CHAPTER 3
NOISE FUNDAMENTALS

While a great deal is known about aircraft noise, the methods used to calculate noise exposure can be difficult to understand. Determining aircraft noise impacts involves logarithmic averages and the noise energy from single events. In 14 CFR Part 150, the FAA-required primary metric for assessing aircraft noise exposure is the Day-Night Average Sound Level (DNL). The DNL combines the noise energy from all aircraft noise events occurring in one day into a 24-hour average sound level and applies a penalty to nighttime events, between the hours of 10:00:00 pm and 6:59:59 am, when people are more negatively affected by unwanted sound and more susceptible to noise impacts. This section of the report will go into detail on what noise is, what metrics exist (including DNL) to measure noise exposure, and how certain metrics relate to one another.

3.1 CHARACTERISTICS OF SOUND

3.1.1 Amplitude and Frequency

Sound can be technically described in terms of its sound pressure (amplitude) and frequency (similar to pitch).

Amplitude is a direct measure of the magnitude, or loudness, of a sound without consideration for other factors that may influence its perception. The ranges of sound pressures that occur in the environment are so large that they are expressed on a logarithmic scale. The standard unit of measurement of sound is the decibel (dB). A sound pressure level in dB describes the pressure of a sound relative to a reference pressure. By using a logarithmic scale, the wide range in sound pressures is compressed to a more usable range of numbers.

For example, a sound level of 70 dB has 10 times as much acoustic energy as a level of 60 dB; while a sound level of 80 dB has 100 times as much acoustic energy as a level of 60 dB. In terms of human response to noise, the perception is very different. A sound 10 dB higher than another sound is usually judged to be twice as loud; 20 dB higher four times as loud; and so forth.

The frequency of sound is expressed as Hertz (Hz) or cycles per second. The normal audible frequency range for young adults is 20 Hz to 20,000 Hz. The prominent frequency range for community noise, including aircraft and motor vehicles, is between 50 Hz and 5,000 Hz. The human ear is not equally sensitive to all frequencies, with some frequencies judged to be louder for a given signal than others. As a result, research studies have analyzed how individuals make relative judgments as to the “loudness” or “annoyance” to a sound. The most prominent of these scales include Loudness Level, Frequency-Weighted Contours (such as the A-weighted scale), and Perceived Noise Level. Noise metrics used in aircraft noise assessments are based upon these frequency weighting scales, which are discussed in the following paragraphs.

3.1.2 Loudness Level

This scale has been devised to approximate the human subjective assessment to the “loudness” of a sound. Loudness is the subjective judgment of an individual as to how loud or quiet a particular sound is perceived. This sensitivity difference varies for different sound pressure levels.

3.1.3 Frequency-Weighted Contours (dBA, dBB and dBC)

In order to simplify the measurement and computation of sound loudness levels, frequency-weighted networks have obtained wide acceptance. The equal loudness level contours for 40 dB, 70 dB, and 100 dB have been selected to represent human frequency response to low, medium, and loud sound levels. By inverting these equal loudness level contours, the A-weighted, B-weighted, and C-weighted frequency weightings were developed. **Figure 3-1** presents these frequency-weighted contours.

The most common weighting is the A-weighted noise curve. The A-weighted decibel scale (dBA) performs this compensation by discriminating against frequencies in a manner approximating the sensitivity of the human ear. In the A-weighted decibel, everyday sounds normally range from 30 dBA (very quiet) to 100 dBA (very loud). Most community noise analyses are based upon the A-weighted decibel scale. **Figure 3-2** presents examples of various sound environments expressed in dBA.

Some interest has developed by communities close to some airports in utilizing a noise curve other than A-weighting for lower frequency noise sources. For example, the C-weighted curve is used for the analysis of the noise impacts from artillery noise. For evaluation of aircraft noise, A-weighting is used because the majority of noise associated with aircraft operations is better suited to the A-weighting; no mitigation methods have been proven to be effective for C-weighted noise (i.e., sound insulation), which is the minority portion of the noise associated with aircraft operations.

3.1.4 Perceived Noise Level

Perceived noisiness is another method of rating sound. It was originally developed for the assessment of aircraft noise. Perceived noisiness is defined as “the subjective impression of the unwantedness of a not-unexpected, nonpain, or fear-provoking sound as part of one’s environment,” (Kryter, 1970). “Noisiness” curves differ from “loudness curves” in that they have been developed to rate the noisiness or annoyance of a sound as opposed to the loudness of a sound.

As with loudness curves, noisiness curves have been developed from laboratory psychoacoustic surveys of individuals. However, in noisiness surveys, individuals are asked to judge in a laboratory setting when two sounds are equally noisy or disturbing if heard regularly in their own environment. These surveys are more complex and are, therefore, subject to greater variability.

FIGURE 3-1
FREQUENCY WEIGHTED CURVES

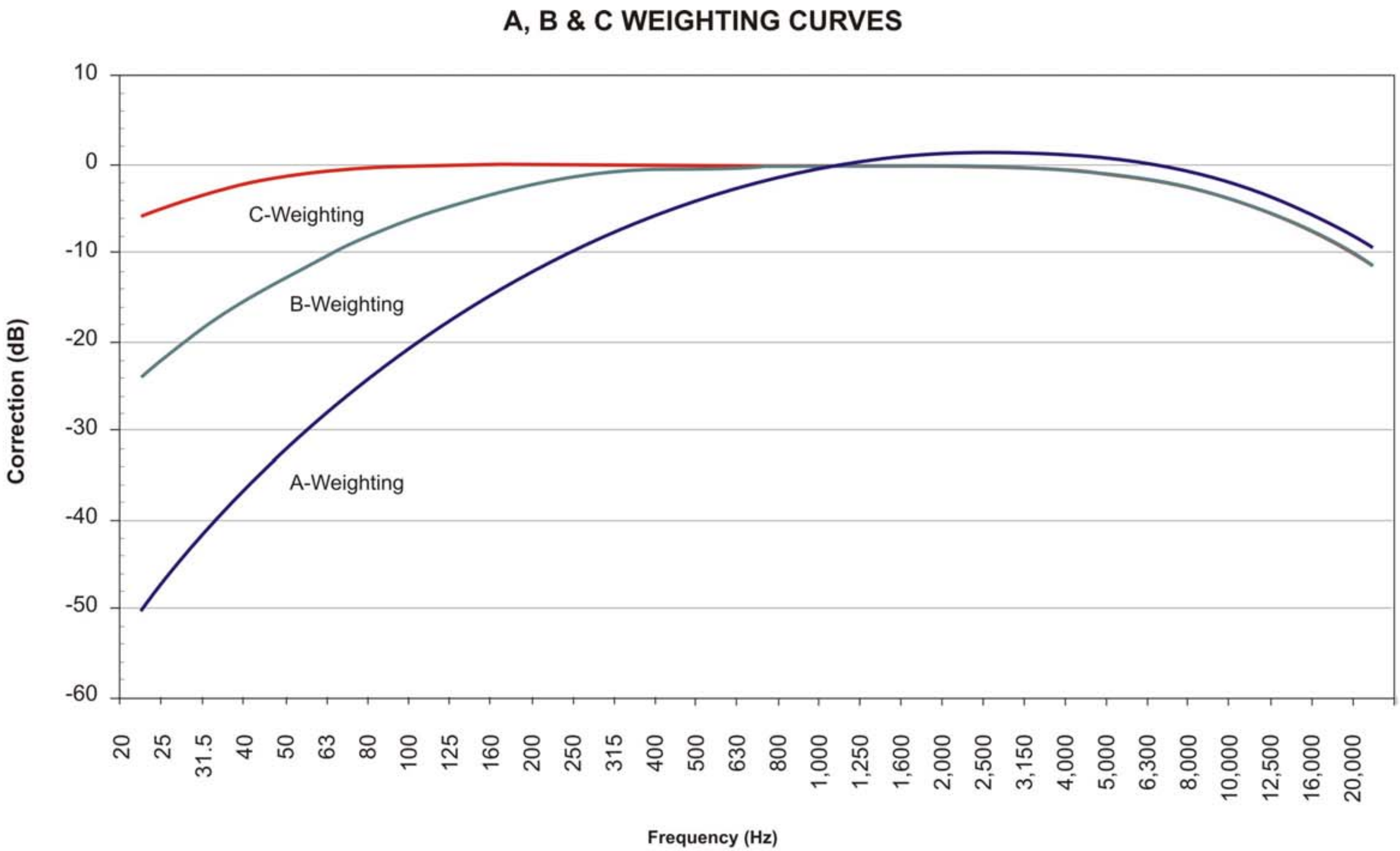
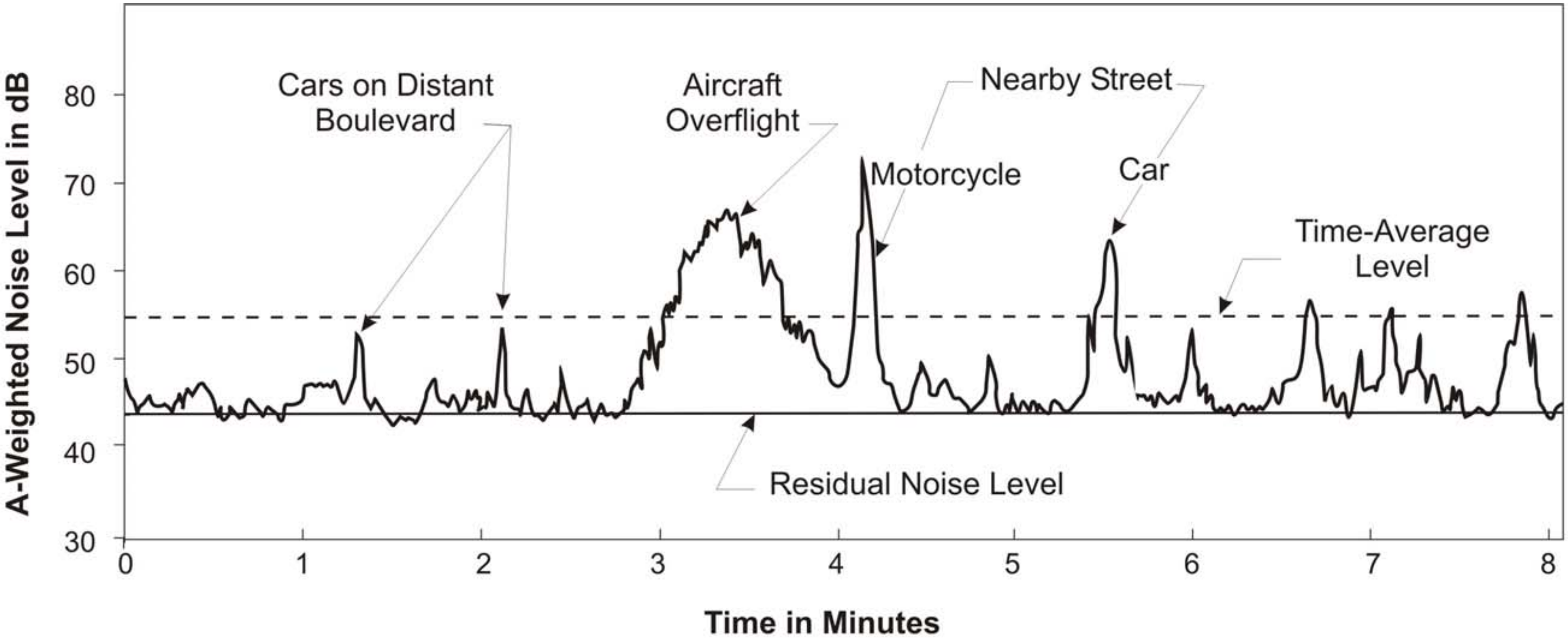


FIGURE 3-2
EXAMPLES OF VARIOUS SOUND ENVIRONMENTS



3.1.5 Propagation of Noise

Outdoor sound levels decrease as a function of distance from the source, and as a result of wave divergence, atmospheric absorption, and ground attenuation. If sound is radiated from a source in a homogenous and undisturbed manner, the sound travels as spherical waves. As the sound wave travels away from the source, the sound energy is distributed over a greater area, dispersing the sound power of the wave. Spherical spreading of the sound wave reduces the noise level, for most sound sources, at a rate of 6 dB per doubling of the distance.

Atmospheric absorption also influences the levels that are received by the observer. The greater the distance traveled, the greater the influence of the atmosphere and the resultant fluctuations. Atmospheric absorption becomes important at distances of greater than 1,000 feet. The degree of absorption is a function of the sound frequency, of the sound as well as the humidity and temperature of the air. For example, atmospheric absorption is lowest at high humidity and higher temperatures. Turbulence and gradients of wind, temperature, and humidity also play a significant role in determining the degree of attenuation. Certain conditions, such as inversions, can also result in higher noise levels that would result from spherical spreading as a result of channeling or focusing the sound waves.

Absorption effects in the atmosphere vary with frequency. The higher frequencies are more readily absorbed than the lower frequencies. Over large distances, the lower frequencies become the dominant sound as the higher frequencies are attenuated.

The effects of ground attenuation on noise propagation are a function of the height of the source and/or receiver and the characteristics of the terrain. The closer the source of the noise is to the ground, the greater the ground absorption. Terrain consisting of soft surfaces, such as vegetation, provide for more ground absorption than hard surfaces such as a body of water. Ground attenuation is important for the study of noise from airfield operations (such as thrust reversals) and in the design of noise berms and engine run-up facilities.

These factors are an important consideration for assessing in-flight and ground noise in the Columbus region. Atmospheric conditions will play a role in affecting the sound levels on a daily basis and how the population perceives these sounds are perceived by the population.

3.1.6 Duration of Sound

Research has shown that the annoyance from a noise event increases as the duration of the event increases. The “effective duration” of a sound is the time between when a sound rises above the background sound level until it drops back below the background level. Psychoacoustic studies have determined a relationship between duration and annoyance. These studies determined the amount a sound must be reduced to be judged equally annoying for increased duration (longer durations at low sound levels are equally annoying as shorter durations at higher levels). Duration is an important factor in describing sound in a community setting.

The relationship between duration and noise level is the basis of the equivalent energy principal of sound exposure. Reducing the acoustic energy of a sound by one half results in a 3 dB reduction. Doubling the duration of the sound increases the total energy of the event by 3dB. This equivalent energy principal is based upon the premise that the potential for a noise event to impact a person is dependent on the total acoustical energy content of the noise.

3.1.7 Change in Noise

The concept of change in ambient sound levels can be understood with an explanation of the hearing mechanism's reaction to sound. Under controlled laboratory conditions, listening to a steady unwavering pure tone sound that can be changed to slightly different sound levels, a person can just barely detect a sound-level change of approximately 1 dB for sounds in the mid-frequency range. When ordinary noises are heard, a young healthy ear can detect changes of 2 to 3 dB. A 5 dB change is readily noticeable, while a 10 dB change is judged by most people as a doubling or halving of the loudness of sound.

3.1.8 Masking Effect

Another characteristic of sound is its ability to interfere with the ability of the listener to hear another sound. This interference is defined as the masking effect. The presence of one sound effectively raises the threshold of audibility for the hearing of a second sound. For a signal to be heard, it must exceed the threshold of hearing for that particular individual and exceed the masking threshold for the background noise.

The masking characteristics of sound depend upon many factors, including the spectral (frequency) characteristics of the two sounds, the sound pressure levels, and the relative start time of the sounds. The masking effect is greatest when the masking frequency is closest to the frequency of the signal. Low frequency sounds can mask higher frequency sounds; however, the reverse is not true.

3.2 SOUND RATING SCALES

The description, analysis, and reporting of community sound levels is made difficult by the complexity of human response to sound and the myriad of sound-rating scales and metrics that have been developed for describing acoustic effects. Various rating scales have been devised to approximate the human subjective assessment to the "loudness" or "noisiness" of a sound. Noise metrics have been developed to account for additional parameters, such as duration and cumulative effect of multiple events.

Noise metrics can be categorized as single-event metrics and cumulative metrics. Single-event metrics describe the noise from individual events, such as an aircraft flyover. Cumulative metrics describe the noise in terms of the total noise exposure throughout the day.

3.2.1 Single Event Metrics

- *Frequency-Weighted Metrics (dBA)* – In order to simplify the measurement and computation of sound loudness levels, frequency-weighted networks have obtained wide acceptance. The A-weighting (dBA) scale has become the most prominent of these scales and is widely used in community noise analysis. Its advantages are that it has shown good correlation with community response and is easily measured.

- *Maximum Noise Level* – The highest noise level reached during a noise event is called the "Maximum Noise Level," or Lmax. For example, as an aircraft approaches, the sound of the aircraft begins to rise above ambient noise levels. The closer the aircraft gets, the louder the sound until the aircraft is at its closest point. As the aircraft passes, the noise level decreases until the sound settles to ambient levels. It is this metric to which people generally respond to when an aircraft flyover occurs. An aircraft flyover is graphically illustrated at the top of **Figure 3-3.**

3.2.2 Supplemental Metrics

- *Time Above (TA)* – The FAA has developed the Time Above metric as a second metric for assessing the impacts of aircraft noise around airports. The TA index refers to the total time in seconds or minutes that aircraft noise levels exceed certain dBA noise levels in a 24-hour period. It is typically expressed as Time Above 75 and 85 dBA sound levels. While this metric is not widely used, it may be used by the FAA in environmental assessments of airport projects that show a significant increase in noise levels (a 1.5 DNL increase within the 65 DNL contour due to a project). There are no noise/land use standards in terms of the TA index.

- *Percent Noise Level (Ln)* – To account for intermittent or fluctuating noise, another method to characterize noise is the Percent Noise Level (Ln). The Percent Noise Level is the level exceeded n% of the time during the measurement period. It is usually measured in dBA, but can be expression of any noise rating scale. For example, L90 is the noise level exceeded 90 percent of the time, L50 is the level exceeded 50 percent of the time, and L10 is the level exceeded 10 percent of the time. L90 is generally regarded as the background sound level, L50 represents the median level, and L10 represents the peak or intrusive noise levels. Percent noise level is commonly used in community noise ordinances that regulate noise from mechanical equipment, entertainment noise sources, etc. It is not normally used for transportation noise regulation. This noise metric is also referred to as Time Above (TA) in certain publications.

Sound Exposure Level (SEL) – This metric takes into account the maximum noise level of the event and the duration of the event. For aircraft flyovers, the SEL value is typically about 10 dBA higher than the maximum noise level. Single event metrics are a convenient method for describing noise from individual aircraft events. This metric is useful in that airport noise models contain aircraft noise curve data based upon the SEL metric. In addition, cumulative noise metrics such as Equivalent Noise Levels (Leq) and DNL can be computed from SEL data. Examples of SEL contours can be seen in **Appendix U**.

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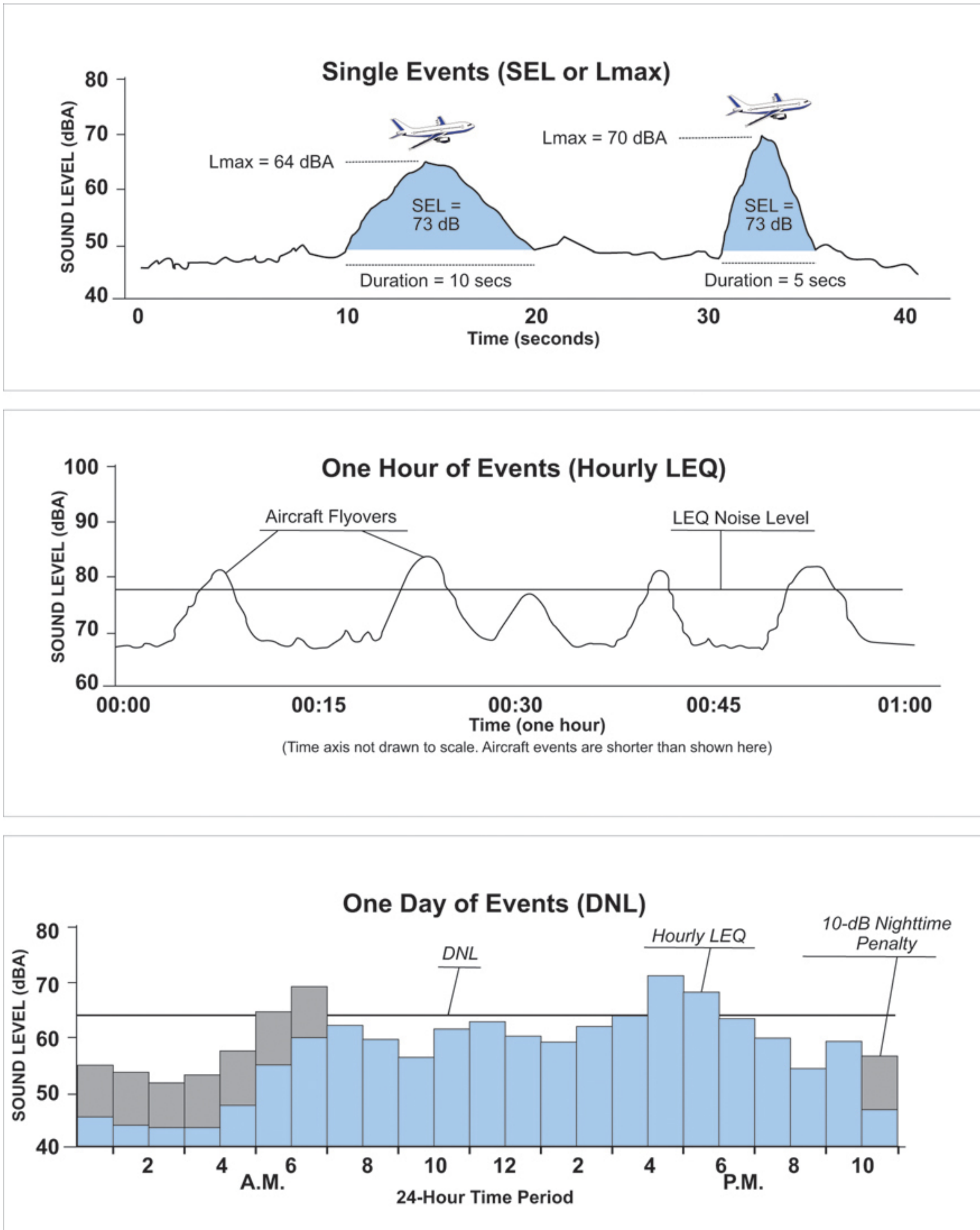
FIGURE 3-3
SEL, LEQ AND DNL ILLUSTRATIONS



3.2.3 Cumulative Metrics

Cumulative noise metrics have been developed to assess community response to noise. They are useful because these scales attempt to include the loudness of the noise, the duration of the noise, the total number of noise events, and the time of day these events occur into one single number rating scale.

- *Equivalent Noise Level (Leq)* – Leq is the sound level corresponding to a steady-state, A-weighted sound level containing the same total energy as a time-varying signal over a given sample period. Leq is the "energy" average noise level during the time period of the sample. It is based on the observation that the potential for a noise to impact people is dependent on the total acoustical energy content of the noise. It is the energy sum of all the sound that occurs during that time period. This is graphically illustrated in the middle graph of Figure 3.3. Leq can be measured for any time period, but is typically measured for 15 minutes, 1 hour, or 24 hours.

- *Day-Night Average Sound Level (DNL)* – The DNL index is a 24-hour, time-weighted energy average noise level based on the A-weighted decibel. It is a measure of the overall noise experienced during an entire day. The time-weighting refers to the fact that noise occurring during certain sensitive time periods is penalized for occurring at these times. In the DNL scale, noise occurring between the hours of 10:00:00 p.m. to 6:59:59 a.m. is penalized by 10 dB. This penalty was selected to attempt to account for the higher sensitivity to noise in the nighttime and the expected further decrease in background noise levels that typically occur in the nighttime. The FAA specifies DNL for airport noise assessment, and the EPA specifies DNL for community noise and for airport noise assessments. DNL is graphically illustrated in the bottom of **Figure 3-3**.

3.3 NOISE MEASUREMENTS

For the purposes of developing a full understanding of community and aircraft noise levels, aircraft noise measurements were made at 13 locations around OSUA. Both short term and long term measurements were made and the data collected were used to identify and compare relative levels of common community noise sources as well as specific aircraft types operating at OSUA. It is important to note that under CFR Part 150 regulations, the measured levels of aircraft noise may not be used to alter the noise data contained in the INM.

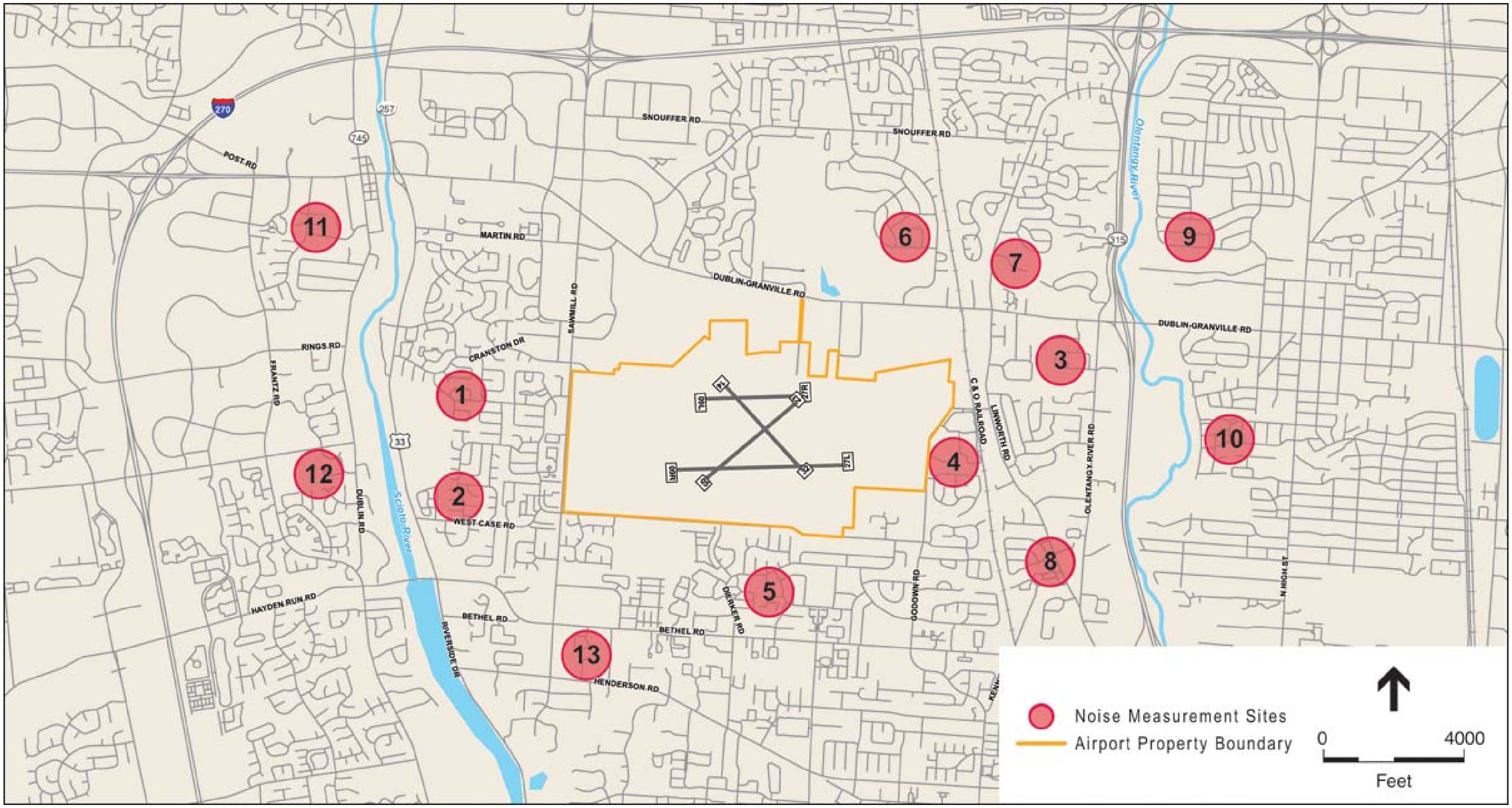
As mentioned, there were 13 locations chosen for the noise measurements, shown in **Figure 3-4**. A significant amount of effort was put forth in choosing the 13 locations for the noise measurements. Fixed wing and helicopter flight patterns at the Airport, both east flow and west flow, were reviewed to determine areas located under or near the flight patterns. Areas of interest were identified on a map and presented to the Part 150 Advisory Committee for input and comment. A discussion took place at the first Part 150 Advisory Committee meeting regarding the measurement locations and a consensus was reached agreeing with the general areas chosen. Committee members were also asked for recommendations on specific addresses within the areas of interest where a noise measurement device should be located. In addition to the address recommendations of the Committee members, records from the noise complaint system at the Airport were also reviewed to identify residents, within the areas of interest for noise measurements, who had voiced concerns regarding aircraft noise in the past. **Table 3-1** presents the final locations used for the noise measurements.

TABLE 3-1
NOISE MEASUREMENT LOCATIONS

Monitor	Location
1	3248 KellingsworthWay
2	3152 Alderridge Court
3	6169 Middlebury Drive West
4	1328 Le Anne Marie Circle
5	5475 Gardenbrooke Street
6	2485 McVey Boulevard West
7	2177 Castle Crest Drive
8	5320 Linworth Road
9	422 Highgate Avenue
10	229 W. Southington Avenue
11	220 Waterford Drive
12	5417 Limestone Ridge Drive
13	5222 Brynwood Drive

The noise measurements were made during the period of October 19 – 26, 2007. This particular time period was chosen to coincide with football homecoming weekend for The Ohio State University to try and capture the Airport during a busy time period. Measurements were conducted for long term and short term durations. Four of the 13 locations had a noise monitor present for seven consecutive days, representing the long term durations. These sites are represented as Sites 1 through 4 on **Figure 3-4** and were chosen for the long term duration measurements because they represent locations closest to the boundaries of what was believed to be the limits of the 65 DNL contour for the Airport. The remaining nine sites had noise measurements made for a minimum of at least one 24-hour period, representing the short term durations.

FIGURE 3-4
NOISE MEASUREMENT LOCATIONS



For each measurement location, a monitor was placed on the property to record the noise levels at that location. Noise levels recorded not only included aircraft overflights, but also the general ambient background levels. Staff also were at each location for periods of time during the measurement timeframe to record observations related to aircraft activities as well as local noise sources such as trains and roadways. Observations recorded during the measurement exercise are included in **Appendix B.**

The amount of noise measurement data collected is quite voluminous. To provide meaningful interpretation of the data, a comparison was made between the measured aircraft noise levels and the modeled aircraft noise levels for each location. For sites 1 through 4, several of the more common aircraft operating at the Airport were chosen to show typical noise levels measured versus modeled. In order to provide this level of detail, the Airport's AirScene system was used to identify the specific aircraft types associated with noise measurements. These four sites were able to provide specific noise levels measured by aircraft types due to their close proximity to the Airport and flight patterns. As one moves further away from the Airport, it becomes more difficult to match up specific aircraft types to measured levels due to the variability that comes into existence with the flight patterns (i.e., aircraft operating characteristics provide more variability in flight tracks the further away from the Airport they are). The aircraft chosen include two jets, the Beechjet 400 and the Cessna Citation 550/560, and two propeller aircraft, the Piper Chieftain and Super King Air. **Figure 3-5** presents the noise measurement analysis for those measurement sites located west of the Airport, and **Figure 3-6** presents the noise measurement analysis for those measurement sites located east of the Airport.

Many people have a difficult time understanding the noise levels measured and what that means. To assist with this, it is often beneficial to associate the noise level measured for an aircraft overflight to everyday common sounds. Everyday common sounds are reported using Lmax, or rather the peak sound level reached. The information presented in **Figures 3-5** and **3-6** shows the SEL metric which accounts for the total noise energy of the event, taking into account the length of time the event occurred and the varying noise levels present. To accurately compare the data from **Figures 3-5** and **3-6** to everyday common sounds, the noise levels in **Figures 3-5** and **3-6** must be converted to Lmax to represent the general peak noise level present. To accomplish this, 10 dBA is subtracted from the SEL value to achieve the general Lmax value. It is important to understand the Lmax of a noise event is always less than the SEL value. **Figure 3-7** presents the general Lmax aircraft noise levels for each measurement location and provides a reference to equivalent everyday common sounds.

FIGURE 3-5
NOISE MEASUREMENT LOCATIONS – WEST

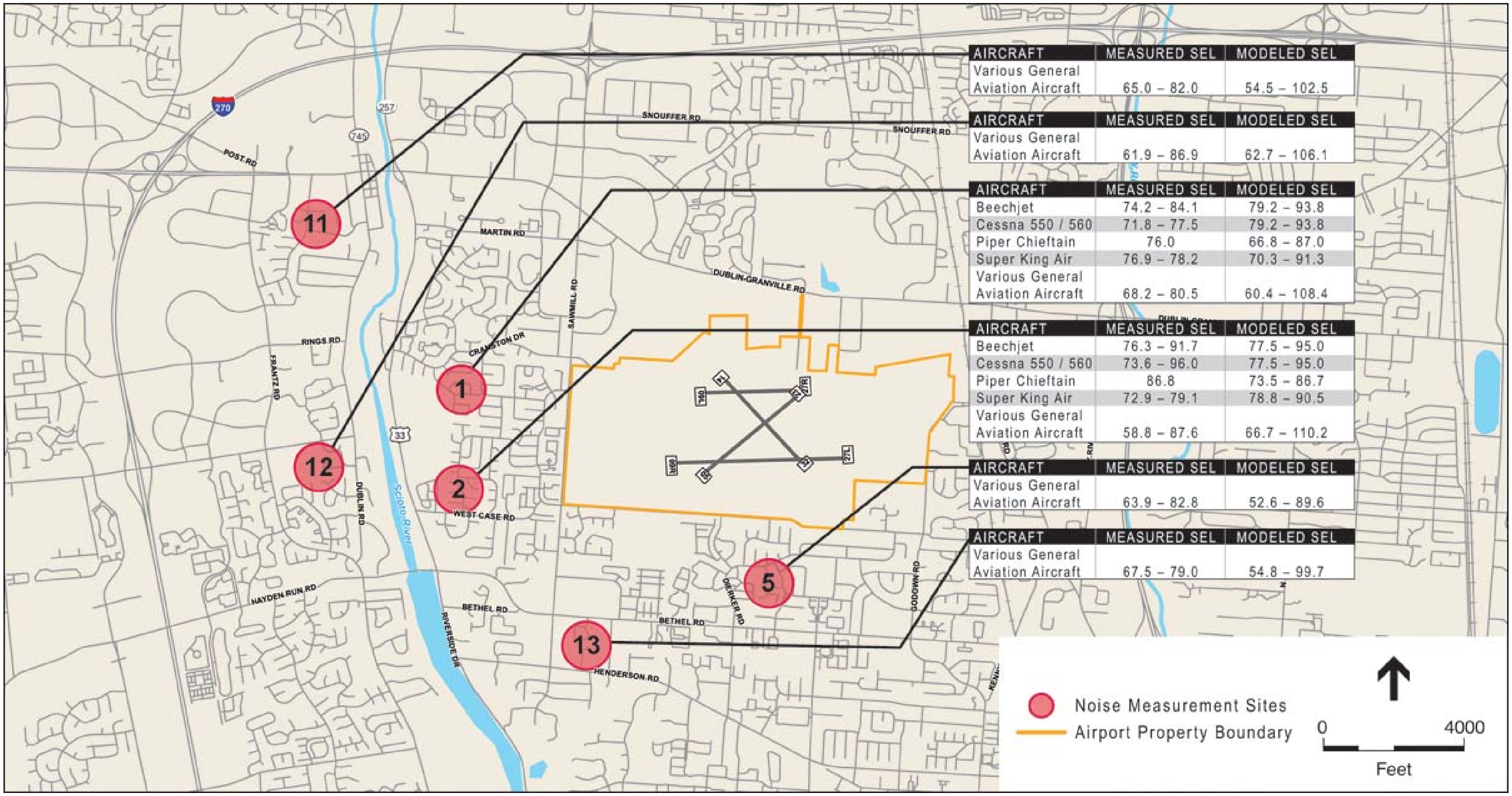


FIGURE 3-6
NOISE MEASUREMENT LOCATIONS - EAST

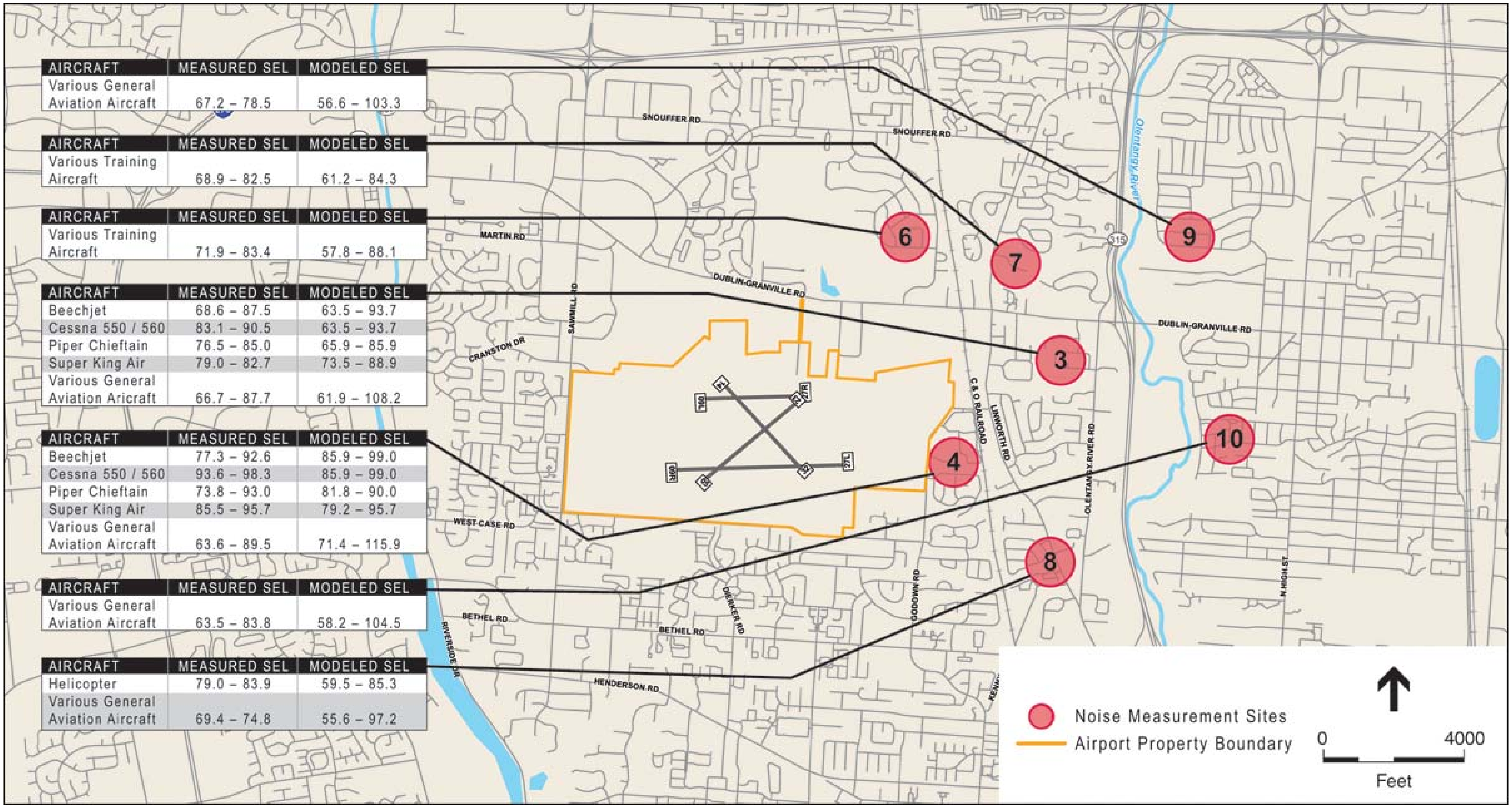
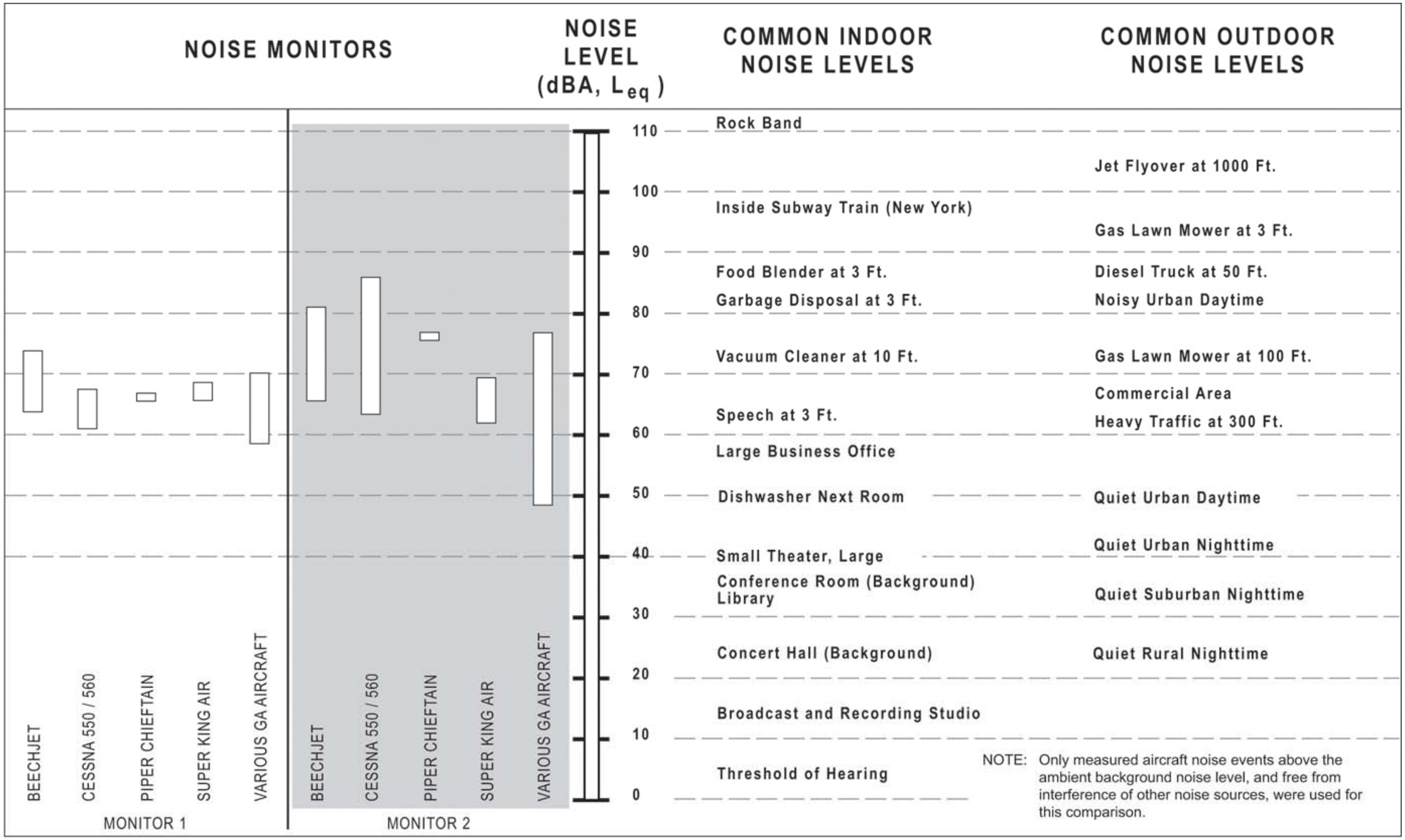
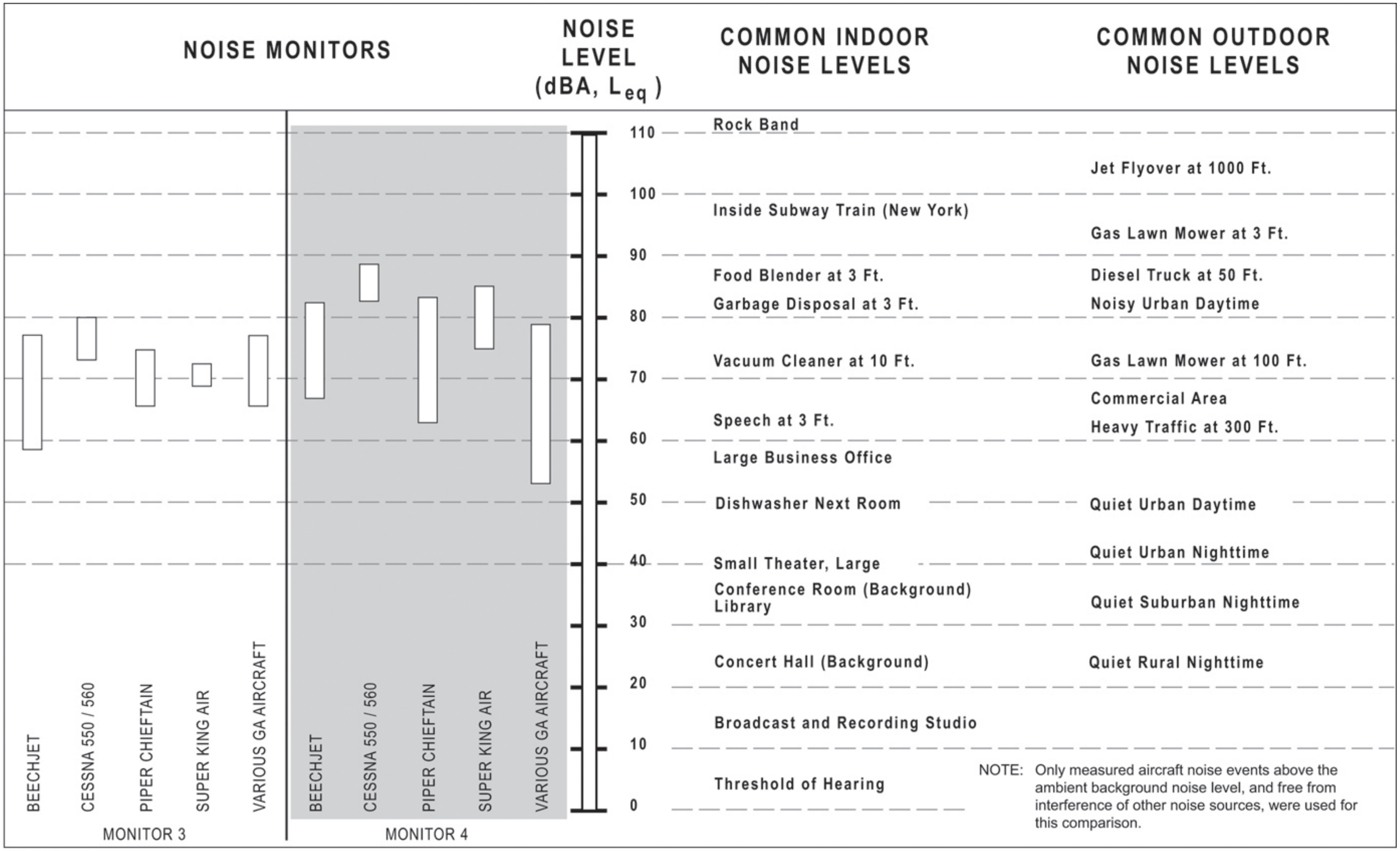


FIGURE 3-7
COMMON SOUND COMPARISON (PAGE 1 OF 3)



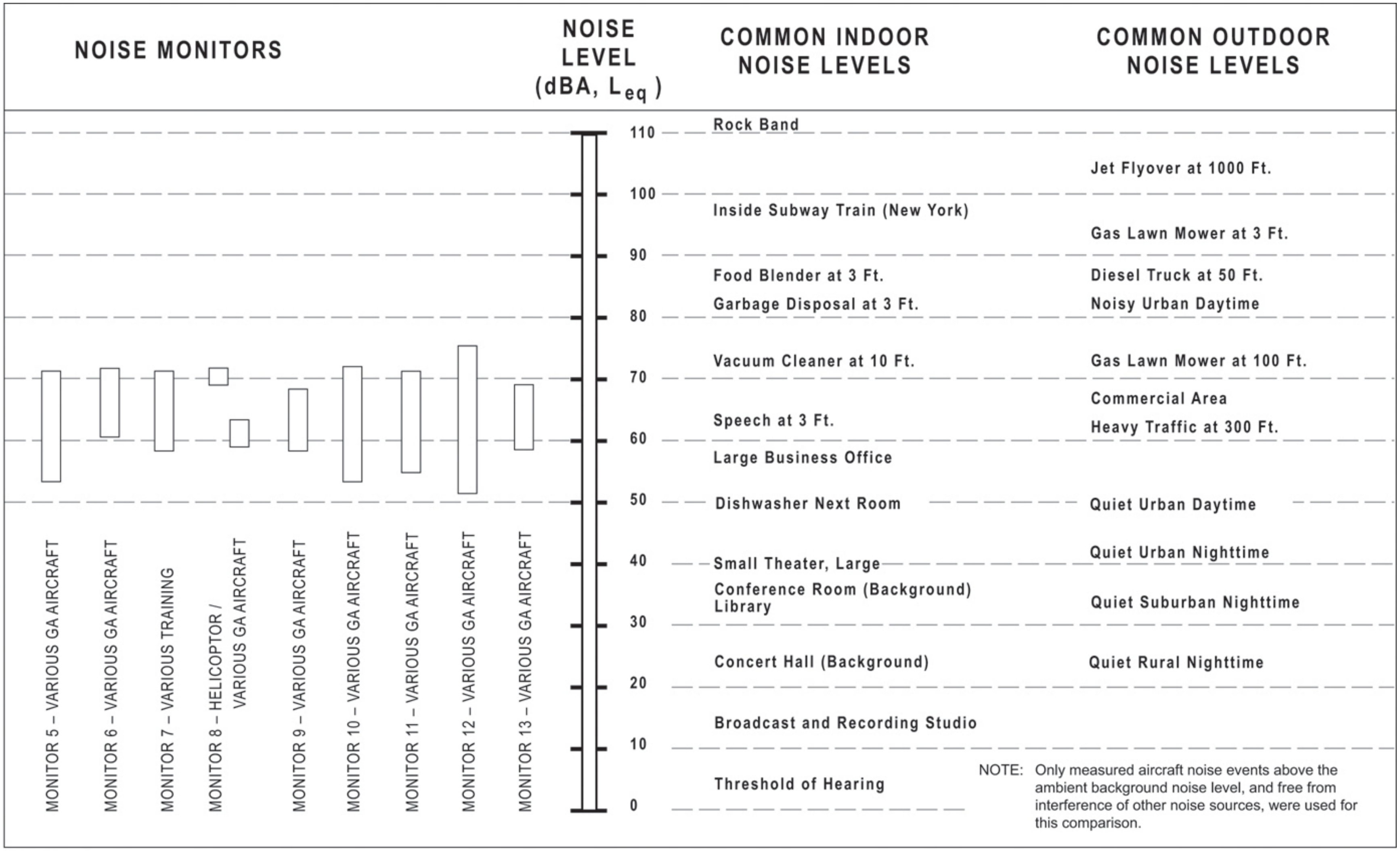
SOURCE: ESA, 2007

FIGURE 3-7
COMMON SOUND COMPARISON (PAGE 2 OF 3)



SOURCE: ESA, 2007

FIGURE 3-7
COMMON SOUND COMPARISON (PAGE 3 OF 3)



SOURCE: ESA, 2007