Town of Eastham

Wind Energy Feasibility Study

March 17, 2006

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MASSACHUSETTS
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Abstract

Black & Veatch reviewed the feasibility of developing a community wind energy project in Eastham, Massachusetts. The wind resource was estimated using wind data collected on site, as well as from nearby sources and the state wind resource map. Land use and operational issues were reviewed, specifically the proximity of the sites to the Cape Cod National Seashore and to privately-owned land. The electrical infrastructure and electrical load profile near the sites were reviewed to understand the feasibility of using some of the energy at the sites. Likely permitting requirements were also listed. The costs for three development options were estimated, and the cash flow of the project was reviewed. Black & Veatch found no obvious fatal flaws for the project, although concerns regarding impacts to tourism and the Cape Cod National Seashore to be explored with the National Park Service and other interested parties as soon as possible.

Keywords

Renewable Energy Trust
Massachusetts Technology Collaborative
Community Wind Collaborative
Town of Eastham
Cape Cod
Wind Energy
Wind Power
Black & Veatch
Feasibility Study

1.0 Conclusions and Recommendations

The Massachusetts Technology Collaborative (MTC) has entered into a Work Order (WO06-1) with Black & Veatch to perform a wind project feasibility study for the Town of Eastham. This report provides the results from this study, and provides recommendations regarding further review of this project. A summary of the results and recommendations are:

- The annual average wind resource at the project site is approximately 5.5 m/s at 50 meters above ground level, 6.7 m/s at 80 meters, and 7.3 m/s at 100 meters. The wind shear component α was estimated at 0.40, based on the collected data. (Section 4)
- Six potential wind turbine sites were identified in North Eastham, of which four are recommended for development. (Section 5)
- There is a distribution-line and transmission-line near the project site, giving the project two interconnection options. (Section 6)
- Due to the proximity to the proposed project to the Cape Cod National Seashore and the Massachusetts Audubon Society Sanctuary, early coordination with these groups will be vital to project success. A wildlife survey may also be necessary with several Threatened species in the area of the project site. (Section 7)
- Production estimates for various turbines vary between 18 and 30 percent capacity factors. Black & Veatch would classify the as "fair" for some turbines, and "good" for others. (Section 9)
- The capital costs for the various project, turbine, and interconnection options range from about $1,260 per kW to $2,430. (Section 10)
- There are several options that meet the likely hurdle rates success. In general the economic payback (and the risk) are higher for Town of Eastham ownership over ownership by a private developer. (Section 11)
- MTC and the Town of Eastham may wish to consider collecting SODAR data at the location of the selected project option, to better determine the true wind shear values from the measurements height (39 meter) to the wind turbine hub heights (as much as 80 meters). The values of the production estimates can vary significantly by small changes in the wind shear. Measurements at one location should be sufficient if the multi-turbine option is selected.

2.0 Review of On-Site and Community Wind Energy

Black & Veatch has included the following section to help readers better understand the technology being evaluated in this study, as well as the feasibility of installing wind turbines near or within facilities and cities.

2.1 Wind Energy Technology

The design of the typical wind turbine has changed greatly over the past twenty years. Although many types of wind turbine designs were initially developed, the "Danish" design of a three-bladed, up-wind horizontal axis turbine has emerged as the standard of the industry.

Although the size and complexity of wind turbines has increased, their basic operating principles have remained virtually unchanged. Figure 2-1 from the U.S. Department of Energy shows the typical layout of equipment in a turbine's nacelle, which is the "pod" of equipment at the top of the tower to which the turbine's blades are connected. Wind energy is captured by the wind turbine blades, causing the rotor to rotate the turbine's low-speed shaft. This shaft will rotate at a speed of about 15 to 20 revolutions per minute (RPM). The low speed shaft is then connected to a gearbox, which transfers the energy to the high-speed shaft connected to the generator. The speed of the high-speed shaft depends on the generator type and electrical frequency of the site, but for the U.S. typical speeds are 1,800 and 3,600 RPM. The electrical output of the generator is then transferred to the base of the wind turbine via electrical droop cables. At the base, these cables connect to a transformer, which increases the voltage of the power from the low voltage of the generator (480 or 600 VAC) to the distribution voltage of the plant (anywhere from 12 kV to 46 kV). The orientation of the wind turbine is kept into the wind by a yaw drive, with the wind direction determined by a wind vane located on top of the nacelle. The turbine's controller has independent control of the wind turbine's operation, without requiring commands from a user or central control center. If the controller senses a problem, the wind speed increases beyond the turbine's operational range, or a shut-down command is given manually, the turbine will come to a stop by means of electrical, mechanical, and aerodynamic brakes (the design of which depend on the turbine).

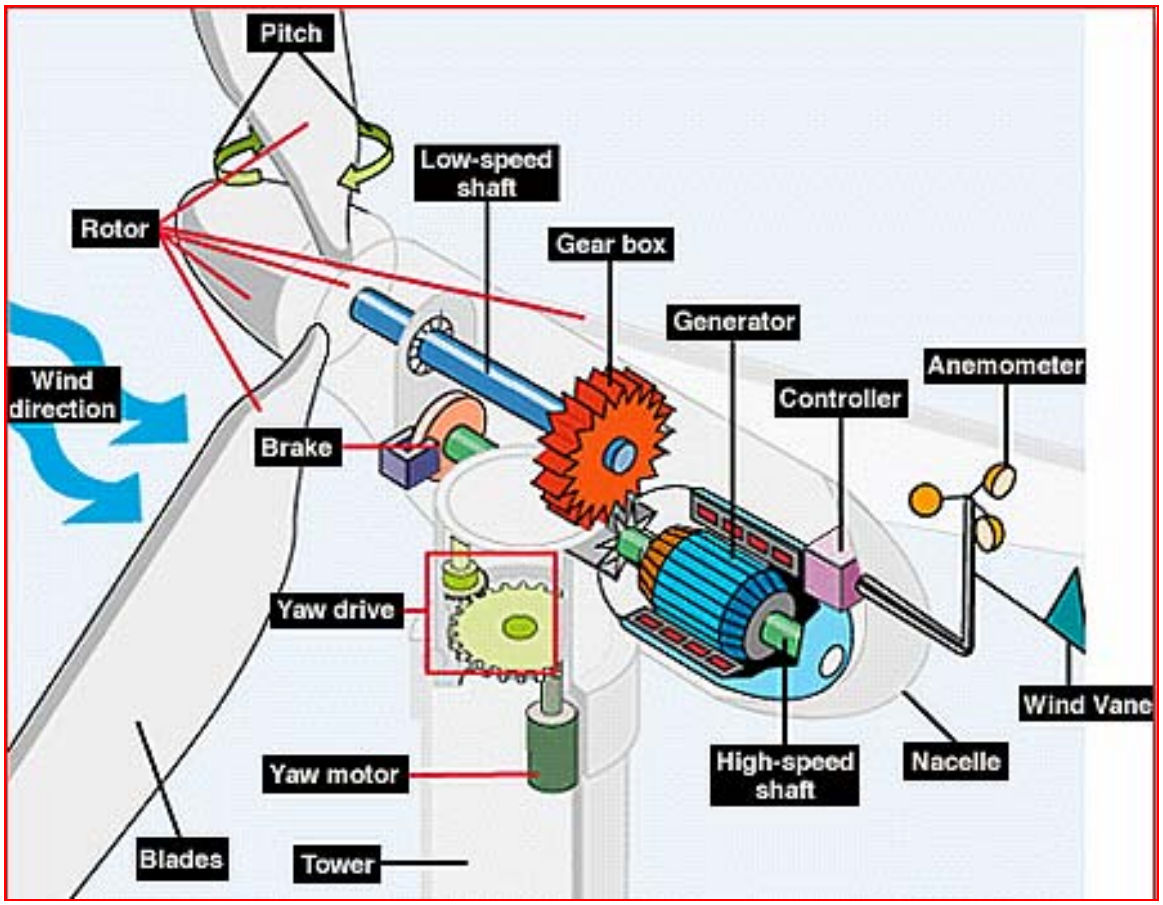


Figure 2-1 Wind Turbine Components (from US Dept. of Energy)

Obviously, the output of the wind turbine is dependent upon wind speed. The relationship of a wind turbine's electrical output as a function of wind speed is given in its power curve. A typical curve will show power production beginning when the wind speed increases beyond the turbine's minimum (cut-in) wind speed. As wind speed increases, the output power also increases in a roughly linear manner until the turbine's rated power is reached. The minimum wind speed at which a wind turbine delivers this nameplate output power is called its rated wind speed. For most modern wind turbines, winds higher than the rated wind speed will not produce any additional power, and turbine will continue to output its rated power. If the wind speed increases beyond the safe operating limits of the turbine (cut-out), the turbine will automatically shutdown and wait for the wind speeds to decrease. The wind speeds and power amounts for the above values depend mostly on the size of the wind turbine and the design of the blade airfoils. On average, larger wind turbines have lower cut-in wind speeds, have higher rated power, and reach that power at lower winds.

Several wind turbine designs were considered in this study as candidates for large commercial wind turbines. The General Electric 1.5MW, Vestas V80, and Vestas V82

are currently popular machine designs for US projects, and may be good choices for a project in Eastham. The Vestas V90 is a newer turbine design from Vestas, which has not yet been installed in a commercial US project. The Gamesa G87 is newer to the US market, but popular in Spain and is the only commercial wind turbine built in the US other than the GE 1.5. The Fuhrländer FL2500 is a large wind turbine design from a German manufacturer specializing in smaller projects.

2.1.1 GE 1.5MW

General Electric (GE) purchased Enron Wind Energy in 2002, and has integrated the company into GE's Power Systems company. GE has applied their efforts since this acquisition to improving the design and production of their only commercial on-shore wind turbine, the GE 1.5MW. This turbine is a 1,500 kW machine with a rotor diameter of 65, 70.5 or 77 meters. The turbine is commonly placed on either 65 or 80 meter towers. Because of its variable-speed ability, the GE 1.5MW has a rotational speed range between 10 and 20 RPM (or one revolution every three to six seconds).

The GE 1.5MW turbine is one of the most popular designs for U.S. wind farms. Projects with this design turbine include the Somerset, Mill Run, and Waymart projects in Pennsylvania and Fenner in New York. GE turbines are manufactured in the U.S.

Figure 2-2 GE 1.5MW turbines at Colorado Green Project

2.1.2 Vestas V80

Vestas is one of the world's largest manufacturers of wind turbines. Based in Denmark, Vestas has about one-third of the market for wind turbine sales. They recently merged with the wind turbine manufacturer NEG Micon, and together represent a major vendor and installer for wind turbines in the United States.

Figure 2-3 Vestas V80s in Buffalo Mountain, Tennessee

For wind projects at sites of medium to high average wind speeds, the V80 has become the primary turbine design from Vestas. The closest wind farms of V80s to Massachusetts are the Maple Ridge project in New York and the Buffalo Mountain project in Tennessee. The Town of Hull (Massachusetts) is currently installing a V80, with many components arriving in January 2006.

2.1.3 Vestas V82

The Vestas V82 turbine was originally developed by NEG Micon, a wind turbine manufacturer that merged with Vestas in 2004. This turbine design is optimized for lower wind conditions than the Vestas V80, by mating a slightly larger rotor on a smaller generator. Two V82s are being installed in Orleans, Massachusetts, in 2006 through the MTC Community Wind Collaborative program.

Figure 2-4 Vestas V82s in West Virginia

2.1.4 Vestas V90

The Vestas V90 is a relatively new design, with no U.S. installations yet. There are versions of this turbine that are rated at 1.8 MW for very low wind sites, and 3.0 MW for high wind sites. For the performance estimates in this study, the 3.0 MW version of the turbine was assumed. Vestas has indicated this turbine design will be available in limited numbers for 2007 projects. It is not yet clear if and when Vestas would be willing to sell the V90 for single-turbine or small project arrangements, which could be 2008 or later.

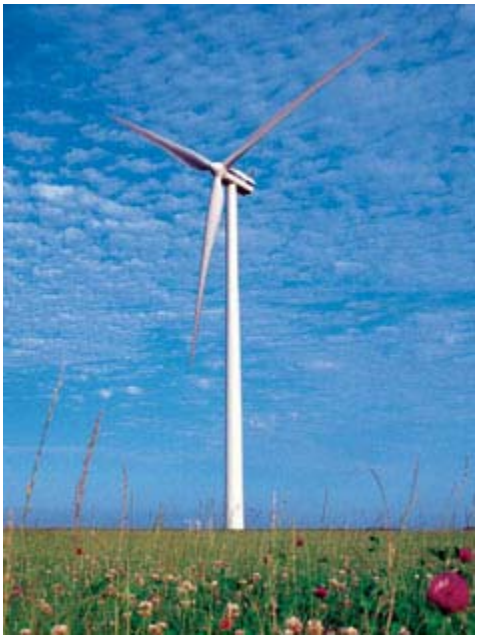


Figure 2-5 Vestas V90 in Europe

2.1.5 Gamesa G87

Gamesa Eólica is a Spanish wind turbine manufacturer. In 2004, Gamesa had an 18 percent world market share, and was the second largest producer of wind turbines. To date, Gamesa reports they have over 5,400 MW of wind turbines installed.

While having an impressive overall record of wind turbine manufacturing, Gamesa is nevertheless relatively new to the U.S. market. Gamesa's U.S. operations are headquartered in Philadelphia, Pennsylvania. Gamesa is in the process of completing facilities in Philadelphia that will fabricate blades and towers, and assemble nacelles. These facilities are all to start operation in spring 2006. Another facility to assemble specifically the G87 turbines is already in operation in Ebensburg, Pennsylvania. The closest G87 turbines to Massachusetts are those at the Bear Creek project in northeast Pennsylvania.

Figure 2-6 Gamesa G87s in California

2.1.6 Fuhrländer FL2500

Based in Germany, Fuhrländer specializes in smaller projects and turbine customization to client needs. In the U.S., Fuhrländer wind turbines are distributed by Lorax Energy Systems in Rhode Island.

The Fuhrländer FL2500 is one of the largest commercial wind turbines available in the U.S. Rated at 2.5 MW, the FL2500 has rotor options with diameters between 80 and 100 meters, installed on towers between 65 and 100 meters. For a site with wind conditions like Eastham, Black & Veatch believes the 90 meter rotor and 100 meter tower are the most appropriate options. There are no FL2500 turbines currently installed in the U.S., and Black & Veatch is not certain how many may be installed elsewhere. Lorax Energy Systems has only recently begun offering this turbine design.

2.2 Examples of On-Site and Community Wind Energy Projects

Black & Veatch has included an example each of wind energy projects installed on a community power level or directly onsite of major power consumers.

2.2.1 Palmdale, California

Black & Veatch was the engineer for the Palmdale Water District in Palmdale, California, for the design and installation a single 950 kW wind turbine at their water treatment facility. The wind turbine is a Micon (now Vestas) NM54, and is connected directly to the 12kV system of the treatment plant. This project was completed in July 2004.

This project was able to make use of two programs unique to California: the Self-Generation Incentive Program and a large Net Energy Metering allowance. The Self-Generation Incentive essentially requires the local utility (Southern California Edison) to pay for half of the costs of the project. The Net Energy Metering program in California allows for wind turbines up to 1MW to qualify for net metering, which is a requirement that the utility purchase of energy produced by the wind turbine at the same rate the customer who owns it buys power, up to the point where the wind turbine offsets the total annual consumption of their site. The Net Energy Metering allows the Palmdale project to have a turbine that will generate power at times greater than the site's consumption. Neither of these programs are presently available in Massachusetts.

Figure 2-7 Palmdale Water District On-Site Wind Turbine

2.2.2 Boston, Massachusetts

There are currently two projects in Boston that utilize wind energy on a community or smaller scale. The first is the single Vestas V47 installed by Hull Municipal Light Plant in Hull, Massachusetts. This project was installed in 2002, and is located near the local high school on the northern tip of the peninsula. The Town of Hull has a Municipal Light Board that provides electricity to the residents of Hull, and because of this they are able to use the wind generation to offset electricity purchases made by the Town. To date the Hull wind turbine has offset over 5,500 MWh of electricity purchases for the town's street and traffic lights. The Hull Municipal Light Board has recently indicated they are so pleased with the performance of this project, they are adding another on-shore wind turbine, and exploring the potential of installed several larger wind turbine just off-shore.

Another example of small wind in Boston is the 100 kW Fuhrländer installed at the International Brotherhood of Electrical Workers (IBEW) training center in Dorchester. This small turbine connects directly into the building's utility connection,

and offsets the electricity purchased for the building in the same manner the Hull turbine offsets a portion of the electricity purchased for the town. The IBEW turbine was installed in 2005.

Figure 2-8 Hull Wind Turbine

Figure 2-9 IBEW Wind Turbine

2.2.3 Toronto, Ontario

As part of a community wind power effort, the people of Toronto developed a single 750kW Lagerway wind turbine project for installation at the city's Exhibition Place. This turbine was installed in 1999, and is used to provide the power for the exhibition complex in downtown Toronto. While intended for a grassroots beginning for wind power in Ontario, this project has proven that urban wind power can work well in North America, as it does in much of Northern Europe.

Figure 2-10 Wind Turbine at Toronto's Exhibition Place

3.0 Project and Site Descriptions

Black & Veatch is supporting MTC in technical aspects of the Community Wind Collaborative. The goal of the Community Wind Collaborative is to support communities in determining the feasibility of developing small to moderate-sized wind energy projects, and aiding in the development of those projects found to be feasible. This report is the result of an initial site screening review and development feasibility analysis for a wind energy project for the Town of Eastham, Massachusetts. Issues of general development feasibility and obvious fatal flaws were reviewed, and Black & Veatch has prepared recommendations for future activities toward development of a project in Eastham. Figure 3-1 shows the location of Eastham on Cape Cod.

Figure 3-1 Eastham Location

The Town of Eastham's Renewable Energy Committee identified three potential locations where there is sufficient land owned by the Town to place one or more wind turbines. These areas were land in North Eastham, the DPW Garage, and the Town Hall location. All three locations are shown in the satellite photo in Figure 3-2. The North Eastham location is an area adjacent to a cellular telephone tower and a gravel mining

operation. A meteorological tower was installed at this location for 13 months for wind resource monitoring (see Section 4). The DPW Garage location includes parcels of land used for the Department of Public Works garage, transfer facility, recycling center, and landfill. The Town Hall location is the land on which the Eastham Town Hall, fire station, police station, and adjacent baseball fields are located.

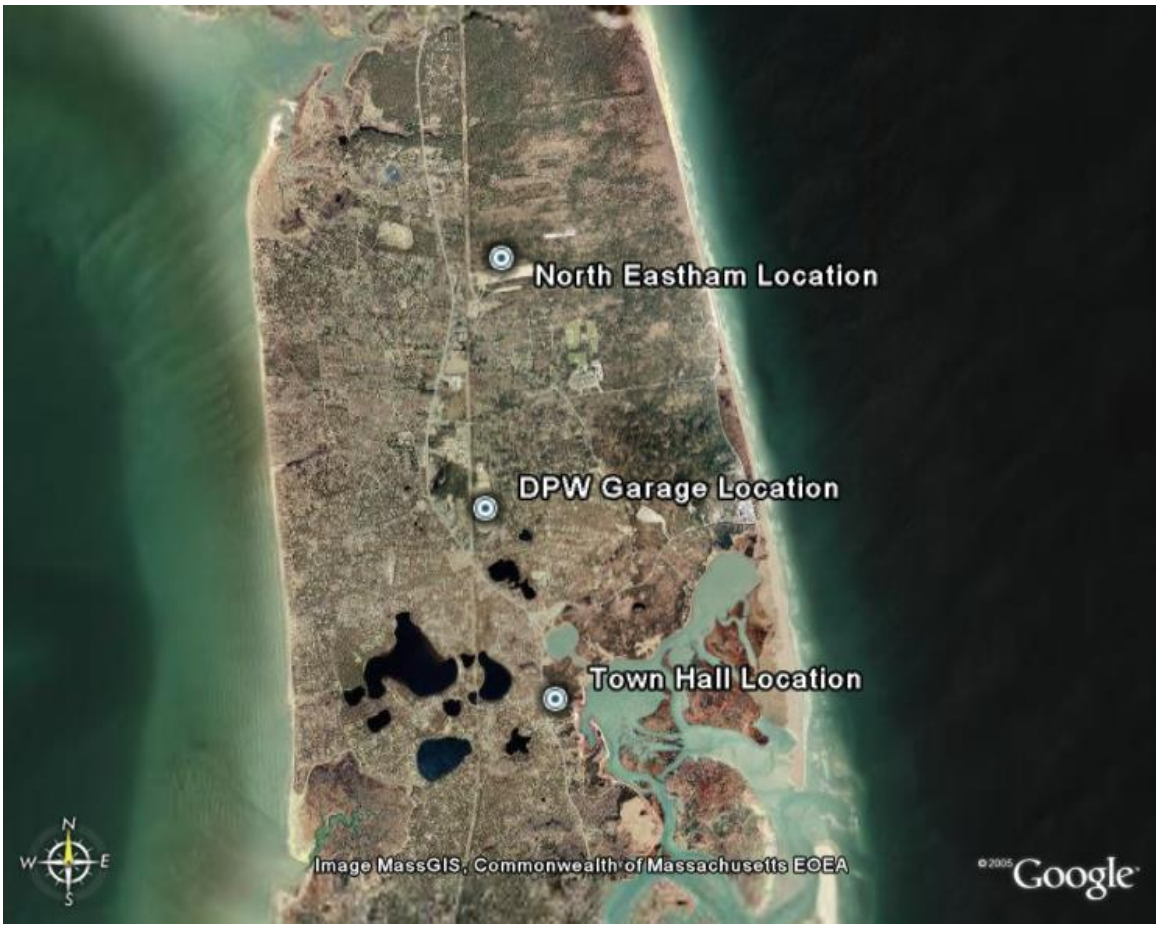


Figure 3-2 Eastham Site Locations

Black & Veatch developed the *Site Screening and Development Options Analysis Report* for the Town of Eastham in November, 2005, which examined the wind energy project potential of all three locations. From the results, the Renewable Energy Committee chose to concentrate on the North Eastham site for this feasibility study. As such, the DPW Garage and Town Hall locations are not discussed further in this report.

4.0 Site Wind Resource

The wind energy resource of a project site is the most critical single aspect to understand, and is one of the few that cannot be overcome with technical solutions. This section discusses the various sources of wind resource information available for the region, and combines them into an estimate of the wind resource for Eastham.

4.1 Wind Data Reviewed

For Eastham, Black & Veatch reviewed six data sources, four of which were generated by the University of Massachusetts Renewable Energy Research Lab (RERL). These sources were:

- Wind data collected by RERL on a meteorological tower at the North Eastham Location (July 2003 – August 2004)
- *Final Wind Data Report: Eastham*, RERL, January 16, 2005
- Wind data recorded at Provincetown, Massachusetts Airport (1993-2005)
- *Accuracy of Wind Shear Models for Estimating the Wind Resource in Massachusetts, Final Report*, RERL, July 5, 2005
- *Accuracy of the AWS TrueWind Model Predictions for Wind Resource Estimation Project*, RERL, July 6, 2005
- The New England Wind Map web site operated by TrueWind Solutions (http://truewind.teamcamelot.com/ne/)

The information available from each above resource is discussed in this section, and the resources are combined into a complete wind resource estimate for Eastham in Section 4.2.

4.1.1 Eastham Met Tower Data and RERL Report

RERL installed a 39 meter (128 feet) tall meteorological (met) tower at the North Eastham location on July 17, 2003. The exact location of the tower was at coordinates 41˚ 52’ 1.6” North, 69˚ 58’ 55.3” West (NAD27) in the southwestern corner of the North Eastham location. The tower collected wind speed and direction data from sensors at 39, 30, and 10 meters above ground level, as well as a low-mounted temperature sensor. The data from the tower was downloaded once per month by Town of Eastham personnel, and transmitted to RERL for data analysis. RERL removed the met tower on August 27, 2004. Due to a problem with data collection, all of the April 2004 data was lost. As the met tower had been removed prior to the site visit, Black & Veatch was not able to verify the met tower’s location or instrumentation.

Nearby trees appeared to be of a height of 10 meters (33 feet) or less, meaning the winds measured by the 10 meter anemometer were likely slowed due to the trees, but the 30 and 39 meter anemometers were not. However, the met tower was 23 meters (75 feet) west of a 67 meter (220 foot) tall cellular telephone tower. Figure 4-1 shows the relative locations of the met and cell towers, and Figure 4-2 are pictures of the cell tower from the reported location of the met tower. Black & Veatch anticipates this tower will significantly slow the wind speed readings of winds from the east. Given that the primary power-producing winds approach from the southwest, the impact of this cell tower is not expected to significantly change the power production estimates.

Because there was almost a year of data available from this met tower, which was equipped and installed primarily for wind energy resource measurement, Black & Veatch concluded this to be the best source of data to base wind energy predictions upon.

Figure 4-1 Eastham Met Tower Location

Figure 4-2 Cell Tower from Met Tower Site

Black & Veatch reviewed the 2005 *Final Wind Data Report: Eastham* RERL report on the met tower's data collection, as well as 10 minute data for August 2003 through July 2004. This information was all obtained from the RERL web site. The monthly average wind speeds are listed in Table 4-1 and shown in Figure 4-3. The values of wind shear were determined between the anemometers mounted at 39 meters and 30 meters above ground level; the results will be discussed further in Section 4.2. Note that almost all the data for April 2004 was not available. The percent energy wind rose for the dataset is shown in Figure 4-4.

Table 4-1
Measured Eastham Monthly Averages: August 2003 – July 2004

Month	Wind Speed			Wind Shear
	39 Meters	30 Meters	10 Meters	
January	6.8	6.0	3.4	0.47
February	5.4	4.8	2.7	0.44
March	6.0	5.4	3.4	0.37
April				
May	4.6	4.2	2.6	0.31
June	4.6	4.1	2.2	0.37
July	4.1	3.7	2.0	0.34
August	4.5	4.0	2.3	0.36
September	4.1	3.6	1.8	0.40
October	5.2	4.6	2.4	0.44
November	5.7	5.0	2.9	0.43
December	7.3	6.6	3.8	0.43
Annual	**5.3**	**4.7**	**2.7**	**0.40**

Notes: **All wind speed values in meters per second.**
Wind speed values are averages of all wind speed sensors at the same height above ground.
Wind shear values determined between anemometers at 39 and 30 meters.
No data available for April 2004.

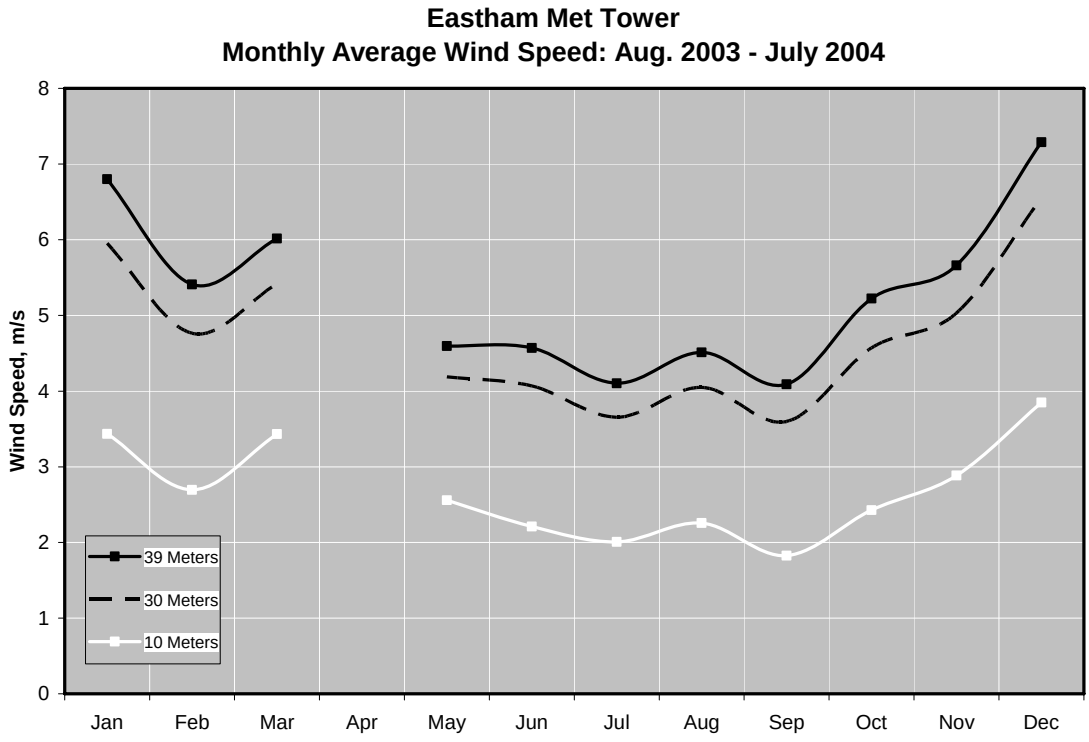


Figure 4-3 Eastham Monthly Wind Speed Averages

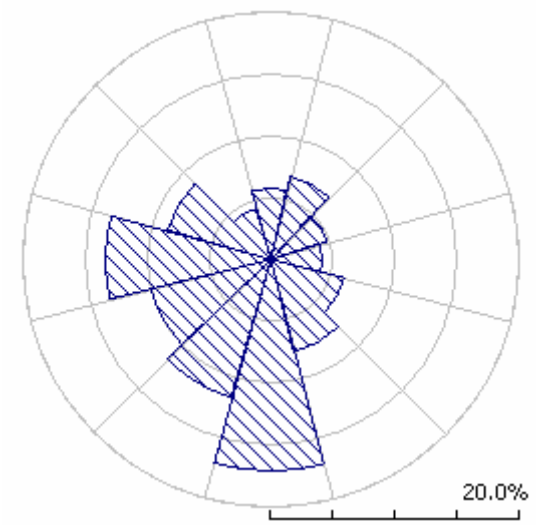


Figure 4-4 Eastham Met Tower 39 Meter Percent Energy Wind Rose

4.1.2 Provincetown Airport Data

While a year of data collection at or near a project site is usually deemed necessary for a wind energy project, a long-term data source is also needed to put the collected data into a historical perspective. Since the wind conditions at a site can change considerably between individual years, comparing the year over which data was collected to a long-term average becomes important to understand a site's average wind resource. Two such nearby long-term sources were available for Eastham: the Provincetown Airport, and the Barnstable Airport. As the primary wind direction is from the west, and the terrain conditions to the west of Provincetown Airport are more similar to Eastham than the Barnstable Airport (open water rather than land), Black & Veatch chose to utilize the Provincetown Airport as the long-term data source.

The Provincetown Airport met tower's location is 42˚ 3' North, 71˚ 11' West (NAD27), and is shown on the map in Figure 4-5. This met tower is approximately 18.6 miles northwest of the Cell Tower location. The Provincetown Airport met tower is a National Oceanic and Atmospheric Administration (NOAA) Airway Weather Observation System (AWOS) station, identified by call sign "PVC" and WBAN Identification Number 64708. Black & Veatch visited this airport on October 7, 2005, and found two wind speed stations: one utilizing a cup anemometer mounted near the terminal building at a height just above the neighboring hanger, and a prop anemometer on a small tower in an open area between the runway and tarmac. While neither location is optimal (the cup anemometer is likely impacted by nearby buildings, and the prop anemometer is impacted by aircraft), both are typical of airport stations. Black & Veatch was not able to determine from which station the data obtained was recorded. Neither sensor appeared to be mounted at the 2.4 meter sensor height specified by NOAA.

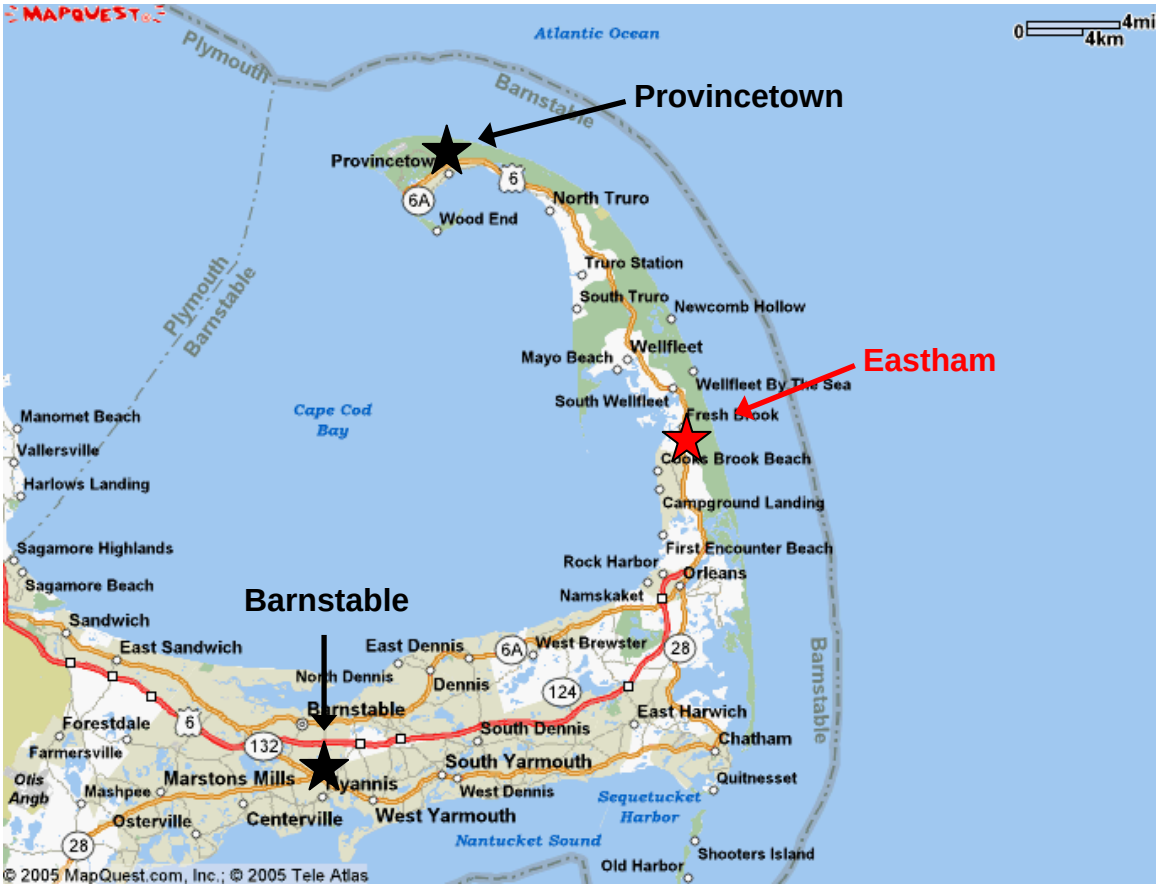


Figure 4-5 Airport Locations

NOAA publishes hourly data collected at this station, and Black & Veatch reviewed the data collected from January 1993 through July 2005. Monthly averages from this period are presented in Table 4-2, and shown in Figure 4-6. As is common at many small airports, poor records-keeping has lead to many months not having sufficient data to estimate the monthly average wind speed. Of the 151 months over the record period, 69 had less than 90 percent data capture, and most of these had less than 10 percent.

Table 4-2
Measured Provincetown Airport Monthly Averages at 2.4 Meters

Month	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave. Year
January	5.9	6.2	5.7	5.7	4.7	4.4	6.1	4.2	3.7	5.0	7.3	7.8	6.7	**6.2**
February	6.4	5.8	5.6	5.6	5.8	4.3	6.0	5.2	6.8	4.6	6.7	5.8	5.6	**5.9**
March	5.4	4.8	3.9	5.0	6.7	6.2	6.5	5.2	6.4	4.1	4.6	6.0	6.0	**5.1**
April	5.2	4.2	4.2	5.1	6.6	3.7	4.6	5.5	4.0	4.3	5.3	5.2	5.8	**4.9**
May	3.6	4.8	3.8	3.7	3.9	3.0	3.5	3.9	4.0	4.2	4.1	4.6	4.9	**4.2**
June	4.3	4.3	3.6	3.3	4.9	3.3	4.1	4.0	3.4	3.9	4.0	4.3	4.6	**4.0**
July	3.4	3.8	3.4	4.6	4.3	2.2	3.9	3.5	3.3	3.9	3.6	4.1	4.3	**3.7**
August	3.1	3.8	3.5	3.0	3.5	2.8	3.9	3.3	3.5	3.8	4.1	4.3		**3.7**
September	4.1	4.1	3.7	4.4	3.9	4.3	4.2	4.1	4.0	4.4	2.9	4.3		**4.1**
October	4.7	4.5	4.3	3.6	4.3	4.6	5.1	4.4	4.3	4.5	4.9	5.5		**4.8**
November	4.9	6.3	4.9	4.9	5.7	5.3	6.0	3.9	5.2		4.5	6.0		**5.3**
December	6.0	6.1	6.1	4.7	6.5	5.7	6.0	6.8	5.5	6.7	6.9	6.5		**6.3**
Annual	4.7	4.9	4.4	4.5	5.1	4.1	5.0	4.5	4.5	4.5	4.9	5.4	5.4	**4.9**

Notes: **All wind speed values in meters per second.**
Wind speed values were collected at 2.4 meters (8 feet) above ground level.
Months with less than 90 percent data available are shown in gray.
Annual values in gray indicate they use monthly averages from months with less than 90 percent data capture.
Overall average monthly values do not include averages from months with less than 90 percent data capture.

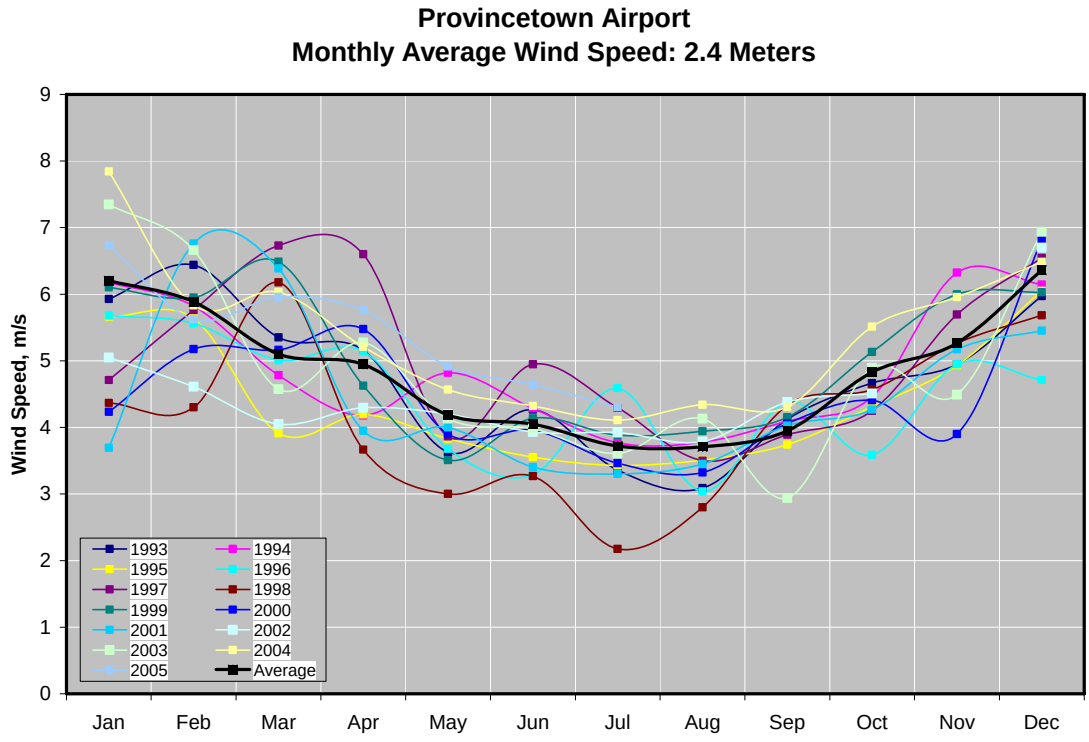


Figure 4-6 Provincetown Airport Monthly Wind Speed Averages

Wind data collected at airports is not intended for wind energy resource measurement, and is commonly collected with instruments fairly low to the ground. At Provincetown Airport, the data was collected at 2.4 meters (8 feet) above ground level, far lower than the 65 meter and 80 meter hub heights of interest in this report. Since scaling this low-level data upward to the proposed turbine hub heights is not preferable when a better data source is available, Black & Veatch did not attempt to use this data directly for wind resource estimation. Instead, Black & Veatch used the Provincetown Airport data to review how the year of Eastham data compares with the long-term average of the same data source. This comparison is done in Section 4.2.

4.1.3 Massachusetts Wind Resource Map Information

Black & Veatch also referenced the New England Wind Resource Map web site (truewind.teamcamelot.com/ne/) for general information on the wind resource for the area around the project site. This map is a model of the wind resources for all of New England, and was created from atmospheric data and calibrated using various data measurement locations. Creation of this map by TrueWind Solutions was funded by MTC, the Connecticut Clean Energy Fund, and the Northeast Utilities System.

By entering the coordinates of the Eastham Met Tower, the web service estimated the annual average wind speed to be 7.0 m/s at 50 meters above ground level, and 7.5 m/s at 70 meters above ground level. A wind rose for the site was also downloaded from the web site and shown below in Figure 4-7. These results should be considered to be a general estimate for the area, and not as accurate at the site collected data. The model has a specified resolution of 200 meters and a standard error estimated at 0.6 m/s.

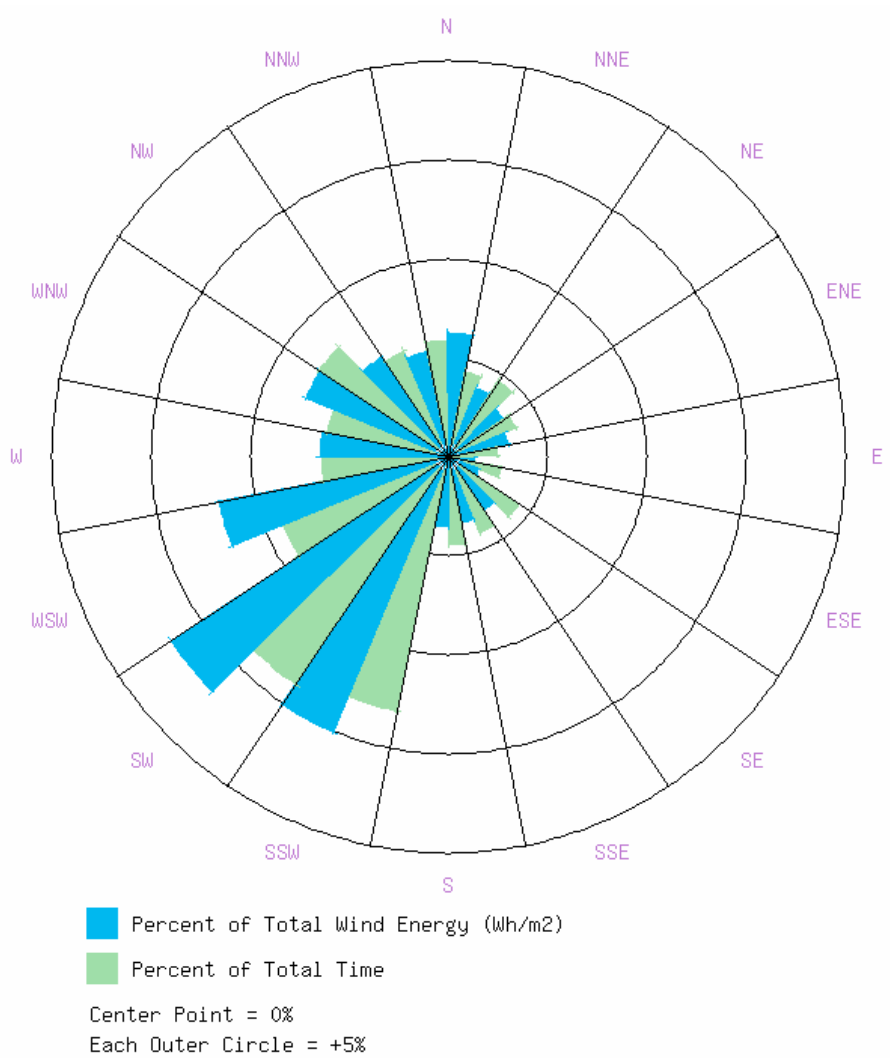


Figure 4-7 TrueWind Wind Rose for Eastham

4.2 Site Wind Resource Estimate

With on-site wind data collected and regional long-term data sources available, Black & Veatch estimated the wind resource of Eastham using the Measure-Correlate-Predict (MCP) method. This method is typical for wind energy projects, and is described for Eastham below.

The ten-minute data collected by RERL at the North Eastham location is the primary source of wind energy information. Black & Veatch utilized the data collected from August 1, 2003 through July 31, 2004. As noted earlier, the Eastham data for April 2004 was lost. To fill this void, Black & Veatch obtained the ten-minute data from the RERL met tower in Orleans. Because the ten-minute data correlated well between Orleans and Eastham, Black & Veatch used the Orleans 40 meter Anemometer A data for April 2004 to complete the Eastham data set. The data correlated well enough that the average wind speed for April 2004 from Orleans was used without adjustment.

The 2003/2004 39 meter Eastham data has an average value of 5.3 m/s. The next step in the MCP process was to put the wind speed into historical perspective. Black & Veatch compared the monthly average wind speeds for the data collected at the long-term reference station (Provincetown Airport) over the period the Eastham data was collected (August 2003 through July 2004) with the monthly average wind speeds of every complete month on record. A set of correction factors were found for each month which align the 2003/2004 data averages with the long-term averages. These factors were then applied to the Eastham data set to create an estimate of the long-term wind resource of Eastham. Based on this correction, the long-term average wind speed for Eastham at 39 meters is estimated to be 5.1 m/s. The factors and resulting 39 meter long-term monthly averages for Eastham are shown in Table 4-3.

The final step in the MCP process is to adjust the wind speed data from the measurement height of 39 meters to the typical wind turbine hub heights of 50, 65, 80, and 100 meters. To make this height adjustment, Black & Veatch utilized the wind shear power law approximation, which defines the relationship between wind speed and height above ground as:

$$V(Z) = V(z_r) \cdot \left(\frac{z}{z_r} \right)^{\alpha}$$

where: $V(z)$ = wind speed at height of interest
$V(z_r)$ = wind speed at reference height
z = height of interest
z_r = reference height

α = wind shear component

Black & Veatch utilized the Eastham data collected at 39 and 30 meters to estimate the wind shear component, alpha (α), at 0.40, a value considerably higher than in most wind energy sites in the U.S. Because this value was found using proper estimation techniques (such as only using wind speed values above 4 m/s), Black & Veatch used an α of 0.40. To estimate the 50 meter long-term average wind speeds at Eastham from the 39 meter data, Black & Veatch multiplied each data point by a factor of 1.104; for 65 meter data, each data point was multiplied by 1.227; for 80 meter data, each data point was multiplied by 1.333; for 100 meter data, each data point was multiplied by 1.457. The resulting long-term averages for Eastham at various heights above ground are given in Table 4-3, and shown in Figure 4-8. The resulting percent energy wind rose for the 65 meter data is shown in Figure 4-9.

Table 4-3
Estimated Eastham Long-Term Monthly Averages

Month	Measured		Long-Term Predictions				
	39 Meters	Historical Correction	39 Meters	50 Meters	65 Meters	80 Meters	100 Meters
January	6.8	0.79	5.4	5.9	6.6	7.2	7.9
February	5.4	1.01	5.5	6.0	6.7	7.3	8.0
March	6.0	0.85	5.1	5.6	6.2	6.8	7.4
April	5.6	0.95	5.3	5.9	6.5	7.1	7.7
May	4.6	0.92	4.2	4.6	5.2	5.6	6.1
June	4.6	0.94	4.3	4.7	5.3	5.7	6.3
July	4.1	0.91	3.7	4.1	4.6	5.0	5.4
August	4.5	0.89	4.0	4.5	5.0	5.4	5.8
September	4.1	1.00	4.1	4.5	5.0	5.5	6.0
October	5.2	0.99	5.2	5.7	6.3	6.9	7.6
November	5.7	1.17	6.6	7.3	8.1	8.8	9.6
December	7.3	0.91	6.6	7.3	8.1	8.8	9.6
Annual	**5.32**	**0.94**	**5.00**	**5.52**	**6.13**	**6.66**	**7.28**

Notes: **All wind speed values in meters per second.**

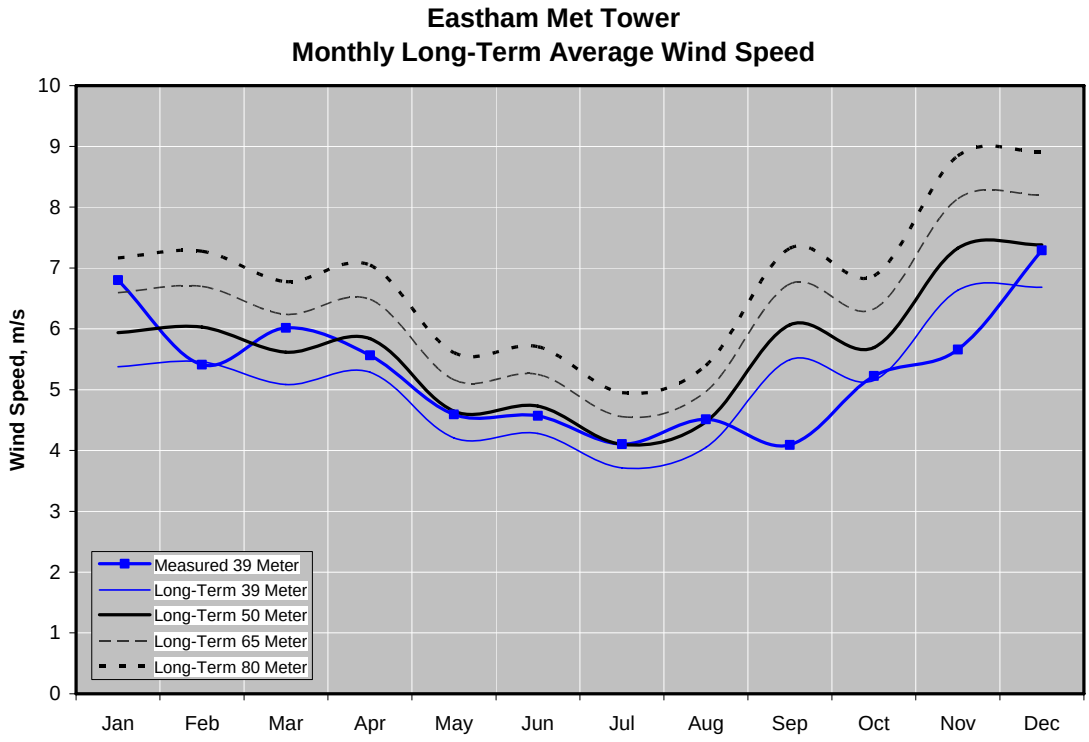


Figure 4-8 Eastham Long-Term Monthly Wind Speed Averages

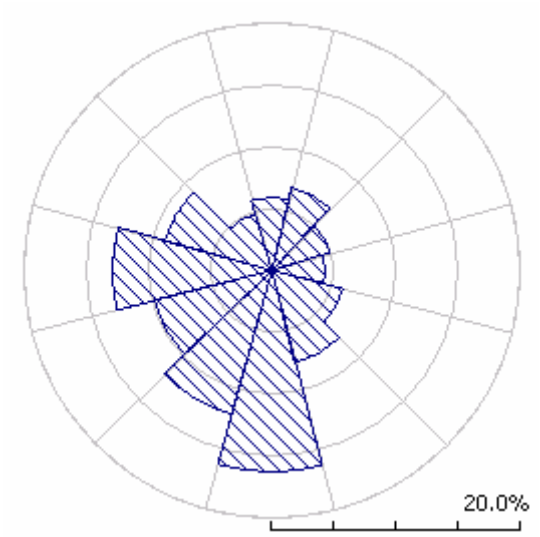


Figure 4-9 Eastham Long-Term 65 Meter Percent Energy Wind Rose

As part of the International Electrotechnical Commission (IEC) 61400 series of standards governing the design of wind turbines, a series of designations are given to the wind resource of a site. These designations are used to match the appropriate turbine designs and models for a site's wind conditions. Based on the on-site wind data collected, the site appears to have a Class IIIA designation. The higher hub heights increase the potential winds to the point that using a Class IIA turbine may be more prudent than a Class IIIA. The designation of the site as it applies to the design of a specific wind turbine will be evaluated by the wind turbine manufacturer, to ensure the proper wind turbine model is provided,

Black & Veatch acknowledges there is disagreement as to the true wind resource on Cape Cod. One of the RERL papers reviewed identifies Eastham as one location where measurements have not yielded results consistent with the TrueWind map. Potential causes for the disagreement may be problems with the mapping methodology, interference of the met tower readings by the cell tower, the relative low height of the met tower (40 meters) compared with the hub height of commercial wind turbines (65 to 80 meters), or inaccurate estimate of wind shear. To address this uncertainty and better understand the wind resource, Black & Veatch identified two possible solutions. Ideally, a new met tower at least 60 meters in height could be installed in a location further away from the cell tower, and operated for at least one year. Given the time requirements of such an option, an alternative would be to install a SODAR system at the proposed turbine site to measure the wind shear characteristics. If the multiple wind turbine option is chosen, Black & Veatch recommends the SODAR be installed at the site closest to the cell tower.

5.0 Site Physical Characteristics

Eastham is located on Cape Cod at the southern end of the north-south peninsula. The topography around the project location is relatively flat with elevations varying between sea-level and 50 feet. There is significant tree cover throughout Eastham and the surrounding areas, with tree heights estimated to be up to about 50 feet tall. Homes and low buildings are close to the location, although no structures other than the cell tower were observed to be higher than the tree cover. The location can be readily accessed from Highway 6 (State Highway), making transport of wind turbine components to the sites relatively easy, although some road improvements and new access roads to some of the more remote sites will be required.

5.1 Wind Turbine Spacing Requirements

Black & Veatch used three general guidelines for locating wind turbines in North Eastham:

- Minimum spacing between the wind turbines so they do not interfere with each other's operation.
- Setbacks recommended for public safety.
- Setbacks required per zoning laws.

Each of these requirements are discussed briefly below, and applied to the evaluation of potential turbine locations in Section 5.2.

5.1.1 Wind Turbine Spacing

Wind turbines generate electricity by transferring energy from the wind to the turbine's drivetrain. Because they take energy from the wind, and because they are large structures, wind turbines create an area around them in which the wind flow is disturbed. Placing wind turbines too close together would place one turbine within the disturbed area of another, causing turbines to "steal" the wind energy from each other. To avoid this, there are two general rules about placement of wind turbines. The first is to place turbine towers at least three times the turbine rotor diameter (3D) from each other in the direction perpendicular of prevailing winds. The second is to place turbines at least 8D from each other in the direction parallel to prevailing winds. The reason for the different spacing is that the wake effects of turbines are much greater downwind than they are cross-wind. Figure 5-1 shows a diagram of this concept.

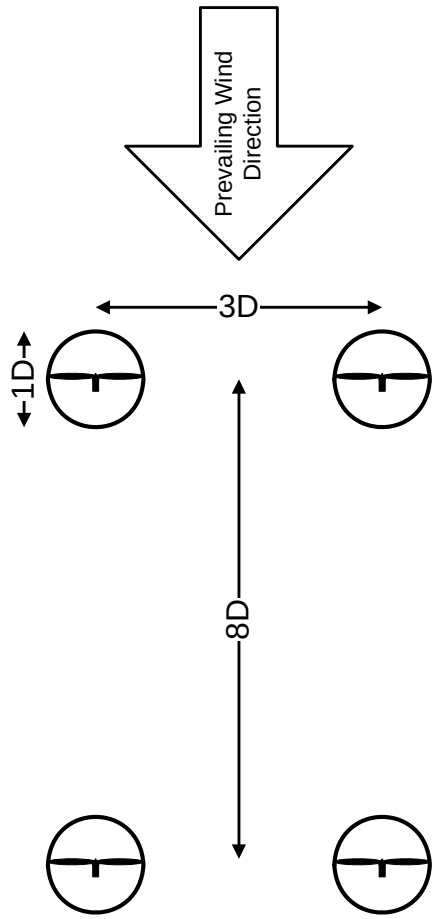


Figure 5-1 Wind Turbine Spacing

The prevailing wind direction for Eastham is expected to be from the southwest (240˚), although the RERL Eastham met tower showed two distinct primary wind directions from the south (180˚) and west (270˚). Therefore, the preferred alignment of the towers is northwest to southeast.

These guidelines are not absolute requirements. Tighter spacing is often done when land use conditions require it. If closer spacing is required, an increase in the corresponding turbine's losses would also be included to account for the lost energy. This will be discussed further in Section 9.2.

5.1.2 Wind Turbine Safety Areas

Wind turbines in general are very safe machines, and cause little impact to their surrounding environments. However, very rare instances of wind turbine failures have occurred (including a wind turbine collapse in 2005), and after a winter storm ice can build-up on wind turbine blades which could create a falling hazard on people below.

While both turbine collapse and ice shedding are extremely uncommon, Black & Veatch nevertheless included this possibility in the site evaluation.

The most conservative approach deemed appropriate was to establish a "safety radius" around each turbine, and place the turbines such that the safety radius does not include any homes, roads, or public areas. Black & Veatch chose to set this safety radius as the distance from the base of the turbine tower equal to the total height of the turbine. By this definition, even the complete collapse of the turbine should not endanger the public. Any issues of ice shedding should occur well within this safety radius.

5.1.3 Wind Turbine Required Setbacks

As with any other structure, wind turbines have a required setback from the boundary of neighboring property. Unlike other structures, the turbine's components at ground level would not be a good indicator of the structure's outer dimensions, as it would not account for the turbine's blades. To make certain the setback was sufficient to account for the turbine's blades, Black & Veatch determined the blade overhang radius and used that to define the outer edges of the wind turbine structure. The zoning requirement of at least 50 feet from a structure to the property boundary was then applied to the overhang radius. See Section 7.1.6 for a discussion on the zoning requirements for the Town of Eastham.

For the purpose of site evaluation, Black & Veatch applied the size characteristics of the largest candidate wind turbine evaluated in this report (Fuhrländer FL2500) to determine the safety and setback distances. The dimensions of the turbine design, and the corresponding area values, are given in Table 5-1 and shown in Figure 5-2 Wind Turbine Spacing Requirements. The subsequent aerial views of potential wind turbine sites also show these areas.

Table 5-1
Wind Turbine Sizing Area Requirements

Turbine Type	Fuhrländer FL2500	
Hub Height	100 m	328 feet
Blade Diameter	90 m	296 feet
Total Height Above Ground	145 m	476 feet
Eastham Setback	15 m	50 feet
Setback Radius	**60 m**	**197 feet**
Safety Radius	**145 m**	**476 feet**

Notes: Green circles in the figures below indicate the setback and safety areas for each wind turbine.

Figure 5-2 Wind Turbine Spacing Requirements

5.2 Potential Turbine Locations

The Town of Eastham owns several parcels of land in North Eastham that are not populated and could potentially be used for a community wind project. Black & Veatch inspected the location on August 1, 2005 with members of the Town of Eastham Wind Energy Committee, and the Massachusetts Technology Collaborative. A follow-up visit to the identified sites was done on October 7, 2005. Black & Veatch identified four sets of Eastham-owned parcels with enough land to support up to six large wind turbines. The approximate boundaries of these areas, and potential wind turbine sites, are shown in Figure 5-3. For reference, the southwest corner of the southern parcel is near the intersection of Highway 6 and Nauset Road, and the southeast corner is just north of Oak Leaf Road and Viola Road. The northwestern corner of the northwestern parcel is adjacent to the Cape Cod Rail Trail, and is just south of Village Lane. Black & Veatch believes the northern two parcels may actually be located within the town borders of Wellfleet.

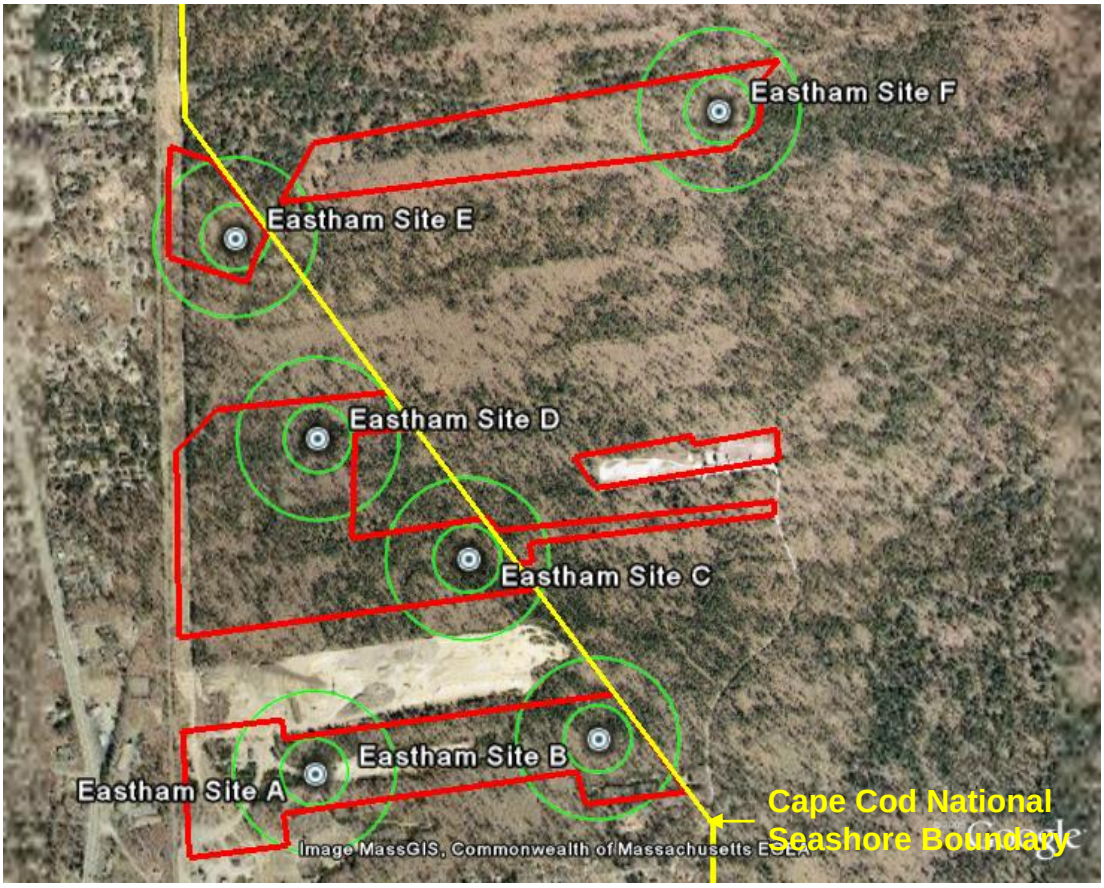


Figure 5-3 North Eastham Location Aerial View

The parcel boundaries shown in Figure 5-3 and subsequent figures were taken from a printed map given to Black & Veatch by the Town of Eastham, and are therefore approximate. Final turbine locations and separations from property boundaries would be determined after site surveying work was performed during the design phase of a project. More information on these parcels and neighboring landowners is provided in Section 7.1.5.

The southern parcel is adjacent to a gravel mining operation. North of this parcel is a gravel mine owned by Nauset Road LLC, and south of this parcel is the mining office and equipment center. This parcel is the location where an RERL met tower was installed from July 2003 through August 2004, and is also the site of the cell tower. This was the only parcel at this location visited by Black & Veatch, MTC, and Town of Eastham representatives on the August 1, 2005 site visit.

The central parcel and northern two parcels are undeveloped wooded areas. A significant amount of the land surrounding the Town of Eastham parcels is owned by the federal government, most likely as part of the Cape Cod National Seashore. Information provided by the Town of Eastham on October 7, 2005 indicates that the eastern edges of the southern, central, and northwestern parcels are adjacent to the Seashore boundary (shown by yellow line). The entire northeastern parcel appears to be within the Seashore. While this may be a fatal flaw to placing a wind turbine on this parcel, Black & Veatch identified a potential turbine site in case the Town was indeed capable of developing one on this parcel. The Town of Eastham has no known electrical loads on any parcels at this location. The cell tower and the gravel mine are both operated by private companies.

5.2.1 Site A

Site A is in the southern parcel, about 110 meters (360 feet) southwest of the cell tower, and near a green waste disposal area. The coordinates of the site are approximately 41˚ 52' 0.7" North, 69˚ 58' 47.2" West (NAD27), and base elevation is about 15 meters (50 feet) above sea level. The land around this site is relatively clear and level, with no significant obstructions nearby expect the cell tower. A wind turbine at this site should not impact the operations of the gravel mine except possibly due to construction vehicles on the road during the turbine's installation. A picture of this site is included as Figure 5-4.

Figure 5-4 Photo of Site A

The only expected potential obstruction to a wind turbine at Site A would be the 67 meter (220 foot) cell tower. This tower is 115 meters (380 feet) northwest of Site A. Although the cell tower is only 1.25D from Site A (using a FL2500), it is not upwind in a prevailing direction, and it has slender profile. Therefore Black & Veatch is not expecting the cell tower to significantly effect the operation of a wind turbine at Site A. What is unknown is how a wind turbine at Site A may impact the operation of the cell tower. An initial literature review by Black & Veatch found no conclusive siting guidelines for wind turbines near cell towers, or the level to which cell operations are

interfered with by operating wind turbines. Black & Veatch recommends the project be discussed with the cell tower operator, and the terms of the land lease agreement reviewed, before a wind turbine is committed to for this site.

The location where RERL installed the met tower is within 23 meters (75 feet) west of the cell tower and 45 meters (150 feet) east of the transmission lines. These obstructions make the site where the met tower had been installed too small to accommodate either a small or large wind turbine.

5.2.2 Site B

Site B is in the southern parcel, and is about 520 meters (1,700 feet) east-northeast of Site A on the opposite side of a large pit. The coordinates of the site are approximately 41˚ 52' 2.8" North, 69˚ 58' 24.9" West (NAD27), and base elevation is about 18 meters (60 feet) above sea level. The land on this side of the pit is wooded, and the trees around the site would require clearing to allow for a wind turbine's installation and maintenance. Also, an access road to the site would need to be cleared and constructed. A picture toward this site from the west side of the pit is included as Figure 5-5.

Figure 5-5 Photo of Site B

5.2.3 Site C

Site C is in the central parcel, about 400 meters (1,310 feet) northwest of Site B and about 480 meters (1,570 feet) northeast of Site A. The coordinates of the site are approximately 41˚ 52’ 13.4” North, 69˚ 58’ 35.0” West (NAD27), and base elevation is about 20 meters (66 feet) above sea level. The land on this site is wooded, and the trees around the site would require clearing to allow for a wind turbine’s installation and maintenance. Also, an access road to the site from the southern parcel would need to be cleared and constructed. Figure 5-6 shows the aerial view of the site.

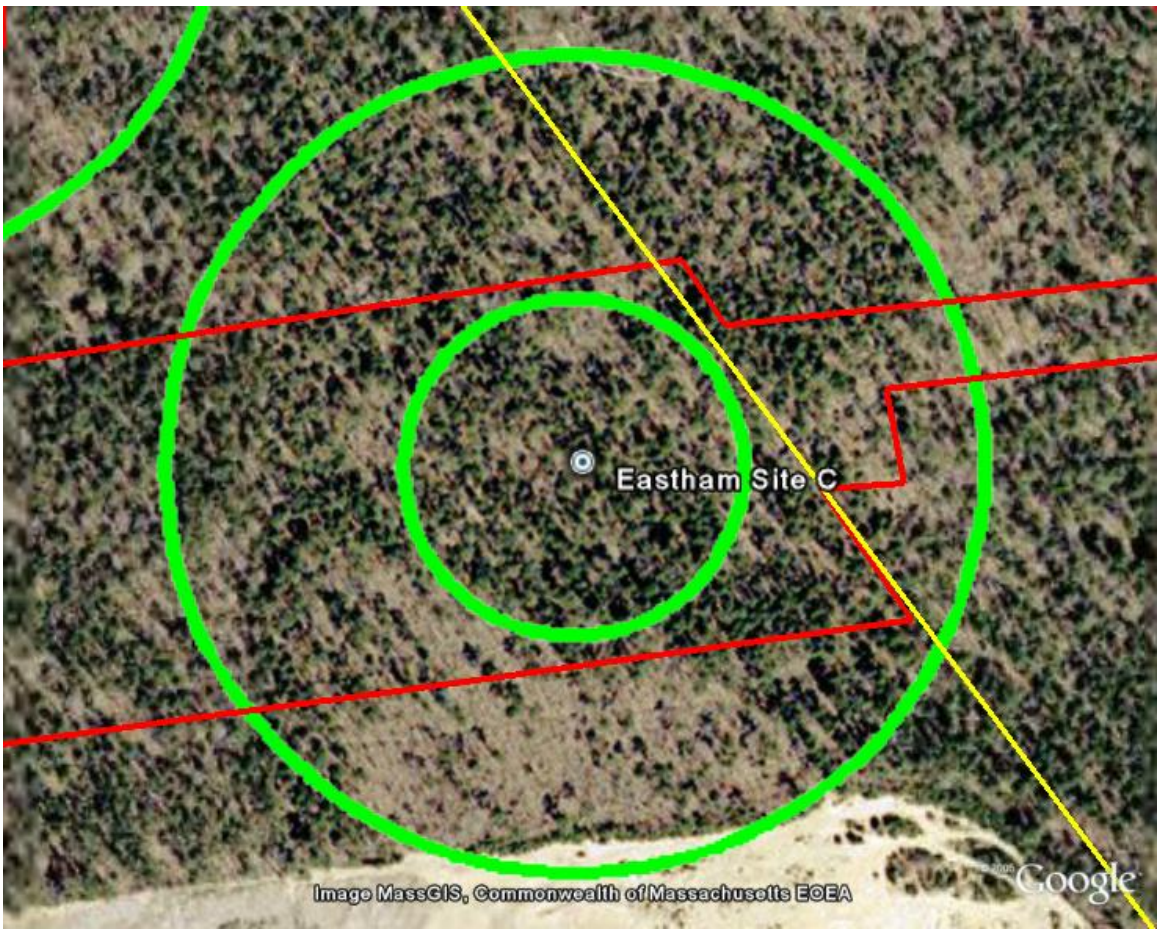


Figure 5-6 Aerial View of Site C

5.2.4 Site D

Site D is in the central parcel, about 350 meters (1,150 feet) northwest of Site C. The coordinates of the site are approximately 41˚ 52’ 20.4” North, 69˚ 58’ 46.9” West (NAD27), and base elevation is about 20 meters (66 feet) above sea level. The land on this site is wooded, and the trees around the site would require clearing to allow for a wind turbine’s installation and maintenance. Also, an access road to the site from the southern parcel would need to be cleared and constructed.

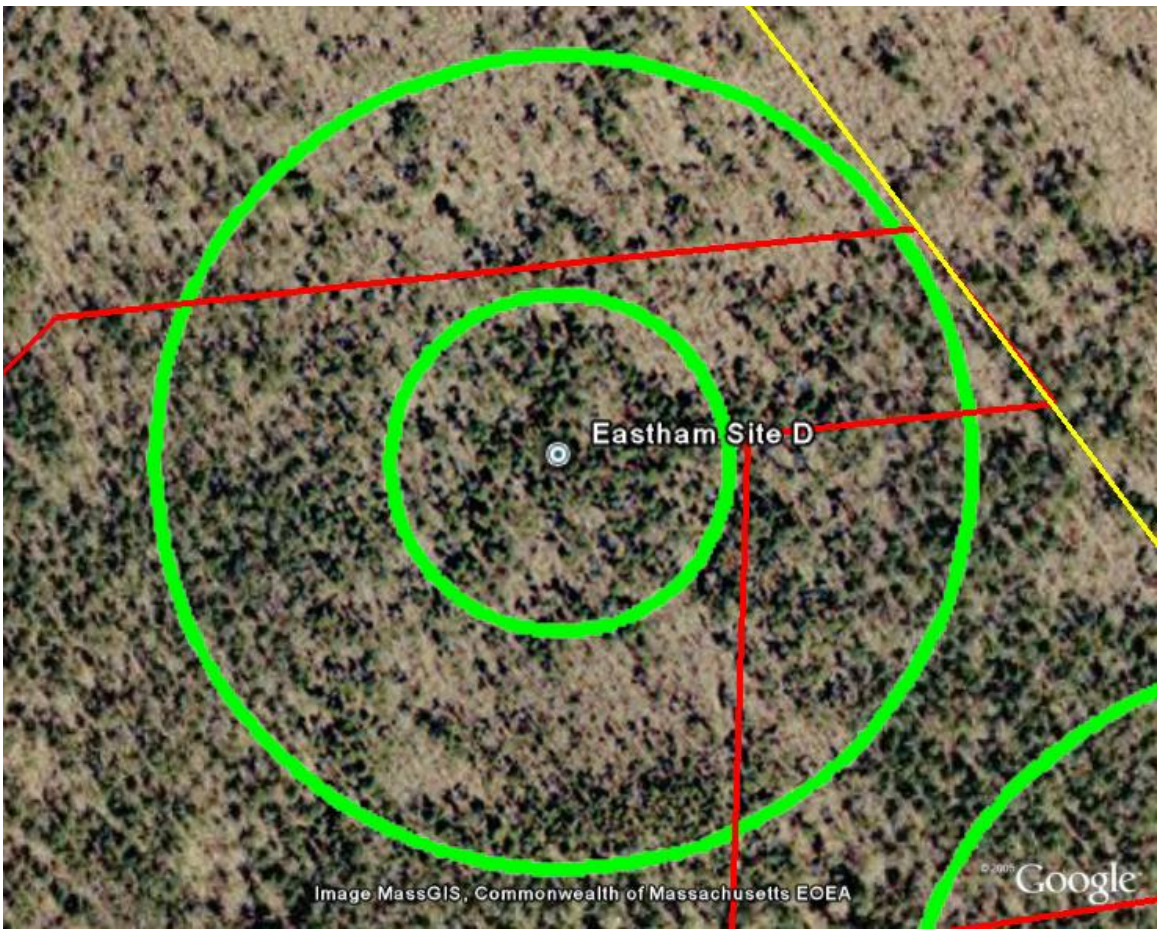


Figure 5-7 Aerial View of Site D

5.2.5 Site E

Site E is in the northwest parcel, and about 400 meters (1,310 feet) northwest of Site D. The coordinates of the site are approximately 41˚ 52' 32.2" North, 69˚ 58' 53.6" West (NAD27), and base elevation is about 11 meters (36 feet) above sea level. This was the only site Black & Veatch was not able to maintain both the setback radius from neighboring property and the safety radius from the nearest homes on Oakwood Road for the largest turbine option. As such, the safety radius was maintained but the setback radius crosses the property boundary. More accurate surveying would be needed to determine if a turbine at this site would indeed violate the setback requirement, and if a smaller turbine would be required. The land on this site is wooded, and the trees around the site would require clearing to allow for a wind turbine's installation and maintenance. Also, an access road to the site from the southern parcel would need to be cleared and constructed. Figure 5-8 shows the safety radius and home locations in more detail.

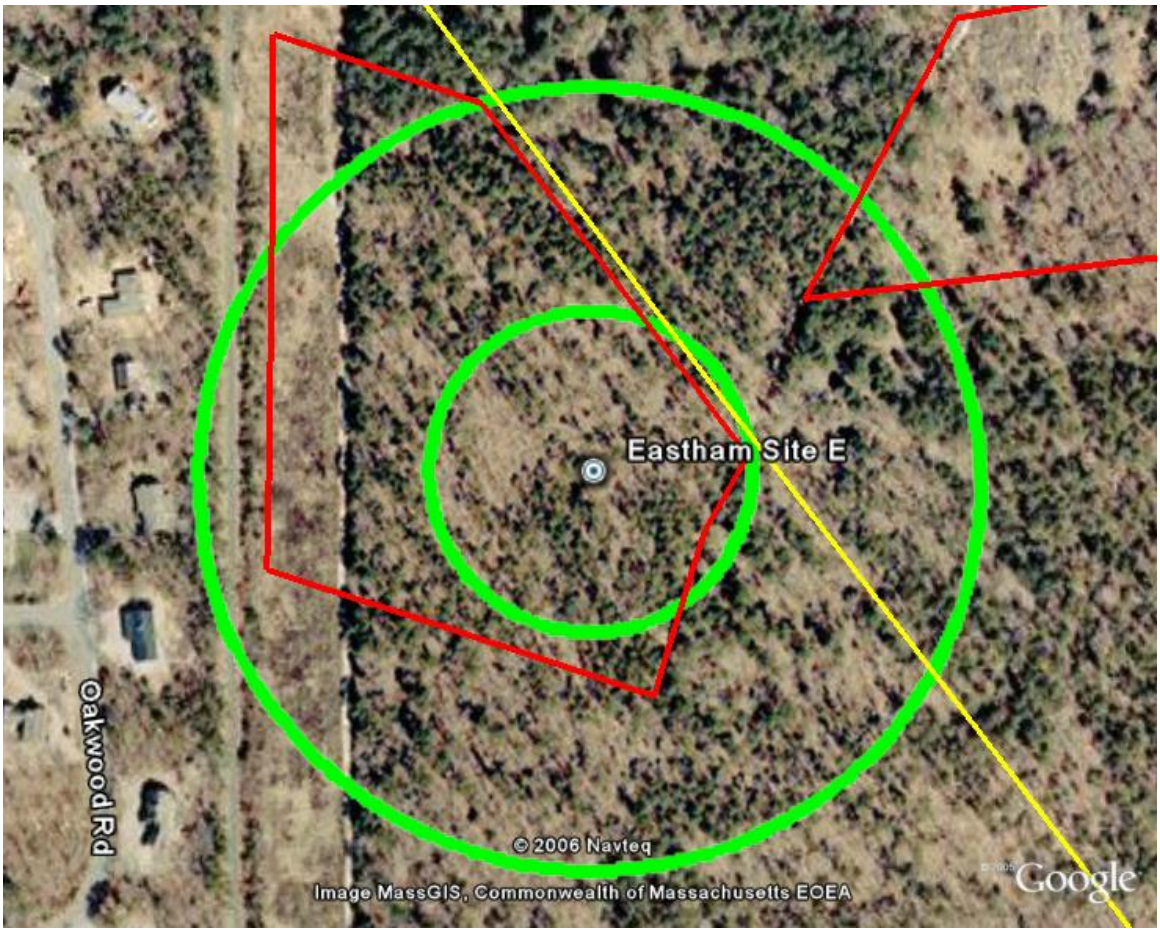


Figure 5-8 Aerial View of Site E

5.2.6 Site F

Site F is in the northeast parcel, about 910 meters (2,990 feet) east-northeast of Site E, and about 930 meters (3,050 feet) northeast of Site C. The coordinates of the site are approximately 41˚ 52’ 39.7” North, 69˚ 58’ 15.4” West (NAD27), and base elevation is about 12 meters (39 feet) above sea level. The land on this site is wooded, and the trees around the site would require clearing to allow for a wind turbine’s installation and maintenance. Also, an access road and electrical line from the southern parcel to the site would need to be cleared and constructed. Although the parcel for this site is owned by the Town of Eastham, it is within the boundary of the Cape Cod National Seashore. As such, this site is very likely fatally flawed, and is not developable.

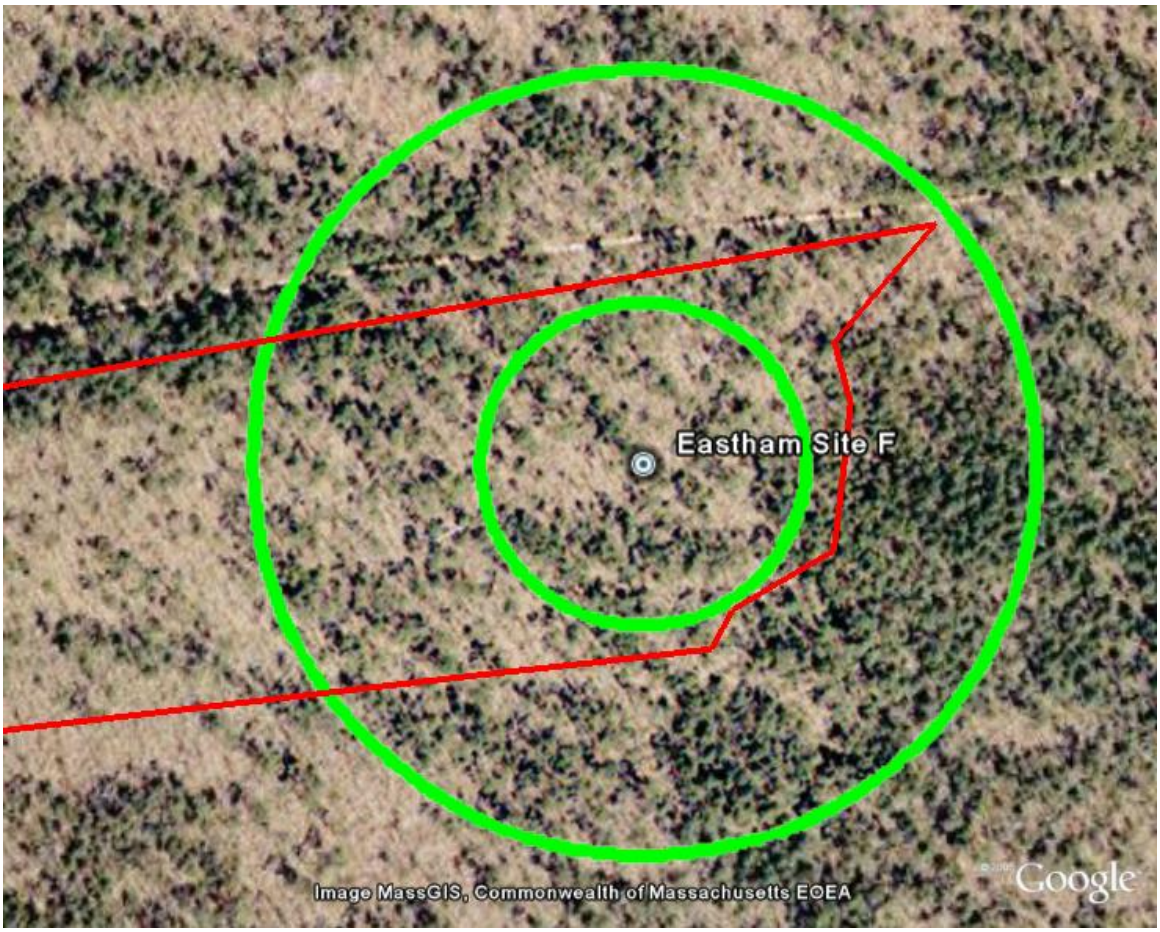


Figure 5-9 Aerial View of Site F

5.3 Black & Veatch Recommendations

Black & Veatch anticipates the North Eastham Location will be the best location within Eastham for a wind energy project large enough to sell power as a commercial power plant. With up to six large wind turbines, there should be enough energy generated by the project to interest developers and investors. The project layout being recommended by Black & Veatch is discussed below, and shown in Figure 5-10.

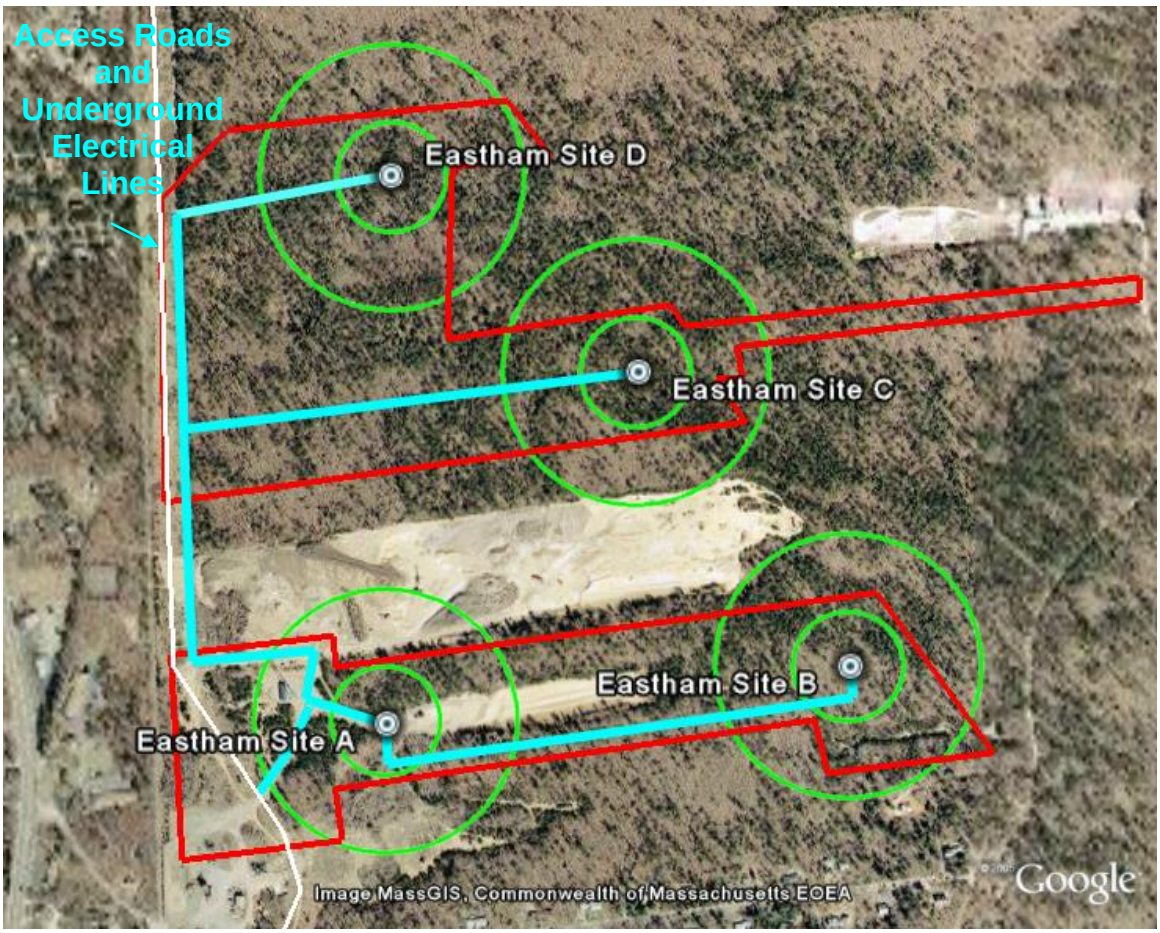


Figure 5-10 Black & Veatch Project Recommendation

Of the sites identified above, Black & Veatch recommends Sites A, B, C, and D for further development. These locations are far enough from homes and public areas that operations safety should not be a concern. Site F is within the Cape Cod National Seashore, and as such Black & Veatch anticipates it is not feasible for development.

At this time, Black & Veatch also cannot recommend Site E for locating a large wind turbine, due to its proximity with the homes on Oakwood Road and potential setback requirements. Although these homes are outside the safety radius of the turbine

site, it is likely these homeowners will hear the wind turbines operating in light winds, and may be impacted by shadow flicker (sunlight strobe effect caused by the rotating turbine blades) during sunrise. If the Town of Eastham has an interest in further developing this site, Black & Veatch recommends the homeowners closest to the site be contacted and the project discussed. Black & Veatch would only recommend wind turbine placements near these homes if all homeowners support the project. Also, the property boundary should be surveyed to confirm the turbine chosen for the project can legally be placed without infringing on neighboring property.

While there is currently sufficient access to Site A, new access roads will need to be built to Sites B, C, and D. Black & Veatch has indicated initial routing for these roads in Figure 5-10, but final routing will depend upon property surveys and topographic details not currently available. Easements on land not owned by the Town may be required for construction of these roads. It is likely that the underground collection system will be run along the edge of the road to limit the amount of tree clearing necessary. There currently exists a dirt road (likely a private road for transmission line access and maintenance) in the north-south corridor on the western edge of the parcels that could be used for site access if improved and permission obtained.

For each turbine site, Black & Veatch recommends that public access be minimized by erecting gates on the access roads and posting warning signs. However, it is likely that fencing each turbine site is neither feasible nor desirable, and therefore some members of the public will walk to the turbines. This is generally acceptable and safe so long as the public is asked not to stand under the turbine while it is in operation, and access doors to the turbines must remain locked.

5.4 Wind Turbine Equipment Access

The components for the wind turbines would likely be shipped via over-road trucks using Highway 6. Site A could be accessed using the existing roads, but new access will be needed for the other sites. While a transportation logistics review would need to be performed by the wind turbine manufacturer, Black & Veatch does not anticipate any height or weight restrictions that would complicate component delivery.

6.0 Electrical Interconnection and Offset

This section discusses the technical and procedural issues associated with interconnecting the wind turbines to the power grid.

6.1 Typical Wind Turbine Electrical Connection

Most wind turbines have low voltage (around 600 V) induction generators in the nacelle. Each turbine will have a transformer to increase the voltage to a medium voltage level (typically between 12 and 34.5 kV), so the power can be transmitted without high-current losses. Some wind turbine manufacturers approach the design and placement of transformers differently than others. The GE 1.5 MW turbine design calls for the transformer to be located external to the wind turbine (similar to the arrangement shown in Figure 6 1); the Vestas V80 design includes the transformer in the nacelle.

Figure 6-1 Typical Wind Turbine Transformer Arrangement

Electrical power is transmitted from a wind turbine at medium voltage using underground cables. These cables connect multiple turbines together and then typically to a common grid connection point. Community wind energy projects can be connected to the grid in two general ways. The first is for the project to connect directly to a

utility's transmission (high voltage) or distribution (medium voltage) line. The wind turbines would sell power directly to the grid, and revenue meters would be positioned at the point of connection. This is the manner large commercial wind energy projects are connected, and the value for the energy would be similar to other commercial power plants. The other connection method is used when the goal is to first offset a large on-site electrical load, and then sell any excess to the grid. For this method, the wind turbine must be located next to the large load, and electrically connected on the load side of the utility's meter. This connection method is sometimes referred to as co-metering, and allows the community to get the benefit of the wind energy at the same price the electricity is purchased. Because there are no on-site loads for the Town at the North Eastham location, a wind project there would need to connect to an electrical transmission or distribution line and sell power to the grid as an Independent Power Producer (IPP).

6.2 Electrical Infrastructure Near Project Site

West of the North Eastham location are two electrical lines: a 115 kV NSTAR transmission line connecting the Orleans and Wellfleet substations, and a 23 kV distribution line for local residents (believed also to be owned by NSTAR). A map showing the location of these lines is shown in Figure 6-2, and a photo of the lines taken near Site A (looking north) is shown in Figure 6-3.

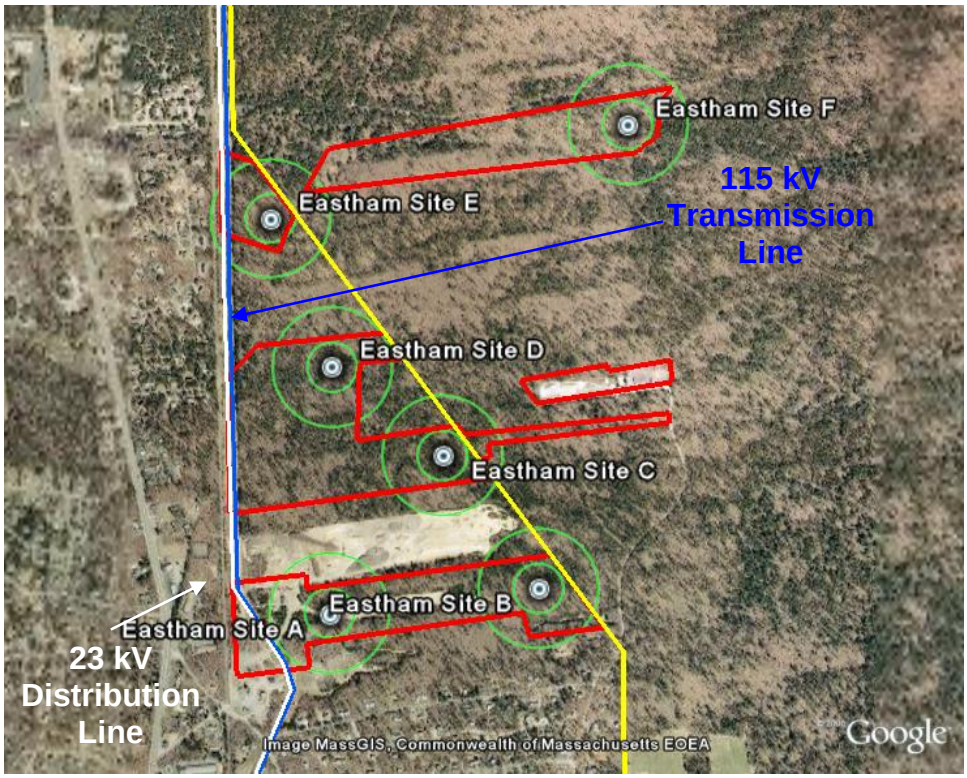


Figure 6-2 Location of North Eastham Electrical Lines

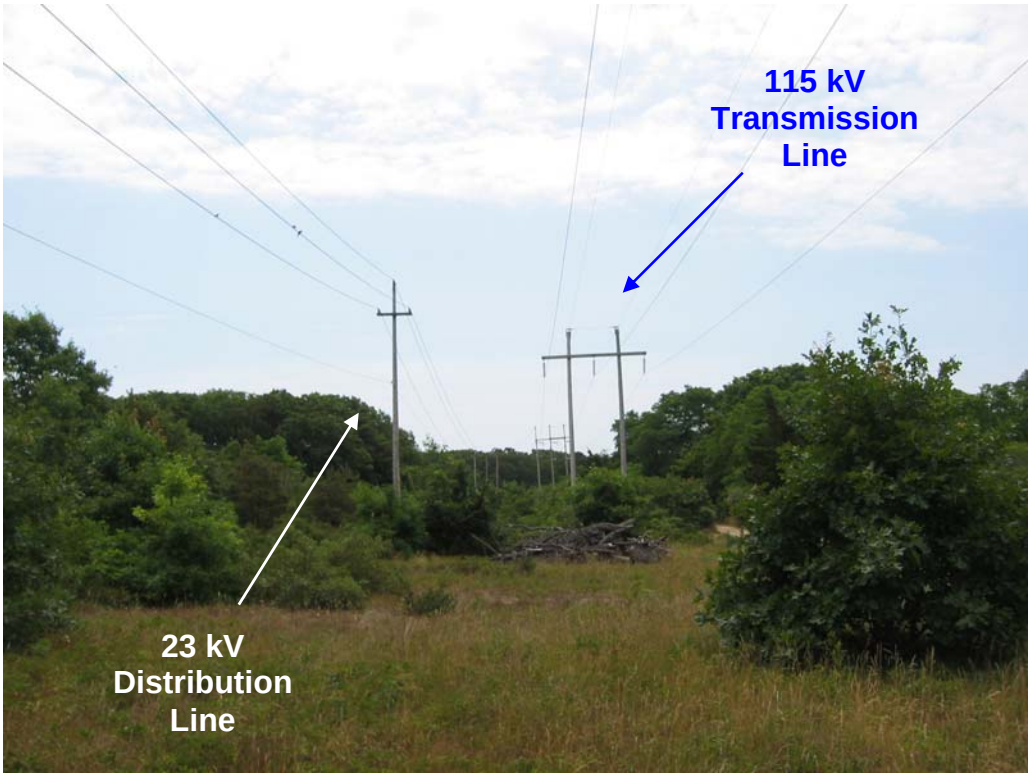


Figure 6-3 North Eastham Electrical Lines

The manner in which the wind energy project would be interconnected will depend upon the capacities of the two NSTAR lines and how large of a wind energy project is built. Connecting to the lower voltage distribution line would likely be less expensive, because it could potentially be done without constructing a project substation. However, the low voltage line may only accommodate the generation from a smaller project. For more turbines, the project may need to connect to the 115 kV transmission line. This line will likely be able to accept the generation from as large a project as could be sited in North Eastham. However, to interconnect to this line a substation with a large transformer will be required. Both options are discussed in greater detail below.

6.2.1 Transmission Line Connection

As mentioned above, it is the expectation of Black & Veatch that connecting a project of any size to an electrical line of transmission voltage (generally defined as 69 kV and higher), a substation would be required. Such a substation would include a collection feeder where all the power from the turbines would be connected to a medium voltage bus. This bus may also have a capacitor bank connected to maintain requirements for voltage support, as well as protection equipment such a breakers. The medium voltage bus would connect to a transformer, which would step-up the voltage to 115 kV and connect to a high voltage bus. A project revenue meter would likely be attached to the high voltage side of the transformer to record the amount of power generated by the project. A riser structure would be used to connect the power from the high voltage bus to the overhead 115 kV transmission line. An example substation of this general design is shown in Figure 6-4.

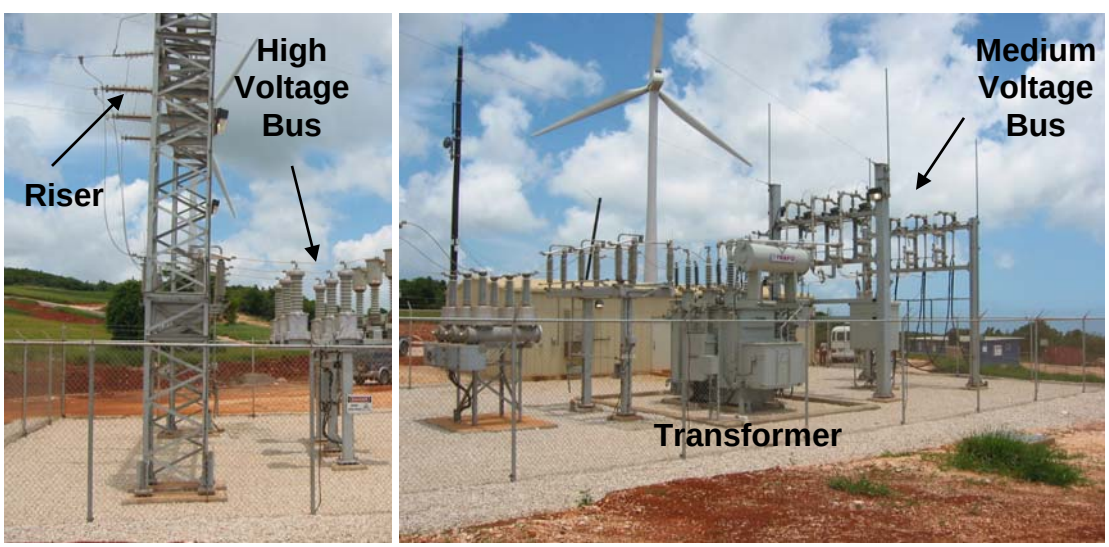


Figure 6-4 Distribution Line Interconnection

6.2.2 Distribution Line Connection

The connection of a small wind energy project to a distribution line can often be done without requiring a substation, nor any other ground-mounted electrical switchgear. The underground collection system would be brought to a point close to the overhead 23 kV distribution line. At this point, the underground collection system would be brought overhead using a transition pole. Using a total of two or three overhead poles, the wind project's collection system would connect to the 23 kV distribution line through a meter, disconnect switch, and recloser. An example of this type of connection is shown in Figure 6-5. The specifics of this design, and what other equipment may be necessary, depend greatly on NSTAR's requirements.

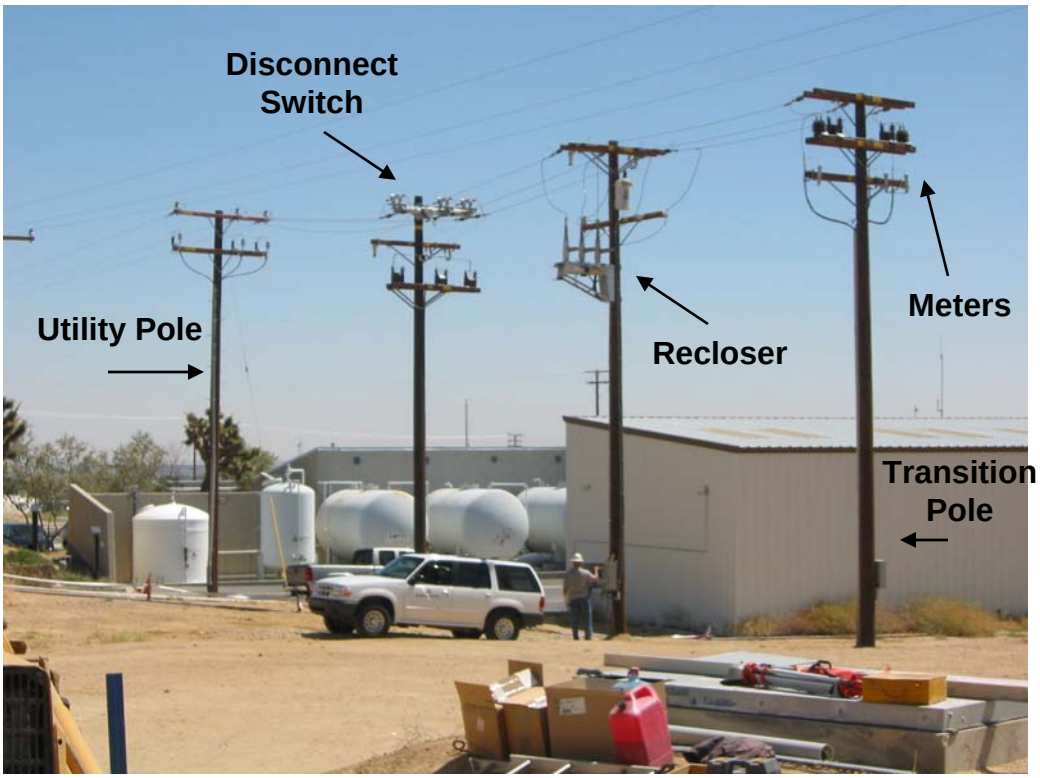


Figure 6-5 Distribution Line Interconnection

6.2.3 Project Connection Assumptions

To further determine the capacities of both transmission lines, and the feasibility of connecting to either, Black & Veatch contacted Mr. Joe Feraci at NSTAR. Mr. Feraci was unable to provide any technical guidance on the line, other than to recommend the project apply for interconnection service to start the interconnection study process (discussed below). Black & Veatch also contacted Mr. Charles Salamone of Cape Power Systems. Mr. Salamone indicated it was his understanding that the 23 kV line had a total

design capacity of about 37 MVA (roughly equivalent to 37 MW). However, Mr. Salamone advised that NSTAR uses the 23 kV distribution line as a back-up to the 115 kV transmission line to provide service to all the customers in northern Cape Cod. As such, the reliability requirements on this line are likely to be as stringent at that of a transmission line, meaning the equipment required to interconnect to it may require that a substation be built. As such, connecting to the 23 kV line may in fact not save a great deal of cost on the project.

Because Black & Veatch was not in a position to start a long and expensive interconnection study, two approaches were assumed. First, each project option was evaluated for connection to the high voltage line, meaning a substation was required regardless of the total project size. The second assumption was that each project option could connect to the 23 kV line without requiring an interconnection approach more complex than the simple recloser and tap described above. The intention of this approach is to estimate the highest and lowest likely costs for interconnecting the project.

6.3 Interconnection Request Procedure

The relatively small size of the project to be an IPP, and the two electrical lines operated differently, seem to place the process for requesting and studying the interconnection of the project into a gray area. Black & Veatch has contacted or evaluated documents from the Federal Energy Regulatory Commission (FERC), ISO New England, and NSTAR regarding interconnecting this project, and has received some conflicting information. The approach described below represents the current understanding of an interconnection request approach that would likely be successful and least-cost to the project. Black & Veatch recommends that this approach be monitored, and modified as needed, as additional information is obtained during the development process.

Step One: Initial Contact and Study by NSTAR. Black & Veatch discussed the project in general with Mr. Joe Feraci at NSTAR, who handles their distributed generation projects. Mr. Feraci provided the *Standards for Interconnection of Distributed Generation*, which applies to power projects installed in a co-metering arrangement. The project being studied here would be in an IPP arrangement, however given the size range of the project and that the least-cost approach would likely be to connect to the distribution line, Mr. Feraci recommended the project begin the interconnection study process by completing the distributed generation application. This is because NSTAR does not have a procedure for connecting an IPP to a distribution line,

so the distributed generation application would be the closest thing NSTAR could use to start the process.

Step Two: Complete NSTAR Study (if applicable). The next step in the interconnection process would depend upon the initial study results. If NSTAR determined that connection of the full project could be done on the 23 kV line, Black & Veatch recommends that the distributed generation study and interconnection agreement process be continued. While NSTAR would not comment on the total cost of this study, they did indicate the total required time normally is less than 6 months. At the completion of this process, the project would have an agreement with NSTAR to connect the project to the 23 kV line, an understanding of the interconnection requirements, and a cost estimate for the upgrades required to accommodate the project. No further interconnection study work would be needed. If NSTAR determined that the 23 kV line could not accept the generation from the project, and that connection to the 115 kV line would be needed, the project would end the study with NSTAR and proceed to Step Three.

Step Three: ISO New England Generation Interconnection Study (if applicable). Interconnection to the 115 kV line would require coordination with the regional Independent System Operations (ISO), which for Massachusetts is ISO New England. This is because ISO's coordinate the use of all transmission lines in their regions, regardless of who owns the lines. When Black & Veatch contacted ISO New England about connecting to the 115 kV line, the procedure provided was specific to ISO New England and not the new FERC-developed Small Generation Interconnection Procedure (SGIP). This is significant because the SGIP is supposed to define the manner in which all generation projects less than 20 MW go through the interconnection process. It could be that ISO New England has either decided not to follow the FERC procedure, has not yet made the change, or has not yet had a small generation interconnection request since the SGIP was issued (in December 2005). The SGIP process would likely require about $50,000 to perform all the studies, and is supposed to take no longer than 1.5 months. If this is indeed ISO New England's first project using the SGIP, it may take longer to complete. At the end of the process, the project would have an agreement to interconnect to the 115 kV line, a basic substation design, and a cost estimate for any system upgrades necessary to accommodate the project.

7.0 Environmental Concerns and Permitting

Given Eastham's location on Cape Cod and adjacent to a National Park, environmental concerns regarding a community wind energy project are expected to be an important component of the project's feasibility. Black & Veatch has prepared an overview of likely issues, and potential permit requirements. This review is preliminary, based on known major environmental components for wind energy projects. A more comprehensive environmental review would be performed as part of the development of a wind energy project.

7.1 Potential Environmental Impacts

Black & Veatch reviewed information on environmental sensitivities at or near Eastham, based on publicly available information. The items listed in this section indicate some issues that need to be explored during a project environmental review.

7.1.1 Natural Heritage and Endangered Species Program

To determine which environmental concerns are likely to exist for a wind energy project in Eastham, Black & Veatch reviewed information obtained from the Massachusetts Division of Fisheries and Wildlife's Natural Heritage and Endangered Species Program (NHESP) web site (www.nhesp.org). This web site identifies areas of the state that are of particular concern for endangered wildlife and plant life. Black & Veatch also reviewed information from the Massachusetts Audubon Society, and Nature Conservancy, and other public sources regarding sensitive areas near the project site. While this information is a good resource for a feasibility study, Black & Veatch would not consider the information below to be an exhaustive list, and would recommend a specific environmental review be done at the project site in future phases of project development.

The NHESP area designations reviewed and mapped for this site include:

- **Areas of Critical Environmental Concern (ACEC):** These are areas in Massachusetts that are considered special and highly significant due to their natural and cultural resources. Nominations for areas to receive ACEC designation are made by communities to the state Secretary of Environmental Affairs. Administration of the ACEC program is done by the Department of Conservation and Recreation. There are no known ACEC areas within or adjacent to the North Eastham project location.

- **Priority Habitat for Rare Species:** These areas are NHESP estimates of habitats for rare species. The boundaries of these habitats are considered approximate. The Cape Cod National Seashore in its entirety has been classified a Priority Habitat, so the North Eastham project location does border a Priority Habitat area.
- **Protected and Recreational Open Space**: These are areas that have been designated at the state or community level as areas for limited or no development. The Massachusetts Geographic Information System (MassGIS), the service from where the data was obtained, indicated the accuracy of the identified open space locations was limited.
- **BioMap Core Habitats**: The BioMap program was completed in 2001 by NHESP, and identified areas considered to represent "habitats for the state's most viable rare plant and animal populations"[1]. BioMap Core Habitats and Living Water Core Habitats encompass almost 1.4 million acres, or about 28 percent of the land area of Massachusetts. All of the North Eastham location is within BioMap Core Habitat 1109, which includes 5 threatened and 6 "special concern" vertebrate species, along with several invertebrate and plant species of similar designations. More information on this habitat and the BioMap program is in Appendix B.
- **Certified Vernal Pools**: NHESP define vernal pools as "small, shallow ponds characterized by lack of fish and by periods of dryness." These pools are deemed critical to some wildlife, and are protected under a variety of state programs including the Massachusetts Wetlands Protection Act. No known vernal pools exist within the North Eastham location.
- **Living Waters Critical Supporting Watersheds**: These watersheds are identified as being critical for supporting Living Waters Core Habitats. They were identified in the Living Waters project completed in 2003 by NHESP. There are no known Living Waters Critical Supporting Watersheds near the North Eastham location.
- **Living Waters Core Habitats**: Similar to the BioMap Core Habitats, the Living Waters Core Habitats are those rivers, streams, lakes, and ponds critical to the biological diversity of Massachusetts. There are

[1] From *BioMap and Living Waters, Core Habitats of Eastham*, Natural Heritage & Endangered Species Program, 2005

no known Living Waters Core Habitats near the North Eastham location.

Figure 7-1 is a map showing these identified areas near Eastham. The narrow north-south strip of open space represents an old railroad line that has been converted into a trail.

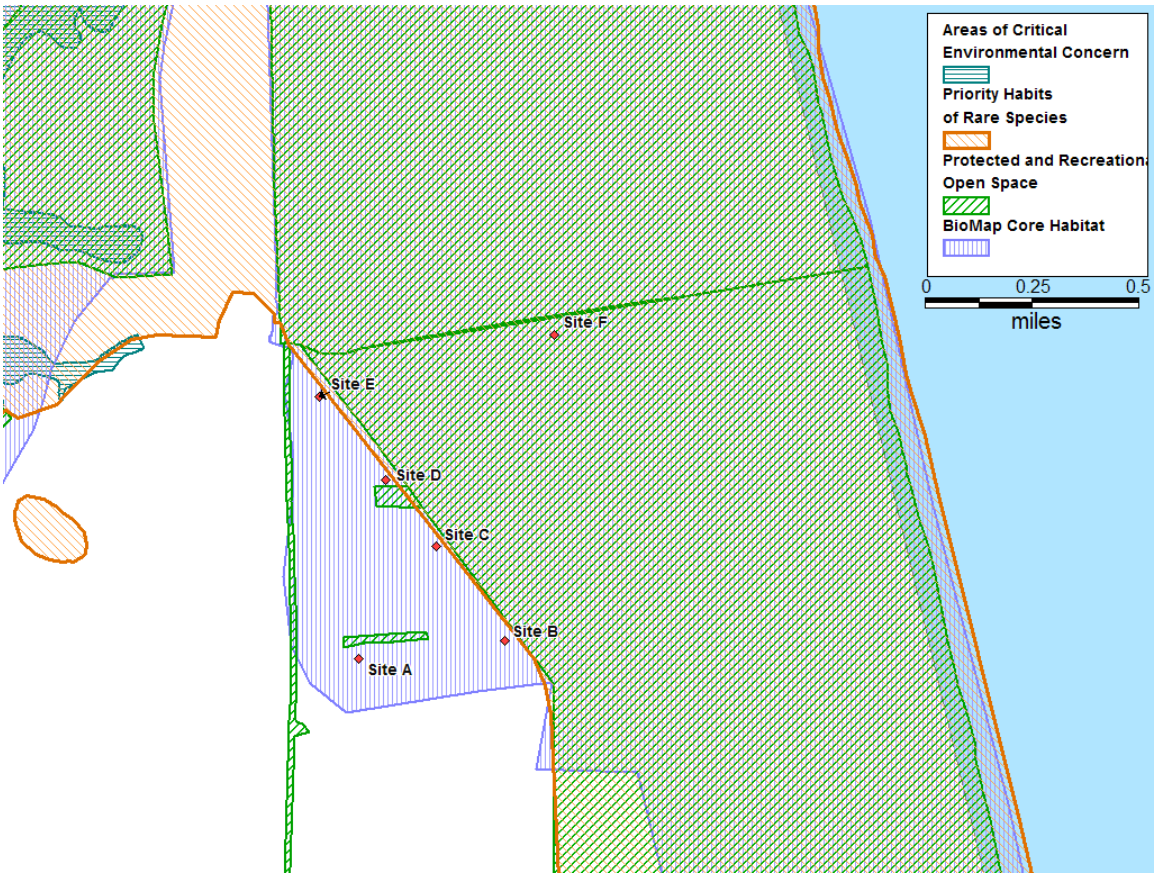


Figure 7-1 Environmental Protected Areas Near Eastham

The NHESP BioMap report *Core Habitats of Eastham*, dated January 2005, includes a listing of those natural communities, plants, invertebrates, and vertebrates that have special designation under the Massachusetts Endangered Species Act (MESA) and an unofficial NHESP watch list. MESA has three levels of classification for rare species: Endangered, Threatened, and Special Concern. As defined in the BioMap report, the definitions of these classifications are:

- **Endangered**: Species in danger of extinction, or of no longer being found in Massachusetts.

- **Threatened**: Species deemed likely to become Endangered in Massachusetts in the foreseeable future.
- **Special Concern**: Species that have suffered a decline that could threaten their existence, or that are very rare in Massachusetts.

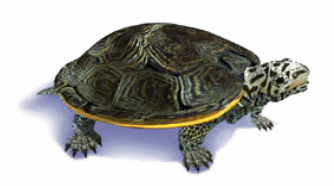
The BioMap report lists no known Endangered vertebrate or invertebrate species in the North Eastham location. There are four invertebrate and seven vertebrate species in North Eastham classified as Threatened, which include:

Chain Fern Borer Moth: No information on this moth was provided in the NHESP web site. The included photo is from the Moth Photographers Group web page, take by Jim Wiker.

Melsheimer's Sack Bearer: This is a medium-sized moth known to exist in scattered habitats throughout the southeastern U.S and the extreme southern tip of Ontario. Massachusetts is as far north as this species is known to be found. Its habitat includes pitch pine and scrub oak barrens. The included photo is from the Canadian Biodiversity Information Facility

Pine Barrens Bluet: This is a small insect about 1 inch in length that is found in coastal plain ponds on Cape Cod and various other locations in New England. The included photo is from the Massachusetts Division of Fisheries and Wildlife.

Water-Willow Stern Borer: This nocturnal moth has been observed in 59 sites throughout Cape Cod and southeast Massachusetts. The included photo is from the Moth Photographers Group web page, take by Jim Wiker.



Diamondback Terrapin: This medium-sized turtle is found along the Atlantic coast from Cape Cod to Cape Hatteras (North Carolina). The included photo is from the University of Delaware Graduate College of Maritime Studies web site.

Eastern Spadefoot: This small toad is found in various locations along the Eastern Seaboard and southeastern U.S. The NHESP report specifies that only 12 current sites for this species have been verified since 1978, although it is not clear that North Eastham is such a site. The included photo is from

the Virginia Department of Game and Inland Fisheries web site.

Northern Harrier: This hawk is common to Massachusetts, with some Harriers wintering on Cape Cod. As a hawk, the Harrier could be susceptible to collisions with wind turbines in a manner similar to the hawks near Altamont Pass, California (see Section 7.1.2.) However, the NHESP report in Appendix B does not show a verified habitat location near Eastham. The included photo is from the U.S. Geological Survey web site.

Piping Plover: This small shorebird is found all along the Atlantic coastline and the Gulf of Mexico. The NHESP report shows verified habitats in the Eastham region, although the exact location is not known. The Piping Plover is the only species on this list that is also listed as Threatened on the national level. The included photo is from the Maryland Department of Natural Resources web page.

Vesper Sparrow: This small ground-nesting songbird is often found in open fields and inland areas. The NHESP web site provided no specific information on this bird. The included photo is from the U.S. Geological Survey web site.

Additionally, BM 1109 has several species listed as Special Concern, along with many invertebrate, plant, and natural community species of several designations. Appendix B includes the NHESP BioMap report for Eastham and summaries for seven of the nine above Threatened species.

Because of the existence of these species, any project development in the North Eastham location should include a wildlife survey that specifically reviews these species. An additional discussion on the impacts to avian species specifically is provided in Section 7.1.2.

7.1.2 Avian Impacts

The largest biological concern for this project's development may be potential or perceived risk to avian species. Three of the seven Threatened species identified as in the BioMap region covering the North Eastham location are birds, including the Piping Plover which is classified as a Threatened species by both state and federal environmental protection laws. During the permitting phase of project development, a

wildlife impact study should be performed to identify any potential avian species that would be at risk. Modern wind turbines include slow rotating blades, and tower and nacelle designs that provide almost no perching or nesting points for birds. While most wind energy projects have little or no recorded bird strikes, it can be a significant problem at a few sites (such as Altamont, California, or the Mountaineer Wind Energy project in West Virginia). It is therefore important to determine if species known to be susceptible to wind turbine strikes can be found at the site, and if the birds found at the site are known to be susceptible to wind turbine strikes. Particular attention should likely be paid to the Northern Harrier, reported by NHESP to be found in the BioMap Core Habitat that includes the North Eastham location. As a hawk, the Harrier may be more susceptible to collisions with wind turbines.

The Massachusetts Audubon Society operates the Wellfleet Bay Wildlife Sanctuary just north of the North Eastham location (just less than one mile northwest of North Eastham Site E). It is recommended the Town begin discussions with the Society early in the project development process to identify potential at-risk species and acceptable wind turbine sites.

The Nature Conservancy also owns land in Eastham. The Boat Meadow Preserve is a salt marsh conserved for the Northern Diamondback Turtle. Black & Veatch believes this site is just less than two miles southwest from the Town Hall location. It is not clear what other land the Nature Conservancy may own in the area.

7.1.3 Cape Cod National Seashore

The Cape Cod National Seashore is a part of the National Park Service system, and includes areas of Cape Cod from Chatham to Provincetown. Founded in 1961, the Seashore includes the entire eastern coastline and varying amounts of land within the Cape. A map of the Seashore is included in Appendix C.

The North Eastham location includes Town of Eastham-owned parcels inside and outside the Seashore. Figure 5-3 shows the parcels and the six identified wind turbine sites along with the approximate location of the Seashore boundary. Black & Veatch expects that the location of Site F within the Seashore makes the site unavailable for wind turbine placement, even though the land is owned by the Town of Eastham. Photo simulations from the Nauset Beach parking lot are shown in Appendix E. Noise impacts form the turbines should not be a significant impact for the North Eastham location, as it is not near any Seashore visitor areas or facilities.

7.1.4 Nearby Residences

Some public concern is likely regarding the visual impact of the project. Black & Veatch recommends that visual simulations of project options be presented to the public at the first hearing of the project, including animations showing the rotational speed of the turbine. Experience shows that sharing this information early in the process can avoid unnecessary concerns regarding what the project might look like. Black & Veatch has prepared some initial visual simulations of candidate wind turbines from various locations, and included them in Appendix E. MTC and the Town of Eastham may wish to consider having additional simulations done in the future from other locations of likely public concern.

Site E is close enough to homes that issues regarding noise and safety may arise. While the turbine site is located far enough from homes that even complete failure of the turbine's structure should not endanger them, public perception may be the site puts the homeowners in undue risk. As mentioned earlier, Black & Veatch recommends these homeowners be contacted directly by the Town of Eastham, and their support on the project obtained, before committing to these sites.

Another issue often faced by community wind energy projects, or any wind project close to cities or landowners, is the project's potential to impact nearby property values. Some study work done in the U.S. has been unable to determine an impact, but this issue is being explored further. Black & Veatch cannot estimate if there will be an impact at these locations.

7.1.5 Land Ownership

The Town of Eastham owns several areas of land in North Eastham on which the proposed project is sited. However, several of the proposed turbine sites are immediately adjacent to parcels not owned by the Town, and access to others require easements through land held by various owners.

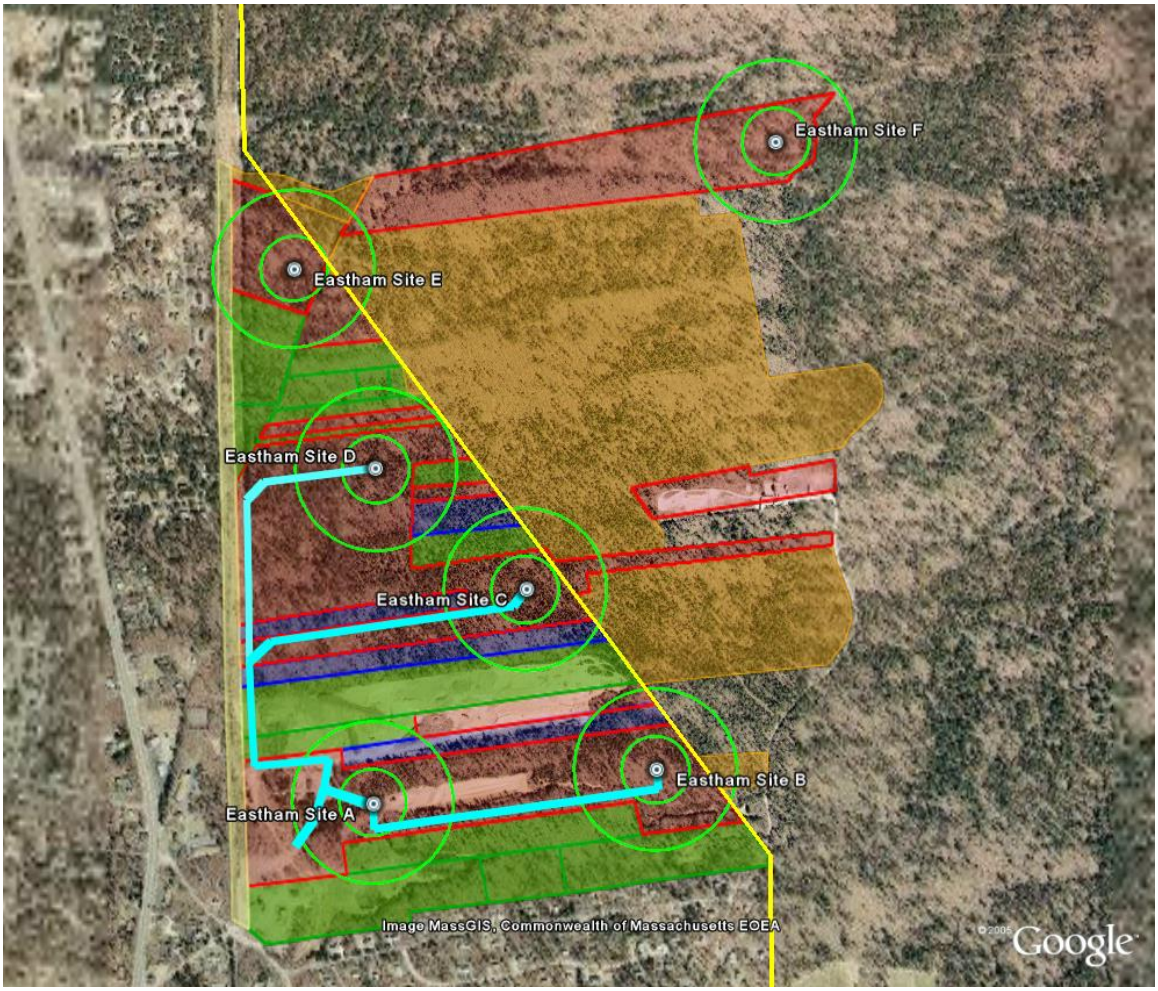


Figure 7-2 North Eastham Land Ownership

Figure 7-2 displays the breakdown of land ownership near the potential turbine sites. The land ownership was determined from a map of the North Eastham area provided to Black & Veatch by the Town of Eastham on August 1, 2005. Land outlined and shaded in red indicates those parcels owned by the Town of Eastham. The orange parcels are listed as owned by the United States of America, mostly within the Cape Cod National Seashore (the boundary is shown by the heavy yellow line, and east of that boundary is the Seashore). Blue shading represents land owned by the Eastham Conservation Foundation, a private non-profit conservation group. Green shading represents land held by various other private landowners, and the heavy green lines indicate boundaries between landowners. The narrow light yellow strip on the western edge represents a former rail line now owned by the Commonwealth of Massachusetts, and currently hosts a pedestrian trail. The blue lines connecting the wind turbine sites are the proposed routes for the access roads and underground electrical collection lines, discussed in Section 6.2.

The safety radius of Sites B and C includes land in the National Seashore, but the area is undeveloped woodland and therefore this should not pose a safety risk. The safety radius of Site D includes the National Seashore, as well as several parcels of land owned by private parties. Again, this land is undeveloped and safety should not be an issue.

The private parcel between the Town owned land on which Sites A and B are located and the land on which Sites C and D are located is owned by Nauset Road LLC. The parcel is currently an active gravel pit mine.

The routing of the access roads and underground electrical lines was done to stay on Town land and avoid other parcels as much as possible. The western portion of the north-south corridor used by the transmission line, distribution line, dirt access road, and paved recreation trail is owned by the Commonwealth of Massachusetts, and Black & Veatch believes this may only cover the land on which the trail is located. The eastern portion appears to be owned by several landowners, meaning this land may be covered by easements owned by NSTAR and possibly other utilities. The existence, ownership, and regulations applied to these easements would need to be evaluated during the project's development to understand what the project may need to do to use the existing dirt road and locate an underground electrical line.

7.1.6 Land Zoning and Setback Requirements

The Town of Eastham has indicated the parcels that make up the North Eastham location are zoned Water Resources Protection District G. Black & Veatch is assuming the placement of wind turbines on this land may require the land be rezoned, or a Special Permit is obtained. To better understand the zoning requirements for wind turbines in this area, as well as the requirements for setbacks of wind turbines from property boundaries, Black & Veatch first evaluated a November 2004 report from the Cape Light Compact titled *A Review of Regulatory Issues Concerning Development of Small Scale Renewable Energy and Distributed Generation on Cape Cod and Martha's Vineyard*. This report evaluated the zoning requirements of all the towns on Cape Cod to determine how the siting of various renewable energy projects would be impacted, including wind energy. The relevant information for Eastham taken from this report was:

- Eastham has no zoning laws that specifically mention wind turbines.
- A Special Permit would be needed from the Town Zoning Board of Appeals (ZBA) regardless of how the land is currently zoned.
- There is no mention of what the setback would be for Eastham.

As there appeared to be no specific zoning requirements for wind turbines in the Town of Eastham, and the Cape Like Compact report did not list the likely setback

requirements, Black & Veatch also reviewed the zoning bylaws for Eastham. The May 2003 version of the Town of Eastham Zoning By-Laws was downloaded from the Town's web site. Section IX.B of the By-Laws specify minimum setbacks for various types of property, however type G is not mentioned. Property zoned as Type C (commercial or industrial) has a minimum setback is 50 feet from a road, and 25 feet from a boundary. As no other zoning type appears to fit for a wind energy project, Black & Veatch applied this requirement to the siting of potential turbine locations. To be conservative, Black & Veatch choose to use a setback limit of 50 feet from any boundary, not just public roads.

7.1.7 Airports

The closest airports to the North Eastham turbine sites are

- Provincetown Municipal Airport (18 miles to the north)
- Chatham Municipal Airport (12 miles to the south)
- Barnstable Municipal Airport (20 miles to the southwest)

Due to this distance, Black & Veatch does not believe the installation of wind turbines in Eastham should interfere with airport operations. Regardless of their distance to the airports, the height of large turbines will require FAA notification and study. Per direction from MTC, Black & Veatch submitted Notifications of Intended Construction (Form 7460-1) to the FAA on January 22, 2005 for Vestas V80s on Sites A, B, C, and D. The project was given an FAA Project Name of MASSA-000032260-06, and the sites were each given a unique study number:

- Site A: ASN 2006-ANE-80-OE
- Site B: ASN 2006-ANE-81-OE
- Site C: ASN 2006-ANE-82-OE
- Site D: ASN 2006-ANE-83-OE

For each of the proposed sites, the FAA reached a determination of no hazard to air navigation. The determinations for each study are included in Appendix G.

7.1.8 Microwave Beam Paths

Another common issue for the siting of wind turbines can be the potential for wind turbines to interfere with microwave beam paths. The beams for microwave transmissions are relatively narrow, and it is believed that if a wind turbine is directly in the path of a microwave beam it could interfere with the beam. Therefore, it is a good idea to perform a communications study during the development of a project to ascertain

the potential of the wind turbines for interference with microwave or any other types of communications systems.

While a comprehensive study was not performed, Black & Veatch did perform an initial review of the known microwave beam paths in the New England area to see which may be near the project site. Only two paths leased from the Federal Communications Commission (FCC) were found to be in the vicinity, but neither was very close to the site (see Figure 7-3). Black & Veatch notes that some military and local microwave beams are not tracked through the FCC database reviewed. A small follow-up study with the relevant entities would need to be commissioned to determine if the project location interferes with any beam paths not tracked by the FCC.

Figure 7-3 Known Microwave Beam Paths

7.2 Permitting Requirements

Black & Veatch has examined the general permitting requirements for energy projects in Massachusetts, as well as major projects on Cape Cod, and has prepared an initial list with our expectations regarding which permits would apply to a wind energy project in Eastham (see Appendix D). Black & Veatch did not contact any local, state, or federal agencies to explore the permit requirements for this project, as it was not known if Eastham has already announced the project or would prefer to make the initial contacts with these agencies. Such consultations will be required before the final permitting requirements can be completely understood.

At present, the permit requirements that seem very likely to apply to a community wind energy project in Eastham are (abbreviations defined in Appendix D):

- Federal Aviation Administration (FAA) Notice of Proposed Construction and Alteration (studies already underway)
- Federal Energy Reliability Commission (FERC) Exempt Wholesale Generator (EWG) and Qualifying Facility (QF) Status
- United States Environmental Protection Agency (EPA) Stormwater Discharge Permit
- Approval from the Massachusetts Department of Public Utilities (MDPU)/Energy Facility Siting Board (EFSB)
- Massachusetts Office of Consumer Affairs and Business Regulation – Division of Energy Resources (DOER) Statement of Qualification for Massachusetts Renewable Portfolio Standard (RPS)
- Massachusetts Aeronautics Commission (MAC) Request for Airspace Review
- Massachusetts Historical Commission (MHC) Archeological and Historical Review
- Barnstable County – Cape Cod Commission Development of Regional Impact Permit
- Town of Eastham Building Permit
- Town of Eastham Zoning Department Conditional Use Permit

To prepare for these permits, it may be advisable to have informal initial meetings with each agency to discuss the project and that agency's study expectations. The majority of the permits listed above are expected to require approximately 3 to 4 months to obtain, following completion of appropriate study work. Black & Veatch recommends that scheduling for the project allow for a total of 6 months for permitting to allow for delays or some level of unexpected difficulty. Black & Veatch understands the political

nature of permitting may add more time to the process, but by meeting with each agency in advance it is believed some of this delay can be avoided.

8.0 Potential Wind Project Options

Based on the recommendations in Section 5, the electrical infrastructure and load information in Section 6, and the environmental issues discussed in Section 7, Black & Veatch determined the most likely feasible project option is for a commercial wind project of one to four turbines in the North Eastham location. This section discusses the potential options for the development of a project on these turbine sites.

As discussed in Section 5.2, Black & Veatch recommends large commercial wind turbines be installed on Sites A, B, C and D. Black & Veatch understands that there may be many reasons for which the Town may wish to install less than four turbines. Therefore, this section discusses the recommended build-out for 1, 2, 3, and 4 total turbines. The performance, cost, and economic estimates for these options are discussed in subsequent sections.

8.1 Option 1: One Turbine

The first option consists of a single large wind turbine located at Site A. This option, shown in Figure 8-1, would mostly likely have a capacity between 1.5 and 2.5 MW. The existing roads on the North Eastham site would likely only require minor upgrading to be sufficient for construction. An underground line would be run from the point of interconnection to the turbine, likely along the existing road.

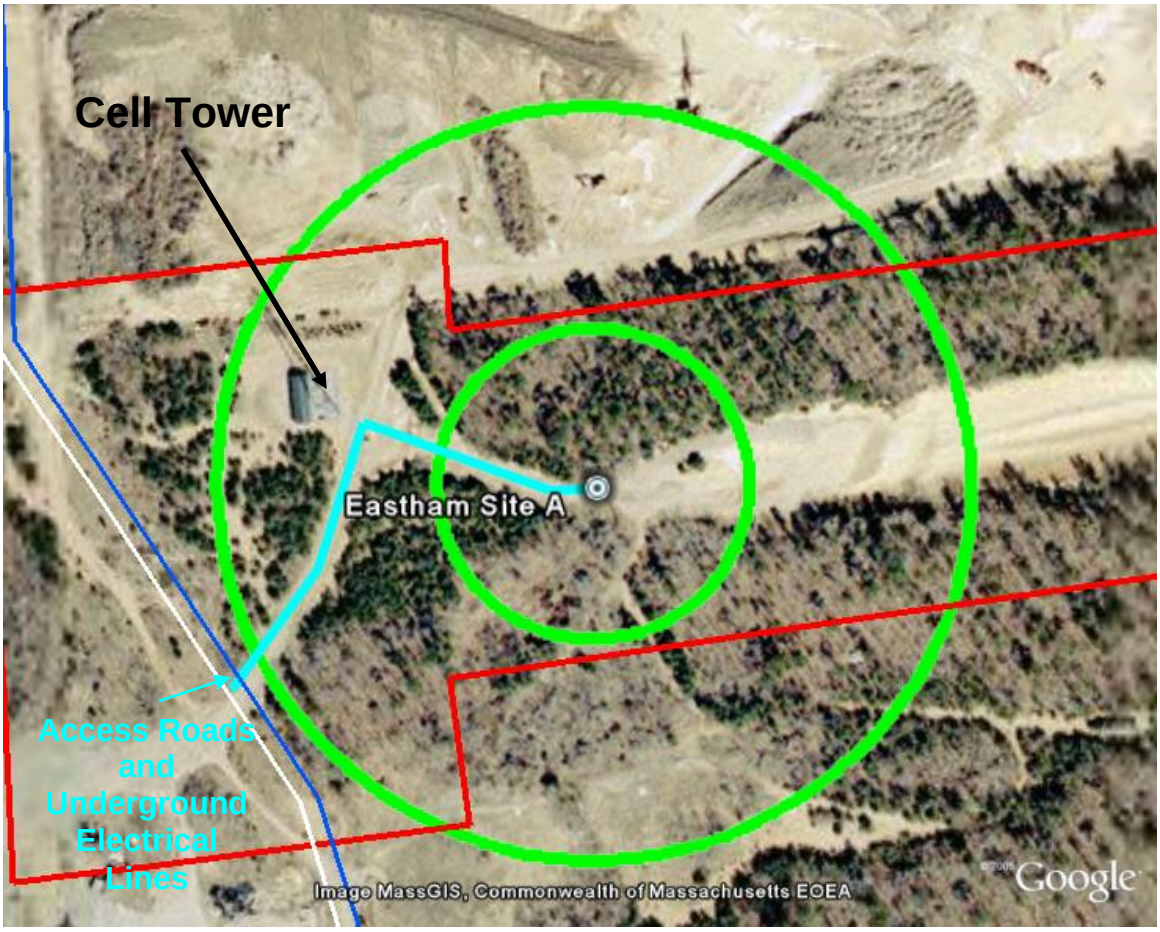


Figure 8-1 Single Turbine Option

This option stands the best chance of being allowed to connect to the 23 kV distribution line, as discussed in Section 6. There may even be some potential of connecting the turbine to the underground line connected to the cell tower, depending upon the capacities of that line.

8.2 Option 2: Two Turbines

Option 2 consists of two large wind turbines at locations A and B. This option, shown in Figure 8-2, would have a capacity between about 3.0 and 5.0 MW. Although the turbines are not aligned northwest to southeast, neither turbine is upwind of the other in the primary wind direction. Because of this wake effects between the two towers should not be an issue.

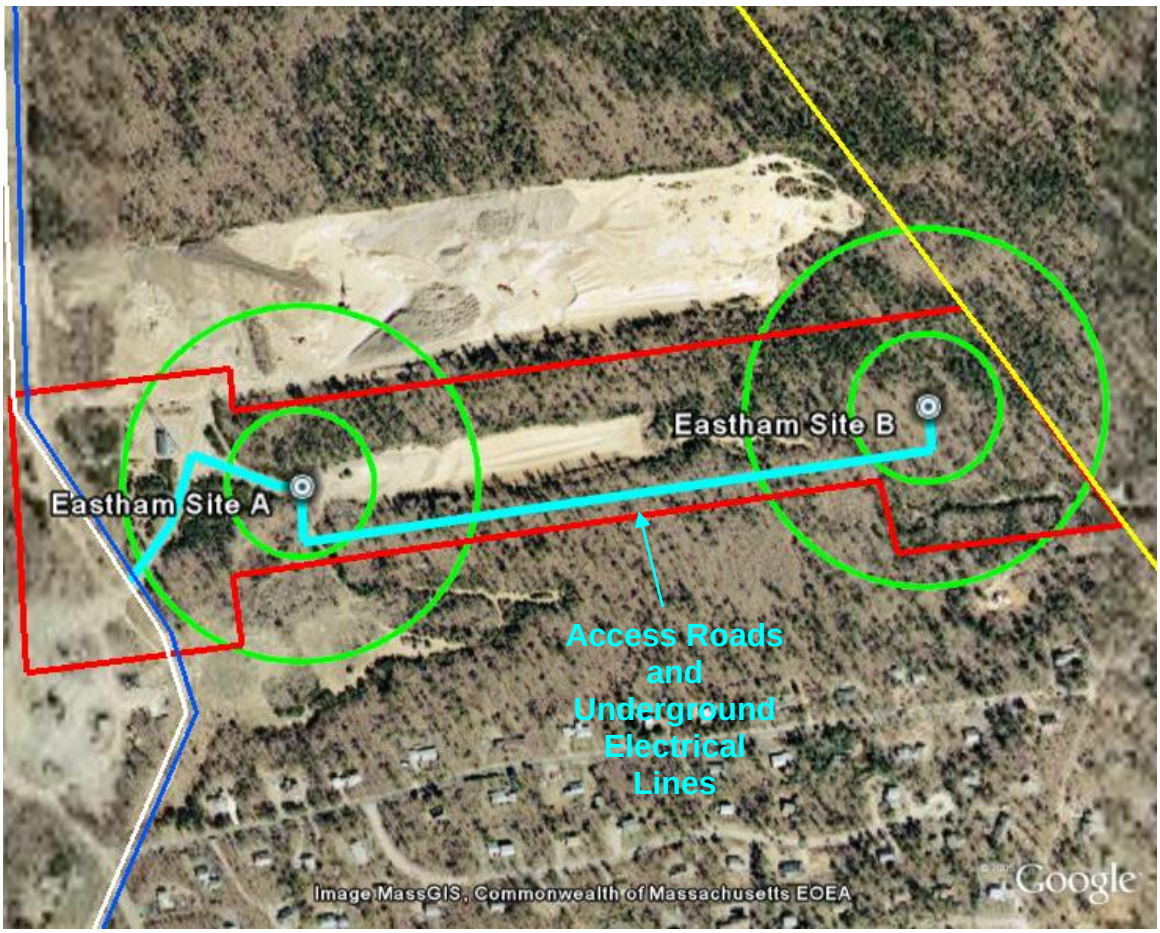


Figure 8-2 Two Turbine Project Layout

A new site access road would need to be built from Site A to B, likely along the southern edge of the existing pit. Some tree clearing would be necessary for both the road and for the turbine site. An underground electrical collection line would connect the turbine at Site B to the one at Site A

8.3 Option 3: Three Turbines

Option 3 consists of three of three wind turbines at Sites A, B, and C. The proposed layout is shown in Figure 8-3. This option would have a capacity between 4.5 and 7.5 MW. Sites B and C are in the preferred alignment discussed in Section 5.1.1. However, Site A is only about 480 meters (1,570 feet) upwind of Site C, which is only about 5.5D with the FL2500. Due to this close spacing, the wake losses expected at Site C due to a turbine at Site A will be greater than those at Site B. These losses are discussed further in Section 9.

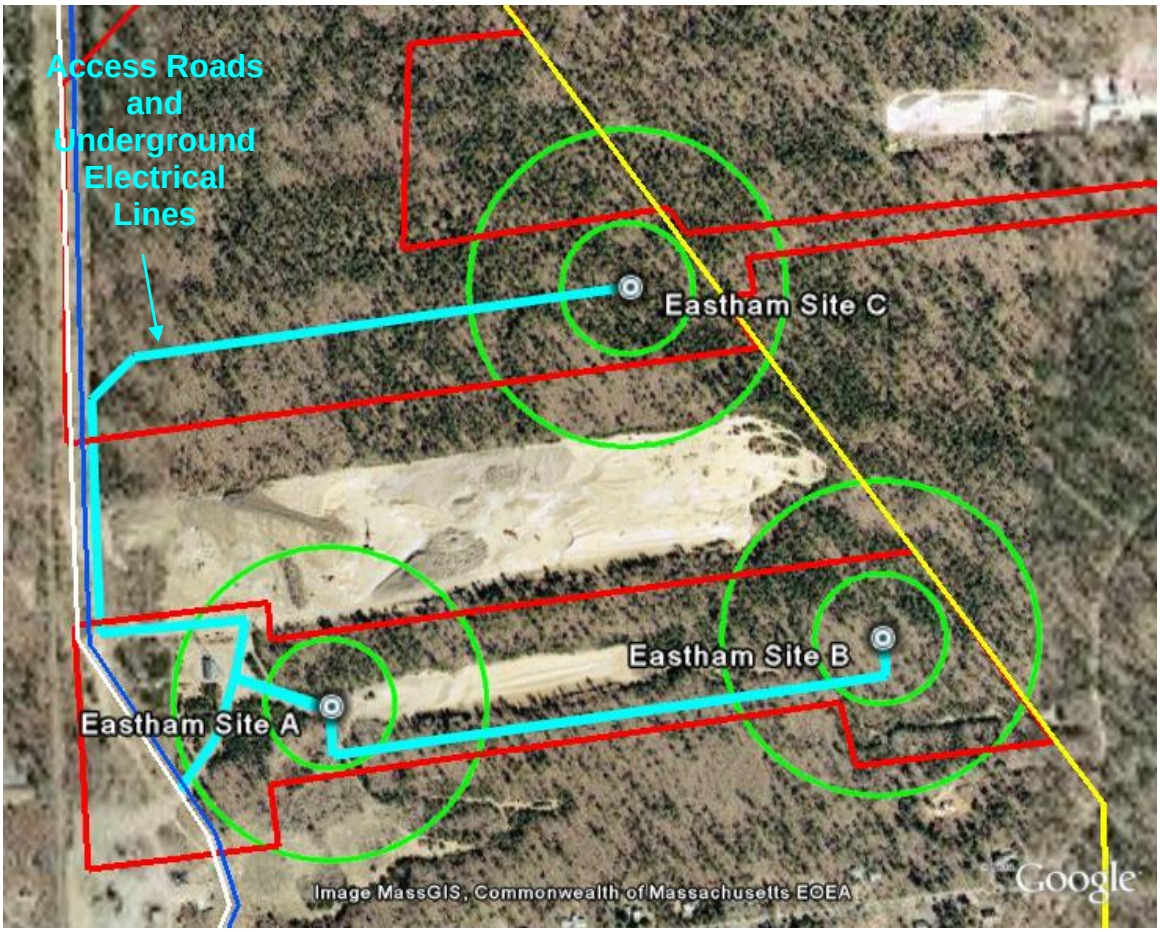


Figure 8-3 Three Turbine Project Layout

To access the turbine at Site C and connect it electrically to the remainder of the project, an easement will be needed across land not owned by the Town of Eastham. As mentioned earlier, there is an existing road just east of the 115 kV transmission line, most likely to facilitate maintenance of this line. If the project can obtain permission to use this road, make minor improvements if needed, and to place a buried electrical line along the road, this would be the least cost approach (and is the one assumed in Figure 8-3).

Another approach could be to run a line and road directly from Site B, but this would also require an easement on land not owned by the Town.

8.4 Option 4: Four Turbines

Option 4 consists of large wind turbines at all four sites recommended in Section 5. The proposed site layout is shown in Figure 8-4. The capacity of this project option would be between 6 MW and 10 MW.

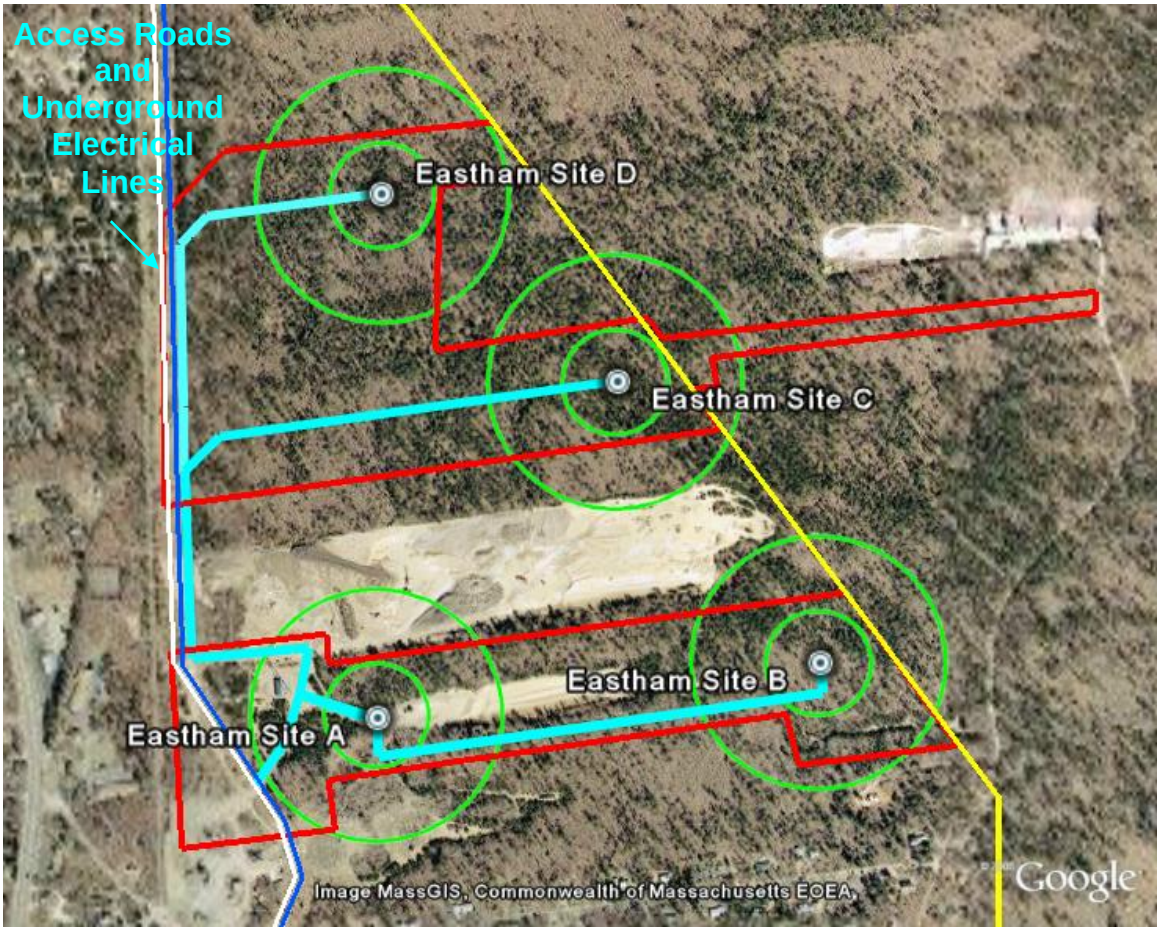


Figure 8-4 Four Turbine Project Layout

As with Site C, the road access to the turbine at Site D would likely use both the existing transmission line maintenance road, and a new road. Another option not shown in Figure 8-4 would be to build a road directly north from the Site C access road. Easements on land not owned by the Town may be required for construction of new roads and electrical transmission. Other options can be explored during the development phases of this project.

9.0 Preliminary Energy Production Estimate

Based on the wind resource analysis of Section 4, Black & Veatch estimated the potential energy production for the three project options discussed in Section 8. The method and assumptions for these estimates are discussed below.

9.1 Wind Turbine Power Curves

Black & Veatch evaluated the following wind turbine designs for a project at the North Eastham location:

- GE 1.5 MW
- Vestas V80 (1.8 MW)
- Vestas V82 (1.65 MW)
- Vestas V90 (3.0 MW)
- Gamesa G87 (2.0 MW)
- Fuhrländer FL2500 (2.5 MW)

These turbines represent the majority of turbines currently available in the U.S. market. Turbines from Suzlon and Mitsubishi were not evaluated due to statements from these companies that they were not interested in small projects unless they were located close to existing maintenance centers (and neither company has a large project near Massachusetts). Black & Veatch anticipates other wind turbine options may become available by the time a project in Eastham is ready to be built, and would recommend the feasibility of these options be evaluated at that time.

With the exception of the Fuhrländer FL2500, the hub height most applicable to a project in North Eastham would be 80 meters (for the FL2500, it would be 100 meters). Black & Veatch estimated the performance of these turbines based on the wind speeds at their applicable hub height, and each turbine's power curve shown in Table 9-1. Lower tower options are available and may decrease the visual impact of the wind turbine, but would also significantly lower the turbine's production (due to the high wind shear in Eastham). As such, Black & Veatch did not consider them in this report.

Based on site elevations between 8 and 20 meters (26 and 66 feet) and the annual average temperature data collected by the RERL met tower (approximately 13ºC or 55ºF), Black & Veatch determined the site's average air density was about 1.23 kg/m^3. The sea level air density power curves from wind turbine manufacturers reference 1.225 kg/m^3, so Black & Veatch used sea level power curves for each turbine (except the V90, for which only the power curve for an air density of 1.04 kg/m^3 was available).

Table 9-1
Comparison Turbines Power Curves

Hub Height Wind Speed, m/s	Output Power, kW					
	GE 1.5MW	V80	V82	V90	G87	FL2500
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	43	3	28	63	78.6	37.6
5	131	99	144	156	181.2	160.4
6	250	260	309	289	335.4	333.3
7	416	465	511	476	549.8	559.2
8	640	735	758	726	831.5	869.4
9	924	1,015	1017	1043	1174.8	1260
10	1,181	1,345	1285	1402	1528.3	1678.3
11	1,359	1,639	1504	1785	1794.7	2113.8
12	1,436	1,775	1637	2203	1931.1	2411.8
13	1,481	1,797	1648	2552	1981	2500
14	1,494	1,802	1650	2766	1995.3	2500
15	1,500	1,802	1650	2895	1998.9	2500
16	1,500	1,802	1650	3000	1999.8	2500
17	1,500	1,802	1650	3000	2000	2500
18	1,500	1,802	1650	3000	2000	2500
19	1,500	1,802	1650	3000	2000	2500
20	1,500	1,802	1650	3000	2000	2500
21	1,500	1,802	0	3000	2000	2500
22	1,500	1,802	0	3000	2000	2500
23	1,500	1,802	0	3000	2000	2500
24	1,500	1,800	0	3000	2000	2500
25	1,500	1,800	0	3000	2000	2500

Notes: All power curves are for sea-level air density except the V90, which was only available for 1.04 kg/m^3

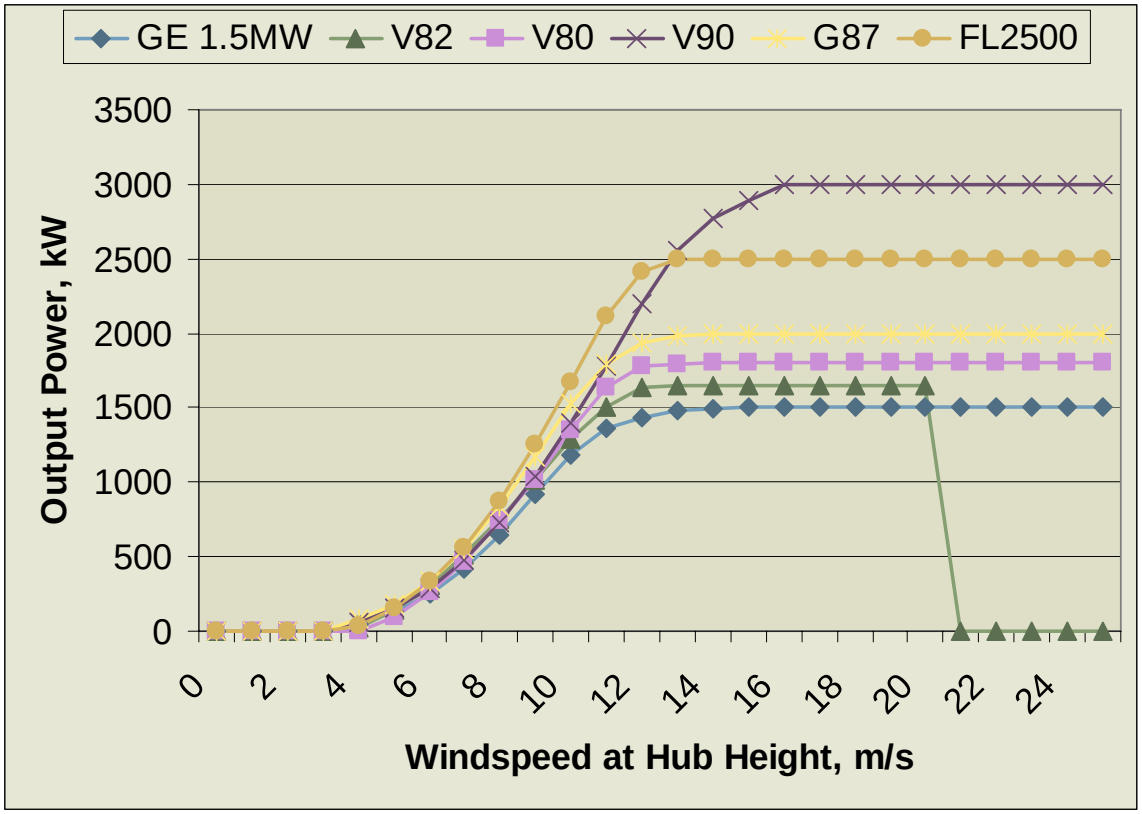


Figure 9-1 Turbine Power Curves

9.2 Production Losses

Black & Veatch has examined each option to estimate the potential production losses that might impact wind turbines. The losses summaries in Table 9-2 were evaluated individually for each site, and the Wake Effect and Electrical Losses were adjusted as necessary.

Table 9-2
Project Production Loss Factors

Loss Factor	Loss Percent			
	Site A	**Site B**	**Site C**	**Site D**
Topographic Effect	0.00%	0.00%	0.00%	0.00%
Wake Effect	0.00%	3.00%	6.00%	3.00%
Turbine Availability	3.00%	3.00%	3.00%	3.00%
Turbine Power Curve	0.00%	0.00%	0.00%	0.00%
Grid Availability	0.50%	0.50%	0.50%	0.50%
Electrical Losses	1.00%	2.00%	3.00%	3.00%
Columnar Losses	0.00%	0.00%	0.00%	0.00%
Blade Contamination	1.00%	1.00%	1.00%	1.00%
Icing	1.00%	1.00%	1.00%	1.00%
Model Estimate	0.00%	0.00%	0.00%	0.00%
High Wind Hysteresis	0.00%	0.00%	0.00%	0.00%
Product of Loss Factors	**6.35%**	**10.08%**	**13.75%**	**11.00%**

- **Topographic Effect:** This is the loss due to wind speed reductions between the met tower and turbine caused by the site's topography.
- **Wake Effect:** This is the energy loss due to the effect one turbine will have on another, or the wake caused by any structure on the wind turbines.
- **Turbine Availability:** Wind turbine manufacturers will specify an availability level to be covered in a warranty (this may be difficult to obtain for single turbine installations). This value assumes the turbine's availability is only at that warranty value.
- **Turbine Power Curve:** The wind turbine manufacturer will warranty a performance level from the turbine at a percentage of the power curve values (this may also be difficult to obtain for a single turbine installation.) Typical warranty levels are 95 to 97 percent of published power curve. However, industry practice is usually not to consider this as a potential loss, given most wind turbines operate at or slightly above their published power curves. For this study, Black & Veatch left the value as a 0 percent loss.
- **Grid Availability:** An estimate is made as to the amount of time the utility will be available to receive power from the project. All grid systems

are off-line periodically for maintenance, and projects in more remote locations will be connected to weaker grid systems that are more prone to failure. Losses for grid availability vary between 0.1 percent for very strong grid system to as high as 5 percent for weak systems (and even larger for systems outside the US). As Black & Veatch has no specific information on grid reliability in the project area, an estimated loss of 0.5 percent was assumed.

- **Electrical Losses:** Losses in the lines and electrical equipment prior to the plant's revenue meters are covered by this factor. Points of significant electrical losses in a wind energy project usually include the underground and overhead distribution lines connecting the turbines to a substation, and the substation's primary transformer. Typical electrical loss values range from as low as 1 percent to 10 percent or more, depending on the layout and equipment used. Turbine Site A will be very close to the connection point, and therefore the only electrical losses will be from the turbine transformer and a small amount of cable. Sites B and C will be further away, causing additional losses due to extra lengths of underground cable. Site D is the furthest from the interconnection point, having the highest expected electrical losses.
- **Columnar Losses:** If the project of many wind turbines is arranged in rows, turbine manufacturers may require the shutdown of some turbines when the winds are coming from directions parallel to the rows. These losses will not to apply to the options defined in this report.
- **Blade Contamination:** Wind turbine performance is sensitive to the cleanliness of the turbine's blades. In areas of high dust or insects, contamination can build on the wind turbine blades that will limit the turbine's performance (causing losses up to 5 percent or more). Often the blades are cleaned by occasional rainfall, but in some areas periodic blade washing is required. As the plant is not an area of high dust, the potential for blade contamination is fairly low and due mostly to insects. As such, an annual loss of 1 percent was assumed for blade contamination.
- **Icing:** During winter storms, snow and ice will build on the wind turbine blades causing the same degradation as caused by dust and insects. While this contamination will build much faster than summer contamination, it is often cleared after a few hours of direct sunlight (even at continued subzero temperatures). Given the anticipated likelihood of several

significant storms per winter, a loss of 1 percent was assumed for the lost energy due to icing.

- **Model Estimate:** Black & Veatch estimated the performance of potential wind turbines using a basic spreadsheet approach. While this approach can have significant uncertainties in complex terrain, it is believed to be fairly accurate for Eastham. Therefore, no losses were assumed due to wind model accuracy.
- **High Wind Hysteresis:** When wind speeds exceed the operational range of a wind turbine, the turbine shuts down to protect itself. Such shut-downs normally require the turbine to remain offline for several minutes, regardless if the wind speed returns to the operational range. Sites with a significant number of these high wind events suffer lost energy due to this hysteresis effect, which is additional to the amount of time the average wind speeds remain above the cut-out wind speed. As the Project site does not have a significant number of high wind events on record, no losses due to this hysteresis effect were applied.

9.3 Production Estimates and Comparisons

Based on the wind analysis discussed in Section 4, Black & Veatch estimated the production for each turbine type at the North Eastham location. The data was "binned" by hub height wind speed for each turbine to determine the number of hours per year the winds would be within a 1 m/s bin (for instance, the 5 m/s bin represents all wind speed data points between 4.5 m/s and 5.5 m/s). With the hours per bin known, the total energy produced each year from winds within each bin was estimated and summed to determine the total annual gross production from the turbine. Each wind turbine site is subject to the losses discussed in Section 9.2. These losses were applied to the gross energy estimate to determine the project's net energy estimate. Finally, a capacity factor was calculated which represents the net annual generation compared to maximum possible generation from the wind turbine (a value of 100% would mean the turbine would operate at rated power every hour of the year; a typical capacity factor for a project in the Northeast U.S. is about 30 percent).

The resulting energy and capacity factor estimates for each turbine type and each project configuration are shown in Table 9-3 through Table 9-8. Figure 9-2 through Figure 9-7 show the wind turbine power curves and wind speed frequency distributions used to create the production estimates. Figure 9-8 compares the monthly generation levels of each project option.

Table 9-3
Eastham Production Estimates: GE 1.5MW Turbines

Turbines	A		A,B		A,B,C		A,B,C,D	
Month	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**
January	418	37.5%	819	36.7%	1,204	36.0%	1,602	35.9%
February	356	35.3%	698	34.6%	1,025	33.9%	1,363	33.8%
March	347	31.1%	689	30.9%	1,001	29.9%	1,331	29.8%
April	368	34.0%	709	32.8%	1,059	32.7%	1,409	32.6%
May	229	20.5%	449	20.1%	659	19.7%	877	19.6%
June	205	19.0%	403	18.6%	592	18.3%	787	18.2%
July	133	12.0%	262	11.7%	384	11.5%	511	11.5%
August	167	15.0%	328	14.7%	482	14.4%	642	14.4%
September	173	16.1%	340	15.7%	500	15.4%	665	15.4%
October	341	30.6%	669	30.0%	983	29.4%	1,307	29.3%
November	482	44.6%	944	43.7%	1,388	42.8%	1,846	42.7%
December	559	50.1%	1,095	49.1%	1,610	48.1%	2,141	48.0%
Annual (P50)	**3,779**	**28.8%**	**7,404**	**28.2%**	**10,888**	**27.6%**	**14,479**	**27.5%**
P90 Average	2,756	21.0%	5,449	20.7%	7,940	20.1%	10,559	20.1%
P95 Average	2,466	18.8%	4,894	18.6%	7,105	18.0%	9,448	18.0%

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedence, as discussed in Section 9.4.

Table 9-4
Eastham Production Estimates: Vestas V80 Turbines

Turbines	**A**		**A,B**		**A,B,C**		**A,B,C,D**	
Month	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**
January	476	35.5%	933	34.8%	1,390	34.6%	1,848	34.5%
February	405	33.4%	794	32.8%	1,183	32.6%	1,571	32.4%
March	389	29.0%	778	29.0%	1,137	28.3%	1,511	28.2%
April	419	32.3%	807	31.1%	1,222	31.4%	1,624	31.3%
May	251	18.7%	492	18.3%	733	18.2%	973	18.2%
June	220	16.9%	431	16.6%	641	16.5%	852	16.4%
July	134	10.0%	263	9.8%	391	9.7%	520	9.7%
August	172	12.9%	338	12.6%	504	12.5%	669	12.5%
September	180	13.9%	354	13.6%	527	13.5%	700	13.5%
October	385	28.7%	755	28.2%	1,125	28.0%	1,495	27.9%
November	560	43.1%	1,097	42.3%	1,635	42.0%	2,172	41.9%
December	649	48.4%	1,273	47.5%	1,897	47.2%	2,520	47.0%
Annual (P50)	**4,241**	**26.9%**	**8,314**	**26.3%**	**12,384**	**26.2%**	**16,456**	**26.1%**
P90 Average	2,999	19.0%	5,940	18.8%	8,759	18.5%	11,639	18.5%
P95 Average	2,648	16.8%	5,267	16.7%	7,732	16.3%	10,274	16.3%

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedence, as discussed in Section 9.4.

Table 9-5
Eastham Production Estimates: Vestas V82 Turbines

Turbines	**A**		**A,B**		**A,B,C**		**A,B,C,D**	
Month	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**
January	469	38.2%	920	37.5%	1,352	36.7%	1,798	36.6%
February	403	36.3%	790	35.6%	1,161	34.9%	1,543	34.8%
March	394	32.1%	781	31.8%	1,136	30.8%	1,511	30.8%
April	416	35.0%	803	33.8%	1,198	33.6%	1,594	33.5%
May	262	21.3%	513	20.9%	754	20.5%	1,003	20.4%
June	236	19.8%	462	19.4%	679	19.0%	903	19.0%
July	153	12.5%	300	12.2%	441	12.0%	587	12.0%
August	193	15.7%	379	15.4%	557	15.1%	740	15.1%
September	200	16.9%	393	16.5%	577	16.2%	768	16.2%
October	388	31.6%	760	31.0%	1,117	30.3%	1,486	30.3%
November	497	41.8%	973	41.0%	1,431	40.1%	1,902	40.0%
December	623	50.8%	1,222	49.8%	1,796	48.8%	2,388	48.6%
Annual (P50)	**4,234**	**29.3%**	**8,294**	**28.7%**	**12,198**	**28.1%**	**16,221**	**28.1%**
P90 Average	3,172	21.9%	6,266	21.7%	9,137	21.1%	12,151	21.0%
P95 Average	2,870	19.9%	5,691	19.1%	8,270	19.1%	10,998	19.0%

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedence, as discussed in Section 9.4.

Table 9-6
Eastham Production Estimates: Vestas V90 Turbines

Turbines	**A**		**A,B**		**A,B,C**		**A,B,C,D**	
Month	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**
January	537	24.1%	1,053	23.6%	1,548	23.1%	2,059	23.1%
February	471	23.4%	923	22.9%	1,356	22.4%	1,804	22.4%
March	431	19.3%	883	19.8%	1,242	18.6%	1,652	18.5%
April	485	22.5%	937	21.7%	1,398	21.6%	1,859	21.5%
May	280	12.6%	549	12.3%	807	12.1%	1,073	12.0%
June	242	11.2%	474	11.0%	697	10.7%	926	10.7%
July	156	7.0%	306	6.9%	450	6.7%	598	6.7%
August	196	8.8%	384	8.6%	564	8.4%	750	8.4%
September	205	9.5%	402	9.3%	592	9.1%	787	9.1%
October	453	20.3%	888	19.9%	1,306	19.5%	1,737	19.5%
November	741	34.3%	1,452	33.6%	2,135	32.9%	2,839	32.9%
December	798	35.8%	1,564	35.0%	2,299	34.3%	3,057	34.2%
Annual (P50)	**4,995**	**19.0%**	**9,816**	**18.7%**	**14,393**	**18.3%**	**19,140**	**18.2%**
P90 Average	3,444	13.1%	6,848	13.0%	9,923	12.6%	13,196	12.6%
P95 Average	3,004	11.4%	6,006	11.4%	8,656	11.0%	11,511	10.9%

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedence, as discussed in Section 9.4.

Table 9-7
Eastham Production Estimates: Gamesa G87 Turbines

Turbines	A		A,B		A,B,C		A,B,C,D	
Month	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**
January	550	37.0%	1,078	36.2%	1,585	35.5%	2,107	35.4%
February	470	34.9%	921	34.3%	1,353	33.6%	1,800	33.5%
March	456	30.7%	907	30.5%	1,315	29.5%	1,749	29.4%
April	486	33.7%	937	32.5%	1,399	32.4%	1,860	32.3%
May	303	20.3%	593	19.9%	872	19.5%	1,160	19.5%
June	272	18.9%	533	18.5%	783	18.1%	1,041	18.1%
July	180	12.1%	352	11.8%	518	11.6%	688	11.6%
August	224	15.0%	438	14.7%	644	14.4%	857	14.4%
September	231	16.1%	453	15.7%	666	15.4%	886	15.4%
October	450	30.3%	883	29.7%	1,298	29.1%	1,726	29.0%
November	637	44.3%	1,249	43.4%	1,836	42.5%	2,442	42.4%
December	737	49.5%	1,444	48.5%	2,123	47.6%	2,823	47.4%
Annual (P50)	**4,995**	**28.5%**	**9,789**	**27.9%**	**14,392**	**27.4%**	**19,139**	**27.3%**
P90 Average	3,652	20.8%	7,223	20.6%	10,522	20.0%	13,993	20.0%
P95 Average	3,271	18.5%	6,495	18.5%	9,425	17.9%	12,534	17.9%

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedence, as discussed in Section 9.4.

Table 9-8
Eastham Production Estimates: Fuhrländer FL2500 Turbines

Turbines	**A**		**A,B**		**A,B,C**		**A,B,C,D**	
Month	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**	**MWh**	**C.F.**
January	737	39.6%	1,445	38.8%	2,124	38.1%	2,824	38.0%
February	626	37.3%	1,227	36.5%	1,804	35.8%	2,399	35.7%
March	615	33.1%	1,216	32.7%	1,771	31.7%	2,356	31.7%
April	652	36.2%	1,253	34.8%	1,877	34.8%	2,497	34.7%
May	408	21.9%	799	21.5%	1,174	21.0%	1,561	21.0%
June	367	20.4%	720	20.0%	1,058	19.6%	1,407	19.5%
July	240	12.9%	471	12.7%	692	12.4%	920	12.4%
August	300	16.1%	588	15.8%	865	15.5%	1,150	15.5%
September	311	17.3%	610	16.9%	896	16.6%	1,192	16.6%
October	600	32.2%	1,175	31.6%	1,727	31.0%	2,297	30.9%
November	828	46.0%	1,623	45.1%	2,385	44.2%	3,172	44.1%
December	973	52.3%	1,907	51.3%	2,804	50.2%	3,729	50.1%
Annual (P50)	**6,656**	**30.4%**	**13,033**	**29.8%**	**19,177**	**29.2%**	**25,503**	**29.1%**
P90 Average	4,993	22.8%	9,825	22.4%	14,385	21.9%	19,131	21.8%
P95 Average	4,522	20.6%	8,915	20.4%	13,027	19.8%	17,324	19.8%

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedence, as discussed in Section 9.4.

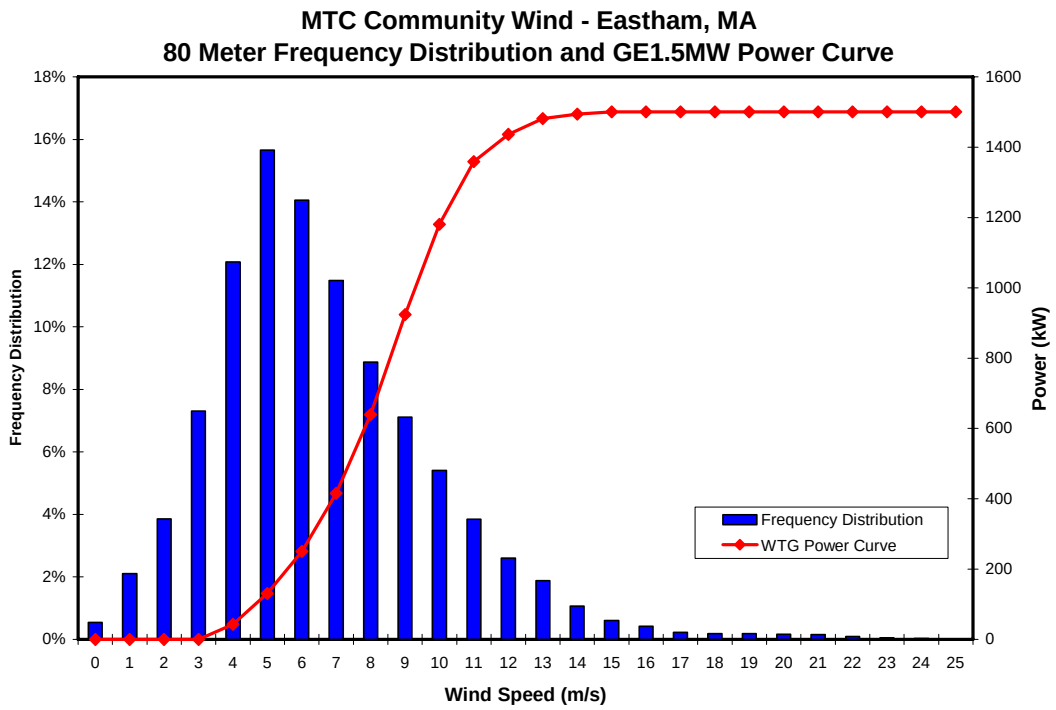


Figure 9-2 80m Wind Distribution and GE 1.5MW Power Curve

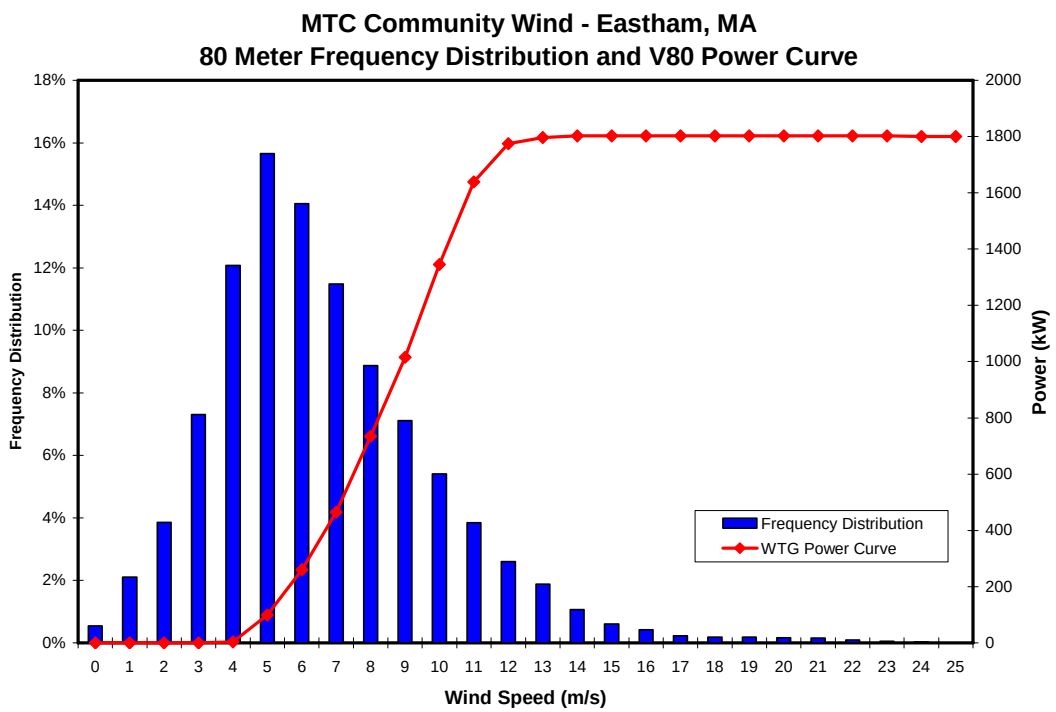


Figure 9-3 80m Wind Distribution and Vestas V80 Power Curve

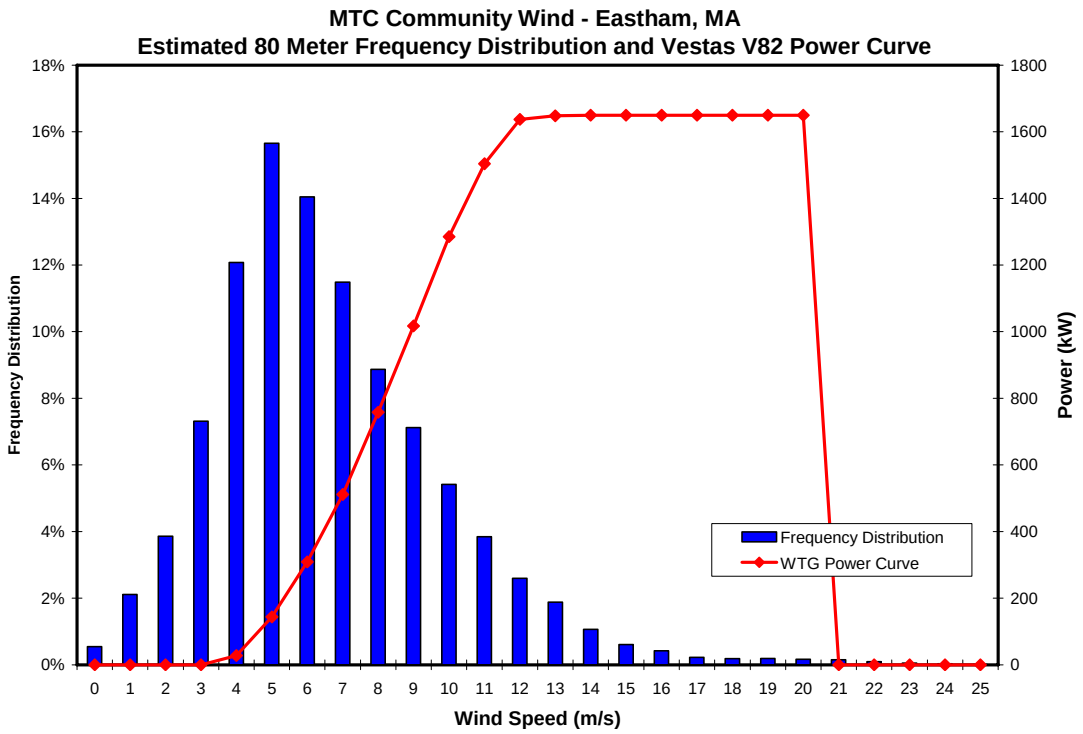


Figure 9-4 80m Wind Distribution and Vestas V82 Power Curve

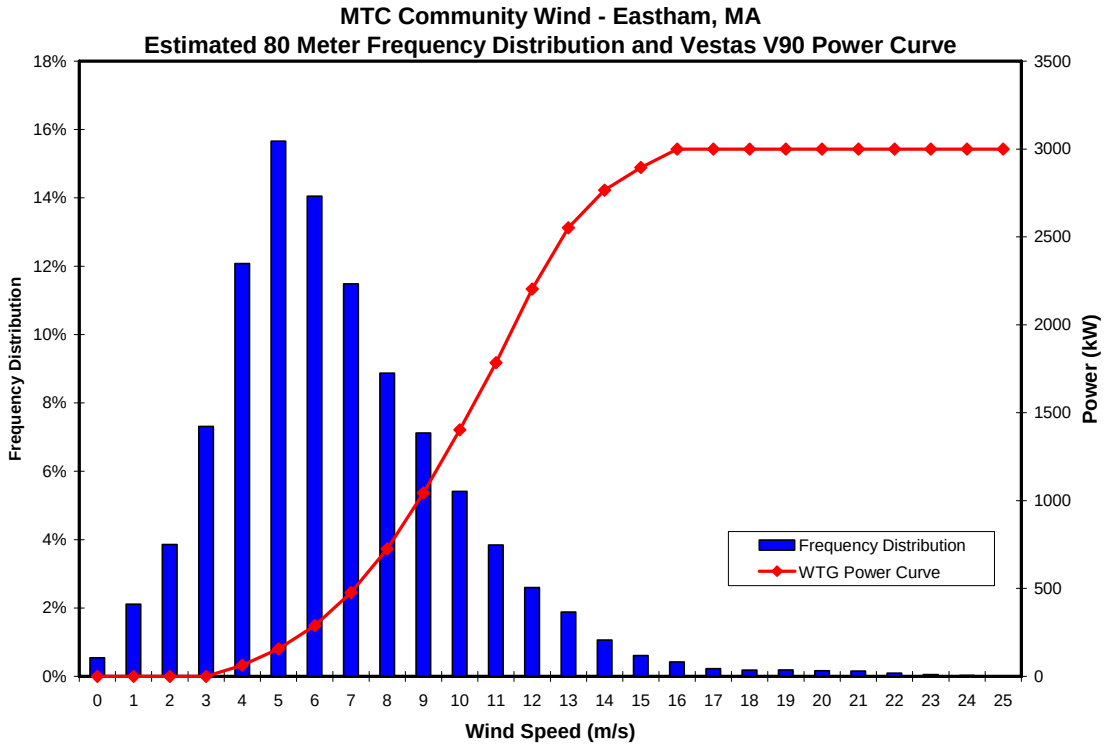


Figure 9-5 80m Wind Distribution and Vestas V90 Power Curve

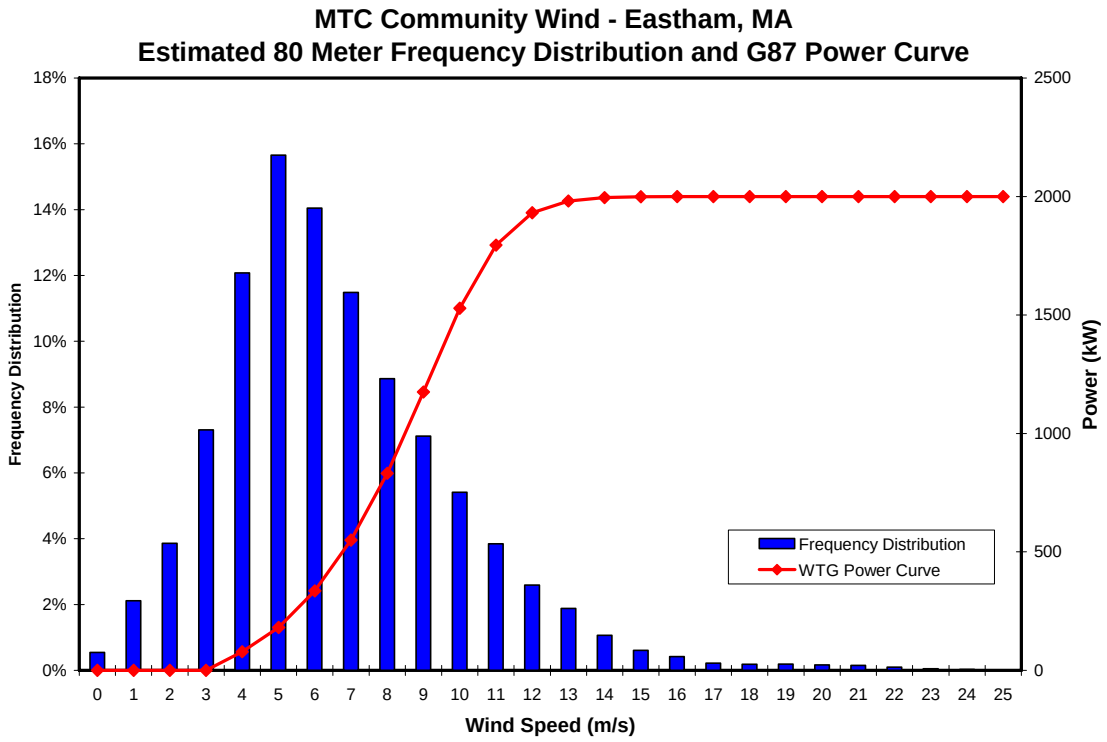


Figure 9-6 80m Wind Distribution and Gamesa G87 Power Curve

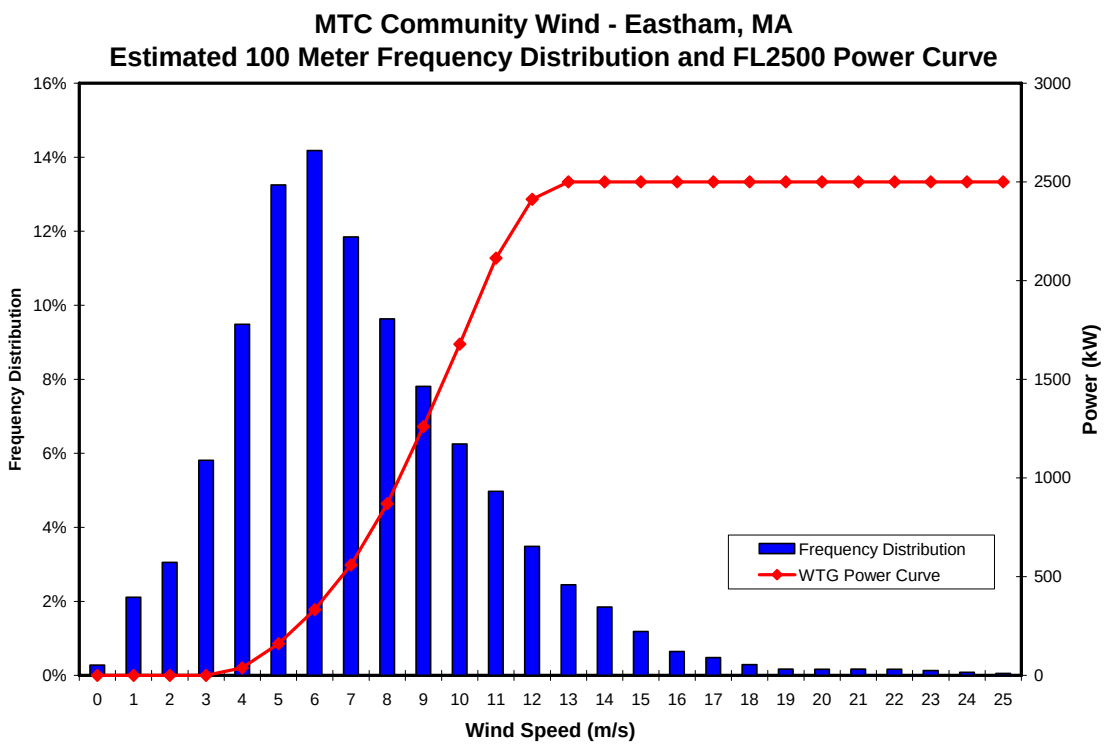


Figure 9-7 80m Wind Distribution and Fuhrländer FL 2500 Power Curve

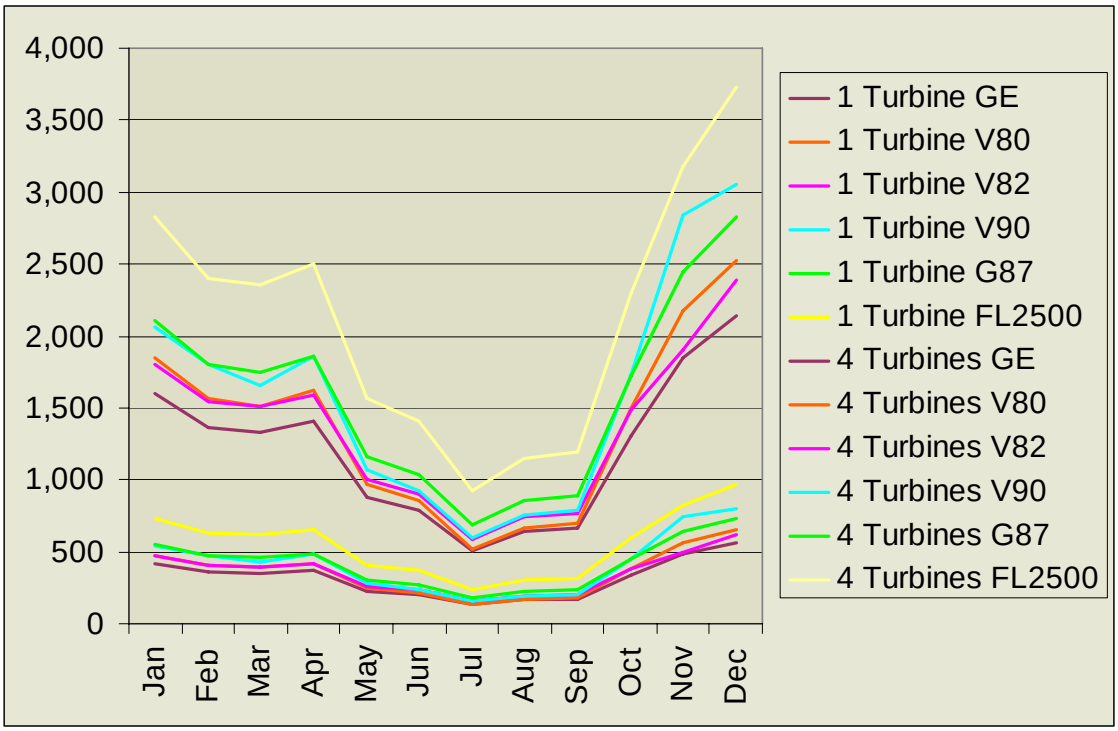


Figure 9-8 Monthly Production Estimates

9.4 Uncertainty Analysis

Based on the analysis detailed above and in Section 4, Black & Veatch has estimated the long-term average wind speed for Eastham to be 6.66 m/s at 80 meters above ground level, and 7.28 m/s at 100 meters above ground level. The corresponding long-term average production for the various turbine types and project options were presented as the Annual Average (P50) in Section 9.3. These values correspond to the 50 percent confidence value estimates, meaning that there is a 50 percent chance that the true long-term average wind speed is higher, and a 50 percent chance it is lower. To determine the sensitivity of the production to variations in wind speed, and to estimate the magnitude of variations possible, the following uncertainty analysis is performed.

To determine the uncertainty magnitude of the various estimates, Black & Veatch combined the following uncertainties:

- **Long-term wind speed variability:** this is a measure for how well understood the long-term wind resource is, and is determined by the length of the long-term data set analyzed.
- **Correlation standard error:** this value is a measure of how well the on-site data correlated to the long-term data source.

- **Anemometer calibration:** this is the stated calibration of the primary anemometer used to measure the on-site wind resource (or in our case, the RERL Eastham met tower). For uncalibrated instruments, the standard accuracy of the anemometer published by its manufacturer is used. For instruments left installed past their calibration period, or for longer than one year for uncalibrated sensors, an increase in the calibration uncertainty may be applied for expected sensor degradation.
- **Topographic and wake modeling:** the models used to estimate the effects of topography and turbine wakes have uncertainty associated to them.
- **Wind variability:** this is a single year estimate of the long-term variability, signifying the uncertainty of estimating the "next year's" power production.

Table 9-9 through Table 9-14 show the breakdown of uncertainty components for each turbine and project option. The resulting Combined Standard Error values are used to calculate the P90 and P95 annual energy estimates. For each option, the true long-term annual average energy has a 90 percent chance of being greater than the P90 estimate, and a 95 percent chance of being greater than the P95. These values can be used for sensitivity evaluations in a project pro forma or payback analysis.

Table 9-9
Production Estimate Uncertainty Analysis: GE 1.5MW Turbines

Number of Turbines			**1**	**2**	**3**	**4**
Project Rating	MW		1.50	3.00	4.50	6.00
P50 Est. Generation	MWh/yr		3,779.0	7,404.3	10,887.8	14,479.2
P50 Wind Speed	m/s		6.66	6.66	6.66	6.66
Energy Sensitivity	MWh/yr/(m/s)		1,231.1	2,353.5	3,546.9	4,716.9
Factor	**Uncertainty**					
	percent	**m/s**	**MWh/yr**	**MWh/yr**	**MWh/yr**	**MWh/yr**
Long-Term Wind Variability[1]	2.3%	0.15	185.9	355.5	535.7	712.4
Correlation[2]		0.45	554.0	1,059.1	1,596.1	2,122.6
Anem. Calibration	2.0%	0.13	164.0	313.5	472.5	628.3
Topo/Wake Model	2.0%	0.13	164.0	313.5	472.5	628.3
Wind Variability	6.0%	0.40	491.9	940.4	1,417.4	1,884.9
Combined Standard Error			**798.3**	**1,526.1**	**2,300.0**	**3,058.6**

Notes: [1]Long-Term variability based on Provincetown Airport data
[2]Correlation done on a monthly average basis

Table 9-10
Production Estimate Uncertainty Analysis: Vestas V80 Turbines

Number of Turbines			**1**	**2**	**3**	**4**
Project Rating	MW		1.80	3.60	5.40	7.20
P50 Est. Generation	MWh/yr		4,240.7	8,314.3	12,384.2	16,456.0
P50 Wind Speed	m/s		6.66	6.66	6.66	6.66
Energy Sensitivity	MWh/yr/(m/s)		1,493.6	2,856.8	4,361.9	5,796.1
Factor	**Uncertainty**					
	percent	**m/s**	**MWh/yr**	**MWh/yr**	**MWh/yr**	**MWh/yr**
Long-Term Wind Variability[1]	2.3%	0.15	185.9	355.5	535.7	712.4
Correlation[2]		0.45	554.0	1,059.1	1,596.1	2,122.6
Anem. Calibration	2.0%	0.13	164.0	313.5	472.5	628.3
Topo/Wake Model	2.0%	0.13	164.0	313.5	472.5	628.3
Wind Variability	6.0%	0.40	491.9	940.4	1,417.4	1,884.9
Combined Standard Error			**798.3**	**1,526.1**	**2,300.0**	**3,058.6**

Notes: [1]Long-Term variability based on Provincetown Airport data
[2]Correlation done on a monthly average basis

Table 9-11
Production Estimate Uncertainty Analysis: Vestas V82 Turbines

Number of Turbines			**1**	**2**	**3**	**4**
Project Rating	MW		1.65	3.30	4.95	6.60
P50 Est. Generation	MWh/yr		4,233.7	8,294.4	12,198.0	16,221.5
P50 Wind Speed	m/s		6.66	6.66	6.66	6.66
Energy Sensitivity	MWh/yr/(m/s)		1,278.2	2,440.7	3,682.7	4,897.5
Factor	**Uncertainty**					
	percent	**m/s**	**MWh/yr**	**MWh/yr**	**MWh/yr**	**MWh/yr**
Long-Term Wind Variability[1]	2.3%	0.15	193.1	368.6	556.2	739.7
Correlation[2]		0.45	575.2	1,098.3	1,657.2	2,203.9
Anem. Calibration	2.0%	0.13	170.3	325.1	490.5	652.3
Topo/Wake Model	2.0%	0.13	170.3	325.1	490.5	652.3
Wind Variability	6.0%	0.40	510.8	975.3	1,471.6	1,957.0
Combined Standard Error			**828.9**	**1,582.7**	**2,388.0**	**3,175.7**

Notes: [1]Long-Term variability based on Provincetown Airport data
[2]Correlation done on a monthly average basis

Table 9-12
Production Estimate Uncertainty Analysis: Vestas V90 Turbines

Number of Turbines			**1**	**2**	**3**	**4**
Project Rating	MW		3.00	6.00	9.00	12.00
P50 Est. Generation	MWh/yr		4,995.4	9,816.1	14,392.5	19,139.9
P50 Wind Speed	m/s		6.66	6.66	6.66	6.66
Energy Sensitivity	MWh/yr/(m/s)		1,866.8	3,571.8	5,378.6	7,152.7
Factor	**Uncertainty**					
	percent	**m/s**	**MWh/yr**	**MWh/yr**	**MWh/yr**	**MWh/yr**
Long-Term Wind Variability[1]	2.3%	0.15	282.0	539.5	812.4	1,080.3
Correlation[2]		0.45	840.1	1,607.3	2,420.4	3,218.7
Anem. Calibration	2.0%	0.13	248.7	475.8	716.4	952.7
Topo/Wake Model	2.0%	0.13	248.7	475.8	716.4	952.7
Wind Variability	6.0%	0.40	746.0	1,427.3	2,149.3	2,858.2
Combined Standard Error			**1,210.5**	**2,316.1**	**3,487.7**	**4,638.1**

Notes: [1]Long-Term variability based on Provincetown Airport data
[2]Correlation done on a monthly average basis

Table 9-13
Production Estimate Uncertainty Analysis: Gamesa G87 Turbines

Number of Turbines			**1**	**2**	**3**	**4**
Project Rating	MW		2.00	4.00	6.00	8.00
P50 Est. Generation	MWh/yr		4,995.2	9,788.9	14,392.0	19,139.1
P50 Wind Speed	m/s		6.66	6.66	6.66	6.66
Energy Sensitivity	MWh/yr/(m/s)		1,616.3	3,088.2	4,656.8	6,192.9
Factor	**Uncertainty**					
	percent	**m/s**	**MWh/yr**	**MWh/yr**	**MWh/yr**	**MWh/yr**
Long-Term Wind Variability[1]	2.3%	0.15	244.1	466.4	703.3	935.3
Correlation[2]		0.45	727.3	1,389.7	2,095.6	2,786.8
Anem. Calibration	2.0%	0.13	215.3	411.4	620.3	824.9
Topo/Wake Model	2.0%	0.13	215.3	411.4	620.3	824.9
Wind Variability	6.0%	0.40	645.9	1,234.1	1,860.9	2,474.7
Combined Standard Error			1,048.1	2,002.5	3,019.7	4,015.7

Notes: [1]Long-Term variability based on Provincetown Airport data
[2]Correlation done on a monthly average basis

Table 9-14
Production Estimate Uncertainty Analysis: Fuhrländer FL2500 Turbines

Number of Turbines			**1**	**2**	**3**	**4**
Project Rating	MW		2.50	5.00	7.50	10.00
P50 Est. Generation	MWh/yr		6,656.2	13,033.5	19,177.4	25,503.1
P50 Wind Speed	m/s		6.66	6.66	6.66	6.66
Energy Sensitivity	MWh/yr/(m/s)		1,907.3	3,679.7	5,495.3	7,308.0
Factor	**Uncertainty**					
	percent	**m/s**	**MWh/yr**	**MWh/yr**	**MWh/yr**	**MWh/yr**
Long-Term Wind Variability[1]	2.3%	0.15	314.9	607.5	907.3	1,206.5
Correlation[2]		0.45	858.3	1,655.9	2,472.9	3,288.6
Anem. Calibration	2.0%	0.13	277.7	535.8	800.1	1,064.0
Topo/Wake Model	2.0%	0.13	277.7	535.8	800.1	1,064.0
Wind Variability	6.0%	0.40	833.1	1,607.3	2,400.4	3,192.1
Combined Standard Error			**1,297.8**	**2,503.7**	**3,739.1**	**4,972.4**

Notes: [1]Long-Term variability based on Provincetown Airport data
[2]Correlation done on a monthly average basis

10.0 Preliminary Project Cost Estimate

Black & Veatch prepared budgetary estimates for the project options described in Section 8, considering all six wind turbine designs.

The estimates detailed on Table 10-1 are based on general pricing data from wind turbine vendors and the cost breakdown of a recent small wind turbine project. A detailed estimate has not been generated for this study, nor has Black & Veatch requested cost proposals from local construction contractors. This estimate is also not an offer from Black & Veatch to install this project for this price, but rather intended for study purposes only. These estimates also do not attempt to capture any internal Town of Eastham costs for any necessary project oversight.

The cost of the project is very much contingent on the interconnection method and the number of turbines. If the town is able to interconnect to the low voltage line with a simple connection, the overall cost is much lower. If a high voltage substation is necessary, then the project has a large cost item that does not depend upon the number or type of wind turbines installed. In general, the more turbines, the lower the cost per kW as the fixed costs can be "spread out" over multiple turbines.

Table 10-1 gives a brief overview of costs, both total and per kW, for all the project options considered. Table 10-2 provides a basic breakdown of estimated project costs. Per kW costs range from as low as $1,265 per kW for 4 V90's using the low-voltage connection, and as high as $2,433 for a single GE 1.5MW turbine using a high voltage substation.

Readers may note the costs per kW are significantly higher than the often quoted industry model of $1,000 per kW for wind farms. The reason for the higher cost is that all the study, engineering, construction mobilization, and permitting work must be amortized over only a few turbines, while these costs are spread across many turbines for a larger wind farm. These prices also reflect the current exchange rate between the U.S. Dollar and the Euro (which is the basis of the Vestas pricing). General increases in steel and concrete prices, and a large current demand for wind turbines in the U.S., have also increased the costs of wind energy projects.

The wind turbine prices are based on the Town receiving turbines after 2008, as there is not expected to be any turbines available until then. Prices may be more favorable in 2008 depending on the status of the Production Tax Credit (PTC), as the cycle of renewing this credit (which currently expires at the end of December, 2007) has led to a "boom and bust" cycle in the wind industry. If the Town can secure turbines during a down period in the market, the prices may be lower.

Table 10-1
Summary of Project Costs and Performance

WTG Model	# WTG	Elec[1]	Capacity MW	Capacity Factor	Cost per kW	Total Cost	Annual MWh
GE 1.5MW	1	LV	1.5	28.8%	$1,967	$2,950	3,779
		HV	1.5	28.8%	$2,433	$3,650	3,779
	2	LV	3	28.2%	$1,745	$5,235	7,404
		HV	3	28.2%	$1,978	$5,935	7,404
	3	LV	4.5	27.6%	$1,671	$7,520	10,888
		HV	4.5	27.6%	$1,827	$8,220	10,888
	4	LV	6	27.5%	$1,634	$9,805	14,479
		HV	6	27.5%	$1,751	$10,505	14,479
Vestas V80	1	LV	1.8	26.9%	$1,761	$3,170	4,236
		HV	1.8	26.9%	$2,150	$3,870	4,236
	2	LV	3.6	26.3%	$1,576	$5,675	8,305
		HV	3.6	26.3%	$1,771	$6,375	8,305
	3	LV	5.4	26.2%	$1,515	$8,180	12,374
		HV	5.4	26.2%	$1,644	$8,880	12,374
	4	LV	7.2	26.1%	$1,484	$10,685	16,443
		HV	7.2	26.1%	$1,581	$11,385	16,443
Vestas V82	1	LV	1.65	29.3%	$1,921	$3,170	4,235
		HV	1.65	29.3%	$2,345	$3,869	4,235
	2	LV	3.3	28.7%	$1,720	$5,676	8,297
		HV	3.3	28.7%	$1,932	$6,376	8,297
	3	LV	4.95	28.1%	$1,653	$8,182	12,198
		HV	4.95	28.1%	$1,794	$8,880	12,198
	4	LV	6.6	28.1%	$1,619	$10,685	16,221
		HV	6.6	28.1%	$1,725	$11,385	16,221
Gamesa G87	1	LV	2	28.5%	$1,585	$3,170	4,995
		HV	2	28.5%	$1,935	$3,870	4,995
	2	LV	4	27.9%	$1,419	$5,676	9,789
		HV	4	27.9%	$1,594	$6,376	9,789
	3	LV	6	27.4%	$1,363	$8,178	14,392
		HV	6	27.4%	$1,480	$8,880	14,392
	4	LV	8	27.3%	$1,336	$10,688	19,139

Table 10-1
Summary of Project Costs and Performance

WTG Model	# WTG	Elec[1]	Capacity MW	Capacity Factor	Cost per kW	Total Cost	Annual MWh
		HV	8	27.3%	$1,423	$11,384	19,139
Vestas V90	1	LV	3	19.0%	$1,432	$4,295	4,995
		HV	3	19.0%	$1,665	$4,995	4,995
	2	LV	6	18.7%	$1,321	$7,925	9,816
		HV	6	18.7%	$1,438	$8,625	9,816
	3	LV	9	18.3%	$1,284	$11,555	14,393
		HV	9	18.3%	$1,362	$12,255	14,393
	4	LV	12	18.2%	$1,265	$15,185	19,140
		HV	12	18.2%	$1,324	$15,885	19,140
FL2500	1	LV	2.5	30.4%	$1,678	$4,195	6,656
		HV	2.5	30.4%	$1,958	$4,895	6,656
	2	LV	5	29.8%	$1,545	$7,725	13,033
		HV	5	29.8%	$1,685	$8,425	13,033
	3	LV	7.5	29.2%	$1,501	$11,258	19,177
		HV	7.5	29.2%	$1,594	$11,955	19,177
	4	LV	10	29.1%	$1,479	$14,790	25,503
		HV	10	29.1%	$1,549	$15,485	25,503

Notes: [1]Elec = Electrical connection method
LV = Low Voltage (23kV) without substation
HV = High Voltage (115kV) with substation

While the cost per kW is important in determining the return of the project, the total cost of the project is also a major factor. The Town or a developer may not be able to obtain financing for larger projects, as a four turbine project costs roughly $10 million. The Town may want to install one or two turbines at first, with the option of adding additional turbines later. The cost to add additional turbines at a later time is roughly the cost difference of the two size options, plus the cost to remobilize necessary construction crews. For instance, the cost to add two FL2500 turbines after two have already been installed using a low-voltage connection is roughly $7.1 million plus the remobilization cost, expected to be about $100,000.

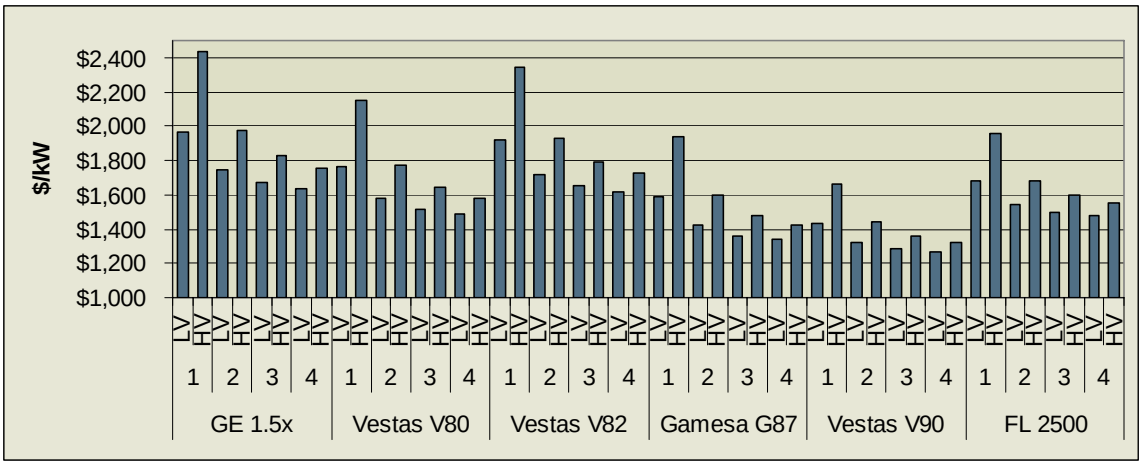


Figure 10-1 Cost per kW of each option

Table 10-2
Project Cost Breakdown

Turbine	GE 1.5MW				Vestas V80				Vestas V82				Gamesa G87				Vestas V90				FL 2500			
Per WTG Rating, kW	1,500	1,500	1,500	1,500	1,800	1,800	1,800	1,800	1,650	1,650	1,650	1,650	2,000	2,000	2,000	2,000	3,000	3,000	3,000	3,000	2,500	2,500	2,500	2,500
Number of WTGs	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Total Project Rating, kW	1,500	3,000	4,500	6,000	1,800	3,600	5,400	7,200	1,650	3,300	4,950	6,600	2,000	4,000	6,000	8,000	3,000	6,000	9,000	12,000	2,500	5,000	7,500	10,000
Planning and Study Costs																								
Pre-Development Consulting	$40	$55	$70	$85	$40	$55	$70	$85	$40	$55	$70	$85	$40	$55	$70	$85	$40	$55	$70	$85	$40	$55	$70	$85
Owner's Engineer/PM	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150
Interconnection Study (SGIP)	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50
Total	**$165**	**$205**	**$245**	**$285**	**$165**	**$205**	**$245**	**$285**	**$165**	**$205**	**$245**	**$285**	**$165**	**$205**	**$245**	**$285**	**$165**	**$205**	**$245**	**$285**	**$165**	**$205**	**$245**	**$285**
Engineering																								
Geotech Testing & Analysis	$35	$40	$45	$50	$35	$40	$45	$50	$35	$40	$45	$50	$35	$40	$45	$50	$35	$40	$45	$50	$35	$40	$45	$50
Civil/Structural Design	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150	$75	$100	$125	$150
Electrical Design w/o Substation	$55	$60	$65	$70	$55	$60	$65	$70	$55	$60	$65	$70	$55	$60	$65	$70	$55	$60	$65	$70	$55	$60	$65	$70
Electrical Design with Substation	$105	$110	$115	$120	$105	$110	$115	$120	$105	$110	$115	$120	$105	$110	$115	$120	$105	$110	$115	$120	$105	$110	$115	$120
Communications Design	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25
Eng. Total (LV)	**$190**	**$225**	**$260**	**$295**	**$190**	**$225**	**$260**	**$295**	**$190**	**$225**	**$260**	**$295**	**$190**	**$225**	**$260**	**$295**	**$190**	**$225**	**$260**	**$295**	**$190**	**$225**	**$260**	**$295**
Eng. Total (HV)	**$240**	**$275**	**$310**	**$345**	**$240**	**$275**	**$310**	**$345**	**$240**	**$275**	**$310**	**$345**	**$240**	**$275**	**$310**	**$345**	**$240**	**$275**	**$310**	**$345**	**$240**	**$275**	**$310**	**$345**
Environmental Permitting																								
Permitting	$100	$125	$150	$175	$100	$125	$150	$175	$100	$125	$150	$175	$100	$125	$150	$175	$100	$125	$150	$175	$100	$125	$150	$175
Equipment and Construction																								
WTG Supply	$1,750	$3,500	$5,250	$7,000	$2,000	$4,000	$6,000	$8,000	$2,000	$4,000	$6,000	$8,000	$2,000	$4,000	$6,000	$8,000	$3,000	$6,000	$9,000	$12,000	$2,900	$5,800	$8,700	$11,600
WTG Shipping	$100	$200	$300	$400	$100	$200	$300	$400	$100	$200	$300	$400	$100	$200	$300	$400	$150	$300	$450	$600	$150	$300	$450	$600
WTG Installation	$175	$275	$375	$475	$175	$275	$375	$475	$175	$275	$375	$475	$175	$275	$375	$475	$225	$375	$525	$675	$225	$375	$525	$675
Civil/Structural	$125	$200	$275	$350	$125	$200	$275	$350	$125	$200	$275	$350	$125	$200	$275	$350	$150	$250	$350	$450	$150	$250	$350	$450
Electrical	$50	$75	$100	$125	$50	$75	$100	$125	$50	$75	$100	$125	$50	$75	$100	$125	$50	$75	$100	$125	$50	$75	$100	$125
Other Costs	$25	$50	$75	$100	$25	$50	$75	$100	$25	$50	$75	$100	$25	$50	$75	$100	$25	$50	$75	$100	$25	$50	$75	$100

Table 10-2
Project Cost Breakdown

Turbine	GE 1.5MW				Vestas V80				Vestas V82				Gamesa G87				Vestas V90				FL 2500			
Total	**$2,225**	**$4,300**	**$6,375**	**$8,450**	**$2,475**	**$4,800**	**$7,125**	**$9,450**	**$2,475**	**$4,800**	**$7,125**	**$9,450**	**$2,475**	**$4,800**	**$7,125**	**$9,450**	**$3,600**	**$7,050**	**$10,500**	**$13,950**	**$3,500**	**$6,850**	**$10,200**	**$13,550**
Utility Upgrades																								
Utility Upgrades	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50
Other Costs																								
Training	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10
2 Year WTG Service/Warranty	$30	$60	$90	$120	$15	$30	$45	$60	$15	$30	$45	$60	$15	$30	$45	$60	$15	$30	$45	$60	$15	$30	$45	$60
Extended WTG Service/Warranty	$80	$160	$240	$320	$65	$130	$195	$260	$65	$130	$195	$260	$65	$130	$195	$260	$65	$130	$195	$260	$65	$130	$195	$260
Total	**$120**	**$230**	**$340**	**$450**	**$90**	**$170**	**$250**	**$330**	**$90**	**$170**	**$250**	**$330**	**$90**	**$170**	**$250**	**$330**	**$90**	**$170**	**$250**	**$330**	**$90**	**$170**	**$250**	**$330**
Electrical Interconnection																								
Low Voltage Tap	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100
Substation	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750	$750
Project Totals																								
Total without Interconnection	$2,795	$5,075	$7,355	$9,635	$3,015	$5,515	$8,015	$10,515	$3,015	$5,515	$8,015	$10,515	$3,015	$5,515	$8,015	$10,515	$4,140	$7,765	$11,390	$15,015	$4,040	$7,565	$11,090	$14,615
Low Voltage Interconnect Total	$155	$160	$165	$170	$155	$160	$165	$170	$155	$160	$165	$170	$155	$160	$165	$170	$155	$160	$165	$170	$155	$160	$165	$170
High Voltage Interconnect Total	$855	$860	$865	$870	$855	$860	$865	$870	$855	$860	$865	$870	$855	$860	$865	$870	$855	$860	$865	$870	$855	$860	$865	$870
LV Project Total	**$2,950**	**$5,235**	**$7,520**	**$9,805**	**$3,170**	**$5,675**	**$8,180**	**$10,685**	**$3,170**	**$5,675**	**$8,180**	**$10,685**	**$3,170**	**$5,675**	**$8,180**	**$10,685**	**$4,295**	**$7,925**	**$11,555**	**$15,185**	**$4,195**	**$7,725**	**$11,255**	**$14,785**
HV Project Total	**$3,650**	**$5,935**	**$8,220**	**$10,505**	**$3,870**	**$6,375**	**$8,880**	**$11,385**	**$3,870**	**$6,375**	**$8,880**	**$11,385**	**$3,870**	**$6,375**	**$8,880**	**$11,385**	**$4,995**	**$8,625**	**$12,255**	**$15,885**	**$4,895**	**$8,425**	**$11,955**	**$15,485**
LV Cost per kW	**$1,967**	**$1,745**	**$1,671**	**$1,634**	**$1,761**	**$1,576**	**$1,515**	**$1,484**	**$1,921**	**$1,720**	**$1,653**	**$1,619**	**$1,585**	**$1,419**	**$1,363**	**$1,336**	**$1,432**	**$1,321**	**$1,284**	**$1,265**	**$1,678**	**$1,545**	**$1,501**	**$1,479**
HV Cost per kW	**$2,433**	**$1,978**	**$1,827**	**$1,751**	**$2,150**	**$1,771**	**$1,644**	**$1,581**	**$2,345**	**$1,932**	**$1,794**	**$1,725**	**$1,935**	**$1,594**	**$1,480**	**$1,423**	**$1,665**	**$1,438**	**$1,362**	**$1,324**	**$1,958**	**$1,685**	**$1,594**	**$1,549**

Notes: All cost values other than Cost per kW are in $1,000's.

11.0 Preliminary Financial Analysis

The financial impacts of the project depend greatly on what ownership structure the project takes. The various ownership structures are discussed in the following section, each with different financial and legal considerations.

For the private ownership and Town ownership options, Black & Veatch reviewed potential economic value for the Eastham community wind project options using two pro forma financial models, one established by MTC and an internal Black & Veatch model. The results from these pro forma analyses are discussed in this section, and the pro forma results for each option are presented in Appendix F.

11.1 Ownership Options

In addition to the decision of how many and what type of turbines will be placed at the site, the Town must also decide how a possible project will be developed and owned. There are a few options: Private development, Town development, and a possible cooperative partnership. As discussed earlier, the site selected precludes the Town from using the wind generated electricity for servicing local Town electrical loads. This would be the most economical use of the power from the Town's perspective. The various ownership options are discussed in more detail below.

11.1.1 Private Ownership

Private developers have experience with developing wind projects and could more easily develop the Eastham site. Private owners are also eligible for federal tax incentives, such as the Production Tax Credit (PTC) and accelerated depreciation, which may make the project more viable financially.

If a private entity were to develop the project, the Town's role would be that of landowner and tax collector. The Town would receive land lease payments from the project, either in the form of a small percentage of gross revenues or as a dollar amount per turbine. The project would also contribute to the tax base of the local community; most projects use a Payment in Lieu of Taxes (PILOT) agreement instead of actual property taxes (because the Town owns the site, it would owe no taxes). It is unclear if the Town of Eastham would need to share this PILOT revenue with Barnstable County. MTC assumes a PILOT payment of $20,000 per turbine per year.

A potential drawback with using a private developer is that it may be difficult for the Town to interest a private developer in such a small project. There is significant risk that a project could be slowed by local opposition or permitting problems, delays that

could prove fatal to a private developer. Black & Veatch informally contacted a few developers, and received an unenthusiastic response about such a small project.

11.1.2 Town Ownership

It is unclear that the Town could even own a wholesale power generation system under Massachusetts law, as it would be operating as a utility. If it was legal, it is also unclear that the Town could issue tax-exempt debt to purchase equipment. Town ownership could have greater economic gains for the Town, but it would also have a high risk. Assistance from MTC is available, however, and if the Town develops the project it has the potential for higher returns than the developer option. Table 11-1 shows the advantages and disadvantages of private versus public ownership.

Table 11-1
Public vs. Private Ownership

Ownership Option	Advantages	Disadvantages
Private Developer	Eligible for Production Tax Credit Takes on risk of project, experience developing wind projects	Higher cost of debt (uncertain) May be difficult to attract developer to such a small project
	Stable Town income from PILOT and lease payments	
Town	Lower cost of debt (uncertain) Potential for greater economic benefit	No Production Tax credit High risk, little experience developing wind projects

The risk/reward of different ownership options can be clearly shown by choosing two different turbine manufacturers, and looking at the net present value of the projects from the town's perspective. For these two cases, all turbine numbers (1-4) were contemplated, with 1 and 2 turbine projects using a low voltage interconnect, and 3 and 4 turbine projects using a high voltage interconnect. The two turbine choices were the Gamesa G87, a turbine with a high return, and the GE 1.5, a turbine with less attractive finances. The Town's net present value for the developer owned options comes from the $20,000 per turbine PILOT agreement, as well as 5 percent of gross revenue as the leaseholder. 5 percent is on the high side for land leases, but may be appropriate given the high value of land on the Cape and the small number of turbines.

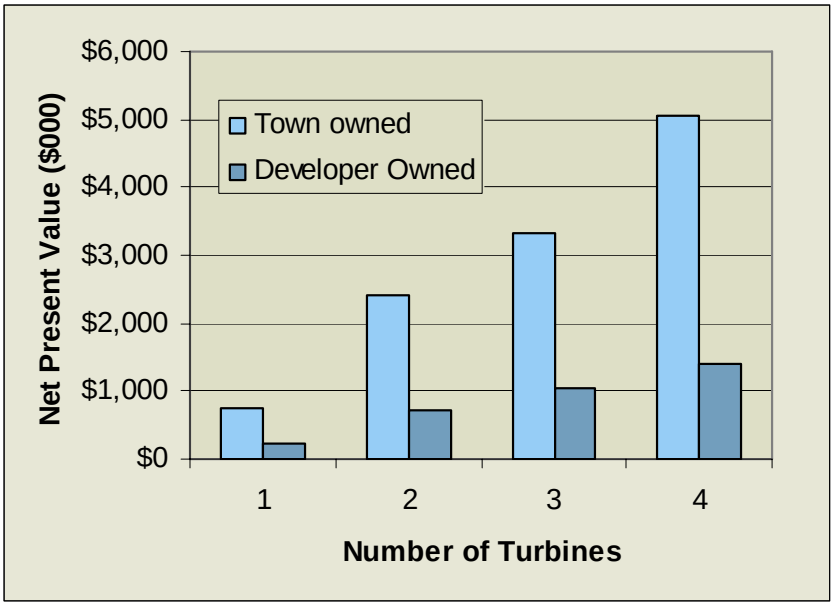


Figure 11-1. Town NPV for Gamesa Turbines

As Figure 11-1 shows, if the project performs well financially, the return to the Town is larger than the PILOT and lease agreements. While the PILOT and lease payments (roughly $40,000-$50,000 per year per turbine) are lower risk, the return is commensurately lower. This risk can be clearly shown in Figure 11-2, where the returns from GE turbines show roughly equal (or even lower) returns for the Town owning the project versus the PILOT and lease payments.

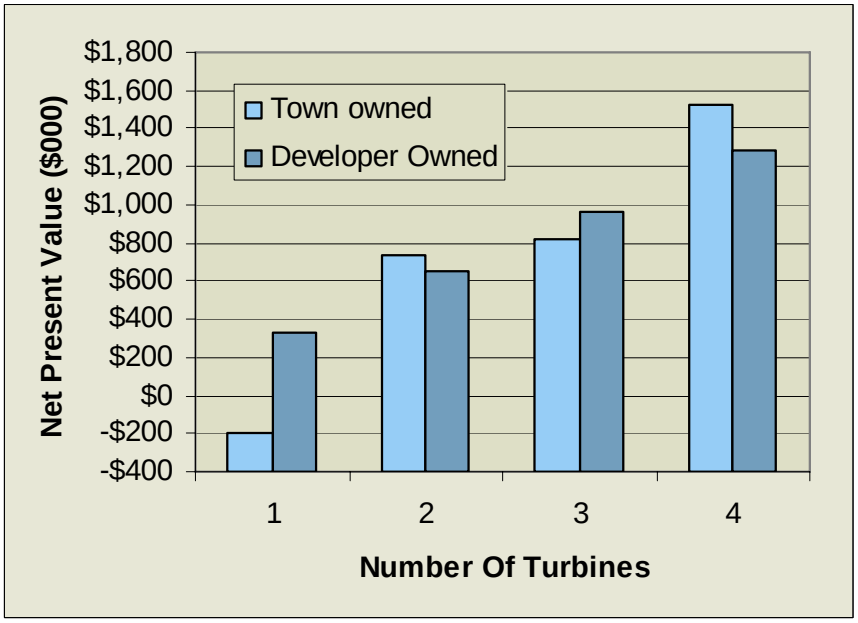


Figure 11-2. Town NPV for GE Turbines

11.1.3 Other Ownership Structures

There are other possibilities for ownership besides the two discussed above. Towns along the Cape could form an energy Cooperative (such an option is apparently being discussed) which would allow the Town of Eastham to purchase power for its loads directly from a power project. The wind project could sell power directly to the Cooperative, which could be a more lucrative market than the wholesale market. While these structures are promising, they are currently only concepts.

11.2 Energy Sales

No matter what the ownership structure, the energy generated by the wind energy project will most likely be sold to an off-taker through a power purchase agreement (PPA). Because the project is not co-metered or located on a Town of Eastham site with local loads, the generated power will be sold wholesale. For the MTC pro forma, the PPA price is assumed to be $60 per MWh. The power could also be sold on the spot market instead of a locked-in price, though such an arrangement makes it more difficult to get financing for a project.

Because the electricity from a wind turbine is generated without air or water emissions, the energy has additional value. This value is usually realized through the creation and sale of Renewable Energy Certificates (RECs), which are tradable certificates signifying a set amount of pollution avoided through wind energy. The MTC pro forma assumes the value of RECs to be $35 per MWh for the first five years of the project's life, and $15 per MWh thereafter. At this time, REC markets are not well established, and the long-term value for the RECs is uncertain.

The Black & Veatch pro forma typically determines the price of power plus RECs that the project would have to secure via a PPA to make the desired return on equity (assumed to be 12 percent for the Town, 15 percent for a private developer). For this study, Black & Veatch assumed the same REC purchase approach as with the MTC pro forma ($35 per MWh for the first five year, then $15 per MWh thereafter) and solved solely for the required PPA value. Using both pro forma methods gives the Town a better picture of which options are most financially advantageous.

The financial assumptions used in both pro formas are listed in Table 11-2. These assumptions are based on MTCs and Black & Veatch's experience in the wind industry and represent the best approximation of actual wind project finances.

Table 11-2
Financial Assumptions

Assumption	Value	Basis
Developer Debt Interest Rate (%)	8.00%	Given by MTC, developer has higher cost of finance
Town Debt Interest Rate (%)	6.50%	MTC generally uses 4.50%, but it is unclear that the town could use tax exempt debt for a profit making venture. B&V used 6.5% as an estimated debt
Project Life (years)	20	Given by MTC, standard wind project timeline
Debt Term (years)	10	Given by MTC – this is standard debt term for private entities, Mass. Town's cannot have longer debt terms.
Developer Minimum DSCR, annual average	1.40	Debt Coverage Service Ratio, ratio of cash flow to debt payments. A ratio of 1.4-1.5 is a typical standard imposed by a lender on a project.
Town Minimum DSCR, annual average	1.25	Town will require a lower DSCR than a developer.
After-tax Developer Equity Internal Rate of Return (IRR) Hurdle Rate	15.0%	This is the return on equity (over the life of the project) demanded by investors, though some projects may ask for higher or lower IRRs. This is a key variable, as the financial model optimizes on this value. This IRR is calculated after taxes and debt payments.
Town Equity IRR Hurdle Rate	12.00%	This is an estimate at the return on equity required by the Town. This is significantly higher than most public entities, which normally use their cost of debt as their equity return. However, the Town would have to raise capital to finance this project and this high rate reflects that cost of capital.
Town Equity/Debt Fraction	30/70	The MTC pro forma optimizes the debt/equity ratio, while the Black & Veatch pro forma uses 30/70. The MTC pro forma ends up with a very similar debt ratio.
Developer Equity/Debt Fraction	Optimized	Both pro formas optimize the debt/equity ratio.
Income Tax Rate	38.9%	Composite tax rate based on 35% federal and 6% state.
Annual Inflation Rate	2.50%	Given by MTC, O&M escalates at this amount
Town Nominal Discount Rate	5%	Given by MTC
IPP Nominal Discount Rate	10%	Given by MTC
PPA Escalation Rate	0%	The rate at which the PPA price escalates each year.
O&M Years 1-5	$0	Included in capital cost
O&M Years 5-10	$30,000/year per turbine	Post warranty O&M
PILOT agreement	$20,000/year per turbine	What the developer pays to the Town in lieu of taxes.
Land Lease	5% of gross revenue	What the developer pays the Town for land lease
Renewable Energy Certificates, years 1-5	$35/MWh	Value used in both pro formas as the REC value for years 1-5
Renewable Energy Certificates, years 6-20	$15/MWh	Value used in both pro formas as the REC value for years 6-20

11.3 Results

The results of the pro forma analyses are shown in the figures below. The corresponding values are listed in Appendix F.

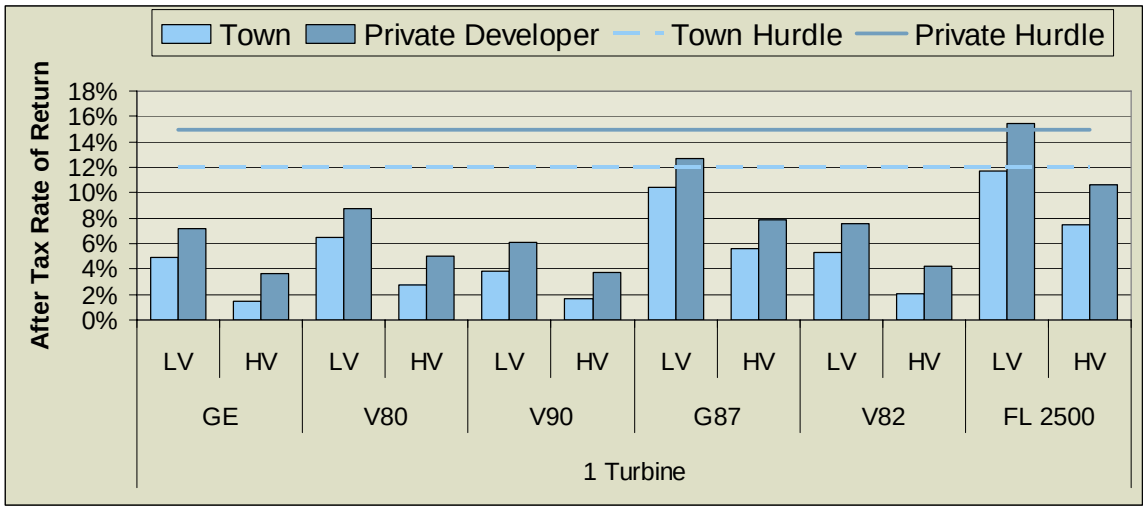


Figure 11-3 MTC Pro Forma Results: Single Turbine Options

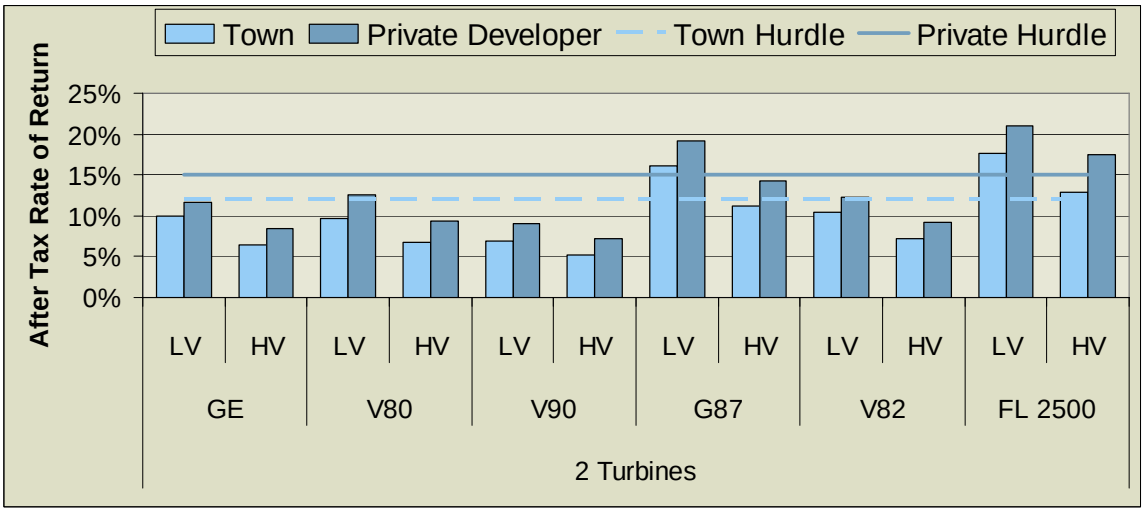


Figure 11-4 MTC Pro Forma Results: 2 Turbine Options

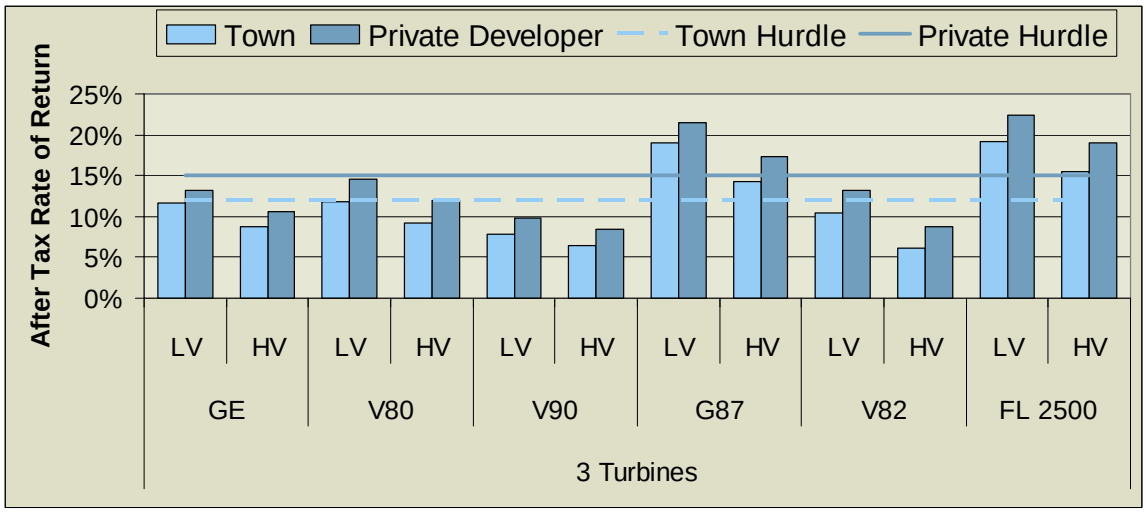


Figure 11-5 MTC Pro Forma Results: 3 Turbine Options

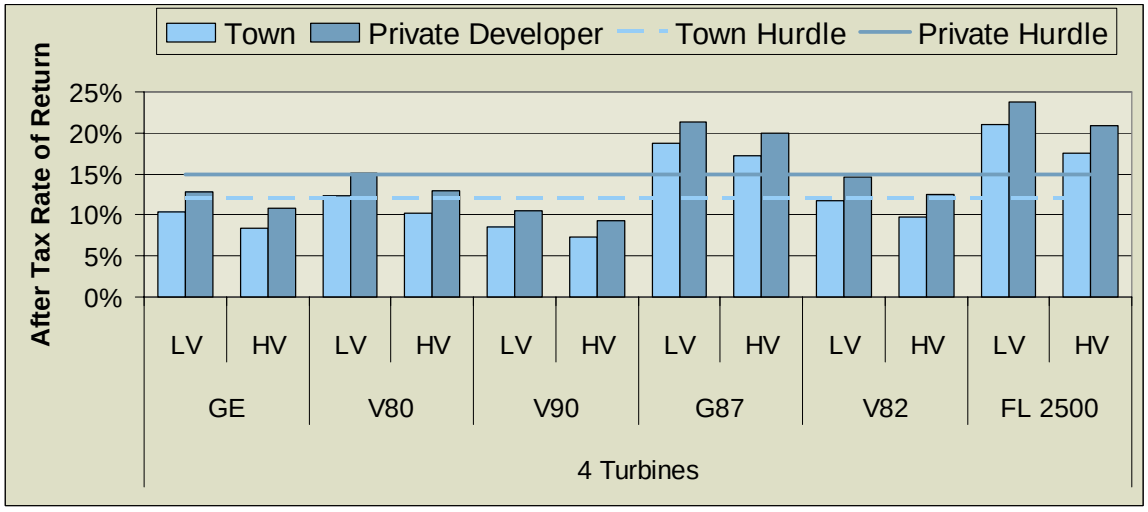


Figure 11-6 MTC Pro Forma Results: 4 Turbine Options

The MTC pro forma results show that as turbines are added, the return of the project increases. The only single turbine project with a return higher than the hurdle rate is the FL 2500 with a low voltage interconnection. Three two-turbine project options pass the hurdle rate, as do four three-turbine options and five four-turbine options. The results also show that those projects that pass the hurdle rate for the Town usually also pass the rate for a private entity with only one exception (the single turbine project).

Even more important than the number of turbines is the turbine type, as some turbines show higher returns than others. All four Fuhrländer options have high returns, while none of the V90 or GE options appear to be viable. The Gamesa G87 for two to

four turbines have good returns, while the V90 only appears viable in a four turbine project with a low voltage interconnect.

11.3.1 Black & Veatch Pro Forma Results

The Black & Veatch pro forma shows the price of power (the PPA price not including RECs) that would be needed for the project to pass the equity return hurdle rates for each entity (12 percent for the Town, 15 percent for the developer). Prices below the MTC rate of $60/MWh are assumed to indicate that the project is viable.

It is difficult to compare the results from the two pro formas, although they have the same assumptions. The Black & Veatch pro forma is similar to the MTC pro forma in that the differences between the Town and private entity are small. The same effects can be seen as well – more turbines have lower prices, and the same turbines (Fuhrländer and Gamesa) are more attractive than others. The difference lies in that the Black & Veatch pro forma only shows a *single* project under the $60/MWh target price, while the MTC pro forma had 15 project options above the return hurdle. The project below $60/MWh is the developer owned 4 turbine Gamesa with a low voltage interconnect. The Black & Veatch pro forma shows a more prominent effect of the PTC as the price gap between the private entity and the town narrows as the number of turbines increases.

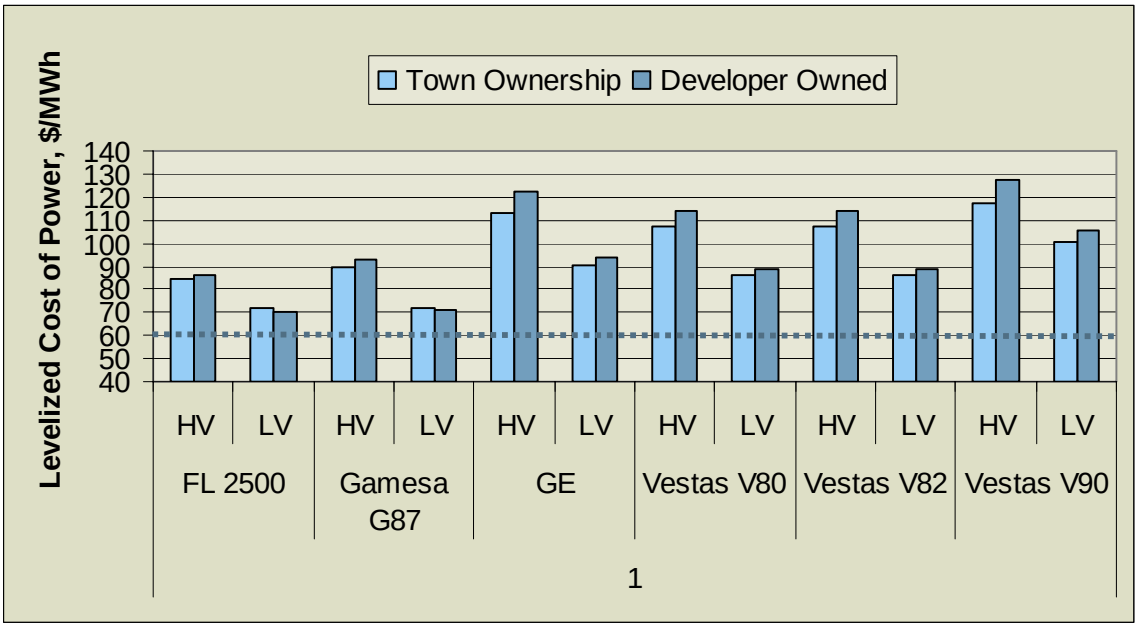


Figure 11-7 Black & Veatch Pro Forma Results: Single Turbine Projects

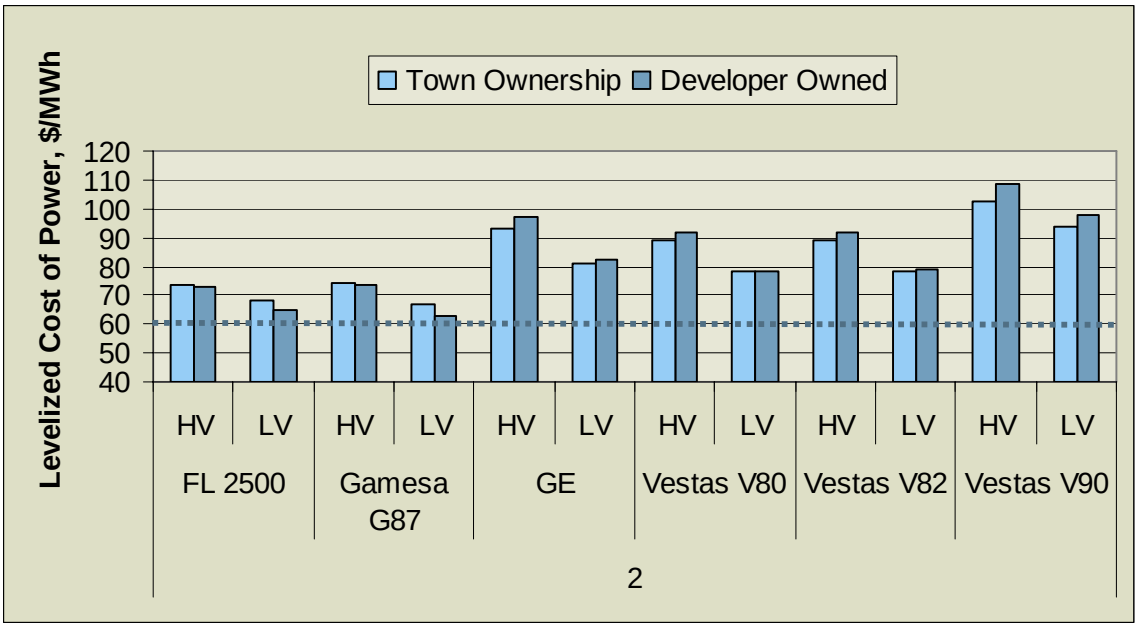


Figure 11-8 Black & Veatch Pro Forma Results: Two Turbine Projects

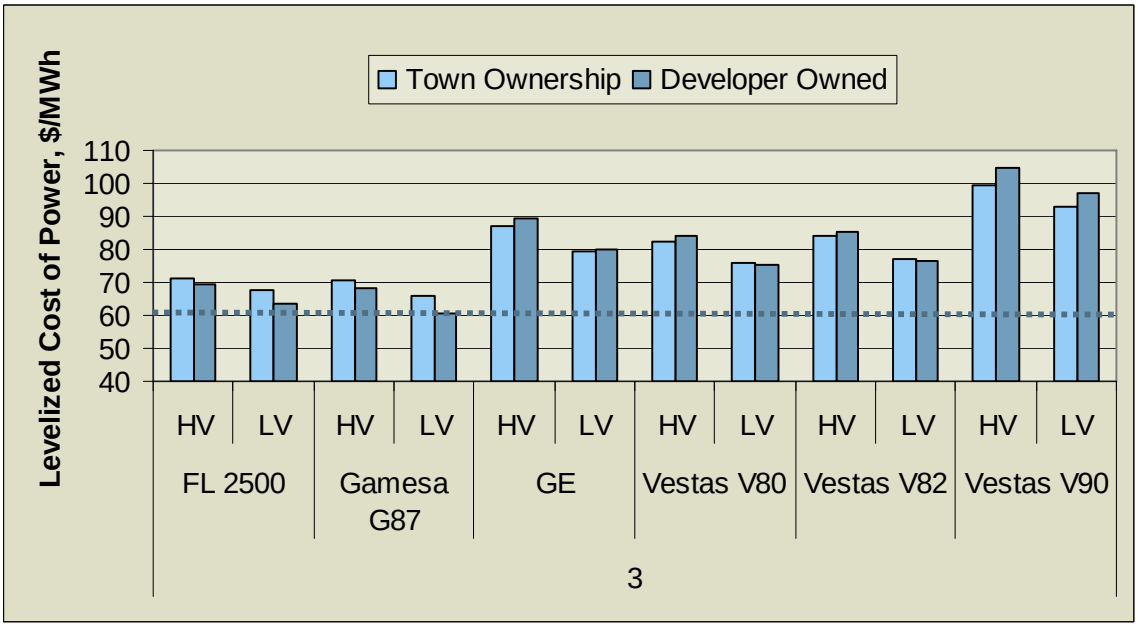


Figure 11-9 Black & Veatch Pro Forma Results: Three Turbine Projects

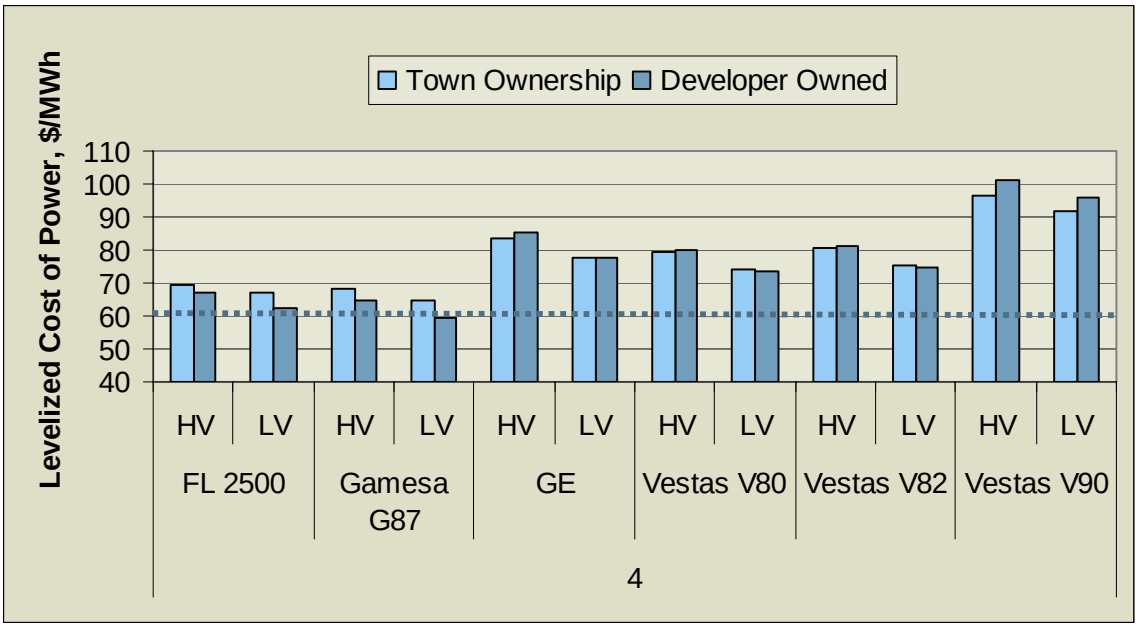


Figure 11-10 Black & Veatch Pro Forma Results: Four Turbine Projects

11.4 Conclusions

A preliminary financial analysis shows that for a turbine with appropriate price and performance characteristics, the project can be financially viable. The ownership of the project needs to be determined, as there appear to be signification barriers to both Town and private ownership. The legal hurdles for Town ownership may be too high, as the Town may need an act of the state legislature in order to sell wholesale power, and it is unclear it could use tax exempt debt to finance the project. While a private developer would bring in low risk income to the town in the form of lease payments, it is unclear whether a private entity would be interested in the risk of such a small project. Other, cooperative ownership options appear promising, but may be years away.

12.0 Project Operation Considerations

If a project is developed and owned by a private developer, the operation, maintenance, and management of the project will be determined by the developer. The Town will likely have little input into the project's operation. However, if the Town chooses to own the project, it will be up to the down to determine the manner in which the project is operated. This section discusses some aspects and options for the Town's operation of a wind energy project at North Eastham.

None of the project options studied would require an on-site operations or maintenance building, nor full-time project staff. It is expected that any spare parts for the wind turbine can be stored within existing Town facilities (such as the DPW Garage) or elsewhere in Eastham. During the turbine's warranty period, turbine performance will be monitored remotely by the manufacturer who will be responsible for dispatching repair personnel as needed. It is likely the manufacturer will request Town of Eastham personnel to perform periodic visual inspections of the wind turbine, but maintenance and repair work will be performed by qualified technicians from the nearest large project (see the discussions of the turbines in Section 2.1 for the nearest projects). Operations and maintenance arrangements will be determined with manufacturers during the turbine purchase negotiation.

When the warranty and service contract period expires, the Town of Eastham will have the option to continue to work with the turbine manufacturer, contract with a third party provider, or train Town personnel to perform these services. The best solution will depend somewhat on how many wind energy projects are installed in the region over the next few years. If an independent service provider or vendor service center is sited in or near Massachusetts, obtaining a contract with that entity will likely be the most cost effective solution. Money for this contract was included in the pro forma analysis assumptions listed in Table 11-2.

Appendix A. Wind Resource Maps

Wind resource map of Massachusetts was downloaded from the New England Wind Map web site (http://truewind.teamcamelot.com/ne/).

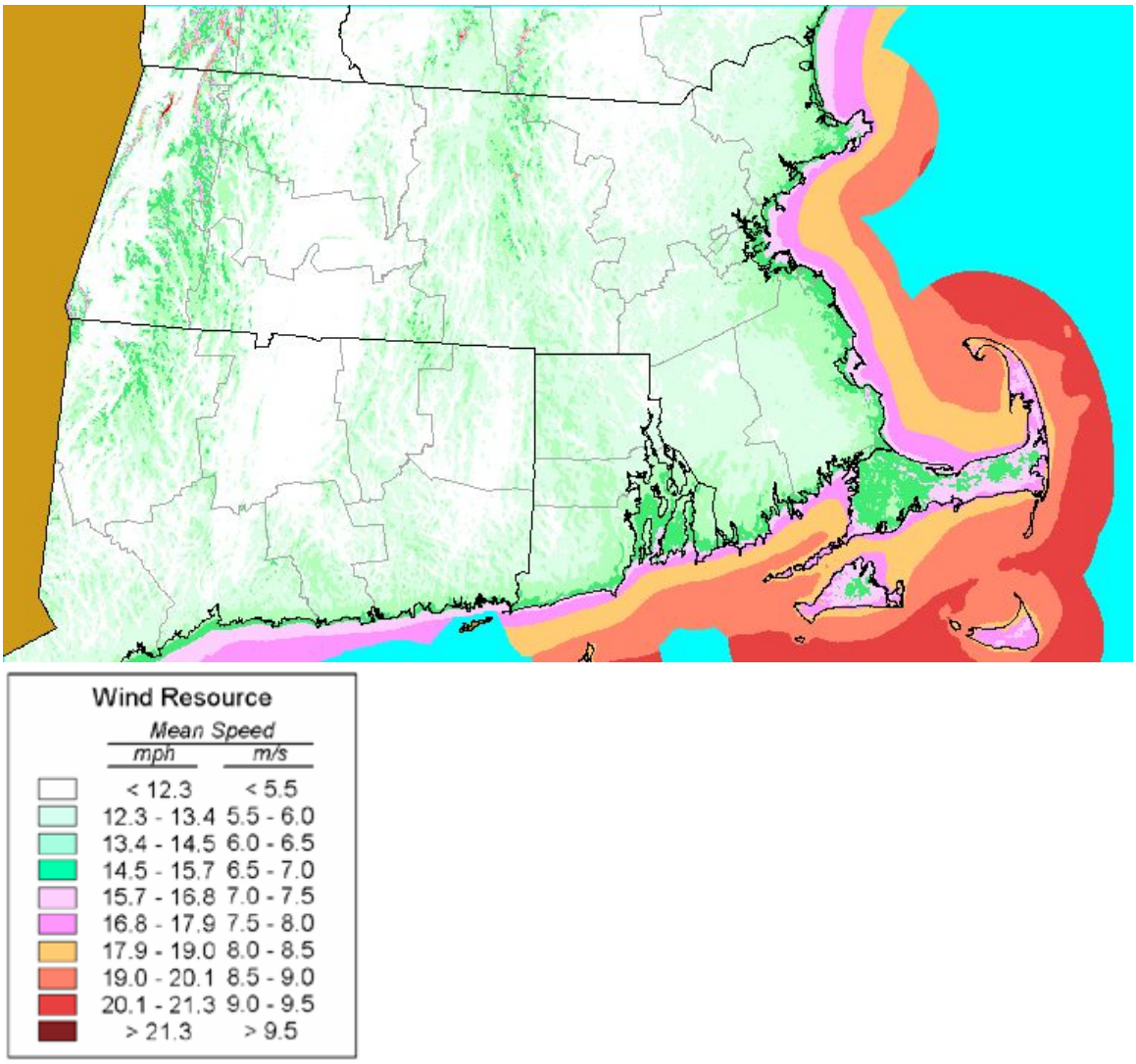


Figure A-1 Massachusetts Wind Resource Map

Appendix B. Core Habitats of Eastham

BioMap and Living Waters

Guiding Land Conservation for Biodiversity in Massachusetts

Core Habitats of Eastham

This report and associated map provide information about important sites for biodiversity conservation in your area.

This information is intended for conservation planning, and is not intended for use in state regulations.

Produced by:

Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries and Wildlife
Executive Office of Environmental Affairs
Commonwealth of Massachusetts

Produced in 2004

Revised January 2005

BioMap and Living Waters:
Guiding Land Conservation for Biodiversity in Massachusetts

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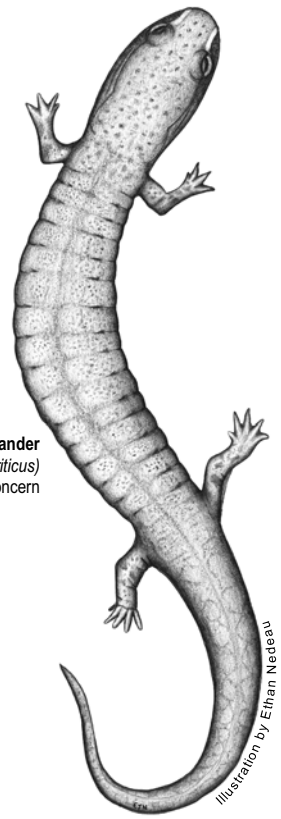
- Protecting Larger Core Habitats
- Additional Information

Local Core Habitat Information*
- BioMap: Species and Natural Communities
- BioMap: Core Habitat Summaries
- Living Waters: Species and Habitats
- Living Waters: Core Habitat Summaries



Spring Salamander
(Gyrinophilus porphyriticus)
Species of Special Concern

* Depending on the location of Core Habitats, your city or town may not have all of these sections.

Funding for this project was made available by the Executive Office of Environmental Affairs, contributions to the Natural Heritage & Endangered Species Fund, and through the State Wildlife Grants Program of the US Fish & Wildlife Service.

Natural Heritage & Endangered Species Program

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http://www.nhesp.org

For more information on rare species and natural communities, please see our fact sheets online at ***www.nhesp.org***

BioMap and Living Waters:
Guiding Land Conservation for Biodiversity in Massachusetts

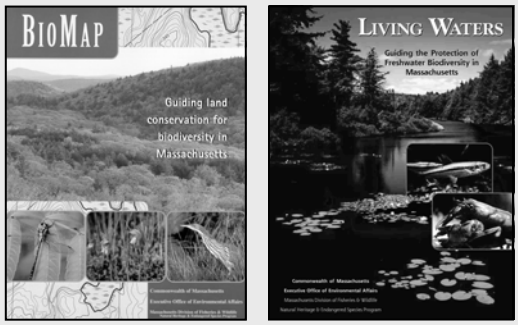
Introduction

In this report, the Natural Heritage & Endangered Species Program provides you with site-specific biodiversity information for your area. Protecting our biodiversity today will help ensure the full variety of species and natural communities that comprise our native flora and fauna will persist for generatons to come.

The information in this report is the result of two statewide biodiversity conservation planning projects, ***BioMap*** and ***Living Waters***. The goal of the BioMap project, completed in 2001, was to identify and delineate the most important areas for the long-term viability of terrestrial, wetland, and estuarine elements of biodiversity in Massachusetts. The goal of the Living Waters project, completed in 2003, was to identify and delineate the rivers, streams, lakes, and ponds that are important for freshwater biodiversity in the Commonwealth. These two conservation plans are based on documented observations of rare species, natural communities, and exemplary habitats.

What is a Core Habitat?

Both BioMap and Living Waters delineate ***Core Habitats*** that identify the most critical sites for biodiversity conservation across the state. Core Habitats represent habitat for the state's most viable rare plant and animal populations and include exemplary natural communities and aquatic habitats. Core Habitats represent a wide diversity of rare species and natural communities (see Table 1), and these areas are also thought to contain virtually all of the other described species in Massachusetts. Statewide, BioMap Core Habitats encompass 1,380,000 acres of uplands and wetlands, and Living Waters identifies 429 Core Habitats in rivers, streams, lakes, and ponds.



Get your copy of the ***BioMap*** and ***Living Waters*** reports! Contact Natural Heritage at 508-792-7270, Ext. 200 or email natural.heritage@state.ma.us. Posters and detailed technical reports are also available.

Core Habitats and Land Conservation

One of the most effective ways to protect biodiversity for future generations is to protect Core Habitats from adverse human impacts through land conservation. For Living Waters Core Habitats, protection efforts should focus on the ***riparian areas***, the areas of land adjacent to water bodies. A naturally vegetated buffer that extends 330 feet (100 meters) from the water's edge helps to maintain cooler water temperature and to maintain the nutrients, energy, and natural flow of water needed by freshwater species.

In Support of Core Habitats

To further ensure the protection of Core Habitats and Massachusetts' biodiversity in the long-term, the BioMap and Living Waters projects identify two additional areas that help support Core Habitats.

In BioMap, areas shown as ***Supporting Natural Landscape*** provide buffers around the Core Habitats, connectivity between Core Habitats, sufficient space for ecosystems to function, and contiguous undeveloped habitat for common species. Supporting Natural Landscape was

generated using a Geographic Information Systems (GIS) model, and its exact boundaries are less important than the general areas that it identifies. Supporting Natural Landscape represents potential land protection priorities once Core Habitat protection has been addressed.

In Living Waters, ***Critical Supporting Watersheds*** highlight the immediate portion of the watershed that sustains, or possibly degrades, each freshwater Core Habitat. These areas were also identified using a GIS model. Critical Supporting Watersheds represent developed and undeveloped lands, and can be quite large. Critical Supporting Watersheds can be helpful in land-use planning, and while they are not shown on these maps, they can be viewed in the Living Waters report or downloaded from www.mass.gov/mgis.

Understanding Core Habitat Species, Community, and Habitat Lists

What's in the List?

Included in this report is a list of the species, natural communities, and/or aquatic habitats for each Core Habitat in your city or town. The lists are organized by Core Habitat number.

For the larger Core Habitats that span more than one town, the species and community lists refer to the entire Core Habitat, not just the portion that falls within your city or town. For a list of all the state-listed rare species within your city or town's boundary, whether or not they are in Core Habitat, please see the town rare species lists available at www.nhesp.org.

The list of species and communities within a Core Habitat contains only the species and natural communities that were explicitly included in a given BioMap or Living Waters Core Habitat. Other rare species or examples of other natural communities may fall within the Core Habitat, but for various reasons are not included in the list. For instance, there are a few rare species that are omitted from the list or summary because of their particular sensitivity to the threat of collection. Likewise, the content of many very small Core Habitats are not described in this report or list, often because they contain a single location of a rare plant

Table 1. The number of rare species and types of natural communities explicitly included in the BioMap and Living Waters conservation plans, relative to the total number of native species statewide.

BioMap

Biodiversity Group	Species and Verified Natural Community Types: Included in BioMap	Species and Verified Natural Community Types: Total Statewide
Vascular Plants	246	1,538
Birds	21	221 breeding species
Reptiles	11	25
Amphibians	6	21
Mammals	4	85
Moths and Butterflies	52	An estimated 2,500 to 3,000
Damselflies and Dragonflies	25	An estimated 165
Beetles	10	An estimated 2,500 to 4,000
Natural Communities	92	> 105 community types

Living Waters

Biodiversity Group	Species: Included in Living Waters	Species: Total Statewide
Aquatic Vascular Plants	23	114
Fishes	11	57
Mussels	7	12
Aquatic Invertebrates	23	An estimated > 2500

species. Some Core Habitats were created for suites of common species, such as forest birds, which are particularly threatened by habitat fragmentation. In these cases, the individual common species are not listed.

What does 'Status' mean?

The Division of Fisheries and Wildlife determines a status category for each rare species listed under the Massachusetts Endangered Species Act, M.G.L. c.131A, and its implementing regulations, 321 CMR 10.00. Rare species are categorized as Endangered, Threatened, or of Special Concern according to the following:

- ***Endangered*** species are in danger of extinction throughout all or a significant portion of their range or are in danger of extirpation from Massachusetts.
- ***Threatened*** species are likely to become Endangered in Massachusetts in the foreseeable future throughout all or a significant portion of their range.
- ***Special Concern*** species have suffered a decline that could threaten the species if allowed to continue unchecked or occur in such small numbers or with such restricted distribution or specialized habitat requirements that they could easily become Threatened in Massachusetts.

In addition, the Natural Heritage & Endangered Species Program maintains an unofficial ***watch list*** of plants that are tracked due to potential conservation interest or concern, but are not regulated under the Massachusetts Endangered Species Act or other laws or regulations. Likewise, described natural communities are not regulated any laws or regulations, but they can help to identify ecologically important areas that are worthy of protection. The status of natural communities reflects the documented number and acreages of each community type in the state:

- ***Critically Imperiled*** communities typically have 5 or fewer documented sites or have very few remaining acres in the state.
- ***Imperiled*** communities typically have 6-20 sites or few remaining acres in the state.
- ***Vulnerable*** communities typically have 21-100 sites or limited acreage across the state.
- ***Secure*** communities typically have over 100 sites or abundant acreage across the state; however excellent examples are identified as Core Habitat to ensure continued protection.

Legal Protection of Biodiversity

BioMap and Living Waters present a powerful vision of what Massachusetts would look like with full protection of the land that supports most of our biodiversity. To create this vision, some populations of state-listed rare species were deemed more likely to survive over the long-term than others.

Regardless of their potential viability, all sites of state-listed species have full legal protection under the Massachusetts Endangered Species Act (M.G.L. c.131A) and its implementing regulations (321 CMR 10.00). Habitat of state-listed wildlife is also protected under the Wetlands Protection Act Regulations (310 CMR 10.37 and 10.59). The ***Massachusetts Natural Heritage Atlas*** shows **Priority Habitats**, which are used for regulation under the Massachusetts Endangered Species Act and Massachusetts Environmental Policy Act (M.G.L. c.30) and **Estimated Habitats**, which are used for regulation of rare wildlife habitat under the Wetlands Protection Act. For more information on rare species regulations, see the *Massachusetts Natural Heritage Atlas*, available from the Natural Heritage & Endangered Species Program in book and CD formats.

BioMap and Living Waters are conservation planning tools and do not, in any way, supplant the Estimated and Priority Habitat Maps which have regulatory significance. Unless and until the combined BioMap and Living Waters vision is fully realized, we must continue to protect all populations of our state-listed species and their habitats through environmental regulation.

Massachusetts Division of Fisheries and Wildlife
North Drive, Westborough, MA 01581
Tel: (508) 792-7270, Ext. 200 Fax: (508) 792-7821
http://www.nhesp.org

Understanding Core Habitat Summaries

Following the BioMap and Living Waters Core Habitat species and community lists, there is a descriptive summary of each Core Habitat that occurs in your city or town. This summary highlights some of the outstanding characteristics of each Core Habitat, and will help you learn more about your city or town's biodiversity. You can find out more information about many of these species and natural communities by looking at specific ***fact sheets*** at www.nhesp.org.

Next Steps

BioMap and Living Waters were created in part to help cities and towns prioritize their land protection efforts. While there are many reasons to conserve land – drinking water protection, recreation, agriculture, aesthetics, and others – BioMap and Living Waters Core Habitats are especially helpful to municipalities seeking to protect the rare species, natural communities, and overall biodiversity within their boundaries. Please use this report and map along with the rare species and community fact sheets to appreciate and understand the biological treasures in your city or town.

Protecting Larger Core Habitats

Core Habitats vary considerably in size. For example, the average BioMap Core Habitat is 800 acres, but Core Habitats can range from less than 10 acres to greater than 100,000 acres. These larger areas reflect the amount of land needed by some animal species for breeding, feeding, nesting, overwintering, and long-term survival. Protecting areas of this size can be very challenging, and requires developing partnerships with neighboring towns.

Prioritizing the protection of certain areas within larger Core Habitats can be accomplished through further consultation with Natural Heritage Program biologists, and through additional field research to identify the most important areas of the Core Habitat.

Additional Information

If you have any questions about this report, or if you need help protecting land for biodiversity in your community, the Natural Heritage & Endangered Species Program staff looks forward to working with you.

Contact the Natural Heritage & Endangered Species Program:

by Phone *508-792-7270, Ext. 200*

by Fax: *508-792-7821*

by Email: *natural.heritage@state.ma.us*.

by Mail: *North Drive*
Westborough, MA 01581

The GIS datalayers of BioMap and Living Waters Core Habitats are available for download from MassGIS: www.mass.gov/mgis

Check out www.nhesp.org for information on:

- Rare species in your town
- Rare species fact sheets
- BioMap and Living Waters projects
- Natural Heritage publications, including:
  - Field guides
  - Natural Heritage Atlas, and more!

BioMap: Species and Natural Communities

Eastham

Core Habitat BM1109

Natural Communities

Common Name	Scientific Name	Status
Atlantic White Cedar Bog		Imperiled
Coastal Atlantic White Cedar Swamp		Imperiled
Coastal Plain Pondshore		Imperiled
Estuarine Intertidal: Saline/Brackish Flats		Vulnerable
Level Bog		Vulnerable
Maritime Dune Community		Imperiled
Sandplain Heathland		Critically Imperiled

Plants

Common Name	Scientific Name	Status
Broom Crowberry	*Corema conradii*	Special Concern
Bushy Rockrose	*Helianthemum dumosum*	Special Concern
Commons's Panic-Grass	*Dichanthelium ovale ssp. pseudopubescens*	Special Concern
Few-Fruited Sedge	*Carex oligosperma*	Endangered
Ovate Spike-Sedge	*Eleocharis ovata*	Endangered
Oysterleaf	*Mertensia maritima*	Endangered
Purple Needlegrass	*Aristida purpurascens*	Threatened
Salt Reedgrass	*Spartina cynosuroides*	Threatened
Swamp Oats	*Sphenopholis pensylvanica*	Threatened
Walter's Sedge	*Carex striata*	Endangered
Weak Rush	*Juncus debilis*	Endangered

Invertebrates

Common Name	Scientific Name	Status
Barrens Buckmoth	*Hemileuca maia*	Special Concern
Blueberry Sallow	*Apharetra dentata*	----------

Chain Dot Geometer	*Cingilia catenaria*	Special Concern
Chain Fern Borer Moth	*Papaipema stenocelis*	Threatened
Coastal Heathland Cutworm	*Abagrotis nefascia benjamini*	Special Concern
Coastal Swamp Metarranthis Moth	*Metarranthis pilosaria*	Special Concern
Comet Darner	*Anax longipes*	Special Concern
Drunk Apamea Moth	*Apamea inebriata*	Special Concern
Dune Noctuid Moth	*Oncocnemis riparia*	Special Concern
Gerhard's Underwing Moth	*Catocala herodias gerhardi*	Special Concern
Melsheimer's Sack Bearer	*Cicinnus melsheimeri*	Threatened
New England Bluet	*Enallagma laterale*	Special Concern
Northern Brocade Moth	*Neoligia semicana*	Special Concern
Oak Hairstreak	*Satyrium favonius*	Special Concern
Pale Green Pinion Moth	*Lithophane viridipallens*	Special Concern
Pine Barrens Bluet	*Enallagma recurvatum*	Threatened
Pine Barrens Zale	*Zale sp. 1 near lunifera*	Special Concern
Pink Sallow	*Psectraglaea carnosa*	Special Concern
Spatterdock Darner	*Aeshna mutata*	Special Concern
Water-Willow Stem Borer	*Papaipema sulphurata*	Threatened
Waxed Sallow Moth	*Chaetaglaea cerata*	Special Concern

Vertebrates

Common Name	Scientific Name	Status
Arctic Tern	*Sterna paradisaea*	Special Concern
Common Tern	*Sterna hirundo*	Special Concern
Diamondback Terrapin	*Malaclemys terrapin*	Threatened
Eastern Box Turtle	*Terrapene carolina*	Special Concern
Eastern Spadefoot	*Scaphiopus holbrookii*	Threatened
Four-toed Salamander	*Hemidactylium scutatum*	Special Concern
Least Tern	*Sterna antillarum*	Special Concern

Northern Harrier	*Circus cyaneus*	Threatened
Piping Plover	*Charadrius melodus*	Threatened
Spotted Turtle	*Clemmys guttata*	Special Concern
Vesper Sparrow	*Pooecetes gramineus*	Threatened

Core Habitat BM1216

Natural Communities

Common Name	Scientific Name	Status
Coastal Plain Pondshore		Imperiled

Plants

Common Name	Scientific Name	Status
Plymouth Gentian	*Sabatia kennedyana*	Special Concern

Invertebrates

Common Name	Scientific Name	Status
New England Bluet	*Enallagma laterale*	Special Concern

Core Habitat BM1226

Natural Communities

Common Name	Scientific Name	Status
Marine Intertidal: Flats		Secure

Plants

Common Name	Scientific Name	Status
Brackish Bulrush	*Scirpus cylindricus*	Watch Listed
Mitchell's Awned Sedge	*Carex mitchelliana*	Watch Listed
Oysterleaf	*Mertensia maritima*	Endangered
Seabeach Dock	*Rumex pallidus*	Threatened

Vertebrates

Common Name	Scientific Name	Status
Diamondback Terrapin	*Malaclemys terrapin*	Threatened

Core Habitat BM1227

Plants

Common Name	Scientific Name	Status
Small Site for Rare Plant		

Core Habitat BM1228

Plants

Common Name	Scientific Name	Status
Small Site for Rare Plant		

BioMap: Core Habitat Summaries

Eastham

Core Habitat BM1109

This large Core Habitat along outer Cape Cod contains a wealth of high-quality and uncommon natural communities that together support incredible species diversity. Several highlights include the many rare species of Coastal Plain dragonflies, damselflies, and moths, as well as the diversity of rare plants. The area's beaches provide some of the most important breeding habitat for Piping Plovers along the Atlantic Coast, and the area contains other important nesting and breeding habitats for rare birds such as Least Terns. In addition, the Core Habitat supports the largest and most extensive populations of Eastern Spadefoot Toads in New England, the largest Diamondback Terrapin population in Massachusetts, and healthy populations of other rare turtles. Much of this large Core Habitat is on protected land, most of which is within the Cape Cod National Seashore, but some of which is in smaller protected areas such as the Wellfleet Bay Massachusetts Audubon Sanctuary.

Natural Communities

This Core Habitat contains over 3000 acres with the largest dune system in the state and in the northeast. It includes excellent examples of a Maritime Dune natural community, the best and largest example of classic bog vegetation on Cape Cod, Atlantic White Cedar Bogs and swamps, the state's best mainland Sandplain Heathlands, and extensive Estuarine Saline/Brackish Flats. The Core Habitat includes very diverse, interdigitated, and often uncommon natural communities.

Plants

A diversity of rare plant species, including several Endangered species, is found within this important area along outer Cape Cod. Among them are most of the state's populations of the Endangered Few-Fruited Sedge. Some of the state's best populations of Broom Crowberry, a low, bushy, heath-like plant with black fruit, are also found here.

Invertebrates

This Core Habitat includes numerous Coastal Plain ponds that are home to rare species of dragonflies and damselflies, including the spectacular red and green Comet Darner and the tiny blue Pine Barrens Bluet. Acidic shrub swamps and bogs associated with the ponds are habitat for rare species of moths such as the Pale Green Pinion moth. Open-canopy pitch pine - scrub oak barrens within this Core Habitat provide habitat for rare moths such as Melsheimer's Sack Bearer and the Barrens Buckmoth. And still other rare moths live in the coastal shrublands and dunes within this Core Habitat, including the Chain Dot Geometer, the Coastal Heathland Cutworm, and the Dune Noctuid moth.

Vertebrates

This Core Habitat contains a number of coastal beaches on both the eastern and western shores of outer Cape Cod that collectively comprise some of the most important breeding habitat for Piping Plovers along the Atlantic Coast. Significant areas of nesting habitat for Least Terns are also present. New Island in Nauset Marsh has traditionally supported one of the largest breeding colonies of Common Terns and Laughing Gulls in Massachusetts; however, birds from this colony are shifting to new locations as natural processes of coastline change weld the island to Nauset Spit and allow easier access by mammalian predators.

In this Core Habitat, the sandy upland habitats dominated by pine-oak forests and barrens support the largest and most extensive populations of Eastern Spadefoot Toads in New England. There are also significant and widespread populations of Eastern Box Turtles as well as Spotted Turtles. These woodlands and shrublands also provide some of the most important habitat in New England for landbirds characteristic of pitch pine - scrub oak barrens, including the Eastern Towhee and the Prairie Warbler. This Core Habitat also encompasses breeding habitat for Vesper Sparrows, including open, sparsely vegetated areas of pitch pine barrens in the Marconi area of Wellfleet, and the sandy habitats of the Provincelands, especially adjacent to the Provincetown airport. Northern Harriers have been observed within this Core Habitat, especially near Pilgrim Lake and Hatches Harbor.

The estuarine, salt marsh, tidal creek, beach, and sandy upland habitats in this Core Habitat support Diamondback Terrapins. Wellfleet Harbor contains perhaps the largest Diamondback Terrapin population in Massachusetts. Over 110 documented observations of nesting are known from this Core Habitat. Within the harbor, Blackfish Creek probably supports the most individuals. Wellfleet Harbor is also the northernmost site at which the species occurs in the U.S. Here the Core Habitat is surrounded and interspersed with development, increasing the likelihood of disturbance, collisions with vehicles, and degradation of foraging and nesting habitat. Entrapment by marine debris is a potential source of mortality for this species.

Much of this Core Habitat is protected as part of the Cape Cod National Seashore, but further protection of other suitable habitat is needed.

Core Habitat BM1216

Natural Communities

Despite being in a highly developed area, the Coastal Plain Pondshore communities in this Core Habitat and in a small cluster of ponds nearby retain narrow strips of natural vegetation around their shorelines. Coastal Plain Pondshores are globally rare herbaceous communities of exposed pondshores with a distinct Coastal Plain flora. Water levels change with the water table, typically leaving an exposed shoreline in late summer where many rare species grow. Each pond in this cluster contributes habitat for rare and common pondshore species; together they contribute to maintaining the overall biodiversity of the ponds of the area.

Plants

A population of the beautiful and globally rare Plymouth Gentian is found along a shoreline within this Core Habitat.

Invertebrates

This Core Habitat includes Minister Pond and two smaller Coastal Plain ponds to the north, all of which are habitat for the rare New England Bluet damselfly, which is native to this region. This Core Habitat appears to be unprotected.

Core Habitat BM1226

This Core Habitat contains a large, impressive Marine Intertidal Flat community in Brewster, Orleans, and Eastham. This area is surrounded by high-quality estuarine communities that support rare seaside plants. The diversity of salt marshes, tidal creeks, and sandy uplands also support Diamondback Terrapins. Conservation of additional Diamondback Terrapin habitat is needed to help protect this species here.

Natural Communities

This Core Habitat contains a large, impressive Marine Intertidal Flat with some species of particular interest, including Brant, horseshoe crabs, and Diamondback Terrapins. The Marine Intertidal Flat community is found in areas protected from intense wave action. Although many flats have little to no vegetation, they are physically and biologically linked to other coastal marine systems. The majority of surrounding land here is occupied by high-quality estuarine communities including Salt Marshes, Eel Grass Beds, and Barrier Beaches.

Plants

Rare plant species adapted to seaside habitats, such as Seabeach Dock and Oysterleaf, are found within this Core Habitat.

Vertebrates

This Core Habitat surrounding the Namskaket/Herring River Marsh contains widespread salt marsh, extensive tidal creeks, beaches, and sandy uplands that support Diamondback Terrapins. At least three nesting sites in sandy uplands have been confirmed. Portions of the marshes, tidal creeks and uplands are protected for conservation, and protection of other suitable habitat is needed. Potential threats to this species include collisions with vehicles and degradation of foraging and nesting habitat.

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THREATENED SPECIES OF MASSACHUSETTS

Melsheimer's Sack-Bearer
(Cicinnus melsheimeri)

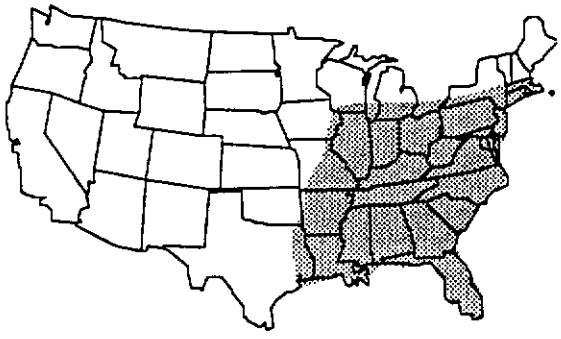
DESCRIPTION: Melsheimer's Sack-Bearer is a medium-sized, hairy moth with a wingspan ranging from 3.5 - 5 cm (1-2 in). Its wings are gray to grayish brown with orangish brown shading and black dusting near the margins of the wings. A solid dark line crosses all the wings abruptly turning inward on the forewings. Melsheimer's Sack-Bearer is the only North American species of the genus *Cicinnus*, and one of the few North American representatives of its family, *Mimallonidae*.

Covell, Charles V., Jr. A Field Guide to the Moths of Eastern North America. Boston: Houghton Mifflin Co., 1984.

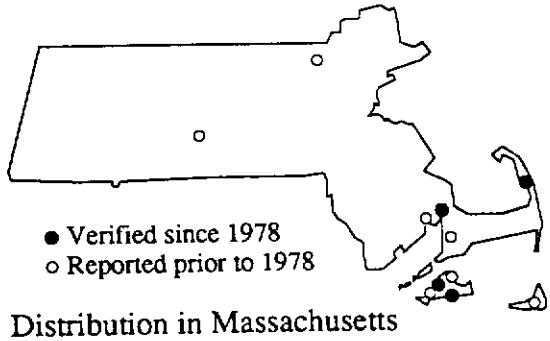
RANGE: Melsheimer's Sack-Bearer occurs widely throughout the southern United States and northward in very scattered, dry habitats into Massachusetts, Pennsylvania, southern Ontario, and Minnesota. The overall range of this species extends from Massachusetts (including the island of Martha's Vineyard) and southern Ontario south to Florida and west to Wisconsin and Texas.

HABITAT IN MASSACHUSETTS: Melsheimer's Sack-Bear occurs in pitch pine/scrub oak barrens. These barrens are an open shrubland plant community, that occurs on outwash sandplains. Characteristic of these barrens is an open canopy of pitch pine, a nearly impenetrable understory of scrub oaks up to 2-3 m (7-10 ft), and shorter huckleberry about a meter (3 ft) tall.

Pitch pine/scrub oak barrens are not floristically very diverse; the combination of species plus the physical structure of the vegetation define the natural community. The main tree species is pitch pine (*Pinus rigida*) with the shrubs scrub oak (*Quercus ilicifolis*) dominant near the coast and dwarf chinquapin oak (*Q. prinoides*) more common inland. Huckleberry (*Gaylussacia baccata*) is shorter than the oaks and often grows in dense clones. Lowbush blueberries (*Vaccinium angustifolium* and *V. Pallidum*) may form large patches, or grow mixed with other



Documented Range of Melsheimer's Sack-Bearer



Distribution in Massachusetts

species. In the openings between the shrubs, there are usually clones of bearberry (*Arctostaphylos uva-ursi*), large patches of fruticose (shrublike) lichens and intermixed areas with sedges (primarily *Carex pensylvanica* and *C. rugosperma*) or little blue stem (*Schizachyrium scoparium*).

LIFECYCLE/BEHAVIOR: The young larvae of Cicinnus melsheimeri, immediately after hatching, draws together two small leaves with strands of silk, and makes its hiding-place between them. When more mature, it detaches two pieces of leaves and makes them into an open-ended case or "sack" which it carries about and can desert at will. When at rest it ties the "sack" to a selected station with a few strands of silk, which it bites off when it desires to restart its journey among the branches feeding on its larval foodplant, scrub oak (*Quericus ilicifolis*). The larvae overwinter in these "sacks," and pupate late in the spring. Adults may be found in Massachusetts in late June.

POPULATION STATUS IN MASSACHUSETTS: Melsheimer's Sack-Bearer is listed as a "Threatened Species" in Massachusetts because of its population decline, decrease in distribution, and current rarity in the state. Historically or prior to 1978, there were 7 sightings or "populations" reported in 7 different locations. Since 1978, there have been 4 populations in 4 locations reported and verified to the Massachusetts Natural Heritage and Endangered Species Program. Threats to this species' pitch pine/scrub oak barrens habitat include development and alteration which changes and fragments its habitat, and fire suppression which causes the area to succeed filling in the open areas this moth prefers.

MANAGEMENT RECOMMENDATIONS: The habitat of the pitch pine/scrub oak barrens needs to be open and should be maintained by controlled, infrequent (every 50 years), patchy fires allowing for current populations to recolonize. Present populations should be monitored and searches made for new populations. This species should be looked for elsewhere. Since it flies very late at night, it may often get overlooked.

Gypsy moth spraying, or other widespread spraying with insecticides in spring or summer will adversely affect or eradicate this species. No insecticides should be used during the active stages of its life cycle (between April 15 and September).

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1994

Partially funded by a grant from DEM Forest Stewardship Program

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Pine Barrens Bluet Damselfly

Enallagma recurvatum

State Status: **Threatened**
Federal Status: None

DESCRIPTION OF ADULT: The Pine Barrens Bluet is a small, semi-aquatic insect of the order Odonata, suborder Zygoptera (the damselflies), and family Coenagrionidae (pond damsels). Like most damselflies, Pine Barrens Bluets have large eyes on the sides of the head, short antennae, and four heavily veined wings that are held folded together over the back. The male's thorax (winged and legged section behind the head) is mostly blue with black stripes on the "shoulders" and top. The Pine Barrens Bluet has a long, slender abdomen, which is composed of ten segments. The abdominal segments are blue with an increasing amount of black distally through segment 7. Segments 8 and 9 are entirely blue, except segment 8 has a small horizontal black dash on each side of the segment. This mark can sometimes be absent. The top of segment 10 is black. Females have thicker abdomens than the males, and are generally brown where the males are blue, though older females may become quite bluish.

Pine Barrens Bluets average just over one inch (26mm to 29mm) in length.

SIMILAR SPECIES: The bluets (genus *Enallagma*) comprise a large group of damselflies, with no less than 20 species in Massachusetts. Identification of the various species can be very difficult and often requires close examination of the terminal appendages on the males (Nikula *et al.* 2003) or the mesostigmal plates (located behind the head) on the females (Westfall and May 1996). The Pine Barrens Bluet is most similar in appearance to the New England Bluet (*E. laterale*), a species of Special Concern in Massachusetts. Both are found at several of their known locations. The two species are most safely distinguished by the shape of the terminal appendages on the male and the mesostigmal plates of the females. The black dash on the sides of segment 8 is generally larger in the New England Bluet, however this feature is highly variable and should not be used for definitive identification.

HABITAT: Pine Barrens Bluets are regional endemics and appear to be restricted to coastal plain ponds. Their range coincides closely with the distribution of those ponds. Some of the common attributes shared by ponds inhabited by the Pine Barrens Bluet include: sandy shallow shores; large amounts of vegetation close to the shore, especially Military Rush (*Juncus militarus*); and yearly natural fluctuations in water levels. The nymphs are aquatic and live among aquatic vegetation and debris. The adults inhabit nearby uplands and emergent vegetation along the shore.

LIFE-HISTORY/BEHAVIOR: The flight season of the Pine Barrens Bluet is generally restricted to the month of June, with emergence generally occurring during the last week of May. Adults are rarely seen after June. Although little has been published specifically on the life history of the Pine Barrens Bluet, it is likely similar to other, better-studied species in the genus. All odonates have three life stages: egg, aquatic nymph, and flying adult. The nymphs are slender with three leaf-like appendages extending from the end of the body which serve as breathing gills. They have a large, hinged lower jaw which they are able to extend forward with lightning speed. This feature is used to catch prey, the nymph typically lying in wait until potential prey passes within striking range. They feed on a wide variety of aquatic life, including insects and worms. They spend most of their time clinging to submerged vegetation or other objects, moving infrequently. They transport themselves primarily by walking, but are also capable of swimming with a sinuous, snake-like motion.

PINE BARRENS BLUET FLIGHT PERIOD

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

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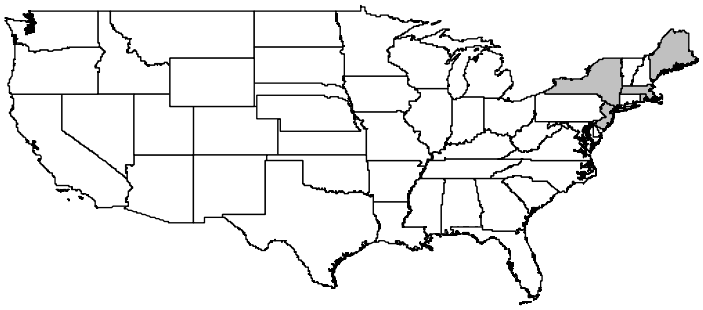
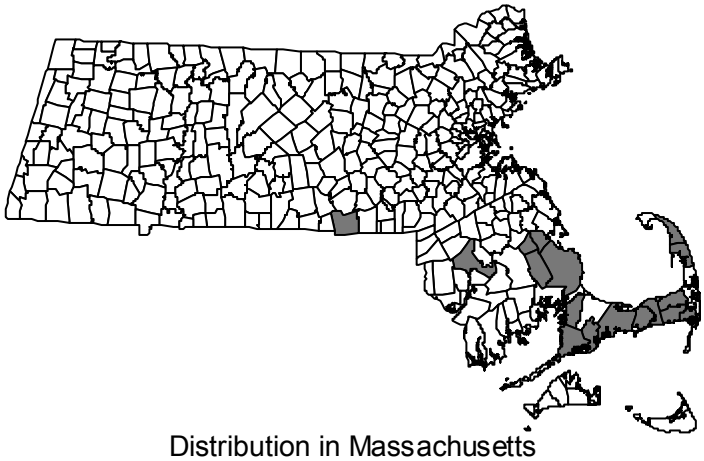
Pine Barrens Bluets have a one-year life cycle. The eggs are laid during the early summer and probably hatch in the fall. The nymphs develop over the winter and spring, undergoing several molts. In early to mid-summer the nymphs crawl up on emergent vegetation and begin their transformation into adults. This process, known as emergence, typically takes a couple of hours, after which the newly developed adults (tenerals) fly weakly off to upland areas where they spend a week or two feeding and maturing. The young adults are very susceptible to predators, particularly birds, ants, and spiders; mortality is high during this stage of the life cycle. The adults feed on a wide variety of smaller insects which they typically catch in flight.

When mature, the males return to the wetlands where they spend most of their time searching for females. When they locate a female, the male attempts to grasp her behind the head with the terminal appendages at the end of his abdomen. If the female is receptive, she allows the male to grasp her, then curls the end of her abdomen up to the base of the male's abdomen where his secondary sexual organs ("hamules") are located. This coupling results in the heart-shaped tandem formation characteristic of all odonates. This coupling lasts for a few minutes to an hour or more. The pair generally remains stationary during this mating but, amazingly, can fly, albeit weakly, while coupled.

Once mating is complete, the female begins laying eggs (ovipositing) in emergent grasses and rushes, using the ovipositor located on the underside of her abdomen to slice into the vegetation where the eggs are deposited. Although the female occasionally oviposits alone, in most cases the male remains attached to the back of the females head. This form of mate-guarding is thought to prevent other males from mating with the female before she completes egg-laying. The adult's activities are almost exclusively limited to feeding and reproduction, and their life is short, probably averaging only three to four weeks for damselflies like the Pine Barrens Bluet.



Range of Species in US



Distribution in Massachusetts
1977 - 2002
Based on records in Natural Heritage Database

RANGE: The Pine Barrens Bluet has a very small range restricted to scattered locations in the northeastern United States. It has been found only in Maine, Massachusetts, Rhode Island, New York and New Jersey.

POPULATION STATUS IN MASSACHUSETTS: The Pine Barrens Bluet is listed as a Threatened Species in Massachusetts. The species is known mainly from southeastern portions of Massachusetts, primarily Barnstable and Plymouth counties. Unlike the closely related New England Bluet, the Pine Barrens Bluet has occasionally been found in large numbers at some locations, though its overall range is more limited.

MANAGEMENT RECOMMENDATIONS: The major threat to the Pine Barrens Bluet is degradation and destruction of the wetlands which are its breeding and nymphal habitat. Threats include construction and development, artificial drawdown of pond water-level by groundwater pumping, and run-off from roadways and sewage. In addition, high-impact recreational use such as off road vehicles driving through pond shores, which may destroy breeding and nymphal habitat, and motor boats, whose wakes swamp delicate emerging adults, are threats. Since Pine Barrens Bluets, like many species of damselflies, spend a period of several days or more away from the pond maturing, it is important to maintain natural upland habitats adjoining the breeding sites for roosting and hunting. Without protected uplands the delicate newly emerged adults are more susceptible to predation and mortality from inclement weather.

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Updated May 2003

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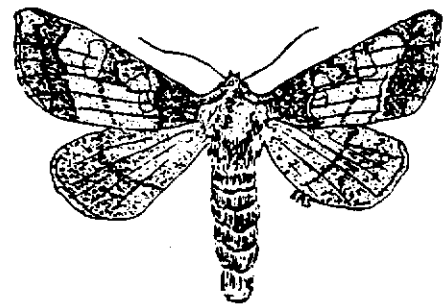
MASSACHUSETTS THREATENED WILDLIFE

Water-willow Borer
(Papaipema sulphurata)

DESCRIPTION: The Water-willow Borer is a nocturnal moth of the Noctuidae Family, with a wingspan of 3 to 4 cm (1.25 to 1.5 inches). The coloration of its forewings is predominantly chrome-yellow to ochre, shaded with purple at the base and outer edges. Reniform (kidney-shaped) spots and orbicular spots are present, but are the same color as the rest of the wing. The hindwings are much duller, brown with ochre shading and a medial band.

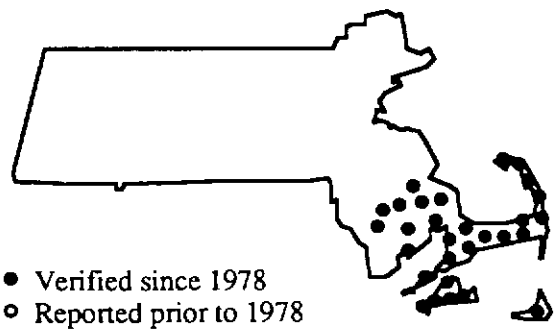


Eileen Sonnenberg, Cape Naturalist, Summer 1988

SIMILAR SPECIES: The Water-willow Borer is almost indistinguishable from the Burdock Borer Moth (Papaipema cataphracta), which is slightly less rusty in color. The larvae of P.cataphracta bore into and feed on many different species of plants, but rarely if ever utilize water-willow (Decodon verticillatus), which is the only plant used by P. sulphurata. In addition, P. cataphracta is absent from the coastal plain and therefore the ranges of the two species do not overlap.

RANGE: The Water-willow Borer is found only in southeastern Massachusetts and nowhere else in the world; it is Massachusetts' most globally restricted species of Lepidoptera.

HABITAT IN MASSACHUSETTS: Water-willow Borers are found only on Massachusetts' coastal plain, in the shallowest portions of vernal ponds and seasonally flooded swamps, and along upland edges of streams, ponds, and other permanent bodies of water. Only wetlands with an significant amount of water-willow within a restricted shallow water zone are inhabited by P. sulphurata.



- Verified since 1978
- Reported prior to 1978

Massachusetts Distribution by Town

BEHAVIOR / LIFE HISTORY: Adult female Water-willow Borers mate and lay eggs in late September or early October, presumably at the base of a clump of water-willows. The eggs lie dormant through the winter, and the larvae hatch in mid to late May. They must immediately find a fresh willow shoot and then bore into the stem, where they feed for most of the summer. A water-willow stem occupied by a larva can be recognized by a large round hole on the lower end of the stem, through which the larva removes its droppings. Pupation occurs inside the stem in mid-August, and the adult Water-willow Borer finally emerges from the stem in mid to late September. Adult Water-willow Borers are excellent fliers, and have a relatively long life span (three weeks) compared to many other moths, during which the adult Water-willow Borers must find a mate and reproduce before they die in early October.

POPULATION STATUS: The Water-willow Borer is listed as a Threatened Species in Massachusetts, due to its extremely small global distribution and low population size. There are 2 historical sites and 59 current sites in 29 towns in Massachusetts. Populations of Water-willow Borers at any given site appear to be unstable; local extinctions may commonly occur, followed by recolonization of the site by Water-willow Borers from other nearby areas. It is unknown why P. sulphurata is restricted to southeastern Massachusetts despite its excellent flying ability and the abundance of water-willow in the eastern United States. There are some possible explanations, however. It may be that the water-table fluctuations in Massachusetts' coastal plain are different from any other area in the Northeast; P. sulphurata may only be able to survive in these very specific water-table conditions, which partially expose the lower stems of water-willows above water in summer, but still leave them in enough water to deter predation by rodents. It is recommended that the water level of P. sulphurata habitats not be changed by damming, draining or other activities, as this could adversely affect the moths. In addition, pesticides should not be used in these areas, and trails should not be established along the upper edges of P. sulphurata ponds to prevent trampling of the water-willow.

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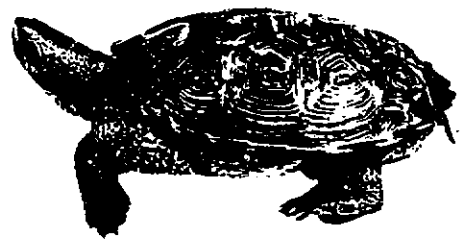
MASSACHUSETTS RARE AND ENDANGERED WILDLIFE

The Northern Diamondback Terrapin
Malaclemys terrapin terrapin

Description
The Northern Diamondback Terrapin is a medium sized salt marsh turtle. It has a wedge shaped carapace (top shell) variably colored in ash greys, light browns, and blacks. Concentric rings pattern the pronounced shell plates often forming ridges and bumps. The bottom of the shell, the plastron, also varies in color from yellowish-gray and orange to greenish yellow. Both sexes have grayish to black skin spotted with dark green flecks. This turtle has very large, paddlelike hind feet that are strongly webbed. The adult females are much larger than the males ranging from 6-9 inches (15-23 cm). Adult males reach a length of 4-6 inches (10-15 cm). Hatchlings range from two and a half to five centimeters in length.



Lazell, James Jr. Reptiles and Amphibians in Massachusetts. p. 25. 1972.

Range
The Northern Diamondback Terrapin is distributed along the Atlantic coast from Cape Cod, Massachusetts south to Cape Hatteras, North Carolina. Other subspecies are found along the southern Atlantic and Gulf coasts to Texas.

Habitat
Northern Diamondback Terrapins inhabit marshes which border quiet salt or brackish tidal waters. They can also be found in mud flats, shallow bays, coves, and tidal estuaries. Adjacent sandy dry upland areas are required for nesting. During the winter, the Northern Diamondback Terrapin hibernates on the bottoms of ponds, streams, and estuary channels.

Feeding Habits
The Northern Diamondback Terrapin feeds on fish, crustaceans, mollusks, insects, and succulent marsh plants. It forages while floating.

Continued Overleaf

Distribution of Northern Diamondback Terrapins

● Verified since 1978
○ Reported prior to 1978

Distribution in Massachusetts by Town

Breeding and Nesting Habits

The Northern Diamondback Terrapin is polygamous (each individual may breed with several others), and mates in the water. Females are capable of retaining viable spermatozoa for up to four years without subsequent matings. After breeding, females start the trip from the water during periods of high tides to their nesting sites which are usually located on high dunes. The journey may reach up to 1600 meters and take as long as 48 hours. The female digs a nest about 5 inches deep and then deposits a clutch of approximately 10 eggs. Laying occurs twice a year, usually in May and again in August. Incubation of the eggs lasts between 87 and 108 days depending on the temperature. When the climate is unseasonably cold, hatchlings may overwinter in their nest waiting until the following April and May to erupt from the sand. It may take from 2 to 11 days after the eggs hatch for the young turtles to emerge and start the hazardous trip from the nest to the water. Part of this time is spent rotating towards the sun in what is thought to be an orientation behavior.

Comprehensive studies of Massachusetts Northern Diamondback Terrapins have revealed nesting behavior and practices atypical of more southern terrapins. On Cape Cod, Northern Diamondback Terrapins were observed nesting during both day and night and on both vegetated and unvegetated dunes in contrast to southern turtles that were reported nesting only during the day and only on vegetated dunes. Eggs laid in unvegetated areas (although more susceptible to wind erosion), receive more heat thereby decreasing incubation time. The few hatchlings that survive the immense risks of early life mature at 5 or 6 years of age.

Population Status

There are only 17 known current occurrences of the Northern Diamondback Terrapin in Massachusetts. Presently, this species is listed as Threatened by the Massachusetts Division of Fisheries and Wildlife. There are a number of factors contributing to the decline of Northern Diamondback Terrapins in the state. Originally, this species was nearly wiped out by gourmet consumption around the turn of the century. Today, the harvest of diamondbacks is illegal in Massachusetts but the species continues to experience a high nest mortality and decline in numbers caused by human made disruptions and environmental impacts. The Northern Diamondback Turtle's strongest population is located on Cape Cod where recreational activity disrupts nesting turtles and hatchlings. Off road vehicles create ruts deep enough so that the chances of migrating hatchlings getting crushed by vehicles is increased as well as their vulnerability to predation by gulls and crows. These predators have been observed standing on the edges and simply scooping up the turtles as they get caught in the ruts. Off road vehicles also interfere with nesting patterns to such an extent that the females will engage in false nesting. They head for the dunes with the intention of egg laying but turn around and go back to the water at any detection of threatening activity. This disrupts the egg laying processes and reduces the viability of the clutch by prolonging the length of time that the eggs are retained by the females. Beach goers and people walking on the dunes also have this effect as well as disrupting the sand substrate so deeply that nests are impaired due to the increased erosion which results.

An additional cause of mortality observed on Cape Cod is the infiltration into nests and eggs of rootlets from the rhizomes of dune grass. In 1978, the grass *Ammophila breviligulata* penetrated and surrounded half of the nests that were located on vegetated dunes. Parasitism by maggots of a Sarcophagidea fly also adversely impacts eggs and hatchlings as do mammalian predators like skunks. Reduction of salt marsh habitat and alteration of water composition due to dredging and channelization, loss of sandy beach habitats, and destruction of dune areas continue to contribute to the decline of the Northern Diamondback Terrapin in Massachusetts.

Massachusetts Natural Heritage Program

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MASSACHUSETTS RARE AND ENDANGERED WILDLIFE

EASTERN SPADEFOOT
(Scaphiopus h. holbrooki)

DeGraaf, R.M. and D.F. Rudis. Amphibians and Reptiles of New England. University of Mass., Amherst. 1983.

DESCRIPTION

The Eastern Spadefoot Toad, only 1.75-2.25" (4.4-5.7cm) long, is a short-legged, squat, big-headed toad. The unmistakable cat-like, vertically elliptical pupils are distinctive. The skin is fairly smooth and scattered with small warts. Colors are somber, grayish or blackish-brown with olive. Two yellowish lines originate from each eye and run down the back to form a lyre-shaped pattern. Another light line runs along each side of the body. The toad's name comes from the horny, sharp-edged, sickle-shaped spade on the inner surface of the hind foot. It belongs to a primitive amphibian family that is neither a true frog nor a true toad.

SIMILAR SPECIES

The Eastern Spadefoot is the only toad in its family occurring east of the Mississippi River. It is distinguished from the true toads by its smoother skin, vertically elliptical pupils and single, sharp-edged spade on each hind foot.

HABITAT IN MASSACHUSETTS

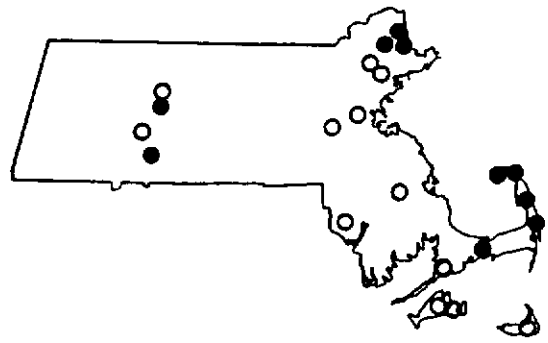
This burrowing species requires dry, sand or sandy loam soils characteristic of Pitch Pine barrens, coastal oak woodlands or sparse shrub growth, interspersed with temporary ponds. It prefers areas with leaf litter, and may be found in farmland areas. Colonies may occur within the floodplains of major rivers.

BEHAVIOR

The Eastern Spadefoot is the most fossorial species of frog or toad in Massachusetts. It burrows up to eight feet below the ground's surface

Range of Scaphiopus h. holbrooki

(continued overleaf)



● Verified since 1978
○ Reported prior to 1978

Breeding Distribution in Massachusetts by Town

1986

to hibernate during the cold months and to avoid desiccation during the rest of the year. It backs down into its burrow, digging with the hind feet and covering itself over with the fore feet. In the warmer months, from April to September, the Spadefoot comes up to breed after prolonged warm and heavy rains. Spadefoots are secretive and nocturnal; activity peaks just after sundown and before sunrise. In the summer months, individuals remain in their burrows an average of 9.5 days between feedings. They emerge uttering explosive, low-pitched grunts, short in duration and repeated at brief intervals. Home range movements are estimated to be an average of 108 sq. ft./10 sq. m., 90% of which falls within an area of 67 sq. ft./6.2 sq. m. Spadefoots have been recaptured in the same ranges after 5 years. Individuals may live for several decades. Adults apparently produce noxious or distasteful skin secretions, because native predators usually ignore them.

BREEDING SCHEDULE

Colonial breeding is initiated by heavy rainfall in April or May and lasts until August or September. This one or two night phenomenon has been likened to an orgy of raucous squawks and frantic courtship. Since Spadefoots do not breed successfully in permanent waters with fishes, they breed in temporary ponds. The adhesive eggs, laid in masses or strings of 1000-2500, are draped over submerged twigs or grass, where they hatch in 5 to 15 days. Metamorphosis of larvae to adults is said to coincide with pond conditions; longer pond life results in longer larval life. In Essex County, a natural population metamorphosed in less than 4 weeks. Sexual maturity is reached during the second year after metamorphosis, males at 15 months and females at 19 months.

FEEDING HABITS

Larvae feed on plankton for the first few days, later becoming vigorously carnivorous and sometimes cannibalistic. Adults eat flies, spiders, crickets, caterpillars, true bugs, other ground-dwelling arthropods, earthworms, snails, moths, and small vertebrates, such as salamanders.

RANGE

The Eastern Spadefoot Toad is found from Massachusetts to New York, south to eastern Florida and some of the Keys, west through Pennsylvania, through the southern Great Lakes region, to Arkansas and south to Louisiana. The species is absent from the higher elevations of the Appalachians and the Everglades. In Massachusetts, the Spadefoot is known only in scattered coastal locations from Plum Island, south to Cape Cod and Martha's Vineyard and several locations in the southern Connecticut Valley.

STATUS

The Eastern Spadefoot is listed as "Threatened" in Massachusetts. Only 12 current sites have been verified since 1978. Museum specimens and literature attest to the former widespread, if not abundant, status of the species. Several factors contribute to the rarity of the species. Plum Island is the northern limit of species' range. Destruction of suitable habitat continues to limit its numbers; Spadefoot populations have been extirpated by development from Middlesex County, inland Essex County and parts of Martha's Vineyard. The species is vulnerable to pesticides, as it was extirpated in Nantucket after WWII by the use of DDT. Many individuals are killed crossing roads, especially during the breeding season.

Adapted from: Lazelle, J.D., Jr., 1987. Eastern Spadefoot. In T. W. French and J. E. Cardoza (eds). Endangered, Threatened, and Special Concern Vertebrates of Massachusetts. Massachusetts Division of Fisheries and Wildlife (in press).

Natural Heritage &
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Commonwealth of Massachusetts
Division of Fisheries & Wildlife
Route 135
Westborough, MA 01581
(508) 792-7270 ext. 200

MASSACHUSETTS THREATENED WILDLIFE

Northern Harrier
(*Circus cyaneus*)

DESCRIPTION: The Northern Harrier or Marsh Hawk is a slim, long-legged, long-tailed hawk, about 40 to 60 cm (16 to 24 in.) in length, with an owl-like face and long, rounded, narrow wings extending up to 1.2 meters (46 in.) from wing tip to wing tip. Males are pale bluish gray on the head and upper surface, white on the undersurface, and have black wing tips; the tail has a broad subterminal bar with 5 to 7 narrower dark brown bars. Females are dusky brown on the head and upper surface, and light brown with darker vertical streaks on the lower surface; the tail is dark in the center, becoming paler near the outer edges, and has 5 to 7 broad brown bars. Both sexes possess a conspicuous white rump patch, white upper tail coverts, light orange-yellow legs, and black bills. Northern Harriers have large ear openings, but they are usually hidden underneath their feathers.

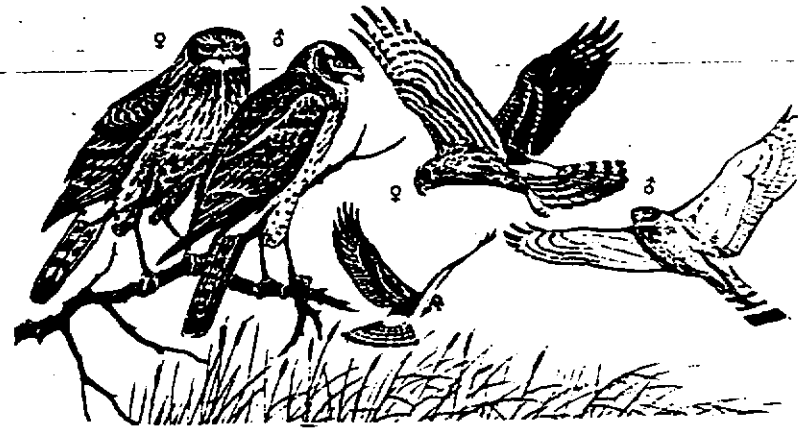
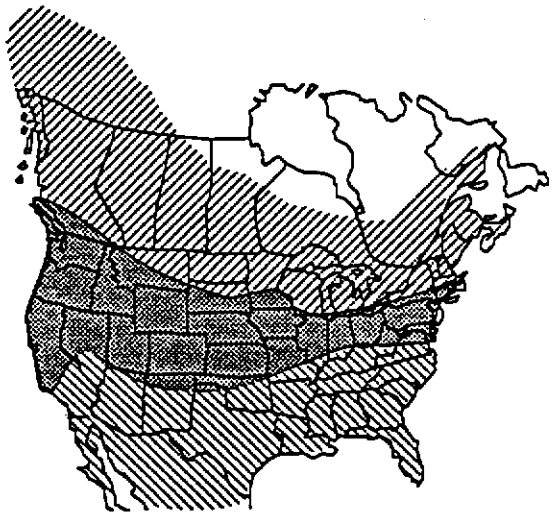


Illustration by Arthur Singer, from Robbins, C.S., Bruun,Bertel, Zim,Herbert. Birds of North America. Golden Press, NY 1966

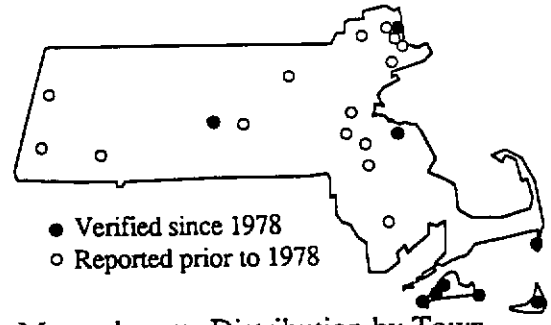
SIMILAR SPECIES IN MASSACHUSETTS: The male Northern Harrier's gray coloration makes it distinct from other local birds. However, the female Northern Harrier vaguely resembles the Short-eared Owl (*Asio flammeus*): both occupy the same habitat type, have a brownish upper surface and white breast with vertical brown streaks, long rounded wings and black wingtips. However, the Short-eared Owl is smaller, with short feathered legs, a white facial disk, and lacks the bright white rump patch possessed by Northern Harriers.

RANGE: The Northern Harrier breeds from Massachusetts north to Newfoundland and Alaska, south to southeastern Virginia, and west to northern Texas and central California. Wintering range extends from New England west to southern British Columbia and south into Central America and the West Indies.



Range of Northern Harrier

- Summer (breeding) range
- Year - round range
- Winter range



Massachusetts Distribution by Town
1990

HABITAT IN MASSACHUSETTS: Northern Harriers establish nesting and feeding territories in wet meadows, grasslands, abandoned fields, and coastal and inland marshes, mostly along the coast. Northern Harriers in Massachusetts are uncommon summer residents or migrants, although they once were much more abundant in the state. Most Harriers in the state which do not migrate south spend the winter in coastal marshes on Cape Cod and the offshore islands. Some Northern Harriers that breed in areas north of Massachusetts may also spend the winter on the offshore islands and along the coast. Northern Harriers are known to share habitat and territory with Short-eared Owls.

LIFE CYCLE / BEHAVIOR: The breeding season of Northern Harriers extends from March to July in Massachusetts and is initiated by a spectacular courtship ritual called skydancing, which is usually performed only by males and is used to attract mates. A skydancing Northern Harrier performs an aerial acrobatic display of dives, somersaults, loops, and tumbles, often accompanied by shrill screaming calls.

Once the male has found a mate, the female Northern Harrier builds a nest made of grasses, weeds, water plants, and other vegetative material supplied to her by her mate. The nest is usually located in a slight hollowed-out area on the ground, among bushes, grasses, and other low vegetation, and consists of a thick pad of grasses surrounded by dry stalks of plants, weeds, and small twigs. Sometimes the nest is built over shallow water on a raised mound of sticks, hollowed in the center and lined with dry grass, stubble and weed stalks.

After courtship and mating have occurred, the female lays from 2 to 9 bluish-white eggs (3 to 6 on average), about 1 egg every other day. Both parents help incubate the eggs until they hatch 30 to 32 days later. The male Harrier provides all the food to his mate and young until they fledge 30 to 35 days after hatching. Although Northern Harriers are known to readily abandon nests when disturbed before the eggs hatch, they vigorously defend their nests once their young have hatched. After the young have fledged, they may hunt together with their parents through the remainder of the summer, until they disperse on their own or are driven off. The Northern Harriers which do not spend the winter in Massachusetts begin to migrate south in late August or early September.

Northern Harriers prey on a variety of small creatures, including rodents, rabbits, and other small mammals, small birds, insects, amphibians, reptiles, and carrion. In Massachusetts, voles constitute a very important component of the Harrier's diet; there is a direct correlation between the breeding success of Northern Harriers and the number of voles found in their territory. When hunting, the Northern Harrier flies low over the ground, slowly and systematically, usually in early morning and late afternoon or early evening. When it detects prey, it hovers a moment before swooping straight down to the ground. The Harrier uses its talons to capture prey and then kills its catch via repeated stabs with its sharp beak.

POPULATION STATUS IN MASSACHUSETTS: The Northern Harrier is listed as a Threatened Species in Massachusetts, with 26 current (post-1978) breeding sites and 16 historical breeding sites. The Northern Harrier was once a common breeder throughout Massachusetts from the mid-1800's to the early 1900's. Today, almost all of the breeding Harriers in the state are confined to the offshore islands, Cape Cod, and Plum Island.

The most significant factor in the Northern Harrier's decline has been destruction of suitable habitat by reforestation of agricultural land and destruction of coastal and freshwater wetlands. In coastal areas, human disturbance may cause some Harriers to abandon their nests. Natural factors such as prey abundance, prolonged periods of rain (which may destroy nests and eggs), and predation on eggs and nestlings all affect the breeding success of Northern Harriers. In order to prevent further decline in the Northern Harrier's population, it is crucial to protect suitable habitats from development and destruction.

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MASSACHUSETTS THREATENED SPECIES

Piping Plover
(Charadrius melodus)

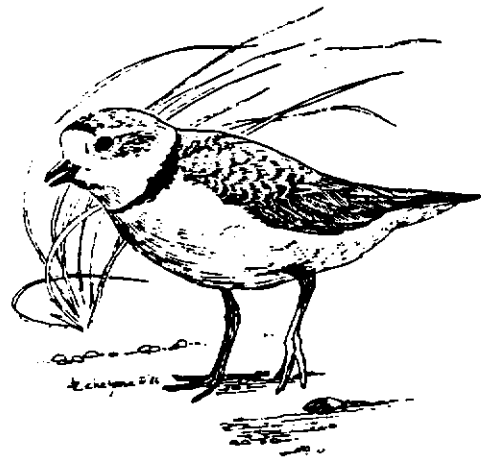


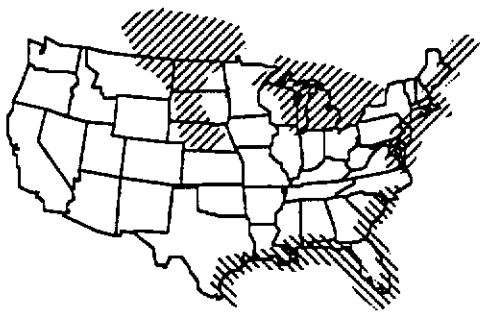
Illustration by J. Zickefoose, 1986

DESCRIPTION: The Piping Plover is a small, stocky shorebird with pale brownish gray or sandy-colored plumage on its backside, with a white breast, forehead, cheeks, and throat, a black streak on the forecrown extending from eye to eye, and a black breastband which may not always form a complete circle. Its coloration gives it excellent camouflage in sandy areas. The average Piping Plover is 15 to 17 cm (6 to 7 in.) long, with a wingspan of 35 to 40 cm (14 to 16 in.). The tail is white at the base and tip, but dark in the middle. It has yellow-orange legs and its short bill is yellow-orange with a black tip in the summer, but turns completely black during the winter. In general, females have darker bills and lighter plumage than males. The Piping Plover runs in a pattern of brief starts and stops; in flight, it displays a pair of prominent white wing stripes. Its call is a series of piping whistles.

SIMILAR SPECIES IN MASSACHUSETTS: The Piping Plover is similar to the Semipalmated Plover (Charadrius semipalmatus) in size, shape, and coloration; both also share the same general habitat. However, the Semipalmated Plover is a darker brown in color, and has much more black on its head than the Piping Plover. The Semipalmated Plover does not breed in Massachusetts but passes through in large numbers from late July to early September during its southward migration.

RANGE: During the summer, the Atlantic Coast population of Piping Plovers nests from the coast of Massachusetts north to Newfoundland, and south to Virginia and North Carolina. In winter they migrate farther south, from South Carolina to Florida, the Gulf of Mexico, and the West Indies. Other populations of Piping Plovers nest along rivers on the Northern Great Plains and along the shores of the Great Lakes, migrating to the Gulf of Mexico in the winter.

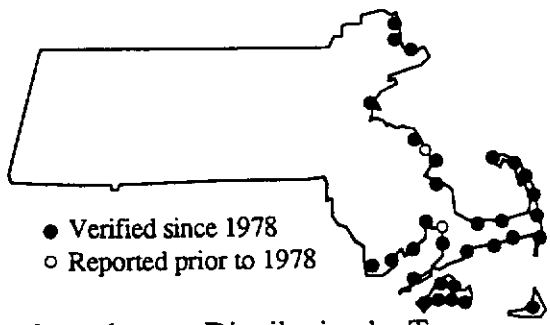
(continued overleaf)



Range of Piping Plover

Winter range

Summer (breeding) range



Massachusetts Distribution by Town

1990

HABITAT: Piping Plovers in Massachusetts require sandy coastal beaches which are relatively flat and free of vegetation. They prefer the dry, light-colored sand found along the outer coastal shores. Piping Plovers often build their nests in a narrow area of land between the high tide line and the foot of the coastal dunes; they also nest in Least Tern colonies. Water is a critical necessity for Piping Plover habitat, since the birds feed exclusively on organisms which live along the shoreline.

LIFE CYCLE / BEHAVIOR: As soon as Piping Plovers return to their breeding grounds in Massachusetts in late March or April, the males begin to set up territories and attract mates. Territorial rivalry between males is very strong; adjacent male Piping Plovers mark off their territories by running side by side down to the waterline. Each bird takes turns, one running forward a few feet, then waiting for the other to do likewise. Nests are usually at least 200 feet apart; the nesting pair will confront any intruding Piping Plover which approaches the nest. Male Piping Plovers also defend feeding territories encompassing beach front adjacent to the nesting territory.

Courtship consists of a ritualized display by the male, who flies in ovals or figure-eights around a female, then displays on the ground by bowing his head, dropping his wings, and walking in circles around the female. The male also scrapes shallow depressions in the sand at potential nest sites. The female then chooses one of these nesting sites, usually in a flat, sandy area. The nest itself is a shallow depression which is often lined with shell fragments and small pebbles, which may aid in camouflaging the eggs. Female Piping Plovers typically lay four eggs per clutch, one egg every other day over a week's time. The eggs are sandy gray in color with dark brown or black spots, and all hatch within 4 to 8 hours of each other. Both parents take part in incubating the eggs until they hatch 3 to 4 weeks later.

The young chicks leave the nest within 2 to 3 hours after hatching and may wander several hundred meters before they become capable of flight. When threatened by predators or human intruders, the young run or lie motionless on the sand while their parents often pretend to have broken wings in an effort to attract the intruder's attention away from the chicks. Young Piping Plovers are brooded by their parents for 3 to 4 weeks and finally fledge 4 to 5 weeks after hatching, at which time they leave the nesting area.

Piping Plovers feed on marine worms, molluscs, insects, and crustaceans. They forage along the waterline, on mudflats at low tide, and in wrack along the beach. Foraging behavior consists of running a short distance, then staring at the ground with the head tilted to one side, often standing on one foot while vibrating the other foot on the ground, and finally pecking at the food item it has detected in the sand.

Piping Plovers begin to migrate southward between late July and early September, although occasional stragglers remain behind until late October. Adult birds often return to the same nesting area every spring, although they frequently change mates from year to year. Young birds may nest anywhere from a few hundred feet to many miles from where they were hatched.

POPULATION STATUS IN MASSACHUSETTS: The Atlantic Coast population of Piping Plovers is listed as Threatened at both the state and federal levels. In 1990, 139 breeding pairs from 58 sites in Massachusetts were documented. Massachusetts has the second largest population of Piping Plovers along the Atlantic Coast.

Habitat loss due to development of coastal areas and waterways has caused a catastrophic decline in the Piping Plover population over the last 50 years. Predation on eggs and young has also increased due to the growing number of foxes, skunks, raccoons, and other predators that thrive in suburban areas. Due to their cryptic coloration, the nearly invisible eggs and chicks are often unintentionally crushed by off-road vehicles (ORV's) and pedestrians on the beach. Continual disturbance of nest sites from recreational use of the state's beaches may lead some breeding pairs to abandon their nests. Severe storms can wash away and destroy eggs.

In recent years, the placement of wire enclosures surrounding Piping Plover nest sites has drastically reduced predation at many nest sites. Protection of essential habitat from development and restriction of ORV use in these areas is crucial in order to maintain a healthy population of Piping Plovers in Massachusetts.

Piping Plover

(Charadrius melodus)

Piping plovers have been described as everything from wind-up toys to tennis balls rolling along the sandy beaches of the coast. Sometimes they blend into the beach so thoroughly that they are almost impossible to see. Like other plovers, they run in short starts and stops.

The piping plover's name comes from its call-notes, plaintive bell-like whistles that are often heard before the birds are seen. When sitting still, their buff-colored plumage, black necks, and black forehead bands make them virtually invisible in the sand. From a distance, the scrapes in the sand that are their nests and their buff-colored eggs speckled with tiny black dots are indistinguishable from the beach. But although these adaptations protect plovers from natural predators, they do not help protect them from human activities, which have become the greatest threat to their survival.

Life History

The piping plover breeds on coastal beaches from Newfoundland and the Gulf of Maine to North Carolina. They winter primarily on the Atlantic Coast from the Carolinas to Florida, but also as far south as the Yucatan Peninsula, the Bahamas, and the West Indies. Between March and April, piping plovers make the long flight from these wintering grounds to the beaches of the mid- and north Atlantic. They establish territories on these beaches, mate, and scratch out shallow nests in the unvegetated sand above the high tide line. Nests are no more than shallow depressions lined with shell fragments or pebbles.

Adults tend to return to beaches where they previously nested, arriving at breeding grounds on Gulf of Maine beaches in early April. Mating involves courtship displays that include mock nest scraping, pebble-tossing, tilts, and low, shallow flights. Incubation responsibilities are shared by both the male and the female. Their four eggs hatch after approximately 28 days, and the hatchlings soon follow their parents to forage for marine worms, crustaceans, and insects on the beach.

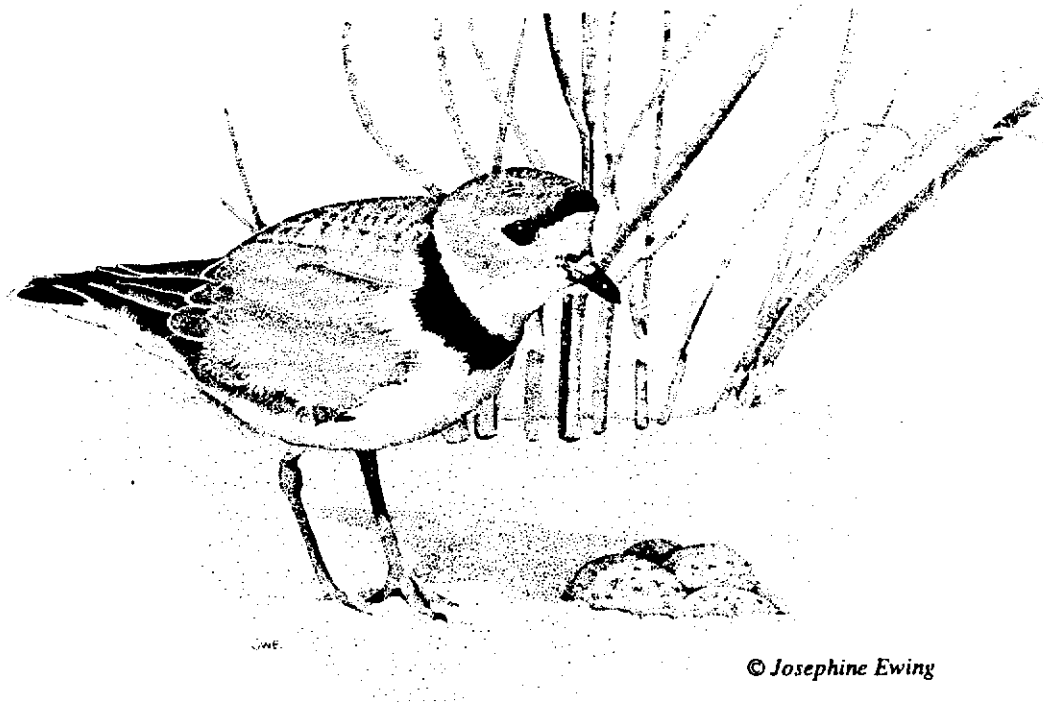
Once the hatchlings emerge, it generally takes about 30 to 35 days for them to learn to fly. If a predator or intruder approaches, the young become motionless while their parents try to divert the intruder's attention to themselves, often by pretending to hobble around with a broken wing.

Distribution, Abundance, and Threats

Historically, piping plovers were abundant in sandy coastal habitat throughout their range. But by the late 1800s, commercial hunting for feathers—primarily to decorate hats—nearly wiped out the species. Federal protection by the Migratory Bird Treaty Act of 1918 allowed piping plovers to recover to record numbers in the 1940s, but recent habitat loss and disturbance on beaches has caused a new and serious decline in their population. Most recent surveys count the entire Atlantic population at less than 1,000 pairs. Two other breeding populations of piping plovers exist in the United States; one on the Great Plains and the other in the Great Lakes region.

Human disturbance currently is the greatest threat to the piping plover's survival. People may intentionally or accidentally destroy nests and eggs by walking or driving over them on the beach. Hatchlings may often seek shelter in tire tracks left on beaches. This further camouflages them and makes them especially vulnerable to beach vehicles. Pets can harass adults off their nests long enough to cause overheating or chilling of eggs or even complete abandonment of chicks, exposing them to natural predators such as crows, gulls, red foxes, skunks, or rats.

Both human activities and natural changes in the piping plover's habitat have had serious impacts on the future of this species in the Gulf of Maine. Recently, beach erosion between breeding seasons



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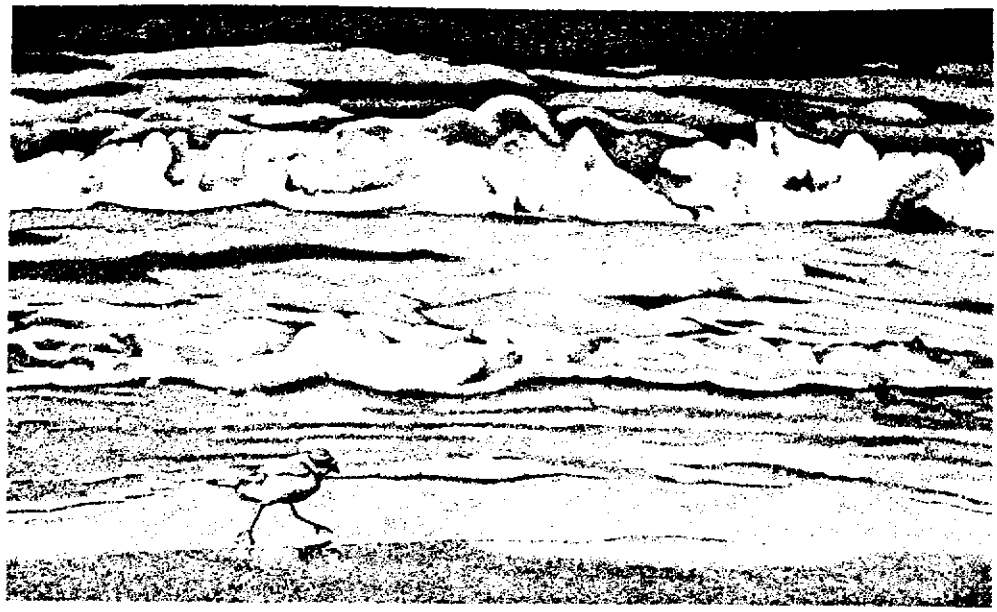

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eliminated nesting sites along the Morse River in Phippsburg, Maine. In the 1960s, construction of a housing development in Scarborough, Maine, completely eradicated a prime nesting area for piping plovers and least terns. Summer storms with high winds or tides can bury or wash out nests. Vegetation can encroach and crowd out plovers, and even dune restoration programs must remain sensitive to the dune characteristics plovers need for their nests.

Piping Plover Facts

- Plovers have been recorded making as many as 5 nesting attempts in a single season, laying a total of 18 eggs.
- If left unattended long enough on sunny days when beachgoers often share plover habitat, plover eggs can actually cook on the hot sand.
- Piping plovers are one of several species of shorebirds nesting in Maine. Others are killdeer, willets, spotted sandpipers, snipe, and woodcock.

Protecting the Piping Plover

The piping plover came under the protection of the Endangered Species Act in January of 1986. It is listed as a threatened species, which means that without protection the remaining population would continue to decline. The Endangered Species Act prohibits taking, harassing, or harming piping plovers and assists in efforts to protect their habitat.

Since listing the piping plover, the U.S. Fish and Wildlife Service has formed recovery teams for the inland and Atlantic coast populations. These U.S. and Canadian research teams establish conservation priorities and procedures for restoring populations. Several projects are underway in the Gulf of Maine to protect the plover's breeding and wintering range. Nest exclosures (wire mesh fences around nest sites to exclude predators) and extensive use of informational signs to inform the public about sensitive areas are helping to protect plover habitat. Negotiations for purchase, easements, and consent agreements are underway with landowners. In some cases, predator control and habitat creation have kept nesting areas intact.

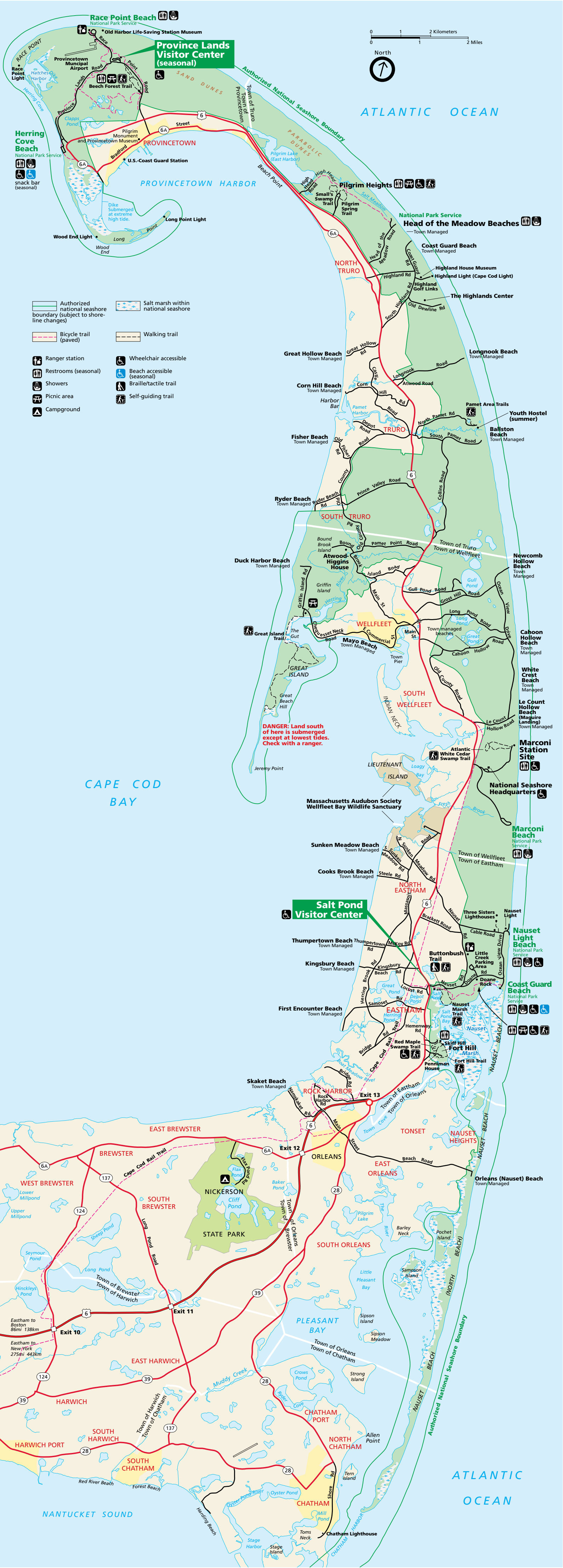
U.S. Fish and Wildlife Service

Protection of migratory birds, seabirds, anadromous fish, and endangered species in the Gulf of Maine is the responsibility of the U.S. Fish and Wildlife Service. The Service established the Gulf of Maine Project in Portland, Maine, to protect and restore the watershed's ecosystems and habitats by providing a bridge between all Service programs in the Gulf of Maine and by building partnerships among state and federal agencies, local organizations, and private citizens working to improve coastal habitats. The Gulf of Maine Project participates in EPA's National Estuary Programs in Massachusetts Bays and Casco Bay, Maine, providing information on fish and wildlife habitat needs in order to promote thorough consideration of living resources in the management planning process. The Project has brought together state, federal, and non-governmental representatives from each jurisdiction in the watershed to conduct a priority habitat identification process as part of the international initiative of the Gulf of Maine Council on the Marine Environment, and has developed a GIS (Geographic Information System) that includes data-sharing and coordination with state fish and wildlife agencies. The Project has established partnerships with local conservation groups and land trusts, and is conducting wetland trends analyses in the watershed to target specific areas for local action. For more information, contact the Gulf of Maine Project in Portland, Maine, at (207) 828-1080.

September 1993

Production of this publication was funded by the U.S. Environmental Protection Agency. EPA

Appendix C. Cape Cod National Seashore Map


Race Point Beach
National Park Service
Old Harbor Life-Saving Station Museum
Province Lands Visitor Center (seasonal)
Authorized National Seashore Boundary
ATLANTIC OCEAN
0 1 2 Kilometers
0 1 2 Miles
North
RACE POINT
Race Point Light
Hatches Harbor
Herring Cove
Provincetown Muncipal Airport
Beech Forest Trail
SAND DUNES
Clapps Pond
Herring Cove Beach
National Park Service
snack bar (seasonal)
Pilgrim Monument and Provincetown Museum
PROVINCETOWN
U.S.-Coast Guard Station
PROVINCETOWN HARBOR
Dike Submerged at extreme high tide.
Long Point Light
Wood End Light
Long Point
Wood End
Town of Provincetown
Town of Truro
PARABOLIC DUNES
Pilgrim Lake (East Harbor)
Beach Point
Pilgrim Heights
Small's Swamp Trail
Pilgrim Spring Trail
Salt Meadow
National Park Service
Head of the Meadow Beaches
Town Managed
Coast Guard Beach
Town Managed
Highland House Museum
Highland Light (Cape Cod Light)
Highland Golf Links
The Highlands Center
NORTH TRURO
Authorized national seashore boundary (subject to shoreline changes)
Salt marsh within national seashore
Bicycle trail (paved)
Walking trail
Ranger station
Restrooms (seasonal)
Showers
Picnic area
Campground
Wheelchair accessible
Beach accessible (seasonal)
Braille/tactile trail
Self-guiding trail
Great Hollow Beach
Town Managed
Longnook Beach
Town Managed
Corn Hill Beach
Town Managed
Harbor Bar
Pamet Harbor
Pamet Area Trails
Youth Hostel (summer)
Ballston Beach
Town Managed
Fisher Beach
Town Managed
TRURO
Ryder Beach
Town Managed
SOUTH TRURO
Bound Brook Island
Atwood-Higgins House
Duck Harbor Beach
Town Managed
Griffin Island
Town of Truro
Town of Wellfleet
Newcomb Hollow Beach
Town Managed
Gull Pond
Great Island Trail
The Gut
Mayo Beach
Town Managed
WELLFLEET
Town managed beaches
Cahoon Hollow Beach
Town Managed
Town Pier
GREAT ISLAND
Great Beach Hill
SOUTH WELLFLEET
INDIAN NECK
White Crest Beach
Town Managed
Le Count Hollow Beach (Maguire Landing)
Town Managed
DANGER: Land south of here is submerged except at lowest tides. Check with a ranger.
Jeremy Point
Atlantic White Cedar Swamp Trail
Marconi Station Site
LIEUTENANT ISLAND
Loagy Bay
National Seashore Headquarters
CAPE COD BAY
Massachusetts Audubon Society Wellfleet Bay Wildlife Sanctuary
Marconi Beach
National Park Service
Sunken Meadow Beach
Town Managed
Town of Wellfleet
Town of Eastham
Cooks Brook Beach
Town Managed
NORTH EASTHAM
Salt Pond Visitor Center
Three Sisters Lighthouses
Nauset Light
Nauset Light Beach
National Park Service
Thumpertown Beach
Town Managed
Buttonbush Trail
Little Creek Parking Area
Kingsbury Beach
Town Managed
Doane Rock
Coast Guard Beach
National Park Service
First Encounter Beach
Town Managed
EASTHAM
Nauset Marsh Trail
Hemenway Rd
Skiff Hill
Fort Hill
Red Maple Swamp Trail
Fort Hill Trail
Penniman House
NAUSET BEACH
Skaket Beach
Town Managed
ROCK HARBOR
Exit 13
Town of Eastham
Town of Orleans
Town Cove
TONSET
NAUSET HEIGHTS
EAST BREWSTER
BREWSTER
Exit 12
ORLEANS
EAST ORLEANS
Orleans (Nauset) Beach
Town Managed
WEST BREWSTER
Lower Millpond
Upper Millpond
SOUTH BREWSTER
NICKERSON STATE PARK
Cliff Pond
Baker Pond
Flax Pond
Sheep Pond
Seymour Pond
Long Pond
Hinckleys Pond
Town of Brewster
Town of Harwich
Town of Orleans
Pilgrim Lake
Barley Neck
Pochet Island
SOUTH ORLEANS
Sampson Island
Little Pleasant Bay
Exit 11
Exit 10
Eastham to Boston 86mi 138km
Eastham to New York 275mi 443km
PLEASANT BAY
Sipson Island
Sipson Meadow
Town of Orleans
Town of Chatham
EAST HARWICH
Muddy Creek
Crows Pond
Strong Island
HARWICH
Ryder Cove
CHATHAM PORT
Allen Point
HARWICH PORT
SOUTH HARWICH
NORTH CHATHAM
Tern Island
SOUTH CHATHAM
Red River Beach
Forest Beach
Oyster Pond
CHATHAM
Mill Pond
Harding Beach
Toms Neck
Chatham Lighthouse
Stage Harbor
Stage Island
CHATHAM HARBOR
NANTUCKET SOUND
ATLANTIC OCEAN
Authorized National Seashore Boundary

Appendix D. List of Permits

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
FEDERAL						
COE	Section 10 Nationwide Permit	Construction activities in navigable waters of the US.	Construction	No	3 - 4 months	Required for construction in navigable waters of the US. Assume nationwide permit, if COE approval required.
COE	Section 404 Nationwide Permit	Discharge of dredge or fill material into US waters, including jurisdictional wetlands.	Construction	Maybe	3 - 4 months	Required only if wetlands will be filled on site or along off-site utility right-of-way. Assume nationwide permit, if COE approval required.
EPA	SPCC Plan	On site storage of oil > 1,320 gallons.	Construction	Maybe	3 months	Threshold may be exceeded due to construction equipment at site. Exceeding threshold not expected for operational activities.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
FAA	Notice of Proposed Construction or Alteration	Construction of an object which has the potential to affect navigable airspace (height in excess of 200' or within 20,000' of an airport).	Construction	Yes	3 - 4 months	Chatham Municipal Airport is approximately 8 miles from the site. FAA will require lighting or marking of turbines or temporary construction crane. The tallest estimated turbine blade height is about 400 feet above sea level. May be concerns about height if close to existing flight paths. Refer also to MAC/MPA review.
FERC	Exempt Wholesale Generator (EWG) Status	Selling electric energy at wholesale to a utility or other generator.	Construction	Yes	3 - 4 months	Assume electricity will be sold to the grid.
FERC	Qualifying Facility Certification	Qualification for PURPA benefits for small power production facility using renewable resources < 80 MW.	Construction	Yes	Formal certification, 3 - 5 months. Self-certification, upon filing.	Assume electricity will likely be sold to the grid. This certification is for facilities producing less than 80 megawatts of power.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
EPA	NPDES Stormwater Construction General Permit	Discharge of stormwater from construction sites disturbing > 1 acre.	Construction	Likely	9 - 12 months	Requires joint approval with MDEP. Project may disturb less than 1 acre if only one small turbine is built, or up to 14 acres if six large turbines and a substation are built.
USFWS	Migratory Bird Treaty Act Compliance	Activity with potential to harm migratory bird species	Construction	Maybe	1 - 2 months	Several state and/or federally listed threatened and/or endangered birds inhabit Eastham and the project area, including the piping plover, least tern, and roseate tern. Avian impact review or study required. ESA compliance review may also incorporate this Migratory Bird Treaty Act review.
USFWS	Endangered Species Act Compliance	Confirmation of no impacts to threatened and endangered species.	Construction	Maybe	1 - 2 months	Consultation may be required if species and/or habitat onsite or along offsite utility interconnection right-of-way may be impacted. May be concerns about avian and other impacts from turbines since Cape Cod National Seashore and other ecologically important areas are in close proximity.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
NPS/Cape Cod National Seashore Advisory Commission	Courtesy Consultation	Locating project adjacent to Cape Cod National Seashore	Construction	Maybe	1 - 2 months	Consultation with the National Park Service and Eastham representative of the Cape Cod National Seashore Advisory Committee is suggested since proposed project location is very close to the seashore.
FEDERAL	NEPA	Major federal action affecting the environment	Construction	Not likely	NA	May be required if COE individual permit needed. Project close to federally administered land, but would not likely be considered a major or federal project.
STATE						
MDPU/EFSB	Approval of the Siting Board	Construction of an energy generating facility.	Construction	Maybe	10 - 12 months	Electricity likely to be sold to the grid.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
DOER	Application for Statement of Qualification pursuant to Massachusetts Renewable Portfolio Standard	Construction and operation of a new renewable energy facility proposing to sell energy to the grid	Construction	Likely	2 - 3 months	Project would be considered a Small Power Production Qualifying Facility with respect to selling power to utilities that are required under Massachusetts law to purchase electricity from certain classes of renewable energy and distributed generation facilities.
EOEA	MEPA Determination: Environmental Notification Form (or expanded form)	Alteration of more than 25 acres of land	Construction	Yes	2 - 3 months	Must be filed if more than 25 acres will be directly altered or certain other criteria met. The turbines for this project are expected to impact a total of 14 acres or less. However, MEPA has requested filings on past community wind projects, and MTC may choose to file even if threshold is not met. The purpose of such a filing would be informational, and may not result in a formal determination.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
EOEA	MEPA Review: Environmental Impact Report	Alteration of more than 50 acres of land	Construction	Not Likely	6 - 9 months	Evaluation of effects of state agency permitting action on the environment based on review of the Environmental Notification Form by the Secretary of Environmental Affairs. Environmental Impact Report required if more than 50 acres of land will be altered or other criteria met. Project will not meet 50 acre threshold.
EOEA	Protected Land Regulation Compliance	Activities on protected land	Construction	Maybe	1 - 2 months	EOEA Article 97 Policy and Massachusetts General Law Chapter 61 govern the use of protected land. Compliance with these laws is necessary for a successful EIR or ENF process. These laws may apply if the project requires access or easements on protected parkland or agricultural land. Cape Cod National Seashore is adjacent to the project site and is a protected land. MEPA has recommended to MTC that an informational document be submitted for all wind projects.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
MDEP	Notice of Intent	Wetland alteration	Construction	Maybe	3 - 4 months	Wetland impacts from wind turbine construction are unlikely.
MDEP	Noise Control Policy Compliance	Noise from wind turbine	Operation	Maybe	1 - 2 months	Policy discourages a broadband noise level greater than 10 dB(A) above ambient, or pure tone noise. Noise is not expected to be an issue as long as the project is properly evaluated and any necessary mitigation requirements are implemented.
MDEP	NPDES Individual Wastewater/Storm Water Discharge Permit	Wastewater discharge and storm water runoff during facility operation. NOTE: This program is jointly administered by EPA and MDEP.	Operation	No	9 - 12 months	Operation of a wind farm is not considered an industrial activity under the stormwater program.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
MDEP	Massachusetts Clean Waters Act, Section 401 Water Quality Certification	Required for federal activities affecting state land.	Construction	Maybe	3 months	Necessary if Section 404 permit is required. Permit required if wetlands will be altered in any way. The permit application is a Notice of Intent and is also sent to the Town of Eastham Conservation Commission. If an area less than 5,000 square feet of wetland is altered, the Order of Conditions also serves as the project's Section 401 Water Quality Certificate. Site reconnaissance needed to determine any wetland impacts.
MDF&G Natural Heritage and Endangered Species Program	Notice of Intent	Wetland alteration	Construction	Maybe	3 - 4 months	Same as form submitted to MDEP. Required if project is in "estimated habitat" of rare wildlife (many rare species live in the area). Wetland impacts from wind turbine construction are unlikely.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
MDF&G Natural Heritage and Endangered Species Program	Endangered Species Act Consultation/ Compliance	Activities that could potentially affect threatened or endangered species.	Construction	Maybe	3 - 4 months	Conservation and Management Permit required for any take of a state endangered species. Many protected species live in the Cape Cod area.
MDOH	General Access Permit	Alteration of state roads	Construction	Maybe	2 - 3 months	May be needed if project involves alterations to state roads.
MDOH	Wide Load Permit	Movement of oversize project equipment.	Construction	Maybe	2 - 3 months	May be necessary for transport of oversized equipment like turbine components or certain construction equipment.
ISO New England (and transmission line owner at interconnection point)	NEPOOL Interconnection System Impact Study and Facility Study	Transmission interconnection	Construction	Maybe	9 - 12 months	Electricity will likely be sold to the grid. Project owner determine participation in NEPOOL.
EFSB	Transmission line approval	Transmission interconnection	Construction	Maybe	2 - 3 months	Electricity will be sold to the grid. Should only apply is final design requires a transmission line.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
MAC	Request for Airspace Review courtesy notice	Structures over 200 feet tall	Construction	Yes	3 - 4 months	Provide courtesy notification of any projects over 200 feet tall (similar to FAA review, but not a permit per se).
MPA	Request for Airspace Review	Structures over 200 feet tall near airports	Construction	Maybe	3 - 4 months	Chatham Municipal Airport is in fairly close proximity, approximately 8 miles from the site. May be concerns about the ~400 foot turbine blade height if close to existing flight paths. If required, this review may be done concurrent with the FAA review.
CZM	Massachusetts General Law Chapter 91 (Public Waterfront Act) authorization	Structures in tidelands, ponds, certain rivers and streams	Construction	Maybe	1 - 2 months	Chapter 91 authorization is required for structures in tidelands, Great Ponds (over 10 acres in natural state) and certain rivers and streams. Types of structures include piers, wharves, floats, retaining walls, revetments, pilings, bridges, dams, and some waterfront buildings (if on filled lands or over water). Can file Determination of Applicability if applicability of Chapter 91 in question.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
MHC	Archeological and Historical Review	Activities that could potentially affect archeological or historical resources.	Construction	Yes	3 - 4 months	The Eastham area has a long history of human habitation and influence on the landscape, including Native American use, Pilgrim landings, and historic areas related to fishing and whaling, as well as historic structures like lighthouses. Many uninventoried archaeological sites are thought to exist in the area of the national seashore.
LOCAL						
Barnstable County - Cape Cod Commission	Development of Regional Impact (DRI) permit	Activity that influences the character of the Cape Cod area	Construction	Likely	2 – 3 months	Large wind farm may be determined a DRI because of visual impacts at the Commission's discretion. It may also be considered a Project of Community Benefit. DRI Exemption Application and Jurisdictional Determination Application are options if developer believes that wind farm is not a DRI.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
Barnstable County - Cape Cod Commission	Request for Joint MEPA/DRI Review	Development in Barnstable County	Construction	Yes	1 – 2 months	There is substantial overlap in jurisdictions of EOEA and the Cape Cod Commission regarding development review.
Town of Eastham Conservation Commission	Order of Conditions/ Wetlands Bylaw compliance review	Alteration of wetlands	Construction	Maybe	3 – 4 months	Permit required if wetlands will be altered in any way. The permit application is a Notice of Intent and is also sent to the Massachusetts Department of Environmental Protection. If an area less than 5,000 square feet of wetland is altered, the OOC also serves as the project's Section 401 Water Quality Certificate. Direct wetlands impacts from wind turbine construction are unlikely.
Town of Eastham - Building Department	Building permit	New construction activity in Eastham	Construction	Yes	2 – 3 months	

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues
Town of Eastham - Planning and Zoning Department	Zoning/Site Plan Approval - Special Permit	Construction of a wind farm outside the scope of current zoning regulations	Construction	Maybe	3 – 4 months	Reviews project for compliance with zoning code.
Town of Eastham - Zoning Board of Appeals	Variances from code	Project outside height limit	Construction	Maybe	3 – 4 months	Height or setback restrictions may require a variance.
Fire Marshal	Fire Code Approval	New development	Construction	Maybe	N/A	Possible substation inclusion in project may trigger need for this approval.

Table D-1
List of Permits

Agency	Permit	Regulated Activity	Required Project Phase	Applicable to Project	Expected Review Time	Comments/Issues

Abbreviations:

COE - Army Corps of Engineers
CZM – Massachusetts Office of Coastal Zone Management
dB(A) - A-weighted decibel
DOE - Department of Energy
DOER – Massachusetts Office of Consumer Affairs and Business Regulation - Division of Energy Resources
EFSB - Energy Facility Siting Board
EOEA - Executive Office of Environmental Affairs
EPA - US Environmental Protection Agency
EWG - Exempt Wholesale Generator
FAA - Federal Aviation Administration
FERC - Federal Energy Regulatory Commission
ISO/NEPOOL - Independent System Operator/New England Power Pool
MAC - Massachusetts Aeronautics Commission
MDEP - Massachusetts Department of Environmental Protection
MDF&G - Massachusetts Department of Fish and Game
MDOH - Massachusetts Department of Highways
MDPU - Massachusetts Department of Public Utilities
MEPA - Massachusetts Environmental Policy Act
MHC - Massachusetts Historical Commission
MNHP - Massachusetts Natural Heritage Program
MPA - Massachusetts Port Authority
NEPA - National Environmental Policy Act
NPDES - National Pollutant Discharge Elimination System
NPS - National Park Service
OOC - Order of Conditions
PURPA - Public Utilities Regulatory Policy Act
SPCC - Spill Prevention, Control and Countermeasure
USFWS - US Fish and Wildlife Service

Appendix E. Photo Simulations

Black & Veatch prepared photo simulations of turbines at Site A, Sites A and B, Sites A, B, and C, and at all four sites. These simulations are based on photos taken at the entrance to the Nauset Road gravel pit, Linda Lane, and the Nauset Beach area. Figure E-1 shows the locations of these photographs.

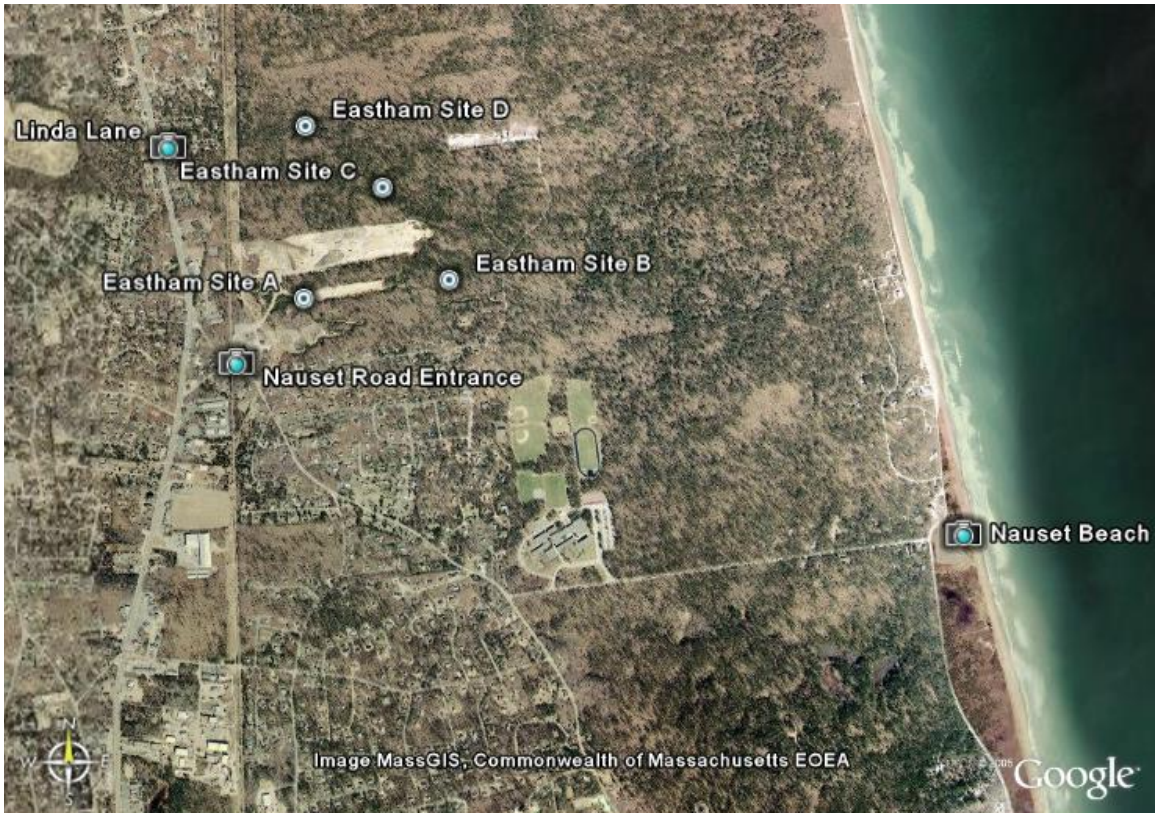


Figure E-1 Eastham Photo Simulation Locations

Two turbine sizes were used for each simulation: an 80 meter rotor on an 80 meter tower (Vestas V80 on an 80 meter tower), and a 90 meter rotor on a 100 meter tower (Vestas V90 on a 100 meter tower). Use of these turbines in the photo simulations does not constitute a particular endorsement of these turbine designs over others.

Nauset Road Entrance Photo Simulations

These simulations are based on two photos taken at the entrance to the Nauset Road gravel pit (41° 51’ 53” N, 69° 58’ 58” W). Simulations of projects of one to four turbines were performed for this site.

Figure E-2 Site A from Nauset Road Entrance, 80 Meter Tower

Figure E-3 Site A from Nauset Road Entrance, 80 Meter Tower

Figure E-4 Site A from Nauset Road Entrance, 100 Meter Tower

Figure E-5 Site A from Nauset Road Entrance, 100 Meter Tower

Figure E-6 Sites A and B from Nauset Road Entrance, 80 Meter Tower

Figure E-7 Sites A and B from Nauset Road Entrance, 80 Meter Tower

Figure E-8 Sites A and B from Nauset Road Entrance, 100 Meter Tower

Figure E-9 Sites A and B from Nauset Road Entrance, 100 Meter Tower

Figure E-10 Sites A, B and C from Nauset Road Entrance, 80 Meter Tower

Figure E-11 Sites A, B and C from Nauset Road Entrance, 80 Meter Tower

Figure E-12 Sites A, B and C from Nauset Road Entrance, 100 Meter Tower

Figure E-13 Sites A, B and C from Nauset Road Entrance, 100 Meter Tower

Figure E-14 All Four Sites from Nauset Road Entrance, 80 Meter Tower

Figure E-15 All Four Sites from Nauset Road Entrance, 80 Meter Tower

Figure E-16 All Four Sites from Nauset Road Entrance, 100 Meter Tower

Figure E-17 All Four Sites from Nauset Road Entrance, 100 Meter Tower

Nauset Beach Photo Simulations

These simulations are based on a photograph taken near the Nauset Beach entrance about 500 feet (150 meters) southeast of the lighthouse (41° 51' 34" N, 69° 57' 06" W). The photograph is looking directly toward the project site to the northwest. Wireframe views are shown because all four turbines are hidden behind the trees.

Figure E-18 All Four Sites from Nauset Beach, 80 Meter Towers

Figure E-19 All Four Sites from Nauset Beach, 100 Meter Towers

Linda Lane Photo Simulations

These simulations are based on a photograph taken on Linda Lane looking to the east (41° 52' 18" N, 69° 59' 08" W). Only a turbine at Site D is visible from this location. The wireframe views show that a turbine at Site C is hidden by trees, though it may be partially visible when there are no leaves on the trees.

Figure E-20 Site D from Linda Lane, 80 Meter Towers

Figure E-21 Sites C and D from Linda Lane, 80 Meter Towers

Figure E-22 Site D from Linda Lane, 100 Meter Towers

Figure E-23 Sites C and D from Linda Lane, 100 Meter Towers

Appendix F. Pro Forma Results

Table: MTC Pro Forma Results						
			Net Present Value		Internal Rate of Return	
Number of Turbines	**Type of Turbine**	**Inter-connection**	**Town Owned**	**Privately Owned**	**Town Owned**	**Privately Owned**
1 Turbine	GE	LV	($59,843)	($181,928)	4.9%	7.2%
		HV	($747,921)	($653,701)	1.5%	3.6%
	V80	LV	$174,973	($45,275)	6.5%	8.8%
		HV	($513,105)	($517,048)	2.8%	5.0%
	V90	LV	($341,897)	($429,982)	3.9%	6.1%
		HV	($1,029,974)	($901,755)	1.6%	3.7%
	G87	LV	$739,369	$303,741	10.4%	12.7%
		HV	$51,291	($168,033)	5.6%	7.9%
	V82	LV	($8,118)	($168,253)	5.3%	7.6%
		HV	($696,196)	($640,026)	2.1%	4.2%
	FL 2500	LV	$1,238,137	$657,163	11.8%	**15.4%**
		HV	$550,059	$185,390	7.5%	10.7%
2 Turbines	GE	LV	$1,015,774	$325,950	9.9%	11.6%
		HV	$327,696	($145,823)	6.5%	8.4%
	V80	LV	$1,130,814	$478,574	9.6%	12.5%
		HV	$442,736	$6,801	6.7%	9.3%
	V90	LV	$629,504	($50,095)	7.0%	9.1%
		HV	($58,574)	($521,868)	5.2%	7.3%
	G87	LV	$2,403,270	$1,294,786	**16.1%**	**19.1%**
		HV	$1,715,192	$823,013	11.2%	14.3%
	V82	LV	$1,284,493	$465,464	10.5%	12.3%
		HV	$591,500	($9,644)	7.3%	9.3%
	FL 2500	LV	$3,571,668	$1,988,501	**17.6%**	**21.0%**
		HV	$2,814,782	$1,637,247	**12.9%**	**17.5%**
3 Turbines	GE	LV	$1,935,508	$738,444	11.7%	13.2%
		HV	$1,247,430	$266,671	8.8%	10.5%
	V80	LV	$2,286,481	$1,079,265	11.8%	14.6%
		HV	$1,598,403	$607,491	9.2%	11.9%
	V90	LV	$1,366,628	$182,477	7.8%	9.9%
		HV	$678,550	($289,297)	6.5%	8.5%
	G87	LV	$4,000,338	$2,180,910	**19.0%**	**21.5%**
		HV	$3,312,261	$1,709,137	**14.3%**	**17.4%**

Table: MTC Pro Forma Results						
			Net Present Value		Internal Rate of Return	
Number of Turbines	Type of Turbine	Inter-connection	Town Owned	Privately Owned	Town Owned	Privately Owned
	V82	LV	$1,912,288	$834,331	10.4%	13.2%
		HV	$268,408	($112,119)	6.1%	8.7%
	FL 2500	LV	$5,589,682	$3,116,346	**19.2%**	**22.3%**
		HV	$4,901,605	$2,644,572	**15.5%**	**19.0%**
4 Turbines	GE	LV	$2,210,149	$907,192	10.3%	12.9%
		HV	$1,522,071	$435,418	8.4%	10.8%
	V80	LV	$3,234,932	$1,546,162	**12.3%**	**15.1%**
		HV	$2,546,854	$1,074,389	10.2%	12.9%
	V90	LV	$2,207,675	$478,638	8.5%	10.5%
		HV	$1,519,597	$6,864	7.4%	9.3%
	G87	LV	$3,950,200	$2,149,550	**18.8%**	**21.3%**
		HV	$5,061,623	$2,698,871	**17.2%**	**20.0%**
	V82	LV	$3,032,153	$1,414,193	11.8%	14.6%
		HV	$2,344,075	$942,420	9.8%	12.5%
	FL 2500	LV	$7,805,909	$4,373,484	**21.0%**	**23.7%**
		HV	$7,117,832	$3,901,711	**17.6%**	**20.9%**
Note: Items in **BOLD** are projects that clear hurdle rate.						

Table: MTC Pro Forma Results, sorted by return						
			Net Present Value		Internal Rate of Return	
Number of Turbines	Type of Turbine	Interconnection	Town Owned	Privately Owned	Town Owned	Privately Owned
4 Turbines	FL 2500	LV	$7,805,909	$4,373,484	**21.0%**	**23.7%**
3 Turbines	FL 2500	LV	$5,589,682	$3,116,346	**19.2%**	**22.3%**
3 Turbines	G87	LV	$4,000,338	$2,180,910	**19.0%**	**21.5%**
4 Turbines	G87	LV	$3,950,200	$2,149,550	**18.8%**	**21.3%**
2 Turbines	FL 2500	LV	$3,571,668	$1,988,501	**17.6%**	**21.0%**
4 Turbines	FL 2500	HV	$7,117,832	$3,901,711	**17.6%**	**20.9%**
4 Turbines	G87	HV	$5,061,623	$2,698,871	**17.2%**	**20.0%**
2 Turbines	G87	LV	$2,403,270	$1,294,786	**16.1%**	**19.1%**
3 Turbines	FL 2500	HV	$4,901,605	$2,644,572	**15.5%**	**19.0%**
2 Turbines	FL 2500	HV	$2,814,782	$1,637,247	**12.9%**	**17.5%**
3 Turbines	G87	HV	$3,312,261	$1,709,137	**14.3%**	**17.4%**
1 Turbine	FL 2500	LV	$1,238,137	$657,163	11.8%	**15.4%**
4 Turbines	V80	LV	$3,234,932	$1,546,162	**12.3%**	**15.1%**
3 Turbines	V80	LV	$2,286,481	$1,079,265	11.8%	14.6%

Table: MTC Pro Forma Results, sorted by return						
			Net Present Value		Internal Rate of Return	
Number of Turbines	Type of Turbine	Interconnection	Town Owned	Privately Owned	Town Owned	Privately Owned
4 Turbines	V82	LV	$3,032,153	$1,414,193	11.8%	14.6%
2 Turbines	G87	HV	$1,715,192	$823,013	11.2%	14.3%
3 Turbines	V82	LV	$1,912,288	$834,331	10.4%	13.2%
3 Turbines	GE	LV	$1,935,508	$738,444	11.7%	13.2%
4 Turbines	V80	HV	$2,546,854	$1,074,389	10.2%	12.9%
4 Turbines	GE	LV	$2,210,149	$907,192	10.3%	12.9%
1 Turbine	G87	LV	$739,369	$303,741	10.4%	12.7%
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4 Turbines	V82	HV	$2,344,075	$942,420	9.8%	12.5%
2 Turbines	V82	LV	$1,284,493	$465,464	10.5%	12.3%
3 Turbines	V80	HV	$1,598,403	$607,491	9.2%	11.9%
2 Turbines	GE	LV	$1,015,774	$325,950	9.9%	11.6%
4 Turbines	GE	HV	$1,522,071	$435,418	8.4%	10.8%
1 Turbine	FL 2500	HV	$550,059	$185,390	7.5%	10.7%
3 Turbines	GE	HV	$1,247,430	$266,671	8.8%	10.5%
4 Turbines	V90	LV	$2,207,675	$478,638	8.5%	10.5%
3 Turbines	V90	LV	$1,366,628	$182,477	7.8%	9.9%
2 Turbines	V80	HV	$442,736	$6,801	6.7%	9.3%
4 Turbines	V90	HV	$1,519,597	$6,864	7.4%	9.3%
2 Turbines	V82	HV	$591,500	($9,644)	7.3%	9.3%
2 Turbines	V90	LV	$629,504	($50,095)	7.0%	9.1%
1 Turbine	V80	LV	$174,973	($45,275)	6.5%	8.8%
3 Turbines	V82	HV	$268,408	($112,119)	6.1%	8.7%
3 Turbines	V90	HV	$678,550	($289,297)	6.5%	8.5%
2 Turbines	GE	HV	$327,696	($145,823)	6.5%	8.4%
1 Turbine	G87	HV	$51,291	($168,033)	5.6%	7.9%
1 Turbine	V82	LV	($8,118)	($168,253)	5.3%	7.6%
2 Turbines	V90	HV	($58,574)	($521,868)	5.2%	7.3%
1 Turbine	GE	LV	($59,843)	($181,928)	4.9%	7.2%
1 Turbine	V90	LV	($341,897)	($429,982)	3.9%	6.1%
1 Turbine	V80	HV	($513,105)	($517,048)	2.8%	5.0%
1 Turbine	V82	HV	($696,196)	($640,026)	2.1%	4.2%
1 Turbine	V90	HV	($1,029,974)	($901,755)	1.6%	3.7%
1 Turbine	GE	HV	($747,921)	($653,701)	1.5%	3.6%

Table: Black & Veatch Pro Forma Results						
			Real LCOE, $2006/MWh		Nominal LCOE, $/MWh	
Turbine Type	**# Turbines**	**Voltage**	**Town**	**Developer**	**Town**	**Developer**
GE 1.5x	1	LV	68.42	73.83	90.44	93.62
		HV	85.83	96.36	113.45	122.28
	2	LV	61.51	64.88	81.30	82.24
		HV	70.39	76.38	93.04	96.86
	3	LV	59.97	62.89	79.27	79.71
		HV	66.01	70.71	87.26	89.65
	4	LV	58.70	61.25	77.59	77.62
		HV	63.24	67.13	83.60	85.10
Vestas V80	1	LV	65.39	69.91	86.43	88.63
		HV	80.92	90.01	106.96	114.19
	2	LV	59.28	61.99	78.36	78.57
		HV	67.20	72.25	88.83	91.61
	3	LV	57.19	59.28	75.59	75.13
		HV	62.50	66.17	82.62	83.88
	4	LV	56.13	57.91	74.19	73.39
		HV	60.13	63.09	79.48	79.97
Vestas V82	1	LV	65.40	69.92	86.45	88.64
		HV	80.92	90.01	106.97	114.20
	2	LV	59.35	62.09	78.46	78.70
		HV	67.28	72.35	88.93	91.74
	3	LV	58.10	60.47	76.80	76.63
		HV	63.48	67.43	83.91	85.48
	4	LV	56.97	59.00	75.30	74.76
		HV	61.02	64.25	80.66	81.44
Gamesa G87	1	LV	54.71	56.06	72.32	71.04
		HV	67.87	73.12	89.71	92.71
	2	LV	50.70	49.40	67.02	62.56
		HV	56.27	58.10	74.38	73.62
	3	LV	49.85	47.98	65.89	60.77
		HV	53.42	53.92	70.62	68.31
	4	LV	49.13	46.79	64.94	**59.25**
		HV	51.80	51.22	68.47	64.88
Vestas V90	1	LV	75.86	83.46	100.28	105.87
		HV	89.03	100.51	117.68	127.54
	2	LV	70.93	77.08	93.76	97.76

Table: Black & Veatch Pro Forma Results						
			Real LCOE, $2006/MWh		Nominal LCOE, $/MWh	
Turbine Type	**# Turbines**	**Voltage**	**Town**	**Developer**	**Town**	**Developer**
		HV	77.64	85.76	102.62	108.79
	3	LV	70.51	76.53	93.20	97.06
		HV	75.08	82.45	99.25	104.58
	4	LV	69.62	75.38	92.03	95.59
		HV	73.06	79.83	96.57	101.25
FL 2500	1	LV	54.39	55.53	71.90	70.36
		HV	64.17	68.33	84.83	86.63
	2	LV	51.64	50.96	68.26	64.55
		HV	55.81	57.50	73.77	72.86
	3	LV	51.23	50.27	67.71	63.67
		HV	53.89	54.70	71.23	69.30
	4	LV	50.71	49.41	67.03	62.58
		HV	52.70	52.73	69.66	66.79

Appendix G. FAA Determinations of No Hazard

Federal Aviation Administration
Air Traffic Airspace Branch, ASW-520
2601 Meacham Blvd.
Fort Worth, TX 76137-0520

Aeronautical Study No.
2006-ANE-82-OE

Issued Date: 02/27/2006

Nils Bolgen
Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has completed an aeronautical study under the provisions of 49 U.S.C., Section 44718 and, if applicable, Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure Type:	Wind Turbine (C)
Location:	Eastham, MA
Latitude:	41-52-13.8 NAD 83
Longitude:	69-58-32.55
Heights:	394 feet above ground level (AGL)
	459 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

As a condition to this Determination, the structure should be marked and/or lighted in accordance with FAA Advisory Circular 70/7460-1 K, Obstruction Marking and Lighting, a med-dual system - Chapters 4,8(M-Dual),&12.

It is required that the enclosed FAA Form 7460-2, Notice of Actual Construction or Alteration, be completed and returned to this office any time the project is abandoned or:

__ At least 10 days prior to start of construction
(7460-2, Part I)

X__ Within 5 days after the construction reaches its greatest height
(7460-2, Part II)

As a result of this structure being critical to flight safety, it is required that the FAA be kept appraised as to the status of the project. Failure to respond to periodic FAA inquiries could invalidate this determination.

See attachment for additional condition(s) or information.

This determination expires on 08/27/2007 unless:

(a) extended, revised or terminated by the issuing office.
(b) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed , as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE POSTMARKED OR DELIVERED TO THIS OFFICE AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

A copy of this determination will be forwarded to the Federal Communications Commission if the structure is subject to their licensing authority.

If we can be of further assistance, please contact our office at (781)238-7522. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2006-ANE-82-OE.

Signature Control No: 449815-441447 (DNE)

Suzanne Dempsey
Technician

Attachment(s)
Additional Information

7460-2 Attached

Additional Information for ASN 2006-ANE-82-OE

The aeronautical study indicates that the structure does not exceed the Obstruction Standards of Federal Aviation Regulations (FAR) Part 77. However, this Determination of No Hazard is issued with the following condition:

Should spurious electromagnetic noise from the wind turbine, or aggregate noise from multiple wind turbines, adversely cause electro-magnetic interference (EMI) to an FAA facility, the proponent agrees to cease operations(s) of the wind turbine(s) until EMI is mitigated.

This determination concerns the effect of the proposal on the safe and efficient use of the navigable airspace by aircraft and does not relieve the sponsor of compliance relating to laws, ordinances, or regulations required by other governmental bodies.

Please refer to Aeronautical Study Number 2006-ANE-82-OE in any correspondence.

Federal Aviation Administration
Air Traffic Airspace Branch, ASW-520
2601 Meacham Blvd.
Fort Worth, TX 76137-0520

Aeronautical Study No.
2006-ANE-81-OE

Issued Date: 02/27/2006

Nils Bolgen
Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has completed an aeronautical study under the provisions of 49 U.S.C., Section 44718 and, if applicable, Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure Type:	Wind Turbine (B)
Location:	Eastham, MA
Latitude:	41-52-2.3 NAD 83
Longitude:	69-58-21.35
Heights:	394 feet above ground level (AGL)
	454 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

As a condition to this Determination, the structure should be marked and/or lighted in accordance with FAA Advisory Circular 70/7460-1 K, Obstruction Marking and Lighting, a med-dual system - Chapters 4,8(M-Dual),&12.

It is required that the enclosed FAA Form 7460-2, Notice of Actual Construction or Alteration, be completed and returned to this office any time the project is abandoned or:

__ At least 10 days prior to start of construction
(7460-2, Part I)

X__ Within 5 days after the construction reaches its greatest height
(7460-2, Part II)

As a result of this structure being critical to flight safety, it is required that the FAA be kept appraised as to the status of the project. Failure to respond to periodic FAA inquiries could invalidate this determination.

See attachment for additional condition(s) or information.

This determination expires on 08/27/2007 unless:

(a) extended, revised or terminated by the issuing office.
(b) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed , as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE POSTMARKED OR DELIVERED TO THIS OFFICE AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

A copy of this determination will be forwarded to the Federal Communications Commission if the structure is subject to their licensing authority.

If we can be of further assistance, please contact our office at (781)238-7522. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2006-ANE-81-OE.

Signature Control No: 449814-441446 (DNE)

Suzanne Dempsey
Technician

Attachment(s)
Additional Information

7460-2 Attached

Additional Information for ASN 2006-ANE-81-OE

The aeronautical study indicates that the structure does not exceed the Obstruction Standards of Federal Aviation Regulations (FAR) Part 77. However, this Determination of No Hazard is issued with the following condition:

Should spurious electromagnetic noise from the wind turbine, or aggregate noise from multiple wind turbines, adversely cause electro-magnetic interference (EMI) to an FAA facility, the proponent agrees to cease operations(s) of the wind turbine(s) until EMI is mitigated.

This determination concerns the effect of the proposal on the safe and efficient use of the navigable airspace by aircraft and does not relieve the sponsor of compliance relating to laws, ordinances, or regulations required by other governmental bodies.

Please refer to Aeronautical Study Number 2006-ANE-81-OE in any correspondence.

Federal Aviation Administration
Air Traffic Airspace Branch, ASW-520
2601 Meacham Blvd.
Fort Worth, TX 76137-0520

Aeronautical Study No.
2006-ANE-80-OE

Issued Date: 02/27/2006

Nils Bolgen
Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has completed an aeronautical study under the provisions of 49 U.S.C., Section 44718 and, if applicable, Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure Type:	Wind Turbine (A)
Location:	Eastham, MA
Latitude:	41-52-0.2 NAD 83
Longitude:	69-58-45.35
Heights:	394 feet above ground level (AGL)
	444 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

As a condition to this Determination, the structure should be marked and/or lighted in accordance with FAA Advisory Circular 70/7460-1 K, Obstruction Marking and Lighting, a med-dual system - Chapters 4,8(M-Dual),&12.

It is required that the enclosed FAA Form 7460-2, Notice of Actual Construction or Alteration, be completed and returned to this office any time the project is abandoned or:

__ At least 10 days prior to start of construction
(7460-2, Part I)

X__ Within 5 days after the construction reaches its greatest height
(7460-2, Part II)

As a result of this structure being critical to flight safety, it is required that the FAA be kept appraised as to the status of the project. Failure to respond to periodic FAA inquiries could invalidate this determination.

See attachment for additional condition(s) or information.

This determination expires on 08/27/2007 unless:

(a) extended, revised or terminated by the issuing office.
(b) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed , as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE POSTMARKED OR DELIVERED TO THIS OFFICE AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

A copy of this determination will be forwarded to the Federal Communications Commission if the structure is subject to their licensing authority.

If we can be of further assistance, please contact our office at (781)238-7522. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2006-ANE-80-OE.

Signature Control No: 449813-441441 (DNE)

Suzanne Dempsey
Technician

Attachment(s)
Additional Information

7460-2 Attached

Additional Information for ASN 2006-ANE-80-OE

The aeronautical study indicates that the structure does not exceed the Obstruction Standards of Federal Aviation Regulations (FAR) Part 77. However, this Determination of No Hazard is issued with the following condition:

Should spurious electromagnetic noise from the wind turbine, or aggregate noise from multiple wind turbines, adversely cause electro-magnetic interference (EMI) to an FAA facility, the proponent agrees to cease operations(s) of the wind turbine(s) until EMI is mitigated.

This determination concerns the effect of the proposal on the safe and efficient use of the navigable airspace by aircraft and does not relieve the sponsor of compliance relating to laws, ordinances, or regulations required by other governmental bodies.

Please refer to Aeronautical Study Number 2006-ANE-80-OE in any correspondence.

Federal Aviation Administration
Air Traffic Airspace Branch, ASW-520
2601 Meacham Blvd.
Fort Worth, TX 76137-0520

Aeronautical Study No.
2006-ANE-83-OE

Issued Date: 02/27/2006

Nils Bolgen
Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has completed an aeronautical study under the provisions of 49 U.S.C., Section 44718 and, if applicable, Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure Type:	WInd Turbine (D)
Location:	Eastham, MA
Latitude:	41-52-21.7 NAD 83
Longitude:	69-58-40.65
Heights:	394 feet above ground level (AGL)
	464 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

As a condition to this Determination, the structure should be marked and/or lighted in accordance with FAA Advisory Circular 70/7460-1 K, Obstruction Marking and Lighting, a med-dual system - Chapters 4,8(M-Dual),&12.

It is required that the enclosed FAA Form 7460-2, Notice of Actual Construction or Alteration, be completed and returned to this office any time the project is abandoned or:

__ At least 10 days prior to start of construction
(7460-2, Part I)

X__ Within 5 days after the construction reaches its greatest height
(7460-2, Part II)

As a result of this structure being critical to flight safety, it is required that the FAA be kept appraised as to the status of the project. Failure to respond to periodic FAA inquiries could invalidate this determination.

See attachment for additional condition(s) or information.

This determination expires on 08/27/2007 unless:

(a) extended, revised or terminated by the issuing office.
(b) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed , as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE POSTMARKED OR DELIVERED TO THIS OFFICE AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

A copy of this determination will be forwarded to the Federal Communications Commission if the structure is subject to their licensing authority.

If we can be of further assistance, please contact our office at (781)238-7522. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2006-ANE-83-OE.

Signature Control No: 449816-441448 (DNE)

Suzanne Dempsey
Technician

Attachment(s)
Additional Information

7460-2 Attached

Additional Information for ASN 2006-ANE-83-OE

The aeronautical study indicates that the structure does not exceed the Obstruction Standards of Federal Aviation Regulations (FAR) Part 77. However, this Determination of No Hazard is issued with the following condition:

Should spurious electromagnetic noise from the wind turbine, or aggregate noise from multiple wind turbines, adversely cause electro-magnetic interference (EMI) to an FAA facility, the proponent agrees to cease operations(s) of the wind turbine(s) until EMI is mitigated.

This determination concerns the effect of the proposal on the safe and efficient use of the navigable airspace by aircraft and does not relieve the sponsor of compliance relating to laws, ordinances, or regulations required by other governmental bodies.

Please refer to Aeronautical Study Number 2006-ANE-83-OE in any correspondence.