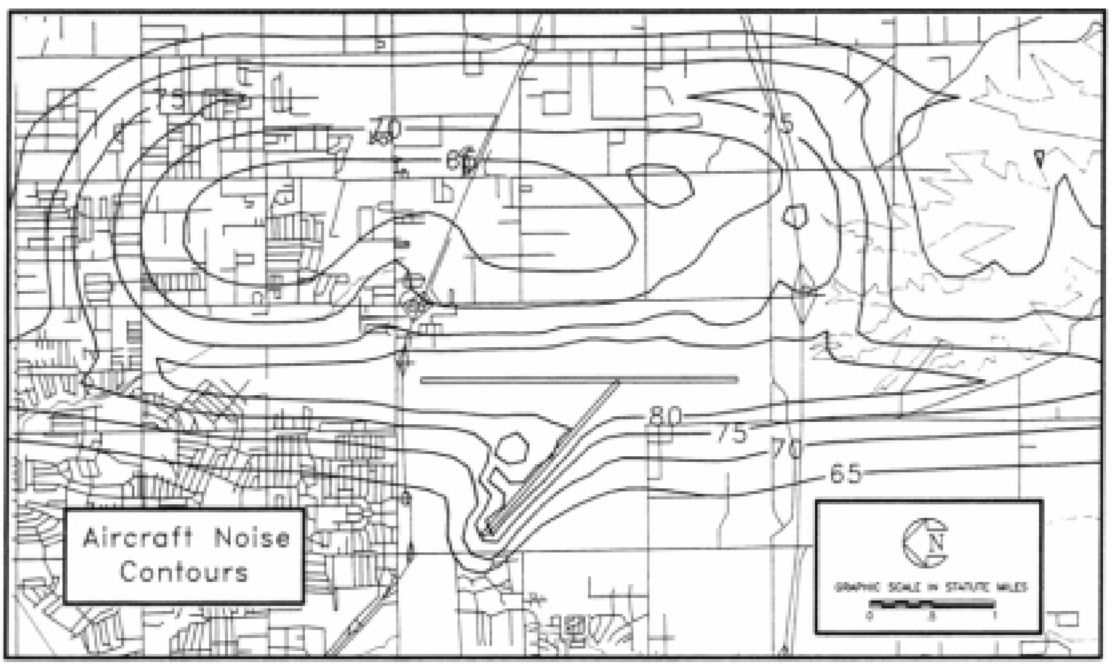
FEDERAL AGENCY REVIEW OF SELECTED AIRPORT NOISE ANALYSIS ISSUES

FEDERAL INTERAGENCY COMMITTEE ON NOISE



AUGUST 1992

FEDERAL
INTERAGENCY COMMITTEE
ON NOISE

The Federal Interagency Committee on Noise has completed its study and is pleased to submit this report, with recommendations, for consideration by member agencies.

The Committee, composed of representatives of the Departments of Transportation (Office of the Secretary and the Federal Aviation Administration), Defense, Justice, Veterans Affairs, Housing and Urban Development; the Environmental Protection Agency; and the Council on Environmental Quality, was chartered to review specific elements of federal agency procedures for the assessment of airport noise impacts and to make appropriate recommendations.

The Committee formed three subgroups: Technical, Policy and Legal. The initial work was performed by the Technical Subgroup, and its study provided the basis for the Policy and Legal Subgroups' findings, conclusions and recommendations. The Legal Subgroup provided an overall legal review of the policy recommendations. The Committee's Report reflects the efforts of all three subgroups. To maximize its utility, the report is formatted with an Executive Summary, a Policy Section which contains the recommendations, and a Technical Section to provide detailed background and support for the recommendations.

Pursuant to agreement by the Legal Subcommittee, this transmittal constitutes the final action of the Federal Interagency Committee on Noise and terminates the Committee.

James Hegland
(Lt. Col, U.S. Air Force)
Chairman, Technical Subgroup

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(Environmental Protection Agency)
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August 21, 1992
(Date)

EXECUTIVE SUMMARY

INTRODUCTION

The 1990 Federal Interagency Committee on Noise (FICON) was formed to review Federal policies that govern the assessment of airport noise impacts. The FICON review focused primarily on:

- The manner in which noise impacts are determined, including whether aircraft noise impacts are fundamentally different from other transportation noise impacts;
- The manner in which noise impacts are described;
- The extent of impacts outside of Day-Night Average A-Weighted Sound Level (DNL) 65 decibels (dB) that should be reviewed in a National Environmental Policy Act (NEPA) document;
- The range of Federal Aviation Administration (FAA)-controlled mitigation options (noise abatement and flight track procedures) analyzed; and,
- The relationship of the FAA Federal Aviation Regulation (FAR) Part 150 process to the NEPA process; including ramifications to the NEPA process if they are separate, and exploration of the means by which the two processes can be handled to maximize benefits.

The FICON was organized into three subgroups to appropriately focus on the technical, legal and policy issues associated with the assessment of airport noise impacts. The Technical Subgroup #1 was tasked to review the body of science associated with methodologies and metrics for assessing airport noise impacts which have evolved since the 1980 meetings of the Federal Interagency Committee on Urban Noise (FICUN). The Policy Subgroup #2 was tasked to review Federal policies that govern the assessment of airport noise impacts. The Legal Subgroup #3 reviewed the legal aspects of current and proposed Federal policies for assessing airport noise impacts. The Subgroup #1 Technical report was used as a basis for the policy report development.

The results of the work of the Policy and Technical Subgroups are contained herein as Volume 1: Policy Review and Volume II: Technical Report. Key conclusions from the Technical Report and the overall FICON recommendations are summarized below.

TECHNICAL CONCLUSIONS

<u>General</u>

- There are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric.
- The methodology employing DNL as the noise exposure metric and appropriate dose-response relationships (primarily the Schultz curve for Percent Highly Annoyed) to determine noise impacts on populations is considered the proper one for civil and military aviation scenarios in the general vicinity of airports.
- Federal agencies generally conduct noise assessments at DNL levels of ≥ 65 dB. For a variety of reasons, noise predictions and interpretations are frequently less reliable

below DNL 65 dB. DNL prediction models tend to degrade in accuracy at large distances from the airport. Therefore, predictions of noise exposure and impact below DNL 65 dB should take the possibility of such inaccuracy into account.

- DNL is sometimes supplemented by other metrics, on a case-by-case basis.
- Noise analyses should address impacts in the following areas: (1) health and welfare, (2) environmental degradation/impact and (3) land use planning.
- Complaints are an inadequate indicator of the full extent of noise effects on a population.

Health and Welfare:

- The dose-effect relationship, as represented by DNL and "Percent Highly Annoyed" (%HA), remains the best available approach for analyzing overall health and welfare impacts for the vast majority of transportation noise analysis situations.
- The 10 dB nighttime penalty levied against noise during the 10 PM to 7 AM period is specifically designed to account for the intrusiveness of noise during this period, and its potential impact on sleep. There are no new hard data which would justify a change in this penalty.
- If supplemental analysis for sleep disturbance is desired, use may be made of an interim dose-response model developed by the AF Armstrong Laboratories (AL) (see Volume II, Section 3.2.2.3). Although this relationship is described in terms of Sound Exposure Level (SEL), single event metrics are of limited use in predicting and interpreting cumulative noise exposure impacts
- Annoyance is a summary measure of the general adverse reaction of people to living in noisy environments that causes speech interference, sleep disturbance, desire for a tranquil environment; and the inability to use the telephone, radio or television satisfactorily.
- No definitive evidence of nonauditory health effects from aircraft noise exists, particularly below DNL 70 dB.
- For supplemental analysis Long-Term Equivalent Sound Level [Leq(x)] (where X represents the time period of concern) or Time Above (TA) may be used for analysis of school and communications requirements indoors during specific hours.
- Public health and welfare effects below DNL 60 dB have not been established, but are assumed to decrease according to the decrease in percent of people highly annoyed.

Environmental Degradation/Impact

- Under NEPA, environmental degradation might have to be assessed around airports even if there is no clear effect on public health and welfare. Other criteria might be appropriate.
- A 3 dB increase in the DNL environment represents a doubling of sound energy, and clearly is an indicator of the need for further analysis, although smaller increases may indicate similar need. In other words, the impact of a given incremental amount of change in noise levels depends, in part, upon the existing level of the noise environment.
- Recent technology and software advances in geographic information systems (GIS),

noise methodology and census data present an enhanced potential for detailed analysis of sound impacts on population and noise-sensitive areas. These technologies should be considered for use to determine noise impacts of present and proposed actions.

Land Use Planning

- DNL represents the accepted noise metric for input to compatible land use planning.
- For cumulative speech interference, Table 3-2 “Effects of Noise on People” contained in FICON Volume II: Technical Report, provides a rough approximation of both outdoor and indoor predicted speech interference parameters for various levels of noise exposure as measured in DNL for residential land use only.
- There is a need for selective updating [including Standard Land Use Coding Manual (SLUCM) updating] and enhanced public understanding of the land-use compatibility guidelines, its application and interpretation through incentives and other programs.

Education of the Public

Education of the public should concentrate on the following frequently misunderstood issues:

- Environmental noise exposure is measured and described most generally by DayNight Average A-Weighted Sound Level (DNL). DNL should be defined clearly and its significance and use explained clearly.
- Relation of DNL to Percent Highly Annoyed describes long-term community response to the overall sound environment (indices of health and welfare effects).
- Although the A-Weighed Maximum Sound Level (L_{max}) for a single flyover is easily understood, it is useful only for analyzing short-term responses.
- Every change in the noise environment does not necessarily impact public health and welfare.
- Aircraft noise predictions below DNL 65 dB can be less accurate and should be interpreted with caution.

POLICY RECOMMENDATIONS

- Continue use of the DNL metric as the principal means for describing long-term noise exposure of civil and military aircraft operations. **[Section 3.1, Volume 1]**
- Continue agency discretion in the use of supplemental noise analysis.**[Section 3.2, Volume 1]**
- Improve public understanding of the DNL, supplemental methodologies and aircraft noise impacts. **[Section 3.3, Volume 1]**
- If screening analysis shows that noise-sensitive areas will be at or above DNL 65 dB and will have an increase of DNL 1.5 dB or more, further analysis should be conducted of noise-sensitive areas between DNL 60-65 dB having an increase of DNL 3 dB or more due to the proposed airport noise exposure. **[Section 3.4, Volume I]**
- If the DNL 65 dB screening test calls for further analysis between DNL 60-65 dB, agency mitigation options will include noise sensitive areas between 60-65 dB that are

projected to have an increase of 3 dB or more as a result of the proposed airport noise exposure. **[Section 3.5, Volume 1]**

- If a FAA FAR Part 150 program is included by the FAA as a NEPA mitigation measure, the FAA and the airport operator are responsible for ensuring that the commitment is carried out and the Part 150 study scope conforms to the NEPA scope of analysis. **[Section 3.6, Volume I]**
- Increase research (R&D) on methodology development and on the impact of aircraft noise. To foster this, a standing Federal interagency committee should be established to assist agencies in providing adequate forums for discussion of public and private sector proposals identifying needed research and in encouraging R&D in these areas. The following initial R&D issues are recommended:
- Evaluate potential modifications to the 1980 FICUN land use compatibility table to improve its usefulness for both routine land use planning and planning for noise-sensitive land uses.
- Continue research into community reaction to aircraft noise, including sleep disturbance, speech interference, and non-auditory health effects of noise.
- Investigate differences in perceptions of aircraft noise, ground transportation noise (highways and railroads), and general background noise.
- Continue and expand research on the airport noise impacts of rotary-wing operations. **[Section 3.7, Volume 1]**

It is the FICON's belief that these recommendations will provide both immediate and longterm improvements in airport noise analysis. Federal interagency encouragement of a continuing review of airport noise analysis will provide for future incorporation of improved airport noise analysis techniques and provide a forum to address related public concerns.

While the FICON is seeking to achieve improved uniformity among Federal agencies in airport noise impact analysis, it must also be recognized that agencies have differing legislative mandates and operating environments. These recommendations should be viewed as general guidance. Each Federal agency must determine how it can best use this guidance, supplementing it as appropriate to meet agency needs, within the framework of the NEPA requirements.

The FICON Report itself neither addresses the adequacy of compliance with NEPA to-date by the participating agencies, attempts to redefine thresholds of significance of impacts under NEPA, nor modifies the NEPA regulations or procedures of the agencies.

FEDERAL INTERAGENCY COMMITTEE ON NOISE

VOLUME 1

POLICY REPORT

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ABBREVIATIONS AND ACRONYMS

%HA	Symbol for Percent Highly Annoyed
AAMRL	Armstrong Aerospace Medical Research Laboratory, now known as Armstrong Laboratory (USAF)
AL/OEBN	Armstrong Laboratory, Noise Effects Branch (USAF)
AEM	Area Equivalent Method
AF	Air Force
AFB	Air Force Base
AFM	Air Force Manual
AGL	Above Ground Level (Altitude in Feet)
AICUZ	Air Installation Compatible Use Zone
ANSI	American National Standards Institute
ASNA	Aviation Safety and Noise Abatement Act of 1979
CAB	Civil Aeronautics Board
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CHABA	Committee on Hearing, Bioacoustics, and Biomechanics (of the National Academy of Science)
CNEL	Community Noise Equivalent Level (used in California)
dB	Decibel
DNL	Day-Night Average A-Weighted Sound Level
DoD	(U.S.) Department of Defense
DOJ	(U.S.) Department of Justice
DOT	(U.S.) Department of Transportation
EA	Environmental Assessment
EECP	Expanded East Coast Plan
EIS	Environmental Impact Statement
EPA	(U.S.) Environmental Protection Agency
FAA	(U.S. DOT) Federal Aviation Administration
FAR	Federal Aviation Regulation
FHWA	(U.S. DOT) Federal Highway Administration
FI	Fractional Impact Method
FICON	Federal Interagency Committee on Noise (1992)
FICUN	Federal Interagency Committee on Urban Noise (1980)
GIS	Geographic Information System
HUD	(U.S.) Department of Housing and Urban Development
Hz	Hertz (formerly cycles/second)
INM	Integrated Noise Model (FAA)
L_{dn}	Symbol for Day-Night Average A-Weighted Sound Level (DNL)
L_{eq}	Long-Term A-Weighted Equivalent Sound Level
$L_{eq(24)}$	Equivalent Sound Level during a 24 hour time period
$L_{eq(x)}$	Equivalent Sound Level during a given time period
L_{max}	A-weighted Maximum Sound Level
LWP	Level Weighted Population
NCA	Noise Control Act

NEPA	National Environmental Policy Act
NIHL	Noise-Induced Hearing Loss
NIOSH	National Institute for Occupational Safety and Health
NIPTS	Noise-Induced Permanent Threshold Shift
NITTS	Noise-Induced Temporary Threshold Shift
NOISEMAP	DoD Noise Model
NSBIT	Noise and Sonic Boom Impact Technology (Air Force Armstrong Laboratory)
SEL	Sound Exposure Level
SIL	Speech Interference Level
SLUCM	Standard Land Use Coding Manual
SPI,	(Third Octave Band) Sound Pressure Level
TA	Time Above
USAF	United States Air Force
USGS	U.S. Geological Survey
VA	(U.S.) Department of Veterans Affairs
YDNL	Yearly Day-Night Average A-Weighted Sound Level

SECTION 1 INTRODUCTION

1.1 Introduction

This report describes the purpose and recommendations of the Federal Interagency Committee on Noise (FICON). The FICON was formed in December 1990 with a basic charter to review specific elements of the assessment of airport noise impacts contained in documents prepared pursuant to the National Environmental Policy Act (NEPA) and to Federal Aviation Regulation (FAR) Part 150, and to make recommendations regarding potential improvements to that process. The technical foundation of this report is contained herein as Volume 11: FICON Technical Report.

1.2 The National Environmental Policy Act (NEPA) Process

The National Environmental Policy Act (NEPA), enacted in 1970, declares a national policy of "encourage(ing) productive and enjoyable harmony between man and his environment," and declares that protection and enhancement of the environment is the "continuing responsibility" of the federal government [42 USC § 4321, 4331(b)]. To ensure that such environmental goals are met, NEPA requires federal agencies to analyze the environmental impacts of proposed actions, to document that such analyses were performed, and to provide the public with an opportunity to comment on those analyses [Sec 42 USC § 4332(2)(c) and 40 CFR Parts 1500- 1508]. This process of considering the environmental impacts of proposed federal actions is known as the "NEPA process."

Briefly, under NEPA and regulations promulgated by the Council on Environmental Quality (CEQ) to implement the procedural provisions of the statute (CEQ 1986), an Executive Branch federal agency is required to prepare an environmental impact statement (EIS) for a proposed action if that action is expected to have a "significant" effect on the quality of the human environment (See 40 CFR Part 1502). When the significance of the anticipated environmental effects of a proposed agency action is unclear, the agency must prepare an environmental assessment (EA) to assist in making that determination (See 40 CFR Part 1508.9). If, on the basis of an EA, the agency determines that the environmental impact(s) of its proposal may be significant, then the agency must prepare an EIS. If the agency determines that the impacts will not be significant, it may issue a "Finding of No Significant Impact" (FONSI) and proceed with its proposal. Only those actions that an agency has determined in advance to have no significant environmental effects, individually or cumulatively (categorical exclusions), are exempt from NEPA documentation (See 40 CFR Part 1508.4).

As required by the CEQ regulations, each Executive Branch federal agency also has its own NEPA implementing regulations that supplement the CEQ regulations (See 40 CFR Part 1507.3). Each agency identifies both those types of actions that typically have significant environmental impacts and thus require preparation of EISs, and those actions that typically have no significant environmental impacts and thus are categorically excluded from NEPA requirements. All other actions require at least the preparation of EAs.

While CEO is authorized to oversee Executive Branch federal agency implementation of NEPA, the Environmental Protection Agency (EPA) is directed in Section 309 of the Clean Air Act to "review and comment in writing" on all EISs prepared by federal agencies (42 USC 7609). If the EPA Administrator determines that a particular agency action is unsatisfactory from the standpoint of public health and welfare or environmental quality, he or she is required to refer the matter to CEO for review.

1.3 Study Purpose

Pursuant to its Section 309 authority, EPA reviewed a draft EIS prepared by the Federal Aviation Administration (FAA) for a proposed expansion of the Toledo Express Airport in Toledo, Ohio. EPA raised specific objections to the draft EIS relating to the analysis and mitigation of noise impacts. Although these issues were eventually resolved at the final EIS stage for the Toledo project, the FAA and EPA agreed to jointly study the underlying basis for the disagreements and to attempt to resolve the identified differences between the two agencies on noise analysis in NEPA documents.

To facilitate resolution of the issues, the respective Deputy Administrators of FAA and EPA initiated an interagency working group to review the technical and policy issues involved (U.S. DOT, FAA 1990; U.S. EPA 1990). Five specific issues were identified that formed the basis for the work group focus. These five issues are:

- The manner in which noise impacts are determined, including whether aircraft noise impacts are fundamentally different from other transportation noise impacts;
- The manner in which noise impacts are described;
- The extent of impacts outside of Day-Night Average A-Weighted Sound Level (DNL) 65 decibels (dB) that should be reviewed in a National Environmental Policy Act (NEPA) document;
- The range of Federal Aviation Administration (FAA) -controlled mitigation options (noise abatement and flight track procedures) analyzed; and,
- The relationship of the FAA Federal Aviation Regulation (FAR) Part 150 process to the NEPA process; including ramifications to the NEPA process if they are separate, and exploration of the means by which the two processes can be handled to maximize benefits.

Although the origin of these issues was specific to FAA and EPA, it was recognized that the issues relating to the use and application of the DNL metric were of vital interest to other Federal agencies involved in aircraft noise related decisions. Since the DNL metric was formally recommended by EPA in 1974 (U.S. Environmental Protection Agency 1974) and agreed upon in 1980 by the Federal Interagency Committee on Urban Noise for use in their Guidelines for Considering

Noise in Land Use Planning and Control (FICUN 1980)[1], the working group was expanded to include those FICUN agencies involved in airport noise issues.

The agencies that participated in the 1980 FICUN included the Department of Defense (DoD), the Department of Housing and Urban Development (HUD), the Environmental Protection Agency (EPA), the Department of Transportation (DOT), and the Department of Veterans Affairs (VA). The policies and programs discussed in the 1980 FICUN all shared a common goal of protecting the public health and welfare with regard to noise. Most FICUN policies also stated additional goals in recognition that noise is a specific constraint on particular agency missions. DoD, for example, stated as a primary goal of its noise policy the continuance of operational integrity at its airfields (FICUN 1980).

By involving these Federal agencies, it was envisioned that any conclusions reached would provide guidance for each agency to adopt and implement consistent with their operational requirements, thereby improving consistency in the federal approach for aircraft noise analysis in NEPA documents.

In addition to the FICUN agencies, the Council on Environmental Quality (CEQ) and the Department of Justice (DOJ) were added to the current working group because of their roles in NEPA issues. This working group has become known as the Federal Interagency Committee on Noise (FICON). The charter of the group is limited to the examination of the issues specified above. The working parameters of the FICON are:

- Review of the issues will be done within the context of the NEPA process and the CEQ regulations and guidance.
- Issues that relate to the operation of fixed wing aircraft in and around airports.
- The review will be limited to existing information, with no conduct of new research.
- Analysis of the issues and presentation of recommendations on these issues will be made to the various agencies for decision on all five issues. No decision making or implementation will occur prior to that presentation.
- Any resulting change in regulations and/or procedures Will follow individual agency's rules for public review and comment prior to adoption.

1.4 Study Approach

To address these issues systematically, three subgroups were formed to examine and analyze the technical, policy and legal implications separately.

Subgroup 1, chaired by the Air Force on the behalf of DoD, reviewed technical and scientific matters related to the adequacy of current data and methodology for use in NEPA (EIS/EA) analysis of airport operations. Their technical report (Volume II) summarizes the results of that evaluation, and was used as the basis for work by the Subgroups 2 and 3.

Subgroup 2, chaired by the EPA, reviewed all the issues from the perspective of agency policy and procedures and the requirements of NEPA/CEQ regulations.

[1] See Section 2.1 for origin and description of 1980 FICUN.

Subgroup 3, chaired by the FAA, reviewed the legal aspects of all issues. The results of their review have been incorporated into the reports of the Technical and Policy Subgroups. Participating agencies and their representatives are listed in Appendix B, Volume I and Appendix C, Volume II.

1.5 Summary of Recommendations

Following its review, the FICON concluded that the federal noise assessment process can and should be improved. The improvements suggested are not radical. They fall within the normal process of periodically reassessing present procedures and techniques to ensure that the most practical and realistic approaches are being used. The specific recommendations are summarized below and are discussed in detail in the section noted at the end of each recommendation.

- Continue use of the DNL metric as the principal means for describing the longterm noise impact of civil and military aircraft operations. **[Section 3.1]**
- Continue agency discretion in the use of supplemental noise analysis. **[Section 3.2]**
- **Improve** public understanding of the DNL, supplemental methodologies and aircraft noise impacts. **[Section 3.3]**
- If screening analysis shows that noise sensitive areas will be at or above DNL 65 dB and will have an increase of DNL 1.5 dB or more, further analysis should be conducted of noise-sensitive areas between DNL 60-65 dB having an increase of DNL 3 dB or more due to the proposed airport noise exposure. **[Section 3.4]**
- If the DNL 65 dB screening test calls for further analysis between DNL 60-65 dB, agency mitigation options may include noise sensitive areas between DNL 60-65 dB that are projected to have an increase of 3 dB or more as a result of the proposed airport noise exposure. **[Section 3.5]**
- If a FAA FAR Part 150 program is included by the FAA as a NEPA mitigation measure, the FAA and the airport operator are responsible for ensuring that the commitment is carried out and the Part 150 study scope conforms to the NEPA scope of analysis. **[Section 3.6]**
- Increase research (R&D) on methodology development and on the impact of aircraft noise. To foster this, a standing Federal interagency committee should be established to assist agencies in providing adequate forums for discussion of public and private sector proposals, identifying needed research, and encouraging R&D in these areas. **[Section 3.7]**

It is the FICON's belief that these recommendations will provide for both immediate and long-term improvements in airport noise analysis. Federal interagency encouragement of the continuing review of airport noise analysis will provide for future incorporation of improved airport noise analysis techniques and provide a forum to address related public concerns.

While the FICON is seeking to achieve improved uniformity among Federal agencies in airport noise analysis, it must also be recognized that agencies have differing legislative mandates and operating environments. Thus, these recommendations should be viewed as general guidance. Each Federal agency must determine how it can best use this guidance, supplementing it as appropriate to meet agency needs within the framework of its NEPA requirements.

SECTION 2 BACKGROUND

2.1 Background

In 1972, Congress enacted the Noise Control Act (NCA), Public Law 92-574. Among the requirements under NCA was a directive to the Administrator of the Environmental Protection Agency (EPA) to "...publish information on the levels of environmental noise, the attainment and maintenance of which in defined areas under various conditions are requisite to protect the public health and welfare with an adequate margin of safety." The resulting report was published as EPA550/9-47-004, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, (1974) commonly referred to as the "Levels Document."

In the "Levels Document," the EPA reported that the best metrics to describe the effects of environmental noise in a simple, uniform and appropriate way were:

- the Long-Term Equivalent A-Weighted Sound Level (L_{eq}); and
- the Day-Night Average Sound Level (DNL), which may be symbolized as L_{dn}; it is a variant of L_{eq} that incorporates a 10 dB "penalty" for nighttime noise.

The protective levels identified in the "Levels Document" do not constitute "standards" since they do not account for the cost or feasibility of achievement. It is also pertinent that the "Levels Document" defines the public health and welfare in broad terms, based on the World Health Organization's definition of "health" as "complete physical and mental well-being and not merely the absence of disease and infirmity".

In response to a request in 1972 by EPA, the National Academy of Science's Committee on Hearing, Bioacoustics and Biomechanics (CHABA) Working Group 69 held deliberations from 1972 to 1976. The result of this effort was the publication of CHABA's Guidelines for Preparing Environmental Impact Statements on Noise (1977). These guidelines were proposed for the uniform description and assessment of the various noise environments potentially requiring an EIS.

Following the publication of the CHABA Guidelines, Schultz published his "Synthesis of Social Surveys on Noise Annoyance" in 1978. Schultz's synthesis of the dosage-effect relationship provided the best tool available to environmental planners to predict noise-induced chronic annoyance. In fact, chronic annoyance is the implicit basis for noise related habitability criteria, such as those adopted by various government agencies (U.S. Department of Defense 1978).

In late 1979, the FICUN was formed to put the various Federal agencies' policy and guidance packages on environmental noise into perspective. The result was the publication of Guidelines for Considering Noise in Land Use Planning and Control (1980). The Guidelines do not replace individual Federal agency criteria, but serve as a point-of-departure for each agency's programs, and for facilitating the consideration of noise in all land use planning and interagency/intergovernmental processes. The FICUN established DNL as the descriptor to be used for all noise sources. The L_{eq} descriptor was included because some highway noise is described in terms of an equivalent sound level for the highway "design hour." Table 2 of the FICUN Guidelines contained land use compatibility guidelines and Table D-1 describes the chronic effects of noise on people in terms of annoyance, speech interference, and hearing loss.

In 1982, the EPA published Guidelines for Noise Impact Analysis based on the CHABA Guidelines. The purpose of the EPA Guidelines was to provide decision-makers, both in the public and private sectors, with analytic procedures that could be used uniformly to express and quantify impacts from noise (U.S. Environmental Protection Agency 1982). Individual agencies have developed their own guidance for assessing aircraft noise in NEPA documents.

In 1990, the American National Standards Institute (ANSI) revised their 1980 Standard on Sound Level Descriptors for Determination of Compatible Land Use (ANSI S12.40-1990). This new standard continues to identify DNL as the "acoustical measure to be used in assessing compatibility between various land uses and outdoor noise environment." The standard further states:

Ordinarily, land uses are of long-term, continuing nature, and the yearly day-night average sound level is appropriate for these land uses. For other land uses, compatibility is to be assessed by the average sound level during the time interval of interest for the land use involved.

2.2 Noise Evaluation Methodologies

As outlined above, the Long-Term A-Weighted Equivalent Sound Level (Leq) and the DayNight Average Sound Level (DNL or L_{dn}) were selected as the appropriate descriptors for noise because they reliably correlate with health and welfare effects. From data on many community social surveys, DNL has been found to correlate well with community annoyance, as measured in terms of percentage of exposed persons who are "Highly Annoyed."

In general, the noise exposure is defined by use of computed DNL contours. While endorsing DNL, not all agencies apply the DNL methodology in the same manner. Most agencies plot noise contours only for DNL ≥ 65 dB. Some plot contours down to DNL ≥ 60 dB, but generally on a case-by-case basis only. Others conduct point analysis down to DNL 60 dB for noisesensitive areas such as schools, hospitals and churches.

Variations among agencies also exist in how DNL is calculated. For example, the 24-hour averaging time is sometimes based on average yearly operations and sometimes on variations of average busy day, whichever is considered most representative of flying conditions. Although seasonal corrections are not included in the definition of the DNL metric, the methodology does not preclude such corrections in any analysis of a special, well-defined noise exposure scenario. Agencies have different policies on whether ground run-up operations are included in the DNL models. Agencies apply various screening criteria for evaluating whether incremental or additional proposed changes warrant further noise analysis. Finally, agencies' methods of summarizing noise impacts vary. Most typically, impacts are summarized in one or more of the following ways: (1) by percent of number of people highly annoyed and the number of people highly annoyed at DNL ≥ 65 dB; (2) by number of people or acres exposed to DNL ≥ 65 dB; and (3) by identification of specific noise-sensitive land uses and areas.

Noise predictions are less reliable at lower noise levels, and at increasing distances from the airport since the ability to determine the contribution of different noise sources decreases with diminishing intensity and increasing distance from the source. There are also problems in interpreting predictions at lower levels since public health and welfare effects below DNL 60 dB (DNL 60 dB includes a 5 dB margin of safety) have not been established. These effects are assumed to decrease according to the decrease in percent of people highly annoyed.

Much of the criticism of the use of DNL for community annoyance (U.S. EPA 1991) and land use compatibility around airports stems from a failure to understand the basis for the measurement or calculation of that metric. This misunderstanding may arise from the fact that although DNL is strongly influenced by the maximum sound level, it is much lower in value, and therefore may not convey to the public the loudness of individual flyovers. DNL takes into account the magnitude of the sound levels of all individual events that occur during the 24- hour period, the number of events, and an increased sensitivity to noise during typical sleeping hours. DNL is an average in that it accumulates all the noise exposure over a 24-hour period and divides the total by the number of seconds in a day. As described in the FICON Technical Report, the logarithmic nature of the decibel (dB) unit on which DNL is based causes sound levels of the loudest events to control the 24-hour average.

2.3 Supplemental Noise Evaluation Methodologies and Metrics

DNL is sometimes supplemented by other metrics to characterize specific effects on a case-by-case basis. This may include the cumulative metric of Leq (Equivalent Sound Level) for varying representative time periods. Single event metrics used for supplemental analysis may include SEL (Sound Exposure Level), Third Octave Band Sound Pressure Level (SPL), L_{max} (A-weighted Maximum Sound Level), and TA (Time Above - expressed in minutes for which aircraft-related noise exceeds specified A-weighted sound levels). In addition, to comply with various State requirements, metrics such as the Community Noise Equivalent Level[2] (CNEL), used in California, and the level exceeded a specified percentage of the time, ($L_{Percent}$) (L_{10} is used in Minnesota) are sometimes included.

The DNL methodology includes a 10-dB nighttime penalty that reflects the potential for added annoyance due to sleep disturbance, speech interference, and other effects. However, supplemental single event analysis is sometimes conducted to evaluate sleep disturbances and, less frequently, speech interference issues, primarily at specific locations where the DNL is below 65 dB. The use of single event analysis is limited because there is no accepted methodology for aggregating these values into some form of cumulative or overall impact description. TA is sometimes considered for evaluating speech interference in schools.

[2] The Community Noise Equivalent Level includes a 5 dB penalty for noise between 7 and 10 p.m. and a 10 dB penalty for noise between 10 p.m. and 7 a.m. California accepts DNL as equivalent to CNEL for planning purposes.

Single event prediction methods have limited application to land use planning. One should not infer that an area is simultaneously exposed to a given single event level, since noise decays with increasing distance from the flight track. Single event levels have been calculated and published for given aircraft, at given distances and power settings (See Volume II, Appendix B, Tables B.2 and B.3). However, in determining the single event level for a given event, one must consider the variations in an aircraft flight profile caused by variations in weight, daily and seasonal weather changes, wind, power settings, etc. Consequently, the single event metric has limited use in determining long-term noise impacts. When single event metrics are used to supplement DNL, they serve only to provide additional information. Single event metrics have been used to evaluate sleep interference, but do not predict long-term human health impacts.

The various approaches to airport noise assessment methodology used by Federal agencies are summarized in Table 2.1

2.4 Noise Effects

2.4.1 Annoyance

Until the 1950s, the effects of aircraft noise were evaluated largely on the basis of anecdotal evidence, case studies, laboratory studies, and a very few social surveys. Even in early days, "annoyance" was given prominence and the severity of annoyance was thought to be very important. In more recent years, there has been emphasis on obtaining data on community response from social surveys of the affected communities. A major effort has been directed toward finding a relationship between noise exposure metrics and a measure of activity interference (assumed by most researchers to be primarily communication interference) or annoyance as measured by a social survey. A wide variety of responses have been used to determine intrusiveness of noise and disturbances such as speech interference, sleep disturbance, interference with TV or radio listening, and interference with outdoor living. The concept of "percent highly annoyed" has provided the most consistent response of a community to a particular noise environment.

In an attempt to meet the demand for a usable and uniform relationship, Schultz reviewed the results of a number of social surveys where data were available to make a consistent judgement concerning what percent of the population was "highly annoyed" (%HA) (Schultz 1978). The surveys were of community reactions to several types of transportation noises such as road traffic, railroad, and aircraft noises. The results agreed fairly well with one another and Schultz developed an equation for describing the relationship between the level of exposure (in DNL) and %HA. This relationship was adopted by CHABA Working Group 69 (National Academy of Sciences 1977) in the guidelines previously discussed. EPA proposed %HA as the appropriate impact criterion to use for evaluating the effects of noise on communities (U.S. Environmental Protection Agency 1982).

The Schultz relationship has been validated in several subsequent studies. Fidell and associates (Fidell 1989) updated the data base originally used by Schultz. Subsequent research documented in the update added 239 data points to the original 161 data points analyzed by Schultz, for a total of 400 points. The Department of the Air Force's Armstrong Laboratory used a

Table 2.1 Federal Agency Policy and Program Summary

AGENCY		1. DEPARTMENT OF DEFENSE (DOD)	2. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)	3. ENVIRONMENTAL PROTECTION AGENCY (EPA)	4. DEPARTMENT OF TRANSPORTATION		5. DEPARTMENT OF VETERANS AFFAIRS (VA)
					Federal Aviation Administration (FAA)	**Federal Highway Administration (FHWA)**	
Type of program of Policy		Air Installation Compatible Use Zone (AICUZ) Program	HUD Noise Regulations	Health & Welfare Guidance	Aviation Noise Abatement Policy Land Use Compatibility	Highway Noise Policy	VA Airport Noise Policy (VA Loan Guarantee Program)
Key Documents		DOD Instruction 4165.57 (1977) Installation AICUZ Studies	24 CFR Part 51 Subpart B; Noise Assessment Guidelines (1980) The noise Guidebook (1985)	EPA "Levels" Document (1974); EPA Guidelines (1982)	DOT/FAA Aviation Noise Abatement Policy (1976) Advisory Circular; 150/5050-6 (1977) FAR Part 150 FAAO 1050 ID FAAO 5050 4A	23 CFR 772	VBA Manual M26-2 Section VIII Appraisal of residential properties near airports (1986)
Noise Levels	Title of Levels	Levels used as "reasonable" guidance to local communities for planning	Levels which determine whether proposed sites are eligible for HUD insurance or assistance	Levels which are required to protect the public health and welfare with an adequate margin of safety	Levels used as "starting points" in determining noise/land use relationships	Noise Abatement Criteria	Property eligibility is based on the noise zone in which it is located: Zone (1) under DNL 65 Zone (2) DNL 65-75 Zone (3) over DNL 75
	Purpose of Levels	Guidance to local communities for planning. Reflects cost, feasibility, past community experience, general program objectives, and consideration of health and welfare goals.	See above. Levels can be used as general planning levels. Reflects cost, feasibility, general program objectives and consideration of health and welfare goals.	These levels identify in scientific terms the threshold of effect. While the levels have relevance for planning, they do not form the sole basis for appropriate land use actions because they do not consider cost, feasibility or the development needs of the community. The user should make such tradeoffs.	Guidance to communities for planning. Reflects safety, cost, feasibility, general program objectives, and consideration of health and welfare goals.	These levels are used in determining where noise mitigation on a particular highway project is warranted. They do not reflect cost or feasibility considerations. They are appropriate land use criteria. Location specific.	Levels are used to determine whether properties are unsuitable for residential use and therefore not eligible for VA guaranteed loans.
	Source to which applied	Military Airfields	All sources	All sources	Civil Airports	Highways only	Civilian and Military Airfields
	Noise Descriptor Used	DNL	DNL	DNL	DNL (CNEL, California only)	L_{eq} or L_{10} for design hour	Various (including DNL)

SOURCE: FICUN 1980. Revised - FICON 1991.

regression analysis procedure to develop a logistic[3] fit equation describing the relationship between DNL and %HA based on the updated data. A comparison of the logistic fit equations based on the original (161 data points) and the updated (400 points) data indicates that the predicted values are so similar (within about 1 percent) that no advantage would be obtained by replacing the original equation for describing the relationship (Fidell 1989).

The relationship is an invaluable aid in assessing community response as it relates the response to increases in both sound intensity and frequency of occurrence. Although the predicted annoyance, in terms of absolute levels, may vary among different communities, the Schultz curve can refiably indicate changes in level of annoyance for defined ranges of sound exposure for any given community.

2.4.2 Health Effects

Regarding public health effects, the "Levels Document" stated, "At this time there is insufficient scientific evidence that non-auditory diseases are caused by noise levels lower than those that cause noise-induced hearing loss." The "Levels Document" identified an $L_{eq(8)}$ not exceeding 70 dB (i.e. 8 hours per day) over a 40-year period for protection against noise-induced hearing loss (U.S. Environmental Protection Agency 1974). In 1981, the National Academy of Sciences, Committee on Hearing, Bioacoustics and Biomechanics (CHABA) was asked by the National Institute for Occupational Safety and Health (NIOSH) to consider research that might be performed to examine the effects on human health from long-term exposure to noise. The CHABA (Working Group 81), in their report, The Effects on Human Health From Long-Term Exposure to Noise, concluded that "evidence from available research is suggestive, but it does not provide definitive answers to the question of health effects other than to the auditory system of the long-term exposure to noise" (National Academy of Sciences 1981). Consequently, the issue of whether significant non-auditory health effects results from aircraft noise still remains and requires additional research.

2.5 Land Use Compatibility

Federal guidelines for compatible land use that take into account the impact of aviation noise have been devised for land near airports. They were derived through an iterative process that started before 1972. Independent efforts by the FAA, HUD, USAF, USN, EPA and other Federal agencies to develop compatible land use criteria were melded into a single effort by the Federal Interagency Committee on Urban Noise in 1979, and resulted in the FICUN Guidelines document (1980). The Guidelines document adopted DNL as its standard noise descriptor, and the Standard Land Use Coding Manual (SLUCM) as its standard descriptor for land uses. The noise-to-land use relationships were then expanded for FAA's advisory circular Airvort-Land Use Compatibility Planning. The current individual agency compatible land use criteria have been, for the most part,

[3] A logistic fit equation is recommended in preference to the polynomial fit equations recommended in the Guidelines because it gives essentially the same predicted values in the range of interest (45 to 75 dB) and does not predict values of less than 0 or more than 100 percent.

derived from those in the FICUN Guidelines. Airport environments pertain only to certain categories of these guidelines.

The Aviation Safety and Noise Abatement Act of 1979 (ASNA) required the adoption of a single descriptor for noise and a single set of standards for assessing the impacts of noise on people. In meeting this requirement, the FAA in FAR Part 150 adopted DNL and a compressed version of the FICUN Guidelines' land use compatibility table, and thus established the first noise exposure-to-land use compatibility criteria in the Code of Federal Regulations.

In general, the basic Federal land use compatibility criteria are derivatives of the FICUN Guidelines. The ANSI Standard S12.40-1990 is not as detailed. All land use compatibility is based on the use of DNIL as the cumulative descriptor representing community noise environments and tends to be expressed in terms of DNL, in DNL contours ≥ 65 dB in 5 dB increments, and in terms of noise reduction levels based on DNL. The FICUN Guidelines treat areas below DNL 65 dB as compatible for residential land uses and above this level as marginally compatible to incompatible, depending on the degree of noise level reduction provided in affected structures.

HUD provides standards (U.S. HUD 1985) for future land use planning in noise environments. HUD's standards are exceptions to the general Federal practice of providing recommended noise guidelines to local communities. The VA Loan Guaranty Service has no regulations concerning noise; however, they have established noise policies and procedures that are used to determine the eligibility of properties for VA guaranteed loans. These policies are based on DoD and DOT noise studies.

The DoD, DOE, HUD and DOT are currently working together to update the Standard Land Use Coding Manual (SLUCM) categories used in land use compatibility guidelines. When SLUCM updating is completed, new land use compatibility guidelines for any new land use codes will need to be determined for each DNL range.

In general, Federal land use compatibility criteria have been broadly accepted. Perhaps the most controversial aspect of the criteria has been the designation of all uses below the DNL ≥65 dB contour as compatible. Additional questions have been raised regarding the compatibility levels selected for some individual noise-sensitive uses, such as park areas.

SECTION 3 AIRPORT NOISE POLICY RECOMMENDATIONS

3.1 DNL Metric

RECOMMENDATION: Continue use of the DNL metric as the principal means for describing longterm noise exposure for civil and military aircraft operations.

The EPA "Levels Document" identified two versions of equivalent sound level to be used to measure noise exposure. These are $L_{eq(24)}$, which represents sound energy averaged over a 24- hour period, and L_{dn} (also known as DNL), which represents the $L_{eq(24)}$ with a 10 dB nighttime penalty. The DNL methodology is generally used to relate noise in residential environments to chronic annoyance by activity interference. The EPA Guidelines for Noise Impact Analysis (1982), recommends DNL as the primary measure of general audible noise and as the environmental noise descriptor for land use compatibility planning.

Some citizens and public interest groups have expressed concern that the DNL "methodology" may not completely reflect the human response to exposure to multiple noise events versus an individual event, and that it may not accurately account for impacts of night flights. These concerns usually result from a lack of understanding of the DNL metric, and how it accounts for these factors. In addition, the use of DNL has sometimes been criticized when the noise analysis in a NEPA document has excluded areas below the DNL 65 dB contour. This particular criticism should be directed at the scope of the application of the DNL metric rather than the metric itself. It is, therefore, important to separate the question of the applicability of the DNL metric as an adequate measure for aircraft noise exposure from its scope of application.

The Aviation Safety and Noise Abatement Act of 1979, as noted in Section 2.5, directed FAA to establish by regulation a single system for measuring noise exposure at airports and surrounding areas which would provide a highly reliable relationship between projected noise exposure and surveyed reactions of people to noise. The FAA adopted DNL. The EPA Guidelines for Noise Impact Analysis (U.S. Environmental Protection Agency 1982) also used DNL as the primary measure of general audible noise. All Federal agencies have now adopted DNL as the metric for airport noise analysis in NEPA (EIS/EA) documents.

The FICON technical subgroup (Subgroup 1) focused extensively on the question of the applicability of the DNL metric. After reviewing all noise exposure metrics, the FICON technical subgroup concluded that no other metrics are of sufficient scientific standing to replace DNL. The available evidence indicates that DNL continues to be the superior metric to account for variations in the noise environment, including such factors as numbers of flights, loudness of individual aircraft, and percentage of night flights.

This conclusion reaffirms the extensive technical efforts that went into selection of DNI, in the first place. The EPA “Levels Document” identified the DNL metric to be used to relate noise in residential environments to chronic annoyance by speech interference and in some part by sleep and activity interference (U.S. Environmental Protection Agency, 1974).

The FICON recommends that DNIL continue to be used as the primary metric for aircraft noise exposure. However, the FICON members consider the problem of public understanding of the DNL methodology as substantive, and have made a specific recommendation (Recommendation 3.3) to address this problem.

The FICON also considered the applicability of the DNL metric to non-aircraft transportation sources (highway and railroad), and concluded that DNL can appropriately be used to analyze other transportation source noise in airport environmental documents. However, other transportation noise is usually not analyzed in airport environmental documents because aircraft noise is considered the dominant noise source and generally “masks” other source noise in the immediate airport vicinity.

3.2 Supplemental Noise Analysis

RECOMMENDATION: Continue agency discretion in the use of supplemental noise analysis.

Some Federal agencies supplement DNL analysis on a case-by-case basis to characterize specific noise effects. Supplemental analyses use various metrics, including the cumulative metric L_{eq} (Equivalent Sound Level) for varying representative time periods; and the single event metrics. SEL (Sound Exposure Level), L_{max} (A-weighted Maximum Sound Level), Third Octave Band Sound Pressure Levels (SPL), and TA (Time Above - expressed in minutes for which aircraft-related noise exceeds specified A-weighted sound levels). A description of these metrics. is contained in Appendix B Volume II: Technical Report.

Supplemental analyses may also be accomplished using the various capabilities of NOISEMAP and INM for specific point analysis. These models can be used in combination wit. geographic information systems (GIS), design programs such as AutoCAD and the 1990 U.S. Census TIGER databases[4] to determine various population impacts within specified areas.

Supplemental analyses are most often used to determine aircraft noise impacts at specific noise-sensitive locations, particularly in analyses of speech interference or sleep disturbance. Single event analysis is sometimes conducted to evaluate sleep disturbance and, less frequently, some speech interference, primarily at locations where the DNL is below 65 dB.

Generally, supplemental metrics are used to further analyze specific noise-sensitive situations. Because of the diversity of such situations, the variety of supplemental metrics available, and the limitations of individual supplemental metrics, the FICON concluded that the use of supplemental metrics to analyze noise should continue to be left to the discretion of individual agencies.

[4] The 1990 Census data are being released in the form of computer readable databases (on either magnetic tape or optical disks). They contain demographic data at the census tract and block levels and information on the geographic location (latitude and longitude) of the geographic area to which the data apply (census block, tract, etc.). The use of a geographic information system (GIS) permits this information to be used in combination with the TIGER (Topologically Integrated Geographic Encoding and Referencing System) fine files which contain digitized versions of the U.S. Geological Survey (USGS) 1:100,000 scale maps to determine the area to which the information is applicable (i.e. the boundaries of the census block of tract). The GIS can then be used to combine population data with the output of noise models to provide detailed estimates of population exposure as wen as other demographic data.

3.3 Improvements in Explanation of Noise Metrics and Supplemental Methodologies

RECOMMENDATION: Improve public understanding of the DNL, supplemental methodologies and aircraft noise impacts.

Federal agencies generally provide a "layman's" explanation of the noise analysis methodologies used in NEPA documents. However, many such explanations need further simplification to achieve a broader understanding of the noise impact of proposals, actions, and alternatives.

A better explanation of the DNL metric must be developed in terms related to an average person's experience. In addition, a good explanation of why DNL is used as the overall metric for analyzing aircraft noise impacts around airports is needed to improve the public's understanding of aviation noise assessment.

The FAA and DoD currently display in their NEPA documents (EAs/EISs) the number of people residing in the various contour intervals DNL $\geq$ 65 dB; the other noise-sensitive land uses within each of these contours (e.g., schools, churches, hospitals); and a table showing compatible and incompatible land uses. Sometimes, but not always, the 1980 FICUN Table D-1 "Effects of Noise on People" is included.

The purpose of a supplemental analysis is to convey ,vith more specificity and detail the potential effect of changes to the environment as the result of a Federal action. Accordingly, the description should be tailored to enhance understanding of the pertinent facts surrounding the changes. Use of supplemental metrics selected should fit the circumstances. There is no single supplemental methodology that is preferable for all situations. The type or nature of activity potentially affected should be considered; e.g. in speech interference (schools, etc.) the use of $L_{eq(x)}$ or TA may be appropriate. An enhanced explanation of the operational changes is also supplemental information that would substantially enhance public understanding. Any additional analysis needs to inform both the Federal decision-maker and the affected public.

3.4 Scope of Airport Noise Analysis between DNL 60 dB and 65 dB

> **RECOMMENDATION:** If screening analysis shows that noise-sensitive areas will be at or above DNL 65 dB and will have an increase of DNL 1.5 dB or more, further analysis should be conducted of noisesensitive areas between DNL 60-65 dB having an increase of DNL 3 dB or more due to the proposed airport noise exposure.

The debate on the scope of analysis for airport noise assessments has been going on for some time, and has involved both Federal agencies and the public sector. Although analysis in areas with DNL values below 65 dB has been performed within existing federal agency procedures, such analysis has not been carried out in a uniform manner. For example, the U.S. Navy includes DNL 60 dB contours in their NEPA documents, but the FAA and U.S. Air Force routinely do not. These agencies provide various types of noise analysis below the DNIL 65 dB level on a case-by-case basis depending upon local circumstances.

After consideration of the issues, FICON has concluded that it is prudent to provide for systematically analyzing noise levels below DNL 65 dB in NEPA documents using the screening procedures indicated below. If done properly, this added level of analysis could provide useful information to both the public and decision maker. There are a number of reasons for moving in this direction at this time. First, the Schultz curve recognizes that some people will be highly annoyed at relatively low levels of noise. This is further evidenced from numerous public response forums that some people living in areas exposed to DNL values less than 65 dB believe they are substantially impacted (U.S. EPA 1991). Secondly, the FICON Technical Subgroup has shown clearly that large changes in levels of noise exposure (on the order of 3 dB or more) below DNL 65 dB can be perceived by people as a degradation of their noise environment. Finally, there now exist computational techniques that allow for cost- effective calculation of noise exposure and impact data in the range below DNL 65 dB.

From a technical standpoint, the concern with expanding noise analysis to lower DNL levels is the reliability of the predictions and the interpretation of results. Noise predictions are less reliable at lower levels, and at increasing distances from the source. There are increased uncertainties associated with variable local atmospheric conditions and large propagation distances that occur with increasing altitude of the aircraft in areas with low DNL levels. The ability to determine the contribution of different noise sources is also diminished at lower noise levels. At lower DNL values, the existing non-aircraft noise may mask the aircraft noise. In the airport environs, the non- aircraft noise may begin to dominate aircraft noise at levels below DNL 60 dB.

These technical problems generally start to become issues for analysis below the DNL 65 dB level. The FICON Technical Subgroup report cautioned that noise predictions below DNL 65 dB should be characterized as to their relative accuracy and be done on a case-by-case basis. In view of these drawbacks and because public health and welfare effects below DNL 60 dB have not been well established, the FICON decided not to recommend evaluation of aviation noise impacts below DNL 60 dB.

To arrive at a systematic way to determine when a level between DNL 60 and 65 dB should be included in a noise analysis, the Technical subgroup developed a criterion based on its conclusion that a 3 dB increase in the DNL, which represents a doubling of energy, is clearly perceptible and suggests the need for further analysis. In addition to this requirement, a second criteria was added to screen out cases where it is unlikely that a 3 dB increase would occur.

Existing FAA guidance specifies that a detailed noise analysis may be required if there is a 1.5 dB increase in DNL in noise-sensitive areas exposed to DNL 65 dB or greater. In practice, it has been found that unless a proposed airport project will cause at least a 1.5 dB increase within the DNL 65 dB or greater area, there will not be a 3 dB or greater increase in the DNL 60-65 dB area.

In view of the above, the recommended screening procedure consists of a two part test: the first part using the 1.5 dB increase criterion at DNL 65 dB to eliminate those cases where a 3 dB increase is unlikely to occur anywhere, and the second part dealing with the remaining cases by determining those areas within the DNL 60-65 dB area where a 3 dB or more increase does occur.

3.5 Scope of Noise Analysis That Will Guide Potential Mitigation Measures

RECOMMENDATION: If the DNL 65 dB screening test calls for further analysis between DNL 60-65 dB, agency mitigation options will include noise-sensitive areas betwee n DNL 60-65 dB that are projected to have an increase of 3 dB or more as a result of the proposed airport noise exposure.

When noise increases to noise-sensitive areas between DNL 60-65 dB are analyzed in a NEPA document, an agency's consideration of appropriate mitigation should include the potential for mitigating noise in these areas. Agencies should consider the same range of mitigation options that are potentially available at DNL ≥ 65 dB, including eligibility for Federal (FAA) civil aviation funding.

This is not to be interpreted as a commitment to fund or otherwise implement noise mitigation measures in any particular area around airports, whether above or below DNL 65 dB. The technical, financial, political practicality and appropriateness of various mitigation measures and the extent of mitigation vary from proposal to proposal. For a major airport development proposal with significant noise impacts, 100 percent mitigation of the identified noise increases is usually far beyond what is practicable to do. NEPA requires an analysis of appropriate and practicable mitigation measures for proposals. Mitigation measures that are not appropriate or practicable, regardless of whether an area is above or below a particular noise level, need not be analyzed.

As a general rule, fewer mitigation measures that are appropriate and practicable exist at lower noise levels. For example, since areas below DNL 65 dB are normally categorized in the FICUN Guidelines as compatible for residential uses, it is not generally the case that civil and joint use airport NEPA documents commit to acquiring property and relocating residents in such areas. Noise abatement adjustments to flight procedures, however, tend to be viewed as the most likely candidates for mitigating noise at lower levels for all types of airports because they are within Federal control and do not involve changes in land uses. However, this tool also has limitations. In order for a noise abatement flight procedure to be considered viable for analysis, there should be a reasonable expectation that a noise benefit of worthwhile magnitude would result, and that implementation of the procedure is appropriate and practicable. Factors affecting these determinations include airfield layout and operational characteristics, air traffic safety and efficiency of operation, the amount and location of noise sensitive land uses around an airport, and whether there are alternate (i.e., non-noise-sensitive) corridors for accepting greater amounts of noise. Procedural changes usually involve moving noise around rather than eliminating it, and may actually result in noise increases for some people, while reducing noise for others. It is generally expected that Federal priority will be given to mitigating noise at higher levels. It would not normally be a mitigation practice to increase the impacted population at higher noise levels in order to reduce increases at lower noise levels.

3.6 Relationship between NEPA and FAA FAR Part 150 Actions

RECOMMENDATION: If an FAA FAR Part 150 program is included by the FAA as a NEPA mitigation measure, the FAA and the airport operator are responsible for ensuring that the commitment is carried out and the Part 150 study scope conforms to the NEPA scope of noise analysis.

The FAA FAR Part 150 process and the NEPA process are essentially separate processes with different purposes. NEPA analyses and Part 150 studies originate from different statutes and NEPA analyses (EAs and EISs) are project specific while Part 150 studies are airport comprehensive. A Part 150 airport noise compatibility study is not generated by a Federal action, and it is not a Federal document. It is a comprehensive airport noise study that is voluntarily undertaken by an airport operator. It examines aircraft noise and non-compatible land uses in entirety around an airport, differing from a noise analysis in a NEPA document which concentrates on the noise impacts of a particular airport development project. The study product is a document which the airport operator submits to the FAA. The FAA may not substitute a federally recommended program in lieu of the local noise program submitted by the airport operator. If an airport operator's recommended program measures meet the specified standards of Part 150, the FAA approves them. If they do not, the FAA disapproves them.

Of the approximately 100 Part 150 programs approved to date, only a handful have been proposed as NEPA mitigation measures. This came about because some airport operators who were proposing major airport development projects voluntarily committed to accomplishment of a Part 150 as supplemental noise mitigation for the project.

FAA guidance is that an airport operator's commitment, within the NEPA context, to undertake and implement a Part 150 study should not be discouraged because Part 150 programs have produced measurable noise benefits. However, simply to state in a NEPA document that a Part 150 study will be done and implemented does not constitute substantive mitigation of a specific airport development proposal because FAA cannot predict with certainty the recommendations that will result from the study and be approved. To the extent that the FAA seeks to include substantive mitigation commitments in a NEPA document, more solid and specific commitments are required.

The FAA has, in some cases, combined specific mitigation commitments and a Part 150 study. In these cases, the NEPA document commits to certain specific noise mitigation and, in addition, indicates that a Part 150 study will be done with the goal of achieving more mitigation. In another example, the NEPA document commits to specific noise mitigation and indicates that the priorities or timing of the mitigation will be refined in a Part 150 study.

By statute, Part 150 is a voluntary program. In all cases in which a Part 150 study has been integrated into NEPA mitigation, it has been a voluntary decision, with FAA concurrence, by the airport operator with respect to Part 150. However, once a Part 150 study has been included in a NEPA document as one of the mitigation commitments, the FAA and the airport operator accept the responsibility to see that it is carried out.

If an airport operator volunteers to undertake a Part 150 study as part of NEPA mitigation when an airport development project includes impacts between DNL 60 and 65 dB, analyzed according to revised agency guidelines resulting from FICON recommendations, it would be expected that the scope of the Part 150 study would include noise sensitive areas between DNL 60-65 dB that were identified in the EIS as having an increase of DNL 3 dB or more due to the proposed project. The scope of the Part 150 study should be explicitly committed to in the NEPA document.

A description of the FAA FAR Part 150 process is provided in Appendix A.

3.7 Research and Development

RECOMMENDATION: Increase research (R&D) on methodology development and on the impact of aircraft noise. To foster this, a standing Federal interagency committee should be established to assist agencies in providing adequate forums for discussion of public and private sector proposals, identifying needed research, and in encouraging the conduct of R&D in these areas.

Although there have been a number of research efforts over the last decade, there remains a need to look at the basic elements of the aircraft noise assessment methodology. While other methodologies are evolving as supplements to the existing DNL methodology, the current system for noise analysis within the NEPA context is based on the implementation of recommendations from the 1980 FICUN report. The essential elements of that report included the DNL metric, the Schultz curve (which provides a relationship between the DNL and the percent of people "highly annoyed"), the "Effects of Noise on People," (Table D-1), and a land use compatibility table depicting the land uses generally compatible with various DNL levels. After ten years of experience in applying these elements, it seems appropriate to review them systematically to determine whether improvements are desirable or feasible.

In addition to reviewing existing methodologies with a view toward improvement, wider application of evolving technologies may improve both the efficiency and effectiveness of noise analyses. As an example of a promising technology, the availability of census data on computer disks now facilitates rapid computer analysis of the number of people exposed to various DNL levels for various alternative scenarios.

Although the R&D effort will foster discussion on a wide range of issues, the FICON recommends the following initial R&D agenda:

- Evaluate potential modifications to the 1980 FICUN land use compatibility table to improve its usefulness for both routine land use planning and planning for noise-sensitive land uses. There has been no systematic, comprehensive review of this table since its development in 1980; however, there is some current activity in this area. The DoD, DOE, HUD and DOT, are updating the land use coding manual used for identifying various types of land use. The U.S. Delegation to the International Civil Aviation Organization Committee on Aviation Environmental Protection is recommending that the organization evaluate land use compatibility standards for potential application on an international scale.
- Continue research into community reactions to aircraft noise, including sleep disturbance, research on non- auditory health effects, speech interference, as well as the

development of improved assessment criteria for these effects. The Schultz curve relating DNL to the percent of people highly annoyed is generally accepted as a valid criterion for noise impact and has been revalidated by recent analyses (Fidell et al. 1989; Finegold et al. 1992). There are, however, no other validated impact criteria related specifically to sleep or speech disturbance or criteria related to short-term impacts associated with supplementary metrics.

- Investigate the differences in perceptions of aircraft noise, ground transportation noise (highways and railroads), and general background noise. While each of these sources can be described using the DNI, metric, direct comparison of their values can produce varying results. There should be further R&D on the "masking" effects of various types of non-aircraft noise when compared to aircraft noise. The background ambient DNL needs to be considered. However, there exists only a generalized, commonly accepted methodology or analytical procedure for addressing these issues. Additional research to develop an approach for inclusion of ambient sound levels in current aviation noise assessment methodologies is recommended.
- The FICON Policy report findings and recommendations are limited to airports dominated by fixed-wing aircraft. Military and civil aviation includes significant numbers of rotary-wing aircraft. Given the unique noise signatures attributable to rotary-wing aircraft and the resulting community response, it is recommended that future Federal interagency deliberations and analysis include discussions and research on the impacts of rotary-wing operations.

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APPENDIX A DESCRIPTION OF FEDERAL AVIATION REGULATION (FAR) PART 150

The Aviation Safety and Noise Abatement Act of 1979 directed the FAA to:

- establish a single system of measuring noise for which there is a highly reliable relationship between projected noise exposure and surveyed reactions of people to noise, to be uniformly applied in measuring the noise at airports and the areas surrounding airports;
- establish a single system for determining the exposure of individuals to noise that results from airport operations which includes consideration of noise intensity, duration, number of occurrences, and time of occurrence;
- identify land uses that are normally compatible with various exposures of individuals to noise;
- establish a program for airport operators to voluntarily develop and submit to FAA (1) noise exposure maps showing present and future non-compatible land uses around an airport, and (2) a noise compatibility program setting forth measures to reduce existing incompatible land uses and to prevent the introduction of additional incompatible land uses around an airport; and
- make Federal funding available for preparing a noise compatibility program and for projects to carry out a noise compatibility program.

The FAA implemented the Aviation Safety and Noise Abatement Act of 1979 through the issuance of Part 150 of the Federal Aviation Regulations (FAR) (DOT, FAA 1989).

In Part 150, FAA designated DNL as the noise metric to be used, and required noise exposure maps to include DNL contours of 65 dB, 70 dB, 75 dB. Noise contours below 65 dB are not required by Part 150, but they are permitted at local airport operator discretion. The FAA has received noise exposure maps that include the DNL 60 dB contour and the DNL 55 dB contour.

Supplemental noise methodologies are not included in Part 150 because the Act directed the establishment of a single system of measuring noise and because DNL is the accepted metric for addressing the land use compatibility that the Act requires. Airport operators may, at their option, include other noise metrics in support of their recommended program. The FAA has reviewed noise compatibility programs that include supplemental metrics, usually some type of single-event analysis.

Part 150 includes the 1980 FICUN land use compatibility criteria. These criteria are guidelines only, and Part 150 specifically allows local discretion in using the criteria. The FAA has received noise exposure maps and noise compatibility programs that include variations to these criteria, usually identifying land uses as incompatible at levels lower than DNL 65 dB.

An airport operator that undertakes airport noise compatibility planning under Part 150 is required to: develop present and future noise exposure maps; examine the airport's current and forecast future noise problems based on these maps; consider ways to reduce the exposure of noisesensitive land uses to levels of aircraft noise that are not compatible with those land uses; recommend noise reduction/land use compatibility measures to be implemented; and submit its maps and recommended program to the FAA.

The Act directs the FAA to approve an airport operator's noise compatibility program if it meets specified standards. These standards require the program to:

- Provide for reduction of existing incompatible land uses and prevention of the establishment of additional incompatible land uses;
- Impose no undue burden on interstate or foreign commerce;
- Not unjustly discriminate among users;
- Not result in derogation of safety or adversly effect on the safe and efficient use of airspace;
- Meet both local needs and needs of the national air transportation system, to the extent practicable, considering tradeoffs between economic benefits derived from the airport and the noise impact;
- Be capable of implementation in a manner consistent with all of the powers and duties of the FAA Administrator; and
- Provide for program revision, if necessary.

The FAA has approved more than 100 airport noise compatibility programs. At any airport with a substantial noise problem, the total implementation of a noise compatibility program will produce noticeable and measurable benefits, but it is not usually practicable to remove all people from areas of significant noise exposure levels.

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FEDERAL INTERAGENCY COMMIT17EE ON NOISE

VOLUME 2

TECHNICAL REPORT

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SECTION 1 INTRODUCTION

1.1 Introduction

This report provides the technical background which underlies the work of the Federal Interagency Committee On Noise (FICON). It presents a brief summary of the scientific basis for the current Federal policies regarding airport noise assessments and provides a brief background on the characteristics of sound and the methodologies and metrics used for analysis of the noise environment. Of the five major issues reviewed by the FICON, two were clearly scientific and technical in nature and two were predominantly related to current and future policy decisions. The remaining issue included elements of both technical and policy decisions.

1.2 Purpose

The FICON Technical Subgroup, chaired by the Air Force (AF) on behalf of DoD, reviewed technical and scientific matters related to the adequacy of current data and methodology for use in environmental impact analysis of airport operations. This technical report summarizes the results of that evaluation and provides the scientific basis for work by other Subgroups.

1.3 Scope/ Limitations

This technical report is limited to discussions of noise as it relates to fixed wing aircraft in the airport environs and focuses on the scientific and technical activities and improvements in airport noise impact assessments since the last interagency review completed in June 1980.

SECTION 2 NOISE METRICS AND IMPACT ASSESSMENT METHODOLOGIES

2.1 The Present Situation

2.1.1 Background

In its 1972 Report to the President and Congress under Title IV of the Clean Air Act (PL 91-601), the Environmental Protection Agency (EPA) presented the results of its “full and complete... study of noise and its effects on public health and welfare.” Among other proposals, this report recommended that the Federal government assess the various methods of evaluating noise and community response, with a goal of “standardization, simplification, and interchangeability of data.” (U.S. EPA 1972).

In 1972, Congress enacted The Noise Control Act (NCA)(PL 92-574). The NCA assigned responsibility to the Administrator of the Environmental Protection Agency (EPA) to coordinate all Federal programs relating to noise research and noise control. It also directed EPA to identify noise levels requisite to protect the public health and welfare with an adequate margin of safety, without regard to technical feasibility or economic costs. As indicated by EPA (1974), it was the intent of Congress that a single, uniform measure of cumulative noise exposure be developed.

The result of this effort was publication of the EPA report Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adeguate Margin of Safety (U.S. EPA 1974), frequently referred to as the “Levels Document.” The intent of “Levels” is to provide information; the caveat that the recommended levels should not be considered “standards” is clearly stated. Furthermore, “public health” is defined in the broadest terms as “complete physical, mental and social well-being and not merely the absence of disease and infirmity.” The phrase “health and welfare” is taken to include personal comfort and well-being and the absence of mental anguish and annoyance. However, the “Levels Document” does point out that annoyance is not recognized as a compensable injury, in the absence of interference with a personal property right (U.S. EPA 1974).

2.1.2 Current Practices

A review of the principles and definitions associated with sound and sound measurement is provided in Appendices A and B. To properly assess the impacts of sound on a diverse spectrum of receptors, a variety of measures (metrics) and associated impact assessment methodologies are employed. Each metric is designed to satisfy different requirements or to emphasize certain sound characteristics. These cumulative and single event metrics are described in detail in Appendix B.

L_{eq} and its DNL variation (symbolized as L_{dn}), which includes a 10 dB penalty added to nighttime noise events, were selected as uniform descriptors of cumulative noise exposure to correlate with health and welfare effects. These cumulative metrics are the primary metrics employed to determine community (population) dose-response and annoyance of sound events. EPA recommends, and most Federal agencies have adopted the, *Yearly Average* DNL (symbolized as L_{dny}) as the basis for describing community noise exposure. The EPA Guidelines (U.S. EPA 1982) provide for flexibility in the application of the noise analysis methodology by each federal agency. The DNL has proved to be a practical and widely accepted metric for defining environmental noise exposure. The methodology for estimating the environmental impact of noise exposure by using an empirical relationship between DNL and community annoyance (Appendix B) has also won widespread acceptance.

Although seasonal corrections are not included in the definition of the DNL metric, their use is not precluded in any analysis of a special, well-defined noise exposure scenario.

Different agencies focus on different aspects of noise exposure and noise impact; therefore, they apply the DNL methodology in somewhat different manners. The three major aspects of concern are:

- health and welfare,
- land use compatibility, and
- environmental degradation.

Some agencies rely solely, or primarily, on measurement of the noise. Others rely primarily on computation using prediction models, and only occasionally employ measurements to validate the model predictions. Most agencies currently analyze the noise environment (frequently by computed DNL contours) only for DNL $\geq$ 65 dB, although some may analyze from DNL $\geq$ 60 dB.

Differences also exist in how DNL is calculated, sometimes being based on the annual average daily operations and sometimes on the basis of an "average busy day" calculated on the basis of the number of "flying days" per year, whichever is considered by the agency most repres entative of flying conditions. Agencies also have different policies on whether ground run-up operations are included in the DNL models. Agencies also apply different screening criteria for evaluating whether incremental or additional proposed changes warrant further noise analysis. Finally, agencies differ in the format used for quantifying noise impacts. Most typically, the noise impact is reported by tabulating the number of persons (and/or other sensitive receptors) exposed within each DNL range. Other approaches to reporting noise impact list the land areas (in acres or square miles) exposed to specific DNL ranges; specify the land use compatibility with regard to various typical land uses such as industrial, commercial, residential, recreational, etc.; and discuss limitations of land use with respect to specified noise-sensitive applications. [Theoretically, the simple approach for human impact analysis is to apply the "Schultz curve" which displays the "percent of (exposed) persons highly annoyed (%HA) as a function of DNL].

In 1982, the EPA, with guidance from the National Research Council's Committee on Hearing, Bloacoustics and Biomechanics (CHABA) of the National Academy of Sciences, recommended reporting noise impact in terms of "Level-Weighted Population" (LWP) (U.S. EPA, 1982). This concept was based on using a "normalized" Schultz curve to determine a "Fractional Impact" (FI) for each DNL range and summing the FIs to determine the total impact. The LWP concept has not been well accepted by the scientific community or applied by Federal agencies, partly because of the degree of abstraction involved. (Strictly speaking, the total number of persons HA is the same as the LWP, except that the "normalizing" has been eliminated.)

2.2 Adequacy of Current Noise Metrics and Impact Evaluation Methodologies

2.2.1 Use of DNL as the Principal Environmental Noise Metric

As noted in Section 1, the FICON reviewed both the noise descriptors and evaluation procedures commonly used by Federal agencies, and the results of research which have become available since the FICUN Guidelines of 1980 were published. The FICON continues to support the need for uniformity that was the Congressional intent in the Noise Control Act of 1972. The review did not identify any new descriptors or metrics of sufficient scientific standing to replace the widely accepted DNL as the primary cumulative noise exposure metric. However, it is noted that other descriptors may be useful as supplements to DNL in characterizing the noise environment and assessing the impacts of noise exposure.

Much of the criticism of the use of DNL for community annoyance and land use compatibility around airports may stem from a lack of understanding of the basis for the measurement, calculation, and application of that metric. An average noise metric, such as Leq or DNL, takes into account both the noise levels of all individual events that occur during a 24 hourperiod, and the number of times those events occur. In addition, the DNL metric incorporates consideration of the time at which the events occur by applying a 10 dB penalty to noise events which occur between 10 p.m. and 7 a.m. As discussed below, the logarithmic nature of the dB unit causes noise levels of the loudest events to control the 24-hour average.

As a simple example of the characteristics of the L_{eq} and DNL metrics, consider a 24-hour period during which a single aircraft flyover occurs in daytime and creates a sound level of 100 dB for 30 seconds. During the remaining 23 hours and 59.5 minutes of the day, the background sound level is low. Both the L_{eq} and DNL for this 24-hour period are 65.5 dB. As a second example, consider another 24-hour period during which a total of ten similar flyovers occur. If all of the flyovers occur during daytime hours, both the L_{eq} and DNL for the 24-hour period would be 75.5 dB. If one of the flyovers occurs during the period between 10 p.m. and 7 a.m., the DNL would increase to 78.1 dB. If all of the flyovers occurred at night, the DNL would be 85.5 dB. The L_{eq} would remain unchanged.

Since the DNL value normally used in an environmental analysis is based on the yearly average operations, if the number of daily operations alternated between one and ten, the yearly average DNL would be based on the average of 5.5 operations per day, resulting in a yearly DNL of 72.8 dB. Clearly, the averaging of noise over a 24- hour period does not ignore the louder single events, and the DNL metric includes consideration of both the sound level of individual events, the number of those events, and the time of day at which they occur. However, it should be noted that, although the DNL is strongly influenced by the maximum sound level, It is much lower than the maximum value, and therefore may not convey to the public the loudness of the individual flyovers at noise- sensitive receptors.

The FICON technical subgroup did not find any technical evidence to support a recommendation to change DNL 65 dB as the threshold of significant exposure as defined in the Guidelines for Considering Noise in Land Use Planning and Control (FICUN, 1980). Qualities such as significance [in the context of NEPA rather than statistics] and acceptability of impacts are not defined by scientific research. The job of the scientist is to provide the best available knowledge for the judgement of the potential degradation of the environment based on consideration of all factors.

However, just because the exposure/impact is not identified as “significant” does not mean that there are no impacts at noise levels below DNL 65 dB. The relationship between DNL and community annoyance recognizes that some people will be highly annoyed at relatively low levels of noise (down to DNL 45 dB). The higher the level, the larger the proportion of the population highly annoyed. As to how far down these impacts should be evaluated, it appears that DNL 60 dB is the practical limit of both known health and welfare impacts and general noise prediction accuracy. For a variety of reasons, noise predictions and interpretations are less reliable below DNL 65 dB. The Technical Subgroup recommends that noise analysis below DNL 65 dB continue to be done on a case-by- case basis. With respect to health and welfare effects, there is not a sufficiently large body of scientific data on the effects of aircraft noise around civilian airports and military airbases to warrant the mandatory inclusion of DNL 60 dB or lower contours in environmental impact analyses. Additionally, there has not been any generally accepted research that shows significant effects of aircraft noise at this level that would impact the public health and welfare.

In addition to DNL, supplemental noise evaluation metrics, as described below, can be used to characterize specific events. These characterizations serve to convey to the affected communities a clearer understanding of the potential effects they can expect to their living environment as a result of the proposed federal action.

2.2.2 Supplemental Noise Evaluation Metrics

DNL is sometimes supplemented by other metrics to characterize specific effects. These analyses are accomplished on a case-by-case basis. The cumulative metric, L_{eq} (Equivalent Sound Level), may be calculated for representative time periods. To comply with the State of California Code, Community Noise Equivalent Level (CNEL) or L_{dn} 60 dB contours are often developed (California accepts DNL as equivalent to CNEL for planning purposes). Although threshold levels have not been established for evaluating the potential significance of single event impacts on structures and animals, supplemental analysis may also include use of single event metrics to assess the potential impacts on structures and animals. Supplemental single event metrics may also be employed to provide additional information in the assessment of human effects. These single event metrics include TA (the time aircraft noise exceeds a specified level), maximum SPL (Sound Pressure Level), L_{max} (Maximum A-Weighted Sound Level), and SEL (Sound Exposure Level).

In addition to DNL, these supplemental metrics are useful in characterizing specific events and conveying to the affected communities and individuals a clearer understanding of the potential effects on their living and working environment which they can expect as a result of proposed changes in aircraft operations. In addition to DNL and supplemental metrics, other information may be equally important to a community in understanding the impacts of a proposed change in aircraft operations. For example, data on the expected number of aircraft overflights by aircraft type and time of day (day/night) is easily understood and may be useful as supplemental information in addition to data on predicted L_{max}, SEL or DNL values.

Supplemental noise analysis, if deemed necessary, can be tailored to convey potential noise effects in terms more understandable to the public. For example, if the action involves an increase in nighttime activity that results in a substantial increase in DNL, a supplemental analysis could focus on the potential for sleep disturbance. If the action involves an increase in daytime activity that results in a substantial increase in DNL, a supplemental analysis could focus on the potential for other activity interference. Agencies should have the flexibility to select the supplemental methodology they determine is suitable to each particular case. A screening process, such as described in Section 3.3.1.1, could be used to determine the extent of the noise analysis (even below what is identified as significant exposure). In addition to DNL, supplemental noise evaluation metrics, as described in Section 2.2.2, can be used to characterize specific events. The technical subgroup report supports the use of SEL and other supplemental single event metrics for informational purposes only, at the discretion of each agency.

2.2.3 Single Event Analysis

Single event analysis is sometimes conducted to evaluate sleep disturbances and, less frequently, specific speech interference issues, primarily at locations where the DNL is below 65 dB. However, it must be noted that: (1) there is no accepted methodology for aggregating the impacts of single events into some form of cumulative impact metric, and (2) single event metrics do not describe the overall noise environment. The DNL methodology includes a nighttime penalty which reflects the potential for increased annoyance associated with nighttime noise intrusions due to sleep disturbance, speech interference, and other effects (U.S. EPA, 1974)

A specified DNL level can be produced by an infinite number of combinations of single events which occur at different times of the day and produce different noise levels. However, it is not correct to infer specific SEL values from a single DNL. Measurements of SEL values for specific aircraft operations in a stable operating environment typically exhibit a range of 20 dB or more.

Single event prediction methods have limited application in land use planning. It should not be inferred that an area (e.g., an entire residential area) is simultaneously exposed to the same single event level, since noise levels decrease rapidly with increasing distance from the flight track. Noise models use average values for the sound energy produced by aircraft operating under specific conditions and the predicted (calculated) SEL values at a specified distance from a given aircraft operating at a given speed and power setting are the same. However, a given aircraft flight operation may produce SEL values which vary significantly from the average values for a variety of reasons, including aircraft weight, temperature, wind speed and direction, precipitation, ground conditions, etc. Thus, actual SELs will vary because of these factors. In addition to the variations in SEL for specific aircraft operations, the noise prediction models used tend to be less accurate as the distance from the source (i.e., the airport or aircraft flight tracks) increases. Factors contributing to the uncertainty include:

- variations in atmospheric propagation, including the effects of variation in temperature, relative humidity and frequency on sound absorption and the effects of wind and temperature gradients, and the effects of topography and ground cover;
- divergence of the aircraft from its assumed flight path;
- noise contributions from other sources; and
- variations in the amount of noise energy emitted by the aircraft engines.

Consequently, the single event metric has limited use in determining long-term noise impacts. When SEL is used to supplement DNL, it serves only to provide additional information. SEL has been used to evaluate sleep interference, but does not predict long-term human health effects.

2.3 Effects of Ambient Sound and Background Noise on Annoyance

The major reason for interest in characterization of ambient sound levels in the vicinity of airports is the possibility that the background against which the aircraft is heard at these sites can produce either a masking or an enhancing effect on the audibility and intrusiveness of aircraft noise and, thus, on the level of human annoyance in response to the aircraft noise. The phenomenon of masking occurs when the aircraft and background noise levels are within a few decibels of each other. Although masking is normally discussed in terms of individual overflight events, the concept can easily be extended in a time-integrated fashion to include longer exposure times, such as one day or even one year. Masking occurs when a listener is either not able to hear an aircraft noise (because it is not sufficiently louder than the background noise level), or when the perceived intrusiveness of the aircraft noise is lower than expected (because the background noise level is sufficiently close to the aircraft overflight noise level to shorten the duration of the time that the latter is clearly audible). Both of these situations might lead to lower individual and community annoyance in response to the aircraft noise.

Enhancement has the opposite effect of increasing the perceived loudness of the aircraft noise level when the aircraft noise exposure and the ambient noise level are significantly different from each other. Enhancement causes the aircraft noise to be perceived as more intrusive because of the contrast resulting from the large difference between the two noise levels (i.e., a high level of aircraft noise vs. low ambient noise levels such as those in rural or suburban environments).

2.3.1 Ambient Sound

"Ambient sound" connotes the ever-present collection of sound of both natural and manmade origin. "Background noise" connotes total acoustic and electrical noise for all sources in the system that interfere with the measurement of the intrusive noise being measured. Sound made by persons exposed to noise, which can become part of the ambient sound, is particularly important for developing noise criteria for National Parks as described in Graser and Moss (1992).

In the 1974 "Levels Document", the EPA listed the effects of "outdoor noise level measured in absence of intruding noise" as one of four corrections in Table D-7. "Corrections to Be Added to the Measured Day-Night Sound Level of Intruding Noise to Obtain Normalized L_{dn} (U.S. EPA 1974)." These empirical correction factors which were based on the work of Eldred (1971)[1] were proposed to improve correlation between DNL and community response in terms of levels of complaints. The range of the correction for background noise was a sizeable twenty decibels. At one extreme, in a "normal suburban community (not located near Industrial activity)", a correction of ten decibels was to be added to the intruding noise. At the other extreme, in a "very noisy urban residential community", ten decibels was to be subtracted from the intruding noise.

The concept of "normalized L_{dn}" was never widely accepted within the scientific community and, within a few years, this approach to relating community response to noise level was supplanted by the "Schultz curve" (see Section 3.2.2.1. for a detailed discussion) which defined a mathematical relationship between two continuous variables (DNL and the percent of the exposed population "highly annoyed"). In contrast, Eldred's (1971) relationship was between a continuous variable (decibels) and an "ordinal[2]" scale (intensity of political/legal response). In science, a continuous (or interval) scale is preferred over an ordinal scale.

To succeed in his endeavor, Schultz had to pay a price - abandoning all variables except "highly annoyed." One of the abandoned variables was the effect of background noise as a modulator of annoyance. While it is true that there are statistical techniques that would have allowed background noise to be incorporated into the mathematical function, these techniques could only have been used if all twelve of the studies reviewed by Schultz had included measurements of background noise; however, this was not the case.

Schultz did not, however, ignore background noise. In discussing this variable, he showed that, in some cases, background noise appeared to reduce the annoyance of a more intrusive noise. He also discussed an English and a French study in which the annoyance of railroad noise was <u>greater</u> in areas with <u>higher</u> background noise. In other words, depending on the specific conditions, it is feasible that background noise can result in "enhancement" of the annoyance of an intrusive noise rather than "masking." In summary, Schultz wrote "a final conclusion about the effect of background noise on the assessment of community noise is evidently premature (Schultz, 1978)."

In reviewing the body of scientific literature on aircraft noise exposure which has become available in the nearly fifteen years since Schultz's original work, the committee found no compelling evidence to contradict Schultz's 1978 opinion. Although psychoacousticians are able to predict

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[1] Using case studies, Eldred (1971) demonstrated that the use of these particular correction factors increased the linear correlation between outdoor day/night sound level and community complaint response (cf. Figures D-7 and D- 8, U.S. EPA, 1974). The "Levels Document" also displayed a curve, Figure D-13, based on combined British and U.S. surveys showing percent of the exposed population who are Highly Annoyed (%HA) as a function of DNL.

[2] The term "ordinal" scale is used by statisticians to describe a variable in which outcomes are ordered but not defined in terms of numerical "intervals" between the points of the scale.

simple auditory masking, such as would occur when an aircraft flyover is heard against the continuous background of an urban highway, there is no consensus procedure for extending the concept to include longer exposure times, such as one year or even one day. Auditory masking is predictable because it involves the simultaneous or contiguous presentation of two or more sounds. When sounds do not occur at the same time (i.e., are not temporally contiguous), the interaction is governed by psychological rules which, to date, have not been defined.

The only U.S. study of the relationship between ambient sound and community response was made by Muldoon and Miller (1989). In this study, the authors examined the relationship between noise complaints and increases in ambient noise due to the Expanded East Coast Plan (EECP). The EECP was initiated in an attempt to reduce airport delays in the New York/New Jersey region by increasing the number of air routes and lowering flight altitudes over western New Jersey. However, in the process, communities having little or no prior exposure to aircraft noise were now experiencing it almost continuously. In Long Valley N.J., the most affected of the eleven communities studied, the DNL increased from 42 to 49 dB, and six percent of the population complained. Muldoon and Miller suggest that their findings are inconsistent with the Schultz curve, which predicts an increase of only 1% to 2% in the percent of highly annoyed within the range of DNL values from 40 to 50 dB. However, the technical committee found Muldoon and Miller's argument to be uncompelling, since "complaints" and "annoyance" are two independent behaviors generated by different psychological mechanisms (Luz, Raspet and Schomer, 1985). While Muldoon and Miller's findings are consistent with Eldred's (1971) work which provided the basis for the "normalizing" factors suggested in Table D-7 of the EPA "Levels Document," they never measured or considered "annoyance", which can only be determined through carefully structured social surveys.

Through application of Signal Detection Theory (SDT), a widely-used decision-making theory, Fidell and Green (1991) demonstrated how the variability in the data points of the Schultz curve could be significantly reduced by assuming that citizens of the same community tend to share common criteria for deciding when an intruding noise is "highly annoying." Fidell and Green achieved this reduction in the variability of the data without taking background noise into account. It should be noted, however, that the work of Fidell and Green is new and not yet fully understood by all. Thus, there does not yet exist a fully developed methodology for applying SDT concepts to the prediction of community annoyance. This work is continuing and may provide a basis for an improved understanding of community response to noise.

Clearly, there is a need for more research if the goal is to anchor Federal policy on ambient sound/background noise on a foundation of sound science and scientific consensus. The only Federal agencies studying the relationship between ambient sound and response to aircraft noise are the U.S. Forest Service (Harrison et al. 1990) and the National Park Service (Ernenwein, 1992). This work is funded under the National Parks Overflights Act (Public Law 100-91). Neither agency was represented on the technical committee, since the charter of the current effort was limited to the immediate environs of airports. Nevertheless, it is possible that new scientific insights into the relationship between ambient and human response may emerge from this new effort.

2.3.2 Relationship of Ambient Sound Levels to Lifestyles

In typical residential settings, ambient sound levels are closely correlated with population density and associated lifestyle variables. High ambient sound levels are associated with high population density and urban lifestyles (i.e., a large amount of time spent indoors, use of mass transit, apartment and condominium living, large numbers of local and distant noise sources, etc.), while low ambient sound levels are associated with low population densities and suburban and rural lifestyles (i.e., larger amounts of time spent outdoors, small numbers of distant noise sources, etc.). The extent to which people select lifestyles on the basis of ambient sound preferences is unclear, as are any effects of this self-selection on annoyance.

Current EPA guidelines (U.S. EPA 1982) for evaluating the environmental impact of noise (not limited to aircraft noise or airports) provide a simplified methodology for estimating "background" noise levels based on a relationship between DNL and population density. This relationship assumes that, in the absence of a specific dominant noise source, the existing environment is dominated by automobile traffic and that the level of traffic noise is proportional to the log of the population density (expressed in persons per square mile). This relationship is generally used by Federal agencies except when there is a dominant non-automobile noise source. However, the FICON recognizes that there is a continuing need for improved procedures which will permit more definitive characterization of the noise environment in the absence of clearly identifiable dominant noise sources.

2.3.3 Scientific Research

Only a few rigorous scientific studies have evaluated the effects of various levels of ambient noise on human annoyance in response to aircraft noise in the vicinities of airports and airfields. However, available research results, proposed hypotheses, and comments from noise-exposed persons in affected communities suggest that there may be real effects attributable to the relative magnitude of aircraft noise levels and background noise levels.

In laboratory tests of the effects of different spectra of background noise on the annoyance of common sounds, Fidell et al. (1979) found that the audibility of the intrusive sound was related to the particular background spectrum as well as level. Johnston and Haasz (1979) showed that reducing the background noise seemed to increase the annoyance of a flyover; however, spectral data were not provided, as was in the case in another study by Willshire (1987).

Duration of the signal, another variable considered by Johnston and Haasz, was found to show a small effect. Stephens and Powell (1983) showed that the effect of background depended on the relative level.

Fidell and Teffeteller (1981) demonstrated that subjects engaged in an attention-demanding foreground task required a higher signal-to-noise ratio to detect intruding sounds than in deliberate listening, whereas people not so engaged could distinguish signal from noise at virtually the same levels.

Other similar research lead generally to the conclusion that, in the present state of the art, there is not sufficient data to establish a quantitative adjustment for background noise in analyzing aircraft noise impact.

2.3.4 Comparing Aircraft DNL to Background DNL

Perhaps the most complicated technical question is when and how to compare aircraft DNL to background DNL. The literature suggests that the answer depends to some extent on the nature of the background noise.

One complexity arises from the fact that people, unlike L_{eq} meters, appear to discriminate between the annoyances of different noise sources in their environment [e.g. Grandjean et al. (1973)]. By comparing responses in areas of high and low traffic and aircraft noise in the four possible combinations, one Australian study (Lawrence and Putra 1989) developed a formula for combining aircraft and road traffic noise. From these data, the authors concluded that annoyance due to aircraft noise decreased as the traffic noise increased. From these and other research results, it may be generally concluded that, although source-specific annoyance of aircraft noise might be greatest in low-noise backgrounds, total annoyance would be greatest in the areas with high background levels because the total noise levels would be higher.

2.3.5 Summary and Conclusions

Although there is sufficient reason to believe that ambient sound levels affect the audibility of and resultant annoyance in response to aircraft noise exposure around commercial airports and military airbases, at this time, there is not a generally accepted methodology for addressing these effects. There is not a sufficient body of scientific research to provide a basis for development of a detailed methodology for addressing ambient sound and background noise prediction and evaluation. Development of these tools will require additional research, including both laboratory studies and field research.

However, enough information does exist to provide some very preliminary guidance to assist in planning and environmental impact analysis processes for proposed changes in airport and airbase flight operations. There are two specific issues that must be addressed in the development of this guidance. The first is the issue of when the background noise level should be addressed at all in an environmental impact analysis. From the existing literature, it appears that when the time-integrated aircraft noise exposure level (L_{eq} or L_{dn}) approaches the background noise level, noise masking may occur and measurements or predictions of background noise levels should be carried out.

Masking, as a background noise effect, can occur for any of several reasons. It will be most common around urban airports where there is a high population density, mainly because of the effect of high levels of street traffic noise. Thus, production of noise contours below DNL 60 dB is problematic because it is difficult to distinguish the contributions of aircraft overflight noise and background noise to the overall predicted community noise exposure. The problem of producing noise exposure contours and noise impact analyses will be more complex at airports in urban areas with high background noise levels at which there are both commercial Jet aircraft and small, propeller-driven general aviation aircraft. It will also be a problem at hub airports, where there are large numbers of local service flights mixed with large commercial carrier aircraft. In most situations, small aircraft-caused long-term DNL is likely to be negligible, because the DNL will probably be dominated by the noise from the large commercial jet aircraft.

For the noise enhancement issue, there is insufficient scientific data to provide a basis for development of guidance on what level of difference between aircraft and ambient noise levels should trigger analysis of possible enhancement noise effects. Noise impact enhancement might occur around suburban and rural airports where the ambient noise level is significantly below the aircraft exposure level. When aircraft noise exposure levels approach 15 dB or more above the ambient, it is probable that enhancement occurs; however, it is difficult to predict the amount of increase in annoyance (the “enhancement” effect). Some research is being conducted on this particular issue, but possible formal policy guidance changes must await the results of these studies.

The second, more difficult issue is how to address possible background noise effects in development of a standardized analysis methodology for situations in which background noise effects, either masking or enhancement, are expected. Unfortunately, no field tested and scientifically validated procedures currently exist. While this issue is being addressed by a few ongoing research programs, more research is needed to develop, test, and validate an acceptable impact analysis methodology to specifically address possible background noise effects.

In conclusion, although background noise effects probably do modify community responses to aircraft noise exposure, through both masking and enhancement, no specific analysis procedures can be recommended with confidence. All that can be recommended at present is that background noise should be addressed in those cases where there is reason to believe that it will have an effect on community annoyance. It is hoped that this issue will continue to be a subject of further research, with the goals of defining more specifically those situations where ambient noise should be addressed in impact analysis and developing a scientifically accepted procedure for analyzing possible effects.

SECTION 3 NOISE EFFECTS

3.1 General

Federal agencies use the DNL metric, predominately, for characterizing three general categories of environmental noise effects:

- Health and Welfare Effects;
- Environmental Degradation/Im pacts;
- Land Use Compatibility.

3.2 Health and Welfare Effects

In addition to direct, potentially harmful health effects, noise interference with various human activities such as speech, sleep, and thought can lead to annoyance and indirect effects on well-being. All of these direct and indirect effects were considered in the EPA "Levels Document" as effects on health and welfare (U.S. EPA 1974). The "Levels Document" focused on the principle that environmental effects on public health and welfare are related primarily to cumulative response to repeated annoyance, and therefore did not explicitly consider the question of short-term annoyance reactions. Table 3.1 reproduces Table 4 of the EPA "Levels Document" which summarizes the yearly average Equivalent Sound Levels (L_{eq} and/or L_{dn}, as appropriate) identified in that document as protective of the public health and welfare with an adequate margin of safety.

3.2.1 Direct Effects

Protection against hearing loss is the guiding consideration in protecting against the direct, potentially harmful health effects of noise (U.S. EPA 1974). In a 1971 publication, Effects of Noise on People, EPA noted that noise induced hearing loss (NIHL) is the only well-established effect of noise on human health and concluded that "if noise control sufficient to protect persons from ear damage and hearing loss were instituted, then it is highly unlikely that noise of lower level and duration from this effort could directly induce non-auditory disease." (EPA 1971b)

Noise induced damage to hearing is typically detected first at the audiometric frequency of 4000 Hertz (Hz) and above. Changes in hearing threshold level (the lowest level at which a sound signal of a specific frequency can be detected by the ear) of less than 5 dB are not generally considered noticeable. A noise-induced permanent threshold shift (NIPTS) of 5 dB or more (i.e., a permanent loss of hearing acuity) is considered significant (U.S. EPA 1974). The EPA recommended an annual average exposure level of $L_{eq(24)}$ 70 dB or less to protect hearing at this level for exposures of 40 years or more (i.e. to protect up to and including the 96th percentile of the population, ranked according to decreasing ability to hear at 4000 (Hz) from NIPTS greater than 5 dB). The Committee on Hearing, Bloacoustics, and Blomechanics (CHABA) Guidelines indicate a level of DNL 75 dB to protect hearing (NRC 1977).

Table 3.1 Yearly Average* Equivalent Sound Levels Identified As Requisite To Protect The Public Health & Wealfare With An Adequate Margin Of Safety

	Measure	Indoor			Outdoor		
		Activity Interference	Hearing Loss Consideration	To Protect Against Both Effects (b)	Activity Interference	Hearing Loss Consideration	To Protect Against Both Effects (b)
Residential with Outside Space and Farm Residences	Ldn Leq(24)	45	 70	 45	55	 70	55
Residential with No Outside Space	Ldn Leq(24)	45	 70	45			
Commercial	Leq(24)	(a)	70	70(c)	(a)	70	70(c)
Inside Transportation	Leq(24)	(a)	70	(a)			
Industrial	Leq(24)(d)	(a)	70	70(c)	(a)	70	70(c)
Hospitals	Ldn Leq(24)	45	 70	45	55	 70	55
Educational	Ldn Leq(24)	45	 70	45	55	 70	55
Recreational Areas	Leq(24)	(a)	70	70(c)	(a)	70	70(c)
Farm Land and General Unpopulated Land	Leq(24)			(a)	70	70(c)	

Source: US Environmental Protection Agency, 1977

CODE:

A. Since different types of activities appear to be associated with different levels, identification of a maximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity. (See Figure D-2 for noise levels as a function of distance which allow satisfactory communications.)

B. Based on lowest level.

C. Based only on hearing loss.

D. An $L_{eq}(8)$ of 70 dB may be identified in these situations so long as the exposure over the remaining 16 hours is low enough to result i a negligible contribution to the 24-hour average, i.e., no greater than an $L_{eq}(24)$ of 60 dB.

NOTE: Explanation of identified level for hearing: The exposure period which results in hearing loss at the identified levell is a period of 40 years.

* Refers to energy rather than arithmetic averages.

The International Standard for predicting hearing loss, *Acoustics - Determination of Occupational Noise Exposure and Estimation of Hearing Loss* [ISO 1999: 1988 (E)], describes the relationship between noise exposure and noise-induced permanent threshold shift (NIPTS) in various population age groups. This standard allows the prediction of hearing loss primarily from occupational noise exposure, although it is also related to any daily repeated noise exposure. It applies to sound frequencies less than 10*kHz* for noise that is steady, intermittent, fluctuating, irregular or impulsive in character. Thus, the calculation procedure recommended in this Standard applies to aircraft noise around airports and may be considered when predicting the effects of increases in noise exposure on humans in this environment.

The 1974 EPA "Levels Document" stated "At this time there is insufficient scientific evidence that non- auditory diseases are caused by noise levels lower than those that cause NIHL." The National Institute for Occupational Safety and Health (NIOSH) asked CHABA to consider research that might be performed to examine the effects on human health from long-term exposure to noise. CHABA (Working Group 81) considered this issue and, in its 1981 report, The Effects on Human Health From Long-Term Exposures to Noise, concluded that evidence from available research is suggestive, but it does not provide definitive answers to the question of health effects other than to the auditory system of the long-term exposure to noise (NRC 1981). Finally, the 1982 EPA publication Guidelines for Noise Impact Analysis stated that "research implicates noise as one of several factors producing stress-related health effects such as heart disease, high blood pressure and stroke, ulcers and other digestive disorders. The relationship between noise and these effects has not yet been quantified" (U.S. EPA 1982).

To determine if long-term exposure to aircraft noise *per se* is a risk factor for cardiovascular or other disorders, highly sophisticated prospective epidemiological studies must be conducted with appropriate controls for some other known risk factors such as age, sex, smoking, caffeine, body weight, diet and hereditary proclivity (NRC 1981; Thompson et al., 1989).

3.2.2 Indirect Effects

Environmental noise may interfere with a broad range of human activities including speech communication, listening to radio, television or recorded music, studying, relaxation, sleep, etc. Such activity interference is generally regarded as an adverse impact on human welfare. The levels of environmental noise which interfere with human activity depend upon the activity and its c ontextual frame of reference. The effect of activity interference is most often described in terms of annoyance. Various factors, such as attitude towards the noise source and local conditions, may influence an individual's reaction to activity interferences (U.S. EPA 1974).

3.2.2.1 Annoyance

Annoyance is a summary measure of the general adverse reaction of people to noise that generates speech interference (including inability to use the telephone, radio, television or recordings satisfactorily) or sleep disturbance or simply interferes with the desire for a tranquil environment. Currently, the best available measure of this response is the percentage of the area population characterized as "highly annoyed" (%HA) by long-term exposure to noise of a specified level (expressed in terms of DNL). An historical perspective of the 60 years of research in the U.S. on community annoyance is provided by Fidell (1990) and provides useful insights for the interested reader.

Noise is often defined as unpleasant or unwanted sound. Based on this definition, characterization of any specific sound as "noise" is a subjective evaluation by each individual. Annoyance has been described as an adverse psychological response to a given noise exposure. It may result from speech or sleep interference, but it can arise in a variety of other circumstances. The perceived unpleasantness of the noise is a factor of annoyance, as is any anxiety or apprehension that the noise may cause (Frankel 1986). Community response is a term used to describe the annoyance of groups of people exposed to environmental noise sources in residential settings.

In general, the effects of noise on people result from complex relationships of numerous factors, and separating the effects of these often confounding factors is impractical, if not impossible. The variability in the way individuals react to noise makes it impossible to accurately predict how any one individual will respond to a given noise. However, when the community is considered as a whole, trends emerge which relate noise to annoyance. The preponderance of case histories and social surveys indicates that the response of a community to aircraft noise is affected not only by how loud the noise is, but also by how often noise events occur, i.e., the total noise exposure in a specified time period. This is consistent with the laboratory results of psychoacoustic experiments that show that the magnitude of sound and its duration are relatively interchangeable on a total energy basis. On the assumption that community response is related to the total noise energy in a specified time period, the total energy of multiple events of equal magnitude is calculated on the basis of the energy of a single event plus 10xLog(N) where N is the number of events. Recent studies have shown that 10xLog(N) can be used to accurately predict community annoyance for daily operations of noise events as low as two per day (Schomer 1981; Schomer 1983; Fields and Powell 1985) while other studies had previously shown that 10xLog(N) worked well for cumulative noise exposure for several hundred events per day.

Because the Schultz curve (discussed in detail below) provides the only widely-accepted dose-response relationship between environmental noise (in terms of DNL) and a health and welfare parameter, annoyance, DNL has been accepted as the most useful and informative metric for describing the noise exposure of a community caused by an airport, and the percent of the exposed population expected to be Highly Annoyed (%HA) as the most useful metric for characterizing or assessing noise impact on people. EPA's "Levels Document" indicates DNL is used to relate noise in residential environments to chronic annoyance by activity interference.

In the 1970s, Schultz analyzed the findings of a number of social surveys and developed a function which relates transportation noise exposure and the prevalence of annoyance in communities. Schultz developed methods for converting noise exposures measured in different units to a common set of units (DNL), and devised ways of comparing annoyance judgements measured on very different response scales. The independent variable Schultz chose for the dosage-effect relationship was a cumulative measure of the time integral of noise intensity to which the communities are exposed, i.e. DNL. The dependent variable "Percent Highly Annoyed" (%HA) was chosen as a measure of the upper portion of the distribution of self-reported annoyance. This relationship and the %HA metric have become the generally accepted model for assessing the effects of long-term noise exposure on communities.

Based on a regression analysis of the 161 data points originally developed by Schultz, the following equation was recommended[3] (U.S. EPA 1982) as providing a simple relationship between noise exposure and annoyance:

$$\%HA = \frac{100}{1+e^{(10.43-0.132L_{dn})}}$$

The relationship between DNL and %HA predicted by the equation based on a logistic fit to the original 161 data points used by Schultz is illustrated in Figure 3.1 This figure also shows the relationship predicted by a similar logistic fit equation based on analysis of a recent update which includes a total of 400 data points (Finegold et al. 1992) based on the fuller analysis of 453 data points reported by Fidell et al. (1989). Comparison of the original and updated curves indicates that they differ by less two than two percent in the DNL range from 45 to 75 dB. Although the differences between the predicted levels of annoyance are small, use of the equation based on the larger data base is recommended. The revised equation is:

$$\%HA = \frac{100}{1+e^{(11.13-0.141L_{dn})}}$$

Finally, the review by Fidell et al. (1989) also concluded that the DNL-%HA relationship is applicable to all types of transportation noise, although they also concluded that communities are slightly more willing to describe themselves as annoyed by aircraft noise than by surface transportation noise.

Thus, the updated "Schultz Curve" remains the best available source of empirical dosage-effect information to predict community response to transportation noise.

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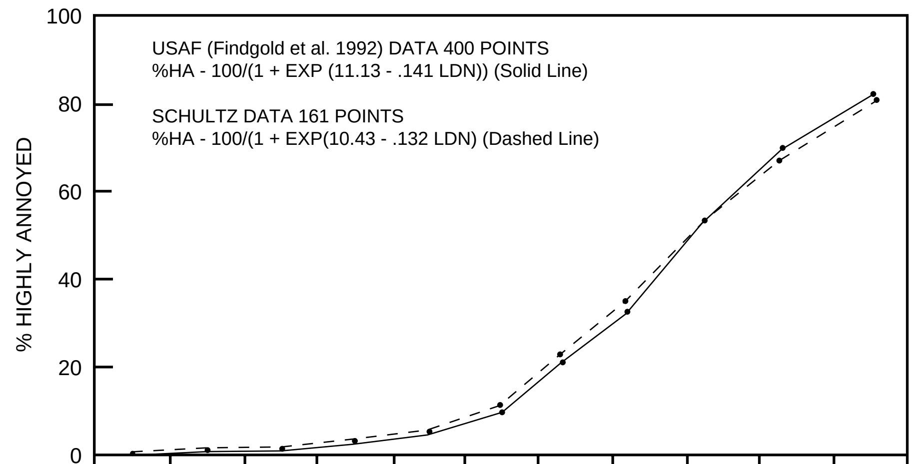
3 The 1982 EPA Guidelines included several equations which can be used to estimate %HA as a function of DNL. The logistic fit equation recommended above is preferred over the third order polynomial equation originally developed by Schultz (1978) or the quadratic equation identified as the most fit by Fidell et al. (1989) to ensure that the dose-effect relationship (1) allows the predicted annoyance to approach but not reach 0 or 100%; (2) predicts very low annoyance at exposure levels below 45 dB. The recommended equation has the same predictive utility as the other algorithms and has been successfully used for over a decade in environmental impact analyses.



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

Figure 3.1 Comparison of logistic fits to original 161 data points of Schultz (1978) and USAF analysis with 400 points (data provided by USAF Armstrong Laboratory).

3.2.2.2 Complaints

Although annoyance is the recommended metric for characterization of community response to noise, complaints are not a measure of community impact. The analysis of complaints by Luz, Raspet and Schomer (1985) supports noise abatement (reduction) policies based on an assessment of the level of annoyance rather than the number of complaints. Annoyance can exist without complaints and, conversely, complaints may exist without high levels of annoyance. The current body of evidence indicates that complaints are an inadequate indicator of the full extent of noise effects on a population (Fields and Hall 1987).

3.2.2.3 Speech and Communication

The sound intensity levels which interfere with listening to a desired sound such as speech or music can be defined in terms of the level of interfering sound required to mask the desired sound. Such levels have been quantified for speech communication by directly measuring the interference with speech intelligibility as a function of the level of the intruding sound relative to the level of speech sounds (U.S. EPA 1974). Most of the research that led to development of methods for predicting speech intelligibility was related to speech communication systems. In general, It was found that intelligibility is related to the amount by which the levels of speech signals exceed steady state noise levels. The difference between speech and noise levels is usually referred to as the speech-to- noise ratio.

No quantitative relationship has been established between speech interference and learning in school classrooms, and therefore no additional criteria have been developed for quantifying speech interference effects on learning by students. However, it is clear that if speech communication is degraded in a classroom, the learning process can be assumed to be degraded. This is especially true for classroom situations that demand a quiet background (e.g., foreign language and music classrooms). In addition, speech interference in classrooms can be a particular problem for students whose native language is not English.

From a technical perspective, whenever intrusive noise exceeds approximately 60 dB indoors, there will be interference with speech communication. This interference may result from masking of the speaker's words or by causing the speaker to pause. Increasing the indoor level of intrusive noise to 80 dB reduces intelligibility to near zero, even if a loud voice is used. Based on the average levels of noise reduction (attenuation) provided by typical residential construction (15 dB with windows open and 25 dB with windows closed)[4], some degree of indoor speech interference would be expected whenever exterior noise levels exceed 75 dB to 85 dB (windows open and closed, respectively).

The 1980 FICUN document, Guidelines for Considering Noise in Land Use Planning and Control (FICUN, 1980), provides information on the levels of both indoor and outdoor speech interference expected to occur in residential areas on the basis of the DNL level. In using these data, it must be noted that an "average sentence intelligibility" of 99 percent at DNL 70 dB does not mean that all sentences are uniformly 99 percent intelligible during the entire day. On the contrary, it indicates that, during most of the day sentences are 100 percent intelligible. However, at various times during the day (in this case one percent of the time, or 0.24 hours; e.g., whenever an aircraft flyover occurs), the intelligibility of sentences may degrade considerably, thus interfering with speech communication. It is clear, however, that all else being equal, the higher the DNL the greater the speech interference. Table 3.2 provides an update of the 1980 FICUN Table D.1, "Effects of Noise on People".

Table 3.3 (U.S. EPA 1973) shows the voice effort required at differing distances and AWeighted sound levels. This figure can be used to obtain a notional idea of the amount of speech interference that a particular sound exposure level might cause. A major limitation on the

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4 EPA review of available data (U.S. EPA 1974) on noise reduction (attenuation) provided by typical building construction indicated that average residential construction provides sound attenuation of approximately 15 dB with windows open and 25 dB with the windows closed (See Section 3.5). Houses in warm climates typically provide lower that average attenuation (12 and 24 dB, respectively), while houses in cold climates provide greater attenuation (17 and 27 dB). Based on the average attenuation values, an interior noise level of 60 dB would correspond to exterior levels of 75 dB (windows open) and 85 dB (windows closed). Depending on the construction materials and methods, schools and commercial buildings may provide greater noise attenuation, particularly with the windows closed.

Effects [1] / Day-Night Average Sound Level in Decibels	Hearing Loss: Qualitative Description	Annoyance [2]: % of Population Highly Annoyed [3]	Average Community Reaction [4]	General Community Attitude Towards Area
75 and above	May begin to occur	37%	Very severe	Noise is likely to be the most important of all adverse aspects of the community environment.
70	Will not likely	22%	Severe	Noise is one of the most important adverse aspects of the community environment.
65	Will not occur	12%	Significant	Noise is one of the important adverse aspects of the community environment.
60	Will not occur	7%	Moderate to slight	Noise may be considered an adverse aspect of the community environment.
55 and below	Will not occur	3%		Noise considered no more important than various other environmental factors.

Source: FICUN, 1980; FICON 1992 (Update)

Table 3.2 Effects of Noise on People (Residential Land Uses Only)

1. All data is drawn from National Academy of Science 1977 report "Guidelines for Preparing Environmental Impact Statements on Noise, Report of Working Group 69 on Evaluation of Environmental Impact of Noise."

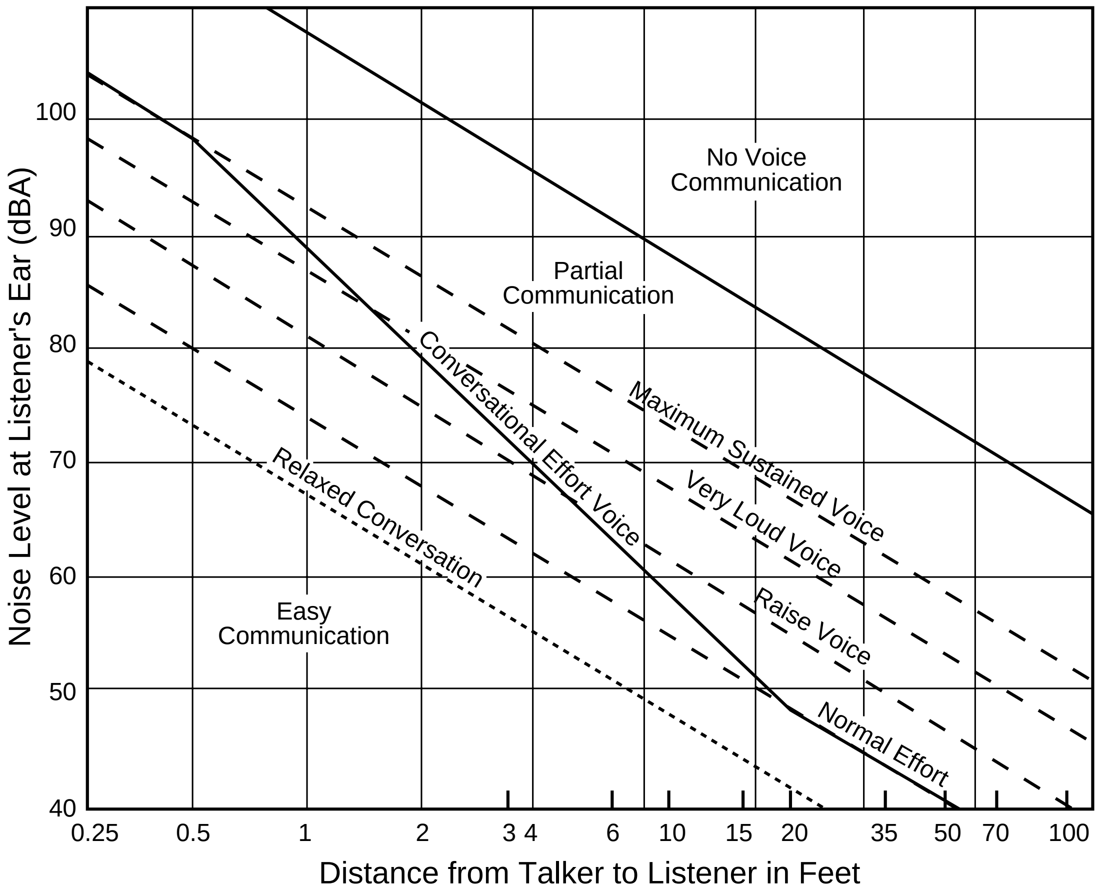
2. A summary measure of the general adverse reaction of people to living in noisy environments that cause speech interference; sleep disturbance; desire for tranquil environment; and the inability to use the telephone, radio or television satisfactorily.

3. The percentages of people reporting annoyance to lesser extents are higher in each case. An unknown small percentage of people will report being "highly annoyed" even in the quietest surroundings. One reason is the difficulty all people have in integrating annoyance over a very long time. USAF Update with 400 points (Finegold et al. 1992)

4. Attitudes or other non-acoustic factors can modify this. Noise at low-levels can still be an important problem, particularly when it intrudes into quier environment.

NOTE: Research implicates noise as a factor producing stress-related health effects such as heart disease, high-blood pressure and stroke, ulcers and other digestivr disorders. the relationships between noise and these effects, however, have not yet been conclusively demosntrated. (Thompson 1981; Thompson et al. 1989; CHABA 1981; CHABA 1982; Hattis et al. 1980; and U.S. EPA 1981)

Table 3.3 Distance at which ordinary speech can be understood (as a function of A-weighted sound levels of masking noise in the outdoor environment)



Source: U.S. EPA 1973

usefulness of this type of SEL analysis is that it does not provide information concerning the precise interference, the total duration of all interference, the number of individual events, or the timing of events relative to activities which are subject to speech interference. Thus, Tables 3.2 and 3.3 provide only general guidance as to the overall level of speech inteference and can not be used for specific events.

If the exposure is for less than a 24-hour day (such as for 8-hour daily operations) or when some noise- exposed areas have special land uses (e.g., schools, outdoor concerts, camping, etc.), some agencies apply special criteria or technical judgment in determining whether a given level of noise exposure is within established guidelines for the particular land use. The metric most commonly used for such evaluations is L_{eq} for the relevant time period (e.g., one hour, eight hours, etc.). In such cases, the usual parameter for impact assessment, %HA, cannot be used and a qualitative judgment of the impact is necessary. Although computation of the appropriate L., may provide additional information, this metric is subject to the same limitations as DNL in that it does not provide information about the number, level, or duration of intrusive events.

Single event analysis is not generally used to evaluate speech interference because there is no accepted impact evaluation criteria, and there is no accepted procedure for deriving a cumulative effects analysis. The American National Standards Institute (ANSI) Standard S3.14 (1977), “Rating noise with respect to speech interference,” includes a Speech Interference Level (SIL) metric which may be used to evaluate the speech interference produced by relatively constant noise sources. However, because this standard is based on steady state noise, its applicability to evaluation of nonsteady state noise events such as aircraft flyovers is limited. This procedure may be useful in evaluation of the impacts of aircraft ground operations, particularly ground run-ups associated with maintenance activities. Use of the SIL would require careful judgement regarding the variability of level, duration, and frequency spectrum of aircraft noise.

If speech interference is a particularly critical issue requiring detailed analysis, the supplemental metric, Time Above (TA) (The total time that the noise level exceeds a “threshold” level during a specified interval), provides a useful “single number” indicator of the potential for speech interference. A major limitation on the usefulness of this metric is that it does not provide information concerning the number of individual events or their timing relative to activities subject to speech interference. The FAA Integrated Noise Model, the computer model most commonly used for modeling aircraft noise levels at civilian airports, includes the capability to calculate TA for airport operations.

For specific locations at which speech interference is a critical concern, tabulation of the individual aircraft operations affecting the location, including the number of each type of operation by aircraft type, the noise levels (SEL and possibly L_{max}) associated with each type of event, and the timing of the events may provide the most useful information. Calculation of this information, particularly for points which are affected by a large number of different types of operations (e.g., points affected by operations on more than one runway or affected by closed pattern operations) requires extensive computation; however, both the FAA INM and the NOISEMAP program developed by the USAF have the capability to identify and tabulate aircraft activities (by aircraft type, flight track and power/altitude/airspeed profile) which are the most significant contributors to the cumulative noise level at up to 20 specific locations. If detailed analysis of the potential for speech interference is determined to be necessary, use of the specific point analysis capability provided by these programs should be considered.

3.2.2.4 Sleep Disturbance

The effects of noise on sleep have long been a concern of parties interested in assessing residential noise environments. Early studies, conducted mainly in the 1970s, measured noise levels in bedrooms in which sleep was apparently undisturbed by noise. Tests were conducted mainly in laboratory environments in which sleep disturbance was measured in a variety of ways. Most frequently, awakening was measured either by a verbal response, or a button push; in some instances, sleep disturbance, as well as awakening, was determined by electroencephalograph (EEG) recordings of brain activity which indicated stages of sleep and awakening. Various types of noise were presented to the sleeping subjects throughout the night. These noises consisted primarily of transportation noises, including those produced by aircraft, trucks, cars and trains. The aircraft noises included both subsonic aircraft flyover noises as well as sonic booms. Synthetic noises, including laboratory- generated sounds consisting of shaped noises and tones, were also studied.

Reviews by Lukas (1975), Griefahn and Muzet (1978), and Pearsons et al. (1989) provide an overview of data available in the 1970s on the effects of different levels of noise on sleep-state changes and waking. Various A-weighted levels between 25 and 50 dB were observed to be associated with an absence of sleep disturbance. Because of the large variability of the data in these reviews, there is some question as to the reliability of the results. Consequently, the dose-response curve developed by Lukas, which plots the probability of awakening as a function of SEL, provides a guide only to the most extreme limits of the potential effects of noise on sleep.

The 10-dB nighttime “penalty” added to noise levels for the period 10 PM to 7 AM in computing DNL is intended to account for the intrusiveness of noise at night, partly due to the lower nighttime ambient, and therefore tends to reflect to some extent the potential for wakeups. However, some agencies believe that if there is an unusual number of nighttime noise events, supplemental analysis to indicate sleep disturbance semi-quantitatively, in terms of the putative number of wakeups, is desirable. Such an analysis is generally based on a “single-event” parameter, such as SEL or L_{max}.

Based on the literature reviewed in a recent Air Force sponsored study of sleep disturbance (Pearsons et al. 1989), no specific adverse health effects have been clearly associated with sleep disturbance, either awakening or sleep-state changes. Nevertheless, sleep disturbance, particularly awakening, is generally considered undesirable, and may be considered an impact caused by noise exposure (consequently, awakening has been selected as the parameter recommended for evaluating the effects of noise on sleep). The U.S. Air Force plans to conduct a field study of sleep disturbance, using awakening as the dependent variable, in the near future (1993/1995) (Finegold et al. 1990).

As reported in the 1989 study by Pearsons et al, the effort to develop an sleep disturbance prediction curve identified the need for substantially more research in this area. Of concern were:

- large discrepancies between laboratory and field studies;
- highly variable and incomplete data bases;
- lack of appropriate field studies;
- the studies’ methodologies;
- the need to consider non-acoustic effects;
- the role of habituation.

In cases where supplemental analysis of potential sleep disturbance is considered necessary, the USAF has developed an <u>interim</u> dose-response curve to predict the percent of the exposed population expected to be awakened (% awakening) as a function of exposure to single event noise levels expressed as SEL (Finegold et al. 1992). This interim prediction curve is based on statistical adjustment of the most recent, inclusive analysis of published sleep disturbance studies conducted by Pearson et al. (1989). The recommended dose-response relationship is expressed by the equation:

$$\%Awaking = (7.079 \times 10\text{-}6) \times SEL^{3.496}$$

This recommended interim dose-response relationship is shown by the curve in Figure 3.2 and the individual points shown in the figure represent groupings of observed data.

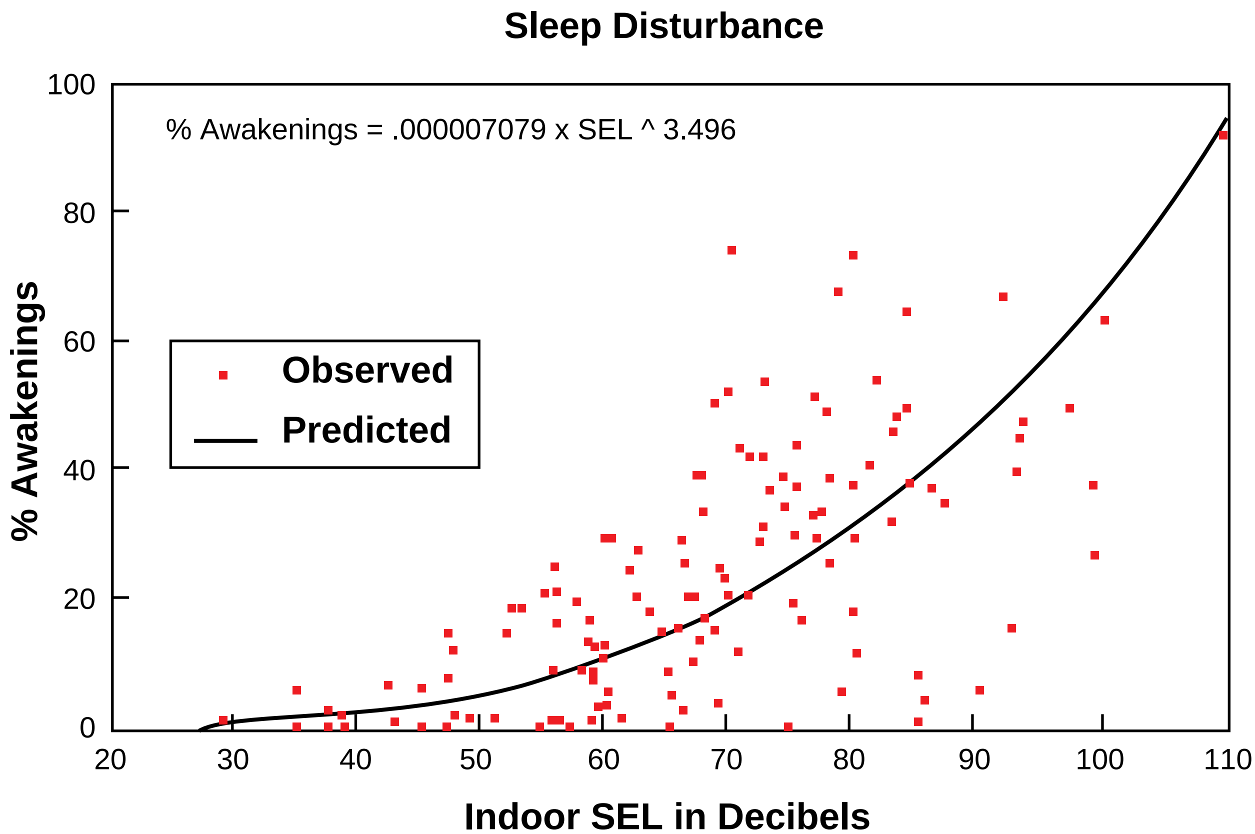


Figure 3.2 Sleep disturbance as a function of single event noise exposure (Finegold et al. 1992)

There should be continued research into community reactions to aircraft noise, including both sleep disturbance and non-auditory health effects of noise.

3.2.3 Levels of Environmental Noise Requisite to Protect Public Health and Welfare

The EPA "Levels Document" identified the environmental noise levels listed in Table 3.4 as requisite to protect public health and welfare with an adequate margin of safety. These levels are not to be construed as standards, criteria, or regulatory goals, as they **do not** take into account cost or technical feasibility and **do** include a margin of safety. According to the report, these levels provide a margin of safety of 5 dB, and should be viewed as levels below which there is no reason to suspect that the general population will be at risk from any of the identified effects of noise (U.S. EPA 1974).

Table 3.4 Yearly average equivalent sound levels identified as requisite to protect the public health and welfare with an adequate margin of safety

EFFECT	LEVEL	AREA
Hearing Loss	Leq (24) < 70 dB DNL < 75 dB	All Areas; CHABA Guidelines recommended the DNL level
Outdoor activity interference and annoyance	DNL < 55 dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	Leq(24) < 55 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	DNL < 45 dB	Indoor residential areas
	Leq(24) < 45 dB	Other indoor areas with human activities such as schools, etc.

Source: U.S. EPA 1974

In Table 3.4, the levels identified for protection from hearing loss represents the annual energy average of the daily level over a period of forty years. The outdoor DNL of 55 dB is identified as that level which, if not exceeded, will protect the public health and welfare with an adequate margin of safety. This is based on the following factors: (1) The identified protective level indoors (to preclude speech interference) is DNL 45 dB; (2) Assuming an attenuation outdoors-to-indoors of 15 dB (which is an average amount of sound attenuation that assumes partly-open windows) the corresponding outdoor level is DNL 60 dB; (3) A "margin of safety' of 5 dB is applied to the outdoor identified level to account for other adverse effects on activity interference and annoyance as well as for the most sensitive fraction of the population. (U.S. EPA 1974)

3.2.4 Nonauditory Health Effects of Aircraft Noise in Airport Environs

Based on summaries of previous research in the field, (Thompson 1981; Thompson et al. 1989; CHABA 1981; CHABA 1982; Hattis et al. 1980; and U.S. EPA 1981) predictions of nonauditory health effects as a result of exposure to aircraft noise in a residential environment have not been conclusively demonstrated. A valid predictive procedure requires: (1) evidence for a causal relationship between aircraft noise exposure and adverse nonauditory health consequences, and (2) knowledge of a quantitative (dose-response) relationship between the amount of noise exposure and specific health effects. Because the results of studies of aircraft noise on health are highly equivocal, there is currently no scientific basis for making valid risk assessments.

Alleged nonauditory health consequences of aircraft noise exposure which have been studied include birth defects, low birth weight, mental problems, cancer, stroke, hypertension, sudden cardiac death, myocardial infarction, and cardiac arrhythmias. Of these, hypertension is the most biologically plausible effect of noise exposure. Noise appears to elicit many of the same biochemical and physiological reactions, including temporary elevation of blood pressure, as do many other everyday stressors. These temporary increases in blood pressure are believed to lead to a gradual resetting of the body's blood pressure control system. Over a period of years, some researchers hypothesize that permanent hypertension may develop (e.g. Peterson et al., 1984).

One mechanism hypothesized is that continuous stimulation of the central nervous system by noise induces changes in cardiac function and peripheral vascular resistance, which in turn raises blood pressure and gradually resets the baro-receptor (blood pressure) control system. Although inconclusive, studies of the prevalence of elevated blood pressure in noise-exposed populations suggest that long-term exposure to high levels of occupational noise may be associated with an increase in hypertension in the later decades of life. These studies, coupled with increases in flight operations around civilian airports and military airbases plus an increase in low altitude overflights in military training areas, have increased public concern about potential health hazards of aircraft noise exposure in recent years.

Studies in residential areas exposed to aircraft noise have produced contradictory results that are difficult to interpret. Early investigations indicated that incidence of hypertension was from two to four times higher in areas near airport than in areas away from airports (Karagodina et al., 1969). Although Meechan and Shaw (1988) continue to report excessive cardiovascular mortality among individuals, 75 years or older, living near the Los Angles International Airport, their findings cannot be replicated (Frerichs et al., 1980). In fact, noise exposure increased over the years while there was a decline in all cause, age-adjusted death rates and inconsistent changes in age-adjusted cardiovascular, hypertension, and cerebrovascular disease rates. Some European research (Ising et al., 1991; Ising and Spreng 1988) has shown more positive association between exposure to aircraft noise and adverse health effects, including a result that showed more pronounced effects in females than males. The adequacy of the methodology and the consistency of the conclusions, however are still being debated. The major problem that requires further consideration is that the methodology of these studies does not lend itself to conclusive proof of significant nonauditory health effects in residential areas exposed to aircraft noise.

Most studies which have controlled for multiple factors have shown no, or a very weak association between noise exposure and nonauditory health effects. This observation holds for studies of occupational and traffic noise as well as for aircraft noise exposure. In contrast to the reports of two- to six-fold increases in incidence of hypertension due to high industrial noise (see review by Thompson et al., 1989), the more rigorously controlled studies (Talbott et al., 1985; and van Dijk et al. 1987) showed equivocal associations between hypertension and prolonged exposure to high levels of occupational noise. In the Talbott et al. (1985) study a significant relationship was shown between noise-induced hearing loss and high blood pressure in the 56 plus age group.

The critical question is whether observed positive associations are causal ones. In the aggregate, studies indicated that the association between street traffic noise and blood pressure or other cardiovascular changes are arguable. Two large prospective collaborative studies (Babish and

Gallacher 1990) of heart disease are of particular interest. To date, cross-sectional data from these cohorts offer contradictory results. Data from one cohort show a slight increase in mean systolic blood pressure [2.4 millimeters of mercury (mmHg)] in the noisiest compared to the quietest area; while data from the second cohort show the lowest mean systolic blood pressure and highest highdensity lipoprotein cholesterol (lipoprotein protective of heart disease) for men in the noisiest area. These effects of traffic noise on blood pressure and blood lipids were more pronounced in men who were also exposed to high levels of noise at work.

More rigorous epidemiologic study designs for investigating causal and dose-response relationships depend upon assignment of noise dose and health status to individuals. The best established environmental noise descriptor, yearly DNL, is inherently place-oriented and may bear little specifiable relationship to personal exposure. Because health consequences of environmental noise exposure are unlikely to appear in less than five to ten years, individual dosimetry may not be practicable. There are three problems with using dosimetry in epidemiologic studies: (1) wearing may be burdensome, (2) irritating, and (3) tedious to the participants.

It is clear from the foregoing that the current state of technical knowledge cannot support inference of a causal or consistent relationship, or a quantitative dose-response model, between residential aircraft noise exposure and health consequences. Thus, no technical means are available for predicting extra-auditory health effects of noise exposure. This conclusion cannot be construed as evidence of no effect of residential aircraft noise exposure on nonauditory health. Current findings, taken in sum, indicate that further rigorous studies, such as an appropriately designed prospective epidemiologic study, are urgently needed.

3.3 Environmental Degradation/Impact

The objectives of environmental noise impact analysis are to determine the magnitude and extent of the community noise exposure and to evaluate the resultant noise impacts, generally through a comparison of conditions before and after the implementation of a proposed change. As stated in the "Levels Document", ". . the ultimate goal is to characterize with reasonable accuracy the noise exposure of whole neighborhoods (within which there may actually exist a fairly wide range of noise levels), so as to prevent extremes of noise exposure at any given time, and to detect unfavorable trends in the future noise climate." Thus, a value judgement must be assigned to reflect the quality of the environment as the result of noise exposure. This is precisely what was done by the FICUN as depicted in Table 1 of their guidelines. Qualities, such as the significance [in the context of NEPA rather than statistics] and acceptability of impacts, are not defined by scientific research, but instead are matters of policy decisions based at least partly on community standards.

3.3.1 Applications of Guidelines Methodology

A 3 dB change in sound level represents a doubling of sound energy. Although it is difficult for the average individual to detect a 3 dB difference in the level of two distinct sounds unless they occur very close together, according to Galloway (1991), in a community noise environment, the majority of a group of persons exposed to a 3 dB change in DNL as a result of changes in aircraft noise exposure would characterize the change as "clearly noticeable." Although a 3 dB change in

DNL may not represent a significant impact on human health or welfare, particularly below DNL 55 dB, a change of this magnitude is considered as an indicator of the need for additional analysis.

3.3.1.1 Screening

Screening is the process for determining the extent of noise analysis required. It must be recognized that changes in noise levels do not translate into impacts until the noise levels are related to a given environment and sensitive receptors (especially humans). Criteria for determining when changes in the noise environment, either as a result of the introduction of new sources or changes in existing sources, require further analysis may include consideration of non-noise criteria such as changes in flight tracks or flying missions.

A wide variety of screening criteria have been developed by Federal agencies. In this context, the determination as to whether a specific level (value of DNL) or increase in level constitutes a “threshold” indicating a need for further analysis is based on a variety of considerations relevant to the agency’s responsibilities and concerns. The related question of determining the “acceptability” of a given DNL (or change in DNL) also entails consideration of not only the nominal degree of annoyance but also economic, social, and political factors in the area under study. From the standpoint of an affected community, the acceptability of a given noise exposure would also be related to the pre-existing “indigenous” noise level. As illustrated by the following FAA practices, variations in thresholds may be appropriate to address varying agency concerns.

FAA Order 1050.1D establishes a change in DNL of 1.5 dB in a noise sensitive area as a threshold of further analysis. Using this threshold, if the proposed FAA action would result in a DNL increase of 1.5 dB or more at a noise sensitive area within the YDNL 65 dB contour for the projected conditions, it would be necessary to conduct further analysis as part of the NEPA process to evaluate impacts in greater detail. Noise-sensitive areas are those identified in FAA Regulations (FAR) Part 150 Land Use tables. Within the DoD, the USAF has established guidance within its AICUZ program that a 2 dB increase within the DNL 65 dB contours is an indicator of the need for further analysis.

FAA Order 1050.1D also discusses the FAA Area Equivalent Method (AEM) as an additional screening tool for determining the need for additional environmental noise analysis. The AEM is a mathematical procedure which calculates the area within the DNL 65 dB or 75 dB noise contours for baseline and projected aircraft operations at a specific airport. If the AEM calculations indicate a proposed action would result in an increase of 17 percent, or more, in the area within the DNL 65 dB contour, it would then be necessary to determine if the proposed action would result in a DNL 1.5 dB or greater increase in a noise-sensitive area. Conversely, if the AEM screening process shows less than a 17 percent increase, it may be concluded that there are no significant impacts on a noise-sensitive area (U.S. Department of Transportation, FAA 1986a).

FAA Notice 7210.360 is a temporary screening procedure to assist FAA Air Traffic in its noise review. It establishes a noise screening procedure for certain air traffic actions involving operations more than 3,000 feet above ground level (AGL) and provides instructions for determining whether the proposed action would result in a 5 dB increase in the DNL in any residential area. This proposed procedure applies only to airports with more than 1,500 operations per year by large jet aircraft (greater than 75,000 lbs). The 5 dB; increase serves as one indicator of whether a proposed action is likely to refer the air traffic specialist or planner to FAA Order 1050.1D to determine extraordinary circumstances (U.S. Department of Transportation FAA 1990).

The EPA "Guidelines for Impact Analysis" indicate that if the expected yearly DNL from the proposed action is at least 10 dB; below the existing yearly DNIL (resulting in an increase of less than 0.5 dB in the cumulative DNL), the project may be "screened out" and no further analysis is required because the change in the environment is not significant (U.S. EPA 1982).

To establish a widely applicable screening criterion for noise analysis within the DNL 60-65 dB range, it appears that a DNL 3 dB; increase due to the proposed project is an appropriate value to use. In addition, a 3 dB increase at the DNL 60 dB level is generally consistent, in terms of impact level, with existing screening criterion used at the DNL 65 dB; level. This can be shown by using the Schultz curve to relate changes in impact level to changes in DNL. Using the Schultz curve in this way shows that an increase of 5 dB; at DNL 55 dB, 3 dB at DNL 60 dB, and 1-5 dB at DNL 65 dB; all resulted in a three percent increase in the %HA. This occurs because the gradient of the Schultz curve decreases with decreasing DNL values. Therefore, as criteria for further analysis, a 3 dB change at DNL 60 dB and a 1.5 dB change at DNL 65 dB; are consistent.

Finally, it is noted that advances in both computer technology and associated software provide the sound analyst with important new tools with which to determine discrete impacts of proposed actions. These tools include the integration of geographic information systems (GIS) with noise modeling software and 1990 U.S. Census Bureau population and TIGER databases[5]. These automated tools can provide a wide variety of detailed population vs DNL statistics, as well as DNL impacts vs noise sensitive land uses.

3.3.1.2 Acceptability

The quantity, percent highly annoyed (%HA), which defines the severity of noise impact on humans at a specified level of DNL, is a measure of environmental quality. The DNL methodology acknowledges that some people will be highly annoyed at relatively low levels of noise. It is estimated that three percent of the exposed population will be highly annoyed at the EPA's identified protective level of DNL 55 dB, and seven percent at DNL 60 dB.

[5] The 1990 Census data are being released in the form of computer readable databases on either magnetic tape or optical disks. These contain demographic data at the census tract and block levels and information on the geographic location (latitude and longitude) of the geographic area to which the data apply (census block, tract, etc.). The use of a geographic information system (GIS) permits this information to be used in combination with the TIGER (Topologically Integrated Geographic Encoding and Referencing System) line files which contain digitized versions of U.S Geological Survey (USGS) 1:100,000 scale maps to determine the area to which the information is applicable (i.e., the boundaries of the census block or tract). The GIS can then be used to combine population data with the output of noise models to provide detailed estimates of population exposure as well as other demographic data.

3.4 Land Use Compatibility

3.4.1 General

In most cases, land use compatibility recommendations regarding noise are in the form of guidelines provided by Federal agencies to State and local communities. The FICUN Guidelines (1980) provided a summary table of Land Use Applications and Compatibilities for this purpose. In general, land use compatibility guidelines tend to be expressed in terms of DNL and include (1) identification of compatible and incompatible land uses on the basis of DNL in 5 dB increments beginning at or below 65 dB, and (2) recommendations for building design and construction methods necessary to achieve specified levels of noise attenuation (reduction) based on the outdoor DNL. Airfield environs, which are the focus of this report, affect only certain categories of these guidelines.

For local agency decisions, these guidelines do not constitute thresholds of impact, because local agencies determine the application of the guidelines taking into consideration economic, technical and political ramifications specific to the communities involved. In general, these guidelines have been broadly accepted. However, there is also general recognition of the need for selective updating to include new types of land use (e.g. biotechnology laboratories) and the need for improved public understanding of the guidelines, their applications and interpretations.

The DoD, DOE, HUD and DOT are currently working together to update the Standard Land Use Coding Manual (SLUCM) land use categories used in land use compatibility guidelines. When SLUCM updating is completed, the FICON will need to establish new land use compatibility guidelines for each DNL range for any new land use codes.

The Secretary of Defense Office of Economic Adjustment has established a program to provide incentives to local governments to study, approve and implement land use plans and controls to protect installations from encroachment.

The standards established by HUD for future land use planning in noise environments are exceptions to the general federal practice of simply providing recommended noise guidelines to local communities.

3.4.2 Agency Regulatory Guidelines

3.4.2.1 HUD and VA

Agencies like HUD have developed regulations related to the overall community noise level, but these affect only their own programs and are not binding on local communities. The Department of Veteran Affairs (VA) program also considers aircraft noise and its findings affect only its own program. The mandate for HUD's involvement with noise is the Housing Act of 1949 (Public Law 81-171). This law sets a national goal of a decent home and suitable living environment for every American family. The Department was also tasked by the Housing and Urban Development Act of 1965 (Public Law 80-117) "to determine feasible methods of reducing the economic loss and hardships suffered by homeowners as a result of the depreciation in the value of their properties following the construction of airports in the vicinity of their homes." Finally, HUD is tasked by Federal Management Circular 75-2, Compatible Land Uses at Federal Airfields, to promote compatible land uses around Federal airfields (HUD 1985).

Regulatory Guidance (Standards

HUD Regulations are based on the DNL metric, and set forth the following exterior noise standards for new construction assisted or supported by the Department. They provide planning guidance only for existing conditions:

- DNL 65 dB or less - Acceptable;
- DNL 65 dB to DNL 75 dB - Normally Unacceptable - appropriate sound attenuation measures must be provided: 5 dB above the attenuation provided by the standard construction required in DNL 65 dB to 70 dB zone; 10 dB additional attenuation in DNL 70 dB to 75 dB zone;
- Exceeding DNL 75 dB - Unacceptable.

HUD's Regulations do not contain standards for interior noise levels. Rather, a level of DNL 45 dB is set forth as a goal for interior noise levels and the regulations specify noise reduction (attenuation) requirements which are directed towards achieving that goal. It is assumed that with standard construction materials and methods, any residential structure will provide sufficient attenuation (i.e., a 20 dB reduction in exterior noise levels) so that if the exterior level is DNL 65 dB, the interior level will be DNL 45 dB or less (Department of Housing and Urban Development 1985).

The HUD impact determination process is clearly spelled out in their Noise Assessment Guidelines, and is fairly simple. The noise level from each source affecting the proposed site is calculated and then combined to derive the overall exposure. The overall noise level is then compared to HUD's standards and the appropriate action, as specified in the regulations, is taken (Department of Housing and Urban Development 1985). HUD's recommended "ideal" solution to a potential problem is to reduce the noise being produced by the source. However, usually the best available solution is to make sure that noise-sensitive uses are located where they will not be exposed to high noise levels.

3.4.2.2 FAA

Part 150 of the Federal Aviation Regulations (FAR Part 150) establishes the recommended procedures, standards and methodology governing the development of airport noise exposure maps and airport noise compatibility planning programs. It is consistent with the EPA "Levels Document" that prescribes a single system for: (1) measuring noise at airports and surrounding areas that generally provides a highly reliable relationship between projected noise exposure and surveyed reaction of people to noise; and (2) determining exposure of individuals to noise that results from the operations of an airport. This Part 150 Regulation also parallels the HUD regulatory guidance in that it identifies those land uses which are normally compatible with various levels of DNL exposure.

FAR Part 150 includes a table titled "Land Use Compatibility with Yearly Day-Night Average Sound Levels." This table identifies various land use recommendations that are compatible or incompatible with yearly DNL levels above 65 dB in 5 dB increments. Levels below DNL 65 dB are considered compatible for all indicated land uses and related structures without restrictions. Levels between DNL 65 and 75 dB are considered incompatible with residential or school land uses unless measures are taken to achieve additional Noise Level Reductions (NLRs). Above DNL 75 dB, residential land uses are considered unacceptable, even with incorporation of noise attenuation measures. However, a variety of non-residential, open space, commercial and manufacturing land uses are identified as compatible in areas with DNL > 75 dB.

3.4.2.3 DoD

The DoD program for land use compatibility around airports is referred to as the Air Installation Compatible Use Zone (AICUZ) program. This program uses land use tables similar to the one in FAR Part 150 for noise levels of DNL 65 dB and above. While screening criteria vary somewhat from Service to Service, new environmental noise analysis is usually conducted when there is any significant change in airfield operations, types of aircraft, or aircraft flight tracks. Additionally, the program provides for periodic updates. When the noise assessments are completed for the airfield, each service provides land use recommendations to the local communities for consideration and potential incorporation into the community land use ordinances. Through the Base Comprehensive Planning process, on-base facility siting also incorporates noise as a planning factor.

The DoD Joint Services Manual, Planning in the Noise Environment (1978) provides military installation planners with a procedural tool to aid in the creation of acceptable noise environments. The acceptable outdoor noise environments for major military and civil uses are described. Planning levels are in terms of DNL values; however, L_{eq} is used for detailed design when occupancy or usage does not extend over 24-hour periods. The land use compatibility tables are consistent with those discussed for the FAA FAR Part 150 and the DoD AICUZ programs.

3.4.2.4 Federal Interagency Committee on Urban Noise (FICUN) Guidelines

The purpose of the 1980 FICUN was to put the various Federal agency policy and guidance packages on environmental noise into perspective. The result was the publication of Guidelines for Considering Noise in Land Use Planning and Control (1980). The "Guidelines" do not replace the individual Federal agency guidelines. They serve as a point-of-departure for dealing with each agency's programs, and facilitate the consideration of noise in all land use planning and interagency/intergovernmental processes. The FICUN established DNL as the descriptor to be used for all noise sources. The L_{eq} descriptor is included because some highway noise is best characterized in terms of an equivalent sound level for the highway "design hour." Table 2 of these "Guidelines" contains suggested land use compatibility guidelines. This table was previously discussed in Section 3.2.2.3 and is reproduced herein as Table 3.2. In addition, the FICUN "Guidelines" provide a reference for describing the effects of noise on people in terms of annoyance, speech, and hearing loss.

3.4.2.5 American National Standards Institute (ANSI)

ANSI recently revised their 1980 Standard on Sound Level Descriptors for Determination of Compatible Land Use (ANSI S12.40-1990). This recently updated standard continues to identify DNL as the "acoustical measure to be used in assessing compatibility between various land uses and outdoor noise environment." The standard further states:

> Ordinarily, land uses are of long-term, continuing nature, and the yearly day-night average sound level is appropriate for these land uses. For other land uses, compatibility is to be assessed by the average sound level during the time interval of interest for the land use involved.

The Standard includes a land use compatibility table. This table is for information only and is not part of the Standard.

3.4.3 Land Use Compatibility Summary

In general, the basic federal land use compatibility criteria as represented in land useenvironmental noise tables provided the FAA, DoD, and the FICUN "Guidelines" are similar. The ANSI Standard S12.40-1990 is not as detailed. All land use compatibility is based on the use of DNL as the descriptor representing community noise environments. FAA, DoD and FICUN have established less than DNL 65 dB as compatible for most residential land uses, and DNL ≥ 65 dB as marginally compatible to incompatible, depending on the degree of noise level reduction provided.

In determining compatible land use, HUD provides standards. The VA has no regulations concerning noise. It has a noise policy and procedures, based on DOT and DoD noise studies, which govern decisions as to whether residential sites in airport environs are "acceptable" for loan guaranty programs to eligible veterans and active duty personnel. The remainder of the compatible land use strategies consist of recommendations by each to local communities.

3.5 Summary of Indoor and Outdoor Sound Levels

3.5.1 Yearly Average Outdoor Sound Levels

The range of DNL in the U.S. is very large, with 20-30 dB estimated for wilderness areas to 63-72 dB in noisy urban areas. Table 3.5 indicates typical DNL values in various types of residential areas. Estimates by EPA (1974) indicate that the majority of people residing in urban areas have outdoor DNL values ranging from 58 dB to 72 dB, with a median value of 59 dB; more recent estimates (U.S. EPA, Ambient Noise Survey, 1982) indicate that 17 percent of the urban population is exposed to DNL 65 dB and above, including aircraft noise. Most of the remaining population residing in rural or other non-urban areas is estimated to have outdoor DNL values ranging between 30 and 50 dB (U.S. EPA 1974).

Table 3.5 Typical DNL values in residential areas

Description	Typical Range DNL in dB	Average DNL in dB	Population Density People/Sq.Mile
Quiet Suburban Residential	48-52	50	630
Normal Suburban Residential	53-57	55	2,000
Urban Residential	58-62	60	6,300
Noisy Urban Residential	63-67	65	20,000
Very Noisy Urban Residential	68-72	70	63,000

Source: U.S. EPA 1974

3.5.2 Indoor Sound Levels

The majority of the existing data regarding levels of environmental noise in residential areas has been obtained outdoors. Such data are useful in characterizing the neighborhood noise environment, evaluating the noise from identifiable sources, and relating measured values to those calculated for planning purposes. For planning, outdoor noise levels have proved more useful than indoor noise levels. Indoor noise levels contain the additional variability of interior noise sources and individual building sound level reduction. This variability among building units results from the type of construction, interior furnishings, orientation of rooms relative to the noise, and the manner in which the dwelling unit is ventilated. As indicated in Table 3.4, the EPA "protective" DNL levels in residential dwellings is 45 dB. Data on the reduction of aircraft noise afforded by a range of residential structures indicates that houses can be broadly categorized as "warm climate" or "cold climate." Additionally, data are available for typical open window and closed window conditions. For planning purposes, the typical reduction in sound level from outside to inside a house can be summarized as indicated in Table 3.6. The open window condition was assumed in the "Levels Document" in estimating conservative sound levels inside dwelling units that result from outside noise (U.S. EPA 1974).

Table 3.6 Sound level reduction for typical residential structures

Climate	Windows *Open*	Windows *Closed*
Warm Climate	12 dB	24 dB
Cold Climate	17 dB	27 dB
Approximate National Average	15 dB	25 dB

Source: U.S. EPA 1974

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APPENDIX A GLOSSARY

Definitions

Audible Sound. Acoustic oscillation capable of exciting the sensation of hearing.

Noise. Any disagreeable or undesired sound or other acoustic disturbance. By extension, any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. Erratic or statistically random oscillation.

Frequency. The number of times per second that the sine-wave of sound repeats itself, or that the sine-wave of a vibrating object repeats itself. Now expressed in Hertz (HZ), formerly in cycles per second (cps).

Pascal. Unit of sound pressure describing the acoustic signal above atmospheric pressure. A pascal is one newton per square meter. The reference pressure is standardized at 20 micropascals (this pressure represents the weakest sound that can be heard by an average young, undamaged car).

Decibel. Because of the large range in the intensity of audible sound, a linear scale of measurements is unmanageable. The logarithmic scale more closely resembles the response of the ear to sound. The unit used to measure sound is called a **decibel**, and is symbolically represented as **dB**. A decibel is not an absolute unit of measurement; for sound, it is defined as 20 times the common (base 10) logarithm of the ratio of the pressure produced by the sound of interest and a reference pressure which has been standardized at 20 micropascals, the pressure of a sound which is at the threshold of normal human hearing. Appendix B provides more discussion on sound basics and SPL.

Loudness. Loudness is a subjective perception of the magnitude of sound. The loudness of sound depends on its intensity, the frequency of the sound, and the characteristics of the human ear. The intensity of sound is a purely physical property; whereas the loudness depends also upon the characteristics of the receptor ear. In other words, the intensity of a given sound striking the ear of a normal hearing person and of a person with a hearing loss might be the same, but the perceived loudness would be different.

Additionally, although a 3 dB increment in noise level represents a doubling of sound energy, the higher level does not sound twice as loud as the lower. In reality, a 3 dB difference in noise levels is only moderately detectable by the human ear. A difference on the order of 10 dB represents a subjective doubling of loudness. Thus, 3 dB corresponds to a factor of two in sound energy , while 10 dB corresponds approximately to a factor of two in subjective loudness.

Noise Indices and Terminology

An array of different measures are used to assess human exposure to noise. Each index satisfies different requirements or emphasizes certain sound characteristics. For example, a measure that accounts for the low frequency and short duration of blast noise may not be appropriate to evaluate the high frequency, continuous nature of a turbine whine.

- A-Weighted Sound Level. A-weighting emphasizes sound components in the frequency range where most speech information resides, and thus yields higher readings (A-weighted levels) for sound in the 2000 to 6000 Hz range, but considerably lower readings for low-frequency noise, than does the overall sound pressure level. The A- weighted sound level is used extensively in the U.S. for measuring community and transportation noises.
- Air Installation Compatible Use Zone (AICUZ). The AICUZ program was initiated by the Department of Defense (DoD) to promote compatible land use development in the proximity of DoD air installations. The program involves working with local governmental agencies to implement the land use recommendations contained in AICUZ reports prepared for each installation having an active flying mission. The AICUZ program provides information to the communities concerning both the noise levels and accident potential associated with aircraft operations at the installation.
- Ambient Sound. The issue of ambient sound is theoretically integral to determining of the usefulness of DNL contours below DNL 65 dB, and to the impact of incremental increases below the DNL 65 dB threshold. Additional comparisons can be hypothesized for urban, rural, and various densities of suburban neighborhoods. The technical literature review on the issue of background noise or ambient sound impacts reveals a need for further research to determine the relationships between ambient sound and proposed metrics and methodologies existing below DNL 65 dB.
- Annoyance. The typical response of humans to aircraft noise is annoyance. The response is remarkably complex and, considered on an individual basis, widely varies for any given noise level. When average annoyance reactions within a community are considered, it is possible to discern aggregate annoyance response/noise level relationships. Frankel defines annoyance as, “a psychological response to a given noise exposure.” It may result from speech or sleep interference, but can arise in a variety of other circumstances. The perceived unpleasantness of the noise is a factor, as is any anxiety or apprehension the noise may cause. Noise does not have to be loud to annoy; a loud noise may be pleasant to one individual and yet annoying to another.

Since one person’s noise may be another person’s music, a measure or index to account for subjective differences is not possible. Instead, the intensity of the noise sufficient to annoy most people is the method used to develop noise measurements. The establishment of noise standards may be based on the health and annoyance levels of the general public. The subjective nature of annoyance results in a small percentage of the population reporting a high degree of annoyance in relatively quiet settings; and other portions of the population unannoyed in environments capable of potential hearing loss (Federal Interagency Committee on Urban Noise 1980). Thus, guidelines directed toward annoyance must consider that some annoyance will occur at relatively quiet noise levels. These guidelines are contained as Table D-1 in the Guidelines for Considering Noise in Land Use Planning and Control, Federal Interagency Committee on Urban Noise, 1980.

- Community Noise Equiva lent Level (CNEL). The 24-hour A-weighted average sound level from midnight to midnight obtained after the addition of 5 dB to sound levels occurring between 1900 and 2200 hours and 10 dB to sound levels occurring between 2200 and 0700 hours. Units used are decibels.
- C-Weighted Sound Level. This measure is widely used for large amplitude impulse sounds such as sonic booms, explosions, and weapons noise. C-weighting reflects both loudness and low frequency vibrational energy. This weighting provides little adjustment to the noise signal in the audible frequency range and therefore may not correlate well with subjective tests.
- Complaints. The analysis of complaints by Luz, Raspet and Schomer supports noise abatement (reduction) policies based on an assessment of the level of annoyance rather than the number of complaints. Annoyance can exist without complaints and, conversely, complaints may exist without adverse noise levels. The current body of evidence indicates that complaints are an inadequate indicator of the full extent of noise effects on a population.
- Day-Night Average Sound Level (DNL or L_{dn}). Day-Night Average Sound Level (DNL) is a single number measure of community noise exposure. It is an enhancement of the 24-hour Equivalent Sound Level (L_{eq}) with a 10 dB penalty applied to nighttime (10 P.M. to 7 A.M.) sound levels to account for increased annoyance due to noise exposure during these hours.
- Effective Perceived Noise Level (EPNQ, expressed in dB or EPNdB. Effective Perceived Noise Level is a single number measure of complex aircraft flyover noise that approximates human annoyance responses. EPNL is used by the FAA as the noise certification metric for large transport and turbojet aircraft and helicopters.
- Equivalent Sound Level (L_{eq}). An average (on an energy basis) of the A-weighted sound levels over a period of time.
- Fast and Slow Sound Level. In decibels, the exponential-time-average sound level obtained with a squared- pressure time constant of 125 milliseconds for FAST and one second for SLOW.
- Habituation. The ability of humans to acclimate to incremental increases in sound levels, intermittent increases in sound levels such as aircraft flyovers, and high ambient sound levels is an area recommended for further research. The issue of habituation has informally been the subject of discussions concerning the long-term consequences of proposed actions below DNL 65 dB; however, little scientific data was found in the technical literature review.
- Highly Annoyed. Before and during the 1950s, the effects of noise were determined largely from anecdotal evidence, case studies, laboratory studies, and a very few social surveys. Even in those early days, “annoyance” was given prominence. How annoyed people were as a consequence of the noise exposure was thought to be very important, and indeed that is the belief to the present day. Also, in recent years, there has been more emphasis on obtaining data on community response from social surveys of the communities involved. There has been a great effort directed toward finding a relationship between the noise exposure metric and some measure of activity interference (assumed by most researchers to be primarily communication interference) or annoyance as measured by a social survey. A wide variety of responses have been used in social surveys in an attempt to determine intrusiveness, disturbance of speech

communications or sleep, interference with TV or radio listening and interference with outdoor living. The overall response to all of these factors was measured by questions on the annoyance reaction. The concept of “percent highly annoyed” in the sampled populations seemed to provide the most consistent response of a community to a particular noise environment. In an attempt to meet the demand for a usable and uniform relationship, Schultz reviewed the results of a number of social surveys where data were available to make a consistent judgment concerning what percent of the population was “highly annoyed” (%HA). The surveys were of community reactions to several types of transportation noise such as road traffic, railroad and aircraft noises. The results agreed fairly well with one another and he developed an equation for describing the relationship between the level of exposure in DNL and the %HA. This relationship was adopted by the CHABA Working Group 69 and was proposed by EPA in the “Levels Document” as the appropriate method for evaluation of the effects of noise on communities. The relationship has held up well for aircraft noise and produced reliable results in several subsequent studies. In 1989, Fidell et al. added 239 data points to the original 161 data points analyzed by Schultz for a total of 400 points. The U.S. Air Force Armstrong Laboratory uses a Logistics type regression curve fit for describing the relationship between DNL and %HA because it gives essentially the same predictive values as the function recommended in by Fidell et al. and has the further advantage that no predictions of less than 0% or more that 100% can be obtained. Logistic fits to the 161 data points and to the 400 data points give such similar predictive values (within about 1%) that no advantage would be obtained by replacing the original Logistic equation for describing the relationship.

One question that still persists is whether the DNL-%HA relationship is the same for all types of transportation noise. Of the 400 data points, 173 were for aircraft noise, 170 for traffic noise, and 57 for railway noise. In the Armstrong Laboratory analysis, plots are given for logistic fits to each of these three sets of data points. Although values for traffic and railway noise are not as high as the values predicted for aircraft noise, at the higher DNL values, there are no statistically significant differences between predicted value at any DNL level.

- Level Weighted Population (LWP). A single number which represents quantitatively the integrated impact of a proposed action on the total population experiencing the different sound levels.
- Maximum Sound Level (L_{max}). The greatest sound level in decibels for a specific exponential-time averaging constant during a given time period. Abbreviation for maximum fast A-weighted sound level: MXFAL; quantity symbol: L..
- Noise-Induced Permanent Threshold Shift (NIPTS). NIPTS is a permanent shift in human hearing threshold (a lowering of the sensitivity) due to noise exposure to noise. It is a sensory-neural type of hearing loss and is not reversible.
- Noise Sensitive Area. An area in which aircraft noise may interfere with the normal activities associated with the use of the land. Noise sensitive areas include residential neighborhoods, educational, health and religious structures and sites and outdoor recreational, cultural, and historic sites. Whether sound interferes with a particular use depends on the timing, level, duration, and frequency of the occupance of the sound exposure received and the type of activities involved.

- Sleep disturbance (wake-ups). The threshold level of noise that will cause arousal from sleep. This threshold depends on the sleep stage and the age of the subject, among other variables. Noise levels that can cause sleep disturbance occur in the A-weighted range of 35 to 70 dB.
- Sound Exposure Level (SEL). The level, in decibels, of the time integral of squared weighted sound pressure over a given time period or event, with reference to the square of the standard reference sound pressure of 20 micropascals and a reference duration of I second. The frequency weighting shall be specified, otherwise Aweighting is understood.
- Speech Interference. The chief effect of intruding noise on speech is to mask the speech sounds and thus reduce intelligibility. The important contributors to intelligibility in speech sounds cover a frequency range from about 2000 to 6000 Hz; and at each frequency, a dynamic level range of about 30 dB. This is a major factor associated with annoyance from aircraft noise. A number of metrics have evolved for assessing the influence of noise on speech. These include: (1) Preferred Speech Interference Level (PSIL), defined as the arithmetic average of the sound pressure levels in the 500 Hz, 1000 Hz and 2000 Hz octave bands; (2) The Speech Interference Level (SIL), defined as the arithmetic average of the sound pressure levels at the. 500, 1000, 2000, and 4000 Hz octave bands; (4) The Sentence Intelligibility as a function of steady ambient noise level; and (3) The Articulation Index (AI), a value between zero and 1.0, that describes the masking of speech by background noise. This value is found by evaluating the signal-to- noise ratio in specific frequency bands. Additionally, the Leq metric that identifies the cumulative noise exposure for a specific period of time may also be used.
- Time Above (TA). Expressed in Minutes. The duration, in minutes, for which aircraftrelated noise exceeded specified A-weighted sound levels during a given period. The day TA metric applies to the period 7 A.M. to 7 P.M., while the evening TA metric applies to the period from 7 P.M. to 10 P.M., and the night TA metric to the period 10 P.M to 7 A.M..
- 24-Hour Time Above (TA), Expressed in Minutes. The duration, in minutes, for which aircraft-related noise exceeded specified A-weighted sound levels during a 24-hour period.

APPENDIX B SOUND BASICS

B.1 PROPERTIES OF SOUND

B.1.1 Sound Wave Properties

To gain an understanding of the principles applied to the analysis of sound effects, it may first be beneficial to examine the characteristics of "sound" and how they relate to "noise." The definitions of sound and noise are bound up in human perceptions of each. Sound is a complex vibration transmitted through the air that, upon reaching the ears, may be perceived as desirable or unwanted. Noise can be defined simply as unwanted sound or, more specifically, as any sound that is undesirable because it interferes with speech and hearing, is intense enough to damage hearing, or is otherwise annoying (U.S. EPA 1976).

Sound can be defined as an auditory sensation evoked by an oscillation (vibratory disturbance) in the pressure and density of a fluid, such as air, or in the elastic strain of a solid, with the frequency in the approximate range of 20 to 20,000 Hz. In air, sound propagation occurs as momentum is transferred through molecular displacement from the displaced molecule to an adjacent one. An object's vibrations stimulate the air surrounding it, and cause a series of compression and rarefaction cycles as it moves outward and inward. The number of times per second the wave passes from a period of compression, through a period of rarefaction, and back to the start of another compression is referred to as the *frequency* of the wave and is expressed in cycles per second, or hertz (Hz). The distance traveled by the wave through one complete cycle is referred to as the *wavelength*. The higher the frequency, the shorter the wavelength and vice versa.

B. 1.2 Sound Intensity and Loudness

As sound propagates from a single source, it radiates more or less uniformly in all directions, forming a sphere of acoustic energy. Although the total amount of acoustic energy remains constant as the spherical wave expands, the intensity of the energy [amount of energy per unit of area on the surface of the sphere, normally expressed in watts per square meter (watts/m^2)] decreases in proportion to the square of the distance (because the same amount of energy must be distributed over the surface area of the sphere which increases in proportion to the square of the distance from the source).

The intensity of the acoustic energy cannot be measured conveniently; however, as the sound waves propagate through the air, they create changes in pressure which can be measured conveniently and provide a meaningful measure of the acoustic power intensity (loudness). The sound intensity is proportional to the square of the fluctuations of the pressure above and below normal atmospheric pressure. Measurements of sound pressure (defined as the root mean square of the fluctuations in pressure relative to atmospheric pressure) is the most common measure of the strength of sound or noise.

B.1.3 The Decibel

The faintest sound audible to the normal human ear has an intensity of approximately 10^{-12} watts/m^2. in contrast, the sound intensity produced by a Saturn rocket at liftoff is approximately 10^8 watts/m^2. The ratio of these two sound intensities is 10^{20} (1 followed by 20 zeros), a range that is difficult to comprehend or use.

To permit comparison of values which vary so greatly in magnitude, it is most convenient to express them in terms of their logarithms - the power to which 10 must be raised to equal the number. The logarithms of the sound intensities indicated above would vary from -12 to 8, a range of 20 units. To avoid the use of negative numbers, it is convenient to express the values in terms of the logarithm of their ratio to a standardized reference value, most frequently the lowest value expected to be encountered. On this logarithmic scale, an increase of 1 unit represents a ten-fold increase in the ratio. On this scale, the values for the sound intensities would vary from 0 to 20.

The unit of measurement on a logarithmic scale is the *Bel*, named in honor of Alexander Graham Bell. The bel is a rather large unit and since each unit represents a 10-fold increase relative to the previous value, it is convenient to divide each unit into 10 subunits known as *decibels* and abbreviated as *dB*. Using the decibel scale, our range of intensity ratios now expands to 0.0 to 200.0 rather than 0 to 20. The decibel scale is commonly used for the measurement of values which vary over extremely large ranges. Because the values are the logarithms of ratios, they are dimensionless (have no units of measurement such as length, mass or time) and are normally referred to as levels. By definition:

$$L = 10 \log \left(\frac{\textit{Measured Quantity}}{\textit{Reference Quantity}} \right) \qquad \textbf{(Eq. B.1)}$$

B. 1.4 Measurement of Sound Intensity

As stated previously, sound pressure can be measured more conveniently and accurately than sound intensity (although measurement techniques are available for measuring sound intensity directly). The sound intensity (power per unit area) varies in proportion to the square of the sound pressure. For example, in a plane progressive ware in air, the sound intensity (I) is defined by the equation:

$$I = \frac{P^2}{d\,C} \qquad \textbf{(Eq. B.2)}$$

Where: *P = Sound Pressure*
d = Density of the air
C = Velocity of sound in air

The change in sound intensity is measured in terms of the *sound pressure level (SPL)* expressed in decibels:

$$SPL = 10 \log \left[\frac{SP^2_{Meas}}{SP^2_{Ref}} \right] \qquad \textbf{(Eq. B.3)}$$

Where: SP_{Meas} = *Measured sound pressure*
SP_{Ref} = *Reference pressure* (20 μP)

B. 1.5 Sound Propagation and Attenuation

As stated previously, sound intensity decreases with increasing distance from the source due to the spreading of the sound energy over an increasing area. The sound intensity varies inversely with the square of distance from the source. For each time the distance from the source doubles, the sound pressure is reduced by a factor of two, and the sound intensity, which is proportional to the square of the pressure, is reduced by a factor of 4. As illustrated by the equation below (Eq. B.4), this is equivalent to a decrease of approximately 6 dB in the sound pressure level for each doubling of distance.

$$L = 10 \log \left(\frac{(0.5P)^2}{P^2_{Ref}} \right) = 10 \log (0.5^2) + 10 \log \left(\frac{P^2}{P^2_{Ref}} \right) = -6 + 10 \log \left(\frac{P^2}{P^2_{Ref}} \right) \qquad \textbf{(Eq. B.4)}$$

In addition to the decrease in sound level which results from the spreading of the sound waves and distribution of the sound energy over an increasingly large area, interaction with the molecules of the atmosphere results in absorption of some of the sound energy. The amount of energy absorbed is dependent on the atmospheric conditions (temperature and humidity) and on the frequency characteristics of the sound. Figure B.1 illustrates the effect of frequency on the absorption of sound under I typical weather conditions of 60, F and 49%relative humidity.

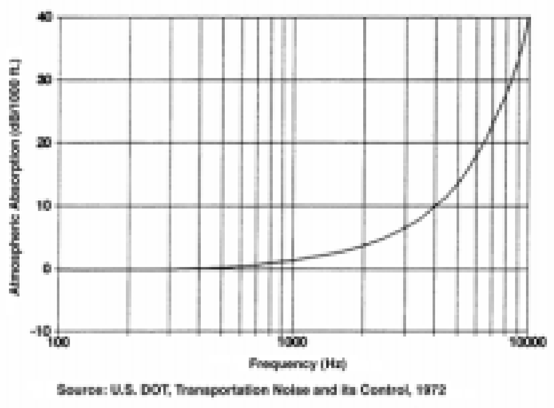


Figure B.1 Typical effect of frequency on atmospheric absorption of sound

As shown in Figure B.1, atmospheric absorption can have a significant influence on the attenuation of sounds with a high frequency. For complex noise signals with a significant high frequency component, such as aircraft noise, atmospheric attenuation can result in significant reduction in sound levels as the distance from the source increases. Figure B.2 illustrates typical noise level variation as a function of distance *with* and *without* atmospheric absorption effects. As shown in Figure B.2, the effect of atmospheric attenuation is significant for high frequency sound (1000 Hz and above) at essentially all distance and becomes significant for mid-frequency sound (around 500 Hz) at large distances.

In addition to molecular absorption, there are a variety of atmospheric phenomena, such as wind and temperature gradients, which affect the propagation of sound through the air. Sound propagating from sources on or near the ground (such as aircraft ground runups and flight at low altitudes) is also influenced by terrain, vegetation, and structures which may either absorb or reflect sound, depending upon their characteristics and location and orientation relative to the source.

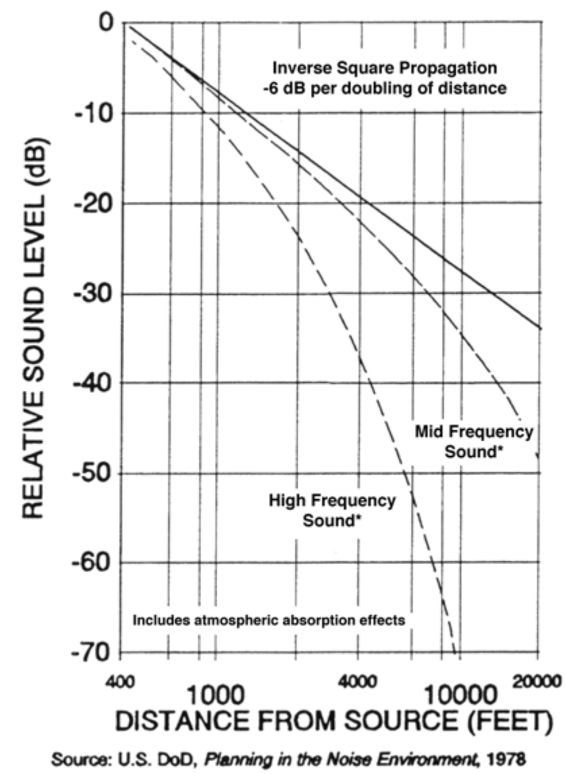


Figure B.2 Typical attenuation of sound with distance from a point source

B. 1.6 Sound Energy Dose Response

Observations that attempt to describe the environmental consequences of discrete events must weigh the characteristics of the individual sound events by the number of those events. These measurements describe an empirical dosage-effect relationship, and are one of the few quantitative tools available for predicting sound-induced annoyance. These metrics are often referred to as dose-response metrics, and will be discussed later in this appendix.

B.2 HUMAN HEARING

B.2.1 How the Human Ear Works

Sound waves entering the ear are enhanced by the resonant characteristics of the auditory canal. Sound waves travel up the ear canal and set up vibrations in the eardrum. Behind the eardrum is a cavity called the middle ear. The middle ear functions as an impedance matcher. It is comprised of three tiny bones that provide frictional resistance, mass, and stiffness, and thus act in opposition to the incoming sound wave and transmit vibrations to the inner ear. More specifically, sound pressure from waves traveling through the air (low impedance) is amplified about 21 times so that it may efficiently travel into the high impedance fluid medium in the inner ear. This is accomplished by the leverage action of the three middle ear bones. The footplate of the stapes, the bone closest to the inner ear, in turn moves in and out of the oval window in the inner ear. The movement of the oval window sets up motion in the fluid that fills the inner ear. The movement of this fluid causes the hairs immersed in the fluid to move. The movement of these hairs stimulates the cells attached to them to send impulses along the fibers of the auditory nerve to the brain. The brain translates these impulses into the sensation of *sound*.

B.2.2 Human Response to Sounds

B.2.2.1 Human Hearing Thresholds

Laboratory experiments have found that the "absolute" threshold of hearing in young adults corresponds to a pressure of about 0.0002 dyne/centimeter^2 (CM^2) or 0.00002 Pascal. This reference level was determined in a quiet noise environment and at the most acute frequency range of human hearing, between 1,000 and 4,000 Hz. The general range of human hearing is usually defined as being between 20 and 20,000 Hz. Frequencies below 20 Hz are called infrasonic, while those above 20,000 Hz are called ultrasonic. Frequencies in the range of 20 to 20,000 Hz are called sonic, and are referred to as the audible frequency area.

B.2.2.2 Loudness

On the decibel scale, an increase in level (SPL) of 3 dB represents a doubling of sound energy. It has been found that a difference in SPL on the order of 10 dB represents a subjective doubling of loudness. Thus, an increase in SPL of 3 dB corresponds to a doubling of sound energy, while an increase in SPL of 10 dB corresponds to a doubling in subjective "loudness" (U.S. DoD 1978). Table B.1 depicts the relative loudness of typical noises encountered in the indoor and outdoor environments.

The loudness of sound (sensation) depends on its intensity, and on the frequency of the sound and the characteristics of the human ear. The intensity of sound is a purely physical property; whereas the loudness depends also upon the characteristics of the receptor ear. In other words, the intensity of a given sound striking the ear of a normal hearing person and of a hard-of-hearing person might be the same, but the perceived loudness would be quite different.

B.2.2.3 Effect of Frequency on Loudness

When human ear response to frequency and intensity is plotted, we find that the response is not linear and that it varies with sensation level. Figure B.3 depicts this response characteristic. The equal loudness levels depicted in the figure were defined as the intensity required to make a given test tone seem equally as loud as the reference tone of 1,000 Hz. The unit of loudness level that is used to plot the data is called the *phon*. Thus, the loudness level in phons of any sound is equal to the intensity level in decibels of a 1,000 Hz tone which is perceived as equal in loudness to the sound under evaluation.

The data in Figure B.3 can be used to illustrate the effects of both frequency and energy level on the sensation of loudness. The effect of frequency on the perceived loudness is most pronounced at frequencies below 1000 Hz and low sound levels. Although 100 Hz and 1000 Hz tones with intensity levels of approximately 37 dB and 0 dB, respectively, are perceived as equally loud (i.e., barely detectable - 0 phons), the 100 Hz tone has 5000 times the sound energy of the 1000 Hz

Table B.1 Sound levels (dB) and relative loudness of typical noise sources in indoor and outdoor environments

dB(A)	Overall level	Community Noise Levels (Outdoor)	Home and Industry Noise Levels (Indoor)	Subjective Loudness (Relative to 70 dB)
120	Uncomfortably loud	Military jet aircraft take-off from aircraft carrier with afterburner at 50 ft . . . . 130 dB	Oxygen torch . . . . 121 dB	32 times as loud
110		Turbo-fan aircraft at takeoff power at 200 ft . . . . 118 dB	Riveting machine . . . . . 110 dB Rock band . . . . 108-114 dB	16 times as loud
100	Very loud	Boeing 707 or DC-8 aircraft at one nautical mile (6080 ft) before landing . . . . 106 dB Jet flyover at 1000 ft . . . . . 103 dB Bell J-2A helicopter at 100 ft . . . . 100 dB		8 times as loud
90		Boeing 737 or DC-9 aircraft at one nautical mile (6080 ft) before landing . . . . 97 dB Power mower . . . . 96 dB Motorcycle at 25 ft . . . . 90 dB	Newspaper press . . . . . . 97 dB	4 times as loud
80		Car wash at 20 ft . . . . 89 dB Propeller plane flyover at 1000 ft . . . . 88 dB Diesel truck 40 mph at 50 ft . 84 dB Diesel train 45 mph at 100 ft 83 dB	Food blender. . . . . 88 dB Milling machine . . . . 85 dB Garbage disposal . . . . . . 80 dB	2 times as loud
70	Moderately loud	High urban ambient sound . . 80 dB Passenger car 65 mph at 25 ft 77 dB Freeway at 50 ft from pavement edge 10 a.m. . . . . 76 dB	Living room music . . . . . 76 dB Radio or TV-audio, vacuum cleaner . . . . 70 dB	70 dB(A)
60		Air conditioning unit at 100 ft . . . . 60 dB	Cash register at 10 ft 65-70 dB Electric typewriter at 10 ft . . . . 64 dB Dishwasher (Rinse) at 10 ft . . . . 60 dB Conversation . . . . 60 dB	1/2 as loud
50	Quiet	Large transformers at 100 ft . 50 dB		1/4 as loud
40		Bird calls . . . . 44 dB Lowest limit of urban ambient sound . . . . 40 dB		
dB Scale Interrupted				
10	Just audible			
0	Threshold of Hearing			

Source: M.C. Branch, et al. 1970. Outdoor Noise and the Metropolitan Environment, Los Angles, California: Department of City Planning, City of Los Angeles.

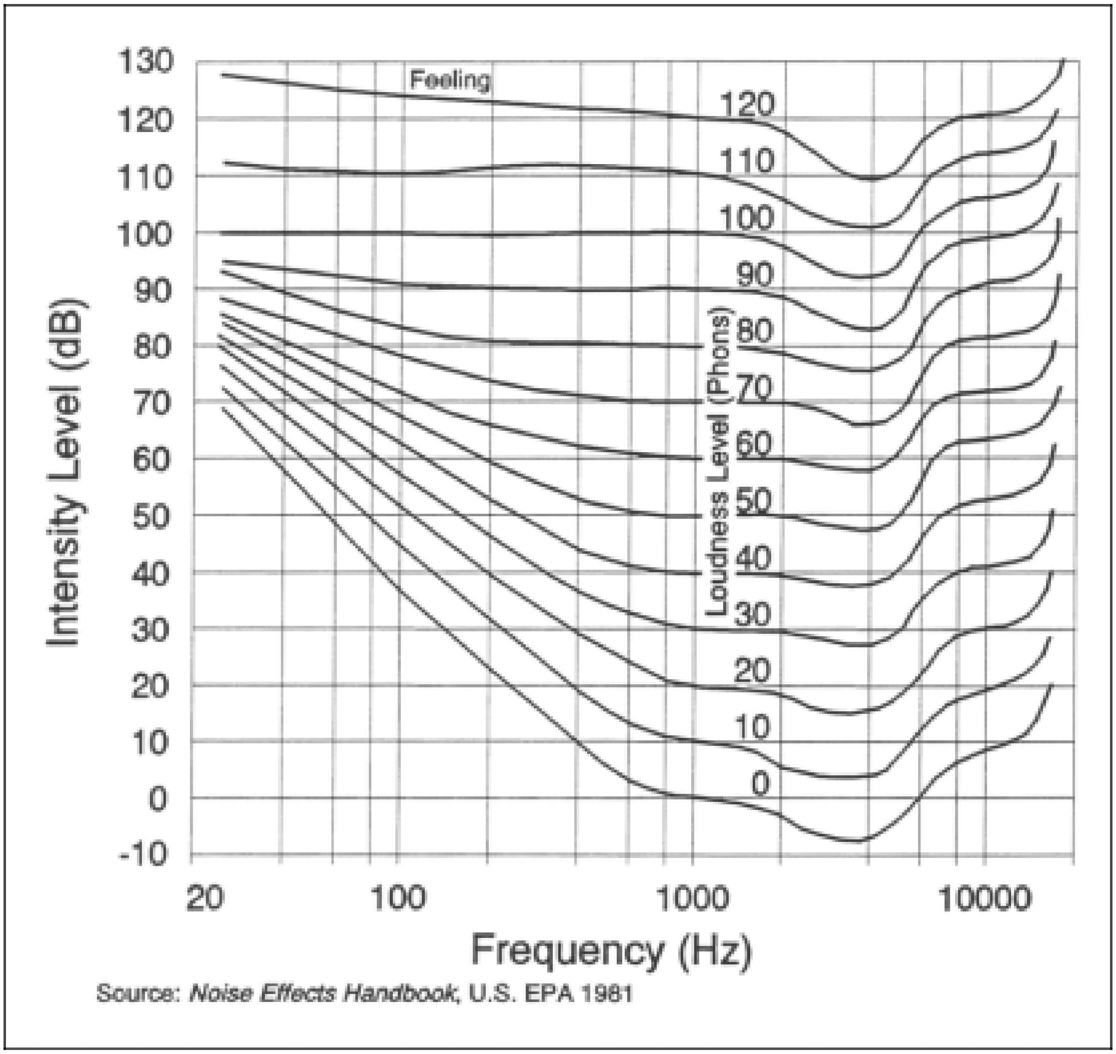


Figure B.3 Equal Loudness Contours

tone. In contrast, 100 Hz and 1000 Hz tones with intensities of 100 dB would sound equally loud - approximately 100 phons. The relationship between frequency, intensity, and loudness is quite complex. However, humans do have a sense of relative loudness, and a fair measure of agreement can be reached on when a sound is one-third as loud as another, one-half as loud, etc.

B.2.2.4 Frequency weighted sound levels

Because the human ear does not respond to sounds of varying frequency and intensity in a linear fashion, various “weighting” factors are applied to noise measurements in an effort to produce results which correspond to human response. These weighting factors are applied to the levels of sound in specific frequency intervals and added or subtracted based on the average human response to sounds in that frequency range; the resultant values are then summed to determine the overall “weighted” level. The most commonly used weighting systems are the “A” and “C” scales.

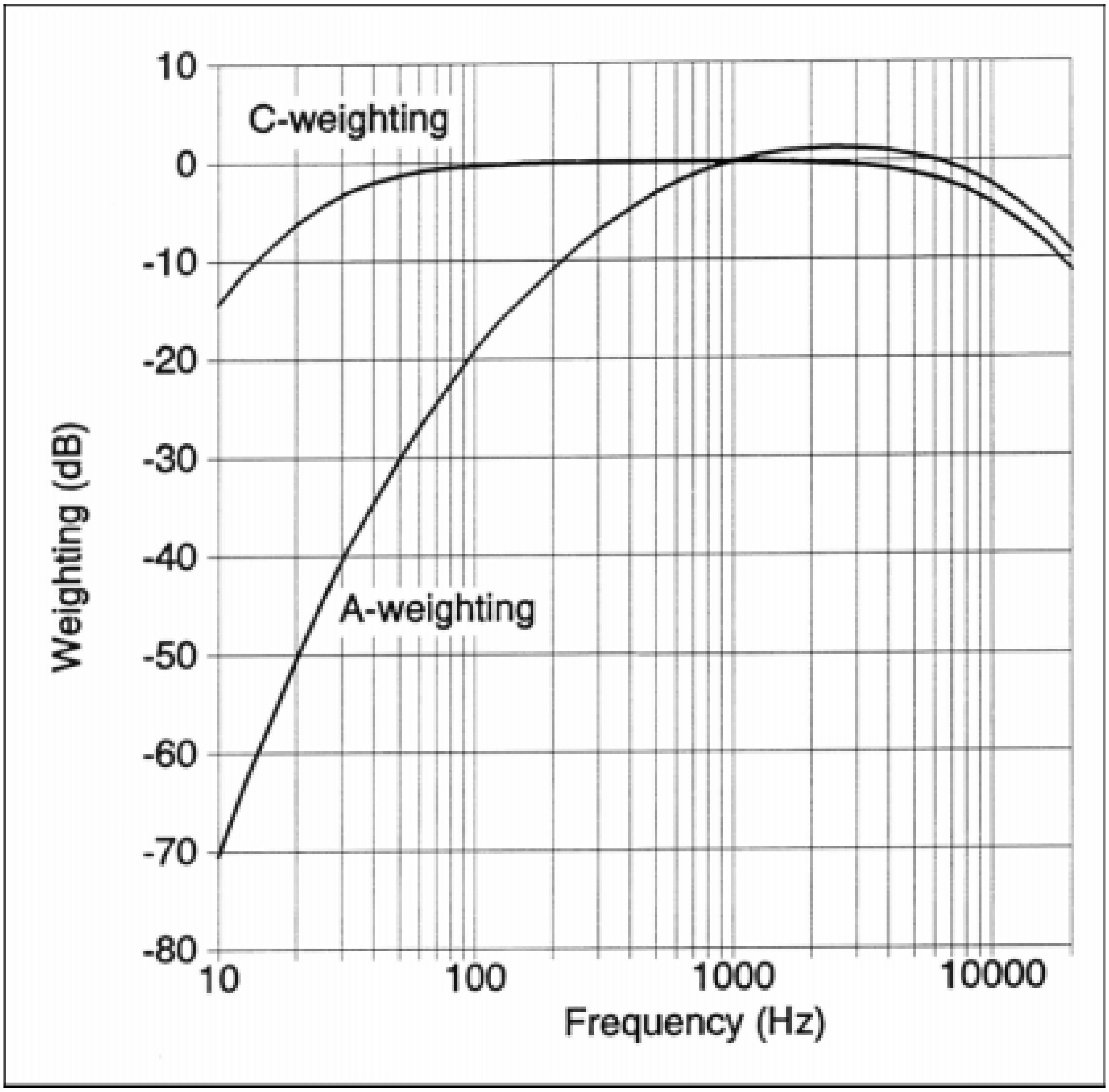


Figure B.4 Frequency Responses for Sound Level Weighting Characteristics

The A-scale de-emphasizes the low- and high-frequency portions of the sound spectrum. This Weighting provides a good approximation of the response of the average human ear and correlates well with the average person's judgement of the relative loudness of a noise event. In contrast, the C-weighting scale gives nearly equal emphasis to sounds of all frequencies and approximates the actual (unweighted) sound level. The C-weighted sound level is used for large amplitude impulse sounds such as sonic booms, explosions, and weapons noise in which the total amount of energy is an important factor. Figure B.4 shows how A-weighting and C-weighting in a sound meter are applied to sounds of various frequencies.

B.3 SOUND METRICS

To assess the impacts of sound on a diverse spectrum of receptors, a variety of metrics may be used. Depending on the specific situation, appropriate metrics may include instantaneous levels, single event, or cumulative metrics. Single event metrics are used to assess the potential impacts of sound on structures and animals, and may be employed for informational purposes in the assessment of some human effects. Cumulative metrics are most useful in characterizing the overall noise environment and are the primary metrics used in development of community (exposed population) dose-response relationships.

B.3.1 Single Event Metrics

Metrics used to characterize a single sound event include the instantaneous sound level as a function of time, the maximum sound level, the equivalent (average) level, and the Sound Exposure Level (SEL), a single number metric which incorporates both level and duration. The relationship between these metrics is illustrated in Figure B.5.

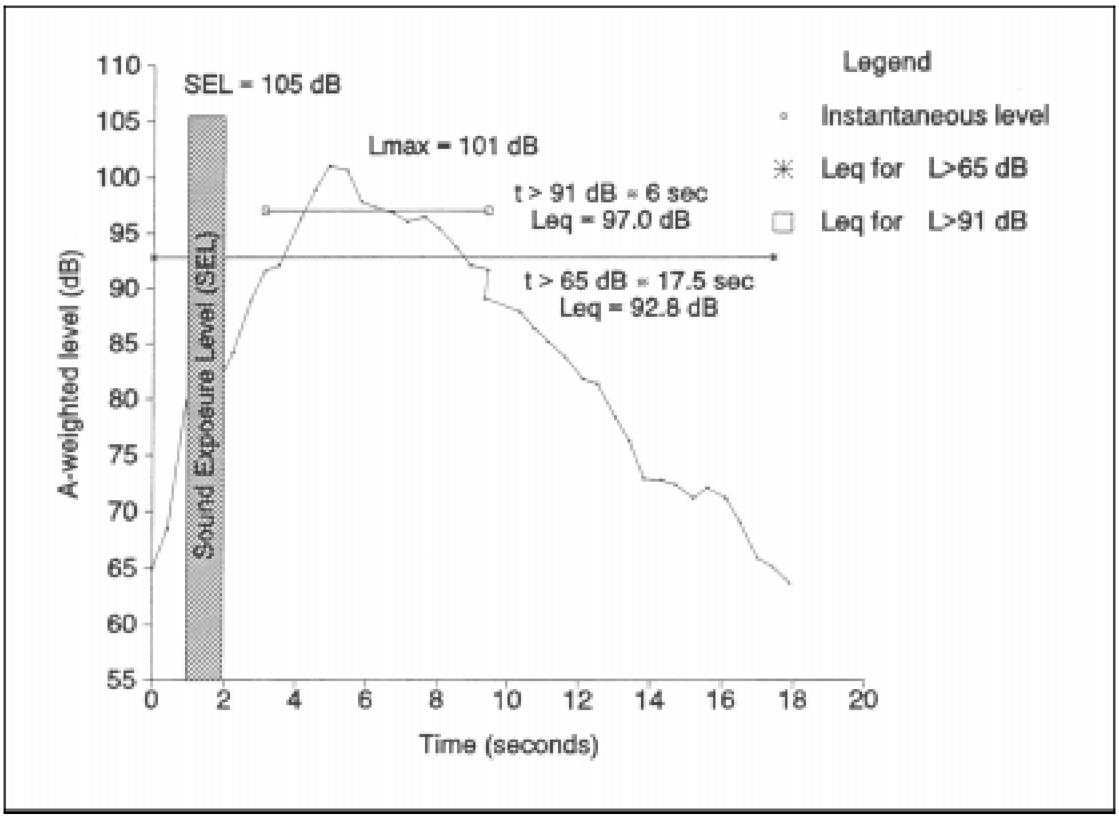


Figure B.5 Relationship between single event sound metrics

B.3.1.1 Single Event Instantaneous Sound Levels

Both the Sound Pressure Level (SPL) and the A-weighted sound level, both expressed in decibels (dB), may be used to characterize single event maximum sound levels for general audible noise. Figure B.5 indicates the variation in the A-weighted sound level (L) for the time during a typical aircraft flyover event when the level exceeds 65 dB. For this event (which is representative of a flyover by a military fighter aircraft at a distance of approximately 1000 feet and a speed of 350 knots), the sound level increases rapidly to a level of approximately 101 dB in approximately 5.5 seconds and then decreases back to less than 65 dB in a period of approximately 12 seconds. By inspection of Figure B.5, the value of two additional metrics, the maximum level and the duration of the event (the time above a specified level), may be determined.

B.3.1.2 Single Event Maximum Sound Level (L_{max})

The single event maximum sound level metric, (L_{max}), is simply the highest A-weighted sound level measured during an event. In the example illustrated in Figure B.5, L_{max} is approximately 101 dB. Although the instantaneous maximum value is the most easily understood descriptor for a noise event, alone it provides relatively little information. Specifically, it provides no information concerning either the duration of the event or the amount of sound energy. This metric is currently used for noise certification of small propeller-driven aircraft and to assess potential effects on animals.

B.3.1.3 Duration

By inspection of the curve in Figure B.5, the "duration" of the event can be determined in terms of the total time in which the level exceeds some specified threshold value. In the example in Figure B.5, the level exceeds 65 dB for approximately 17.5 seconds. Major limitations on the usefulness of this metric is the absence of a standardized threshold value and the inability to quantify the amount of sound energy associated with the event.

B.3.1.4 Equivalent Level (L_{eq})

For any specified period, the equivalent sound level, i.e., the level of a steady tone which provides an equivalent amount of sound energy, may be calculated using the relationship:

$$L_{eq(T)} = 10 \log \left[\frac{1}{T} \int_0^T 10^{\frac{L_A(t)}{10}} dt \right] \qquad \textbf{(Eq. B.5)}$$

Where: $L_{eq(T)}$ is the equivalent sound level for the period T
T is the length of the time interval during which the average is taken, and
$L_A(t)$ is the time varying value of the A-weighted sound level in the interval 0 to T.

Although the equivalent level metric includes all of the sound energy during an event, the absence of a standardized averaging period makes it difficult to compare data for events of different duration. In the example in Figure B.5, the equivalent level for the 17.5 second duration of the event above 65 dB; ($L_{eq(17\text{-}5sec)}$) is approximately 92.8 dB; if the L_{eq} is calculated for the approximately 6 seconds during which the sound level exceeds 90 dB, the result is approximately 97.0 dB.

B.3.1.5 Single Event Energy (Sound Exposure Level)

Subjective tests indicate that human response to noise is a function not only of the maximum level, but also of the duration of the event and its variation with respect to time. Evidence indicates that two noise events with equal sound energy will produce the same response. For example, a noise with a constant level of SPL 85 dB; lasting for 10 seconds would be judged to be equally as annoying as a noise event with an SPL 82 dB; and a duration of 20 seconds. (i.e., onehalf the energy lasting for twice the time period). This is known as the "equal energy principle."

The Sound Exposure Level (SEL) is a measure of the physical energy of the noise event which takes into account both intensity and duration. The SEL is based on the integral of the Aweighted sound level during the period it is above a specified threshold (that is at least 10 dB below the maximum value measured during the noise event) with reference to a standardized duration of 1 second. Thus, the SEL is the level of a constant sound with a duration of 1 second which would provide an amount of sound energy equal to the energy of the event under consideration. It may be calculated using the equation for the equivalent level (Eq. B.5) with the duration (T) replaced by the referenced time (T_{ref}) of 1 second.

$$SEL = 10 \log \left[\frac{1}{T_{Ref}} \int_{t_1}^{t_2} 10^{\frac{L_A(t)}{10}} dt \right] = 10 \log \left[\int_{t_1}^{t_2} 10^{\frac{L_A(t)}{10}} dt \right] \qquad \textbf{(Eq. B-6)}$$

Where: T_{Ref} is equal to 1 second
t_1 is the time at which the level exceeds 10 dB below the maximum value; and
t_2 is the time at which the level drops below 10 dB below the maximum value.

For the example illustrated in Figure B.5, the SEL is approximately 105 dB. The value of the SEL in providing consideration of both total energy and duration is illustrated by comparison of the calculated SEL values based on the time above 65 dB and the time above 91 dB (10 d13 less than the maximum recorded value of 101 dB). The SEL calculated on the basis of the levels during the approximately 17.5 seconds when the sound level is above 65 dB is 105.3 dB; based on the approximately 6 seconds when the level exceeds 91 dB, the calculated SEL is 105.0 dB, a difference of only 0.3 dB. By comparison, the L_{eq} values for the same periods were 92.8 and 97.0 dB, respectively, a difference of 4.2 dB. This comparison illustrates the value of SEL as a single number metric which considers both total energy and duration.

Table B.2 and Table B.3 provide SEL and L_{max} values for military and commercial aircraft, respectively, while operating at takeoff thrust and airspeed, and measured at a slant distance of 1000 ft. By definition, SEL values are referenced to a duration of 1 second and should not be confused with either the average or maximum noise levels associated with a specific event. As noted in the example, the SEL value for the flyover event was approximately 105 dB while the equivalent level based on a duration of approximately 17 seconds was 92.8, a difference of 12.2 dB. By definition, noise levels that exceed the SEL value must have durations of less than one second. For aircraft overflights, maximum noise levels would typically be 5 to 10 dB below the SEL value.

Table B.2 Sound Exposure Level (SEL) and Maximum A-Weighted Level (L_{max}) Data for Military Aircraft

Aircraft Type	Sound Exposure Level (SEL)*	Maximum Sound Level (Lmax)
Jet Bomber/Tanker/Transport		
B1B	123.5	118.3
B52G	121.5	113.9
B52H	112.2	105.2
C17	100.0	94.5
C5	113.5	106.3
C135B	106.6	101.9
C141	105.8	99.7
KC135A	117.8	109.1
KC135R	92.2	87.1
Other Jet Aircraft with Afterburners		
F4	115.7	109.7
F14	109.7	106.4
F15	112.0	104.3
F16	106.7	101.0
F18	116.9	108.0
FB111	108.1	102.3
T38	105.5	98.3
Other Jet Aircraft without Afterburners		
A6	112.3	108.3
A7	111.3	107.7
A10	96.9	93.2
C21	91.1	84.6
T1A	99.4	90.3
T37	97.7	91.0
T39	103.3	96.8
T43	100.8	94.1
Propeller Aircraft		
C12	79.3	73.2
C130	90.5	83.7
P3	96.8	91.0

* At nominal takeoff thrust and airspeed and at a slant distance of 1,000 ft from the aircraft.
Source: U.S. Air Force, AL/OEBN 1992.

Table B.3 Sound Exposure Level (SEL) and Maximum A-Weighted Level (L_{max}) Data for Civilian Aircraft

Aircraft Type	Sound Exposure Level (SEL)*	Maximum Sound Level (Lmax)
Civil jet Aircraft		
707, DC-8	113.5	104.4
727	112.5	106.5
737, DC-9	110.0	104.0
747	102.5	96.3
757	97.0	31.5
767	96.7	91.2
DC-10, L-1011	100.0	92.3
Learjet	97.1	89.4

* At nominal takeoff thrust and airspeed and at a slant distance of 1,000 ft from the aircraft.
Source: U.S. Air Force, AL/OEBN 1992.

The SEL is a measure of the total energy associated with a single noise event, and is useful for making calculations involving aircraft flyovers. The frequency characteristics, sound level, and duration of aircraft flyover noise events vary according to aircraft type and model (engine type), aircraft configuration (i.e., flaps, landing gear, etc.), engine power setting, aircraft speed, and the distance between the observer and the aircraft flight track. Therefore, extensive noise data are collected for various types of aircraft/engines at different power settings and phases of flight. SEL versus slant range values are derived from noise measurements made according to a source noise data acquisition plan developed by Bolt, Beranek, and Newman, Inc., in conjunction with the U.S. Air Force's Armstrong Laboratory[6] (AL) and carried out by AL. This extensive database of aircraft noise data which is adjusted to standard-day, sea-level values provides the basis for calculation of average individual-event sound descriptors for a specific aircraft operations at any location under varying meteorological conditions. These reference values are adjusted to a location by applying appropriate corrections for temperature, humidity, altitude, and variations from standard aircraft operating conditions (power settings and speed).

B.3.2 Application of Single Event Metrics

Single event analysis is sometimes conducted to evaluate sleep disturbances at nighttime and less frequently, some speech interference issues, primarily at locations where the cumulative, A-weighted sound is below DNL 65 dB. However, there is no accepted methodology for

[6] The U.S. Air Force Armstrong Laboratory was formerly known as the Armstrong Aerospace Medical Research Laboratory (AAMRL) and the majority of the work discussed in this section was conducted under that designation.

aggregating effects into some form of cumulative impact metric; and single event metrics do not describe the overall noise environment. As described below, the day-night cumulative methodology includes a 10 dB nighttime penalty that reflects the potential for added annoyance due to sleep disturbance, speech interference, and other effects (Department of Defense, Air Force, AAMRL 1991).

Single event prediction methods have limited application to land use planning. One should not infer that an area is simultaneously exposed to a given noise level, since sound decays with increasing distance from the flight track. The databases used in noise models are based on the average of numerous SEL values collected under carefully controlled conditions and normalized to standard acoustic conditions and aircraft operating parameters. Although these values may be adjusted to reflect specific meteorological conditions (temperature and humidity) and aircraft operating parameters (power setting and speed), they represent average values for that type of aircraft operating under the specified conditions. However, for a variety of reasons including daily/seasonal weather changes, wind speed and direction, variations in aircraft power settings and speed due to weight or weather conditions, etc., SEL values measured for specific events under field conditions may vary significantly from the average values predicted on the basis of the standardized values. Consequently, the single event metric has limited use in evaluating sound impacts. When SEL is used to supplement cumulative metrics, it serves only to provide additional information. SEL has been used to evaluate sleep interference, but does not predict long-term human health effects. Sleep interference evaluation using SEL does not presently account for habituation.

B.3.3 Cumulative energy average metrics

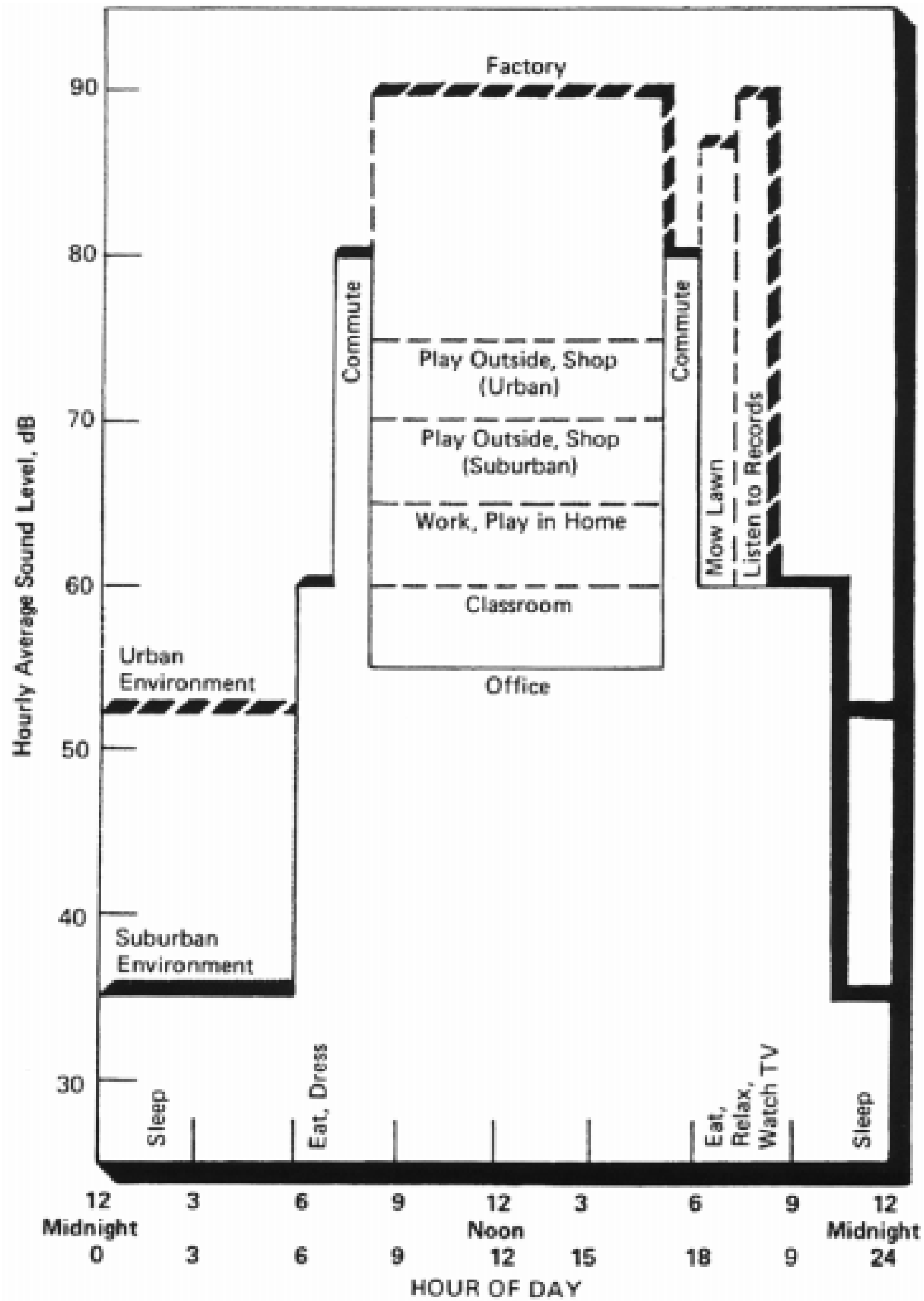
Urban traffic is by far the most pervasive outdoor residential sound source, although aircraft sound is a significant source as well. Over 96 million persons are estimated to be exposed, in and around their homes, to high traffic noise levels. Figure B.6 depicts the typical daily sound exposure of a homemaker, student, and various workers.

Cumulative energy average metrics correlate well with aggregate community response to the sound environment. They may be derived from single event sound levels or computed from measured data. Although they were not designed as single event measures, they use single event data averaged over a specified time period. Thus cumulative measures, like single event measures, can relate to speech and sleep disturbance, although the relationship between cumulative measures and sleep disturbance is not clearly established (Dean 1992; Newman and Beattie 1985).

B.3.3.1 Equivalent Sound Level

The Equivalent Sound Level (L_{eq}) is the Energy-Averaged Sound Level (usually A-weighted) integrated over a specified time period. The term "equivalent" indicates that the total acoustical energy associated with a varying sound (measured during the specified period) is equal to the acoustical energy of a steady state level of L_{eq} for the same period of time. The purpose of the L_{eq} is to provide a single number measure of sound averaged over a specified time period (Newman and Beattie 1985).

Figure B.6 Hypothesized life style sound exposure patters



Source: *Noise Effects Handbook*, U.S. EPA 1981

B.3.3.2 Day-Night Average Sound Level

The Day-Night Average Sound Level (DNIL) is the Energy-Averaged Sound Level (L_{eq}) measured over a period of 24 hours, with a 10 dB penalty applied to nighttime (10 p.m. to 7 a.m.) sound levels to account for increased annoyance by sound during the night hours. The annual average DNL (DNL y-avg.) is the value specified in the FAA Federal Aviation Regulation (FAR) Part 150 noise compatibility planning process, and provides the basis for the land use compatibility planning guidelines in the Air Force Air Installation Compatible Use Zone (AICUZ) program (Newman and Beattie 1985; U.S. DoD 1984). The typical range of outdoor DNL levels is illustrated in Figure B.7.

B.3.4 Basis for use of DNL as the single environmental descriptor

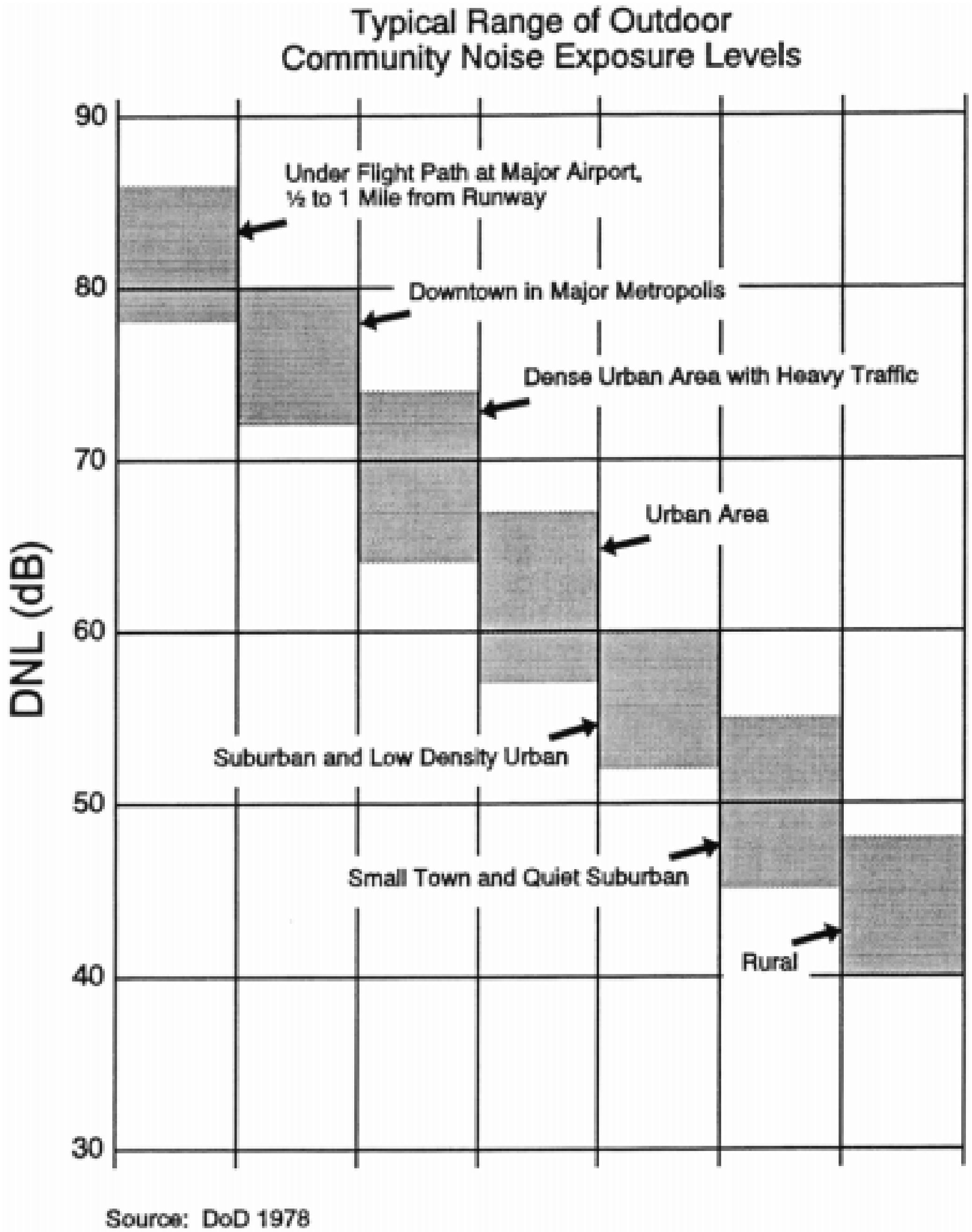
The DNL (L_{eq} with a 10 dB; penalty for nighttime exposure) was selected by EPA as the uniform descriptor of cumulative sound exposure to correlate with health and welfare effects (EPA 1974, 1982). Subsequently, all Federal agencies adopted yearly average DNL (YDNL or L_{dny}) as the basis for describing community noise exposure. DNL methodology has given consistent results in the national and international literature under a wide range of noise conditions (including loud and soft noise levels, and frequent and infrequent numbers of discrete aircraft events). Although seasonal corrections are not included in the definition of the DNL metric, the methodology does not preclude its use in any analysis of a special, well-defined noise exposure scenario.

Sound predictions are less reliable at lower levels (as low as 2 events per day) and at increasing distances from the airport, where the ability to determine the contribution of different sound sources is diminished. Since public health and welfare effects have not been established at these lower levels, there are problems in interpreting predictions below DNIL 60 dB (DNL 55 dB plus a 5 dB margin of safety). Much of the criticism of the use of YDNL for community annoyance and land use compatibility around airports may stem from a failure to understand the metric. Another factor may be that some persons exposed to aircraft noise do not accept DNL 65 dB as the appropriate lower limit of noise exposure in considering noise impact. An average sound metric such as DNL takes into account the sound levels of all individual events that occur during a 24 hour period, and the number of times those events occur. The averaging of sound over a 24 hour period does not ignore the louder single events, and it actually tends to emphasize both the sound level and number of those events. This is the basic concept of a time- averaged sound metric, and specifically DNL. The logarithmic nature of the dB unit causes sound levels of the loudest events to control the 24 hour average.

B.3.5 Supplemental Sound Metrics

DNL is sometimes supplemented by other metrics to characterize specific effects. These analyses are accomplished on a case-by-case basis, as required, and include L_{eq} (Equivalent Sound Level), composite one-third octave band SPL (Sound Pressure Level), SEL (Sound Exposure Level), and L_{max} (Maximum Sound Level). Sound pressure levels are the starting points for all other metrics. Composite one-third octave band SPL is used to analyze sound impacts on structures; L_{max} is used to assess impacts on animals. SPL and L_{max} are expressed in units of decibels (dB).

Figure B.7 Typical Range of Outdoor Community Day0Night Average Noise Levels (DNL)



B.4 SOUND ANALYSIS METHODOLOGY

B.4.1 NOISEMAP Computer Program

The NOISEMAP program is actually a group of computer programs developed by the U.S. Air Force to predict noise exposures in the vicinity of an air base due to aircraft flight, maintenance, and ground run-up operations. These programs can also be used for noise exposure prediction at civilian or joint-use (military-civilian) airfields if appropriate noise reference files are available. The NOISEMAP programs utilize a database of aircraft noise emission characteristics (NOISEFILE) that is accessed by the OMEGA10 and OMEGA11 subprograms to produce SEL versus slant range values specific to the aircraft operating parameters and meteorological conditions.

Data describing flight tracks, flight profiles, power settings, flight paths and profile utilization, and ground run-up information by type of aircraft/engine are assembled and processed for input into a central computer. The NOISEMAP program uses this information to calculate DNL values at points on a regularly spaced 100x100 grid surrounding the airfield. This information is then input to another subprogram that generates contour lines connecting points of equal DNL values in a manner similar to elevation contours shown on topographic maps. Contours are normally generated at 5 dB intervals beginning at a lower limit of DNL 65 dB, the maximum level considered acceptable for unrestricted residential use. The model generates a wide variety of reports which the analyst may use in their analysis.

B.4.2 Integrated Noise Model (INM) Computer Program

The INM program was initially released in January 1978 by the FAA. The model has been substantially updated since that time, and is the recommended tool for site analysis for Airport Noise Control and Land Use Compatibility Planning (ANCLUC) studies. The INM contains computer models for determining the impact of aircraft noise in and around airports. This noise impact can be given in terms of contours of equal noise exposure for Noise Exposure Forecast (NEF), Equivalent Sound Level (L_{eq}), Day-Night Average Sound Level (DNL), and Time Above a specified threshold of A-weighted sound (TA).

The contours are presented in the form of a printout of the contour coordinates and area impacted, and as a plot of the contours. In addition, a printout report of populations within the contour areas may be produced. The model also allows for the calculation of several noise measures at specific points (grid) in the airport vicinity. The output from this type of calculation is a printout report. The model also produces a number of supporting reports.

APPENDIX C PARTICIPANTS TECHNICAL SUBGROUP

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