NEBRASKA WIND ENERGY SITE DATA STUDY

FINAL REPORT

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GEC also thanks Nebraska State Senators Chris Beutler and Don Preister for their support for this program and the wind energy industry.

INTRODUCTION

In March of 1994, the Nebraska Legislature's Natural Resources Committee, the Nebraska Power Association (NPA), and the Nebraska Energy Office (NEO) reached an agreement to complete a statewide wind energy resource assessment in the State of Nebraska. The projected $300,000 study would be funded with contributions by the NPA in the amount of $200,000 and the NEO would pursue funding sources of $100,000.

The purpose of this study was to identify and quantify the wind resource at locations within the State of Nebraska with potential for wind energy development. The results of the study include a high-quality database that characterizes the wind energy resource at eight sites throughout the state.

This study was conducted under the authority of the NPA Joint Planning Subcommittee, through the use of the Nebraska Wind Energy Site Task Force (Task Force). The NPA is a voluntary organization representing the electric utility industry in the State of Nebraska. The Task Force issued a Request for Proposals in June 1994. Global Energy Concepts (GEC), formerly RLA Consulting, was awarded this work through a competitive bid process and signed a contract with the NPA in September 1994. GEC is an engineering consulting firm that specializes in wind energy applications.

The NEO obtained funding for this project from two sources. This resulted in additions to the original scope of work and amendments to the contract between the NPA and GEC. The first source was the Utility Wind Interest Group (UWIG) which contributed $59,600 as part of the Utility Wind Resource Assessment Program (U*WRAP). The second source was the National Renewable Energy Laboratory (NREL) with a contribution of $74,428 for the Sustainable Technology Energy Partnerships Pilot Program (STEP). The NPA obtained an American Public Power Association (APPA) Demonstration of Energy-Efficient Developments (DEED) grant in the amount of $10,000 that required no changes to the scope of the project. Budget details are provided in Appendix A.

GEC also obtained additional funding in the amount of $7,500 through a separate contract with NREL. This funding was provided for the installation and testing of lightning mitigation measures for wind measurement equipment. GEC installed lightning protection equipment on four of the eight monitoring stations in this study and tracked equipment failures related to lightning and electrostatic discharge. A report on the results was submitted to NREL in January 1998 and is provided in Appendix B.

GEC's site selection work focused on 16 regions of Nebraska that had been pre-selected by the Task Force. The Task Force chose these regions based on considerations such as transmission corridors and line loading, as well as work that had been conducted by the Union of Concerned Scientists to identify broad-based wind resources.[1] The site selection work began in the Fall of 1994 and the proposed monitoring sites were approved by the Task Force shortly thereafter. Data collection began in April 1995 and continued through March 1999, resulting in four consecutive years of wind resource data.

This report is organized into four sections. The remainder of this section provides an overview of the project and site descriptions. The second section contains background information on the project including the site selection methodology, equipment specifications, data collection and processing procedures, and data archiving and reporting activities. The results of the four-year study are provided in the third section. This section includes data recovery rates, an overview of the wind speed and direction data, information on wind shear and turbulence intensity, energy production estimates, and solar insolation values. The conclusions are contained in the final section. In addition to this report,

[1] Union of Concerned Scientists, *Powering the Midwest: Renewable Electricity for the Economy and the Environment*, Cambridge, MA, 1993.

GEC has submitted 16 quarterly and four annual reports describing the wind resource data over the four-year data collection period.

PROJECT OVERVIEW

The initial phase of this study included locating potentially promising areas for wind energy development, narrowing the list to eight sites for wind monitoring, negotiating land lease agreements, and procuring and installing monitoring equipment at the eight sites. Once the equipment was installed, GEC collected wind resource data, processed the data, summarized the results, produced quarterly and annual reports, and maintained the monitoring equipment for a period of four years. In addition, GEC completed Site Commissioning Forms that detail the equipment installations and configurations, and submitted complete data sets and reports on a quarterly basis for 2 years for U*WRAP and collected an additional five parameters at two of the monitoring sites for the STEP program.

GEC developed a project team to conduct this work that included NRG Systems, Zond, University of Nebraska High Plains Climate Center (HPCC), and local personnel. NRG provided all equipment for the monitoring stations and Zond installed the stations and conducted equipment maintenance. The HPCC collected and quality-checked the data daily. GEC also utilized local personnel for troubleshooting and minor maintenance work. The local personnel included landowners and their families and other people as recommended by the landowners.

SITE DESCRIPTIONS

Figure 1 shows the location of the final eight monitoring stations. Site Evaluation Reports, which include additional details on each site, are provided in Appendix C. Brief descriptions of each site's unique characteristics are provided below.

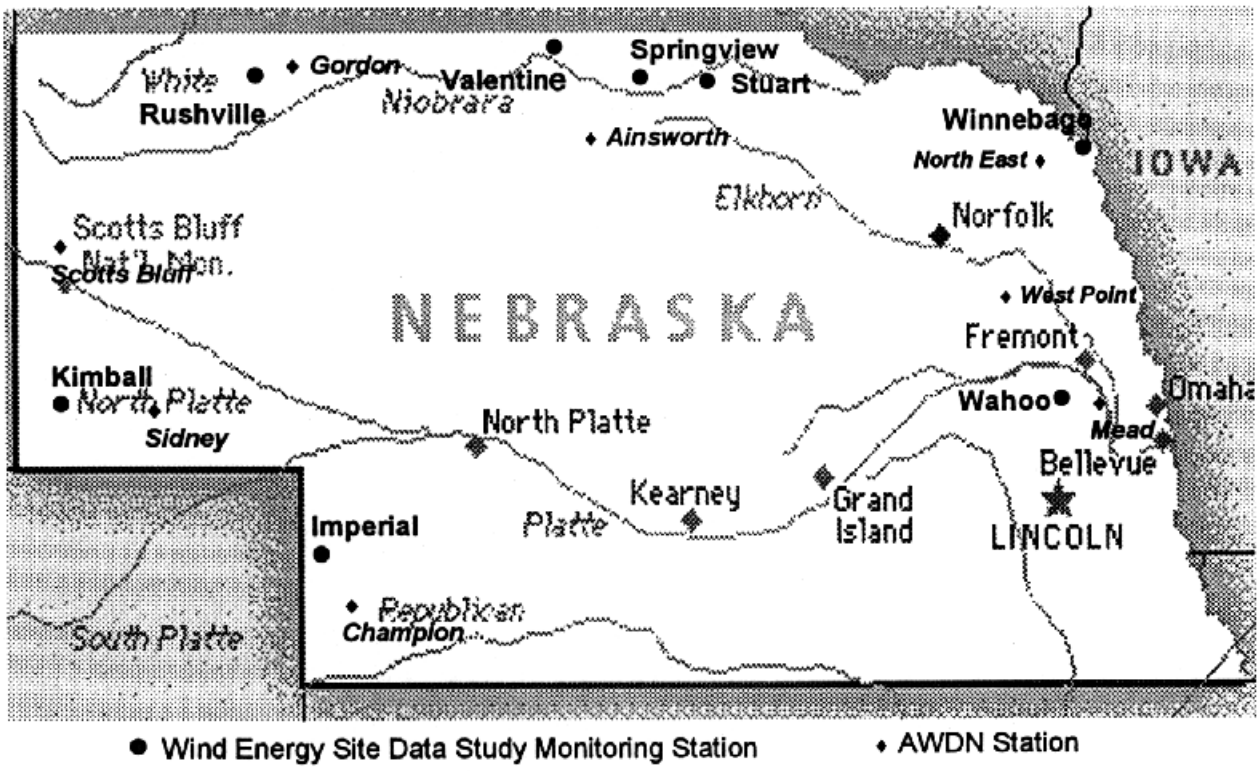

Figure 1. Locations of Wind Resource Monitoring Stations

Site 101-Imperial: This station is located in Chase County in a well exposed location in the sand hills of southwestern Nebraska within a few miles of the Colorado border. The site is in complex, hilly terrain.

Site 102-Rushville: This station is located in Sheridan County on an east-west ridgeline two miles northwest of the town of Hay Springs. The surrounding area consists of diverse terrain and ground cover including areas that are forested and complex.

Site 103-Winnebago: This station is located in Thurston County on a well exposed ridgeline midway between the towns of Winnebago and Macy, three miles west of the Missouri River. The site is in elevated, hilly terrain that separates the river valley from Nebraska's eastern plains.

Site 104-Wahoo: This station is located in a well-exposed location approximately 30 miles north of Lincoln. The site is in the rolling hills of west central Saunders County.

Site 105-Kimball: This station is located in Kimball County south of Kimball in the southern part of the Nebraska panhandle. The site is on flat to gently rolling terrain which gains elevation toward the western state border with Wyoming.

Site 106-Valentine: This station is located in Cherry County in the high plains north of Valentine within five miles of the Nebraska-South Dakota border. The plains run for miles along the state border and are significantly higher in elevation than areas to the south where the town of Valentine is located.

Site 107-Springview: This station is located in Keya Paha County on a gentle east-west ridge approximately one mile west of the town of Springview. Similar terrain runs for miles east and west of Springview and is bordered by lower terrain to the north and south.

Site 108-Stuart: This monitoring station is located in northern Holt County approximately six miles north of the town of Stuart. The site is in a well-exposed location in the broad plains that are characteristically divided by tree shelterbelts along property boundaries.

PROJECT BACKGROUND

SITE SELECTION METHODOLOGY

Eight monitoring sites were selected for wind resource data collection. The selection of these sites was the result of a screening process based on estimates of the wind resource, distance to transmission lines, sufficient land area for utility-scale project development, and exposure of local terrain features to the prevailing wind directions. More than thirty specific areas were identified, visited, and evaluated. The sites were surveyed and local residents were interviewed. Sites were ranked for consideration based on landowner interest, suitability for development, environmental and public acceptance issues, and site access. An effort was made to avoid the selection of relatively equivalent sites in adjacent resource areas and to assemble a set of recommended monitoring locations that would provide the most useful information to the Task Force.

As part of the site selection process, GEC identified and reviewed existing wind data in Nebraska. Three existing data sets were significant in the site selection process. The first data set was from the Automated Weather Data Network (AWDN) stations maintained by the High Plains Climate Center (HPCC) at the University of Nebraska in Lincoln. These stations are primarily utilized for agricultural purposes and wind data from these stations are collected at approximately 3 meters (10 feet) above ground level, just slightly higher than most crops. The influence of crop height on the wind speed data and the difference in the measurement height versus the hub-height of utility scale wind turbines

resulted in this data being of limited value for wind energy resource assessment purposes. However, this data did prove useful for site-to-site comparisons and for replacing missing or erroneous data for this study. The locations of the AWDN stations closest to the final eight monitoring stations are provided in Figure 1.

The second data set reviewed was from a jointly funded project between the National Renewable Energy Laboratory (NREL) and the Nebraska Public Power District (NPPD) to characterize turbulence at a site in Ainsworth. This monitoring station had a similar equipment configuration to that used in this study, with wind speed and direction data collected at multiple heights. The site is well exposed in all directions and provides a good representation of the wind characteristics in the surrounding vicinity. The Ainsworth site is also shown on Figure 1.

The third data set identified was collected near Scottsbluff by a private landowner, Mr. Stephen Joyner. Mr. Joyner was operating two 24.4-meter (80-foot) wind monitoring stations on his property located on a high table in the bluffs north of Scottsbluff. He collected data for several years and was pursuing wind farm development on his property. However, he was not interested in releasing his wind resource data under the terms and conditions of the Nebraska Wind Energy Site Data Study. The presence of a landowner collecting wind resource data and actively pursuing wind energy project development is a positive sign for the potential of wind energy development in the area. Although the data were not available for this study, collecting additional data in the immediate vicinity was determined to be of limited value for encouraging wind power development.

After reviewing the existing wind data and considering the other site selection criteria, GEC identified the twelve most promising sites and presented detailed Site Evaluation Reports for these sites to the Task Force. GEC and the Task Force mutually agreed upon the final eight sites by considering geographical diversity within the state. Additionally, two site locations were chosen because of their close proximity to major utility load centers in eastern Nebraska as a requirement for this study.

EQUIPMENT INSTALLATION AND SPECIFICATIONS

Extensive documentation of the installation work was completed for each site. This documentation included a Site Information Logsheet, Equipment Configuration Form, U*WRAP Site Commissioning Form, and photographs of the site and equipment. The Site Information Logsheet was used to maintain information on the anemometer serial numbers, data logger programming parameters, contact information, and a map with directions to the site. GEC developed the Equipment Configuration Form to provide site-specific instructions such as the desired sensor orientation and any special marking or fencing requirements. The U*WRAP Site Commissioning Form was completed to meet the requirements of the U*WRAP program. This form was used to document the installation, proper functioning, and acceptance of the monitoring equipment, and to provide information in a consistent format as the other participants in the program.

All equipment used in this study was purchased from NRG Systems, in Hinesburg, Vermont. NRG specializes in the manufacturing of wind energy resource monitoring equipment. The monitoring stations were installed according to the procedures provided by NRG. The equipment specifications for each monitoring station are as follows:

- *Tower:* New 40-meter tilt-up NRG TallTower™ and grounding system installed at all stations with the exception of Sites 101, 105, and 108, which utilized existing lattice towers.

- *Data Logger*: NRG Systems CELLogger™ or TelePort™ Logger with cellular or land line telephone communications, respectively, for collecting and downloading data. Each data logger is equipped with a 12-volt battery, two 9-volt backup batteries, 5 watt photovoltaic panel for battery charging, removable 256 kbyte data storage card, and steel shelter box.

- *Anemometers*: Calibrated wind speed sensors (anemometers) were located at 10-, 25-, and 40-meters above ground level. A redundant sensor was located at the 40-meter level to ensure a high data recovery rate. An additional sensor at the 50-meter level was installed at Sites 101, 105, and 108 to take advantage of the extra height of the existing lattice towers. The anemometers were calibrated by OTECH Engineering prior to installation. OTECH uses an open atmosphere calibration test and provides a summary report of the test results.

- *Wind Direction Vanes*: Direction vanes were located at 25 and 40 meters above ground level.

- *Temperature Sensors*: Temperature sensors were located at 10 and 40 meters above ground level.

- *Pyranometer*: Radiation sensors were located approximately 5 meters above ground level.

Additional equipment was added to some of the stations during the course of the study for the STEP program and the Lightning Mitigation Measures study. The equipment additions are as follows:

- *Wind Direction Vanes:* Sites 101 and 103 were equipped with wind direction vanes at 10 meters in July 1997 as part of the STEP program. The data collected from these sensors were not included in the data reports for this study; this data was delivered to NREL directly by the HPCC.

- *Lightning Protection*: Sites 102, 103, 106, and 107 were equipped with static dissipating air terminals, grounded anemometers, additional ground rods, and surge suppressors. Details on this equipment are provided in the Lightning Mitigation Measures Final Report in Appendix A.

Table 1 provides a summary of the installation heights for the equipment previously described.

Table 1. Equipment Installation Heights (meters)

Site	Wind Speed Sensor	Wind Direction Sensor	Temperature Sensor
101 – Imperial	10, 25, 40, 50	10*, 25, 40	10, 40
102 – Rushville	10, 25, 40	25, 40	10, 40
103 – Winnebago	10, 25, 40	10*, 25, 40	10, 40
104 – Wahoo	10, 25, 40	25, 40	10, 40
105 – Kimball	10, 25, 40, 50	25, 40	10, 40
106 – Valentine	10, 25, 40	25, 40	10, 40
107 – Springview	10, 25, 40	25, 40	10, 40
108 – Stuart	10, 25, 40, 50	25, 40	10, 40

* data collected for STEP only and not processed for this study

DATA COLLECTION AND PROCESSING

Data were downloaded daily from each site by the HPCC, a subcontractor to GEC. The HPCC was responsible for weekly data collection and quality-checks, notifying GEC of any equipment malfunctions, delivering all data to GEC monthly, and archiving the raw and corrected data sets and data reports produced by GEC.

All data points were collected as hourly averages. In July 1997, this program began collecting 10-minute averaged data from Sites 101 and 103 for the STEP program. Only hourly averaged data

were processed and analyzed for this report. The 10-minute averaged raw data were delivered to NREL by the HPCC.

Data collection parameters include:

- hourly average and hourly standard deviation,
- minimum and maximum one-second sample average and standard deviation,
- time and date of occurrence of minimum and maximum one-second samples, and
- average turbulence intensity.

Data Quality Control

An initial screening of the data was used to identify equipment problems in a timely manner. GEC provided the HPCC with quality-check parameters for verifying that the data were accurate. Data that did not pass the screening criteria were noted and evaluated with regard to whether or not they represented a system problem. The HPCC was responsible for conducting the quality-check on all data within the same day that it was received and notifying GEC of any potential equipment problems.

The data quality-check parameters included two types of procedures: (1) general system checks and (2) measured parameter checks. Initially the data were checked to verify that the correct number of sequential records was retrieved for the specified period of record and that the data time stamps were all sequential. These tests helped to verify that the system was functioning properly and that data were being recorded from all sensors.

The data were also screened according to range, relational, and trend tests. Range tests verify that each hourly value from a sensor falls within the upper and lower limits set by the criteria values. Relational tests verify that the relationship between the sensor value and another related value is within the limits set by the range criteria (for example, the difference between the hourly average wind speeds at 40 meters and 25 meters may range between -5 and +10 mph). Trend tests verify that the rate of change of a measured value falls within the criteria range over the most recent time period.

Documenting and Responding to Equipment Problems

Equipment problems that were identified through the data quality-control process were documented in either an Advisory Report or a Condition Report. Advisory Reports were used to identify problems with the data that were not a result of a permanent equipment malfunction. The most common example of the use of this report is for an icing event. If a sensor collects enough ice it will freeze in place and record zero average values. While this type of event results in invalid data it does not require a site visit or maintenance work.

Condition Reports were generated by the HPCC when events occurred that could potentially have affected the data quality of the program and required action (i.e., failure of a site to call in, evidence of a failed sensor, a fallen tower). A Condition Report facilitates the resolution of events that could affect the data quality and provides a comprehensive record of each event in four sections: Condition, Verification, Action Request, and Resolution.

These two reports were maintained in the Monitoring Site LogBook along with other information on each site including the Site Information Logsheet, Equipment Configuration Form, and Site Visit Checklist. Two copies of the LogBook were maintained, one by GEC and the other by the HPCC. Both parties exchanged information regularly to ensure that all records were current.

The Site Visit Checklist was completed each time a site visit was conducted. The purpose of the checklist is to ensure that all required tasks have been completed and the necessary information has been appropriately documented.

Unscheduled maintenance visits were also periodically required at the sites. The purpose of these visits was to verify proper equipment operation and make sure the installation was secure or to repair or replace equipment as needed. A Site Visit Checklist was completed for all unscheduled visits.

Data Validation and Replacement

All data were reviewed by GEC on a quarterly basis to identify erroneous or invalid data points. Data were considered erroneous if they did not appear to be representative of the actual wind conditions. Typical causes of erroneous data include icing, lightning, equipment malfunction, and maintenance activities. Data determined to be invalid were documented on a Site Data Validation Logsheet. The Logsheets include of a list of the invalid data periods for each sensor, an explanation of missing or erroneous data, and the source of any replacement values used.

All invalid wind speed data were replaced. Several methods of data replacement were used in order to complete the wind speed data sets. When only a few hours of data were missing the data were replaced with the average of the hours before and after the missing data. Replacement methods for periods of missing data greater than a few hours are discussed below.

The first preference in data replacement is to establish a correlation to a functioning sensor on the same tower. A correlation was developed using a linear regression analysis from a period of time when both sensors were functioning. The missing data were then filled in based on the wind speeds recorded at the functioning sensor during the same period of time.

When all anemometers at a site were missing data for the same period of time, a correlation to anemometers at another site within this study was established. The correlation was developed and applied in the same manner as described previously with the reference data from a different site. A good correlation could not be established for some of the sites due to the large distances between sites. In this case, a correlation to a reference station outside this program was used. Data from some of the AWDN stations provided successful correlations in replacing missing data.

In the event a good correlation to a nearby reference station could not be established, the missing data were replaced with the average diurnal value of good data in the same month. All missing and removed data and the replacement methods used are identified in data validation tables provided in the four quarterly reports.

DATA ARCHIVING AND REPORTING

The raw data were received and archived by the HPCC daily. GEC obtained the raw data from the HPCC monthly. Data were processed by GEC quarterly to create a corrected data set and data report. The raw and corrected data were archived by both GEC and the HPCC quarterly. GEC maintained two electronic copies of the raw and corrected data, one on floppy disk and the other on CD-ROM. The HPCC also archived hard copies of all quarterly and annual reports produced by GEC.

Data processing and reporting were performed on a quarterly basis using NRG's MicroSite software program as well as spreadsheet and database programs developed by GEC specifically for wind resource data processing. A summary of the data tables and graphs that are included in the quarterly and annual reports is provided below. Copies of these reports are available from the HPCC.[2]

Quarterly Report Tables and Graphs:

- Quarterly average wind speed table
- Quarterly average wind shear exponent and turbulence intensity table
- Quarterly 40-meter wind speed data recovery rate table

[2] The HPCC is located at the University of Nebraska in Lincoln, Nebraska. They can be reached by phone at 402/472-6706 or through their web site at http://hpccsun.unl.edu.

- Quarterly equipment maintenance summary table
- Monthly wind speed tables and graphs
- Diurnal wind speed tables and graphs
- Monthly frequency distribution tables
- Monthly joint frequency distribution of wind speed and direction tables
- Monthly wind rose graphs (wind direction) with turbulence intensity by direction
- Monthly average turbulence intensity by direction (on wind rose graph)
- Monthly temperature tables
- Monthly hourly solar radiation (insolation) tables
- Data validation logsheet

Annual Report Tables and Graphs

- Seasonal wind speed graphs
- Diurnal wind speed graphs
- Monthly wind speed summaries
- Monthly frequency distribution graphs
- Annual wind rose graphs (wind direction) with turbulence intensity by direction
- Annual solar radiation (insolation) tables
- Annual wind shear tables
- Annual energy production estimate tables

RESULTS

The hourly averaged data for this study were validated and all wind speed data were replaced. The following data summary is based on the corrected data sets for the period of April 1995 through March 1999.

DATA RECOVERY

This program has achieved high data recovery at all eight stations during the four-year data collection period. All data are of a quality and accuracy that is consistent with measurements made throughout the wind energy industry to identify and characterize potential sites for wind energy development. The wind speed data recovery rate at the 40-meter level for all eight monitoring stations was 95.4% during the four-year monitoring period. The recovery rate is based on the percentage of data remaining after erroneous data were removed in the validation process. Table 2 provides the recovery rates for each year and provides the causes of invalid data as a percent of the total invalid data.

Table 2. Recovery Rates for 40-Meter Wind Speed Data

Time Period	Overall Data Recovery	Causes of Invalid Data				
		Ice Events	Lightning / Static Discharge	Equipment Malfunction	Equipment Maintenance	Unknown
1995-1996	96.9%	59.0%	20.0%	18.0%	1.0%	2.0%
1996-1997	95.1%	59.0%	36.7%	4.2%	0.0%	0.1%
1997-1998	94.7%	77.0%	1.5%	20.0%	0.5%	1.1%
1998-1999	94.8%	14.4%	0.0%	75.7%	0.0%	2.0%

Figure 2 shows the causes of invalid data over the four-year monitoring period as a percent of the total invalid data. Icing events were the greatest cause of invalid data accounting for more than 50%. Ice build-up can cause the sensors to slow down and often stop completely, which results in erroneous data

readings. There was a dramatic decrease in the number of data hours lost due to icing during the last year of this study. This is most likely a result of an increased average temperature between April 1998 and March 1999 of approximately 1.5°C (3°F) over the average of the previous three years.

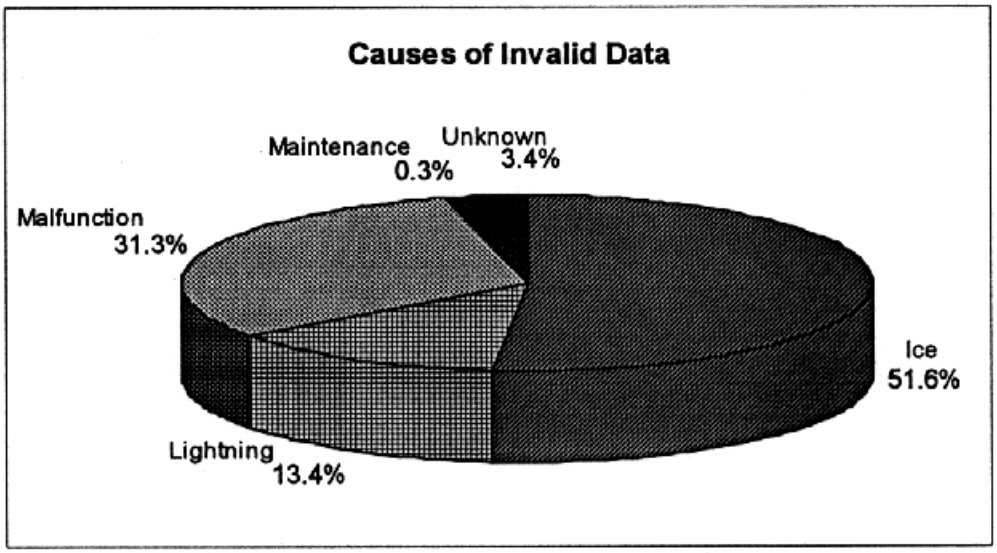

Figure 2. Causes of Invalid Data

The second largest cause of invalid data was due to equipment malfunctions (31%). Causes of equipment malfunctions included vandalism, damage from excessive ice build-up or falling ice, extreme weather conditions such as hail, and fatigue. A unique event that contributed greatly to this category occurred during the third year of this study. The monitoring tower at the Wahoo site collapsed when the landowner accidentally clipped one of the guy wires at the ground level with his farm equipment. All the equipment required replacement with the exception of the data logger, which continued to call and download data after the tower collapse.

The significant increase in the percent of equipment malfunctions during the fourth year does not represent an increase in the number or frequency of failed components. Rather, this increase is attributed to difficulties with the data quality control system. The collection of 10-minute data from one of the sites included in the STEP program hindered the HPCC's quality control program such that particular sensor outages could not be detected. Therefore, the HPCC was not able to provide a Condition Report to GEC. This problem was discovered by GEC when the third quarter 1998 data analysis was conducted, by which time a significant amount of data had already been lost. An additional equipment failure during the last quarter of the program was not reported by the HPCC.

Equipment malfunctions due to lightning and electrostatic discharge were considered a separate category for use in the Lightning Mitigation Measures Study performed by GEC. Lightning and the build-up of electrostatic discharge in the equipment damaged loggers and wind measurement sensors resulting in 13% of the invalid data. None of the monitoring stations in this study received a direct lightning strike; however, lightning activity in the area did cause data logger failures.

Approximately 3% of the invalid data causes are unknown. Typically this was a data file that was received but corrupt or a data logger failure that could not be explained. Less than 1% of the invalid data was due to equipment maintenance.

WIND SPEED

Over the four-year study period, the annual average wind speeds at the 40-meter level ranged from 13.9 – 16.8 mph (6.2 – 7.5 m/s) at the eight monitoring sites. Based on wind power density, the sites are rated as Class 3, 4 and 5 wind sites.[3] Class 3 is generally considered to be the minimum rating at which wind power development is technically viable. All of the sites performed within the Wind Class rating predicted by the Union of Concerned Scientists with the exception of Rushville which was lower than predicted.

The highest annual wind speeds were recorded at Imperial and Valentine with an average of 16.3 mph (7.3 m/s) at the 40-meter level. The lowest annual wind speeds were recorded at Rushville and Wahoo with averages of 14.5 mph (6.5 m/s) and 14.3 mph (6.4 m/s), respectively. Lower winds were anticipated at Wahoo because one of the criteria in choosing this site was its proximity to a utility load center, not only its potential for energy producing winds. Figure 3 provides the four-year average wind speeds at the 40-meter level for each site. Figure 4 provides the annual average wind speed at each site for each of the four years as measured at 40-meters.

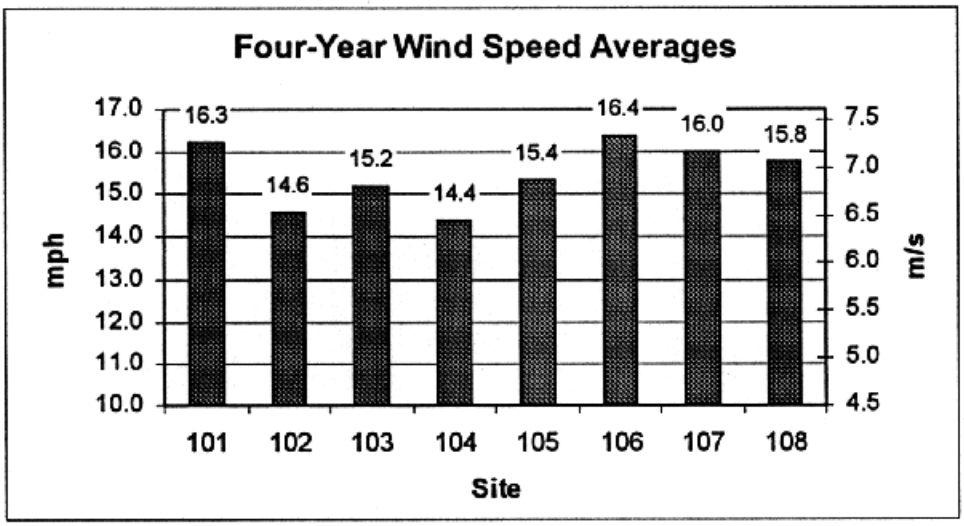

Figure 3. Four-Year Average Wind Speeds at 40 Meters

Seasonal Patterns

The seasonal wind speed pattern for each site is provided in Figure 5. The pattern illustrated in this graph represents the four years of data collected at each site. This figure shows that the seasonal patterns are similar across the state. The winds are highest during the fall and winter, decrease during the spring, and are lowest in the summer months of July and August.

Figure 6 shows the monthly wind speed average and standard deviation over four years for each site as measured at the 40-meter level. The solid line in the middle represents the wind speed average and the gray lines on the top and bottom show the standard deviation from the average. The standard deviation is calculated from hourly averaged data. The standard deviation describes the variability in the wind

[3] Based on wind power density range of 289-450 W/m^2 according to the rating scale presented in the *Wind Energy Resource Atlas of the United States*, prepared by Pacific Northwest Laboratory for the US Department of Energy (reprinted April 1991).

speed. Figure 6 illustrates that all eight monitoring sites have a similar range of standard deviation and that the standard deviation is lower at lower wind speeds.

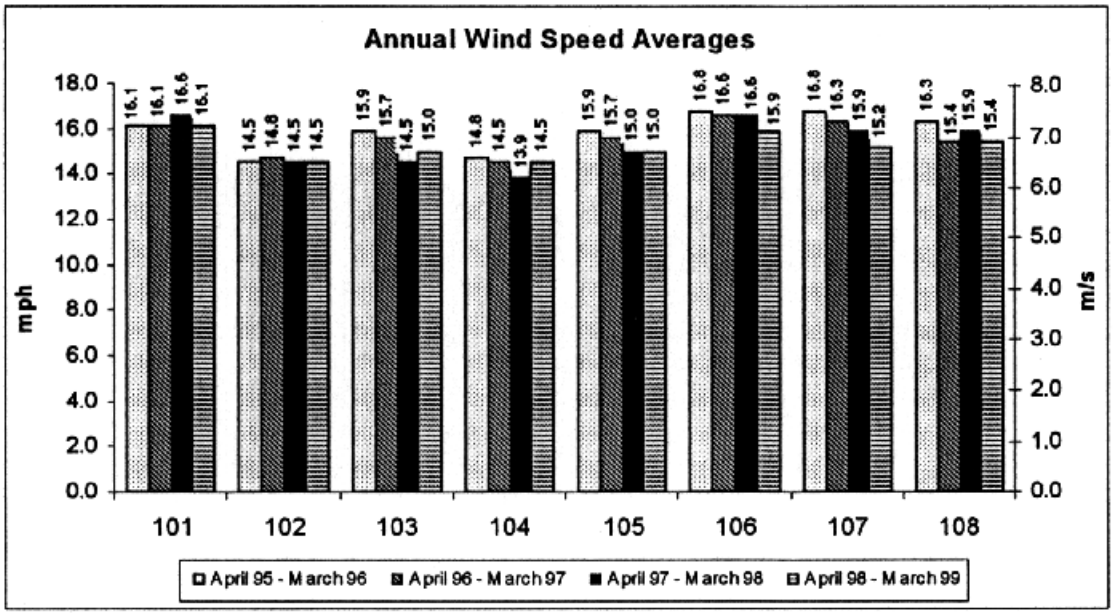

Figure 4. Annual Wind Speed Averages at 40 Meters

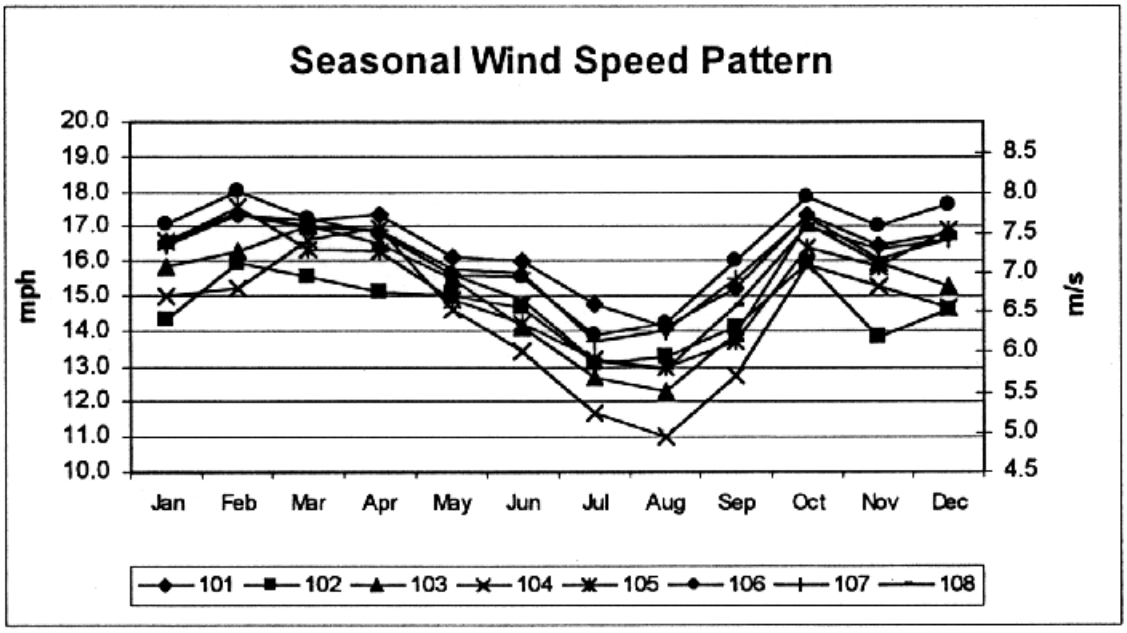

Figure 5. Seasonal Wind Speed Patterns at 40-Meters (Four-Year Averages)

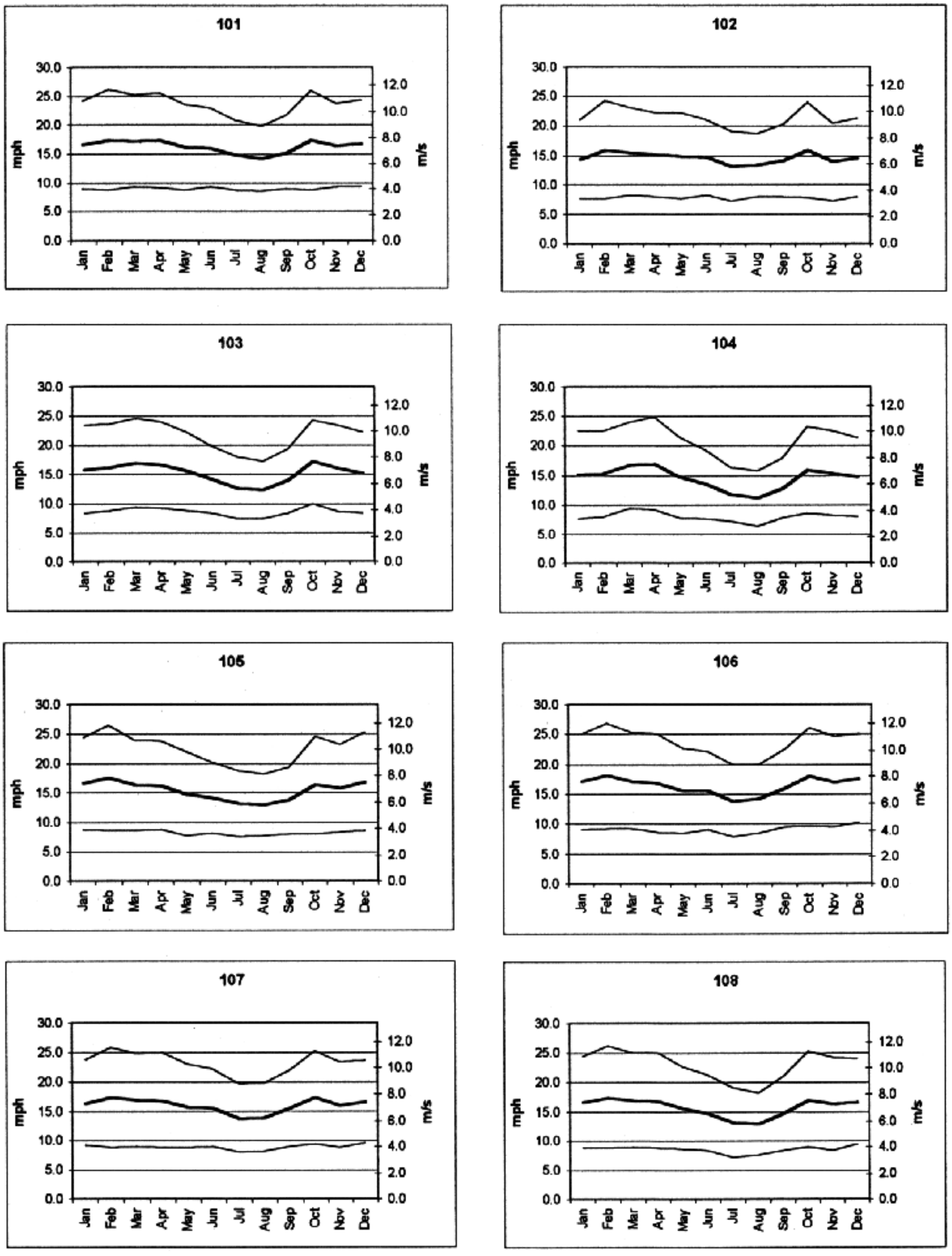

Figure 6. Monthly Wind Speed Averages and Standard Deviations at 40-Meters (Four-Year Averages)

Diurnal Patterns

Figure 7 illustrates the diurnal wind speed pattern at all eight sites as measured at 40 meters over the four-year monitoring period. This figures shows that the diurnal wind speed pattern is similar at all sites across the state. This figure also indicates that the wind speeds decrease slightly in the early morning and evening hours.

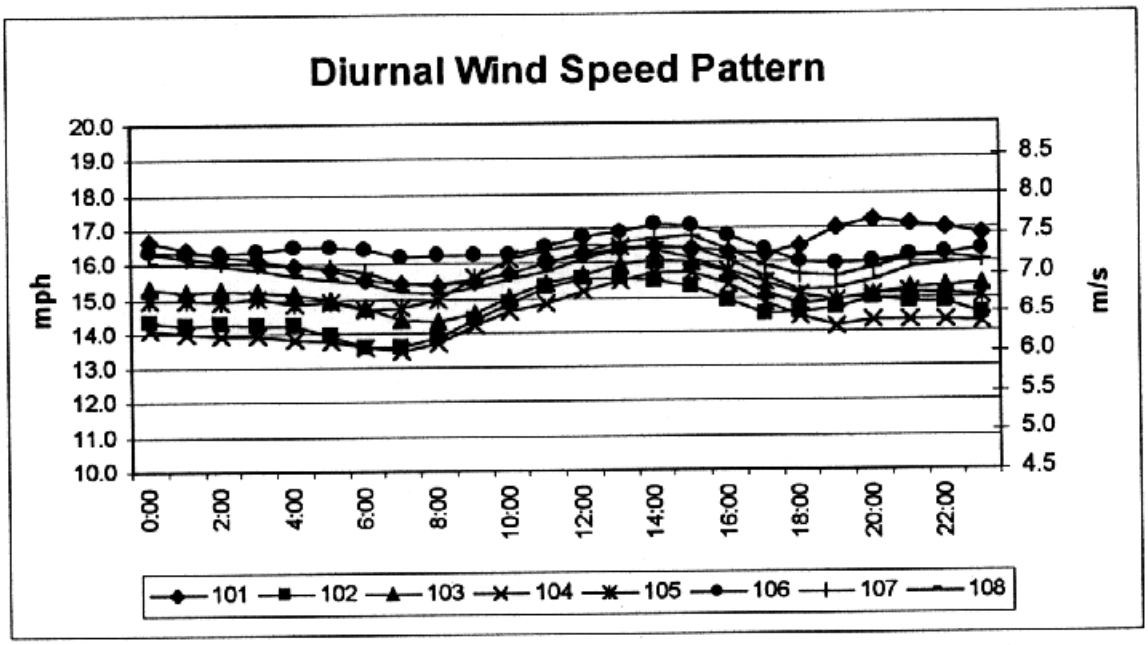

Figure 7. Diurnal Wind Speed Patterns at 40-Meters (Four-Year Averages)

Figure 8 provides the diurnal average and standard deviation for each site at the 40-meter level for four years. As with Figure 6, the solid line represents the wind speed average and the gray lines represent the standard deviation from the average. This figure illustrates that all eight monitoring sites have a similar diurnal variation of wind speed.

WIND SHEAR

Wind shear is calculated based on the power law formulation where the increase in wind speed with height above ground level is assumed to change exponentially with the height.[4] A higher shear exponent indicates a greater increase in wind speed with an increase in height. The theoretically derived value for wind shear over smooth, flat terrain is 0.14. Wind shear not only varies between different levels but also between sites, wind speeds, wind directions, and seasons.

[4] For wind speed (v_1 and v_2) at respective heights (h_1 and h_2), $v_2/ v_1 = (h_2/h_1)^{\alpha}$ where α is the wind shear exponent.

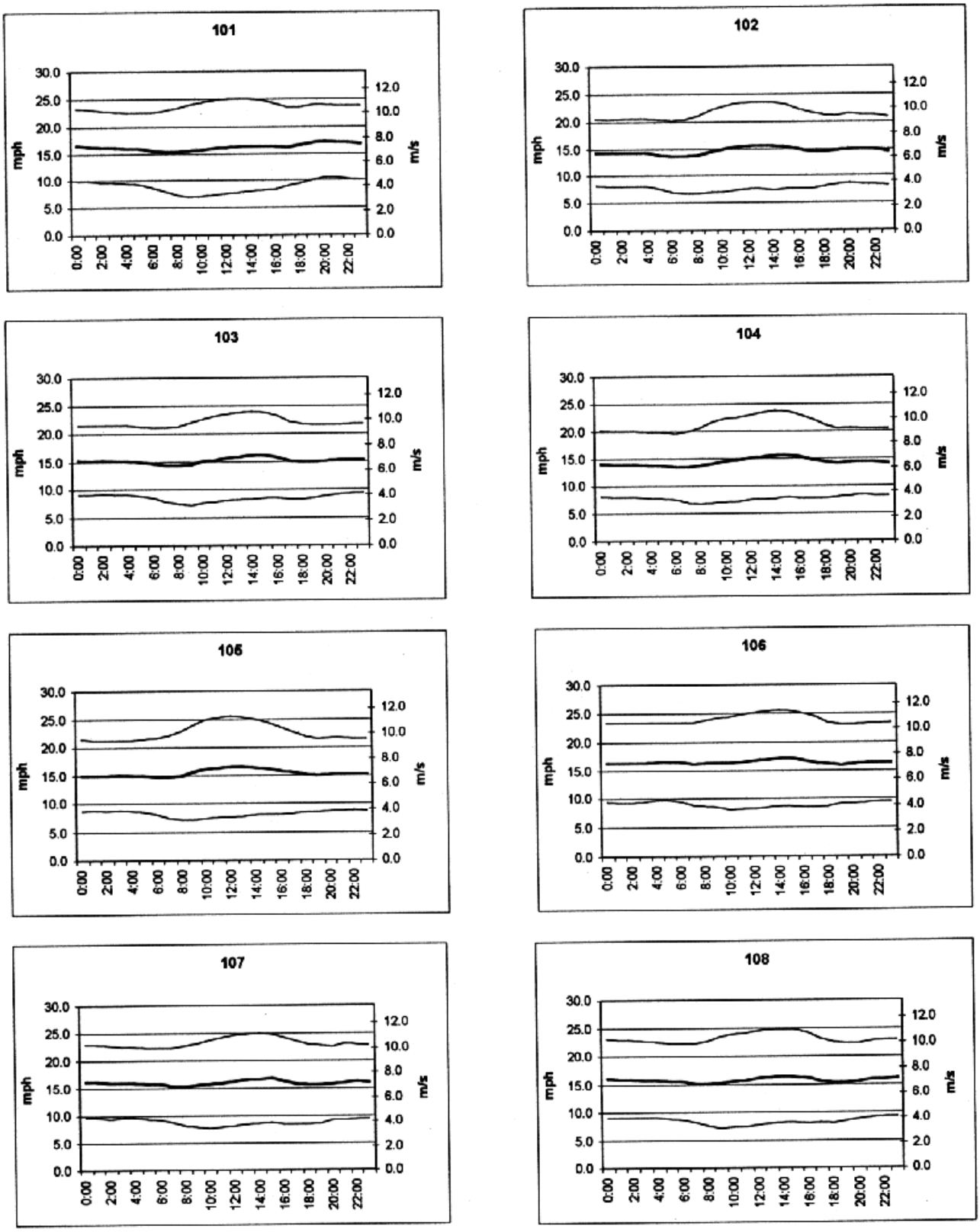

Figure 8. Diurnal Wind Speed Averages and Standard Deviations at 40-Meters (Four-Year Average)

Table 3 provides the average wind shear exponent over the four-year monitoring period for each site. Six of the eight sites had an average wind shear exponent greater than 0.20 between the 25m and 40m levels over the four-year period. Sites 104 and 105, Wahoo and Kimball, recorded the highest average shear exponent at 0.27; Site 101, Imperial, had the lowest wind shear at 0.16. A review of the monthly wind speed averages shows that there is a slight increase in wind shear during the low wind months of June through September.

Table 3. Four-Year Average Wind Shear Exponent

Site Name	Shear Exponent
101 – Imperial	0.16
102 - Rushville	0.25
103 - Winnebago	0.21
104 - Wahoo	0.27
105 - Kimball	0.27
106 - Valentine	0.19
107 - Springview	0.24
108 - Stuart	0.25

TURBULENCE INTENSITY

Turbulence intensity (TI) is a relative indicator of turbulence and not an absolute value. According to the American Wind Energy Association (AWEA), a relatively low turbulence intensity is 0.10 or less, moderate turbulence is indicated by values of between 0.10 and 0.25, with high turbulence levels indicated by values above 0.25. Turbulence intensity is calculated as the standard deviation of the wind speed divided by the average wind speed.

During this study's four-year monitoring period, the maximum monthly average TI values from the predominant wind direction at all eight stations ranged from 0.17 to 0.21. These TI values are in the "moderate" range based on the AWEA guidelines and on experience with developed wind sites. A review of the monthly TI shows that there was no significant seasonal variation. The TI for each directional wind sector is included on the wind rose graphs provided in the quarterly reports.

WIND DIRECTION

All eight monitoring stations exhibit similar wind direction characteristics. Figure 9 provides annual wind rose graphs for Site 101 for each of the four years of this study. Because monthly wind rose graphs were provided in the quarterly reports and all stations exhibit similar patterns, only information on Site 101 is included in this report.

The wind rose graphs in Figure 9 are based on wind speed and direction data at the 40-meter level. These graphs provide both percent total time and percent total energy from 16 direction sectors. As shown in this figure, the predominant wind direction was consistently from the northwest each year.

The data collected in this study indicate that the direction characteristics are distinct in two different seasons. Figure 10 illustrates the seasonal variation in wind direction for one calendar year at Site 101. The first wind rose graph in this figure is for the period of October 1995 through May 1996 and the second is for June 1996 through September 1996. This figure shows that the predominant wind direction is from the northwest during late fall through spring and then shifts to the southeast in the summer months. All sites in this study exhibit the same seasonal wind direction pattern.

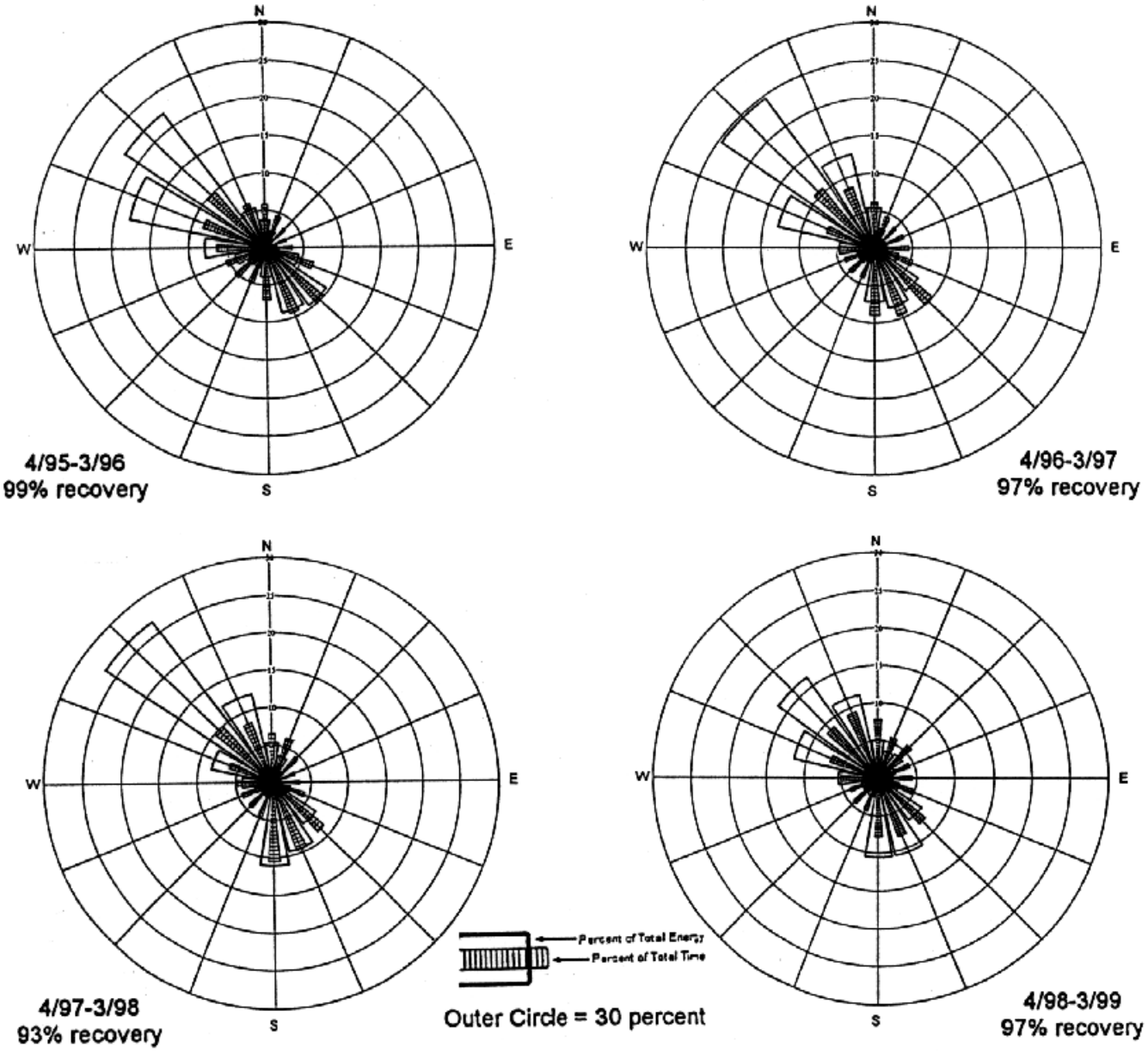

Figure 9. Comparison of Annual Wind Direction

ENERGY PRODUCTION ESTIMATES

To provide additional insight into the development potential at the sites, energy production was estimated based on the wind speed frequency distribution at each site and a wind turbine power curve. Table 4 provides annual energy estimates for each site. These estimates were calculated based on the power output characteristics of one 750 kW wind turbine with a 40-meter hub height and an assumed air density of 1.225 kg/m^3. Data from the 40-meter corrected data set were used for these estimates and no energy losses were taken into account.

Sites 101 and 106 have the highest estimated energy production and annual wind speed average. Note that the average wind speed at these two sites are the same, yet Site 106 has a higher estimated energy production. This is due to the difference in frequency distribution between the two sites.

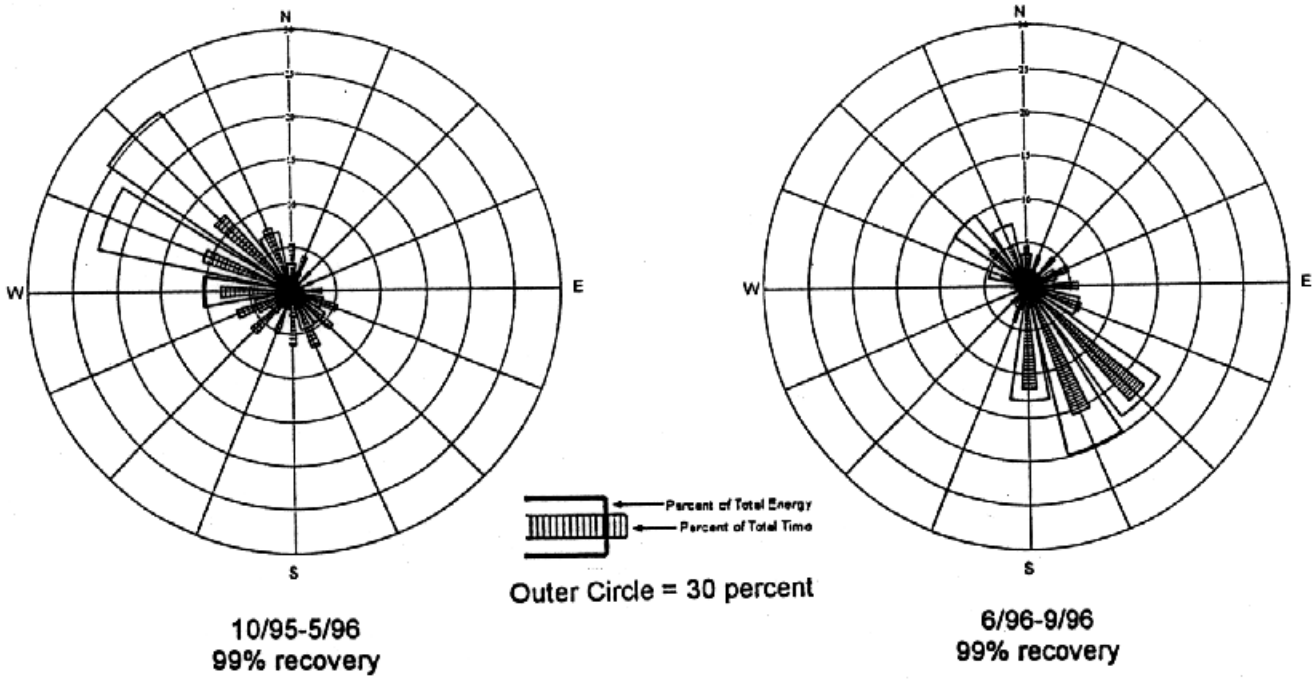

Figure 10. Seasonal Wind Direction

Table 4. Annual Energy Production Estimates

Site	Energy Estimates (MWh) 4/95-3/96	4/96-3/97	4/97-3/98	4/98-3/99	Total	Wind Speed Avg mph (m/s)
101-Imperial	1,990	1,977	2,024	1,929	7,920	16.3 (7.3)
102-Rushville	1,503	1,626	1,554	1,553	6,236	14.6 (6.5)
103-Winnebago	1,896	1,818	1,518	1,631	6,863	15.2 (6.8)
104-Wahoo	1,604	1,572	1,410	1,548	6,134	14.4 (6.4)
105-Kimball	1,860	1,806	1,669	1,659	6,993	15.4 (6.9)
106-Valentine	2,057	2,045	2,023	1,877	8,003	16.4 (7.3)
107-Springview	2,115	2,007	1,861	1,693	7,676	16.0 (7.2)
108-Stuart	2,018	1,826	1,875	1,766	7,485	15.8 (7.0)

SOLAR INSOLATION

Table 5 provides a summary of the solar insolation for four years. As expected, there was not a significant variation in the solar resource on a year-to-year basis.

Table 5. Solar Insolation

Site	First year kWh/m2/day	Second year kWh/m2/day	Third year kWh/m2/day	Fourth year kWh/m2/day
101 – Imperial	4.54	4.52	4.47	4.63
102 - Rushville	4.30	4.26	4.31	4.33
103 - Winnebago	3.94	3.89	3.82	3.97
104 - Wahoo	4.03	4.01	3.72	4.11
105 - Kimball	4.47	4.54	6.19	4.41
106 - Valentine	4.19	4.22	4.16	4.28
107 - Springview	4.19	4.22	4.07	4.27
108 - Stuart	4.04	4.03	3.93	4.12
Average	4.21	4.21	4.07	4.24

CONCLUSIONS

The Nebraska Wind Site Data Study provided valuable information regarding the potential for wind energy development in Nebraska. The wind speeds at all eight sites are within a range technically sufficient for commercial wind farm development. The four years of data establishes both a diurnal and seasonal pattern in the wind speed averages. Wind direction seasonal patterns were also established. The consistency in both the wind speed and direction data throughout the four-year data collection period indicates the data is highly representative of the wind resource. An overall data recovery rate of greater than 95% also provides confidence in the integrity of the data.

In addition, the Lightning Mitigation Measures Study conducted by GEC under separate contract with NREL provided information on cost-effective ways to improve data recovery in areas with a high level of lightning activity. The mitigation measures installed appeared to improve the data recovery rates at those stations and GEC has utilized some of these measures in other monitoring studies where lightning and electrostatic discharge pose a problem.

APPENDIX A

PROJECT BUDGET WORKSHEETS

BUDGET: Amendment #2

(Add U*WRAP Grant, Misc Others)

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	TOTAL	Cumulative
Oct-94	$9,357	$11,994	$4,780									$26,131	$26,131
Nov-94			$4,480									$4,480	$30,611
Dec-94				$630								$630	$31,241
Jan-95				$630	$58,541							$59,171	$90,412
Feb-95					$6,634							$6,634	$97,046
Mar-95				$2,520	$6,634							$9,154	$106,200
Apr-95						$1,197	$1,218				$628	$3,043	$109,244
May-95						$1,197	$1,218				$628	$3,043	$112,287
Jun-95						$1,197	$1,218				$628	$3,043	$115,330
Jul-95						$1,197	$1,218	$1,323			$628	$4,366	$119,697
Aug-95						$1,197	$1,218				$628	$3,043	$122,740
Sep-95						$1,197	$1,218				$628	$3,043	$125,783
Oct-95						$1,197	$1,218	$1,323			$628	$4,366	$130,149
Nov-95						$1,197	$1,218				$628	$3,043	$133,193
Dec-95						$1,197	$1,218				$628	$3,043	$136,236
Jan-96						$1,197	$1,218	$1,323			$628	$4,366	$140,602
Feb-96						$1,197	$1,218				$628	$3,043	$143,646
Mar-96				$2,520		$1,197	$1,218				$628	$5,563	$149,209
Apr-96					$960	$1,197	$1,218	$1,323	$3,293		$628	$8,619	$157,828
May-96					$17,983	$1,197	$1,218				$628	$21,026	$178,854
Jun-96						$1,197	$1,218		$578		$628	$3,621	$182,475
Jul-96						$1,197	$1,218	$1,323			$628	$4,366	$186,841
Aug-96						$1,197	$1,218	$88	$750		$628	$3,881	$190,722
Sep-96						$1,197	$1,218				$628	$3,043	$193,765
Oct-96						$1,197	$1,218	$1,323			$628	$4,366	$198,131
Nov-96						$1,197	$1,218	$88			$628	$3,131	$201,262
Dec-96						$1,197	$1,218				$628	$3,043	$204,305
Jan-97						$1,197	$1,218	$1,323			$628	$4,366	$208,671
Feb-97						$1,197	$1,218	$88			$628	$3,131	$211,802
Mar-97				$2,520		$1,197	$1,218				$628	$5,563	$217,366
Apr-97						$1,197	$1,218	$1,323	$3,293		$628	$7,659	$225,025
May-97						$1,197	$1,218	$88			$628	$3,131	$228,155
Jun-97						$1,197	$1,218				$628	$3,043	$231,199
Jul-97						$1,197	$1,218	$1,323			$628	$4,366	$235,565
Aug-97						$1,197	$1,218	$88			$628	$3,131	$238,696
Sep-97						$1,197	$1,218				$628	$3,043	$241,739
Oct-97						$1,197	$1,218	$1,323			$628	$4,366	$246,105
Nov-97						$1,197	$1,218	$88			$628	$3,131	$249,236
Dec-97						$1,197	$1,218				$628	$3,043	$252,280
Jan-98						$1,197	$1,218	$1,323			$628	$4,366	$256,646
Feb-98						$1,197	$1,218	$88			$628	$3,131	$259,776
Mar-98				$2,520		$1,197	$1,218				$628	$5,563	$265,340
Apr-98						$1,197	$1,218	$1,323	$3,293		$628	$7,659	$272,999
May-98						$1,197	$1,218	$88			$628	$3,131	$276,130
Jun-98						$1,197	$1,218				$628	$3,043	$279,173
Jul-98						$1,197	$1,218	$1,323			$628	$4,366	$283,539
Aug-98						$1,197	$1,218				$628	$3,043	$286,582
Sep-98						$1,197	$1,218				$628	$3,043	$289,626
Oct-98						$1,197	$1,218	$1,323			$628	$4,366	$293,992
Nov-98						$1,197	$1,218				$628	$3,043	$297,035
Dec-98						$1,197	$1,218				$628	$3,043	$300,079
Jan-99						$0	$1,218	$1,323	$3,293		$628	$6,462	$306,540
Feb-99						$0	$1,218				$628	$1,846	$308,386
Mar-99						$0	$1,218			$5,100	$628	$6,946	$315,332
Apr-99				$500		$0	$1,000	$3,520	$2,400		$0	$7,420	$322,752
May-99						$0	$1,000				$0	$1,000	$323,752
Jun-99						$0	$1,000				$0	$1,000	$324,752.34
TOTAL	$9,357	$11,994	$9,260	$11,840	$90,752	$53,878	$61,456	$24,060	$16,899	$5,100	$30,156	$324,752	

Revenues

Date	Total Utility	NEO STEP	NEO UWRAP	Subtotal	Interest Earnings	Total	Cumulative
May-94	$35,610			$35,610	$0.00	$35,610.00	$35,610.00
Jun-94	$69,700			$69,700	$0.00	$69,700.00	$105,310.00
Jul-94	$0			$0	$94.83	$94.83	$105,404.83
Aug-94	$0			$0	$140.06	$140.06	$105,544.89
Sep-94	$0			$0	$135.71	$135.71	$105,680.60
Oct-94	$0			$0	$140.40	$140.40	$105,821.00
Nov-94	$0			$0	$135.96	$135.96	$105,956.96
Dec-94	$10,000			$10,000	$152.21	$10,152.21	$116,109.17
Jan-95	$0			$0	$143.25	$143.25	$116,252.42
Feb-95	$0			$0	$117.48	$117.48	$116,369.90
Mar-95	($100)			($100)	$71.36	($28.64)	$116,341.26
Apr-95	$84,990			$84,990	$113.95	$85,103.95	$201,445.21
May-95	$0			$0	$140.46	$140.46	$201,585.67
Jun-95	$0			$0	$120.29	$120.29	$201,705.96
Jul-95	$0			$0	$116.92	$116.92	$201,822.88
Aug-95	$0			$0	$109.56	$109.56	$201,932.44
Sep-95	$0			$0	$104.83	$104.83	$202,037.27
Oct-95	$0			$0	$99.57	$99.57	$202,136.84
Nov-95	$0			$0	$86.71	$86.71	$202,223.55
Dec-95	$0			$0	$73.41	$73.41	$202,296.96
Jan-96	$0			$0	$70.17	$70.17	$202,367.13
Feb-96	$0			$0	$61.44	$61.44	$202,428.57
Mar-96	$0			$0	$55.00	$55.00	$202,483.57
Apr-96	$0			$0	$41.27	$41.27	$202,524.84
May-96	$0			$0	$39.04	$39.04	$202,563.88
Jun-96	$0		$1,987	$1,987	$34.28	$2,020.94	$204,584.82
Jul-96	$0		$17,880	$17,880	$32.84	$17,912.84	$222,497.66
Aug-96	$0			$0	$23.77	$23.77	$222,521.43
Sep-96	$0	$8,619		$8,619	$15.62	$8,634.27	$231,155.70
Oct-96	$0			$0	$17.41	$17.41	$231,173.11
Nov-96	$0			$0	$12.97	$12.97	$231,186.08
Dec-96	$0	$8,619		$8,619	$11.47	$8,630.22	$239,816.30
Jan-97	$0		$19,867	$19,867	$24.79	$19,891.46	$259,707.75
Feb-97	$0			$0	$36.79	$36.79	$259,744.54
Mar-97	$0			$0	$31.75	$31.75	$259,776.29
Apr-97	$0	$8,619		$8,619	$33.25	$8,652.00	$268,428.29
May-97	$0			$0	$36.17	$36.17	$268,464.46
Jun-97	$0	$8,619		$8,619	$26.71	$8,645.46	$277,109.92
Jul-97	$0		$19,867	$19,867	$45.29	$19,911.97	$297,021.89
Aug-97	$0			$0	$59.00	$59.00	$297,080.89
Sep-97	$0			$0	$44.66	$44.66	$297,125.55
Oct-97	$0	$8,619		$8,619	$48.54	$8,667.29	$305,792.84
Nov-97	$0			$0	$47.93	$47.93	$305,840.77
Dec-97	$0			$0	$48.48	$48.48	$305,889.25
Jan-98	$0	$8,619		$8,619	$54.55	$8,673.30	$314,562.55
Feb-98	$0			$0	$50.78	$50.78	$314,613.33
Mar-98	$0	$8,619		$8,619	$55.33	$8,674.08	$323,287.41
Apr-98	$0			$0	$52.58	$52.58	$323,339.99
May-98	$0			$0	$51.15	$51.15	$323,391.14
Jun-98	$0	$8,619		$8,619	$45.54	$8,664.29	$332,055.43
Jul-98	$0			$0	$51.51	$51.51	$332,106.94
Aug-98	$0			$0	$44.45	$44.45	$332,151.39
Sep-98	$0	$985		$985	$39.68	$1,024.68	$333,176.07
Oct-98	$0			$0	$33.65	$33.65	$333,209.72
Nov-98	$0			$0	$31.51	$31.51	$333,241.23
Dec-98	$0	$985		$985	$30.72	$1,015.72	$334,256.96
Jan-99	$0			$0	$28.49	$28.49	$334,285.44
Feb-99	$0			$0	$19.30	$19.30	$334,304.74
Mar-99	$0	$985		$985	$16.39	$1,001.39	$335,306.13
Apr-99	$0			$0	$14.75	$14.75	$335,320.88
May-99	$0			$0	$12.51	$12.51	$335,333.39
Jun-99	$0			$0	$10.55	$10.55	$335,343.94
Jul-99	$0	$1,407		$1,407	$10.46	$1,417.04	$336,760.98
Aug-99	$0			$0	$12.00	$12.00	$336,772.98
TOTAL	$200,200	$73,312	$59,600	$333,112	$3,661	$336,773	
	Actuals in Bold Type						

GEC Contract Expenses

Date	Prof Services	Travel	Hach/ Zond	NRG	HPCC	Leases	Insur.	RLA Fee	Other	Subtotal	Cumulative Expenses	Revised Budget	Over (Under)
May-94										$0.00	$0.00	$0.00	$0
Jun-94										$0.00	$0.00	$0.00	$0
Jul-94										$0.00	$0.00	$0.00	$0
Aug-94										$0.00	$0.00	$0.00	$0
Sep-94										$0.00	$0.00	$0.00	$0
Oct-94	$8,605	$920						$0	$207	$9,732.06	$9,732.06	$26,131.14	($16,399)
Nov-94	$6,263	$1,987						$0	$0	$8,249.36	$17,981.42	$30,611.14	($12,630)
Dec-94	$7,973	$1,344						$71	$77	$9,464.00	$27,445.42	$31,241.14	($3,796)
Jan-95	$1,393							$0	$0	$1,392.50	$28,837.92	$90,411.64	($61,574)
Feb-95	$2,273			$47,513				$4	$86	$49,875.64	$78,713.56	$97,045.97	($18,332)
Mar-95	$2,140		$13,372	$4,196		$2,000		$978	$0	$22,686.70	$101,400.26	$106,200.31	($4,800)
Apr-95	$715		$5,597	$350		$89		$302	$0	$7,052.93	$108,453.19	$109,243.70	($791)
May-95	$885						$940	$47	$0	$1,871.58	$110,324.77	$112,287.09	($1,962)
Jun-95	$3,163		$1,327	$688				$101	$0	$5,277.52	$115,602.29	$115,330.48	$272
Jul-95	$5,038		$443		$6,336			$339	$0	$12,156.80	$127,768.09	$119,696.54	$8,062
Aug-95	$2,113							$0	$0	$2,112.50	$129,870.59	$122,739.93	$7,131
Sep-95	$3,208			$1,217	$3,168			$230	$103	$7,925.69	$137,796.28	$125,783.32	$12,013
Oct-95	$5,000				$1,584			$80	$10	$6,673.18	$144,469.46	$130,149.37	$14,320
Nov-95	$2,013				$1,584			$124	$891	$4,611.98	$149,081.44	$133,192.76	$15,889
Dec-95	$2,315				$1,584		$1,200	$139	$0	$5,238.20	$154,319.64	$136,236.16	$18,083
Jan-96	$5,575				$1,584			$79	$0	$7,238.20	$161,557.84	$140,602.21	$20,956
Feb-96	$973		$728		$1,584			$116	$0	$3,400.44	$164,958.28	$143,645.60	$21,313
Mar-96	$79				$1,584			$79	$0	$1,742.20	$166,700.48	$149,208.99	$17,491
Apr-96	$6,213				$1,584			$79	$0	$7,876.70	$174,576.18	$157,827.80	$16,748
May-96	$3,799		$4,345	$8,000	$1,584	$2,000		$796	$0	$20,524.20	$195,100.38	$178,853.84	$16,247
Jun-96	$278		$3,562		$1,584			$286	$578	$6,287.23	$201,387.61	$182,474.75	$18,913
Jul-96	$4,150		$598		$1,584			$109	$0	$6,441.55	$207,829.16	$186,840.81	$20,988
Aug-96	$1,191			$298	$1,584			$94	$750	$3,917.39	$211,746.55	$190,721.70	$21,025
Sep-96	$693		$315		$1,584			$95	$0	$2,687.30	$214,433.85	$193,765.09	$20,669
Oct-96	$2,955		$195		$1,584			$89	$0	$4,822.95	$219,256.80	$198,131.14	$21,126
Nov-96	$509				$1,584			$79	$0	$2,172.20	$221,429.00	$201,262.03	$20,167
Dec-96	$709				$1,584			$79	$0	$2,372.20	$223,801.20	$204,305.42	$19,496
Jan-97	$3,693				$1,584		$999	$129	$0	$6,406.15	$230,206.35	$208,671.48	$21,535
Feb-97	$128				$1,584			$79	$0	$1,791.20	$231,997.55	$211,802.37	$20,195
Mar-97	$1,330				$1,584	$2,000		$179	$0	$5,093.20	$237,090.75	$217,365.76	$19,725
Apr-97	$2,603				$1,584			$79	$0	$4,266.20	$241,356.95	$225,024.57	$16,332
May-97	$1,473				$1,584			$79	$0	$3,135.70	$244,492.65	$228,155.46	$16,337
Jun-97	$589			$3,644	$1,584			$264	$58	$6,138.80	$250,631.45	$231,198.85	$19,433
Jul-97	$2,299		$3,602	$161	$1,584			$267	$0	$7,913.75	$258,545.20	$235,564.91	$22,980
Aug-97	$1,169			($505)	$1,584			$79		$2,326.93	$260,872.13	$238,695.80	$22,176
Sep-97	$0				$1,584			$79		$1,663.20	$262,535.33	$241,739.19	$20,796
Oct-97	$1,064				$1,584			$79		$2,727.20	$265,262.53	$246,105.24	$19,157
Nov-97	$143				$1,584			$79		$1,805.70	$267,068.23	$249,236.13	$17,832
Dec-97	$86				$1,584			$79		$1,748.70	$268,816.93	$252,279.52	$16,537
Jan-98	$3,671				$1,584			$86		$5,340.25	$274,157.18	$256,645.58	$17,512
Feb-98	$946				$1,584			$79		$2,609.51	$276,766.69	$259,776.47	$16,990
Mar-98	$578				$1,584			$79		$2,240.70	$279,007.39	$266,339.86	$13,668
Apr-98	$4,388			$132	$1,584			$92	$125	$6,320.05	$285,327.44	$272,998.67	$12,329
May-98	$2,666				$1,584			$79		$4,329.45	$289,656.89	$276,129.56	$13,527
Jun-98	$94				$1,584	$2,000		$0		$3,677.75	$293,334.64	$279,172.96	$14,162
Jul-98	$3,911				$1,584			$101	$426	$6,021.75	$299,356.39	$283,539.00	$15,817
Aug-98	$461				$1,584			$79		$2,124.45	$301,480.84	$286,582.39	$14,898
Sep-98	$128		$0		$1,584			$79		$1,790.70	$303,271.54	$289,625.78	$13,646
Oct-98	$1,534				$1,584			$79		$3,196.95	$306,468.49	$293,991.84	$12,477
Nov-98	$266				$1,584			$79		$1,929.45	$308,397.94	$297,035.23	$11,363
Dec-98	$330				$1,584			$0		$1,914.00	$310,311.94	$300,078.62	$10,233
Jan-99	$3,625				$1,000			$129		$4,753.70	$315,065.64	$306,540.14	$8,525
Feb-99	$986				$1,000			$50		$2,036.25	$317,101.89	$308,386.24	$8,716
Mar-99	$248				$1,000			$50		$1,297.50	$318,399.39	$315,332.34	$3,067
Apr-99	$1,395				$0			$0		$1,395.00	$319,794.39	$322,752.34	($2,958)
May-99	$0				$0			$0		$0.00	$319,794.39	$323,752.34	($3,958)
Jun-99	$4,196	$762			$0			$0		$4,957.96	$324,752.34	$324,752.34	($0)
Jul-99	$0				$0			$0		$0.00	$324,752.34	$324,752.34	($0)
Aug-99	$0				$0			$0		$0.00	$324,752.34	$324,752.34	($0)
TOTAL	$124,212	$5,012	$34,085	$65,695	$74,280	$8,089	$3,139	$6,931	$3,310	$324,752.34			

Actuals in Bold Type

Total Contract Expenses

Date	GEC	UCS	MEAN	Other	Bank Fees	TOTAL	Cumulative Expenses	Revenues	Bank Statement*
May-94	$0.00				$47.71	$47.71	$47.71	$35,610.00	$35,562.29
Jun-94	$0.00					$0.00	$47.71	$106,310.00	$106,262.29
Jul-94	$0.00			$41.22		$41.22	$88.93	$106,404.83	$106,315.90
Aug-94	$0.00				$10.15	$10.15	$99.08	$106,544.89	$106,445.81
Sep-94	$0.00				$10.00	$10.00	$109.08	$106,680.60	$106,571.52
Oct-94	$9,732.06				$10.00	$9,742.06	$9,851.14	$106,821.00	$106,701.92
Nov-94	$8,249.36			$88.29	$10.00	$8,347.65	$18,198.79	$106,956.96	$106,739.59
Dec-94	$9,464.00				$10.15	$9,474.15	$27,672.94	$116,109.17	$115,881.66
Jan-95	$1,392.50				$10.34	$1,402.84	$29,075.78	$116,252.42	$106,282.50
Feb-95	$49,875.64				$10.15	$49,885.79	$78,961.57	$116,369.90	$58,877.31
Mar-95	$22,686.70				$10.15	$22,696.85	$101,658.42	$116,341.26	$49,374.52
Apr-95	$7,052.93	$3,346.44	$729.01		$10.30	$11,138.68	$112,797.10	$201,445.21	$118,387.74
May-95	$1,871.58		$484.92		$11.35	$2,367.85	$115,164.95	$201,585.67	$95,345.23
Jun-95	$6,277.52				$10.30	$5,287.82	$120,452.77	$201,705.96	$88,402.29
Jul-95	$12,155.80				$10.15	$12,165.95	$132,618.72	$201,822.68	$86,637.48
Aug-95	$2,112.50				$10.16	$2,122.65	$134,741.37	$201,932.44	$81,459.37
Sep-95	$7,925.69				$10.15	$7,935.84	$142,677.21	$202,037.27	$81,554.05
Oct-95	$6,673.18				$10.00	$6,683.18	$149,360.39	$202,136.84	$67,376.32
Nov-95	$4,611.98				$10.30	$4,622.28	$153,982.67	$202,223.55	$67,451.73
Dec-95	$5,238.20				$10.00	$5,248.20	$159,230.87	$202,296.96	$52,916.27
Jan-96	$7,238.20				$10.30	$7,248.50	$166,479.37	$202,367.13	$48,364.16
Feb-96	$3,400.44		$598.24		$10.15	$4,008.83	$170,488.20	$202,428.57	$47,817.21
Mar-96	$1,742.20				$12.16	$1,754.36	$172,242.56	$202,483.57	$35,383.65
Apr-96	$7,875.70				$12.16	$7,887.86	$180,130.42	$202,524.84	$32,012.32
May-96	$20,524.20				$12.16	$20,536.36	$200,666.78	$202,563.88	$30,297.00
Jun-96	$6,287.23				$12.16	$6,299.39	$206,966.17	$204,584.82	$24,430.08
Jul-96	$6,441.55				$12.48	$6,454.03	$213,420.20	$222,497.66	$21,806.24
Aug-96	$3,917.39				$12.16	$3,929.55	$217,349.75	$222,521.43	$15,530.62
Sep-96	$2,687.30				$12.16	$2,699.46	$220,049.21	$231,155.70	$17,711.18
Oct-96	$4,822.96				$12.44	$4,835.39	$224,884.60	$231,173.11	$13,798.76
Nov-96	$2,172.20				$12.16	$2,184.36	$227,068.96	$231,186.08	$11,112.27
Dec-96	$2,372.20				$12.16	$2,384.36	$229,453.32	$239,816.30	$14,907.38
Jan-97	$6,405.15				$12.44	$6,417.59	$235,870.91	$259,707.75	$32,614.19
Feb-97	$1,791.20				$12.44	$1,803.64	$237,674.55	$259,744.54	$30,266.34
Mar-97	$5,093.20				$12.16	$5,105.36	$242,779.91	$259,776.29	$23,880.78
Apr-97	$4,266.20				$12.16	$4,278.36	$247,058.27	$268,428.29	$30,729.42
May-97	$3,135.70				$12.44	$3,148.14	$250,206.41	$268,464.46	$25,659.95
Jun-97	$6,138.80				$12.16	$6,150.96	$256,357.37	$277,109.92	$30,027.05
Jul-97	$7,913.75				$13.25	$7,927.00	$264,284.37	$297,021.89	$49,925.77
Aug-97	$2,326.93				$12.32	$2,339.25	$266,623.62	$297,080.89	$40,697.95
Sep-97	$1,663.20				$12.16	$1,675.36	$268,298.98	$297,125.55	$32,816.70
Oct-97	$2,727.20				$13.02	$2,740.22	$271,039.20	$305,792.84	$39,144.04
Nov-97	$1,805.70				$12.44	$1,818.14	$272,857.34	$305,840.77	$39,179.53
Dec-97	$1,748.70				$12.00	$1,760.70	$274,618.04	$305,889.25	$37,552.81
Jan-98	$5,340.25				$13.15	$5,353.40	$279,971.44	$314,562.55	$46,212.96
Feb-98	$2,609.51				$12.38	$2,621.89	$282,593.33	$314,613.33	$41,718.46
Mar-98	$2,240.70				$12.16	$2,252.86	$284,846.19	$323,287.41	$43,291.43
Apr-98	$6,320.05				$13.76	$6,333.81	$291,180.00	$323,339.99	$40,720.74
May-98	$4,329.45				$12.16	$4,341.61	$295,521.61	$323,391.14	$38,619.03
Jun-98	$3,677.75				$12.16	$3,689.91	$299,211.52	$332,065.43	$40,851.11
Jul-98	$6,021.75				$13.52	$6,035.27	$305,246.79	$332,106.94	$36,569.66
Aug-98	$2,124.45				$12.16	$2,136.61	$307,383.40	$332,151.39	$32,914.19
Sep-98	$1,790.70				$12.16	$1,802.86	$309,186.26	$333,176.07	$27,904.96
Oct-98	$3,196.95				$13.16	$3,210.11	$312,396.37	$333,209.72	$25,801.00
Nov-98	$1,929.45				$12.16	$1,941.61	$314,337.98	$333,241.23	$24,029.66
Dec-98	$1,914.00				$12.16	$1,926.16	$316,264.14	$334,256.95	$25,033.21
Jan-99	$4,753.70				$12.95	$4,766.65	$321,030.79	$334,285.44	$19,922.36
Feb-99	$2,036.25				$12.16	$2,048.41	$323,079.20	$334,304.74	$18,015.49
Mar-99	$1,297.50				$10.15	$1,307.65	$324,386.85	$335,306.13	$14,253.03
Apr-99	$1,395.00				$10.80	$1,405.80	$325,792.65	$335,320.88	$12,220.73
May-99	$0.00				$10.15	$10.15	$325,802.80	$335,333.39	$10,925.59
Jun-99	$4,957.95				$10.15	$4,968.10	$330,770.90	$335,343.94	$9,530.99
Jul-99	$0.00				$10.15	$10.15	$330,781.05	$336,760.98	$10,937.88
Aug-99	$0.00				$10.15	$10.15	$330,791.20	$336,772.98	$5,981.78
TOTAL	$324,752.34	$3,346.44	$1,812.17	$129.51	$730.44	$330,770.90			
					$6,018.56				
	Actuals in Bold Type					$330,770.90			
	* Two or three month lag in RLA Bill					$0			

APPENDIX B

LIGHTNING MITIGATION MEASURES

FINAL REPORT

Lightning Mitigation Measures

Final Report

(Subcontract No. ACX-7-16485-01)

January 30, 1998

Prepared for

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Prepared by

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INTRODUCTION

Pursuant to NREL Subcontract No. ACX-7-16485-01, Global Energy Concepts, Inc., (GEC) has completed the installation of lightning and static mitigation measures on four wind monitoring stations in Nebraska. Table 1 provides the location of the four monitoring stations and the installation date of the mitigation measures. This report provides details on the lightning mitigation measures installed at each site and comparison of the data recovery rates and frequency of equipment failures before and after the installations.

Table 1. Monitoring Station Information

Site Number	Site Name	Latitude/ Longitude	Site Location	Installation Date
102	Rushville	N 42° 42' 38" W 102° 42' 54"	Northwest	10/09/96
103	Winnebago	N 42° 10' 13" W 96° 25' 15"	North Central	10/07/96
106	Valentine	N 42° 57' 23" W 100° 30' 13"	North Central	10/08/96
107	Springview	N 42° 49' 22" W 99° 47' 14"	Northeast	10/08/96

BACKGROUND

The DOE/NREL Utility Wind Resource Assessment Program (U*WRAP) provides technical and financial support to utilities conducting wind resource assessment programs in various regions of the United States. One of the major problems encountered in these programs has been lightning and static related failures of the wind resource monitoring equipment. Current strategies for improving the protection of structures from lightning and static damage suggest a three-part approach as described below.

BONDING AND GROUNDING

Differences in electrical potential across or within a piece of equipment can cause damage. The proper bonding of a tower's components (electrical and metallic) assures that the various components have the same electrical potential, therefore preventing the conductive pathways between and within equipment from becoming an unintended route of damaging equalizing potential.

For lightning and static protection a good low-impedance ground is necessary to get energy off a tower as quickly as possible. A good ground brings the bonded tower to the potential of the surface of the earth therefore reducing lightning strike and static accumulation risks. In and of themselves the bonding and grounding subsystems will not protect a monitoring tower. The proper interconnection of these two systems is imperative.

SURGE SUPPRESSION

Transient voltage and current surges, as opposed to direct lightning strikes, cause the majority of lightning damage to electronic equipment. Electromagnetic fields created during a lightning strike can induce strong currents in nearby conductors and electrical equipment. Microprocessors, which operate on very low

internal voltages, are particularly sensitive to these surges. Microprocessors, like the monitoring station data loggers, can be damaged by a nearby strike even if the microprocessor is not connected to a power or telephone line. Surge suppressors protect the microprocessors by redirecting the surges to the grounding system.

STRUCTURAL LIGHTNING PROTECTION

Structural lightning protection generally consists of the traditional lightning rod system. Lightning rod systems are designed to intercept a lightning strike and to safely convey the energy to the ground. Included in this category are devices known as static dissipating air terminals. While by design a lightning rod will promote the formation of streamers, the precursor to a lightning strike, a static dissipator will retard the formation. Lightning rods are intended to receive what some consider to be an inevitable strike, and carry the energy away from the protected structure. Static dissipating air terminals are designed to prevent the strike in the first place.

EQUIPMENT INSTALLATION

The four monitoring stations selected for use in this study are part of the eight station Nebraska U*WRAP network. These four stations were chosen based on the high frequency of lightning and static related equipment failures that occurred at these stations during the first 2 years of the program. Three of the four stations not used in this study utilize existing communication towers which were already equipped with extensive lightning protection equipment and therefore are not comparable to the four stations used in this study. The fourth station not used in this study (Site 104, Wahoo) is a 40-meter NRG TallTower™ with the same equipment configuration as the four stations used in this study. This site was used to compare the frequency of equipment failures with and without additional mitigation measures for the same time period.

The lightning protection system used at all the U*WRAP stations was provided by the wind monitoring equipment manufacturer, NRG Systems. This system consists of one lightning spike, one ground rod, and a copper ground wire of sufficient length to connect the spike to the ground rod. The three-part strategy summarized above was incorporated into the existing lightning and static protection systems for the four Nebraska U*WRAP stations selected for this study. The installation of the mitigation measures is described below.

IMPROVED GROUND CONNECTION

The effectiveness of each tower's grounding system was determined using an AEMC Instruments Model 3700 Clamp-on Ground Resistance Tester. Additional ground rods were installed at sites with ground resistance measurements greater than 10 Ohms. The additional eight-foot ground rods were installed at all four sites due to the poor soil conditions. The lowest ground resistance measurement at a site after the installation of addition rods was 68 Ohms. The grounding cable on each tower was inspected to ensure that it was secure and in contact with the tower in at least one location for each tower section and connected well to the ground rods.

STATIC DISSIPATING AIR TERMINALS

Multi-point, brush-type, static dissipating air terminals were installed at each site. At two of the stations, Springview and Winnebago, Lightning Master® model TLGS-4 dissipators were installed. A Lightning Master® Candelabra model dissipator set was installed on each of the remaining two stations, Rushville and Valentine. The model TLGS-4 consists of two brush-type, static dissipating air terminals mounted approximately 12 inches apart on a common base. The Candelabra model consists of four brush-type static dissipating air terminals mounted at each end of two 18-inch cross members. The air terminals were attached to the tip of the lightning rod originally installed on each monitoring tower.

GROUNDED ANEMOMETERS

At each station the standard anemometers at the 40-meter level were replaced with grounded anemometers from NRG Systems. The grounded anemometers have a grounding terminal on the sensor body as well as additional coil insulation. The grounded units were connected to the ground cable that descends each tower to provide a conductive path for the release of static charges.

LOWERING REDUNDANT ANEMOMETER

Lightning and static protection of sensors is greatly improved when sensors are located within a hypothetical 45° angle from the top of the air terminal. Since the U*WRAP program allows a ± 1 meter tolerance for all prescribed measurement heights, at each site the 40-meter redundant anemometer was lowered by one meter to place it farther within the "cone of protection" provided by the air terminals.

SURGE SUPPRESSION

Transient voltage surge suppressers were installed across each counter and analog input on the NRG 9300 CELLoggerTM at each monitoring station. This measure allows surges induced in the sensor cables to be redirected from the logger terminal strip to the upgraded tower bonding and grounding system.

CONCLUSIONS

Table 2 provides the equipment outages, hours of data lost, and frequency of equipment failures for each of the four stations in this study as well as Site 104. This table provides information from each of the first 2 years before the mitigation measures were installed and the one year following. The failure frequency for the sensors represents the number of sensor replacements required during that period. For the data logger, the failure frequency represents the number of site visits required to troubleshoot the problem and is not indicative of data logger replacements. Equipment failures that were clearly not a result of lightning/static are not included in this table. It should be noted that a few of the equipment failures included in this table could not be absolutely attributed to lightning/static problems; however, lightning/static was determined to be the most likely cause.

Table 2. Equipment Failures and Data Recovery Rates

	Before Mitigation Measures						*After Mitigation Measures*		
	3/95 – 12/95			*1/96 – 9/96*			*10/96 – 12/97*		
Site	*Equipment Failure*	*Hours Lost*	*Failure Freq.*	*Equipment Failure*	*Hours Lost*	*Failure Freq*	*Equipment Failure*	*Hours Lost*	*Failure Freq.*
102	Data logger	0	1	40m anemometer	1878	1	NONE	---	---
				25m direction vane	2208	1			
103	40m anemometer	489	1	Data logger	142	4	25m anemometer	2814	1
				40m anemometer	3616	2			
				40m direction vane	1253	1			
106	Data logger	224	2	Data logger	357	1	Data logger	0	1
	40m anemometer	4930	1	40m anemometer	2096	1			
107	Data logger	487	3	Data logger	396	1	NONE	---	---
	40m anemometer	5359	2	40m anemometer	4939	1			
104	Data logger	8	3	40m anemometer	3340	2	Data logger	801	3
							40m anemometer	807	1

Despite the uncertainties in the data, it is clear that the frequency of equipment failures were significantly higher at the four stations used in this study prior to the installation of the mitigation measures. In comparison, Site 104 experienced more equipment failures than did any of the four stations in this study after the installation of the mitigation measures.

GEC has successfully implemented some of these mitigation measures in other wind resource assessment programs. Of particular interest are the ten 40-meter NRG TallTowers™ operated by GEC for the Colorado U*WRAP. All ten stations experienced anemometer failures at the 40-meter level during the first lightning season of the program. All 40-meter anemometers were replaced with NRG grounded anemometers in October 1996 and since have experienced only one failure. The cause of this recent failure has not yet been determined but preliminary data indicates the sensor was damaged by heavy icing. The only other lightning protection used in the Colorado U*WRAP is the standard system provided by NRG with the 40-meter TallTower™ as previously described.

The results from the Colorado program indicate the grounded anemometers alone to be a significant improvement in mitigating the effects of lightning and static on wind measurement equipment. The surge suppressors and additional grounding system also appear to have been successful, as there were no data logger failures at any of the four stations used in this study. The effectiveness of the static dissipating air terminals cannot be determined because none of the towers operated by GEC have received a direct lightning strike since the installation of this equipment. It is impossible to determine whether a direct lightning strike would have occurred without this equipment installed.

APPENDIX C

SITE EVALUATION REPORTS

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **IMPERIAL**

Date Visited: October 26, 1994

Summary: Monitoring equipment is proposed to be mounted on an existing communications tower located on a well-exposed area representative of the sand hills of southwest Nebraska within a few miles of the Colorado border. Data collected from the Imperial site will be transmitted by either existing telephone lines or by relaying to a nearby cellular tower.

1. Wind Resource

The wind resource at this site is estimated to be approximately 15.8 mph at a height of 120 feet above ground level. UCS estimated the wind resource to be between Class 4 and Class 5. The nearby HPCC AWDN station is at a lower elevation and although the ten foot monitoring height may be appropriate for measurements related to plant evapo-transpiration rates, the adjacent cornfield is likely to have a significant impact on wind shear rates and average wind speed at the station's measurement height. There were no biological indicators in the vicinity to observe signs of flagging.

2. Land Availability

There is sufficient land in the vicinity of the proposed monitoring site to develop a utility-scale wind power plant. The local uses range from pasture/grazing to corn, sunflower, and other crop cultivation. The general land use pattern is grazing in the hills and cropland in any available flat areas between the hills. Potential wind power plants would be located in well-exposed locations in the hills and would not conflict with the existing uses. Residential use is limited primarily to homes and buildings associated with farming applications. Buildings are infrequent. There are no zoning restrictions that would apply to wind farm developments. The Imperial Airport is more than 15 miles from the monitoring location.

3. Terrain Suitability

The soil is sandy and, based on the experience of communication tower owners, it is adequate for construction and does not present any specific civil engineering challenges. There was no apparent evidence that blowouts are a concern in this area. The terrain is complex with no readily discernible pattern; however, there are a number of ridges in the vicinity of the proposed monitoring site that would provide opportunities for wind farm development. In general, the hills are rounded with few ravines. The variability of the terrain would likely require that wind turbine rows be oriented and spaced according to the local terrain features. Beyond normal siting considerations, there do not appear to be any specific terrain-related obstacles to wind farm development and construction.

4. Utility Access

There are two 115 kV lines that could provide immediate access to wind farm sites in this area and electrical interconnection can be made along existing roads without interfering with agricultural practices. The closest of the two transmission lines is within one mile of the proposed monitoring site.

5. Access and Logistical Support

The nearby town of Imperial has a population of about 2,000 and a full range of typical services. Skilled labor may be locally available.

A crane of sufficient size for construction of a wind power plant is not locally available; however, heavy equipment has been brought in from other locations for local projects such as the installation of the existing communication tower. Local grading equipment is used to maintain municipally owned sand hill roads and farm roads.

Although the sand hill roads are not surfaced, trucks loaded with corn, grain, and other agricultural products frequently travel them and it appears that they would be adequate for construction purposes.

6. Public/Environmental Sensitivity

This location is within the possible occurrence areas of several endangered species; however, there do not appear to be any insurmountable environmental concerns that would preclude wind power development. The area is under extensive cultivation and grazing, more than 15 miles from the Enders Reservoir, and approximately three (3) miles from Frenchman Creek, which is reported to have been running at very low levels in recent years. Due to the limited residences in the area, there do not appear to be any significant public concerns that could not be addressed by appropriate siting.

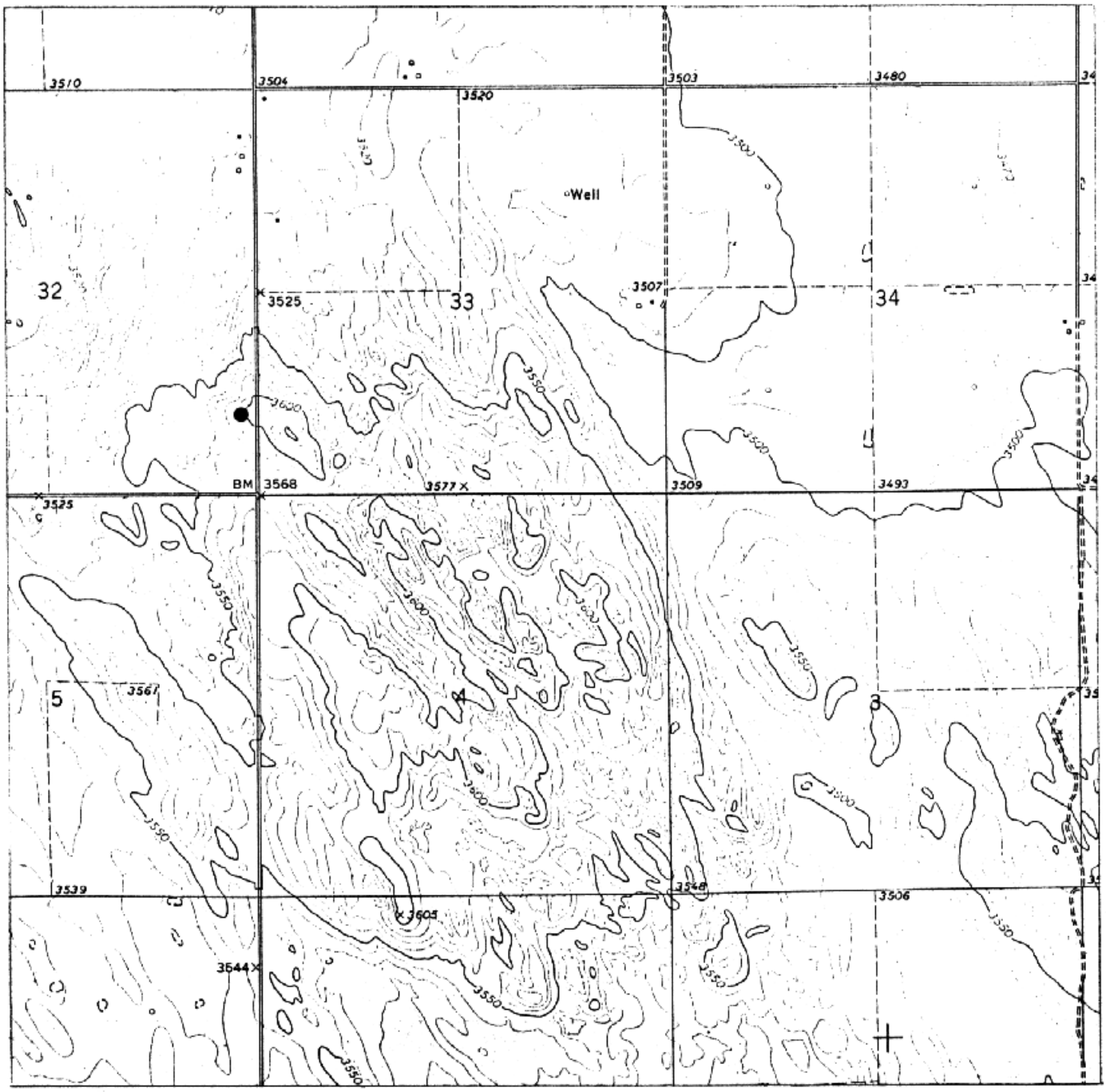
7. Owner Acceptance

Because an existing tower is proposed for use as a monitoring station, the tower owner was contacted during the field visit. Land owners in this area have not yet been contacted. Discussions with the county surveyor, who knew many of the residents, and experience in other areas of Nebraska indicate that successful farmers are open to the idea of diversified profitable land uses and would not rule out wind energy development.

8. Cellular Phone Coverage

A new cellular tower was recently installed nearby. Coverage was adequate for uninterrupted conversation and should be adequate for data transmission. However service from telephone lines used to serve local residences may also be available at the monitoring site at a minimum cost.

Existing Tower Owner: Arlan Scholl



Scale: 1:24,000
County: Chase
Map: Arterburn Lake, Nebr.

Location: S32-T6N-R31W
Latitude: 40°26'30"N
Longitude: 101°59'30"W

● Monitoring Location (Existing Communication Tower)

N

Imperial Site Map

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **RUSHVILLE**

Date Visited: November 6, 1994

Summary: A monitoring station, including a new meteorological tower, is proposed to be located on an exposed area of an east-west ridgeline west of Rushville. There are several other select, developable sites in the Rushville area. The data collected from the Rushville site will most likely be transmitted to the HPCC base station via cellular telephone service.

1. Wind Resource

The annual average wind speed is estimated to be approximately 17 miles per hour at 120 feet above ground level. UCS estimated the wind resource as Class 5. The currently proposed monitoring station is representative of well-exposed sites along the ridge and is reasonably representative of other well-exposed locations nearby.

2. Land Availability

There is sufficient land in the vicinity of the proposed monitoring site to develop a utility-scale wind power plant and the land along the ridge is expected to be readily available for wind energy development. The east-west ridgeline is approximately five miles long and one to three miles wide. It is parallel to and roughly two to three miles north of Highway 20. The proposed monitoring location is representative of the exposed ridgeline and sufficient land is available to develop a utility-scale wind power plant; however, it is not necessarily representative of the entire region. The predominant land uses of wheat crops and cattle grazing are compatible with wind energy. Some of the other well-exposed areas in the region may also be available for wind energy projects; however, the higher elevation areas several miles to the north are densely forested and would be significantly more difficult to develop. There are no airports in the immediate vicinity and no zoning restrictions exist that would place restrictions on wind farm development.

3. Terrain Suitability

The ridgeline terrain is well suited to wind power development. It is flat across its length and is unobstructed by vegetation. The high elevation forested area to the north is sufficiently distant to minimize any impact on the wind resource at the ridgelines, and there are no major terrain features that present obstacles to wind energy project development. The soil conditions do not impose any unusual problems for construction.

4. Utility Access

The main utility access is via a 115 kV transmission running east-west immediately to the south of the proposed monitoring location. The transmission line passes within two miles of the proposed monitoring location and, in general, along the entire ridge area.

5. Access and Logistical Support

The town of Rushville, approximately eight miles east of the proposed monitoring location, has a population of about 1,000, offers limited services, and is not likely to be a local labor source for wind farm construction and maintenance purposes. Chadron (pop. 5,588) 38 miles west of the monitoring site is the closest likely source of equipment and skilled labor; however, a crane would probably need to be obtained or purchased from outside of the local community.

Route 20 runs between Chadron and Rushville and is a principal, paved, two-lane state highway leading to within three miles of the potential monitoring location. The county roads are typical of those found throughout the state and currently support a variety of transportation uses. They should adequately support the needs of wind farm construction and maintenance activities.

6. Public/Environmental Sensitivity

This location is within the possible occurrence areas of several endangered species; however, there do not appear to be any insurmountable environmental concerns that would preclude wind power development. Conversations with area residents were limited to the land owner at the proposed monitoring location and a nearby resident. Both expressed an interest in the monitoring program and the possibility of potential wind farm development in the local area.

7. Owner Acceptance

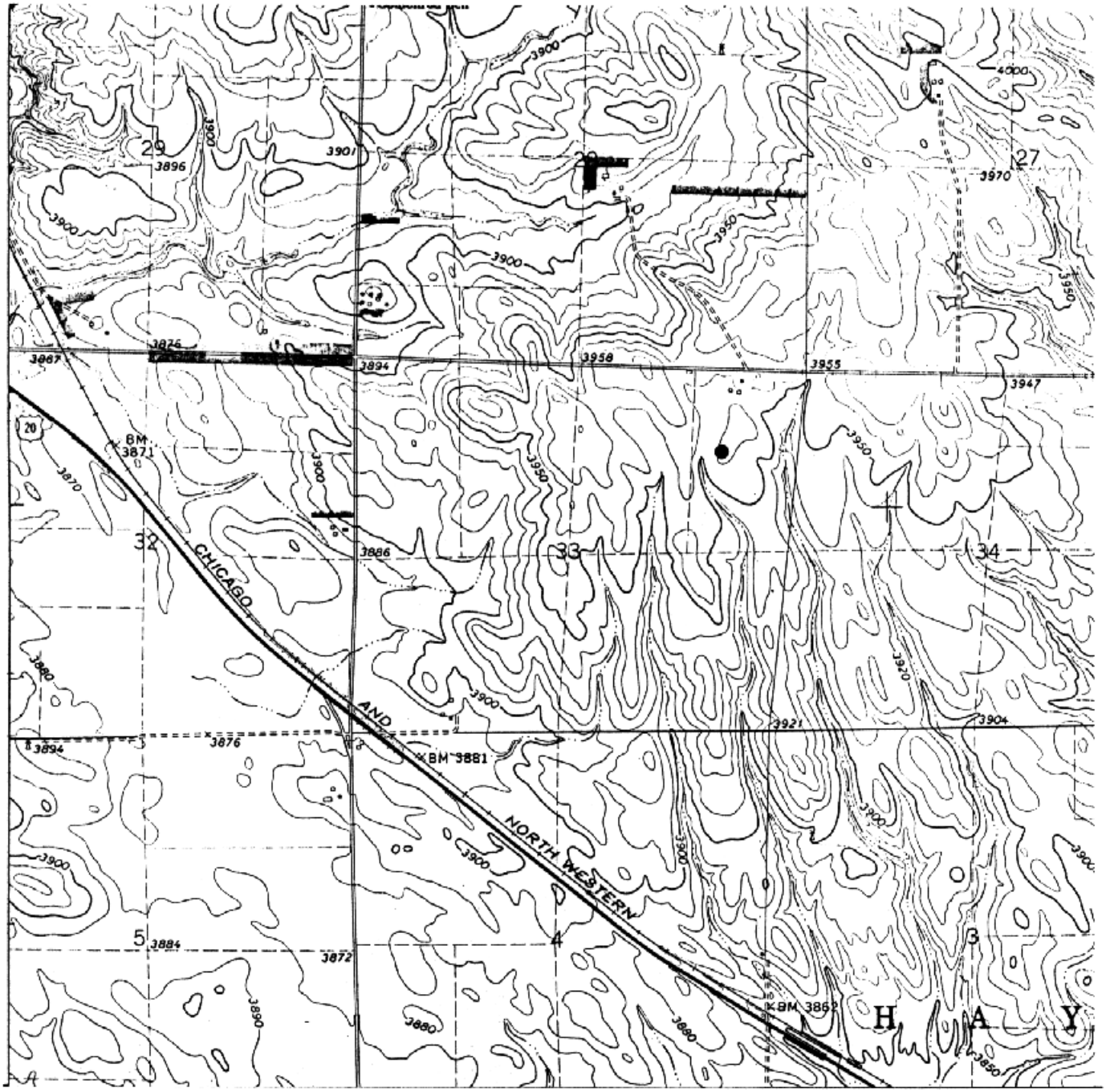
Another local area land owner was identified in addition to the one at the proposed monitoring location. Although he was not available at the time of the field survey, his neighbor indicated that he would likely also be interested in the potential of diversifying his land uses by adding wind power generation.

8. Cellular Phone Coverage

The cellular signal at the monitoring location is adequate for data transmission from the site.

Land Owner:

Dean Krueger
HC 74 Box 41
Hay Springs, NE 69347
(308) 638-7480



Scale: 1:24,000
County: Sheridan
Map: Hay Springs, Nebr.

Location: S33-T32N-R46W
Latitude: 42°42'15"N
Longitude: 102°43'00"W

● Monitoring Location (40M NRG TallTower™)

N

Rushville Site Map

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **WINNEBAGO**

Date Visited: November 1, 1994

Summary: A monitoring station, including a new meteorological tower, is proposed to be located on a well-exposed ridgeline midway between Macy and Winnebago, three (3) miles west of the Missouri River. There are several potential monitoring locations in this area for which land owner interest has been established. The proposed monitoring station is representative of the ridgelines and hilltops west of the Missouri River. The data collected from the Winnebago site will be transmitted to the HPCC base station via cellular telephone service.

1. Wind Resource

The annual average wind speed is estimated to be approximately 16 mph at 120 feet above ground level. UCS estimated the wind resource to be Class 4. There are two types of terrain in the hilly areas to the west of the Missouri River valley: rugged hills and rolling hills. The majority of the terrain (and the proposed monitoring site) is characteristic of the more rugged hills. Other potential monitoring sites in the area represent a mixture of the two resource area types.

2. Land Availability

Land availability for wind energy project development is more limited by terrain factors than by competing uses. The rugged hill areas are of limited agricultural use and are commonly set aside as part of the U.S. Government's Crop Rotation Program (CRP Land), cultivated for feed crops, or used for cattle grazing. These are relatively low land value uses, but are compatible uses with wind energy project development. Suitable land for development in the rugged terrain areas is limited to the exposed ridgelines and hilltops and further limited by those that are well oriented to the prevailing wind directions and relatively near to utility transmission access. The proposed monitoring site represents an area with sufficient land for a utility-scale wind power plant.

3. Terrain Suitability

In many locations, the relief of the hills impacts the prevailing winds. Construction and siting studies may require more effort in these sites than in plains sites. The soil characteristics do not present any unusual problems for construction.

4. Utility Access

There are two utility transmission lines passing north-south through the area, 161 kV and 115 kV, both owned by Omaha Public Power District. Both of the transmission lines are within two (2) miles of the proposed monitoring location and are accessible to other potential development locations in this area. For the purposes of this monitoring program, the difficulties and implied additional costs associated with the rugged terrain features must be weighed against the desire to identify high-value wind energy sites near to the state's major load centers of Lincoln, Omaha, and South Sioux City.

5. Access and Logistical Support

The town of Winnebago has a population of about 700. The town includes the Winnebago Tribal Office and offers limited services. Skilled construction labor is likely to be locally available in either Winnebago or from South Sioux City (pop. 9,677), approximately 20 miles to the north.

It is likely that the local grading equipment used to maintain county roads would be available for wind farm construction purposes and a crane would likely be available from South Sioux City on an as-needed basis for wind farm construction and maintenance.

Route 75 north and south from Blair to Winnebago is a standard, paved, two-lane state highway that runs to within a few miles of the potential monitoring location. The county roads are typical of those found throughout the state and currently support a variety of transportation uses, including trucks used to haul harvested crops, and should adequately support the needs of wind farm construction and maintenance activities.

6. Public/Environmental Sensitivity

There do not appear to be any significant public sensitivity to project development. Appropriate siting practices can reduce any visual impact on scenic vistas. The Winnebago Indian Reservation is going through a land consolidation process where they are buying back property within the reservation boundaries. As a result, there is a possibility that a potential wind energy project could be located on Tribal Lands. The tribal realty officer indicated that the tribal commission would likely look favorably on project development in the area as an economic opportunity for the Tribe and a valuable use of natural resources. Culturally significant areas need to be identified.

This location is within the possible occurrence areas of several endangered species; however, there does not appear to be any insurmountable environmental concerns that would preclude wind power development. There may be concerns about interaction between potential wind energy projects and migrating birds that use the Missouri River as a temporary resting area. Additional investigation may be required at this site; however, careful siting should reduce any potential problems.

7. Owner Acceptance

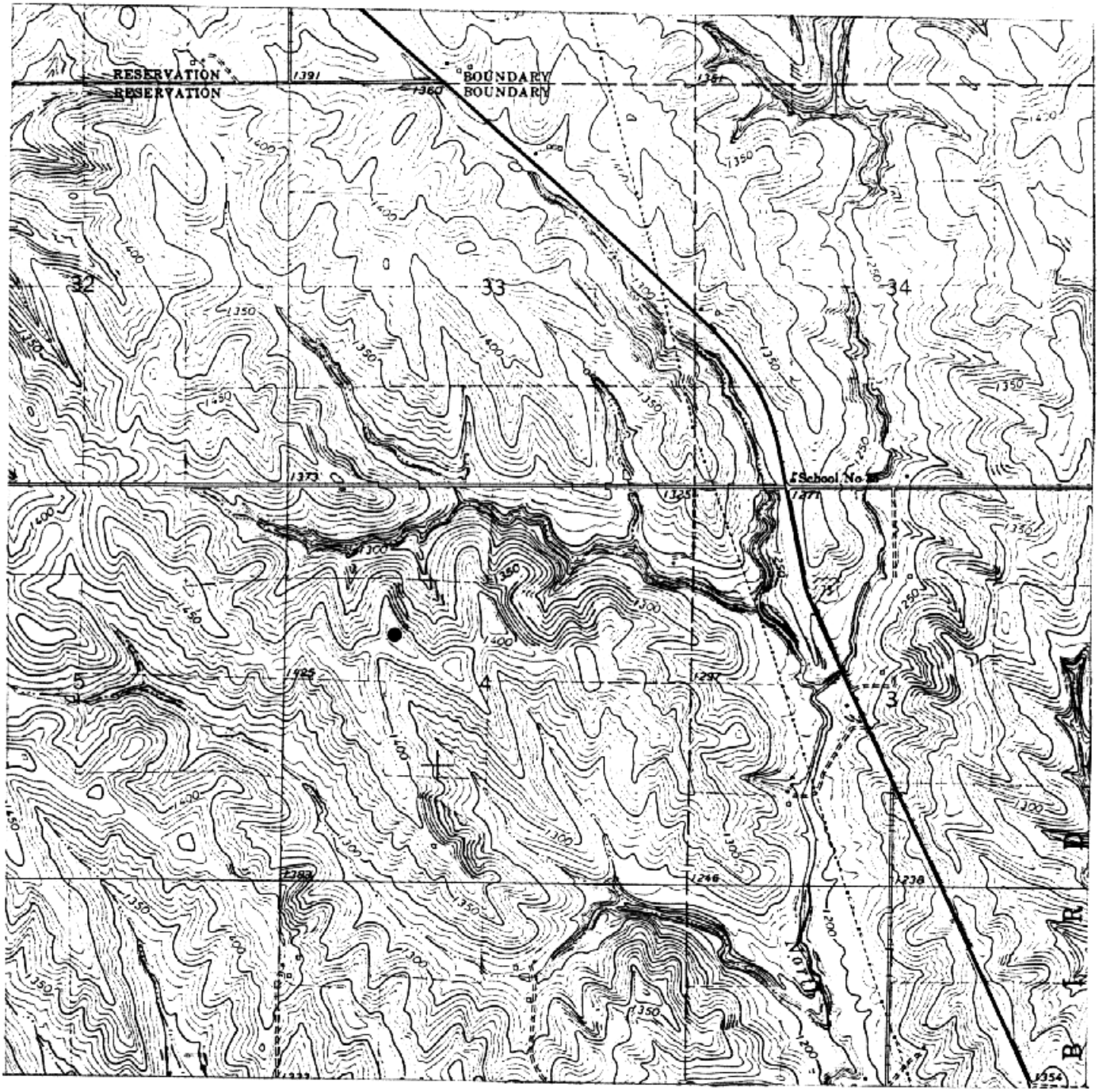
Representatives of the Omaha and Winnebago tribe realty offices and the land owner at the proposed location all stated interest in participating in the program and in the potential of future wind energy project developments in their area.

8. Cellular Phone Coverage

Although cellular signal strength has not been confirmed for this precise location, other nearby hilltops indicated adequate coverage for cellular data transmission and RLA is confident that a suitably representative site can be established that has adequate cellular coverage.

Land Owner:

Max Morgan
RR 1 Box 72
Walphill, NE 68067
(402) 846-5664



Scale:	1:24,000	Location:	S4-T25N-R9E
County:	Thurston	Latitude:	42°10'00"N
Map:	Walthill, Nebr.	Longitude:	96°25'00"W

● Monitoring Location (40M NRG TallTower™)

N

Winnebago Site Map

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **WAHOO**

Date Visited: October 30, 1994

Summary: A monitoring station, including a new meteorological tower, is proposed to be located on an open area to the northwest of Wahoo. The site is representative of well-exposed locations in the rolling hills in west-central Saunders County. The purpose of this site is to identify a potential wind energy location near to the major utility load of Lincoln. Note that there are considerable difficulties in identifying valuable, developable wind energy sites in this area. Potential sites in this area typically suffer from three obstacles: relatively higher density residential populations (as in Seward County), complex hilly terrain (such as near David City) further reducing the effective area for project development, and lower estimated average wind speeds when compared to other areas of Nebraska. The proposed site is in a relatively sparsely settled area of broad, rolling hills. The data collected from the Wahoo site will be transmitted to the HPCC base station via cellular telephone service.

1. Wind Resource

The annual average wind speed is estimated as approximately 14.5 mph at 120 feet above ground level. UCS estimated the wind resource as Class 3. The broad, rolling hills offer more land area available and exposed for wind energy development. Some property boundaries are marked by rows of trees, but in general there do not appear to be any major obstructions to the wind from the prevailing wind directions at the majority of developable locations.

2. Land Availability

There is sufficient land in the vicinity of the proposed monitoring location to develop a utility-scale wind power plant. The prevailing land use is crop cultivation, and due to the gentler nature of the land relief, even the higher hill tops are capable of being cultivated. Although corn is one of the primary crops grown in this area, the use of center pivots is scarce, so wind energy projects could be compatibly developed in combination with the current agricultural uses. There are no zoning restrictions to inhibit wind energy project development.

3. Terrain Suitability

The terrain is well suited to wind energy development with few obstructions and gentle terrain that poses no difficulties for wind farm construction. Trees belts can be found on many of the property borders, but in general, there is little vegetation other than the crops and the scattered bordering tree belts.

4. Utility Access

Utility access is available via an east-west 115 kV transmission line north of highway 92. The proposed monitoring station is within approximately two (2) miles of the transmission line.

5. Access and Logistical Support

The town of Wahoo has a population of about 3,500 and offers a full range of typical services and local labor is likely to be available for wind farm construction and maintenance purposes.

It is likely that the local grading equipment used to maintain county roads would be available for wind farm construction purposes and a crane should be available from Lincoln for wind farm construction and maintenance with relatively short lead time for any major repairs.

Route 92 west out of Wahoo is a principal, paved, two-lane state highway that leads to within a few miles of the potential monitoring location. The county roads are typical of those found throughout the state and currently support a variety of transportation uses, including trucks used to haul harvested crops, and should adequately support the needs of wind farm construction and maintenance activities.

6. Public/Environmental Sensitivity

This location is within the possible occurrence area of several endangered species; however, there do not appear to be any insurmountable public or environmental issues that would preclude wind energy project development. The Platte River Valley lies roughly 10 miles north of the proposed monitoring location and should be sufficiently distant to preclude any environmental sensitivities related to nesting or migrating birds attracted to the river valley.

7. Owner Acceptance

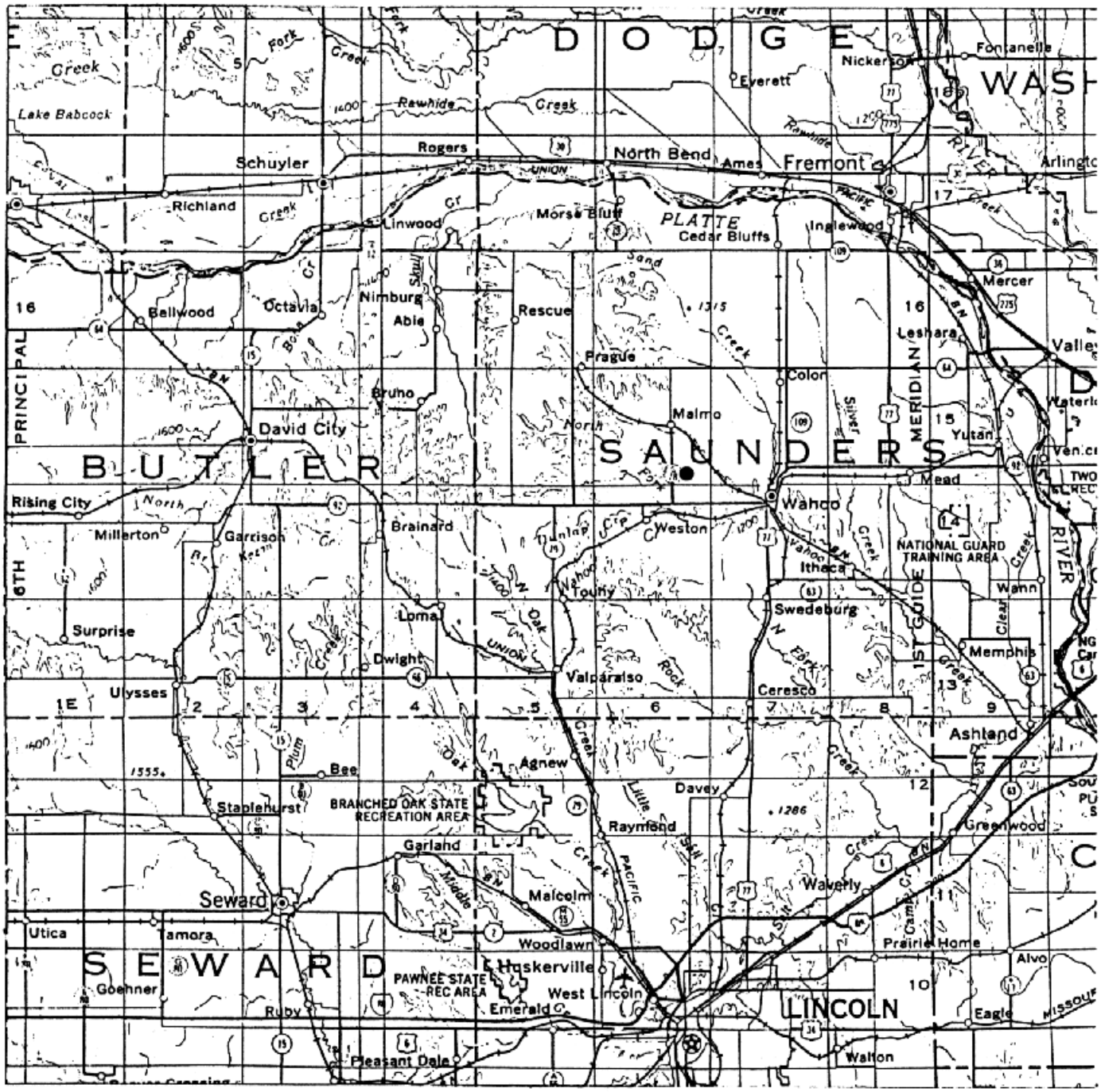
Specific land owners were not available to be contacted in this area, but based on the type of land use and reactions from land owners in other Nebraska locations, it is anticipated that they will react favorably to study participation and the potential for wind energy project development in the future.

8. Cellular Phone Coverage

The cellular signal from a nearby, well-exposed hilltop was strong, and it is expected that the signal will be adequate for data transmission.

Land Owner:

Norman Lindgren
RR 1 Box 83
Malmo, NE 68040
(402) 642-9266



Scale:	1:500,000	Location:	S27-T15N-R6E
County:	Saunders	Latitude:	41°14'00"N
Map:	State of Nebraska	Longitude:	96°43'30"W

● Monitoring Location (40M NRG TallTower™)

↑ N

Wahoo Site Map

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **KIMBALL**

Date Visited: October 27, 1994

Summary: Monitoring equipment is proposed to be either mounted on an existing communications tower or installed on a new meteorological tower on the property of a nearby land owner. The two alternative proposed sites are within two miles of each other on gently rolling terrain that gradually gains in elevation heading to the west until within a few miles of the Nebraska-Wyoming border. Data collected from the Kimball site will most likely be relayed to the HPCC base station via cellular phone service, although ground lines may be available.

1. Wind Resource

The wind resource at this site is estimated to be approximately 16.4 mph at a height of 120 feet above ground level. UCS estimated the wind resource to be between Class 4 and Class 5. The plateau south of the I-80 corridor is likely to experience winds similar to the plateau to the north of the I-80 corridor. The nearest HPCC AWDN station is north of Sidney in a location that is sheltered from northerly winds by a shrub-belt, and from southerly winds by a number of buildings across the road. There were no biological indicators in the vicinity to observe signs of flagging.

2. Land Availability

There is sufficient land in the vicinity of the proposed monitoring sites to develop a utility-scale wind power plant. Most of the area is used for crop cultivation; some of the area is used for oil production. Several land owners expressed an interest in participating in this study as well as in potential wind energy projects in the future. There is a waste incineration plant located between the proposed monitoring site and the City of Kimball. If a wind energy project were proposed that would provide an equitable benefit to the land owner(s), it does not appear that there would be any difficulty in identifying available land in this area.

Unmarked missile silos can be found in locations in this region. The City Inspector from the City of Sidney indicated that residences are not allowed to be constructed within 1,000 feet of the silos (for a combination of security and safety reasons); it is expected that similar restrictions would apply to wind energy projects. In general, however, the silos are fairly scarce in this area and do not pose a major restriction on land availability.

Other than the missile silos, there are no zoning restrictions in the area that would affect wind energy project development. The Kimball Municipal Airport is roughly 7 miles north of the proposed monitoring sites.

3. Terrain Suitability

The terrain is relatively flat and open plateau with few (if any) trees. The soil ranges from rocky in some places to mixed clay in others. Most of the available land is currently utilized for crop

cultivation. The flat open terrain would facilitate wind energy project development and soil conditions can be expected to vary by location.

4. Utility Access

A 115 kV transmission line runs through this area from east to west, paralleling the Nebraska-Colorado border approximately 4½ miles to the north of the proposed monitoring location.

5. Access and Logistical Support

The nearby town of Kimball has a population of about 2,500 and a full range of typical services. It would be adequate to serve the residential needs of maintenance personnel. Skilled labor may be locally available.

It is likely that the local grading equipment used to maintain county roads would be available for wind farm construction purposes; however, a crane would probably need to be obtained or purchased from outside of the local community for wind farm construction and maintenance.

Route 71 south from Kimball is a standard, paved, two-lane state highway that leads to within a few miles of the potential monitoring locations. The county roads are typical of those found throughout the state and currently support a variety of transportation uses, including trucks used to haul harvested crops, and should adequately support the needs of wind farm construction and maintenance activities.

6. Public/Environmental Sensitivity

This location is within the possible occurrence areas of several endangered species; however, there do not appear to be any insurmountable environmental concerns that would preclude wind power development. There do not appear to be any significant public concerns regarding visual or noise impacts.

7. Owner Acceptance

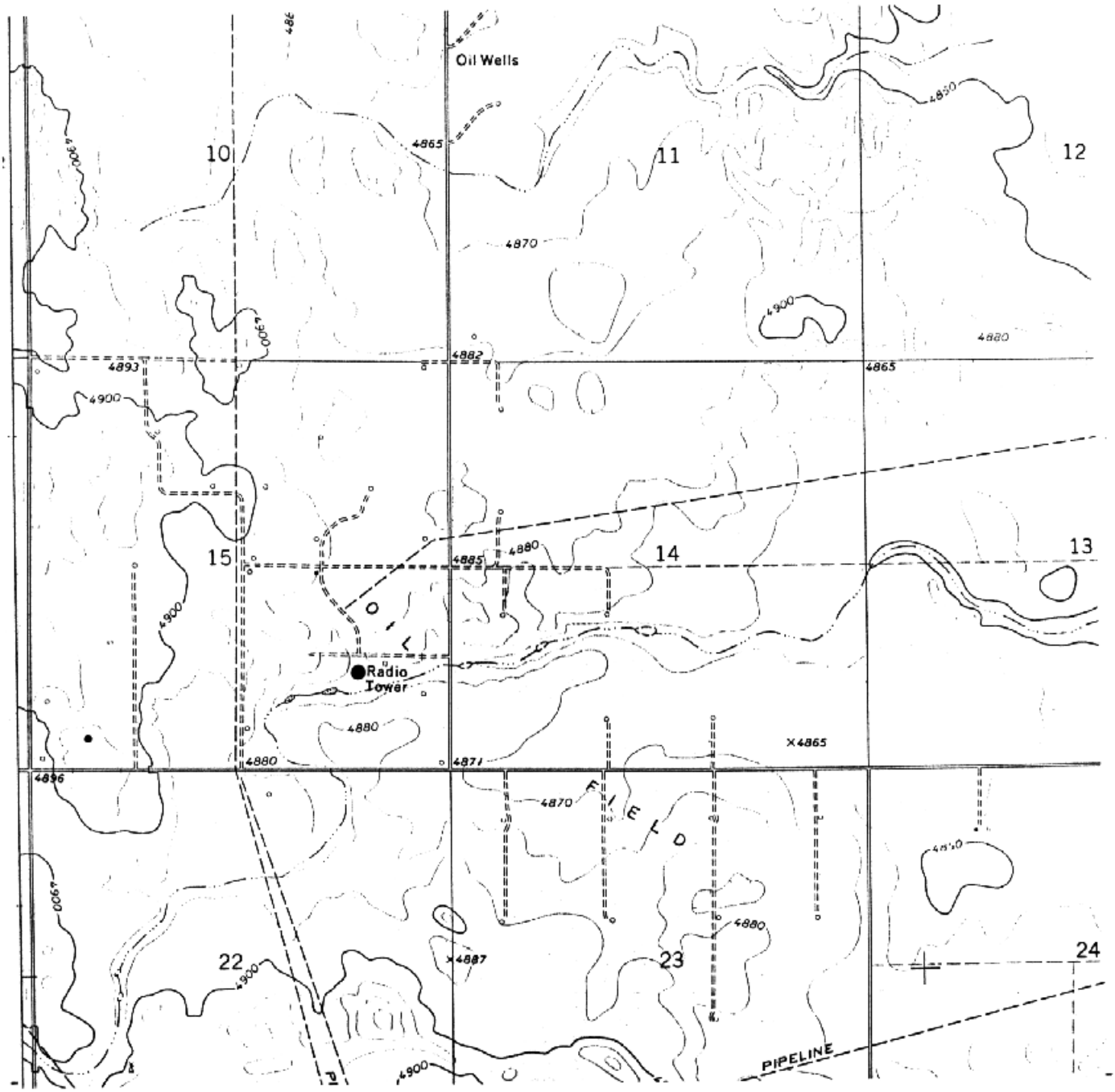
Several local land owners were interviewed and indicated that they would be interested in the possibility of wind energy development in their area and on their property.

8. Cellular Phone Coverage

The cellular signal was checked at the two potential monitoring locations and determined to be sufficient for data transmission; however, it is possible that ground-line telephone service may be available as well.

Existing Tower Owner:

Dallen Juelfs
STANCO Petroleum, Inc
P.O. Box 202
Kimball, NE 69145
(308) 235-2390



Scale: 1:24,000
County: Kimball
Map: Kimball SE, Nebr.

Location: S15-T13N-R55W
Latitude: 41°05'30"N
Longitude: 103°36'30"W

● Monitoring Location (Existing Communication Tower)

N

Kimball Site Map

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **VALENTINE**

Date Visited: November 5, 1994

Summary: A monitoring station, including a new meteorological tower, is proposed to be located on the high plains north of Valentine within five miles of the Nebraska-South Dakota border. The most desirable location in terms of transmission access and exposure may be immediately adjacent to the border. However, due to the location of a casino and the proximity to the Rosebud Indian Reservation, a site has been selected with similar exposure, but which is removed from the potential threat of vandalism. Several local land owners have been identified and at least one has indicated a strong interest in installing a monitoring station. Data collected from the Valentine site will be transmitted to the HPCC base station via ground-line telephone service.

1. Wind Resource

The annual average wind speed at this site is estimated to be approximately 16.3 mph at a height of 120 feet above ground level. UCS estimated the wind resource to be between Class 4 and Class 5. The plain runs for miles along the border and extends into South Dakota. Although there are several significant hills in the vicinity (Crabb Hill is the highest point in Cherry County), there do not appear to be any major obstructions to the wind from any direction.

2. Land Availability

There is sufficient land available to develop a utility-scale wind power plant in the vicinity of the proposed monitoring site. The land is primarily used as pasture land for cattle and growing hay and other feed crops. In most cases, wind energy projects would be compatible with the existing uses. There are no zoning restrictions or airports in the vicinity that would limit wind energy development.

3. Terrain Suitability

The Plain has a few distinct hills but is primarily flat for miles along the South Dakota border. To the south, the edge is steep as the rugged slope drops into the sand hills and town of Valentine. In the plains, there are no major obstacles to wind energy project development and the soil conditions do not pose any unusual problems for construction.

4. Utility Access

A 115 kV line runs north out of Valentine and west along the Nebraska-South Dakota border before heading north into South Dakota. The proposed monitoring site will be located within two (2) miles of the transmission line. While the plain continues to the east, the cost of interconnection to the transmission line will increase with distance.

5. Access and Logistical Support

The City of Valentine has a population of about 3,000 and a full range of typical services. It would be adequate to serve the residential needs of maintenance personnel and local labor may be available.

It is likely that the local grading equipment used to maintain county roads would be available for wind farm construction purposes; however, a crane would probably need to be obtained or purchased from outside of the local community for wind farm construction and maintenance.

Route 83 north from Valentine is a principal, paved, two-lane state highway that runs within a few miles of the potential monitoring locations. The county roads are typical of those found throughout the state and currently support a variety of transportation uses, including trucks used to haul harvested crops, and should adequately support the needs of wind farm construction and maintenance activities.

6. Public/Environmental Sensitivity

This location is within the possible occurrence areas of several endangered species; however, there do not appear to be any insurmountable environmental concerns that would preclude wind power development. The proximity to the Niobrara River, a designated Wild and Scenic River, and steep forested slopes to the south, could pose some debate, particularly because of Whooping Crane and raptor populations. Careful siting to maintain adequate distance from the canyons near the river should reduce potential problems. Additional environmental investigation may be prudent at this site. There are locations suitable for wind power plant development 3-5 miles north of the Niobrara River. If an environmental review indicates this to be a sufficient distance to minimize environmental concerns, there should be no major environmental sensitivities to project development.

7. Owner Acceptance

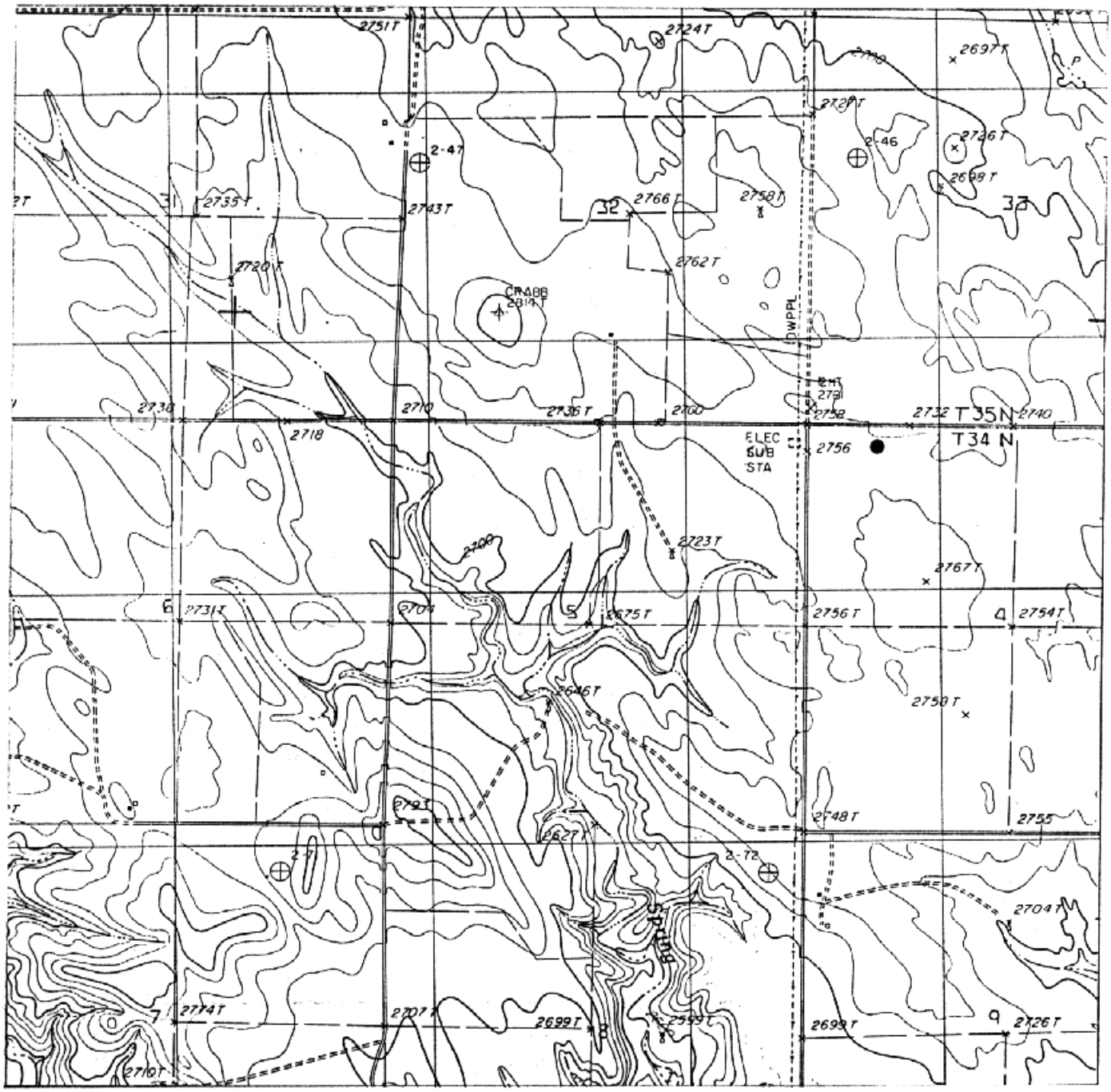
A land owner in the vicinity of the proposed monitoring site was interviewed and he indicated that he was very interested in the potential for wind farm development in the area. He also indicated that other local land owners were likely to be interested as well.

8. Cellular Phone Coverage

Cellular phone coverage in the area is weak or non-existent, but telephone service access is available due to ground lines buried next to some of the county roads.

Land Owner:

Kenneth Stephens
HC 13 Box 22
Valentine, NE 69201



Scale: 1:24,000
County: Cherry
Map: Valentine North, Nebr.-S. Dak.

Location: S4-T34N-R27W
Latitude: 42°57'15"N
Longitude: 100°30'15"W

● Monitoring Location (40M NRG TallTower™)

N

Valentine Site Map

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **SPRINGVIEW**

Date Visited: November 3, 1994

Summary: A monitoring station, including a new meteorological tower, is proposed to be located on a plain near the town of Springview. The plain extends for miles both east and west of town and is bordered by lower valleys to the north and south. Data collected from the Springview site will be transmitted to the HPCC base station via ground line telephone service.

1. Wind Resource

The annual average wind speed at this site is estimated to be approximately 17 mph at a height of 120 feet above ground level. UCS estimated the wind resource as Class 5. The transition from lower to higher elevation land is gradual in most locations and is likely to result in local acceleration of the wind speed. Some property boundaries are marked by rows of trees, but, in general, there do not appear to be any major obstructions that would impact the wind from the prevailing wind directions at the most developable locations.

2. Land Availability

Center pivot irrigation is common in the areas surrounding the town of Springview, and the irrigation well and equipment represent a significant investment on the part of the owner. In most cases, center pivot irrigation and wind energy project development represent non-compatible land uses. However, a significant fraction of the developable land is <u>not</u> irrigated with center pivots and the current land use in these areas is compatible with wind energy project development. A small landing strip with little to no facilities, Springview Municipal Airport, is located roughly ½ mile northeast of the town center, approximately 2 miles to the east of the proposed monitoring location. No known zoning restrictions exist that would restrict wind farm development other than to maintain a reasonable distance from the town and airport facilities.

3. Terrain Suitability

The plain is relatively flat and is unobstructed by natural features other than scattered property boundary tree belts. There are no major terrain features that present obstacles to wind energy project development and the soil characteristics do not present any unusual problems for construction.

4. Utility Access

The main utility access is via a 69 kV transmission line extending approximately 25 miles from an Ainsworth substation where it is interconnected with the 115 kV network.

5. Access and Logistical Support

The town of Springview has a population of about 300 and offers limited services. Local labor may not be available; however, the town is a small, active community that showed a distinct interest in wind energy for their area. Local labor would likely be available from Ainsworth (pop. 1,870).

It is likely that the local grading equipment used to maintain county roads would be available for wind farm construction purposes; however, a crane would probably need to be obtained or purchased from outside of the local community for wind farm construction and maintenance.

Route 183 south out of Springview is a standard, paved, two-lane state highway that runs within a few miles of the potential monitoring location. The county roads are typical of those found throughout the state and currently support a variety of transportation uses, including trucks used to haul harvested crops, and should adequately support the needs of wind farm construction and maintenance activities.

6. Public/Environmental Sensitivity

This location is within the possible occurrence areas of several endangered species; however, there do not appear to be any insurmountable environmental concerns that would preclude wind power development. Conversations with approximately ten local residents and land owners yielded interest and willingness to cooperate to gather local information and simplify the process of installing a wind resource monitoring station. Also, as a result of local land owner's highly-publicized, residential, grid-connected wind energy system, residents are familiar with some of the aspects of modern wind energy applications.

The plain near Springview is roughly four to six (4-6) miles north of the Niobrara River and most of the land has been cultivated for years. The proximity to the Niobrara River, a designated Wild and Scenic River, could pose some debate, particularly because of Whooping Crane and raptor populations. Careful siting to maintain adequate distance from the canyons near the river should reduce potential problems. Additional environmental investigation may be prudent at this site.

7. Owner Acceptance

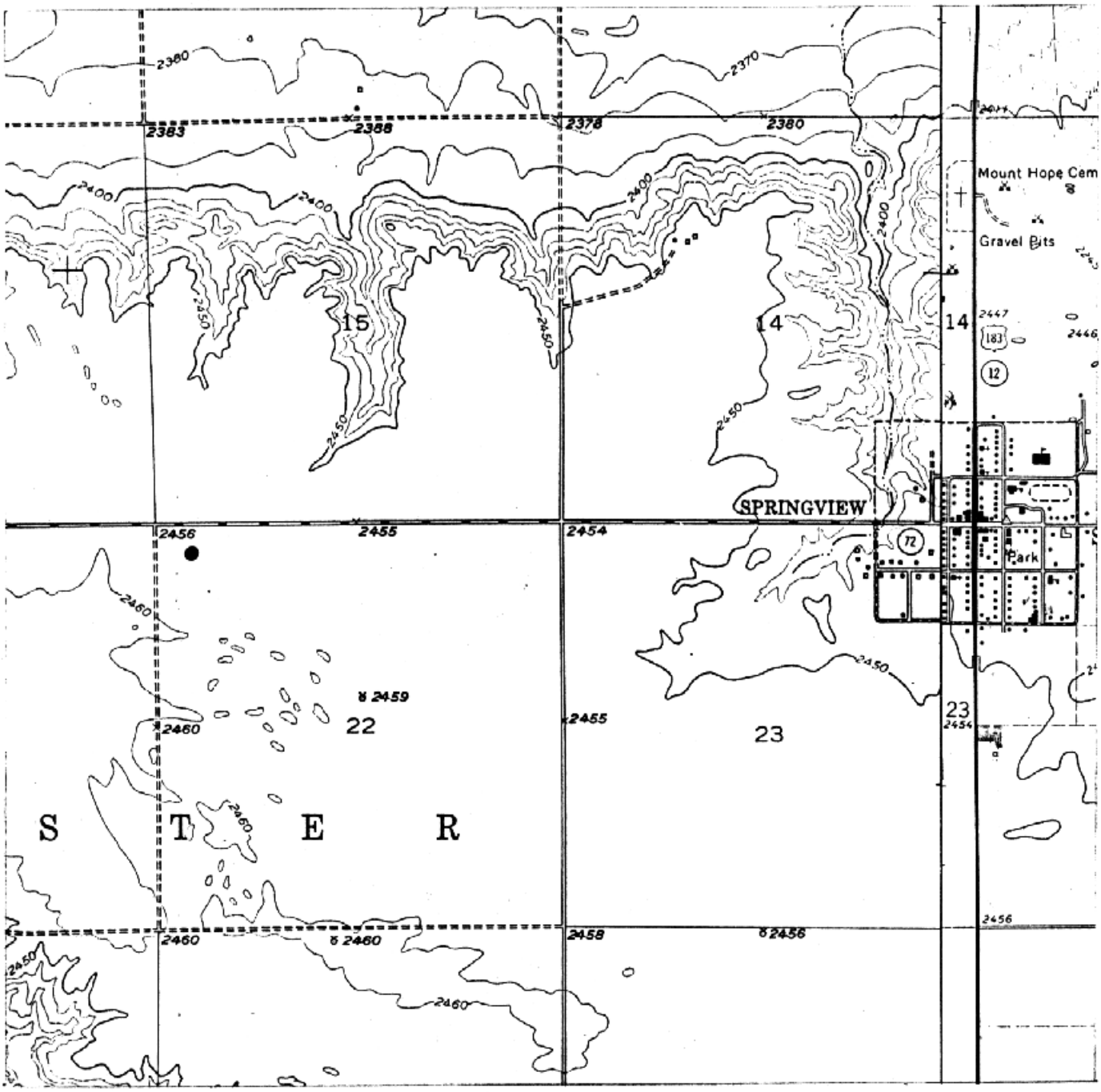
Two land owners with property in well-exposed areas have expressed a willingness to participate in the monitoring program and an interest in wind energy development in the area.

8. Cellular Phone Coverage

Cellular phone coverage in the area is weak or non-existent, but telephone service access is available through ground lines buried next to the county road immediately adjacent to the proposed monitoring site.

Land Owner:

Wayne Forgey
Box 268
Main Street
Springview, NE 68778



Scale:	1:24,000	Location:	S22-T33N-R21W
County:	Keya Paha	Latitude:	42°49'30"N
Map:	Meadville, Nebr. & Springview, Nebr.	Longitude:	99°46'30"W

● Monitoring Location (40M NRG TallTower™)

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Springview Site Map

NEBRASKA WIND ENERGY SITE DATA STUDY
SITE EVALUATION REPORT

Site Name: **STUART**

Date Visited: November 3, 1994

Summary: Monitoring equipment is proposed to be mounted on an existing communications tower on a well-exposed site near the western edge of the plains in northern Holt County. The site is representative of similar locations in the surrounding area. Data collected at the Stuart site will be transmitted to the HPCC base station via ground line (most likely) or cellular phone service.

1. Wind Resource

The annual average wind speed is estimated to be approximately 16.5 mph at 120 feet above ground level. UCS estimated the wind resource to be between Class 4 and Class 5. The landscape is flat, with limited trees in all directions. A few trees are in scattered stands identifying property boundary lines or kept as shelter belts for residences. The area immediately surrounding the base of the tower contains low (approximately 6 foot) trees, but those are not expected to significantly impact the wind speed measurements. Wind shear at the site may vary with crop cultivation cycles in the surrounding fields.

2. Land Availability

There is sufficient land in the vicinity of the proposed monitoring station for development of a utility-scale wind power plant. The areas represented by the monitoring site are the flat plains used for agriculture five to ten miles north of Stuart (and north of nearby Atkinson). Most of the land is used for corn or wheat cultivation with scattered use of center pivot irrigation equipment Several landowners here and in the adjoining (and similar) Atkinson area expressed an interest in participating in this study as well as in potential wind energy projects in the future.

3. Terrain Suitability

The plain is relatively flat and unobstructed by natural features other than scattered property boundary tree belts. There are no major terrain features that present obstacles to wind energy project development and the soil characteristics do not present any unusual problems for construction.

4. Utility Access

The proposed monitoring station is located on property immediately adjacent to a north-south 69 kV line that ties in to the 115 kV transmission system at O'Neill and Ainsworth and is nine (9) miles north of an east-west 115 kV transmission line on that system.

5. Access and Logistical Support

The town of Stuart has a population of about 650 and offers limited services. Local labor may not be available; however, the town of O'Neill (pop. 3,900) is roughly 35 miles to the southeast by road.

It is likely that the local grading equipment used to maintain county roads would be available for wind farm construction purposes; however, a crane would probably need to be obtained or purchased from outside of the local community for wind farm construction and maintenance.

The north-south road adjacent to the proposed monitoring site is a paved, two-lane local road which runs within a few miles of the potential monitoring location. The surrounding county roads are typical of those found throughout the state and currently support a variety of transportation uses, including trucks used to haul harvested crops, and should adequately support the needs of wind farm construction and maintenance activities.

6. Public/Environmental Sensitivity

This location is within the possible occurrence areas of several endangered species; however, there do not appear to be any insurmountable environmental concerns that would preclude wind power development. However, the wetlands to the west of the proposed monitoring site have been identified as an environmentally sensitive area to be avoided due to high expected use by migrating Whooping Cranes.

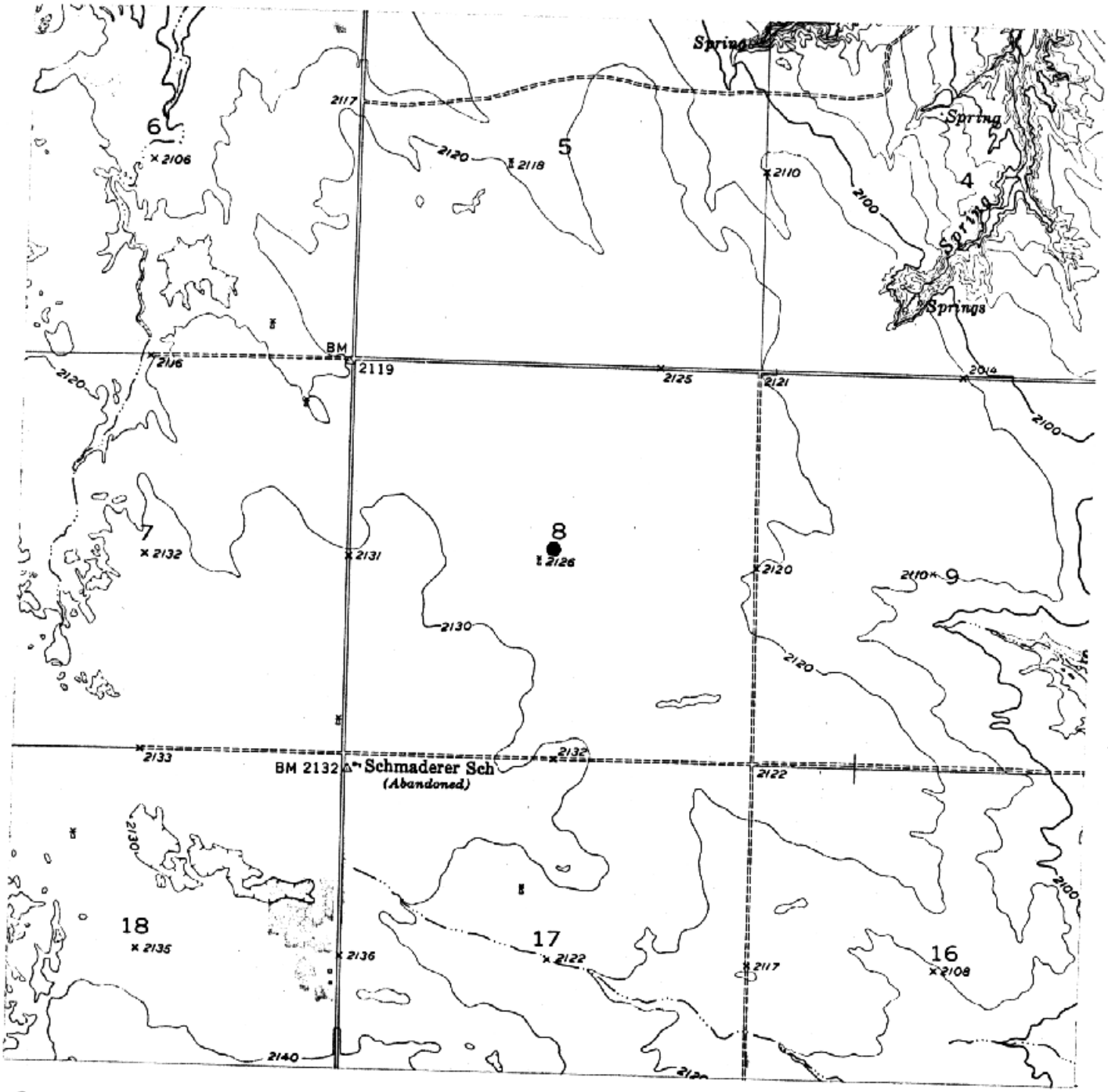
7. Owner Acceptance

Several area land owners were interviewed and expressed interest in the practical details of wind energy development and stated their willingness to participate in the study and to consider wind energy development on their property at some time in the future.

8. Cellular Phone Coverage

Cellular phone coverage at the proposed monitoring locations is marginally acceptable for data transmission using cellular telephone equipment, but the land owner indicated that telephone service access is available through buried ground lines leading to the proposed monitoring site. The availability of telephone service to the monitoring site will be confirmed before a choice of data logger model can be confirmed.

Existing Tower Owner: Tim Peterson



Scale: 1:24,000
County: Holt
Map: Stuart NE, Nebr.

Location: S8-T31N-R15W
Latitude: 42°40'30"N
Longitude: 99°06'00"W

● Monitoring Location (Existing Communication Tower)

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Stuart Site Map