Clark's Point, Alaska Wind Resource Report

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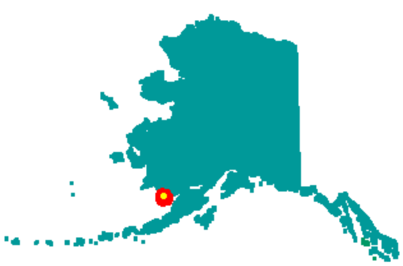
Photo © Doug Vaught



Summary Information

The wind resource study in Clark's Point indicates excellent potential for the development of wind power to augment the village's diesel engine power supply. One advantage for the village is the bluff where the meteorological test tower was located. This bluff is high and exposed and has superb exposure to onshore winds off the bay.

Meteorological Tower Data Synopsis

Wind power class (at 50 meters)	Class 4 – Good
Wind speed annual average (30 meters)	6.94 m/s
Maximum wind gust (2 sec. Average)	34.8 m/s, 10/17/05
Mean wind power density (50 meters)	491 W/m^2 (calculated)
Mean wind power density (30 meters)	423 W/m^2 (measured)
Weibull distribution parameters	k = 2.01, c = 7.77 m/s
Roughness Class	0.94 (fallow field)
Power law exponent	0.143 (moderate wind shear)
Turbulence Intensity	0.095 (low)
Data start date	July 6, 2005
Data end date	July 12, 2006

Community Profile

Current Population:	65 (2005 State Demographer est.)
Incorporation Type:	2nd Class City
Borough Located In:	Unorganized
School District:	Southwest Region Schools
Regional Native Corporation:	Bristol Bay Native Corporation

Location:

Clark's Point is located on a spit on the northeastern shore of Nushagak Bay, 15 miles from Dillingham and 337 miles southwest of Anchorage. It lies at approximately 58.844170° North Latitude and 158.550830° West Longitude. (Sec. 25, T015S, R056W, Seward Meridian.) Clark's Point is located in the Bristol Bay Recording District. The area encompasses 3.1 sq. miles of land and 0.9 sq. miles of water.

History:

The point originally had an Eskimo name, "Saguyak," yet there is no evidence of a settlement at the site prior to the Nushagak Packing Company cannery, established in 1888. The community was named for John Clark, who was the manager of the Alaska Commercial Company store at Nushagak. Clark is reputed to have operated a saltery prior to the establishment of the cannery. In 1893 the cannery became a member of the Alaska Packers Association. In 1901 a two-line cannery was built. During World War II the canning operation ceased, and only salting was done at Clark's Point. The plant was shut down permanently by 1952, and the Alaska Packers Association used the facility as the headquarters for its fishing fleet. In 1929, a major flood occurred. The City was incorporated in 1971. The village has been plagued by severe erosion. A housing project in 1982 was constructed on high and safe ground on the bluff.

Culture:

The community was founded on fishing operations of non-Native settlers, although presently it is predominantly Yup'ik Eskimo. The population increases by about 300 in summer months due to the commercial fishery.

Economy:

The economic base in Clark's Point is primarily commercial fishing. Trident Seafoods operates an on-shore facility. Sixteen residents hold commercial fishing permits. Everyone depends on subsistence to some extent, and travel over a great area if necessary. Salmon, smelt, moose, bear, rabbit, ptarmigan, duck and geese are utilized. Exchange relationships exist between nearby communities, for example, whitefish from Ekwok, New Stuyahok and Bethel are traded for smelt, and ling cod from Manokotak are traded for moose.

Facilities:

Spring-fed wells provide water to the community, treated with chlorine and fluoride. Nearly 80% of residents are connected to the piped water system; the remainder use individual wells. Approximately 40% of homes and the school -- those located on the bluff -- are served by a piped gravity sewage system. Residents below the bluff rely on septic tanks or pit privies. In all, 21 homes have piped water and sewer. The clinic and city offices use honeybuckets. Trident Seafoods supplies its own power, and the school has back-up generators.

Transportation:

Air transport is the primary method of reaching Clark's Point. Regular and charter flights are available from Dillingham. There is a State-owned 2,600' long by 70' wide gravel runway, and float planes land on Nushagak River. Freight is brought by barge to Dillingham, and then flown or lightered to the community. The only boat moorage is an undeveloped spit dock owned by the City; boats land on the beach. Trident Seafoods owns a private dock for fish processing. ATVs and snowmachines are the primary means of local transportation.

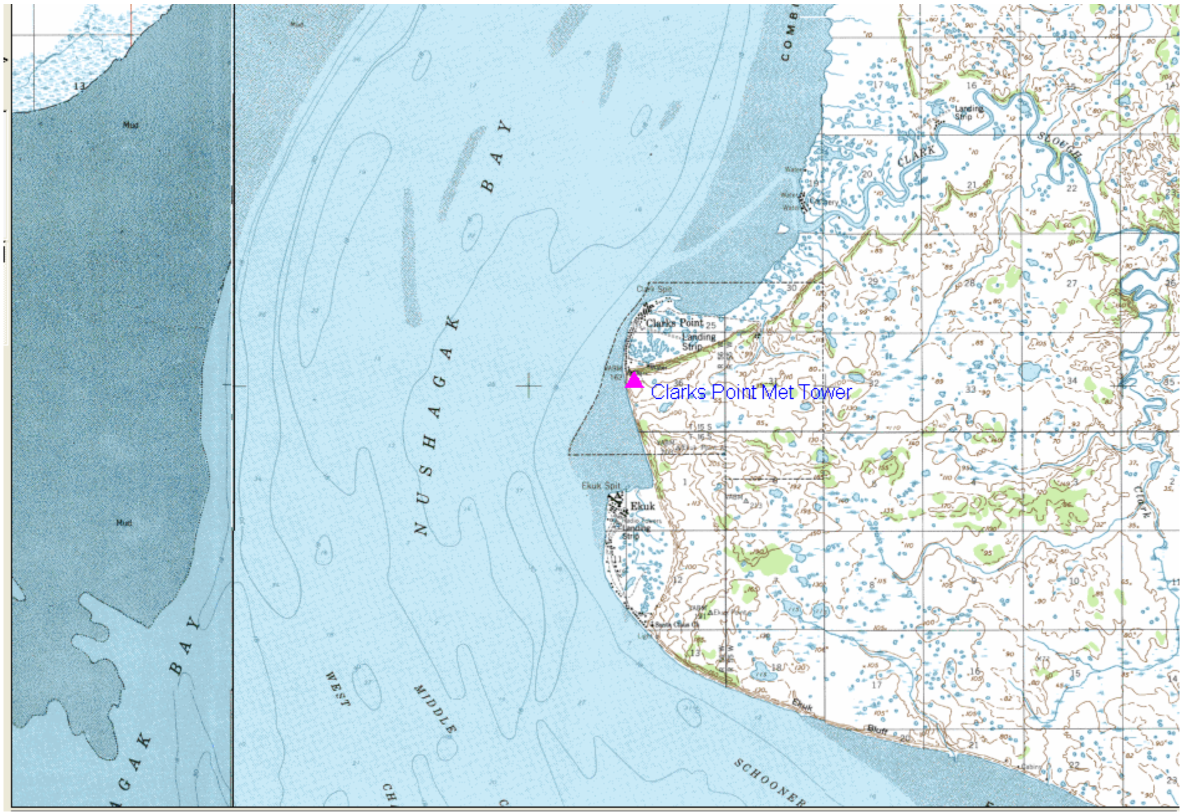
Climate:

Clark's Point is located in a climatic transition zone. The primary influence is maritime, although the arctic climate also affects the region. Average summer temperatures range from 37 to 66 degrees Fahrenheit. Average winter temperatures range from 4 to 30 degrees Fahrenheit. Annual precipitation is 20 to 26 inches, and annual snowfall is 82 inches. Fog and low clouds are common during winter months. The Nushagak Bay is ice-free from June through mid-November.

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

Site Information and Location

Site number	5046
Site Description	On ocean side of bluff edge in the upper village area
Latitude/longitude	N 58° 49.944' W 158° 33.389'
Site elevation	40 meters
Datalogger type	NRG Symphonie
Tower type	NRG 30-meter tall tower, 152 mm (6 in) diameter



Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.765	0.35	northeast
2	NRG #40 anemometer	30 m (B)	0.765	0.35	southwest
3	NRG #40 anemometer	20 m	0.765	0.35	northeast
7	NRG #200P wind vane	30 m	0.351	250	northeast
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Data Quality Control

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. Note that data recovery during the months of February through October was nearly 100%, but during the months of November through January some data was filtered, with November being quite ice prone as far as data loss is concerned. Temperature data recovery was 100 percent, indicating full functioning of the temperature sensor. To make up for the lost icing data and to create a complete data set representative of all sensors fully functional, the removed icing data was synthesized with the data gap fill feature of the Windographer® wind analysis software. The gap-filled data set was used through the remainder of this wind resource report.

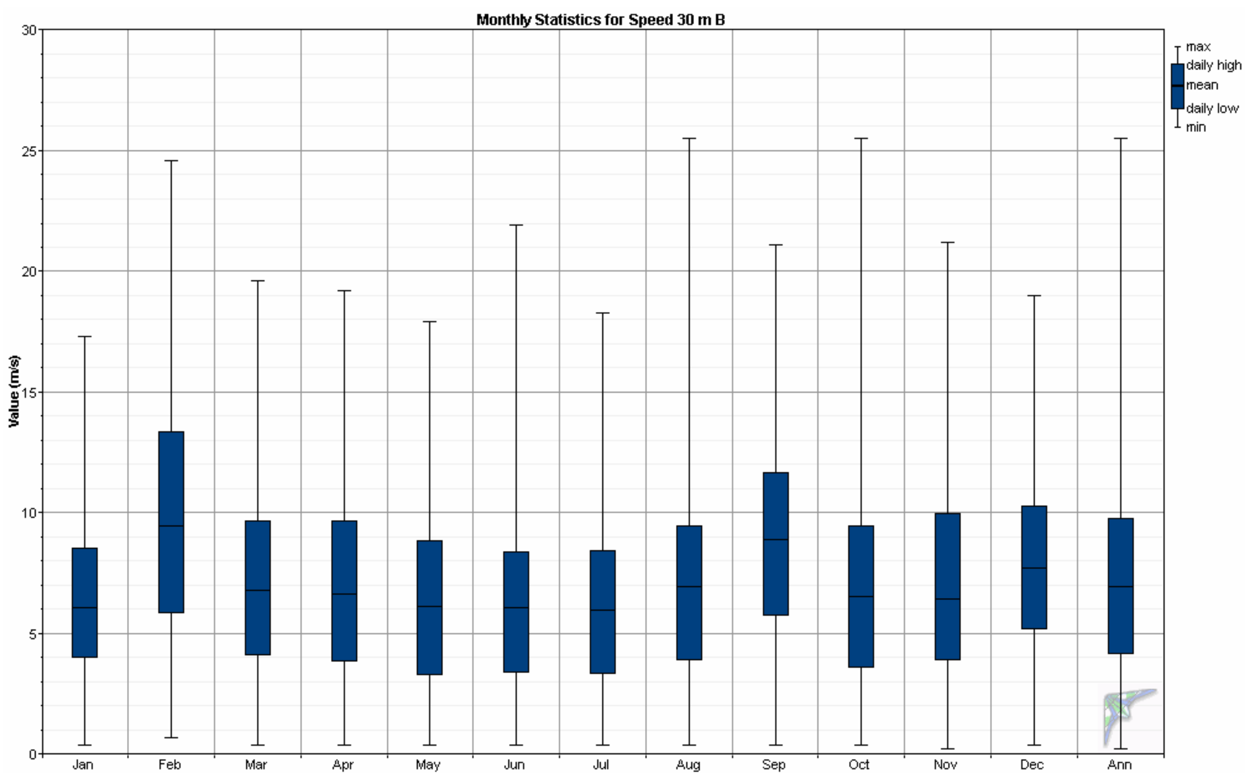
		Ch 1 30 m (A)		Ch 2 30 m (B)		Ch 3 20 m	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2005	Jul	3,664	100	3,664	100	3,664	100
2005	Aug	4,464	100	4,464	100	4,464	100
2005	Sep	4,320	100	4,320	100	4,320	100
2005	Oct	4,461	99.9	4,460	99.9	4,459	99.9
2005	Nov	2,525	58.4	2,308	53.4	2,238	51.8
2005	Dec	4,237	94.9	4,451	99.7	3,732	83.6
2006	Jan	4,163	93.3	4,164	93.3	4,168	93.4
2006	Feb	4,028	99.9	4,029	99.9	4,028	99.9
2006	Mar	4,441	99.5	4,444	99.6	4,443	99.5
2006	Apr	4,310	99.8	4,312	99.8	4,308	99.7
2006	May	4,444	99.6	4,444	99.6	4,460	99.9
2006	Jun	4,320	100	4,320	100	4,320	100
2006	Jul	1,638	100	1,638	100	1,638	100
All data		51,015	95.5	51,018	95.5	50,242	94.1

		Ch 7 vane		Ch 9 temperature	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2005	Jul	3,664	100	3,664	100
2005	Aug	4,464	100	4,464	100
2005	Sep	4,320	100	4,320	100
2005	Oct	4,459	99.9	4,464	100
2005	Nov	2,525	58.4	4,320	100
2005	Dec	4,237	94.9	4,464	100
2006	Jan	4,163	93.3	4,464	100
2006	Feb	4,028	99.9	4,032	100
2006	Mar	4,440	99.5	4,464	100
2006	Apr	4,307	99.7	4,320	100
2006	May	4,443	99.5	4,464	100
2006	Jun	4,320	100	4,320	100
2006	Jul	1,638	100	1,638	100
All data		51,008	95.5	53,398	100

Measured Wind Speeds

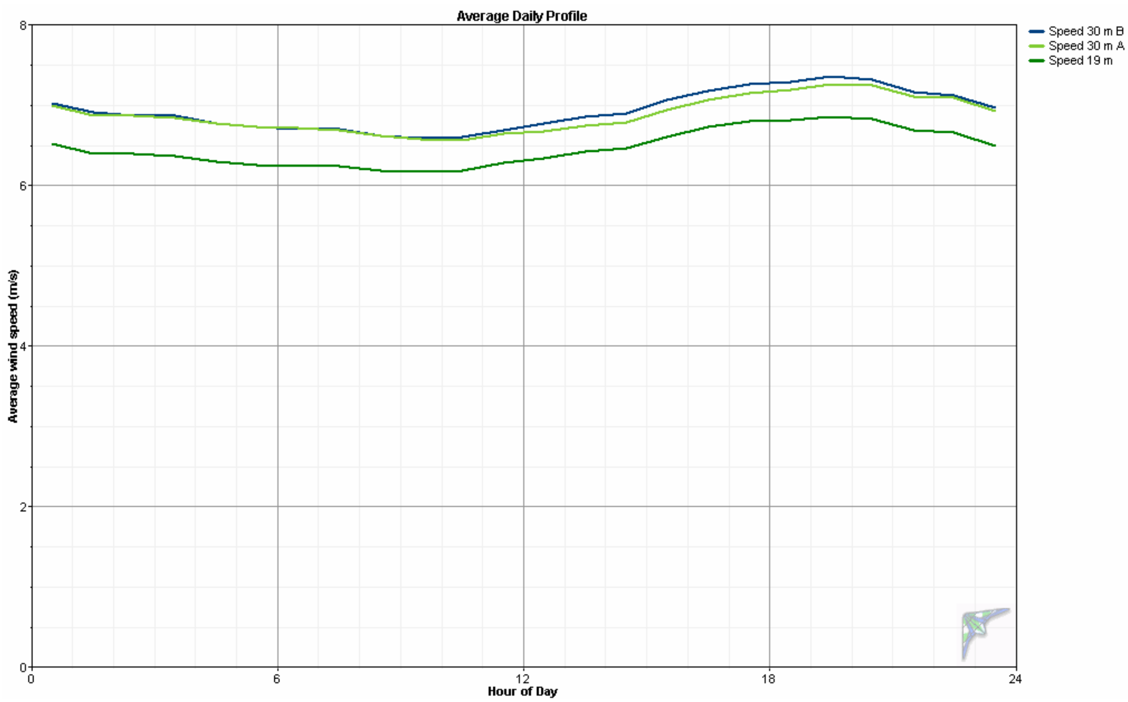
The 30 meter (B) anemometer annual wind speed average for the reporting period is 6.94 m/s, the 30 meter (A) anemometer wind speed average is 6.88 m/s and the 20 meter anemometer wind speed average is 6.47 m/s.

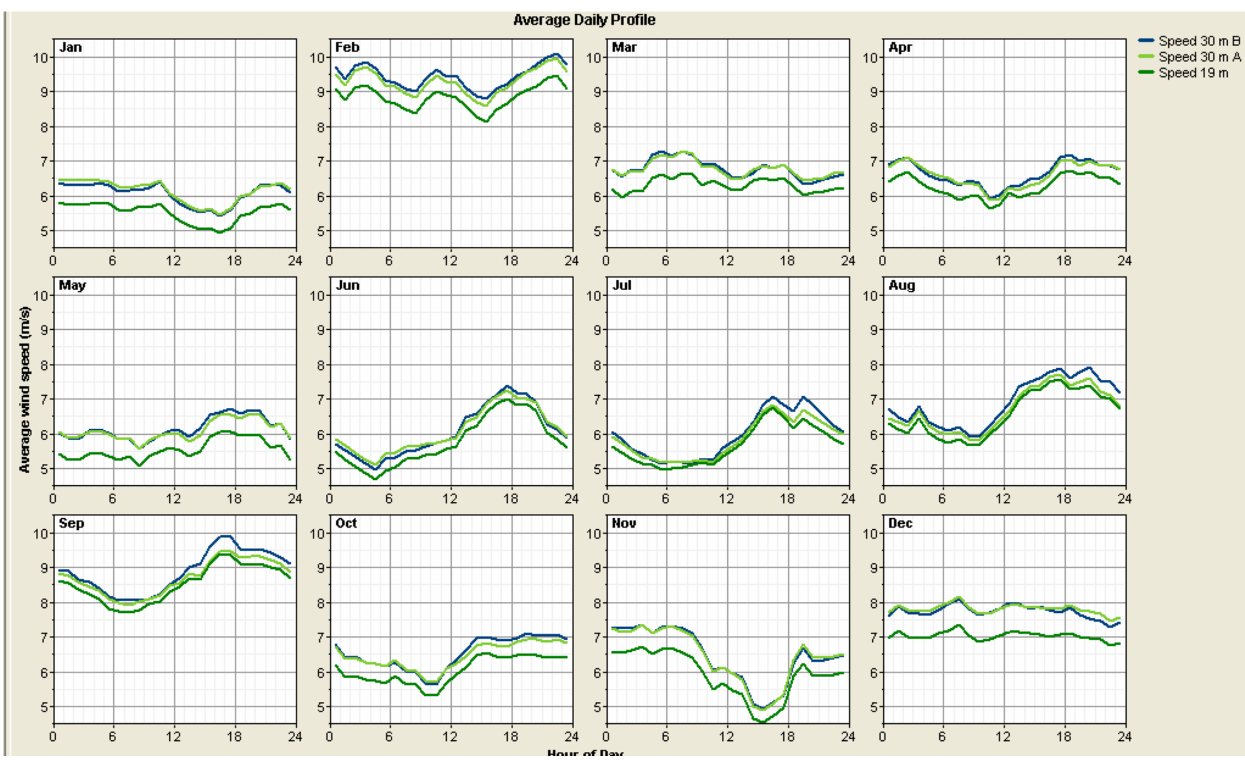
	30 m (B) speed					30 m (A) speed		20 m speed	
Month	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)	Mean (m/s)	Max (m/s)
Jan	6.07	17.3	3.34	1.87	6.83	6.14	17.0	5.53	15.3
Feb	9.45	24.6	4.60	2.18	10.68	9.30	24.0	8.84	23.2
Mar	6.79	19.6	3.24	2.19	7.65	6.79	19.1	6.32	18.5
Apr	6.65	19.2	3.40	2.06	7.51	6.61	18.7	6.27	19.6
May	6.15	17.9	2.95	2.18	6.93	6.09	16.5	5.55	17.6
Jun	6.06	21.9	3.41	1.88	6.84	6.09	21.3	5.77	20.6
Jul	5.97	18.3	2.94	2.14	6.75	5.85	17.9	5.68	17.5
Aug	6.93	25.5	4.47	1.66	7.80	6.74	25.8	6.58	25.0
Sep	8.89	21.1	3.41	2.82	9.96	8.72	20.1	8.53	19.7
Oct	6.54	25.5	3.85	1.80	7.38	6.47	25.2	6.06	25.3
Nov	6.45	21.2	3.45	1.94	7.27	6.45	20.5	5.92	20.9
Dec	7.74	19.0	3.43	2.40	8.73	7.81	20.9	7.04	18.7
Annual	**6.94**	25.5	3.72	1.96	7.83	**6.88**	25.8	**6.47**	25.3



Daily Wind Profile

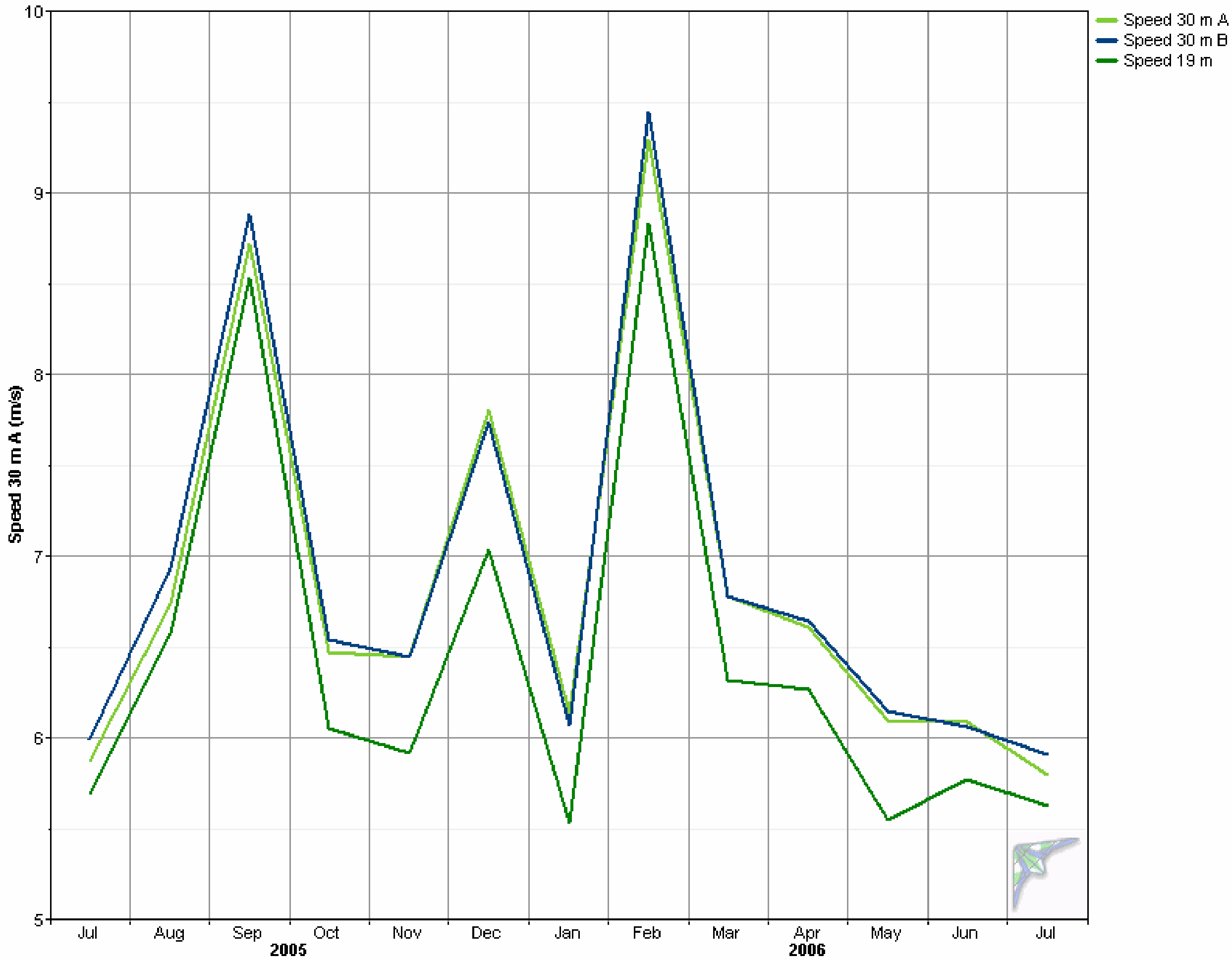
The daily wind profile indicates that the lowest wind speeds of the day occur in the morning hours of 8 a.m. to 11 a.m. and the highest wind speeds of the day occur during the afternoon and evening hours of 5 p.m. to 9 p.m. The daily variation of wind speed is minimal on an annual basis, but as shown below, more pronounced on a monthly basis.





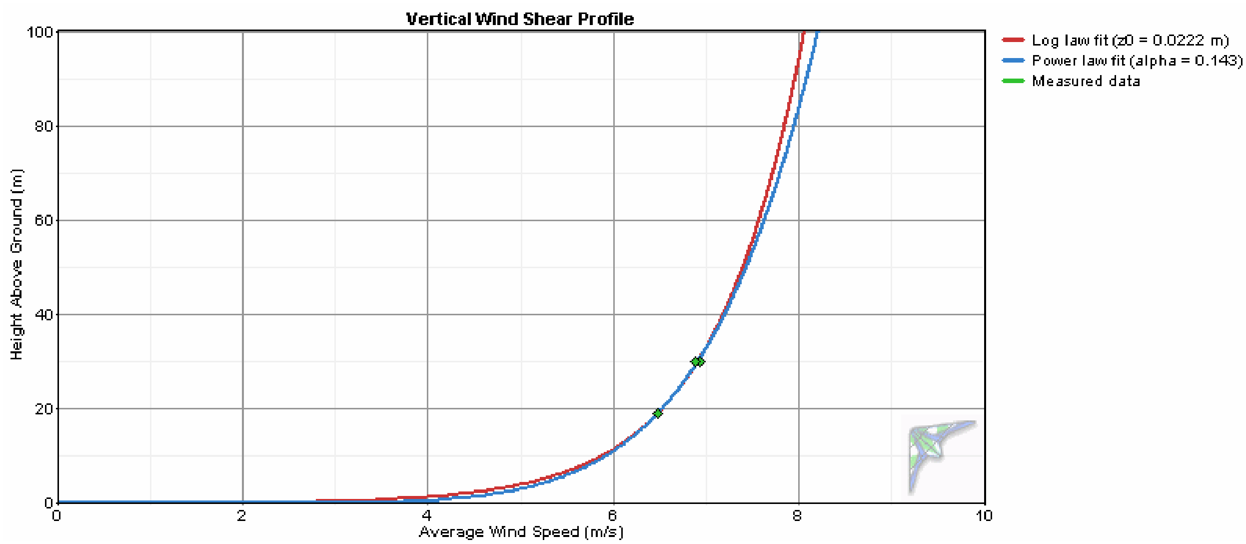
Time Series of Wind Speed Monthly Averages

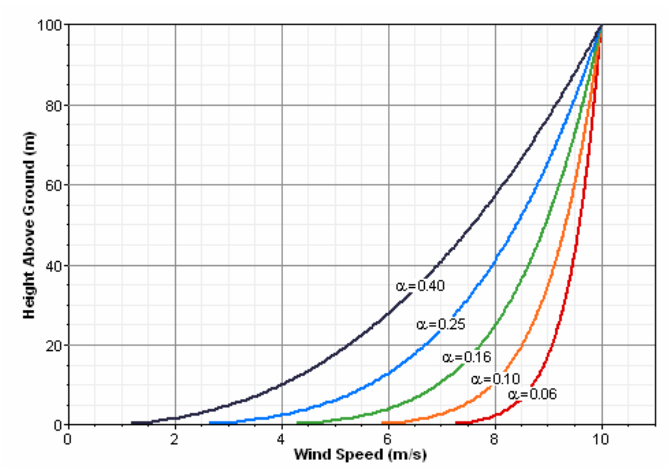
Typically, Clark’s Point’s highest winds occur during the fall and winter months of September through March with the lowest winds during the spring-summer-autumn months of April through August. The unusually low winds measured in January 2006 were due to a persistent high pressure system over Alaska that month that yielded calm winds and extremely cold weather Statewide. Had the January winds been higher and more representative of a typical year, it is expected that the wind power average for this site would be higher, possibly in the low Class 5 range.

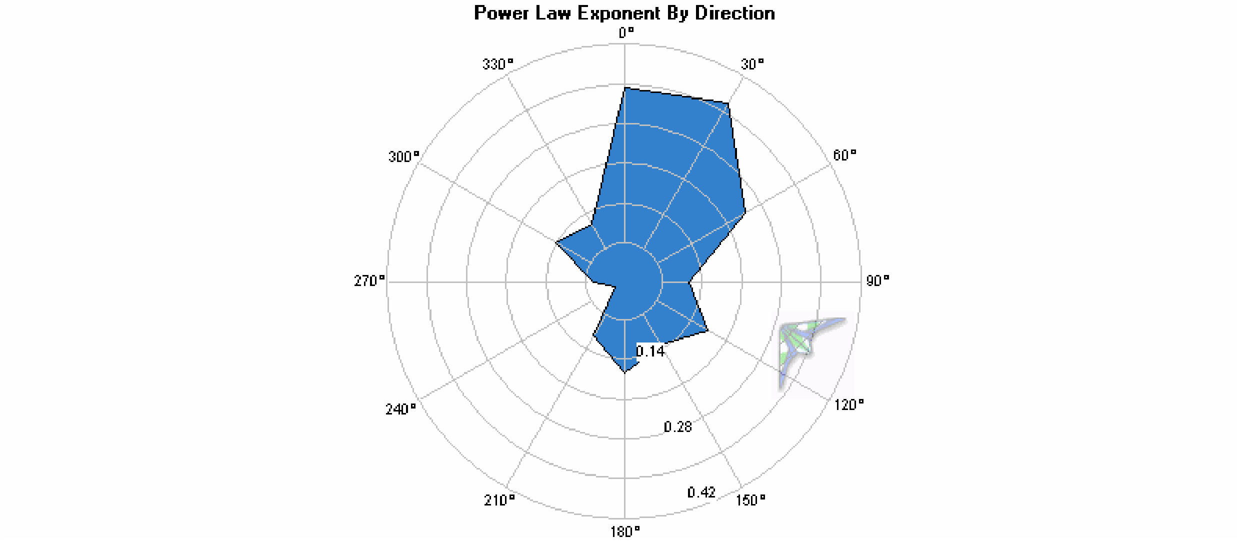


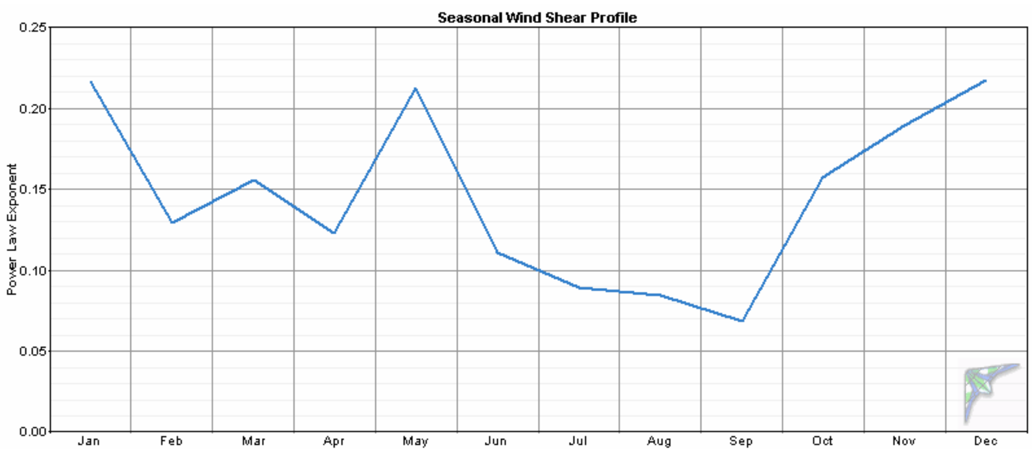
Wind Shear Profile

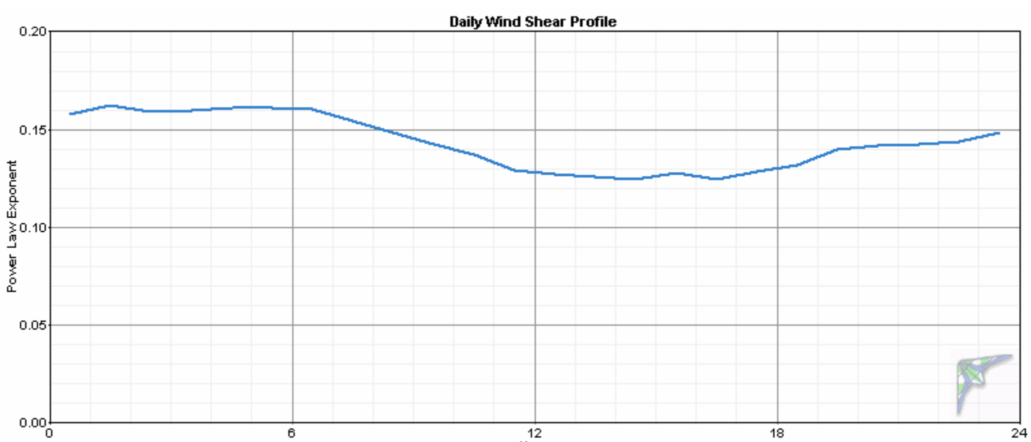
The power law exponent was calculated at 0.143 indicating moderate wind shear at the Clark's Point test site. The practical application of this data is that a higher turbine tower height is advantageous there will be an appreciable gain in wind speed/power recovery with additional height. A tower height/power recovery/construction cost tradeoff study is advisable.





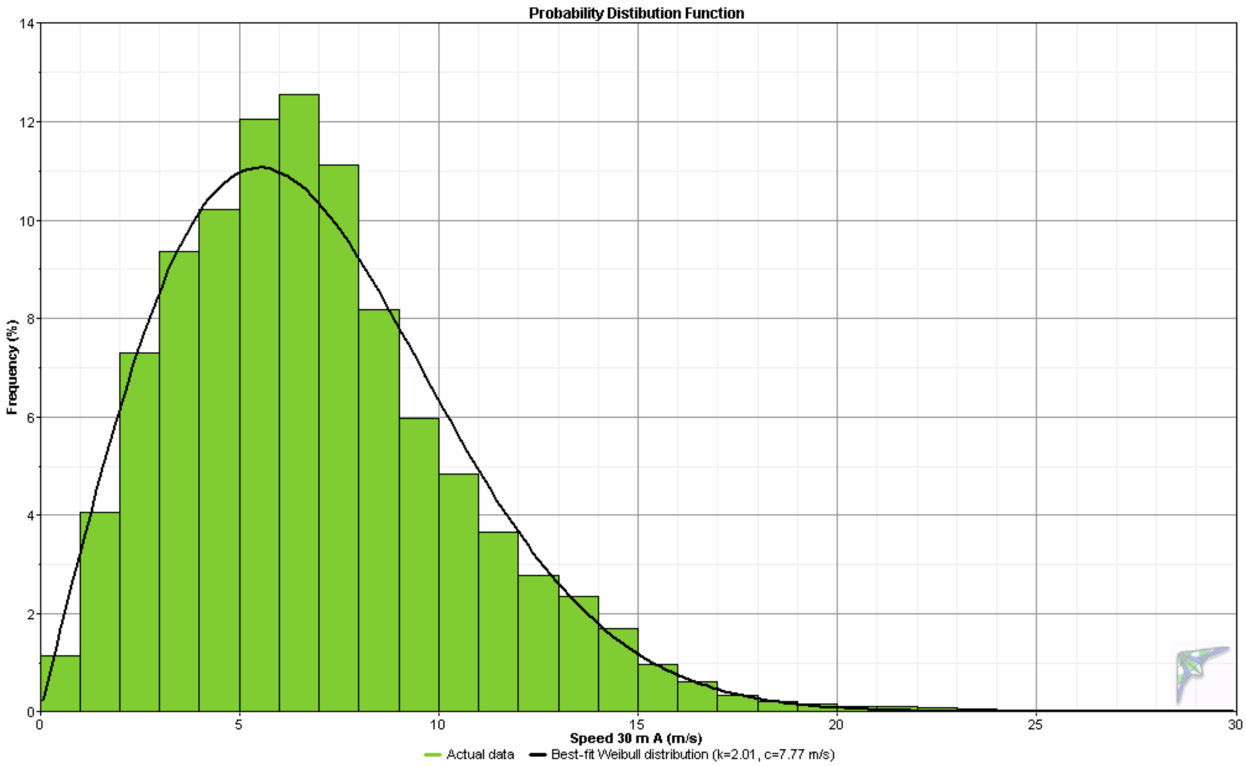

Power Law Exponent By Direction
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
0.14
0.28
0.42

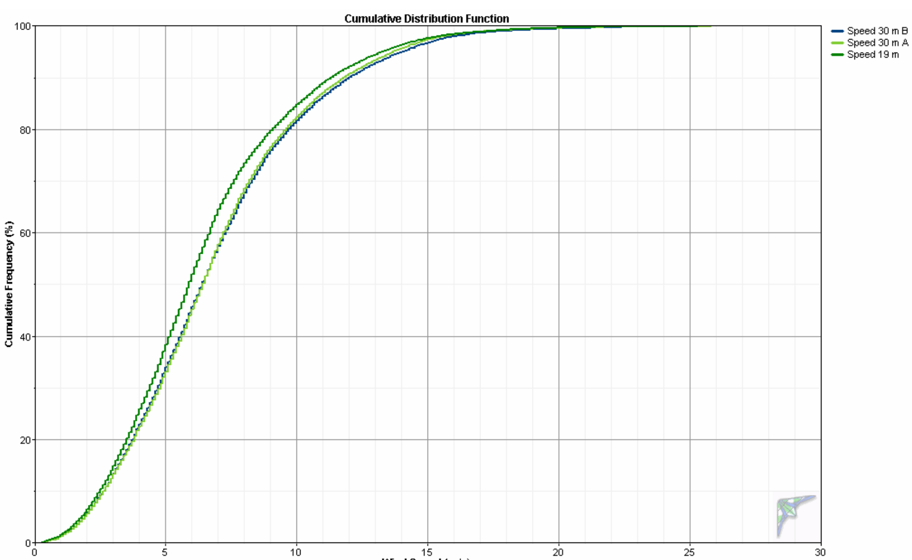

Seasonal Wind Shear Profile
Power Law Exponent
0.25
0.20
0.15
0.10
0.05
0.00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Daily Wind Shear Profile
Power Law Exponent
0.20
0.15
0.10
0.05
0.00
0
6
12
18
24
Hour

Probability Distribution Function

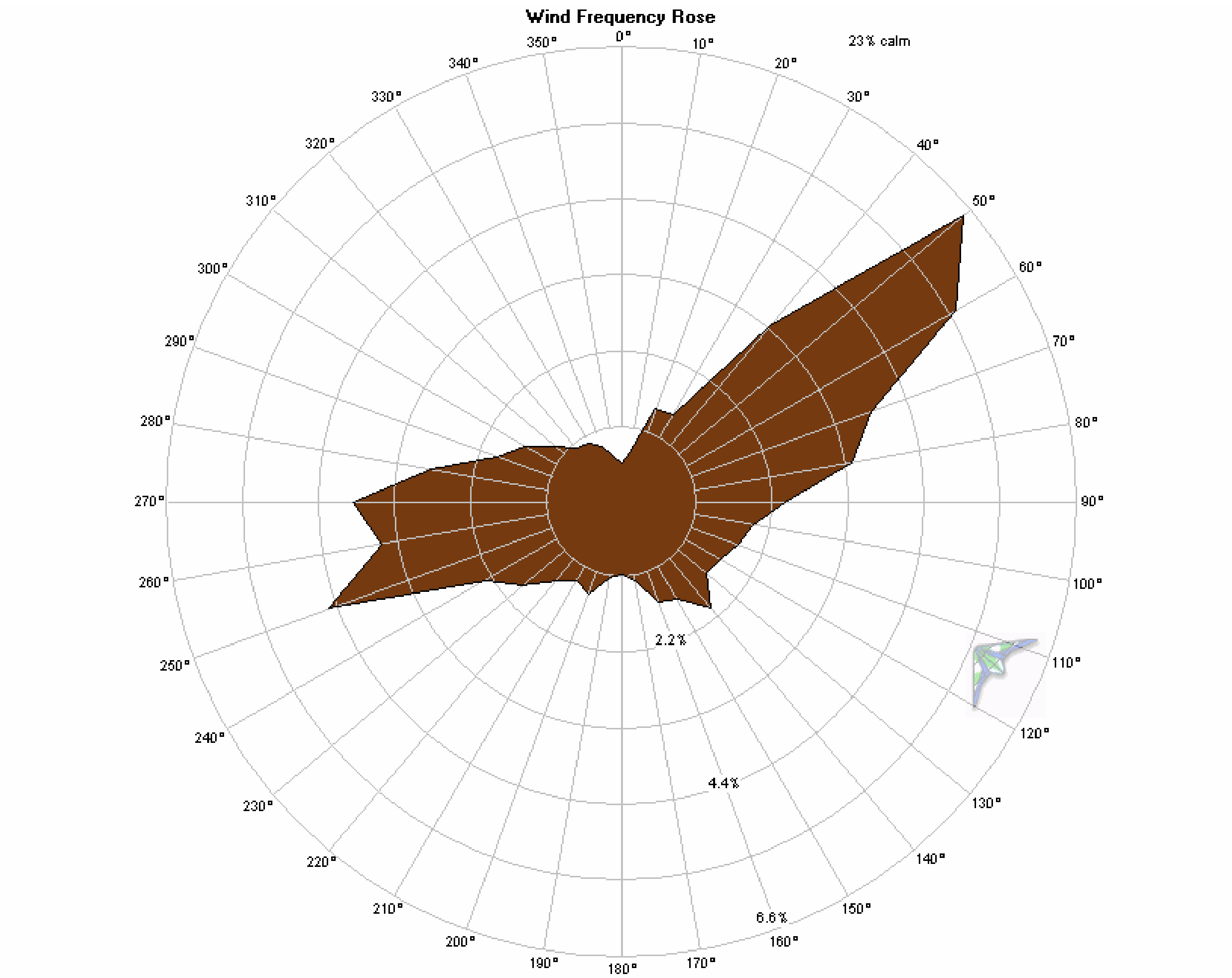
The probability distribution function provides a visual indication of measured wind speeds in one meter per second "bins". Note that most wind turbines do not begin to generate power until the wind speed at hub height reaches 4 m/s. The black line in the graph is a best fit Weibull distribution. At the 30 meter level, Weibull parameters are k = 2.01 (indicates a broad distribution of wind speeds) and c = 7.77 m/s (a scale factor for the Weibull distribution). The PDF information is shown visually in another manner in the second graph, the cumulative distribution function.



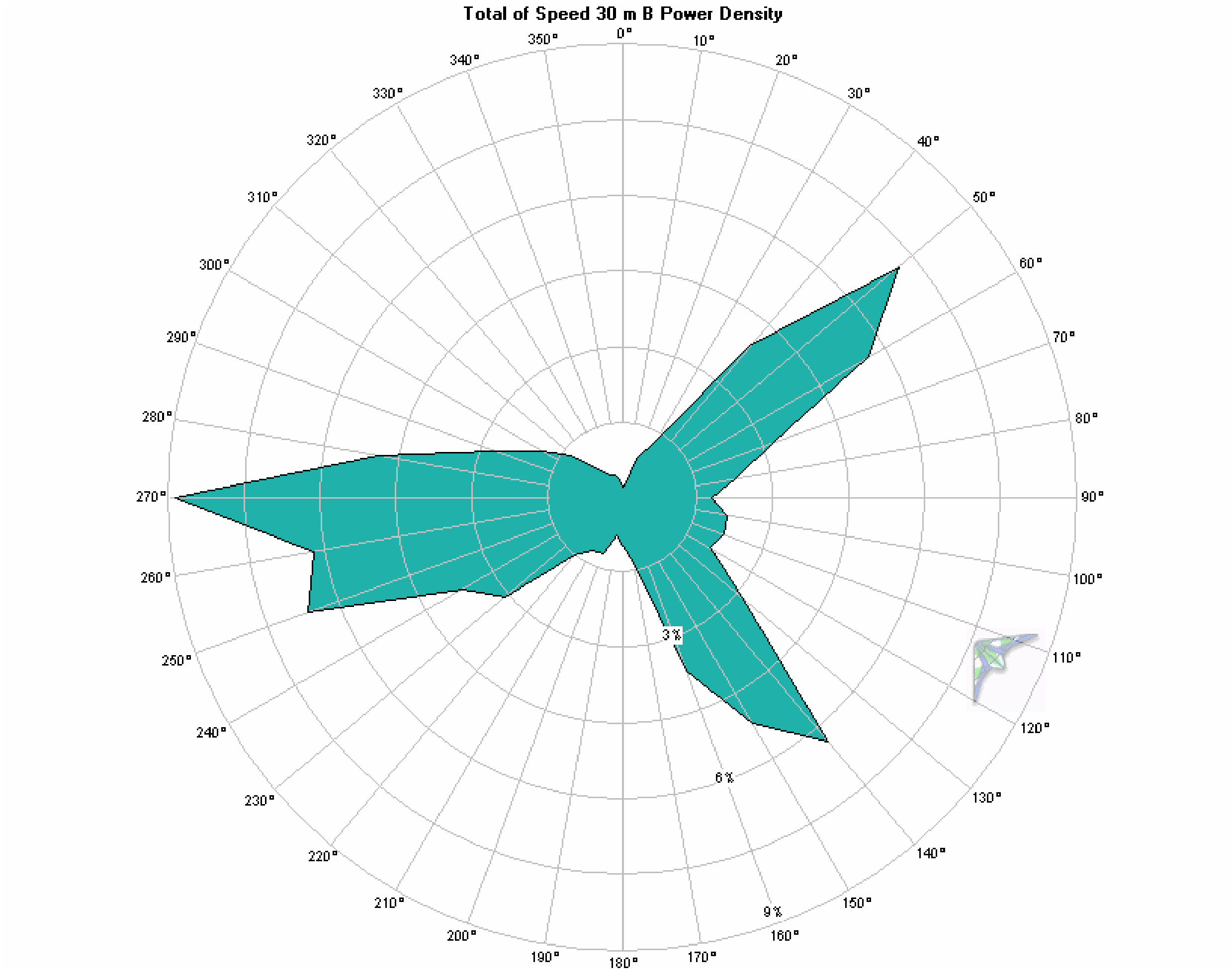


Wind Roses

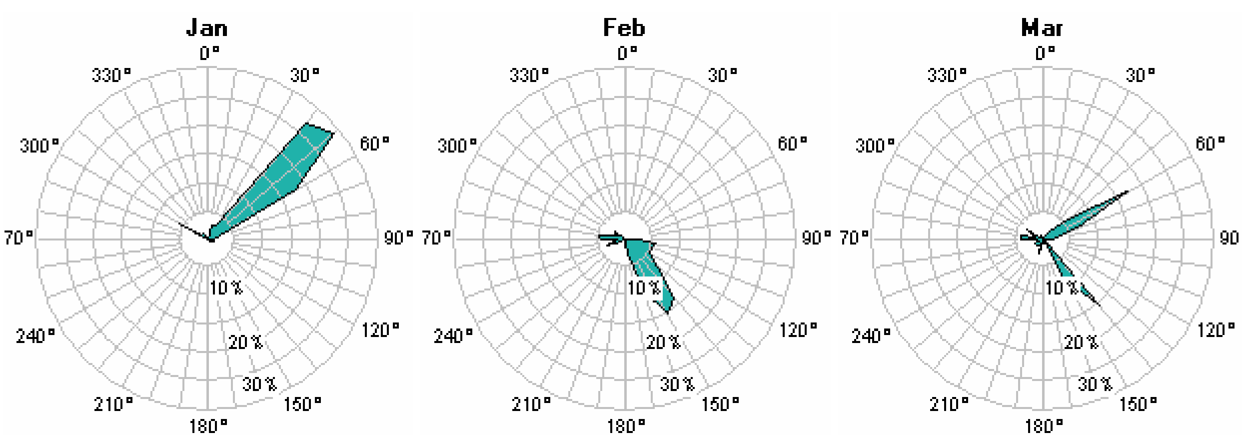
Clark's Point winds are rather directional; the wind frequency rose indicates northeast and westerly wind. This observation is reinforced with reference to the power density rose below. Power producing winds are chiefly also northeast and west, although infrequent but powerful southeast winds characterize the wind power density rose. The practical application of this information is that a site should be selected with adequate freedom from ground interference in especially northeast, west and southeast directions and if more than one wind turbine is installed, the turbines should be adequately spaced apart to prevent downwind (from the power producing winds) interference problems between the turbines. The indication below of 23 percent calm winds is calculated with a 4 m/s wind speed threshold, the typical cut-in speed of wind turbines.

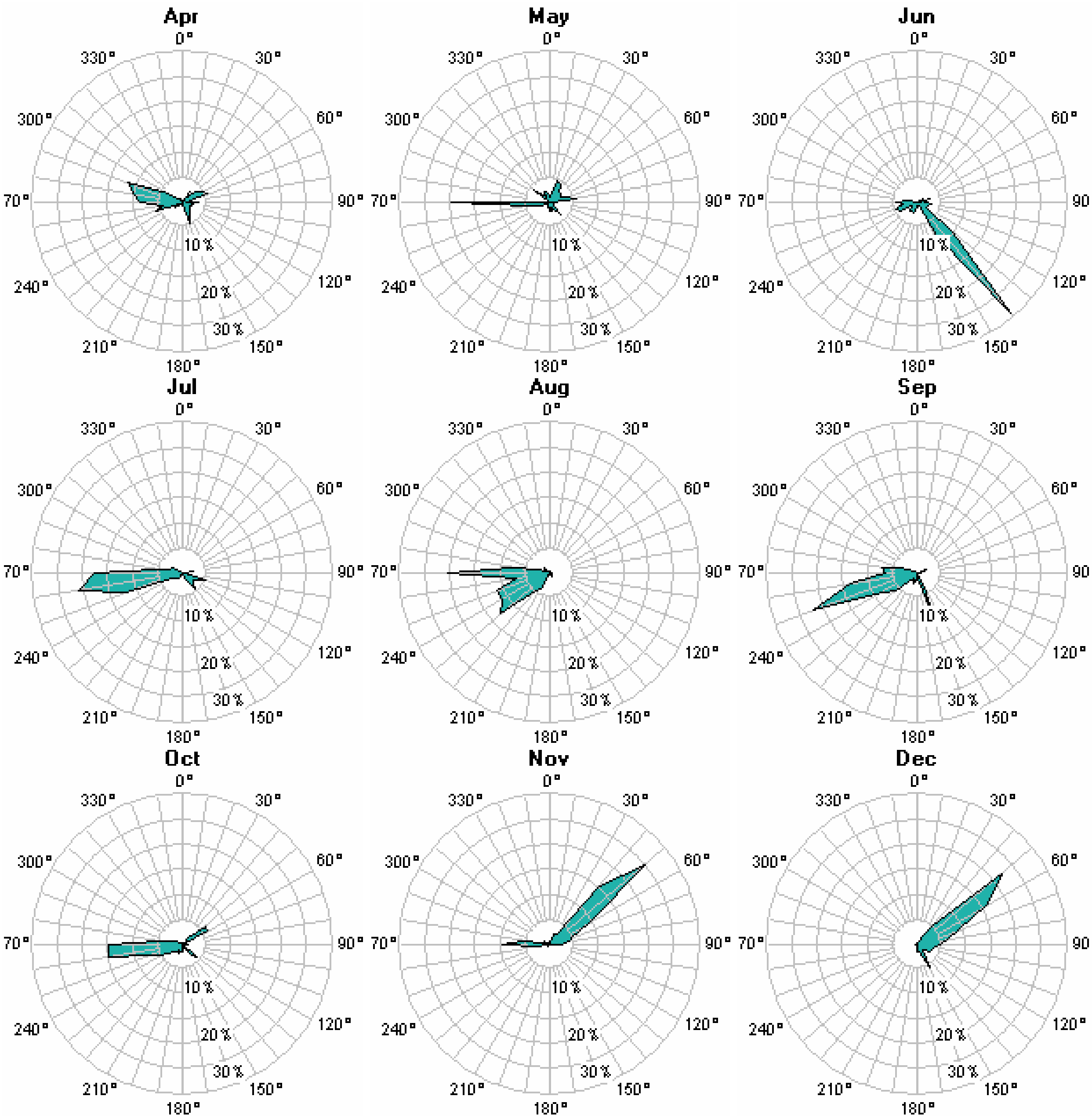


Wind Power Density Rose (30 meters)



Wind Power Density Rose by Month (30 meters)

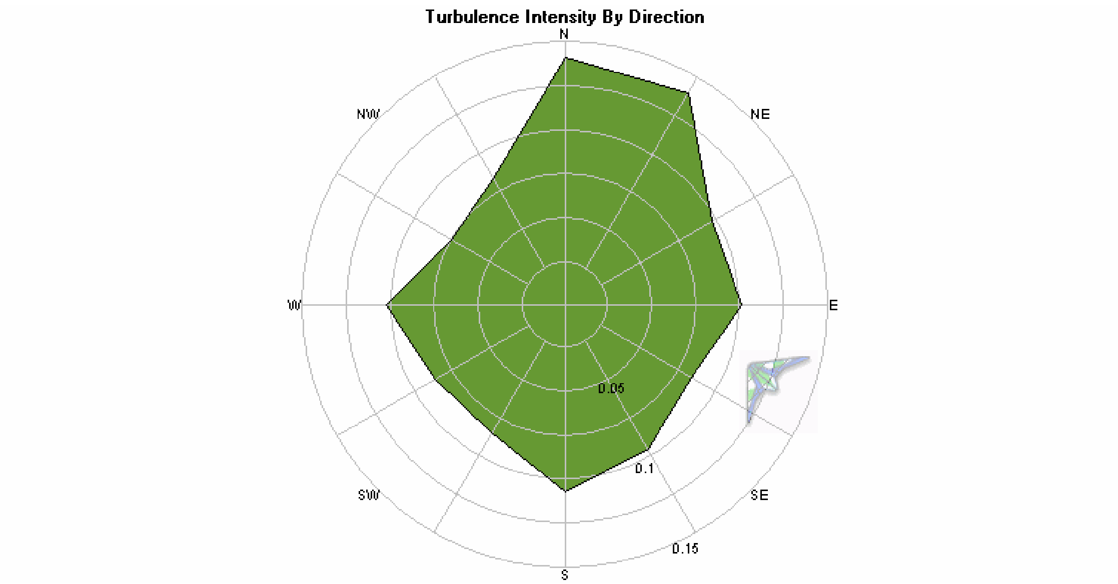



Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0°
30°
60°
90°
120°
150°
180°
210°
240°
70°
300°
330°
10 %
20 %
30 %

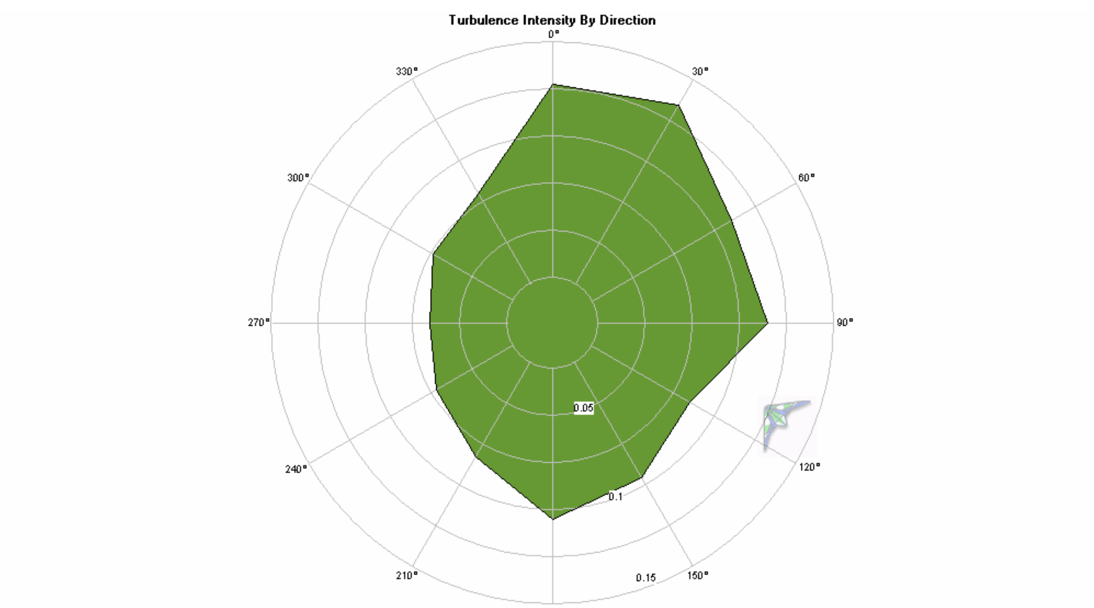
Turbulence Intensity

The turbulence intensity (TI) is acceptable for all wind direction, with a mean turbulence intensity of 0.0942 (30 meter A) and 0.0954 (30 meter B), indicating relatively smooth air. These TIs are calculated with a threshold wind speed of 4 m/s. The spike of relatively high turbulence to the north to northeast in both graphs may be due to the presence of two old water tanks located several hundred meters north of the met tower test site and heavy brush and higher terrain both north and northeast of the met tower location, but it is relatively unimportant at NNE is an infrequent wind direction.

30 meter (A) Turbulence Intensity

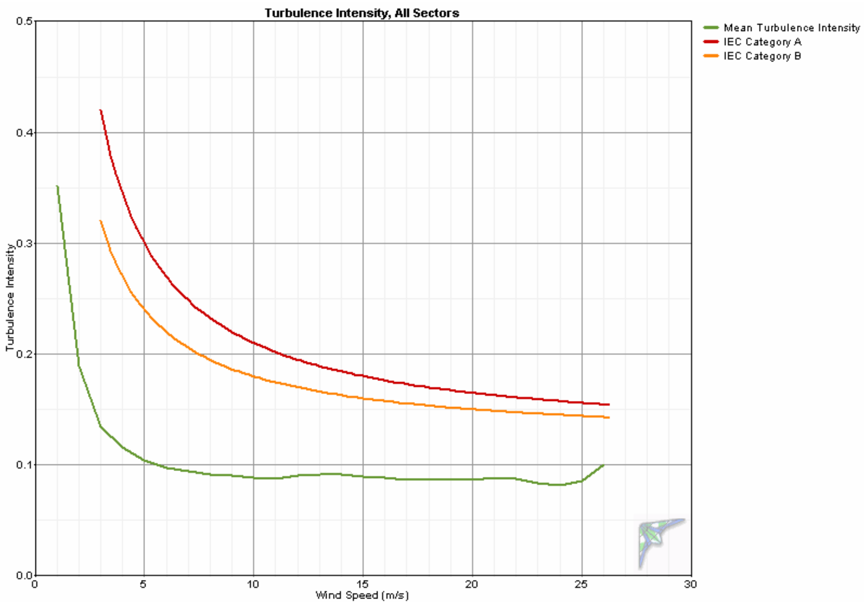


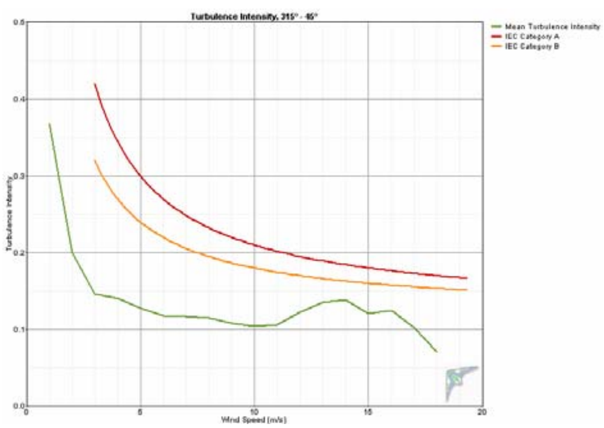
30 meter (B) Turbulence Intensity

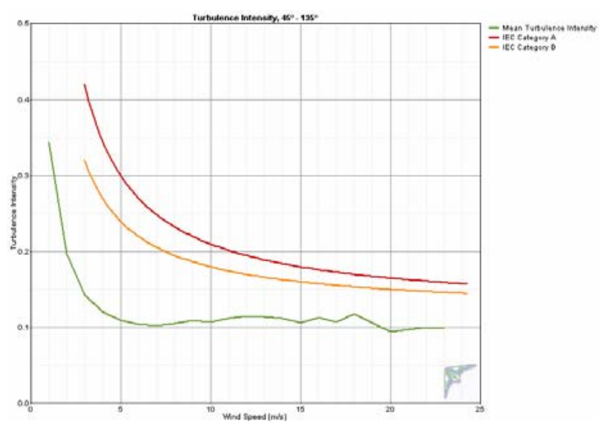


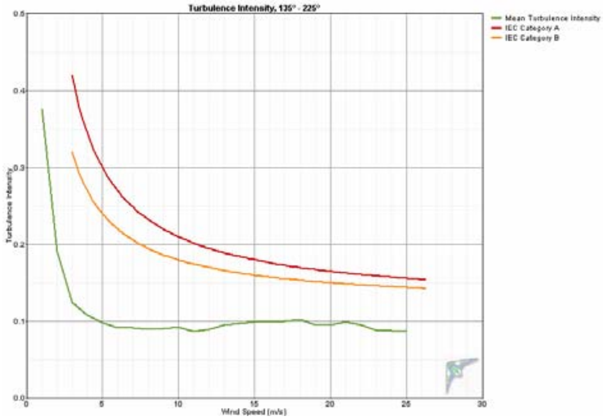
IEC Turbulence Intensity Standards

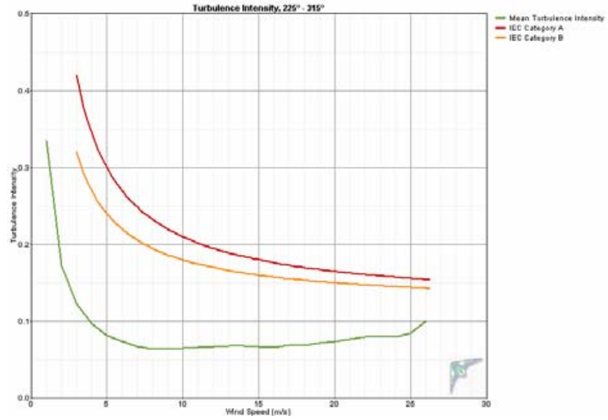
As indicated below, turbulence at the Clark's Point project test site is well below International Electrotechnical Commission (IEC) standards at all measured wind speeds and from all four quadrants of the wind rose. The somewhat high turbulence in the 315° to 45° sector is not so important as the wind rarely blows from this quadrant.











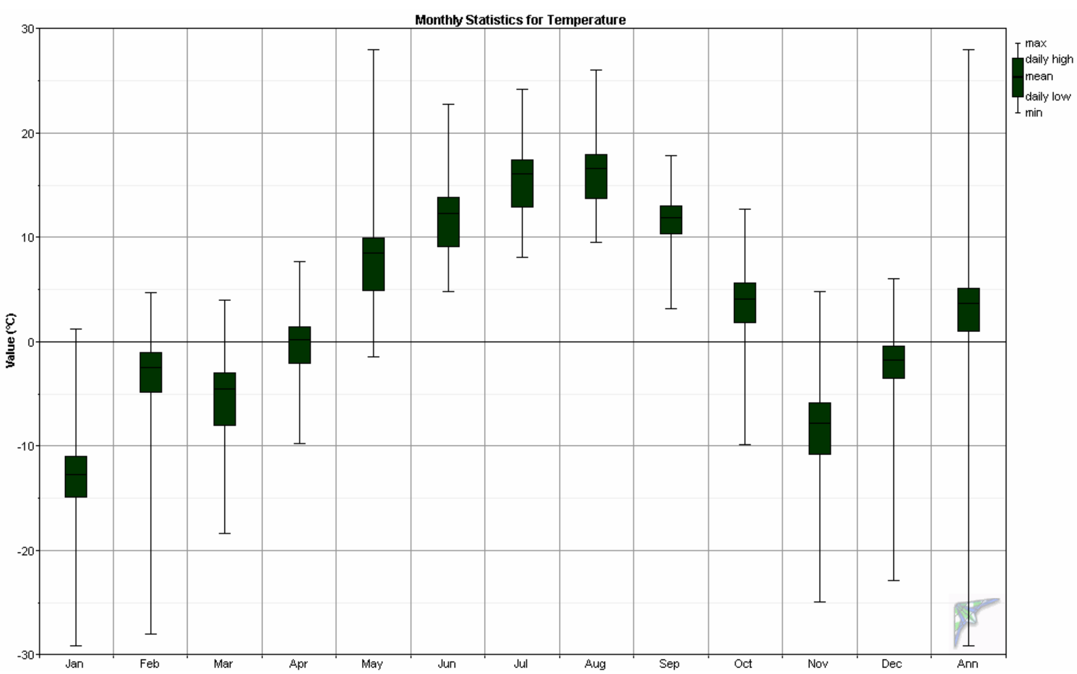
Turbulence Table

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records In Bin	Standard Deviation of Wind Speed (m/s)	Mean Turbulence Intensity	Standard Deviation of Turbulence Intensity	Characteristic Turbulence Intensity
1	0.5	1.5	1294	0.342	0.352	0.169	0.521
2	1.5	2.5	3152	0.372	0.189	0.094	0.283
3	2.5	3.5	4590	0.398	0.135	0.068	0.203
4	3.5	4.5	5360	0.458	0.116	0.059	0.175
5	4.5	5.5	6051	0.514	0.104	0.054	0.158
6	5.5	6.5	6473	0.580	0.097	0.049	0.147
7	6.5	7.5	5940	0.657	0.095	0.048	0.143
8	7.5	8.5	5134	0.728	0.092	0.045	0.137
9	8.5	9.5	3830	0.807	0.091	0.042	0.133
10	9.5	10.5	2862	0.883	0.089	0.038	0.127
11	10.5	11.5	2223	0.958	0.088	0.038	0.126
12	11.5	12.5	1759	1.085	0.091	0.036	0.127
13	12.5	13.5	1358	1.188	0.092	0.034	0.126
14	13.5	14.5	1064	1.269	0.091	0.032	0.123
15	14.5	15.5	856	1.337	0.090	0.029	0.119
16	15.5	16.5	492	1.414	0.089	0.029	0.118
17	16.5	17.5	320	1.454	0.086	0.025	0.111
18	17.5	18.5	162	1.544	0.086	0.025	0.111
19	18.5	19.5	103	1.637	0.087	0.021	0.108
20	19.5	20.5	83	1.719	0.086	0.018	0.104
21	20.5	21.5	73	1.852	0.088	0.017	0.106
22	21.5	22.5	77	1.922	0.088	0.014	0.102
23	22.5	23.5	51	1.906	0.083	0.013	0.096
24	23.5	24.5	28	1.957	0.082	0.016	0.098
25	24.5	25.5	8	2.112	0.085	0.018	0.104
26	25.5	26.5	2	2.550	0.100	0.014	0.114

Air Temperature and Density

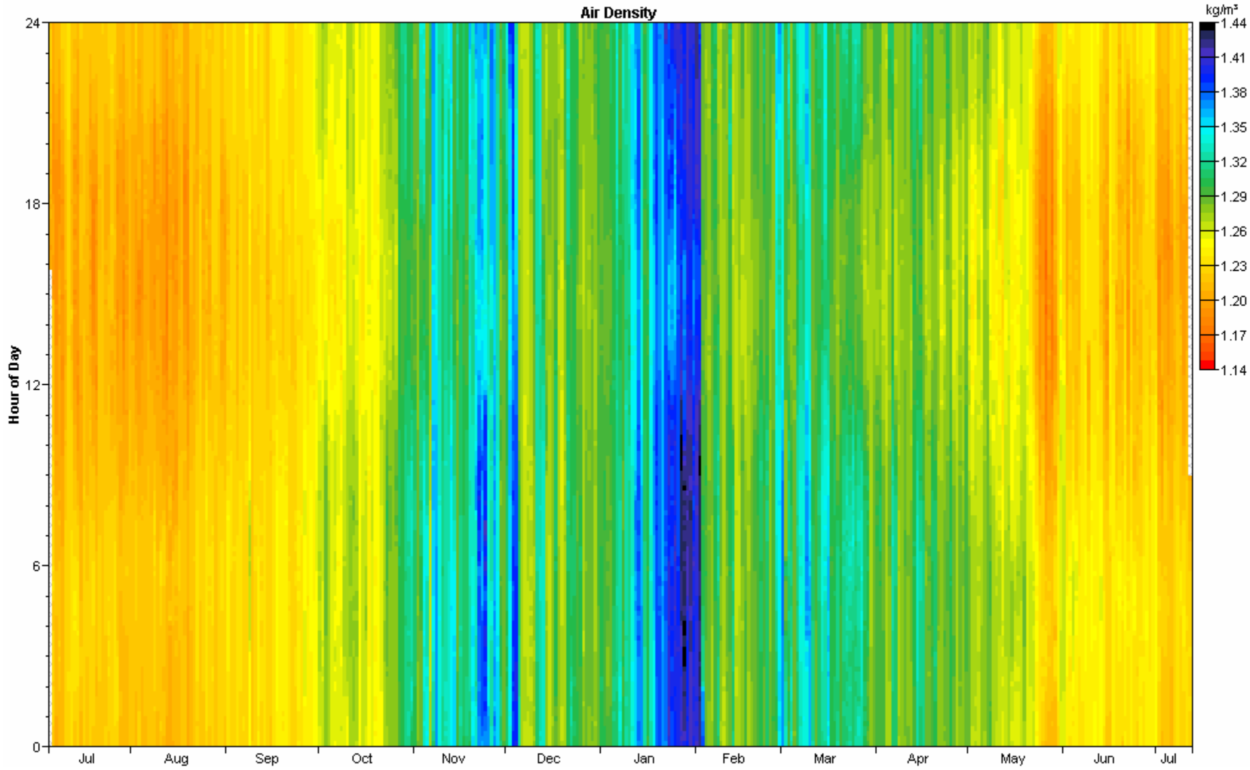
Over the reporting period, Clark's Point had an average temperature of 3.7° C. The minimum recorded temperature during the measurement period was -29.1° C and the maximum temperature was 28.0° C, indicating a wide variability of the ambient temperature operating environment important to wind turbine operations. Consequent to Clark's Point's cool temperatures, the average air density of 1.271 kg/m^3 is approximately four percent higher than the standard air density of 1.225 kg/m^3 (at 15.01° C temperature and 101.29 kPa pressure), indicating that Clark's Point, due to its cool annual temperature average, has denser air than the standard air density used to calculate turbine power curves.

	Temperature				Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-12.7	-29.1	1.2	8.00	1.350	1.280	1.439
Feb	-2.5	-28.0	4.7	7.08	1.299	1.264	1.433
Mar	-4.5	-18.4	4.0	4.65	1.308	1.267	1.379
Apr	0.3	-9.7	7.7	3.12	1.285	1.251	1.333
May	8.6	-1.4	28.0	6.03	1.247	1.166	1.292
Jun	12.4	4.8	22.8	3.04	1.230	1.187	1.264
Jul	16.1	8.1	24.2	2.93	1.214	1.181	1.249
Aug	16.6	9.5	26.0	2.70	1.212	1.174	1.243
Sep	11.9	3.2	17.8	2.10	1.232	1.207	1.271
Oct	4.1	-9.8	12.7	4.61	1.267	1.229	1.334
Nov	-7.8	-24.9	4.8	5.61	1.324	1.264	1.415
Dec	-1.8	-22.9	6.1	6.18	1.295	1.258	1.403
Annual	**3.7**	-29.1	28.0	10.62	**1.271**	1.166	1.439



Air Density DMap

The DMap below is a visual indication of the daily and seasonal variations of air density (and hence temperature). Air densities higher than standard will yield higher turbine power than predicted by the turbine power curve, while densities lower than standard will yield lower turbine power than predicted. Density variance from standard is accounted for in the turbine performance predictions.



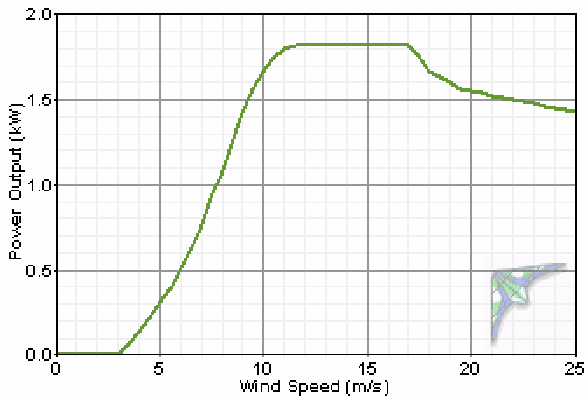
Turbine Performance Predictions

The turbine performance predictions noted below are based on 100 percent and 90 percent turbine availabilities. The 100 percent data is for use as a baseline of comparison, but it is realistic to expect ten percent or more of losses or downtime for wind turbines located in a small, remote community.

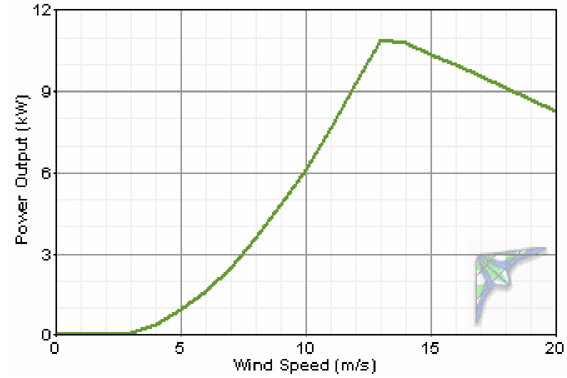
Note that these performance estimates were predicted with use of Windographer® wind analysis software; power curves provided by manufacturers are not independently verified and are assumed to be accurate. The power curves are presented for a standard air density of 1.225 kg/m^3 at sea level and at standard temperature and pressure. 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, accounting for the site elevation.

A number of smaller village-scale grid-connected turbines are profiled in this report for comparison purposes. These turbines were selected because they have market availability and they are deemed to be within a suitable range for consideration of wind power development in a village the size of Clark’s Point.

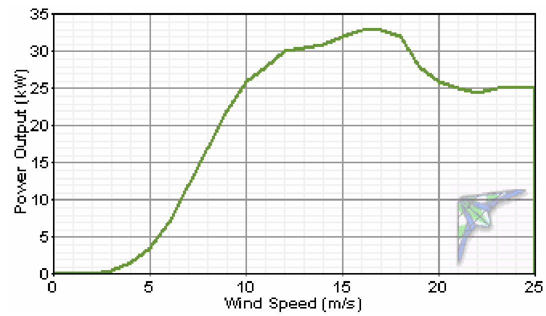
Southwest Skystream 3.7: 1.8 kW rated power output, 3.7 meter rotor diameter, stall-controlled. Available tower heights: 10.7 and 33.5 meters. Additional information is available at www.skystreamenergy.com.



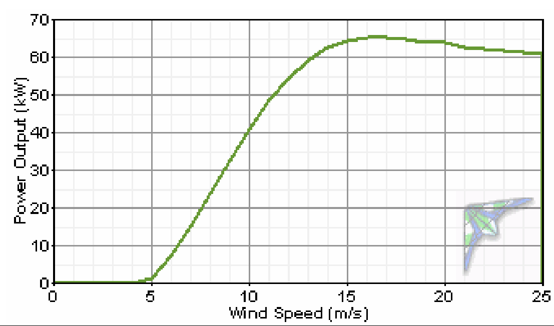
Bergey Excel-S: 10 kW rated power output, 6.7 meter rotor diameter, stall-controlled. Available tower heights: 18, 24, 30, 37 and 43 meters. Additional information is available at www.bergey.com.



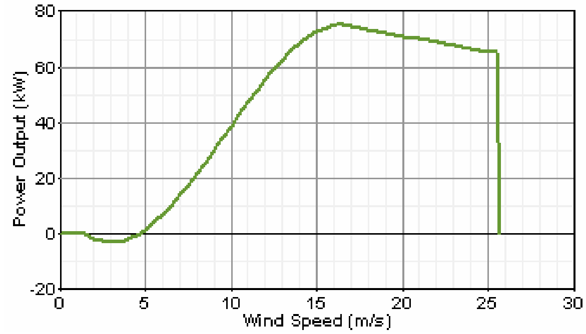
Fuhrländer FL30: 30 kW rated power output, 13 meter rotor, stall-controlled (power curve provided by Lorax Energy, LLC). Available tower heights: 26 and 30 meters. Additional information is available at http://www.fuhrlaender.de/ and http://www.lorax-energy.com/.



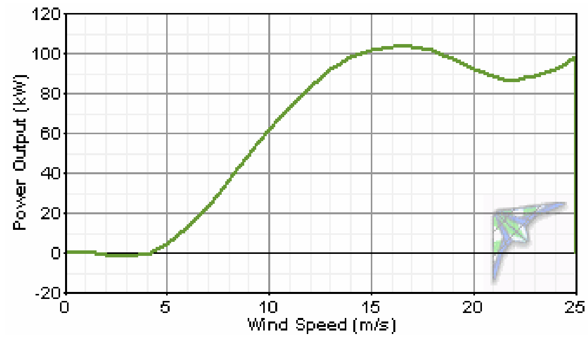
Entegrity eW-15: 65 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Entegrity Energy Systems). Available tower heights: 25 and 31 meters. Additional information is available at http://www.entegritywind.com/.



Vestas V15: 75 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Powercorp Alaska LLC). Available tower heights: 25, 31 and 34 meters. Additional information is available at http://www.pcorpalaska.com/.



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). Available tower heights: 25 and 32 meters. Additional information is available at http://www.northernpower.com/.



Turbine Power Output Comparison (100% turbine availability)

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Net Power Output (kW)	Annual Net Energy Output (kWh/yr)	Average Net Capacity Factor (%)
Southwest Skystream 3.7	10.7	6.04	16.9	9.5	0.63	5,481	34.8
Southwest Skystream 3.7	33.5	6.98	13.1	14.8	0.81	7,113	45.1
Bergey Excel-S	24	6.69	6.1	6.1	2.96	25,938	29.6
Bergey Excel-S	37	7.07	5.9	7.5	3.30	28,886	33.0
Fuhrländer FL30	26	6.75	5.8	2.6	12.0	104,977	36.3
Fuhrländer FL30	30	6.94	5.8	3.0	12.5	109,910	38.0
Entegrity eW-15 60 Hz	25	6.72	23.4	3.5	18.1	158,538	27.8
Entegrity eW-15 60 Hz	31	6.90	22.8	4.1	19.3	168,634	29.6
Vestas V15	25	6.72	29.6	1.9	17.2	150,482	22.9
Vestas V15	34	6.99	27.9	2.5	19.0	166,271	25.3
Northern Power NW 100/20	25	6.72	23.4	3.4	26.6	233,420	26.6
Northern Power NW 100/20	32	6.93	22.6	4.1	28.6	250,517	28.6

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

Assumed turbine losses for predictions of average power output, annual energy output, and average capacity factor:

Downtime (%)	0
Array (%)	0
Icing/soiling (%)	0
Other (%)	0
Total (%)	0

Turbine Power Output Comparison (90% availability)

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Net Power Output (kW)	Annual Net Energy Output (kWh/yr)	Average Net Capacity Factor (%)
Southwest Skystream 3.7	10.7	6.04	16.86	9.5	0.57	4,949	31.4
Southwest Skystream 3.7	33.5	6.98	13.13	14.8	0.73	6,424	40.7
Bergey Excel-S	24	6.69	6.10	6.1	2.67	23,424	26.7
Bergey Excel-S	37	7.07	5.88	7.5	2.98	26,086	29.8
Fuhrländer FL30	26	6.75	5.75	2.6	10.8	94,801	32.8
Fuhrländer FL30	30	6.94	5.83	3.0	11.3	99,257	34.3
Entegrity eW-15 60 Hz	25	6.72	23.43	3.5	16.3	143,171	25.1
Entegrity eW-15 60 Hz	31	6.90	22.77	4.1	17.4	152,288	26.7
Vestas V15	25	6.72	29.64	1.9	15.5	135,896	20.7
Vestas V15	34	6.99	27.94	2.5	17.1	150,155	22.9
Northern Power NW 100/20	25	6.72	23.43	3.4	24.1	210,794	24.1
Northern Power NW 100/20	32	6.93	22.62	4.1	25.8	226,234	25.8

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

Assumed turbine losses for predictions of average power output, annual energy output, and average capacity factor:

Downtime (%)	5	
Array (%)	0	
Icing/soiling (%)	3	
Other (%)	2	
Total (%)	9.69	(factors are multiplicative)

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

Turbine	Annual Energy Output (kW-hr/yr)	Fuel Quantity Avoided (liters)	Fuel Quantity Avoided (gallons)	Fuel Price (USD/gallon)							Turbine Hub Height (m)
				$1.75	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	
Southwest Skystream 3.7	4,949	1,499	396	$693	$792	$891	$990	$1,089	$1,188	$1,287	10.7
Southwest Skystream 3.7	6,424	1,945	514	$899	$1,028	$1,156	$1,285	$1,413	$1,542	$1,670	33.5
Bergey Excel-S	23,424	7,094	1,874	$3,279	$3,748	$4,216	$4,685	$5,153	$5,622	$6,090	24
Bergey Excel-S	26,086	7,900	2,087	$3,652	$4,174	$4,695	$5,217	$5,739	$6,261	$6,782	37
Fuhrländer FL30	94,801	28,709	7,584	$13,272	$15,168	$17,064	$18,960	$20,856	$22,752	$24,648	26
Fuhrländer FL30	99,257	30,058	7,941	$13,896	$15,881	$17,866	$19,851	$21,837	$23,822	$25,807	30
Entegrity eW-15 60 Hz	143,171	43,357	11,454	$20,044	$22,907	$25,771	$28,634	$31,498	$34,361	$37,224	25
Entegrity eW-15 60 Hz	152,288	46,118	12,183	$21,320	$24,366	$27,412	$30,458	$33,503	$36,549	$39,595	31
Vestas V15	135,896	41,154	10,872	$19,025	$21,743	$24,461	$27,179	$29,897	$32,615	$35,333	25
Vestas V15	150,155	45,472	12,012	$21,022	$24,025	$27,028	$30,031	$33,034	$36,037	$39,040	34
Northern Power NW 100/20	210,794	63,835	16,864	$29,511	$33,727	$37,943	$42,159	$46,375	$50,591	$54,806	25
Northern Power NW 100/20	226,234	68,511	18,099	$31,673	$36,197	$40,722	$45,247	$49,771	$54,296	$58,821	32

Notes:
1. Clark's Point electrical energy production efficiency assumed to be 12.5 kW-hr/gal
2. Assumes **90**% wind turbine availability with no diversion of power to a thermal or other dump load
3. Assumes linear diesel generator fuel efficiency (i.e., 1:1 tradeoff of wind turbine kW-hr to diesel genset kW-hr)

Temperature Conversion Chart °C to °F

°C	°F	°C	°F	°C	°F
-40	-40	-10	14	20	68
-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	-5	23	25	77
-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	32	30	86
-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	5	41	35	95
-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	10	50	40	104
-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	15	59	45	113
-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
0.5	1.1	10.5	23.5	20.5	45.9
1.0	2.2	11.0	24.6	21.0	47.0
1.5	3.4	11.5	25.7	21.5	48.1
2.0	4.5	12.0	26.8	22.0	49.2
2.5	5.6	12.5	28.0	22.5	50.3
3.0	6.7	13.0	29.1	23.0	51.4
3.5	7.8	13.5	30.2	23.5	52.6
4.0	8.9	14.0	31.3	24.0	53.7
4.5	10.1	14.5	32.4	24.5	54.8
5.0	11.2	15.0	33.6	25.0	55.9
5.5	12.3	15.5	34.7	25.5	57.0
6.0	13.4	16.0	35.8	26.0	58.2
6.5	14.5	16.5	36.9	26.5	59.3
7.0	15.7	17.0	38.0	27.0	60.4
7.5	16.8	17.5	39.1	27.5	61.5
8.0	17.9	18.0	40.3	28.0	62.6
8.5	19.0	18.5	41.4	28.5	63.8
9.0	20.1	19.0	42.5	29.0	64.9
9.5	21.3	19.5	43.6	29.5	66.0
10.0	22.4	20.0	44.7	30.0	67.1

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.