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Measuring background noise with an attended, mobile survey during nights with stable atmospheric conditions

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ABSTRACT

In response to sound studies from commercial wind developers, a series of background noise surveys were conducted in Cape Vincent, NY between May and July 2008. The survey approach included sampling at night under stable atmospheric conditions and systematically selecting monitoring stations at 1.6 km intervals. Stable conditions occurred in 67% of nights and in 30% of those nights, wind velocities represented worst-case conditions where ground level winds were less than 2 m/s and hub-height winds were greater than wind turbine cut-in speed, 4 m/s. The median A-weighted $L_{90A,9\text{-hr}}$ sound pressure level was 25.7 dBA for five, fixed monitoring stations. For two mobile surveys, the medians ($L_{90A,5\text{-min}}$) were comparable, 25.5 and 26.7 dBA. C-weighted SPLs from the two mobile surveys were 40.0 dBC and 43.9 dBC. Assuming 45 dBA background noise, developers of the St. Lawrence Wind Farm predicted noise impacts would not exceed local and New York guidelines. However, assuming worst-case conditions using 25.6 dBA background noise, nearly all residences within range of the St. Lawrence Wind Farm exceeded New York guidelines and more than half would have noise levels considered “objectionable” to “intolerable.”

1. INTRODUCTION

The impetus for this study began in 2007, shortly after AES-Acciona Energy submitted a sound study for their proposed St. Lawrence Wind Farm Project located in the town where I reside, Cape Vincent, New York USA (Figure 1). By the end of 2007, another wind developer, BP Alternative Energy, also completed a series of studies in support of their proposed Cape Vincent Wind Power Facility Project (Figure 1). Collectively, the two wind energy projects plan to erect nearly 200 wind turbines (1.5 turbines/km^2) within the Town of Cape Vincent. The sound studies submitted by the two developers had a number of deficiencies. AES-Acciona was directed by the Town of Cape Vincent’s Planning Board[b] to conduct an accurate assessment of background noise in lieu of assuming 45 dBA as typical of rural environments.[1] BP’s sound study[2] had issues related to monitoring sites and estimating background levels that were identified by the Town’s acoustic consultant[3].

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[b] http://www.stlawrencewind.com/pdf/planning_comments_061507.pdf

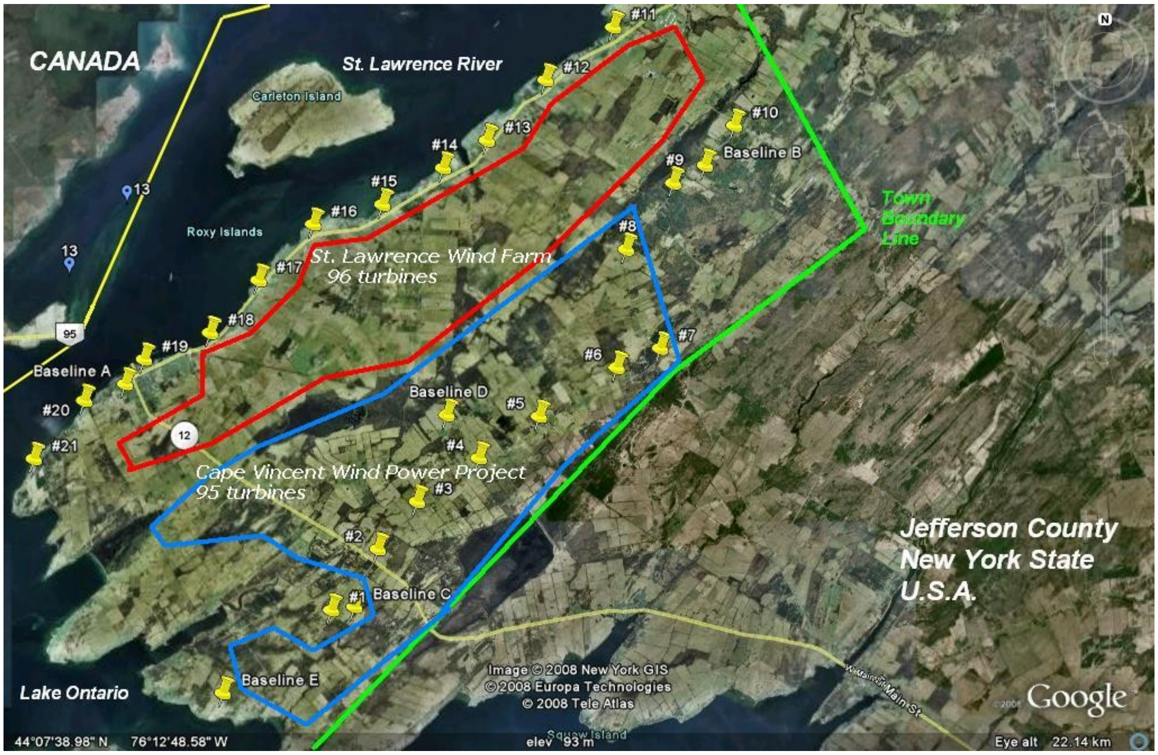

Figure 1. Map of the Town of Cape Vincent, NY showing the location of two proposed wind power projects, NYS Rte 12E road-based survey route(yellow pins no. 11-21), Burnt Rock Road road-based survey route (yellow pins no. 1-10), and location of baseline, night-time monitoring sites (yellow pins letters A-E.

In addition, the two Cape Vincent commercial wind developers neglected to consider night-time, worst-case wind conditions and noise impacts. Swedish and Dutch residents who live near wind farms described wind turbine noise as much louder and more perceptible during evenings and night, and they also reported excessive noise annoyance was associated with sleep disturbance[4,5]. In a study of the noise immissions from the Rhede Wind Park along the Dutch-German border, most of the complaints about noise focused on evenings and night-time, and wind turbine noise was found to be greater than predicted due to stable atmospheric conditions[6]. Stable atmospheric conditions occur when land begins to cool with the setting sun and calm ground level winds become de-coupled from winds aloft. Calm winds at ground level provide no masking sounds thereby making wind turbine noise more noticeable. The term worst-case has been commonly used by New York wind developers modeling noise impacts[1,7,8,9,10]. Yet, in none of their assessments have they completed an analysis of noise impacts during evenings and nights with stable atmospheric conditions, when wind turbine noise will be most noticeable and the worst-case impact will occur[11].

In this study I attempt to address some of these concerns related to site selection and atmospheric stability. A major problem with arbitrary site selection, the industry norm, is that it does not provide a means for establishing accuracy[12]. Probability sampling, on the other hand, allows the calculation of sample error and understanding the degree to which the sample differs from actual community levels. Systematic sampling is a form of probability sampling that uses a random start and a predetermined sample interval for site selection.[12] For this study I used systematic sampling by measuring sound pressure levels (SPL) at regular intervals along secondary rural roads. These roads are little traveled, particularly at night, concurring with the suggestion by van den Berg,[11] "*in order to reduce wind induced sound, it helps to measure over a low roughness surface and in a stable atmosphere, as both factors help to reduce* *turbulence*[11].”

Specific objectives of this study were to answer the following questions: 1)How common is atmospheric stability in Cape Vincent, and under these conditions, how often will winds be strong enough at hub-height to operate commercial wind turbines, 2) what background noise level is typical during stable nights in Cape Vincent, and do levels vary much within the Town, 3) how will predicted wind turbine noise levels exceed estimated background noise and how will these exceedences compare with the Town’s and New York State guidelines[13], and 4) how practical is a night-time, mobile survey and how will results compare with a fixed-station survey?

2. METHODS

I collected wind velocity data using two Inspeed Vortex anemometers with Madgetech Pulse data loggers. One anemometer was located on a mast 10 m above ground level and the other 1.3 m above ground on a portable mount. I field calibrated the anemometers by comparing wind speed with a newly calibrated HOBO weather station. Wind velocity was collected for 10-minute sampling intervals and then averaged for day, evening and night periods, 07:00-18:00, 18:00-22:00 and 22:00-07:00 hours, respectively. I used night-time average wind speed at 10-m (V_{10}) and average percentage cloud cover from the Watertown, NY weather station to categorize Pasquill stability classifications for each night, using the criteria outlined in Table 1. For each stability classification I assigned an associated wind shear exponent (*m*) and then calculated hub-height wind velocities (80-m) according to van den Berg[11]:

$$V_{80\text{-m}} / V_{10\text{-m}} = (h_{80\text{-m}} / h_{10\text{-m}})^{m} \qquad (1)$$

For the 140-night study period, there were 21 nights with no cloud cover information. For 17 of these nights I calculated wind shear using 10-m and 1.3-m wind speeds:

$$m_{h1,h2} = \ln(V_{h2}/V_{h1})/\ln(h_2/h_1) \qquad (2)$$

The adjusted database provided complete data for 135 of the 140 nights.

Table 1: Pasquill stability class observational criteria[c] and associated wind shear exponents[11].

	DAY			NIGHT		Pasquill		
Wind speed	Incoming solar radiation			Cloud Cover		Class	Name	*m*
(m/s)	Strong	Moderate	Slight	>50%	<50%	A	Very unstable	0.09
< 2	A	A – B	B	E	F	B	Moderately unstable	0.20
2-3	A – B	B	C	E	F	C	neutral	0.22
3-5	B	B – C	C	D	E	D	Slightly stable	0.28
5-6	C	C – D	D	D	D	E	stable	0.37
> 6	C	D	D	D	D	F	very stable	0.41

During sound measurements, the portable anemometer was located at the same height as the sound level meter (e.g., 1.3 m above ground level), but approximately 15 meters away. Noise measurements were made with a Quest Model 2900 Type II Integrated and Logging Sound Level Meter. An annual factory calibration of the sound meter and the field calibrator was completed in Arpil 2008, prior to data collection. The meter was fitted with a ½ inch Electret Microphone and a 75 mm diameter, open-cell wind screen.

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[c] U.S. National Oceanic & Atmospheric Administration. Air Resources Laboratory. http://www.arl.noaa.gov/READYpgclass.php

I used two methods to collect A-weighted background noise data in Cape Vincent. First, five fixed-unattended monitoring sites were sampled. Sound pressure levels were collected for L_{90A}, L_{EQA}, and L_{10A} metrics. Three different methods were used to summarize the SPL in order to examine recommended approaches for assessing the quietest period. Two methods were based on recommended procedures submitted to the Town of Cape Vincent: the lowest 1-hr mean SPL of 10-min sample intervals[14], and the lowest 10-min SPL for a continuous night-time series[15]. The third method measured sound metrics for approximately a 9-hr period. I chose monitoring sites much the same as developer's consultants chose their sites, I picked them arbitrarily (Figure 1). I did not, however, place the sound level meter close to roads, homes and other buildings. Instead, I kept my meter at least 50 m from these locations and chose sites more in line with the Town of Cape Vincent's zoning guidelines, which called for measuring noise impacts at the property lines. I surveyed only nights when the atmosphere was calm and stable.

For the mobile survey, I employed a systematic sampling methodology with a random start. I selected two routes that ran along the longitudinal axis of the town and the two proposed wind projects (Figure 1). Survey nights were selected to coincide with forecasts for stable atmospheric conditions, i.e., calm winds and a clear sky. One survey ran along Burnt Rock Road on May 29-30, and a second along NYS Rte 12E on June 13 (Figure 1). Combined, twenty-one sites were sampled for approximately 10 minutes each. I randomly selected a starting point on the route near the end of the project boundaries, but then systematically chose the next site along the path by traveling 1.6 km (1 mile), as measured on my vehicle's odometer. Both A-weighted and C-weighted noise measurements were recorded in 1-second intervals for approximately 5 minutes for each weighting. The noises associated with walking to and from the sound level meter and passing vehicles did not influence L_{90} levels, but they did affect L_{EQ} and L_{10} levels. Therefore, L_{EQ} and L_{10} levels were recalculated for the two mobile surveys after removing 30 seconds each from the start and finish of A and C-weighted data collection and removing infrequent passing vehicle noise.

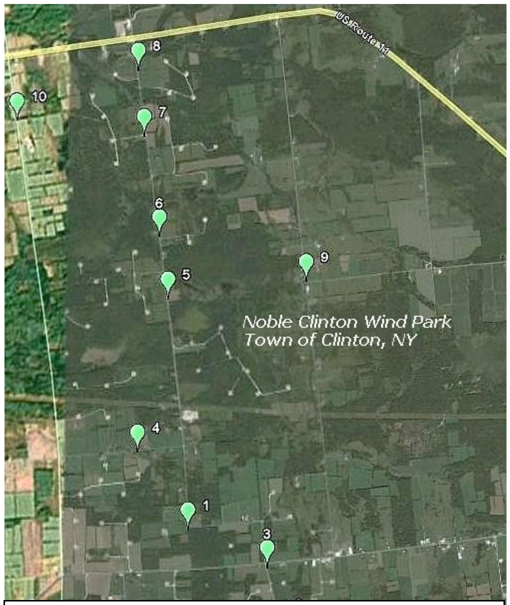

Figure 2: Mobile survey of Clinton Wind Park. Town of Clinton. NY

I also conducted a mobile survey at the Clinton Wind Park in the Town of Clinton, NY on June 24-25 (Figure 2). The monitoring stations were not systematically selected along every mile (1.6 km) of roadway. Rather, I chose stations near non-participating landowner residences, similar to what might be done with a compliance survey. Nevertheless, the sample sites were uniformly distributed. Atmospheric conditions were stable, winds at ground level were less than 1 m/s, but all wind turbines within view were operating.

I used Microsoft Excel to consolidate and summarize the wind and noise data. I did not edit the data files to remove anthropogenic (man-made) noise. I used the statistical software program MyStat and relied on simple statistical tests for normality and nonparametric procedures to establish differences in sample distributions.

3. RESULTS

A. **Prevalence of atmospheric stability:**

Stable night-time atmospheric conditions (classes E and F) predominated from June through October in Cape Vincent (Table 2). The prevalence of stable (E) and very stable (F) conditions occurred 22.2% and 45.2% of nights; the overall average was 67.4% for both classes; higher rates occurred in July and August. Although 67.4% of summer night conditions were classified as stable, not all of these nights had sufficient winds at hub-height (e.g., 80 m) to operate commercial wind turbines. I examined a subset of the data filtering two variables. First, I limited 1.3-m wind speeds to 2 m/s and less, knowing that winds this calm would provide very little leaf and grass rustle and that background noise levels under these conditions were usually very quiet. Next, I filtered 80-m wind speed to allow only those nights where velocities exceeded 4 m/s, which is a typical cut-in speed for commercial wind turbines. For an area with an operational wind farm, this represents a worst-case condition where ground level winds are calm yet wind turbines are fully operational, generating both electricity and noise.

Overall, 29.6% of the nights between June 10 and October 27 had worst-case conditions where wind turbine noise would have been dominant (Table 2). In June and July, wind turbine noise would have been more problematic with worst-case conditions occurring more than 40% of summer nights.

Table 2: Prevalence of Pasquill stability classification and worst-case noise impact conditions for nights in Cape Vincent, NY from June 10-October 27, 2008. Worst-case conditions were those stable nights with calm ground level winds ($\leq$2 m/s) and hub-height winds at or above cut-in speed ($\geq$4m/s).

STABILITY	JUN		JUL		AUG		SEP		OCT		JUN-OCT	
CONDITIONS	No.	%	No.	%	No.	%	No.	%	No.	%	Total	%
D	9	42.9	6	20.7	6	20.0	10	35.7	13	48.1	44	32.6
E	3	14.3	8	27.6	11	36.7	8	28.6	0	0.0	30	22.2
F	9	42.9	15	51.7	13	43.3	10	35.7	14	51.9	61	45.2
TOTAL	21	100	29	100	30	100	28	100	27	100	135	100
E + F	12	57.1	23	79.3	24	80.0	18	64.3	14	51.9	91	67.4
Worst-case	9	42.9	12	41.4	6	20.0	7	25.0	6	22.2	40	29.6

B. Statistical treatment of acoustic data:

Visual inspection of the $L_{90A,5\text{-min}}$ sound level data from the two mobile surveys suggested a skewed, non-normal distribution. I calculated Shapiro-Wilk test statistics for A-weighted and C-weighted L_{90}, L_{EQ} and L_{10} SPLs and found that L_{90A} , L_{EQA} and L_{90C} distributions were significantly different from normal ($P \leq 0.05$). Consequently, I used medians instead of means to describe central tendency and Kruskal-Wallis non-parametric ANOVA to test differences in the distributions of the sound pressure levels.

C. Fixed surveys for baseline background noise:

$L_{90A,9\text{-hr}}$ sound pressure levels are plotted for 10-minute intervals at five baseline monitoring locations in Figure 3. At locations A, B and D sound pressure levels were consistently low, ~25 dBA, from 9:00 PM throughout the night, then increased around 4:30 AM due to bird vocalizations. Monitoring location C was similar except for elevated levels from 9:00-11:00 PM, which were attributable to barn noises in early evening and frog choruses later. The $L_{90A,9\text{-hr}}$ for location E was 6.2 dBA higher than the other four sites. This site was 200 m from the lakeshore, and in spite of an average wind speed of 1.3 m/s, there was additional background noise associated with wave action on the shoreline.

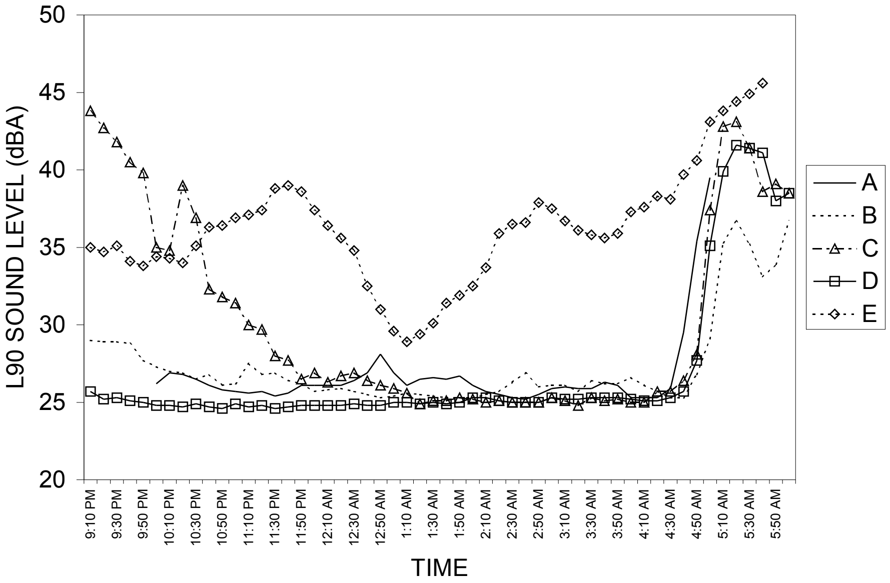

Figure 3: Night-time sound pressure levels (SPL) at five fixed monitoring stations A-E in Cape Vincent, NY

Collecting unattended, background sound pressure levels (SPL) in 10-min intervals is how consultants in New York normally acquire and report background noise, although they more typically collect data for a week or two. I used fixed survey data as a baseline to help gauge the accuracy of the mobile survey. At the five fixed survey sites, SPL was consistently low: the median $L_{90A,9\text{-hr}}$ level for the five monitoring locations was 25.7 dBA (Table 3). The median SPL based on two alternate methods were comparable: 25.2 dBA for the lowest 1-hr arithmetic average of 10-min SPL[14] and 25.0 dBA for the lowest 10-min SPL[15]. The night-time sound levels at these fixed stations were also typified by a floor in the meter response at 25-26 dBA (Figure 3).

Table 3: Summary of fixed survey, A-weighted sound pressure levels comparing three reporting time frames: 1) 9-hr period, 2) the lowest 1-hr arithmetic mean for the 9-hr period[14], and 3) the lowest 10-min interval within the 9-hr period[15].

	Monitor	Wind	9-hr Period			Lowest 1-hr Average			Lowest 10-min		
Date	Location	Speed	L90	LEQ	L10	L90	LEQ	L10	L90	LEQ	L10
11-12MAY08	A	0.1	25.7	36.8	33.0	25.6	26.1	26.5	25.2	25.7	26.1
13-14MAY08	B	0.0	25.7	36.2	37.8	25.4	25.8	26.2	25.3	25.6	25.8
15-16MAY08	C	0.0	25.7	44.1	49.0	25.0	36.8	39.3	24.8	30.2	31.9
16-17MAY08	D	0.0	24.9	45.7	41.6	24.8	28.1	26.8	24.6	24.8	25.0
25-26MAY08	E	0.6	31.9	41.3	43.7	30.2	30.8	31.4	28.9	29.3	29.6
Median			**25.7**	41.3	41.6	**25.2**	27.1	26.7	**25.0**	25.7	26.0

D. Cape Vincent mobile, background noise surveys:

For the 10 survey stations along Burnt Rock Road, the median $L_{90A,5\text{-min}}$ SPL was 25.5 dBA (Table 4). Both the L_{EQA} and L_{10A} median background noise levels were 1.7 and 2.3 dBA greater than L_{90} levels, respectively. Median C-weighted background $L_{90C,5\text{-min}}$ was 40.0 dBC. All three C-weighted sound metrics were 14-17 dB greater than their A-weighted equivalents.

Table 4: Summary for Mobile-Background Noise Survey, May 29-30, 2008, Burnt Rock Rd., Cape Vincent, NY

Monitor	Wind		A-weighted			C-weighted	
Location	Speed (m/s)	L90	LEQ	L10	L90	LEQ	L10
1	0	26.9	27.8	28.5	41.6	42.9	43.4
2	0.1	30.6	32.7	34.1	41.6	48.6	52.1
3	0	24.8	25.8	26.8	39.6	45.6	42.7
4	0	24.8	25.1	25.3	39.1	45.5	45.1
5	0	24.8	25.3	25.8	38.8	43.7	41.7
6	0.1	24.9	26.0	27.1	38.7	44.5	44.0
7	0	28.3	31.4	32.9	38.7	40.1	40.8
8	0	25.2	26.6	26.2	42.4	45.5	46.1
9	0	25.7	27.9	29.5	41.3	43.1	44.2
10	0	26.5	28.3	29.6	40.3	42.3	43.4
Median		**25.5**	27.2	27.8	**40.0**	44.1	43.7

The summary for the second part of the mobile survey, along NYS Rte 12E, is presented in Table 5. Median background noise $L_{90A,5\text{-min}}$ SPL level was 26.7 dBA. The $L_{EQA,5\text{-min}}$. and $L_{10A,5\text{-min}}$ medians were 1.9 and 3.0 dB greater than $L_{90A,5\text{-min}}$ levels, respectively. C-weighted noise levels along NYS Rte 12E were 43.9, 46.2 and 47.5 dBC for $L_{90C,5\text{-min}}$, $L_{EQC,5\text{-min}}$ and $L_{10C,5\text{-min}}$, respectively (Table 5). All three metrics were about 4 dBC higher than their C-weighted counterparts from the Burnt Rock Road survey. Moreover, the median C-weighted L_{90C} was 17.2 dB greater than the A-weighted L_{90A}, compared to a 14.5 dB differential at Burnt Rock Road.

Table 5: Summary for Mobile-Background Noise Survey, June 13, 2008, NYS Rte 12E, Cape Vincent, NY

Monitor	Wind		A-weighted			C-weighted	
Location	Speed (m/s)	L90	LEQ	L10	L90	LEQ	L10
11	0	27.3	28.2	28.4	42.6	43.7	44.4
12	0.1	30.5	30.4	30.9	44.6	46.2	48.0
13	0	25.1	27.4	28.3	40.2	41.7	42.7
14	0	32.2	32.6	32.9	45.3	47.0	48.3
15	0	26.5	28.6	29	42.9	44.5	45.6
16	0.1	26.7	29.3	31.3	43.9	47.2	49.9
17	0	26.5	27.3	28.2	43.9	46.3	47.9
18	0	25.7	26.1	26.3	44.5	45.8	46.5
19	0	36.0	36.3	36.6	52.4	53.1	53.4
20	0	29.2	30.8	32	45.1	46.9	47.5
21	0	26.7	28.2	29.7	42.2	43.8	44.5
Median		**26.7**	28.6	29.7	**43.9**	46.2	47.5

A single site for each of the mobile survey's L_{90} SPL is plotted in Figure 4. The sites selected for the plot were those that best conformed to the medians for each survey. At the start of each A-weighted sample and the crossover to C-weighted measurements, there were 5-10 dB increases in noise associated with my walking to and from the meter. Passing vehicles were noisy (e.g., 60-70 dB), but were infrequent occurrences, less so along Burnt Rock Road. Passing vehicles occurred at one site on Burnt Rock Road (site 2) and at five sites along NYS Rte 12E (sites 12, 13, 16, 19 and 21). Other sources of anthropogenic noise were a plane (site 1), dairy farm barn cleaner (site 12), and refrigeration fans (sites 14 and 19). Elevated noise was also attributable to natural causes, too: birds and frogs (sites 7 and 10), barking dogs and coyotes (sites 9 and 16), and waves on a nearby beach along the St. Lawrence River (site 20). Most of these short-duration noises, however, had little effect on the $L_{90A,5\text{-min}}$ SPL. As noted in the fixed survey, the L_{90A} measurements at a number of sites went down to 25 dBA and no lower, again indicating a “floor” in meter readings.

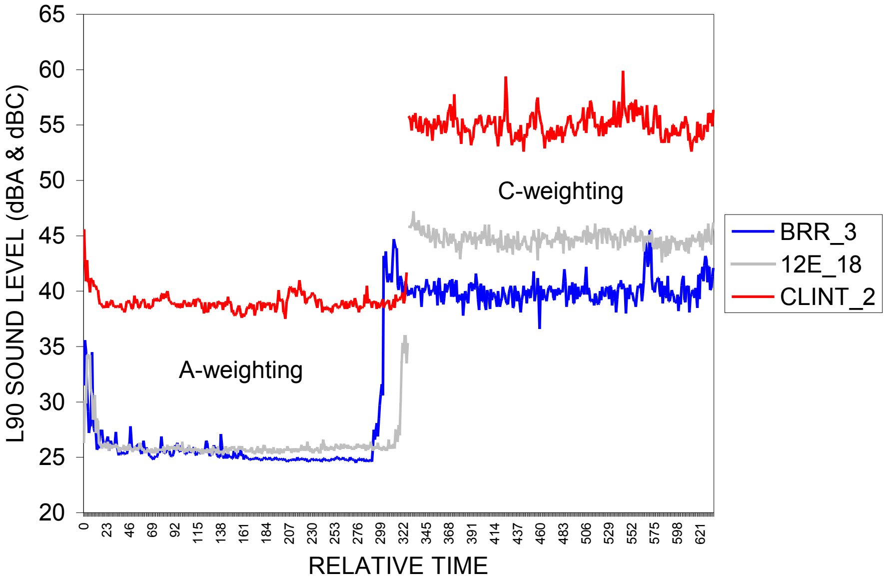

Figure 4: L_{90} sound pressure levels (SPL) for three mobile surveys: BRR_3 =Burnt Rock Rd. survey, site #3; 12E_18 =NYS Rte 12E survey, site #18 and CLINT_2 =Clinton Wind Park survey, site #2. Sites selected to best conform to medians listed in Tables 4, 5 and 6.

Statistical tests showed that L_{90A} noise levels for the fixed survey and two mobile surveys were the same, but the low frequency L_{90C} levels were different. The L_{90A} medians were 25.7, 26.7 and 25.5 dBA for the fixed, NYS Rte 12E and Burnt Rock Road surveys, respectively. The Kruskal-Wallis test indicated that all three surveys had the same distribution (H = 4.8082,df=2, P= 0.0903). However, for the low frequency L_{90C} noise levels the Kruskal-Wallis statistic showed a highly significant difference between the two Cape Vincent mobile surveys[d]. The C-weighted $L_{90C,5\text{-min}}$ medians were 43.9 and 40.0 dBC for NYS Rte 12E and Burnt Rock Road, respectively, and were significantly different (U= 104.00, P=0.001).

E. Clinton Wind Park background noise survey:

For the ten monitoring locations within the Clinton Wind Park, A-weighted $L_{90A,5\text{-min}}$ SPL ranged from 35-43 dBA with a median of 38.0 dBA. C-weighted $L_{90C,5\text{-min}}$ SPL ranged from 49-58 dBC with a median of 52.6 dBC (Table 6). Aside from two cars that passed during the C-weighting data collection at site 3, there was no other noise intrusion, other than wind turbine sounds. A typical site plot of A and C-weighted SPL is shown in Figure 4 in comparison with the Cape Vincent mobile surveys.

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[d] No C-weighted data was collected for the fixed survey. Hence, the Mann-Whitney two-sample test in lieu of Kruskal-Wallis for three or more samples.

Table 6: Summary for Mobile-Background Noise Survey, June 24-25, 2008, Clinton Wind Park, Clinton, NY

Monitor	Wind	A-WEIGHTED			C-WEIGHTED		
Location	Speed (m/s)	L90	LEQ	L10	L90	LEQ	L10
1	0.4	36.0	44.8	38.6	51.9	54.7	54.3
2	0.8	38.6	39.8	40.0	54.4	57.0	57.7
3	0.1	40.3	41.7	42.4	53.3	57.8	55.5
4	0.1	35.0	37.0	37.2	48.8	52.3	52.2
5	0.2	36.3	37.8	37.4	51.0	54.3	53.3
6	0.1	37.3	39.8	39.2	51.7	55.3	54.7
7	0.1	41.0	42.7	43.2	55.9	57.9	58.4
8	0.6	41.5	42.9	43.3	55.8	58.5	59.0
9	0.3	34.4	36.0	35.7	49.6	53.9	53.5
10	0.1	43.3	45.0	43.3	57.6	59.4	60.0
Median		**38.0**	40.8	39.6	**52.6**	56.2	55.1

The $L_{90A,5\text{-min}}$ SPL for Clinton were compared with the samples from the two mobile surveys in Cape Vincent. The higher levels at Clinton were significantly different from the sample distributions observed in Cape Vincent (Kruskal-Wallis H= 20.7080, P< 0.001); the mean ranks for the two Cape surveys were similar while Clinton was significantly greater. Comparisons of C-weighted SPL were significantly different for each of the distributions and mean ranks (H= 23.9684, P< 0.001); again the samples at Cape Vincent and Clinton were all significantly different.

4. DISCUSSION - CONCLUSIONS

Night-time, stable atmospheric conditions were very common in Cape Vincent between June and October, 2008. The prevalence of Pasquill stability classes E and F were 22% and 45% of nights, respectively. Putting aside any differences in meteorological equipment, prevalence of stability at Cape Vincent is similar to 34% (E) and 32% (F) reported by van den Berg[11] for the northern part of the Netherlands. He also noted that high wind shears at night are a very common feature of the night atmosphere in temperate zones. Furthermore, the frequent occurrence of stability in Cape Vincent, along with the operation of the Clinton Wind Park during a calm night, contradict the observation that wind turbines "do not operate during calm, still or tranquil conditions."[16]

Having demonstrated that atmospheric stability is a common occurrence in Cape Vincent, the graphic in Figure 5, taken from the Flat Rock Wind Farm sound report[17], illustrates why stable, night-time atmospheric conditions represent a worst-case wind turbine noise state. At night, predicted wind turbine noise (upper blue lines) will be most noticeable, e.g., 17 dBA louder than ambient background (lower red lines), at the lowest wind speeds. At higher wind speeds, however, wind turbine noise will be masked (e.g., no difference) by background noise (Figure 5). During daytime, the difference between predicted wind turbine and background noises at low wind speeds would be one-half as great as at night. Therefore, worst-case wind turbine noise impacts will occur at night with stable atmospheric conditions, and consequently, environmental assessments should focus on these worst-case conditions.

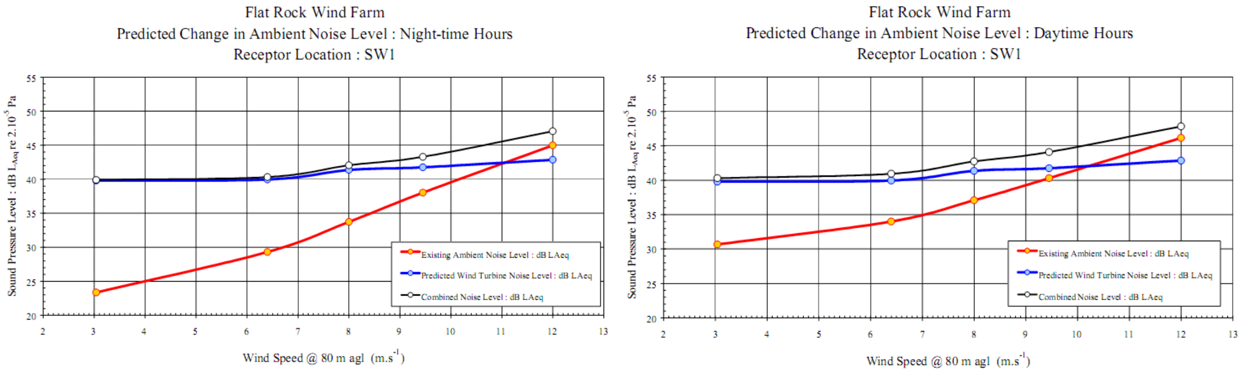

Figure 5: Night-time (left pane) and daytime (right pane) background A-weighted SPL in relation to wind speed at monitoring site SW1 from Hayes McKenzie Partnership's Flat Rock Wind Farm Noise Assessment[17], Lowville, NY. Upper, blue lines represent predicted wind turbine noise and lower, red lines the existing ambient background noise.

Background sound pressure levels measured in this study were far lower than the levels reported by wind power developers in their sound level studies. For the fixed surveys the L_{90A} medians were 25.7, 25.2, and 25.0 dBA for the 9-hr, lowest 1-hr arithmetic average, and lowest 10-min interval summary approaches, respectively. All three methods provided similar estimates of background noise, suggesting any of the three methods will provide adequate estimates of the "quietest periods." For two mobile surveys, the L_{90A} medians were 25.5 dBA and 26.7 dBA for Burnt Rock Road and NYS Rt. 12E surveys, respectively, and they were consistent with those levels measured for the fixed surveys. At the same time, the 25 dBA "floor"observed in both the fixed and mobile surveys indicate that a more sensitive meter and microphone combination would probably exhibit even lower A-weighted background noise levels. Any future study should include the use of the most sensitive instrumentation available.

A-weighted sound pressure levels from the mobile surveys in Cape Vincent were the same as levels observed at fixed, unattended monitoring locations. The fact the SPL distributions were not statistically different seems to suggest arbitrarily selected monitoring locations are just as efficient and accurate as a systematic survey with a random start. Yes, a few fixed sites can be accurate and efficient if care is taken to find appropriate sites and operating conditions. However, I could have increased the measured SPL if I had located equipment closer to homes, barns and roads, and if I had picked nights with moderate winds.

A systematic mobile survey removes the subjective selection of sites, and thus, it can help minimize potential abuse. There are other advantages as well: no landowner permission is required, no extensive hiking off-road at night, no security problems with unattended metering far from landowner premises, little time needed to prepare a survey, and no requirement for big battery packs and waterproof environmental housings. There are also the advantages of attended metering, such as being able to document various noise intrusions. A mobile survey could also be used to help verify and supplement fixed station SPLs in cases where a few fixed sites were used to characterize background noise over a large geographic area.

AES-Acciona and BP Alternative Energy reported background noise levels in Cape Vincent as 45 dBA and 47 dBA, respectively, more than 20 dBA greater than this study.[1,2] Neither developer, however, focused their studies on the night-time period, even though night noise levels are far quieter than daytime and represent worst-case conditions. Rather, they chose to include daytime, windy conditions where background noise is greater and wind turbine noise impacts the least. The median A-weighted and C-weighted levels measured within the Clinton Wind Park were 13-16 dB greater than Cape Vincent. These increases in background noise are undoubtedly due to wind turbine operation. It also suggests that the quiet, night-time, rural soundscape, which residents value most[18], could be transformed into one where night-time sound levels more closely resemble suburban and urban environments[19].

The low background sound levels reported in this study result in very different wind turbine noise impacts than those predicted by AES-Acciona. Columns A-C in Table 7 are taken from AES-Acciona's sound level report's predicted impacts from the St. Lawrence Wind Farm, assuming 45 dBA background noise.[1] With no impacts more than 5 dBA above background levels (col. C) they concluded, *"As a result, noise levels from the proposed St. Lawrence Wind Energy Project are in compliance with State guidelines, local draft zoning ordinance criteria for noise associated with commercial wind turbine operation, and will not produce noise impacts above New York policy."* However, recalculating worst-case impacts using 25.6 dBA, background SPL (col. D) show that most receptors will have night levels exceeding the local ordinance and State guidelines (e.g., ≤6 dBA above background). Moreover, applying probable human responses from New York State policy[13], shows that 34.4% of residences within range will consider turbine noise "Objectionable" and 19.4% "Very objectionable to intolerable." In total, more than half of the residents may find night-time wind turbine noise "objectionable" to "intolerable".

Table: 7. Predicted sound levels at nearest receptors to turbines. Columns A-C from Table 4 of the St. Lawrence Wind Farm sound level report.[1] Column D is the predicted sound level to nearest receptors using 25.6 dBA worst-case background levels from this study. Column E is expected human reactions to new predicted noise levels in column D, according to NYSDEC Assessing and Mitigating Noise Impacts.[13]

A Predicted Sound Level Range (dBA)	B Number of Residences Within Range	C Predicted Increase in 45 dBA Ambient (dBA)	D Predicted Increase in 25.6 dBA Ambient (dBA)	E Human Reaction NYSDEC Policy[13]
22.9 – 24.9	7	0	0	Unnoticed to tolerable
25 – 29.9	3	0-0.1	0-4.3	Unnoticed to tolerable
30 – 34.9	38	0.1-0.4	4.4-9.3	Intrusive
35 – 39.9	67	0.4-1.2	9.4-14.3	Very noticeable
40 – 44.9	84	1.2-3.0	14.4-19.3	Objectionable
45 – 48.3	48	3.0-5.0	19.4-24.7	Very objectionable to intolerable

In its most recent wind turbine noise impact assessment for the St. Lawrence Wind Farm[20], AES-Acciona assumed a background noise level of 37 dBA, used the NYSDEC noise increase guideline of 6 dBA above background, and adopted a Project-only sound level of 42 dBA to assess potential adverse impacts. They concluded *"..the numerous houses along the St. Lawrence River shoreline, are well outside of the area of adverse Project noise impacts."* Again, if AES-Acciona had assumed a worst-case background level of 25.6 dBA from this study, they would have to conclude that nearly all the houses along the river will be within the area of adverse noise impacts from the St. Lawrence Wind Farm.

The difference between C- and A-weighted SPL is used as a simple screening method for assessing potential low frequency noise problems.[15,21] If this difference exceeds 20 dB, then a low frequency problem may exist. For the mobile surveys in Cape Vincent, the differentials in median L_{EQC}–L_{EQA} were below this threshold.

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6. REFERENCES

[1] Tetra Tech EC, Inc. (TtEC). 2007. Proposed St. Lawrence Wind Energy Project Sound Level Report. Prepared for: AES-Acciona. January 2007. 8pp.

[2] Hessler, D.M. 2008. Environmental sound level survey – summertime conditions. Cape Vincent Wind Farm. BP Alternative Energy N. A., Inc. REPORT NO. 1810-112607-0, Nov. 27, 2007. 22pp.

[3] Cavanaugh Tocci Associate. 2008. Review: Cape Vincent Wind Power Project. Prepared for: Bernier & Carr Associates, P.C. for Town of Cape Vincent. January 30, 2008. 6pp.

[4] Pedersen, E. 2007. Human response to wind turbine noise: Perception annoyance and moderating factors. Dept. Public Health &Community Medicine. The Sahlgrenska Academy. Univ. Goteborg. 88pp.

[5] Van den Berg, G.P., E. Pedersen, J. Bouma, and R. Bakker. 2008. WINDFARMperception - Visual and acoustic impact of wind turbine farms on residents. University of Groningen: FP6-2005-Science-and-Society-20 Specific Support Action Project no. 044628. 99pp.

[6] Van den Berg, G.P. 2004. Effects of the wind profile at night on wind turbine sound. Journal of Sound and Vibration 277 (4-5), pp. 955-970

[7] Envrionmental Design and Research (EDR). 2007. DEIS Howard Wind Power Project. Prepared for: Steuben County Industrial Development Agency. February 27, 2007. 226pp.

[8] ESS Group, Inc. 2006. DEIS Marble River Wind Farm, Clinton & Ellenburg, N.Y. Prepared for: Marble River Wind Farm LLC. March 30, 2006. 209pp.

[9] Hessler, D.M. 2008. Environmental Sound Study and Noise Impact Assessment. Prepared for: New Grange Wind Farm, LLC. February 7, 2008. 65pp.

[10] Tetra Tech EC, Inc. (TtEC). 2008. Jericho Rise Wind Farm Envrionmental Noise Assessment, Franklin County, NY. Prepared for: Jericho Rise Wind Farm, LLC. January 31, 2008. 64pp.

[11] Van den Berg, G.P. 2006. The sounds of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise. PhD Dissertation. University of Groningen. Groningen, The Netherlands.

[12] Cochran, W.G. 1977. Sampling Techniques. Wiley & Son. 428pp.

[13] NYSDEC. 2001. Assessing and Mitigating Noise Impacts. Program Policy, Department ID: DEP 00-01, Rev: Feb 2, 2001. 28PP.

[14] Cavanaugh Tocci Associate. 2008b. Draft Noise Ordinance Town of Clayton, New York. Prepared for: Bernier & Carr Associates, P.C. for Town of Clayton. March 14, 2008. 5pp.

[15] Kamperman, G.W., R.R. James. 2008. How-to guide: Criteria for citing wind turbines to prevent health risks from sound. July 30, 2008. 35pp.

[16] Hessler, G.W. and D.M. Hessler. 2006. Baseline Environmental Sound Levels for Wind Turbine Projects. J. Sound and Vibration. November 2006: p. 10-14.

[17] Hayes McKenzie Partnership. 2003. Flat Rock Wind Farm : Noise Impact Assessment. Appendix 7: Flat Rock Wind Farm Change in Ambient Noise Levels. 16pp.

[18] Willits, F.K., R.C. Bealer and V.L. Timbers. 1990. Popular images of “rurality”: data from a Pennsylvania survey. Rural Sociology 55(4):559-578.

[19] ARI GUIDELINE L-1997. 1997. Assessing the Impact of Air-Conditioning Outdoor Sound Levels in the Residential Community. The Air-Conditioning, Heating, and Refrigeration Institute (AHRI). Adapted by R.James, E-Coustic Solutions.

[20] Tetra Tech EC, Inc. (TtEC). 2009. Supplemental Draft Environmental Impact Statement: St. Lawrence Wind Farm Report. Prepared for: AES-Acciona. March 25, 2009.

[21] Casella Stanger. 2001. Low frequency noise – Technical research support for DEFRA Noise Programme.