APPENDIX K DEVELOPMENT OF THE ANSI SLEEP STANDARD

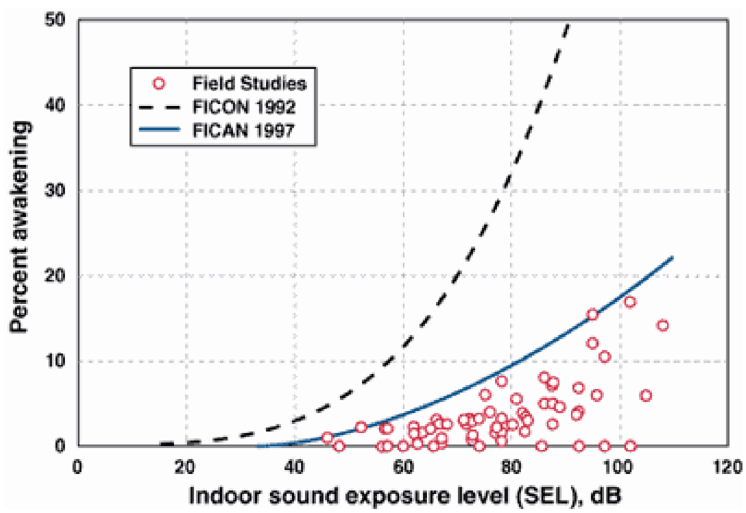
The Origins of the Methods Described in the ANSI Standard

Years of sleep disturbance research and then synthesis of those research results provided a practical method to compute number of people awakened from a full night of aircraft operations. That practical method eventually led to development of the current version of the ANSI Standard.[20]

Sleep Disturbance Research

Night time aircraft noise can awaken people living near an airport, and there have long been efforts to quantify the circumstances that produce such awakenings. Such research has involved documenting the reactions of sleeping subjects to measured noise levels, either in a laboratory or in "field studies" in their homes. The subjects are sometimes attached to instrumentation that measures such things as heart rate, brain activity and physical movement, or they may be asked to simply press a button on a computer next to their bed or on a bracelet whenever they awaken. Noise events may be played through speakers, or may be a result of aircraft flying over their homes. In general, the results of such studies are summarized in a form similar to Figure K-1.

Figure K-1 Typical Experimentally Determined Relationship between Indoor SEL and Percent of Population Awakened



Curves like those plotted in Figure K-1 mathematically represent the summation of the results, showing what percent of the people who experienced the various sound levels were awakened. In the figure, the FICAN 1997 curve shows, for example, that for an indoor Sound Exposure Level of 80 dB, a maximum of about 10 percent of those who experience it are likely to be awakened.

But the issue with most night time noise is not what percent will be awakened by a single event, but what percent or number of people will be awakened by the full night of events. The answer to the

[20] American National Standard, ANSI / ASA S12.9-2008 / Part 6, "Quantities and Procedures for Description and Measurement of Environmental Sound — Part 6: Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes." This Standard is available for purchase at: http://webstore.ansi.org/.

second question is much more practical, particularly in assessing changes in night time noise or ways to reduce the effects of night time noise.

Putting Sleep Research Results to Practical Use

In 2007, a pragmatic approach for using sleep research results was proposed. [21] This approach used the awakening data on each of 84 subjects who lived around Los Angeles International (31 subjects), Denver International Airport (29 subjects) and Castle Air Force Base (24 subjects). The U.S. Air Force provided these data, which were previously obtained by Dr. Sanford Fidell and his co-workers under contract to the U.S. Air Force and NASA and were previously reported. [22,23,24,25] The data on each subject included the time and level of each aircraft noise event as measured in the sleeping room, and whether the subject awoke or not.

First Analysis Result – New Awakening Relationships

The first level of analysis provided by Anderson and Miller developed two primary equations that gave the probability that an average person would awaken dependent on the indoor Sound Exposure Level (SEL). One equation gave the probability independent of when during the night the aircraft noise event occurred, while the second one included the time of night. The results for the second equation showed that the later in the night an event occurred, the more likely a person is to awaken – probability of awakening depends on time of night.

Figure K-2 and Figure K-3 present examples of how, when the time of an event is later, the probability of awakening increases. These results, however, still provide no way to account for a full night of aircraft noise events. The second analysis of the article (footnote 21), gives a method.

[21] Anderson, G.S. and Miller, N.P., "Alternative analysis of sleep-awakening data," Noise Control Eng. J. 55 (2), 2007 March-April

[22] S. Fidell et al, "Noise-induced sleep disturbance in residential settings," Report AL/OE-TR-1994-0131, Occupational & Environmental Health Division, Armstrong Laboratory, Wright Patterson Air Force Base, Ohio (1994).

[23] S. Fidell et al, "Field study of noise-induced sleep disturbance," J. Acoust. Soc. Am. 98(2), (1995)

[24] S. Fidell et al, "Effects on sleep disturbance of changes in aircraft noise near three airports," J. Acoust. Soc. Am. 107(5), (2000)

[25] S. Fidell et al, "Noise-induced sleep disturbance in residences near two civil airports," NASA Contractor Report 198252, Contract NAS1-200101 (December 1995)

Figure K-2 Analysis Results for 1 Hour after Retiring

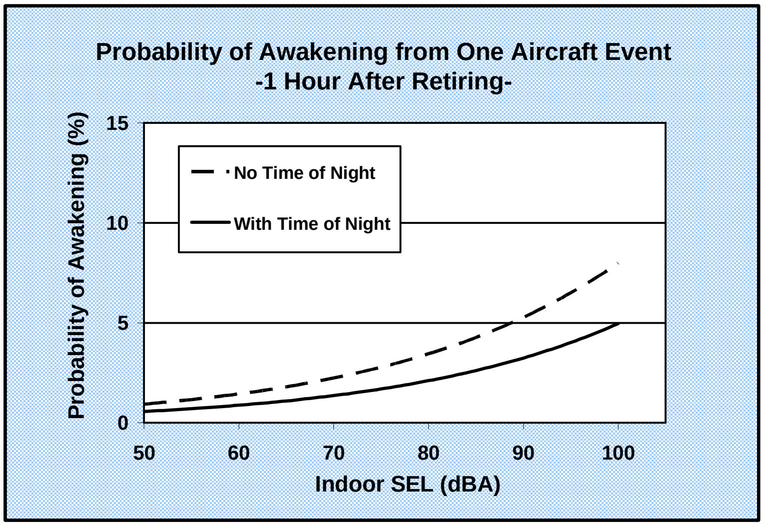
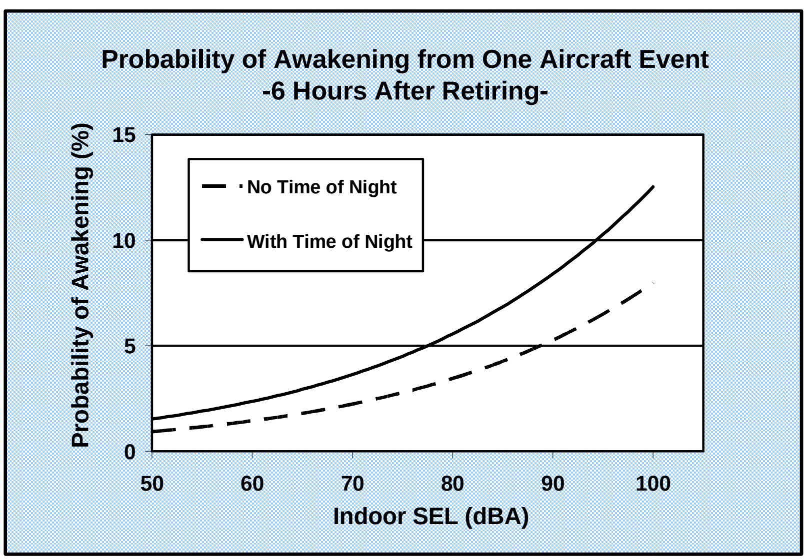


Figure K-3 Analysis Results for 6 Hours after Retiring

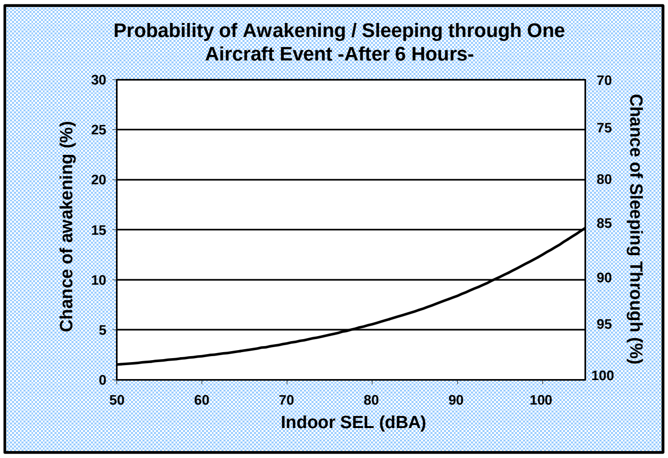


Second Analysis Results – Accounting for a Full Night of Operations

The relationships shown in Figure K-2 and Figure K-3 give probability of awakening. Figure K-4 shows how this probability is translated simply to the probability of sleeping through; i.e., of not awakening from the event. Sleeping through is simply one minus the probability of awakening. If the probability of awakening is 10%, then the probability of not awakening is 90%. If there are two events, then the probability of sleeping through both is 90% times 90% or 81% chance of not awakening.

In the same way, the probability of sleeping through any number of events can be computed. Once all the events in a night are included, then one minus the total probability of sleeping through all events is the probability of not sleeping through them all or the probability of awakening at least once during the night. The result can be interpreted as the percent of people likely to be awakened at least once during the night since the equations of the first analysis are based on averages. The result can also be interpreted as the probability the average person will be awakened at least once during the night.

Figure K-4 Translating Probability of Awakening to Probability of Sleeping Through an Aircraft Event



DEVELOPMENT OF THE STANDARD

The American National Standards Institute, Inc. (ANSI) has served as administrator and coordinator of the United States private sector voluntary standardization system for more than 90 years. ANSI has as its primary goal the enhancement of global competitiveness of U.S. business and the American quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems and promoting their integrity.

ANSI facilitates the development of American National Standards by accrediting the procedures of standards developing organizations. One of those standards organizations is the Acoustical Society of America, providing several ANSI accredited Standards Committees on topics related to acoustics. Specifically, Standards Committee S12 develops and revises standards related to noise.

Committee S12 recognized that since the awakening Standard was first approved in 2000, considerable additional data on sleep disturbance had become available. Following its approved operating procedures, the Working Group 15 of Committee S12 met over the course of several years, reviewing available data and methods developed by credible sleep disturbance studies, both in the U.S. and in other countries. [26]

The committee reached consensus on several important issues, including the following two. First, actual (behavioral) awakening would be the type of sleep disturbance addressed. Several European researchers suggest that physical movement ("motility") is the appropriate indicator of sleep disturbance, [27] while others consider changes in or time spent in different sleep stages the important

[26] Note that Committee S12 has a number of working groups, each working on different aspects of noise and noise control. Working Group 15 is "Measurement and Evaluation of Outdoor Community Noise"

[27] Miedema, H.M.E., W. Passchier-Vermeer, H. Vos, "Elements for a position paper on night-time transportation noise and sleep disturbance," TNO Inro report 2002-59, 2002

measure of sleep disturbance.[28] This decision was based in part on the limited ability to relate these other measures to actual awakenings, the overall uncertainty of the relationship of any type sleep disturbance to health effects, and on the ease of communicating to a lay public the concept of increased or decreased behavioral awakenings.

Second, rather than use a cumulative noise metric such as the Day-Night Average Sound Level, DNL, or the equivalent night-time level, Lnight (as proposed in the reference of footnote 27), the method of Anderson and Miller would be used to compute the percent of populations likely to be awakened at least once during the night as a result of a stated distribution of aircraft SELs. It was noted that the metric of Lnight has been shown to have no correlation with awakenings.[29]

The resultant Standard, after detailed review, comments and changes by Working Group 15, was approved by Committee S12 and approved in July 2008 by the American National Standards Institute, Inc. Later that year, the Standard was reviewed by the Federal Interagency Committee on Aviation Noise (FICAN) and recommended for use in predicting awakenings from aircraft noise; see FICAN Recommendation, Appendix L.

APPLICATION OF THE STANDARD TO CHANGES IN NIGHT OPERATIONS

This section provides the technical detail on use of the Standard to estimate the percent or number of people awakened by nighttime operations at an airport.

The Equation

The relationship that predicts the probability of awakening from a single event is given by Equation K-1.

$$p_{awake,single} = \frac{1}{1 + e^{-Z}}$$

Equation K-1

In this equation, the variable Z is expanded in **Error! Reference source not found.**.

$$Z = \beta_0 + \beta_L L_{AE} + \beta_T T_{retire}$$

Equation K-2

Where:

β_0, β_L, β_T = Constants

L_{AE} = Indoor SEL

T_{retire} = Time since retiring (minutes)

[28] Griefahn, B., S. Robens, P. Bröde, M. Basner, "The sleep disturbance index – a measure for structural alterations of sleep due to environmental influences," Proceedings ICBEN 2008, Foxwoods, CT, U.S.A

[29] Ibid, Fidell, 1994

Table K-1 gives the values of the constants. The constants are different depending on whether or not the times of night of the aircraft noise events (which are translated to time since retiring) are known.

Table K-1 Values of Equation Constants for Calculating Probability of Awakening
Source: ANSI SI12.9-2008

Determine Awakenings Using:	Values of the Constants		
	β_0	β_L	β_T
SEL values only	-6.8884	0.04444	0
SEL and Time Since Retiring	-7.594	0.04444	0.00336

The Method

Define a Grid of Points about the Airport

The Standard is used by computing percent awakened at individual points around the airport. Each point should be associated with a population number. Using census block centroids is one useful means to identify the grid of points. Alternatively, a regular grid of points may be defined, but then the population values need to be associated with the closest or most appropriate grid point. [30]

Run INM to Compute Distribution of SEL Values at each Point

The FAA's Integrated Noise Model (INM) is particularly useful because it can provide (by setting up a "detailed grid point analysis") a complete list of SEL values at each grid point. When accounting for time of night (as done in the Part 161 study) the computations are run once for the operations in each third of the night: 10:00 p.m. to 01:00 a.m., 01:00 a.m. to 04:00 a.m., and 04:00 a.m. to 07:00 a.m.

Determine Outdoor-to-Indoor Noise Level Reductions

In the sleep research, indoor SEL values that are less than about 50 dB have generally been determined to awaken few if any subjects. Hence, any indoor SEL's less than 50 dB may be eliminated from the calculations. (The Standard states that "…the probability of awakening shall be set to zero for any [SEL] that is less than 50 dB."). Because the INM computes outdoor sound levels, an outdoor-to-indoor noise level reduction needs to be selected for each grid point. For some airports, this reduction can be different for the areas where the homes have received sound insulation. [31] Adjust all computed SEL values by the outdoor –to-indoor reduction and eliminate any resulting SEL less than 50 dB.

[30] For example, if population is concentrated away from the centroid, a grid point more closely associated with the actual distribution may be selected.

[31] In realistic applications of the Standard, sound insulation reduces the number of awakenings by 20% to 25%.

Adjust Number of Operations for Seven Hours of Sleep

The Standard recognizes that the nighttime used in the U.S. is nine hours long from 10 p.m. to 7 a.m. yet average U.S. adults sleep seven hours a night. Hence, the number of operations at each SEL value is multiplied by seven-ninths.

Compute the Number or Percent of People Awakened

The computation may be thought of as iterative across grid points and step-wise for each grid point:

- At a grid point, for each SEL value in each of the three night time periods, Equation 1 and Equation 2 with the second row of constants in Table 1 are used to compute the probability of awakening from each SEL; time since retiring that should be used for each third of the night is:
    - For events between 10:00 p.m. to 01:00 a.m. – 70 minutes
    - For events between 01:00 a.m. to 04:00 a.m. – 210 minutes
    - For events between 04:00 a.m. to 07:00 a.m. – 350 minutes
- Compute the probability of not awakening for each SEL by subtracting the probability of awakening from one
- Multiply the probability of not awakening times every other probability of not awakening during the entire night
- Subtract the resulting entire night probability of not awakening from one
- Multiply the entire night probability of not awakening by the population for that grid point
- Repeat the calculation for each grid point
- If desired, the numbers of people awakened at all grid points may be summed to yield:
    - Total number of people awakened
    - Percent of all people awakened

The following tables provide an example calculation at one point with population of 1000.

This page intentionally left blank

Probability of not Awakening 2200-0100
0.69489806

Distribution of Indoor SEL and Number of Aircraft Operations at Each SEL 2200-0100												
Indoor SEL	59	61	63	65	67	69	71	73	75	77	79	81
Number of Ops, each SEL	1	2	3	2	1	2	3	2	1	2	3	2
Tretire	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
7/9 * Ops	0.777778	1.555556	2.333333	1.555556	0.777778	1.555556	2.333333	1.555556	0.777778	1.555556	2.333333	1.555556
Prob Not Awake	0.99131	0.98111	0.969232	0.977497	0.987646	0.973208	0.95648	0.968121	0.982464	0.962096	0.938669	0.954973

Probability of not Awakening 0100-0400
0.67343872

Distribution of Indoor SEL and Number of Aircraft Operations at Each SEL 0100-0400												
Indoor SEL	59	61	63	65	67	69	71	73	75	77	79	81
Number of Ops, each SEL	1	2	1	2	0	1.5	1	2	1	2	3	0
Tretire	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00
7/9 * Ops	0.777778	1.555556	0.777778	1.555556	0	1.166667	0.777778	1.555556	0.777778	1.555556	2.333333	0
Prob Not Awake	0.986163	0.97002	0.983515	0.964344	1	0.968051	0.976642	0.9497	0.972224	0.940357	0.904227	1

Probability of not Awakening 0400-0700
0.50453709

Distribution of Indoor SEL and Number of Aircraft Operations at Each SEL 0400-0700												
Indoor SEL	59	61	63	65	67	69	71	73	75	77	79	81
Number of Ops, each SEL	1	1	2.5	2	1	0	3	0	1	2	1	3
Tretire	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00
7/9 * Ops	0.777778	0.777778	1.944444	1.555556	0.777778	0	2.333333	0	0.777778	1.555556	0.777778	2.333333
Prob Not Awake	0.978034	0.976041	0.935955	0.943837	0.968947	1	0.893415	1	0.95627	0.907063	0.948203	0.840324

For Entire Night

Population at Point	Probability of not Awakening	Probability of Awakening	Number Awakened
1000	0.236109	0.763891	763.8911

Percent Awakened or Chance Average Person Awakened	**76.38911**

APPLICATION OF THE ANSI STANDARD TO ESTIMATE AWAKENINGS

A sleep disturbance study area, which extends beyond the extent of the ANSA for analysis purposes, for this analysis was identified as depicted in Figure K-5, encompassing neighborhoods east and south of LAX that are currently overflown by the non-conforming flights that would be affected by the proposed restriction. It included the parcel boundaries roughly bounded by Interstate Highway 10 to the north, Interstate Highway 605 to the east, and the Pacific Ocean shoreline to the west and south.

For calculating awakenings at a specific location using the ANSI standard, a list of all the SEL values produced by all night-time operations is required. The FAA's Integrated Noise Model (INM, version 7.0b) provides this output in the form of a "detailed grid" which lists for each point, the specific aircraft type and the SEL value produced. The user identifies each grid point where this information is needed, in this case for four scenarios – 2013 with and without the restriction in place, and 2018 with and without the restriction. For computation of the SEL values for the four different cases, detailed grid points were located at the 28,464 census block centroids within the supplemental sleep disturbance study area, using the latest 2010 data from the U.S. Census Bureau.

The ANSI standard requires that the nighttime be divided into three separate time periods, because the likelihood of awakening from noise increases when the time is closer to normal morning awakening. The INM input and computations were therefore done for three separate runs, one representing the hours from 10:00 p.m. to 1:00 a.m., one for the hours from 1:00 to 4:00 a.m., and the third for the hours from 4:00 to 7:00 a.m. Additional consideration was given to the first and third set of nighttime hours because they included only portions of time when the proposed use restriction would be applicable.

Figure K-6 provides a condensed example of detailed grid results for one location. It is condensed in that the numbers of SELs are summed in 5 dB ranges, though the INM reports the SEL values to tenths of a decibel.

With the computation of three different distributions of SEL values for the three nighttime sleep-sensitivity periods at each of the 28,464 population block centroids within the sleep disturbance study area, post processing was applied to determine the percent of people likely awakened at least once at each centroid in accordance with the ANSI standard.

The first step in post processing was to adjust the INM-computed SEL values, which are outdoor values, to equivalent values inside a home, as required for use with the ANSI standard. A single Noise Level Reduction (NLR) value of 27.5 dB[32] was used, based on measurement data reported previously in the 2003 LAX Master Plan. Also, the ANSI standard recommends that no indoor SEL values less than 50 dB be considered since most research has shown that aircraft levels below 50 dB SEL indoors are unlikely to produce an awakening. Applying these two adjustments to the data of Figure K-6 yields the data of Figure K-7. Multiplication of the percent probabilities by the populations of the centroids and summing the results across all 28,464 centroids yields the estimate of total number of people awakened.

[32] Landrum & Brown, Appendix LAX Master Plan Supplement to the Draft EIS/EIR: S-C1, "Supplemental Aircraft Noise Technical Report", June 2003.

Figure K-5 Change in Awakenings due to the Proposed Runway Use Restriction on January 27, 2012

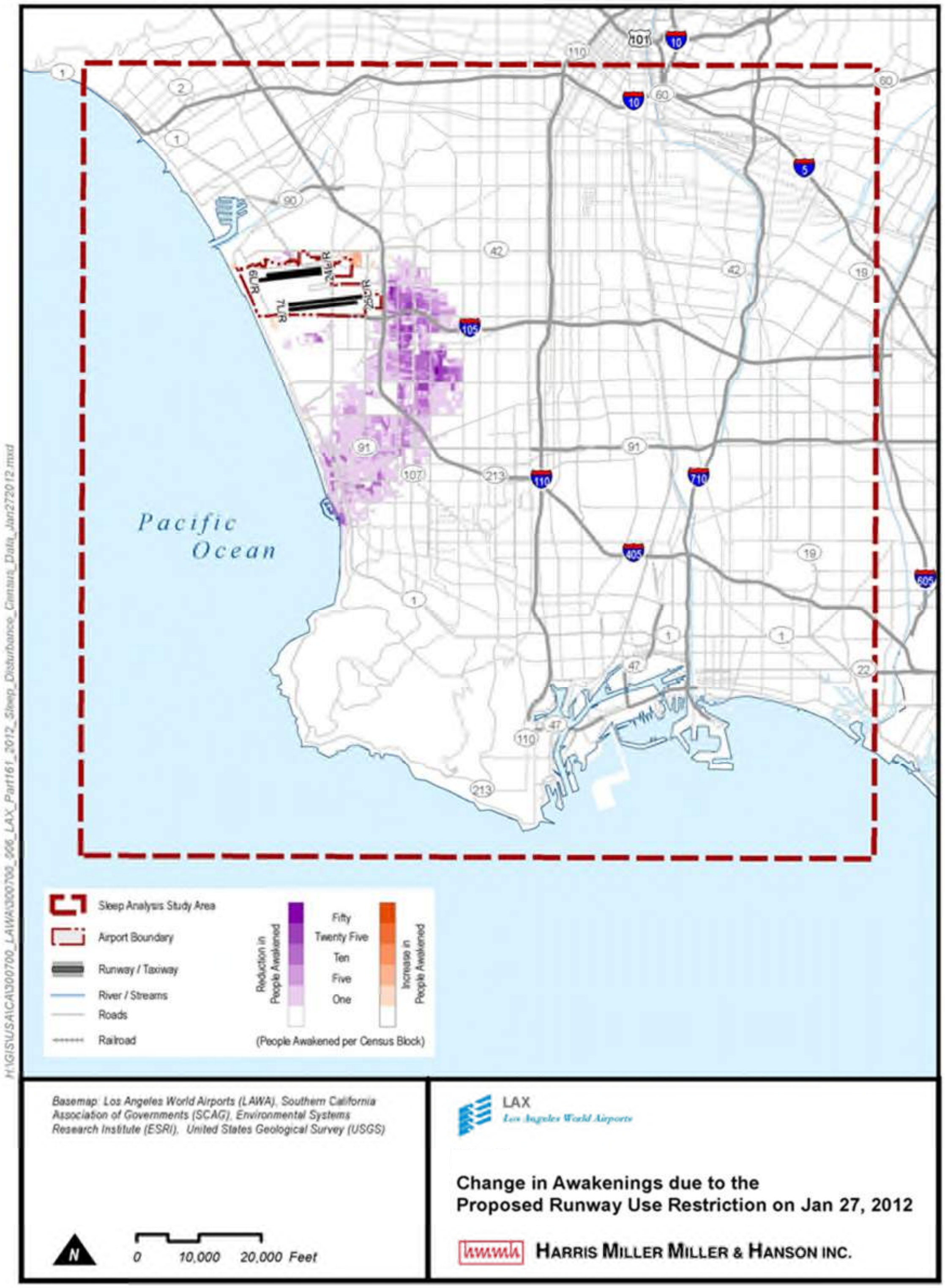


Figure K-6 Typical INM Computed Distribution of Outdoor SEL Values at a Detailed Grid Point
Source: HMMH

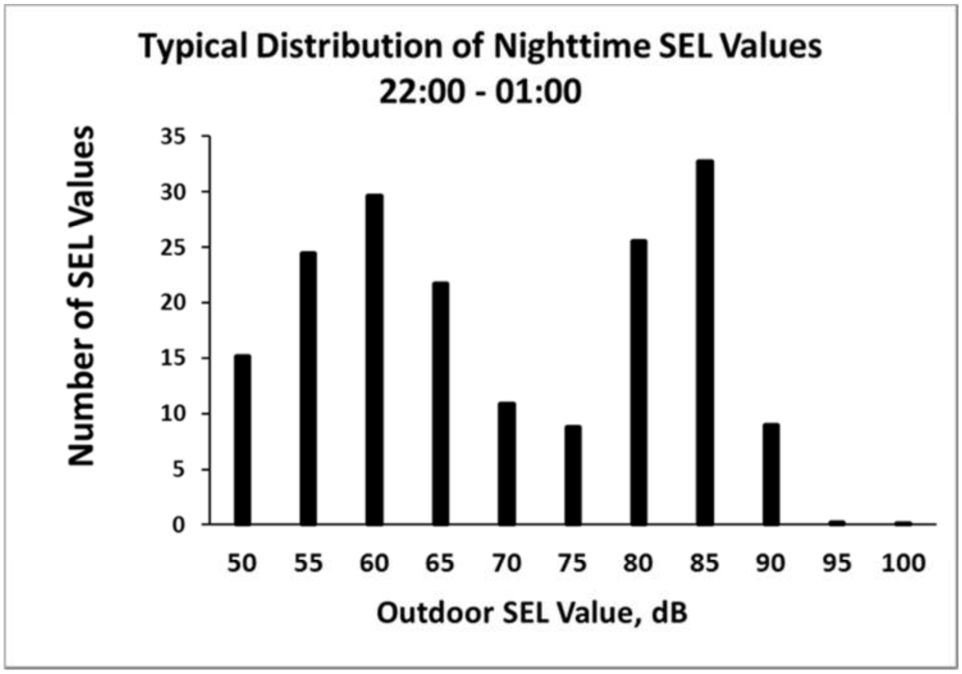
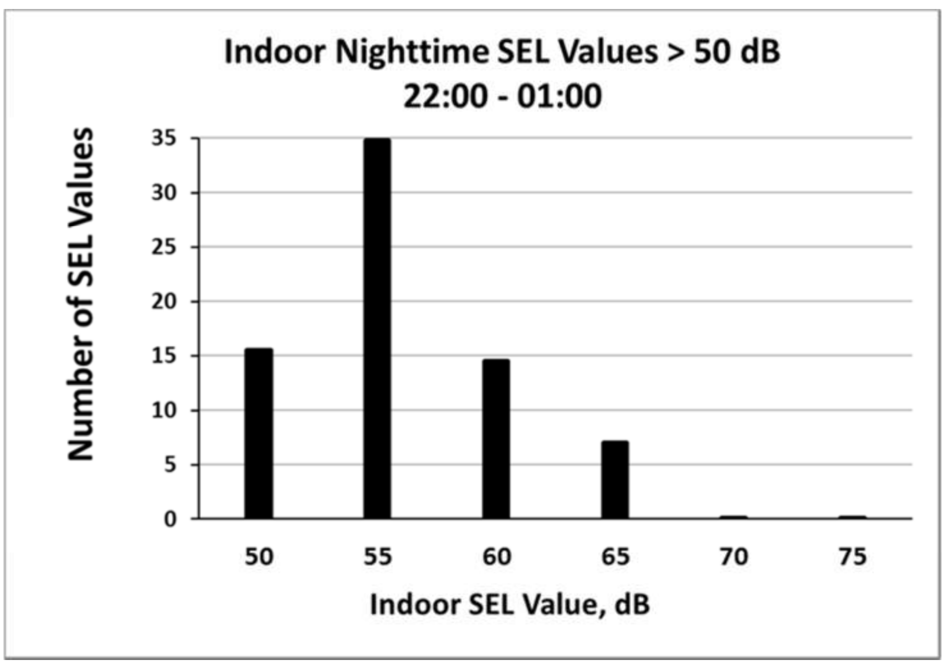


Figure K-7 Outdoor SEL Values Adjusted to Indoors (-27.5 dB)
Source: INM, HMMH



Applying the methods described to the values for this one time period (22:00 to 01:00) analyzed in Figure K-5 and Figure K-7 yields a probability of awakening of about 35%. If this were the total percentage for the grid point (for example if there were no nighttime operations after 01:00) then the population of the associated census block would be multiplied by 35% to yield the estimated number of people awakened at least once by these operations.

The ANSI standard described above was applied to the following operations on January 27, 2012: (1) all nighttime operations as actually flown at the actual time flown; (2) same as (1), except moving the seven non-conforming operations to depart west. The difference between these two scenarios showed that an estimated 8,627 additional awakenings occurred in scenario (1) as compared with scenario (2), which estimates 8,627 fewer awakenings would have resulted on January 27, 2012 with the proposed restriction.

Figure K-5 shows the areas where the awakenings from the seven flights occur during the 1:00 AM hour of January 27, 2012. This estimate is conservative because: (1) standard INM flight profiles were used in conjunction with the ANSI standard[33], which do not extend to the coast line (INM limitation); and (2) these non-conforming operations are not regular occurences during the late-night hours, which may cause awakening in more people than for regular aircraft operations.

Table K-2 shows the total arrivals and departures for the night of January 27, 2012 grouped by the three ANSI nighttime periods (2200-0100, 0100-0400, 0400-0700) including the seven non-conforming flights that occurred in the 2200–0100 time period.

Table K-2 LAX Flight Operations the Night of January 27, 2012
Source: LAWA, HMMH

Time Period	INM Aircraft Type	Arrivals Runway						Departures Runway					
		6R	7L	24L	24R	25L	Total	7L	24L	24R	25L	25R	Total
2200-0100	7373B2				2		2						0
	737500				1	1	2					1	1
	737700			1	8		9		3				3
	737800				1	6	7		1			10	11
	747200					1	1						0
	747400						0					4	4
	757300					1	1						0
	757PW					4	4				1	1	2
	757RR					2	2					1	1
	767300						0					2	2
	767CF6					1	1					2	2
	767JT9					1	1						0
	777200					1	1		1			4	5
	777M						0		1			4	5
	A300-622R					1	1				1		1
	A300B4-203					2	2					1	1
	A319-131	1			4	3	8					3	3

[33] INM standard departure flight tracks end when an aircraft reaches an altitude of 10,000, which is prior to some aircraft reach the coastline. Because the computed noise also ends at this flight track end, the sound exposure levels near the coast are under estimated.

Time Period	INM Aircraft Type	Arrivals Runway						Departures Runway					
		6R	7L	24L	24R	25L	Total	7L	24L	24R	25L	25R	Total
	A320-211				4	1	5		3				3
	A320-232				2	1	3		4			1	5
	A321-232					1	1		2				2
	A330-301				1		1					2	2
	A340-642						0					1	1
	A380-841						0				2		2
	CL601				1	1	2					4	4
	CRJ9-ER					2	2		1			7	8
	DHC830						0		2				2
	EMB120						0		4		2		6
	EMB145						0					2	2
	GIV					1	1				1		1
	GV					1	1				1		1
	MD83					1	1						0
	MD9028						0					1	1
Non-Conforming	747400							**2**					2
	767300							**1**					1
	777200							**2**					2
	777M							**2**					2
	Subtotal	1	0	1	24	33	59	**7**	23	0	6	53	82
0100 - 0400	1900D						0					1	1
	737700						0		1				1
	737800						0		1		1		2
	74720B						0				1		1
	747400		1				1						0
	A300-622R		1				1						0
	A300B4-203						0					1	1
	A319-131		1				1		4				4
	DC1010		2				2						0
	GIV		1				1						0
	MD11PW		1				1						0
	Subtotal	0	7	0	0	0	7	0	6	0	2	2	10
0400 - 0700	1900D						0					1	1
	7373B2				1		1		1			1	2
	737400						0					1	1
	737500						0					1	1
	737700					1	1		4	1		2	7
	737800	1	1				2				1	2	3
	747400				1	1	2					1	1
	757300		1				1					1	1
	757PW	2	3				5					5	5
	757RR		1				1					1	1
	767300	1	4			1	6					1	1
	767CF6					1	1						0
	777M				1	1	2						0

Time Period	INM Aircraft Type	Arrivals Runway						Departures Runway					
		6R	7L	24L	24R	25L	Total	7L	24L	24R	25L	25R	Total
	A300-622R		2				2					1	1
	A320-211						0					1	1
	A320-232				1		1						0
	A321-232						0		2				2
	A330-301					1	1						0
	CL600						0					2	2
	CL601				2	2	4						0
	CNA55B						0					1	1
	CRJ9-ER	1				5	6						0
	DC1010		2				2					1	1
	EMB120	1		1	1	2	5						0
	EMB145				3	1	4					3	3
	F10062						0					1	1
	GIV					2	2						0
	MD11GE		3				3					2	2
	SD330				1		1						0
Subtotal		6	17	1	11	18	53	0	7	1	1	29	38
Grand Total		7	24	2	35	51	119	**7**	36	1	9	84	137

As Table K-2 shows, there was a total of 137 night departures of which 7 (5%) were non-conforming departing to the east.