Final Project Report

Bristol Bay Native Corporation Wind and Hydroelectric Feasibility Study

Grant Number DE-FG36-03G013023, A000

Submitted to:

U.S. Department of Energy, Golden, Colorado, Field Office
Tribal Energy Program

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Table of Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

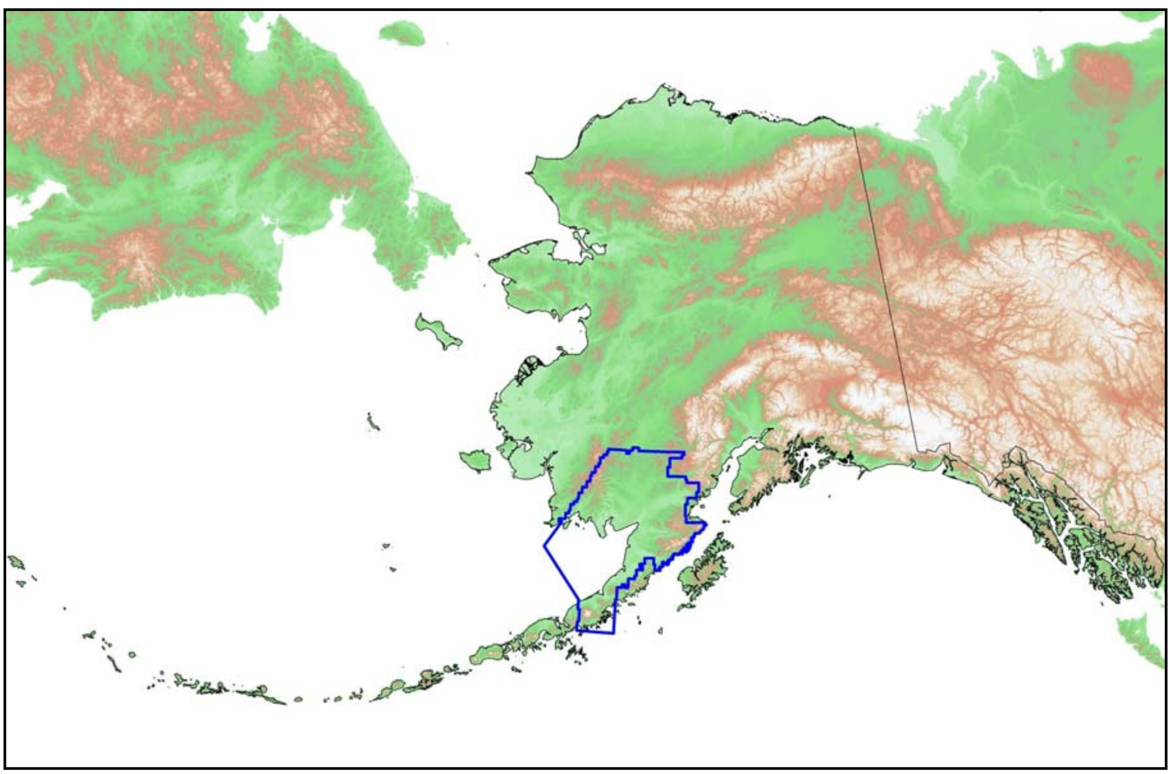
AEA	Alaska Energy Authority
AVEC	Alaska Village Electric Cooperative
BBNA	Bristol Bay Native Association
BBNC	Bristol Bay Native Corporation
DOE	U.S. Department of Energy
ETS	Enterprise Technology Services
met tower	meteorological tower
NEA	Naknek Electric Association
NEC	Nushagak Electric Cooperative
NRG	NRG Systems, Inc.
NREL	National Renewable Energy Laboratory
NWTC	National Wind Technology Center
TEP	Tribal Energy Program
WEATS	Wind Energy Applications and Training

EXECUTIVE SUMMARY

The Bristol Bay Native Corporation (BBNC) grant project focused on conducting nine wind resource studies in eight communities in the Bristol Bay region of southwest Alaska and was administered as a collaborative effort between BBNC, the Alaska Energy Authority, Alaska Village Electric Cooperative, Nushagak Electric Cooperative (NEC), Naknek Electric Association (NEA), and several individual village utilities in the region. BBNC's technical contact and the project manager for this study was Douglas Vaught, P.E., of V3 Energy, LLC, in Eagle River, Alaska.

The Bristol Bay region of Alaska (Figure 1) is comprised of 29 communities ranging in size from the hub community of Dillingham with a population of approximately 3,000 people, to a few Native Alaska villages that have a few tens of residents. Communities chosen for inclusion in this project were Dillingham, Naknek, Togiak, New Stuyahok, Kokhanok, Perryville, Clark's Point, and Koliganek. Selection criteria for conduction of wind resource assessments in these communities included population and commercial activity, utility interest, predicted Class 3 or better wind resource, absence of other sources of renewable energy, and geographical coverage of the region.

Figure 1 Bristol Bay Regional Map of Alaska

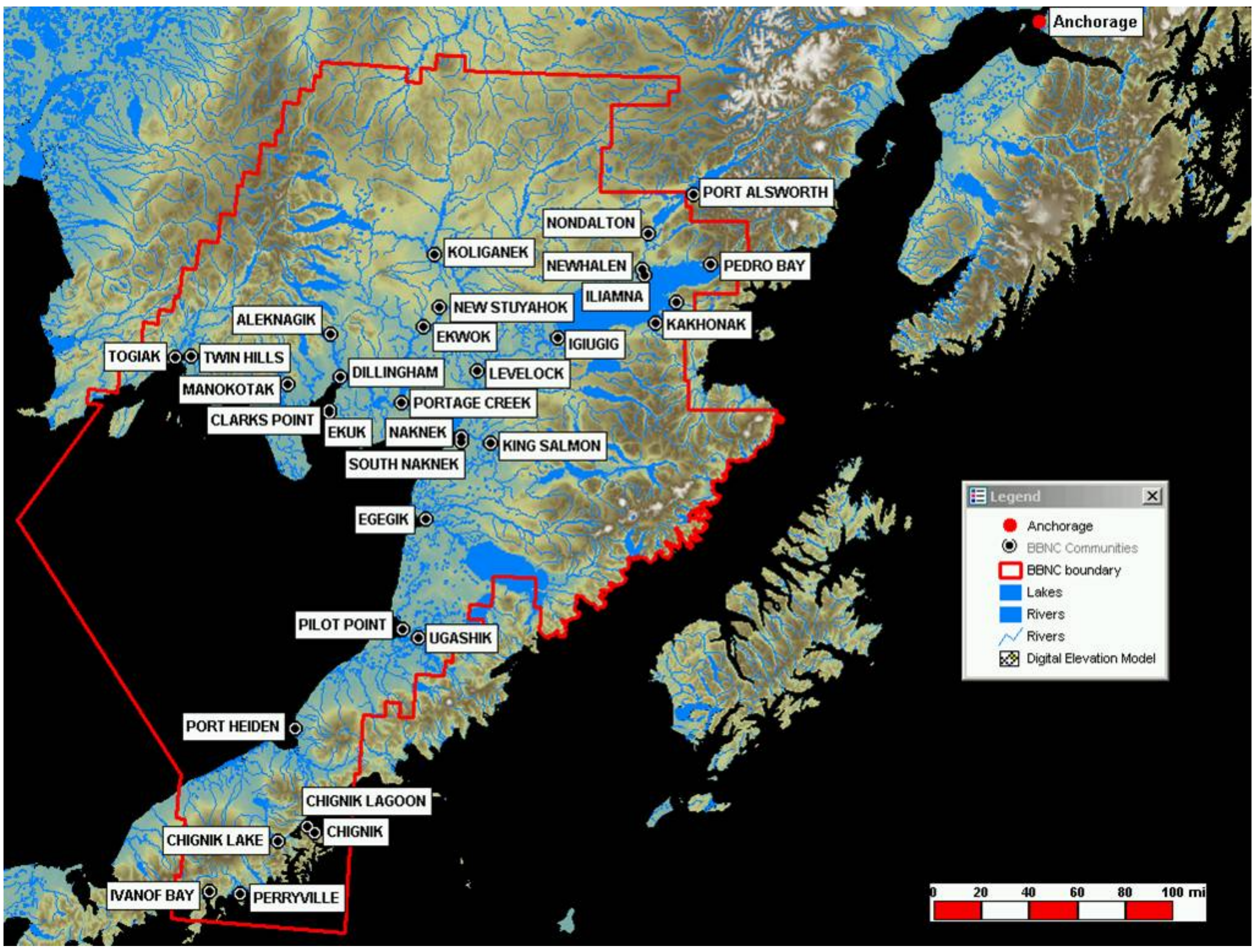


Beginning with the first meteorological tower installation in October 2003, wind resource studies were completed at all sites with at least one year, and as much as two and a half years, of data. In general, the study results are very promising for wind power development in the region with Class 6 winds measured in Kokhanok; Class 4 winds in New Stuyahok, Clark's Point, and Koliganek; Class 3 winds in Dillingham, Naknek, and Togiak; and Class 2 winds in Perryville. Measured annual average wind speeds and wind power densities at the 30 meter level varied from a high of 7.87 meters per second and 702 watts per square meter in Kokhanok (Class 6 winds), to a low of 4.60 meters per second and 185 watts per square meter in Perryville (Class 2 winds).

PROJECT OVERVIEW

This project was defined primarily by the installation of meteorological towers (met towers) and/or sensors on existing tower structures, and collection and analysis of wind data to support local utilities with wind power development efforts. Although there are 29 villages in the Bristol Bay region, we did not have the time, money, nor did we deem it necessary to attempt to instrument and study wind resources in each village. Instead we decided to focus on the two larger hub communities, Dillingham and Naknek, and then on smaller villages selected with consideration given to geographic spread, utility interest, potential for developable wind power, and community request (Figure 2).

Figure 2 Bristol Bay Village Map



Because the U.S. Department of Energy (DOE) grant funds were insufficient to purchase transport and erect met towers for all nine communities (ten sites) eventually completed under this project, we accepted offers of collaboration from the Alaska Energy Authority (AEA) and Alaska Village Electric Cooperative (AVEC) to pool resources and money to enable more fieldwork to be accomplished than would have been possible had we stayed on our own. So, in a general sense, AEA purchased the met towers, paid for transportation from the manufacturer to Anchorage and on to the communities, and in some cases provided a state employee to assist with erection and dismantling efforts. AVEC provided labor assistance, personnel expenses and transport costs for equipment to its two villages within the region, while Bristol Bay Native Corporation (BBNC) provided project management, supervisory labor during field activities, and data management and analysis. The data activities and report formats were coordinated with the larger State of Alaska wind program efforts of AEA.

This project's objective, installation of met towers in several or more communities with a focus toward wind resource data collection and analysis, is different from the early project intent. When initially proposed, our thought had been more of a survey of renewable energy possibilities and a compilation of completed work for every village and community in the region. At the request of DOE and prior to award of the grant, we revised the objective of the grant to focus on the village of Perryville. The leadership of Perryville had expressed interest in alternative energy. Because of the village's location on the Alaska Peninsula, we thought it was a good candidate site for a project that would consist of a met tower installation and data study, preliminary wind-diesel system design, and financial study to support a business plan. However, after project award, but before commencing project activities, BBNC was approached by AEA with the proposal for a multi-village met tower installation effort as described above. Part of the AEA's rationale for their proposal was to maximize field effort and minimize paper studies; in other words, AEA felt that the Bristol Bay region, and Alaska in general, needed solid, high-quality wind resource studies and this need far outweighed the need for another cost study. We agreed that this proposal had significant merit and decided we would like to refocus the project one last time along these lines. This new focus was discussed with DOE and the National Renewable Energy Laboratory (NREL), and approved for the project.

Understanding the change of objectives of this project helps explain why the title of our project, *Bristol Bay Native Corporation Wind and Hydroelectric Feasibility Study,* does not accurately describe the work we eventually accomplished. A wind and hydroelectric feasibility project was the objective of the original proposal, but as mentioned, the objective subsequently changed twice: first to a renewable energy feasibility and business plan project for the Native Village of Perryville, and lastly to a multi-village wind resource assessment effort in collaboration with AEA and AVEC. A better description of the final version of our project would have been "Bristol Bay Regional Wind Resource Assessment", but the original title was never changed and hence has remained.

Besides the collaboration and labor and funding assistance from AEA and AVEC (for New Stuyahok and Togiak), BBNC hired Douglas Vaught, P.E., of V3 Energy, LLC, in Eagle River, Alaska, to manage the project, install and remove the met towers, and perform the data collection and data analysis tasks. Mr. Vaught, in part, appreciates the considerable assistance and technical advice of Mr. Reuben Loewen and Ms. Mia Devine of the AEA. BBNC also appreciates the assistance and contributory labor, equipment, supplies, and planning activities of Nushagak Electric Cooperative (NEC), Naknek Electric Association (NEA), and the village-owned utilities in Perryville, Kokhanok, Clark's Point, and Koliganek.

DESCRIPTION OF ACTIVITIES PERFORMED

This grant project lasted much longer than originally anticipated. It was awarded in September 2003 and originally planned to be complete in December 2004, although the original completion date had been based on an earlier award date. Because of the change of project objectives to a multi-village wind resource assessment and the time requirements necessary to accomplish so much work over a large geographic area, two 1-year extensions were requested and approved, resulting in a project end date of December 2006.

In an effort to describe what happened and when, a chronological summary is presented below to note significant project field events. In addition to those events noted below, data collection and analysis were ongoing efforts throughout the project. Because village wind power is a small niche market, at the beginning of the project there was no analysis software package geared toward small wind. The large and well-known software tools were too expensive and unnecessarily sophisticated for village power applications; through experience we found that analysis using Microsoft® Excel worked, but was tedious and difficult to standardize among all the sites. The solution to our problem came with the development and release of the Windographer Software Program by Tom Lambert, owner of Mistaya Engineering, Inc., in Calgary, Alberta, Canada. We have used the Windographer software for the past two years from the very first release to the latest version with its quite comprehensive capabilities. All analyses and graphics in the Wind Resource Reports in the appendices were produced with the use of Windographer.

YEAR 2003

Wind Energy Workshop

Several significant project activities occurred immediately after BBNC was awarded the grant in September 2003. First was project funding support for and attendance at a Wind Energy Workshop in Dillingham in early October 2003. This workshop was sponsored by AEA as a kick-off to the State's wind resource assessment project (with which BBNC had recently decided to collaborate). Participants included a large number of Alaskans involved with rural utilities and representatives from NREL and their consultants, equipment suppliers, regional organizations and interested citizens. This two-day project, held at the community Fire Hall and Bristol Bay Native Association (BBNA) property consisted of a number of lectures and presentations on many aspects of rural wind power, and during the final day included a demonstration sensor assembly and mounting, datalogger installation, and erection and lowering of one of AEA's new 30-meter NRG Systems, Inc., (NRG) met towers on the BBNA land.

Wind Site Reconnaissance

The workshop was followed immediately by a charter reconnaissance flight to investigate potential wind power/met tower locations in the Dillingham area, and in the village of Togiak. Togiak is an AVEC village and AVEC had expressed a desire to install a met tower as soon as possible to begin collecting data to support a possible wind-diesel power plant design that they are considering. This flight included Doug Vaught; John Wade; NREL's wind consultant from Portland, Oregon; Karen Kronner, an avian specialist from Pendleton, Oregon; and three AVEC employees – Brent Petrie, Eric Marchegiani, and Marie Becker. A number of potential met tower locations were selected as good possibilities for wind power development.

New Stuyahok Met Tower Installation

The day after the reconnaissance flight, Doug Vaught, Eli Reich of Global Energy Concepts of Seattle, and Eric Marchegiani and Marie Becker of AVEC, traveled to New Stuyahok (the second AVEC village in the region) with the 30-meter NRG met tower used for the demonstration in the Wind Energy Workshop and the intent to install it at a site previously selected and approved by AVEC as a possible site for wind turbine installation during a power plant upgrade project being planned. With the assistance of a power plant operator and a few interested residents and school students, the tower was erected in a one-day effort and began collecting data for the project's first field effort.

Tribal Energy Program (TEP) Review Meeting and Wind Energy Applications and Training (WEATS)

In mid-October Doug Vaught of V3 Energy, LLC, and April Ferguson of BBNC attended the week-long TEP Review Meeting in Colorado where they presented our planned project. In late October, Mr. Vaught returned to Colorado to attend the five-day Wind Energy Application and Training (WEATS) at the National Wind Technology Center (NWTC) in Boulder, Colorado. WEATS was a great introduction not only to the basics of wind energy and wind resource testing, but also a very worthwhile tour of the NWTC and also provided a great opportunity to spend time with NREL staff discussing how best to proceed with the wind analysis project.

YEAR 2004

Dillingham Met Tower Installation

The first field effort of the year occurred in April when Doug Vaught traveled to Dillingham for two days to erect a 30-meter met tower (owned by the AEA wind energy program) on Choggiung Ltd. (a local Native corporation) land near the Kanakanak Hospital. BBNC paid Choggiung Ltd. a nominal fee for this purpose. This site was selected during the previous October reconnaissance flight because of the relatively open nature of the terrain in an otherwise heavily forested community, easy road access, proximity to power lines, and uncomplicated land ownership. Mr. Vaught was assisted by James Thames, the NEC Operations Manager, and several of his line crew. Because of the excellent assistance of NEC, this installation occurred very quickly.

The following day, Mr. Vaught worked with Mr. Thames and a line crewman to install anemometers and a wind vane on the approximately 130-foot-tall State of Alaska Department of Administration Enterprise Technology Services (ETS) communications tower on a prominent knoll on Woodriver Road. A memorandum of understanding was signed between the State of Alaska, ETS, and BBNC to install our meteorological monitoring equipment on their tower. Although a lattice tower of this nature is not an ideal measurement platform by any means, the State made it available to BBNC and NEC, and we elected to install sensors and monitor at this site. The alternative would have been no monitoring at this location, as a second met tower was not available in Dillingham at the time. The labor and expense assistance from NEC were a welcome contribution to this project and were not charged to the grant.

Naknek Met Tower Installation

In mid-July Doug Vaught traveled to Naknek for two days to install an AEA-provided 30-meter met tower at a site near the borough landfill. This site was one of two in Naknek identified as desirable for potential wind power development by meteorologist John Wade and Larry Flowers of NREL in October 2003. The landfill site is situated on a hill with excellent wind exposure in all directions, but particularly to the northeast which is the direction of winter prevailing winds. Mel Coghill, NEA's Operations Manager, and several of his crew provided vehicles and equipment and assisted with the tower installation. As with NEC in Dillingham, the NEA labor and expenses were a welcome contribution to this project and were not charged to the grant.

Kokhanok Met Tower Installation

In mid-August Doug Vaught traveled to Kokhanok on the south shore of Lake Iliamna to install another AEA-provided 30-meter met tower. Site selection for Kokhanok had begun earlier in the summer with reviews of Alaska Department of Community and Economic Development maps and discussions with village representatives. A site of superior potential was chosen. It is located near the end of a natural spit of land that juts north into the Lake. This is the location of the former village airstrip, which was moved a number of years ago to a calmer location because of strong winds on the spit. Indications from local residents were that it is frequently very windy at the site and too windy for any future residential or commercial use. The local plant operator and his assistant assisted Mr. Vaught with the tower installation.

Alaska Peninsula Reconnaissance Flight

In early August, Doug Vaught accompanied Reuben Loewen, AEA wind program manager, and meteorologist John Wade on a reconnaissance flight to the Alaska Peninsula to scout wind development locations. The villages of Port Heiden, Chignik Bay, and Chignik Lagoon were investigated. This flight was paid for by the AEA as part of their efforts to develop wind power in rural Alaska. While on the ground in Port Heiden, Doug, Reuben, and John assisted Scott Anderson of Port Heiden with a non-functional datalogger mounted on a 10 kilowatt Bergey turbine that the community had installed. At that time, AEA was interested in installing a full-scale wind-diesel system in Port Heiden; however, that plan has been postponed indefinitely.

Note: At one point it was our intent to add the analysis of wind resources in Port Heiden to our project, but because AEA was working so closely with the community and writing their own wind resource assessment, we decided that it would be redundant. AEA's Port Heiden analysis is available on AEA's wind program website.

Togiak Met Tower Installation

In late August, Doug Vaught traveled to Togiak and, with the assistance of the power plant operator and a local man hired for this effort, installed the 30-meter NRG tall tower in Togiak that had been stored at the power plant since the previous autumn. Because Togiak is an AVEC community, AVEC and AEA (owner of the met tower) paid most of the expenses for this tower installation. Togiak is an important and relatively large Bristol Bay region village, and BBNC supported plans to development wind power there in an effort to lower electrical costs and help spur economic development.

Chignik Lagoon and Perryville Met Tower Installations

In early October Doug Vaught, traveled with Reuben Loewen, AEA's Wind Energy Program Manager, to the lower Alaska Peninsula to install wind sensors in Chignik Lagoon and a met tower in Perryville. In Chignik Lagoon, an anemometer, wind vane, and temperature sensor were installed on an existing 60-foot tower that supports an out-of-commission Jacobs wind turbine installed approximately 20 years ago. This turbine is on private land and landowner permission was obtained.

The following day, Doug Vaught and Reuben Loewen flew with an NRG 30-meter tower package on a chartered flight from King Salmon to Perryville. Perryville is an isolated but picturesque native village on the south shore of the Alaska Peninsula. Two men from the community assisted with the installation of the tower on a village-owned site just inland of the shoreline barrier sand dunes and near the village power plant.

Wind-Diesel Conference

Doug Vaught and Tiel Smith, BBNC's Land and Resources Manager, attended the NREL-sponsored International Wind-Diesel conference in Girdwood, Alaska, September 28 through October 2, 2004. Tiel Smith attended only the Girdwood workshop portion; however, Doug Vaught also participated in a conference field trip on October 1 and 2 to inspect and observe wind-diesel power systems in St. Paul, Kotzebue, and Selawik, Alaska. The trip included an overnight stay in Kotzebue.

Tribal Energy Program Review Meeting

In mid-October, Tiel Smith and Doug Vaught attended the Tribal Energy Program Review Meeting in Golden, Colorado. Tiel and Doug presented a progress report of the BBNC renewable energy grant project to the meeting attendees.

YEAR 2005

Clark's Point Met Tower Installation

In early July, Doug Vaught traveled with Mia Devine, the AEA assistant program manager, and two AEA summer university student interns, Hannah Manser from the University of Alaska Anchorage and Zachary Adam from the University of Washington, to Clark's Point to for a day and a half visit to install an AEA-owned 30-meter met tower (note that AEA also paid for transport of the tower to Clark's Point) on a site near a bluff overlooking Bristol Bay. The site was chosen because it is relatively near the power plant and existing power lines; it is on property controlled by the city, but it is not too close to existing homes and is reasonably far from the airport.

New Stuyahok Met Tower Removal

After the Clark's Point met tower installation, Doug, Mia, Hannah, and Zach flew to New Stuyahok for the night. On the following day, with the assistance of the local power plant operator, they lowered the 30-meter met tower that had been collecting data since October 2003 and packaged it for transport.

Koliganek Met Tower Installation

Following removal of the New Stuyahok met tower, an aircraft was chartered at AEA's expense, as part of their wind-monitoring program, to fly the tower and Doug to Koliganek. Mia, Hannah, and Zach flew to Koliganek on scheduled flights via Dillingham. The initial selected site in Koliganek proved to be unsatisfactory because of the presence of permafrost soils which had not been anticipated, and for which appropriate anchors had not been purchased. After discussion with a village council representative, an alternate site on an abandoned airstrip was selected. This new site is clearly superior in that the soils are stable and future wind power development would be relatively easy with respect to better access and easier foundation issues.

Dillingham – Kanakanak Met Tower Removal

In early October, Doug Vaught returned to Dillingham to remove the met tower installed in April 2005. He was assisted once again by James Thames, NEC's Operations Manager, and a member of his crew. Because the met tower is owned by AEA, arrangements were made to transport it by air freight to Anchorage for use elsewhere in the State.

YEAR 2006

Naknek Electric Association Board Presentation

In late January, Doug Vaught and Reuben Loewen of AEA traveled to Naknek to present a synopsis of the wind resource data collected in Naknek since July 2004 and a general discussion of the wind power development process to the NEA board of directors. The presentation was during NEA's monthly board meeting. There was strong board interest in the possibility of wind power for the utility, given the high and increasing cost of diesel fuel in the region.

Nushagak Electric Cooperative Board Presentation

As he had done in Naknek the previous month, Doug Vaught traveled to Dillingham in late February to present a synopsis of Dillingham's wind resource and information regarding wind power development to the NEC board of directors. The presentation was during the monthly board meeting, but in this case the audience also included several local residents and a reporter for KDLG, Dillingham's public radio affiliate. After the presentation, Doug was interviewed by the KDLG reporter and that interview was broadcast statewide on the following day on the Alaska Public Radio Network.

NEC, NEA, and Kokhanok Grant Proposals

During February and March, Doug Vaught assisted NEA, NEC, and Kokhanok Village Council Utility with preparing the wind resource assessments and other information for grant proposals in response to Requests for Proposal offered by the AEA for rural communities in Alaska to develop wind power. The purpose of the grant was to lessen rural Alaska's dependence on fossil fuel for electric power generation. In the case of Kokhanok, this proposal was written with the assistance of Dennis Meiners of Powercorp Alaska, LLC. Tom Hawkins, Tiel Smith, and April Ferguson of BBNC also assisted with this effort by working with individuals in the communities to obtain and organize information needed for the grant applications. Although AEA awarded their grant to a community not in the Bristol Bay region, this effort helped the three utilities plan for eventual wind power projects.

Kokhanok Met Tower Removal

In mid-June, Doug Vaught traveled to Kokhanok with Reuben Loewen of AEA and Dennis Meiners of Powercorp Alaska, LLC, to remove the met tower installed two years previous and return it to Anchorage. They were assisted by the power plant operator and another man from the village. Dennis accompanied Doug and Reuben at his expense in order to get a better understanding of Kokhanok's layout and electrical power infrastructure, and the logistical issues involved should a wind-diesel power project involving Powercorp ever be constructed in Kokhanok.

Clark's Point and Koliganek Met Tower Removals

In early July, Doug Vaught traveled with Mia Devine of AEA to Clark's Point and Koliganek to remove the met towers installed the previous July and return them to Anchorage via Dillingham. Also during this trip, Doug and Mia removed the datalogger from the State ETS tower on Woodriver Road in Dillingham; NEC personnel later removed the anemometers and wind vane from the tower.

Naknek Met Tower Relocation

In mid-July, Doug Vaught traveled to Naknek to relocate the 30-meter met tower installed at the borough landfill two years prior. Despite its proximity to existing power lines and its location between the major load centers of Naknek and King Salmon, NEA decided that the landfill location was not really a desirable site for a wind power project. Apparently, the borough has intentions to expand the landfill toward the direction of the met tower placement. A less significant issue was the problems associated with large numbers of brown bears in the area and their attraction to the landfill; this was seen as an undesirable nuisance issue for construction and operation of wind turbines.

Instead of considering the second site selected by John Wade and Larry Flowers in 2003 (later deemed by NEA as too close to a small aircraft airfield), NEA preferred to move the met tower to their new preferred wind power project location closer to Naknek itself, and also closer to Naknek Bay where the winds are perceived to be stronger. Doug Vaught was assisted with this two-day effort to move the met tower by a NEA line crew. With the termination of this grant project, NEA has accepted responsibility for data analysis and the eventual removal of the met tower from this site.

Tribal Energy Program Review Meeting

In October, Tiel Smith and Doug Vaught attended the Tribal Energy Program Review Meeting in Golden, Colorado. Tiel and Doug presented their final progress report to DOE and other tribal participants of the BBNC renewable energy grant project.

Manokotak Site Preparation

The leadership in the village of Manokotak, approximately midway between Dillingham and Togiak but not connected by road to either, had expressed strong interest throughout the grant project for a wind resource assessment, but the constraints of money, time, and met tower availability prevented it. To assist Manokotak, BBNC helped the village select and permit a site for a met tower in late autumn. At BBNC's expense this spring or summer, our intention is to erect a met tower in Manokotak and conduct a wind resource study for them.

YEAR 2007 WRAP-UP

A few field-related tasks were not fully complete at the end of the grant project period in December 31, 2006. These tasks include the met tower in Togiak, the met tower in Perryville, and the datalogger and instrumentation in Chignik Lagoon. AVEC has stated that they plan to remove the Togiak met tower in spring and make it available for use in Manokotak. The met tower in Perryville is still in place and the instrumentation in Chignik Lagoon is still attached to the old, inoperative Jacobs wind turbine. This situation will be discussed with AEA and it is anticipated that they will arrange for removal of this equipment in Perryville and Chignik Lagoon using their wind program funds.

PROJECT TEST RESULTS SUMMARY

Dillingham is the largest community in the Bristol Bay region, with approximately 2,300 residents. It, along with Naknek/King Salmon, are hub communities with a concentration of industry and services not typically found in the smaller outlying villages. Our intent at the beginning of this project was to concentrate initially on Dillingham and Naknek with the philosophy that helping to solve the problems of high energy costs in the Bristol Bay hub communities would have a ripple effect that would indirectly benefit the smaller villages as well. With this in mind, early on in the project we worked with NEC in Dillingham and NEA in Naknek to identify sites and secure permits and landowner permission to install met towers.

Once the Dillingham and Naknek met towers were installed and wind resource studies started, we devoted more attention to planning which villages in the region we wanted to concentrate on. The AVEC villages of New Stuyahok and Togiak were pre-selected in a sense that before this grant was even awarded, AVEC had expressed the desire for AEA to install State met towers in the two villages. After award of this grant and the initiation of the collaboration model of work, New Stuyahok and Togiak were an immediate focus of attention.

The other villages eventually chosen for wind resource studies were, for the most part, selected in 2004 by a combination of geographic representation, anticipated likelihood of a developable wind resource, and expression of community interest. Several communities in the Bristol Bay region already had wind resource studies completed or underway either by an interest group in the case of Sustainable Energy Coalition for the Alaska Peninsula for Port Heiden and Pilot Station, or Chignik which was pursuing grant funding for a met tower through another agency. For one group of three villages in the region – Iliamna, Nondalton, and Newhalen – a combination of a low predicted wind resource and reliance on a very good hydroelectric power supply led us to look elsewhere for villages to conduct wind resource assessments. Eventually we installed met towers or instrumentation and conducted wind resource studies in the non-AVEC villages of Kokhanok, Perryville, Chignik Lagoon, Clark's Point, and Koliganek. The wind study efforts were successful in all locations, except Chignik Lagoon where a loss of contact with the responsible person in the village and then eventual recovery of a damaged and unreadable data card resulted in essentially no recoverable data from this site.

In all, eight communities representing nine separate wind resource studies were successfully completed in this project. Chignik Lagoon was not successfully studied and will not be presented in the discussion below. For all nine studies, in addition to the summary information presented in this section, separate full reports are included in the appendices. These full reports are also available online on the Alaska Energy Program wind resource website at http://www.akenergyauthority.org/programwindresourcedata.html. Below is summary information for the nine wind resource studies completed for this project, listed in order of data start date.

NEW STUYAHOK

A met tower, erected in October 2003 on village corporation property near the airport, was the first one installed in the Bristol Bay region for this project. The met tower was removed in July

2005 and erected in the upriver village of Koliganek as a continuation of the grant wind resource study project.

The wind resource report for New Stuyahok indicates a low Class 4 wind resource at 50 meters, although as explained in the report, the 50-meter wind power density is high compared to the 30-meter wind power density and likely due to the high wind shear measured at the particular site. If another met tower were to be installed in New Stuyahok, but in a location less affected by trees and other ground clutter, it is predicted that a lower wind shear would be measured and hence Class 3 winds at 50 meters would be calculated.

AVEC, the electrical utility for New Stuyahok, is at present in the design and planning stage of a new bulk fuel and power plant upgrade project. The desire and intent of AVEC is to incorporate wind power into the New Stuyahok power system with a medium to high penetration wind-diesel hybrid system. The Wind Resource Report completed for New Stuyahok was forwarded to AVEC and will be used to support the design effort. Specific wind turbines have not yet been selected, although, AVEC has installed Northern Power Systems Northwind 100 turbines in other communities and has been pleased with their performance.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 3 and 4), from the New Stuyahok, Alaska Wind Resource Report (see Appendix A), is presented below in Table 1.

Table 1 New Stuyahok Summary Data

Wind power class	Class 4 – Good
Wind speed annual average (30 meters)	5.46 m/s
Maximum wind gust	33.6 m/s, November 2004
Mean wind power density (50 meters)	414 W/m^2 (calculated*)
Mean wind power density (30 meters)	232 W/m^2 (measured)
Weibull distribution parameters	k = 1.76, c = 6.29 m/s
Roughness Class	4.39 m (suburban)
Power law exponent	0.382 (high wind shear)
Turbulence Intensity	0.151 (moderate to high)
Data start date	October 10, 2003
Data end date	July 7, 2005

*Wind power density at 50 meters is likely an overestimate due to a high measured power law exponent

Figure 3 New Stuyahok Seasonal Wind Speed Profile

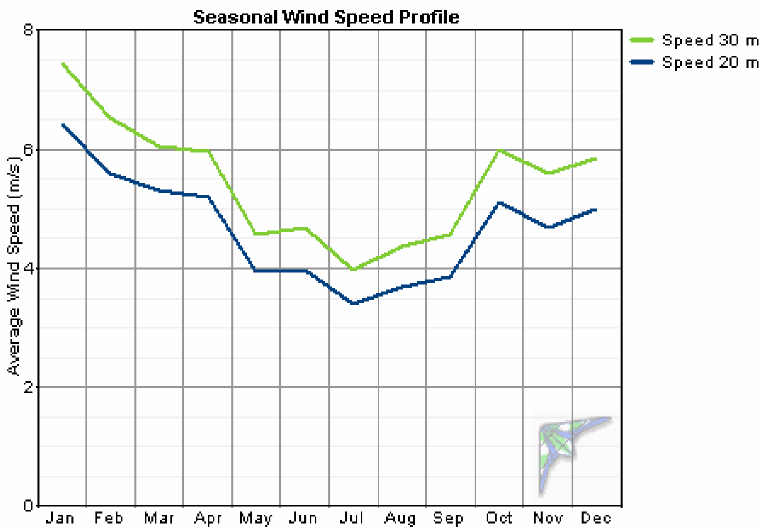
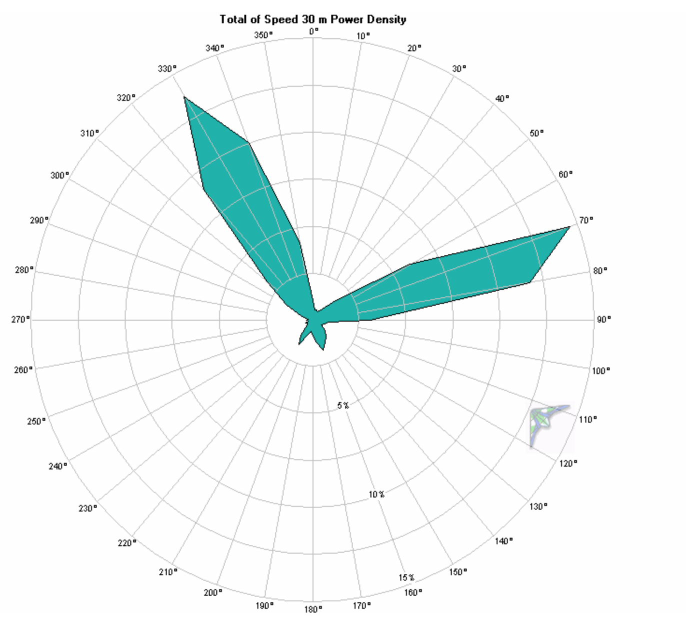


Figure 4 New Stuyahok Wind Power Density Rose



DILLINGHAM – KANAKANAK

The measured wind resource at the Dillingham Kanakanak site showed good potential for wind energy development with a high Class 3 wind power density and good turbulence behavior. Should wind power be developed in Dillingham, this site presents easy road access, nearby power infrastructure, is well away from the airport, and the owner is enthusiastic about wind development. Potential land area at this site available for turbine installations is relatively large, so it is reasonable that a more open location than the site chosen for the met tower can be found. The relatively high wind shear measured at the site is likely due to the nearby forest margin that undoubtedly negatively impacted the 20-meter anemometer on the met tower.

The wind power density at the Kanakanak site in Dillingham is about average, compared to other study sites in the Bristol Bay Region. But, because Dillingham is the largest community in the region and given the high cost of energy and the associated high cost of business in Dillingham, the potential benefit of wind power is greater than in smaller communities with stronger wind resources. If wind power is developed in the future, care must be exercised to find the most suitable site free that will be free of upwind ground obstructions and place turbines on high towers to maximize the available wind resource.

At this time, however, the board of NEC, Dillingham's electric utility company, has elected to not consider wind power for any part of its near-term energy needs. This consideration may change, of course, should the price of diesel fuel increase or other potential alternative sources of power prove to be infeasible.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 5 and 6), from the Dillingham, Alaska Wind Resource Report – Kanakanak site (see Appendix B), is presented below in Table 2.

Table 2 Dillingham – Kanakanak Summary Data

Wind power class	Class 3 – Fair
Wind speed annual average (30 meters)	5.78 m/s
Maximum wind gust	30.9 m/s, April 2005
Mean wind power density (50 meters)	374 W/m^2 (calculated)
Mean wind power density (30 meters)	230 W/m^2 (measured)
Weibull distribution parameters	k = 2.01, c = 6.29 m/s
Roughness Class	3.66 (forest)
Power law exponent	0.286 (high wind shear)
Turbulence Intensity	0.124 (moderate)
Data start date	April 23, 2004
End data date	October 5, 2005

Figure 5 Dillingham – Kanakanak Seasonal Wind Speed Profile

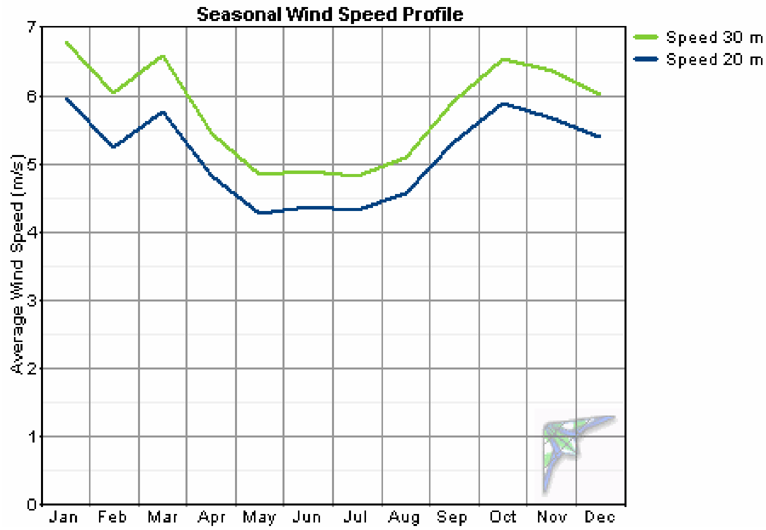
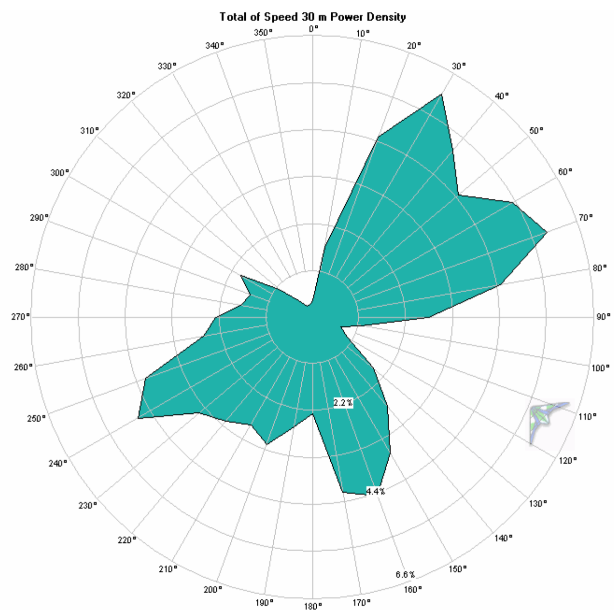


Figure 6 Dillingham – Kanakanak Wind Power Density Rose



DILLINGHAM – WOODRIVER ROAD

The measured wind resource at the Dillingham Woodriver Road site also showed good potential for wind energy development with a high Class 3 wind power density and good turbulence behavior. As at the Kanakanak site, and compared to other sites in the Bristol Bay Region, the wind power density at the Woodriver Road site in Dillingham is about average.

Should wind power be developed in Dillingham, this site, similar to the Kanakanak site, also presents easy road access and nearby power infrastructure, but it is closer to the airport and land ownership questions have not yet been researched. Potential land area at this site available for turbine installations is not especially large, but there is sufficient room for a few larger turbines. The relatively high wind shear measured at the site is likely due to the positioning of the anemometers on the tower and the lattice nature of the tower itself, as well the presence of trees nearby.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 7and 8), from the Dillingham, Alaska Wind Resource Report – Woodriver Road site (see Appendix C), is presented below in Table 3.

Table 3 Dillingham – Woodriver Summary Data

Wind power class	Class 3 – Fair
Wind speed annual average (33 meters)	5.99 m/s (measured)
Wind speed annual average (30 meters)	5.88 m/s (calculated)
Maximum wind gust	31.3 m/s, April 2005
Mean wind power density (50 meters)	375 W/m^2 (calculated)
Mean wind power density (33 meters)	289 W/m^2 (measured)
Mean wind power density (30 meters)	272 W/m^2 (calculated)
Weibull distribution parameters	k = 1.85, c = 6.64 m/s
Roughness Class	3.06 (forest)
Power law exponent	0.235 (high wind shear)
Turbulence Intensity	0.110 (moderate)
Data start date	April 22, 2004
End data date	July 13, 2006

Figure 7 Dillingham – Woodriver Seasonal Wind Speed Profile

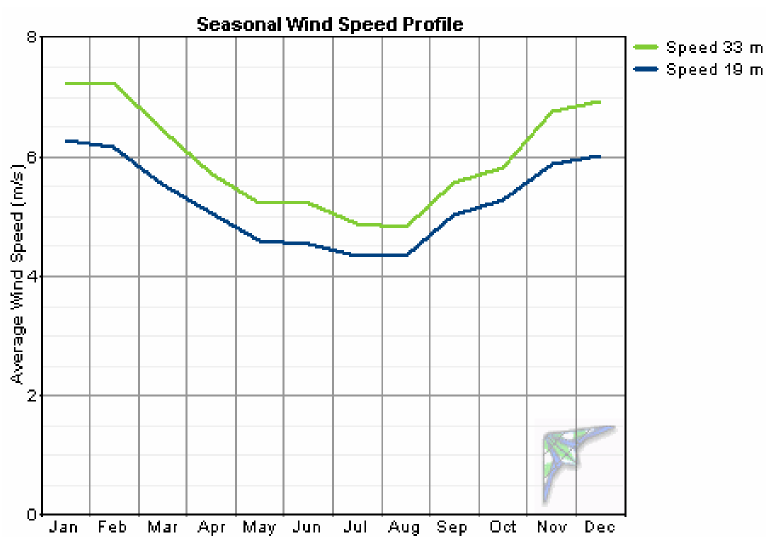
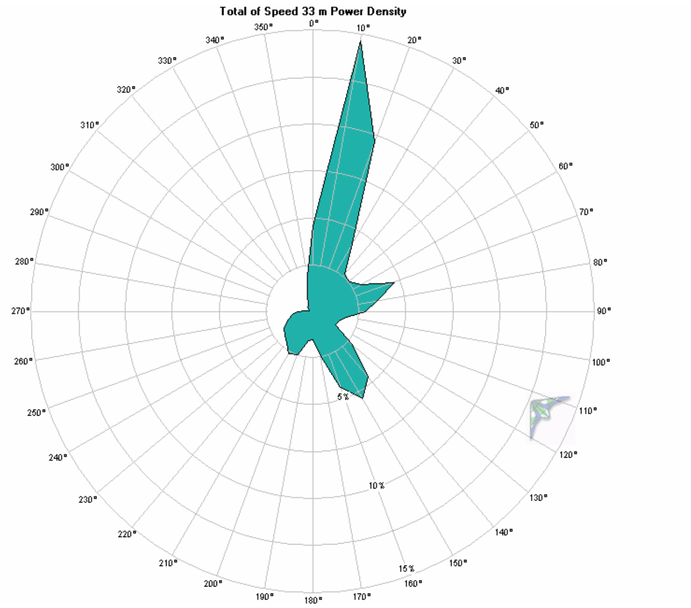


Figure 8 Dillingham, Woodriver Wind Power Density Rose



NAKNEK

The measured wind resource in Naknek showed good potential for wind energy development with a mid-to-high Class 3 wind power density and excellent turbulence behavior. The monitored site, near the borough landfill, does exhibit more wind shear than desirable, necessitating tall turbine towers, and, in other respects, may not be desirable to develop. However, there is plenty of similar terrain nearby that would be suitable for wind power development. In July 2006, the meteorological test tower was moved to a site closer to Naknek Bay, which may prove superior to the landfill site because of its better exposure to onshore winds. Early data recovery from the new site suggests that this will be the case.

NEA is keenly interested in developing sources of renewable energy to augment their diesel power system and view wind power as a strongly viable solution. Given the more open terrain and proximity to the bay, the new met tower site is now the designated wind power site in Naknek. NEA has initiated engineering and permitting work necessary for installation of wind turbines, should they decide to develop wind power in the near future.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 9 and 10), from the Naknek, Alaska Wind Resource Report (see Appendix D), is presented below in Table 4.

Table 4 Naknek Summary Data

Wind power class	Class 3 – Fair
Wind speed annual average (30 meters)	6.22 m/s
Maximum wind gust	32.9 m/s, April 2005
Mean wind power density (50 meters)	368 W/m^2
Mean wind power density (50 meters)	301 W/m^2
Weibull distribution parameters	k = 1.99, c = 7.02 m/s
Roughness Class	1.86 (few trees)
Power law exponent	0.175 (moderate wind shear)
Turbulence Intensity (30 meters)	0.102 (excellent)
Data start date	July 27, 2004
Data end date	July 19, 2006

Figure 9 Naknek Seasonal Wind Speed Profile

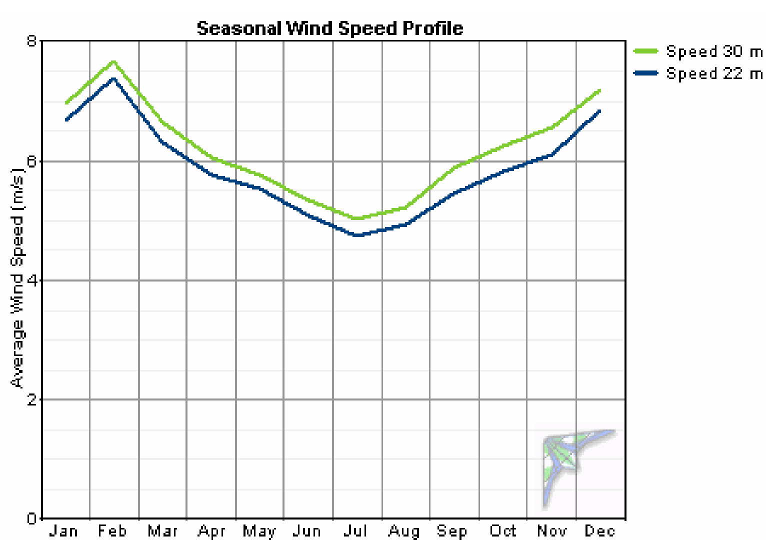
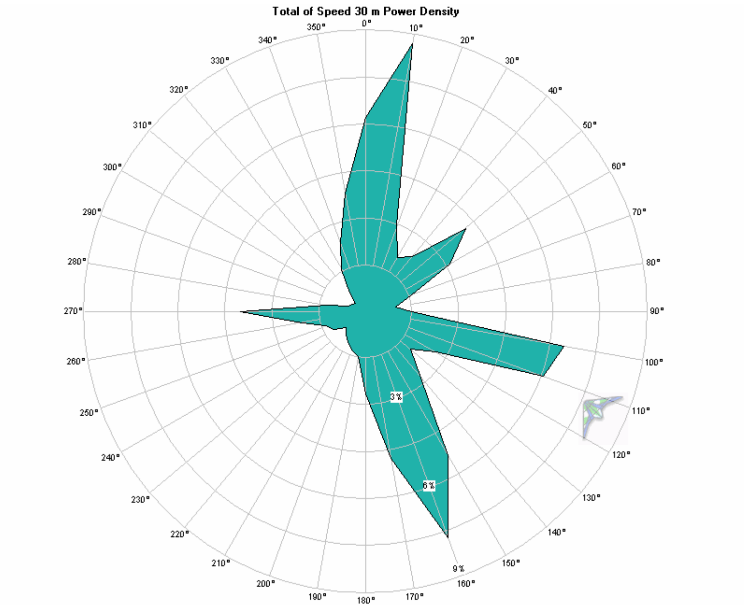


Figure 10 Naknek Wind Power Density Rose



KOKHANOK

The wind resource in Kokhanok is superb by any measure – the winds are steady, smooth, low shear, highly directional, and high power class. The selected wind site, near the tip of the spit of land jutting into Lake Iliamna, is ideal for wind turbine installations as it is relatively far from the village, but near an existing overhead power line it is comprised of stable rocky soil and is in a location unlikely to be desired for other village uses (because of the wind). The truly great aspect about the wind resource in Kokhanok is that the strong winds at the prospective wind site are not felt so keenly in the village itself, because of topographic features and heavy forest that mute the winds considerably.

Kokhanok was recognized early in the data collection and analysis process as having outstanding potential for wind power development, and has been the focus of attention to obtain grant money to fund a wind-diesel system. Although the Kokhanok wind power proposal in response to an AEA Request for Proposals in February 2006 was not successful, Kokhanok's wind resources were recognized and in late 2006 the Alaska legislature appropriated approximately $150,000 to Kokhanok to begin planning and design work for a wind power system. Active management of this funding was transferred from the Kokhanok Village Council to the Lake and Peninsula Borough, and at this writing an effort is underway to secure additional funding for a complete project. We anticipate actual construction of a wind power project in Kokhanok no later than summer 2008.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 11 and 12), from the Kokhanok, Alaska Wind Resource Report (see Appendix E), is presented below in Table 5.

Table 5 Kokhanok Summary Data

Wind power class	Class 6 – Outstanding
Wind speed annual average (30 meters)	7.84 m/s
Maximum wind gust	40.1 m/s (November 2004)
Mean wind power density (50 meters)	763 W/m^2 (calculated)
Mean wind power density (30 meters)	690 W/m^2 (measured)
Weibull distribution parameters	k = 1.64, c = 8.77 m/s
Roughness class	0.00 (smooth)
Power law exponent	0.0725 (very low wind shear)
Turbulence intensity	0.0985 (low)
Data start date	August 12, 2004
Data end date	June 14, 2006

Figure 11 Kokhanok Seasonal Wind Speed Profile

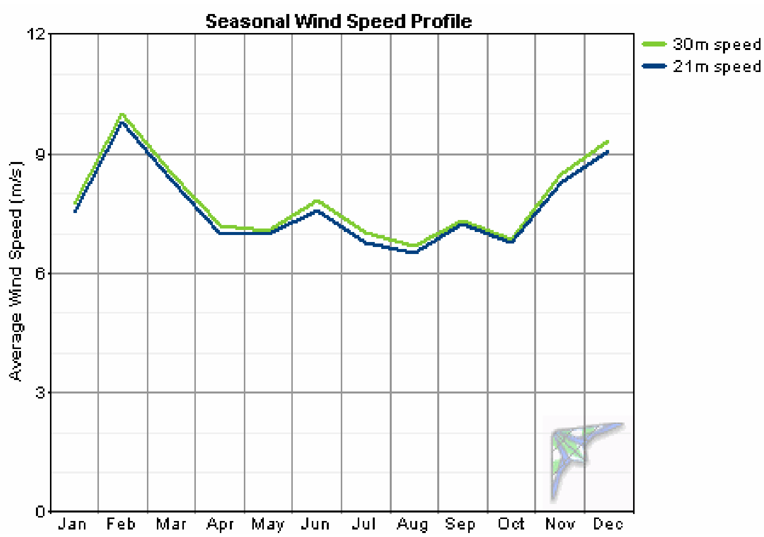
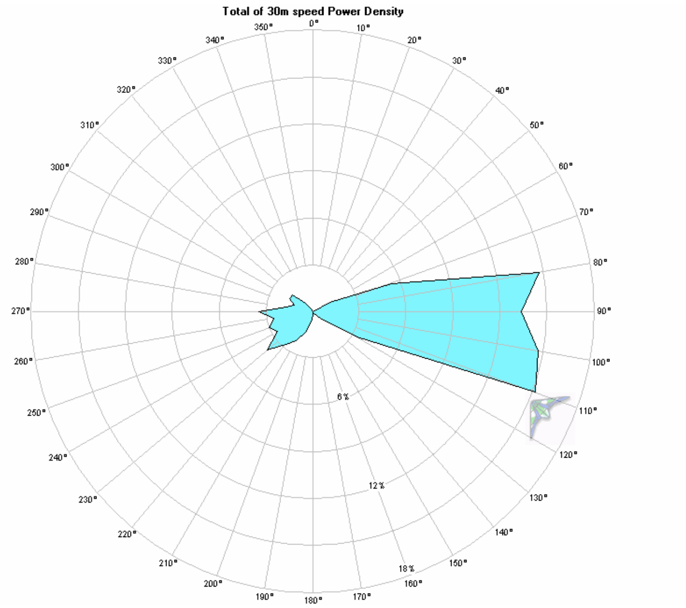


Figure 12 Kokhanok Wind Power Density Rose



TOGIAK

A met tower was installed in Togiak in September 2004. The original plan had been to install the tower immediately after the Dillingham Wind Energy Workshop in October 2003, as was the met tower in New Stuyahok, but time constraints and weather forced a delay until the following summer. The intent was to erect the Togiak met tower in May, but the site selected during the previous October's reconnaissance trip proved to be unacceptable due to land ownership issues, construction of housing nearby, and relocation of the planned new power plant. A new site was selected, but the need for permits and other approval delayed the met tower installation until autumn. The Togiak met tower is still on site and will be removed by AVEC in summer 2007.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 13 and 14), from the Togiak, Alaska Wind Resource Report (see Appendix F), is presented below in Table 6.

Table 6 Togiak Summary Data

Wind power class	Class 3 – Fair
Wind speed annual average (30 meters)	5.68 m/s
Maximum wind gust	32.9 m/s (April 2005)
Mean wind power density (50 meters)	311 W/m^2 (calculated)
Mean wind power density (30 meters)	256 W/m^2 (measured)
Weibull distribution parameters	k = 1.75, c = 6.40 m/s
Roughness Class	1.11 (fallow field)
Power law exponent	0.151 (moderate wind shear)
Turbulence Intensity	0.104 (low)
Data start date	September 11, 2004
Data end date	July 12, 2006

Figure 13 Togiak Wind Speed Profile

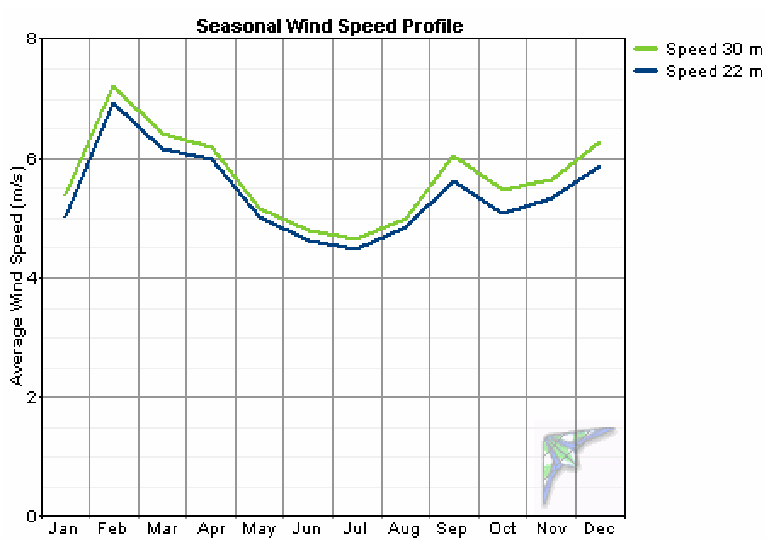
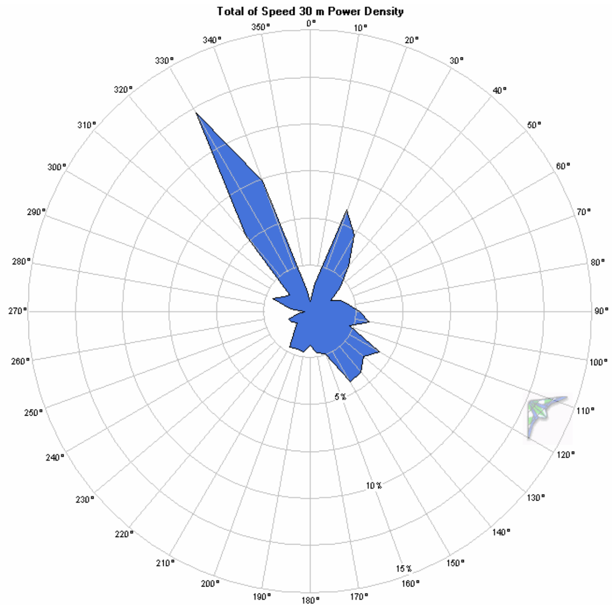


Figure 14 Togiak Wind Power Density Rose



The Togiak test site is a Class 3 wind resource, and not as promising as we had hoped. One thought is that perhaps the met tower site is not the best site for wind power development in the village. The site, after an extensive effort with Togiak Natives Ltd., to select a suitable parcel, was selected because of uncomplicated ownership and accessibility issues. However, other, and likely superior, sites were not available for testing at the time because of complicated ownership issues.

The electrical utility in Togiak, AVEC, is presently in the design and planning stage of a new bulk fuel and power plant upgrade project. As in New Stuyahok, the desire and intent of AVEC is to incorporate wind power into the Togiak power system with a medium-to-high penetration wind-diesel hybrid system. The Wind Resource Report completed for Togiak was forwarded to AVEC, and has and will continue to be used to support the design effort. Given the test results, the desirability of the test site as an actual turbine location is still undetermined. There has been discussion and some planning to connect Togiak to the nearby non-AVEC village of Twin Hills by electrical intertie. Should this occur, AVEC is interested in measuring the wind resource on a prominent ridge, near Twin Hills, that they think may be a superior wind location than the present test site. Given the timeline of the decision of Twin Hills to join AVEC and a possible decision to build an intertie line across Togiak Bay, this new test site is not likely to be monitored until 2008.

PERRYVILLE

The wind resource study in Perryville defied expectations of measuring strong winds. It appears that local geographic features effectively shield the test site, and the nearby village, from the ferocious winds common to the southern Alaska Peninsula coast. With a measured wind power Class of 2 (marginal), Perryville does not appear at this time to be a promising location for village-scale wind power development, although, there is always the possibility of successful home-scale wind power development. This is unfortunate as the leadership of Perryville has been very aggressive in their desire to develop renewable energy, but wind power does not appear to be a good solution to their high energy cost problem.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 15 and 16), from the Perryville, Alaska Wind Resource Report (see Appendix G), is presented below in Table 7.

Table 7 Perryville Summary Data

Wind power class	Class 2 – Marginal
Wind speed annual average (30 meters)	4.60 m/s (at 30 meters)
Maximum wind gust	24.4 m/s (November 2004)
Mean wind power density (50 meters)	240 W/m^2 (calculated)
Mean wind power density (30 meters)	185 W/m^2 (measured)
Wiebull distribution parameters	k = 1.36, c = 5.02 m/s
Roughness Class	1.93 (few trees)
Power law exponent	0.181 (moderate wind shear)
Turbulence intensity	0.158 (moderate to high)
Data start date	October 9, 2004
Most recent data date	October 4, 2006

Figure 15 Perryville Wind Speed Profile

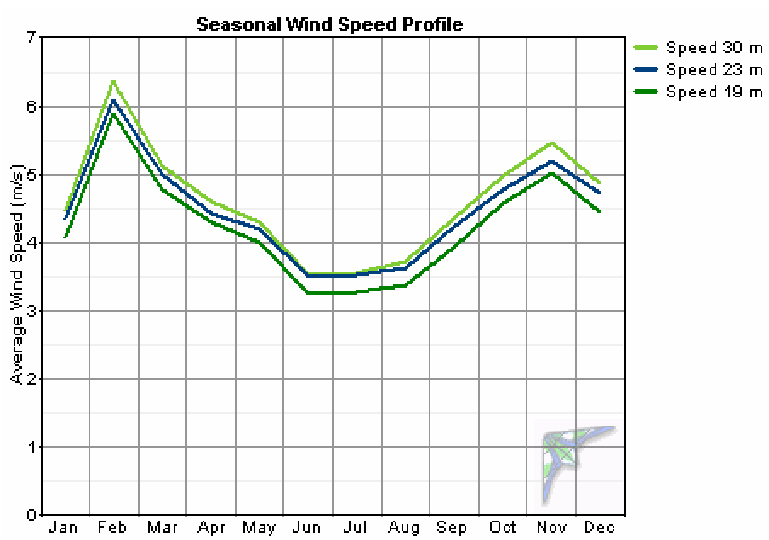
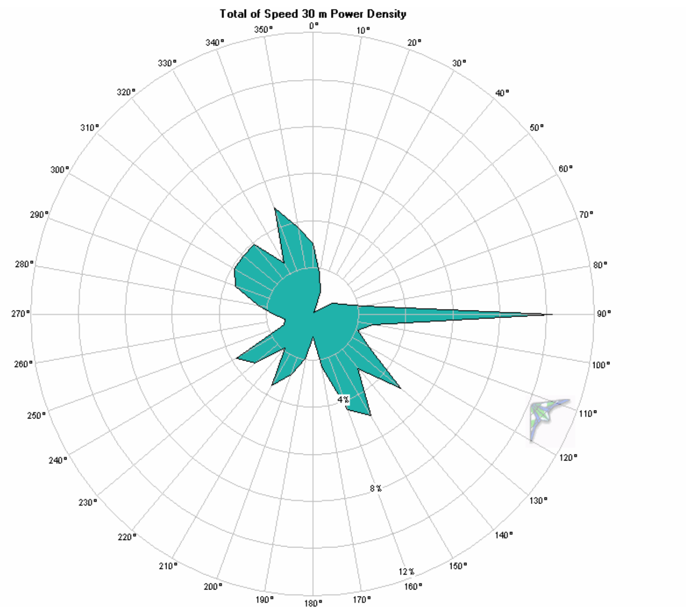


Figure 16 Perryville Wind Power Density Rose



CLARK'S POINT

The wind resource study in Clark's Point indicates excellent potential for the development of wind power to augment the village's diesel engine power supply. One advantage for the village is the bluff where the meteorological test tower was located. This bluff is high and exposed and has superb exposure to onshore winds off the bay. A disadvantage for wind power development is the relative isolation and small population of Clark's Point. Clark's Point has a small, local utility that would likely need outside help and support to successfully initiate and construct a wind power project. It is hoped that this wind resource study will aid a future wind power development effort.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 17 and 18), from the Clark's Point, Alaska Wind Resource Report (see Appendix H), is presented below in Table 8.

Table 8 Clark's Point Summary Data

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

Figure 17 Clark's Point Wind Speed Profile

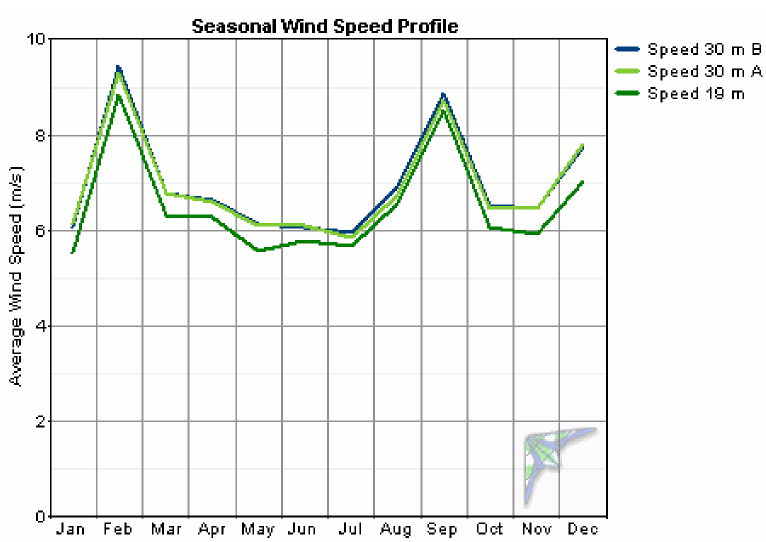
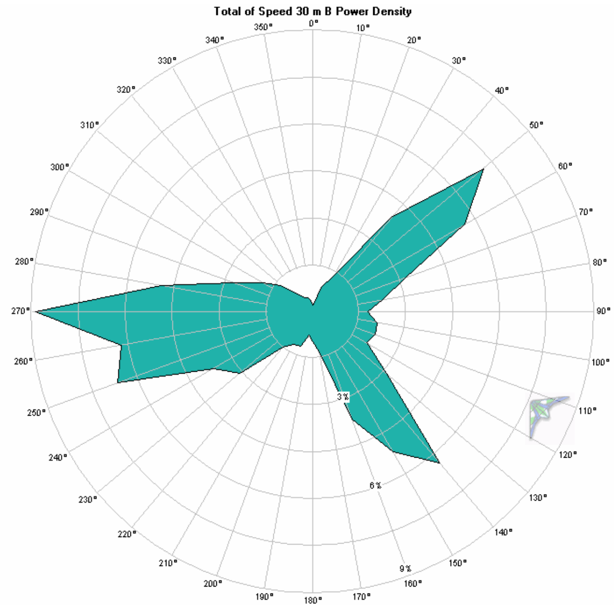


Figure 18 Clark's Point Wind Power Density Rose



KOLIGANEK

The wind resource study in Koliganek indicates very good potential for the development of wind power to augment the village's diesel power supply. One excellent advantage for the village is the old airstrip where the meteorological test tower was located. Because the village and surrounding area is comprised of permafrost soils, construction of wind turbines on the old airstrip would significantly reduce construction costs. A disadvantage for village-scale wind power development is the relative isolation, small population, and small power load of Koliganek. Koliganek has a small, local utility that would likely need outside help and support to successfully initiate and construct a wind power project. It is hoped that this wind resource study will aid a future wind power development effort.

Notable wind resource information, including a wind speed profile and annual wind density rose (Figures 19 and 20), from the Koliganek, Alaska Wind Resource Report (see Appendix I), is presented below in Table 9.

Table 9 Koliganek Summary Data

Wind power class (at 50 meters)	Class 4 – Good
Wind speed annual average (30 meters)	5.72 m/s
Maximum wind gust	36.5 m/s, December 2005
Mean wind power density (50 meters)	404 W/m^2 (calculated)
Mean wind power density (30 meters)	320 W/m^2 (measured)
Weibull distribution parameters	k = 1.60, c = 6.40 m/s
Roughness class	2.92 (many trees)
Power law exponent	0.227 (high wind shear)
Turbulence intensity	0.115 (moderate)
Data start date	July 8, 2005
Data end date	July 13, 2006

Figure 19 Koliganek Wind Speed Profile

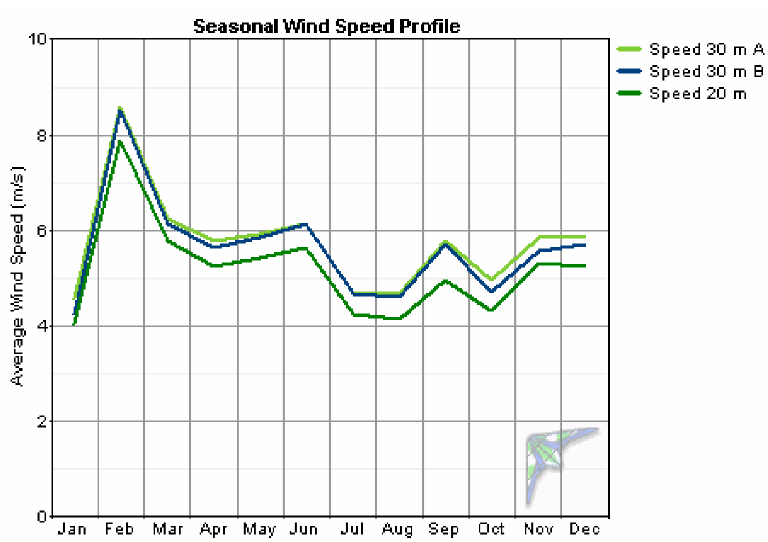
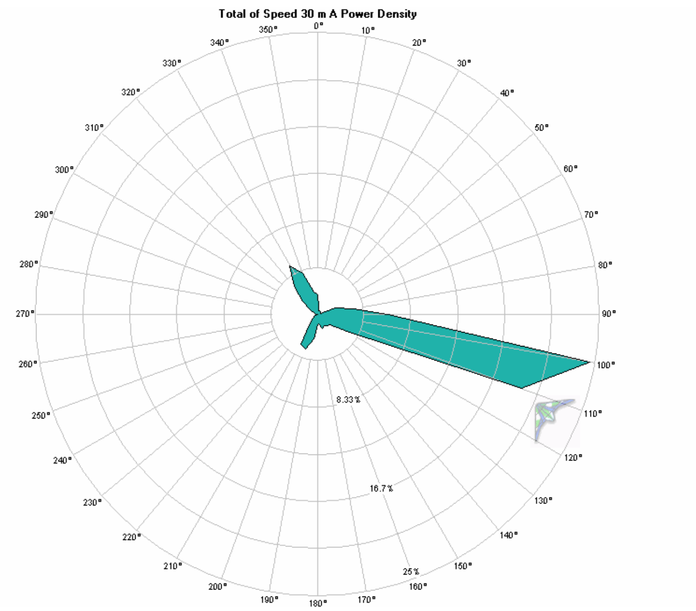


Figure 20 Koliganek Wind Power Density Rose



PROJECT DATA COMPARISONS

Comparing the project sites to each other would appear to be a reasonable way to summarize the nine separate studies, but we are including this comparison at the end of the results summary only as matter of interest. Because the wind resources were conducted in different communities, except for the two in Dillingham, comparing sites is not of much interest to people in the individual communities, nor to the local utilities, or a private project developer. The particular wind power project opportunities and challenges in each community are individual enough to render inter-village comparisons of marginal use.

Still, comparisons are interesting and may potentially be useful information. Below are two comparison tables: Table 10 orders the sites by wind power density at 50 meters, which in all cases estimates were calculated by the Windographer software program and Table 11 orders the sites by wind power density measured at 30 meters. The 50-meter wind power density is useful as 50 meters is the normative height for classification of wind class, and is broadly used throughout the wind industry in North America and Europe as a common measure of wind power.

Table 10 50-meter Wind Power Density Site Comparison

	Site	Wind Power Density 50 meters, W/m^2	Wind Power Density 30 meters, W/m^2	Average Wind Speed 30 meters, m/s	Wind Power Class	Wind Class Description
1	Kokhanok	763	690	7.84	6	Outstanding
2	Clark's Point	491	423	6.94	4	Good
3	New Stuyahok	414	232	5.46	4	Good
4	Koliganek	404	320	5.72	4	Good
5	Dillingham - Woodriver	375	272	5.88	3	Fair
6	Dillingham - Kanakanak	374	230	5.78	3	Fair
7	Naknek	368	301	6.22	3	Fair
8	Togiak	311	256	5.68	3	Fair
9	Perryville	240	185	4.60	2	Marginal

Note: Wind Power Class and description based on 50-meter wind power density data

Because all of the project met towers were 30 meters in height, all 50-meter wind power density data is calculated and therefore subject to error if the power law exponent calculation was compromised by unusual effects at the relatively low elevation of 20 meters, rather than would be true if anemometers were located at higher elevations closer to 50 meters. For this reason, the 30 wind power density is perhaps a better comparative tool and in one sense is a more reasonable measure of ranking the nine project sites to each other. Note that the site rankings change quite a bit between the two tables, but in both cases, Kokhanok is clearly the superior location for wind power development and Perryville the least. It is unfortunate that the Kokhanok test site is not closer to a larger population of people or an electrical transmission line, because the wind resources at the Kokhanok test site were so good that a wind power development would unquestionably be highly cost effective.

Table 11 30-meter Wind Power Density Site Comparison

	Community	Wind Power Density 30 meters, W/m^2	Wind Power Density 50 meters, W/m^2	Average Wind Speed 30 meters, m/s	Wind Power Class	Wind Class Description
1	Kokhanok	690	763	7.84	6	Outstanding
2	Clark's Point	423	491	6.94	4	Good
3	Koliganek	320	404	5.72	4	Good
4	Naknek	301	368	6.22	3	Fair
5	Dillingham - Woodriver	272	375	5.88	3	Fair
6	Togiak	256	311	5.68	3	Fair
7	New Stuyahok	232	414	5.46	4	Good
8	Dillingham - Kanakanak	230	374	5.78	3	Fair
9	Perryville	185	240	4.60	2	Marginal

Note: Wind Power Class and description based on 50 meter wind power density data

Lastly, a final comparison of the sites by average wind speed at 30 meters is presented below in Table 12. Comparison of sites by wind speed can be somewhat misleading because of the non-linear relationship between wind speed and wind power density – the different wind power densities that result from sits with equivalent average wind speeds can be understood with reference to the Weibull distribution – but again, it is a useful measure for an intuitive understanding of how one site compares against another. Note again that Kokhanok ranks first and Perryville ranks last by this alternate comparative measure.

Table 12 30-meter Average Annual Wind Speed Comparison

	Community	Average Wind Speed 30 meters, m/s	Wind Power Density 30 meters, W/m^2	Wind Power Density 50 meters, W/m^2	Wind Power Class	Wind Class Description
1	Kokhanok	7.84	690	763	6	Outstanding
2	Clark's Point	6.94	423	491	4	Good
3	Naknek	6.22	301	368	3	Fair
4	Dillingham - Woodriver	5.88	272	375	3	Fair
5	Dillingham - Kanakanak	5.78	230	374	3	Fair
6	Koliganek	5.72	320	404	4	Good
7	Togiak	5.68	256	311	3	Fair
8	New Stuyahok	5.46	232	414	4	Good
9	Perryville	4.60	185	240	2	Marginal

Note: Wind Power Class and description based on 50 meter wind power density data

CONCLUSIONS AND RECOMMENDATIONS

Despite the presence of wind resources that are well suited for wind power developed, the successful design and construction of wind turbines in rural Alaska communities is difficult and expensive. As with any construction project in rural Alaska, significant reasons are high transportation costs, lack of easy availability of heavy construction equipment, the high cost of fuel, and difficult permafrost soil conditions. The Bristol Bay region experiences these issues as well, but in some respects to a lesser degree than further north or inland in Alaska. Winter sea ice is less of a problem in Bristol Bay than elsewhere, and the region's proximity to Anchorage results in somewhat lower transportation costs than further north. Also, permafrost is discontinuous in much of the region, enabling more standard and hence less expensive foundation costs.

Our very early decision in this project to collaborate with AEA and AVEC in order to conduct as many wind resource studies as possible with the grant funds had a very pragmatic motivation: we wanted these studies to not be an end in themselves, but rather be just enough information for the utilities to decide whether or not they wish to develop wind power in their communities. If a utility does decide to develop wind power, it was our hope that the wind resource assessment reports would help the utility with the information they will need to properly locate wind turbines, select the best turbine for their needs, specify tower hub heights, and predict wind energy recovery and fuel displacement for economic planning and modeling.

With our project goal of supporting the construction of renewable energy projects in the Bristol Bay region, but playing a support role, BBNC considers our DOE grant project to be very successful. Already based on the outstanding wind resources proven by our wind resource study in the village, Kokhanok has received initial State grant funding for a wind power project and is working to secure the remaining money needed to move ahead with design and construction. AVEC has stated their strong intention to install wind turbines in New Stuyahok and would like to do so as well in Togiak, although, they may move the monitor to another more promising site before proceeding. NEA decided to fund a wind resource study as the second location, which will have obtained one year of data in July, and are actively planning for wind power to augment their diesel generator power system.

We hope that when one or two projects are successfully completed in the region, other communities will also want to develop wind power and will have a road map to follow so to speak. As the native corporation representing the entire Bristol Bay region, it is BBNC's plan to share information as best we can to support utilities and communities desiring to develop wind power. BBNC would like to once again thank the people at the DOE's Golden, Colorado Field Office, Tribal Energy Program, for awarding to us the funding for this project in 2003. Their help, along with the support and advice of the excellent people at the NREL in Golden and Boulder, Colorado, proved invaluable in our efforts.

APPENDICES

Wind Resource Reports