Appendix A

THE AICUZ CONCEPT, PROGRAM, METHODOLOGY, AND POLICIES

THIS PAGE INTENTIONALLY LEFT BLANK

THE AICUZ CONCEPT, PROGRAM, METHODOLOGY, AND POLICIES

A.1 Concept

Federal legislation, national sentiment, and other external forces, which directly affect the Air Force mission, serve greatly to increase the role of the Air Force in environmental and planning issues. Problems of airfield encroachment from incompatible land uses surrounding installations, as well as air and water pollution and socioeconomic impact, require continued and intensified Air Force involvement. The nature of these problems dictates direct Air Force participation in comprehensive community and land use planning. Effective, coordinated planning that bridges the gap between the federal government and the community requires establishment of good working relationships with local citizens, local planning officials, and state and federal officials. This depends on creating an atmosphere of mutual trust and helpfulness. The AICUZ concept has been developed in an effort to:

- protect local citizens from noise exposure and accident potential associated with flying activities; and
- prevent degradation of the capability of the Air Force to achieve its mission by promoting compatible land use planning.

The land use guidelines developed herein are a composite of a number of other land use compatibility studies that have been refined to fit the Tinker AFB aviation environment.

A.2 Program

Installation commanders establish and maintain active programs to promote the maximum feasible land use compatibility between air installations and neighboring communities. The program requires that all appropriate government bodies and citizens be fully informed whenever AICUZ or other planning matters affecting the installation are under consideration. This includes positive and continuous programs designed to:

- provide information, criteria, and guidelines to federal, state, regional, and local planning bodies, civic associations, and similar groups;
- inform such groups of the requirements of the flying activity, noise exposure, aircraft accident potential, and AICUZ plans;
- describe the noise reduction measures that are being used; and
- ensure that all reasonable, economical, and practical measures are taken to reduce or control the impact of noise-producing activities. These measures include such considerations as proper location of engine test facilities, provision of sound suppressors where necessary, and adjustment of flight patterns and/or techniques to minimize the noise impact on populated areas. This must be done without jeopardizing safety or operational effectiveness.

A.3 Methodology

The AICUZ consists of land areas upon which certain land uses may obstruct the airspace or otherwise be hazardous to aircraft operations, and land areas that are exposed to the health, safety, or welfare hazards of aircraft operations. The AICUZ includes:

- Accident Potential Zones (APZ) and Clear Zones (CZ) based on past Air Force aircraft accidents and installation operational data (see Appendix B);
- Noise zones (NZ) produced by the computerized DNL modeling of the noise created by aircraft flight and maintenance operations (see Section 3 of the Study); and
- The area designated by the FAA and the Air Force for purposes of height limitations in the approach and departure zones of the base (see Section 4 of the Study).

The APZ, CZ, and NZ are the basic building blocks for land use planning with AICUZ data. Compatible land uses are specified for these zones, and recommendations on building materials and standards to reduce interior noise levels inside structures are provided in Section 7.

As part of the AICUZ Program, the only real property acquisition for which the Air Force has requested and received Congressional authorization, and for which the installation and major commands request appropriation, are the areas designated as the CZ. Tinker AFB does not own all property in the CZs. Compatible land use controls for the remaining airfield area of influence should be accomplished through the community land use planning processes.

A.4 AICUZ Land Use Development Policies

The basis for any effective land use control system is the development of, and subsequent adherence to, policies which serve as the standard by which all land use planning and control actions are evaluated. Tinker AFB recommends the following policies be considered for incorporation into the comprehensive plans of agencies in the vicinity of the Base's area of influence:

A.4.1 Policy 1

To promote the public health, safety, peace, comfort, convenience, and general welfare of the inhabitants in the airfield area of influence, it is necessary to:

- guide, control, and regulate future growth and development;
- promote orderly and appropriate use of land;
- protect the character and stability of existing land uses;
- prevent destruction or impairment of the airfield and the public investment therein;
- enhance the quality of living in the areas affected; and
- protect the general economic welfare by restricting incompatible land use.

A.4.2 Policy 2

In furtherance of Policy 1, it is appropriate to:

- establish guidelines of land use compatibility;
- restrict or prohibit incompatible land use;
- prevent establishment of any land use which would unreasonably endanger aircraft operations and the continued use of the airfield;
- incorporate the AICUZ concept into community land use plans, modifying them when necessary; and
- adopt appropriate ordinances to implement airfield area of influence land use plans.

A.4.3 Policy 3

Within the boundaries of the CZ, certain land uses are inherently incompatible. The following land uses are not in the public interest and must be restricted or prohibited:

- uses that release into the air any substance, such as steam, dust, or smoke which would impair visibility or otherwise interfere with the operation of aircraft;
- uses that produce light emissions, either direct or indirect (reflective), which would interfere with pilot vision;
- uses that produce electrical emissions which would interfere with aircraft communication systems or navigation equipment;
- uses that attract birds or waterfowl, such as operation of sanitary landfills, maintenance or feeding stations, or growth of certain vegetation; and
- uses that provide for structures within 10 feet of aircraft approach-departure and/or transitional surfaces.

A.4.4 Policy 4

Certain noise levels of varying duration and frequency create hazards to both physical and mental health. A limited, though definite, danger to life exists in certain areas adjacent to airfields. Where these conditions are sufficiently severe, it is not consistent with public health, safety, and welfare to allow the following land uses:

- residential;
- retail business;
- office buildings;
- public buildings (schools, churches, etc.); and
- recreation buildings and structures.

A.4.5 Policy 5

Land areas below takeoff and final approach flight paths are exposed to significant danger of aircraft accidents. The density of development and intensity of use must be limited in such areas.

A.4.6 Policy 6

Different land uses have different sensitivities to noise. Standards of land use acceptability should be adopted, based on these noise sensitivities. In addition, a system of Noise Level Reduction guidelines (Appendix C) for new construction should be implemented to permit certain uses where they would otherwise be prohibited.

A.4.7 Policy 7

Land use planning and zoning in the airfield area of influence cannot be based solely on aircraft-generated effects. Allocation of land used within the AICUZ should be further refined by consideration of:

- physiographic factors;
- climate and hydrology;
- vegetation;
- surface geology;
- soil characteristics;
- intrinsic land use capabilities and constraints;
- existing land use;
- land ownership patterns and values;
- economic and social demands;
- cost and availability of public utilities, transportation, and community facilities; and
- other noise sources.

A.5 Basic Land Use Compatibility

Research on aircraft accident potential, noise, and land use compatibility is ongoing at a number of federal and other agencies. These and all other compatibility guidelines must not be considered inflexible standards. They are the framework within which land use compatibility questions can be addressed and resolved. In each case, full consideration must be given to local conditions such as:

- previous community experience with aircraft accidents and noise;
- local building construction and development practices;

- existing noise environment due to other urban or transportation noise sources;
- time periods of aircraft operations and land use activities;
- specific site analysis; and
- noise buffers, including topography.

These basic guidelines cannot resolve all land use compatibility questions, but they do offer a reasonable framework within which to work.

A.6 Accident Potential

Each end of Runways 17/35 and 12/30 at Tinker AFB has a 3,000 foot by 3,000 foot CZ and two APZs (see Section 5). Accident potential on or adjacent to the runway or within a CZ is so high that the necessary land use restrictions would prohibit reasonable economic use of land. As stated previously, it is Air Force policy to request Congress to authorize and appropriate funds for the necessary real property interests in this area to prevent incompatible land uses.

Accident Potential Zone I is less critical than the CZ, but still possesses a significant risk factor. This 3,000 foot by 5,000 foot area has land use compatibility guidelines which are sufficiently flexible to allow reasonable economic use of the land, such as industrial/manufacturing, transportation, communication/utilities, wholesale trade, open space, recreation, and agriculture. However, uses that concentrate people are not acceptable.

Accident Potential Zone II is less critical than APZ I, but still possesses potential for accidents. Accident potential zone II, also 3,000 feet wide, is 7,000 feet long extending to 15,000 feet from the runway threshold. Acceptable uses include those of APZ I, as well as low density single family residential and those personal and business services and commercial/retail trade uses of low intensity or scale of operation. High density functions such as multistory buildings, places of assembly (theaters, churches, schools, restaurants, *etc*.), and high density office uses are not considered appropriate.

High density populations should be limited to the maximum extent possible. The optimum density recommended for residential usage (where it does not conflict with noise criteria) in APZ II is one dwelling per acre. For most nonresidential usage, buildings should be limited to one story, and the lot coverage should not exceed 20 percent.

Land use guidelines for the two APZs are based on a hazard index system that compares the relationship of accident occurrence for five areas:

- on or adjacent to the runway;
- within the CZ;
- in APZ I;
- in APZ II; and

- in all other areas within a 10 nautical mile radius of the runway.

Accident potential on or adjacent to the runway or within the CZ is so high that few uses are acceptable. The risk outside APZ I and APZ II, but within the 10 nautical mile radius area, is significant, but is acceptable if sound engineering and planning practices are followed.

Land use guidelines for APZs I and II have been developed. The main objective has been to restrict all people-intensive uses because there is greater risk in these areas. The basic guidelines aim at prevention of uses that:

- have high residential density characteristics;
- have high labor intensity;
- involve above-ground explosives, fire, toxic, corrosive, or other hazardous characteristics;
- promote population concentrations;
- involve utilities and services required for area-wide population, where disruption would have an adverse impact (telephone, gas, etc.);
- concentrate people who are unable to respond to emergency situations, such as children, elderly, handicapped, etc.; and
- pose hazards to aircraft operations.

There is no question that these guidelines are relative. Ideally, there should be no people-intensive uses in either of these APZs. The free market and private property systems prevent this where there is a demand for land development. To go beyond these guidelines, however, substantially increases risk by placing more people in areas where there may ultimately be an aircraft accident.

A.7 Noise

Nearly all studies analyzing aircraft noise and residential compatibility recommend no residential uses in noise zones above DNL 75 dB. Usually, no restrictions are recommended below noise zone DNL 65 dB. There is currently no consensus between DNL 65-74 dB. These areas may not qualify for federal mortgage insurance in residential categories according to United States Department of Housing and Urban Development (HUD) Regulation 24 CFR 51B. In many cases, HUD approval requires noise attenuation measures, the Regional Administrator's concurrence, and an Environmental Impact Statement. The United States Department of Veterans Affairs also has airfield noise and accident restrictions which apply to its home loan guarantee program. Whenever possible, residential land use should be located below DNL 65 dB according to Air Force land use recommendations. Residential buildings within the DNL 65-75 dB noise contours should contain noise level reduction in accordance with the Air Force land use compatibility guidelines in the AICUZ Study, Table 4.3.

Most industrial/manufacturing uses are compatible in the airfield area of influence. Exceptions are uses such as research or scientific activities that require lower noise levels.

Noise attenuation measures are recommended for portions of buildings devoted to office use, receiving the public, or where the normal background noise level is low.

The transportation, communications, and utilities categories have a high noise level compatibility because they generally are not people-intensive. When people use land for these purposes, the use is generally very short in duration. Where buildings are required for these uses, additional evaluation is warranted.

The commercial/retail trade and personal and business services categories are compatible without restriction up to DNL 70 dB; however, they are generally incompatible above DNL 80 dB. Between DNLs 70-79 dB, noise level reduction measures should be included in the design and construction of buildings.

The nature of most uses in the public and quasi-public services category requires a quieter environment, and attempts should be made to locate these uses below DNL 65 dB (an Air Force land use recommendation), or else provide adequate noise level reduction.

Although recreational use has often been recommended as compatible with high noise levels, recent research has resulted in a more conservative view. Above DNL 75 dB, noise becomes a factor that limits the ability to enjoy such uses. Where the requirement to hear is a function of the use (*e.g.*, music shell, *etc.*), compatibility is limited. Buildings associated with golf courses and similar uses should be noise attenuated.

With the exception of forestry activities and livestock farming, uses in the resources production, extraction, and open space category are compatible almost without restrictions.

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix B

CLEAR ZONES AND ACCIDENT POTENTIAL ZONES

THIS PAGE INTENTIONALLY LEFT BLANK

CLEAR ZONES AND ACCIDENT POTENTIAL ZONES

B.1 Guidelines For Accident Potential

Areas around airports are exposed to the possibility of aircraft accidents even with well-maintained aircraft and highly trained aircrews. Despite stringent maintenance requirements and countless hours of training, history makes it clear that accidents do happen.

When the AICUZ Program began, there were no current comprehensive studies on accident potential. To support the program, the Air Force completed a study of Air Force aircraft accidents that occurred between 1968 and 1972 within 10 nautical miles of airfields. The study of 369 accidents revealed that 75 percent of aircraft accidents occurred on or adjacent to the runway (1,000 feet to each side of the runway centerline) and in a corridor 3,000 feet (1,500 feet either side of the runway centerline) wide, extending from the runway threshold along the extended runway centerline for a distance of 15,000 feet. The Air Force updated these studies and this information is presented later in this section.

The CZ, APZ I, and APZ II were established based on crash patterns. The CZ starts at the end of the runway and extends outward 3,000 feet. It has the highest accident potential of the three zones. The Air Force adopted a policy of acquiring property rights to areas designated as CZs because of the high accident potential. APZ I extends from the CZ an additional 5,000 feet. It includes an area of reduced accident potential. APZ II extends from APZ I an additional 7,000 feet in an area of further reduced accident potential.

Research in accident potential conducted by the Air Force was the first significant effort in this subject area since 1952 when the President's Airport Commission published "The Airport and Its Neighbors," better known as the "Doolittle Report." The recommendations of this earlier report were influential in the formulation of the APZ concept.

The risk to people on the ground being killed or injured by aircraft accidents is small. However, an aircraft accident is a high consequence event, and when a crash does occur, the result is often catastrophic. Because of this, the Air Force does not attempt to base its safety standards on accident probabilities. Instead, the Air Force approaches this safety issue from a land use planning perspective.

B.2 Guidelines For Accident Potential

Military aircraft accidents differ from commercial air carrier and general aviation accidents because of the variety of aircraft used, the type of missions, and the number of training flights. In 1973, the Air Force performed a service-wide aircraft accident hazard study to identify land near airfields with significant accident potential. Accidents studied occurred within 10 nautical miles of airfields.

The study reviewed 369 major Air Force accidents during 1968-1972, and found that 61 percent of those accidents were related to landing operations, and 39 percent were takeoff related. It also found that 70 percent occurred in daylight, and that fighter and training aircraft accounted for 80 percent of the accidents.

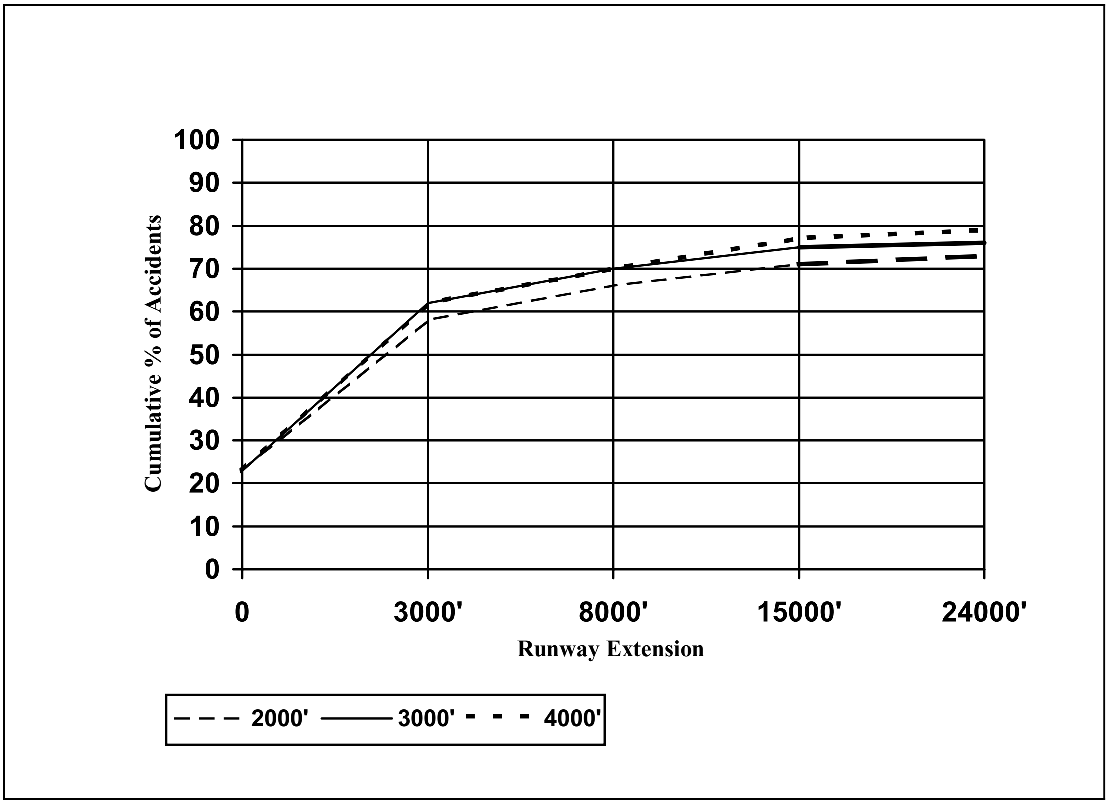
Because the purpose of the study was to identify accident hazards, the study plotted each of the 369 accidents in relation to the airfield. This plotting found that the accidents clustered along the runway and its extended centerline. To further refine this clustering, a tabulation was prepared that described the cumulative frequency of accidents as a function of distance from the runway centerline along the extended centerline. This analysis was done for widths of 2,000, 3,000, and 4,000 total feet. Table B.1 reflects the location analysis.

Table B.1 Location Analysis

	Width of Runway Extension (feet)		
Length From Both Ends of Runway (feet)	**2000**	**3000**	**4000**
Percent of Accidents			
On or Adjacent to Runway (1,000 feet to each side of runway centerline)	23	23	23
0 to 3,000	35	39	39
3,000 to 8,000	8	8	8
8,000 to 15,000	5	5	7
Cumulative Percent of Accidents			
On or Adjacent to Runway (1,000 feet to each side of runway centerline)	23	23	23
0 to 3,000	58	62	62
3,000 to 8,000	66	70	70
8,000 to 15,000	71	75	77

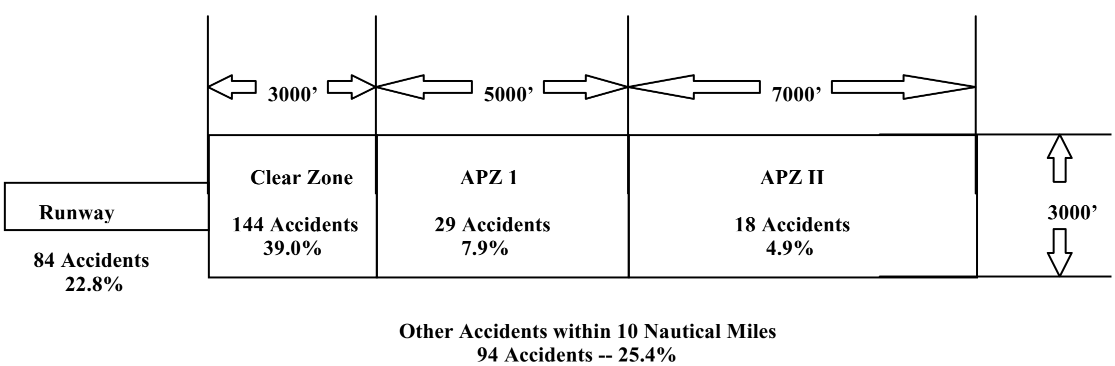
Figure B.1 indicates that the cumulative number of accidents rises rapidly from the end of the runway to 3,000 feet, rises more gradually to 8,000 feet, then continues at about the same rate of increase to 15,000 feet, where it levels off rapidly. The location analysis also indicates 3,000 feet as the optimum runway extension width and the width which includes the maximum percentage of accidents in the smallest area.

Figure B.1 Distribution of Air Force Aircraft Accidents (369 Accidents - 1968 - 1972)



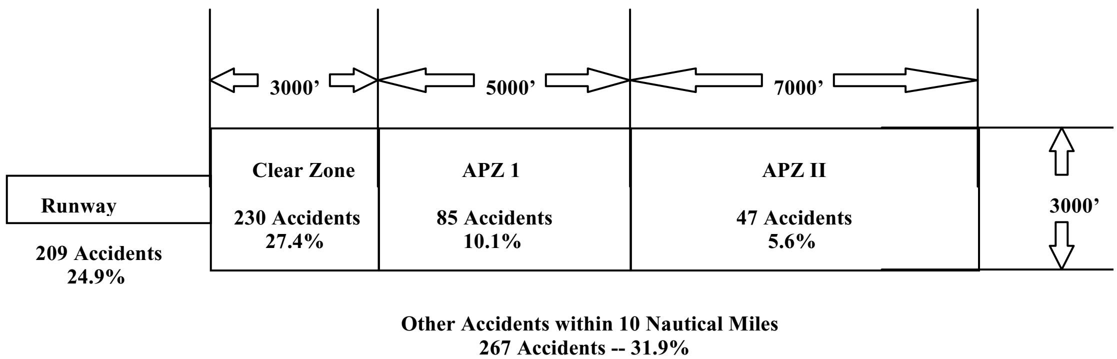
Using the optimum runway extension width, 3,000 feet, and the cumulative distribution of accidents from the end of the runway, zones were established that minimized the land area included and maximized the percentage of accidents included. The zone dimensions and accident statistics for the 1968-1972 study are shown in Figure B.2.

Figure B.2 Air Force Aircraft Accident Data (369 Accidents - 1968 - 1972)



The original study was updated to include accidents through September 1995. This updated study includes 838 accidents during the 1968-1995 period. Using the optimum runway extension width of 3,000 feet, the accident statistics of the updated study are shown in Figure B.3.

Figure B.3 Air Force Aircraft Accident Data (838 Accidents - 1968 - 1995)



Using the designated zones and accident data, it is possible to calculate a ratio of percentage of accidents to percentage of area size. These ratios indicate the CZ, with the smallest area size and the highest number of accidents, has the highest ratio, followed by the runway and adjacent area, APZ I, and then APZ II. Table B.2 reflects this data.

Table B.2 Accident to Area Ratio

Ratio of Percentage of Accidents to Percentage of Area

(Air Force Accident Data 1968 - 1995)

	Area[1] (Acres)	Number[2] Accident	Accident Per Acre	Percent of Total Area	Percent of Total Accidents	Ratio:[3] % Accidents to % Area
Runway Area	487	209	1 Per 2.3 acres	0.183	24.9	136
Clear Zone	413	230	1 Per 1.8 acres	0.155	27.4	177
APZ I	689	85	1 Per 8.1 acres	0.258	10.1	39
APZ II	964	47	1 Per 20.5 acres	0.362	5.6	16
Other Area	264,053	267	1 Per 989 acres	99.042	31.9	0.3

1 Area includes land within 10 nautical miles of runway.

2 Total number of accidents is 838 (through 1995).

3 Percent total accidents divided by percent total area.

Additional accident data for 1986 through July 1995 has been analyzed. Specific location data for some of the 1986-1995 accidents was not available and these were not included in the analysis. Table B.3 compares the 1968-1985 data with the data through July 1995:

Table B.3 Additional Accident Data

	1968-1985		1968-1995	
ZONE	**Accidents**	**% of Total**	**Accidents**	**% of Total**
On-Runway	197	27.1	209	24.9
Clear Zone	210	28.8	230	27.4
APZ I	57	7.8	85	10.1
APZ II	36	5.0	47	5.7
Other (Within 10 nautical miles)	228	31.3	267	31.9
Total	728	100.0	838	100.0

Analysis has shown that the cumulative changes evident in accident location through July 1995 reconfirm the dimensions of the CZs and APZs.

B.3 Definable Debris Impact Areas

The Air Force also determined which accidents had definable debris impact areas, and in what phase of flight the accident occurred. Overall, 75 percent of the accidents had definable debris impact areas, although they varied in size by type of accident. The Air Force used weighted averages of impact areas, for accidents occurring only in the approach and departure phase, to determine the following average impact areas:

<u>Average Impact Areas for Approach and Departure Accidents</u>

Overall Average Impact Area	5.06 acres
Fighter, Trainer, and Misc. Aircraft	2.73 acres
Heavy Bomber and Tanker Aircraft	8.73 acres

B.4 Findings

Designation of safety zones around the airfield and restriction of incompatible land uses can reduce the public's exposure to safety hazards.

Air Force accident studies have found that aircraft accidents near Air Force installations occurred in the following patterns:

- 61% were related to landing operations.
- 39% were related to takeoff operations.
- 70% occurred in daylight.
- 80% were related to fighter and training aircraft operations.

- 25% occurred on the runway or within an area extending 1,000 feet out from each side of the runway.
- 27% occurred in an area extending from the end of the runway to 3,000 feet along the extended centerline and 3,000 feet wide, centered on the extended centerline.
- 15% occurred in an area between 3,000 and 15,000 feet along the extended runway centerline and 3,000 feet wide, centered on the extended centerline.

Air Force aircraft accident statistics found 75% of aircraft accidents resulted in definable impact areas. The size of the impact areas were:

- 5.06 acres overall average.
- 2.73 acres for fighters and trainers.
- 8.73 acres for heavy bombers and tankers.

Appendix C

NOISE AND NOISE LEVEL REDUCTION GUIDELINES

THIS PAGE INTENTIONALLY LEFT BLANK

NOISE AND NOISE LEVEL REDUCTION GUIDELINES

C.1 General

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

Sound is a physical phenomenon consisting of minute vibrations that travel through a medium such as air, and are sensed by the human ear. Whether that sound is interpreted as pleasant (*e.g.*, music) or unpleasant (*e.g.*, aircraft noise) depends largely on the listener's current activity, past experience, and attitude toward the source of that sound. It is often true that one person's music is another person's noise.

The measurement and human perception of sound involves two basic physical characteristics - intensity and frequency. Intensity is a measure of the acoustic energy of the sound vibrations and is expressed in terms of sound pressure. The higher the sound pressure, the more energy carried by the sound and the louder the perception of that sound. The second important physical characteristic is sound frequency, that is, the number of times per second the air vibrates or oscillates. Low-frequency sounds are characterized as rumbles or roars, while high-frequency sounds are typified by sirens or screeches.

The loudest sounds, which can be detected comfortably by the human ear, have intensities that are a trillion times larger than those of sounds that can be detected at the lower end of the spectrum. Because of this vast range, any attempt to represent the intensity of sound using a linear scale becomes very unwieldy. As a result, a logarithmic unit known as the decibel (dB) is used to represent the intensity of a sound. Such a representation is called a sound level.

A sound level of 0 dB is approximately the threshold of human hearing and is barely audible under extremely quiet listening conditions. Normal speech has a sound level of approximately 60 dB. Sound levels above 120 dB begin to be felt inside the human ear as discomfort and eventually pain at still higher levels.

Because of the logarithmic nature of the decibel unit, sound levels cannot be added or subtracted directly and are somewhat cumbersome to handle mathematically. However, some simple rules are useful in dealing with sound levels. First, if a sound's intensity is doubled, the sound level increases by 3 dB, regardless of the initial sound level. Thus, for example:

$$60 \text{ dB} + 60 \text{ dB} = 63 \text{ dB, and}$$

$$80 \text{ dB} + 80 \text{ dB} = 83 \text{ dB.}$$

The total sound level produced by two sounds of different levels is usually only slightly more than the higher of the two. For example:

$$60.0 \text{ dB} + 70.0 \text{ dB} = 70.4 \text{ dB}.$$

Because the addition of sound levels behaves differently than that of ordinary numbers, such an addition is often referred to as "decibel addition" or "energy addition." The latter term arises from the fact that what is really happening when decibel values are added is each decibel value is first converted to its corresponding acoustic energy, then the energies are added using the normal rules of addition, and finally the total energy is converted to its decibel equivalent.

An important facet of decibel addition arises later when the concept of time-average sound levels is introduced to explain Day-Night Average A-Weighted Sound Level (DNL). Because of the logarithmic units, the louder levels that occur during the averaging period dominate the time-average sound levels. As a simple example, consider a sound level that is 100 dB and lasts for 30 seconds, followed by a sound level of 50 dB which also lasts for 30 seconds. The time-average sound level over the total 60-second period is 97 dB, not 75 dB.

Sound frequency is measured in terms of cycles per second (cps), or hertz (Hz), which is the preferred scientific unit for cps. The normal human ear can detect sounds that range in frequency from about 20 Hz to about 15,000 Hz. All sounds in this wide range of frequencies, however, are not heard equally well by the human ear, which is most sensitive to frequencies in the 1000 to 4000 Hz range. In measuring community noise, this frequency dependence is taken into account by adjusting the sound levels of the very high and low frequencies to approximate the human ear's lower sensitivity to those frequencies. This is called "A-weighting" and is commonly used in measurements of community environmental noise.

Sound levels measured using A-weighting are most properly called A-weighted sound levels while sound levels measured without any frequency weighting are most properly called sound levels. However, since most environmental impact analysis documents deal only with A-weighted sound levels, the adjective "A-weighted" is often omitted, and A-weighted sound levels are referred to simply as sound levels. In some instances it will be indicated that the sound levels have been A-weighted by using the abbreviation dBA or dB(A), rather than the abbreviation dB, for decibel. As long as the use of A-weighting is understood to be used, there is no difference implied by the terms "sound level" and "A-weighted sound level" or by the units dB, dBA, and dB(A).

In this document and most AICUZ documents, all sound levels are A-weighted sound levels and the adjective "A-weighted" has been omitted and dB is used for the decibel units.

Sound levels do not represent instantaneous measurements but rather averages over short periods of time. Two measurement time periods are most commonly used - one second and one-eighth of a second. Most environmental noise studies use slow response measurements, and the adjective "slow response" is usually omitted. It is easy to understand why the proper descriptor "slow response A-weighted sound level" is usually shortened to "sound level" in environmental impact analysis documents.

C.2 Noise Metrics

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

Various federal agencies involved in environmental noise mitigation agree on common metrics for environmental impact analysis documents, and both the Department of Defense (DoD) and the FAA specified those which should be used for federal aviation noise assessments. These metrics are as follows.

C.2.1 Maximum Sound Level

The highest A-weighted sound level measured during a single event in which the sound level changes value as time goes on (*e.g.*, an aircraft overflight) is called the maximum A-weighted sound level or maximum sound level, for short. It is usually abbreviated by ALM, $L_{max,}$ or L_{Amax}.

C.2.2 Sound Exposure Level

Individual time-varying noise events have two main characteristics - a sound level which changes throughout the event and a period of time during which the event is heard. Although the maximum sound level, described above, provides some measure of the intrusiveness of the event, it alone does not completely describe the total event. The period of time during which the sound is heard is also significant. The Sound Exposure Level (abbreviated SEL or L_{AE}) combines both of these characteristics into a single metric.

Sound Exposure Level is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the sound level of the constant sound that would, in one second, generate the same acoustic energy as did the actual time-varying noise event. Since aircraft overflights usually last longer than 1 second, the SEL of an overflight is usually greater than the ALM of the overflight.

Note that sound exposure level is a composite metric that represents both the intensity of a sound level of the constant sound and its duration. It does not directly represent the sound level heard at any given time, but rather provides a measure of the net impact of the entire acoustic event. It has been well established in the scientific community that SEL measures this impact much more reliably than just the ALM.

Because the SEL and the ALM are both A-weighted sound levels expressed in decibels, there is sometimes confusion between the two, so the specific metric used should be clearly stated.

C.2.3 Day-Night Average Sound Level

Time-average sound levels are measurements of sound levels that are averaged over a specified length of time. These levels provide a measure of the average sound energy during the measurement period.

For the evaluation of community noise effects, and particularly aircraft noise effects, the DNL (mathematically represented as L_{dn}) is used. DNL averages aircraft sound levels at a location over a complete 24-hour period, with a 10-dB adjustment added to those noise events that take place between 10:00 p.m. and 7:00 a.m. (local time). This 10-dB "penalty" represents the added intrusiveness of sounds that occur during normal sleeping hours, both because of the increased sensitivity to noise during those hours and because ambient sound levels during nighttime are typically about 10 dB lower than during daytime hours.

As noted earlier for SEL, DNL does not represent the sound level heard at any particular time. DNL provides a single measure of overall noise impact, but does not provide specific information on the number of noise events or the individual sound levels which occur during the day. For example, a DNL of 65 dB could result from a very few noisy events, or a large number of quieter events.

Scientific studies and social surveys which have been conducted to evaluate community annoyance to all types of environmental noise have found the DNL to be the best measure to predict annoyance. Its use is endorsed by the scientific community (See References C.1 through C-5 at the end of this section).

There is, in fact, a remarkable consistency in the results of attitudinal surveys about aircraft noise conducted in different countries to find the percentages of groups of people who express various degrees of annoyance when exposed to different levels of DNL.

Reference C.6 was published in 1978. A more recent study has reaffirmed this relationship (Reference C.7). In general, correlation coefficients of 0.85 to 0.95 are found between the percentages of groups of people highly annoyed and the level of average noise exposure. The correlation coefficients for the annoyance of individuals are relatively low, however, on the order of 0.5 or less. This is not surprising, considering the varying personal factors that influence the manner in which individuals react to noise. Nevertheless, findings substantiate that community annoyance to aircraft noise can be predicted quite reliably using DNL.

This relation between community annoyance and DNL has been confirmed, even for infrequent aircraft noise events. Reference C.8 reported the reactions of individuals in a community to daily helicopter overflights correlated quite well with the daily time-average sound levels over this range of numbers of daily noise events.

The use of DNL has been criticized as not accurately representing community annoyance and land-use compatibility with aircraft noise. Much of that criticism stems from a lack of understanding of the basis for the measurement or calculation of L_{dn}. One frequent criticism is based on the principle that people inherently react more to single noise events and not as much to "meaningless" time-average sound levels.

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

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

C.3 Noise Effects

C.3.1 Hearing Loss

Noise-induced hearing loss is probably the best-defined of the potential effects of human exposure to excessive noise. Federal workplace standards for protection from hearing loss allow a time-average level of 90 dB over an 8-hour work period, or 85 dB averaged over a 16-hour period. An outdoor DNL of 75 dBA is considered the threshold above which the risk of hearing loss should be evaluated. Following guidelines recommended by the Committee on Hearing, Bioacoustics, and Biomechanics of the National Research Council, the average change in the threshold of hearing for people exposed to DNL equal to or greater than 75 dBA was evaluated. Results indicated that an average of 1 dBA hearing loss could be expected for people exposed to DNL equal to or greater than 75 dBA. For the most sensitive 10 percent of the exposed population, the maximum anticipated hearing loss would be 4 dBA. These hearing loss projections must be considered conservative as the calculations are based on an average daily outdoor exposure of 16 hours (7:00 a.m. to 10:00 p.m.) over a 40-year period. Since it is unlikely that airport neighbors will remain outside their homes 16 hours per day for extended periods of time, there is little possibility of hearing loss below a DNL of 75 dB, and this level is extremely conservative.

C.3.2 Nonauditory Health Effects

Nonauditory health effects of long-term noise exposure, where noise may act as a risk factor, have never been found to occur at levels below those protective against noise-induced hearing loss, described above. Most studies attempting to clarify such health effects have found that noise exposure levels established for hearing protection will also protect against any potential nonauditory health effects, at least in workplace conditions. The best scientific summary of these findings is contained in the lead paper at the National Institute of Health Conference on Noise and Hearing Loss, held on 22-24 January 1990 in Washington, D.C.

> "The nonauditory effects of chronic noise exposure, when noise is suspected to act as one of the risk factors in the development of hypertension, cardiovascular disease, and other nervous disorders, have never been proven to occur as chronic manifestations at levels below these criteria (an average of 75 dBA for complete protection against hearing loss for an eight-hour day). At the recent (1988) International Congress on Noise as a Public Health Problem, most studies attempting to clarify such health effects did not find them at levels below the criteria protective of noise-induced hearing loss, and even above these criteria, results regarding such health effects were ambiguous. Consequently, one comes to the conclusion that establishing and enforcing exposure levels protecting against noise-induced hearing loss would not only solve the noise-induced hearing loss problem but also any potential nonauditory health effects in the work place." (Reference C.9; parenthetical wording added for clarification.)

Although these findings were directed specifically at noise effects in the work place, they are equally applicable to aircraft noise effects in the community environment. Research studies regarding the nonauditory health effects of aircraft noise are ambiguous, at best, and often contradictory. Yet, even those studies which purport to find such health effects use time-average noise levels of 75 dB and higher for their research.

For example, in an often-quoted paper, two University of California at Los Angeles (UCLA) researchers apparently found a relationship between aircraft noise levels under the approach path to Los Angeles International Airport and increased mortality rates among the exposed residents by using an average noise exposure level greater than 75 dB for the "noise-exposed" population (Reference C.10). Nevertheless, three other UCLA professors analyzed those same data and found no relationship between noise exposure and mortality rates (Reference C.11).

In summary, there is no scientific basis for a claim that potential health effects exist for aircraft DNL below 75 dB.

C.3.3 Annoyance

The primary effect of aircraft noise on exposed communities is one of annoyance. Noise annoyance is defined by the U.S. Environmental Protection Agency as any negative subjective reaction on the part of an individual or group (Reference C.3). As noted in the discussion of DNL above, community annoyance is best predicted by that metric.

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

- provides a valid basis for comparing and assessing community noise effects;
- represents a noise exposure level which is normally dominated by aircraft noise and not other community or nearby highway noise sources; and
- reflects the FAA's threshold for grant-in-aid funding of airport noise mitigation projects.
- United States Department of Housing and Urban Development also establishes a DNL standard of 65 dB for eligibility for federally guaranteed home loans.

C.3.4 Speech Interference

Speech interference associated with aircraft noise is a primary cause of annoyance to individuals on the ground. The disruption of routine activities such as radio or television listening, telephone use, or family conversation gives rise to frustration and irritation. The quality of speech communication is also important in classrooms, offices, and industrial settings and can cause fatigue and vocal strain in those who attempt to communicate over the noise. Research has shown that "whenever intrusive noise exceeds approximately 60 dB indoors, there will be interference with speech communication" (Reference C.5). A steady A-weighted background sound level of 60 dB will produce 93 percent intelligibility; that of 70 dB will produce 66 percent intelligibility; and that of 75 dB will produce 2 percent intelligibility (Figure D-1 in Reference C.3).

C.3.5 Sleep Interference

Sleep interference may be measured in either of two ways. "Arousal" represents actual awakening from sleep, while a change in "sleep stage" represents a shift from one of four sleep stages to another stage of lighter sleep without actual awakening. In general, arousal requires a somewhat louder noise level than does a change in sleep stage.

A recent analysis sponsored by the Air Force summarized 21 published studies concerning the effects of noise on sleep (Reference C.14). The analysis concluded that a lack of reliable studies in homes, combined with large differences among the results from the various laboratory studies and the limited in-home studies, did not permit development of an acceptable accurate assessment procedure. The noise events used in the laboratory studies and in contrived in-home studies were presented at much higher rates of occurrence than would normally be experienced in the home. None of the laboratory studies was of sufficiently long duration to determine any effects of habituation, such as those which would occur under normal community conditions.

Nevertheless, some guidance is available in judging sleep interference. The U.S. Environmental Protection Agency (USEPA) identified an indoor DNL of 45 dB as necessary to protect against sleep interference (Reference C.3). Assuming a very conservative structural noise insulation of 20 dB for typical dwelling units, this corresponds to an outdoor DNL of 65 dB as minimizing sleep interference.

The Federal Interagency Committee on Noise (Reference C.5) reviewed the sleep disturbance issue and presented an Air Force-developed sleep disturbance dose-response prediction curve, which is based on data from Reference C.14, as an interim tool for analysis of potential sleep disturbance. This interim curve shows that for an indoor SEL of 65 dB, approximately 15 percent or less of those exposed should be awakened.

C.3.6 Noise Effects on Domestic Animals and Wildlife

Animal species differ greatly in their responses to noise. Each species has adapted, physically and behaviorally, to fill its ecological role in nature, and its hearing ability usually reflects that role. Animals rely on their hearing to avoid predators, obtain food, and communicate with and attract other members of their species. Aircraft noise may mask or interfere with these functions. Secondary effects may include nonauditory effects similar to those exhibited by humans - stress, hypertension, and other nervous disorders. Tertiary effects may include interference with mating and resultant population declines.

Many scientific studies are available regarding the effects of noise on wildlife and some anecdotal reports of wildlife "flight due to noise." Few of these studies or reports include any reliable measures of the actual noise levels involved.

In the absence of definitive data on the effect of noise on animals, the Committee on Hearing, Bioacoustics, and Biomechanics proposed that protective noise criteria for animals be taken to be the same as for humans (Reference C.16).

C.3.7 Effects of Noise-Induced Vibration on Structures and Humans

The sound from an aircraft overflight travels from the exterior to the interior of the house in one of two ways: through the solid structural elements and directly through the air. The sound transmission starts with noise impinging on the wall exterior. Some of this sound energy will be reflected away and some will make the wall vibrate. The vibrating wall radiates sound into the airspace, which in turn sets the interior finish surface vibrating, with some of the energy lost in the airspace. This surface then radiates sound into the dwelling interior. Vibrational energy also bypasses the air cavity by traveling through the studs and edge connections.

Normally, the most sensitive components of a structure to airborne noise are the windows and, infrequently, the plastered walls and ceilings. An evaluation of the peak sound pressure impinging on the structure is normally sufficient to determine the possibility of damage. In general, at sound levels above 130 dB, there is the possibility of structural damage. While certain frequencies (such as 30 Hz for window breakage) may be of more concern than other frequencies, conservatively, only sounds lasting more than 1 second above a sound level of 130 dB are potentially damaging to structural components (Reference C.17).

In terms of average acceleration of wall or ceiling vibration, the thresholds for structural damage (C.18) are:

- 0.5 meters/sec/sec—threshold of risk of damage to sensitive structures (e.g., ancient monuments); and
- meters/sec/sec—threshold of risk of damage to normal dwellings (e.g., houses with plaster ceilings and walls).

Noise-induced structural vibration may also cause annoyance to dwelling occupants because of induced secondary vibrations, or "rattle," of objects within the dwelling - hanging pictures, dishes, plaques, and bric-a-brac. Loose window panes may also vibrate noticeably when exposed to high levels of aircraft noise, causing homeowners to fear breakage. In general, such noise-induced vibrations occur at sound levels above those considered normally compatible with residential land use. Thus, assessments of noise exposure levels for compatible land use should also be protective of noise-induced secondary vibrations.

In the assessment of vibrations on humans, the following factors determine if a person will perceive and possibly react to building vibrations:

- Type of excitation: steady state, intermittent, or impulsive vibration;
- Frequency of the excitation. ISO 2631-2 (Reference C.18) recommends a frequency range of 1 to 80 Hz for the assessment of vibration on humans;
- Orientation of the body with respect to the vibration;
- The use of the occupied space; and
- Time of day.

C.3.8 Noise Effects on Terrain

It has been suggested that noise levels associated with low-flying aircraft may affect the terrain under the flight path by disturbing fragile soil or snow structures, especially in mountainous areas, causing landslides or avalanches. There are no known instances of such effects, and it is considered improbable that such effects will result from routine, subsonic aircraft operations.

C.3.9 Noise Effects on Historical and Archaeological Sites

Because of the potential for increased fragility of structural components of historical buildings and other historical sites, aircraft noise may affect such sites more severely than newer, modern structures. Again, there are few scientific studies of such effects to provide guidance for their assessment.

One study involved the measurements of sound levels and structural vibration levels in a superbly restored plantation house, originally built in 1795, and now situated approximately 1,500 feet from the centerline at the departure end of Runway 19L at Washington Dulles International Airport. These measurements were made in connection with the proposed scheduled operation of the supersonic Concorde airplane at Dulles (Reference C.19). There was a special concern for the building's windows, since roughly half of the 324 panes were original. No instances of structural damage were found. Interestingly, despite the high levels of noise during Concorde takeoffs, the induced structural vibration levels were actually less than those induced by touring groups and vacuum cleaning.

As noted above for the noise effects of noise-induced vibrations of normal structures, assessments of noise exposure levels for normally compatible land uses should also be protective of historic and archaeological sites.

C.4 Noise Level Reduction Guidelines

A study that provides in-depth, state-of-the-art noise level reduction guidelines was prepared for the Naval Facilities Engineering Command (NAVFAC) in April 2005. The title of the document is *Guidelines for the Sound Insulation of Residences Exposed to Aircraft Operations* (C.20). A copy of this document can be obtained from NAVFAC Southern Division, Charleston, SC.

C.5 References

C.1. "Sound Level Descriptors for Determination of Compatible Land Use," American National Standards Institute Standard ANSI S3.23-1980.

C.2. "Quantities and Procedures for Description and Measurement of Environmental Sound, Part 1," American National Standards Institute Standard ANSI S12.9-1988.

C.3. "Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare With an Adequate Margin of Safety," U.S. Environmental Protection Agency Report 550/9-74-004, March 1972.

C.4. "Guidelines for Considering Noise in Land-Use Planning and Control," Federal Interagency Committee on Urban Noise, June 1980.

C.5. "Federal Agency Review of Selected Airport Noise Analysis Issues," Federal Interagency Committee on Noise, August 1992.

C.6. Schultz, T.J. "Synthesis of Social Surveys on Noise Annoyance," J. Acoust. Soc. Am., 64, 377-405, August 1978.

C.7. Fidell, S., Barger, D.S., and Schultz, T.J., "Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise," J. Acoust. Soc. Am., 89, 221-233, January 1991.

C.8. "Community Reactions to Helicopter Noise: Results from an Experimental Study," J. Acoust. Soc. Am., 82,479-492, August 1987.

C.9. Von Gierke, H.R., "The Noise-Induced Hearing Loss Problem," NIH Consensus Development Conference on Noise and Hearing Loss, Washington D.C., 22-24 January 1990.

C.10. Meacham, W.C., and Shaw, N., "Effects of Jet Noise on Mortality Rates," British J. Audiology, 77-80, August 1979.

C.11. Frericks, R.R., *et al*., "Los Angeles Airport Noise and Mortality: Faulty Analysis and Public Policy," Am J. Public Health, 357-362, April 1980.

C.12. Jones, F.N., and Tauschr, J., "Residence Under an Airport Landing Pattern as a Factor in Teratism," Archives of Environmental Health, 10-12 Jan/Feb 1978.

C.13. Edmonds, L.D., *et al*., "Airport Noise and Teratogenesis," Archives of Environmental Health, 243-247, July/August 1979.

C.14. Pearsons, K.S., Barber, D.S. and Tabachick, B.G., "Analyses of the Predictability of Noise-Induced Sleep Disturbance," USAF Report HSD-TR-89-029, October 1989.

C.15. Kryter, K.D., "Physiological, Psychological, and Social Effects of Noise," NASA Reference Publication 1115, 446, July 1984.

C.16. "Guidelines for Preparing Environmental Impact Statements on Noise," Committee on Hearing, Bioacoustics and Biomechanics, The National Research Council, National Academy of Sciences, 1977.

C.17. Von Gierke, H.E., and Ward, W.D., "Criteria for Noise and Vibration Exposure," Handbook of Acoustical Measurements and Noise Control, Third Edition, 1991.

C.18. "Evaluation of Human Exposure to Whole-Body Vibration - Part 2: Continuous and Shock-Induced Vibration in Buildings (1 to 80 Hz)", International Organization for Standardization, Standards 2631-2, February 1989.

C.19. Wesler, J.E., "Concorde Operations at Dulles International Airport," NOISEEXPO '77, Chicago, IL, March 1977.

C.20. *Guidelines for the Sound Insulation of Residences Exposed to Aircraft Operations*, Department of the Navy, Naval Facilities Engineering Command, Washington Navy Yard, 1322 Patterson Avenue, S.W., Suite 1000, Washington, DC 20374-5065.

THIS PAGE INTENTIONALLY LEFT BLANK

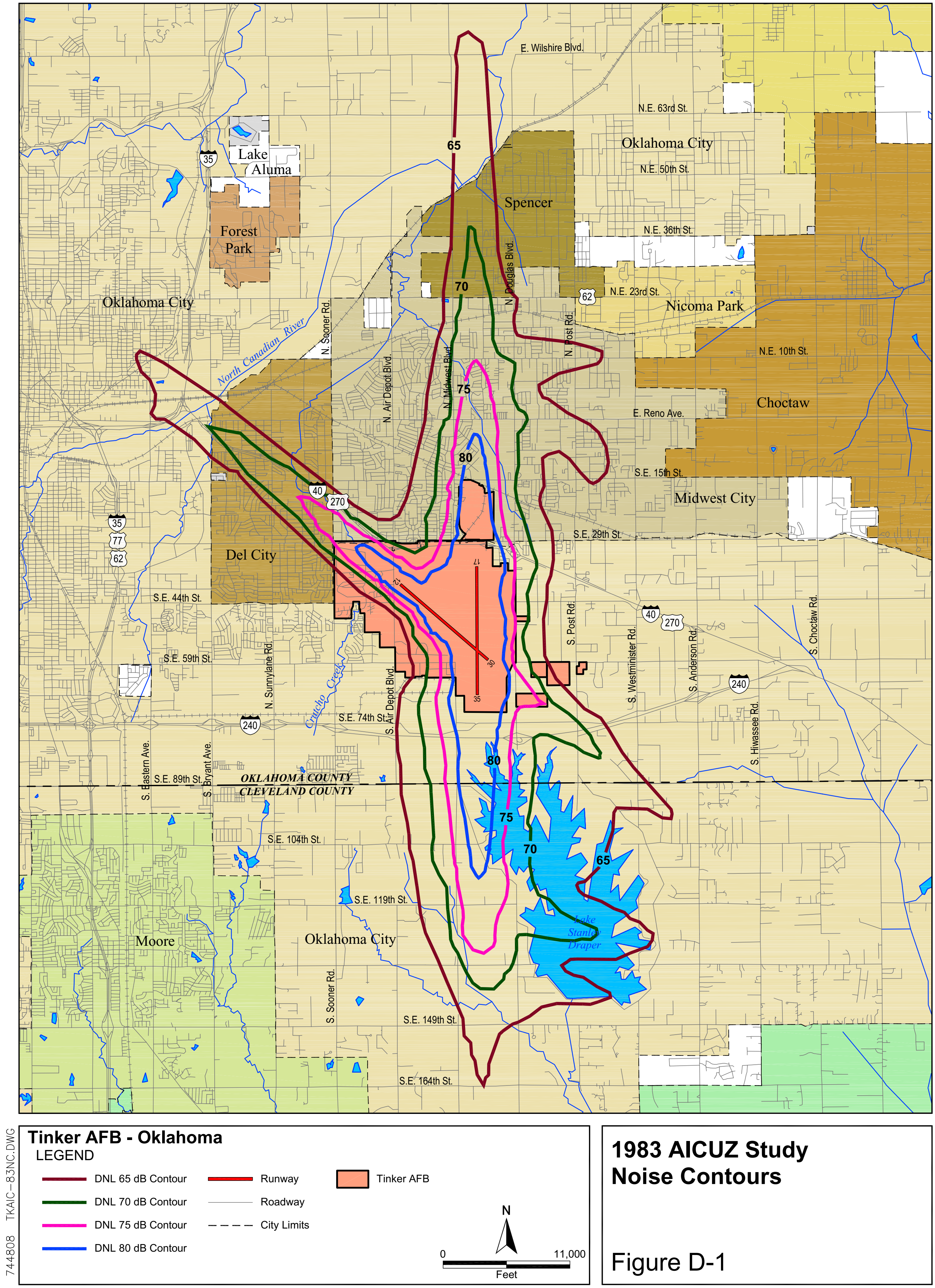
Appendix D

1983 AICUZ Study Noise Contours

THIS PAGE INTENTIONALLY LEFT BLANK

Midwest City implements a conventional zoning ordinance that contains a supplement, "Tinker Air Force Base Zoning Ordinance." This ordinance regulates development within APZ I. Del City also implements a conventional zoning ordinance and has recently incorporated a section, "Airport Zoning", that controls development within APZ I. Oklahoma City's zoning ordinance contains a section (Oklahoma City Airports Zoning Ordinance) that regulates height restriction zones around airports and airport environs zones created by the existing and future potential noise impact. Oklahoma City requires sound proofing new construction within noise contour levels above DNL 60 dB. The city also restricts incompatible uses within noise zones above DNL 65 dB. The overlay zoning in the vicinity of Tinker AFB is based on the noise contours published in the 1983 AICUZ study. These contours are shown on Figure D-1.

THIS PAGE INTENTIONALLY LEFT BLANK



1983 AICUZ Study Noise Contours

Figure D-1

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix E

Headquarters Air Force Materiel Command Letter

THIS PAGE INTENTIONALLY LEFT BLANK

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE OHIO

10 AUG 2006

MEMORANDUM FOR 72 ABW/CE

FROM: HQ AFMC/A7C
4225 Logistics Avenue
Wright-Patterson AFB OH 45433-5746

SUBJECT: Review of Air Installation Compatible Use Zone (AICUZ) Submittal – Tinker AFB

1. We reviewed your submittal (90 percent) of the Tinker AFB AICUZ report and congratulate you on an excellent product. For the final submittal, please include Accident Potential Zone II (APZ II) for the cross-wind runway. Recommendations are provided (Atch) to mitigate some potential concerns from the local community with inclusion of APZ II.

2. If you have any questions, please have your staff contact Mr. Ray Henderson, HQ AFMC/A7CPX, DSN 986-0427, (937) 656-0427, raymond.henderson@wpafb.af.mil.

JEFF MUNDEY, P.E.
Deputy Command Civil Engineer
Directorate of Installations and
Mission Support

Attachment:
Supplemental Comments – APZ II

cc:
HQ AFMC/A7
HQ USAF/A7CPB
HQ AFCEE/TDN

Supplemental comments pertaining to APZ II:

1. In order to mitigate potential concerns from the local community, the following is recommended for inclusion in para 4.5.2. Exact words can be modified to fit with the rest of the section as long as the meaning is essentially provided.

a. Since 1976, APZ II has not been included in the AICUZ document for the cross-wind runway, RW 12-30. Primary reasons were, the majority of flying activity occurred on the north-south runway and there would be little benefit since the majority of land to the northwest was already developed.

b. With release of this AICUZ report, we included APZ II with the understanding that existing land uses are grandfathered. While they are incompatible based on the AICUZ land use recommendations, we do not expect or request they be removed. For all intent and purposes they will be considered pre-existing conditions. This recommended APZ II criteria is intended to apply to new developments/future redevelopments only.

c. The Air Force policy on APZs is not predicated on the level of runway usage, therefore it is important the policy be consistently applied. With minimal use of the cross-wind runway, the likelihood of an accident is much less than on the main runway; nevertheless, situations will occur such as with runway repairs where the use will increase. It is important we provide all the information necessary for the local communities to make smart decisions relative to protecting the health, safety, and welfare of the citizens since this is still an area of higher than normal accident potential when that runway is in use. To not depict this accident potential zone, may give people a false sense that they are not located in an area of higher than normal accident potential.

d. With a Joint Land Use Study (JLUS) currently underway, it was determined by the Major Command and Air Staff the standard Air Force policy would be provided to the communities and that APZ II would be shown for the cross wind runway. These APZ II recommendations should be considered by the communities as the JLUS program is accomplished.

2. With inclusion of APZ II, fig 4.5, fig 5.1, table 5.2, fig 5.2, table 5.4, table 5.5, fig 5.3, fig 5.4, para 5.5.2.5 (new), para 5.5.2.6 (new), and para A.6 will also need revising.