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TECHNICAL MEMORANDUM

To:	Laurel Carlson, Acting Deputy Regional Director, MassDEP John Winkler, Chief, Permit Section, MassDEP Marc Wolman, Environmental Engineer, MassDEP
cc:	Heather Harper, Town Manager, Town of Falmouth Jerry Potamis, Manager, Falmouth Wastewater Treatment Facility David Carignan, Agent, Falmouth Board of Health
From:	Christopher Menge
Subject:	Addendum to HMMH Report No. 304390 "Falmouth Wind Turbine Noise Study," dated September 2010
Reference:	HMMH No. 304390
Date:	April 1, 2011

This memorandum provides supplemental information about Harris Miller Miller & Hanson Inc.'s (HMMH's) noise study to the Massachusetts Department of Environmental Protection (MassDEP, or DEP) in connection with the existing Falmouth Wind-1 wind turbine and the planned Wind-2 turbine. This memo addresses comments that were provided to the town and its consultants by the MassDEP in a letter dated January 24, 2011, a meeting on March 4, 2011, meeting minutes dated March 14, 2011, and subsequent discussions with DEP representatives.

It was suggested that noise metrics be reported based on one-hour intervals instead of the 10-minute intervals that HMMH had used in the report. In addition, the DEP requested that the lowest measured one-hour L90 per wind speed category be used to characterize the background at each site. We believe that using a minimum measured value as a criterion is not appropriate, since measurements are not repeatable and the approach discourages and penalizes extended data collection. Nevertheless, we have complied with the DEP request in our revised analysis. The DEP agreed with our approach to characterize the periods with the turbine operating by the L90 value instead of an average or maximum value, given that the monitoring was unattended and that was the only way to get a truly fair characterization of the noise generated by the turbine. In addition, during the meeting of March 4th, it was agreed that it would be appropriate to match the periods with turbine running and turbine off by hour of the day, wind speed at the turbine hub and wind speed near the microphone. It was observed from review of the data set that there were periods when the one-hour average wind speeds at the hub were the same, while the average wind speeds at the microphone were very different, resulting in significantly different background noise levels at the site.

Measured Increases in Broadband Ambient Background Sound Level

Wind speeds at the hub were grouped by increments of one meter per second. Specifically, recorded one-hour average speeds ranging from 3.5 m/s to 4.4 m/s were rounded to 4 m/s and grouped together. Since the wind turbine's cut-in speed (minimum operating speed) is

3.5 m/s, the 4m/s average speed represents the lowest wind speed operating condition for the turbine. Since wind speeds near the microphone are so much lower, with one-hour averages ranging up to only about 1.1 m/s, these were matched to the nearest 0.2 m/s (one meter/second equals 2.2 miles per hour).

After times of day and wind speeds were matched, the number of matching hours was found to be limited; therefore, matched times of day were organized in 10-minute increments, thereby increasing the data set and degree of confidence. These are all one-hour period metrics, but simply incremented in 10-minute intervals, so the hour starting 1:10 spans the period from 1:10 AM to 2:10 AM, for example. Using this approach provided many more matches than matching periods incremented by one hour, and therefore shows the noise level trends with greater confidence. Figures 1 and 2 depict the periods and hub wind speeds for all the matching periods with turbine on and turbine off for Sites LT-1 and LT-2, respectively. Please note, the reason that few matches were found during daytime mid-day periods is that most often when the turbine was turned off for maintenance during the day, the hub anemometer was inadvertently turned off, so no wind speed information is available during these maintenance periods. When the turbine was turned off deliberately at night for the purpose of the sound study, the hub anemometer continued to record data, resulting in more nighttime matches. Only periods when the turbine was running during the entire hour or wind speeds were sufficient such that it would have been running during the entire hour were chosen for the matching.

Table 1 is a summary of all matched periods for Site LT-1, and includes wind speed at the hub and at the site, date, hour start time and measured L90 for each operating condition for the turbine. The difference in L90 values, which is the increase in the broadband ambient sound level, is given as RunL90 – OffL90. The table is sorted in order of increasing hub wind speed. The increase in ambient L90 noise level ranges from a negative - 4.7 decibels to a maximum increase of 7.7 decibels. Most periods with the greatest increase (7.0 to 7.7 decibels) occur in the early morning hours when the background is the quietest. This is the only time of day when other noise sources are reliably quiet enough such that sound from the turbine dominates the overall noise level. Also, such increases only occur at the lower wind speeds, from 4 m/s up to 7 m/s. At higher wind speeds, the background noise levels are high enough such that the turbine increases the background by generally less than 6 decibels

At the highest wind speeds of 9 and 10 m/s, many of the computed differences are negative, meaning the sound level with the turbine running was lower than the level with the turbine off. Nearly all of these occur during the daytime and early evening hours, when normal human activities contribute most significantly to background sound levels. There are many sources of sound in the study area that can and do control the background sound levels, other than wind in the trees and the wind turbine. These include birds, vehicular traffic, and air conditioners, among others. Birds, in particular, become very significant after 4:00 AM. It is also useful to point out that most of the negative values derive from a comparison of two particular days – June 20 when the turbine was on and June 24 when it was off. Therefore, no particular import should be given to these occurrences of negative increases, since the measurements were unattended and it is not known what was controlling the sound levels at these times.

Table 2 summarizes all of the matched periods for Site LT-2, which is located among the closest homes to the Wind-2 turbine (which was not constructed at the time), and also near Route 28. Limited data are available at this site during nighttime hours with the turbine shut down, due to an instrument failure. However, several matches were found at the lower wind speeds of 4 and 5 m/s. The largest increase in broadband ambient sound level observed was 2.8 decibels. Such a small increase is not surprising, since the Wind-1 turbine is at a distance of approximately 1,800 feet from this location and sounds from the turbine have attenuated more than at LT-1.

Measured Octave Band Sound Levels for Pure Tone Evaluation

As mentioned and shown earlier, the early morning hours represent the time of day when the noise from the turbine operation can (if it is running) most clearly dominate the background noise level in the community. Therefore, only those periods were selected to determine whether the turbine creates a pure tone condition in the community. At other times of day, other noise sources contribute significantly to both the measured background levels and the levels with the turbine operating. Turbine noise levels do not vary by time of day; they only vary by wind speed. Therefore, we have selected one-hour octave band L90 data during the three representative nights with differing wind speeds, when the turbine dominated the L90 (and overall) noise level during period of the night shown to be the quietest from the background measurements – midnight to 3:00 AM.

Figure 3 presents three graphs of the octave-band one-hour L90 values recorded at LT-1 on the night of June 19th, when one-hour average hub wind speeds ranged from 8.5 to 8.8 m/s. No pure tone conditions are found. The 125 Hz band during the hour starting at midnight reaches a value of 2.4 decibels higher than the 63 Hz band (41.6 dB vs. 39.2 dB), which is below the threshold used to define a pure tone condition.

Figure 4 presents comparable graphs during the night of June 26th, when the average hub wind speeds ranged from 7.0 to 7.6 m/s. No pure tone condition is present.

Figure 5 presents comparable graphs during the night of June 21st, when the average hub wind speeds were quite low – ranging from 3.2 to 3.8 m/s. A pure tone condition is present in the 250 Hz band during the hour starting at 1:00 AM, which is not attributable to the wind turbine. The increase in that band is also evident during the hours starting at 12:00 midnight and 2:00 AM, although it does not exceed both adjacent bands by three decibels or more. Both wind speeds and turbine noise levels are quite low during this time. Figure 6 presents graphs of the same time from the same time period for the night of June 24th, when wind speeds were comparable (3.6 to 4.8 m/s) and the turbine was <u>not</u> running, representing a comparable ambient background condition. Note that peaks in the same 250 Hz band are evident during all hours of this night – and create a pure tone condition in one of the hours. By comparing the 250 Hz band octave band sound levels between the two figures – 29 to 30 dB with the turbine off and 30 to 31 dB with the turbine running – one can conclude that the source of this sound is not the wind turbine. We suspect the source may be an air conditioner.

Characterizing Broadband Ambient Background Sound Level for Comparison with Modeled Turbine Noise

To assess compliance with the DEP increase in broadband sound criterion, HMMH initially separated all of the available one-hour L90 data into daytime and nighttime periods. The data were then sorted by hub wind speed. Wind speeds were rounded to whole meter-per-second values, in the same way as the data presented earlier in this report. Then, for each wind speed, the lowest measured one-hour L90 is selected to characterize the background for that speed. Tables 3 and 4 present the daytime and nighttime L90 data, respectively, for Site LT-1; Tables 5 and 6 present the daytime and nighttime data for Site LT-2. The lowest L90 at each wind speed is shown in **bold** font. Note that the daytime L90 values are significantly higher than the nighttime values at comparable wind speeds, as would be expected. As a result, only the nighttime data are used in the evaluation, as the quieter nighttime period represents the greatest potential for the wind turbines to exceed the DEP criteria.

In the final characterization of the ambient background sound level, in some cases the L90 from a higher wind speed hour is used to characterize that of a lower wind speed, if the sound level at the lower wind speed is higher. For example, Table 4 shows that the quietest nighttime L90 at Site LT-1 was 27.2 dBA at a 4 m/s wind speed, but 27.1 dBA at the higher 5 m/s speed. Therefore, 27.1 dBA was used to characterize the background for the 4 m/s speed as well, to be conservative and consistent. The same occurs at the 6 m/s speed, where the lowest measured L90 was 33.2 dBA, whereas the lowest level at 7 m/s was 28.4. The lower value was used for the lower wind speed here as well.

The lowest nighttime background L90 sound levels at site LT-2 (Table 6) are slightly higher than those at LT-1, likely because it is closer to Route 28. The level is 1.2 decibels higher at the 4 m/s average hub wind speed and 1.8 decibels higher at 5 m/s. No nighttime data are available at this site at higher wind speeds. To characterize the background at this site at the higher wind speeds, we added 1.2 decibels (the lower of the two measured differences) to the measured values at LT-1 to develop a conservative estimate of the background sound levels at Site LT-2.

Modeled Turbine Noise Levels Compared with Ambient Background

Based on this revised analysis, the background L90 values to be compared with the turbine operational noise levels are slightly lower than those presented in the original study. These reductions in the reference background values result in changes to the wind speeds where increases in the background are potentially the largest. Figures 7 and 8 are similar to Figure 15 in the original noise study report. These figures plot the ambient background L90 and the modeled turbine noise Leq from both Wind-1 and Wind-2. Figure 7 depicts the levels at LT-1; Figure 8 represents LT-2.

Tabulated values for the turbine noise levels, ambient background and increases in the background are given in Table 7. Each box in the table is for one hub wind speed. Within each box on the first two pages of the table (wind speeds 4, 5, 6, and 7 m/s), the computed turbine and measured background sound levels are shown in separate columns for Sites LT-1,

LT-2 and the home closest to Wind-2. This home is very near LT-2, but slightly closer to the turbine. The rows of the table in each box show the computed noise levels in groups. The first group is for the noise levels from Wind-1 + Wind-2 turbines running together, the second group for the Wind-1 turbine operating alone, and the third group for Wind-2 alone. The third page of the table presents comparisons for both Wind-1 + Wind-2 combined, at hub wind speeds of 8 m/s, 9 m/s, and 11 m/s, when turbine emissions and the ambient background are the highest. Note that under no conditions with only one of the two turbines running, does the increase exceed 10 dBA. Therefore, the facility is in complete compliance if only one turbine is operating.

However, with both turbines operating, the DEP criterion is exceeded by up to one decibel at all three of these closest sites at the 4 m/s wind speed. At the 5 m/s wind speed, the criterion is exceeded at LT-1 and at the closest home to Wind-2. At the 6 m/s and 7 m/s speeds, only the home closest to the Wind-2 turbine would experience increases greater than 10 dBA. No increases above the criterion are expected at wind speeds greater than 7 m/s, as presented on the third page of Table 7.

The final table attached to this report is a revised version of Table 9 from the original report, which reported, for the worst-case noise increase wind scenario, the measured background, computed turbine, and combined noise levels with increase above background at all of the noise prediction sites in the study area. In this version, the table is presented for the 4 m/s hub wind speed with the minimum hourly ambient background sound levels.

Discussion

HMMH believes that it is important to recognize that this noise study is different from most wind turbine noise evaluations because so many measurements of the noise levels from the Wind-1 turbine operations were obtained. These measurements add a significant degree of confidence and conservatism to the noise model computations. The original September 2010 report showed data on close-in reference measurements that corroborated the manufacturer's noise specifications for the turbine. And, as this report showed in the first section, the greatest measured increase in background noise level was 7.7 dBA, at Site LT-1. As Table 7 in this report shows, the noise model computes increases up to 10.0 dBA at LT-1 at the 5 m/s hub wind speed. This 2.3 decibel over-prediction represents a significant margin and underscores the conservatism incorporated in the noise modeling exercise.

The data presented indicate that at lower wind speeds, the Town of Falmouth's Windmill zoning bylaw noise limit of 40 dBA will not be exceeded. It should be noted that at the higher wind speeds, ambient background noise levels exceed 40 dBA, as represented in Figures 7 and 8.

Recommendations

The sound level results presented in Table 7 of this report make it clear that neither the Falmouth Wind-1 nor the Wind-2 wind turbines operating alone will increase the quietest existing nighttime background noise level by more than 10 dBA. Therefore, individually, they will be in compliance with the DEP broadband increase criterion. However, the criterion is

predicted to be exceeded by the combined operation of Wind-1 and Wind-2 at a small number of receptors during the quietest early morning hours between about midnight and 3:00 AM, and when the wind speeds are relatively low – between the cut-in speed of 4 m/s and 7 m/s.

HMMH recommends that to maintain compliance with the DEP increase in broadband noise criterion, one of the two turbines be set for a higher cut-in speed of 8 m/s during the quietest nighttime hours. It makes no difference with regard to the noise criteria which turbine is chosen for this operational curtailment.

Figure 1. Falmouth Site LT-1: Matched periods for time of day, hub wind speed and local wind speeds

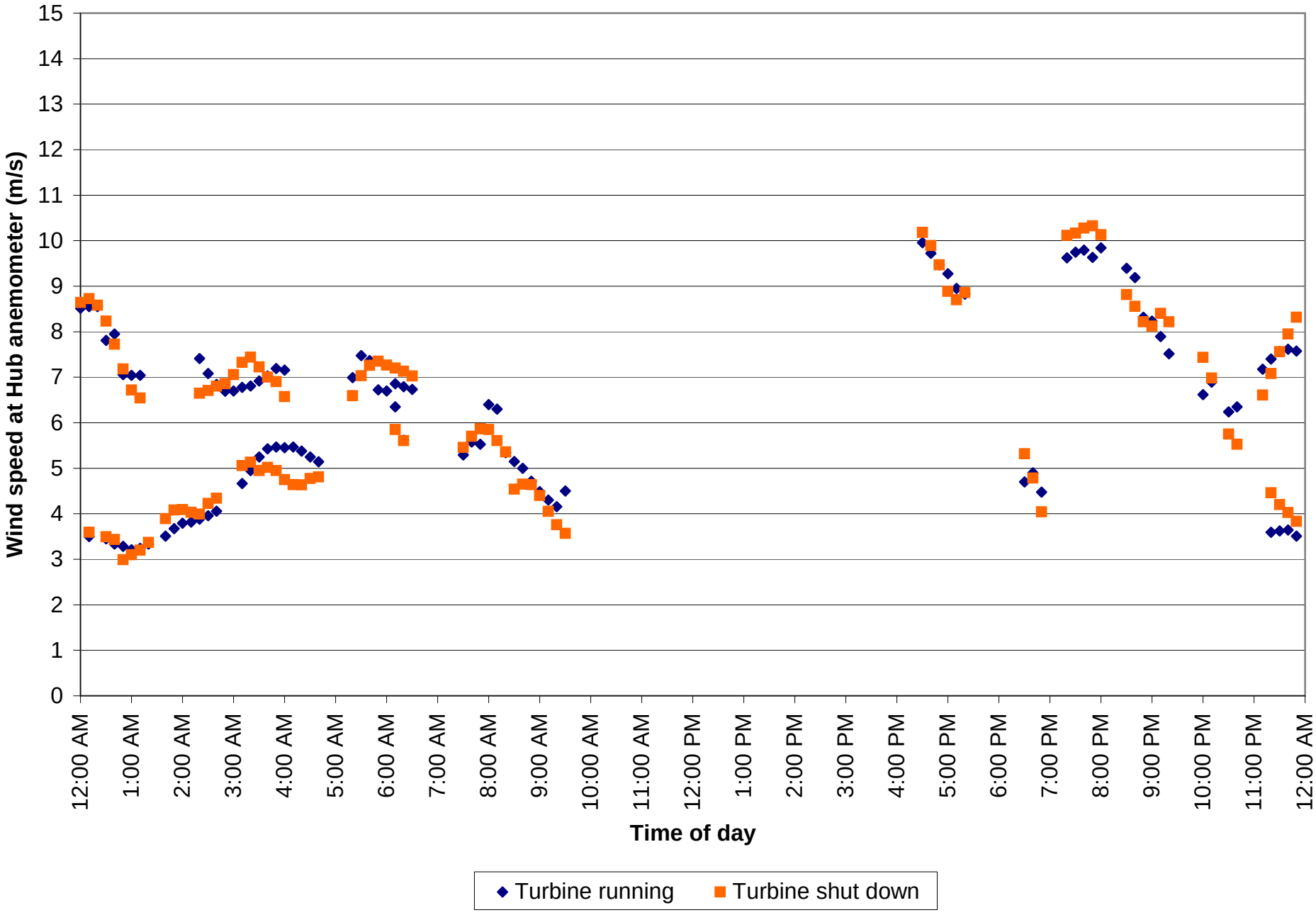

Figure 2. Falmouth Site LT-2: Matched periods for time of day, hub wind speed and local wind speeds

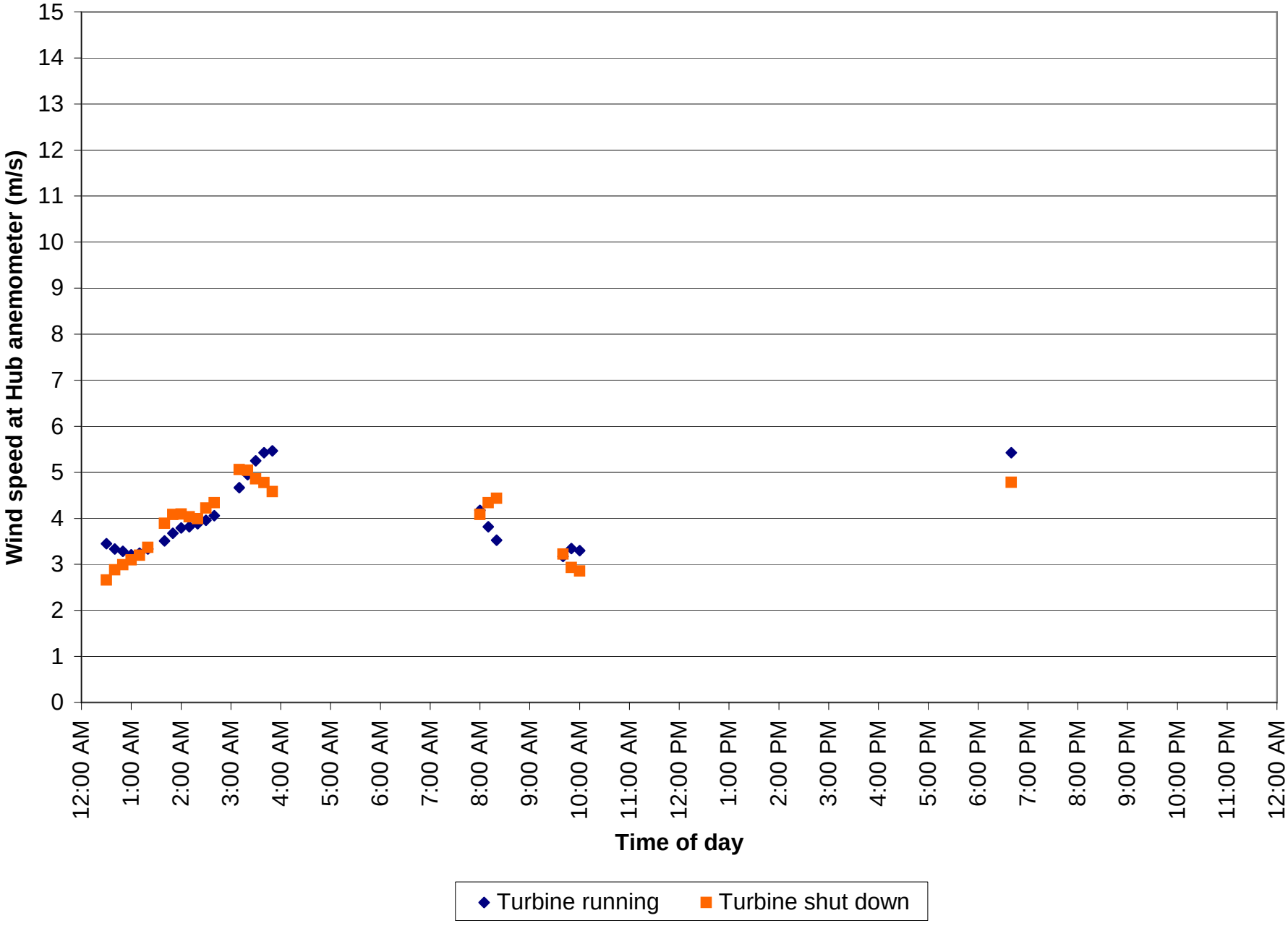

Table 1. One-hour wind and noise metrics at Falmouth Site LT-1, with time of day, hub wind speed and local wind speeds matched

Turbine	WIND 1 Hub	Wind at LT1	Date	Hr Start	L90	Turbine	WIND 1 Hub	Wind at LT1	Date	Hr Start	L90	RunL90 - OffL90
RUN	3	0.21	21-06-2010	0:30	30.9	OFF	3	0.15	24-06-2010	0:30	28.3	**2.6**
RUN	3	0.21	21-06-2010	0:40	30.8	OFF	3	0.15	24-06-2010	0:40	28.2	**2.7**
RUN	3	0.20	21-06-2010	0:50	30.1	OFF	3	0.17	27-06-2010	0:50	28.6	**1.5**
RUN	3	0.20	21-06-2010	1:00	30.1	OFF	3	0.18	27-06-2010	1:00	28.6	**1.5**
RUN	3	0.20	21-06-2010	1:10	29.4	OFF	3	0.19	27-06-2010	1:10	28.2	**1.2**
RUN	3	0.20	21-06-2010	1:20	29.4	OFF	3	0.22	27-06-2010	1:20	28.2	**1.2**
RUN	4	0.21	21-06-2010	0:10	31.2	OFF	4	0.14	24-06-2010	0:10	28.5	**2.7**
RUN	4	0.19	21-06-2010	1:40	29.4	OFF	4	0.22	27-06-2010	1:40	27.2	**2.1**
RUN	4	0.18	21-06-2010	1:50	30.1	OFF	4	0.23	27-06-2010	1:50	27.2	**2.8**
RUN	4	0.19	21-06-2010	2:00	31.5	OFF	4	0.22	27-06-2010	2:00	27.2	**4.4**
RUN	4	0.20	21-06-2010	2:10	34.2	OFF	4	0.24	27-06-2010	2:10	27.1	**7.1**
RUN	4	0.22	21-06-2010	2:20	34.6	OFF	4	0.20	27-06-2010	2:20	27.1	**7.5**
RUN	4	0.21	21-06-2010	2:30	34.7	OFF	4	0.24	27-06-2010	2:30	26.9	**7.7**
RUN	4	0.21	21-06-2010	2:40	34.7	OFF	4	0.26	27-06-2010	2:40	26.9	**7.7**
RUN	4	0.60	19-06-2010	9:00	40.9	OFF	4	0.68	27-06-2010	9:00	33.7	**7.2**
RUN	4	0.61	19-06-2010	9:10	40.9	OFF	4	0.63	27-06-2010	9:10	33.5	**7.4**
RUN	4	0.64	19-06-2010	9:20	40.9	OFF	4	0.61	27-06-2010	9:20	33.5	**7.4**
RUN	4	0.53	22-06-2010	18:50	34.4	OFF	4	0.36	26-06-2010	18:50	35.8	**-1.4**
RUN	4	0.24	20-06-2010	23:20	30.9	OFF	4	0.14	23-06-2010	23:20	30.3	**0.6**
RUN	4	0.24	20-06-2010	23:30	31.2	OFF	4	0.14	23-06-2010	23:30	30.3	**1.0**
RUN	4	0.24	20-06-2010	23:40	31.2	OFF	4	0.14	23-06-2010	23:40	29.4	**1.8**
RUN	4	0.24	20-06-2010	23:50	31.2	OFF	4	0.14	23-06-2010	23:50	29.3	**2.0**
RUN	5	0.19	21-06-2010	3:10	35.3	OFF	5	0.25	27-06-2010	3:10	27.5	**7.7**
RUN	5	0.19	21-06-2010	3:20	35.4	OFF	5	0.15	24-06-2010	3:20	28.0	**7.3**
RUN	5	0.20	21-06-2010	3:30	35.5	OFF	5	0.18	24-06-2010	3:30	28.0	**7.5**
RUN	5	0.17	21-06-2010	3:40	35.5	OFF	5	0.21	24-06-2010	3:40	28.0	**7.5**
RUN	5	0.15	21-06-2010	3:50	35.6	OFF	5	0.20	24-06-2010	3:50	28.4	**7.2**
RUN	5	0.14	21-06-2010	4:00	35.6	OFF	5	0.21	24-06-2010	4:00	28.4	**7.2**
RUN	5	0.13	21-06-2010	4:10	36.4	OFF	5	0.24	24-06-2010	4:10	31.3	**5.1**
RUN	5	0.11	21-06-2010	4:20	39.1	OFF	5	0.28	24-06-2010	4:20	33.1	**6.0**
RUN	5	0.10	21-06-2010	4:30	39.8	OFF	5	0.27	24-06-2010	4:30	41.1	**-1.3**
RUN	5	0.11	21-06-2010	4:40	41.3	OFF	5	0.28	24-06-2010	4:40	42.6	**-1.2**
RUN	5	0.30	21-06-2010	7:30	38.9	OFF	5	0.42	25-06-2010	7:30	38.7	**0.2**
RUN	5	0.56	19-06-2010	8:20	42.0	OFF	5	0.45	25-06-2010	8:20	37.8	**4.2**
RUN	5	0.57	19-06-2010	8:30	42.0	OFF	5	0.73	27-06-2010	8:30	35.0	**7.0**
RUN	5	0.58	19-06-2010	8:40	41.8	OFF	5	0.73	27-06-2010	8:40	35.0	**6.8**
RUN	5	0.62	19-06-2010	8:50	40.9	OFF	5	0.71	27-06-2010	8:50	34.7	**6.2**
RUN	5	0.41	23-06-2010	18:30	39.3	OFF	5	0.37	26-06-2010	18:30	35.8	**3.5**
RUN	5	0.35	23-06-2010	18:40	39.5	OFF	5	0.35	26-06-2010	18:40	35.8	**3.7**
RUN	6	0.23	19-06-2010	6:10	39.5	OFF	6	0.32	25-06-2010	6:10	37.6	**1.9**
RUN	6	0.14	21-06-2010	6:20	40.8	OFF	6	0.33	25-06-2010	6:20	38.5	**2.3**
RUN	6	0.53	19-06-2010	7:40	42.8	OFF	6	0.45	25-06-2010	7:40	38.5	**4.3**

Table 1. One-hour wind and noise metrics at Falmouth Site LT-1, with time of day, hub wind speed and local wind speeds matched

Turbine	WIND 1 Hub	Wind at LT1	Date	Hr Start	L90	Turbine	WIND 1 Hub	Wind at LT1	Date	Hr Start	L90	RunL90 - OffL90
RUN	6	0.53	19-06-2010	7:50	42.0	OFF	6	0.45	25-06-2010	7:50	38.4	**3.6**
RUN	6	0.55	26-06-2010	8:00	40.8	OFF	6	0.47	25-06-2010	8:00	37.8	**3.0**
RUN	6	0.52	26-06-2010	8:10	40.8	OFF	6	0.48	25-06-2010	8:10	37.8	**3.0**
RUN	6	0.20	25-06-2010	22:30	38.1	OFF	6	0.26	23-06-2010	22:30	32.5	**5.7**
RUN	6	0.21	25-06-2010	22:40	38.1	OFF	6	0.23	23-06-2010	22:40	32.2	**5.9**
RUN	7	0.23	26-06-2010	0:50	37.1	OFF	7	0.25	25-06-2010	0:50	29.7	**7.4**
RUN	7	0.23	26-06-2010	1:00	36.5	OFF	7	0.24	25-06-2010	1:00	29.4	**7.1**
RUN	7	0.24	26-06-2010	1:10	36.4	OFF	7	0.25	25-06-2010	1:10	29.4	**7.0**
RUN	7	0.26	26-06-2010	2:20	35.9	OFF	7	0.32	25-06-2010	2:20	28.4	**7.5**
RUN	7	0.25	26-06-2010	2:30	35.7	OFF	7	0.31	25-06-2010	2:30	28.4	**7.3**
RUN	7	0.26	26-06-2010	2:40	35.7	OFF	7	0.33	25-06-2010	2:40	28.4	**7.3**
RUN	7	0.27	26-06-2010	2:50	35.7	OFF	7	0.36	25-06-2010	2:50	28.6	**7.1**
RUN	7	0.31	26-06-2010	3:00	35.7	OFF	7	0.36	25-06-2010	3:00	29.0	**6.7**
RUN	7	0.34	26-06-2010	3:10	35.4	OFF	7	0.41	25-06-2010	3:10	29.0	**6.4**
RUN	7	0.38	26-06-2010	3:20	35.4	OFF	7	0.42	25-06-2010	3:20	29.7	**5.7**
RUN	7	0.38	26-06-2010	3:30	35.7	OFF	7	0.42	25-06-2010	3:30	29.9	**5.8**
RUN	7	0.39	26-06-2010	3:40	35.7	OFF	7	0.40	25-06-2010	3:40	29.9	**5.8**
RUN	7	0.43	26-06-2010	3:50	36.0	OFF	7	0.38	25-06-2010	3:50	29.9	**6.1**
RUN	7	0.39	26-06-2010	4:00	36.1	OFF	7	0.37	25-06-2010	4:00	29.9	**6.1**
RUN	7	0.46	26-06-2010	5:20	37.6	OFF	7	0.40	24-06-2010	5:20	38.6	**-0.9**
RUN	7	0.28	19-06-2010	5:30	41.2	OFF	7	0.43	24-06-2010	5:30	38.6	**2.6**
RUN	7	0.26	19-06-2010	5:40	41.1	OFF	7	0.44	24-06-2010	5:40	38.6	**2.5**
RUN	7	0.45	26-06-2010	5:50	37.7	OFF	7	0.46	24-06-2010	5:50	38.6	**-0.8**
RUN	7	0.50	26-06-2010	6:00	38.2	OFF	7	0.50	24-06-2010	6:00	38.6	**-0.5**
RUN	7	0.55	26-06-2010	6:10	38.8	OFF	7	0.52	24-06-2010	6:10	38.6	**0.2**
RUN	7	0.55	26-06-2010	6:20	40.2	OFF	7	0.54	24-06-2010	6:20	38.8	**1.4**
RUN	7	0.58	26-06-2010	6:30	40.3	OFF	7	0.55	24-06-2010	6:30	38.8	**1.5**
RUN	7	0.46	22-06-2010	22:00	35.1	OFF	7	0.30	24-06-2010	22:00	34.8	**0.3**
RUN	7	0.46	22-06-2010	22:10	35.5	OFF	7	0.27	24-06-2010	22:10	34.8	**0.7**
RUN	7	0.26	25-06-2010	23:10	37.9	OFF	7	0.15	24-06-2010	23:10	33.1	**4.8**
RUN	7	0.25	25-06-2010	23:20	37.9	OFF	7	0.15	24-06-2010	23:20	32.2	**5.7**
RUN	8	0.41	20-06-2010	0:30	37.2	OFF	8	0.24	25-06-2010	0:30	30.4	**6.9**
RUN	8	0.41	20-06-2010	0:40	37.2	OFF	8	0.25	25-06-2010	0:40	30.1	**7.2**
RUN	8	0.63	19-06-2010	20:50	39.8	OFF	8	0.46	24-06-2010	20:50	38.5	**1.3**
RUN	8	0.45	20-06-2010	21:00	37.7	OFF	8	0.44	24-06-2010	21:00	38.0	**-0.3**
RUN	8	0.42	20-06-2010	21:10	37.5	OFF	8	0.40	24-06-2010	21:10	37.5	**0.0**
RUN	8	0.37	20-06-2010	21:20	36.1	OFF	8	0.39	24-06-2010	21:20	37.0	**-0.9**
RUN	8	0.25	25-06-2010	23:30	37.7	OFF	8	0.16	24-06-2010	23:30	32.2	**5.5**
RUN	8	0.26	25-06-2010	23:40	37.6	OFF	8	0.17	24-06-2010	23:40	32.2	**5.4**
RUN	8	0.25	25-06-2010	23:50	37.6	OFF	8	0.17	24-06-2010	23:50	32.2	**5.3**
RUN	9	0.33	19-06-2010	0:00	37.0	OFF	9	0.19	25-06-2010	0:00	32.2	**4.8**
RUN	9	0.32	19-06-2010	0:10	36.9	OFF	9	0.20	25-06-2010	0:10	31.0	**5.9**

Table 1. One-hour wind and noise metrics at Falmouth Site LT-1, with time of day, hub wind speed and local wind speeds matched

Turbine	WIND 1 Hub	Wind at LT1	Date	Hr Start	L90	Turbine	WIND 1 Hub	Wind at LT1	Date	Hr Start	L90	RunL90 - OffL90
RUN	9	0.32	19-06-2010	0:20	36.6	OFF	9	0.22	25-06-2010	0:20	31.0	**5.7**
RUN	9	0.74	20-06-2010	16:50	40.3	OFF	9	0.75	24-06-2010	16:50	45.1	**-4.7**
RUN	9	0.72	20-06-2010	17:00	40.1	OFF	9	0.71	24-06-2010	17:00	44.8	**-4.7**
RUN	9	0.70	20-06-2010	17:10	40.1	OFF	9	0.71	24-06-2010	17:10	44.6	**-4.5**
RUN	9	0.67	20-06-2010	17:20	40.1	OFF	9	0.69	24-06-2010	17:20	44.6	**-4.5**
RUN	9	0.59	20-06-2010	20:30	39.1	OFF	9	0.47	24-06-2010	20:30	38.7	**0.4**
RUN	9	0.57	20-06-2010	20:40	38.4	OFF	9	0.47	24-06-2010	20:40	38.6	**-0.3**
RUN	10	0.69	20-06-2010	16:30	43.1	OFF	10	0.83	24-06-2010	16:30	46.4	**-3.3**
RUN	10	0.73	20-06-2010	16:40	43.1	OFF	10	0.78	24-06-2010	16:40	45.6	**-2.5**
RUN	10	0.61	20-06-2010	19:20	40.1	OFF	10	0.53	24-06-2010	19:20	43.0	**-3.0**
RUN	10	0.62	20-06-2010	19:30	40.1	OFF	10	0.52	24-06-2010	19:30	42.8	**-2.7**
RUN	10	0.62	20-06-2010	19:40	40.1	OFF	10	0.50	24-06-2010	19:40	42.2	**-2.2**
RUN	10	0.63	20-06-2010	19:50	40.1	OFF	10	0.48	24-06-2010	19:50	40.6	**-0.6**
RUN	10	0.65	20-06-2010	20:00	40.5	OFF	10	0.45	24-06-2010	20:00	40.1	**0.4**

MAX	**7.7**
MIN	**-4.7**

Table 2. One-hour wind and noise metrics at Falmouth Site LT-2, with time of day, hub wind speed and local wind speeds matched

Turbine	WIND 1 Hub	Wind at LT2	Date	Hr Start	L90	Turbine	WIND 1 Hub	Wind at LT2	Date	Hr Start	L90	RunL90 - OffL90
RUN	3	0.27	21-06-2010	0:30	27.9	OFF	3	0.25	27-06-2010	0:30	30.7	**-2.7**
RUN	3	0.25	21-06-2010	0:40	27.9	OFF	3	0.24	27-06-2010	0:40	29.2	**-1.3**
RUN	3	0.22	21-06-2010	0:50	27.1	OFF	3	0.23	27-06-2010	0:50	29.2	**-2.1**
RUN	3	0.21	21-06-2010	1:00	27.1	OFF	3	0.23	27-06-2010	1:00	29.2	**-2.1**
RUN	3	0.21	21-06-2010	1:10	26.9	OFF	3	0.22	27-06-2010	1:10	28.3	**-1.4**
RUN	3	0.21	21-06-2010	1:20	26.9	OFF	3	0.21	27-06-2010	1:20	28.3	**-1.4**
RUN	3	0.44	21-06-2010	9:40	44.0	OFF	3	0.44	27-06-2010	9:40	44.3	**-0.4**
RUN	3	0.44	21-06-2010	9:50	43.3	OFF	3	0.46	27-06-2010	9:50	44.3	**-1.0**
RUN	3	0.43	21-06-2010	10:00	43.3	OFF	3	0.51	27-06-2010	10:00	44.3	**-1.0**
RUN	4	0.22	21-06-2010	1:40	27.1	OFF	4	0.21	27-06-2010	1:40	28.3	**-1.1**
RUN	4	0.24	21-06-2010	1:50	28.1	OFF	4	0.21	27-06-2010	1:50	28.3	**-0.2**
RUN	4	0.23	21-06-2010	2:00	29.6	OFF	4	0.24	27-06-2010	2:00	28.3	**1.3**
RUN	4	0.22	21-06-2010	2:10	29.6	OFF	4	0.26	27-06-2010	2:10	28.6	**1.1**
RUN	4	0.24	21-06-2010	2:20	29.6	OFF	4	0.26	27-06-2010	2:20	28.6	**1.1**
RUN	4	0.23	21-06-2010	2:30	29.7	OFF	4	0.27	27-06-2010	2:30	28.0	**1.7**
RUN	4	0.21	21-06-2010	2:40	29.7	OFF	4	0.28	27-06-2010	2:40	28.0	**1.7**
RUN	4	0.29	21-06-2010	8:00	45.7	OFF	4	0.43	27-06-2010	8:00	42.8	**2.8**
RUN	4	0.31	21-06-2010	8:10	44.8	OFF	4	0.44	27-06-2010	8:10	42.8	**1.9**
RUN	4	0.33	21-06-2010	8:20	44.8	OFF	4	0.44	27-06-2010	8:20	42.8	**1.9**
RUN	5	0.20	21-06-2010	3:10	30.0	OFF	5	0.30	27-06-2010	3:10	28.9	**1.2**
RUN	5	0.19	21-06-2010	3:20	30.3	OFF	5	0.33	27-06-2010	3:20	38.9	**-8.6**
RUN	5	0.18	21-06-2010	3:30	30.4	OFF	5	0.37	27-06-2010	3:30	38.9	**-8.5**
RUN	5	0.19	21-06-2010	3:40	30.4	OFF	5	0.36	27-06-2010	3:40	36.1	**-5.7**
RUN	5	0.17	21-06-2010	3:50	30.9	OFF	5	0.35	27-06-2010	3:50	36.1	**-5.2**
RUN	5	0.44	21-06-2010	18:40	43.5	OFF	5	0.52	26-06-2010	18:40	41.7	**1.8**

MAX	**2.8**
MIN	**-8.6**

Figure 3. LT-1 One-hour Octave Band L90, Nighttime, Turbine Running, Hub Wind 8.5 to 8.8 m/s

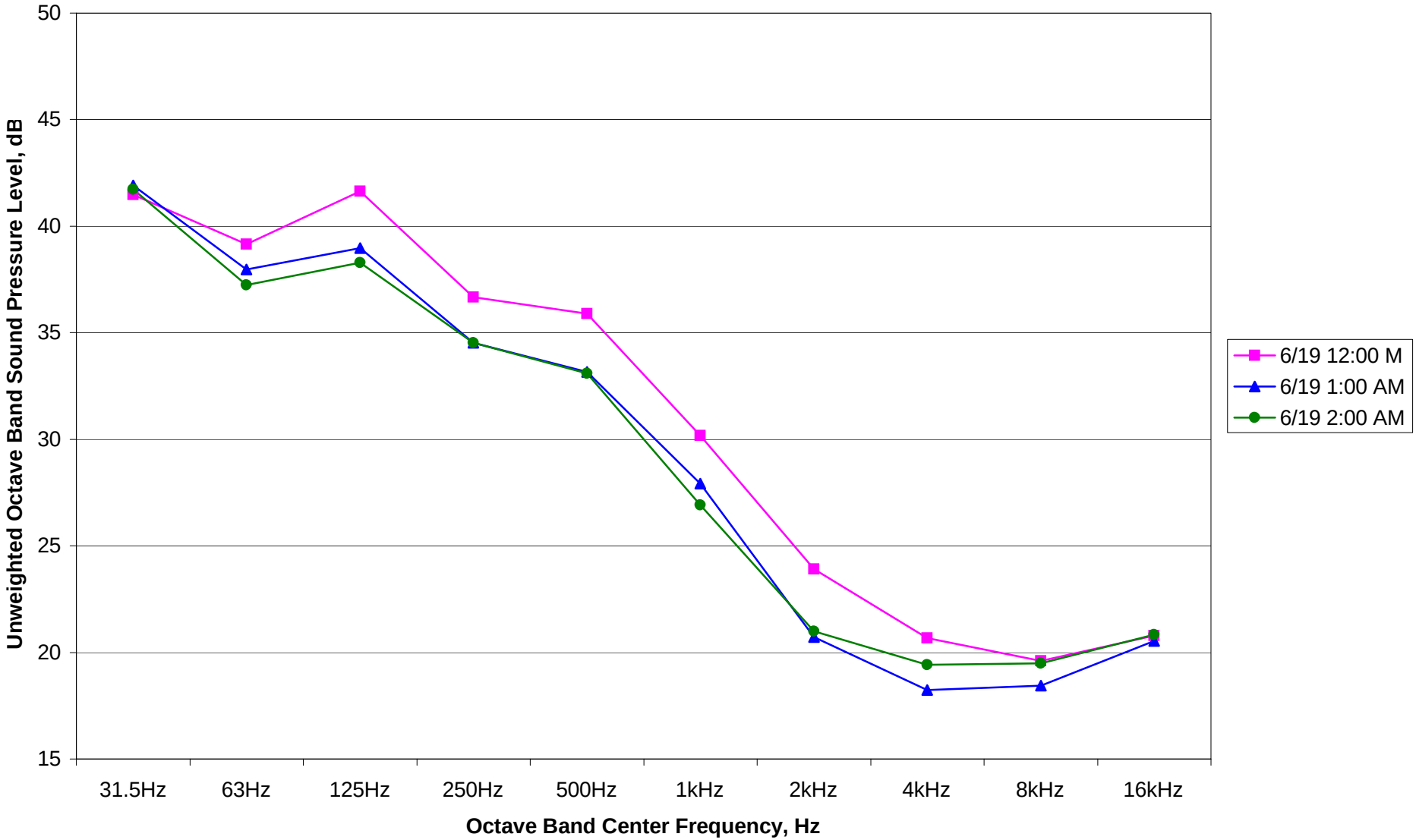

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Figure 4. LT-1 One-hour Octave Band L90, Nighttime, Turbine Running, Hub Wind 7.0 to 7.6 m/s

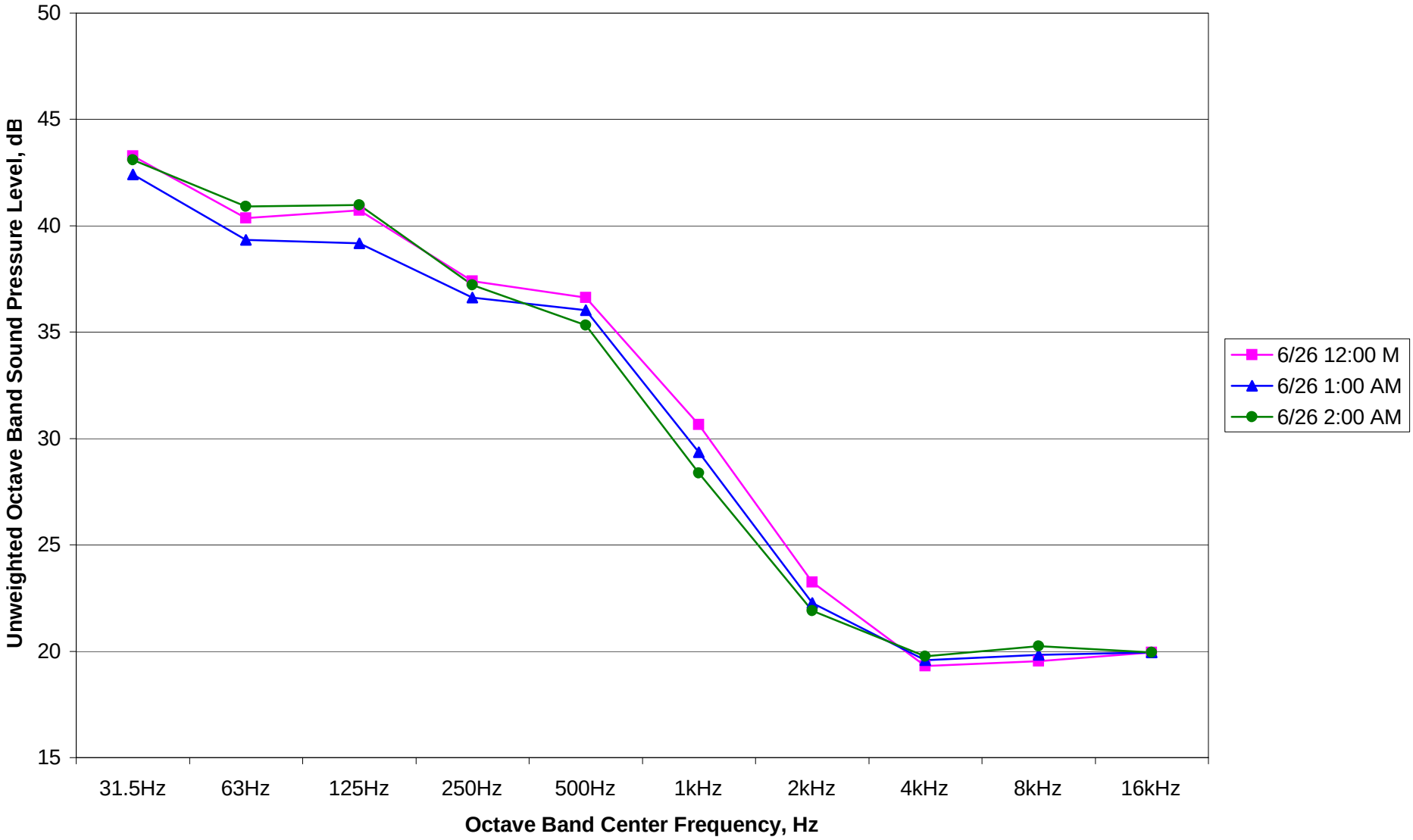

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Figure 5. LT-1 One-hour Octave Band L90, Nighttime, Turbine Running, Hub Wind 3.2 to 3.8 m/s

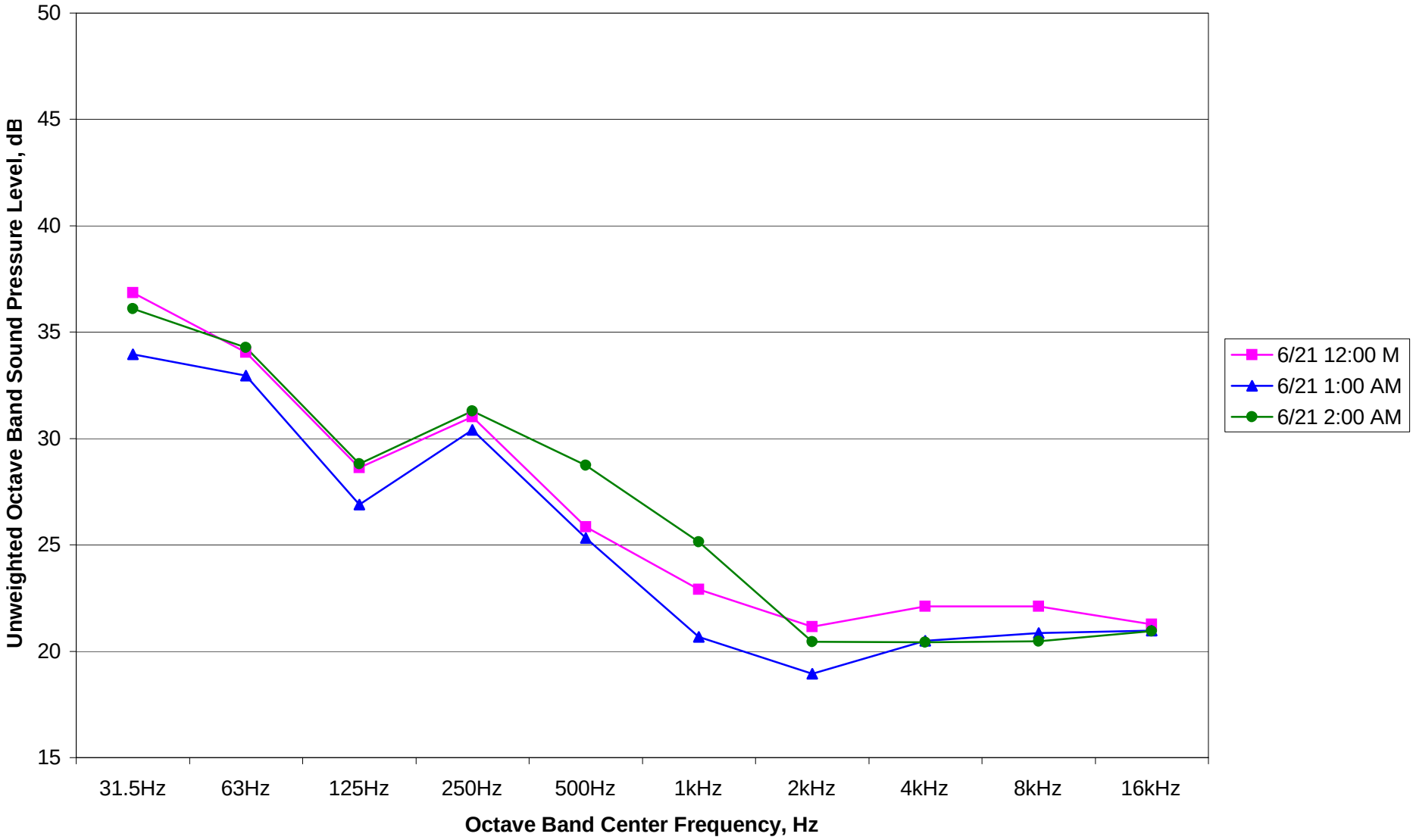

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Figure 6. LT-1 One-hour Octave Band L90, Nighttime, Turbine Off, Hub Wind 3.6 to 4.8 m/s

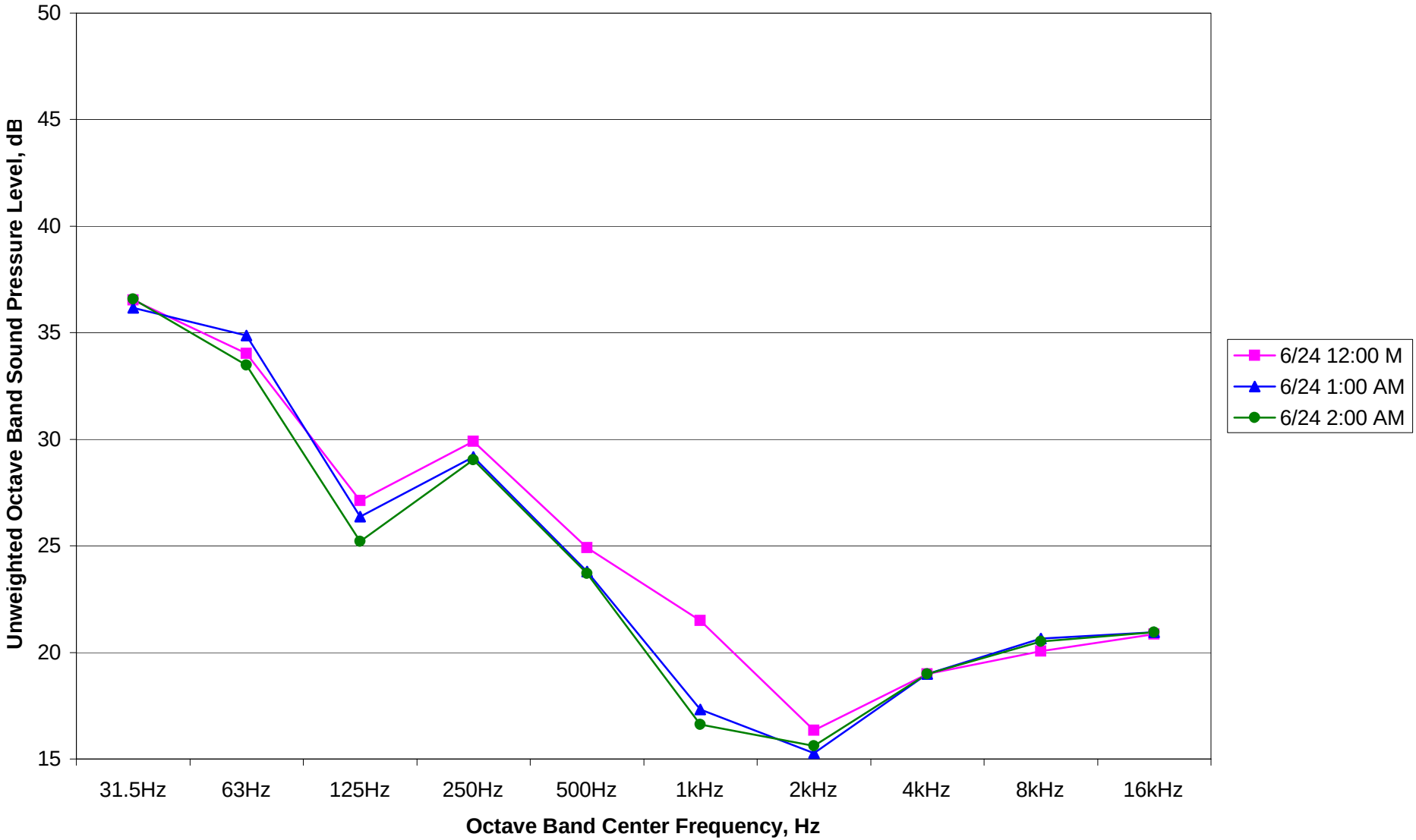

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Table 3. Measured one-hour daytime ambient background L90 values at Site LT-1

WIND-1 Hub Avg. speed (m/s)*	Date	Hour start	One-hour L90 dBA*
2	21-06-2010	12:00	33.3
2	21-06-2010	13:00	35.9
3	27-06-2010	10:00	34.6
3	26-06-2010	19:00	35.8
4	26-06-2010	21:00	34.8
4	26-06-2010	20:00	35.0
4	27-06-2010	6:00	**32.2**
4	27-06-2010	8:00	34.6
4	27-06-2010	9:00	33.7
4	27-06-2010	7:00	33.7
5	22-06-2010	16:00	**35.5**
5	25-06-2010	7:00	39.5
6	25-06-2010	8:00	37.8
6	25-06-2010	6:00	**37.6**
7	24-06-2010	6:00	**38.6**
7	24-06-2010	7:00	42.4
8	24-06-2010	21:00	**38.0**
9	24-06-2010	17:00	**44.8**
10	24-06-2010	18:00	45.6
10	24-06-2010	20:00	**40.1**
10	24-06-2010	19:00	43.2

* Note: Lowest L90 values at each wind speed above turbine cut-in speed in **bold** font

Table 4. Measured one-hour nighttime ambient background L90 values at Site LT-1

WIND 1 Hub Avg. speed (m/s)*	Date	Hour start	One-hour L90 dBA*
2	26-06-2010	23:00	29.2
2	27-06-2010	0:00	28.4
3	27-06-2010	5:00	30.5
3	26-06-2010	22:00	33.9
3	27-06-2010	1:00	28.6
4	24-06-2010	0:00	28.8
4	24-06-2010	1:00	27.9
4	27-06-2010	2:00	**27.2**
4	27-06-2010	4:00	33.4
5	24-06-2010	4:00	28.4
5	27-06-2010	3:00	**27.1**
5	24-06-2010	2:00	27.6
5	23-06-2010	23:00	30.7
5	24-06-2010	3:00	28.0
6	24-06-2010	5:00	39.2
6	25-06-2010	5:00	36.8
6	24-06-2010	23:00	**33.2**
7	25-06-2010	4:00	29.9
7	25-06-2010	1:00	29.4
7	25-06-2010	2:00	**28.4**
7	25-06-2010	3:00	29.0
7	24-06-2010	22:00	34.8
9	25-06-2010	0:00	**32.2**

* Note: Lowest L90 values at each wind speed above turbine cut-in speed in **bold** font

Table 5. Measured one-hour daytime ambient background L90 values at Site LT-2

WIND-1 Hub Avg. speed (m/s)*	Date	Hour start	One-hour L90 dBA*
2	21-06-2010	12:00	46.4
2	21-06-2010	13:00	42.7
3	27-06-2010	10:00	44.3
3	26-06-2010	19:00	41.7
4	26-06-2010	21:00	**37.5**
4	26-06-2010	20:00	40.9
4	27-06-2010	6:00	38.2
4	27-06-2010	8:00	42.8
4	27-06-2010	9:00	46.0
4	27-06-2010	7:00	40.6
5	22-06-2010	16:00	**47.3**

* Note: Lowest L90 values at each wind speed above turbine cut-in speed in **bold** font

Table 6. Measured one-hour nighttime ambient background L90 values at Site LT-2

WIND-1 Hub Avg. speed (m/s)*	Date	Hour start	One-hour L90 dBA*
2	26-06-2010	23:00	34.9
2	27-06-2010	0:00	29.1
3	27-06-2010	5:00	37.1
3	26-06-2010	22:00	36.6
3	27-06-2010	1:00	29.2
4	27-06-2010	2:00	**28.3**
4	27-06-2010	4:00	36.1
5	27-06-2010	3:00	**28.9**

* Note: Lowest L90 values at each wind speed above turbine cut-in speed in **bold** font

Figure 7. LT-1: Lowest Background L90 and Computed Wind-1 + Wind-2 Turbine Leq Sound Levels as a Function of Hub Wind Speed

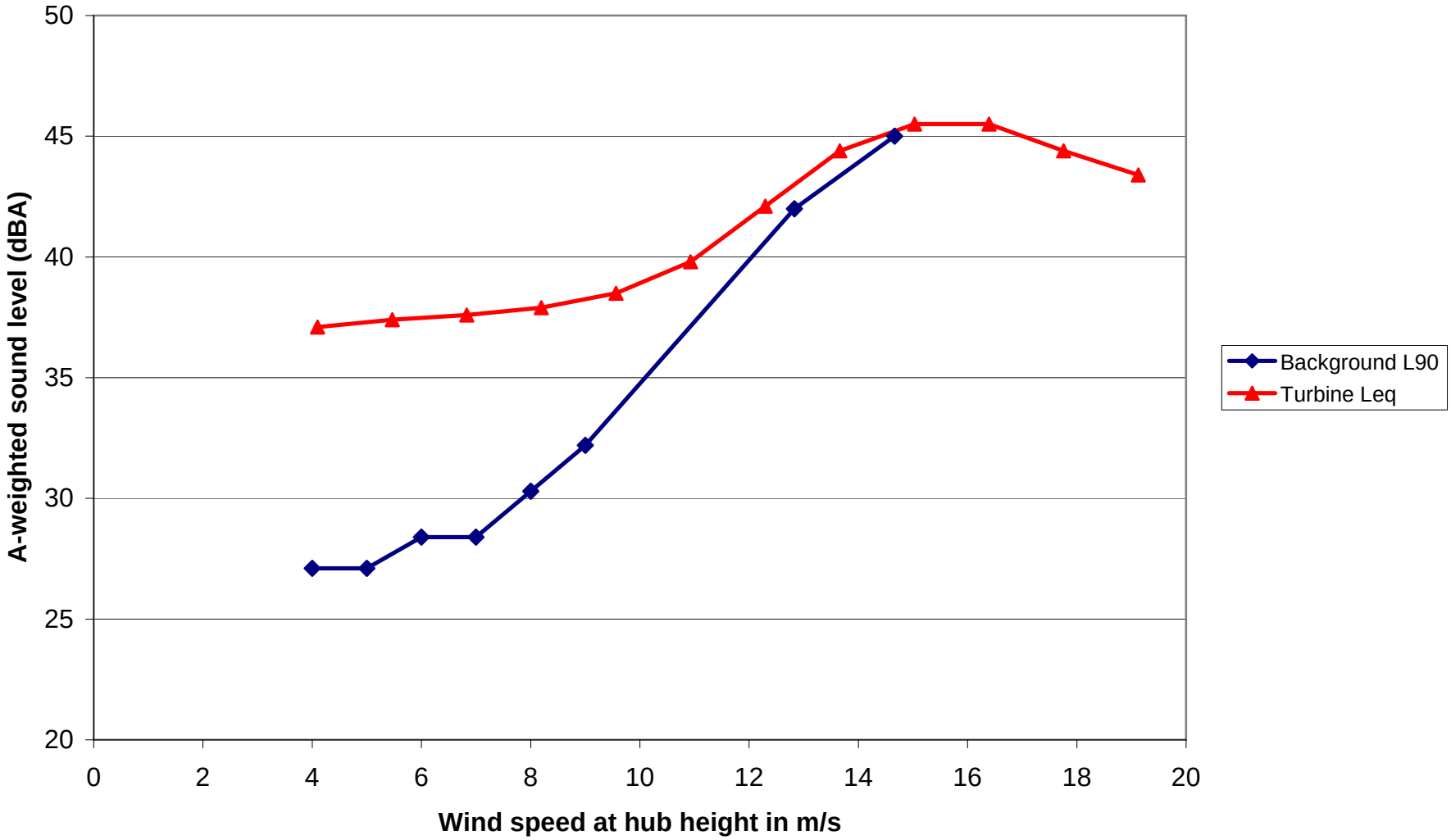

Figure 8. LT-2: Lowest Background L90 and Computed Wind-1 + Wind-2 Turbine Leq Sound Levels as a Function of Hub Wind Speed

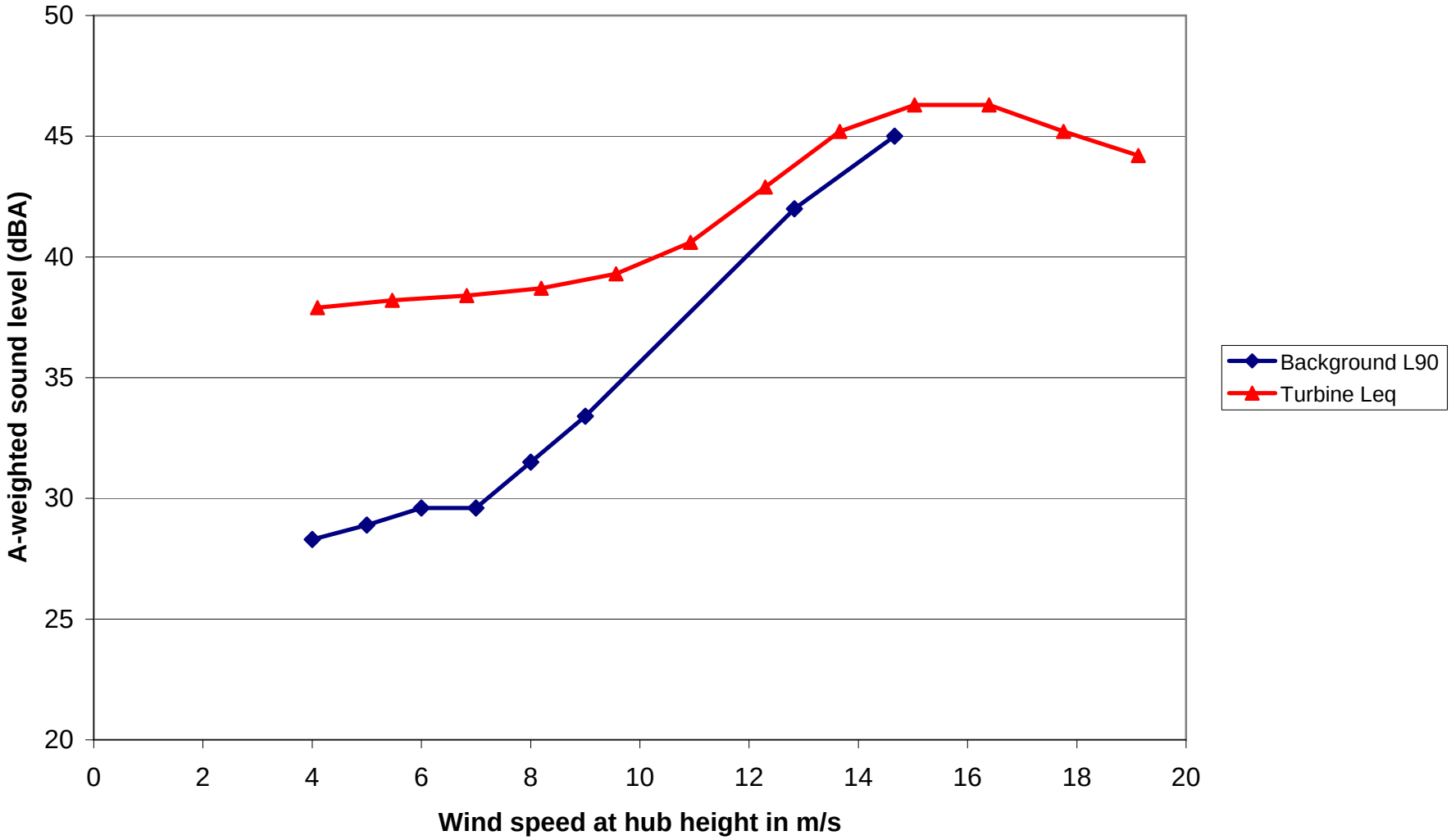

Table 7. Falmouth Wind1 & Wind2 noise levels compared with ambient background sound levels at different wind speeds

	Site LT-1	Site LT-2	Home closest to Wind2
Hub wind speed of 4 m/s			
Wind1 + Wind2 Turbines together			
Background L90 =	27.1	28.3	28.3
Turbine Leq noise level =	37.1	37.9	39.2
Total Turbine Leq + background=	37.5	38.4	39.5
Increase in background =	**10.4**	**10.1**	**11.2**
Wind1 noise level alone 4m/s			
Background L90 =	27.1	28.3	28.3
Turbine Leq noise level =	36.4	32.3	33.4
Total Turbine Leq + background=	36.9	33.8	34.6
Increase in background =	**9.8**	**5.5**	**6.3**
Wind2 noise level alone			
Background L90 =	27.1	28.3	28.3
Turbine Leq noise level =	28.8	36.5	37.8
Total Turbine Leq + background=	31.1	37.1	38.3
Increase in background =	**4.0**	**8.8**	**10.0**
Hub wind speed of 5 m/s			
Wind1 + Wind2 Turbines together			
Background L90 =	27.1	28.9	28.9
Turbine Leq noise level =	37.3	38.1	39.4
Total Turbine Leq + background=	37.7	38.6	39.7
Increase in background =	**10.6**	**9.7**	**10.8**
Wind1 noise level alone 5m/s			
Background L90 =	27.1	28.9	28.9
Turbine Leq noise level =	36.6	32.5	33.6
Total Turbine Leq + background=	37.1	34.1	34.9
Increase in background =	**10.0**	**5.2**	**6.0**
Wind2 noise level alone			
Background L90 =	27.1	28.9	28.9
Turbine Leq noise level =	29.0	36.7	38.0
Total Turbine Leq + background=	31.2	37.4	38.5
Increase in background =	**4.1**	**8.5**	**9.6**

Table 7. Falmouth Wind1 & Wind2 noise levels compared with ambient background sound levels at different wind speeds

	Site LT-1	Site LT-2	Home closest to Wind2
Hub wind speed of 6 m/s			
Wind1 + Wind2 Turbines together			
Background L90 =	28.4	29.6	29.6
Turbine Leq noise level =	37.5	38.3	39.6
Total Turbine Leq + background=	38.0	38.8	40.0
Increase in background =	**9.6**	**9.2**	**10.4**
Wind1 noise level alone 4m/s			
Background L90 =	28.4	29.6	29.6
Turbine Leq noise level =	36.8	32.7	33.8
Total Turbine Leq + background=	37.4	34.4	35.2
Increase in background =	**9.0**	**4.8**	**5.6**
Wind2 noise level alone			
Background L90 =	28.4	29.6	29.6
Turbine Leq noise level =	29.2	36.9	38.2
Total Turbine Leq + background=	31.8	37.6	38.8
Increase in background =	**3.4**	**8.0**	**9.2**
Hub wind speed of 7 m/s			
Wind1 + Wind2 Turbines together			
Background L90 =	28.4	29.6	29.6
Turbine Leq noise level =	37.6	38.4	39.7
Total Turbine Leq + background=	38.1	38.9	40.1
Increase in background =	**9.7**	**9.3**	**10.5**
Wind1 noise level alone 7m/s			
Background L90 =	28.4	29.6	29.6
Turbine Leq noise level =	36.9	32.8	33.9
Total Turbine Leq + background=	37.5	34.5	35.3
Increase in background =	**9.1**	**4.9**	**5.7**
Wind2 noise level alone			
Background L90 =	28.4	29.6	29.6
Turbine Leq noise level =	29.3	37.0	38.3
Total Turbine Leq + background=	31.9	37.7	38.9
Increase in background =	**3.5**	**8.1**	**9.3**

Table 7. Falmouth Wind1 & Wind2 noise levels compared with ambient background sound levels at different wind speeds

	Site LT-1	Site LT-2	Home closest to Wind2
Wind1 + Wind2 Turbines together			
At 8 m/s hub wind speed			
Background L90 =	30.3	31.5	31.5
Turbine Leq noise level =	37.9	38.7	40.0
Total Turbine Leq + background=	38.6	39.5	40.5
Increase in background =	**8.3**	**8.0**	**9.0**
At 9 m/s hub wind speed			
Background L90 =	32.2	33.4	33.4
Turbine Leq noise level =	38.3	39.1	40.4
Total Turbine Leq + background=	39.3	40.1	41.2
Increase in background =	**7.1**	**6.7**	**7.8**
At 11 m/s hub (8 m/s @ 10m) wind speed			
Background L90 =	37.5	37.5	37.5
Turbine Leq noise level =	39.8	40.6	41.9
Total Turbine Leq + background=	41.8	42.3	43.2
Increase in background =	**4.3**	**4.8**	**5.7**

Revised Table 9 from HMMH Report No. 304390 with minimum hourly L90 values measured at LT-1 and LT-2 at the cut-in wind speed of 4 m/s at the hub. Turbine noise emissions are 0.4 dB lower at 4 m/s compared with 6 m/s.

Table 9 Background and Computed Turbine Noise Levels at Measurement and Property-line Sites, with Wind Speed 3 m/s at 10m, 4 m/s at Hub

Site ID	Address	Nighttime Bkgrnd L90 (dBA)	Computed Turbine Leq (dBA)		Turbine Leq plus Bkgrnd (dBA)		Increase above Bkgrnd (dB)	
			Wind-1 alone	Wind-1 & Wind-2	Wind-1 alone	Wind-1 & Wind-2	Wind-1 alone	Wind-1 & Wind-2
LT-1	211 Blacksmith Shop Rd.	27.1	36.4	37.1	36.9	37.5	9.8	10.4
LT-2	124 Ambleside Drive	28.3	32.3	37.9	33.8	38.4	5.5	10.1
ST-1	161 Blacksmith Shop Rd.	28.3	33.3	34.7	34.5	35.6	6.2	7.3
ST-2	27 Ridgeview Street	28.3	35.0	37.5	35.8	38.0	7.5	9.7
ST-3	Research Rd & Thomas B Landers Rd.	27.1	25.5	30.3	29.4	32.0	2.3	4.9
ST-4	30 Durham Rd.	27.1	31.0	32.4	32.5	33.5	5.4	6.4
PL-1	South property line	27.1	36.8	37.6	37.2	38.0	10.1	10.9
PL-2	Prop. line west of Wind-1	28.3	36.2	39.3	36.9	39.6	8.6	11.3
PL-3	Prop. line west of Wind-2	28.3	34.0	43.3	35.0	43.4	6.7	15.1
PL-4	Northeast property line	27.1	28.1	32.3	30.6	33.4	3.5	6.3
PL-5	Southeast property line	27.1	34.1	35.1	34.9	35.7	7.8	8.6