AGENDA ITEM # 9

CITY COUNCIL COMMUNICATION FORM

FROM:	**Tyler Gibbs, AIA, Director of Planning and Community Development (Ext. 244)**
THROUGH:	**Wendy DuBord, Interim City Manager (Ext. 219)**
DATE:	**April 5, 2011**
RE:	**Amendment to Steamboat Springs Municipal Code, Article III Noise Pollution.**
NEXT STEP:	**This item will be scheduled for Planning Commission and City Council Public Hearings in April and May.**

___ DIRECTION
_X_ INFORMATION
___ ORDINANCE
___ MOTION
___ RESOLUTION

I.	**PROJECT NAME:**	**Noise Ordinance:** Revisions providing clear, measurable standards governing the creation, measurement, effects and enforcement measures related to noise having off-site impacts.
II.	**REQUEST OR ISSUE:**	Provide recommendation for further action, including, but not limited to, moving ordinance forward to public hearing at Planning Commission and City Council.
III.	**LOCATION:**	All zone districts
III.	**FISCAL IMPACTS:**	No direct implementation costs. Sound monitoring equipment and training has already been obtained. Benefits may include more efficient confirmation of noise complaints and more reliable enforcement of documented violations.

IV. EXECUTIVE SUMMARY:

1. Background

Controversy and conflicts between venues featuring live entertainment and surrounding residential uses have frequently been prominent public issues during the past year. Representatives of local entertainment venues have appeared before council to present their efforts to mitigate impacts, promote the value of their businesses to the Steamboat's resort economy, and request unambiguous criteria to guide what is acceptable and what is not. Residents and guests have also shared stories of unanticipated disturbance and interrupted vacations.

The Steamboat Springs community recognizes the immense value of both a thriving entertainment scene as well as the ongoing revitalization of our downtown and mountain village as true mixed-use neighborhoods. Successful cities across the country have seen perhaps their greatest renaissance in the success of their most diverse urban districts. Steamboat is not unique in the need to address the challenges of this success.

In response, the City has begun several initiatives seeking to address and mitigate these issues. A survey of ordinances from around the country has been compiled to provide background on how other communities have responded to the need for noise regulation. Both similar resort communities as well as large cities with vibrant mixed-use districts have been included.

In addition, the City has acquired more sophisticated noise measurement equipment that allows a digital record of a noise monitoring session to be downloaded to a computer for an accurate, lasting record. The program also allows for the comparison of typical background noise relative to specific over laid sources. Police officers have been trained in the use of this equipment and have begun to monitor noise levels at a variety of local venues to gain experience as well as understanding of the potential implementation of the proposed code.

The proposed ordinance has been provided to interested parties and the planning director has met with representatives of the entertainment venues.

2. Proposal Summary

The proposed amendments to Steamboat Springs' current noise ordinance address both standards and enforcement.

- Maximum noise levels in a commercial district during the evening hours would be raised from the current 55 decibels to 60 decibels.
- Evening hours would be defined as 11:00PM to 7:00AM rather than the current 7:00PM to 7:00AM.
- Better definition is provided as to what may be considered separate violations when excessive noise is either intermittent or continuous during the period of time that it is monitored.
- Reference is provided to the State Liquor Code to affirm that repeated noise

ordinance violations may be considered a violation of the State's "conduct of business" regulations and therefore relevant to any hearings pertaining to liquor license renewal, suspension or revocation. This is current practice whether directly referenced or not and has been considered in license reviews in Telluride and Golden among other communities.

3. **Next Steps**
With the City Council's direction, staff will move the proposed ordinance to public hearing at Planning Commission and City Council. Staff also recommends continuing to work with all parties and the Responsible Hospitality Institute to implement strategies for cooperative working relationships based on common sense and appropriate courtesy and tolerance.

V. LIST OF ATTACHMENTS:

Attachment 1. Proposed Ordinance Amending Article III, Chapter 7 of the Steamboat Springs Revised Municipal Code.

Attachment 2. Table: Comparison of Allowable Noise Levels in 14 Cities.

Attachment 3. Chapter 15, Community Noise; co-authored by Dennis Driscoll, Certified Noise Control Engineer and consultant to the City. Although much of this gets fairly technical, pages 601-608 provide a good overview of the basis for Federal, State and Local noise regulations. The section titled "Factors Other Than Absolute Sound Level Influencing Community Reaction to Noise" (pgs 607-608) provides some real-world observations on how people react to noise disturbances. This is drawn from research by the EPA and others in the field.

AN ORDINANCE AMENDING ARTICLE III, CHAPTER 7 OF THE STEAMBOAT SPRINGS REVISED MUNICIPAL CODE

WHEREAS, the City of Steamboat Springs wishes to promote vibrant mixed-use districts with the community; and

WHEREAS, live music is a valued part of the community's arts and entertainment offerings; and

WHEREAS, full time and vacation residential uses are an important component of active, 24 hour districts; and

WHEREAS, considerations for compatible design and operation of entertainment and residential uses are key to the success of our mixed-use districts; and

WHEREAS, clear enforceable standards are a necessary complement to appropriate courtesy and tolerance in mixed-use districts.

NOW, THEREFORE, IT IS HEREBY ORDAINED BY THE CITY COUNCIL OF THE CITY OF STEAMBOAT SPRINGS THAT:

SECTION 1. Article III, Chapter 7 of the Steamboat Springs Revised Municipal Code is hereby amended to read as follows:

"ARTICLE III. NOISE POLLUTION.

Sec. 7.61 - Definitions.

The following words, terms and phrases, when used in this article, shall have the meanings ascribed to them in this section, except where the context clearly indicates a different meaning:

(1) *Commercial zone* means:

a. An area where offices, clinics and the facilities needed to serve them are located;

b. An area with local shopping, entertainment and service establishments located within walking distances of the residents served;

c. A tourist-oriented area where hotels, motels, retail, entertainment and services ~~and gasoline stations~~ are located;

d. A large integrated regional shopping center;

e. A business strip along a main street containing offices, retail businesses and commercial enterprises;

f. A central business district; or

g. A commercially dominated mixed-use area with multiple-unit dwellings.

(2) *db(A)* means sound levels in decibels measured on the "A" scale of a standard sound level meter having characteristics defined by the American National Standards Institute, publication S1.4-1971, and approved by the industrial commission of the state.

(3) *Decibel* is a unit used to express the magnitude of a change in sound level. The difference in decibels between two (2) sound pressure levels is twenty (20) times the common logarithm of their ratio. In sound pressure measurements sound levels are defined as twenty (20) times the common logarithm of the ratio of that sound pressure level to a reference level of 2×10^{-5} newtons per square meter. As an example of the effect of the formula, a three-decibel change is a one hundred (100) percent increase or decrease in the sound level, and a ten-decibel change is a one thousand (1,000) percent increase or decrease in the sound level.

(4) *Industrial zone* means an area in which noise restrictions on industry are necessary to protect the value of adjacent properties for other economic activity, but shall not include agricultural operations.

(5) *Light industrial and commercial zone* means:

a. An area containing clean and quiet research laboratories;

b. An area containing light industrial activities which are clean and quiet;

c. An area containing warehousing; or

d. An area in which other activities are conducted where the general environment is free from concentrated industrial activity.

(6) *Residential zone* means an area of single-family or multifamily dwellings, where businesses may or may not be conducted in such dwellings. The zone includes an area where multiple-unit dwellings, high-rise apartment districts and redevelopment districts are located. A residential zone may include areas containing accommodations for transients such as motels and hotels and residential areas with limited office development, but it may not include retail shopping facilities. The term "residential zone" includes hospitals, nursing homes and similar institutional facilities.

Sec. 7-62. - Exemptions.

(a) *Emergency vehicles.* The requirements, prohibitions and terms of this article shall not apply to any authorized emergency vehicle when responding to an emergency call or acting in time of emergency.

(b) *Parades, fireworks and other special activities.* The terms of this article shall not apply to those activities of a temporary duration permitted by law for which a license or permit has been granted by the city, including but not limited to parades, and fireworks displays.

(c) *Commercial refuse haulers.* The terms of this article shall not apply to the activities of commercial refuse haulers operating under a license issued pursuant to the provisions of division 2, of article II, of chapter 19 of this Code when such commercial refuse haulers operate between the hours of 5:00 a.m. and 7:00 a.m. in all industrial zone districts and in commercial zone districts located within Old Town, Ski Time Square, Gondola Square. For purposes of this subsection Old Town shall be deemed to be the area bounded by Oak, Yampa, Third, and Twelfth Streets, including all lots accessible from said streets. Ski Time Square shall be deemed to be Ski Time Square Drive and all streets, alleys, and parking lots accessible from Ski Time

Square Drive, and Gondola Square shall be deemed to be all streets, alleys, and parking lots serving Gondola Square and located east of Mt. Werner Circle, north of Apres Ski Way, and South of Ski Time Square.

Sec. 7-63. - Authority to grant relief from noise level standards.

(a) Applications for a permit for relief from the noise level designated in this article on the basis of undue hardship may be made to the city manager or his duly authorized representative. Any permit granted by the city manager under this section shall contain all conditions upon which the permit has been granted and shall specify a reasonable time that the permit shall be effective. The city manager or his duly authorized representative may grant the relief as applied for if he finds that:

(1) Additional time is necessary for the applicant to alter or modify his activity or operation to comply with this article;

(2) The activity, operation or noise source will be of temporary duration and cannot be done in a manner that would comply with this article; or

(3) No other reasonable alternative is available to the applicant.

(b) The city manager may prescribe any conditions or requirements he deems necessary to minimize adverse effects upon the surrounding neighborhood.

Sec. 7-64. - Prohibited noise generally.

(a) The making and creating of an excessive or unusually loud noise within the city as heard without measurement or heard and measured in the manner prescribed in section 7-65 is unlawful, except as exempted under the provisions of section 7-62 or when made under and in compliance with a permit issued pursuant to section 7-63 or 7-66.

(b) No person shall operate any type of vehicle, machine or device or carry on any other activity in such a manner as would be a violation of subsection (a) of this section.

Sec. 7-65. - Maximum noise levels.

For the purpose of determining and classifying any noise as excessive or unusually loud as declared to be unlawful and prohibited by this article, the following test measurements and requirements may be applied; ~~provided, however, a violation of this article may occur without the measurements being made:~~ The point of measurement for determining violation shall be at the property line of the impacted property.

(1) Every activity to which this article is applicable shall be conducted in a manner so that any noise produced is not objectionable due to intermittence, beat frequency or shrillness. Sound levels of noise radiating from any property ~~line at a distance of twenty-five (25) feet or more therefrom~~ in excess of the db(A) established for the following time periods and zones shall constitute prima facie evidence that such noise is a public nuisance:

Zone	7:00 a.m. to next ~~7~~11:00 p.m.	~~7~~11:00 p.m. to next 7:00 a.m.
Residential	55 db(A)	55 ~~55~~ db(A)
Commercial	~~60~~ 65 db(A)	~~55~~ 60db(A)
Light industrial	70 db(A)	65 db(A)
Industrial	80 db(A)	75 db(A)
Agriculture and recreation	55db(A)	55db(A)

(including parks and open space)

(2) In the hours between 7:00 a.m. and the next 711:00 p.m., the noise levels permitted in subsection (1) of this section may be increased by ten (10) db(A) for a period not to exceed fifteen (15) minutes in any one-hour period. [t1]

Intermittent violations by the same source separated in time by five (5) minutes or more may be considered individual violations within each five minute period.

(3) Continuous violations from a single source exceeding15 minutes in duration may be considered multiple violations for every 15 minutes the violation continues.

(43) Periodic, impulsive noise including low frequency and/or shrill noises shall be considered a public nuisance when such noises are at a sound level of five (5) db(A) less than those listed in subsection (1) of this section.

(45) This section is not intended to apply to the operation of aircraft or to other activities which are subject to federal law with respect to noise control.

(65) Construction projects shall be subject to the maximum permissible noise levels specified for industrial zones for the period within which construction is to be completed pursuant to any applicable construction permit issued by proper authority or, if no time limitation is imposed, for a reasonable period of time for completion of project. Construction projects in residential neighborhoods shall not exceed 55db(A).

(76) All railroad rights-of-way shall be considered as industrial zones for the purposes of this section, and the operation of trains shall be subject to the maximum permissible noise levels specified for such zone.

(87) This section is not applicable to the use of property for purposes of conducting speed or endurance events involving motor vehicles or other vehicles, but such exception is effective only during the specific period to time within which such use of the property is authorized by the political subdivision or governmental agency having lawful jurisdiction to authorize such use.

(98) For the purposes of this section, measurements with sound level meters shall be made when the wind velocity at the time and place of such measurement is not more than five (5) miles per hour.

(109) In all sound level measurements, consideration shall be given to the effect of the ambient noise level created by the encompassing noise of the environment from all sources at the time and place of such sound level measurement.

(110) This section is not applicable to the use of property for the purpose of manufacturing, maintaining or grooming machine-made snow.

(121) This article shall not apply to the operation of snow removal equipment for purposes of snow removal.

Sec. 7-66. - Use of vehicle equipped with loudspeaker, amplifier, etc.

It is unlawful to play, operate or use any device known as a sound truck, or any loudspeaker, sound amplifier, radio or phonograph with loudspeaker or sound amplifier, or instruments of any kind or character which emits loud or raucous noises and which is attached to and upon any vehicle upon a public place, unless the person in charge of such vehicle has first applied to and received permission from the city manager or his duly authorized representative to operate any such vehicle so equipped.

Sec. 7-67. - Muffler required on motor vehicles.

It is unlawful for any person to operate a motor vehicle which is not at all times equipped with a muffler upon the exhaust thereof in good working order and in constant operation to prevent excessive or unusual noise, and it is unlawful for any person operating any motor vehicle to use a cutout, bypass or similar muffler elimination appliance.

Sec. 7-68 – Penalties

(1) Individuals or businesses found to be in violation of the provisons of Article III, Noise Pollution ~~may~~shall be assessed fines as follows:

Number of Violations	M~~aximum~~inimum Fine
~~1~~	~~Warning~~
~~2~~1	$250.00
~~3~~2	$500.00
~~4~~3 or more	$999.00
~~Continuing~~	~~See Section 7-68 (2)~~

(2) In addition to the penalties for general violations of the City's municipal code set forth in Sec. 1-15 entitled "General penalty; continuing violations", or Sec. 7-68(1), a fourth or subsequent conviction for violating this Chapter 7 by a person licensed under Article 46, 47, or 48 of Title 12, Colorado Revised Statutes, generally referred to as the State Liquor Code, or by any employee or agent of such licensee, may be considered by the local liquor licensing authority as a violation of the "conduct of business" regulation of the state liquor code, currently set forth in Colorado Code of Regulations, 1 CCR 203-2, Regulation 47-900 entitled "Conduct of Establishment" and may be the basis for a suspension or revocation hearing for said liquor license, or for the non-renewal of said license."

Section 2. The City Council hereby finds, determines and declares that this ordinance is necessary for the immediate preservation of the public peace, health, and safety.

Section 3. That pursuant to Section 7-11 of the Charter of the City of Steamboat Springs, Colorado, the second publication of this ordinance may be by reference, utilizing the ordinance title.

Section 4. This ordinance shall take effect immediately upon the expiration of five (5) days from and after its publication following final passage, as provided in Section 7.6(h) of the Steamboat Springs Home Rule Charter.

Section 5. All ordinances heretofore passed and adopted by the City Council of the City of Steamboat Springs, Colorado, are hereby repealed to the extent that said ordinances, or parts thereof, are in conflict herewith.

Section 6. A public hearing on this ordinance shall be held on _______________, 2011, at 5:15 P.M. in the City Council Chambers at Centennial Hall, Steamboat Springs, Colorado.

INTRODUCED, READ AND ORDERED published, as provided by law, by the City Council of the City of Steamboat Springs, at its regular meeting held on the _____ day of ________________, 2011.

x____________________________________
Cari Hermacinski, President
Steamboat Springs City Council

____
Julie Franklin, City Clerk

FINALLY READ, PASSED AND APPROVED this ___ day of _____________, 2011.

x____________________________________
Cari Hermacinski, President
Steamboat Springs City Council

____
Julie Franklin, City Clerk

Comparison of Allowable Noise Levels in 14 Cities

City	**Point of Measurement**	**Residential**		**Commercial**	
		Day	Evening/Night	Day	Evening/Night
Aspen	Prop line of Impacted Prop	7:00AM – 9:00PM Res. 55dBA Lodging 60dBA	9:00PM – 7:00AM 50dBA 55dBA	7:00AM – 9:00PM 65dBA	9:00PM – 7:00AM 60dBA
Austin	Prop line of Source	10:00AM-10:00PM 75dBA	10:00PM-7:00AM Not allowed if audible to adj. property	10:00AM–2:00AM 85dBA Com. Recreation District 70dBA Restaurant 70dBA Outdoor Music 70dBA	2:00AM -10:00AM Not allowed if audible at property line
Boulder		7:00AM – 11:00PM 55dBA	11:00PM - 7:00AM 50dBA	7:00AM – 11:00PM 65dBA	
Breckenridge	Prop line of Source	7:00AM – 11:00PM 55dBA	11:00PM - 7:00AM 50dBA	7:00AM – 11:00PM 70dBA	11:00PM – 7:00AM 65dBA
Carbondale	Prop line of Source	7:00AM – 8:00PM Res. 60 db Lodging 60dB	8:00PM – 7:00AM Res. 55 db Lodging 55dB	7:00AM – 8:00PM 75dB	8:00PM – 7:00AM 60dB
Denver	Prop line of Impacted Prop	7:00AM-10:00PM 55dBA	10:00PM-7:00AM 50dBA	7:00AM-10:00PM 65dBA	10:00PM-7:00AM 60dBA
Durango	25' from Prop line of Source	To be determined by officer based on time of day, nature of source, type of neighborhood and disruptive effect.			
Park City	Prop line of Source	NA	NA	NA	10:00PM – 7:00AM Not permitted to be audible beyond prop. line of source

San Diego	Prop line of Source	7:00AM-7:00PM 55/60dBA	7:00PM-10:00PM 50/55dBA 10:00PM-7:00AM 45/50dBA	7:00AM-7:00PM 65dBA	7:00PM-10:00PM 60dBA 10:00PM-7:00AM 60dBA
Seattle	Prop line of Impacted Prop	7:00AM-10:00PM 55dBA	10:00PM-7:00AM 45dBA	7:00AM-10:00PM 60dBA	10:00PM-7:00AM 60dBA
Telluride	50 feet from building or source				9:00PM-7:00AM Plainly audible at 50’
Vail	Prop line of Source	7:00AM – 11:00 PM 55 dB	11:00PM – 7:00AM 50 dB	7:00AM – 11:00 PM 65 dB	11:00PM – 7:00AM 60 dB
Washington DC	Prop line of Source	7:00AM-9:00PM 60dBA	9:00PM-7:00AM 55dBA	7:00AM-9:00PM 65dBA	9:00PM-7:00AM 60dBA
Steamboat Springs	25’ from Prop line of Source	7:00AM – 7:00PM 55dBA	7:00PM – 7:00AM 55dBA	7:00AM – 7:00PM 60dBA	7:00PM – 7:00AM 55dBA

There is a great deal of consistency in limiting noise levels to the 55dBA-60dBA range during late evening hours. Some cities measure at the property line of the source, some at the property line of the impacted property, others at an arbitrary distance.

The Noise Manual, revised 5th edition, edited by E.H. Berger,
L.H. Royster, J.D. Royster, D.P. Driscoll, and M. Layne

15 Community Noise

Dennis P. Driscoll, Noral D. Stewart,
and Robert R. Anderson

Contents

Concepts in Community Noise

Introduction

There are historic references to noise being a problem in cities. In the 1920s, noise sources such as new modes of transportation, ventilation systems, industrial plants, and loudspeakers were becoming more common. The coming of jet aircraft renewed interest in environmental noise in the 1960s. In fact, transportation noise as a whole is a major source of community annoyance. However, this chapter will focus on sources the industrial hygienist can control, namely industrial noise.

In 1972 the United States Congress affirmed the growing danger that noise presents to the health and welfare of the nation's population, particularly in urban areas, through its Congressional finding and statement of policy (Anon., 1972). Over 25 years later this statement is being echoed by the recent formation of public action and awareness groups,[1] and the increased attention in the media to noise in our society. This attention has led to the call for rational environmental noise standards in local communities (Erdreich, 1998).

The primary reasons for limiting noise in the community are to reduce speech and/or sleep interference, and to limit annoyance. People are not usually annoyed if the sound is of the level and quality they expect in their community, and does not interfere with speech or sleep. A side effect of annoyance is stress that can affect some health conditions. Besides the physical effect on people, increased noise in a previously quiet community can change the value of property.

The quality of the sound and a community's characteristics also must be considered. Much depends on the existing conditions and expectations of the community. In densely populated areas, the emphasis is on controlling the overall growth of noise. However, in quieter, less densely populated areas, a new noise that might go undetected in a noisier community can become very noticeable and cause complaints. Often, in these quieter areas, the quality of the sound is as

[1] A clearinghouse of related information is available from the public awareness group at Noise Pollution Clearinghouse, Montpelier, VT, and through their website at www.nonoise.org.

important as the quantity. Unusual sounds such as discrete tones and impulsive sounds need more attention. Sometimes tones are masked near a source, but clearly audible in quieter areas farther away. The frequency content of sound changes with distance. A source with an acceptable spectrum nearby can sound like a rumble at greater distances. Sounds with strong low-frequency content require special attention (Berglund and Lindvall, 1995; Berglund et al., 1996). Most criteria for community noise based on overall sound levels measured outdoors assume a balanced sound spectrum. When there is strong low-frequency dominance, the sound can more easily penetrate homes. Thus, such sounds are more annoying indoors than a sound of similar overall level but balanced spectrum.

Congress intended that states and cities retain primary responsibility for control of community noise when it passed the Noise Control Act of 1972. This has resulted today in a diversity of noise regulations among local communities and states, as well as in many locations that lack any noise ordinances at all. The widely varying approaches to regulating noise in communities pose a significant challenge to companies that operate multiple facilities, and to the people charged with the responsibility to assess compliance with those regulations.

An industrial hygienist may need to evaluate community noise for several reasons:

- Compliance of noise produced by facilities operating in regions with local ordinances,
- Determination of acceptable noise levels and noise characteristics for new equipment,
- Evaluation of site suitability for a new facility,
- Resolution of complaints from neighbors.

Research on community noise has concentrated on sources related to transportation (airports, trains, highway and street traffic, etc.), military (aircraft low-level fly-overs, heavy vehicles maneuvering, firing ranges, etc.), and ventilation systems (outside air conditioners and blowers, noise from ventilation stacks, etc.). These sources are widespread, affect large areas, and there are readily available mechanisms to fund the research. This research has emphasized establishing acceptable quantities of sound for typical areas that are affected, and reducing sound accordingly. Less research is available on isolated and unique noise sources in quieter communities where the noise is unexpected. An industrial hygienist is most likely to be faced with noise from an industrial plant disturbing a few local neighbors. However, in some cases, distinctive or new sounds can annoy neighbors several kilometers away. In some circumstances people farther from the source can be more annoyed than those near it.

Measures of Noise in the Community

The basic noise measures or descriptors used in community noise are discussed in Chapter 3. These include the sound level, the *equivalent continuous sound level* ($L_{eq,T}$) (now called time-average sound level in most standards), and the sound exposure level (SEL). Overall sound levels for community noise are usually A-weighted. The C-weighted sound level is used in special circumstances related to impulsive noise. A 3-dB (equal-energy) exchange rate is always used for time-average sound levels. Octave-band or 1/3 octave-band levels are sometimes used to evaluate sound quality.

A long-term average sound level over a 24-hour period can be used to describe community noise. The *day–night average sound level* (DNL), symbolized as L_{dn}, has a 10-dBA night-time penalty added to all sound between 10:00 p.m. and 7:00 a.m. (Equation 15.1a). A variation of this adds an evening penalty of 5 dBA from 7:00 p.m. until 10:00 p.m. It is used primarily in California, where it is called the *community noise equivalent level* (CNEL). Communities with very different noise characteristics can have the same DNL. Without a strong local noise source, such as an airport, freeway, or industrial plant, the expected DNL in communities of at least 200 people per km^2 can be estimated using Equation 15.1b (EPA, 1974).

$$L_{dn} = 10 \log 1/24[15 \times 10^{(L_d/10)} + 9 \times 10^{(L_n+10)/10}] \text{ dBA} \quad (15.1a)$$

where, L_d is the equivalent-continuous sound level from 7 a.m. until 10 p.m.
L_n is the equivalent-continuous sound level from 10 p.m. until 7 a.m.

$$L_{dn} = 26 + 10 \log (\text{number of people/km}^2) \text{ dBA} \quad (15.1b)$$

Community sound levels are also sometimes analyzed using statistical measures. The sound level is sampled using a fast or slow time response, or sometimes very short samples of equivalent (time-average) sound level. The levels exceeded various percentages of time are calculated, with the results, which are called percentile levels, used to give an indication of the variation in the sound. The level exceeded 90% of the time is often used as a measure of the background sound present without transient or intermittent sounds. Many early regulations, before the widespread availability of averaging meters, were based on the sound level exceeded 10% of a measurement period. The number of samples measured should be at least 10 times the difference in decibels between the highest and lowest level.

United States Federal Government Guidelines and Regulations

Most United States federal guidelines for community noise are based on the DNL (EPA, 1974). The Environmental Protection Agency (EPA) recommended that DNL should be kept below 55 dBA in residential areas “to protect public health and welfare with an adequate margin of safety” (EPA, 1974). This level corresponds to that normally present in a typical suburban community of about 770 people per km^2. This goal did not consider economic or technological feasibility and was not intended as a regulation. The study recognized that many people lived in both quieter and noisier areas, including densely populated urban areas. It provided methods to evaluate problems and the potential for noise complaints based on DNL. These involved adjusting or normalizing the DNL for specific circumstances before comparing the DNL to criteria based primarily on expectations in densely populated urban areas.

The United States Department of Housing and Urban Development (HUD) has noise criteria for areas where it funds or finances housing (HUD, 1979). These recognize the need to build housing in densely populated areas where the desirable noise levels of DNL 55 cannot be achieved. They are based on surveys of the percentage of people highly annoyed by existing noise in areas where they live. Sound levels up to DNL 65 dBA are considered normally acceptable by HUD. Sound levels between DNL 65 and DNL 75 are normally unacceptable. However, housing can be funded when steps are taken to reduce the noise reaching the interior of homes. For single-family homes, there is often a requirement for barriers to reduce outside noise over DNL 70. The Department of Defense and Federal Aviation Administration also use DNL 65 as their regulatory goal. They do not recognize significant noise impacts from aircraft or military activities below this level. The Federal Highway Administration (FHA) uses a 1-hour equivalent (time-average) sound level criteria of 67 dBA to determine when to consider noise barriers for new highway projects. Before actually building barriers, the project has to further qualify based on the cost and benefit of the barrier per protected home.

DNL and normalized DNL work best to characterize the long-term acoustical character of a community as influenced by noise sources that are continually present as steady-state sounds or frequently occurring events over most of the day every day. DNL does not work well for infrequently occurring loud sounds that may be disturbing to a community without strongly affecting the long-term average sound level. Even the normalized DNL for continuous sounds may not always properly account for unique characteristics of the sound. For instance, the correction for discrete tone sounds may be insufficient (see *Assessment for Prediction of Community Response*). DNL also is not a practical measure for enforcement use by communities because of the long-term evaluations needed to establish it.

Local Noise Ordinances

Noise from industry and business in North America is regulated, if at all, primarily by local governments. There are state noise regulations in approximately 13 states; however, enforcement is often tenuous at best. Community ordinances can be classified as general nuisance ordinances or as a combination of nuisance and quantitative components. A nuisance ordinance is typically a prohibition of making or allowing to be made any unreasonable or excessive noise. Because this type of ordinance does not specify a sound level limit, compliance is a matter of satisfying subjective response by typically two or more listeners. Quantitative ordinances specify sound level limits and usually provide stronger legal control over undesirable sound levels than is attainable with an ordinance containing only nuisance provisions. However, these ordinances can vary greatly in the measurements required. They can range from a single not-to-exceed A-weighted sound level at a nonspecified location, to a matrix of source and receiver land-use categories with different limits for day and night and requirements for averaging or sampling over specified periods. Some also can contain octave or 1/3 octave-band criteria, or criteria to evaluate discrete-tone noises.

Quantitative ordinances usually require measurements over periods of less than an hour. The measurement method may be a simple A-weighted sound level, an equivalent (time-average) sound level, and/or a level exceeded 10% or 50% of the measurement period. If the measurement does not involve sampling or averaging, the regulation may have different limits depending on the duration of the noise. If the primary limit is based on levels exceeded 10% or 50% of the time, there is often a higher limit never to be exceeded. Sometimes the ordinance will only mention a level not to be exceeded using slow response. The limits in such cases are often too low for a sound of short duration or too high for continuous sounds.

The primary limits for sound entering residential areas are usually 55 to 60 dBA in the daytime, and 50 to 55 dBA at night as measured at the boundary or property line of the complainant. It is worth noting that some local ordinances impose limits on noise at the boundary of the source property. Sometimes, night-time limits are as low as 45 dBA especially in rural areas or less densely populated cities, and daytime limits are as high as 65 dBA especially in densely populated areas (EPA, 1975). Ordinances will usually allow higher levels for sound entering commercial or industrial properties. Sometimes, ordinances allow more noise entering residential areas from industrial properties than from other residential properties. The definition of daytime and night-time varies, but night is most commonly 10:00 p.m. until 7:00 a.m. Without access to expert advice, local governments sometimes set limits unreasonably high or low, or require instruments no longer available. Because conditions and expectations vary within different parts of most local jurisdictions, and the ordinances must usually be kept simple, they cannot prevent all problems. Sound levels that comply with the ordinance can still be objectionable to a portion of the population. It is particularly difficult to prevent problems from distinctive sounds like discrete tones without some complexity in the ordinance.

Voluntary Noise Measurement and Assessment Standards

Where there is no regulatory requirement, or when there are complaints in spite of regulatory compliance, the investigator must determine the best way to evaluate the noise. Sometimes, a voluntary standard developed by a national or international group such as the International Standards Organization (ISO) can help. Many countries (but not the United States) have adopted a three-part international standard for description and measurement of environmental noise which addresses (1) basic quantities and procedures (ISO, 1982), (2) acquisition of data pertinent to land use (ISO, 1987a, 1998), and (3) application to noise limits (ISO, 1987b).

In North America, the Acoustical Society of America develops American National Standards Institute (ANSI) standards related to community noise. Additional standards are also provided by the American Society for Testing and Materials (ASTM). The ANSI standards concentrate primarily on measurement and evaluation methods rather than setting specific criteria for acceptability based on those methods.

ANSI S12.9, *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound*, is a five-part standard which (in separate documents) addresses (1) descriptors for noise (ANSI, 1988), (2) measurement of long-term, wide-area sound (ANSI, 1992), (3) short-term measurements with an observer present (ANSI, 1993), (4) noise assessment and prediction of long-term community response (ANSI, 1996), and (5) sound level descriptors for determination of compatible land use (ANSI, 1998). Part Four provides adjustments to measured sound levels for certain sound characteristics such as tonality and impulsiveness. Note that long-term community response and land-use compatibility are best used as indicators of acceptance of existing noise by people who choose to live with it. They may not indicate the reaction of an existing community to a new noise. The land-use compatibility and community-response criteria assume noises without characteristics such as tonality, impulsiveness, low-frequency dominance, or clearly heard speech or music.

ASTM E1686 *Standard Guide for Selection of Environmental Noise Measurements and Criteria* (ASTM, 1996a) discusses additional methods to measure and evaluate community noise which are not covered in this chapter. Other ASTM standards include the guide E1014 for measuring sound levels using simple instruments (ASTM, 1984), guide E1780 for measuring outdoor sound received from a nearby fixed source (ASTM, 1996c), and guide E1779 for preparing a measurement plan for conducting outdoor sound measurements (ASTM, 1996b). ASTM E1503 *Standard Test Method for Conducting Outdoor Sound Measurements Using a Digital Statistical Analysis System* (ASTM, 1992) provides a detailed method for using sophisticated instruments in major studies.

Sometimes the sound emitted by a source must be established to allow calculation of the sound expected at a distant location. Standards for individual sources include ANSI/ASTM PTC 36 (ASME, 1985), ANSI S12.34 (ANSI, 1997a), and ANSI S12.36 (ANSI, 1997b). ISO 8297 (ISO, 1994) provides a method to determine the sound emission of multi-source industrial plants.

Factors Other Than Absolute Sound Level Influencing Community Reaction to Noise

Most noise regulations are based on sound level, possibly with lower limits at night or penalties for sounds with tonal or impulsive characteristics. However, research indicates many important factors influence community reaction and annoyance produced by noise. Those identified by the EPA (1974) were:

- Frequency content of the noise,
- Duration of the noise,
- Time of day the noise occurs,
- Time of year the noise occurs,
- History of prior exposure to the noise source,
- Perceived attitude of the noise source owner,
- Special characteristics of the noise that make it especially irritating,
- Ratio of intruding noise level to normal background noise level.

Other studies have identified additional factors that are very much related to community reaction and annoyance. These include whether the complainant believes s/he is being ignored or treated unfairly, or perceives the noise as:

- Unnecessary, or unnecessarily loud,
- A threat to personal health or safety,
- A threat to economic investment (property value),
- Beyond his or her control.

A most important factor is the difference in sound level between a new noise and other expected and existing noise in the neighborhood. The most significant finding of the EPA community reaction studies (EPA, 1974) was that widespread complaints and legal actions are likely when the average level of nondistinctive noise from a single source is regularly more than 5 dB above the average level of other existing sounds in the community. Vigorous community action results for differences of 20 dB. Some noises such as discrete tones are more irritating or difficult to ignore because of the way they sound. People expect not only quiet, but a pleasant sound quality if sound is audible. These unpleasant and distinctive sounds often cause complaints if they are detectable at any level. The acoustical designers of vehicles, appliances, and other products today spend much of their effort on “sound quality.” Some common industrial sources such as high-pressure or material-handling fans or positive-displacement blowers produce strong discrete tones. Power presses can produce repetitive impulsive sounds. Speech and music have information content that makes them difficult to ignore. These factors affect the quality of the sound in the community even at otherwise acceptable levels.

Factors and Conditions Affecting Sound Propagation Outdoors

As sound propagates outdoors it generally decreases in magnitude with increasing distance from the source; however, the attenuation is not totally a function of spherical divergence. There are several meteorological and physical conditions that affect the rate of attenuation. The meteorological conditions include variations in air temperature with increased elevation, relative humidity, wind speed and direction, and atmospheric factors such as cloud coverage. The physical effects include topography, natural and artificial barriers, and vegetation.

Often a primary question one needs to answer is what will be the effect on community noise when an industrial plant is built, expands, or adds new equipment outside the building, or a residential subdivision encroaches upon the facility’s property line? To answer this question it is important to know what factors affect outdoor sound propagation, and how to estimate attenuation to select locations. ANSI S12.18, *American National Standard for Outdoor Measurement of Sound Pressure Level (SPL)* describes procedures for outdoor sound measurement, including a discussion of the attenuation effects due to the various elements mentioned above (ANSI, 1994). This standard is useful, not only for measurement procedures, but also for estimating SPLs at different locations from the source. For sound radiating from a point source in a free field (directivity factor, Q=1), the SPL per octave band at a given distance may be calculated from:

$$L_p = L_W - A_{total} - 10.9, \text{ dB} \tag{15.2}$$

where,

- L_p = the octave-band sound pressure level, in dB, at the location of interest,
- L_W = the octave-band sound power level (PWL) of the source, in dB, and
- A_{total} = the total attenuation at each octave band, in dB.

The total attenuation (A_{total}) for each octave band in Equation 15.2 is calculated by:

$$A_{total} = A_{div} + A_{air} + A_{env} + A_{misc}, \text{ dB} \tag{15.3}$$

where,

- A_{div} is the attenuation due to geometrical divergence,
- A_{air} is the air absorption,
- A_{env} is the sound reduction due to the effects of the environment, and
- A_{misc} is the attenuation resulting from all other factors, such as foliage, barriers, etc.

Because high-frequency sounds have relatively short wavelengths their sound energy will decrease rapidly with increasing distance due to atmospheric absorption. Conversely, low-frequency sounds with much longer wavelengths will often carry several kilometers from the source and are usually the cause of complaints from citizens. This variation by frequency must be accounted for when calculating the total attenuation. Once the individual attenuation values are known for each octave band, they can be logarithmically added together using Equation 2.11, and the resultant value may be used in Equation 15.2 along with the known PWL to estimate the SPL (see example problem presented later in this chapter).

Geometrical Divergence (A_{div})

Geometrical divergence, often termed spreading losses, occurs as sound waves propagate and expand from a source, and in turn become less intense as they dissipate over larger spherical areas. The divergence is not a function of frequency, and attenuation is estimated by:

$$A_{div} = 20 \log (r/r_0), \text{ dB} \tag{15.4}$$

Where,

r = distance from the point source in meters (m), and

r_0 = reference distance of 1 m.

For distances far from the source, the geometrical divergence results in a 6-dB decrease per doubling of distance from a point source, which equates to a 20-dB decrease for each tenfold increase of distance. For a line source, such as a busy highway or long runs of noisy pipelines stretching perpendicular to the measurement location (e.g., a petrochemical plant), the geometrical divergence will be 3-dB decrease per doubling of distance.

Air Attenuation or Atmospheric Absorption (A_{air})

Sound energy decreases in a quiet calm atmosphere by two mechanisms: (1) heat conduction and viscosity in the air, and (2) relaxation of air molecules as they vibrate (Kurze and Beranek, 1988). The atmospheric absorption losses depend on frequency, temperature, and relative humidity. Of these three factors, relative humidity is the dominant variable, followed by the frequency and then the temperature.

For various temperatures the attenuation due to air absorption may be determined by (Piercy and Daigle, 1991):

$$A_{air} = \alpha' r/1000 \text{ dB} \tag{15.5}$$

where,

α' = the air attenuation coefficient, dB/km, and

r = distance from source to receiver, m.

The air attenuation coefficient values are presented in Table 15.1 for various temperatures and relative humidity, as a function of frequency (ANSI, 1994). Should temperature and humidity values differ from those presented in Table 15.1, interpolation may be used to estimate the air attenuation coefficients. Calculations employing Equation 15.5 reveal that air attenuation becomes significant at distances over 300 m and frequencies above 1000 Hz. For example, at 20°C and relative humidity of 70%, the attenuation at 1000 Hz is 5.0 dB/km. At 200 meters this amounts to an attenuation of 1.0 dB. However, at 2 km the attenuation is a significant 10 dB. For dry air with a relative humidity of 10%, these attenuation values are 2.8 dB and 28 dB for 200 m and 2 km, respectively. For the same 10% relative humidity at 20°C, at a distance of 2 km using the absorption coefficients at 250 Hz and 2000 Hz, these attenuation values are 3.2 dB and 90 dB, respectively. Clearly, as distance from the source increases, there is a significant increase in sound attenuation at the higher frequencies with a relatively small increase at the lower frequencies (see Table 15.1).

TABLE 15.1
Air attenuation coefficients ∝′, at 1 atmosphere for sound propagation in open air (db/km).*

Temperature	Relative Humidity (Percent)	Octave-Band Frequency (Hz) 125	250	500	1000	2000	4000
	10	0.96	1.8	3.4	8.7	29	96
	20	0.73	1.9	3.4	6.0	15	47
30°C	30	0.54	1.7	3.7	6.2	12	33
(86°F)	50	0.35	1.3	3.6	7.0	12	25
	70	0.26	0.96	3.1	7.4	13	23
	90	0.20	0.78	2.7	7.3	14	24
	10	0.78	1.6	4.3	14	45	109
	20	0.71	1.4	2.6	6.5	22	74
20°C	30	0.62	1.4	2.5	5.0	14	49
(68°F)	50	0.45	1.3	2.7	4.7	9.9	29
	70	0.34	1.1	2.8	5.0	9.0	23
	90	0.27	0.97	2.7	5.3	9.1	20
	10	0.79	2.3	7.5	22	42	57
	20	0.58	1.2	3.3	11	36	92
10°C	30	0.55	1.1	2.3	6.8	24	77
(50°F)	50	0.49	1.1	1.9	4.3	13	47
	70	0.41	1.0	1.9	3.7	9.7	33
	90	0.35	1.0	2.0	3.5	8.1	26
	10	1.3	4.0	9.3	14	17	19
	20	0.61	1.9	6.2	18	35	47
0°C	30	0.47	1.2	3.7	13	36	69
(32°F)	50	0.41	0.82	2.1	6.8	24	71
	70	0.39	0.76	1.6	4.6	16	56
	90	0.38	0.76	1.5	3.7	12	43

*Note: Air attenuation coefficient values of temperature and relative humidity (or frequency) intermediate to those shown in the table may be obtained by interpolation.
Source: From ANSI S12.18-1994: “Outdoor Measurement of Sound Pressure Level,” with permission.

Attenuation Due to Environmental Effects (A_{env})

In addition to divergence and air absorption, sound propagating from a source is also attenuated by the environment, such as the ground, wind, and temperature gradients. Figure 15.1 illustrates the propagation path from source to receiver. The magnitude of the reflected sound will depend upon the type of ground surface, the angle of incidence (ψ), and frequency (Piercy and Daigle, 1991). ANSI S12.18 classifies ground surfaces for grazing angles less than 20° as follows (ANSI, 1994):

- *Hard Ground*—Open water, asphalt, or concrete pavement, and other ground surfaces having very low porosity tend to be highly reflective, absorbing very little acoustic energy upon reflection. Tamped ground, for example, as often occurs around industrial sites, can be considered as hard ground.

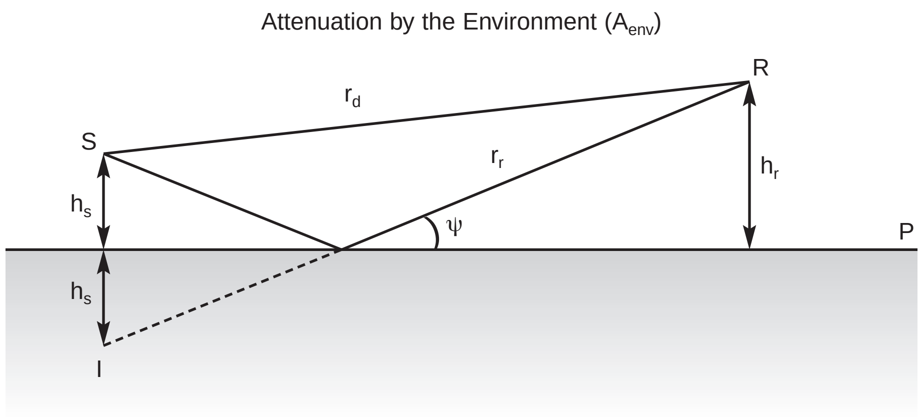


Figure 15.1 — Paths for propagation from source S to receiver R. The direct ray is r_d, and the ray reflected from the plane P (which effectively comes from image source I) is r_r, whose length is measured from plane P to R. Source: From Piercy and Daigle (1991), with permission.

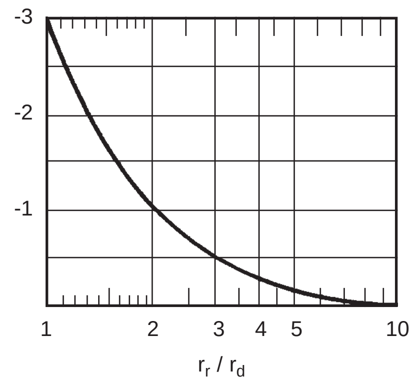
- *Soft Ground*—Ground covered by grass, shrubs, or other vegetation, and all other porous grounds suitable for the growth of vegetation such as farming land.
- *Very Soft Ground*—New-fallen snow is even more absorptive at low frequencies than grass-covered ground, as is ground covered in pine needles or similarly loose material. It is recommended by ANSI that measurements above snow-covered ground be avoided unless operation of the sound source is intimately tied with the ground condition.
- *Mixed Ground*—A ground surface which includes both hard and soft areas.
- *At angles off the ground greater than 20°*, which can commonly occur at short ranges or in the case of elevated sources, soft ground becomes a good reflector of sound and can be considered hard ground.

Sound outdoors reaches a receiver by both direct and reflected paths. For distances of approximately 100 m or less, termed short-range propagation, the attenuation values are primarily due to ground effects and the presence of any barriers. Table 15.2 presents the attenuation values at each octave band from 125 – 4000 Hz for hard, soft, and very soft ground surfaces. For mixed ground conditions the attenuation values will need to be calculated for both hard and soft surface areas. A_{env} then becomes the value interpolated between these two results based on the proportion of soft to hard ground.

For distances over 100 m, termed long-range propagation, the wind and temperature conditions will play an important role, while barriers and ground effects have minimal influence. The effects of wind and temperature on sound transmission are described later in this chapter; however, for purposes of determining the long-range attenuation of sound these conditions should be assumed to be

TABLE 15.2
Values of environmental attenuation A_{env} in decibels for short-range propagation [r < 100 m (300 ft)].*

Hard ground (asphalt, concrete)

$(r_r - r_d) \ll$ all λ	$(r_r - r_d) \gg$ all λ
– 6.0	

Soft ground (grass, vegetation), h_r *= 1.8 m*

Source Height (m)	*Distance (m)*	*Frequency (Hz)* 125	250	500	1000	2000	4000
0.01	10	- 5.7	- 5.0	- 3.6	- 1.4	1.1	4.1
	20	- 5.6	- 4.6	- 1.8	1.9	5.1	8.5
	40	- 5.5	- 3.9	- 1.4	6.7	10.1	13.7
	60	- 5.4	- 3.3	4.2	9.8	13.2	16.9
	80	- 5.4	- 2.7	6.8	12.2	15.5	19.3
	100	- 5.3	- 2.2	9.2	14.0	17.4	21.1
0.3	10	-5.4	- 4.3	- 0.9	5.9	- 2.5	- 1.9
	20	- 5.4	- 4.0	- 0.1	6.3	- 0.1	- 3.0
	40	- 5.4	- 3.4	2.9	10.2	4.1	- 2.9
	60	- 5.3	- 2.8	5.8	13.1	7.1	- 0.4
	80	- 5.2	- 2.2	8.4	15.3	9.3	1.7
	100	- 5.2	- 1.7	10.8	17.1	11.1	3.4
1.2	10	- 4.0	2.0	0.1	- 3.0	- 3.0	- 3.0
	20	- 4.8	- 1.9	7.5	- 2.7	- 3.0	- 3.0
	40	- 4.9	- 2.1	6.9	0.5	- 3.0	- 3.0
	60	- 4.9	- 1.6	9.1	2.9	- 3.0	- 3.0
	80	- 4.8	-1.0	11.6	4.8	- 2.8	- 3.0
	100	- 4.8	- 0.5	13.8	6.4	- 1.5	- 3.0

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*Note: Refer to Figure 15.1 for illustration of r_d and r_r, which are the paths for sound wave propagation from source to reviewer.
Source: From Piercy and Daigle (1991), with permission.

TABLE 15.2 — continued
Values of environmental attenuation A_{env} in decibels for short-range propagation [r < 100 m (300 ft)].*

Very soft ground (snow, pine forest), h_r *= 1.8 m*							
Source	*Distance*	*Frequency (Hz)*					
Height (m)	*(m)*	*125*	*250*	*500*	*1000*	*2000*	*4000*
0.01	10	- 3.1	0.8	3.9	6.0	7.3	7.0
	20	- 1.5	5.2	8.6	10.9	12.3	11.9
	40	1.4	11.1	14.0	16.3	17.7	17.3
	60	3.9	14.8	17.3	19.6	21.0	20.7
	80	6.2	17.3	19.7	22.0	23.4	23.1
	100	8.4	19.3	21.6	23.8	25.3	24.9
0.3	10	- 2.3	2.8	5.0	- 0.8	- 3.0	- 3.0
	20	- 0.8	7.0	9.1	2.9	- 2.9	- 3.0
	40	2.0	12.8	14.2	7.9	1.4	- 3.0
	60	4.6	16.5	17.5	11.2	4.5	- 1.3
	80	6.9	19.0	18.2	13.5	6.8	0.8
	100	9.1	21.0	21.7	15.4	8.6	2.6
1.2	10	0.1	4.5	- 2.5	- 2.5	- 2.5	- 2.5
	20	0.9	7.0	- 0.7	- 3.0	- 3.0	- 3.0
	40	3.6	11.6	3.3	- 3.0	- 3.0	- 3.0
	60	6.3	14.8	6.3	- 0.6	- 3.0	- 3.0
	80	8.7	17.1	8.5	- 1.5	- 3.0	- 3.0
	100	10.9	18.9	10.3	3.2	- 2.6	- 3.0

*Note: Refer to Figure 15.1 for illustration of r_d and r_r, which are the paths for sound wave propagation from source to reviewer.
Source: From Piercy and Daigle (1991), with permission.

advantageous to sound propagation. Toward long-range propagation, the distance between source and receiver is divided into three zones, as depicted in Figure 15.2. The environmental factor for each zone is as follows (Piercy and Daigle, 1991):

1. The *source zone* covers a distance of $30h_s$ between the source and receiver (see Figure 15.2), with a maximum of r, where h_s is the source height and r is the distance from the source S to receiver R.

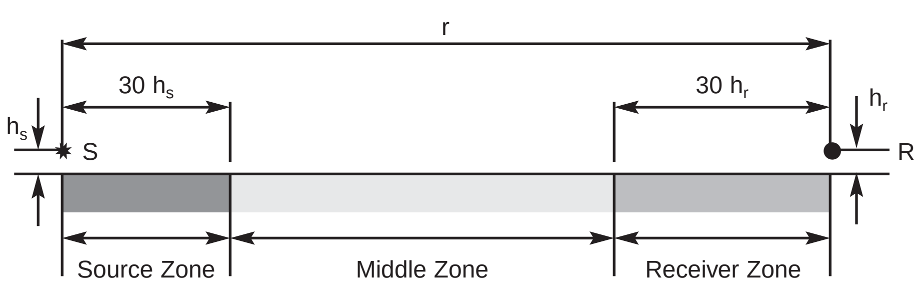

Figure 15.2 — Three zones between a source *S* and receiver *R* separated by distance *r*, used in determining the ground attentuation A_{env} at long ranges.
Source: From Piercy and Daigle (1991), with permission.

2. The *receiver zone* starts at the receiver and stretches back a distance of 30 h_r, with a maximum of r, where h_r is the receiver height.
3. The *middle zone* covers the region between the source and receiver zones.

The surface area around each zone has the following *ground factor* G:
Hard ground: G = 0,
Soft ground: G = 1,
Mixed ground: G equals the fraction of the ground that is soft.
Note: For very soft ground there is no available value. However, it is suggested a value of 1 be used. The user is cautioned that using a factor of 1 for very soft ground will underestimate the actual ground attenuation, particularly in the lower frequency range from 100 – 500 Hz.

For the octave-band environmental attenuation values at long-range, Table 15.3 is utilized as follows:

TABLE 15.3
Expressions to be used in calculating the octave-band environmental attenuation (A_{env}) in decibels at long range.*

Octave-Band Frequency (Hz)	A_s *and* A_r *(dB)*	A_m *(dB)*
63	- 1.5	- 3e
125	(*a*)(*G*) - 1.5	- 3e(1 - *G*)
250	(*b*)(*G*) - 1.5	- 3e(1 - *G*)
500	(*c*)(*G*) - 1.5	- 3e(1 - *G*)
1000	(*d*)(*G*) - 1.5	- 3e(1 - *G*)
2000	(*1* - *G*)(- 1.5)	- 3e(1 - *G*)
4000	(*1* - *G*)(- 1.5)	- 3e(1 - *G*)
8000	(*1* - *G*)(- 1.5)	- 3e(1 - *G*)

	Source or Receiver Height (m)				
Distance r(m)	*0.5*	*1.5*	*3.0*	*6.0*	*> 10.0*
Factor a					
50	1.7	2.0	2.7	3.2	1.6
100	1.9	2.2	3.2	3.8	1.6
200	2.3	2.7	3.6	4.1	1.6
500	4.6	4.5	4.6	4.3	1.6
> 1000	7.0	6.6	5.7	4.4	1.7
Factor b					
50	6.8	5.9	3.9	1.7	1.5
100	8.8	7.6	4.8	1.8	1.5
> 200	9.8	8.4	5.3	1.8	1.5

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*G is the ground factor, h is height, and r is distance from source to receiver. The subscripts s, r, and m indicate source, receiver, and middle zones, respectively. (See Figure 15.2.) The factor e is equal to $\{1 - [30(h_s + h_r)/r]\}$.
Source: From Piercy and Daigle (1991), with permission.

TABLE 15.3 — continued
Expressions to be used in calculating the octave-band environmental attenuation (A_{env}) in decibels at long range.*

	Source or Receiver Height (m)				
Distance (m)	***0.5***	***1.5***	***3.0***	***6.0***	***> 10.0***
Factor c					
50	9.4	4.6	1.6	1.5	1.5
100	12.3	5.8	1.7	1.5	1.5
> 200	13.8	6.5	1.7	1.5	1.5
Factor d					
50	4.0	1.9	1.5	1.5	1.5
> 100	5.0	2.1	1.5	1.5	1.5

*G is the ground factor, h is height, and r is distance from source to receiver. The subscripts s, r, and m indicate source, receiver, and middle zones, respectively. (See Figure 15.2.) The factor e is equal to $\{1 - [30(h_s + h_r)/r]\}$.
Source: From Piercy and Daigle (1991), with permission.

Step 1: Determine A_s, which is the source zone attenuation portion of A_{env}, using the appropriate ground factors,
Step 2: Determine A_r, which is the receiver zone attenuation portion of A_{env},
Step 3: Calculate A_m, which is the middle zone attenuation portion of A_{env}. Note: for the middle zone to exist, $r > 30(h_s + h_r)$ must be satisfied,
Step 4: The total A_{env} in any octave band will be:

$$A_{env} = A_s + A_r + A_m \quad (15.6)$$

EXAMPLE 15.1, Predicting Sound Levels at the Property Line

Consider the following example:

Management of a manufacturing plant plans an expansion that will include a large gas turbine located in the center of a 20 m × 20 m concrete skid or pad outside the new building structure. It is anticipated the turbine's exhaust will be a dominant source of noise and could significantly impact a residential area located at the facility's property line 1450 meters away. The point of the turbine discharge is 3 m above grade and the receiver height is 1.5 m. The ground surface area around the concrete skid and at the receiver is grass, while the ground cover between the source and receiver zones is 75% grass and 25% asphalt parking lot. Finally, there is no foliage or trees between the source and receiver locations. To investigate whether a potential community noise problem will result, it is necessary to estimate the overall A-weighted sound level at the property line. The turbine manufacturer reports the following exhaust sound power levels per octave band:

Octave-band center frequency (Hz):	125	250	500	1000	2000	4000
Exhaust L_W (dB):	144	145	144	138	137	134

Equation 15.2 is used to calculate the SPL at the location of interest, however, Equation 15.3 is needed to first determine the total attenuation (Recall $A_{total} = A_{div} + A_{air} + A_{env} + A_{misc}$). Note: many of the attenuation factors are frequency-dependent. For purposes of this example and to demonstrate use of the equations and tables, *all values will be estimated for 250 Hz.*

Step 1: Use Equation 15.4 to predict A_{div}, the attenuation due to divergence

$A_{div} = 20 \log r/r_0$

$= 20 \log (1450/1) = 63.2$ dB

Step 2: Calculate the A_{air} value using Equation 15.5 and Table 15.1. For calculation purposes assume the temperature is 20°C with a relative humidity of 70%. From Table 15.1 at 250 Hz for the given temperature and relative humidity, the attenuation coefficient is 1.1 dB/km. Therefore, the A_{air} at this frequency is:

$A_{air} = \alpha' r/1000 = (1.1)(1450)/1000 = 1.6$ dB

Step 3: Calculate the environmental attenuation using Equation 15.6 and Table 15.3. Recall that Equation 15.6 is:

$A_{env} = A_s + A_r + A_m$ dB

The first term to determine is A_s:

For the source zone: $30h_s = (30)(3) = 90$ m,

Next, from Table 15.3 at 250 Hz:

$A_s = (b)(G) - 1.5$ dB

Note: Since the proposed turbine is to be located in the center of a 20 m × 20 m concrete skid, 10 m of the source zone is classified as "hard," and the remaining 80 m is grass or "soft." Thus, the ground factor G is:

$G = (90 - 10)/90 = 0.89$

Therefore, using Table 15.3:

$A_s = (b)(G) - 1.5 = (5.3)(0.89) - 1.5 = 3.2$ dB

Note: b = 5.3 at 250 Hz, which is given in the table.

The second term to calculate is A_r:

Here for the receiver zone: $30h_r = (30)(1.5) = 45$ m,

From Table 15.3 at 250 Hz:

$A_r = (b)(G) - 1.5$ dB

Since the receiver is located on grass, the ground is considered "soft" and G = 1. Therefore,

$A_r = (b)(G) - 1.5 = (8.4)(1) - 1.5 = 6.9$ dB

Note: b = 8.4 at 250 Hz, which is given in the table.

The final component to determine is the middle zone. Recall for A_m to exist the expression

$r > 30(h_s + h_r)$ must be satisfied. In this example, r = 1450, and

$1450 > 30(3 + 1.5) = 135$ is satisfied.

Therefore, from Table 15.3 at 250 Hz:

$A_m = -3e(1 - G)$ dB, where $e = \{1 - [30(h_s + h_r)/r]\}$

Now, $e = \{1 - [30(3 + 1.5)/1450]\} = 0.91$

and,

$A_m = -3(0.91)(1 - 0.75) = -0.7$ dB

Note: G = 0.75 since 75% of the ground cover in the middle is grass.

Finally, sum up each term to get A_{env}:

$A_{env} = A_s + A_r + A_m$ dB

$= 3.2 + 6.9 - 0.7 = 9.4$ dB

Step 4: Since there is no interfering foliage or trees to provide additional attenuation, A_{misc} is zero.

Step 5: Determine the total attenuation at 250 Hz from Equation 15.3: $A_{total} = A_{div} + A_{air} + A_{env} + A_{misc} = 63.2 + 1.6 + 9.4 = 74.2$ dB

Step 6: Use Equation 15.2 to calculate the L_p at this frequency:

$L_p = L_W - A_{total} - 10.9$ dB

$= 145 - 74.2 - 10.9 = 59.9$ dB

Step 7: Find the A-weighted sound level for the 250-Hz octave band: The sound level for the 250-Hz band is 59.9-8.6 = 51.3 dBA. Note: the -8.6 value is the conversion factor at 250 Hz when going from linear SPL to A-weighting (see Table 3.1).

Step 8: Repeat steps 1–7 for all other frequencies of concern, then use Equation 2.11 to logarithmically add all A-weighted octave-band values to calculate the overall A-weighted sound level at the property line. Completing steps 1–7 for 125, 500, 1000, 2000, and 4000 Hz, yields A-weighted octave-band values of 45.3, 58.3, 56.9, 52.0, and 28.4 dBA, respectively. Then inputting these data into Equation 2.11, including 51.3 dBA at 250 Hz, results in an estimated overall sound level of 62 dBA. As discussed previously, many local noise ordinances limit sound entering residential areas to 55–60 dBA during daytime hours and 50–55 dBA at night; therefore, it is likely that a sound level of approximately 62 dBA will be unacceptable according to the local noise ordinance, as well as in the perception of the neighbors.

Effects of Wind and Temperature

Sound wave propagation follows a predictable model in a still environment. However, sound will not conform to any predictable pattern in windy conditions. As temperature changes occur, there is a corresponding change in the speed of sound as follows:

$$c = c_o \sqrt{\frac{T}{T_o}} \quad \textbf{(15.7)}$$

Where,

c = speed of sound
T = temperature (K° or R°)
c_o = speed of sound in air at reference temperature T_o

It is a natural phenomenon that temperature usually decreases with increasing elevation during daytime hours, and increases with elevation at night. Under normal daytime conditions, the velocity of sound is greatest at lower elevations, and sound waves bend or refract upward as depicted in Figure 15.3. This often results in a shadow zone near the ground, and the attenuation significantly increases with distance. This additional sound reduction will typically be 10–20 dB or more above the expected attenuation due to ground effects.

Figure 15.4 exhibits the sound spreading pattern that occurs during temperature inversions when the temperature increases with elevation. This condition is more common at night due to radiation cooling of the ground, and during sunrise and sunset. Since the speed of sound is faster in warmer upper layers of air,

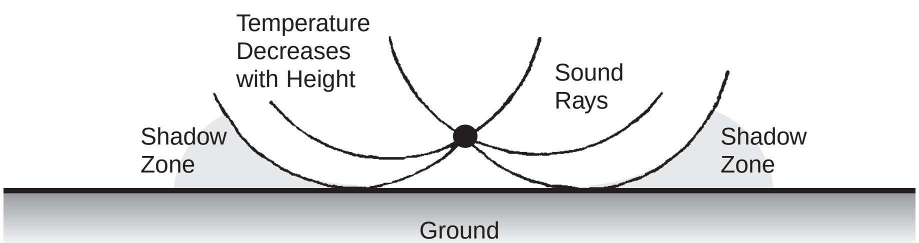

Figure 15.3 — Wave propagation during daytime.

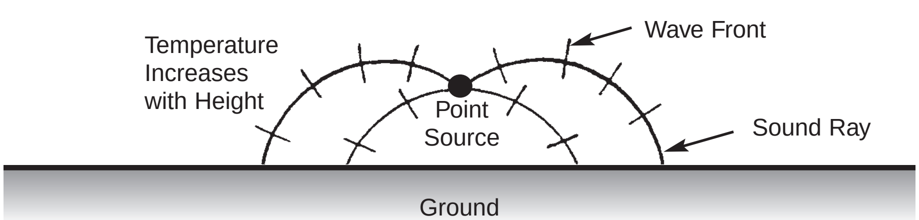

Figure 15.4 — Wave propagation during inversion.

sound waves will actually bend downward as they propagate from the source. This condition results in little to no attenuation due to the environment for several hundred meters, and produces a favorable condition for sound propagation.

Figure 15.5 illustrates how sound wave propagation behaves with wind gradients. As sound extends upwind, the spreading waves refract upward and create a shadow zone with excess attenuation near the ground. Because of this condition, it is not recommended that sound level measurements be conducted upwind of the source. On the other hand, as sound radiates downwind, the waves bend downward resulting in a condition advantageous to propagation. This explains why sound levels downwind of a noise source are more easily detected or heard as compared to the listening conditions upwind. Consequently, it is recommended that measurements be conducted downwind of the source.

One other phenomenon that often occurs is sound traversing large distances. Since spreading patterns for sound will vary or fluctuate with increased elevation, wind, and temperature, it is common to hear or detect sound as a warble or intermittent event several kilometers away. This is especially true for low-frequency sounds, such as a locomotive horn, or an outside warning alarm at an industrial facility.

Miscellaneous Attenuation Effects (A_{misc})

Attenuation of sound resulting from rain, dense fog, and falling snow is practically zero. Therefore, these conditions may be ignored, with the possible exception of snow-covered ground that may change the classification of the ground-surface rating as described previously. For the most part, these conditions affect other environmental factors such as altering the wind and temperature gradients, which are accounted for when calculating the air and environmental attenuation values.

A common misconception is that a few rows of trees can be planted along the property line to help reduce community noise. While it is true that trees often block the visual line of sight to the source, and as a result provide a psychological noise-reduction benefit, in reality a series of trees a few meters deep is acoustically transparent and provides no measurable attenuation. Table 15.4 presents the attenuation due to sound propagation through foliage, such as trees

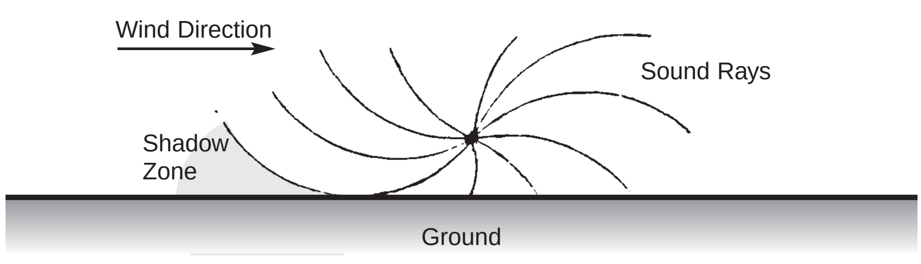

Figure 15.5 — Wave propagation with wind.

TABLE 15.4
The attenuation due to propagation through foliage, such as trees and bushes.

	Octave-Band Center Frequency (Hz)								
	31.5	63	125	250	500	1000	2000	4000	8000
A_{misc} (dB/m)	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.08	0.12

Source: From Piercy and Daigle (1991), with permission.

and bushes. The type of tree, density of planting, and noise source characteristics are the controlling factors toward their acoustical benefit. A good rule of thumb is that for the first 100 m of dense forest, the average attenuation will be approximately 4–8 dBA provided both the source and receiver are within, or relatively close to, the trees. For distances greater than 100 m, no rule of thumb applies, however, a more detailed discussion of this issue may be found in Piercy and Daigle (1991).

Measuring Community Noise

A person measuring community noise must often comply with the requirements of appropriate ordinances and standards. The referenced standards provide technical guidelines, some of which are discussed briefly in this section. The measurement guidelines should match the goal of the sound survey. Some standards require that measurements be conducted under the most favorable weather and physical conditions for sound propagation. This requirement ensures that data are collected during sound propagation conditions that typically correspond to a majority of complaints from neighbors. However, the goal of many community noise measurements is to document noise in the community for various propagation conditions.

Factors that Influence Community Noise Measurement

Seasonal factors, weather, measurement locations, and source operating parameters are all conditions that will affect community noise measurement results. These factors should be identified during the planning of the measurement process, and should be accounted for to the greatest degree practical.

Seasonal Factors Affecting Sound Present in a Community

Seasonal variations in plant, insect, and wildlife conditions can influence the sound present. Suppose the distance between the source and receiver is less than 100 m and heavily forested with deciduous trees. Sound levels from the source reaching the receiver could be much less in the summer than the winter. Insects and wildlife produce sound that will significantly influence sound measurements. In some cases, almost steady sound from insects, tree frogs, or large flocks of wild birds can dominate the overall A-weighted sound level.

Intermittent bird sounds can be eliminated by measuring percentile levels. Frequency analysis is essential when the overall level is dominated by steady, high-frequency insect sounds. It is not unusual in some places for insect sounds to exceed the limits of local ordinances for several hours, especially at night. However, this high-frequency insect noise does not mask annoying noises with lower spectral content.

Monitoring and Documenting Meteorological Conditions

Weather has a major effect on the propagation of sound as described previously. Therefore, weather conditions must be monitored and documented for community noise measurements.

- Wind speed and direction should be monitored directly at the measurement site and documented. Measurements should be avoided when wind speeds approach 19 kph (5 meters per second, 12 mph). For low SPLs or low-frequency sound, even winds more than 10 kph can cause problems. One problem is wind interaction with the microphone. Therefore, a windscreen should always be used to minimize this problem. Sound levels radiated from sources at considerable distances in the presence of high wind speeds may be highly variable and not representative of conditions with lesser wind.
- Ambient air temperature, relative humidity, barometric pressure and cloud cover corresponding to time of measurement should be recorded. These data are typically available via radio or the Internet from a nearby meteorological station, usually located at an airport.
- Measurements should not be conducted during measurable precipitation or thunder, since these conditions will artificially raise the background sound level, as well as potentially affect the performance of the acoustical instrumentation.
- Recognize that snow cover or water-saturated ground can influence results (see *Attenuation Due to Environmental Effects*).

Measurement Location

Measurement location factors directly influence measurement results. They include distance from the source, topography, ground surface cover, and reflective surfaces. Locations of measurement sites should be documented on a scaled map to permit estimation of distance from the source as well as to facilitate repeat measurements. The following factors should be noted and considered in the selection of the measurement sites.

- Topography and elevation changes affecting line-of-sight to the source are factors to consider in selection of measurement location(s).
- Measurements over large paved areas should be avoided unless the goal is specifically to document the sound level at such areas.
- Large reflecting surfaces such as buildings will influence sound levels. The locations of such surfaces should be carefully documented. If the goal is to obtain data easily related to the output of a source, measurements should be avoided near such surfaces. In such cases, measure at least

7.5 m and preferably 15 m from such surfaces. However, the goal of community noise measurements is often to measure sound at and near a home. In those cases, measurements are appropriately made at locations near the home with documentation of reflecting surfaces. It is a good survey procedure to locate the microphone at least 1.5 m from smaller objects such as trees, posts, bushes, etc., if possible.

Source Conditions

The operating conditions of the source also influence measurement results. The operating conditions desired for testing should be selected and documented. This may include particular production or process conditions correlated to the time of measurement. When measurements are made far from a source, simultaneous measurements near the source are advisable, especially if source output is variable.

Measurement Protocol

Site Selection

Selecting a measurement location will depend upon the purpose of the sample. If the goal is to assess the sound reaching a specific location at a specific time, then the terrain must be accepted as is. However, if the primary purpose is to document the sound output of a specific source, it is best to optimize the conditions. The site may be specified by standard or ordinance. Otherwise, measurement sites should be selected to allow for description of the acoustic environment and to be able to assess its impact on the surrounding community. The most common location to start with is the source property line near potentially affected neighbors. This site will allow for initial assessment without intrusion. Sometimes it may not be possible to measure at the boundary line. That location may not be feasible or representative because of extreme elevation differences, obstructions to the source, etc. In this case, select a location closer to and within line of sight of the source in question.

Microphone Height and Orientation

The microphone position above the ground should usually be between 1.2 and 1.8 m. This may be specified by ordinance or standard. Higher microphone locations may be needed if the line of sight between source and receiver is high above the ground. The microphone orientation should provide a sound incidence angle for the primary source according to manufacturer's instructions. Brief measurements can be made with a hand-held sound level meter being careful to hold it away from the body. For longer measurement periods, the meter or preferably the microphone should be mounted on a tripod. This allows the operator to stay away from the microphone during measurements.

Measurement and Observation

The sensitivity calibration of the measurement system should be checked before and after the survey period. While measurements are occurring, the person conducting the tests should note environmental conditions and events, logging them with observations of levels. Background sound levels with the source under study shut down should be measured where possible. If this is not possible, try to estimate the background level with a measurement at a similar site removed from the source.

The measurement period will often be specified by a standard, regulation, or local ordinance. Otherwise, professional judgment is required by the surveyor to determine the appropriate amount of sampling time needed to satisfy the goals of the survey. The purpose of the measurements and the characteristics of the sound must then be considered. If the measurement only needs to demonstrate levels above a given criterion, and steady sound is clearly above that criterion, a very short period (less than 1 minute) can be acceptable. However, very long periods may be necessary to document statistically reliable indications of long-term sound levels. For DNL measurements it may be necessary to sample the noise over several days, even weeks.

Instrumentation

The quantities to be measured and required instrumentation will vary depending on the goals of the measurement and the procedure specified by standard, regulation, or ordinance.

Conventional Sound Level Meter

For simple ordinances specifying sound levels not to be exceeded, and for steady sound near a source, a conventional sound level meter can be used. Sampled data with a conventional meter also can be used to estimate a time-average sound level or percentile sound levels. This method is not advised if the data are part of a litigation record, unless the method is specified by the governing ordinance. The period of observation should be established based on the operating characteristics of the source. If the noise is comparatively steady, less time is needed (e.g., 5 minutes). If the noise fluctuates, more sampling time (e.g., 20 minutes) is recommended. Set the instrument for slow response and log the sound level at 10-second intervals. See both ANSI S12.9 Part 3 and ASTM 1014 for additional information and guidance on measurement procedures (ANSI, 1993; ASTM, 1984).

Integrating Sound Level Meter

An integrating sound level meter can be used to measure time-average sound level, maximum sound level, and peak sound pressure levels. The measurement period should be established based on the nature of the source and local ordinance requirements. Measurement periods typically range from 10 minutes to 1 hour. During the measurement, log events and conditions that may influence the measurement. The log will serve as the record to explain the measurement. An example log sheet is shown below (see Figure 15.6).

Time	L_{AS}	L_{ASmax}	Local Noise/ Traffic	Train	Plane	Tone?	Description of Events	Wind Dir	Wind Speed (mph)	Temp (Deg F)	Cloud Cover
10:00	67	84			X		Plane overhead, intermittent traffic	WSW	<10	67	Cloudy
10:10	64	76					Intermittent traffic	WSW	<10	67	Cloudy
10:20	63	73					Intermittent traffic	WSW	<10	67	Cloudy
10:30	64	76					Intermittent traffic	WSW	<10	67	Cloudy
10:40	67	82	X				Intermittent traffic, lawn mowing	WSW	<10	67	Cloudy
10:50	68	83	X				Intermittent traffic, lawn mowing	WSW	<10	67	Cloudy
11:00	64	75					Intermittent traffic	WSW	<10	67	Cloudy
11:10	62	72					Intermittent traffic	WSW	<10	67	Cloudy
11:20	61	73					Intermittent traffic	WSW	<10	67	Cloudy
11:30	65	79			X		Plane overhead, intermittent traffic	WSW	<10	67	Cloudy
11:40	64	71					Intermittent traffic	WSW	<10	67	Cloudy
11:50	65	81		X			Distant train horn	WSW	<10	67	Cloudy
12:00	64	79					Intermittent traffic	WSW	<10	67	Cloudy

Figure 15.6 — Example data log sheet.

Data-Logging Devices

There are a variety of microprocessor-based data-logging devices that may be used to maintain descriptive statistics of the data sampled. These systems range from the more sophisticated integrating sound level meters to environmental monitoring stations. Industrial dosimeters also can be used. However, make sure they are set for a 3-dB exchange rate and an adequately low threshold level (not the default threshold of 80 dB). Data logged by the instrument are stored in memory for later retrieval and analysis. These devices are typically programmable and can include valuable statistics such as percentile levels and DNL. Measurement periods are typically designed to be longer in these instruments with sampling rates corresponding to sample length (limited by memory). These instruments can be left unattended. However, it is advisable to have an observer, especially if the data are to be used in litigation. The most useful percentile levels are the time-average sound levels that are exceeded 10% and 90% of the time. The level exceeded 10% of the time is a criterion used in some ordinances. The 90th percentile level can help define the steady noise level in the absence of intermittent noises. The level exceeded 1% of the time can be a useful indication of normal maximum sound levels due to short events when the actual maximum varies among events. Note that the percentile levels and maximum levels will be influenced by the selection of fast or slow response, or sample duration for instruments using short samples of time-average sound level.

Frequency Analyzers

The frequency spectrum of the community sounds can be measured and recorded using octave-band or 1/3 octave-band filters or fast Fourier transform (FFT) analyzers. Octave-band and 1/3 octave-band filters may allow measurement of all frequencies simultaneously or require serial measurement of each band. The data can be compared to criteria specified in an ordinance or regulation. Some ordinances specify a method of evaluating the presence of a discrete tone using 1/3 octave-band data. For the tone to be considered present, the 1/3 octave band of concern must exceed the arithmetic average for the two adjacent bands by some specified amount. Annex C of ANSI S12.9-1996 Part 4 gives guidance defining these differences, as shown in Table 15.5 (ANSI, 1996). This method will not always properly identify a discrete-tone problem. The user of Table 15.5

TABLE 15.5
Guidance for determining the existence of a pure tone.

Range of 1/3 Octave-Band Center Frequencies (Hz)	***Difference Between Arithmetic Average of SPLs in Two Adjacent Bands (dB)***
25-125	15
160-400	8
500-10,000	5

Note: Obtain the arithmetic average of the SPLs in the 1/3 octave bands immediately above and below the frequency of concern. Subtract this average value from the SPL in the 1/3 octave band containing the suspected pure tone. If the difference equals or exceeds the value indicated for the respective frequency range listed in Table 15.5, a discrete or pure tone may be assumed to exist.
Source: From ANSI S12.9-1996 Part 4, Annex C, with permission.

is cautioned that a tone at or near the boundary between 1/3 octave bands will share the sound energy between the two bands giving a false indication of no tone. Also, nontonal sound covering most of a band, but with little content in adjacent bands, will falsely indicate that a tone is present. An FFT analyzer is used to measure narrow-band frequencies, with the frequency resolution determined by the surveyor. A method using FFT analysis over octave-band and 1/3 octave-band measurements to more clearly identify the presence of a pure tone is described by Lilly (1994).

Interpreting Results

After collection, data must be organized and analyzed. Similar techniques can be applied to project the effect of new noise sources and to evaluate the need for noise control. There are numerous methods for describing and classifying community noise. This section will discuss interpreting the data for compliance with existing or potential regulations, and for community reaction.

Compliance with Existing or Potential Regulations

Depending on the jurisdiction (local, state, or provincial), rules limiting noise in the community may be found in general ordinances, zoning codes, or health regulations. However, compliance with these regulations does not assure community satisfaction. Most businesses want to be perceived as good neighbors. Regulatory compliance also is not always a satisfactory defense in legal proceedings. Many local ordinances contain specific clauses preserving the rights of plaintiffs to bring legal action against noise sources that comply with the ordinance. The plaintiff faces a heavy burden in that case, to prove the noise either is a nuisance or reduces property value. In some communities there also may be multiple applicable regulations. If there are no regulations, it is advisable to search for regulations in nearby jurisdictions. This could suggest the type of regulation the community might adopt in the future. Realize that simplified ordinances can sometimes be very restrictive. A 55-dBA limit is more stringent for unsteady sound if interpreted as a maximum or instantaneous level rather than an average level over a reasonable time. Lacking local guidance, typical regulation limits can be considered as references.

Assessment for Prediction of Community Response

A procedure for evaluating community reaction based on DNL was proposed by the EPA (1974) and updated by two of the original authors (von Gierke and Eldred, 1993). This procedure works best when the sound is broad-band in content, and present most days for much of the day. It normalizes the sound for various factors including existing sound levels. The expected DNL of the new source alone is first determined and adjusted by the factors shown in Table 15.6. These factors correct for seasonal variation, previous exposure and community attitudes, and the presence of tones or impulses. Larger correction factors than the EPA-proposed values, taken from ANSI S12.9 Part 4, have been added to this

TABLE 15.6
Corrections added to the measured noise level to obtain normalized level.

Type of Correction	*Description*	*Amount Added to Measured Level in dB*
Seasonal correction	Summer (or year-round operation).	0
	Winter only (or windows always closed).	- 5
Correction for previous exposure & community attitudes	No prior experience with intruding noise.	+5
	Community has had some previous exposure to intruding noise, but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to the intruding noise, and the noise maker's relations with the community are good.	- 5
	Community is aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	-10
Pure tone or impulse	No pure tone or impulsive character.	0
	Pure tone or impulsive character present.	+5
	Highly impulsive sounds, gunfire, hammering, drop hammering, pile driving, drop forging, pneumatic hammering, pavement breaking, metal impacts during rail-yard shunting operation, and riveting.	+12

Source: From EPA (1974).

table for highly impulsive sounds. The existing DNL without the new source is then arithmetically subtracted from the DNL expected for the new source alone. The DNL existing in the community can be estimated from sound measurements using Equation 15.1a, Equation 15.1b or from Table 15.7. The resulting difference is then compared to Table 15.8 to predict response. Notice that even the addition of a new sound, equal in level to the existing sound, will produce an increase in the overall level. Thus, some sporadic complaints are expected even when the normalized change is zero. A clearly dominant sound from a single new source will produce widespread complaints.

TABLE 15.7
Typical community noise levels.

Community Description	*DNL (dBA)*
Rural and sparsely populated areas	35–50
Quiet suburban (260 people/km^2, remote from large cities and from industrial activity and trucking)	50
Normal suburban community (770 people/km^2 not located near industrial activity)	55
Urban residential community (2600 people/km^2 not immediately adjacent to heavily traveled roads and industrial areas)	60
Noisy urban residential community (near relatively busy road or industry or 7700 people/km^2)	65
Very noisy urban residential community (26,000 people/km^2)	70

Source: Adapted from EPA (1974).

TABLE 15.8
Expected community reaction for normalized DNL difference.

Normalized Change in DNL (dBA)	*Reaction*
- 5	None
0	Sporadic complaints
+ 5	Widespread complaints
+ 14	Threats of legal action
+ 21	Vigorous action

Source: From EPA (1974).

EXAMPLE 15.2, Expected Community Reaction to a New Noise Source

For example, suppose a new industrial plant is to be built in a suburban area. It is not near other industry but there are two existing residential communities nearby. Noise controls can eliminate tones and impulsive sounds, and the sound produced will be steady 24 hours a day. Atmospheric effects will produce some variation in sound level reaching the communities. The DNL reaching the communities will be 52 – 55 dBA for the closer community and 45 – 46 dBA for the other. The population densities are about 500 people per km^2 for the closer community and 1000 people per km^2 for the other. What is the expected reaction in the two communities?

Table 15.7 indicates the existing DNL in the communities will be close to 55 dBA. Actual DNL for the two communities can be estimated to be 53 and 56 dBA using Equation 15.1b. Since the communities have no prior experience with or expectation of the noise, Table 15.6 indicates 5 dBA should be added to the source noise level or DNL reaching each community (52 – 55 dBA and 45 – 46 dBA) as described above. This gives a normalized DNL for the source of 57 – 60 dBA in the closer community and 50 – 51 dBA in the other. Next, we subtract the estimated existing DNL in the communities from the normalized DNL due to the source. For the closer community we subtract 53 from 57 – 60 and get a difference of 4 to 7 dBA. For the other community, we subtract 56 from 50 – 51 and get -4 to -5 dBA. From Table 15.8, we see there will probably be no reaction in the more distant and densely populated community. However, we can expect widespread complaints from the closer and more sparsely populated area.

In some cases the use of DNL will underestimate community reaction. This is most likely when the sound occurs only occasionally (once a day or less) in short periods of loud sound not typical for the community. These short periods of noise could be loud when they occur but not significantly change the DNL. This can be a particular problem if the noise occurs during evening or weekend periods when people are home and possibly trying to enjoy the outdoors. It is better in these cases to use actual sound levels during the events, rather than the DNL, for both the new noise and the existing noise. Using actual sound levels may overestimate community reaction but will be more reliable when the normalized change is large with them and small using DNL.

DNL or any measure based on overall A-weighted sound levels will not work well for distinctive sounds, such as speech, music, or discrete tones. The A-weighted sound level also can be misleading for strong low-frequency sounds where the C-weighted sound level is more than 10 dB greater than the A-weighted sound level. This includes high-energy impulsive sounds such as quarry and mining explosions, demolition and industrial processes using high explosives, explosive industrial circuit breakers, and other explosive sources where the equivalent mass of dynamite exceeds 25 g. Other sources of disturbing low-frequency noise include industrial exhaust stacks, outside blowers or fans, vacuum trucks used to clean parking lots, heavy vehicles (e.g, 18-wheel trucks) traveling on highways and over bridges, wind turbines, etc. It is worth noting that when the SPLs are less than 65 dB and relatively steady at the octave-band frequencies of 16, 31.5, and 63 Hz, it is unlikely that an annoyance problem exists. Residents may be annoyed, however, when sound less than 65 dB in these same frequencies fluctuates rapidly. See Annexes B and D of ANSI S12.9 Part 4 (1996) for guidance.

Often the problems due to strong low-frequency noise are evident only inside homes. The long wavelengths of low-frequency sounds can easily penetrate a building’s structure and excite room resonances. The results include audible sound and possibly rattles due to vibration induced by the noise. Such rattles make the annoyance equivalent to a noise at least 10-dB higher. Resonant tones will often be amplified leaving the sound inside the home even more dominated by low frequencies.

Adjustments to Account for Background Sound Levels

When the difference between the level due to the source of concern and the background level is less than 10 dB, it is sometimes desirable to determine the level due solely to the primary source. This can be done by using Equation 2.13. The result can also be approximated using Table 15.9.

TABLE 15.9
Adjustments to account for background sound levels.
The contribution of the background sound level (without source under study operating) may be accounted for under the following conditions.

Condition	*Comment*	*Action*
The sound pressure level increases over the background sound pressure level by 10 dB or more.	The measured operating sound pressure level is due to the source.	No adjustment necessary.
The sound pressure level increases over the background sound pressure level between 4 and 10 dB.	The measured operating sound pressure level consists of elements of both source and background.	Apply adjustment to measured level using Table.
The sound pressure level increases over the background sound pressure level by 3 dB or less.	The sound pressure level due to the source is equal to or less than the background sound pressure level.	The two contributions cannot be separated.

NOTE: Where the difference is 3 dB or less, report the unadjusted source level and identify it as being “masked” by the background level.

Adjustment of measured level to account for the effect of background sound.

Difference Between Measured Level and Background Level (dB)	*Adjustment to be Made to Measured Level (dB) to Obtain Corrected Source Level*
4	- 2.2
5	- 1.7
6	- 1.3
7	- 1.0
8	- 0.8
9	- 0.6
10	- 0.4
Greater than 10	0

Source: From ANSI S12.18-1994, with permission.

Report and Documentation

The report of noise measurements taken in the community should reflect the purpose of the study. The report must adequately describe the conditions of the measurements so that the findings are taken in context. Furthermore, in the event that measurements need to be repeated, the report should be sufficient to serve as a reference for future measurements.

Elements that should be considered for a report include:

1. A clear statement of the purpose of the measurements (e.g., cursory check of conditions, documentation of a source output, evaluation of ordinance compliance, evaluation of land use compatibility, prediction of community response, etc.).
2. Description of methodology for obtaining measurements—including rationale for choice (e.g., ordinance specification, satisfaction of purpose, limitations in source operation, etc.).
3. Description of the setting—including the surrounding area, terrain, land use classifications, etc.
4. Description of noise source(s) within the environment—including temporal characteristics, tonal qualities, operation/process relationship of major sources. The description should also include background and transient sources.
5. Description of measurement site(s)—including specific location of site, rationale for selection, position relative to source(s), description of terrain and objects near the site.
6. Plan view of site—a topographic map including source locations, measurement sites, significant objects such as buildings, major vegetation, and other locations of interest (including nearby residences etc.). Significant ground slopes should also be indicated. An example of a plan view is shown in Figure 15.7.
7. The sound descriptors (e.g., maximum sound level, equivalent sound level, percentile sound level, day–night average sound level, etc.) used to describe/evaluate the source(s)—including rationale for use of such descriptors.
8. Documentation of instrumentation—including manufacturer, model, and serial numbers of all meters, microphones, calibrators, and other instrumentation used in the study. Sampling rates and settings should also be included, as well as the pre- and postsurvey calibration readings.
9. Description of meteorological conditions—including typical wind speed and direction, temperature, relative humidity, and cloud cover, supplemented with a brief description of weather conditions during time of measurements. Wind speed and direction corresponding to time intervals should also be documented in a separate log appended to the report.
10. Exceptions to standard procedures—including deviations due to ordinance requirements, site limitations, or purpose.
11. Other observations—including description of occurrences during the measurement periods that could have an effect on the data collected.

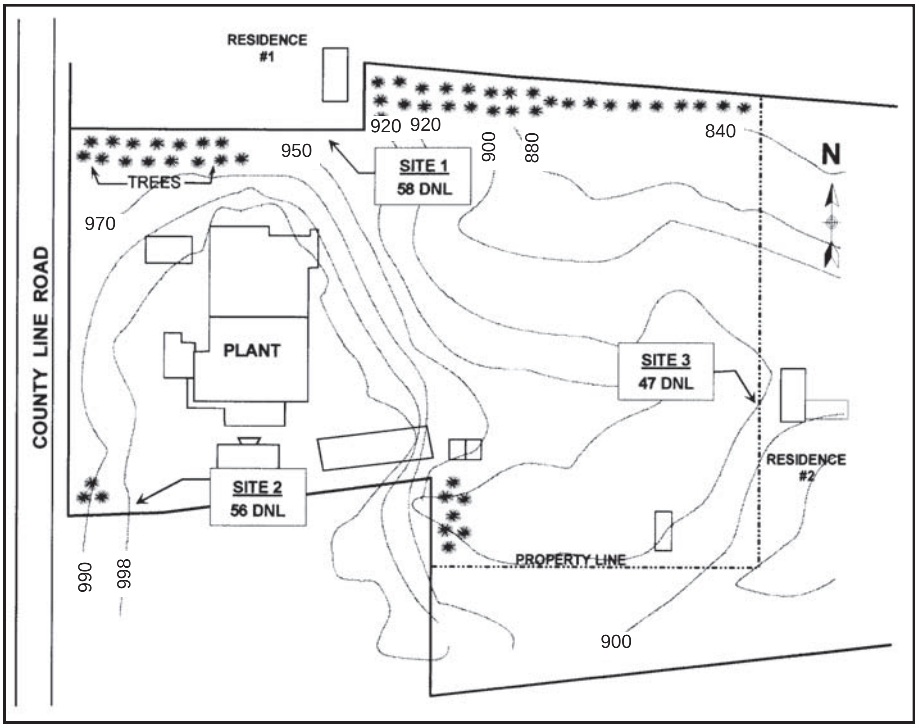

Figure 15.7 — Example plot plan depicting the two residences, three measurement sites, principal geographic features, elevation contours, and measured sound descriptors.

12. Acoustical data—including measurement data (background and source test data), results of comparisons to criteria or ordinances, and other conclusions. Measurement data should be presented with the knowledge that the readers may not have any technical understanding of sound or the evaluation criteria. Methods to simplify understanding should be used where possible. A time-history of the measurement can be illustrative of the conditions as shown in Figure 15.8.
13. Executive summary—it is recommended that a summary of the study including purpose and findings be included at the beginning of the report.

Summary

Most industrial companies will face the potential of a community noise problem. Each surrounding community is different and will tolerate varying levels of noise. Factors influencing community tolerance include:

- Visibility of noise source. Some members of the community may be more concerned with “visual” noise sources (e.g., stacks, vents, etc.).

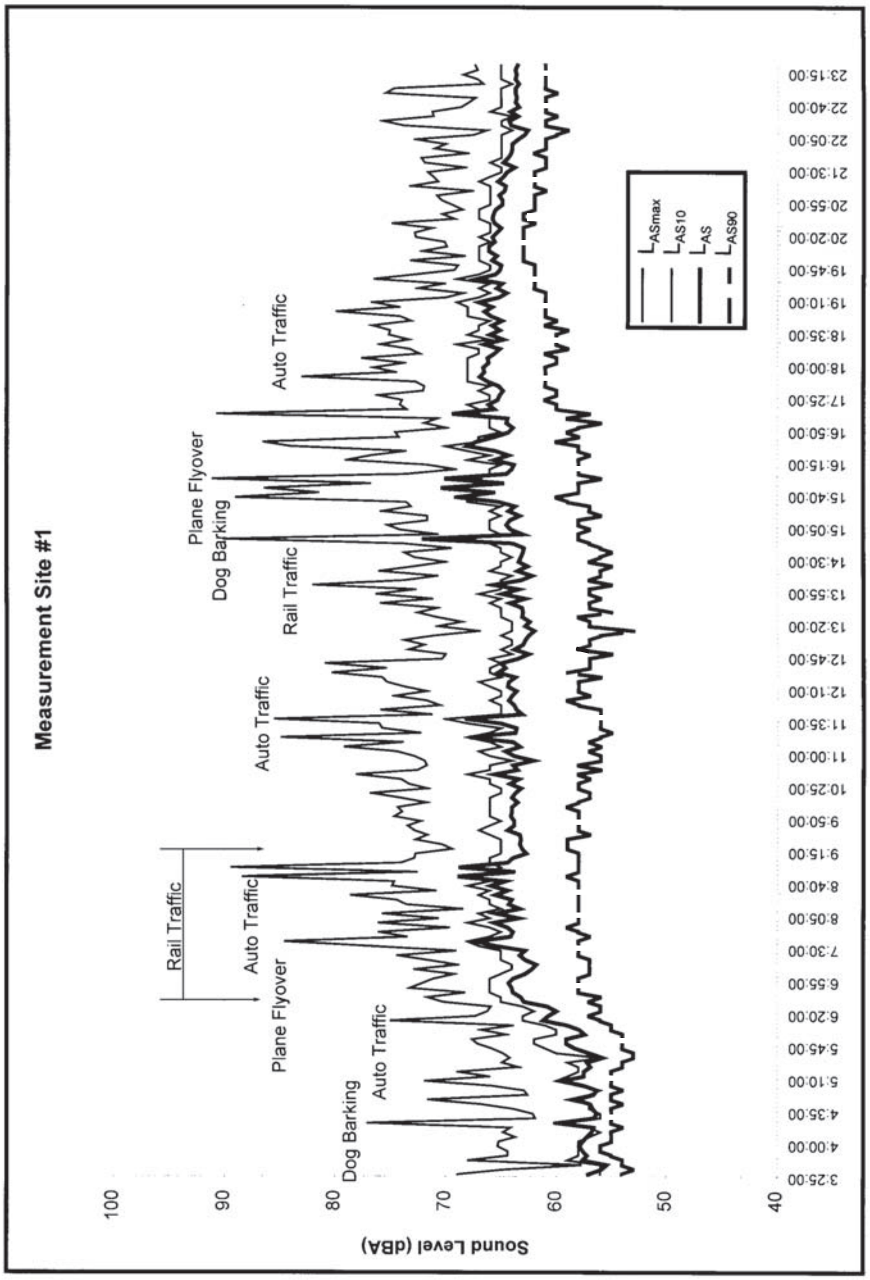

Figure 15.8 — Example of time-history log.

- Noise sources that cannot be associated with the operation of the facility or seem foreign to the community. Some members of the community may interpret these sources as potentially dangerous.
- Noise centered within a narrow frequency band (pure tones).
- Noises that can startle the community (impulsive noise).
- Noise that is random in occurrence and duration (may be related to lack of control).
- Low-frequency noise that may cause vibrations and/or resonances within residential structures.
- A very low pre-existing background noise level.

If a community noise problem is suspected, the following information should be considered:

- Review current local noise control ordinance. If there is none, refer to any state guidelines for information on what is expected for monitoring and compliance.
- Conduct perimeter (property line) sound level measurements. Compare to limits specified in the local ordinance. Check for pure tones. Many ordinances have definitions and special restrictions for tone generation.
- Be aware of the time of the noise complaint. Certain sounds may be noticed at greater distances in the evening or early morning due to meteorological effects, as well as lower background noise, and may not be discernable during the day.

Additional follow-up steps may include the following:

- Meet with the community/complainant. This shows that the company is concerned about being a good neighbor. Sometimes the noise complaint is related to another issue and noise is being used to get attention and response.
- Open communications. Consider creating a “noise hot-line” that the community can call 24 hours a day. Avoidance or quick resolution of a noise issue is always in the plant’s best interest. In addition, a well-documented list of complaint calls can be cross-referenced with plant operating conditions to track down possible problems.
- Inform the community of any unusual noise emissions prior to noise generation. Typically, complaints will come when a “normal” noise environment changes. In addition, a noise generated between 7 p.m. and 7 a.m. is generally more likely to cause complaints than an identical noise occurring during daytime hours.
- Elimination of noise sources may also cause complaints—if the old noise source masked a dominant tone or other “offensive” noise.

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