ACOUSTIC STUDY OF THE UD / GAMESA WIND TURBINE PROJECT

LEWES, DELAWARE

January 2009

SUSTAINABLE ENERGY DEVELOPMENTS INC.

TECH environmental

FOCUSED KNOWLEDGE. REAL SOLUTIONS.

ACOUSTIC STUDY OF THE UNIVERSITY OF DELAWARE / GAMESA WIND TURBINE PROJECT LEWES, DELAWARE

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1.0 EXECUTIVE SUMMARY

The University of Delaware (UD), Lewes proposes to locate a Gamesa G90 2.0MW wind turbine on a parcel of land south of the UD College of Marine Studies. A study of the wind turbine sounds at nearby residential areas, at the Virden Conference Center, and at nearby UD campus buildings was performed. The Gamesa G90 will be on a tower with a hub height of 80 meters. The guaranteed sound power levels for this wind turbine are as follows: 94.8 dBA for the cut-in wind speed condition (hub heights winds at or above 4.2 m/s) and 108.4 dBA for the design wind condition (hub height winds at or above 9.7 m/s). Maximum sound power is first produced by the wind turbine at the design wind speed. The study's conclusions are as follows:

- When winds are sufficient to support turbine operation, existing L_{90}[1] ambient sound levels in the nearby residential and campus areas are in the range of 31 to 55 dBA. Existing L_{eq} average sound levels are in the range of 34 to 56 dBA.
- The maximum wind turbine sound level under design wind conditions at the closest residential receivers (Class A noise zone) is 44 dBA. The maximum wind turbine sound level under design wind conditions at the closest university receivers (Class B noise zone) are 43 dBA.
- The wind turbine Project fully complies with the Delaware Noise Regulations that set limits of 55 dBA and 75 dBA for the Class A and B noise zones, respectively, and limits the project sound level to no more than 10 dBA above the ambient level.
- The G90 wind turbine does not produce pure tones as defined in the Delaware Noise Regulations.

The acoustic modeling results are conservative due to the following assumptions:

1. All wind turbine sound power levels correspond to the IEC 64100-11 test values plus the IEC uncertainty level and approximate the vendor guaranteed maximum sound power levels.
2. The acoustic model assumed the most favorable conditions for sound propagation, corresponding to a ground-based temperature inversion, such as might occur on a calm, clear night or during a moderate (10 mph) downwind condition.
3. No attenuation from trees or other vegetation was assumed.
4. Winter frozen ground conditions were assumed for minimal ground absorption.

[1] The L_{90} sound level represents the quietest 10 percent of the time in any sampling interval.

2.0 COMMON MEASURES OF COMMUNITY SOUND

All sounds originate with a source – a human voice, vehicles on a roadway, or an airplane overhead. The sound energy moves from the source to a person's ears as sound waves, which are minute variations in air pressure. The loudness of a sound depends on the sound pressure level[2], which has units of decibel (dB). The decibel scale is logarithmic to accommodate the wide range of sound intensities to which the human ear is subjected. On this scale, the quietest sound we can hear is 0 dB, while the loudest is 120 dB. Every 10-dB increase is perceived as a doubling of loudness. Most sounds we hear in our daily lives have sound pressure levels in the range of 30 dB to 90 dB.

A property of the decibel scale is that the numerical values of two separate sounds do not directly add. For example, if a sound of 70 dB is added to another sound of 70 dB, the total is only a 3-decibel increase (or 73 dB) on the decibel scale, not a doubling to 140 dB. In terms of sound perception, 3 dB is the minimum change most people can detect. Table 1 describes the subjective effect of different changes in sound levels.

TABLE 1

SUBJECTIVE EFFECT OF CHANGES IN SOUND PRESSURE LEVELS

Change in Sound Level	Apparent Change in Loudness
3 dB	Just perceptible
5 dB	Noticeable
10 dB	Twice (or half) as loud

[2] The sound pressure level is defined as $20*\log_{10}(P/P_o)$ where P is the sound pressure and P_o is the reference pressure of 20 micro-Pascals (20 μPa), which by definition corresponds to 0 dB.

Sound exposure in a community is commonly expressed in terms of the A-weighted sound level (dBA); A-weighting approximates the frequency response of the human ear. Typical sound levels associated with various activities and environments are presented in Table 2.

Sound levels change from moment to moment. Some are sharp impulses lasting one second or less, while others rise and fall over much longer periods of time. There are various measures of sound pressure designed for different purposes. To establish the background ambient sound level in an area, the $\mathbf{L_{90}}$ metric, which is the sound level exceeded 90 percent of the time, is sometimes used. The $\mathbf{L_{90}}$ can be thought of as the level representing the quietest 10 percent interval of any time period. The $\mathbf{L_{eq}}$, or equivalent sound level, is the steady-state sound level over a period of time that has the same acoustic energy as the fluctuating sounds that actually occurred during that same period. It is commonly referred to as the average sound level. The $\mathbf{L_{max}}$, or maximum sound level, represents the $1/8^{th}$-second peak level recorded during a given time period.

Sound level measurements typically include an analysis of the sound spectrum into its various frequency components to determine tonal characteristics. The unit of frequency is Hertz (Hz), measuring the cycles per second of the sound pressure waves, and typically the frequency analysis examines nine octave bands from 32 Hz to 8,000 Hz. A source creates a pure tone, as defined by American National Standards Institute (ANSI) Standard S12.9, if acoustic energy is concentrated in a narrow frequency range and a 1/3-octave band has a sound level 5 to 15 dB greater than both adjacent bands (5 dB for high frequencies, 8 dB for middle frequencies, and 15 dB for low frequencies).

TABLE 2

COMMON INDOOR AND OUTDOOR SOUND PRESSURE LEVELS

Outdoor Sound Levels	Sound Pressure (μPa)	Sound Level (dBA)	Indoor Sound Levels
	6,324,555	110	Rock Band at 5 m
Jet Over-Flight at 300 m		105	
	2,000,000	100	Inside New York Subway Train
Gas Lawn Mower at 1 m		95	
	632,456	90	Food Blender at 1 m
Diesel Truck 60 mph at 15 m		85	
Noisy Urban Area--Daytime	200,000	80	Garbage Disposal at 1 m
		75	Shouting at 1 m
Automobile 45 mph at 15 m	63,246	70	Vacuum Cleaner at 3 m
Suburban Commercial Area		65	Normal Speech at 1 m
	20,000	60	
Quiet Urban Area--Daytime		55	Quiet Conversation at 1m
	6,325	50	Dishwasher Next Room
Quiet Urban Area--Nighttime		45	
	2,000	40	Empty Theater or Library
Quiet Suburb--Nighttime		35	
	632	30	Quiet Bedroom at Night
Quiet Rural Area--Nighttime		25	Empty Concert Hall
Rustling Leaves	200	20	Average Whisper
		15	Broadcast and Recording Studios
	63	10	
		5	Human Breathing
Reference Pressure Level	20	0	Threshold of Hearing

Notes: μPa, or micro-Pascals, describes sound pressure (force/area). dBA, or A-weighted decibels, describes sound the pressure level on a logarithmic scale with respect to 20 μPa (the reference pressure**).**

3.0 DELAWARE NOISE REGULATIONS

The Department of Natural Resources and Environmental Control administers the Delaware Noise Regulations (Part VII, 7 Del. C., Chapter 71), the full text for which is provided in Appendix A. Section 71-1-6.0.1 establishes a 24-hour L_{eq} limit for a new sound source that depends on the emitting and receiving noise zone. Class A noise zone includes single or multiple-family homes, hotels, or land intended for residential use. Class B noise zone includes colleges and universities, government lands, commercial and institutional uses, and agricultural lands. The proposed Gamesa G90 wind turbine is in a Class B noise zone and the nearest Class A receiving lands are residential areas to the northeast and two motel buildings next to the Virden Conference Center to the northeast. The nearest Class B receiving lands are the University of Delaware, Center of Marine Studies to the north and agricultural lands to the west and south. The L_{eq} sound limit for a Class A noise zone is 55 dBA, and that for Class B noise zone is 75 dBA.

Section 71-1-6.0.2 sets an incremental limit of 10 dBA above the ambient level for Class A noise zones. The ambient level is ambiguously defined in Section 71-1-3.0.1 as "the all-encompassing background noise associated with a given environment" without any time average specified. The term ambient level is elsewhere defined as the L_{90} sound level. Whereas the regulatory limit in Section 71-1-6.0.1 uses a 24-hour average, it is reasonable to assume that time interval applies to both regulatory limits, and thus the incremental limit for a new source is 10 dBA above the 24-hour L_{90} background level. For this study, the 24-hour ambient level was determined by averaging L_{90} measurements taken day and night at several locations in Class A and B noise zones during hours when winds were high enough to sustain wind turbine operation.

For the Gamesa G90 wind turbine examined in this report, operation occurs whenever the wind speed at the 78-meter hub height is greater than the turbine cut-in wind speed of 4.2 m/s. At the cut-in wind speed the G90 produces a guaranteed sound power level of 94.8 dBA (IEC 61400 test value of 92.8 dBA plus a 2-dBA uncertainty margin). The design wind speed is the hub height wind speed of 9.7 m/s and it is the lowest speed at which the maximum guaranteed sound power level of 108.4 dBA occurs (IEC 61400 test value of 106.4 dBA plus a 2-dBA uncertainty margin).

4.0 AMBIENT SOUND LEVEL AND WIND MEASUREMENTS

The Gamesa G90 2.0MW wind turbine will be located on land currently owned by the State of Delaware that is south of the University of Delaware (UD) College of Marine Studies; the land will be transferred to the University as part of this project. Figure 1 shows the four sound monitoring locations: 1) At the UD College of Marine Studies (Class B noise zone); 2) At the residential units next to the Virden Center (Class A noise zone); 3) Hoornkill Avenue residential area (Class A noise zone); and 4) Cedar Street residential area (Class A noise zone).

All sound level measurements were taken with a CEL Model 593 real-time sound level analyzer, equipped with precision condenser microphones having an operating range of 5 dB to 140 dB, and an overall frequency range of 3.5 to 20,000 Hz. This instrument meets or exceeds all requirements set forth in the American National Standards Institute (ANSI) Standards for Type 1 for quality and accuracy. Prior to and immediately following both measurement sessions, the sound analyzer was calibrated (no level adjustment was required) with an ANSI Type 1 calibrator which has an accuracy traceable to the National Institute of Standards and Technology (NIST). All instrumentation was laboratory calibrated per ANSI recommendations. For all measurement sessions, the microphone was fitted with an environmental windscreen to negate wind noise and mounted at a height of 1.3 meters above grade. Measurements were made away from any vertical reflecting surfaces in compliance with ANSI Standard S12.9.[3]

Sound level and wind measurements were made on Monday/Tuesday November 16/17, 2009. The skies were clear, the temperature ranged from 49-57^{o}F, and the winds at the surface were at the surface ranged from calm to 5-10 mph from the north. Audible sounds near the UD Marine Studies buildings (NSA 1) included an exhaust stack on the roof of the Cannon Laboratory, small compressors outside the west wall of the Cannon Laboratory and natural sounds such as crickets and birds. At the Virden Conference Center residential units (NSA 2), audible sounds were HVAC equipment on the south side of the conference center, the Cannon Laboratory building exhaust stack, wind in the trees, some local and distant traffic, and natural sounds such as crickets and birds.

[3] Acoustical Society of America, ANSI Standard S12.9-1997/Part 2, "Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of Long-Term Wind-Area Sound."

At the end of Hoornkill Avenue (NSA 3), audible sounds were the Cannon Laboratory building exhaust stack, distant traffic, wind in the trees, natural sounds such as birds and crickets, and sounds from nearby residents such as car doors closing, dogs barking, people talking, and light home construction. During the final monitoring session a brush clearing operation occurring to the west of the Smith Laboratory was also audible at the first three monitoring locations. On Cedar Street (NSA 4), audible sound were waves crashing along the beach, local and distant traffic, wind in the trees and grass, and natural sounds such as crickets and birds.

Ten-minute average wind speeds were obtained from the 50-m instruments on the project's meteorological tower and extrapolated to the hub height using the wind profile law. A minimum of three 10-minute sound level measurements were made at each monitoring location, both day and night. The sound and wind speed data are provided in Tables B-1 through B-4 in Appendix B and are categorized by whether the winds were strong enough to support cut-in or design speed operation of the wind turbine. The L_{90} and L_{eq} sound levels for day and night were combined to form 24-hour average sound levels at each monitoring location. A summary of existing sound levels is presented in Table 3.

TABLE 3

SUMMARY OF EXISTING SOUND LEVELS

Sound Monitoring Location	24-Hour Average L_{90} (dBA)	24-Hour Average L_{eq} (dBA)	Range of L_{90} (dBA)	Range of L_{eq} (dBA)
UD College of Marine Studies	53.4	54.7	51-55	52-56
Virden Center Residential Units	44.2	46.1	36-47	38-49
Hoornkill Avenue Residences	37.4	39.5	32-40	34-42
Cedar Street Residences	40.6	52.1	36-49	46-55

The sound monitoring data in Table 3 reveal that during periods when the turbine will operate the existing L_{eq} average sound levels range from 34 to 56 dBA, levels typical of a suburban area. The existing L_{90} (quietest 10% of the time) sound levels range from 31 to 55 dBA. The Delaware Noise Regulations set a sound limit for the wind turbine of 10 dBA above the 24-hour L_{90} ambient levels, which are listed in the first column of Table 3.

FIGURE 1.

Sound Monitoring and Potential Turbine Locations
Lewes, Delaware

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5.0 CALCULATED FUTURE SOUND LEVELS

5.1 Methodology

Future sound levels from the UD/Gamesa wind turbine were calculated with the Cadna/A acoustic model. Cadna/A is a sophisticated 3-D model for sound propagation and attenuation based on International Standard ISO 9613[4]. Atmospheric absorption, the process by which sound energy is absorbed by the air, was calculated using ANSI S1.26-1995.[5] Absorption of sound assumed standard day conditions and is significant at large distances. Ground surfaces were assumed to be mixed ground consisting of both hard and porous (vegetated) surfaces.[6] This is a reasonable worst-case assumption and approximates winter frozen ground conditions in the area between the turbine and the nearest residences. United States Geological Survey (USGS) 30-meter (7.5 minute) ASCII Digital Elevation Models were utilized to obtain terrain heights. The model assumes favorable sound propagation, as occurs under downwind conditions or a ground-based temperature inversion, such as might occur on a clear night. At other times, atmospheric turbulence and wind shadow effects will reduce sound levels by 5 to 20 dBA from those presented below.

5.2 Results and Conclusions

Figures 2 and 3 show color-coded decibel contours (5 feet above ground level) for the operation of the wind turbine in cut-in wind speed and design wind speed conditions, respectively. Note that Figures 2 and 3 present a composite worst-case in which all locations are simultaneously downwind of the wind turbine. The broadband acoustic modeling results are summarized in Tables 4 and 5 for the cut-in wind speed and design wind speed operating conditions. The Gamesa wind turbine will not create a pure tone condition, as defined in the Delaware Noise Regulations.

Maximum project sound levels at the Class A receivers are 36.9 to 44.4 dBA and in compliance with the Delaware Noise Regulation limit of 55 dBA. The maximum project sound level at the nearest

[4] International Standard, ISO 9613-2, Acoustics – Attenuation of Sound During Propagation Outdoors, -- Part 2 General Method of Calculation.

[5] American National Standards Institute, ANSI S1.26-1995, American National Standard Method for the Calculation of the Absorption of Sound by the Atmosphere, 1995.

[6] Ground absorption factor G set equal to 0.5 in Cadna-A.

Class B receiver is 43.2 dBA and in compliance with the Delaware Noise Regulation limit of 75 dBA. Tables 4 and 5 reveal that all project sound levels are in compliance with the 10 dBA incremental limit in the Delaware Noise Regulations.

In conclusion, the proposed Gamesa G90 wind turbine at the University of Delaware Lewes campus fully complies with the Delaware Noise Regulations.

TABLE 4

DELAWARE NOISE REGULATION COMPLIANCE FOR THE CUT-IN WIND SPEED OPERATING CONDITION (dBA)

Residential Location (Land Use Zone)	Maximum Project Sound	Sound Limit	Ambient L_{90} Level	Project Sound Exceeds Ambient By
UD College of Marine Studies	29.6	55	53.4	0.0
Virden Center Residential Units	30.8	75	44.2	0.0
Hoornkill Avenue Residences	24.6	55	37.4	0.0
Cedar Street Residences	23.3	55	40.6	0.0

Note: Delaware Noise Regulations limit the Project Sound Level to no more than 10 dBA above the Ambient Level.

TABLE 5

DELAWARE NOISE REGULATION COMPLIANCE FOR THE DESIGN WIND SPEED OPERATING CONDITION (dBA)

Residential Location (Land Use Zone)	Maximum Project Sound	Sound Limit	Ambient L_{90} Level	Project Sound Exceeds Ambient By
UD College of Marine Studies	43.2	55	53.4	0.0
Virden Center Residential Units	44.4	75	44.2	0.2
Hoornkill Avenue Residences	38.2	55	37.4	0.8
Cedar Street Residences	36.9	55	40.6	0.0

Note: Delaware Noise Regulations limit the Project Sound Level to no more than 10 dBA above the Ambient Level.

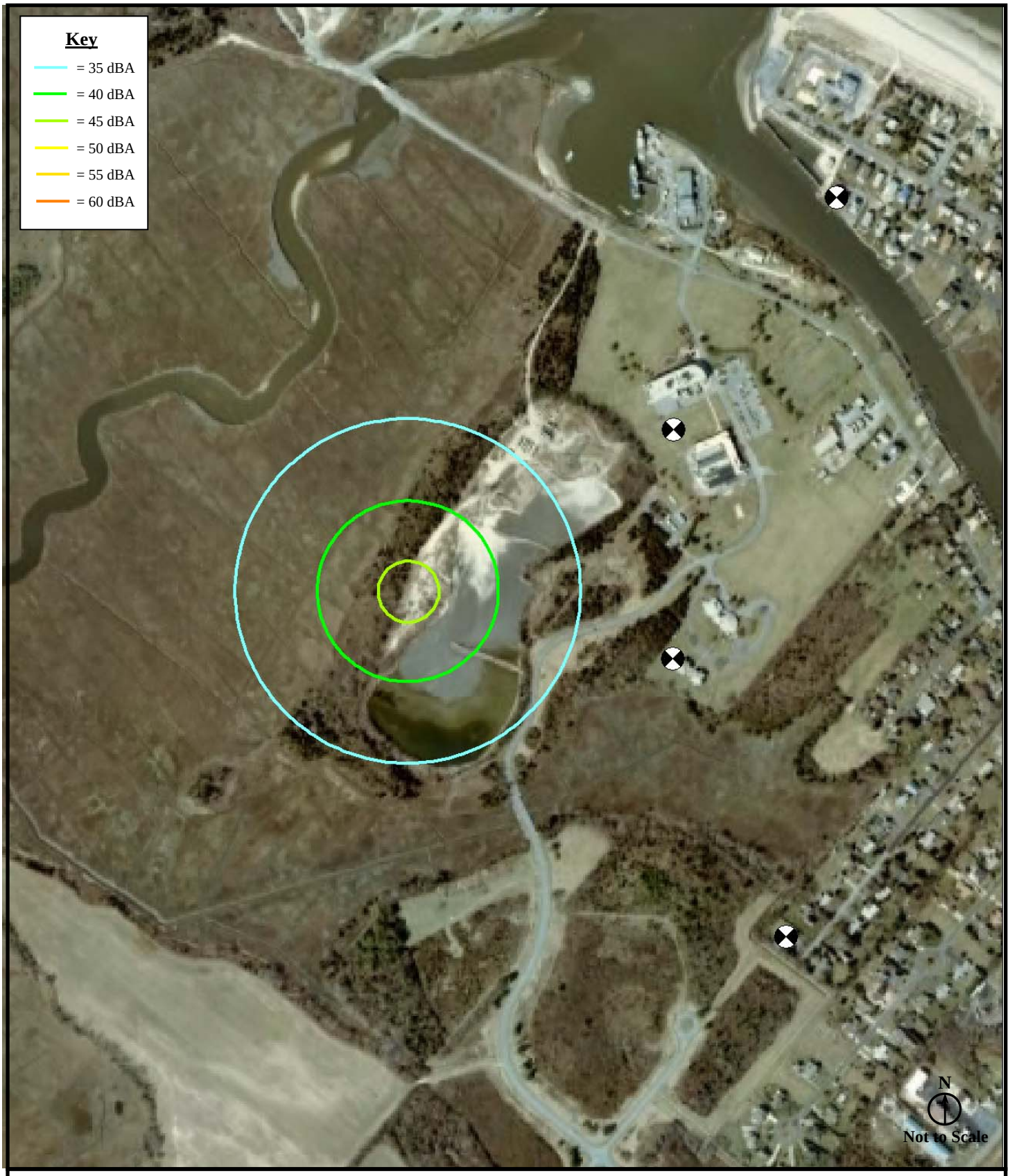

FIGURE 2.

Sound Level Impacts – Cut-In Speed
Lewes, Delaware

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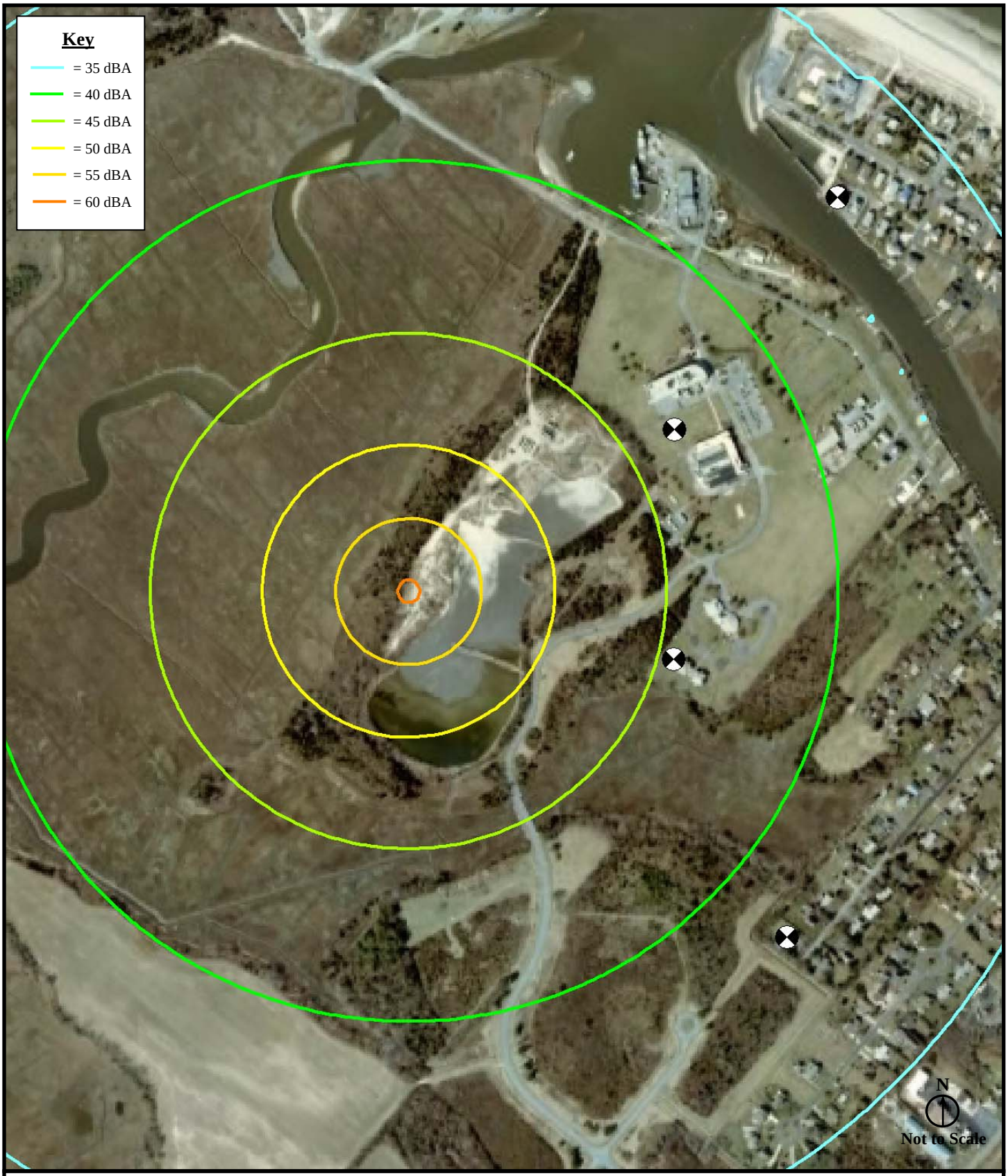

FIGURE 3.

Sound Level Impacts – Design Speed
Lewes, Delaware

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APPENDIX A

DELAWARE NOISE REGULATION

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF ENVIRONMENTAL CONTROL
AIR RESOURCES SECTION
EDWARD TATNALL BUILDING
PO Box 1401
DOVER, DELAWARE 19901

TELEPHONE (302) 736 - 4791

Pursuant to Provisions of
Part VII, 7 Del. C., Chapter 71, Section 7105
Regulations Governing the Control of Noise
Per 0rder No. 82-A-2 of January 20, 1982
As Amended July 8, 1982

Sec. 71-I-1 Short Title

These regulations may be cited as the "Noise Regulations of the State of Delaware".

Sec. 71-I-2 Scope

Pursuant to the provisions of Part VII, Title 7, Chapter 71 of the Delaware Code, these regulations are to prevent, prohibit and provide for the abatement of excess and unnecessary noise and/or vibration which may endanger the health, safety and welfare, jeopardize the value of property and erode the integrity of the environment of the people of this state.

Sec. 71-I-3 Definitions

3.0.1 "Ambient Noise" means the all-encompassing background noise associated with a given environment without the sound contribution of the specific source in question.

3.0.2 "A-Weighted Sound Level" means the sound pressure level in decibels as measured with a sound level meter using the A-weighting network, which compensates for human hearing characteristics. The level so read is designated dB(A) or dBA.

3.0.3 "Best Practical Noise Control Measures" means noise control devices, technology, and procedures determined or approved by the Secretary to be the best practical, taking into consideration the age of the equipment and facilities involved, the process employed, capital expenditures, maintenance cost, technical feasibility and the engineering aspects of the applicable noise control techniques in relation to the control achieved and the non-noise control environmental impact.

REGULATIONS GOVERNING THE CONTROL 0F NOISE - page two

3.0.4 "Commercial Area" means land used for purposes such as retail sales, personal services, civic centers, hotels, offices and office buildings, wholesale and warehouse storage.

3.0.5 "Construction" means any site preparation, assembly, erection, placement, demolition, substantial repair, alteration or similar action for public or private rights-of-way, structures, utilities or similar property.

3.0.6 "Day" means the hours between 7:00 a.m. and 10:00 p.m.

3.0.7 "Day-Night Average Sound Level (Ldn)"means the 24-hour energy average of the A-weighted sound pressure level, with the levels during the period 10:00 p.m. to 7 a.m. weighted by 10 dBA before averaging.

3.0.8 "Decibel (dB)" means a standard unit for measuring the sound pressure level. It is equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to a reference pressure, which is 20 micropascals.

3.0.9 "Emergency" means any occurrence or set of circumstances involving actual or imminent physical trauma or property damage which demands immediate actions.

3.0.10 "Equivalent A-Weighted Sound Level, abbreviated Leq (x)dB(A), means the constant sound level that, in a given situation and time period (x),contains the same sound energy as the actual time-varying A-weighted sound.

3.0.11 "Farm Vehicle" means a wheeled device used for transportation in farming operations.

3.0.12 "Hertz (Hz) means a unit of measurement of frequency formerly stated as, and numerically equal to, cycles per second.

3.0.13 "Impulse Sound" means sound of sshort duration, much less than one second, with an abrupt onset and rapid decay, separated in time by at least one second.

3.0.14 "Industrial Area" means land used for purposes such as publishing, research, development, testing, manufacturing, processing, fabricating or repairing, and may include residential land use, for a caretaker, watchman or janitor.

3.0.15 "Infrasonic Sound" means sound pressure levels having frequencies below16 Hz.

3.0.16 "Intrusion Alarm" means a device with an audible signal which, when activated, indicates intrusion by an unauthorized person.

REGULATIONS GOVERNING THE CONTROL 0F NOISE - page three

3.0.17 "Intrusive Noise" means unwanted sound which intrudes over and above the existing noise at a given location. The relative intrusiveness of the sound depends upon its amplitude, duration, frequency, time of occurrence and tonal or informational content as well as the prevailing ambient noise level. A sound pressure level of 3 dB(A) above the ambient level is normally just discernable, with levels of 5 dB(A) to10 dB(A) the lower level region for complaints.

3.0.18 "Motorboat" means any vessel which operates on water and is propelled by machinery.

3.0.19 "Night" means the hours between 10:00 p.m. and 7:00 a.m.

3.0.20 "Noise" means any sound which annoys or disturbs humans or which causes or tends to cause an adverse psychological or physiological effect on humans, excluding all aspects of noise regulated by the Federal occupational Safety and Health Act.

3.0.21 "Noise Disturbance" means any sound which (a) endangers or injures the safety or health of humans or animals, or (b) ' annoys or disturbs a reasonable person of normal sensitivities, or (c) jeopardizes the value of property and erodes the integrity of the environment. Compliance with Sec. 71-I-6 herein shall constitute elimination of a noise disturbance.

3.0.22 "0ctave" means the interval embracing eight diatonic degrees between two sounds having a basic frequency ratio of two. (0ne unit of the musical scale).

3.0.23 "Percentile Level" means the sound levels exceeded for the percentage of time in any measured period. L10, L50 and L90, the levels exceeded for 10%, 50% and 90% of the time, are frequently used as measures of peak, average and ambient levels respectively.

3.0.24 "Person" means any individual(s), corporation, company, association, society, firm, partnership or joint stock company, and includes the State and all of its political subdivisions, agencies and instrumentalities as well as any department, board or agency of the government of the United States.

3.0.25 "Pure Tone" means any sound which can be distinctly heard as a single pitch or a set of single pitches. For the purpose of this section, a pure tone shall exist if the one-third octave band sound pressure level in the band with the tone exceeds the arithmetic average of the sound pressure levels of the two contiguous one-third octave bands by 15 dB for bands with center frequencies less than 160 Hz, by 8 dB for bands with center frequencies of 160 Hz to 400 Hz, and by 5 dB for bands with center frequencies greater than 400 Hz.

REGULATIONS GOVERNING THE CONTROL 0F NOISE - page four

3.0.26 "Real Property Boundary" means an imaginary line along the ground surface, and its vertical extension, which separates the real property owned by one person from that owned by another person, but not including intra-building real property divisions.

3.0.27 "Residential Area" means land used for the primary purpose of providing human living accommodations.

3.0.28 "Secretary" means the Secretary of the Department of Natural Resources and Environmental Control.

3.0.29 "Sound" means an oscillation in pressure, particle displacement, particle velocity or other phyysical parameters, in a medium with internal forces that causes compression and rarefaction of that medium. The description of sound may include any characteristic of such sound, including duration, intensity and frequency.

3.0.30 "Sound Amplifying Equipment" means any device for increasing the magnitude of the human voice, music or other sound.

3.0.31 "Sound Level" means the sound pressure level (SPL) obtained by the use of a sound level meter and frequency weighting network, such as A, B or C as specified in American National Standards Institute specifications for sound level meters (ANSI Sl.4-1971, or the latest approved revision thereof). The unit of measurement is the decibel. If the frequency weighting employed is not indicated, the A-weighting shall apply.

3.0.32 "Sound Pressure" means the instantaneous difference between the actual pressure and the average or barometric pressure at a given point in space, as produced by sound energy.

3.0.33 "Stationary Noise Source" means a device which creates sound while fixed in position, including but not limited to residential, commercial or industrial machinery, pumps, fans, compressors, air conditioners and refrigeration equipment.

3.0.34 "Ultrasonic Sound" means sound pressure levels above 20,000 Hz. having frequencies

3.0.35 "Vibration" means an oscillatory motion of solid bodies of deterministic or random nature described by displacement, velocity, or acceleration with respect to a reference point, such that;

Peak

v = 2Àf d where v = Velocity, f = Frequency and d = Displacement

a = 2Àf v where a = Acceleration Amplitude

3.0.36 "Weekday" means any day Monday through Friday which is not a legal holiday.

REGULATIONS GOVERNING THE CONTROL 0F NOISE - page five

Sec. 71-1-4 Prohibited Acts

4.0.1 Noise Disturbance Prohibited - No person shall make, continue, or cause to be made or continued, any noise disturbance. Non-commercial public speaking and public assembly activities conducted on any public space or public right-of-way shall be exempt from this section provided they conform to all local ordinances.

4.0.2 Specific Prohibitions

(1) Radios, Television Sets, Musical Instruments and Similar

Devices - 0perating, playing or permitting the operation or playing of any radio, television, phonograph, drum, musical instrument, sound amplifier, automobile radio, automobile stereo or high fidelity equipment or similar device which produces, reproduces or amplifies sound:

(a) In such a manner as to create a noise disturbance within a receiving property.

(b) In such a manner as to create a noise disturbance within any receiving property when operated in or on a motor vehicle on a public right-of-way or public space, or in a boat on public waters.

(c) In such a manner as to create a noise disturbance to any person other than the operator of the device, when operated by any passenger on a common carrier.

(2) Animals and Birds - 0wning, possessing, harboring or controlling any animal or bird which barks, bays, cries, squawks or makes any other noise continuously or incessantly for a period of ten minutes or makes such noise intermittently for one-half hour or more causing a noise disturbance within a receiving property; provided, however, that at the time the animal or bird is making such noise no person is trespassing or threatening to trespass upon private property in or upon which the animal or bird is situated or for any other legitimate cause which teased or provoked the animal or bird.

REGULATIONS GOVERNING THE CONTROL 0F NOISE - page six

(3) Loading or Unloading - Loading, unloading, opening, closing, or other handling of boxes, crates, containers, building materials, garbage cans, or similar objects between the hours of 10:00 p.m. and 7:00 a.m. the following day in such a manner as to cause a noise disturbance within a Class A receiving property. This section shall not apply during an emergency.

(4) Construction - 0perating or permitting the operation of any tools or equipment used in construction, drilling, or demolition work:

(a) Between the hours of 10:00 p.m. and 7:00 a.m. the following day, on weekdays and Saturdays, or at any time on Sundays or holidays, such that the sound therefrom creates a noise disturbance within a Class A receiving property, except during an emergency.

(b) At any other time such that the sound level within any receiving property exceeds an Leq of 85 dBA for a period of one hour.

(c) This section shall not apply to the use of domestic power tools subject to Section 4.0.2(8).

(5) Vehicle, Motorboat, or Aircraft Repairs and Testing - Repairing, rebuilding, or testing any motor vehicle, motorcycle, motorboat, or aircraft in such a manner as to cause a noise disturbance within a Class A receiving property between the hours of10 p.m. and 7 a.m.

(6) Places of Public Entertainment - 0perating, playing, or permitting the operation or playing of any radio, television, phonograph, drum, musical instrument, sound amplifier or any other device which produces, reproduces, or amplifies sound within any place of public entertainment at a sound level greater than 85 dB(A) as read by the slow response on a sound level meter at any point that is normally occupied by a customer unless a conspicuous and legible sign is located outside such place, near each public entrance stating "WARNING: SOUND LEVELS WITHIN MAY CAUSE PERMANENT HEARING IMPAIRMENT". All places of public entertainment shall also be required to comply with all of the provisions of this Regulation, specifically Section 6.

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(7) Explosives, Firearms, and Similar Devices - The use or firing of explosives, firearms, or similar devices which create impulsive sound so as to cause a noise disturbance within a Class A receiving property or on a public right-of-way, except for licensed game-hunting activities on property where such activities are authorized.

(8) Domestic Power Tools - 0perating or permitting the operation of any mechanically powered saw, drill, sander, grinder, lawn or garden tool, snowblower, or similar device in residential areas between the hours of 10:00 p.m. and 7:00 a.m. so as to cause a noise disturbance within a Class A receiving property.

(9) Tampering

(a) No person shall operate any equipment unless all noise and/or vibration control devices installed hereon are in full operation.

(b) No person shall tamper with, circumvent or remove any sound level monitoring instrument, meter or device positioned by or for the Department.

(c) No person shall remove or deface a noise label on any product.

4.0.3 Motor Vehicle Prohibitions.

(1) Motor Vehicle and motorcycles on Public Rights-of-Way.

No person shall operate or cause to be operated a public or private motor vehicle or motorcycle, or any equipment attached to such a vehicle, on a public right-of-way at any time in such a manner that the sound level emitted by the motor vehicle or motorcycle, or any equipment attached to such a vehicle, exceeds the level set forth in Title 7, Chapter 71, Subchapter II, Delaware Motor Vehicle Noise Regulations.

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(2) Standing Motor Vehicles and Motorcycles - No person shall operate or permit the operation of any motor vehicle, motorcycle, or any auxiliary equipment attached to such a vehicle in such a way as to cause a noise disturbance within a Class A receiving property, for a period longer than twenty minutes in any hour while the vehicle is stationary, for reasons other than traffic congestion. (Also see Sec. 71-I-4.02 (3) Loading or Unloading).

(3) Unnecessary Horn Blowing - No person shall at any time sound the horn or other warning device of a vehicle in such a way as to cause a noise disturbance within a Class A receiving property except when absolutely necessary as a warning while actually driving such vehicle. Sec. 71-1-5 Classification of Land According to Use

5.01 Class A noise zone

Lands designated Class A shall generally be residential areas where human beings sleep or areas where serenity and tranquility are essential to the intended use of the land.

The land uses, in this category shall include, but not be limited to, single and multiple family homes, hotels, prisons, hospitals, religious facilities, cultural activities, forest preserves, and land intended for residential or special uses requiring such protection.

5.0.2 Class B noise zone

Lands designated Class B shall generally be commercial in nature, areas where human beings converse and such conversation is essential to the intended use of the land.

The land uses in this category shall include, but not be limited to, retail trade, personal, business and legal services, educational institutions, government services, amusements, agricultural activities, and lands intended for such commercial or institutional uses.

5.0.3 Class C noise zone

Lands designated Class C shall generally be industrial where protection against damage to hearing is essential, and the necessity for conversation is limited.

The land uses in this category shall include, but not be limited to, manufacturing activities, transportation facilities, warehousing, military bases, mining, and other lands intended for such uses.

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5.0.4 Mixed Class Noise Zone

Good land planning arranges for Class A zones to be buffered from Class C zones by a Class B zone. Some areas are mixed zones in practice, wherein Class C land uses abut, adjoin or include Class A use. Whenever this situation comes to the attention of the Department, the person responsible for the objectionable noise source shall make every effort to conform with Section 71-1-6. A final acceptable noise limit shall be determined by the Secretary based on Best Practical Noise Control Measures.

Sec. 71-1-6 Maximum Noise and Vibration Limits

6.0.1 No person(s) shall operate or cause to be operated any stationary source of sound in such a manner as to create a 24-hour equivalent A-weiqhted sound level which exceeds the Leq limits set forth for the receiving land use category in Table I when measured at the point of complaint origination within the property boundary of the receiving land use. Any excedence of these values shall constitute a noise disturbance.

Table I Sound Levels by Receiving Land Use Zones, Leq (24) dBA

Emitter(s)	Receptor-C	Receptor-B	Receptor A 7 a.m. - 10 p.m.	Receptor A 10 p.m. - 7a.m.
A	65	65	65	55
B	75	75	65	55
C	85	75	65	55

6.0.2 INTRUSIVE NOISE LEVEL

NOT WITHSTANDING THE PROVISIONS 0F SECTION 6.0.1 A SOURCE

SHALL BE CONSIDERED T0 CAUSE A NOISE DISTURBANCE IF THE SOUND

LEVEL, OTHER THAN AN IMPULSE, INFRASONIC 0R ULTRASONIC SOUND,

EMITTED BY SUCH SOURCE EXCEEDS THE AMBIENT NOISE LEVEL BY 10

dBA WHEN MEASURED AT THE POINT 0F C0MPLAINT ORIGINATION WITHIN THE RECEIVING PROPERTY.

Note: The relative intrusiveness of sound depends upon its amplitude, duration, frequency, time of occurrence and tonal or informational content as well as the prevailing ambient noise level. A sound pressure level of 3 dB(A) above the ambient level is normally just discernable, with levels of 5 dB(A) to 10 dB(A) the lower level region for complaints.

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6.0.3 Correction for Character of Sound

For any stationary source of sound which emits a pure tone, cyclically varying sound or repetitive impulse sound, the limits set forth in Sec. 71-I-6 shall be reduced by 5 dBA.

6.0.4 Impulse Peak Limit

For any source of sound which emits an impulse (duration less than one second with an abrupt onset and rapid decay) including metal to metal impacts or exploding impacts, shall not exceed the peak levels set forth below when measured at the point of complaint origination within the receiving property.

Class A zone Nighttime ---------- 80 dB

Anytime Any Zone except the above ---------- 100 dB

6.0.5 Infrasonic and Ultrasonic Peak Limit

For any source of sound which emits infrasound (below 16 Hertz) or ultrasound (above 20 kHz) frequencies, the sound pressure level shall not exceed 100 dB when measured at the point of complaint origination within the receiving property.

6.1.0 Maximum Permissible Vibration Levels

No person shall operate or cause to be operated any single vibration source or combination of sources in such a manner as to cause vibration levels in excess of those set forth below as measured at the point of complaint origination within the boundary of the receiving property.

a) Class A Zone Stationary Source --- Velocity of 0,15 inch per second

b) Class A Zone Temporary or Mobile Source --- Velocity of 0.7 inch per second

c) Class B Zone --- Velocity of 0.7 inch per second

d) Any Zone under any condition --- Velocity of 3 inches per second. (Caution level for structure damage)

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Sec. 71-I-7 Exceptions.

Exempted from these regulations are:

7.0.1 FAA Controlled 0perations - Noise directly caused by aircraft flight operations specifically preempted by the Federal Aviation Administration.

7.0.2 Recreational, Sports and Musical Activities - Noise created by the use of property for the purposes of recreational, sports or musical activities, provided such exemption is effective only during the specific period of time authorized by the political subdivision or government entity having lawful jurisdiction to sanction such use.

7.0.3 Emergencies - Noise created as a result of, or related to, an emergency, including (a) the emission of sound for the purpose of alerting persons to the existence of an emergency, or (b) the emission of sound in the performance of emergency work.

7.0.4 Emergency Signaling Device Tests -

(a) Testing of emergency signaling devices the same time of day each time such tests are performed, using a minimum cycle test time.

(b) Testing of the complete emergency signaling system, including the function of signaling devices and the personnel response to the signal, shall not occur more than once in each calendar month.

7.0.5 Religious Activities - Sounds created by bells, carillons or chimes associated with religious observances.

7.0.6 Public Celebrations - Patriotic or public celebrations not extending more than one day or as authorized by the public subdivision or government entity empowered to sanction such activity.

7.0.7 Farm - All farm vehicles are exempt while engaged in farming operations.

7.0.8 The Unamplified Human Voice - including children at schools, playgrounds, etc.

7.0.9 Interstate Railway Locomotives and Rail Cars - Noise directly caused by railway operations specifically preempted by the Federal Government.

Sec. 71-1-8 Validity of Regulations

If any section or subsection of these regulations is found invalid the remainder shall continue to be valid and enforceable.

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APPENDIX B

MEASURED SOUND LEVEL AND WIND DATA

TABLE B-1

MEASURED AMBIENT SOUND LEVELS AND MEASURED WIND SPEEDS AT THE UD COLLEGE OF MARINE STUDIES

Date	Starting Time (EST)	10-Min. L_{90} Sound Level (dBA)	10-Min. L_{eq} Sound Level (dBA)	10-Min. Average Wind Speed at 80 m Hub Height (m/s)
11/16/2009	17:16	51.0	52.3	**6.2**
11/16/2009	17:26	51.0	51.9	**5.5**
11/16/2009	17:36	51.0	56.3	**4.9**
11/17/2009	0:15	52.0	52.7	**6.5**
11/17/2009	0:25	52.0	52.7	**7.2**
11/17/2009	0:35	52.0	52.8	**8.3**
11/17/2009	9:24	55.0	56.4	**7.5**
11/17/2009	9:34	55.0	56.4	**6.9**
11/17/2009	9:44	55.0	56.4	**5.8**

Wind speeds in bold are at or above the cut-in speed of 4.2 m/s. Wind speeds in bold and italics are at or above the design wind speed of 9.7 m/s.

TABLE B-2

MEASURED AMBIENT SOUND LEVELS AND MEASURED WIND SPEEDS AT THE VIRDEN CONFERENCE CENTER

Date	Starting Time (EST)	10-Min. L_{90} Sound Level (dBA)	10-Min. L_{eq} Sound Level (dBA)	10-Min. Average Wind Speed at 80 m Hub Height (m/s)
11/16/2009	17:54	36.0	37.9	**4.9**
11/16/2009	18:04	36.0	37.6	4.1
11/16/2009	18:14	36.0	37.3	3.9
11/17/2009	0:49	39.0	41.5	**8.2**
11/17/2009	0:59	40.0	41.1	**7.4**
11/17/2009	1:09	39.0	40.8	**7.3**
11/17/2009	9:57	47.0	48.5	**8.8**
11/17/2009	10:07	48.0	49.0	**9.0**
11/17/2009	10:17	47.0	49.1	**9.4**

Wind speeds in bold are at or above the cut-in speed of 4.2 m/s. Wind speeds in bold and italics are at or above the design wind speed of 9.7 m/s.

TABLE B-3

MEASURED AMBIENT SOUND LEVELS AND MEASURED WIND SPEEDS AT THE HOORNKILL AVENUE RESIDENTIAL AREA

Date	Starting Time (EST)	10-Min. L_{90} Sound Level (dBA)	10-Min. L_{eq} Sound Level (dBA)	10-Min. Average Wind Speed at 80 m Hub Height (m/s)
11/16/2009	18:30	32.0	34.5	**4.2**
11/16/2009	18:40	32.0	34.2	3.9
11/16/2009	18:50	31.0	35.4	3.4
11/17/2009	1:25	32.0	33.3	**7.4**
11/17/2009	1:35	32.0	33.5	**7.9**
11/17/2009	1:45	32.0	34.1	**8.0**
11/17/2009	10:33	40.0	41.9	**8.9**
11/17/2009	10:43	41.0	42.6	**8.7**
11/17/2009	10:53	39.0	41.8	**8.9**

Wind speeds in bold are at or above the cut-in speed of 4.2 m/s. Wind speeds in bold and italics are at or above the design wind speed of 9.7 m/s.

TABLE B-4

MEASURED AMBIENT SOUND LEVELS AND MEASURED WIND SPEEDS AT THE CEDAR STREET RESIDENTIAL AREA

Date	Starting Time (EST)	10-Min. L_{90} Sound Level (dBA)	10-Min. L_{eq} Sound Level (dBA)	10-Min. Average Wind Speed at 80 m Hub Height (m/s)
11/16/2009	19:13	35.0	39.9	4.1
11/16/2009	19:23	36.0	38.6	4.1
11/16/2009	19:33	37.0	50.5	3.8
11/17/2009	2:05	45.0	46.3	**8.8**
11/17/2009	2:15	45.0	46.3	**8.7**
11/17/2009	2:25	45.0	46.8	**9.2**
11/17/2009	11:17	49.0	55.7	***10.4***
11/17/2009	11:27	49.0	51.7	***10.8***
11/17/2009	11:37	49.0	55.8	**9.1**

Wind speeds in bold are at or above the cut-in speed of 4.2 m/s. Wind speeds in bold and italics are at or above the design wind speed of 9.7 m/s.