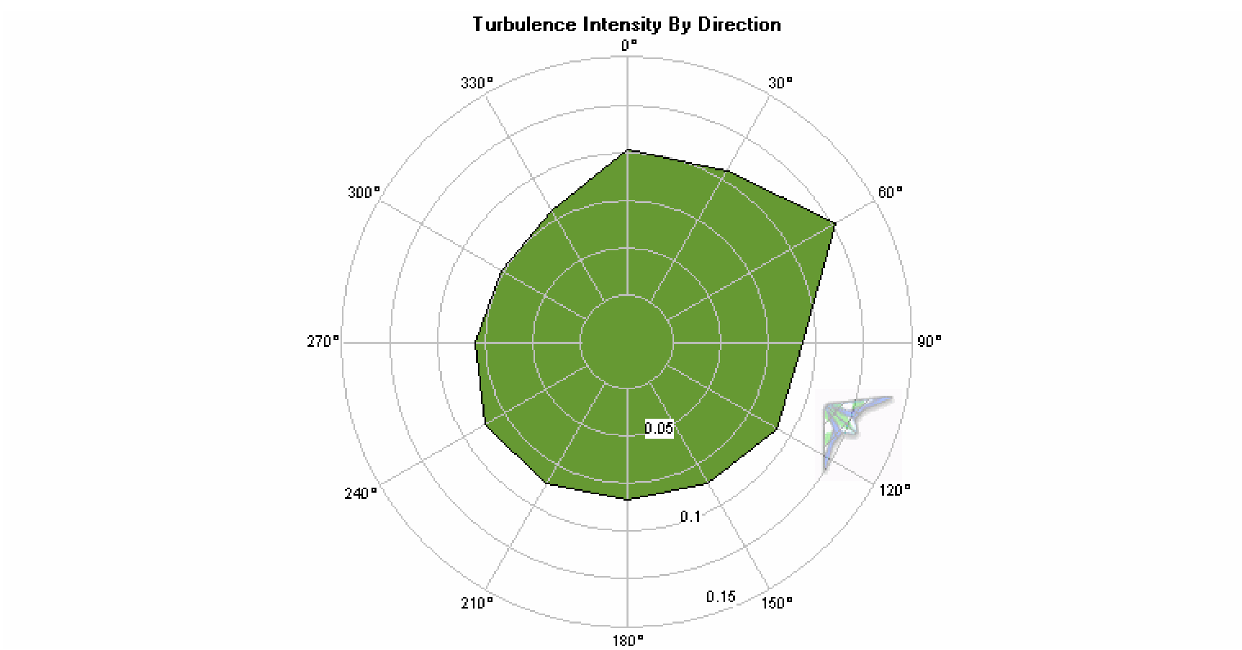
Monthly wind power density roses; scale is common

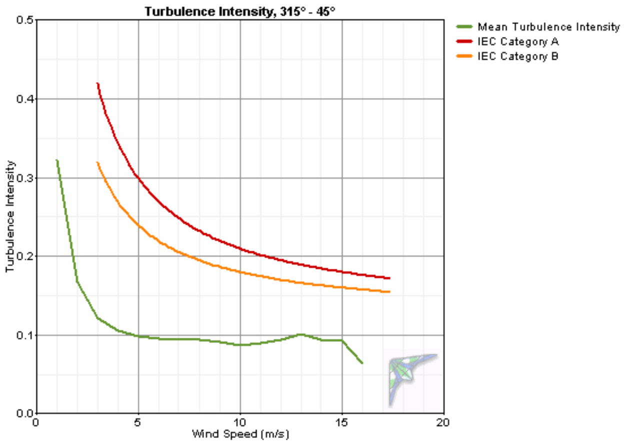


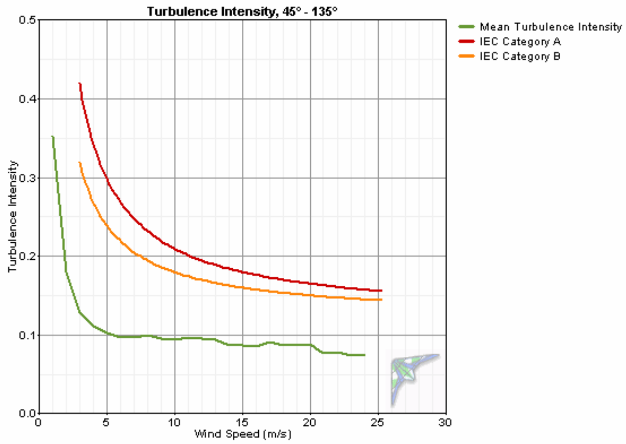


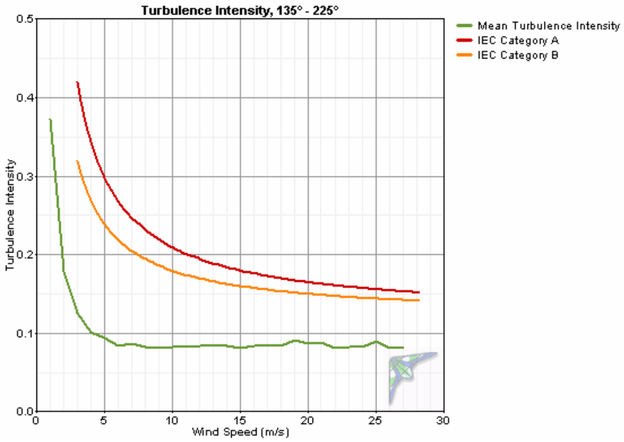
Turbulence Intensity

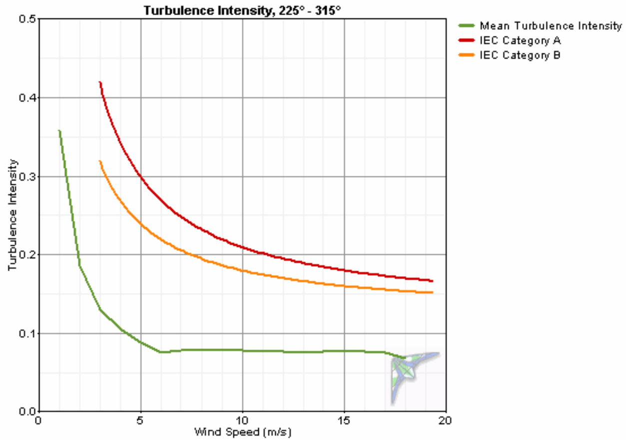
The turbulence intensity is quite acceptable for the north-northeast and southeast wind directions, with mean turbulence intensity (TI) of 0.0912, indicating relatively smooth air. This TI is calculated with a threshold wind speed of 4 m/s (only wind speeds exceeding 4 m/s are considered). The spike of relatively high turbulence to the NE is inconsequential as essentially no power producing winds blow from this direction. As indicated below, turbulence at the Quinhagak project test site is well within International Energy Agency (IEA) Category A and B acceptability standards.











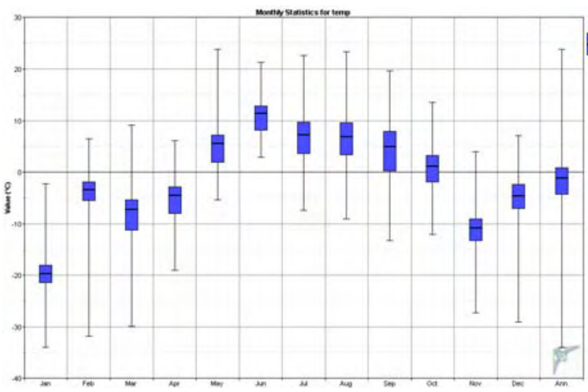
Air Temperature and Density

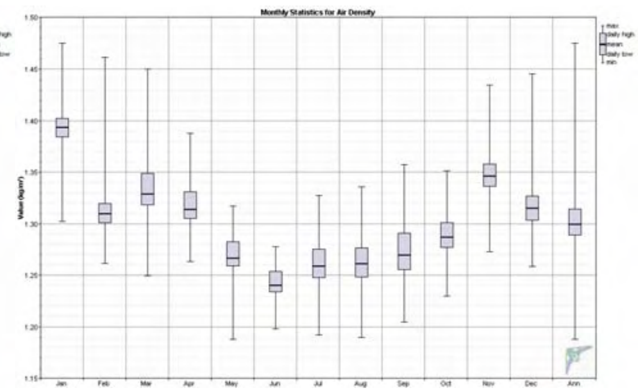
Over the reporting period, Quinhagak had an average temperature of -1.2 degrees C. The minimum recorded temperature during the test period was -34.0° C and the maximum temperature 28.0° C. Note that on July 7, the temperature sensor experienced an unusual fault in that although it continues to record what appear to be normal variations of temperature, the offset changed by approximately 30° C. This offset change was added to subsequent temperature data in order to produce a best likely temperature record of Quinhagak, but because the nature of the fault is unknown, the corrective measure may be faulty to some extent.

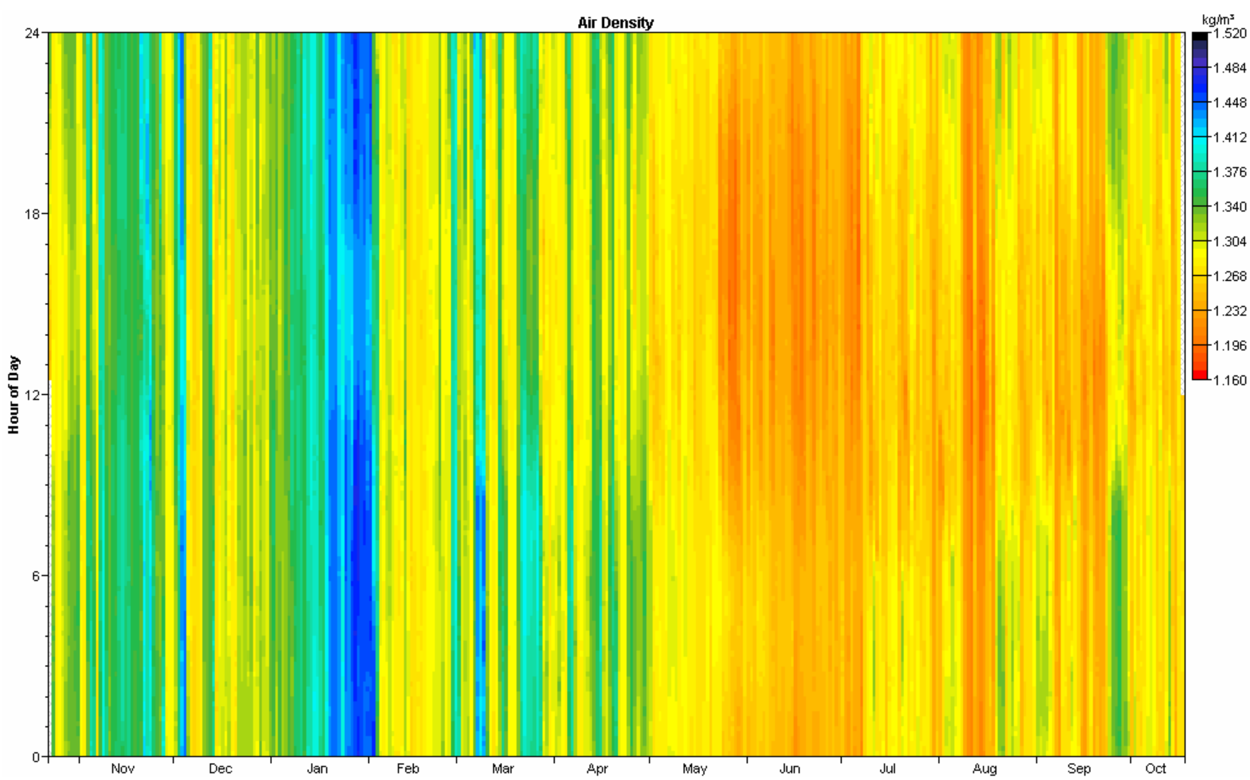
Consequent to the rather cool average temperature in Quinhagak, air density is rather high, boosting the nominal performance of wind turbines. The average air density in Quinhagak is 1.299 kg/m^3, approximately six percent higher than standard atmospheric air density of 1.225 kg/m^3. This density variance from standard *is* accounted for in turbine performance predictions in this report.

		Temperature				Density	
Year	Month	Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Mean (kg/m³)	Max (kg/m³)
2005	Oct	-3.7	-12.1	9.4	4.6	1.309	1.351
2005	Nov	-10.9	-27.2	4.0	6.9	1.346	1.434

2005	Dec	-4.6	-29.1	7.1	7.7	1.315	1.445
2006	Jan	-19.7	-34.0	-2.3	8.0	1.393	1.475
2006	Feb	-3.5	-31.8	6.5	8.6	1.309	1.462
2006	Mar	-7.3	-29.9	9.1	8.6	1.328	1.450
2006	Apr	-4.5	-19.0	6.1	5.5	1.314	1.388
2006	May	5.5	-5.4	23.8	5.4	1.266	1.317
2006	Jun	11.4	2.9	21.3	3.3	1.240	1.278
2006	Jul	7.2	-7.4	22.7	5.1	1.259	1.327
2006	Aug	6.8	-9.1	23.3	7.0	1.261	1.336
2006	Sep	4.9	-13.3	19.6	7.3	1.269	1.357
2006	Oct	3.8	-8.5	13.6	3.8	1.274	1.333
All data		**-1.2**	-34.0	23.8	11.0	**1.299**	1.475



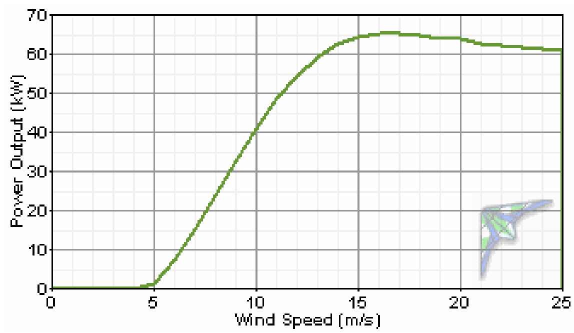




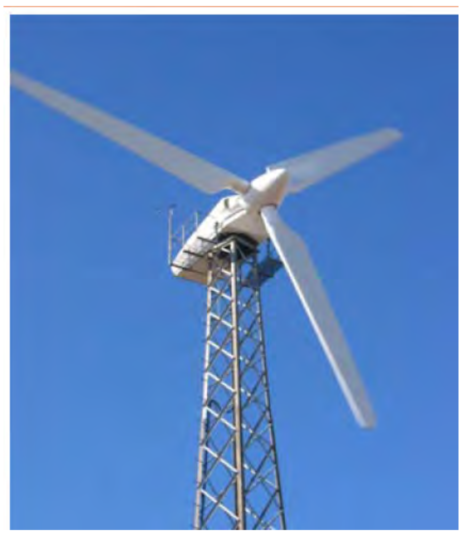
Wind Turbine Performance

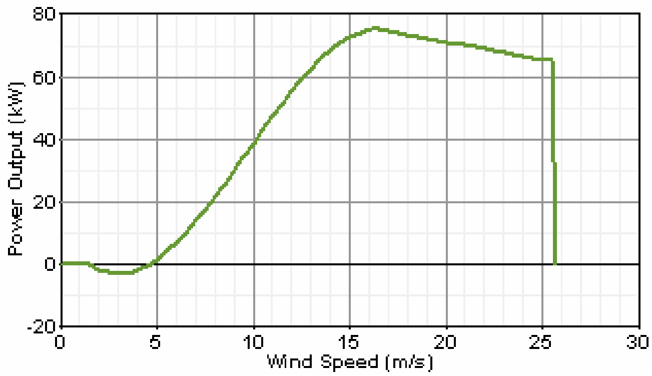
The turbine performance predictions noted below are based on 90% turbine availability with an expected 10% downtime for maintenance, repairs and/or other outages. Note that these performance estimates were predicted with use of Windographer® wind analysis software; power curves provided by manufacturers are not independently verified and are assumed to be accurate. The power curves are presented for a standard air density of 1.225 kg/m^3 at 20° C; however the predictions of power production are density compensated by multiplying the standard density power output by the ratio of the measured air density to standard air density.

Entegrity eW-15: 65 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Entegrity Energy Systems)

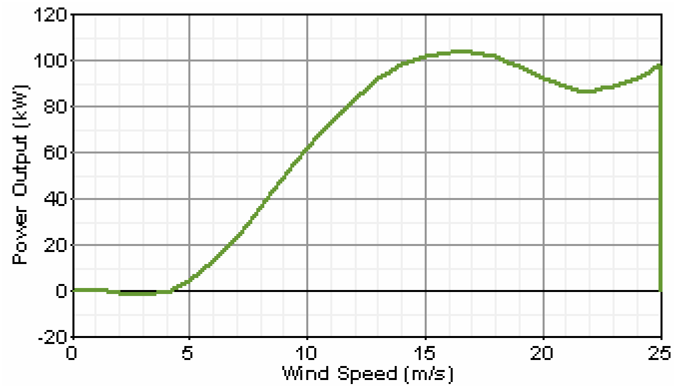


Vestas V15: 75 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Powercorp Alaska LLC)

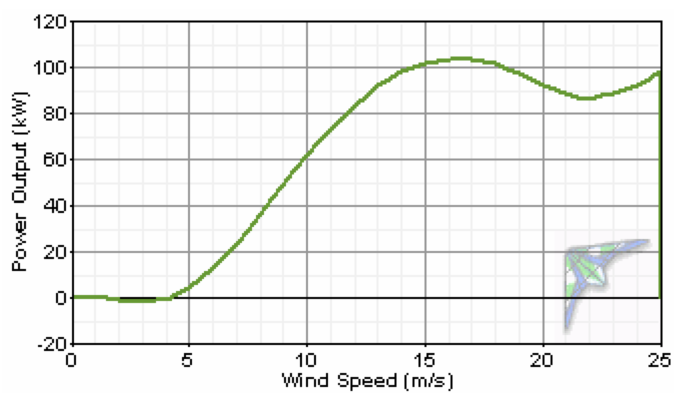




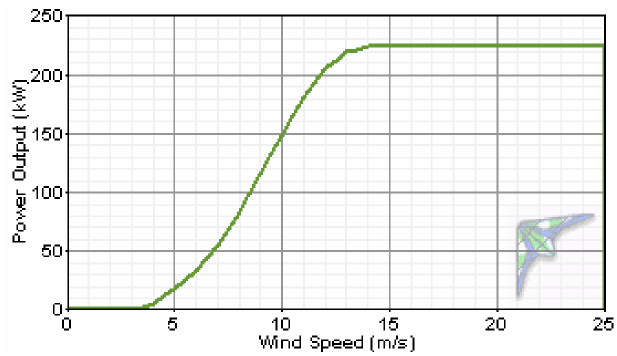
Northwind 100/19: 100 kW rated power output, 19 meter rotor, stall-controlled (power curve provided by Northern Power Systems)



Northwind 100/20: 100 kW rated power output, 20 meter rotor (19 meter rotor blades with 0.6 meter blade root extensions added), stall-controlled (power curve provided by Northern Power Systems)



Vestas V27: 225 kW rated power output, 27 meter rotor, pitch-controlled (power curve provided by Alaska Energy Authority)


Power Output (kW)
250
200
150
100
50
0
0
5
10
15
20
25
Wind Speed (m/s)

Turbine Power Output Comparison

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Power Output (kW)	Annual Energy Output (kWh/yr)	Average Capacity Factor (%)
Entegrity eW-15 60 Hz	25	6.18	27.62	2.79	15.3	120,342	23.5
Entegrity eW-15 60 Hz	31	6.41	25.44	3.37	16.6	130,672	25.5
NW 100/19	25	6.18	28.29	1.67	21.1	166,035	21.1
NW 100/19	32	6.44	25.68	2.12	23.2	182,942	23.2
NW 100/20	25	6.18	28.06	2.99	23.9	188,557	23.9
NW 100/20	32	6.44	25.55	3.58	26.3	207,100	26.3
Vestas V15	25	6.18	35.74	1.54	14.1	111,276	18.8
Vestas V15	31	6.41	33.01	1.91	15.5	122,223	20.7
Vestas V27	32	6.44	9.55	2.20	62.5	492,778	27.8
Vestas V27	42	6.77	8.69	2.72	68.9	543,432	30.6
Fuhrländer FL100	35	6.55	6.21	3.51	34.8	274,129	27.8

Capacity Factor <20%
Capacity Factor >20%, <30%
Capacity Factor >30%, <40%
Capacity Factor >40%, <50%
Capacity Factor >50%

Note: Annual energy output assumes a turbine availability of 90% (100% turbine output x 0.90)

Annual Fuel Cost Avoided for Energy Generated by Wind Turbine vs. Diesel Generator

Turbine	Annual Energy Output (kW-hr/yr)	Fuel Quantity Avoided (gallons)	Fuel Price (USD/gallon) $1.75	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	Turbine Hub Height (m)
Entegrity eW-15										
	120,342	8,914	$15,600	$17,828	$20,057	$22,286	$24,514	$26,743	$28,971	25
	130,672	9,679	$16,939	$19,359	$21,779	$24,199	$26,618	$29,038	$31,458	31
NPS NW100/19										
	166,035	12,299	$21,523	$24,598	$27,672	$30,747	$33,822	$36,897	$39,971	25
	182,942	13,551	$23,715	$27,103	$30,490	$33,878	$37,266	$40,654	$44,042	32
NPS NW100/20										
	188,557	13,967	$24,443	$27,934	$31,426	$34,918	$38,410	$41,902	$45,393	25
	207,100	15,341	$26,846	$30,681	$34,517	$38,352	$42,187	$46,022	$49,857	32
Vestas V15										
	111,276	8,243	$14,425	$16,485	$18,546	$20,607	$22,667	$24,728	$26,789	25
	122,223	9,054	$15,844	$18,107	$20,370	$22,634	$24,897	$27,161	$29,424	31
Vestas V27										
	492,778	36,502	$63,879	$73,004	$82,130	$91,255	$100,381	$109,506	$118,632	32
	543,432	40,254	$70,445	$80,508	$90,572	$100,636	$110,699	$120,763	$130,826	42
Fuhrländer FL100										
	274,129	20,306	$35,535	$40,612	$45,688	$50,765	$55,841	$60,918	$65,994	35

Note: Quinhagak electrical energy production efficiency is 13.5 kW-hr/gal
Note: Assumes 90% turbine availability with no diversion of power to a thermal or other dump load

NW100/20 Wind Turbine Monthly Performance at 32 Meter Hub Height

Month	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Power Output (kW)	Average Energy Output (kWh)	Average Capacity Factor (%)
Jan	5.0	40.0	1.2	15	10,880	14.6
Feb	9.7	9.6	13.6	54	36,047	53.6
Mar	6.8	26.2	6.1	32	23,479	31.6
Apr	6.9	20.4	4.1	31	22,127	30.7
May	6.3	22.7	2.0	24	18,116	24.3
Jun	6.0	26.3	0.2	21	14,944	20.8
Jul	6.4	22.2	2.1	24	18,130	24.4
Aug	5.7	32.0	0.1	19	14,258	19.2
Sep	5.1	41.8	1.9	14	10,283	14.3
Oct	7.0	21.7	6.9	31	23,259	31.3
Nov	7.2	17.6	5.5	36	25,720	35.7
Dec	5.7	24.1	0.8	18	13,469	18.1
Overall	6.4	25.6	3.6	26	230,111	26.3

Note: Energy output assumes 100% turbine availability

Temperature Conversion Chart °C to °F

°C	°F	°C	°F	°C	°F
-40	-40.0	-10	14.0	20	68.0
-39	-38.2	-9	15.8	21	69.8
-38	-36.4	-8	17.6	22	71.6
-37	-34.6	-7	19.4	23	73.4
-36	-32.8	-6	21.2	24	75.2
-35	-31.0	-5	23.0	25	77.0
-34	29.2	-4	24.8	26	78.8
-33	-27.4	-3	26.6	27	80.6
-32	-25.6	-2	28.4	28	82.4
-31	-23.8	-1	30.2	29	84.2
-30	-22.0	0	32.0	30	86.0
-29	-20.2	1	33.8	31	87.8
-28	-18.4	2	35.6	32	89.6
-27	-16.6	3	37.4	33	91.4
-26	-14.8	4	39.2	34	93.2
-25	-13.0	5	41.0	35	95.0
-24	-11.2	6	42.8	36	96.8
-23	-9.4	7	44.6	37	98.6
-22	-7.6	8	46.4	38	100.4
-21	-5.8	9	48.2	39	102.2
-20	-4.0	10	50.0	40	104.0
-19	-2.2	11	51.8	41	105.8
-18	-0.4	12	53.6	42	107.6
-17	1.4	13	55.4	43	109.4
-16	3.2	14	57.2	44	111.2
-15	5.0	15	59.0	45	113.0
-14	6.8	16	60.8	46	114.8
-13	8.6	17	62.6	47	116.6
-12	10.4	18	64.4	48	118.4
-11	12.2	19	66.2	49	120.2

Wind Speed Conversion Chart, m/s to mph

m/s	mph	m/s	mph	m/s	mph	m/s	mph	m/s	mph
0.5	1.1	10.5	23.5	20.5	45.9	30.5	68.2	40.5	90.6
1.0	2.2	11.0	24.6	21.0	47.0	31.0	69.3	41.0	91.7
1.5	3.4	11.5	25.7	21.5	48.1	31.5	70.5	41.5	92.8
2.0	4.5	12.0	26.8	22.0	49.2	32.0	71.6	42.0	93.9
2.5	5.6	12.5	28.0	22.5	50.3	32.5	72.7	42.5	95.1
3.0	6.7	13.0	29.1	23.0	51.4	33.0	73.8	43.0	96.2
3.5	7.8	13.5	30.2	23.5	52.6	33.5	74.9	43.5	97.3
4.0	8.9	14.0	31.3	24.0	53.7	34.0	76.1	44.0	98.4
4.5	10.1	14.5	32.4	24.5	54.8	34.5	77.2	44.5	99.5
5.0	11.2	15.0	33.6	25.0	55.9	35.0	78.3	45.0	100.7
5.5	12.3	15.5	34.7	25.5	57.0	35.5	79.4	45.5	101.8
6.0	13.4	16.0	35.8	26.0	58.2	36.0	80.5	46.0	102.9
6.5	14.5	16.5	36.9	26.5	59.3	36.5	81.6	46.5	104.0
7.0	15.7	17.0	38.0	27.0	60.4	37.0	82.8	47.0	105.1
7.5	16.8	17.5	39.1	27.5	61.5	37.5	83.9	47.5	106.3
8.0	17.9	18.0	40.3	28.0	62.6	38.0	85.0	48.0	107.4
8.5	19.0	18.5	41.4	28.5	63.8	38.5	86.1	48.5	108.5
9.0	20.1	19.0	42.5	29.0	64.9	39.0	87.2	49.0	109.6
9.5	21.3	19.5	43.6	29.5	66.0	39.5	88.4	49.5	110.7
10.0	22.4	20.0	44.7	30.0	67.1	40.0	89.5	50.0	111.8

Distance Conversion m to ft

m	ft	m	ft
5	16	35	115
10	33	40	131
15	49	45	148
20	66	50	164
25	82	55	180
30	98	60	197

Selected definitions (courtesy of Windographer® software by Mistaya Engineering Inc.)

Wind Power Class

The wind power class is a number indicating the average energy content of the wind resource. Wind power classes are based on the average wind power density at 50 meters above ground, according to the following table. Source: Wind Energy Resource Atlas of the United States (http://rredc.nrel.gov/wind/pubs/atlas/tables/A-8T.html)

Wind Power Class	Description	Power Density at 50m (W/m^2)
1	Poor	0-200
2	Marginal	200-300
3	Fair	300-400
4	Good	400-500
5	Excellent	500-600
6	Outstanding	600-800
7	Superb	800-2000

Windographer classifies any wind resource with an average wind power density above 2000 W/m^2 as class 8.

Probability Distribution Function

The probability distribution function f(x) gives the probability that a variable will take on the value x. It is often expressed using a frequency histogram, which gives the frequency with which the variable falls within certain ranges or bins.

Wind Turbine Power Regulation

All wind turbines employ some method of limiting power output at high wind speeds to avoid damage to mechanical or electrical subsystems. Most wind turbines employ either stall control or pitch control to regulate power output.

A stall-controlled turbine typically has blades that are fixed in place, and are designed to experience aerodynamic stall at very high wind speeds. Aerodynamic stall dramatically reduces the torque produced by the blades, and therefore the power produced by the turbine.

On a pitch-controlled turbine, a controller adjusts the angle (pitch) of the blades to best match the wind speed. At very high wind speeds the controller increasingly feathers the blades out of the wind to limit the power output.