355
4118180

14. 1098
DOE/SEA-3707-20741/80/1

APPLICATION OF WIND ENERGY TO GREAT PLAINS IRRIGATION PUMPING

Final Report

By
L. J. Hagen
Leon Lyles
E. L. Skidmore

October 1979

Work Performed Under Contract No. EX-76-A-29-1026

Department of Agronomy
Kansas State University
Agricultural Experiment Station
Manhattan, Kansas

U.S. Department of Energy

Solar Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

"This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Paper Copy \$11.00
Microfiche \$3.50

APPLICATION OF WIND ENERGY
TO GREAT PLAINS IRRIGATION PUMPING

Final Report

L. J. Hagen, Leon Lyles, and E. L. Skidmore

October 1979

As a Part of The
US DEPARTMENT OF ENERGY
DIVISION OF DISTRIBUTED SOLAR TECHNOLOGY
WIND ENERGY RESEARCH PROGRAM

Interagency Agreement EX-76-A-29-1026

APPLICATION OF WIND ENERGY TO GREAT PLAINS IRRIGATION PUMPING

ABSTRACT

We investigated application of dedicated wind energy systems without energy storage for irrigation in the Great Plains. Major uses of irrigation energy were identified as pumping for surface distribution systems, which could be supplied by variable flow, and pumping for sprinkler systems using constant flow.

A computer program was developed to simulate operation of wind-powered irrigation wells. Pumping by wind turbine systems was simulated for 2 variable and 2 constant flow operational modes in which auxiliary motors were used in 3 of the modes. Using the simulation program, we compared the well yields and maximum pumping rates among the 4 modes as a function of drawdown in a typical well.

The program also was used to determine monthly well yields using a 250 m² swept area wind turbine system in each mode if located at Columbus, Nebraska; Garden City, Kansas; and Amarillo, Texas. Irrigation requirements for various crops at these locations were then matched to monthly water yields. Management practices such as preplant irrigation, limited irrigation, and various crop combinations were compared to determine how they affected the amount of annual, capturable wind energy used. Last, percentage of fossil fuel replaceable by wind energy was computed for the most efficient constant and variable flow modes of wind-powered systems.

We concluded that wind-powered systems could supply half or more of the Great Plains irrigation energy demand if the present mix of sprinkler and surface distribution systems were used. However, in the variable flow modes that used little or no auxiliary energy, two wells would be required to yield amounts of water similar to a continuously pumped well.

Proper irrigation management is important to maximize wind energy use. Fully irrigated summer crops with preplant irrigation will use 30 to 60 percent of the annual, capturable wind energy, depending on crop and location. Equal areas of fully irrigated corn and winter wheat will use 70 to 85 percent of the wind energy, depending on location. With limited irrigation, 50 to 100 percent of the wind energy can be used, depending on practices followed.

Key words: wind power, wind systems, agriculture, irrigation, pumping, model.

EXECUTIVE SUMMARY

TABLE OF CONTENTS

	<u>Page</u>
Objectives	ii
Procedure	iii
Conclusions	ix

APPLICATION OF WIND ENERGY TO GREAT PLAINS IRRIGATION PUMPING

In the Great Plains, the locations of high windspeed areas and major groundwater aquifers coincide. Thus, both wind energy and energy demand for irrigation pumping are present, but it must be determined to what extent the use of wind power will be constrained by technical characteristics of irrigation systems and irrigated crops.

Objectives: We investigated the applications for dedicated wind energy systems without energy storage in Great Plains irrigation schemes and determined some of the irrigation management and engineering problems associated with the chosen applications. Specific objectives of the investigation were to:

1. Survey the irrigation methods, crops, fuels (energy), lifts, and water pumped in the Great Plains and determine the operational modes of wind turbines needed if large amounts of fossil fuels are to be replaced by wind energy.
2. Develop a general procedure to calculate effects of wind turbine size, rated windspeed, and operational mode on resultant well yield and drawdown for a given aquifer and wind regime.
3. Determine crop combinations and management practices that permit maximum use of wind energy to pump irrigation water.

4. Determine amount of fossil fuels that could be replaced by wind power in Great Plains irrigation.

Procedure: From a literature review of irrigation in the Great Plains, we identified the major uses for wind energy in irrigation as (1) pumping for sprinkler systems using constant flow. Calculations were made to determine amount of energy used by each system.

Next, a computer program was developed to simulate operation of wind-powered irrigation wells to supply water for sprinkler and surface distribution systems. Only dedicated wind turbine systems without energy storage were considered because they are the first systems being tested for irrigation pumping. Overall efficiencies (wind-to-water) were calculated as a function of windspeed from performance curves of representative vertical axis wind turbines (VAWT) and vertical turbine pumps coupled by 90-percent-efficient transmissions. Wind turbine systems were simulated for 2 constant flow and 2 variable flow operational modes. The 4 different modes of operation studies are shown in Figures i through iv. Auxiliary motors were used in all except one of the variable flow modes (Table S-1). The program contained approximate equations to describe the behavior of a water-table aquifer under cyclic pumping and an approximate model of cyclic wind power inputs based on Weibull windspeed distributions at a location.

The simulation program was used to compare capturable wind energy among the 4 modes. Also, performance of a typical well was simulated

Figure 1. Conceptual illustration of wind turbine used in Mode 1 for irrigation pumping.

Figure 2. Conceptual illustration of wind turbine used in Mode 2 for irrigation pumping.

Figure 3. Conceptual illustration of wind turbine used in Mode 3 for irrigation pumping.

Figure 4. Conceptual illustration of wind turbine used in Mode 4 for irrigation pumping.

Table S-1. Summary of characteristics of various modes of operation studied.

Characteristic	Mode			
	1	2	3	4
Wind turbine to pump transmission ratio	Fixed	Variable	Fixed	Variable
Auxiliary motor power	1.0 x wind-turbine rating	1.0 x wind-turbine rating	None	0.4 x wind-turbine rating
Irrigation distribution system	Sprinkler	Sprinkler	Surface flow	Surface flow
Pump speed and well discharge	Constant	Constant	Variable	Variable

using 4 operational modes of the wind turbine to determine well yields and maximum pumping rates as a function of drawdown.

The computer program was next used to determine monthly yields of a typical well for a 250 m² swept area wind turbine system operated in each of 4 modes at Columbus, Nebr., Garden City, Kans.; and Amarillo, Tex. Irrigation requirements for various crops were then matched to monthly water yields. Management practices such as preplant irrigation, crop combinations, and limited irrigation were compared to determine how they affected percentage use of the annual capturable wind energy. Last, percentage of fossil fuel replaced by wind energy using the most efficient constant and variable flow modes for the wind turbine systems was calculated.

Conclusions:

1. Sprinkler irrigation requires a relatively constant flow mode capable of nearly continuous operation during peak water-use periods. About 45 percent of the irrigation energy demand is in this mode--25 percent to power the sprinklers and 20 percent to lift water for the sprinklers. A wind turbine with variable-ratio transmission and auxiliary motor sized to equal the rated power of the wind turbine (mode 2) can supply 30 to 45 percent of the sprinkler energy demand from wind power, depending on crop and location.
2. About 55 percent of the energy demand is for lifting water for surface distribution systems. By using small reservoirs or irrigation canals as temporary storage, surface distribution

systems can be supplied by variable flow pumping. A wind turbine with variable-ratio transmission and auxiliary motor sized at 0.4 the rated power of the wind turbine (mode 4) can supply 60 to 70 percent of this demand from wind power.

3. From the preceding results, we conclude that wind turbine systems in modes 2 and 4 could supply half or more of the energy demand of Great Plains irrigation using the present mix of sprinkler and surface distribution systems.
4. Comparison of 4 wind turbine operational modes showed 2 and 4 were superior. The variable-ratio transmissions used in modes 2 and 4 increased the capturable wind energy by 10 to 25 percent compared to the fixed-ratio transmissions of modes 1 and 3.
5. Using an auxiliary motor with a wind turbine requires fossil fuels and increases capital costs, but also has some advantages. Motors increase the area which can be fully irrigated from each well in summer and, thus, increase the area that each wind turbine can preplant irrigate. This resulted in a 10 to 20 percent increase in use of the annual wind energy on fully irrigated summer crops as compared with use by a wind-alone system (mode 3).
6. The computer program developed in this study can be used to determine needed wind turbine size for given well and aquifer characteristics. Simulation of performance of a typical well showed that for a wind turbine operated with little or no

auxiliary energy (modes 3 and 4), 2 wells were required to yield amounts of water similar to those from a continuously pumped well. Maximum permissible flow rates through the well-screen limit maximum well yield under cyclic pumping. At 60 percent drawdown, inflow rates were 23 to 33 percent greater with cyclic than with continuous pumping.

7. Adoption of various irrigation management practices increases use of annual capturable wind energy. In modes 2 and 4, fully irrigating corn with a preplant irrigation used about 30 percent of the annual wind energy at Amarillo and 45 percent at Columbus and Garden City. Without preplant irrigation, 25 percent or less was used. In the same modes, fully irrigating equal areas of corn and winter wheat used 70 to 85 percent of the annual wind energy, depending on location. Substituting grain sorghum, or cotton in the South, for corn permits slightly higher use of annual wind energy. Fully irrigating alfalfa in eastern Nebraska used 56 percent of the annual wind energy. Thus, fully irrigating summer crops with preplant irrigation will use 30 to 56 percent of the capturable wind energy, depending on crop and location.
8. When available water is limited or energy is expensive (relative to returns), farmers often use limited irrigation of crops adapted to dryland farming. With limited irrigation, 52 to 100 percent of the annual wind energy can be used, depending on crops and management practices.

TABLE OF CONTENTS	Page
EXECUTIVE SUMMARY -----	i
LIST OF FIGURES -----	xiii
LIST OF TABLES -----	xvi
LIST OF SYMBOLS -----	xvii
INTRODUCTION -----	1
OBJECTIVES -----	4
PROCEDURE -----	5
APPLICATIONS FOR WIND ENERGY IN GREAT PLAINS IRRIGATION -----	6
WIND ENERGY AND WELL YIELD -----	13
Modes of Operation -----	13
Response of Water-Table Aquifer to Complex Pumping Cycles ---	29
Modeling Cyclic Power Input -----	36
Well Performance -----	41
MATCHING CROP WATER NEEDS AND WIND ENERGY -----	45
CONCLUSIONS -----	59
REFERENCES -----	62
 APPENDIX A - State Summaries of Energy Used for Great Plains Irrigation -----	 A-1
APPENDIX B - Method of Determination and Summary of Weibull Parameters at Selected Great Plains Weather Stations -----	 B-1
APPENDIX C - Computer Program to Simulate Wind-Powered Irrigation Wells and Examples of Output at 3 Locations -----	 C-1

LIST OF FIGURES

Figure number	Page
1. Mean annual wind power (watts/m ²) estimated at 50 m above exposed areas. Over mountainous regions (shaded areas), the estimates are lower limits expected for exposed mountain tops and ridges (Elliot, 1977). -----	2
2. Major ground-water aquifers in the Great Plains (Geraghty et al., 1973). -----	3
3. Pump performance curves for a vertical turbine pump with N _s of 4,000. Dotted lines (---) indicate possible operational behavior at various speeds with a fixed and a linearly increasing head. -----	15
4. Pump performance curves for a vertical turbine pump with N _s of 2,500. Dotted lines (---) indicate possible operational behavior at fixed and a linearly increasing head. -----	16
5. Average power coefficient (C _p) data as a function of tip speed ratio (R _w /U) for a Darrieus VAWT with NACA 0012 blades (Blackwell, Sheldahl, and Feltz, 1976). -----	17
6. Overall efficiency and water power of a wind turbine and pump in modes 1 and 2. -----	21
7. Overall efficiency and water power of a wind turbine and pump in modes 3 and 4. -----	22
8. Schematic diagrams of 4 modes of operation considered. -----	24
9. Overall efficiency and wind energy as a function of average July windspeeds at 20 m, at 3 locations. -----	27
10. July water energy from wind as a function of wind turbine operational mode at Garden City, Kans.; Amarillo, Tex.; and Columbus, Nebr., for a 0.13 solidity Darrieus VAWT and vertical turbine pump with N _s = 4,000. -----	28
11. Diagram of a horizontal water-table aquifer showing notation used in text. -----	30
12. Relative water levels at a well in a water-table aquifer pumped continuously and in 6-day cycles (3 days on and 3 days off). Aquifer and well characteristics were K = 18.3 m/day, D _w = 45.7 m, R _w = 30.5 cm, E = 0.2, and Q = 0.126 m ³ /s (2,000 g.p.m.) Later ^w computer simulations were performed using somewhat different characteristics, but chosen to give similar water level behavior. -----	33

Figure number	Page
13. Minimum water levels at a water-table aquifer well pumped continuously and in 6-day cycles with various fractions of time on. Aquifer and well characteristics same as Figure 12. ----	34
14. Schematic of monthly pumping cycles. Zero power level represents time windspeeds were less than wind turbine cut-in windspeeds, while width of other steps represents durations of various power (windspeed) levels. For illustration only, 2 complete cycles are shown for the first month; however, 10 cycles per month were used in calculations. -----	37
15. Percentage of time when windspeeds remained equal or greater than a given windspeed for a successive number of hours (July 1977, Garden City, Kans.) -----	39
16. Relative water levels at a well in a water-table aquifer pumped continuously at 3 rates shown. Aquifer and well characteristics were $K = 18.3$ m/day, $D_o = 45.7$ m, $E = 0.20$, and $R_w = 30.5$ cm. -----	40
17. Variation in maximum inflow and total well yield as a function of maximum drawdown for modes 1-4 and various sizes of wind turbines at Garden City, Kans., for average of spring and summer windspeeds. Steady state (ss) operation was defined as a drawdown of 60 percent with continuous pumping.-	43
18. Monthly percentage of annual water pumped at Garden City, Kans.; Amarillo, Tex.; and Columbus, Nebr., for well of Table 5 and wind turbines in operational modes 2, 4 (continuous in July and August), and mode 3. -----	46
19. Annual water allocation from pumping and soil moisture to meet the NIR of 1 ha of corn and 1.36 ha of winter wheat at Garden City, Kans., using a wind turbine pumping in mode 4 operating continuously in July and August. -----	50
20. Effects of preplant irrigation of corn on wind energy use by wind turbines operated in 4 modes at Columbus, Nebr. -----	52
21. Effects of preplant irrigation of corn on wind energy use by wind turbines operated in 4 modes at Amarillo, Tex. -----	53
22. Effects of preplant irrigation of corn on wind energy use by wind turbines operated in 4 modes at Garden City, Kans. -----	54
23. Effects of mixing various ratios of corn and wheat on wind energy use by wind turbines operated in 4 modes at Garden City, Kans. -----	56

Figure
number

Page

24. Effects of mixing various ratios of corn and wheat on wind
energy use by wind turbines operated in 4 modes at Amarillo,
Tex. ----- 57

LIST OF TABLES

Table number		Page
1.	Energy used for lifting and distributing irrigation water in the Great Plains States. -----	7
2.	Area irrigated by surface and sprinkler distribution systems by type of fuel in the Great Plains States. -----	10
3.	Area of various irrigated crops in the Great Plains. -----	12
4.	Summary of characteristics of various modes of operation studied. -----	25
5.	Specifications for aquifer, well, pump, and wind turbine used to calculate drawdown, maximum pumping rate, and yield of example. -----	42
6.	Monthly net irrigation requirement (cm) for fully irrigated crops in eastern Nebraska (1), southwest Kansas (2), and Texas High Plains (3). -----	47
7.	Average available water capacity for Kansas soils. -----	49

LIST OF SYMBOLS

CN	Number of windspeed cycles per month (mo^{-1})	$(Q_{wt})_{\text{max}}$	Maximum pumping rate of wind turbine (m^3s)
C_p	Power coefficient of wind turbine	(Q_{ss})	Steady-state pumping rate (m^3s)
D_L	Well depth (m)	R	Maximum radius of VAWT (m)
D_o	Saturated thickness of aquifer (m)	R_e	Radial distance from well where water table equals D_o
D_w	Height of water at well radius (m)	R_t	Transmission ratio
E	Specific yield of aquifer	R_w	"Effective" well radius (m)
H	Head at pump (m)	t	Time (days)
h_w	Height of water in well (m)	T_i	Windspeed cycle step
K	Hydraulic conductivity of aquifer (m/day)	U	Windspeed (m/s)
m	Empirical function of τ	VAWT	Vertical axis wind turbine
N	Pump rotational speed (rpm)	WL	Well-loss coefficient (s^2/m^5)
N_p	Pump efficiency	WUE	Crop water use efficiency
N_s	Specific speed of pump $[\frac{\text{rpm}}{\text{ft}^{3/4}} (\frac{\text{gal}}{\text{min}})^{1/2}]$	λ	Wind turbine tip speed ratio
NIR	Crop net irrigation requirement (cm)	τ	Dimensionless time parameter
P	Wind turbine power (kW)	ω	Rotational speed of wind turbine (rad/s)
Q	Pumping rate or well discharge (m^3/s)		

INTRODUCTION

The potential for using wind power for irrigation pumping in the Great Plains becomes apparent by comparing distributions of wind power (Figure 1) and major irrigation aquifers (Figure 2).

A region of high wind power extends northward from northern Texas in which average annual wind power exceeds 300 watts/m². In portions of the area, average power exceeds 500 watts/m². The Ogallala aquifer also extends from northern Texas to the South Dakota border and supplies a major portion of the irrigation water in the Great Plains. Thus, both the wind power and power demand are present, but it must be determined to what extent this use of wind power will be constrained by technical characteristics of irrigation systems and irrigated crops.

Figure 1. Mean annual wind power (watts/m^2) estimated at 50 m above exposed areas. Over mountainous regions (shaded areas), the estimates are lower limits expected for exposed mountain tops and ridges (Elliot, 1977).

Figure 2. Major ground-water aquifers in the Great Plains (Geraghty et al., 1973).

OBJECTIVES

The purpose of this investigation was to identify the applications for wind energy systems without energy storage in Great Plains' irrigation schemes and determine some of the irrigation management and engineering problems associated with the chosen applications. Specific objectives of the investigation included:

1. Survey the irrigation methods, crops, fuels (energy), lifts, and water pumped in the Great Plains and determine the operational modes of wind turbines needed if wind energy is to replace large amounts of fossil fuels.
2. Develop a general procedure to calculate effects of wind turbine size, rated windspeed, and operational mode on resultant well yield and drawdown for a given aquifer and wind regime.
3. Determine crop combinations and management practices that permit maximum use of wind energy to pump irrigation water.
4. Determine amount of fossil fuels that could be replaced by wind power in Great Plains irrigation.

PROCEDURE

The literature on irrigation in the Great Plains was reviewed to accomplish objective one. Much of the necessary data has been compiled by Sloggett (1976b) and the Editors of the Irrigation Journal (1977). Calculations from their data were made to determine where large amounts of wind energy could be used in Great Plains irrigation.

Objective two was accomplished by first determining realistic operation modes for a vertical axis wind turbine (VAWT) directly coupled to a vertical turbine pump. Next, approximate equations were formulated to describe the behavior of a water table aquifer under cyclic pumping, and finally, a computer program was developed to solve those equations for complex cyclic inputs of wind power and to calculate the reduction in well yield by various modes of wind turbine operation.

The third objective was accomplished by matching the irrigation requirements of various crop combinations to stored soil water and calculated well yield on a monthly basis. Management practices were determined that would utilize wind energy most efficiently.

The final objective was accomplished by calculating the percentage of wind energy that could be used to power sprinkler and surface distribution irrigation systems using appropriate modes of wind turbine operation.

APPLICATIONS FOR WIND ENERGY IN GREAT PLAINS IRRIGATION

Total 1975 irrigated acreage in the United States was estimated to be 21,989,451 ha, with slightly more than 50 percent of the irrigated acreage located in the 10 Great Plains States. Sloggett (1976b) estimated that in 1974 more than 14 million ha in the United States were irrigated with the aid of energy-using pumps on farms and ranches; about 8 million ha of those were in the Great Plains. Although irrigated acreage in some states, such as Texas, may decline in a few years because of dropping water tables, in others, such as Nebraska, continued rapid expansion of irrigated acreage is expected. Thus, there is a large and continuing need for energy to power farm irrigation pumps in the Great Plains.

Sloggett (1976b) estimated that in 1974, irrigation pumping consumed 20 percent of U.S. energy used for on-farm production and totaled 76.6 billion kWh. About 66 percent of this total was used in the Great Plains. Nearly 70 percent of the energy consumed by Great Plains irrigation was used for lifting groundwater, and about 25 percent was consumed by sprinklers (Table 1).

Table 1. Energy used for lifting and distributing irrigation water in the Great Plains States.^{a/}

Region	Pumping		Distribution system		Total
	Groundwater	Surface water	Sprinkler	Surface	
	----- Billion kWh -----				
Great Plains	35.10	1.07	12.58	1.88	50.62
Percent	69.3	2.1	24.9	3.7	100.0

^{a/} Calculated from data of Sloggett (1976a).

The two major types of distribution systems shown in Table 1, sprinkler systems and surface systems, place distinctly different operating restraints on the pumping unit used. Sprinkler systems are usually designed for constant flow and nearly continuous operation during peak water-use periods. They are recommended for fields with a high or variable infiltration rate, low water-holding capacity, or rolling topography. Sprinklers are used on about 28 percent of the irrigated area in the Great Plains. To provide satisfactory operation, sprinkler systems must operate at a constant pressure, which in turn requires constant pump speed. To supply power for sprinkler systems, wind turbines must be coupled to auxiliary power sources to produce a steady output. The water will likely be pumped as it is used by the sprinkler, so about 20 percent of the total (28 percent of the pumping energy) would be used to lift and 25 percent used to pressure water for sprinklers. Thus, if wind powered, about 45 percent of the total energy consumed would be used by sprinkler systems requiring auxiliary power sources.

The remaining 55 percent of the energy is used for pumping water into surface distribution systems. This energy can be supplied by wind turbines and auxiliary power sources from which the flow is allowed to vary. Small reservoirs or large canals can be used to store water temporarily for the surface distribution systems to buffer short-term variations in flow to permit efficient irrigation.

Nebraska, Kansas, and Texas contain 80 percent of the Great Plains irrigated acreage. Water can be pumped all months of the year in Texas and from 9 to 11 months in Kansas and Nebraska. Pumping time varies widely from farm to farm and somewhat between years, depending on precipitation. Anschutz and Lipper (1975) reported county averages of operating time for electric pumps were about 1,000 hours (11 to 12 percent of the year) in western Kansas. Increasing irrigated areas and decreasing water tables, however, are causing many farmers to extend their pumping time each year, particularly in dry years. New (1975) reported that, in 1974, many pumps in Texas were operated nearly continuously from February through August, or about 5,000 hours. The average lift for groundwater decreases from south to north and ranges from 107 to 21 m (Appendix A).

It is also important to consider the kind of fuel wind turbines might replace in pumping water. Table 2 shows that natural gas is used to supply water for more than 50 percent of the irrigated acreage in the Great Plains, with the largest amounts used in Texas, Nebraska, Kansas, and New Mexico. When supplies of natural gas become limited in the future, wind power might supply a replacement for natural gas in Great Plains irrigation. Outside the Great Plains, electricity is the dominant power source.

Table 2. Area irrigated by surface and sprinkler distribution systems
by type of fuel in the Great Plains States.^{a/}

Energy source	Distribution systems		Percent by fuel
	Surface	Sprinkler	
	----- 1,000 ha -----		
Electricity	1,557.43	605.68	27.0
Diesel	552.46	214.84	9.6
Gasoline	95.57	37.21	1.7
Natural gas	2,911.54	1,132.29	50.5
LPG	648.48	252.17	11.2
Total	5,765.48	2,242.19	
Percent of U.S.	57.1	54.6	
Total U.S.	10,090.0	4,104.70	

^{a/} Calculated from data of Sloggett (1976a).

Finally, in adapting new systems, one must consider the crops irrigated. Table 3 shows that corn comprises the largest acreage, and it is usually fully irrigated. Large acreages of sorghum and wheat also are irrigated, but these crops can be grown under partial irrigation. Cotton is limited to the southern portion of the Great Plains, while some irrigated alfalfa is grown in every state. Crops in the "other" category include sugarbeets, potatoes, popcorn, soybeans, peanuts, vegetables, and fruits. Total irrigated area in Table 3 exceeds 12 million ha. This area exceeds Sloggett's (1976b) data because it includes areas irrigated by water not pumped on the farm as well as increases in irrigated area with time.

Table 3. Area of various irrigated crops in the Great Plains.^{a/}

State and region	Corn	Sorghum	Hay and pasture ^{b/}	Small grains	Cotton	Other
	1,000 ha					
North Dakota	19.0	0	18.2	6.1	0	11.4
South Dakota	72.9	3.2	60.7	8.5	0	6.4
Nebraska	2,174.8	80.9	344.0	40.5	0	199.0
Kansas	657.6	210.4	141.6	224.6	0	43.5
Oklahoma	50.0	74.9	75.8	102.0	35.2	47.0
Texas	647.5	971.3	182.1	728.5	768.9	256.6
Montana	0	0	1,054.9	135.9	0	28.8
Wyoming	64.8	0	466.7	101.2	0	38.7
Colorado	360.2	35.6	624.4	109.3	0	108.5
New Mexico	0	50.1	153.8	72.4	30.0	8.5
Totals	4,406.8	1,426.4	3,122.2	1,529.0	834.1	748.4
Percent	36.5	11.8	25.9	12.7	6.9	6.2

^{a/} Data from Irrigation Journal, 1977 Survey Issue, Nov.-Dec. 1977,
Brantwood Publications Inc., Elm Grove, Wis.

^{b/} Includes alfalfa.

WIND ENERGY AND WELL YIELD

Modes of Operation

In designing an irrigation system to use wind power, one must supply power for a variable or constant flow mode. Gilmore, Barieau, and Nelson (1977) discussed the problems of wind-powered irrigation using positive displacement and airlift pumps coupled to horizontal axis rotors. Here, we will compare modes of operation for a wind turbine mechanically coupled to a deep-well vertical turbine pump of conventional design. The specific wind turbine used in this analysis is a Darrieus VAWT. The Darrieus design was used because the only commercial wind turbine available with mechanical power output at the time of this study was of this design. Thus, it most likely represented the type of wind turbine to be used in irrigation experiments in the immediate future.

To compare modes, one needs the following information for the range of operating conditions: (a) efficiency of pump, (b) power coefficient of the wind turbine, (c) efficiency of the transmission, and (d) wind energy distribution at a location.

Deep-well turbine pumps used for on-farm irrigation pumping have moderate specific speeds (N_s), which range from about 1,500 to 5,000. N_s is the similarity criterion for turbine pumps and determines many important dimensions of the pump. It is defined at the pump's best efficiency point as:

$$N_s = N\sqrt{Q}/H^{.75}$$

where the units N in rpm, Q in gal of flow per min, and H in feet of head are used in U.S. practice (Karassik et al., 1976).

Figure 3 shows behavior of a typical turbine pump if operated at variable speed with a constant head or a head that increases linearly with output. The maximum rpm range has a ratio of final to initial operational rpm of about 1.8. At lower than 1,160 rpm, shutoff head would likely be encountered in most applications, and above 2,060 rpm, problems with critical shaft speeds and cavitation may be encountered in usual designs. (For a discussion of these latter problems, see Stepanoff, 1957). Lines of constant efficiency also denote lines of constant N_s . This fact was used to estimate performance of the pump at 2,060 rpm, whereas the performance at lower speeds was obtained from the manufacturer's test results. We used the operational line of increasing head with output from Figure 3 in our calculations. Pumps with low N_s differ slightly, as illustrated in Figure 4.

Results of wind-tunnel tests conducted by Sandia personnel using a small Darrieus VAWT of 0.13 solidity are shown in Figure 5 (Blackwell, Sheldahl, and Feltz, 1976). Because performance improves with increasing blade Reynolds number, these results are predicted to be conservative for a large VAWT (Strickland, 1975). However, effects of atmospheric turbulence and support struts will tend to reduce the performance of large machines. Thus, for our calculations the test results in Figure 5 were used unchanged. Finally, the efficiency of constant-ratio or variable-ratio speed-increasing transmissions used in the various modes was assumed to be 90 percent.

Figure 3. Pump performance curves for a vertical turbine pump with N_s of 4,000. Dotted lines (---) indicate possible operational behavior at various speeds with a fixed and a linearly increasing head.

Figure 4. Pump performance curves for a vertical turbine pump with N_s of 2,500. Dotted lines (---) indicate possible operational behavior at fixed and a linearly increasing head.

Figure 5. Average power coefficient (C_p) data as a function of tip speed ratio ($\frac{R\omega}{U}$) for a Darrieus VAWT with NACA 0012 blades (Blackwell, Sheldahl, and Feltz, 1976).

Many ways of using wind power for irrigation pumping can be readily conceived. However, those which are most feasible will be those which best exploit (or cause least conflict among) the known characteristics of wind turbines, deep-well pumps, wells, irrigation distribution systems, and infiltration of water into the soil. In addition, because wind power systems are capital intensive in themselves, it is assumed that wind power irrigation schemes which require a minimum of other capital investment (i.e., additional wells, battery storage units, large water storage reservoirs) are more likely to be feasible. These factors led us to narrowing the many possibilities to the following four modes of wind turbine operation for specific consideration. These are:

Mode 1

In this mode, the wind turbine drives the turbine pump through an overrunning clutch using a fixed-ratio transmission system. The turbine pump is also driven by a speed-governed auxiliary power source having a capacity equal to that of the rated power of the wind turbine. The constant-speed pump operation would be suitable for use with a sprinkler distribution system. Because of the fixed transmission ratio and the constant pump speed, the wind turbine will operate at a constant rotational velocity when the wind is blowing, regardless of the windspeed. The overall efficiency (wind-to-water) for this mode of operation can be calculated using estimates of pump efficiency (80 percent) and permitting the coefficient of performance (C_p) of the wind turbine to vary with the windspeed. The result is shown in Figure 6. It can be seen that as windspeed is reduced, the constant-speed wind turbine operates at a tip speed ratio which increases well beyond the optimum. This reduces the power coefficient of the wind turbine and greatly reduces the power produced at low windspeeds.

Mode 2

This mode of operation is identical to mode 1 with the exception that a variable-speed transmission system is used at low windspeeds, permitting the wind turbine to slow down at low windspeeds to maintain a tip speed ratio which maximizes the power coefficient. The performance of this system is also shown in Figure 6.

Mode 3

In this operation, the wind turbine is coupled to the pump with a constant-ratio transmission, with no auxiliary power source. By properly matching the size of the pump to the size of the wind turbine, the wind turbine will tend to operate at a speed which is proportional to the windspeed, since it will produce power proportional to the cube of its rotational speed and it is driving a turbine pump whose power demand is proportional to the cube of its rotational speed. However, the efficiency of the pump will vary with rotational speed with lowest efficiencies occurring at the lowest and highest rotational speeds. Using published data on pump efficiency (Figure 3) and assuming constant C_p of the wind turbine of 0.29, the overall efficiency of mode 3 operation can be calculated, as shown in Figure 7. Maximum rotational speed was assumed to occur at 11 m/s, and an overspeed control device would be necessary to prevent higher rotational speeds when windspeeds exceed 11 m/s.

Figure 6. Overall efficiency and water power of a wind turbine and pump in modes 1 and 2.

Figure 7. Overall efficiency and water power of a wind turbine and pump in modes 3 and 4.

Mode 4

This mode of operation uses a small auxiliary power source to supplement the wind turbine at low windspeeds and uses a variable-ratio transmission between the wind turbine and pump. For our analysis we chose an auxiliary power source size of 40 percent of the rated wind turbine power. This size keeps the speed of the pump high enough so that it operates near maximum efficiency at low windspeeds. Performance and operational characteristics for such a system were computed and are shown in Figure 7. The motor and variable-ratio transmission reduce the pump speed range, which may reduce the number of pump stages needed also.

Figure 8 shows schematically the major system components of four different modes of wind turbine operation, while Table 4 summarizes different characteristics of these various modes.

Figure 8. Schematic diagrams of 4 modes of operation considered.

Table 4. Summary of characteristics of various modes of operation studied.

Characteristic	Mode			
	1	2	3	4
Configuration				
Wind turbine to pump transmission ratio	Fixed ($R_t = \text{constant}$)	Variable ($R_t \propto 1/U$)	Fixed ($R_t = \text{constant}$)	Variable $U > U_c, R_t = \text{constant}$ $U < U_c, R_t \propto 1/U$
Auxiliary motor power	1.0 x wind turbine rating	1.0 x wind turbine rating	None	0.4 x wind turbine rating
Irrigation distribution system suitability	Sprinkler or surface flow	Sprinkler or surface flow	Surface flow	Surface flow
Operation				
Pump speed	Constant	Constant	Variable	Variable at high wind Constant at low wind
Well discharge	Constant	Constant	Variable	Variable
Pump efficiency	Constant	Constant	$f(U)$	$f(U)$
Wind turbine speed	Constant	$\omega \propto U$	$\omega \propto U$	$\omega \propto U$
Wind turbine tip speed ratio	$\lambda \propto 1/U$	$\lambda = \text{constant}$	$\lambda = \text{constant}$	$\lambda = \text{constant}$
Wind turbine power coefficient	$f(U)$	Constant	Constant	Constant

The overall efficiency curves can be moved right or left by changing the gear ratio of transmission and size of pump or wind turbine. However, to maximize useful work from the wind turbine, maximum efficiencies should coincide with windspeeds where maximum wind energy occurs (Figure 9).

The wind energy here and in other parts of this study was calculated as follows: a monthly Weibull distribution (Appendix B) was calculated from the windspeed summaries reported by Reed (1975). The windspeed measurements were assumed to be from the 10-m height; the probable center height of a wind turbine is estimated to be 20 m. The windspeeds at 20 m were estimated as

$$U_{20} = U_{10} (2)^{1/7}.$$

Finally, the wind energy (P_i) at the midpoint of each 1-m/s windspeed group was calculated as

$$P_i = 6,125 \times 10^{-7} U_i^3 (\Delta t_i)$$

where P_i is kWh/m² per month, U_i is m/s, and Δt_i is hours per month in the i th windspeed group using an average month of 730 hours. Energy distributions from locations representing high, medium, and low windspeeds during July were calculated (Figure 9).

The product of wind energy and efficiency was integrated over all windspeeds to determine monthly energy from the VAWT in the 4 modes (Figure 10). Mode 3 extracts 5 to 10 percent more energy than mode 1, while using a variable-ratio transmission (modes 2 and 4) increases useful energy 10 to 25 percent.

Figure 9. Overall efficiency and wind energy as a function of average July windspeeds at 20 m, at 3 locations.

Figure 10. July water energy from wind as a function of wind turbine operational mode at Garden City, Kans.; Amarillo, Tex.; and Columbus, Nebr., for a 0.13 solidity Darrieus VAWT and vertical turbine pump with $N_s = 4,000$.

Response of Water-Table Aquifer to Complex Pumping Cycles

It is necessary to determine the behavior of the aquifer under complex pumping cycles in order to determine both the well drawdown and yield of irrigation water a wind-powered irrigation pump might produce. Several approaches to the problem are possible. Transient aquifer behavior can be described by differential equations, which can be solved by finite difference methods (McWhorter and Sunada, 1977). When complex pumping cycles are imposed as part of the problem, however, long computing times are necessary to reach a solution.

A relatively simple model of the pumping cycles and water table response was used in this study. Equations in the model are outlined here, and the computer program to solve the equations is listed in Appendix C. The model applies only to horizontal, nonleaky, water-table aquifers, but these represent most of the Great Plains aquifers used for irrigation.

Useful, approximate solutions to the differential equations of drawdown were reported by Hantush (1964). The solutions are for $\tau < 5$ and for $\tau > 5$, where τ is a dimensionless time factor of the form

$$\tau = (Kt/ED_0) \quad [1]$$

where K is hydraulic conductivity (m/day), t is time since discharge of well began (days), E is specific yield (dimensionless), and D_0 is saturated thickness of aquifer (m) (Figure 11).

Figure 11. Diagram of a horizontal water-table aquifer showing notation used in text.

For $\tau < 5$, Hantush (1964) reported drawdown is approximately

$$D_o - D_w = (Q/2\pi K D_o) [m + \ln(D_o/R_w)] \quad [2]$$

where m is a function of τ and given by the empirical relation

$$m = -0.1 + 4.628(\tau) - 4.014(\tau^{1.05}). \quad [3]$$

Q is well discharge, R_w is "effective" well radius, and D_w is height of water at the well radius.

For the case of $\tau > 5$, the aquifer response is approximated as

$$D_o^2 - D_w^2 = \frac{Q}{\pi K} \ln(1.5 D_o \sqrt{\tau}/R_w). \quad [4]$$

Equations 2 and 4 apply only to wells that completely penetrate the aquifer and neglect drawdown from well losses. Near $\tau = 5$, a weighted average of equations 2 and 4 was used to calculate the drawdown.

Hantush (1964) also noted that water levels at any time after pumping ceases can be obtained by adding the effects of a well recharging at rate Q from the time pumping ceases to the effects of a well continuously discharging at rate Q from the time pumping begins. Thus, we can add the drawdown caused by previous cycles to the drawdown caused by the current pumping cycle.

To illustrate the solution obtained from equations 2 and 4, the behavior of a typical large irrigation well was calculated for 6-day cycles (3 days on and 3 days off) at constant Q , compared with the same well continuously pumped (Figure 12). Maximum drawdown and average head were less, and total yield was half in the cycled well as compared with the continuous well. Of course, for equal total water yields, the least energy is required if the well is pumped continuously. Reducing the fraction of pumping time also reduces the maximum drawdown (Figure 13).

The cyclic drawdown is composed of two parts--the drawdown caused by current Q and the residual from previous cycles. After 30 days (Figure 12), the residual causes 7 percent and the current Q about 30 of the aquifer to be dewatered. The residual drawdown is small, but exact computation from equations 2 and 4 requires a large number of computer iterations unless the cycles have constant Q , as in our example. Thus, to simplify calculations, the residual was calculated as the drawdown caused by a well pumping at Q averaged over the preceding cycles plus a well recharging at average Q from the beginning of the current "on" period.

To this point, we have considered regular cycles with constant Q . A wind turbine produces a series of power levels, however, and the Q and drawdown must vary to absorb the input power levels. Now the well discharge $Q(\text{m}^3/\text{s})$ at power level P (kw) is

$$Q[(D_L - D_w) + WL(Q^2)] = PN_p/9.806 \quad [5]$$

where N_p is pump efficiency, WL is well loss coefficient (s^2/m^5), and other quantities are identified in Figure 11.

Figure 12. Relative water levels at a well in a water-table aquifer pumped continuously and in 6-day cycles (3 days on and 3 days off). Aquifer and well characteristics were $K = 18.3$ m/day, $D_o = 45.7$ m, $R_w = 30.5$ cm, $E = 0.2$, and $Q = 0.126$ m³/s (2,000 g.p.m.). Later computer simulations were performed using somewhat different characteristics, but chosen to give similar water level behavior.

Figure 13. Minimum water levels at a water-table aquifer well pumped continuously and in 6-day cycles with various fractions of time on. Aquifer and well characteristics same as Figure 12.

Well loss is defined as the drawdown in a discharging well caused by the turbulent flow of water into and inside the well (the difference between D_w and h_w in Figure 11). According to Reinke and Kill (1970), well loss should account for 20 percent or less of the total drawdown in properly designed wells. Thus, it is a significant factor and should be included in determining well discharge. Jacob (1947) suggested well loss could be described as a constant times the square of the discharge rate, and we have adopted this suggestion in equation 5. Rorabaugh (1953) has given a slightly different form for well loss, but his results generally agree with those of Jacob.

Equations 1 through 5 can be used in an iterative procedure to determine maximum drawdown and yield in a well with complex cycles of power input as follows: for a given power input, estimate Q and calculate a residual and current drawdown using equations 1 to 4. Check the results in equation 5 to see if the available power is matched. If not, adjust Q and calculate a new drawdown. Continue iteration until drawdown and Q match the power input for each step of the cycle.

Modeling Cyclic Power Input

In the preceding section, the equations to determine well yield and drawdown from arbitrary power inputs were presented. The duration and magnitude of the power outputs can be obtained in two ways from a wind turbine with known or assumed operating characteristics: (a) use actual serial windspeed records, or (b) use monthly summaries of windspeed distribution and assume some "model" of the windspeed cycles during the month. Because summarized distributions are readily available and easily described using the Weibull distribution (see Appendix B), we used the latter procedure.

A plausible model of a wind-powered system is an arbitrary number of cycles per month (CN), with each cycle consisting of a number of constant-power steps (Figure 14). The number of steps depends on the windspeed increments desired (1-m/s increments are a reasonable choice), and the cut-in, rated, and cut-out windspeeds selected for the wind turbine. The duration of each step is the monthly windspeed duration at each speed increment divided by CN. The power level of each step depends on the windspeed and size and efficiency of wind turbine, pump, and transmission.

Figure 14. Schematic of monthly pumping cycles. Zero power level represents time windspeeds were less than wind turbine cut-in windspeeds, while width of other steps represents durations of various power (windspeed) levels. For illustration only, 2 complete cycles are shown for the first month; however, 10 cycles per month were used in calculations.

Modeling the windspeed distribution as a series of constant length cycles permits exact values of total energy, power levels, and total duration to be used. The model does not use a range of durations for the cycles, however, as found in the serial windspeed record. This feature could be easily incorporated, if reliable statistics were available, to describe the range of durations of windspeed cycles.

Large-scale weather systems generally cause 5 to 10 major wind periods per month. In addition, a diurnal wind pattern is imposed upon the major weather systems. Thus, calculations from serial windspeed records show a range of durations for each windspeed (Figure 15). At Garden City, the windspeed exceeded 6 m/s about 60 times during the month, but duration rarely exceeded 24 hours. Windspeeds of 10 and 12 m/s were exceeded only 33 and 9 times, respectively. Thus, one might choose a range of about 10 cycles for high and 60 cycles for low windspeeds. Drawdown varies slowly with pumping time, particularly at low windspeeds, so the number of cycles is not very critical (Figure 16). To predict maximum drawdowns caused by high windspeeds, we used 10 cycles per month in our calculations.

Figure 15. Percentage of time when windspeeds remained equal or greater than a given windspeed for a successive number of hours (July 1977, Garden City, Kans.)

Figure 16. Relative water levels at a well in a water-table aquifer pumped continuously at 3 rates shown. Aquifer and well characteristics were $K = 18.3$ m/day, $D_0 = 45.7$ m, $E = 0.20$, and $R_w = 30.5$ cm.

Well Performance

The total yield and maximum pumping rate of a well must be considered in designing wind-powered irrigation systems. The model described in previous sections was used to determine the performance of a typical irrigation well at Garden City, Kans., using 4 operational modes of the wind turbine (Table 5). Steady-state (ss) operation of the well was considered as a drawdown of 18 m (60 percent) after 60 days of continuous pumping at $.063 \text{ m}^3/\text{s}$ ($\approx 1,000 \text{ g.p.m.}$). Well loss accounted for 18 percent of the ss drawdown.

A range of wind turbine sizes was used to create unsteady well drawdowns of 45 to 75 percent of the saturated thickness (D_0).

When the wind-powered well reached 60 percent drawdown, the maximum Q to the well exceeded the steady state Q by 23 to 33 percent, depending on operational mode (Figure 17). The upper limits of safe inflow to a well are dictated by well screen areas, packing, and aquifer characteristics (Reinke and Kill, 1970). Thus, special attention is necessary in well development to ensure maximum yields of a wind-powered system. Wells with somewhat larger diameters and better packing would permit increased flow rates, and their economics should be considered if new wells are developed specifically for wind-powered irrigation.

Table 5. Specifications for aquifer, well, pump, and wind turbine used to calculate drawdown, maximum pumping rate, and yield of example.

Variable	Units	Value	VAWT mode
Aquifer:			
Hydraulic conductivity (K)	m/day	20.0	1-4
Specific yield (E)	dimensionless	0.20	1-4
Well:			
Well depth (D_L)	m	70.0	1-4
Saturated thickness (D_o)	m	30.0	1-4
Well loss coefficient (WL)	s^2/m^5	800.0	1-4
Effective well radius (R_w)	m	0.3	1-4
Pump and transmission:			
Efficiency (N_p)	decimal fraction	0.72 variable	1, 2 3, 4
Wind turbine:			
Cut-in windspeed	m/s	5.0	2, 4
		6.0	1, 3
Rated windspeed	m/s	11.0	3, 4
		15.0	1, 2
Cut-out windspeed	m/s	15.0	1-4
Efficiency	decimal fraction	0.3	3, 4
		variable	1, 2
Height above surface	m	20.0

Figure 17. Variation in maximum inflow and total well yield as a function of maximum drawdown for modes 1-4 and various sizes of wind turbines at Garden City, Kans., for average of spring and summer windspeeds. Steady state (ss) operation was defined as a drawdown of 60 percent with continuous pumping.

At 60 percent drawdown, the wind-powered well yielded 50 to 75 percent of total water volume of the steady-state well when auxiliary power sources were not operated below cut-in windspeed in modes 1, 2, and 4 (Figure 17). The lines marked continuous in modes 1 and 2 occurred when auxiliary power was used below cut-in windspeed.

At locations with windspeeds lower than at Garden City, well yield also will be lower. An increase of wind turbine size and a decrease in rated windspeed can be used to increase yields at those locations while maintaining Q the same as at Garden City. It is clear, however, that in modes 3 and 4 two wind-powered wells will be necessary to replace the yield from a single, continuously pumped well. In modes 1 and 2, the auxiliary power source is large and can be operated when windspeed is below cut-in to equal the steady-state output if needed in peak water-use periods. If mode 1 or 2 is used to power sprinklers, then continuous operation is likely, and a second well would be unnecessary.

MATCHING CROP WATER NEEDS AND WIND ENERGY

For economic reasons, a wind turbine should be used as much of the year as possible. Here, we assumed that the wind turbine was large, relative to other farm energy needs, and dedicated to irrigation pumping alone. Thus, it was necessary to determine irrigation management practices and operational modes that would maximize the annual operating time and also replace a high percentage of fossil fuels in the pumping application.

Calculations were made for Amarillo, Tex.; Garden City, Kans.; and Columbus, Nebr., as follows: First, monthly well yields for the well described in Table 5 were calculated for a year using 4 modes of operation of a 250 m² wind turbine and the windspeed distribution for each location (Figure 18 and Appendix C). The wind turbine size was chosen to provide maximum well yield without dewatering the aquifer which would cause a shutdown during maximum pumping periods. The calculated maximum drawdowns ranged from 48 to 78 percent of the saturated thickness during various months. In modes 1, 2, and 4, the auxiliary motor was used to operate the pump continuously in July and August. Second, the monthly well yields were matched to the net irrigation requirements (NIR, Table 6) using various irrigation management practices. Finally, the annual percentage of capturable wind energy used for irrigation and the percentage of fossil fuels replaced in each mode were calculated. Note that using NIR rather than actual irrigation application does not affect the results as long as the irrigation efficiency remains nearly constant throughout the season.

Figure 18. Monthly percentage of annual water pumped at Garden City, Kans.; Amarillo, Tex.; and Columbus, Nebr., for well of Table 5 and wind turbines in operational modes 2, 4 (continuous in July and August), and mode 3.

Table 6. Monthly net irrigation requirement (cm) for fully irrigated crops in eastern Nebraska (1), southwest Kansas (2), and Texas High Plains (3).^{a/}

Month	Crop Areas								
	Corn			Sorghum			Alfalfa		
	1	2	3	1	2	3	1	2	3
Jan								1.5	1.0
Feb								3.0	4.3
March								9.1	12.5
April							0.6	0.7	10.7
May							5.1	8.4	15.0
June	1.7	7.1	9.3	1.1	0.1		10.2	13.1	19.3
July	13.4	17.4	21.2	14.3	15.4	9.7	16.7	16.3	18.0
Aug	13.9	16.4	20.9	12.2	15.7	18.9	13.6	14.4	10.9
Sept	7.6	5.3		4.5	3.9	9.1	7.4	8.7	12.9
Oct	1.5							3.4	8.1
Nov								4.6	1.5
Dec								1.0	0.8
Totals	38.1	46.2	51.4	32.1	35.1	37.7	53.6	65.0	114.1

^{a/} Irrigation requirements account for a rainfall amount which will be equaled or exceeded 80 percent of the time. Data from McDaniels (1960) and USDA Soil Conservation Service in Kansas and Nebraska.

For fully irrigated crops, two management practices, preplant irrigation and crop combinations, were considered. Preplant irrigation is widely practiced in areas of the Great Plains where precipitation does not usually fill the soil profile between crops. Most irrigated soils can store 20 cm or more of water in a 1.5-m profile, and only the shallow, coarse-textured or clay soils store less (Table 7). Of course, not all the water can be withdrawn from the profile before irrigation is needed, and we assumed 12 cm (about 60 percent depletion) as maximum allowed in the calculations.

Many irrigators also grow crop combinations to spread farm workload and risks. For example, averaging the irrigated area in Texas, Oklahoma, and Kansas shows there are about 2.5 ha of corn and grain sorghum for each hectare of small grains, which are principally winter wheats (Table 3).

Figure 19 illustrates how the water pumped in mode 4 could be used to fully irrigate a combination of corn and winter wheat at Garden City, Kans. During part of the winter the water was not allocated because weather sometimes prohibits irrigation. A similar pumping procedure was followed for all modes at the 3 locations. Water was allocated for corn without preplant irrigation, for corn with preplant irrigation, and for corn in combination with winter wheat. The annual percentage of capturable wind energy used for irrigation and the proportion of total irrigation energy derived from the wind were summarized.

Table 7. Average available water capacity for Kansas soils.^{a/}

Soil texture	0-30 cm soil layer			30-152 cm soil layer		
	Field capacity	Wilting point	Available water content	Field capacity	Wilting point	Available water content
	cm/cm					
Sand	0.14	0.06	0.08	0.12	0.05	0.07
Loamy sand	0.19	0.07	0.12	0.17	0.07	0.10
Sandy loam	0.24	0.09	0.15	0.22	0.09	0.13
Fine sandy loam	0.29	0.11	0.18	0.29	0.13	0.16
Loam	0.34	0.13	0.21	0.35	0.16	0.19
Silt loam	0.38	0.15	0.23	0.40	0.19	0.21
Silty clay loam	0.39	0.18	0.21	0.40	0.21	0.19
Sandy clay loam	0.38	0.19	0.19	0.39	0.22	0.17
Clay loam	0.38	0.21	0.17	0.39	0.24	0.15
Silty clay	0.37	0.23	0.14	0.39	0.26	0.13
Clay	0.37	0.25	0.12	0.39	0.28	0.11

^{a/} Data from USDA Soil Conservation Service (1975).

Figure 19. Annual water allocation from pumping and soil moisture to meet the NIR of 1 ha of corn and 1.36 ha of winter wheat at Garden City, Kansas, using a wind turbine pumping in mode 4 operating continuously in July and August.

Use of annual, capturable wind energy increases substantially in each mode if preplant irrigation is used (Figures 20-22). By using the water allocation procedure at Columbus, Nebr., one finds that 43 to 47 percent of the wind energy would be used for fully irrigated corn as compared with 22 percent without preplant irrigation in modes 2 and 4. Fully irrigated alfalfa uses water over a longer season and would use 56 percent of the wind energy in the same modes.

Depending on mode, 20 to 33 percent of the wind energy at Amarillo, Tex., and 38 to 52 percent at Garden City, Kans., can be used on fully irrigated corn with preplant irrigation. Without preplant irrigation, generally less than 25 percent of the wind energy can be used.

Use of auxiliary motors adds to system and fuel costs but has some advantages. Use of motors in modes 1 and 2 (necessary for sprinklers) requires most auxiliary energy but also permits largest percentage use of wind energy. This is because continuous July and August operation produces maximum summer well yield and, thus, maximum area for preplant irrigation per well.

Mode 4 requires only limited auxiliary energy but still uses a high percentage of the capturable wind energy. While not investigated here, the large annual variations in precipitation and wind energy also dictate use of an auxiliary motor to ensure acceptable yields in years with low wind energy. Conversely, the full potential of the wind turbine can be used in years with above-average wind energy.

Figure 20. Effects of preplant irrigation of corn on wind energy use by wind turbines operated in 4 modes at Columbus, Nebr.

Figure 21. Effects of preplant irrigation of corn on wind energy use by wind turbines operated in 4 modes at Amarillo, Tex.

Figure 22. Effects of preplant irrigation of corn on wind energy use by wind turbines operated in 4 modes at Garden City, Kans.

The annual wind energy can be used most effectively by growing a mixture of crops which use water in different seasons. For example, irrigating 1 ha of winter wheat for each hectare of corn permits 70 percent or more of the capturable wind energy to be used, except in mode 3 (wind power alone) where 2 ha of wheat are necessary (Figures 23, 24). In the South, if grain sorghum or cotton were substituted for corn, the amounts of capturable wind energy used would be slightly increased because their NIR is less than that of corn. Increasing the ratio of winter wheat to corn at Garden City, Kans., or Amarillo, Tex., would permit all of the wind energy to be used there. Little irrigated winter wheat is grown in the Columbus, Nebr., area, so it was not considered there.

Limited irrigation is the practice of providing less water than the full NIR for certain crops adapted to dryland farming such as alfalfa, winter wheat, and sorghum. Because crop water-use efficiencies (WUE) are highest at less than full irrigation, farmers adopt limited irrigation whenever energy is expensive or water is limited. Because the Ogallala aquifer is being mined, extensive areas in the states south of Nebraska will only have enough water for limited irrigation by the year 2000 (Solomon, 1971). Thus, although limited irrigation is less common now, it may become more acceptable in the future when water is limited. Because the summer proportion of the annual water application is less and the timing of the application is often not as critical with most uses of limited irrigation compared with full irrigation, the energy available from a wind turbine can be used a much higher percentage of the year in a limited irrigation scheme.

Figure 23. Effects of mixing various ratios of corn and wheat on wind energy use by wind turbines operated in 4 modes at Garden City, Kans.

Figure 24. Effects of mixing various ratios of corn and wheat on wind energy use by wind turbines operated in 4 modes at Amarillo, Tex.

Limited irrigation works best with crops usually grown under dry-land conditions in an area. For example, Stone (1978) reported 3-year-average sorghum yields of 5,221, 5,912, and 6,353 kg/ha (83, 94, and 101 bu/ac) for preplant, preplant plus one summer irrigation, and full irrigation, respectively, in southwestern Kansas. He concluded that preplant plus one summer irrigation should be used to obtain high yields and highest WUE. He also noted that timing of the summer irrigation was not critical and yields were acceptable with only a preplant irrigation. Thus, in western Kansas limited irrigation of grain sorghum could use all the capturable wind energy whenever weather permitted irrigation.

In Texas, Musick and Dusek (1971) found a preplant irrigation and a single 10-cm irrigation applied at heading to milk stage gave high WUE and good yields. In this case, 58 and 52 percent of the annual wind energy in modes 2 and 4, respectively, would be used in limited irrigation of sorghum. It is also possible to reduce the summer irrigation below 10 cm, with some yield reduction, and further increase annual wind energy use.

Winter wheat too responds well to limited irrigation. Fall preplant irrigation of winter wheat at Garden City averaged 3,033 kg/ha compared with 3,309 kg/ha for full irrigation in a 5-year study (Grimes, Herron, and Musick, 1962).

CONCLUSIONS

In this study, we investigated the application of dedicated wind turbine systems, without energy storage capability, to irrigation pumping in the Great Plains and concluded:

1. Sprinkler irrigation requires a relatively constant flow mode, and about 45 percent of the irrigation energy demand is in this mode--25 percent to power the sprinklers and 20 percent to lift water for the sprinklers. A wind turbine with variable-ratio transmission and auxiliary motor sized to equal the rated power of the wind turbine (mode 2) can supply 30 to 45 percent of the sprinkler energy demand from wind power, depending on crop and location.
2. About 55 percent of the energy demand is for lifting water for surface distribution systems. By using small reservoirs or irrigation canals for temporary storage, surface distribution systems can be supplied by variable flow pumping. A wind turbine with variable-ratio transmission and auxiliary motor sized at 0.4 the rated power of the wind turbine (mode 4) can supply 60 to 70 percent of this demand from wind power.
3. From the preceding results, we conclude that wind turbine systems in modes 2 and 4 could supply approximately 47 to 59 percent of the energy demand of Great Plains irrigation using the present mix of sprinkler and surface distribution systems and present cropping patterns. Based on present published estimates of energy usage for Great Plains irrigation, this would be equivalent to 23.8×10^9 to 29.9×10^9 kWh per year.

4. Comparison of 4 wind turbine operational modes showed modes 2 and 4 were superior. The variable-ratio transmissions used in these two modes increased the capturable wind energy by 10 to 25 percent compared to the fixed-ratio transmissions of modes 1 and 3.
5. Using an auxiliary motor with a wind turbine requires fossil fuels and increases capital costs, but also has some advantages. Motors increase well yields in summer and, thus, increase area that can be preplant irrigated with the wind turbine in other seasons. This resulted in a 10 to 20 percent increase in use of the annual wind energy on summer irrigated crops as compared with use by the wind-alone system (mode 3).
6. The computer program (Appendix C) developed in this study can be used to determine needed wind turbine size for given well and aquifer characteristics. Simulation of performance of a typical well showed that for a wind turbine operated in modes 3 and 4, 2 wells were required to yield amounts of water similar to a continuously pumped well. Maximum permissible flow rates through the well-screen limit maximum well yield under cyclic pumping. At 60 percent drawdown, inflow rates were 23 to 33 percent greater with cyclic than with continuous pumping.

7. Adoption of various irrigation management practices increases the use of annual, capturable wind energy. In modes 2 and 4, fully irrigated corn with a preplant irrigation used about 30 percent of the annual wind energy at Amarillo and 45 percent at Columbus and Garden City. Without preplant irrigation, less than 25 percent of the energy was used. Fully irrigating equal areas of corn and winter wheat used 70 to 85 percent of the annual wind energy, depending on location. Substituting grain sorghum, or cotton in the South, for corn permits slightly higher use of annual wind energy. Fully irrigated alfalfa in eastern Nebraska used 56 percent of the annual wind energy. Thus, fully irrigated summer crops with preplant irrigation will use 30 to 60 percent of the capturable wind energy, depending on crop and location.
8. When available water is limited or energy is expensive (relative to returns), farmers often use limited irrigation of crops adapted to dryland farming. With limited irrigation, 50 to 100 percent of the annual wind energy can be used, depending on crops and management practices.

REFERENCES

- Anschutz, J. A., and Ralph Lipper. 1975. Summary of electrical irrigation pumping loads in Kansas. In: Report of 50th Annual Meeting, Kansas Committee on the Relation of Electricity to Agriculture, 1974-75, Agr. Engr. Dept., Kansas State Univ., Manhattan, Kansas.
- Apt, K. E. 1976. Applicability of the Weibull distribution function to atmospheric radioactivity data. Atmos. Environ. 10(9):777-782.
- Blackwell, B. F., R. E. Sheldahl, and L. V. Feltz. 1976. Wind tunnel performance data for the Darrieus wind turbine with 0012 blades. Report No. Sand 76-0130, Sandia Laboratories, Albuquerque, New Mexico, 61 pp.
- Elliot, Dennis L. 1977. Synthesis of national wind assessments. In: Annual Report of Wind Characteristics Program Element for the Period April 1976 through June 1977. Battelle Pacific Northwest Laboratories Report No. BNWL-Wind-10, Richland, Washington, pp. 104-106.
- Geraghty, J. J., D. W. Miller, F. Van Der Leeden, and F. L. Troise. 1973. Water Atlas of the United States. Water Information Center, Inc., Water Research Bldg., Manhasset Isle, Port Washington, New York.
- Gilmore, Earl , R. E. Barieau, and V. Nelson. 1977. Feasibility of using wind power to pump irrigation water. Report No. 77-101 prepared for Governor's Energy Advisory Council, Austin, Texas, 58 pp.

- Grimes, D. W., G. M. Herron, and J. T. Musick. 1962. Irrigation and fertilizing winter wheat in southwestern Kansas. Kans. Agr. Expt. Sta. Bul. 442, Manhattan, Kansas.
- Hantush, M. S. 1964. Hydraulics of wells. In: Advances in Hydroscience, Ed. Ven Te Chow, 1:282-430, Academic Press, New York.
- Irrigation Journal. 1977. Survey Issue, Nov.-Dec. 1977. Brantwood Publications Inc., Elm Grove, Wisconsin.
- Jacob, C. E. 1947. Drawdown test to determine effective radius of artesian wells. Trans. Amer. Soc. Civil Engr. 112:1047-1070.
- Justus, C. G., W. R. Hargraves, and Amir Mikhail. 1976. Reference windspeed distributions and height profiles for wind turbine design and performance evaluation applications. Technical Report for ERDA Div. of Solar Energy under Contract No. E(40-1)-5108, Georgia Institute of Technology, Atlanta, Georgia.
- Karassik, I. J., W. C. Krutzsch, W. H. Fraser, and J. P. Messina (editors). 1976. Pump handbook. McGraw-Hill Book Co., New York.
- McDaniels, L. L. 1960. Consumptive use of water by major crops in Texas. Bul. 6019, Texas Board of Water Engineers, Austin, Texas.
- McWhorter, D., and D. K. Sunada. 1977. Ground-water hydrology and hydraulics. Water Resources Publication, P. O. Box 303, Fort Collins, Colorado, 290 pp.
- Musick, J. T., and D. A. Dusek. 1971. Grain sorghum response to number, timing, and size of irrigations in the Southern High Plains. Trans. Amer. Soc. Agr. Engr. 14(3):401-404, 410.
- New, Leon. 1975. 1974 High Plains irrigation survey. Texas Agr. Extension Serv. Rpt., Texas A&M Univ., College Station, Texas, 23 pp.

- Reed, J. W. 1975. Wind power climatology of the United States. Report No. Sand 74-0348, Sandia Laboratories, Albuquerque, New Mexico.
- Reinke, J. W., and D. L. Kill. 1970. Modern design techniques for efficient high-capacity irrigation wells. Amer. Soc. Agr. Engr. Paper No. 70-732, presented at 1970 Winter Meeting of ASAE, Chicago, Illinois.
- Rorabaugh, M. I. 1953. Graphical and theoretical analysis of step-drawdown test of artesian wells. Trans. Amer. Soc. Civil Engr. 79:362.
- Sloggett, Gordon. 1976a. Energy used for pumping irrigation water in the U.S., 1974. Presented at Conference on Energy in Agriculture, Washington University, St. Louis, June 17.
- Sloggett, Gordon. 1976b. Energy and U.S. agriculture irrigation pumping, 1974. Agricultural Economics Report No. 3/6, Economics Research Service, U.S. Dept. of Agriculture, 39 pp.
- Solomon, Bekury. 1971. An economic analysis of intertemporal allocation of groundwater in the central Ogallala formation. Unpublished Ph.D. dissertation, Oklahoma State Univ., Stillwater, Oklahoma.
- Stepanoff, A. J. 1957. Centrifugal and axial flow pumps. John Wiley and Sons, Inc., New York, 462 pp.
- Stone, Loyd. 1978. Maximizing yield benefits when using limited amounts of irrigation water. Proc. Irrigation Workshop. Cooperative Extension Service, Kansas State Univ., Manhattan, Kansas, February 22-23.

Strikland, J. H. 1975. The Darrieus turbine: a performance prediction model using multiple streamtubes. Report No. Sand 75-0431, Sandia Laboratories, Albuquerque, New Mexico.

USDA, Soil Conservation Service. 1972. Irrigation guide for Nebraska, 1972. Lincoln, Nebraska.

USDA, Soil Conservation Service. 1975. Kansas irrigation guide, 1975. Lincoln, Nebraska.

APPENDIX A

State Summaries of Energy Used for Great Plains Irrigation

Table A-1. Energy used for lifting and distributing irrigation water
in the Great Plains.^{a/}

State	Pumping		Distribution systems		Total
	Groundwater	Surface water	Sprinkler	Surface	
----- million kWh -----					
North Dakota	9.0	2.9	27.9	1.0	40.8
South Dakota	21.7	98.1	165.5	1.9	287.2
Nebraska	5,019.5	119.4	3,688.8	444.6	9,272.3
Kansas	5,092.3	12.4	1,626.1	257.0	6,987.8
Oklahoma	1,772.0	8.3	732.5	41.7	2,554.5
Texas	16,780.8	663.2	4,301.5	892.8	22,638.2
Montana	25.7	148.1	121.3	23.9	319.0
Wyoming	152.3	7.3	177.1	4.5	341.1
Colorado	1,179.3	2.9	690.8	85.8	1,958.7
New Mexico	5,050.5	4.0	1,047.0	122.3	6,223.7
Great Plains	35,103.1	1,066.6	12,578.5	1,875.5	50,623.4
Percent of G.P.	69.3	2.1	24.9	3.7	

^{a/} Calculated from unpublished data of Sloggett (1976a).

Table A-2. Energy used by type of fuel for lifting and distributing irrigation water in the Great Plains.^{a/}

State	Electricity	Diesel	Gasoline	Natural gas	LPG
	----- million kWh -----				
North Dakota	19.3	13.7	5.7	0	1.9
South Dakota	44.2	103.4	25.7	0	113.8
Nebraska	938.1	3,454.9	161.9	1,899.4	2,818.0
Kansas	133.5	329.3	71.1	5,969.4	484.5
Oklahoma	108.3	161.1	81.7	1,830.2	373.2
Texas	1,408.3	245.6	256.9	19,701.8	1,025.9
Montana	178.6	86.4	44.1	2.0	7.8
Wyoming	208.9	66.4	9.6	37.6	18.5
Colorado	400.4	48.4	11.2	1,447.4	51.3
New Mexico	404.5	385.3	286.9	4,670.1	476.9
Great Plains	3,844.1	4,894.5	954.8	35,557.9	5,371.8
Percent of G.P.	7.6	9.7	1.9	70.2	10.6

^{a/} Data of Sloggett (1976b).

Table A-3. Area irrigated with pumped water by type of energy in the Great Plains compared to total U.S.^{a/}

State	Electricity	Diesel	Gasoline	Natural gas	LPG
	----- 1,000 ha -----				
North Dakota	17.07	3.59	1.35	0	0.45
South Dakota	21.09	14.60	3.25	0	15.14
Nebraska	529.48	550.38	47.89	257.99	538.82
Kansas	68.76	55.93	9.07	725.21	74.06
Oklahoma	41.28	19.73	8.26	176.12	45.90
Texas	770.81	41.48	35.61	2,552.41	160.04
Montana	109.47	14.95	5.56	0.16	1.32
Wyoming	77.46	7.29	1.11	2.83	2.43
Colorado	445.16	40.47	8.09	133.55	40.47
New Mexico	82.53	18.88	12.59	195.95	22.02
Great Plains	2,163.11	767.30	132.78	4,043.82	900.65
Percent by fuel	27.0	9.6	1.7	50.5	11.2
Percent of U.S.	34.2	48.2	21.2	94.0	66.7
United States	6,322.6	1,593.4	626.5	4,304.1	1,351.0
Percent by fuel	44.5	11.2	4.4	30.3	9.6

^{a/} Data from Sloggett (1976b).

Table A-4. Average lift and quantity of water pumped on farms by water source in the Great Plains, 1974.^{a/}

State	Groundwater		Surface water	
	Lift ^{b/} (m)	Amount (1,000 ha-m)	Lift (m)	Amount (1,000 ha-m)
North Dakota	22.9	4.07	10.7	2.78
South Dakota	21.3	6.63	45.7	13.98
Nebraska	30.5	961.18	6.1	114.35
Kansas	54.9	41.46	4.6	12.12
Oklahoma	76.2	111.84	6.1	6.54
Texas	61.0	1,359.55	12.2	268.65
Montana	30.5	9.87	18.3	94.89
Wyoming	45.7	39.58	7.6	11.35
Colorado	35.1	213.80	3.0	5.99
New Mexico	106.7	239.82	1.5	13.20
Great Plains		2,987.80		543.84
Percent of U.S.		45.0		30.0
Total U.S.		6,671.91		1,828.90

^{a/} Unpublished data of Sloggett (1976a).

^{b/} Estimated state-wide average weighted by number of wells at each depth.

B-1

APPENDIX B

Method of Determination and Summary of Weibull Parameters
at Selected Great Plains Weather Stations

Monthly amounts of wind energy can be readily calculated from summaries of the monthly windspeed distribution. Monthly windspeed distributions can be conveniently described by the two-parameter Weibull distribution function with the form

$$f(U) = (k/C) (U/C)^{k-1} \exp [- (U/C)^k]$$

where U is windspeed and C and k are the scale and shape parameters, respectively (Justus, et al. 1976; Apt, 1976). Note that k is dimensionless, and C has units of velocity.

Determination of C and k can be accomplished by a weighted least-squares approximation applied to the cumulative distribution function of the Weibull distribution

$$F(U) = 1 - \exp [- (U/C)^k]$$

by rewriting as

$$1 - F(U) = \exp [- (U/C)^k]$$

and taking the logarithm of each side twice to give

$$\ln [- \ln (1 - F(U))] = k \ln U - k \ln C$$

which has the form

$$y = ax - b.$$

Now the least-squares solutions for a and b are:

$$a = \frac{\sum_{i=1}^n W_i (X_i - \bar{X}) (Y_i - \bar{Y})}{\sum_{i=1}^n W_i (X_i - \bar{X})^2}$$

and $b = a\bar{x} - \bar{y}$ where $w_i = \frac{p(U_i)}{\sum_{i=1}^n p(U_i)}$ and $p(U_i)$ is the number of observa-

tions in the U_i velocity interval.

Use of a weighted regression helps reduce the influence of the end points of the frequency distribution where there are few observations and the windspeeds are either below the cut-in windspeed or well above the rated windspeed.

When the C and k parameters are known, the decimal fraction of time (Δt) between windspeed U_1 and U_2 is then

$$\Delta t = \exp \left[- \left(\frac{U_1}{C} \right)^k \right] - \exp \left[- \left(\frac{U_2}{C} \right)^k \right]$$

and total power in the wind (P_w) for 1 m/s windspeed intervals is then

$$P_w = CA \sum_{i=1}^n (\Delta t_i) (\bar{U}_i)^3$$

where $\bar{U}_i$ is mean windspeed in the interval, A is area, and C is a coefficient dependent upon the units. For P_w in kWh/mo, C is $6,125 \times 10^{-7}$ when A is m^2 and U_i is m/s. Thus, use of the Weibull distribution provides a convenient method of handling windspeed distributions in simulation studies of wind turbines and pumps.

From windspeed frequency summaries of Reed (1975), the Weibull parameters were calculated for various Great Plains locations. Most of the headings are self-explanatory, but a few comments are necessary. The headings in line 1 use international station number, the period of record (-0--0 shows broken record periods), the state and station name. The latter two are in alphabetical order to facilitate location of a specific station. Line 2 presents the speed ranges given in Reed's summarized data.

The column with coefficient of determination (R^2) was included to indicate those months when the Weibull parameters do not provide a good fit of the data. Finally, the month labeled 13 represents the annual average or total.

23061	48-72	CO	ALAMOSA APT						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	3.17	1.11	0.99	82.		6.			
2.	3.68	1.19	0.99	103.		7.			
3.	5.19	1.38	1.00	202.		14.			
4.	5.95	1.48	1.00	264.		18.			
5.	5.57	1.46	1.00	221.		15.			
6.	5.09	1.46	1.00	170.		11.			
7.	3.85	1.41	1.00	80.		5.			
8.	3.63	1.42	1.00	65.		4.			
9.	3.78	1.36	1.00	81.		5.			
10.	3.57	1.24	0.99	85.		6.			
11.	3.10	1.16	0.99	67.		5.			
12.	2.90	1.09	0.99	67.		5.			
13.	4.09	1.25	1.00	125.		100.			

23036	62-70	CO	AURORA CO, BUCKLEY FLD						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	3.83	1.75	1.00	54.		8.			
2.	3.75	1.71	0.99	53.		8.			
3.	4.09	1.67	1.00	71.		10.			
4.	4.63	1.65	0.99	105.		15.			
5.	4.23	1.81	0.99	70.		10.			
6.	3.89	1.72	0.99	58.		8.			
7.	3.84	1.91	0.99	49.		7.			
8.	3.75	1.91	0.99	46.		7.			
9.	3.80	1.96	1.00	46.		7.			
10.	3.72	1.89	0.99	45.		6.			
11.	3.67	1.71	0.99	49.		7.			
12.	3.72	1.71	0.99	51.		7.			
13.	3.92	1.76	0.99	58.		100.			

93037	43-71	CO	COLOR SPRINGS, PETERSON FLD						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	5.07	1.87	0.96	115.		8.			
2.	5.25	1.83	0.96	131.		9.			
3.	5.75	1.80	0.97	175.		12.			
4.	6.00	1.92	0.98	186.		13.			
5.	5.83	1.95	0.98	166.		11.			
6.	5.57	1.98	0.98	143.		10.			
7.	4.80	2.09	0.98	87.		6.			
8.	4.61	2.14	0.98	75.		5.			
9.	4.86	2.06	0.98	92.		6.			
10.	4.88	2.11	0.97	90.		6.			
11.	4.95	1.88	0.96	107.		7.			
12.	4.86	1.90	0.95	100.		7.			
13.	5.17	1.93	0.97	118.		100.			

23062	-0--0	CO	DENVER				
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38 39-46
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	5.07	1.97	1.00	109.	8.		
2.	5.28	1.90	1.00	128.	10.		
3.	5.60	1.82	0.99	160.	12.		
4.	5.70	1.85	1.00	166.	12.		
5.	5.26	1.93	1.00	124.	9.		
6.	5.15	1.91	1.00	118.	9.		
7.	4.69	1.93	1.00	88.	7.		
8.	4.47	1.87	1.00	79.	6.		
9.	4.48	1.88	1.00	79.	6.		
10.	4.36	1.83	1.00	76.	6.		
11.	5.00	1.92	1.00	107.	8.		
12.	2.19	0.79	0.96	96.	7.		
13.	5.02	1.85	1.00	113.	100.		

23012	-0--0	CO	DENVER, LOWRY AFB				
MPH	1-3	4-12	13-24	25-31	32-46		
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	4.54	1.74	0.99	91.	9.		
2.	4.11	1.62	0.99	75.	7.		
3.	4.68	1.70	0.98	103.	10.		
4.	4.97	1.66	0.98	128.	12.		
5.	4.44	1.69	0.99	89.	9.		
6.	4.37	1.76	0.99	80.	8.		
7.	4.31	1.78	0.98	75.	7.		
8.	4.05	1.70	0.99	67.	6.		
9.	4.33	1.72	0.98	80.	8.		
10.	4.17	1.76	0.99	69.	7.		
11.	4.70	1.78	0.98	98.	9.		
12.	4.48	1.67	0.98	93.	9.		
13.	4.42	1.71	0.99	86.	100.		

94015	67-70	CO	FT CARSON,BUTTS AAF						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. PCWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	3.24	1.25	0.99	62.		5.			
2.	3.94	1.47	0.99	78.		7.			
3.	4.76	1.50	1.00	133.		12.			
4.	5.75	1.58	1.00	213.		19.			
5.	4.80	1.67	1.00	113.		10.			
6.	4.76	1.58	1.00	121.		11.			
7.	3.83	1.67	1.00	58.		5.			
8.	3.90	1.58	1.00	67.		6.			
9.	3.89	1.67	1.00	61.		5.			
10.	4.30	1.49	0.99	100.		9.			
11.	3.49	1.39	0.99	61.		5.			
12.	3.50	1.29	0.98	73.		6.			
13.	4.19	1.46	1.00	95.		100.			

23067	43-54	CO	LA JUNTA						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. PCWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	4.47	1.61	0.99	98.		7.			
2.	4.83	1.67	0.99	116.		9.			
3.	5.56	1.65	1.00	180.		14.			
4.	5.49	1.67	0.99	169.		13.			
5.	5.28	1.71	0.99	146.		11.			
6.	5.31	1.81	0.99	138.		10.			
7.	4.42	1.76	0.99	83.		6.			
8.	4.27	1.79	0.99	73.		5.			
9.	4.26	1.77	0.99	74.		6.			
10.	4.05	1.67	1.00	68.		5.			
11.	4.30	1.52	0.99	96.		7.			
12.	4.27	1.55	0.99	91.		7.			
13.	4.69	1.65	0.99	108.		100.			

93058	55-71	CO	PUEBLO, MEMORIAL APT						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. PCWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	3.62	1.25	0.99	87.		7.			
2.	4.09	1.36	0.99	103.		8.			
3.	4.69	1.36	0.99	154.		12.			
4.	5.52	1.50	1.00	206.		16.			
5.	5.11	1.53	1.00	158.		12.			
6.	4.82	1.63	1.00	120.		9.			
7.	4.52	1.63	1.00	99.		7.			
8.	4.09	1.56	1.00	79.		6.			
9.	4.07	1.58	1.00	76.		6.			
10.	3.72	1.43	0.99	70.		5.			
11.	3.73	1.33	0.99	82.		6.			
12.	3.68	1.26	0.99	90.		7.			
13.	4.29	1.41	1.00	110.		100.			

152	-0--0	KS	CASSODAY			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	6.98	1.86	0.99	300.	9.	
2.	7.59	2.00	0.99	357.	10.	
3.	8.49	2.22	0.98	453.	13.	
4.	8.49	2.22	0.98	453.	13.	
5.	7.05	2.01	1.00	285.	8.	
6.	6.85	2.13	1.00	247.	7.	
7.	6.40	3.11	1.00	159.	5.	
8.	6.65	3.26	1.00	175.	5.	
9.	6.48	1.98	1.00	225.	7.	
10.	6.48	1.98	1.00	225.	7.	
11.	6.98	1.86	0.99	300.	9.	
12.	6.45	1.79	0.99	250.	7.	
13.	7.08	1.90	0.99	307.	100.	

13985	-0--0	KS	DODGE CITY APT			
KNOTS	1-3	4-10	11-21	22-27	28-40	
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	7.18	2.38	1.00	260.	7.	
2.	7.72	2.31	1.00	329.	9.	
3.	8.31	2.41	1.00	398.	11.	
4.	8.53	2.48	1.00	423.	11.	
5.	7.90	2.44	1.00	339.	9.	
6.	8.05	2.57	1.00	347.	9.	
7.	6.96	2.45	1.00	232.	6.	
8.	6.96	2.70	1.00	218.	6.	
9.	7.47	2.62	1.00	274.	7.	
10.	7.43	2.52	1.00	276.	7.	
11.	7.68	2.49	0.99	307.	8.	
12.	7.54	2.46	0.99	294.	8.	
13.	7.67	2.45	1.00	309.	100.	

13947	39-67	KS	FT RILEY			
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27 28-33 34-40
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	4.25	1.39	1.00	110.	6.	
2.	4.51	1.44	1.00	122.	7.	
3.	5.57	1.45	1.00	226.	13.	
4.	5.70	1.43	0.99	246.	14.	
5.	5.07	1.44	1.00	172.	10.	
6.	4.58	1.41	1.00	132.	8.	
7.	3.95	1.41	0.99	85.	5.	
8.	4.18	1.38	0.99	106.	6.	
9.	4.40	1.26	0.99	151.	9.	
10.	4.26	1.22	0.99	148.	9.	
11.	4.17	1.27	0.99	128.	7.	
12.	4.01	1.32	1.00	104.	6.	
13.	4.53	1.34	1.00	143.	100.	

23064 -0--0 KS GARDEN CITY APT
 MPH 0-3 4-7 8-12 13-18 19-24 25-31 32-38 39-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	6.46	2.07	0.98	214.	6.
2.	7.11	1.99	0.99	295.	8.
3.	7.96	2.03	0.99	406.	11.
4.	8.23	2.16	0.99	421.	12.
5.	7.82	2.04	0.99	382.	11.
6.	8.48	2.23	0.99	448.	12.
7.	7.25	2.48	0.99	259.	7.
8.	7.32	2.69	0.95	254.	7.
9.	7.56	2.61	0.94	285.	8.
10.	7.08	2.60	0.95	235.	7.
11.	6.16	1.84	0.99	210.	6.
12.	6.27	2.17	0.98	186.	5.
13.	7.23	2.29	0.98	274.	100.

93990 -0--0 KS HILL CITY APT
 MPH 1-3 4-12 13-24 25-31 32-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	4.50	1.55	1.00	106.	6.
2.	5.25	1.58	1.00	163.	9.
3.	6.33	1.63	0.99	269.	14.
4.	6.38	1.87	1.00	229.	12.
5.	5.73	1.76	1.00	179.	10.
6.	6.32	2.04	1.00	202.	11.
7.	5.36	1.95	1.00	129.	7.
8.	4.91	1.87	1.00	105.	6.
9.	5.16	1.71	1.00	136.	7.
10.	4.82	1.59	1.00	125.	7.
11.	4.88	1.56	1.00	134.	7.
12.	4.65	1.65	0.99	105.	6.
13.	5.36	1.67	1.00	158.	100.

93905 -0--0 KS HUTCHINSON
 MPH 3-7 8-12 13-20 21-30 31-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	5.86	1.97	1.00	167.	8.
2.	6.16	1.96	1.00	196.	9.
3.	6.50	2.08	0.99	216.	10.
4.	6.47	2.00	1.00	221.	10.
5.	6.17	2.01	1.00	191.	9.
6.	6.48	2.15	1.00	207.	10.
7.	5.53	2.22	0.99	125.	6.
8.	5.42	2.42	1.00	111.	5.
9.	6.20	2.18	1.00	180.	9.
10.	5.93	2.06	1.00	165.	8.
11.	6.18	2.14	0.99	180.	9.
12.	5.87	2.15	1.00	154.	7.
13.	6.09	2.07	1.00	179.	100.

93909	-0--0	KS	OLATHE	NAS				
MPH	1-3	4-12	13-24	25-31	32-46			
MONTH	WEIBULL PARAMETERS		COEFFICIENT		AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION		(W/M2)	OF ANNUAL		
1.	5.27	2.01	1.00		120.	9.		
2.	5.54	2.09	1.00		133.	10.		
3.	6.06	1.95	1.00		187.	14.		
4.	5.82	1.99	1.00		162.	12.		
5.	5.07	1.83	1.00		118.	9.		
6.	4.84	1.99	1.00		94.	7.		
7.	3.86	2.05	0.98		46.	4.		
8.	4.08	2.05	0.99		54.	4.		
9.	4.36	1.89	1.00		73.	6.		
10.	4.69	2.09	1.00		81.	6.		
11.	5.47	2.08	1.00		129.	10.		
12.	5.14	1.99	1.00		112.	9.		
13.	5.06	1.90	1.00		112.	100.		

13922	43-65	KS	SALINA,	SCHILLING	AFB			
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL PARAMETERS		COEFFICIENT		AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION		(W/M2)	OF ANNUAL		
1.	4.80	1.52	1.00		133.	7.		
2.	5.20	1.54	1.00		166.	9.		
3.	6.09	1.69	1.00		227.	13.		
4.	6.06	1.73	1.00		217.	12.		
5.	5.60	1.71	1.00		174.	10.		
6.	5.39	1.81	1.00		145.	8.		
7.	4.75	1.88	1.00		94.	5.		
8.	4.92	1.83	1.00		108.	6.		
9.	5.23	1.68	1.00		146.	8.		
10.	4.91	1.60	1.00		130.	7.		
11.	4.97	1.53	1.00		145.	8.		
12.	4.49	1.52	1.00		108.	6.		
13.	5.22	1.64	1.00		151.	100.		

13996	-0--0	KS	TOPEKA					
MPH	3-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46
MONTH	WEIBULL PARAMETERS		COEFFICIENT		AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION		(W/M2)	OF ANNUAL		
1.	5.33	1.81	0.99		139.	7.		
2.	5.56	1.93	0.99		146.	8.		
3.	6.46	1.83	0.99		245.	13.		
4.	6.50	1.92	0.99		235.	12.		
5.	5.74	1.79	0.98		177.	9.		
6.	5.74	1.93	0.99		161.	8.		
7.	4.74	1.71	0.99		105.	5.		
8.	5.02	1.87	0.99		111.	6.		
9.	5.21	1.71	0.98		141.	7.		
10.	5.20	1.71	0.99		140.	7.		
11.	5.74	1.95	0.99		158.	8.		
12.	5.74	1.93	0.99		161.	8.		
13.	5.58	1.81	0.99		160.	100.		

13920	-0--0	KS	TOPEKA, FORBES AFB						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT				
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL				
1.	4.99	1.85	1.00	111.	8.				
2.	5.22	1.83	1.00	128.	9.				
3.	5.89	1.86	1.00	181.	13.				
4.	5.84	1.83	1.00	180.	13.				
5.	5.27	1.90	1.00	127.	9.				
6.	4.99	1.86	1.00	111.	8.				
7.	4.11	1.79	1.00	65.	5.				
8.	4.39	1.87	1.00	75.	5.				
9.	4.53	1.84	1.00	84.	6.				
10.	4.62	1.86	1.00	88.	6.				
11.	5.10	1.85	1.00	119.	9.				
12.	4.81	1.86	1.00	99.	7.				
13.	4.98	1.81	1.00	114.	100.				

3928	-0--0	KS	WICHITA						
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT				
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL				
1.	6.78	2.16	1.00	236.	8.				
2.	7.08	2.23	1.00	263.	9.				
3.	7.67	2.21	1.00	336.	12.				
4.	7.71	2.32	0.99	327.	11.				
5.	7.00	2.21	1.00	255.	9.				
6.	7.17	2.26	1.00	269.	9.				
7.	6.05	2.33	0.99	158.	5.				
8.	6.32	2.53	0.99	170.	6.				
9.	6.49	2.34	0.99	194.	7.				
10.	6.67	2.30	1.00	214.	7.				
11.	6.91	2.28	1.00	239.	8.				
12.	6.68	2.13	1.00	229.	8.				
13.	6.91	2.22	1.00	245.	100.				

3923	-0--0	KS	WICHITA, MCCONNELL AFB						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT				
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL				
1.	6.29	1.86	1.00	220.	8.				
2.	6.37	1.85	1.00	230.	9.				
3.	7.29	1.96	1.00	323.	12.				
4.	7.28	2.01	1.00	314.	12.				
5.	6.68	2.00	1.00	243.	9.				
6.	6.48	1.91	1.00	234.	9.				
7.	5.68	2.09	1.00	144.	6.				
8.	5.48	2.07	0.99	130.	5.				
9.	5.74	1.79	0.99	177.	7.				
10.	5.89	1.84	1.00	184.	7.				
11.	5.98	1.78	1.00	200.	8.				
12.	5.99	1.76	1.00	205.	8.				
13.	6.28	1.87	1.00	218.	100.				

25033 48-70 MT BILLINGS, LOGAN FLD								
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	6.45	1.97	1.00	229.	12.			
2.	6.30	1.99	1.00	206.	10.			
3.	5.83	1.88	1.00	174.	9.			
4.	6.04	1.93	1.00	188.	10.			
5.	5.66	1.98	1.00	150.	8.			
6.	5.30	2.01	0.99	121.	6.			
7.	4.99	2.12	0.99	96.	5.			
8.	4.81	2.09	0.99	87.	4.			
9.	5.24	2.05	0.99	115.	6.			
10.	5.59	2.01	1.00	143.	7.			
11.	6.38	1.99	1.00	214.	11.			
12.	6.67	2.06	1.00	235.	12.			
13.	5.79	1.96	1.00	162.	100.			

24136 -0--0 MT BUTTE, SILVER BOW CO APT							
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38 39-46
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT	
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL	
1.	2.84	0.93	0.99	105.		8.	
2.	3.19	0.98	0.99	121.		9.	
3.	3.58	1.07	1.00	128.		10.	
4.	4.63	1.25	0.99	178.		13.	
5.	4.56	1.35	0.99	145.		11.	
6.	4.40	1.39	1.00	121.		9.	
7.	3.85	1.38	1.00	83.		6.	
8.	3.85	1.36	1.00	86.		6.	
9.	3.74	1.24	1.00	97.		7.	
10.	3.53	1.15	0.99	101.		8.	
11.	3.22	1.08	0.99	92.		7.	
12.	2.96	1.03	0.99	84.		6.	
13.	3.70	1.17	0.99	111.		100.	

94010 60-68 MT GLASGOW AFB								
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	5.06	1.78	1.00	121.		8.		
2.	4.91	1.71	1.00	118.		8.		
3.	4.93	1.75	1.00	115.		8.		
4.	5.70	1.84	1.00	167.		11.		
5.	6.02	1.90	1.00	189.		13.		
6.	5.05	1.79	1.00	120.		8.		
7.	4.69	1.83	1.00	94.		6.		
8.	4.62	1.75	1.00	95.		6.		
9.	4.91	1.63	1.00	127.		9.		
10.	4.80	1.71	0.99	110.		7.		
11.	4.69	1.72	0.99	101.		7.		
12.	4.75	1.65	1.00	112.		8.		
13.	5.00	1.74	1.00	121.		100.		

777	-0--0	MT	HAVRE				
MPH	4-15	16-31					
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	5.54	2.62	1.00	112.	11.		
2.	4.86	2.30	1.00	83.	8.		
3.	5.64	2.67	1.00	117.	11.		
4.	5.44	2.58	1.00	108.	10.		
5.	5.11	2.42	1.00	93.	9.		
6.	4.99	2.36	1.00	88.	8.		
7.	3.95	1.92	1.00	53.	5.		
8.	3.95	1.92	1.00	53.	5.		
9.	4.37	2.09	1.00	66.	6.		
10.	5.11	2.42	1.00	93.	9.		
11.	5.34	2.52	1.00	103.	10.		
12.	5.23	2.47	1.00	98.	9.		
13.	4.99	2.36	1.00	88.	100.		

24144	-0--0	MT	HELENA	APT			
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	4.76	1.37	0.98	158.	15.		
2.	3.66	1.27	0.98	87.	8.		
3.	4.98	1.64	0.99	131.	13.		
4.	4.99	1.61	0.98	136.	13.		
5.	4.01	1.88	1.00	57.	5.		
6.	4.63	1.71	0.97	98.	9.		
7.	4.23	1.78	0.99	71.	7.		
8.	3.48	1.75	1.00	41.	4.		
9.	4.50	1.53	0.99	108.	10.		
10.	2.88	1.44	0.99	32.	3.		
11.	3.26	1.34	0.99	54.	5.		
12.	3.48	1.32	0.97	68.	7.		
13.	4.10	1.47	1.00	88.	100.		

24036	-0--0	MT	LEWISTON	AFB			
MPH	1-3	4-12	13-24	25-31	32-46		
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	5.29	1.48	0.96	187.	12.		
2.	5.02	1.39	0.97	179.	12.		
3.	4.50	1.40	0.98	128.	8.		
4.	5.21	1.67	0.99	145.	9.		
5.	4.64	1.53	0.98	119.	8.		
6.	4.17	1.46	1.00	94.	6.		
7.	3.56	1.40	0.98	64.	4.		
8.	3.90	1.46	0.99	77.	5.		
9.	3.90	1.26	0.99	107.	7.		
10.	4.10	1.31	0.99	113.	7.		
11.	5.11	1.44	0.98	177.	12.		
12.	4.27	1.22	0.96	151.	10.		
13.	4.47	1.39	0.98	128.	100.		

678	-0--0	MT	LIVINGSTON				
MPH	0-3	4-15	16-31	32-47			
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	8.04	1.64	0.89	530.	11.		
2.	8.59	1.83	0.90	562.	12.		
3.	7.83	1.73	0.96	460.	10.		
4.	7.08	1.74	0.99	342.	7.		
5.	6.45	1.69	0.99	271.	6.		
6.	5.59	1.60	1.00	193.	4.		
7.	5.60	1.64	1.00	186.	4.		
8.	5.78	1.64	1.00	204.	4.		
9.	6.47	1.73	1.00	264.	6.		
10.	7.42	1.68	0.97	411.	9.		
11.	8.59	1.89	0.93	544.	12.		
12.	9.16	1.93	0.85	643.	14.		
13.	7.25	1.65	0.97	394.	100.		

24037	-0--0	MT	MILES CITY APT				
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38 39-46
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	4.95	1.77	1.00	115.	9.		
2.	5.08	1.89	0.99	114.	9.		
3.	5.14	2.01	0.99	111.	9.		
4.	5.71	2.07	0.99	147.	12.		
5.	5.35	2.01	0.99	125.	10.		
6.	4.68	1.81	0.99	95.	8.		
7.	4.50	1.89	0.99	80.	6.		
8.	4.66	1.86	0.99	90.	7.		
9.	4.63	1.76	1.00	95.	8.		
10.	4.74	1.86	0.99	95.	8.		
11.	4.51	1.92	0.99	79.	6.		
12.	4.74	1.75	1.00	102.	8.		
13.	4.89	1.86	0.99	104.	100.		

24153	-0--0	MT	MISSOULA				
MPH	0-3	4-7	8-12	13-18	19-24	25-31	
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	1.95	0.84	0.98	54.	8.		
2.	2.08	0.96	0.95	39.	6.		
3.	2.75	0.99	0.97	77.	12.		
4.	3.22	1.09	0.97	90.	14.		
5.	3.08	1.09	0.98	79.	12.		
6.	3.28	1.18	0.98	75.	11.		
7.	2.78	1.02	0.98	74.	11.		
8.	2.63	1.16	0.97	41.	6.		
9.	2.48	0.97	0.98	63.	9.		
10.	1.67	0.91	0.97	25.	4.		
11.	1.50	0.90	0.98	20.	3.		
12.	1.69	0.89	0.96	29.	4.		
13.	2.40	0.96	0.98	60.	100.		

24161	-0--0	MT	WHITEHALL					
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	8.36	1.30	0.90	706.		16.		
2.	7.67	1.33	0.95	583.		13.		
3.	6.67	1.35	0.97	416.		9.		
4.	6.15	1.37	0.96	329.		7.		
5.	5.73	1.46	0.98	242.		5.		
6.	6.00	1.51	0.99	261.		6.		
7.	5.52	1.56	0.99	193.		4.		
8.	4.96	1.41	0.99	168.		4.		
9.	5.37	1.30	0.99	248.		6.		
10.	5.30	1.21	0.99	277.		6.		
11.	6.50	1.24	0.97	437.		10.		
12.	7.79	1.37	0.95	591.		13.		
13.	6.30	1.32	0.98	369.		100.		

94017	-0--0	MT	WOLF POINT					
KNOTS	1-3	4-6	7-10	11-16	17-27	28-40		
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	3.28	1.02	0.94	117.		6.		
2.	1.59	0.90	0.95	24.		1.		
3.	3.86	1.26	0.89	103.		5.		
4.	5.81	1.28	0.93	316.		17.		
5.	5.38	1.32	0.94	244.		13.		
6.	3.86	1.13	0.93	136.		7.		
7.	3.65	1.21	0.89	98.		5.		
8.	4.35	1.22	0.92	157.		8.		
9.	4.60	1.10	0.91	235.		12.		
10.	4.26	1.02	0.94	227.		12.		
11.	3.79	1.05	0.91	158.		8.		
12.	2.87	1.02	0.85	80.		4.		
13.	4.09	1.07	0.94	185.		100.		

24044	-0--0	NB	ALLIANCE					
KNOTS	1-3	4-6	7-10	11-16	17-27	28-40		
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	5.47	1.64	1.00	173.		7.		
2.	5.67	1.70	1.00	182.		8.		
3.	6.22	1.86	0.98	214.		9.		
4.	7.00	1.84	0.99	307.		13.		
5.	6.55	1.87	0.99	248.		10.		
6.	6.05	1.90	0.99	191.		8.		
7.	5.57	1.80	1.00	160.		7.		
8.	5.63	1.82	0.99	163.		7.		
9.	5.97	1.93	0.98	181.		8.		
10.	5.42	1.52	0.98	191.		8.		
11.	5.63	1.55	0.99	205.		9.		
12.	5.33	1.56	0.99	174.		7.		
13.	5.90	1.71	0.99	204.		100.		

161	-0--0	NB	BIG SPRINGS					
MPH	4-15	16-31	32-47					
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL			
1.	6.28	1.90	1.00	214.	8.			
2.	6.00	1.65	0.99	225.	8.			
3.	7.14	1.79	0.96	337.	12.			
4.	7.44	1.89	0.97	359.	13.			
5.	6.67	1.76	0.99	281.	10.			
6.	6.28	1.90	1.00	214.	8.			
7.	5.21	1.56	1.00	162.	6.			
8.	5.21	1.56	1.00	162.	6.			
9.	5.34	1.60	1.00	168.	6.			
10.	5.62	1.55	0.99	207.	7.			
11.	6.23	1.72	0.99	238.	9.			
12.	5.96	1.79	1.00	197.	7.			
13.	6.12	1.69	0.99	231.	100.			

73084	-0--0	NB	COLUMBUS					
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL			
1.	5.51	1.49	0.97	209.	8.			
2.	5.53	1.44	0.97	223.	9.			
3.	6.73	1.54	0.97	350.	14.			
4.	7.00	1.70	0.94	340.	14.			
5.	6.51	1.73	0.96	269.	11.			
6.	5.62	1.63	0.95	189.	8.			
7.	4.72	1.60	0.96	116.	5.			
8.	4.52	1.45	0.96	121.	5.			
9.	4.57	1.41	0.96	133.	5.			
10.	5.44	1.42	0.96	218.	9.			
11.	4.96	1.41	0.97	169.	7.			
12.	5.01	1.48	0.98	159.	6.			
13.	5.53	1.48	0.97	213.	100.			

14935	-0--0	NB	GRAND ISLAND APT					
KNOTS	1-3	4-10	11-21	22-27	28-40			
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL			
1.	5.79	2.09	0.99	152.	7.			
2.	6.03	2.15	1.00	167.	8.			
3.	6.78	2.08	1.00	246.	11.			
4.	7.32	2.30	1.00	282.	13.			
5.	6.75	2.26	1.00	225.	10.			
6.	6.46	2.35	1.00	191.	9.			
7.	5.60	2.20	1.00	131.	6.			
8.	5.62	2.34	1.00	126.	6.			
9.	5.92	2.27	1.00	151.	7.			
10.	5.73	2.04	0.99	151.	7.			
11.	6.44	2.15	0.99	204.	9.			
12.	6.09	2.15	0.99	172.	8.			
13.	6.22	2.15	1.00	184.	100.			

14904	-0--0	NB	LINCOLN AFB			
MPH	1-3	4-12	13-24	25-31	32-46	
MONTH	WEIBULL C(M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	5.08	1.61	1.00	143.	9.	
2.	5.27	1.68	1.00	149.	9.	
3.	6.30	1.75	1.00	240.	14.	
4.	6.25	1.76	0.99	233.	14.	
5.	5.61	1.75	1.00	171.	10.	
6.	5.18	1.88	1.00	121.	7.	
7.	4.36	1.80	1.00	77.	5.	
8.	4.55	1.92	1.00	81.	5.	
9.	4.37	1.71	1.00	83.	5.	
10.	4.46	1.56	1.00	102.	6.	
11.	4.98	1.51	1.00	150.	9.	
12.	4.89	1.64	1.00	124.	7.	
13.	5.14	1.66	1.00	141.	100.	

14941	-0--0	NB	NORFOLK, STEFAN APT			
MPH	1-3	4-12	13-24	25-31	32-46	
MONTH	WEIBULL C(M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	5.21	1.73	1.00	139.	8.	
2.	5.27	1.84	1.00	132.	8.	
3.	5.79	1.83	1.00	177.	10.	
4.	6.52	1.93	1.00	236.	14.	
5.	5.71	1.92	1.00	159.	9.	
6.	5.19	2.02	0.99	113.	6.	
7.	4.37	1.86	1.00	74.	4.	
8.	4.67	1.81	1.00	94.	5.	
9.	5.02	2.00	0.99	104.	6.	
10.	5.52	1.75	1.00	161.	9.	
11.	6.20	1.85	1.00	212.	12.	
12.	5.23	1.71	1.00	143.	8.	
13.	5.39	1.80	1.00	145.	100.	

562	-0--0	NB	NORTH PLATTE			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL C(M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	4.91	1.48	0.99	150.	7.	
2.	5.06	1.41	0.98	180.	8.	
3.	6.68	1.71	0.97	296.	13.	
4.	7.24	1.82	0.97	345.	15.	
5.	6.66	1.86	1.00	262.	12.	
6.	6.20	2.99	1.00	147.	6.	
7.	5.57	2.64	1.00	114.	5.	
8.	5.57	2.64	1.00	114.	5.	
9.	5.21	1.56	1.00	162.	7.	
10.	5.35	1.48	0.98	194.	9.	
11.	5.06	1.41	0.98	180.	8.	
12.	4.25	1.31	0.99	125.	6.	
13.	5.49	1.51	0.98	200.	100.	

14942	-0--0	NB	OMAHA					
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	5.77	1.65	0.99	200.	9.			
2.	5.91	1.80	0.99	191.	9.			
3.	6.04	1.61	0.98	240.	11.			
4.	6.89	1.82	0.98	298.	14.			
5.	5.91	1.76	0.97	198.	9.			
6.	5.49	1.81	0.98	152.	7.			
7.	4.81	1.78	0.98	105.	5.			
8.	4.90	1.88	0.98	103.	5.			
9.	5.04	1.73	0.98	125.	6.			
10.	5.45	1.68	0.99	165.	7.			
11.	6.08	1.68	0.99	229.	10.			
12.	5.94	1.80	0.99	194.	9.			
13.	5.74	1.74	0.99	184.	100.			

14949	48-70	NB	OMAHA, OFFUTT AFB					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	4.44	1.42	1.00	119.	9.			
2.	4.49	1.43	1.00	123.	9.			
3.	5.40	1.48	0.99	197.	14.			
4.	5.60	1.55	0.99	202.	15.			
5.	4.89	1.54	1.00	138.	10.			
6.	4.38	1.57	1.00	96.	7.			
7.	3.75	1.52	1.00	64.	5.			
8.	3.61	1.53	0.99	56.	4.			
9.	3.68	1.45	0.99	66.	5.			
10.	4.08	1.42	1.00	93.	7.			
11.	4.23	1.39	1.00	108.	8.			
12.	4.31	1.43	1.00	108.	8.			
13.	4.39	1.44	1.00	113.	100.			

154	-0--0	NB	OVERTON					
MPH	4-15	16-31	32-47					
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	5.21	1.56	1.00	162.	7.			
2.	4.91	1.48	0.99	150.	7.			
3.	6.66	1.86	1.00	262.	12.			
4.	6.90	1.77	0.97	310.	14.			
5.	6.38	1.94	1.00	220.	10.			
6.	5.84	1.75	1.00	191.	9.			
7.	5.57	2.64	1.00	114.	5.			
8.	5.48	2.59	1.00	109.	5.			
9.	5.66	2.69	1.00	118.	5.			
10.	5.06	1.52	1.00	156.	7.			
11.	6.23	1.72	0.99	238.	11.			
12.	4.60	1.39	0.99	138.	6.			
13.	5.47	1.64	1.00	174.	100.			

24082	-0--0	NB	SCOTT SBUFF	APT		
MPH	1-3	4-12	13-24	25-31	32-46	
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT	
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL	
1.	4.96	1.68	1.00	124.	6.	
2.	5.89	1.79	1.00	191.	10.	
3.	6.41	1.82	1.00	240.	12.	
4.	6.43	1.92	1.00	227.	12.	
5.	5.94	2.05	1.00	167.	9.	
6.	5.69	1.93	1.00	157.	8.	
7.	4.86	1.93	1.00	97.	5.	
8.	4.96	2.00	1.00	100.	5.	
9.	4.88	1.97	1.00	97.	5.	
10.	5.18	1.72	1.00	137.	7.	
11.	6.05	1.70	1.00	221.	11.	
12.	5.67	1.70	1.00	182.	9.	
13.	5.45	1.82	1.00	148.	100.	

563	-0--0	NB	SIDNEY			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT	
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL	
1.	5.31	1.41	0.95	206.	9.	
2.	5.16	1.38	0.95	199.	8.	
3.	6.57	1.67	0.97	289.	12.	
4.	7.01	1.80	0.98	317.	14.	
5.	6.23	1.72	0.99	238.	10.	
6.	5.60	1.68	1.00	180.	8.	
7.	4.91	1.48	0.99	150.	6.	
8.	5.66	2.69	1.00	118.	5.	
9.	4.60	1.39	0.99	138.	6.	
10.	4.91	1.37	0.97	174.	7.	
11.	5.21	1.44	0.98	187.	8.	
12.	4.76	1.44	0.99	144.	6.	
13.	5.35	1.48	0.98	194.	100.	

24032	-0--0	NB	VALENTINE, MILLER FLD			
MPH	1-3	4-12	13-24	25-31	32-46	
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	4.95	2.01	0.99	99.	6.	
2.	5.18	1.85	0.99	124.	7.	
3.	5.74	2.02	1.00	153.	9.	
4.	6.15	2.01	1.00	190.	11.	
5.	6.05	2.22	1.00	165.	10.	
6.	5.60	2.06	0.99	140.	8.	
7.	5.22	2.18	1.00	107.	6.	
8.	5.40	2.04	0.99	126.	7.	
9.	5.45	2.07	1.00	128.	8.	
10.	5.50	1.86	0.98	148.	9.	
11.	6.18	1.99	0.98	194.	11.	
12.	5.31	1.87	0.97	132.	8.	
13.	5.56	1.98	0.99	143.	100.	

170	-0--0	NM	ACOMITA			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	5.48	2.59	1.00	109.	8.	
2.	5.75	2.73	1.00	122.	9.	
3.	6.00	1.65	0.99	225.	17.	
4.	5.47	1.64	1.00	174.	13.	
5.	5.57	2.64	1.00	114.	9.	
6.	5.38	2.54	1.00	105.	8.	
7.	4.49	2.14	1.00	69.	5.	
8.	4.11	1.99	1.00	58.	4.	
9.	3.88	1.90	1.00	51.	4.	
10.	4.79	2.27	1.00	80.	6.	
11.	5.38	2.54	1.00	105.	8.	
12.	5.28	2.49	1.00	100.	8.	
13.	4.25	1.31	0.99	125.	100.	

23002	-0--0	NM	ALAMOGORDO, HOLLOMAN AFB			
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27 28-33 34-40
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	2.88	1.29	1.00	41.	7.	
2.	3.24	1.34	1.00	53.	8.	
3.	3.79	1.36	1.00	82.	13.	
4.	4.03	1.42	1.00	91.	14.	
5.	3.95	1.50	1.00	76.	12.	
6.	3.79	1.50	1.00	67.	11.	
7.	3.40	1.51	1.00	48.	8.	
8.	3.11	1.49	1.00	38.	6.	
9.	2.99	1.45	1.00	35.	6.	
10.	2.67	1.32	1.00	31.	5.	
11.	2.67	1.25	0.99	35.	6.	
12.	2.68	1.26	1.00	35.	5.	
13.	3.24	1.36	1.00	51.	100.	

23050	42-72	NM	ALBUQUERQUE, KIRTLAND AFB						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	3.70	1.47	0.98	65.		6.			
2.	4.29	1.54	0.98	93.		8.			
3.	4.92	1.58	0.99	133.		12.			
4.	5.36	1.66	0.99	160.		14.			
5.	5.10	1.65	0.99	139.		12.			
6.	4.75	1.64	0.99	113.		10.			
7.	4.44	1.74	0.98	85.		8.			
8.	3.77	1.74	0.99	52.		5.			
9.	4.14	1.67	0.98	73.		7.			
10.	4.03	1.55	0.98	77.		7.			
11.	3.74	1.47	0.99	67.		6.			
12.	3.48	1.44	0.98	57.		5.			
13.	4.32	1.56	0.98	93.		100.			

160	-0--0	NM	ANTON CHICO						
MPH	1-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	5.45	1.53	1.00	192.		11.			
2.	5.79	1.57	1.00	220.		13.			
3.	6.22	1.64	1.00	254.		15.			
4.	5.98	1.70	1.00	213.		13.			
5.	5.03	1.75	1.00	122.		7.			
6.	4.99	1.70	1.00	125.		7.			
7.	4.07	1.69	1.00	68.		4.			
8.	4.05	1.85	1.00	60.		4.			
9.	4.16	1.77	1.00	69.		4.			
10.	4.68	1.83	1.00	93.		6.			
11.	4.89	1.59	1.00	130.		8.			
12.	4.91	1.63	1.00	127.		8.			
13.	5.00	1.63	1.00	134.		100.			

23051	-0--0	NM	CLAYTON						
MPH	1-3	4-12	13-24	25-31	32-46				
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT				
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL				
1.	8.06	2.26	0.99	382.	10.				
2.	7.63	2.22	1.00	329.	9.				
3.	8.27	2.15	0.98	430.	12.				
4.	4.58	0.89	0.89	340.	9.				
5.	7.90	2.19	0.99	369.	10.				
6.	7.65	2.22	1.00	332.	9.				
7.	6.45	2.18	1.00	202.	6.				
8.	6.20	2.13	1.00	183.	5.				
9.	6.88	2.34	1.00	231.	6.				
10.	6.94	2.20	1.00	249.	7.				
11.	7.35	2.17	1.00	300.	8.				
12.	7.49	2.13	0.99	323.	9.				
13.	7.37	2.15	1.00	305.	100.				

23008	44-67	NM	CLOVIS, CANNON AFB						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT				
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL				
1.	5.64	1.84	1.00	162.	8.				
2.	6.06	1.85	1.00	199.	10.				
3.	6.86	1.85	1.00	288.	14.				
4.	6.79	1.94	1.00	264.	13.				
5.	6.33	1.93	1.00	216.	10.				
6.	6.22	2.02	1.00	196.	10.				
7.	5.15	1.91	1.00	118.	6.				
8.	4.57	1.83	0.99	86.	4.				
9.	4.85	1.86	0.99	102.	5.				
10.	4.87	1.73	1.00	113.	5.				
11.	5.38	1.75	1.00	149.	7.				
12.	5.57	1.76	1.00	166.	8.				
13.	5.71	1.80	1.00	172.	100.				

373	-0--0	NM	EL MORRO						
MPH	4-15	16031	32-47						
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT				
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL				
1.	4.31	2.07	1.00	64.	6.				
2.	5.05	2.39	1.00	90.	8.				
3.	5.06	1.41	0.98	180.	16.				
4.	5.34	1.60	1.00	168.	15.				
5.	4.76	1.44	0.99	144.	13.				
6.	5.38	2.54	1.00	105.	9.				
7.	4.65	2.21	1.00	75.	7.				
8.	3.88	1.90	1.00	51.	4.				
9.	3.88	1.90	1.00	51.	4.				
10.	4.65	2.21	1.00	75.	7.				
11.	4.65	2.21	1.00	75.	7.				
12.	4.49	2.14	1.00	69.	6.				
13.	4.93	2.33	1.00	85.	100.				

23090	54-59	NM	FARMINGTON APT				
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33 34-40
MONTH	WEIBULL C(M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL		
1.	3.67	1.78	0.99	47.	5.		
2.	3.99	1.72	0.99	63.	7.		
3.	4.88	1.64	0.99	123.	14.		
4.	5.12	1.68	0.99	137.	16.		
5.	4.73	1.83	0.99	96.	11.		
6.	4.69	1.86	1.00	92.	10.		
7.	4.11	1.80	0.98	64.	7.		
8.	3.82	1.88	0.99	49.	6.		
9.	3.70	1.87	0.99	45.	5.		
10.	4.09	1.91	0.98	59.	7.		
11.	3.91	1.53	0.99	71.	8.		
12.	3.29	1.76	0.98	34.	4.		
13.	4.17	1.71	0.99	72.	100.		

23081	-0--0	NM	GALLUP				
MPH	1-3	4-12	13-24	25-31	32-46		
MONTH	WEIBULL C(M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL		
1.	1.90	0.72	0.90	97.	5.		
2.	2.16	0.69	0.94	146.	8.		
3.	3.76	0.84	0.91	263.	15.		
4.	4.72	0.98	0.91	311.	17.		
5.	4.38	0.94	0.92	286.	16.		
6.	4.43	1.03	0.92	244.	13.		
7.	2.58	0.91	0.93	87.	5.		
8.	2.39	0.88	0.96	82.	5.		
9.	2.06	1.14	0.84	21.	1.		
10.	2.16	0.72	0.93	129.	7.		
11.	1.53	0.66	0.92	82.	5.		
12.	0.79	0.52	0.93	62.	3.		
13.	2.64	0.76	0.93	165.	100.		

23039	-0--0	NM	LAS CRUCES, WHITE SANDS				
KNOTS	1-3	4-10	11-21	22-27	28-40		
MONTH	WEIBULL C(M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL		
1.	2.75	0.91	0.99	104.	10.		
2.	3.27	1.06	1.00	103.	10.		
3.	4.52	1.25	0.99	168.	17.		
4.	4.52	1.36	1.00	139.	14.		
5.	4.37	1.50	1.00	103.	10.		
6.	3.87	1.53	1.00	70.	7.		
7.	2.86	1.32	1.00	38.	4.		
8.	2.74	1.36	1.00	31.	3.		
9.	2.65	1.32	1.00	30.	3.		
10.	2.47	1.18	1.00	33.	3.		
11.	2.68	0.97	1.00	77.	8.		
12.	2.64	0.91	0.99	95.	10.		
13.	3.23	1.13	1.00	81.	100.		

272	-0--0	NM	RODEO					
MPH	4-15	16-31	32-47					
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	5.06	1.52	1.00	156.	8.			
2.	5.47	1.64	1.00	174.	9.			
3.	5.49	1.51	0.98	200.	11.			
4.	6.33	1.67	0.98	262.	14.			
5.	6.18	1.87	1.00	208.	11.			
6.	6.06	2.90	1.00	139.	7.			
7.	5.75	2.73	1.00	122.	6.			
8.	5.28	2.49	1.00	100.	5.			
9.	5.28	2.49	1.00	100.	5.			
10.	5.66	2.69	1.00	113.	6.			
11.	5.34	1.60	1.00	168.	9.			
12.	4.60	1.39	0.99	138.	7.			
13.	5.21	1.56	1.00	162.	100.			

23043	-0--0	NM	ROSWELL APT					
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	3.92	1.13	1.00	142.	7.			
2.	4.49	1.18	0.99	185.	10.			
3.	5.85	1.38	0.99	282.	15.			
4.	5.73	1.45	0.99	243.	13.			
5.	5.68	1.55	0.99	212.	11.			
6.	5.63	1.72	0.98	175.	9.			
7.	4.51	1.58	0.97	104.	5.			
8.	4.12	1.56	0.98	80.	4.			
9.	4.06	1.45	0.98	89.	5.			
10.	4.02	1.26	0.98	115.	6.			
11.	3.88	1.16	1.00	129.	7.			
12.	3.86	1.08	0.99	155.	8.			
13.	4.67	1.32	0.99	163.	100.			

23009	-0--0	NM	ROSWELL, WALKER AFB					
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	2.79	0.92	0.97	104.	7.			
2.	3.45	1.04	0.97	127.	9.			
3.	4.45	1.22	0.97	169.	12.			
4.	4.45	1.24	0.97	163.	12.			
5.	4.37	1.28	0.97	144.	10.			
6.	4.85	1.43	0.96	154.	11.			
7.	4.27	1.47	0.95	100.	7.			
8.	3.69	1.36	0.95	75.	5.			
9.	3.62	1.38	0.96	69.	5.			
10.	3.48	1.22	0.96	82.	6.			
11.	3.33	1.09	0.97	99.	7.			
12.	2.98	0.97	0.98	106.	8.			
13.	3.81	1.19	0.97	116.	100.			

23049	-0--0	NM	SANTA FE APT				
MPH	1-3	4-12	13-24	25-31	32-46		
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	6.05	1.87	1.00	195.	9.		
2.	5.89	1.88	1.00	179.	8.		
3.	6.64	1.83	0.99	266.	12.		
4.	6.73	1.80	1.00	283.	13.		
5.	6.30	1.79	1.00	233.	11.		
6.	6.03	1.81	1.00	201.	9.		
7.	5.08	1.83	1.00	119.	5.		
8.	4.73	1.88	1.00	93.	4.		
9.	5.06	1.87	1.00	115.	5.		
10.	5.28	1.82	1.00	135.	6.		
11.	5.72	1.86	1.00	166.	8.		
12.	5.71	1.76	1.00	178.	8.		
13.	5.76	1.79	1.00	179.	100.		

364	-0--0	NM	TUCUMCARY				
MPH	4-15	16-31	32-47				
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	5.88	1.62	0.99	219.	9.		
2.	6.22	1.63	0.98	255.	11.		
3.	6.46	1.64	0.96	282.	12.		
4.	6.57	1.67	0.97	289.	13.		
5.	6.23	1.72	0.99	238.	10.		
6.	5.60	1.68	1.00	180.	8.		
7.	5.75	2.73	1.00	122.	5.		
8.	5.57	2.64	1.00	114.	5.		
9.	5.75	2.73	1.00	122.	5.		
10.	5.21	1.56	1.00	162.	7.		
11.	5.21	1.56	1.00	162.	7.		
12.	5.21	1.56	1.00	162.	7.		
13.	5.62	1.55	0.99	207.	100.		

93044	-0--0	NM	ZUNI				
MPH	1-3	4-7	8-12	13-18	19-24	25-31	32-38
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	4.93	1.74	0.99	117.	8.		
2.	4.42	1.62	0.99	93.	7.		
3.	5.59	1.55	0.99	203.	15.		
4.	5.71	1.66	0.99	194.	14.		
5.	5.53	1.74	0.99	164.	12.		
6.	5.27	1.81	0.99	134.	10.		
7.	3.90	1.81	0.99	55.	4.		
8.	3.88	1.95	0.99	49.	4.		
9.	4.56	2.09	0.99	74.	5.		
10.	4.78	1.90	0.99	95.	7.		
11.	4.61	1.82	0.99	89.	6.		
12.	4.79	1.67	0.99	113.	8.		
13.	4.83	1.72	0.99	111.	100.		

24011 49-71 ND BISMARCK APT
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	5.07	1.60	1.00	144.	7.
2.	5.01	1.61	1.00	137.	7.
3.	5.66	1.68	1.00	186.	9.
4.	6.47	1.78	1.00	253.	13.
5.	6.20	1.82	0.99	217.	11.
6.	5.62	1.75	1.00	170.	9.
7.	4.94	1.78	1.00	114.	6.
8.	4.95	1.75	1.00	117.	6.
9.	5.25	1.62	1.00	156.	8.
10.	5.26	1.57	1.00	165.	8.
11.	5.35	1.52	1.00	183.	9.
12.	4.92	1.53	1.00	141.	7.
13.	5.42	1.64	1.00	167.	100.

24012 -0--0 ND DICKINSON
 MPH 0-3 4-7 8-12 13-18 19-24 25-31 32-38 39-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	7.94	2.15	1.00	382.	9.
2.	7.79	2.25	1.00	345.	9.
3.	8.01	1.93	0.99	435.	11.
4.	8.21	2.04	0.99	442.	11.
5.	7.81	2.17	0.99	359.	9.
6.	7.69	1.97	1.00	377.	9.
7.	6.63	2.05	1.00	232.	6.
8.	6.32	2.06	1.00	200.	5.
9.	6.80	1.85	1.00	280.	7.
10.	7.26	2.04	0.99	306.	8.
11.	7.94	2.11	0.99	386.	10.
12.	7.33	2.04	1.00	316.	8.
13.	7.48	2.02	1.00	337.	100.

14914 48-68 ND FARGO, HECTOR APT
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40 41-
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	6.84	1.98	1.00	265.	9.
2.	6.75	2.01	1.00	250.	8.
3.	7.10	2.09	1.00	279.	9.
4.	7.85	2.14	1.00	368.	12.
5.	7.05	2.13	1.00	269.	9.
6.	6.31	2.05	1.00	200.	7.
7.	5.53	2.05	1.00	134.	5.
8.	5.80	2.13	1.00	149.	5.
9.	6.48	2.10	1.00	212.	7.
10.	6.94	2.07	1.00	264.	9.
11.	7.25	2.05	1.00	303.	10.
12.	6.74	1.97	1.00	255.	9.
13.	6.72	2.03	1.00	245.	100.

94925	-0--0	ND	GRAND FORKS AFB						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	5.51	1.71	1.00	166.		10.			
2.	5.38	1.53	1.00	184.		11.			
3.	5.39	1.61	1.00	171.		10.			
4.	5.87	1.76	1.00	192.		11.			
5.	5.49	1.71	1.00	164.		10.			
6.	4.53	1.65	0.99	97.		6.			
7.	4.01	1.69	1.00	65.		4.			
8.	4.42	1.78	1.00	82.		5.			
9.	4.85	1.71	1.00	113.		7.			
10.	5.22	1.75	1.00	137.		8.			
11.	5.24	1.72	1.00	143.		8.			
12.	5.44	1.67	1.00	166.		10.			
13.	5.11	1.65	1.00	140.		100.			

94011	60-70	ND	MINOT AFB						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	5.83	1.73	0.99	193.		11.			
2.	5.46	1.62	1.00	176.		10.			
3.	5.41	1.66	1.00	165.		9.			
4.	5.88	1.76	1.00	194.		11.			
5.	5.73	1.75	1.00	181.		10.			
6.	4.76	1.66	1.00	112.		6.			
7.	4.35	1.62	1.00	89.		5.			
8.	4.38	1.63	1.00	90.		5.			
9.	4.75	1.59	1.00	120.		7.			
10.	5.27	1.65	1.00	154.		9.			
11.	5.22	1.61	1.00	155.		9.			
12.	5.42	1.58	1.00	179.		10.			
13.	5.21	1.62	1.00	152.		100.			

94014	-0--0	ND	WILLISTON, SLOULIN FLD						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	4.26	1.77	1.00	73.		7.			
2.	4.41	1.83	1.00	78.		7.			
3.	4.94	1.94	1.00	102.		9.			
4.	5.47	1.95	1.00	138.		13.			
5.	5.40	1.97	1.00	131.		12.			
6.	4.90	2.00	1.00	97.		9.			
7.	4.40	2.00	1.00	70.		6.			
8.	4.47	1.94	1.00	76.		7.			
9.	4.71	1.85	1.00	94.		9.			
10.	4.56	1.80	1.00	88.		8.			
11.	4.54	1.93	1.00	80.		7.			
12.	4.17	1.79	0.99	68.		6.			
13.	4.69	1.87	1.00	91.		100.			

13902	44-72	OK	ALTUS AFB					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	4.18	1.44	1.00	97.	7.			
2.	4.72	1.48	1.00	133.	10.			
3.	5.71	1.64	1.00	197.	15.			
4.	5.70	1.73	1.00	180.	13.			
5.	5.16	1.70	1.00	138.	10.			
6.	5.14	1.84	1.00	122.	9.			
7.	4.10	1.76	1.00	66.	5.			
8.	3.98	1.79	1.00	59.	4.			
9.	4.19	1.68	1.00	75.	6.			
10.	4.12	1.46	1.00	90.	7.			
11.	4.09	1.47	1.00	88.	7.			
12.	4.14	1.48	1.00	90.	7.			
13.	4.60	1.57	1.00	111.	100.			

13903	-0---0	OK	ARDMORE AFB, AUTREY FLD					
MPH	1-3	4-12	13-24	25-31	32-46			
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	4.89	1.67	1.00	121.	9.			
2.	5.26	1.72	1.00	144.	11.			
3.	5.76	1.76	1.00	182.	14.			
4.	5.84	1.83	1.00	181.	14.			
5.	4.84	1.83	1.00	103.	8.			
6.	4.71	1.86	1.00	93.	7.			
7.	3.93	1.87	1.00	54.	4.			
8.	3.96	1.84	1.00	56.	4.			
9.	4.17	1.79	1.00	68.	5.			
10.	4.30	1.69	1.00	80.	6.			
11.	4.64	1.59	1.00	111.	9.			
12.	4.50	1.65	1.00	95.	7.			
13.	4.73	1.70	1.00	106.	100.			

3932	59-67	OK	CLINTON-SHERMAN AFB					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT			
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL			
1.	5.67	1.74	1.00	177.	9.			
2.	5.99	1.84	1.00	194.	10.			
3.	6.92	1.95	1.00	279.	14.			
4.	6.84	2.01	1.00	260.	13.			
5.	6.68	2.21	1.00	222.	11.			
6.	5.80	2.13	0.99	150.	8.			
7.	4.72	2.23	1.00	78.	4.			
8.	4.54	2.16	1.00	72.	4.			
9.	4.99	1.99	1.00	103.	5.			
10.	4.96	1.90	1.00	105.	5.			
11.	5.35	1.86	1.00	136.	7.			
12.	5.50	1.76	1.00	159.	8.			
13.	5.68	1.89	1.00	160.	100.			

13906	42-67	OK	ENID, VANCE AFB					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	5.19	1.56	1.00	161.		10.		
2.	5.49	1.68	1.00	169.		10.		
3.	6.22	1.79	1.00	224.		14.		
4.	5.90	1.81	0.99	189.		12.		
5.	5.32	1.82	1.00	137.		8.		
6.	5.45	1.98	1.00	134.		8.		
7.	4.63	1.95	1.00	84.		5.		
8.	4.48	1.94	1.00	76.		5.		
9.	4.68	1.80	0.99	95.		6.		
10.	4.67	1.70	1.00	103.		6.		
11.	5.05	1.69	1.00	131.		8.		
12.	5.12	1.68	0.99	138.		8.		
13.	5.18	1.74	1.00	135.		100.		

13945	40-67	OK	FT SILL					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	5.11	1.41	0.99	184.		9.		
2.	5.71	1.51	0.99	226.		11.		
3.	6.36	1.60	0.99	279.		13.		
4.	6.40	1.75	0.99	251.		12.		
5.	5.74	1.66	1.00	195.		9.		
6.	5.69	1.71	1.00	183.		9.		
7.	4.66	1.71	0.99	100.		5.		
8.	4.35	1.61	0.99	90.		4.		
9.	4.76	1.53	0.99	129.		6.		
10.	4.85	1.46	0.99	148.		7.		
11.	4.99	1.39	0.99	176.		8.		
12.	5.02	1.41	0.99	176.		8.		
13.	5.30	1.52	0.99	178.		100.		

13975	-0--0	OK	GAGE					
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	5.64	1.52	0.99	215.		8.		
2.	5.78	1.60	0.99	211.		8.		
3.	6.63	1.79	0.99	271.		11.		
4.	7.10	1.86	0.98	318.		13.		
5.	6.25	1.64	0.99	257.		10.		
6.	7.02	1.95	0.97	291.		11.		
7.	5.63	1.85	0.98	160.		6.		
8.	5.17	1.78	0.99	130.		5.		
9.	5.42	1.61	0.96	173.		7.		
10.	5.10	1.52	0.97	160.		6.		
11.	5.03	1.44	0.99	169.		7.		
12.	5.19	1.45	0.99	182.		7.		
13.	5.92	1.63	0.99	222.		100.		

13916 -0--0 OK MUSKOGEE
 MPH 1-3 4-12 13-24 25-31 32-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	4.76	1.55	1.00	124.	10.
2.	5.35	1.67	0.99	157.	12.
3.	5.75	1.72	0.99	187.	15.
4.	6.09	1.98	1.00	187.	15.
5.	4.60	1.57	1.00	111.	9.
6.	4.15	1.61	1.00	78.	6.
7.	3.37	1.66	1.00	40.	3.
8.	3.84	1.74	1.00	55.	4.
9.	3.77	1.55	1.00	63.	5.
10.	4.32	1.58	0.99	90.	7.
11.	4.41	1.59	1.00	96.	8.
12.	4.22	1.61	1.00	82.	6.
13.	4.60	1.58	1.00	109.	100.

13967 -0--0 OK OKLAHOMA CITY
 MPH 0-3 4-7 8-12 13-18 19-24 25-31 32-38 39-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	7.38	2.35	0.99	285.	10.
2.	7.48	2.28	0.99	303.	10.
3.	7.89	2.34	0.99	348.	12.
4.	8.10	2.48	0.99	362.	12.
5.	7.12	2.38	0.99	253.	9.
6.	7.03	2.54	0.99	233.	8.
7.	6.14	2.59	0.99	153.	5.
8.	6.10	2.83	0.99	143.	5.
9.	6.36	2.63	0.99	169.	6.
10.	6.58	2.42	0.99	198.	7.
11.	6.90	2.38	0.99	230.	8.
12.	7.12	2.42	0.99	250.	9.
13.	7.02	2.40	0.99	241.	100.

13913 43-67 OK OKLAHOMA CITY, TINKER AFB
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	6.49	1.78	1.00	256.	8.
2.	6.71	1.85	1.00	270.	9.
3.	7.51	1.92	1.00	362.	12.
4.	7.76	1.94	1.00	393.	13.
5.	6.94	1.80	1.00	308.	10.
6.	7.13	1.93	1.00	307.	10.
7.	5.81	2.02	1.00	159.	5.
8.	5.74	2.11	1.00	147.	5.
9.	6.03	1.92	1.00	188.	6.
10.	6.18	1.76	1.00	226.	7.
11.	6.34	1.82	1.00	232.	8.
12.	6.33	1.76	1.00	242.	8.
13.	6.57	1.85	1.00	254.	100.

13968	-0--0	OK	TULSA IAP			
KNOTS	1-3	4-10	11-21	22-27	28-40	
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	5.50	2.08	1.00	131.	10.	
2.	5.78	2.08	1.00	152.	11.	
3.	6.04	2.14	1.00	169.	12.	
4.	5.94	2.18	1.00	158.	11.	
5.	5.43	2.05	1.00	128.	9.	
6.	4.89	2.19	1.00	88.	6.	
7.	4.51	2.20	1.00	69.	5.	
8.	4.42	2.26	0.99	64.	5.	
9.	4.69	2.01	1.00	84.	6.	
10.	4.86	2.04	1.00	92.	7.	
11.	5.26	2.01	1.00	119.	9.	
12.	5.37	2.06	0.99	123.	9.	
13.	5.23	2.04	1.00	115.	100.	

358	-0--0	OK	WAYNOKA			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	6.23	1.72	0.99	238.	7.	
2.	6.93	1.73	0.96	323.	10.	
3.	8.05	1.98	0.95	430.	13.	
4.	7.95	1.95	0.94	422.	13.	
5.	7.27	1.97	0.99	319.	10.	
6.	6.85	2.13	1.00	247.	7.	
7.	6.58	2.02	1.00	231.	7.	
8.	6.59	3.22	1.00	171.	5.	
9.	6.38	1.94	1.00	220.	7.	
10.	6.45	1.79	0.99	250.	8.	
11.	6.45	1.79	0.99	250.	8.	
12.	5.62	1.55	0.99	207.	6.	
13.	6.77	1.80	0.99	288.	100.	

14936	-0--0	SD	ABERDEEN APT			
MPH	1-3	4-12	13-24	25-31	32-46	
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	6.12	1.84	1.00	206.	8.	
2.	6.19	1.93	1.00	202.	8.	
3.	6.87	1.85	0.99	288.	11.	
4.	7.61	2.08	0.99	346.	13.	
5.	6.69	1.99	0.99	246.	9.	
6.	6.22	1.91	0.98	206.	8.	
7.	5.52	1.93	0.98	143.	6.	
8.	5.60	1.93	0.98	149.	6.	
9.	5.99	1.82	0.99	197.	8.	
10.	6.12	1.78	0.99	215.	8.	
11.	6.25	1.80	0.97	225.	9.	
12.	5.88	1.88	0.99	179.	7.	
13.	6.26	1.87	0.99	216.	100.	

94013	-0--0	SD	HGT SPRINGS				
KNUTS	1-3	4-6	7-10	11-16	17-27	28-40	
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	3.88	1.40	0.99	82.	6.		
2.	4.10	1.53	0.96	82.	5.		
3.	4.87	1.82	0.97	106.	7.		
4.	6.06	1.57	0.98	252.	17.		
5.	5.49	1.62	0.98	178.	12.		
6.	4.76	1.46	0.99	139.	9.		
7.	3.59	1.40	0.96	65.	4.		
8.	4.15	1.33	0.99	112.	8.		
9.	4.23	1.54	0.95	90.	6.		
10.	4.06	1.24	0.98	125.	8.		
11.	5.17	1.53	0.99	164.	11.		
12.	4.30	1.53	0.95	94.	6.		
13.	4.56	1.40	0.99	133.	100.		

14936	-0--0	SD	HURON				
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	5.49	1.67	0.99	170.	8.		
2.	5.68	1.78	0.99	172.	8.		
3.	6.46	1.94	0.99	227.	10.		
4.	6.98	2.01	0.99	277.	12.		
5.	6.25	1.89	0.99	213.	9.		
6.	5.69	1.85	0.99	165.	7.		
7.	5.24	1.82	0.99	131.	6.		
8.	5.26	1.84	0.99	132.	6.		
9.	5.64	1.82	0.99	164.	7.		
10.	5.88	1.80	0.99	189.	8.		
11.	6.39	1.84	1.00	235.	10.		
12.	5.60	1.71	1.00	175.	8.		
13.	5.88	1.80	0.99	188.	100.		

24025	49-71	SD	PIERRE APT				
KNUTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	5.67	1.53	1.00	216.	10.		
2.	5.57	1.59	1.00	192.	9.		
3.	6.23	1.66	1.00	250.	11.		
4.	6.67	1.75	1.00	286.	13.		
5.	5.97	1.76	1.00	203.	9.		
6.	5.21	1.73	1.00	139.	6.		
7.	5.08	1.87	1.00	116.	5.		
8.	5.17	1.84	1.00	125.	6.		
9.	5.37	1.78	1.00	146.	6.		
10.	5.39	1.67	1.00	161.	7.		
11.	5.78	1.58	1.00	217.	10.		
12.	5.47	1.48	1.00	205.	9.		
13.	5.64	1.66	1.00	186.	100.		

24090	-0--0	SD	RAPID CITY					
MPH	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	4.61	1.20	0.99	194.		8.		
2.	4.96	1.33	0.99	189.		8.		
3.	5.81	1.45	0.99	255.		11.		
4.	6.11	1.63	0.99	243.		11.		
5.	5.73	1.74	0.99	181.		8.		
6.	5.30	1.73	0.99	146.		6.		
7.	5.06	1.83	1.00	118.		5.		
8.	5.27	1.80	1.00	135.		6.		
9.	5.55	1.77	1.00	162.		7.		
10.	5.39	1.54	1.00	183.		8.		
11.	5.98	1.41	0.99	290.		13.		
12.	4.87	1.26	1.00	203.		9.		
13.	5.42	1.51	1.00	192.		100.		

24006	40-67	SD	RAPID CITY, ELLSWORTH AFB					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40 41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	5.17	1.25	0.99	243.		9.		
2.	5.31	1.32	0.99	234.		8.		
3.	5.98	1.40	0.99	294.		11.		
4.	6.54	1.56	1.00	316.		11.		
5.	5.95	1.62	1.00	227.		8.		
6.	5.41	1.57	1.00	180.		6.		
7.	5.11	1.56	1.00	152.		5.		
8.	5.14	1.55	1.00	157.		6.		
9.	5.40	1.52	1.00	189.		7.		
10.	5.33	1.38	1.00	216.		8.		
11.	5.85	1.33	0.99	301.		11.		
12.	5.43	1.28	0.99	264.		10.		
13.	5.57	1.42	1.00	232.		100.		

14944	-0--0	SD	SIOUX FALLS, FOSS FLD					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL		
1.	5.43	1.75	1.00	153.		8.		
2.	5.49	1.82	1.00	151.		8.		
3.	6.22	1.92	1.00	206.		11.		
4.	6.69	1.89	1.00	261.		14.		
5.	5.98	1.87	1.00	188.		10.		
6.	5.26	1.92	1.00	125.		7.		
7.	4.69	1.89	1.00	90.		5.		
8.	4.61	1.88	1.00	86.		5.		
9.	5.04	1.82	0.99	117.		6.		
10.	5.26	1.75	1.00	140.		8.		
11.	5.89	1.74	1.00	197.		11.		
12.	5.32	1.79	1.00	140.		8.		
13.	5.48	1.79	1.00	154.		100.		

14946	-0--0	SD	WATERTOWN			
MPH	1-3	4-12	13-24	25-31	32-46	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER	PERCENT	
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL	
1.	6.12	1.84	1.00	206.	8.	
2.	6.19	1.93	1.00	202.	8.	
3.	6.87	1.85	0.99	288.	11.	
4.	7.61	2.08	0.99	346.	13.	
5.	6.69	1.99	0.99	246.	9.	
6.	6.22	1.91	0.98	206.	8.	
7.	5.52	1.93	0.98	143.	6.	
8.	5.60	1.93	0.98	149.	6.	
9.	5.99	1.82	0.99	197.	8.	
10.	6.17	1.78	0.99	215.	8.	
11.	6.25	1.80	0.97	225.	9.	
12.	5.88	1.88	0.99	179.	7.	
13.	6.26	1.87	0.99	216.	100.	

13910	44-70	TX	ABILENE, DYERS AFB				
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT	
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL	
1.	4.29	1.59	0.99	88.		8.	
2.	4.58	1.66	0.99	100.		9.	
3.	5.30	1.74	0.99	144.		13.	
4.	5.37	1.78	1.00	145.		13.	
5.	5.15	1.88	0.99	120.		11.	
6.	4.91	2.02	1.00	96.		9.	
7.	4.14	2.07	1.00	57.		5.	
8.	3.69	1.83	1.00	46.		4.	
9.	3.71	1.63	1.00	55.		5.	
10.	3.82	1.57	0.99	63.		6.	
11.	4.16	1.53	1.00	85.		8.	
12.	4.21	1.57	1.00	85.		8.	
13.	4.45	1.68	1.00	90.		100.	

23047	44-68	TX	AMARILLO, ENGLISH FLD						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C (M/S)	K	DETERMINATION		(W/M2)		OF ANNUAL		
1.	6.53	2.16	0.99		212.		8.		
2.	7.05	2.19	0.99		263.		10.		
3.	7.67	2.21	1.00		334.		12.		
4.	7.58	2.30	1.00		312.		12.		
5.	7.29	2.29	1.00		279.		10.		
6.	6.99	2.51	1.00		231.		9.		
7.	6.10	2.39	1.00		159.		6.		
8.	5.67	2.42	1.00		127.		5.		
9.	6.30	2.44	1.00		172.		6.		
10.	6.38	2.28	1.00		189.		7.		
11.	6.46	2.13	1.00		207.		8.		
12.	6.47	2.14	0.99		207.		8.		
13.	6.73	2.24	0.99		224.		100.		

13904 -0--0 TX AUSTIN, BERGSTROM AFB
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	4.62	1.31	0.99	159.	11.
2.	4.78	1.42	0.99	148.	11.
3.	5.30	1.54	0.99	174.	12.
4.	5.24	1.67	0.99	147.	10.
5.	4.78	1.60	0.99	120.	8.
6.	4.81	1.63	0.99	119.	8.
7.	4.42	1.72	0.99	85.	6.
8.	3.98	1.58	0.99	71.	5.
9.	3.47	1.44	0.99	56.	4.
10.	3.62	1.33	1.00	75.	5.
11.	4.19	1.27	0.99	128.	9.
12.	4.15	1.26	0.99	127.	9.
13.	4.47	1.44	0.99	118.	100.

12925 46-70 TX BEEVILLE NAAS
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	4.16	1.64	1.00	77.	8.
2.	4.61	1.71	1.00	97.	10.
3.	5.06	1.84	1.00	116.	12.
4.	5.25	1.94	1.00	122.	13.
5.	4.77	1.72	1.00	107.	11.
6.	4.26	1.65	1.00	81.	8.
7.	4.04	1.68	1.00	68.	7.
8.	3.65	1.55	1.00	56.	6.
9.	3.51	1.57	0.99	49.	5.
10.	3.50	1.60	1.00	48.	5.
11.	4.04	1.61	1.00	72.	7.
12.	4.01	1.67	1.00	67.	7.
13.	4.22	1.64	1.00	80.	100.

23005 43-67 TX BIG SPRING, WEBB AFB
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	5.43	1.79	1.00	149.	8.
2.	5.92	1.84	1.00	187.	9.
3.	6.82	2.03	1.00	256.	13.
4.	6.90	2.08	1.00	258.	13.
5.	6.66	2.22	1.00	219.	11.
6.	6.66	2.33	1.00	210.	11.
7.	5.53	2.32	1.00	121.	6.
8.	5.09	2.32	1.00	95.	5.
9.	5.18	2.17	1.00	106.	5.
10.	5.12	1.87	1.00	119.	6.
11.	5.23	1.85	1.00	128.	6.
12.	5.11	1.73	1.00	130.	7.
13.	5.82	1.96	1.00	165.	100.

93042 -0--0 TX DALHART APT
 MPH 0-3 4-7 8-12 13-18 19-24 25-31 32-38 39-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	7.50	2.18	0.97	317.	8.
2.	7.42	2.09	0.97	319.	8.
3.	8.25	2.15	0.99	426.	11.
4.	8.27	2.18	0.99	425.	11.
5.	8.14	2.09	0.99	421.	11.
6.	8.98	2.29	0.99	522.	13.
7.	7.31	2.14	0.99	297.	8.
8.	6.96	2.24	0.99	248.	6.
9.	7.10	2.31	0.99	256.	7.
10.	6.58	2.25	0.99	209.	5.
11.	6.51	2.11	0.96	213.	5.
12.	6.86	2.11	0.96	250.	6.
13.	7.46	2.13	0.99	319.	100.

93901 46-70 TX DALLAS NAS
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	5.33	1.65	0.99	158.	10.
2.	5.52	1.72	1.00	166.	10.
3.	6.19	1.86	1.00	211.	13.
4.	6.16	1.92	1.00	199.	12.
5.	5.61	1.92	1.00	151.	9.
6.	5.60	2.05	1.00	140.	9.
7.	4.93	2.17	1.00	91.	6.
8.	4.56	2.03	1.00	77.	5.
9.	4.41	1.77	1.00	81.	5.
10.	4.53	1.66	1.00	96.	6.
11.	4.91	1.54	0.99	139.	8.
12.	5.04	1.68	1.00	131.	8.
13.	5.24	1.78	1.00	135.	100.

22001 44-67 TX DEL RIO, LAUGHLIN AFB
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	3.77	1.50	1.00	66.	7.
2.	4.41	1.57	1.00	97.	10.
3.	4.77	1.73	1.00	107.	11.
4.	5.00	1.80	1.00	116.	12.
5.	5.17	1.99	1.00	114.	12.
6.	5.37	2.35	1.00	110.	11.
7.	4.96	2.41	0.99	85.	9.
8.	4.44	2.31	1.00	63.	6.
9.	3.97	1.90	1.00	55.	6.
10.	3.84	1.79	1.00	53.	5.
11.	3.53	1.54	1.00	52.	5.
12.	3.36	1.39	1.00	54.	6.
13.	4.41	1.77	1.00	81.	100.

12918	-0--0	TX	HOUSTON				
MPH	0-3	4-7	8-12	13-18	19-24	25-31	
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	6.45	2.60	0.99	177.	10.		
2.	6.74	2.63	0.99	201.	11.		
3.	6.67	2.46	0.98	204.	11.		
4.	6.92	2.60	0.98	219.	12.		
5.	6.23	2.27	0.99	176.	10.		
6.	5.64	2.27	1.00	131.	7.		
7.	5.02	2.63	0.96	84.	5.		
8.	4.40	2.07	0.99	68.	4.		
9.	4.89	2.04	1.00	94.	5.		
10.	5.32	2.25	1.00	111.	6.		
11.	6.25	2.41	0.99	170.	10.		
12.	5.95	2.34	0.99	150.	8.		
13.	5.83	2.21	0.99	148.	100.		

12906	42-72	TX	HOUSTON, ELLINGTON AFB				
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	4.31	1.66	1.00	83.	10.		
2.	4.52	1.70	0.99	93.	11.		
3.	4.90	1.78	1.00	111.	13.		
4.	4.73	1.76	0.99	101.	12.		
5.	4.17	1.61	0.99	79.	9.		
6.	3.58	1.54	0.99	54.	6.		
7.	3.01	1.44	1.00	36.	4.		
8.	3.09	1.50	1.00	37.	4.		
9.	3.40	1.45	1.00	52.	6.		
10.	3.49	1.52	1.00	52.	6.		
11.	4.05	1.51	0.99	81.	9.		
12.	4.10	1.66	1.00	72.	8.		
13.	3.92	1.55	0.99	70.	100.		

12961	-0--0	TX	KERRVILLE				
KNOTS	1-3	4-6	7-10	11-16	17-27	28-40	
MONTH	WEIBULL	PARAMETERS	COEFFICIENT	AVG. POWER	PERCENT		
	C(M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL		
1.	3.88	1.61	0.97	64.	8.		
2.	4.08	1.62	0.96	73.	9.		
3.	4.90	1.86	0.99	105.	13.		
4.	5.01	2.16	0.97	96.	11.		
5.	4.78	1.90	0.99	95.	11.		
6.	4.57	2.08	0.99	75.	9.		
7.	4.46	1.90	1.00	77.	9.		
8.	3.46	1.68	0.99	42.	5.		
9.	3.66	1.86	0.99	44.	5.		
10.	3.25	1.35	1.00	52.	6.		
11.	3.51	1.38	0.99	64.	8.		
12.	3.05	1.31	0.97	47.	6.		
13.	4.06	1.62	0.99	72.	100.		

3933 51-68 TX KILLEEN, FORT HOOD AAF						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27 28-33 34-40
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL
1.	4.92	1.67	1.00	123.		10.
2.	5.11	1.70	1.00	133.		11.
3.	5.32	1.70	1.00	152.		12.
4.	5.52	1.79	0.99	157.		12.
5.	5.13	1.76	1.00	129.		10.
6.	4.83	1.78	0.99	106.		8.
7.	4.45	1.92	1.00	76.		6.
8.	3.98	1.90	1.00	55.		4.
9.	3.81	1.73	1.00	54.		4.
10.	4.05	1.62	1.00	72.		6.
11.	4.28	1.50	1.00	96.		8.
12.	4.66	1.59	1.00	112.		9.
13.	4.70	1.71	1.00	103.		100.

12928 46-70 TX KINGSVILLE NAAS						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27 28-33 34-40 41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL
1.	4.65	1.64	1.00	106.		7.
2.	5.02	1.72	1.00	125.		8.
3.	5.56	1.83	1.00	156.		10.
4.	5.92	1.93	1.00	177.		12.
5.	5.65	1.78	1.00	169.		11.
6.	5.38	1.69	1.00	157.		11.
7.	5.18	1.70	1.00	139.		9.
8.	4.53	1.49	1.00	115.		8.
9.	4.02	1.48	1.00	83.		6.
10.	4.03	1.57	1.00	74.		5.
11.	4.49	1.61	1.00	99.		7.
12.	4.41	1.62	1.00	93.		6.
13.	4.89	1.63	1.00	124.		100.

12907 43-67 TX LAREDO AFB						
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27 28-33
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL
1.	4.58	1.90	1.00	83.		5.
2.	5.26	2.05	1.00	116.		7.
3.	5.82	2.22	1.00	146.		9.
4.	6.36	2.41	1.00	179.		11.
5.	6.68	2.55	1.00	200.		12.
6.	7.03	2.91	1.00	217.		13.
7.	6.95	2.96	1.00	208.		12.
8.	6.38	2.74	1.00	167.		10.
9.	5.43	2.31	1.00	115.		7.
10.	5.06	2.26	1.00	95.		6.
11.	4.79	2.09	1.00	86.		5.
12.	4.45	1.92	1.00	75.		4.
13.	5.75	2.19	1.00	142.		100.

23021 43-67 TX LUBBOCK, REESE AFB
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40 41-
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	5.29	1.73	0.99	145.	8.
2.	5.94	1.78	1.00	197.	11.
3.	6.56	1.86	0.99	250.	14.
4.	6.59	1.96	0.99	239.	13.
5.	6.21	2.00	0.99	195.	11.
6.	6.15	2.08	0.99	183.	10.
7.	4.69	2.04	1.00	83.	5.
8.	4.18	1.99	0.99	60.	3.
9.	4.56	1.91	0.99	82.	5.
10.	4.67	1.82	1.00	93.	5.
11.	5.23	1.82	0.99	130.	7.
12.	5.38	1.70	1.00	157.	9.
13.	5.45	1.81	0.99	149.	100.

93987 -0--0 TX LUFKIN, ANGELINA CO APT
 MPH 1-3 4-12 13-24 25-31
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	3.67	1.54	0.84	58.	10.
2.	3.66	1.45	0.86	65.	11.
3.	3.55	1.11	0.70	112.	19.
4.	3.53	1.24	0.77	82.	14.
5.	2.96	1.34	0.87	41.	7.
6.	2.65	1.61	1.00	21.	4.
7.	2.39	1.31	0.87	23.	4.
8.	2.32	1.61	1.00	14.	2.
9.	2.51	1.59	1.00	18.	3.
10.	2.56	1.20	0.88	34.	6.
11.	3.17	1.31	0.88	53.	9.
12.	3.37	1.38	0.87	56.	10.
13.	3.03	1.32	0.88	45.	100.

23022 -0--0 TX MARFA APT
 MPH 1-3 4-12 13-24 25-31 32-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	3.61	1.12	1.00	117.	9.
2.	4.51	1.22	0.99	174.	14.
3.	4.72	1.37	1.00	155.	12.
4.	5.17	1.47	1.00	176.	14.
5.	4.55	1.43	1.00	127.	10.
6.	4.52	1.68	0.99	94.	7.
7.	4.04	1.71	1.00	66.	5.
8.	3.35	1.45	1.00	50.	4.
9.	3.68	1.40	1.00	71.	6.
10.	3.73	1.43	1.00	70.	5.
11.	3.45	1.22	1.00	79.	6.
12.	3.35	1.11	0.99	95.	7.
13.	4.13	1.33	1.00	110.	100.

23023 -0--0 TX MIDLAND
 MPH 0-3 4-7 8-12 13-18 19-24 25-31 32-38 39-46
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	4.65	1.92	1.00	87.	7.
2.	5.58	2.20	0.99	130.	10.
3.	5.62	2.09	0.99	139.	11.
4.	5.96	2.37	0.99	149.	12.
5.	5.70	2.46	0.99	127.	10.
6.	5.56	2.51	0.99	117.	9.
7.	4.99	2.32	0.99	89.	7.
8.	4.61	2.31	0.99	71.	6.
9.	4.75	2.21	0.99	80.	6.
10.	4.62	1.99	0.99	81.	7.
11.	4.70	2.01	1.00	85.	7.
12.	4.90	1.99	1.00	97.	8.
13.	5.14	2.14	0.99	104.	100.

93985 49-65 TX MINERAL WELLS APT
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	5.12	1.92	0.99	114.	8.
2.	5.50	1.98	1.00	138.	9.
3.	6.29	2.06	1.00	197.	13.
4.	6.41	2.22	1.00	195.	13.
5.	5.87	2.11	1.00	157.	11.
6.	5.86	2.28	1.00	146.	10.
7.	5.14	2.36	1.00	96.	6.
8.	4.70	2.37	0.99	73.	5.
9.	4.52	2.10	1.00	72.	5.
10.	4.60	1.93	1.00	83.	6.
11.	4.89	1.83	1.00	106.	7.
12.	4.92	1.87	1.00	105.	7.
13.	5.32	2.02	1.00	122.	100.

3943 49-70 TX MINERAL WELLS, FT WALTERS AAF
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C(M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	4.95	1.80	0.99	112.	8.
2.	5.24	1.83	1.00	131.	9.
3.	6.09	1.97	1.00	188.	14.
4.	6.11	2.07	1.00	180.	13.
5.	5.59	1.96	1.00	146.	11.
6.	5.51	2.09	1.00	131.	9.
7.	4.83	2.15	1.00	86.	6.
8.	4.40	2.12	1.00	66.	5.
9.	4.26	1.90	1.00	67.	5.
10.	4.39	1.80	0.99	78.	6.
11.	4.58	1.69	1.00	97.	7.
12.	4.71	1.75	1.00	100.	7.
13.	5.05	1.87	1.00	114.	100.

12910 -0--0 TX SAN MARCOS
 KNOTS 1-3 4-10 11-21 22-27 28-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	3.90	1.27	1.00	105.	10.
2.	4.06	1.30	0.99	110.	11.
3.	4.40	1.38	1.00	123.	12.
4.	4.37	1.57	0.99	95.	10.
5.	4.68	1.72	0.99	101.	10.
6.	4.29	1.77	1.00	75.	8.
7.	3.52	1.86	0.98	39.	4.
8.	3.61	1.67	1.00	49.	5.
9.	3.09	1.42	1.00	41.	4.
10.	3.22	1.23	1.00	64.	6.
11.	3.61	1.18	0.99	100.	10.
12.	3.70	1.24	1.00	95.	10.
13.	3.87	1.40	1.00	82.	100.

13923 -0--0 TX SHERMAN, PERRIN AFB
 KNOTS 1-3 4-6 7-10 11-16 17-21 22-27 28-33 34-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	5.60	1.73	1.00	171.	11.
2.	5.58	1.81	1.00	160.	10.
3.	6.30	1.91	1.00	214.	13.
4.	6.30	1.95	1.00	210.	13.
5.	5.50	2.00	1.00	137.	8.
6.	5.25	2.09	1.00	113.	7.
7.	4.58	2.23	0.99	71.	4.
8.	4.51	2.24	0.99	68.	4.
9.	4.54	2.03	0.99	75.	5.
10.	4.81	1.83	1.00	101.	6.
11.	5.33	1.69	0.99	153.	9.
12.	5.46	1.81	1.00	150.	9.
13.	5.29	1.88	1.00	130.	100.

12912 -0--0 TX VICTORIA, FOSTER AFB
 KNOTS 1-3 4-10 11-21 22-27 28-40
 MONTH WEIBULL PARAMETERS COEFFICIENT AVG. POWER PERCENT
 C (M/S) K DETERMINATION (W/M2) OF ANNUAL

1.	4.72	1.60	1.00	116.	11.
2.	5.36	1.74	1.00	149.	14.
3.	5.51	1.73	1.00	163.	15.
4.	4.95	1.78	1.00	114.	11.
5.	4.49	1.74	1.00	88.	8.
6.	4.10	1.70	0.99	69.	7.
7.	3.52	1.84	0.97	40.	4.
8.	3.44	1.50	1.00	50.	5.
9.	3.23	1.55	1.00	39.	4.
10.	3.40	1.60	1.00	43.	4.
11.	4.01	1.45	1.00	85.	8.
12.	4.31	1.44	1.00	106.	10.
13.	4.24	1.54	1.00	89.	100.

172	-0--0	WY	BITTER CREEK			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER	PERCENT	
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL	
1.	8.12	2.21	0.99	397.	11.	
2.	8.49	2.22	0.98	453.	13.	
3.	8.86	2.27	0.97	504.	15.	
4.	7.36	2.00	0.99	326.	9.	
5.	6.23	1.72	0.99	238.	7.	
6.	5.60	1.68	1.00	180.	5.	
7.	5.48	2.59	1.00	109.	3.	
8.	5.47	1.64	1.00	174.	5.	
9.	5.21	1.56	1.00	162.	5.	
10.	6.00	1.65	0.99	225.	7.	
11.	6.98	1.86	0.99	300.	9.	
12.	8.12	2.21	0.99	397.	11.	
13.	6.88	1.83	0.99	294.	100.	

24005	-0--0	WY	CASPER AAF			
MPH	1-3	4-12	13-24	25-31	32-46	
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER	PERCENT	
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL	
1.	7.72	1.87	0.98	404.	14.	
2.	7.30	1.79	0.98	360.	12.	
3.	7.19	1.89	0.99	323.	11.	
4.	6.00	1.67	0.99	223.	7.	
5.	5.34	1.60	0.99	168.	6.	
6.	5.58	1.66	0.99	181.	6.	
7.	5.02	1.75	0.99	121.	4.	
8.	5.08	1.75	1.00	126.	4.	
9.	5.61	1.71	0.99	175.	6.	
10.	5.71	1.74	1.00	180.	6.	
11.	6.79	1.69	0.99	314.	11.	
12.	7.95	2.00	0.98	408.	14.	
13.	6.32	1.71	0.99	251.	100.	

173	-0--0	WY	CHEROKEE			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER	PERCENT	
	C (M/S)	K	DETERMINATION	(W/M2)	OF ANNUAL	
1.	9.73	2.92	1.00	501.	13.	
2.	9.57	2.56	0.98	583.	13.	
3.	9.20	2.56	0.99	519.	12.	
4.	7.95	2.14	0.99	384.	9.	
5.	7.05	2.01	1.00	285.	6.	
6.	6.86	1.93	1.00	274.	6.	
7.	6.07	1.83	1.00	203.	5.	
8.	6.38	1.94	1.00	220.	5.	
9.	6.48	1.98	1.00	225.	5.	
10.	7.23	2.08	1.00	297.	7.	
11.	8.52	2.40	1.00	430.	10.	
12.	9.24	2.81	1.00	499.	11.	
13.	7.80	2.18	1.00	357.	100.	

24018	48-67	WY	CHEYENNE	APT					
KNOTS	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	7.79	1.90	0.99	406.		12.			
2.	7.98	1.94	0.99	426.		13.			
3.	7.65	1.90	0.99	387.		12.			
4.	7.47	1.92	0.99	355.		11.			
5.	6.58	2.05	1.00	226.		7.			
6.	5.99	2.17	0.99	163.		5.			
7.	5.37	2.16	1.00	117.		4.			
8.	5.44	2.14	1.00	123.		4.			
9.	5.75	2.12	1.00	147.		4.			
10.	6.19	2.04	0.99	191.		6.			
11.	7.45	1.89	0.99	360.		11.			
12.	7.85	1.88	0.99	422.		13.			
13.	6.78	1.92	0.99	267.		100.			

24045	-0--0	WY	CODY	APT					
KNOTS	1-3	4-6	7-10	11-16	17-27	28-40			
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	4.23	1.05	0.90	210.		8.			
2.	5.06	1.13	0.92	279.		10.			
3.	5.05	1.17	0.93	262.		10.			
4.	5.87	1.29	0.93	324.		12.			
5.	5.15	1.28	0.95	228.		8.			
6.	4.73	1.31	0.94	172.		6.			
7.	4.33	1.27	0.95	142.		5.			
8.	4.65	1.28	0.96	170.		6.			
9.	4.57	1.22	0.95	181.		7.			
10.	4.51	1.11	0.95	217.		8.			
11.	4.72	1.06	0.93	267.		10.			
12.	4.45	0.99	0.92	271.		10.			
13.	4.82	1.16	0.94	236.		100.			

177	-0--0	WY	GRANGER						
MPH	4-15	16-31	32-47						
MONTH	WEIBULL PARAMETERS		COEFFICIENT	AVG. POWER		PERCENT			
	C (M/S)	K	DETERMINATION	(W/M2)		OF ANNUAL			
1.	6.22	1.63	0.98	255.		11.			
2.	5.72	1.50	0.97	228.		10.			
3.	6.93	1.73	0.96	323.		13.			
4.	5.85	1.53	0.97	235.		10.			
5.	5.35	1.48	0.98	194.		8.			
6.	5.62	1.55	0.99	207.		9.			
7.	4.06	1.26	0.99	119.		5.			
8.	4.91	1.48	0.99	150.		6.			
9.	4.43	1.35	0.99	132.		6.			
10.	4.60	1.39	0.99	138.		6.			
11.	5.62	1.55	0.99	207.		9.			
12.	5.62	1.55	0.99	207.		9.			
13.	5.49	1.51	0.98	200.		100.			

573	-0--0	WY	KNIGHT			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	6.00	1.65	0.99	225.	9.	
2.	6.47	1.61	0.95	292.	12.	
3.	6.68	1.71	0.97	296.	12.	
4.	5.85	1.53	0.97	235.	9.	
5.	5.62	1.55	0.99	207.	8.	
6.	5.21	1.44	0.98	187.	8.	
7.	4.43	1.35	0.99	132.	5.	
8.	4.76	1.44	0.99	144.	6.	
9.	5.31	1.41	0.95	206.	8.	
10.	5.21	1.56	1.00	162.	7.	
11.	5.06	1.41	0.98	180.	7.	
12.	5.75	1.58	0.99	213.	9.	
13.	5.49	1.51	0.98	200.	100.	

164	-0--0	WY	LARAMIE			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	7.87	1.98	0.97	401.	12.	
2.	7.96	2.02	0.97	409.	13.	
3.	8.15	2.08	0.97	423.	13.	
4.	6.96	1.97	1.00	279.	9.	
5.	6.56	1.83	0.99	256.	8.	
6.	6.76	2.09	1.00	242.	8.	
7.	5.57	2.64	1.00	114.	4.	
8.	5.83	2.78	1.00	127.	4.	
9.	5.34	1.60	1.00	168.	5.	
10.	6.18	1.87	1.00	208.	6.	
11.	6.96	1.97	1.00	279.	9.	
12.	7.18	1.93	0.99	313.	10.	
13.	6.56	1.83	0.99	256.	100.	

165	-0--0	WY	MEDICINE BOW			
MPH	4-15	16-31	32-47			
MONTH	WEIBULL C (M/S)	PARAMETERS K	COEFFICIENT DETERMINATION	AVG. POWER (W/M2)	PERCENT OF ANNUAL	
1.	9.35	2.34	0.93	579.	13.	
2.	8.82	2.15	0.91	521.	12.	
3.	9.41	2.34	0.92	590.	13.	
4.	7.82	1.93	0.95	405.	9.	
5.	6.22	1.58	0.96	268.	6.	
6.	6.34	1.76	0.99	244.	5.	
7.	5.49	1.51	0.98	200.	4.	
8.	5.60	1.68	1.00	180.	4.	
9.	5.97	1.52	0.95	253.	6.	
10.	6.73	1.65	0.93	315.	7.	
11.	7.85	1.92	0.94	413.	9.	
12.	9.04	2.24	0.93	542.	12.	
13.	7.41	1.81	0.94	372.	100.	

C-1,

APPENDIX C

Computer Program to Simulate Wind-Powered Irrigation Wells
and Examples of Output at 3 Locations

The computer program was developed to solve the problem of determining drawdown and yield of a water table aquifer caused by cyclic pumping. The approximate drawdown equations and other methodology used to develop the program are presented in the section of this report entitled "Wind Energy and Well Yield." The Weibull windspeed distribution parameters for the example locations as well as other locations are in Appendix B. The program input parameters are in Table C-1 along with their explanations.

The program has several options and can be used to calculate well yield for any of the 4 VAWT modes described in the report. In addition, by specifying the parameter, K_0 , equal 1, the program will determine the VAWT size necessary to produce a given minimum allowable well water height. In this case, the wind turbine parameters will be printed again with the final turbine area (A_T) used in the calculations.

The program also permits specification of minimum power levels and minimum time durations that can be used to simulate the effects of an auxiliary motor operated alone or with the VAWT.

The output data are printed once for each month of input data. Examples of the output are given after the program for 4 modes of VAWT operation at Garden City, Kansas, Columbus, Nebraska, and Amarillo, Texas. The output wind power is that supplied by the wind turbine operating in a specific mode, which is added to the supplementary motor power to produce the calculated well yields and minimum water heights.

Table C-1. Program notation for input data.

Symbol	Definition	Units
Aquifer data		
AK	Aquifer isotropic hydraulic conductivity	m/day
AE	Aquifer specific yield = effective porosity	decimal fraction
HWM	Minimum allowable water height	m
Well data		
DL	Depth of well (fully penetrates aquifer)	m
DO	Saturated thickness of aquifer	m
WL	Well loss coefficient	s ² /m ⁵
RW	Well "effective" radius	m
Pump data		
PN	Pump and transmission efficiency (if not constant, indicate mode 3 or 4)	decimal fraction
Wind turbine data		
WSCI	Turbine cut-in windspeed	m/s
WSRT	Turbine rated windspeed	m/s
WSCO	Turbine cut-out windspeed	m/s
TN	Turbine efficiency (if not constant, indicate mode 1 or 2)	decimal fraction
AT	Turbine area	m ²
HT	Height of turbine above ground	m
KO	Program parameter (1 - find AT to give HWM, 2 - no change in AT)	dimensionless
Wind data		
C	Weibull distribution parameter	m/s
EK	Weibull distribution parameter	dimensionless
HTA	Height of anemometer above ground	m
CN	Number of pumping cycles per month	dimensionless
PMIN	Minimum power to pump per unit area of turbine	kw
TMIN	Minimum monthly operation time	decimal fraction
MO	Number of the month	dimensionless

Abbreviated program
flow chart

Subroutine to calculate drawdown and well yield.

```

      DIMENSION TF(15), P(15), QSUN(12), PP(1400), T(1400), HW(12),
      C PSUN(12), STA(8), PSUP(12), QMAX(12)
C FORMATS AND OUTPUT OF SYSTEM DATA
2 FORMAT (3X,4F5.1, 2F5.2, 15)
3 FORMAT (8A4)
4 FORMAT (1H1, 'INPUT DATA'//)
5 FORMAT(1X, 'AQUIFER: AK=', F7.1, ' AE=', F5.2, ' HWM=', F5.1/)
6 FORMAT (1X, 'WELL: DL=', F5.0, ' DO=', F5.0, ' WL=', F7.0, ' RW=',
CF5.1/)
7 FORMAT (1X, 'PUMP: PN=', F5.2/)
8 FORMAT (1X, 'W.TURBINE: WSCI=', F5.1, ' WSRT=', F5.1, ' WSCC=',
C F5.1, ' TN=', F5.2, ' AT=', F5.0, ' HT=', F4.0, ' KO=', I2/)
9 FORMAT (1X, 'STATION:', 8A4)
10 FORMAT (1X, 'WIND: C', 4X, 'EK', 3X, 'FFA', 3X, 'CN', 3X, 'PMIN', 2X, 'TMIN',
13X, 'MO'//)
36 FORMAT (1X, 'OUTPUT DATA'//)
11 FORMAT(7X, 'WIND POWER', 6X, 'MIN. WATER', 7X, 'PUMPED', 9X, 'MAX. RA
CTE', 2X, 'SUP. POWER')
12 FORMAT (4X, '(KW-HR)', 2X, '(KW-HR/M2)', 1X, 'HEIGHT(M)', 3X, '(M3)
C', 5X, '(M3/M2)', 4X, '(M3/S)', 6X, '(KW-HR)')
19 FORMAT (6F10.4, 110)
C AQUIFER DATA
1 READ (5,19) AK,AE,HWM
IF(AK.EQ.0) GO TO 100
C WELL DATA
READ (5,19) DL,DO,WL,RW
C PUMP DATA
READ (5,19) PN
C WIND TURBINE DATA
READ (5,19) WSCI, WSRT, WSCC, TN, AT, HT, KO
PRINT 4
PRINT 5, AK, AE, HWM
PRINT 6, DL, DO, WL, RW
PRINT 7, PN
PRINT 8, WSCI, WSRT, WSCC, TN, AT, HT, KO
TNN = TN
PNN = PN

```

```

C  WIND DATA
    M3 = 0
    TJ = 0.
    J2 = 0
    READ(5,3) (STA(I), I = 1,8)
    PRINT 9, (STA(I), I = 1,8)
    PRINT 10
13  READ (5,19)  C, EK, HTA, CN, PMIN, TMIN, MC
    IF (C.EQ.0.) GO TO 21
    PRINT 2,C,EK,HTA,CN,PMIN, TMIN, MC
    PMIN = PMIN*AT
    M3 = M3 + 1
    QSUM(M3) = 0
    QMAX(M3) = 0.
    HW(M3) = 0
    KK = 0
    PSUM(M3) = 0
    PSUP(M3) = 0
    M = 1
    V1 = WSCI
14  V2 = V1 + 1.0
    IF (V2 .GT. WSRT) V2 = WSCD
    IF (V2 .GE. WSCD) KK = 1
    V3 = V1*(HTA/HT) **.14
    V4 = V2*(HTA/HT) **.14
    TF( M ) = (EXP(-(V3/C)**EK) - EXP(-(V4 /C)**EK))/CN
    IF (KK.EQ.1) V2 = WSRT
    IF (TNN.LT. 1.) GO TO 40
C  WHEN TN NOT CONSTANT USE MODE 1 OR 2
    VW = (V1 + V2)/2.
    TN = -2.911 + .818*VW -.06615*VW**2 + .00165*VW**3
    IF (TNN.NE.2) GO TO 40
    IF (VW .LE. 9.5) TN = .3
40  P(M) = ((V1+V2)/2)**3.*0.6125*TN*AT/1000.
15  PSUM(M3) = PSUM(M3) + P(M)*TF( M ) *730.*CN
    IF (P(M) .GE. PMIN) GO TO 16
    PSUP(M3) = PSUP(M3) + (PMIN-P(M)) *TF( M ) *730.*CN
    P (M) = PMIN
16  IF (KK.EQ.1) GO TO 17
    V1 = V2
18  M = M + 1
    GO TO 14

```

```

17 TWND = EXP(-(WSC1*(HTA/HT)**.14/C)**EK) - EXP(-(WSC2*(HTA/HT)**.14/
CC)**EK)
TADD = TMIN - TWND
IF (TADD .LE. 0.) GO TO 20
TF(1) = TF(1) + TADD/CN
PSUP(M3) = PSUP(M3) + TADD*PMIN*730.
TWND = TMIN
C PREPARE T,PP ARRAYS
20 M1= M+1
P(M1) = 0
TF(M1) = (1-TWAD)/CN
N=CN
DO 31 J=1,N
DO 32 I= 1,M1
J1= I+(J-1)*M1 +J2
IF (J1 .GT. 1) TJ = T(J1-1)
T(J1) = TF(I)*30.42 +TJ
IF (PNM.LT. 1.) GO TO 42
C WHEN PN NOT CCNTANT USE MODE 3 OR 4
VW = WSCI + 0.5 + I-1.
PN = -1.361+ .4477*VW -.0238*VW**2
IF (PNM.NE. 4.) GO TO 42
IF (VW .LE. 9.5) PN = .72
IF (VW .GE. 11.) PN = .66
42 PP(J1) = P(I)*PN
32 CONTINUE
31 CONTINUE
J2= J1
GO TO 13
C CALCULATION OF Q AND HW
21 CALL HWQSP (DL,DO,WL, RW,AK,AE,T,PP,J2,M3,QSUM,HW,QMAX)
C CALCULATE TURBINE AREA FOR HWM (IF WANTED)
IF (K0 .NE. 1) GO TO 28
DO 22 I=1,M3
TPR = ABS (HWM - HW(I))
IF (TPR .GT. 1.) GO TO 23
22 CONTINUE
GO TO 26
23 R = (DO-HWM)/(DO-HW(I))
AT = AT+R

```

```

      DO 24 K=1,M3
      QSUM(K)= 0.
      QMAX(K) = 0.
      PSUP(K) = PSUP(K)*R
      HW(K) = DO
24  PSUM(K) = PSUM(K)*R
      DO 25 I = 1,J2
25  PP(I)= PP(I)*R
      GO TO 21
26  PRINT 8,WSOI,WSRT,WSOO,TN,AT,HT,KO
28  PRINT 36
      PRINT 11
      PRINT 12
27  FORMAT (1X,5F10.1, F10.3, F14.0)
      DO 30 K=1,M3
      QS = QSUM(K)
      PA = PSUM(K)/AT
      QSA = QS/AT
      PRINT 27, PSUM(K), PA, HW(K), QS, QSA, QMAX(K), PSUP(K)
30  CONTINUE
      GO TO 1
100 STOP
      END

```

C

```

SUBROUTINE HWQSR (DL, DO, WL, RN, K, AE, T, P, M, L, QSUM, HWM, QMAX)
DIMENSION T(M), P(M), QSUM(L), HWM(L), QMAX(L)
C2=2.*3.1416*AK/(24.*3600.)
C3=(1.5*DO/RN)**2*AK/(DO*AE)
TA=AK/(AE*DO)
TT1=0.
  N=0
  QS = 0.
  DO 30 I=1,M
  K=1
  Q=0.
  IF (P(I).EQ.0.0) GO TO 28
  IF (T(I) .LE. 30.42*N) GO TO 4
  N=N+1

```

```

4 SWR=0.
  IF (1.EQ.1) GO TO 9
6 TT = T(I) - TT1
  K=K+1
  GO TO 8
7 TT= T(I)
  K=K+1
8 Q=QBAR
  GO TO 10
9 TT=T(I)-TT1
  Q = P(I)/(((DL - DO) +.2*DO) *9.806)
10 TAU= (TA*TT)
  F=0.
  HW1=0.
11 IF (TAU .GT. 6.0) GO TO 12
  TM= -0.1+4.628*TAU - 4.014*TAU**1.05
  HW1 = DO - (Q/(C2*DO))*(TM + ALOG(DO/RW))
  HW = HW1
  IF (TAU .LE. 2.) GO TO 13
  F=(3.-TAU)/6.
12 HW2= SQRT(DO*DO - (Q/C2)*ALOG(C3*TT))
  HW =HW1*F+HW2*(1.-F)
13 GO TO (24,21,22,24),K
21 HWR1=HW
  GO TO 7
22 SWR=HWR1-HW
  K=K+1
  GO TO 9
24 HW = HW -SWR - WL *Q*Q
  PP = Q* (DL-HW) *9.806
  Q = Q*SQRT(P(I)/PP)
  TPR = ABS ((PP-P(I))/ P(I))
  IF (TPR .GT. .02) GO TO 11
  IF (HWM(N) .GT. HW) HWM(N)=HW
  IF (QMAX(N) .LT. Q) QMAX(N) = Q
  QSUM(N)=QSUM(N)+Q* TT*24.*3600.
28 QS=QS+Q*TT
  QBAR=QS/T(I)
  TT1=T(I)
30 CONTINUE
  RETURN
  END

```

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DO= 30. WL= 800. RW= 0.3

PUMP: PN= 0.72

W.TURBINE: WSCI= 6.0 WSRT= 15.0 WSCO= 15.0 TN= 1.00 AT= 250. HT= 20. KO= 2

STATION: GARDEN CITY KS

WIND: C EK HTA CN PMIN TMIN MO

6.5	2.1	10.0	10.0	0.26	0.00	1
7.1	2.0	10.0	10.0	0.26	0.00	2
8.0	2.0	10.0	10.0	0.26	0.00	3
8.2	2.2	10.0	10.0	0.26	0.00	4
7.8	2.0	10.0	10.0	0.26	0.00	5
8.5	2.2	10.0	10.0	0.26	0.00	6
7.3	2.5	10.0	10.0	0.26	1.00	7
7.3	2.7	10.0	10.0	0.26	1.00	8
7.6	2.6	10.0	10.0	0.26	0.00	9
7.1	2.6	10.0	10.0	0.26	0.00	10
6.2	1.8	10.0	10.0	0.26	0.00	11
6.3	2.2	10.0	10.0	0.26	0.00	12

OUTPUT DATA

WIND POWER	MIN. WATER	PUMPED	MAX. RATE	SUP. POWER
(KW-HR)	(KW-HR/M2)	HEIGHT(M)	(M3)	(M3/M2)
9512.4	38.0	11.6	105889.4	423.6
11503.4	46.0	11.3	114106.0	456.4
13589.4	54.4	10.9	123888.3	495.6
14636.6	58.5	10.6	130357.5	521.4
13346.5	53.4	10.4	121951.1	487.8
15403.9	61.6	10.2	133723.8	534.9
12508.0	50.0	8.3	207240.9	829.0
12389.2	51.6	7.8	205336.1	821.3
12358.8	55.4	8.6	132700.3	530.8
11305.1	47.2	8.6	123367.8	493.6
8644.4	34.6	8.7	90275.9	361.1
8711.7	34.8	8.9	98172.8	392.7

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DO= 30. WL= 800. RW= 0.3

PUMP: PN= 0.72

W.TURBINE: WSCI= 5.0 WSRT= 15.0 WSCD= 15.0 TN= 2.00 AT= 250. HT= 20. KO= 2

STATION: GARDEN CITY KS

WIND: C EK HTA CN PMIN TMIN MG

6.5	2.1	10.0	10.0	0.26	0.00	1
7.1	2.0	10.0	10.0	0.26	0.00	2
8.0	2.0	10.0	10.0	0.26	0.00	3
8.2	2.2	10.0	10.0	0.26	0.00	4
7.8	2.0	10.0	10.0	0.26	0.00	5
8.5	2.2	10.0	10.0	0.26	0.00	6
7.3	2.5	10.0	10.0	0.26	1.00	7
7.3	2.7	10.0	10.0	0.26	1.00	8
7.6	2.6	10.0	10.0	0.26	0.00	9
7.1	2.6	10.0	10.0	0.26	0.00	10
6.2	1.8	10.0	10.0	0.26	0.00	11
6.3	2.2	10.0	10.0	0.26	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	MIN. WATER (KW-HR/M2)	HEIGHT(M)	PUMPED (M3)	PUMPED (M3/M2)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
11614.4	46.5	10.0	130835.8	523.3	0.085	17267.
13445.8	53.8	10.3	135430.1	541.7	0.081	16828.
15403.7	61.6	9.9	142288.9	569.2	0.081	16639.
16465.7	65.9	9.5	148012.8	592.1	0.080	17081.
15195.5	60.8	9.3	140530.8	562.1	0.080	16795.
17205.4	68.8	9.1	150344.6	601.4	0.079	17142.
14738.0	59.2	7.8	205049.3	820.2	0.079	32662.
15284.1	61.1	7.3	203080.3	812.3	0.078	32166.
16122.8	64.5	7.5	153565.3	614.3	0.077	19865.
14218.5	56.9	7.5	146812.8	587.3	0.077	20227.
10551.0	42.2	7.5	111855.6	447.4	0.077	15645.
10924.2	43.7	7.7	122760.9	491.0	0.078	17760.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DC= 30. WL= 800. RW= 0.3

PUMP: PN= 3.00

W.TURBINE: WSCI= 6.0 WSRT= 11.0 WSCD= 15.0 TN= 0.30 AT= 250. HT= 20. KO= 2

STATION:GARDEN CITY KS

WIND: C EK HTA CN PMIN TMIN MO

6.5	2.1	10.0	10.0	0.00	0.00	1
7.1	2.0	10.0	10.0	0.00	0.00	2
8.0	2.0	10.0	10.0	0.00	0.00	3
8.2	2.2	10.0	10.0	0.00	0.00	4
7.8	2.0	10.0	10.0	0.00	0.00	5
8.5	2.2	10.0	10.0	0.00	0.00	6
7.3	2.5	10.0	10.0	0.00	0.00	7
7.3	2.7	10.0	10.0	0.00	0.00	8
7.6	2.6	10.0	10.0	0.00	0.00	9
7.1	2.6	10.0	10.0	0.00	0.00	10
6.2	1.8	10.0	10.0	0.00	0.00	11
6.3	2.2	10.0	10.0	0.00	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	MIN. WATER (KW-HR/M2)	HEIGHT(M)	PUMPED (M3)	PUMPED (M3/M2)	MAX. RATE (M3/S)	SUF. POWER (KW-HR)
11269.2	45.1	15.7	55892.2	223.6	0.074	0.
13420.2	53.7	15.3	65106.1	260.4	0.074	0.
15716.5	62.9	14.9	75044.2	300.2	0.073	0.
16960.3	67.4	14.7	80046.9	320.2	0.073	0.
15446.6	61.8	14.7	73378.7	293.5	0.073	0.
17699.6	70.8	14.5	83433.7	333.7	0.072	0.
14543.0	58.2	14.7	70379.8	281.5	0.072	0.
14966.2	59.9	14.6	72754.1	291.0	0.072	0.
15978.2	63.9	14.5	75936.2	307.7	0.072	0.
13822.1	55.3	14.6	67266.9	269.1	0.072	0.
10266.2	41.1	14.6	49421.1	197.7	0.072	0.
10438.1	41.8	14.8	50901.0	203.6	0.073	0.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DC= 30. WL= 800. RW= 0.3

PUMP: PN= 4.00

W.TURBINE: WSCI= 5.0 WSRT= 11.0 WSCO= 15.0 TN= 0.30 AT= 250. HT= 20. KO= 2

STATION: GARDEN CITY KS

WIND: C	EK	HTA	CN	PMIN	TMIN	MO
6.5	2.1	10.0	10.0	0.10	0.00	1
7.1	2.0	10.0	10.0	0.10	0.00	2
8.0	2.0	10.0	10.0	0.10	0.00	3
8.2	2.2	10.0	10.0	0.10	0.00	4
7.8	2.0	10.0	10.0	0.10	0.00	5
8.5	2.2	10.0	10.0	0.10	0.00	6
7.3	2.5	10.0	10.0	0.10	1.00	7
7.3	2.7	10.0	10.0	0.10	1.00	8
7.6	2.6	10.0	10.0	0.10	0.00	9
7.1	2.6	10.0	10.0	0.10	0.00	10
6.2	1.8	10.0	10.0	0.10	0.00	11
6.3	2.2	10.0	10.0	0.10	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	MIN. WATER (KW-HR/M2)	HEIGHT(M)	PUMPED (M3)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
11952.0	47.8	14.7	77662.4	0.075	3003.
14027.4	56.1	14.3	84554.0	0.075	2733.
16257.0	65.0	14.0	92600.9	0.074	2507.
17388.8	69.6	13.7	97405.9	0.074	2500.
18000.2	64.0	13.6	91135.6	0.074	2560.
18208.8	72.8	13.4	100221.5	0.073	2442.
15211.2	60.8	13.4	119068.8	0.073	3198.
15645.3	62.6	13.2	118717.5	0.073	7759.
16614.8	66.5	13.1	97174.6	0.073	3073.
14529.6	58.1	13.2	89377.2	0.073	3328.
10907.4	43.6	13.2	68143.8	0.073	2757.
11164.8	44.7	13.3	72488.2	0.073	3177.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DG= 30. WL= 800. RW= 0.3

PUMP: PN= 0.72

W.TURBINE: WSCI= 6.0 WSRT= 15.0 WSCD= 15.0 IN= 1.00 AT= 250. HT= 20. KO= 2

STATION: COLUMBUS, NB.

WIND: C EK HTA CN PMIN TMIN MO

5.5	1.5	10.0	10.0	0.26	0.00	1
5.5	1.4	10.0	10.0	0.26	0.00	2
6.7	1.5	10.0	10.0	0.26	0.00	3
7.0	1.7	10.0	10.0	0.26	0.00	4
6.5	1.7	10.0	10.0	0.26	0.00	5
5.6	1.6	10.0	10.0	0.26	0.00	6
4.7	1.6	10.0	10.0	0.26	1.00	7
4.5	1.4	10.0	10.0	0.26	1.00	8
4.6	1.4	10.0	10.0	0.26	0.00	9
5.4	1.4	10.0	10.0	0.26	0.00	10
5.0	1.4	10.0	10.0	0.26	0.00	11
5.0	1.5	10.0	10.0	0.26	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	MIN. WATER (KW-HR/M2)	HEIGHT (M)	PUMPED (M3)	PUMPED (M3/M2)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
7090.2	28.4	12.5	77923.3	311.7	0.086	9662.
7159.8	28.6	12.4	76908.6	307.6	0.084	9463.
9667.2	38.7	12.1	94859.3	379.4	0.084	10930.
10602.6	42.4	11.8	103389.8	413.6	0.083	11965.
9580.6	38.3	11.6	97932.6	391.7	0.083	11872.
7246.0	29.0	11.6	80564.9	322.3	0.083	10418.
4712.3	18.8	8.1	206957.0	827.8	0.083	42738.
4630.6	18.5	7.7	205288.9	821.2	0.082	42819.
4882.0	19.5	10.2	56848.1	227.4	0.081	7859.
6966.9	27.9	10.5	72635.1	290.5	0.081	9267.
5860.0	23.4	10.6	64689.5	253.8	0.081	8559.
5848.4	23.4	10.8	66166.0	264.7	0.082	8873.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DC= 30. WL= 800. RW= 0.3

PUMP: PN= 0.72

W.TURBINE: WSCI= 5.0 WSRT= 15.0 WSCD= 15.0 IN= 2.00 AT= 250. ET= 20. K0= 2

STATION: COLUMBUS, NB.

WIND: C EK HTA CN PMIN TMIN MO

5.5	1.5	10.0	10.0	0.26	0.00	1
5.5	1.4	10.0	10.0	0.26	0.00	2
6.7	1.5	10.0	10.0	0.26	0.00	3
7.0	1.7	10.0	10.0	0.26	0.00	4
6.5	1.7	10.0	10.0	0.26	0.00	5
5.6	1.6	10.0	10.0	0.26	0.00	6
4.7	1.6	10.0	10.0	0.26	1.00	7
4.5	1.4	10.0	10.0	0.26	1.00	8
4.6	1.4	10.0	10.0	0.26	0.00	9
5.4	1.4	10.0	10.0	0.26	0.00	10
5.0	1.4	10.0	10.0	0.26	0.00	11
5.0	1.5	10.0	10.0	0.26	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	MIN. WATER (KW-HR/M2)	HEIGHT(M)	PUMPED (M3)	PUMPED (M3/M2)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
8648.6	34.6	11.8	98741.2	395.0	0.086	12781.
8669.1	34.7	11.8	96723.1	386.9	0.083	12474.
11251.4	45.0	11.4	114008.3	456.0	0.083	13802.
12311.7	49.2	11.0	123302.3	493.2	0.082	14949.
11360.7	45.4	10.8	119118.8	476.5	0.082	15095.
8947.0	35.3	10.8	102210.9	408.8	0.081	13792.
6281.8	25.1	7.7	205077.3	824.3	0.081	41168.
6041.5	24.2	7.3	204213.3	816.9	0.080	41408.
6270.4	25.1	9.4	75588.3	302.4	0.080	10911.
8452.9	33.8	9.6	91367.1	365.5	0.080	12254.
7301.8	29.2	9.8	83585.1	334.3	0.080	11593.
7360.0	29.4	9.9	86052.3	344.2	0.080	12057.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DO= 30. WL= 800. RW= 0.3

PUMP: PN= 3.00

W.TURBINE: WSCI= 6.0 WSRT= 11.0 WSCO= 15.0 TN= 0.30 AT= 250. HT= 20. KO= 2

STATION: COLUMBUS, NB.

WIND: C EK HTA CN PMIN TMIN MO

5.5	1.5	10.0	10.0	0.00	0.00	1
5.5	1.4	10.0	10.0	0.00	0.00	2
6.7	1.5	10.0	10.0	0.00	0.00	3
7.0	1.7	10.0	10.0	0.00	0.00	4
6.5	1.7	10.0	10.0	0.00	0.00	5
5.6	1.6	10.0	10.0	0.00	0.00	6
4.7	1.6	10.0	10.0	0.00	0.00	7
4.5	1.4	10.0	10.0	0.00	0.00	8
4.6	1.4	10.0	10.0	0.00	0.00	9
5.4	1.4	10.0	10.0	0.00	0.00	10
5.0	1.4	10.0	10.0	0.00	0.00	11
5.0	1.5	10.0	10.0	0.00	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	MIN. WATER (KW-HR/M2)	HEIGHT (M)	PUMPED (M3)	(M3/M2)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
8452.6	33.8	16.0	41725.5	166.9	0.074	C.
8518.0	34.1	15.9	41783.1	167.1	0.074	0.
11345.4	45.4	15.6	54897.5	219.6	0.074	C.
12404.6	49.6	15.4	59897.0	239.6	0.074	0.
11274.4	45.1	15.4	54722.7	218.9	0.074	0.
8665.2	34.7	15.6	42427.6	169.7	0.074	C.
5828.5	23.3	15.8	28946.8	115.8	0.074	0.
5675.1	22.7	15.8	28064.6	112.3	0.074	C.
5944.5	23.8	15.8	29311.0	117.2	0.074	0.
8296.5	33.2	15.7	40420.4	161.7	0.074	0.
7048.2	28.2	15.8	34556.6	138.2	0.074	C.
7057.7	28.2	15.8	34710.7	138.8	0.074	0.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DO= 30. WL= 800. RW= 0.3

PUMP: PN= 4.00

W.TURBINE: WSCI= 5.0 WSRT= 11.0 WSCD= 15.0 TN= 0.30 AT= 250. HT= 20. KO= 2

STATION: COLUMBUS, NB.

WIND: C EK HTA CN PMIN TMIN MO

5.5	1.5	10.0	10.0	0.10	0.00	1
5.5	1.4	10.0	10.0	0.10	0.00	2
6.7	1.5	10.0	10.0	0.10	0.00	3
7.0	1.7	10.0	10.0	0.10	0.00	4
6.5	1.7	10.0	10.0	0.10	0.00	5
5.6	1.6	10.0	10.0	0.10	0.00	6
4.7	1.6	10.0	10.0	0.10	1.00	7
4.5	1.4	10.0	10.0	0.10	1.00	8
4.6	1.4	10.0	10.0	0.10	0.00	9
5.4	1.4	10.0	10.0	0.10	0.00	10
5.0	1.4	10.0	10.0	0.10	0.00	11
5.0	1.5	10.0	10.0	0.10	0.00	12

OUTPUT DATA

WIND POWER		MIN. WATER		PUMPED		MAX. RATE	SUP. POWER
(KW-HR)	(KW-HR/M2)	HEIGHT(M)	(M3)	(M3/M2)	(M3/S)	(KW-HR)	
9002.6	36.0	15.2	58756.0	235.0	0.076	2291.	
9049.6	36.2	15.1	58092.5	232.4	0.075	2217.	
11869.2	47.5	14.7	71491.2	286.0	0.075	2272.	
12956.4	51.8	14.5	77514.9	310.1	0.075	2431.	
11862.6	47.5	14.5	73163.2	292.7	0.075	2555.	
9262.1	37.0	14.6	60415.3	241.7	0.075	2497.	
6422.9	25.7	14.5	107090.1	428.4	0.075	13566.	
6210.6	24.8	14.3	106855.9	427.4	0.074	13838.	
6466.7	25.9	14.3	43989.6	176.0	0.074	2092.	
8822.5	35.3	14.3	55645.5	222.6	0.074	2187.	
7574.4	30.3	14.4	49636.1	198.5	0.074	2147.	
7609.8	30.4	14.4	50575.1	202.3	0.074	2252.	

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DG= 30. WL= 800. RW= 0.3

PUMP: PN= 0.72

W.TURBINE: WSCI= 6.0 WSRT= 15.0 WSCO= 15.0 TN= 1.00 AT= 250. HT= 20. KO= 2

STATION:AMARILLO,TEX

WIND: C EK HTA CN PMIN TMIN MG

6.5	2.2	10.0	10.0	0.26	0.00	1
7.1	2.2	10.0	10.0	0.26	0.00	2
7.7	2.2	10.0	10.0	0.26	0.00	3
7.6	2.3	10.0	10.0	0.26	0.00	4
7.3	2.3	10.0	10.0	0.26	0.00	5
7.0	2.5	10.0	10.0	0.26	0.00	6
6.1	2.4	10.0	10.0	0.26	1.00	7
5.7	2.4	10.0	10.0	0.26	1.00	8
6.3	2.4	10.0	10.0	0.26	0.00	9
6.4	2.3	10.0	10.0	0.26	0.00	10
6.5	2.1	10.0	10.0	0.26	0.00	11
6.5	2.1	10.0	10.0	0.26	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	POWER (KW-HR/M2)	MIN. WATER HEIGHT(M)	PUMPED (M3)	PUMPED (M3/M2)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
9716.5	38.9	11.5	109005.8	436.0	0.085	14076.
11576.1	46.3	11.1	118737.7	475.0	0.082	14619.
13508.8	54.0	10.7	127497.0	510.0	0.082	14818.
13453.8	53.8	10.4	128550.6	514.2	0.081	15268.
12492.6	50.0	10.3	123507.8	494.0	0.081	15199.
11426.1	45.7	10.1	122687.9	490.8	0.081	16155.
7635.3	30.5	7.6	204924.1	819.7	0.081	39815.
5717.9	22.9	7.2	202540.3	810.2	0.080	41732.
8429.4	33.7	8.7	102154.4	408.6	0.079	15052.
9011.4	36.0	8.9	102357.7	409.4	0.079	14457.
9475.7	37.9	9.1	101993.0	408.0	0.079	13852.
9505.8	38.0	9.2	102539.3	410.2	0.079	13912.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DO= 30. WL= 800. RW= 0.3

PUMP: PN= 0.72

W.TURBINE: WSCI= 5.0 WERT= 15.0 WSCD= 15.0 TN= 2.00 AT= 250. HT= 20. KO= 2

STATION:AMARILLO,TEX

WIND: C EK HTA CN PMIN TMIN MO

6.5	2.2	10.0	10.0	0.26	0.00	1
7.1	2.2	10.0	10.0	0.26	0.00	2
7.7	2.2	10.0	10.0	0.26	0.00	3
7.6	2.3	10.0	10.0	0.26	0.00	4
7.3	2.3	10.0	10.0	0.26	0.00	5
7.0	2.5	10.0	10.0	0.26	0.00	6
6.1	2.4	10.0	10.0	0.26	1.00	7
5.7	2.4	10.0	10.0	0.26	1.00	8
6.3	2.4	10.0	10.0	0.26	0.00	9
6.4	2.3	10.0	10.0	0.26	0.00	10
6.5	2.1	10.0	10.0	0.26	0.00	11
6.5	2.1	10.0	10.0	0.26	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	WIND POWER (KW-HR/M2)	MIN. WATER HEIGHT(M)	MIN. WATER (M3)	PUMPED (M3/M2)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
11891.6	47.6	10.0	134399.3	537.6	0.085	17839.
13689.9	54.8	10.1	141433.8	565.7	0.081	18033.
15500.0	62.0	9.6	147355.7	589.4	0.080	17823.
15524.9	62.1	9.3	148882.6	595.5	0.080	18358.
14629.3	58.5	9.1	144928.8	579.7	0.079	18497.
13799.8	55.2	8.9	146542.8	586.2	0.079	19809.
10062.6	40.3	7.4	203595.3	814.4	0.079	37387.
8165.3	32.7	6.5	200590.5	802.4	0.078	39285.
10883.8	43.5	7.5	123902.5	515.6	0.077	19334.
11313.1	45.3	7.6	127324.1	509.3	0.078	18477.
11632.4	46.5	7.8	125309.7	501.2	0.078	17631.
11670.4	46.7	7.9	125904.6	503.6	0.078	17696.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DO= 30. WL= 800. RW= 0.3

PUMP: PN= 3.00

W.TURBINE: WSCI= 6.0 WSRT= 11.0 WSCD= 15.0 TN= 0.30 AT= 250. HT= 20. KO= 2

STATION:AMARILLO,TEX

WIND: C EK HTA CN PMIN TMIN MO

6.5	2.2	10.0	10.0	0.00	0.00	1
7.1	2.2	10.0	10.0	0.00	0.00	2
7.7	2.2	10.0	10.0	0.00	0.00	3
7.6	2.3	10.0	10.0	0.00	0.00	4
7.3	2.3	10.0	10.0	0.00	0.00	5
7.0	2.5	10.0	10.0	0.00	0.00	6
6.1	2.4	10.0	10.0	0.00	0.00	7
5.7	2.4	10.0	10.0	0.00	0.00	8
6.3	2.4	10.0	10.0	0.00	0.00	9
6.4	2.3	10.0	10.0	0.00	0.00	10
6.5	2.1	10.0	10.0	0.00	0.00	11
6.5	2.1	10.0	10.0	0.00	0.00	12

OUTPUT DATA

WIND POWER	MIN. WATER	PUMPED	MAX. RATE	SUP. POWER		
(KW-HR)	(KW-HR/M2)	HEIGHT(M)	(M3)	(M3/M2)	(M3/S)	(KW-HR)
11512.0	46.0	15.7	57199.5	228.8	0.074	0.
13516.9	54.1	15.3	66029.2	264.1	0.074	0.
15613.1	62.5	15.0	75122.5	300.5	0.073	0.
15549.2	62.2	14.9	74812.8	299.3	0.073	0.
14512.1	58.0	14.8	70031.0	280.1	0.073	0.
13407.7	53.6	14.9	65551.8	262.2	0.073	0.
9384.4	37.5	15.1	46606.2	186.4	0.073	0.
7361.9	29.4	15.3	36940.1	147.8	0.073	0.
10243.7	41.0	15.2	50882.6	203.5	0.073	0.
10795.9	43.2	15.2	53162.0	212.6	0.073	0.
11245.4	45.0	15.1	54930.3	219.7	0.073	0.
11280.5	45.1	15.1	55086.2	220.3	0.073	0.

INPUT DATA

AQUIFER: AK= 20.0 AE= 0.20 HWM= 12.0

WELL: DL= 70. DO= 30. WL= 300. RW= 0.3

PUMP: PN= 4.00

W.TURBINE: WSCI= 5.0 WSRT= 11.0 WSCD= 15.0 TN= 0.30 AT= 250. HT= 20. KO= 2

STATION: AMARILLO, TEX

WIND: C	EK	HTA	CN	PMIN	TMIN	MO
6.5	2.2	10.0	10.0	0.10	0.00	1
7.1	2.2	10.0	10.0	0.10	0.00	2
7.7	2.2	10.0	10.0	0.10	0.00	3
7.6	2.3	10.0	10.0	0.10	0.00	4
7.3	2.3	10.0	10.0	0.10	0.00	5
7.0	2.5	10.0	10.0	0.10	0.00	6
6.1	2.4	10.0	10.0	0.10	1.00	7
5.7	2.4	10.0	10.0	0.10	1.00	8
6.3	2.4	10.0	10.0	0.10	0.00	9
6.4	2.3	10.0	10.0	0.10	0.00	10
6.5	2.1	10.0	10.0	0.10	0.00	11
6.5	2.1	10.0	10.0	0.10	0.00	12

OUTPUT DATA

WIND POWER (KW-HR)	MIN. WATER (KW-HR/M2)	HEIGHT (M)	PUMPED (M3)	MAX. RATE (M3/S)	SUP. POWER (KW-HR)
12210.3	48.8	14.7	79568.9	0.075	3096.
14167.0	56.7	14.3	86919.9	0.075	2960.
16200.5	64.8	13.9	94135.7	0.074	2744.
16156.1	64.6	13.8	94467.9	0.074	2649.
15151.0	60.6	13.7	90425.9	0.074	2962.
14116.5	56.5	13.7	88135.6	0.074	3294.
10188.8	40.8	13.7	109387.6	0.074	10627.
8222.4	32.9	13.7	105489.0	0.074	11636.
11035.8	44.1	13.6	74575.4	0.073	3506.
11539.2	46.2	13.5	75342.5	0.073	3286.
11943.3	47.8	13.5	78713.5	0.073	3073.
11579.9	47.9	13.5	75185.1	0.073	3088.

C-24