Appendix C

Noise Background

Federal environmental studies are usually largely based on a description of airport noise exposure using Day-Night Average Sound Level (DNL) contours. Studies can also involve the use of supplemental noise metrics in addition to DNL to provide comprehensive analysis for quantifying a specific situation. To assist reviewers in interpreting these complex noise metrics, this appendix presents an introduction to the relevant fundamentals of acoustics and noise terminology and the effects of noise on human activity.

Noise and its Metrics

Noise, often defined as unwanted sound, is one of the most common environmental issues associated with aircraft operations. Of course, aircraft are not the only sources of noise in an urban or suburban surrounding, where interstate and local roadway traffic, rail, industrial, and neighborhood sources may also intrude on the everyday quality of life. Nevertheless, aircraft are readily identifiable to those affected by their noise and are typically singled out for criticism. Consequently, aircraft noise problems often dominate analyses of environmental impacts.

A “metric” is defined as something “of, involving, or used in measurement.” As used in environmental noise analyses, a metric refers to the unit or quantity that quantitatively measures the effect of noise on the environment. Noise studies have typically involved a confusing proliferation of noise metrics used by individual researchers who have attempted to understand and represent the effects of noise. As a result, literature describing environmental noise or environmental noise abatement has included many different metrics.

Recently, however, various federal agencies involved in environmental noise mitigation have agreed on common metrics for environmental impact analysis documents. Furthermore, the FAA has specified which metrics, such as DNL, should be used for federal aviation noise assessments.

This chapter discusses the following acoustic terms and metrics:

- Decibel, dB
- A-Weighted Decibel, dBA
- Maximum Sound Level, L_{max}
- Sound Exposure Level, SEL
- Low-Frequency Sound Level, LFSL
- Equivalent Sound Level, L_{eq}
- Day-Night Average Sound Level, DNL

The Decibel, dB

All sounds come from a sound source—a musical instrument, a speaking voice, and an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source is transmitted through the air in sound waves—tiny, quick oscillations of pressure just above and just below atmospheric pressure. These oscillations, or sound pressures, impinge on the ear, creating the sound we hear.

The human ear is sensitive to a wide range of sound pressures. The loudest sound that humans hear without pain has about one trillion times more energy than the quietest sounds we hear. As this range, on a linear scale, is unwieldy, we compress the total range of sound pressures to a more meaningful range by introducing the concept of sound pressure level (SPL) and its logarithmic unit of decibel (dB).

SPL is a measure of the sound pressure of a given noise source relative to a standard reference value (typically the quietest sound that a young person with good hearing can detect). Decibels are logarithmic quantities —logarithms of the ratio of the two pressures, the numerator being the pressure of the sound source of interest, and the denominator being the reference pressure (the quietest sound we can hear).

The logarithmic conversion of sound pressure to SPL means that the quietest sound we can hear (the reference pressure) has a SPL of about zero decibels, while the loudest sounds we hear without pain have SPLs less than or equal to about 120 dB. Most sounds in our day-to-day environment have SPLs from 30 to 100 dB.

Because decibels are logarithmic quantities, they do not behave like regular numbers. For example, if two sound sources each produce 100 dB and are operated together, they produce only 103 dB—not 200 dB as might be expected. Four equal sources operating simultaneously result in a total SPL of 106 dB. In fact, for every doubling of the number of equal sources, the SPL (of all of the sources combined) increases another three decibels. A ten-fold increase in the number of sources makes the SPL increase by 10 dB. A hundredfold increase makes the level increase by 20 dB, and it takes a thousand equal sources to increase the level by 30 dB.

If one source is much louder than another, the two sources together will produce the same SPL (and sound to our ears) as if the louder source were operating alone. For example, a 100 dB source plus an 80 dB source produce 100 dB when operating together. The louder source “masks” the quieter one. But if the quieter source gets louder, it will have an increasing effect on the total SPL. When the two sources are equal, as described above, they produce a level 3 decibels above the sound level of either one by itself.

From these basic concepts, note that one hundred 80 dB sources will produce a combined level of 100 dB; if a single 100 dB source is added, the group will produce a total SPL of 103 dB. Clearly, the loudest source has the greatest effect on the total.

There are two useful rules of thumb to remember when comparing SPLs: (1) most of us perceive a 6 to 10 dB increase in the SPL to be an approximate doubling of loudness, and (2) changes in SPL of less than about 3 dB are not readily detectable outside of a laboratory environment.

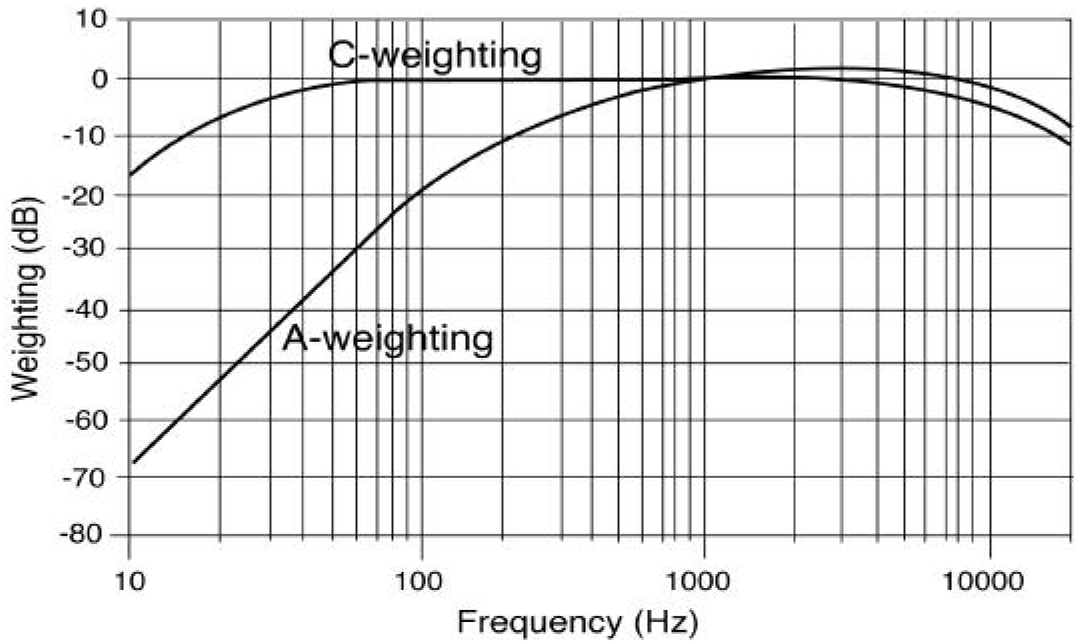
A-Weighted Decibel, dBA

Another important characteristic of sound is its frequency, or “pitch.” This is the rate of repetition of the sound pressure oscillations as they reach our ear. Frequency can be expressed in units of cycles per second (cps) or Hertz (Hz). Although cps and Hz are equivalent, Hz is the preferred scientific unit and terminology.

A very good ear can hear sounds with frequencies from 16 Hz to 20,000 Hz. However, most people hear from approximately 20 Hz to approximately 10,000 - 15,000 Hz. People respond to sound most readily when the predominant frequency is in the range of normal conversation, around 1,000 to 4,000 Hz. Acousticians have developed and applied “filters” or “weightings” to SPLs to match our ears' sensitivity to the pitch of sounds and to help us judge the relative loudness of sounds made up of different frequencies. Two such filters, “A” and “C,” are most applicable to environmental noises.

A-weighting significantly de-emphasizes noise at low and high frequencies (below approximately 500 Hz and above approximately 10,000 Hz) where we do not hear as well. The filter has little or no effect at intervening frequencies where our hearing is most efficient. **Figure C-1** shows a graph of the A-weighting as a function of frequency and its aforementioned characteristics.

Figure C-1
Frequency Response Characteristics of Various Weighting Networks



Source: ANSI S1.4 -1983 "Specification of Sound Level Meters"

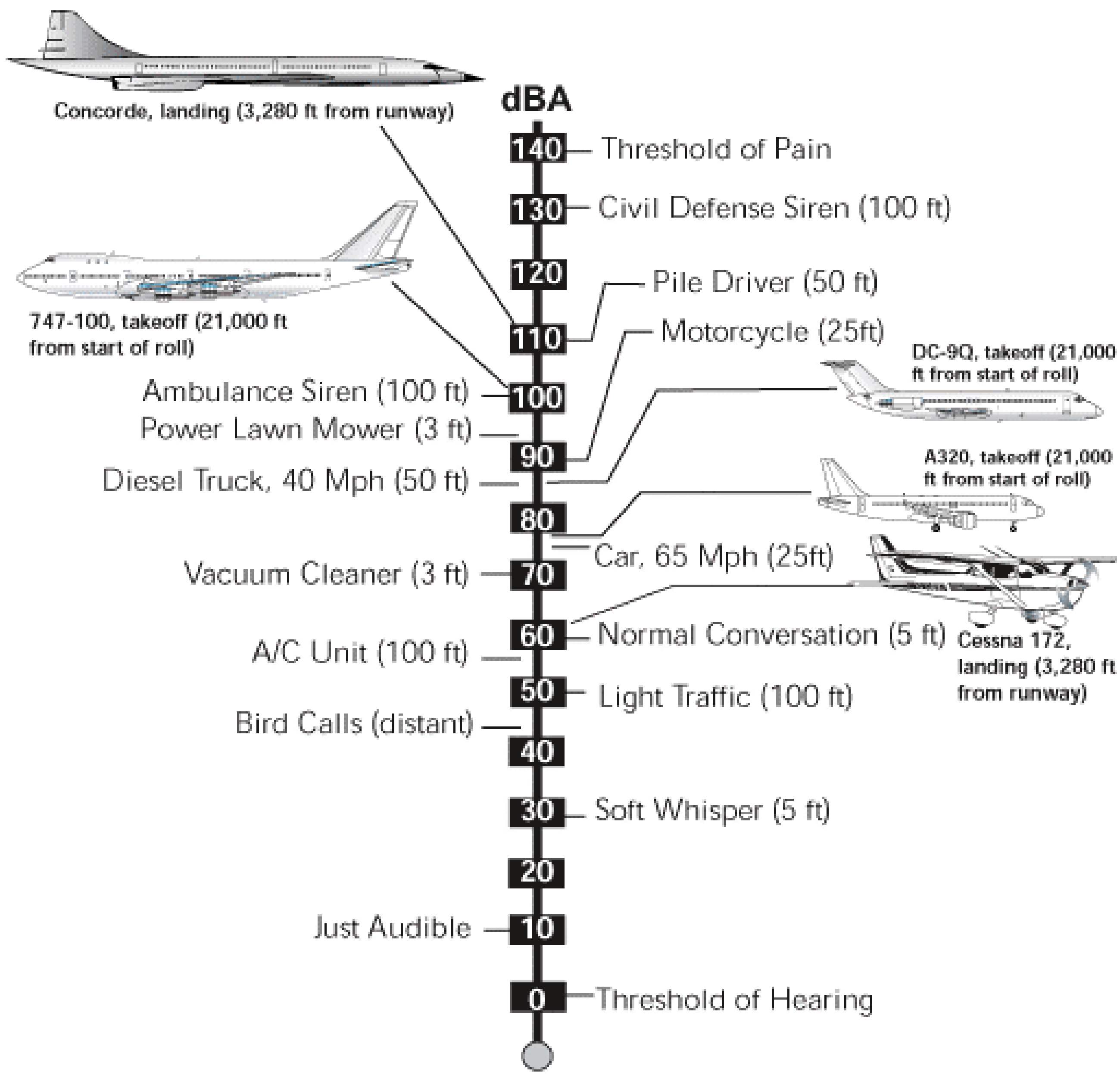
Because this filter generally matches our ears' sensitivity, sounds having higher A-weighted sound levels are usually judged to be louder than those with lower A-weighted sound levels, a relationship which does not always hold true for unweighted levels. Therefore, A-weighted sound levels are normally used to evaluate environmental noise. SPLs measured through this filter are referred to as A-weighted decibels (dBA).

As shown in Figure C-1, C-weighting is nearly flat throughout the audible frequency range, hardly de-emphasizing the low frequency noise. C-weighted levels are not used as frequently as A-weighted levels, but they may be preferable in evaluating sounds whose low-frequency components are responsible for secondary effects such as the shaking of a building, window rattle, perceptible vibrations, or other factors that can cause annoyance and complaints. Uses include the evaluation of blasting noise, artillery fire, sonic boom, and, in some cases, aircraft noise inside buildings. SPLs measured through this filter are referred to as C-weighted decibels (dBC).

Other weighting networks have been developed to correspond to the sensitivity and perception of other types of sounds, such as the "B" and "D" filters. However, A-weighting has been adopted as the basic measure of community environmental noise by the U.S. Environmental Protection Agency (EPA) and nearly every other agency concerned with aircraft noise throughout the United States.

Figure C-2 presents typical A-weighted sound levels of several common environmental sources. Sound levels measured (or computed) using A-weighting are most properly called "A-weighted sound levels" while sound levels measured without any frequency weighting are most properly called "sound levels." *However, since this document deals only with A-weighted sound levels, the adjective "A-weighted" will be hereafter omitted, with A-weighted sound levels referred to simply as sound levels.*

	Sound Levels of Typical Noise Sources (dBA)	**Figure C-2**

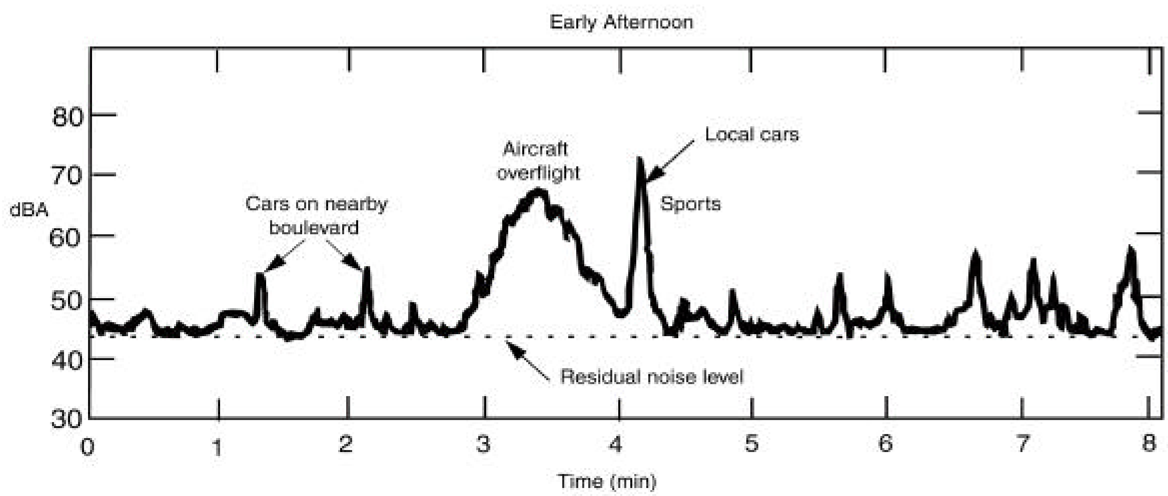


As long as the use of A-weighting is understood, there is no difference implied by the terms "sound level" and "A-weighted sound level" or by the dB or dBA units.

An additional dimension to environmental noise is that sound levels vary with time, as shown in **Figure C-3.** For example, the sound level increases as an aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance (although even the background varies as birds chirp, the wind blows, or a vehicle passes by).

Figure C-3

Variation of Community Noise in a Suburban Neighborhood



Source: "Community Noise," NTID 300.3 EPA, December 1971.

Maximum Sound Level, L_{max}

The variation in sound level over time often makes it convenient to describe a particular noise "event" by its maximum sound level, abbreviated as L_{max}. For the aircraft over-flight event in Figure 2-3, the L_{max} is approximately 67 dBA.

The maximum level describes only one dimension of an event; it provides no information on the cumulative noise exposure generated by a sound source. In fact, two events with identical maxima may produce very different total exposures. One may be of short duration, while the other may continue for an extended period.

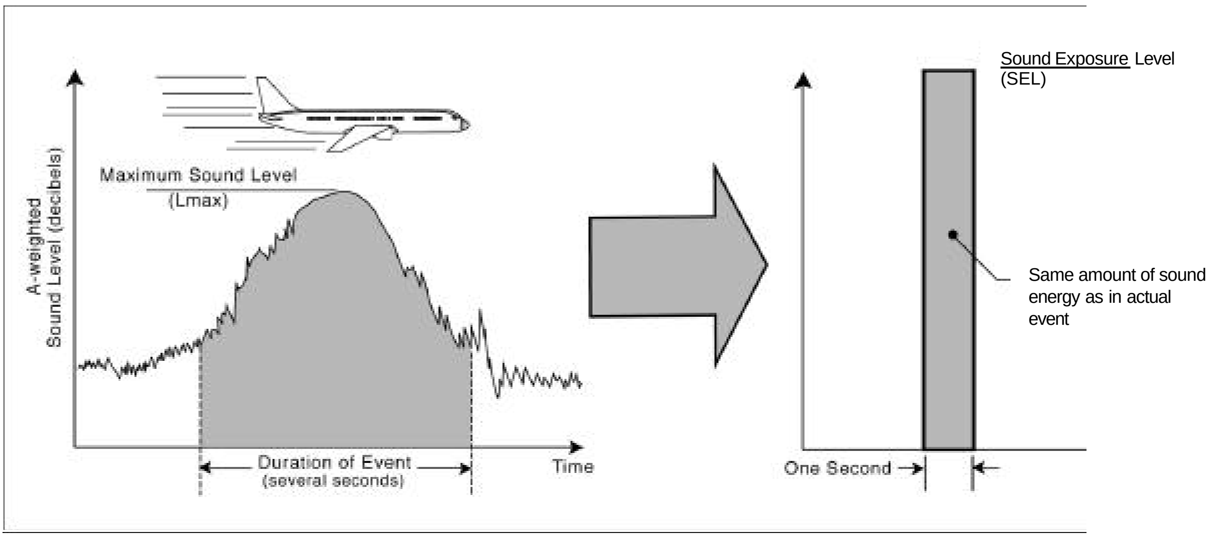
Sound Exposure Level, SEL

A frequently used metric of noise exposure for a single aircraft flyover is the Sound Exposure Level, or SEL. SEL may be considered an accumulation of the sound energy over the duration of an event. The shaded area in **Figure C-4** illustrates that portion of the sound energy (or "dose") included in an SEL computation. The dose is then normalized (standardized) to a duration of one second. This "revised" dose is the SEL, shown as the shaded rectangular area in Figure C-4. Mathematically, the SEL represents the sound level of the constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For events that last more than one second, *SEL does not directly represent the sound level heard at any given time but rather provides a measure of the net impact of the entire acoustic event*.

Note that, because the SEL is normalized to one second, it will always be larger in magnitude than the maximum A-weighted level for an event that lasts longer than one second. In fact, for most aircraft overflights, the SEL is on the order of 7 to 12 dBA higher than the L_{max}. The fact that it is a cumulative measure means that not only do louder flyovers have higher SELs than quieter ones (of the same duration), but *longer* flyovers also have greater SELs than shorter ones (of the same L_{max}).

Figure C-4

Relationship Between Single Event Noise Metrics



It is the SEL's inclusion of both the intensity and duration of a sound source that makes SEL the metric of choice for comparing the single-event levels of varying duration and maximum sound level. This metric provides a comprehensive basis for modeling a noise event in determining overall noise exposure.

Low-Frequency Sound Level, LFSL

The LFSL metric has been recently developed as the preferred quantifier of low-frequency sound exposure in the vicinity of MSP. The LFSL is the sum of the maximum (unweighted) sound pressure levels in the 25-80 Hz one-third octave bands during individual noise events. The (arithmetic) average of the greatest LFSLs in excess of 60 dB LFSL is defined as the effective low-frequency aircraft noise dose.

The frequency scale is divided into sections called bands. The bandwidth can be described in terms of octaves where the upper frequency of each octave is double that of the lower frequency. If the octave is split into thirds, then each third is referred to as a "one-third octave band" set of frequencies. Instead of denoting a specific one-third octave band by its lower and upper frequencies, the band's center frequency is traditionally listed.

Equivalent Sound Level, L_{eq}

Maximum A-weighted level, SEL, and LFSL are used to measure the noise associated with individual events. The remaining metrics in this section apply to longer-term cumulative noise exposure that often includes many events.

The first cumulative noise metric, the Equivalent Sound Level (abbreviated L_{eq}), is a measure of the exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest (e.g., an hour, an 8-hour school day, nighttime, or a full 24-hour day). However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric. Such durations are often identified through a subscript, for example $L_{eq(8)}$ or $L_{eq(24)}$.

Conceptually, L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as the actual time-varying sound level with its normal “peaks” and “valleys,” as illustrated in Figure C-3. In the context of noise from typical aircraft flight events and as noted earlier for SEL, L_{eq} does not represent the sound level heard at any particular time, but rather represents the total sound exposure for the period of interest. Also, it should be noted that the “average” sound level suggested by L_{eq} is not an arithmetic value, but a logarithmic, or “energy-averaged,” sound level. Thus, loud events tend to dominate the noise environment described by the L_{eq} metric.

As for its application to airport noise issues, L_{eq} is often presented for consecutive 1-hour periods to illustrate how the hourly noise dose rises and falls throughout a 24-hour period, as well as how certain hours are significantly affected by a few loud aircraft.

Day-Night Average Sound Level

The DNL, a slightly more complicated measure of noise exposure, be used to describe the cumulative or total noise exposure during an annual average day.

DNL is the same as L_{eq} (an energy-average noise level over a 24-hour period) except that 10 dB is added to those noise events occurring at night (between 10:00 p.m. and 7:00 a.m.). This weighting reflects the added intrusiveness of nighttime noise events attributable to the fact that community background noise levels typically decrease by about 10 dB during those nighttime hours. *DNL does not represent the sound level heard at any particular time, but rather represents the total (and partially weighted) sound exposure.*

Typical DNL values for a variety of noise environments are shown in **Figure C-5** to indicate the range of noise exposure levels usually encountered.

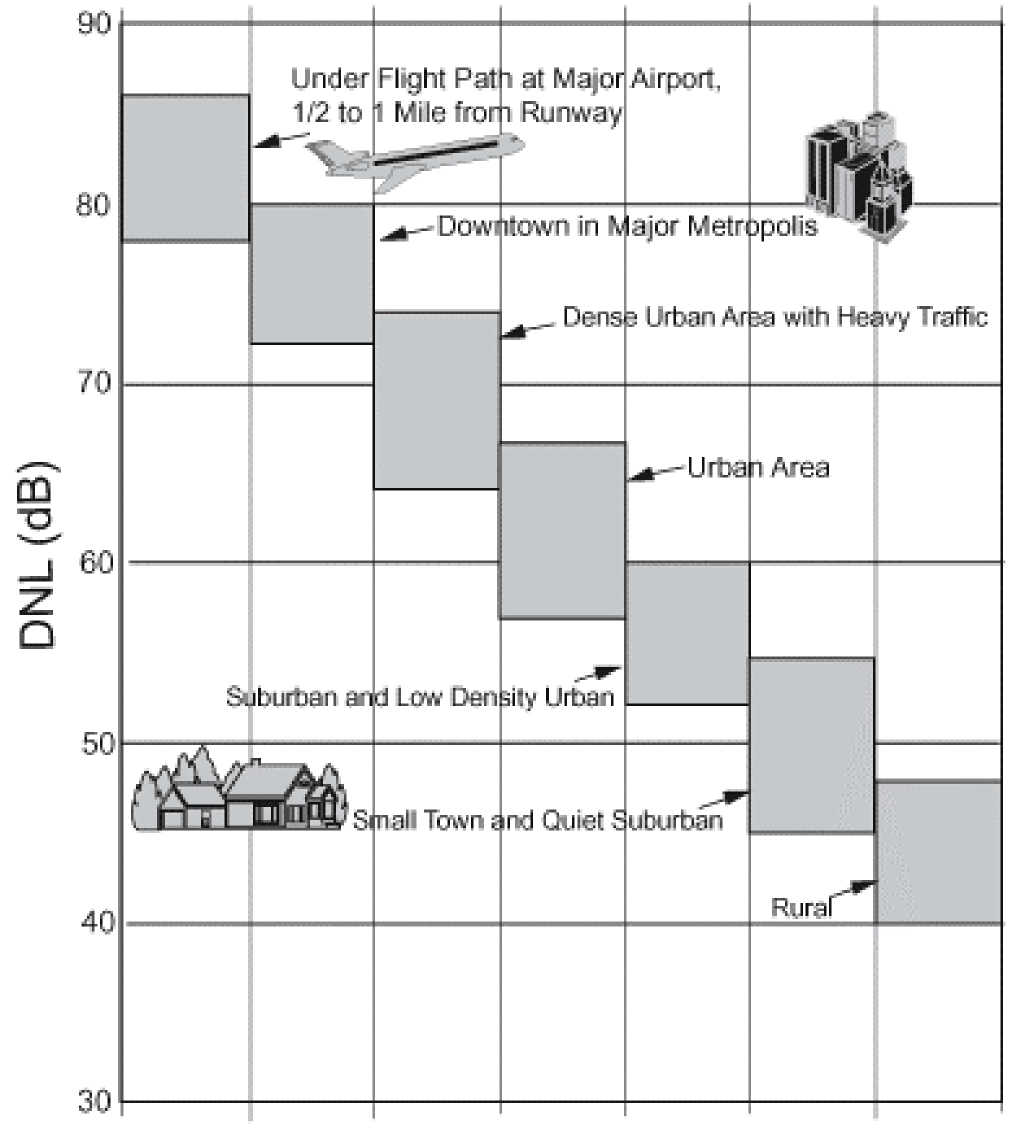
Due to the DNL metric’s excellent correlation with the degree of community annoyance from aircraft noise, DNL has been formally adopted by most federal agencies dealing with noise exposure. These agencies include the EPA, FAA, Department of Defense, Department of Housing and Urban Development (HUD), and Veterans Administration. Furthermore, Federal programs like Part 150 *require* that DNL be used in describing cumulative noise exposure and in identifying aircraft noise/land use compatibility issues.

Part 150 also requires that the annual average 65, 70, and 75 dB DNL contour lines (or contours) be depicted. DNL contours are lines of equal noise exposure.

This is analogous to topographic contours that are lines of equal elevation. In order to create DNL contours, the DNL must be assessed for many points on the ground. Measurements of DNL are practical only for obtaining values for a relatively limited number of points. Instead, many airport noise

Typical Range of Outdoor Community Day-Night Average Sound Levels

Figure C-5



Source: U.S. Department of Defense. Departments of the Air Force, the Army, and the Navy, 1978. *Planning in the Noise Environment*. AFM 19-10. TM 5-803-2, and NAVFAC P-970. Washington, D.C.: U.S. DoD.

studies, including this document, are based on estimates of DNL using a FAA-approved computer-based noise model.

The Effects of Aircraft Noise on People

To residents around airports, aircraft noise can be an annoyance and a nuisance. It can interfere with conversation and listening to television, disrupt classroom activities in schools, and disrupt sleep. Relating these effects to specific noise metrics aids in the understanding of how and why people react to their environment. This section addresses three ways we are potentially affected by aircraft noise: annoyance, interference of speech, and disturbance of sleep.

Community Annoyance

The primary potential effect of aircraft noise on exposed communities is one of annoyance. The U.S. EPA defines noise annoyance as any negative subjective reaction on the part of an individual or group.[12]

Scientific studies [9 13 14 15 16] and a large number of social/attitudinal surveys[17 18] have been conducted to appraise U.S. and international community annoyance due to all types of environmental noise, especially aircraft events. These studies and surveys have found the DNL to be the best measure of that annoyance.

This relation between community annoyance and time-average sound level has been confirmed, even for infrequent aircraft noise events. For helicopter overflight frequencies of occurrence from 1 to 52 per day, the stated reactions of community individuals correlated with the daily time-average sound levels of the helicopter overflights.[19]

The relationship between annoyance and DNL that has been determined by the scientific community and endorsed by many federal agencies, including the FAA, is shown in **Figure C-6**. Two lines in Figure C-6 representing two large sets of social/ attitudinal surveys: one for a curve fit of 161 data points compiled by an individual researcher, Ted Schultz, in 1978 and one for a curve fit of 400 data points (which include Schultz's 161 points) compiled in 1992 by the U.S. Air Force. The agreement of these two curves simply means that when one combines the more recent studies with the early landmark surveys in 1978, the results of the early surveys (i.e., the quantified effect of noise on annoyance) are confirmed.

Figure C-6 shows the percentage of people "highly annoyed" by a given DNL. For example, the two curves in the figure yield a value of about 13 percent for the percentage of the people that would be highly annoyed by a DNL exposure of 65 dB. The figure also shows that at very low values of DNL, such as 45 dB or less, one percent or less of the exposed population would be highly annoyed.

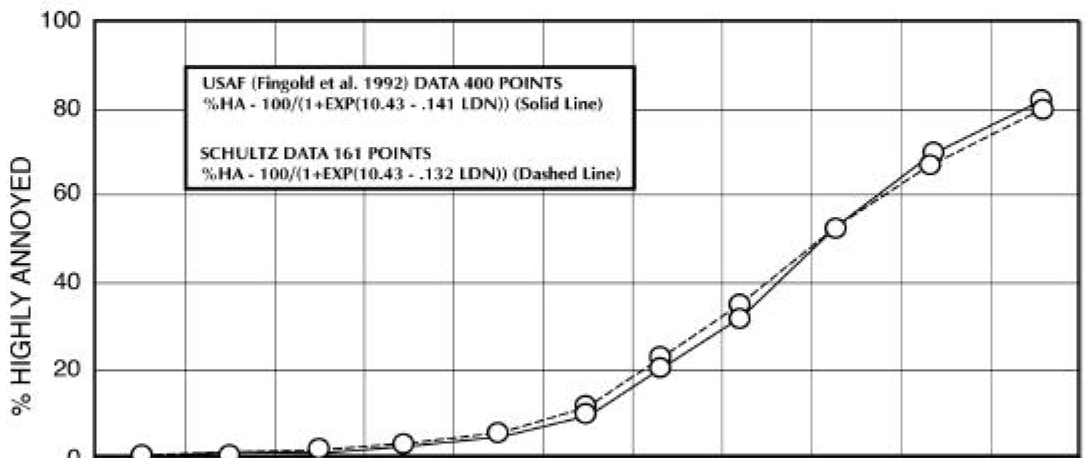
[12] U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety," Report 550/9-74-004, March 1974.
[13] "Sound Level Descriptors for Determination of Compatible Land Use," American National Standards Institute Standard ANSI S3.23-1980."
[14] Federal Interagency Committee on Noise, "Federal Agency Review of Selected Airport Noise Analysis Issues," August 1992.
[15] "Quantities and Procedures for Description and Measurement of Environmental Sound, Part I," American National Standards Institute Standard ANSI S21.9-1988.
[16] "Guidelines for Considering Noise in Land Use Planning and Control," Federal Interagency Committee on Urban Noise, June 1980.
[17] Schultz, T.J., "Synthesis of Social Surveys on Noise Annoyance," J. Acoust. Soc. Am., 64, 377-405, August 1978.
[18] Fidell, S., & Barger, D.S., & Schultz, T.J., "Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise." J. Acoust. Soc. Am, 89, 221-233, January 1991.
[19] "Community Reactions to Helicopter Noise: Results from an Experimental Study," J. Acoust. Soc. Am, 479-492, August 1987.

Furthermore, at very high values of DNL, such as 90 dB, more than 80 percent of the exposed population would be highly annoyed.

Recently, the use of DNL has been criticized as not accurately representing community annoyance and land-use compatibility with aircraft noise. One frequent criticism is based on the inherent feeling that people react more to single noise events and not as much to “meaningless” time-average sound levels.

Figure C-6

Relationship Between Annoyance and Day-Night Average Sound Level



	Day - Night Average Sound Level in dB	40	45	50	55	60	65	70	75	80	85	100
Calculated %HA Points	USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
	SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

Source: Federal Interagency Committee on Noise (FICON), "Federal Agency Review of Selected Airport Noise Analysis Issues", August 1992, p.3-6, Figure 3-1.

In fact, a time-average noise metric, such as DNL, takes into account both the noise levels of all individual events which occur during a 24-hour period and the number of times those events occur. As described briefly above, the logarithmic nature of the decibel unit causes the noise levels of the loudest events to control the 24-hour average.

As a simple example of this characteristic, consider a case in which only one aircraft overflight occurs in daytime hours during a 24-hour period, creating a sound level of 100 dB for 30 seconds. During the remaining 23 hours 59 minutes and 30 seconds of the day, the ambient sound level is 50 dB. The DNL for this 24-hour period is 65.5 dB. As a second example, assume that 10 such 30-second overflights occur in daytime hours during the next 24-hour period, with the same ambient sound level of 50 dB during the remaining 23 hours and 55 minutes of the day. The DNL for this 24-hour period is 75.4 dB. Clearly, the averaging of noise over a 24-hour period does not ignore the louder single events and tends to emphasize both the sound levels and number of those events. This is the basic concept of a time-average sound metric, and, specifically, the DNL.

It is often suggested that a lower DNL, such as 60 or 55 dB, be adopted as the threshold of community noise annoyance for airport environmental analysis documents. While there is no technical reason why a lower level cannot be measured or calculated for comparison purposes, a DNL of 65 dB:

- Provides a valid basis for comparing and assessing community noise effects.
- Represents a noise exposure level that is normally dominated by aircraft noise and not other community or nearby highway noise sources.
- Reflects the FAA's threshold for grant-in-aid funding of airport noise mitigation projects.
- HUD also established a DNL standard of 65 dB for eligibility for federally guaranteed home loans.

For this EA, DNLs equal to and greater than 60 dB were used for assessing community noise impact. This EA considers a standard of 60 dB for the following reasons:

- The 1996 MSP Noise Mitigation Committee recommended that sound insulation should be provided to residents within the 60 dB DNL contour.
- Minnesota legislation dealing with the Dual Track Planning Process Environmental Impact Statement (EIS) required MAC to make a recommendation to the State Advisory Council on Metropolitan Airport Planning. The legislation stated that "the recommendation shall examine mitigation measures to the 60 dB DNL level."[20] Therefore, the State of Minnesota Advisory Council on Metropolitan Airport Planning, pursuant to the Legislature's direction to review the recommendation and comment to the Legislature, reviewed the recommendation and concurred with the Commission's recommendation.[21]
- Metropolitan Council (MC) Land Use Policy guidance indicates that residential land use within the 60 dB DNL contour is inconsistent without sound attenuation.

Speech Interference

A primary effect of aircraft noise is its tendency to drown out or "mask" speech, making it difficult to carry on a normal conversation.

Speech interference associated with aircraft noise is a primary cause of annoyance to individuals on the ground. The disruption of routine activities, such as radio or television listening, telephone use, or family conversation, causes frustration and aggravation. Research has shown that "whenever intrusive noise exceeds approximately 60 dB indoors, there will be interference with speech communication."[22]

Indoor speech interference[9] can be expressed as a percentage of sentence intelligibility among two people speaking in relaxed conversation approximately one meter apart in a typical[23] living room or bedroom. The percentage of sentence intelligibility is a non-linear function of the (steady) indoor background sound level, as shown in **Figure C-7**. This curve was digitized and curve-fitted for the purposes of this document. Such a curve-fit yields 100 percent sentence intelligibility for background levels below 57 dB and yields less than 10 percent intelligibility for background levels above 73 dB. Note that the function is especially sensitive to changes in sound level between 65 dB and 75 dB. As

[20] Dual Track Airport Planning Process, Chapter 464, House 3012, Article 3, Metropolitan Airport Provisions.
[21] Minnesota Advisory Council on Metropolitan Airport Planning, February 10, 1997.
[22] "Sound Level Descriptors for Determination of Compatible Land Use," American National Standards Institute Standard ANSI S3.23-1980."
[23] "Typical' is defined as a room with about 300 sabins of sound absorption, which is representative of living rooms and bedrooms. See note 6.

an example of the sensitivity, a 1 dB increase in background sound level from70 dB to 71 dB yields a 14 percent decrease in sentence intelligibility.

In the same document from which Figure C-7 was taken, the EPA established an indoor criterion of 45 dB DNL as requisite to protect against speech interference indoors.

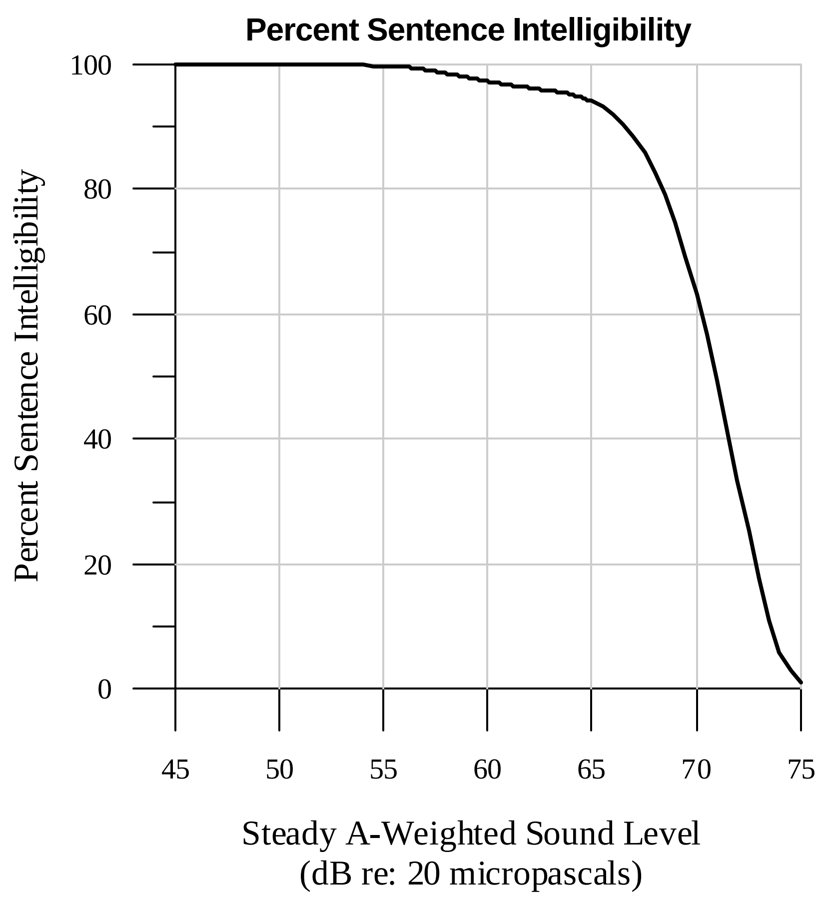
For previously cited reasons, this EA utilizes an outdoor DNL of 60 dB to assess community noise impact.

Sleep Disturbance

Sleep disturbance is another source of annoyance associated with aircraft noise. This is especially true because of the intermittent nature and content of aircraft noise, which is more disturbing than continuous noise of equal energy and neutral meaning.

Sleep disturbance can be measured in one of two ways. "Arousal" represents awakening from sleep, while a change in "sleep stage" represents a shift from one of four sleep stages to another stage of lighter sleep without awakening. In general, arousal requires a higher noise level than does a change in sleep stage.

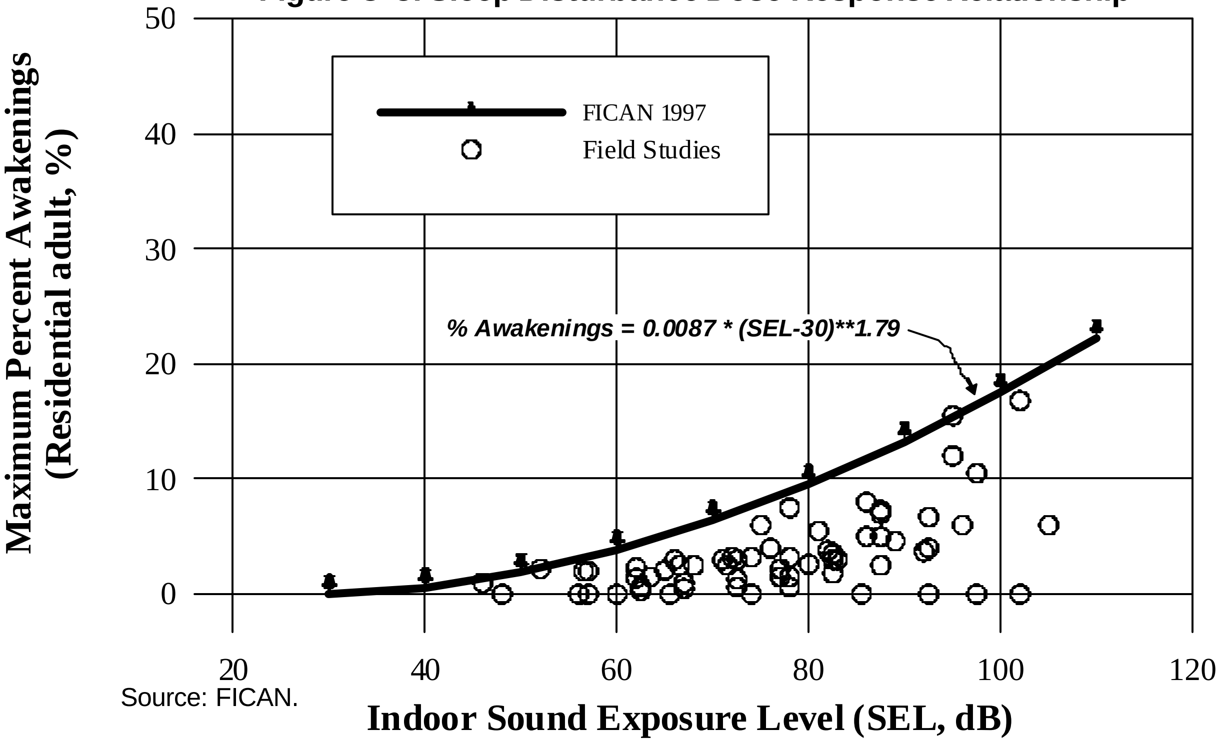
Figure C-7



In terms of average daily noise levels, some guidance is available to judge sleep disturbance. The EPA identified an indoor DNL of 45 dB as necessary to protect against sleep interference.[12]

In June 1997, the Federal Interagency Committee on Aviation Noise (FICAN) reviewed the sleep disturbance issue and presented a sleep disturbance dose-response prediction curve.[24] FICAN based their curve on data from field studies [25] [26] [27] [28] and recommends the curve as the tool for analysis of potential sleep disturbance for residential areas. **Figure C-8** shows this curve which, for an indoor SEL of 60 dB, predicts that a maximum of approximately 5 percent of the residential population exposed are expected to be behaviorally awakened. FICAN cautions that this curve should only be applied to long-term adult residents.

Figure C-8: Sleep Disturbance Dose-Response Relationship



Source: FICAN.

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[24] Federal Interagency Committee on Aviation Noise (FICAN), "Effects of Aviation Noise on Awakenings from Sleep," June 1997.

[25] Pearson, K.S., Barber, D.S. Tabachnick, B.G., "Analyses of the Predictability of Noise-Induced Sleep Disturbance," USAF Report HSD-TR-89-029, October 1989.

[26] Ollerhead, J.B., Jones, C.J., Cadous, R.E., Woodley, A., Atkinson, B.J., Horne, J.A., Pankhurst, F., Reyner, L, Hume, K.I., Van, F., Watson, A.., Diamond, I.D., Egger, P., Holmes, D., McKean, J., "Report of a Field Study of Aircraft Noise and Sleep Disturbance," London Department of Safety, Environment, and Engineering, 1992.

[27] Fidell, S., Pearsons, K., Howe, R., Tabachnick, B., Silvati, L., Barber, D.S., "Noise-Induced Sleep Disturbance in Residential Settings," AL/OE-TR-1994-0131, Wright Patterson AFB, OH, Armstrong Laboratory, Occupational Environmental Health Division, 1994.

[28] Fidell, S., Howe, R., Tabachnick, B., Pearsons, K., Sneddon, M., "Noise-Induced Sleep Disturbance in Residences Near Two Civil Airports," Langley Research Center, 1995.