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COMMUNITY NOISE ASSESSMENT MANUAL

ACOUSTICAL SURVEY OF A COMMUNITY

July 1981

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Noise Abatement and Control
Washington, D.C. 20460

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16. ABSTRACT

This report was prepared by EPA, Office of Noise Abatement and Control, in support of its function to provide technical assistance to communities. It is one of nine which comprises the Community Noise Assessment Manual. The Manual provides a comprehensive and computerized system for assessing the noise problems of a community and then planning a noise control strategy for its abatement.

This Manual presents the technical instructions and guidelines needed by municipal authorities to carry out an initial noise survey. This survey will determine average noise levels and major noise sources for the community as a whole. It can be used in planning noise reduction measures to benefit the entire community or a substantial portion thereof.

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FOREWORD

The extremely detailed step-by-step procedures presented in this manual may lead the reader to believe that the monitoring of community noise is a hardened, thoroughly developed science. Although it is true that the procedures contained herein have evolved over a period of several years and have undergone developmental application in at least four cities, it should be understood that sampling and description of the community noise environment remain at this time in a state of rapidly advancing evolution. New research appears frequently that addresses sampling theory and its application, sampling accuracy, and the relationships between various measures of community noise and associated human response. Although the steps given in this manual represent the current state-of-the-art on the subject and should be followed closely, the specificity of the material should not preclude the incorporation of appropriate informed modifications as this field becomes better understood.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

CHAPTER 1

INTRODUCTION

Section 1.1 Purpose of the Manual

The Noise Control Act of 1972[1] was passed because of the determination by Congress that "...inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population..." The Act declares a federal policy "...to promote an environment for all Americans free from noise that jeopardizes their health or welfare..." The community noise measurement procedures presented by this manual have been developed under sponsorship of the U.S. Environmental Protection Agency, Office of Noise Abatement and Control (EPA/ONAC), as one effort toward implementing this policy.

The manual itself was created as one of three basic elements in EPA's Quiet Communities Program (QCP), a program which was designed for application by communities with populations between 50,000 and 150,000 people to assess and improve their noise environment. The QCP scheme begins with a comprehensive community-wide noise measurement survey and a community-wide social survey of attitudes including attitudes toward noise.[2] Data from both surveys can then be integrated in a noise reduction strategy development program which develops an optimal plan for resource allocation among the most effective noise reduction measures for the surveyed community.[3] This manual presents the specific technical instructions and guidelines needed by municipal authorities to carry out the initial noise level survey. The survey is of a type that will determine average noise levels and major noise sources for the community as a whole, and can be used in planning noise reduction measures to benefit the entire community, or substantial portions thereof. Typically, the survey will take between 1 and 3 months for planning and execution, and will require at least two staff members plus several field personnel. Although tailored to supply acoustical data for use in the attitudinal and strategy portions of the QCP, the procedures given in the manual can be applied

[1] Superscript numbers indicate references at end of manual text.

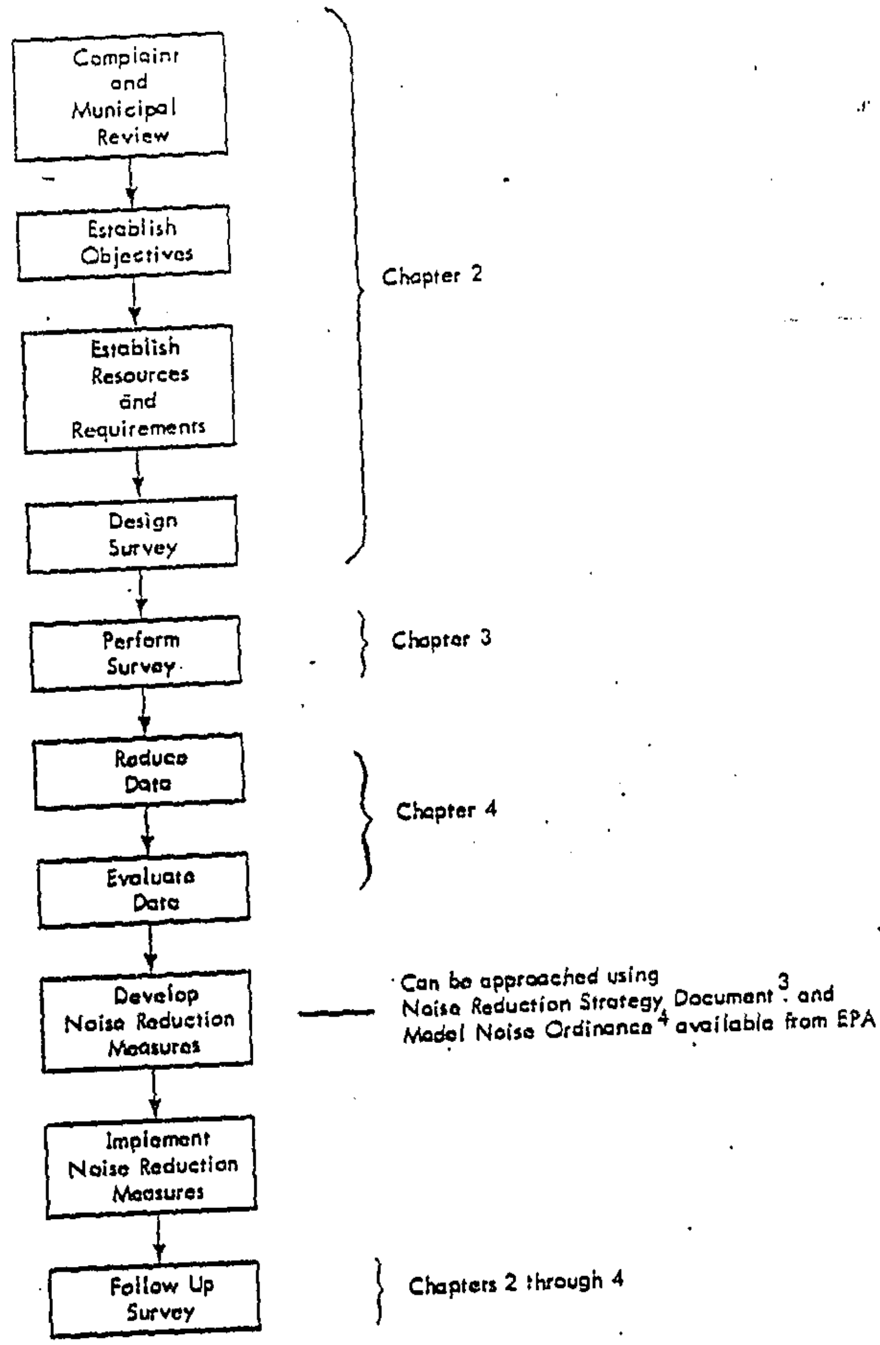


Figure 1-1. Elements of Community Noise Measurement/Noise Reduction Included in this Manual

LIST OF FIGURES (Continued)

independently to obtain a detailed description of the community noise environment useful of itself in evaluating and improving the quality of life. Although measurement or improvement of individual localized noise problems (i.e., a single noisy small factory causing complaints) is not the basic purpose of the manual, the discussion of this topic is included in Appendix B, a good background for anyone charged with developing solutions to such problems.

The instructions presented herein are directed primarily to the nonspecialist audience of administrators, city planners, or other officials who might be responsible for implementing a community noise measurement program once the decision to conduct such a program has been reached and the responsible city agency assigned. Throughout the manual, emphasis is placed on "what to do," with detailed procedures arranged in a step-by-step fashion for cost-conscious survey planning, field noise measurement, and data reduction. Limited guidance is also provided for program management and interpretation of results. For the benefit of specialists in acoustic measurement, technical background supportive of many of the procedures given in the manual has been included in appendices.

Section 1.2 Monitoring Program Overview

A community-wide noise measurement program, such as the one discussed in this manual, should be implemented in sequenced stages as shown in Figure 1-1. Those stages that are included within the scope of the manual are indicated in the figure, and described briefly below.

The process is begun with a formal summary of existing knowledge of noise and noise problems in the community derived principally from complaint histories and interviews with select municipal figures. Objectives for the noise measurement program are then selected based on this information and practical resource constraints of the performing agency. At this point, the survey program can be designed, with preparation and field implementation following directly. These activities involve selection of noise measurement sites, establishing a plan for sampling these sites, logistics of manpower and equipment use, and actual field measurements normally performed using a simple noise measuring device called a sound level meter. Following this, the raw data collected must be processed or reduced to determine average sound levels for large areas of the community and the contributions of specific noise sources. Evaluation of these values regarding the acoustical acceptability of various community areas will evolve into noise reduction measures such as educational programs, noise ordinances, or heightened enforcement efforts. Such measures may be selected through application of the Noise Reduction Strategy Program, or from a general consideration of community noise levels and local needs. Implementation of these measures will normally be the responsibility of the municipal agency most closely related to the nature of the measure. Finally, a simpler, follow-up noise survey should be performed at an appropriate future time to assess the changes or effects resulting from the measures taken.

Section 1.3 Sound In the Community

1.3.1 Introduction

Outdoor noise in a community is quite complex in its detail, varying both randomly and systematically in space and time. One might picture the phenomena like the complex ripples on a pond generated in a heavy hailstorm, where the impact of each hailstone generates its own familiar expanding ripple in the water analogous to a sound wave in air created by a single source. The summation of all of the ripples from all of the hailstones creates a complex pattern of waves, indeed, not unlike the complex spatial and temporal pattern of sound waves in a community from many noise sources. There are, of course, more recognizable patterns to community noise than to the more or less random pattern of hail striking a pond — yet the physical picture is useful to indicate the degree of complexity involved in monitoring community noise — like trying to determine the average height of the complex pattern of ripples on the pond. Compound the problem by picturing many obstructions in the pond to correspond to communities with widely varied geographic and building characteristics, and one begins to have some idea of the difficulty in making an area noise survey. The remainder of this section will discuss the nature of sound and its measurement in the community.

1.3.2 Sound Level and the Decibel

The sound we hear is really made up of very minute and rapid variations in the air pressure at our ears, which are very sensitive to such pressure changes. We perceive these minute pressure variations as sound. Commonly, if the sound is unwanted, it is referred to as noise. Sound is generated in many ways but most commonly by vibrating or moving objects or gases which perturb the nearby air. Like the expanding ripples in the pond, sound radiates out from the source in waves traveling at a speed of about 340 meters/second (1115 ft/sec) under typical atmospheric conditions with a temperature of 15 degrees Celsius.

If we could measure the pressure of a sound wave in space that is radiated by a simple source such as a tuning fork, for example, and observe it for a short time, we would find two characteristic features of the sound wave – the amplitude, and rate of variation of the minute pressure changes – that is the time between each cycle of the varying air pressure, as illustrated in Figure 1-2.

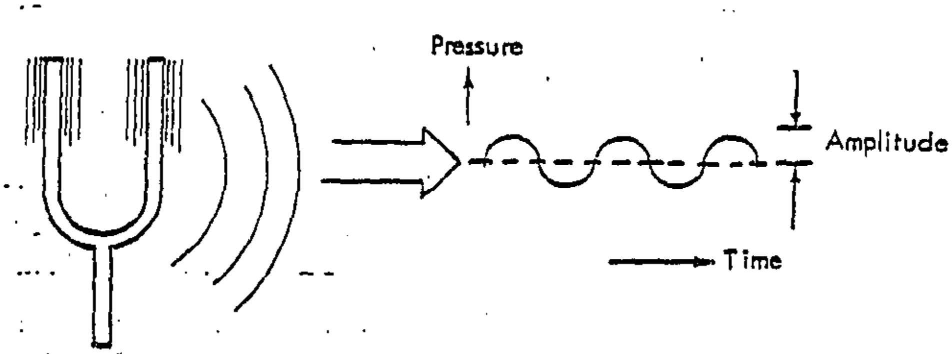


Figure 1-2. Sound Wave Radiation by a Tuning Fork

The amplitude of a sound is expressed on a scale given in decibels — a term which can be explained in the following way. If we assign the number 1 to the sound pressure corresponding to the smallest sound that can be heard by the human ear, then the sound pressure of our voice in quiet conversational tones would correspond approximately to the number 1000. A loud voice would be approximately 30,000 and physical pain would be felt in the ear at a sound pressure of over 1,000,000.

While our brains have no trouble perceiving this wide range of sound pressures sensed by our ears, it is inconvenient for us to express the magnitude of such numbers with all these zeros. It becomes more convenient, therefore, if we base our scale of sound on the number of zeros rather than the actual number itself. The logarithm to the base 10 does just this. Thus, we assign zero in our scale to the sound magnitude we can just hear, since the logarithm of 1 is zero. Our quiet conversational tones will then be assigned the number 3, since the logarithm to the base 10 of 1000 is 3, and the sound magnitude causing the physical pain would receive the number 6.

When we use logarithms to express the magnitude of sound such as in the example above, the quantity measured in such a scale is called a level. As indicated above, the basic physical parameter that allows us to actually hear a passing sound wave is the sound pressure. Engineers and scientists prefer, however, to work in terms of sound intensity, which is proportional to sound pressure squared instead of sound pressure. Thus, all the above numbers for sound pressures must be squared. Making this adjustment, 1 squared becomes 1; 1,000 squared becomes 1,000,000; and 1,000,000 squared becomes 1,000,000,000,000. Fortunately, the logarithm of a squared number is just two times the logarithm of the number; so, instead of the level ranging from 0 to 6, it ranges from 0 to 12. In the fields of electronics and acoustics, the unit on this scale is called the bel in honor of Alexander Graham Bell. For convenience, the bel is divided up into 10 smaller units, so that the scale of level in the previous example now extends from 0 to 120 decibels or tenths of bels. Figure 1-3 provides an illustration of these concepts for converting from the inconvenient amplitude scale (linear pressure) to a more convenient scale of level (logarithmic) with decibels as the units.

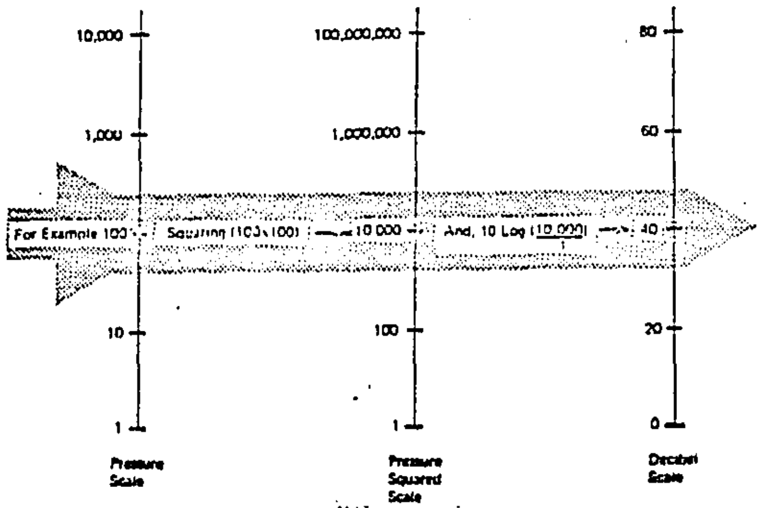


Figure 1-3. Conversion from the Linear Pressure Scale to the Decibel Scale

Utilizing this basic idea of a level scale, acousticians have invented a profusion of different measures of sound levels, all in decibels, abbreviated dB. The most common of these is the sound pressure level (SPL), which can be read directly in dB from a sound level meter during a community noise survey. For any given sound or noise, as the sound pressure level increases, so does the loudness that we sense.

By design, the zero point on the decibel scale of sound pressure level was chosen to correspond approximately to the lowest sound pressure which the average person can hear. The actual magnitude of this so-called reference pressure is 20 millionths of a Newton per square meter, or simply, 20 micropascals, abbreviated 20 μPa. In more familiar units, this minute pressure corresponds to about 3 billionths of a pound per square inch.

1.3.3 Frequency and Weighting Networks

The rate of variation of pressure in the sound wave is called its frequency. For example, the tone on the musical scale designated as "A" occurs when the pressure changes through a complete cycle 440 times per second. The frequency of this tone, that is, the number of cycles occurring each second, is then said to be 440 hertz, where "hertz," abbreviated "Hz," has been adopted to designate this rate (or number of cycles per second) as the preferred unit of frequency. An increase in the frequency of a tone will be sensed as an elevation of pitch. A doubling of frequency, say from 440 to 880 Hz, is equivalent to an octave increase in musical tones. Thus, a tone of 880 Hz is the pitch of "high A." Many prefixes are used with the unit of frequency, but the one that is common in acoustics is "kilo-," abbreviated "k," which stands for a factor of 1000. Thus, 8000 Hz can be abbreviated as 8 kHz. The normal young adult, without any history of medical problems with his ears and no excessive noise exposure, can hear sound with frequencies from about 20 Hz to 20,000 Hz (20kHz). Thus, the sound measurement instrumentation used in the noise survey need only be sensitive to sounds contained within this frequency range.

The "simplest" physical measure of a noise that contains sounds of many frequencies is its overall sound pressure level. However, such a measure would give no indication of the frequency content of the noise; neither would it give any information as to its perception by people. However, it is possible to give a noise measuring instrument certain characteristics which make the measured results much more useful. This has been done with the sound level meter and similar measuring instruments. Modern sound level meters incorporate circuits that shape the electrical frequency response of the device to approximate the frequency response of the human ear. The circuit which performs this function is called a "weighting network," and the most common form of weighting network used in sound level meters is referred to as A-weighting.

The A-weighting response — shown on Figure 1-4 — provides a close approximation of the response of the human ear to a normal range of sound levels, and many national and international standards for noise measurement and evaluation recommend its use.[5] Note that for the A-weighting network, sounds with frequencies below about 500 Hz are substantially attenuated, or reduced, to simulate the reduced sensitivity of the ear to such low frequencies. The terms noise level or sound level, used interchangeably throughout this manual, will always assume that the A-weighting network is employed in community noise measurements so that we will always be working with A-weighted sound pressure levels. Figure 1-5 illustrates the range of typical noise levels for familiar sounds.

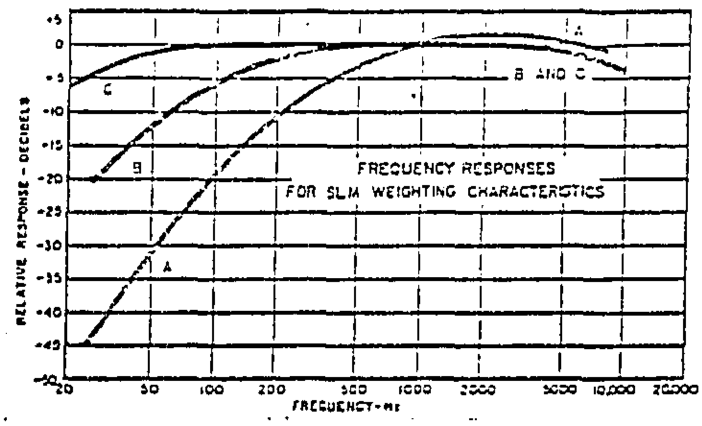


Figure 1-4. Frequency Weighting Networks for Sound Level Meters[5]

At a Given Distance from Noise Source	Decibels re 20 μPa	Environmental
	140	
50 hp Siren (105')		
	130	
Jet Takeoff (200')		
	120	
Riveting Machine	110	Casting Shakeout Area
Cut-off Saw Pneumatic Peen Hammer	100	Electric Furnace Area
Textile Weaving Plant Subway Train (20')	90	Boiler Room Printing Press Plant
Pneumatic Drill (50')	80	Tabulating Room Inside Sport Car (50 mph)
Freight Train (100') Vacuum Cleaner (10') Speech (1')	70	
	60	Near Freeway (Auto Traffic) Large Store Accounting Office
Large Transformer (200')	50	Private Business Light Traffic (100') Average Residence
	40	Min Levels Residential Areas in Chicago at Night
Soft Whisper (5')	30	Studio (Speech)
	20	Studio for Sound Pictures
Threshold of Hearing Youths	0	

Figure 1-5. Typical Range of Noise Levels (A-Weighted) for Familiar Sounds[5]

1.3.4 Sound in the Community

To begin our consideration of sound in the community, we can identify four features of outdoor noise which are characteristic of any environment:

- The instantaneous noise level at a location is simply the noise level at any particular moment in time due to all sources of noise reaching the observer. In our analogy to ripples on a pond, this level corresponds to the height (or depth) of the wave at any location in the pond at a given instant.
- The background ambient noise level is the level of the ever-present "rushing" noise you can hear anytime outdoors near a city when there are no identifiable noise sources nearby. It is composed of contributions from numerous unidentifiable distant sources. This level corresponds to the average of the low points of waves on the pond.
- The maximum noise levels from individual (usually identifiable) intrusive sources in the vicinity of the observer correspond to the peak of the waves near each hailstone.
- The average or equivalent sound level represents the composite energy average level of the sound received from all sources at a location over a specified period of time. Note that this energy equivalent level is not equal to a simple arithmetic average of sound levels (see Glossary). This level roughly corresponds to the average height of all the waves passing a given point in our pond..

The use of these terms to describe the detailed character of community noise is best illustrated by an example of just how outdoor noise varies from moment to moment. A short time history of the noise levels in a typical residential area is illustrated in Figure 1-6. Community noise levels generally fall in the range shown in the figure. This 8-minute sample illustrates only a small portion of the noise

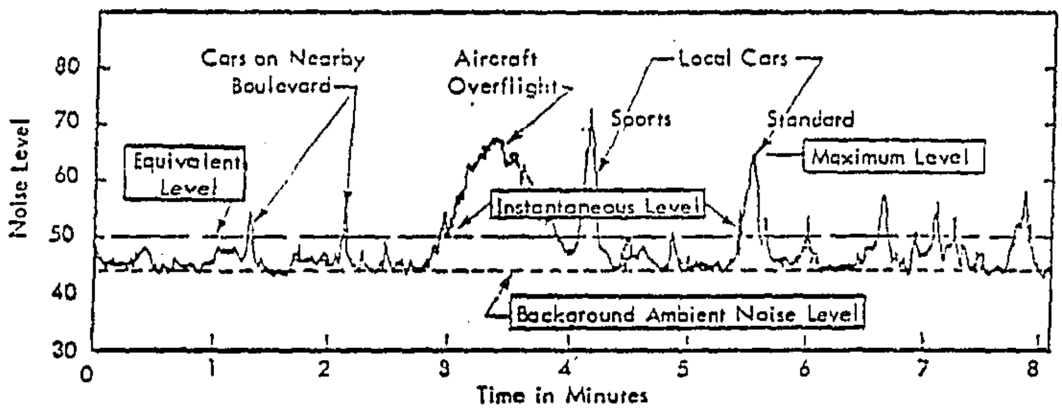


Figure 1-6. Short Time History of Noise Levels in a Typical Residential Community[6]

environment which could be measured at a point during a normal day. For certain periods, the noise environment is dominated by specific sources such as aircraft and automobiles, and is characterized by their maximum levels. At other times, it consists of a constant background of many indistinguishable sources and is best characterized by the background ambient noise level. Over a long period of time, such as the entire day, an average level is the most appropriate measure. One average measure, day-night sound level (L_{dn}), has been shown to correspond well with community reaction to the noise environment.[7] The day-night sound level represents the energy-average level for a 24-hour period with a 10 dB increase in level applied to the nighttime hours of 10:00 p.m. to 7:00 a.m. This 10 dB penalty is added to account for the increased sensitivity of people to intrusive noise while they are sleeping or engaged in leisure activities within their home environment. A more technical definition of L_{dn} is given in the Glossary. Figure 1-7 illustrates the approximate range of L_{dn}'s found in various outdoor locations. Measured values of L_{dn}, representative of various portions of the city, will be the principal result of the community noise survey.

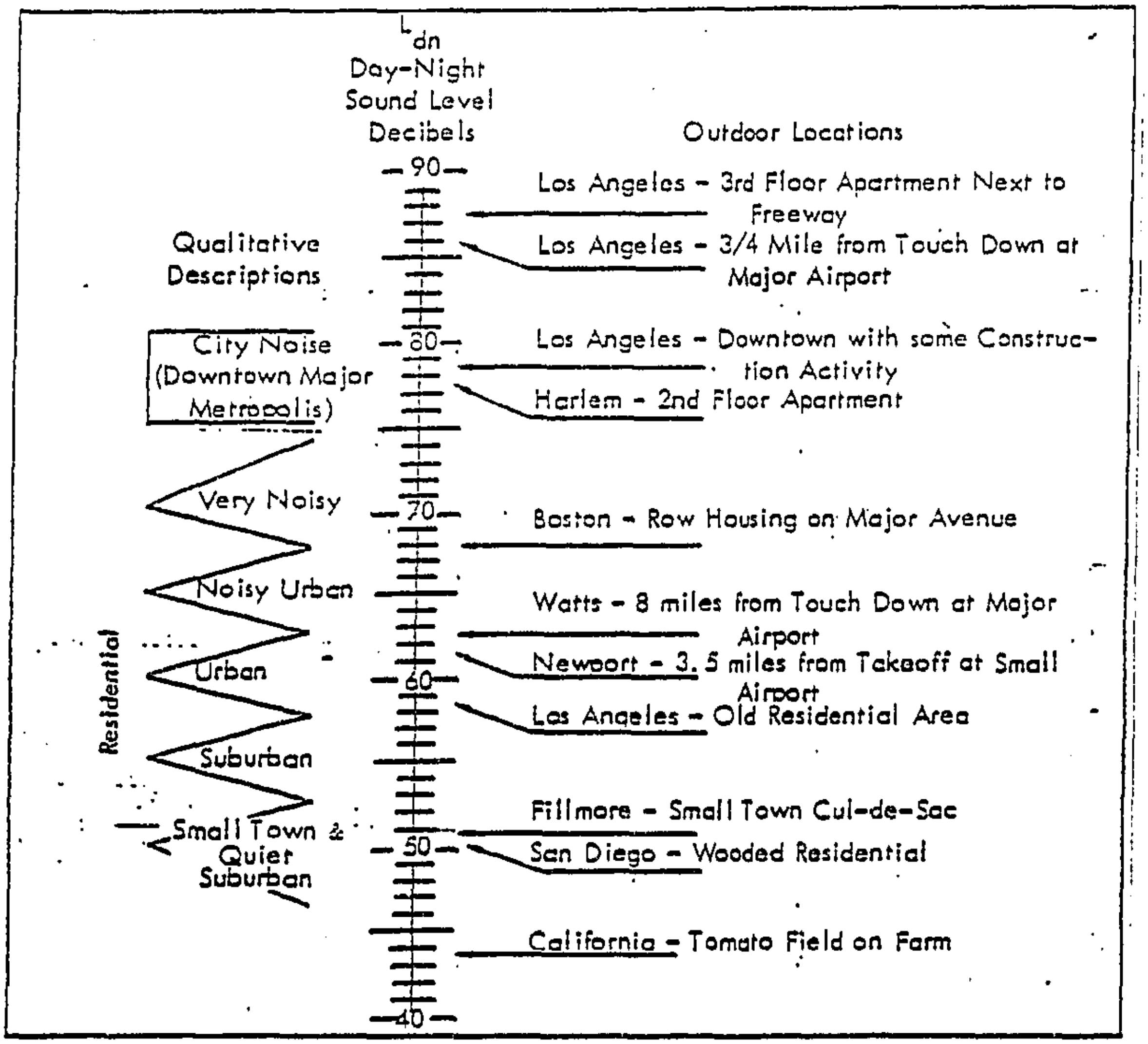


Figure 1-7. Outdoor Day-Night Sound Level, L_{dn} in Decibels at Various Locations[7]

Section 1.4 Noise Sampling

In order to determine values for L_{dn} or any of the other noise metrics described in Section 1.3 to represent a populous and geographically varied community, samples of noise levels must be taken at many discrete locations and during several time periods. If these samples are chosen in the proper fashion, the degree to which levels resulting from averages taken over the selected sample represent the "true" values can be determined according to established sampling theory. Proper sampling construction thus provides the basis for carrying out a statistical analysis of the results.

Our analogy relating community noise to waves in a pond illustrates the spatial and temporal variations with which a proper noise sampling method must contend. It is evident that all methods, short of measuring each point in the community at all times, will only yield approximations to the "true" value. A method is presented in this manual which balances these statistical considerations of accuracy with the practical constraints of time, budget, and flexibility which characterize most agencies for which this survey is designed.

In brief, the sampling procedure has the following characteristics:

1. Division of the community into broad, readily-definable <u>survey areas</u>.
2. Division of the community into <u>noise zones</u>. Each noise zone is expected to consist of regions which have similar noise characteristics, and may be defined in more than one survey area.
3. Random selection of measurement sites in each noise zone. A sufficient number of measurement sites must be selected for each zone to correctly characterize its noise climate.
4. Identification of proper times to measure. During the survey, samples of noise level will be made during normal daytime working hours, and during late night hours.

5. Measurement of the instantaneous noise level at 15-second intervals for a 20-minute period. This rate of sampling has been found to adequately portray actual temporal noise level variations and to give proper averages for typical community environments. Recommendations for additional measurements over a 24-hour period are also specified in Appendix A.

Section 1.5 How to Use the Manual

Application of the manual consists of following the straightforward procedures outlined by the chapters in the manual:

CHAPTER 2 SELECTION OF MONITORING PROGRAM

This involves selection of specific survey elements to address the city's particular monitoring objectives within resource limitations.

CHAPTER 3 NOISE MONITORING PROCEDURES

This section describes noise measurement sampling, selection of measurement locations, and application of measurement techniques.

CHAPTER 4 DATA REDUCTION AND PRESENTATION

Included are ways to reduce and display the measurement data to indicate the noise climate and, to some extent, noise problems.

Each of these chapters contains an introduction which summarizes the chapter procedures and provides instructions for their application. To use the manual, it is recommended that the user first read the introduction to each chapter and study the related diagram of activities. Then proceed through each chapter, using the introduction as a guide for following the step-by-step procedures of the subsections. All necessary generalized data and worksheets are included in the manual, and potential sources of necessary specific municipal data are suggested. A list of terms which have been given specific meanings for use in the manual is presented in Table 1-1. Become familiar with these terms. Definitions for standard technical terminology can be found in the Glossary. Certain portions of the manual become quite complex, and for smooth execution of a noise survey program it is imperative that the project director read and understand the entire manual before beginning actual planning, personnel acquisition, or field activities.

Table 1-1

List of Terms

The following terms and associated definitions are used in this manual:

Survey Class	–	One of two degrees of resource commitment which yield corresponding degrees of noise assessment accuracy (Class I – lower commitment and accuracy; Class II – higher commitment and accuracy).
Extra Survey Features	–	Components of a survey which may be added to either one of the survey classes to obtain additional measures of the noise environment.
Survey Area	–	A large subdivision of a city characterized by the unique geography, topography, or other obvious distinguishing features.
Noise Zone	–	All areas in the community having a particular kind of noise environment. For instance, regions near well-traveled railroad tracks are included in the railroad noise zone.
Cell	–	The square area bounded by grid lines which divide the community in .32 kilometer (0.2 mi) intervals for measurement sampling purposes.
Measurement Site	–	Center of any cell selected to be measured.
Microphone Location	–	Exact position of the measuring microphone relative to nearby buildings, streets, etc.
Roadway	–	An arterial road. For purposes of this manual, roadways with an average daily traffic count of 6,000 to 36,000 vehicles per day are defined as "minor" roadways. "Major" roadways are defined as having an average daily traffic count of more than 36,000.
Highway	–	A high-speed, limited access road such as a freeway, throughway, or parkway.

CHAPTER 2

SELECTION OF MONITORING PROGRAM

Section 2.1 Introduction

In this chapter, procedures are given to select the type of noise monitoring program that will meet the city's monitoring objectives, taking into account cost and resource considerations. First, basic goals and objectives are established. Based on these, a fundamental choice of the type of survey to be used is made. Finally, the survey method is refined and finalized based on the objectives and available program resources. The entire process is diagrammed in Figure 2-1.

The basic types of survey considered in this process are described in Figure 2-2. As stated in Chapter 1, the manual's intended purpose is to provide instructions for performance of a thorough survey of community noise levels in all regions of a city. Hence, it is the procedures for a Class I or Class II survey, as described in Figure 2-2, that are given in detail in the manual text. The second two types of survey described in the figure are limited procedures for assessing a specific individual noise source within a community, and only generalized instructions for these methods, located in Appendix B, are provided. Although these methods may be applied by a city in a special case program to determine noise levels of specific sources, normal application of the manual will be for a complete community noise survey. This activity begins with selection of a Class I or Class II basic survey--each of which provides basic community noise information, but to differing extent and degrees of accuracy. The Class II survey yields more extensive and accurate results than the Class I survey due to survey technique additions. Whichever basic survey is chosen, certain extra features can be added to enhance or increase the resulting information. These features are initially selected from a schedule based on specific objectives of the monitoring program, and final selection considers the available program resources.

MONITORING PROGRAM SELECTION PROCEDURE

- Identify Monitoring Program Objectives (Section 2.2)

STEP 1	Establish a Municipal Program Advocate
STEP 2	Ascertain Municipal Needs
STEP 3	Summarize Contact Information
STEP 4	Select Program Objectives

- Select Preliminary Survey Method (Section 2.3)

STEP 1	Identify Relevant Survey Class and Features
STEP 2	Select Preliminary Survey Method
STEP 3	Tabulate Preliminary Cost Requirement

- Finalize Survey Method (Section 2.4)

STEP 1	Determine Available Resources
STEP 2	Compare Costs
STEP 3	Finalize Survey Method
STEP 4	Consider 24-Hour Measurements

Figure 2-1 Diagram of the Noise Monitoring Program Selection Procedures Presented in Chapter 2

Class I Community Noise Survey: A low cost survey which covers the entire city and provides adequate results for general community planning. Full procedures are given in main text.

Class II Community Noise Survey: An extensive survey which covers the entire city and provides results sufficiently accurate to support specific community-wide programs such as developing noise emission regulations or ordinances. Full procedures are given in the main text.

Stationary Source Survey: A limited noise survey used to establish local noise levels around a specific stationary noise source such as a powerplant, race track, factory, etc. Guidelines for this survey are given in Appendix B.

Distributed Source Survey: A limited noise survey used to establish noise levels of particular types of noise sources in use throughout the community such as trucks, lawnmowers, air conditioners, etc. Guidelines for this survey are given in Appendix B.

Figure 2-2. Types of Community Noise Surveys Considered in this Manual

Section 2.2 Identify Monitoring Program Objectives

STEP 1 - Enlistment of a Municipal Program Advocate

It will be advantageous for the program to have a principal supporter within the municipal government. A formal working affiliation with the mayor or another city executive is recommended. This program advocate could provide valuable assistance in initial program development.

STEP 2 - Ascertain Municipal Needs

Determine the specific needs within the city and its agencies for a noise measurement or noise control program. Indications of specific requirements or desires of various municipal agencies may be collected by the staff of the program advocate or a member of the noise survey team assigned to his office for this purpose. Four principal agencies should be interviewed in detail: the Mayor's office, City Manager's office, Health and Safety Department, and Environmental Department to identify both existing noise information and possible uses of new noise monitoring information. When conducting such interviews, it should be made clear that the need for a community noise control program is being investigated, and that all relevant opinions or complaint histories available from the agency are desired. A form such as shown in Figure 2-3 should be used to organize the response. Information of value in planning a noise measurement program is also often available from other city agencies or citizens groups such as airport, planning, health and education departments, local newspapers and environmental or anti-noise citizens groups. Contact with all agencies should be carefully conducted in a manner which emphasizes this co-operative approach in defining the city's noise control needs. Similarly, any public or citizens groups that may become aware of the impending program should understand that the program will be developed to investigate all significant noise sources within the city.

Noise Survey Uses - Interview Form

Agency ________________________ Interviewer ________________________

Representative ________________________ Date ________________________

Telephone ________________________

1. What is the frequency and nature of noise-related complaints you receive?

____

2. Of what current noise-related problems are you aware?

____

3. Of what specific problematical noise sources are you aware?

____

4. What are your concerns regarding the occurrence of future noise-related problems based on expected growth and development?

____

5. Do you think that __________ is causing or may cause a noise problem? (Blank can be any source suspected by interviewer.)

6. What information concerning the present or future noise environment would you like to have?

____

7. Of what reports or documents relevant to the noise issue are you aware?

____

Figure 2-3. Example Interview Form for Identifying Noise Survey Uses

It may often be best to provide reassurance that indeed the opinion of all those contacted will be taken into account in developing municipal needs and program goals.

STEP 3 – Summarize Contact Information

Summarize all the accumulated information to determine:

- Types of noise complaints or problems;
- Locations or areas of frequent complaints;
- Time-of-day of frequent complaints;
- Specific noise sources recognized as significant contributors to the community noise environment;
- Expressed needs or desires for community noise information.

STEP 4 – Select Program Objectives

Considering the specific important noise sources and desired noise information identified in Step 3, select those noise monitoring program objectives from Table 2-1 that represent the principal needs and desires of the municipality. Only those particular objectives that strongly align with the city or public's needs should be selected. Some judgement may be necessary here in selecting or rejecting listed objectives which were less extensively indicated. A careful interpretation of the city's needs will be required.

Section 2.3 Select Preliminary Survey Program

STEP 1 – Identify Relevant Survey Class and Features

a. Review Schedule 2-A (located on page 2-20 at the end of this chapter) to become familiar with the noise survey classes and extra survey features which were briefly described in the chapter introduction.

b. Now review Table 2-2 and locate each monitoring program objective which was previously selected from Table 2-1. Using the table, identify the survey

Table 2-1

Monitoring Program Objectives

1.	Assess the general community noise climate and establish baseline noise levels for comparison with future studies.
2.	Perform a repeat measurement to determine trends or determine effectiveness of previous noise control efforts.
3.	Compare the general noise environments of various areas within the city, or determine areas of greatest impact.
4.	Guide the planning of land use and traffic control.
5.	Compare the overall noise climate of the city with those of other cities.
6.	Relate levels of environmental noise to public attitudes toward noise, or results of a noise attitudinal survey.
7.	Provide a basis for a noise ordinance, area noise limits, and enforcement efforts.
8.	Provide a basis for appeal from theoretically developed restrictions.
9.	Provide information in accordance with any state-imposed municipal noise plan requirements.
10.	Determine whether noise levels identified by EPA or required for HUD or FHWA funding are currently met.
11.	Identify the principal noise sources responsible for the general noise environment.
12.	Provide a basis for developing a cost effective community noise reduction strategy which might include various measures such as educational programs, noise ordinance, construction requirements, etc.
13.	Determine the extent of influence of a limited number of previously identified specific individual noise sources or types of noise sources which are the only principal noise concern of the community. Determine also the potential for reduction of noise from these sources through regulation.

SURVEY CLASS AND EXTRA FEATURES REQUIRED TO SATISFY PROGRAM OBJECTIVES

Monitoring Program Objectives (To be selected from Table 2-1)	Survey Class (See Schedule 2-A for Descriptions)		Extra Survey Features (See Schedule 2-A for Descriptions)							
	Class I	Class II	A	B	C	D	E	F	G	H
1. Assess General Noise Climate	R	–	0	0	0	0	0	–	–	–
2. Perform Repeat Measurement	R	–	0	0	0	0	0	–	–	–
3. Compare Various Areas	R	–	0	0	0	0	0	–	–	–
4. Generally Guide Planning	R	–	0	0	0	R	0	–	–	–
5. Compare Cities	R	–	0	0	0	0	0	–	–	–
6. Relate Noise to Attitudes	R	–	0	R	R	R	0	0	–	–
7. Provide Noise Ordinance Basis	–	R	0*	–*	–*	0*	0	0	0*	–
8. Provide Appeal from Theoretical Restrictions	–	R	0*	–*	–*	0*	0	0	0*	–
9. Obtain Noise-Element Information	–	R	–*	–*	–*	R*	R	R	–*	0
10. Check EPA, or FHWA Levels	–	R	–*	R*	–*	–*	R	–	–*	–
11. Identify Principal Noise Sources	R	–	–	–	–	R	0	0	–	–
12. Provide Noise Reduction Strategy Basis	–	R	–*	–*	–*	R*	0	R	0*	0
13. Investigate Identified Specific Sources	This objective does not require a complete community noise survey. See other procedures given in Appendix B.									

Legend: R: Normally required to meet objective.
0: Consider as an optional survey enhancement.
* Automatically provided by computerized data reduction for Class II Survey –

class required to achieve all of these objectives. If this is a Class I survey, also identify all required extra survey features. If a Class II survey is required, most extra features will be automatically implemented by computerized data reduction procedure (available through EPA).

STEP 2 - Select Preliminary Survey Program

a. Record the necessary survey class and required extra features, as determined from Table 2-2, in Column 1 of Table 2-3.

Example 2-1 Selection of Preliminary Survey Program

Suppose it is desired to meet objectives 3, 4, 7, and 11 as given in Table 2-1. This is a typical set of objectives which will allow the city to identify noisy areas or principal noise sources, and justify noise control ordinances regarding them. Table 2-2 indicates that objectives numbered 3, 4, and 11 can be met with a Class I survey, but that the more accurate and complex Class II survey is necessary to meet objective number 7. Thus, in order to fulfill all of the chosen objectives, a Class II survey will be required. Table 2-2 also indicates that for objectives numbered 4, 7, and 11, extra survey feature D is normally required. Thus, to address all of the chosen objectives, a program consisting of a Class II survey plus extra feature D should be preliminarily selected and recorded in the first column of Table 2-3. As indicated above in Step 1, the Class II survey automatically includes extra feature D and the computerized data reduction procedure may be used.

b. If extra feature E, Survey of Additional Noise Zones, or feature F, Survey of Stationary Noise Sources or Regions, is required, estimate the number of additional noise zones to be included.

Noise zones are geographical regions into which the survey region will be divided as a basis for noise ~~measurement~~ and analysis. The boundaries of each different type of noise zone to be considered will be identified precisely by procedures given in Chapter 3 which are based on land use or predominant activities that are expected to produce distinctive environmental noise characteristics within the zone. The types of noise zone that are explicitly considered in the manual are indicated in Table 2-4. The five zones, which include residential, highway, major roadway A and B, and minor roadway, are automatically incorporated into both the Class I and Class II basic survey procedures. The other zones listed in the table increase the detail of the survey and would be included as extra survey feature E or F. As will be discussed in Section 3.2, further breakdown of the community into detailed noise zones can be done to accommodate specific local conditions or community needs. For instance, it will frequently be desirable to divide the residential noise zone into new and old residential areas, or according to high and low population density. Alternatively, it may be desired to separate a residential area of special interest (i.e., subject to increased development or increased traffic due to development elsewhere, etc.), or to examine independent commercial and industrial zones if they would be reasonably large and distinct. Survey procedures are then applied independently to each noise zone, regardless of whether it is one of the zones listed in Table 2-4 or one created to address specific local needs.

To estimate the number of additional noise zones which will be included under extra survey feature E, use the following procedures. The exact final selection of noise zones will be made in Chapter 3 when noise zone boundaries are determined. If the city contains a fairly dense central business district surrounded by considerably less dense residential areas, plan on establishing two residential noise zones. If a Class II survey is necessary, and if the less dense residential regions can be logically separated into zones of significantly differing characteristics, i.e., different density, age, income, etc., then plan an additional residential

2.3 Select Preliminary Survey Program, Step 2 (Continued)

noise zone for each distinctive type of region, up to a maximum of four. For a Class II survey in a city that contains multi-lane high traffic volume arterial roads which feed the central areas, assume that there will be two separate minor roadway noise zones. If the city contains industrial or commercial areas (as most certainly will) then assume a commercial/industrial noise zone will be used to represent these areas. When performing a Class II survey, if the industrial and commercial land uses are quite different in character, and if each represents a large enough area to be of individual interest to the city, then plan to have separate commercial and industrial noise zones. If the city contains a small general aviation airport, assume an airport noise zone type B (low noise levels) will be present. If the city contains or is adjacent to a commercial jetport, assume that both airport noise zones type A and B will be established. If railroads of any sort pass through the area, plan on having one railroad noise zone. For the use of stationary source noise zones based on local needs and conditions see Schedule 2-A located at the end of this chapter. Then determine whether such zones would be necessary to provide the desired assessement of noise in the community.

Table 2-3

Noise Monitoring Program Cost Estimate Form

1 Program Cost Segment	2 Prep. & Planning Costs Hrs x ALR = Cost	3 Data Acquisition Hrs x ALR = Cost	4 Data Reduction Hrs x ALR = Cost	5 Data Analysis Hrs x ALR = Cost	6 Per Zone Sub-Total	7 Total No. of Noise Zones (Basic Plus Extra Zones)	8 Noise Zone Sub-Total Cost	9 Instru. & Equipment Costs	10 Other Materials Costs	11 Report Preparation Costs	12 Total Segment Cost
Survey Class ______	| $	| $	| $	| $							
	$	+ $	+ $	+ $	= $______	* →	$______	$______	$______	$______	$______
Extra Feature ______	| $	| $	| $	| $							
	$	+ $	+ $	+ $	= $______	× ______	= $______	+ $______	+ $______	+ $______	= $______
Extra Feature ______	| $	| $	| $	| $							
	$	+ $	+ $	+ $	= $______	× ______	= $______	+ $______	+ $______	+ $______	= $______
Extra Feature ______	| $	| $	| $	| $							
	$	+ $	+ $	+ $	= $______	× ______	= $______	+ $______	+ $______	+ $______	= $______
Extra Feature ______	| $	| $	| $	| $							
	$	+ $	+ $	+ $	= $______	× ______	= $______	+ $______	+ $______	+ $______	= $______
Extra Feature ______	| $	| $	| $	| $							
	$	+ $	+ $	+ $	= $______	× ______	= $______	+ $______	+ $______	+ $______	= $______
									Total Noise Monitoring Program Cost		$\sum$ = $______

Note: Instrument requirements, manpower requirements, and other associated costs for Class I and II basic surveys and extra survey features are given in Schedule 2-A and 2-B beginning on page 2-20 at the end of this chapter.

* Class I and II cost estimates from Schedule 2-B are for the five zones included in Class I and Class II surveys. Costs for extra features apply for one zone only.

Table 2-4

Types of Noise Zones Considered in This Manual

Noise Zones Included in Basic Class I or Class II Survey:
• Residential Noise Zone
• Highway Noise Zone
• Major Roadway Noise Zone Type A
• Major Roadway Noise Zone Type B
• Minor Roadway Noise Zone
Noise Zones Suitable for Addition under Extra Survey Features E or F:
• Sub-division of Residential Noise Zone Residential Low Density Residential Medium Density Residential High Density Residential Very High Density Other Residential - based on other distinction of interest
• Sub-division of Minor Roadway Noise Zone Minor Roadway Low Volume Minor Roadway High Volume
• Commercial/Industrial Noise Zone (Or Commercial Noise Zone and Industrial Noise Zone)
• Airport Noise Zone Type A
• Airport Noise Zone Type B
• Railroad Noise Zone
• Stationary Source Noise Zone

2.3 Select Preliminary Survey Program, Step 2 (Continued)

Count the number of noise zones that appear necessary in addition to those normally included in the survey. Practical considerations make it increasingly difficult to implement a survey when the total number of noise zones exceeds ten, but extra zones can normally be accommodated up to a maximum of about 15 for a Class II survey. It would usually not be desirable to exceed six or eight for the limited Class I effort.

STEP 3 Tabulate Preliminary Cost Requirement

Continue to complete Table 2-3, adding costs and man-hour requirements obtained for the basic survey and extra features from Schedule 2-B at the end of this chapter. This schedule provides estimates of the minimum labor and material required for survey implementation.

a. For columns 2 through 5, obtain and record an estimate for the number of hours required for each task of the basic survey or extra feature from Schedule 2-B. Now multiply this time by the average burdened labor rate (ALR) you expect will apply for the type of work in each column. The product of these two values should be entered as the total item cost. For a Class II survey, the costs for extra features A, B, C, D and G will be included in the basic survey cost data from Schedule 2-B, and no separate calculations for these features need be made.

b. For the basic survey and each extra feature (each row), add the products from columns 2 through 5 as indicated on the table, and enter the sum in column 6.

c. For each extra feature, enter the total number of noise zones that may be included in the entire survey. This number should include the five noise zones which are normally part of the basic survey plus any new zones added by extra features E or F and counted in Step 2b. Enter the total number of noise zones in column 7 of each extra feature and multiply as shown by the value in column 6 to determine a sub-total cost to be recorded in column 8.

d. Determine the approximate instrumentation and other costs for columns 9, 10, and 11 from Schedule 2-B and record these for the basic survey and each extra feature.

e. Add the cost values from columns 8 through 11 and record them in column 12.

f. Now add, in a vertical direction, all of the values in column 12 to arrive at the preliminary program cost estimate.

Example 2-2 Preliminary Cost Tabulation

This is a continuation of Example 2-1 based on filling out Table 2-3, and is illustrated in Figure 2-3. Assume an ALR of $10/hour. Using Schedule 2-B, the per zone total will be: (160 x 10) + (288 x 10) + (72 x 10) + (168 x 10) = 6880, which is the labor cost for doing a Class II survey with five zones. Assuming instrumentation is supplied at no charge, and (per Schedule 2-B report preparation costs are $500, the total segment cost is $7380. Add to this extrea feature D - which is $400 per zone for data reduction labor or $2000 (for five zones) and the total monitor program cost becomes $9380.

Section 2.4 Finalize Survey Program

In this section, a sequence of steps is given to develop a final noise survey program based on a simple cost versus objectives trade-off method.

STEP 1 - Determine Available Resources

Determine the resources, in terms of equipment, manpower, and money, that are available for conducting the monitoring program. A list of specific potential sources is given in Table 2-5. The local government should be aware that there may be resources in terms of federal assistance or public involvement available which could substantially reduce the projected program cost to the city. Determine the extent of federal (and state) interaction in local programs and policies. Government financial assistance to alleviate or prevent noise problems has taken the form of specific grants or loans assigned to programs for low noise impact planning and reduction of existing noise levels. Criteria for eligibility to access funds for several government-assisted programs require that certain low noise impact standards be met. These programs are administered primarily through the Department of Housing and Urban Development (HUD) and the Federal Highway Administration (FHWA). Many unique low-cost manpower resources can also be effectively tapped. For instance, volunteer high school students have been successfully used to accomplish noise measurements, federally funded senior citizen employment programs can make manpower available at low cost, and local universities or affiliated research organizations may be able to provide computer assistance for data reduction.

STEP 2 - Compare Costs

Compare the cost and manpower requirements of the preliminary survey program with the resources available. First, using the completed Table 2-3, subtract any available volunteer manhours from those required for the program phase in which the volunteers would participate, and re-calculate the associated labor cost. In a similar way, account for reductions in labor rate that result from opportunities identified in

Table 2-5

Some Noise Monitoring Program Resources

- Municipal Funds
- Municipal Employees
- County or Regional Financial or Manpower Assistance (i.e., Planning Agency)
- Citizen Volunteers
  - Citizens Groups
  - High School or College Students
- University Cooperation
  - Students work and obtain academic credit
  - Loan of measurement equipment
  - Provide acoustical expertise
  - Perform data reduction
  - Provide assistance through University affiliated research institutes
- Federal and State financial assistance
  - American Association of Retired People
  - Comprehensive Education and Training Act
  - Senior Community Service Employment Program
  - Other program or environmental assistance
- Federal Environmental Protection Agency Regional Office - various types of assistance through:
  - Quiet Communities Program (QCP)
  - Each Community Helps Others Program (ECHO)
  - Equipment Loan Program
  - Program tools and documents
- Local Chapter of Acoustical Society of America - various type of assistance
- Local Chapter, Otolaryngological Society of America - various types of assistance

2.4 Finalize Survey Program, Step 2 (Continued)

Step 1. Also subtract the costs of any required equipment available on loan or otherwise without cost. When the costs of this available equipment and manpower are subtracted from the total estimated cost of the preliminary survey program, the result should approximate the available funds. If not, the survey scope should be modified.

STEP 3 - Finalize Survey Program

a. If Requirements Exceed Resources - If the available funds and resources do not meet the requirements of the preliminary survey, and additional resources cannot be identified, then some survey activities will need to be deleted. This can be approached in two ways.

- Cost Method - Scan Table 2-3 to determine the most expensive extra features, and simply begin eliminating these until the budget is met.

- Objectives Method - A more comprehensive approach is to rank the program objectives selected from Table 2-2 in order of importance to the city and program. Then, by progressively eliminating the least important objectives, the normally required extra survey features which were indicated in Table 2-2 for achievement of these objectives and which were not recommended for any chosen objectives of higher importance, could be removed from the program. This process can lead to a reduction of program class from Class II to Class I if the objectives requiring a Class II program are of low importance and can be eliminated.

The user may apply a combination of these approaches to meet his needs, choosing to eliminate objectives of low importance for which extra features of high cost are indicated. Regardless of the approach, the resulting resources must adequately satisfy the requirements for at least a Class I basic survey if a community-wide measurement program is to be undertaken.

2.4 Finalize Survey Program, Step 3 (Continued)

b. If Resources Exceed Preliminary Requirements - In the event that the available manpower and fiscal resources exceed the estimated preliminary requirements, consider supplementing the program with additional extra survey features. To select these additional features, review Table 2-2 to identify those extra survey features that are associated with each program objective and that may be considered for survey enhancement. Review the details of these optional features as given in Schedule 2-A to select additional features which would add new information or support to those objectives of highest importance. Then add these extra features, their required manpower, and costs to Table 2-3 to determine the increased total survey requirements. These can again be compared with resources to determine whether further optional features may be added.

STEP 4 - Consider 24-Hour Measurements

The application of automatic 24-hour measurement equipment can be considered as an activity supplemental to the basic survey process. It will not provide extensive new information, and hence was not listed as a regular survey option. However, 24-hour data can considerably enhance confidence in survey results by providing an independent noise level check, as well as complete descriptions of hourly noise level fluctuations. Continuous measurements are also the best method for obtaining noise level information for use in conjunction with attitudinal data from the companion QCP attitudinal assessment program. The use of 24-hour measurements is described in Appendix A, along with related cost considerations. At this point, read Appendix A to determine if automatic measurements would be desirable and feasible for your program. If so, use the cost discussion provided to include these measurements in the previous assessment of total program resource requirements.

SCHEDULE 2-A

A LISTING OF CLASSES OF NOISE SURVEY AND EXTRA SURVEY FEATURES FOR USE IN THIS MANUAL

SURVEYS

<u>Class I - Community Noise Survey</u> - This is the fundamental community noise survey upon which this manual is based. It provides a general community noise climate description and can be increased in scope through the addition of the extra features described later in this schedule.

Activity:	Partitioning of the city into noise zones; selection of measurement sites; noise measurements - one 20-minute daytime measurement during the week at each site plus nighttime measurements at a portion of these sites, all made using simple sound level meter equipment. Data reduction is by hand or computer tabulation.
Results:	L_{dn}, ± 6 dB, for five noise zones - highway, major roadway A, major roadway B, minor roadway, residential.
Interpretation:	The L_{dn} values give a general indication of the noise environment quality and potential public annoyance.
Requirements:	The basic data can be obtained using the sound level meter techniques given in the manual, or with a noise level distribution analyzer, community noise analyzer, or an energy averaging L_{eq} meter. See Schedule 2-B for manpower and materials cost estimates.

<u>Class II - Community Noise Survey</u> - Similar to the Class I survey, but employing additional techniques to obtain more extensive information and more accurate numerical results.

Activity:	Similar to Class I except - number of measurement sites is increased; computerized data reduction (available separately) automatically performs extra survey features A, B, C, D, and G; normally, more extra features will be included; measurements also made on weekends.

* 95 percent confidence limits

Results: L_{dn}, ± 4 dB,* for the five noise zones.

Interpretation: The numerical results are appropriate for ordinance, compliance, or enforcement purposes, are often most useful if determined for several independent zones using extra feature E, and provide extensive individual source data using feature D.

Requirements: Measurement equipment may be the same as for the Class I survey unless extra features are chosen which restrict the equipment type to manually operated. See "Extra Features" below in this schedule. See Schedule 2-B for manpower and materials cost estimates.

EXTRA SURVEY FEATURES

Extra Feature A.

Calculation of L_{90}

Activity: Additional data reduction to determine L_{90} from standard survey data. Provided automatically if computerized data reduction for Class II survey is used.

Results: L_{90} value for any noise zone and time period surveyed; accuracy approximately that of the general survey class L_{dn}.

Interpretation: L_{90} is often considered a good indication of the "ambient," "background," or "residual" quality of community noise, indicating lower bounds of typical community noise levels.

Requirements: Adequate data for this feature can be obtained using the sound level meter technique or a distribution analyzer, but cannot be obtained with a simple "L_{eq} meter."

* 95 percent confidence limits

Extra Feature B

Calculation of L_1

Activity: Additional data reduction to determine L_1 from the standard survey data. Provided automatically if computerized data reduction for Class II survey is used.

Results: L_1 value for any noise zone and time period surveyed; accuracy approximately equal to that of general survey class L_{dn}.

Interpretation: L_1 is an indication of the highest community noise levels achieved.

Requirements: Adequate data for this feature can be obtained using the sound level meter technique, or a distribution analyzer, but cannot be obtained with a simple "L_{eq} meter."

Extra Feature C

Comparison of L_1 with L_{dn}

Activity: Additional comparative analysis once L_{dn} and L_1 have been determined. Provided automatically if computerized data reduction for Class II survey is used.

Results: Difference in dB between L_1 and L_{dn} for any noise zone or time period surveyed.

Interpretation: The exceedence of L_1 above L_{dn} is an indication of the "peakedness" or unevenness of the noise level. The greater the difference, the less constant the environmental noise level, and the greater the incidence of intrusive high levels. This quality is related to annoyance and acceptability of the noise environment.

Requirements: Same instrumentation restrictions as for "A" or "B."

Extra Feature D

Determination of Common Noise Sources

Activity: When survey data obtained using the SLM, records of individual intrusive sources that are recognizable are made. These data are later reduced to graphical display form, and can be extensively applied in a subsequent noise level reduction strategy document available from EPA. This feature is automatically included in the Class II survey.

Results: Pictorial indication of the numbers and proportions of loud intrusive noise sources in noise level intervals for any noise zone or time periods monitored.

Interpretation: Useful for assessment of most important noise sources, and selection of sources for regulation.

Requirements: Data required for this feature cannot be obtained using the distribution analyzer or L_{eq} meter, and the manual sound level meter procedures given in the text should be used. No extra data taking time or personnel.

Extra Feature E

Survey of Additional Noise Zones

Activity: Further division of the survey area to establish additional noise zones according to actual land use, land use zoning, population density, or other characteristics of interest to the community. Normally, the noise zones added should be confined to the following: sub-division of residential or minor roadway, and railroad, airport, and commercial and/or industrial as indicated in Table 2-4 and described in the text of Chapter 3.

Results: Any results from the basic survey and extra features may be determined for each of these new noise zones.

Interpretation: This information allows comparison of noise characteristics of noise zones with differing land use (i.e., residential versus commercial/industrial). This feature should be used where such comparison is desired, or whenever complaint histories or other data indicate that various zones of the city have noise qualities so different that a single average measure over the entire area would not adequately indicate the noise climate within the city.

Requirements: No instrument restrictions due to this feature alone. Site selection, measurement, and analysis procedures already selected must be applied to each new noise zone.

Extra Feature F

Survey of Stationary Noise Sources or Regions

Activity: Survey of areas affected by large stationary noise source within the city that may project a noise influence over substantial residential or other areas. Apply special technique (see Chapter 3) to define zone of influence, then Class I or II survey and analysis procedures to yield the desired assessments.

Results: Any results available from basic survey and extra feature techniques applied to the zone defined.

Interpretation: These procedures can reveal how large stationary noise sources (powerplants, factories, etc.) affect the levels of community noise in the community surrounding them, and may be applied where there is a complaint history or other indication of a stationary source noise problem extending over an area of many blocks.

Requirements: No instrument restrictions due to this feature alone.

Extra Feature G

Determination of Cumulative Statistical Distribution

Activity: Analysis of survey data to determine a curve of L_x. Provided automatically if computerized data reduction for Class II survey is used.

Results: Chart showing noise level versus percent of time exceeded for any noise zone.

Interpretation: The chart indicates any statistical values included in previous survey features, such as L_1 or L_{90}, and thus these need not be calculated separately. It also indicates the frequency of occurrence of the higher noise levels for which regulation might be desirable. Recommended for use only with Class II surveys.

Requirements: Same instrumentation restrictions as for "A" or "B."

Extra Feature H

Impact Evaluation

Activity: Collect detailed demographic data for combination with survey data to calculate Level Weighted Population (LWP) an indicator of noise impact for any noise zone surveyed.

Results: Numerical value of LWP in number of equivalent people impacted for any noise zone surveyed.

Interpretation: This indicator can provide an assessment of noise exposure in addition to noise levels for any noise zone surveyed. Recommended as an addition to Class II surveys only.

Requirements: No instrument restrictions. Maps and population data for census tracts are necessary.

Schedule 2-B

Approximate Cost Elements for Use for Designing a Noise Measurement Program

Program Element (see Schedule 2-A for descriptions)	COST ITEM Prep. & Planning Hours	Data Acquisition Hours	Data Reduction Hours	Data Analysis Hours	Instru. & Equipment Costs, $	Other Materials & Costs, $	Report Prep. Hours
Class I Survey	160	288	72	168	*	$500	80
Extra Feature A Calculation of L_{90}	-	-	40	-	-	-	-
Extra Feature B Calculation of L_I	-	-	4	-	-	-	-
Extra Feature C Comparison of L_I with L_{dn}	-	-	-	4	-	-	-
Extra Feature D Common Noise Sources	-	-	40	40	-	-	-
Extra Feature E Extra Noise Zones	8	24	16	32	-	-	-
Extra Feature F Stationary Source Noise Zone	16	24	16	32	-	-	-
Extra Features G and H Cumulative Distribution/Impact Evaluation	Not Recommended for Class I Survey						
Class II Survey (includes Extra Features A,B,C, D & G)	240	656	56	280	*	1500	160
Extra Feature E Extra Noise Zones	8	128	8	48	-	-	-
Extra Feature F Stationary Source Noise Zone	16	128	8	48	-	-	-
Extra Feature H Impact Evaluation	-	8	64	16	-	-	-

* See Section 3.4.2 for Field Equipment Requirements and Section C3.3.3 of Appendix C for Instrumentation Cost Data

CHAPTER 3

NOISE MONITORING PROCEDURES

Section 3.1 Introduction

This chapter of the manual presents procedures for planning and accomplishing the actual noise measurements once the basic survey class and extra features have been selected using Chapter 2. Figure 3-1 illustrates these noise monitoring procedures. In Section 3.2, details are presented for an initial partitioning of the city into distinct noise zones of expected individual noise characteristics. This is followed, in Section 3.3, with methods for selecting the number and location of noise measurement sites within these zones. Section 3.4 contains procedures for actual performance of the noise measurement programs. Various sources for related information and assistance are included in these sections where appropriate. To complete the measurement activities, follow the step-by-step procedures of this chapter for the chosen survey class and extra features.

It is clear upon examining Figure 3-1 that the measurement planning and execution require considerable coordination of equipment, material, facility, and manpower resources. Suggestions to guide the handling of such management tasks are offered in Section 3.5. Upon completion of measurement activities, the data will be reduced using the methods of Chapter 4.

Section 3.2 Estimate Noise Zone Boundaries

3.2.1 Introduction

In this section, procedures are given to divide the survey region into geographical areas called noise zones, which become the basis for noise measurement and analysis. To assist in selecting the noise zones to be utilized, the city will first be separated into several (probably five to seven) geographical areas of internal similarity. The noise zone boundaries will then be identified considering these areas and land use or predominant

Noise Monitoring Procedures

- Estimate Noise Zone Boundaries (Section 3.2)

STEP 1	Obtain Survey Base Map
STEP 2	Obtain Base Data
STEP 3	Become Familiar with Survey Base Map
STEP 4	Identify Characteristic Survey Areas and Plot Vacant or Open Spaces
STEP 5	Estimate and Plot Airport Noise Zones
STEP 6	Estimate and Plot Railroad Noise Zones
STEP 7	Estimate and Plot Commercial/Industrial Noise Zones
STEP 8	Estimate and Plot Roadway Noise Zones
STEP 9	Estimate and Plot Residential Noise Zones
STEP 10	Estimate and Plot Stationary Source Noise Zones
STEP 11	Check for Accuracy and Correctness
STEP 12	Review Costs Based on Final Noise Zone Selection

- Select Noise Measurement Sites and Microphone Locations (Section 3.3)

STEP 1	Overlay a Square Grid onto the Base Map
STEP 2	Identify Cell Centers
STEP 3	Overlay Linear Intervals Along Roads on the Base Map
STEP 4	Identify Road Interval Points
STEP 5	Determine Required Number of Noise Measurement Sites
STEP 6	Select Measurement Sites (Except Railroads)
STEP 7	Select Microphone Locations (Except Railroads)
STEP 8	Select Sites for Night and Weekend Measurements
STEP 9	Select Microphone Locations for Railroads

- Perform Noise Measurements (Section 3.4)

STEP 1	Establish Measurement Team
STEP 2	Prepare for Measurements
STEP 3	Train Field Personnel
STEP 4	Hold Practice Measurements
STEP 5	Perform Measurements
STEP 6	Document all Procedures

Figure 3-1. Diagram of the Noise Measurement Procedures Presented in Chapter 3

3.2.1 Introduction (Continued)

activities identified which are expected to produce distinctive environmental noise characteristics within the zone. The noise zones that are considered in the manual were indicated previously in Table 2-4.

The names of the noise zones listed in Table 2-4 reflect the type of activity or land use around which the noise zone will be formed. For example, a railroad noise zone will consist of a strip of land extending in width some distance to either side of a railroad track and following the route through the survey area, roughly indicating the extent of the noise impact zone for the train noise. If there were three or four railroad routes crossing the survey area, a railroad noise zone could be considered to exist along each one of them, defining several strips of land influenced by railroad noise. For our purpose, these several areas, whether or not they are physically connected, will be considered collectively to be the single railroad noise zone for the survey area. Similarly for the other zones, all areas which possess the qualities of a particular zone type will be considered together as a single zone. Thus, each noise zone will usually consist of many small individual areas located throughout the survey region. Figure 3-2 illustrates this concept.

It is important to realize that the noise zone boundaries which will be developed according to the procedures in this chapter are approximate. Essentially, they are estimates of noise influence areas made using procedures that have been simplified for presentation in this manual, but which are considered adequate for planning a community-wide noise survey. The noise zones (with the exception of airport noise zones) do not define specific noise level contours or regions with sufficient accuracy to be used exclusively as a sharp geographical basis for community planning or the expenditure of public funds for relief from noise on an extremely local scale. In cases where accurate local delineations of equal noise contours are required, a noise survey technique that is generally more complex than the one treated in this manual is required and will ordinarily require the services of qualified acousticians.

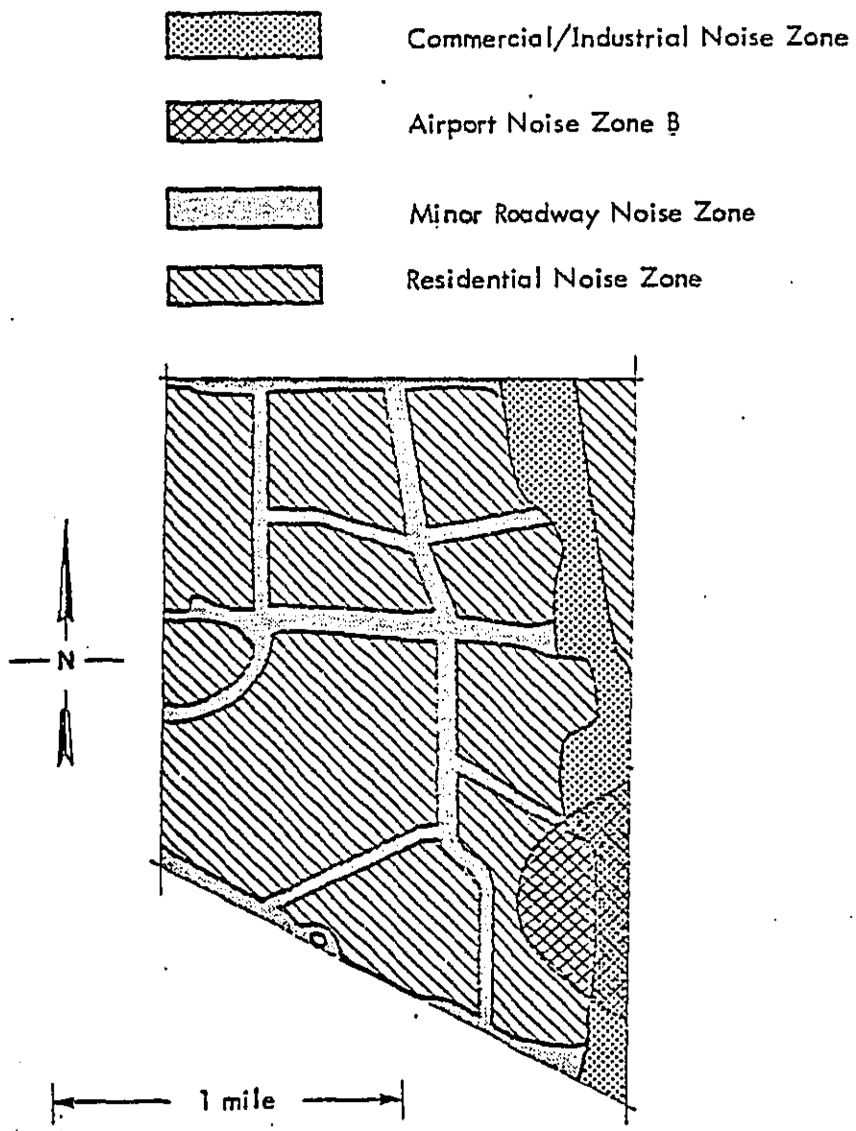


Figure 3-2. Example Noise Zones Plotted on a Portion of a City Map

3.2.1 Introduction (Continued)

The step-by-step procedures given below provide specific instructions concerning collection of requisite data on land use and activity characteristics, and identification and plotting of zone boundaries on a project base map. A sequence of examples utilizing the same portion of an example city is presented to guide the user through some of the final steps. Follow these steps, and once the noise zones are identified, apply the procedures of the subsequent sections to plan the actual noise measurements.

3.2.2 Procedures for Plotting Noise Zones

STEP 1 - Obtain Survey Base Map

Obtain a large scale map (or series of maps) of the city or study area including all roads, railroads and airports for use throughout the project. Minimum recommended scale is 1:24,000 or 1 inch to 2000 feet, and a larger scale should be used if available. The map can be a hand-drawn type or a large aerial photograph showing the required detail. Such a map is normally available from the U.S. Geological Survey, Bureau of the Census, or county or municipal planning and engineering departments, and will subsequently be referred to as the project base map. The map scale and true north should always be identified graphically on this map.

STEP 2 - Obtain Base Data

Obtain the following existing data for use in estimating noise zone boundaries. Items a, b, and c will be required for all surveys. Items d and e below should be accomplished only if applicable noise zones were selected in Section 2.4 of the manual as part of extra survey feature E.

a. Roadway Traffic Data - Obtain Average Daily Traffic (ADT) counts for all arterials and limited access highways within the survey area. (ADT is the average number of vehicles that passes a given point traveling in either direction in 24 hours.) ADT counts are usually available for all types of roads from municipal transportation, highway, engineering or

3.2.2 Procedures for Plotting Noise Zones, Step 2 (Continued)

planning offices. Often they are indicated on a road map with ADT values given for points along major roadways. An example of such a map is presented in Figure 3-3. In the event that municipal offices cannot provide ADT for limited access highways, consult similar county or state departments.

b. Land Use and Population Data - Assemble data for existing land use within the survey area. This will often take the form of maps of existing land use normally available from municipal or county planning and engineering agencies. The existing land use in all portions of the survey area should be described. NOTE: land use zoning maps may be used as a guide, but may differ from actual existing land use data due to undeveloped areas, zoning changes, etc.

In addition, if the residential noise zone may be divided into two noise zones based on population density, obtain population density maps from the same planning or engineering agencies. These agencies may include a community analysis staff that has developed or mapped population density values for various portions of the city in terms of number of people per square mile. This type of information, in the proper form, is extremely useful to the program and should be obtained in the most detailed form available. If this is not available, another type of population density assessment that is commonly developed for planning and analysis purposes can be indirectly used. This is the number of housing units per acre, normally available for specific neighborhoods and developments. By applying to these data the approximate number of people per household for the types of units in the various areas, estimates of population density can be made. Municipal planning departments normally have good estimates of average number of people per household for various regions or residence types within the city. Be sure when checking this data source

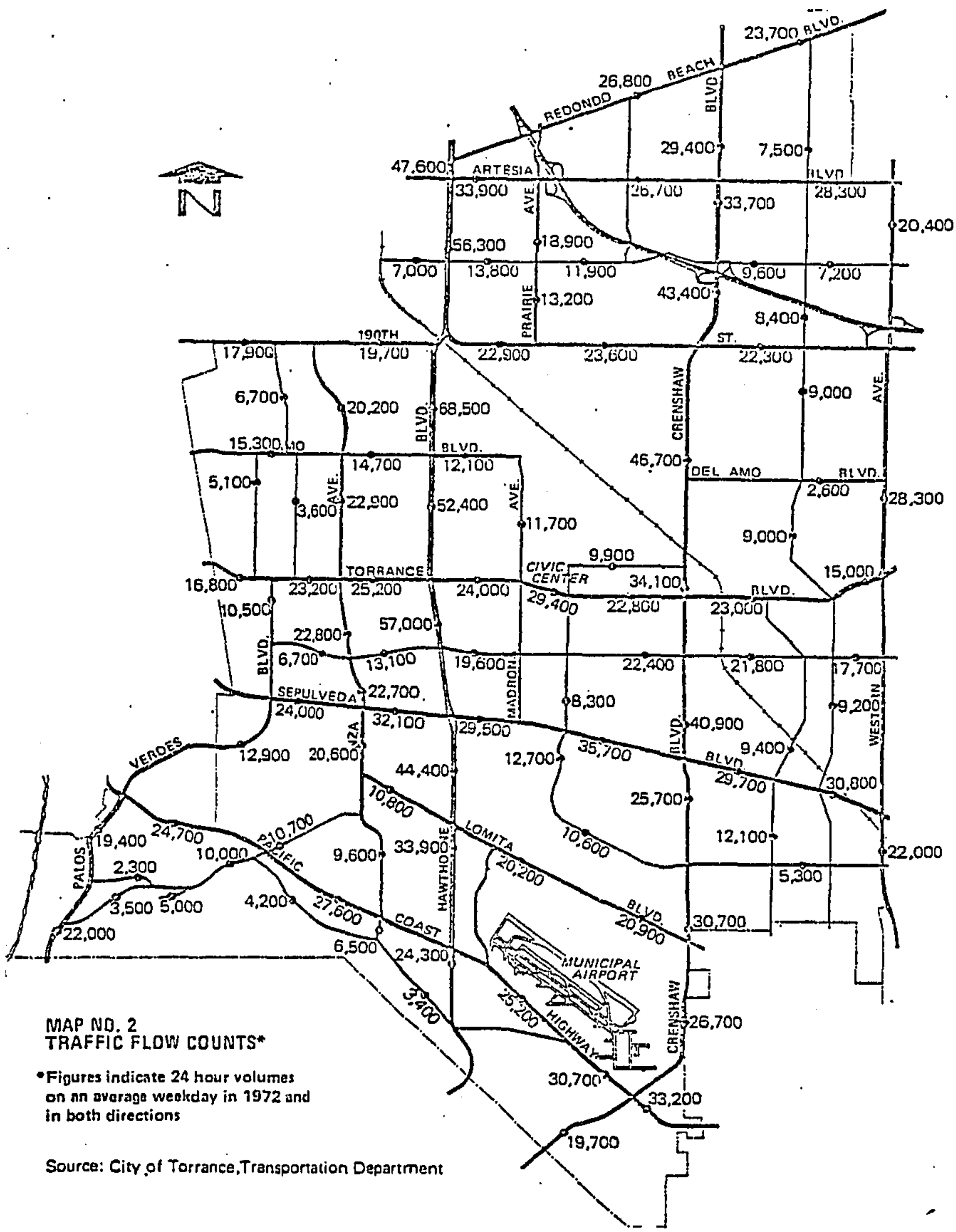


Figure 3-3. Typical Traffic Flow Map Showing Average Daily Traffic Counts (ADT).

3.2.2 Procedures for Plotting Noise Zones, Step 2 (Continued)

to determine whether the "per acre" figures actually represent total area, or are based on net acreage — that occupied by housing and neglecting vacant areas and streets. The former is the desired value, but net values may be used if no other basis is available. As a final approach to numerical population density data, the average density for census tracts may be obtainable. The U.S. Bureau of the Census makes available Block Statistics Reports for numerous populated areas across the country. These reports indicate the population of census tracts — small parcels of land used in census administration. If this information is at hand, and if the land areas of the tracts are known, then the average population density for each tract within the city may be computed directly. The Bureau of the Census does not provide tract land areas, however, and these would need to be obtained from the appropriate municipal agencies, or be measured directly from census tract maps. This is a time-consuming procedure, but would provide data useful in the following steps. As a final approach to population density information, check to see if the planning or engineering department has prepared a qualitative density map, using designations such as "low," "medium," or "high" density instead of numerical values or ranges. If available, this type of data can be applied in the following steps.

c. Airport Influence Area Data - Obtain noise level contours for local commercial, military, and general aviation airports which may have a noise influence extending over the survey area. This can include airports located near, but not actually within, the area. These contours should be the most recent, and may include projections of future airport use if it is desired to include that basis in the program. The contours may be in terms of any of the four common methods listed below in order of preference for describing the cumulative levels of noise exposure that result from airport operations:

3.2.2 Procedures for Plotting Noise Zones, Step 2 (Continued)

- Day-Night Sound Level (L_{dn})
- Noise Exposure Forecast (NEF)
- Community Noise Equivalent Level (CNEL) – (used in California only)
- Composite Noise Rating (CNR)

A typical set of airport noise contours is shown in Figure 3-4.

Noise contours will be available for any airport which has been required by the Federal Government to prepare an Environmental Impact Statement (EIS). Contours will not be available for some small general aviation airports for which an EIS has not been required. These small airports will have minimal noise influences and it will not be necessary to obtain noise data for them. Airport noise contours for civil airports can usually be obtained from airport planning agencies, airport managers, municipal planning departments, or regional Federal Aviation Administration (FAA) offices. Contours for military airports are normally available through the office of the military base commander.

d. Railroad Operations Data – For each principal individual railroad route in the survey region, obtain the average daily number of daytime and nighttime operations. An operation should be considered a single passing of a train or engine, and the daytime and nighttime hours should be taken as 7 a.m. to 10 p.m. and 10 p.m. to 7 a.m., respectively. It is important to determine these values for each principal individual rail line passing through the survey area or connecting separate points within it since activity may differ appreciably between through-routes and local shuttle or switching routes. If several closely spaced tracks run parallel to one another for a distance, they should all be considered portions of the same route. Do not include railroad yards themselves, as these should be

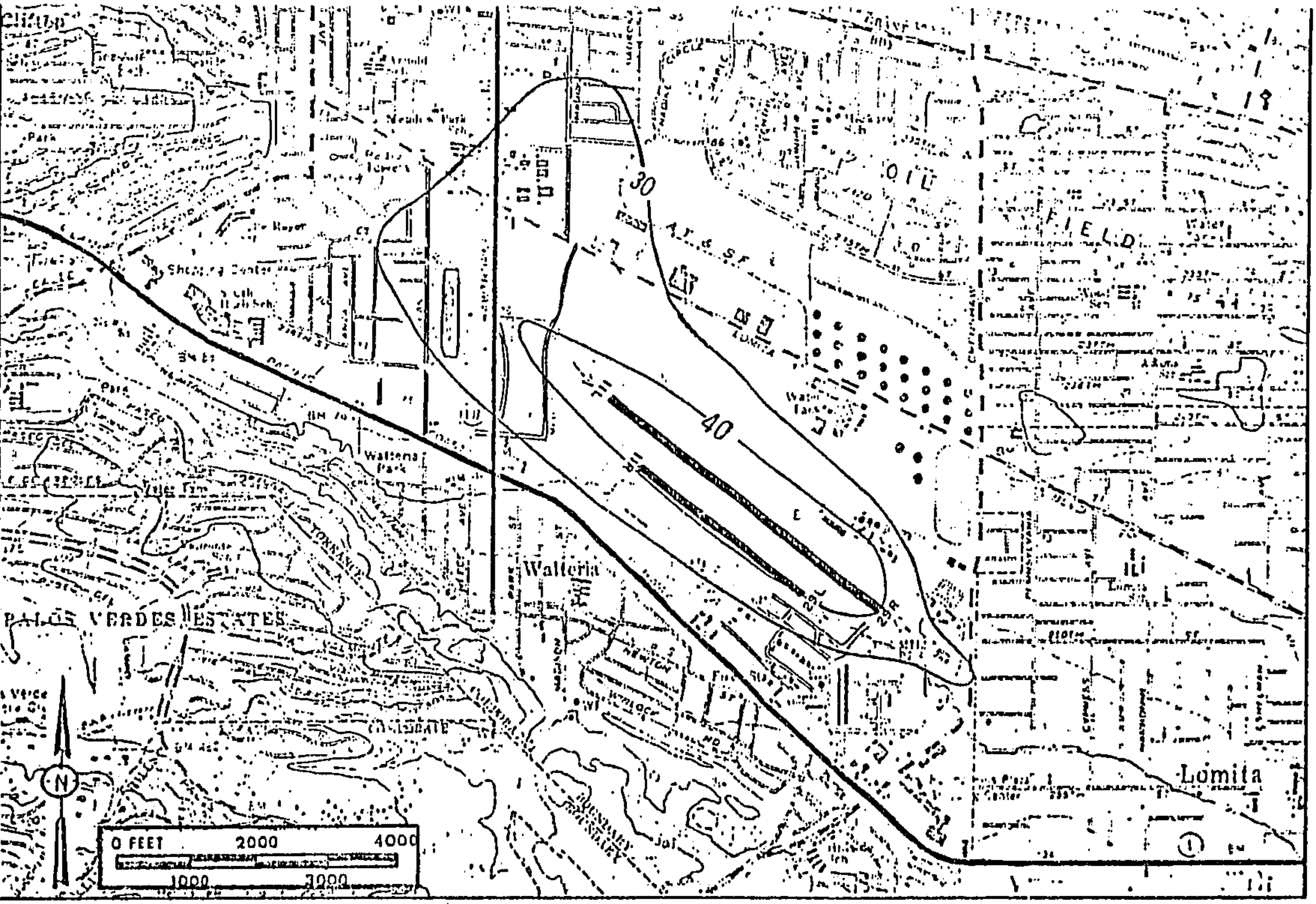


Figure 3-4. Hypothetical NEF Contours for a Small Airport

3.2.2 Procedures for Plotting Noise Zones, Step 2 (Continued)

treated separately as stationary noise sources. The required railroad line operations information is usually available in typical or average form from the railroad company linemaster, dispatcher, superintendent of line operations, or engineering department for the area.

e. Stationary Noise Source Data – Summarize any existing noise complaint histories or community information on the specific stationary noise sources to be investigated. This information was previously obtained in Section 2.3 of the manual.

STEP 3 – Become Familiar with the Survey Base Map

a. Survey the base map, using the data accumulated in Step 2, to become familiar with the following features:

- Areas of residential land use
- Areas of commercial/industrial land use
- Areas where growth or development is occurring
- Major and minor roads
- Limited-access highways (freeways, turnpikes, etc.)
- Railroad through routes
- Commercial, general aviation, and military airports
- Other stationary noise sources of interest (power plants, refineries, railroad yards, etc.)
- Vacant or Open land areas

STEP 4 – Identify Characteristic Survey Areas and Plot Vacant or Open Areas

At this point, a preliminary recognition of distinctive general areas within the survey region will be made that will assist later in the delineation of noise zones, and will be used to identify vacant or unused land areas.

a. From the base map survey performed in Step 3, determine an area or neighborhood pattern to the city's configuration. First examine land

3.2.2 Procedures for Plotting Noise Zones, Step 4 (Continued)

use distribution to identify a dense commercial centralized business district as opposed to surrounding areas of greater residential use. Such central districts may take the form of a compact "hub," or of a linear area following main streets. Population density information or land use data may be used to help define a boundary for this area. From this, lightly sketch the outline of what can be judged to constitute the central business district onto the base map. Now considering the surrounding portion of the city, separate this portion into no more than six general areas that appear naturally distinctive or unique in characteristics. Use residential population density as a major criterion. Large areas having densities that are internally fairly uniform but that differ significantly between areas should be outlined on the base map. The amount of density difference which may be judged significant will depend on an understanding of local conditions, and may be modified by other factors such as neighborhood age, types of structures, typical lot size or typical land value in selecting areas of true distinctiveness for the particular survey region. Large portions of the region consisting greatly of industrial or other nonresidential use should be separately outlined as well. Finally, topographical features should be considered for separation of the city into distinctive areas. Large residential areas that possess a distinctive nature by virtue of elevation of separation by hills, rivers, or other large topographical boundaries should be delineated. When completed, the city or noise survey region should be divided on the base map into about four to seven major areas of independent characteristics. To review, these may include a centralized business area, outlying residential areas separated topographically, or other large nonresidential but internally similar areas.

3.2.2 Procedures for Plotting Noise Zones, Step 4 (Continued)

use distribution to identify a dense commercial centralized business district as opposed to surrounding areas of greater residential use. Such central districts may take the form of a compact "hub," or of a linear area following main streets. Population density information or land use data may be used to help define a boundary for this area. From this, lightly sketch the outline of what can be judged to constitute the central business district onto the base map. Now considering the surrounding portion of the city, separate this portion into no more than six general areas that appear naturally distinctive or unique in characteristics. Use residential population density as a major criterion. Large areas having densities that are internally fairly uniform but that differ significantly between areas should be outlined on the base map. The amount of density difference which may be judged significant will depend on an understanding of local conditions, and may be modified by other factors such as neighborhood age, types of structures, typical lot size or typical land value in selecting areas of true distinctiveness for the particular survey region. Large portions of the region consisting greatly of industrial or other nonresidential use should be separately outlined as well. Finally, topographical features should be considered for separation of the city into distinctive areas. Large residential areas that possess a distinctive nature by virtue of elevation of separation by hills, rivers, or other large topographical boundaries should be delineated. When completed, the city or noise survey region should be divided on the base map into about four to seven major areas of independent characteristics. To review, these may include a centralized business area, outlying residential areas separated topographically, or other large nonresidential but internally similar areas.

3.2.2 Procedures for Plotting Noise Zones, Step 5 (Continued)

b. For the airport noise contour system being used, plot individual noise zone boundaries following the contour lines around each airport on the study base map as follows:

L_{dn} 75 and L_{dn} 65, or
NEF 40 and NEF 30, or
CNEL 75 and CNEL 65, or
CNR 110 and CNR 100.

If only the lower numbered contour line is shown, plot a boundary along only that line. If all of the contours given for an airport which fall outside the airport boundary have values less than L_{dn} 65, NEF 30, CNEL 65, or CNR 100, then no airport noise zones need be considered. Similarly, if the airport is so small that an EIS has not been required, and no contours exist, it is not necessary to consider the airport noise influence in the survey. Airport contours and noise zones may be plotted across vacant land areas.

c. Indicate the areas bounded by these contours to be either an Airport Noise Zone A or an Airport Noise Zone B, based on Table 3-1, regardless of the type of land use or other noise zones covered. One color should be assigned to indicate all Airport Noise Zone A areas and another to show all Airport Noise Zone B areas when plotting around all airports. An example of plotted airport noise zones is shown in Figure 3-5, based on the NEF contours shown in Figure 3-4.

3.2.2 Procedures for Plotting Noise Zones, Step 5 (Continued)

Table 3-1

Airport Noise Zone Criteria

Airport Noise Contour Area	Airport Noise Zone
Inside: L_{dn} 75 Contour or NEF 40 Contour or CNEL 75 Contour or CNR 110 Contour	Airport Noise Zone A
Between: L_{dn} 65 and L_{dn} 75 Contours NEF 30 and NEF 40 Contours CNEL 65 and CNEL 75 Contours CNR 100 and CNR 110 Contours	Airport Noise Zone B

STEP 6 - Estimate and Plot Railroad Noise Zones

If railroad noise zones are to be included in the program, plot the zones along railroad through-routes in the program region according to the procedures given below. These procedures apply only to principal railroad routes passing through the survey area or connecting separate points within it. They should not be applied to railroad yards, which can be dealt with using Step 9. If railroad noise zones are not being considered in the program, proceed to Step 7.

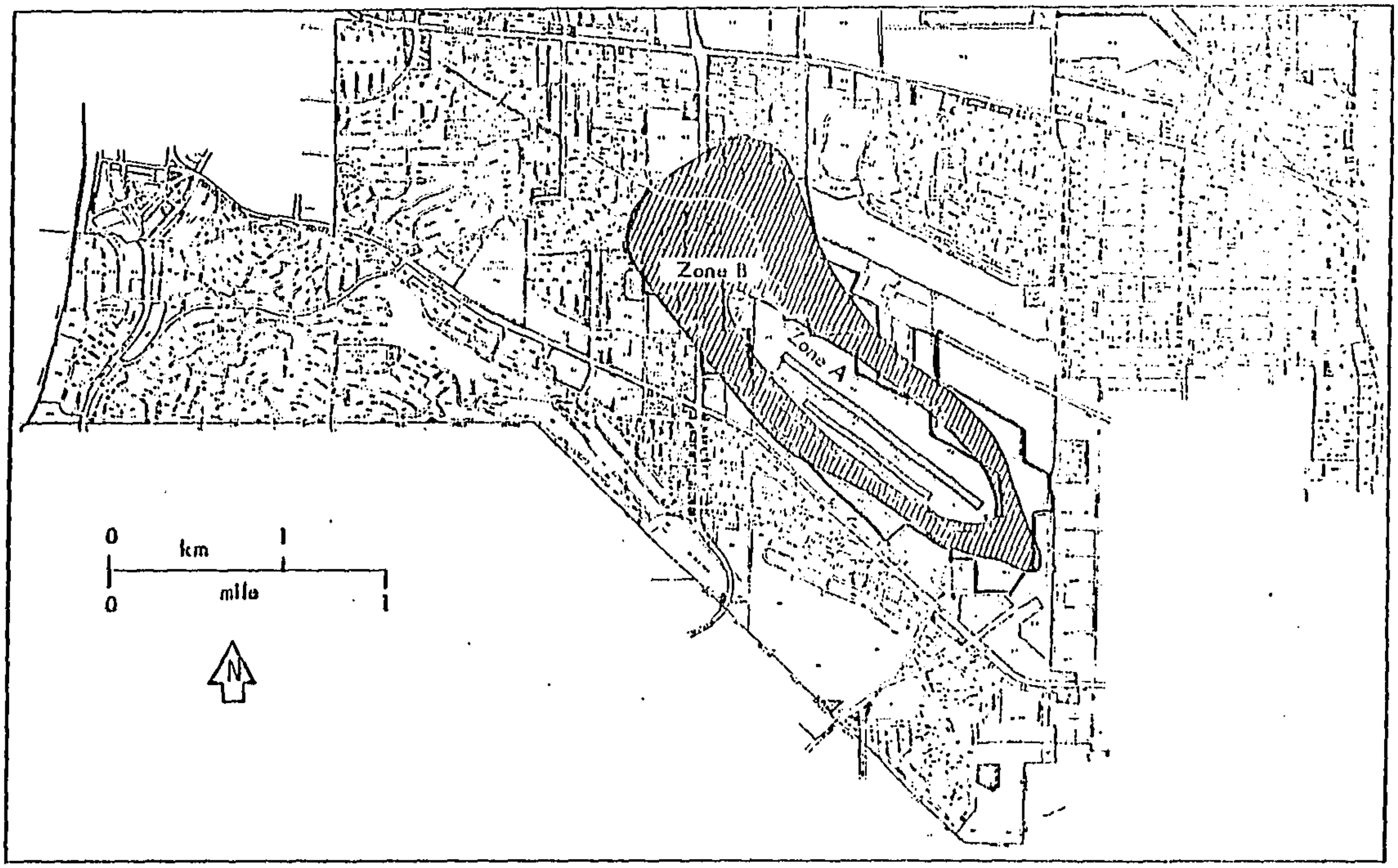


Figure 3-5. Example Plot and Labeling of Airport Noise Zones Based on the Hypothetical Data Shown in Figure 3-4.

3.2.2 Procedure for Plotting Noise Zones, Step 6 (Continued)

a. Review the data obtained in Step 2d to determine the number of day and night operations for each railroad route. If several parallel tracks run along close together for a distance, consider this length of several tracks as one route. Remember, daytime should be taken as 7 a.m. to 10 p.m. and night as 10 p.m. to 7 a.m. If the only operations data available were for different but similar time periods, such as 6 a.m. to 9 p.m., etc., these may be used in the following steps as they exist.

b. For each route, calculate the equivalent number of operations, N, which is equal to the number of daytime operations plus ten times the number of nighttime operations:

$$N = N_{day} + 10\,N_{night}$$

c. The noise zone area around each railroad route will consist of a strip of land following along the route and extending a certain width to each side of the track. Determine the width of the railroad noise zone for each railway from Table 3-2. Note that if N is less than 5, no railroad zone need be considered for that route.

d. Plot a railroad noise zone along each side of each route regardless of adjacent land use. However, do not extend the railroad zone into regions already covered by an airport noise zone. The noise zone boundaries should follow local streets that are nearest the zone width determined in "c" above. The zone boundary should not cross the interior of populated blocks, but may cross open spaces that do not contain residences.

Example 3-1 Railroad Noise Zone

If there are an average of two daytime operations and five nighttime operations, the equivalent number of operations, N, is

$$N = 2 + 10 \times (5) = 52.$$

3.2.2 Procedures for Plotting Noise Zones, Step 6 (Continued)

Example 3-1 (Continued)

Thus, from Table 3-2, the railroad noise zone half-width (track to outer edge) is 153 meters (500 feet). This zone is shown plotted for a portion of an example community in Figure 3-6.

Table 3-2

Railway Noise Zone Width From Track

Equivalent Number of Train Operations $N = N_{day} + 10\ N_{night}$	Railway Noise Zone Width from the Track Centerline in meters (feet)
< 5	No Railroad Zone
5 to 7	31 m (100')
8 to 10	46 m (150')
11 to 16	61 m (200')
17 to 19	76 m (250')
20 to 35	92 m (300')
36 to 50	122 m (400')
51 to 80	153 m (500')
81 to 140	183 m (600')
141 to 250	244 m (800')
251 to 400	305 m (1000')

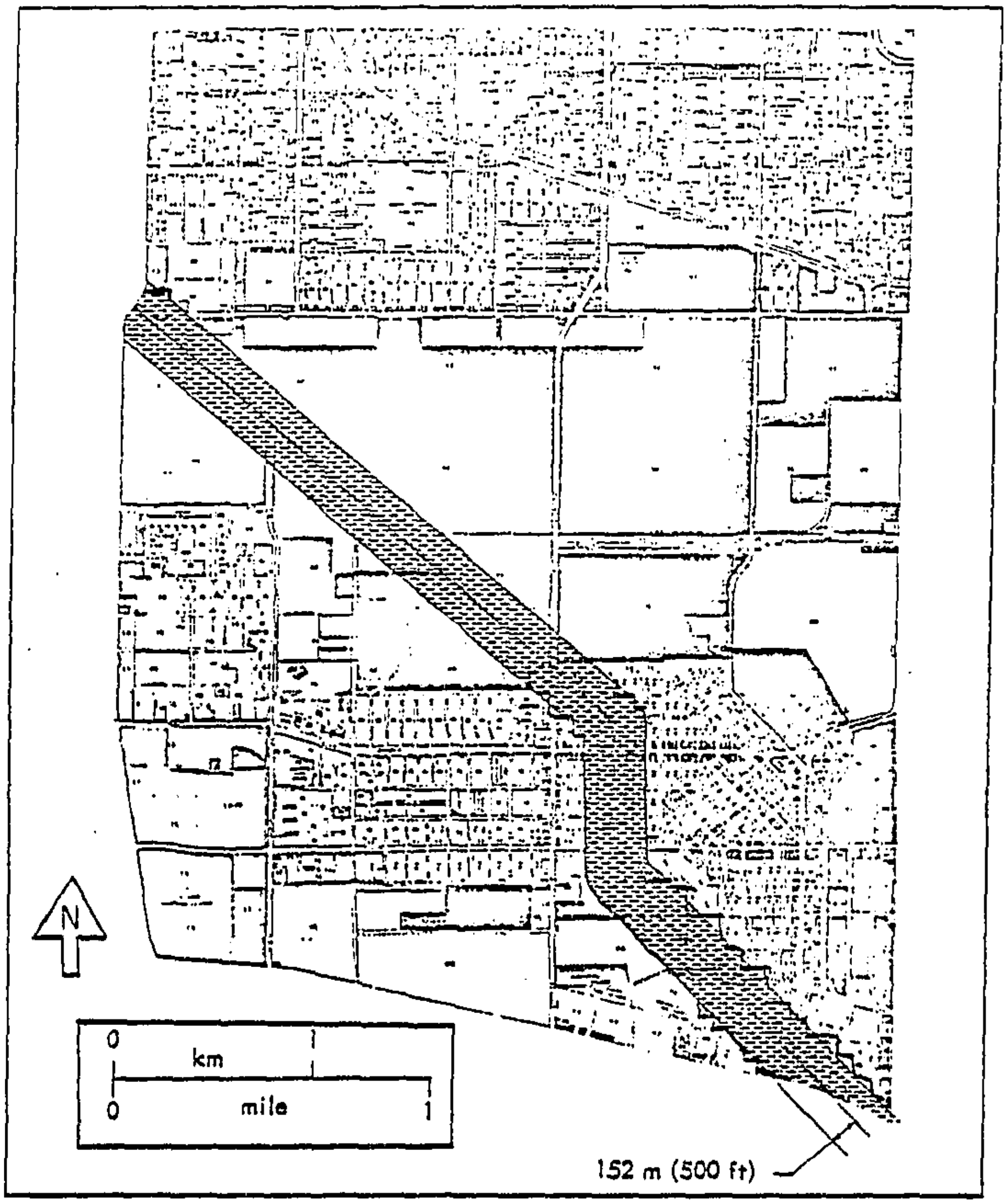


Figure 3-6. Example Plot of Railroad Noise Zone

3.2.2 Procedures for Plotting Noise Zones (Continued)

STEP 7 - Estimate and Plot Commercial/Industrial Noise Zones

In Section 2.3, Step 2b, an estimate was made of the number and types of noise zones to be included in the program. If it was planned at that point to include one or more commercial or industrial type noise zones, follow this step to establish them.

a. Determine the regions of commercial or industrial land use by examining maps of existing land use and any additional land use data. If necessary, use a land use zoning map, but with caution, since it may not reflect actual land use due to vacant land, zoning changes, etc.

b. At this point, determine whether commercial and industrial regions will be combined to constitute one noise zone, or whether separation into two separate noise zones will best support the program goals. This would normally only be done in a Class II survey, when the survey region contains large areas of commercial and industrial land use that are quite different in nature, i.e., shopping as compared to heavy manufacturing. In such cases, the most representative noise level values will be obtained by defining two individual noise zones for independent sampling and noise measurement.

c. To establish the boundaries of a commercial or combined commercial/industrial noise zone, identify all areas having this actual land use. Normally, a central business area of the city will become apparent, as was previously checked for in Step 4. Locate the most dense portion of this area having approximately half or more of the land on each typically sized block under commercial use. This dense central region, including all contained roadways, residential, or other land use areas, should be designated as part of the commercial (or commerial/industrial) noise zone. In addition, locate all other portions of the city under commercial use (and industrial if being combined), and consider these areas as additional sections of the overall commercial or commercial/industrial noise zone. If such an outlying location consists of a normal sized block, half or more of which is devoted to commercial (or industrial) use, and the remainder is predominantly residential, then assign the entire block to the former type of noise zone. Assign a separate color to indicate the commercial (or commercial/industrial) noise zone and color in these areas on the portions of the base map which have not previously been covered by airport or railroad zones. These colored portions of the map will eventually appear as many areas separated by portions of other noise zone types. A combined commercial/industrial noise zone for our sample community is shown plotted in Figure 3-7.

d. If it is desired to establish a separate industrial noise zone, identify only the patches of land subject to current industrial activity, and mark these on the base map with a separate color. This zone will not include the central business district as will the commercial noise zone. Similarly, if a block or parcel of land is more than half devoted to industrial activity, and the remainder is residential, include the entire parcel as a portion of the industrial noise zone.

STEP 8 - Estimate and Plot Roadway Noise Zones

For all survey programs, noise zones must be drawn on the survey base map along each side of our types of roadways. These will be termed:

- Minor Roadways Low Volume ($4000 \leq$ Average Daily Traffic 12000)
- Minor Roadways High Volume ($12000 \leq$ ADT $< 36,000$)
- Major Roadways; those with ADT $\geq 36,000$
- Limited Access Highways; such as tollways or freeways.

To estimate and plot and appropriate noise zones, follow the procedures below.

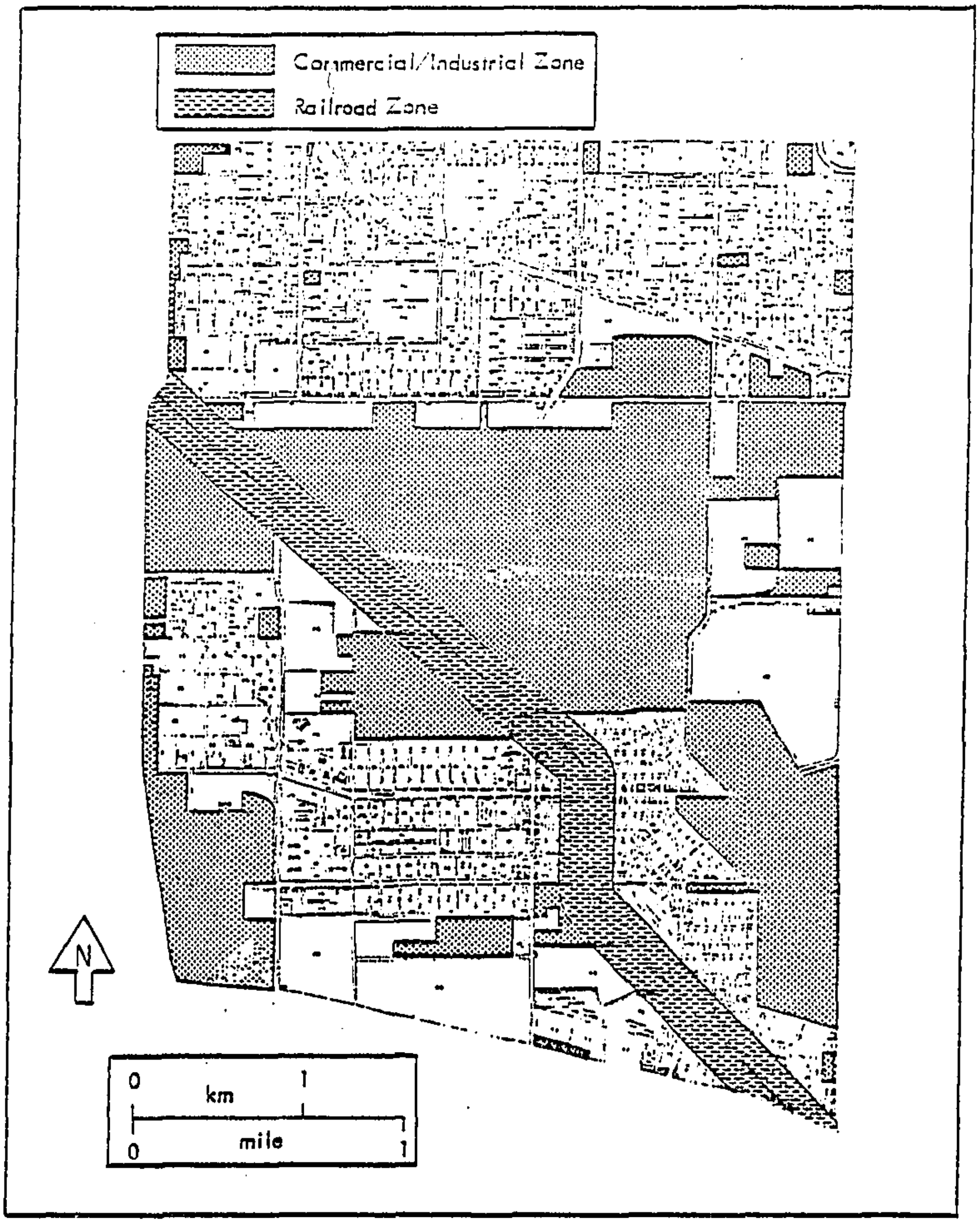


Figure 3-7. Plot of Commercial/Industrial Noise Zones Added to the Railroad Noise Zone Plot for the Example Community.

3.2.2 Procedures for Plotting Noise Zones, Step 8 (Continued)

a. Review and base map and the traffic flow data accumulated in Step 2a. Already indicated on the base map should be the commercial/industrial noise zone (if used), railroad noise zone (if used), and airport noise zone (if used).

b. Locate on the survey base map the two groups of minor surface roadway segments for which traffic data indicate ADT between 4000 and 12,000 vehicles per day, and between 12,000 and 36,000 vehicles per day. Further, identify the portions of these roads that are not yet included in noise zones, or are within or adjacent to vacant land use areas. Frequently, many roadways in the 4000 vehicle per day range have not undergone ADT measurements. For the purpose of this zone identification, it is only necessary to locate those roadways for which ADT data are available.

Note: The ADT count often varies along different segments of the same roadway so that some segments of a street may constitute a major roadway and other segments may be a minor roadway. However, ADT counts are normally given for points rather than for segments of streets. Therefore, if it is necessary to distinguish between minor and major roadway segments of a street, use intersections with major crossroads which appear on the traffic flow map as the boundaries for the segments.

c. Plot sections of the minor roadway noise zones along each side of the portions of these roads where the zone would cover as yet unzoned or vacant areas. The zones should not be plotted over areas already covered by airport, railroad, or commercial/industrial zones. Designate separately the zones for roads with ADT from 4000 to 12,000 vehicles per day, and from 12,000 to 36,000 vehicles per day. The noise zone along the former will be called the minor roadway low volume noise zone, and that for the latter will be named the minor roadway high volume noise zone.

3.2.2 Procedures for Plotting Noise Zones, Step 8 (Continued)

For each zone type, the zone width on each side of the road should equal the average distance from the pavement to the far end of the adjacent residential property along the road, or 61 meters (200 ft), whichever is less. Plot these areas on the map using an assigned color to indicate that all such areas that constitute both of the minor roadway noise zones.

d. Locate on the base map all major surface roadways for which traffic data indicate ADT greater than 36,000 vehicles per day, and identify the portions within or adjacent to vacant or as yet unzoned land. Two separate zones will be plotted around the major roadways, but neither should be plotted over areas covered by airport, railroad, or commercial/industrial noise zones.

e. Plot the first noise zone adjacent to each portion of these roadways as was done in "c" above. These zones should be plotted in an assigned color and collectively referred to as major roadway noise zone A.

f. Immediately outside of each major roadway noise Zone A, plot a second zone in a different color. This outside zone should begin at the boundary of Zone A and extend a sufficient distance from the road to include the second row of residences and their full lot depth, but not more than an additional 61 meters (200 ft). These collective areas should be referred to as major roadway noise Zone B.

g. On the base map, locate the portions of all limited access highways within or adjacent to as yet unzoned or vacant land.

h. Plot a highway noise zone adjacent to each side of these highway sections where the zone will cover residential or open land, and does not interfere with airport, commercial/industrial, or railroad noise zones.

3.2.2 Procedures for Plotting Noise Zones, Step 8 (Continued)

The highway noise zone may cover and include other roadway noise zones. The zone width on each side of the highway should equal the average distance from the pavement to the far end of the adjacent residential property along the highway but should not exceed 244 meters (800 ft). These areas should be plotted with an assigned color to indicate the collective highway noise zone. Example: Roadway and highway noise zones are shown added to the previous noise zone plots for our example community in Figure 3-8. Note that these zones do not extend into railroad or commercial/industrial noise zone areas, and that only one minor roadway noise zone was present in the example community.

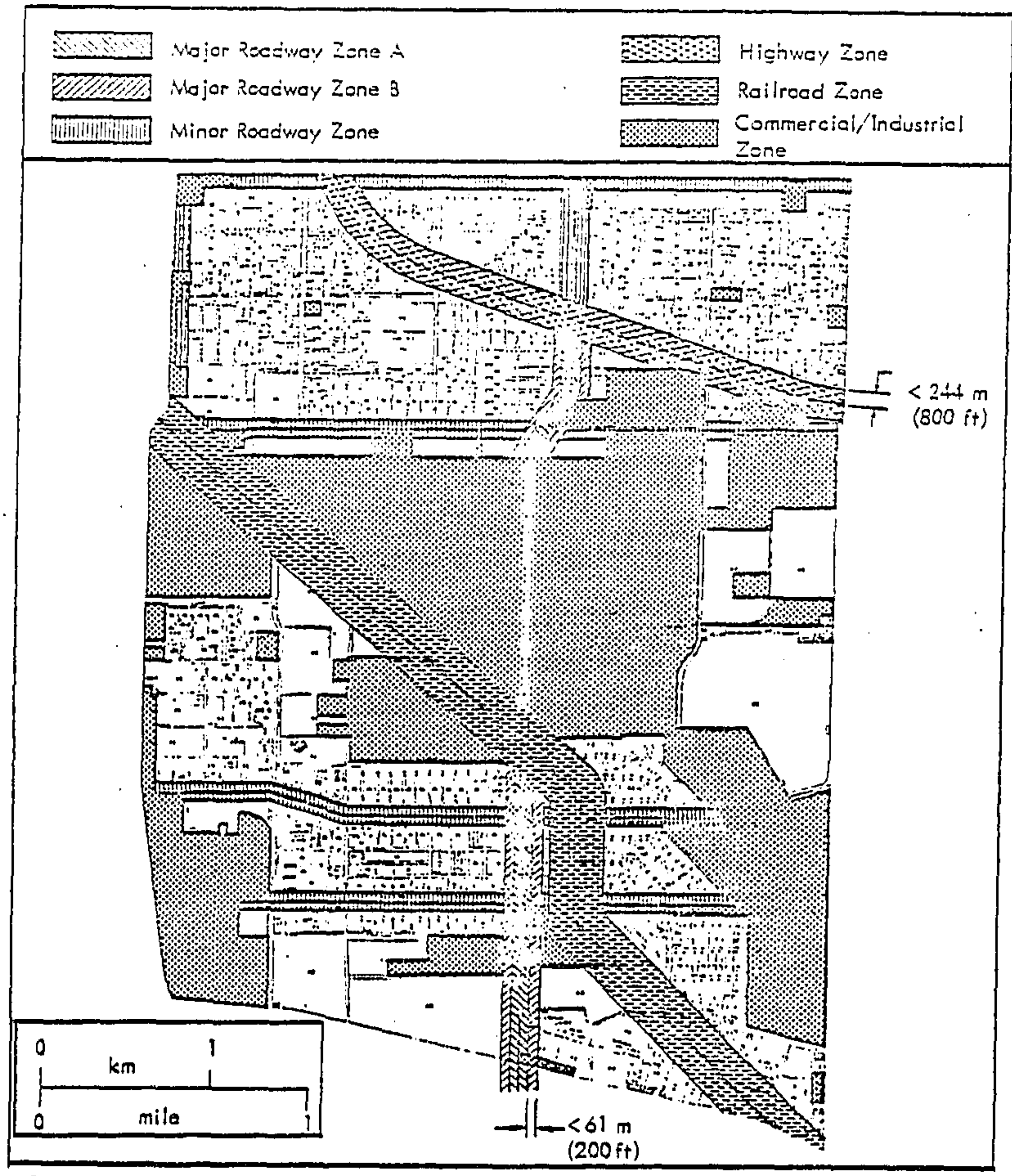


Figure 3-8. Example Plot of the Roadway and Highway Noise Zones Added to Other Plotted Zones for the Example Community

3.2.2 Procedures for Plotting Noise Zones (Continued)

STEP 9 - Estimate and Plot Residential Noise Zones

In Section 2.3, Step 2b, an estimate was made for the number and types of noise zones to be included in the program. If it was planned at that point to include several types of residential noise zones, particularly for a Class II survey, then follow this step to establish these zones.

a. Determine the locations of residential land use by examining the available maps of existing land use and any other land use data. Exercise caution with land use zoning maps since they may not reflect actual land use due to vacant land, zoning changes, etc. In addition, review in detail the population density data accumulated in Chapter 2.

b. If only one general residential noise zone is to be established, assign a color to indicate this zone and color in all residential sections on the base map which are not already covered by railroad, airport, commercial/industrial, roadway, or highway noise zones. This will complete the establishment of the residential noise zone.

c. If the distinctions that can be provided by the use of several residential noise zones are desired, establish these zones using the following population density guidelines. The intent of these guidelines is to assist in separating the residential areas of the city into noise zones having unique and individual character. Other boundaries that may be used for this purpose would consist of discontinuities that have occurred naturally within the city structure, such as between single family dwellings adjacent to a section of high-rise multi-family units, or topographical separation as applied when defining general survey areas in Step 4. Additionally, if a large residential section exists principally within one of the major geographical areas as defined in Step 4, it should be considered a separate noise zone based on the distinctiveness of that area. Thus establish criteria for the different residential noise zones based on a combination of these unique local conditions as well as the numerical population density guidelines if necessary to meaningfully accommodate actual differences between residential areas as they exist in the city. In the event that few or no natural boundaries within the residential areas of the city are clearly distinguishable, the following guidelines may be applied directly:

> Residential Low Density Noise Zone: 0 to 2000 People per square mile (0 to 770 people per square kilometer or 0 to 3 people per acre)
>
> Residential Medium Density Noise Zone: 2000 to 6000 people per square mile (770 to 2320 people per square kilometer or 3 to 9 people per acre)
>
> Residential High Density Noise Zone: 6000 to 18,000 people per square mile (2320 to 6950 people per square kilometer or 9 to 28 people per acre)
>
> Residential Very High Density Noise Zone: Over 18,000 people per square mile (Over 6950 people per square kilometer or over 28 people per acre).

In the event that numerical population data for small regions of the city are not available, but a density map based on qualitative statements of density, such as "low," "medium low," etc. has been prepared, use this qualitative map along with local knowledge of the area to outline distinctive noise zones with population differences.

Having established the specific residential noise zone criteria, review the population density data and the area outlines on the base map, and identify regions or small land portions on the base map that will constitute no more than four types of residential noise zones. If the four density ranges indicated above are present and the zones are established in approximate accordance with them, then the associated zone names should be used. Note that not all of these density ranges may be present (i.e., densities, over 18,000 people per square mile will be unusual in the size of community for which this manual is intended). If one or more residential noise zones are defined based on area location or other non-population criteria, then an appropriate zone name should be assigned. Assign a color to each type of residential noise zone and color in the portion of the map that constitute each zone, but do not extend the residential zones into the previously defined noise zones. Depending on the method of zone definition, each particular zone will finally appear either as a collection of several sections separated by other noise zone types (as if defined strictly by detailed areas of given population density), or as a fairly continuous region (as if defined based on topographical separation).

STEP 10– Estimate and Plot Stationary Source Noise Zones

The large stationary noise sources to be investigated in the program were discussed in Sections 2.3 and 2.4. For each type of large stationary source to be investigated, a noise zone must be formed by establishing an area of influence around each source of the specific type. Plot these zones on the base map using the following procedure.

a. On the base map, locate the large stationary noise sources to be subjected to noise measurements. Become familiar with the local terrain, local roadways, and large buildings.

b. Determine the noise zone boundary for each source by making a site visit to identify the approximate area of audible influence. Starting from several points around the noise source perimeter, walk or travel directly away from the source into the affected residential, commercial/industrial, or other areas until the sounds from the source appear to be masked about half the time by sounds produced in the surrounding noise zone (local streets, children at play, etc.), (Stationary source noise zones should not extend across railroad or airport noise zones.) The location where this occurs marks one point on the noise perimeter. Perform an adequate number of these "walk away tests" (normally between four and eight) to sufficiently define a smooth noise zone boundary for the stationary noise source. All tests should be performed over a short period of time, during non-peak traffic hours and normal weather conditions, and when the noise source is audible to at least a normal degree. Mark this stationary source noise zone on the base map in an assigned color, adjusting the zone outward if necessary to include areas which have been sources of noise complaints. The stationary source noise zone may be superimposed over any of the previously defined zones or areas.

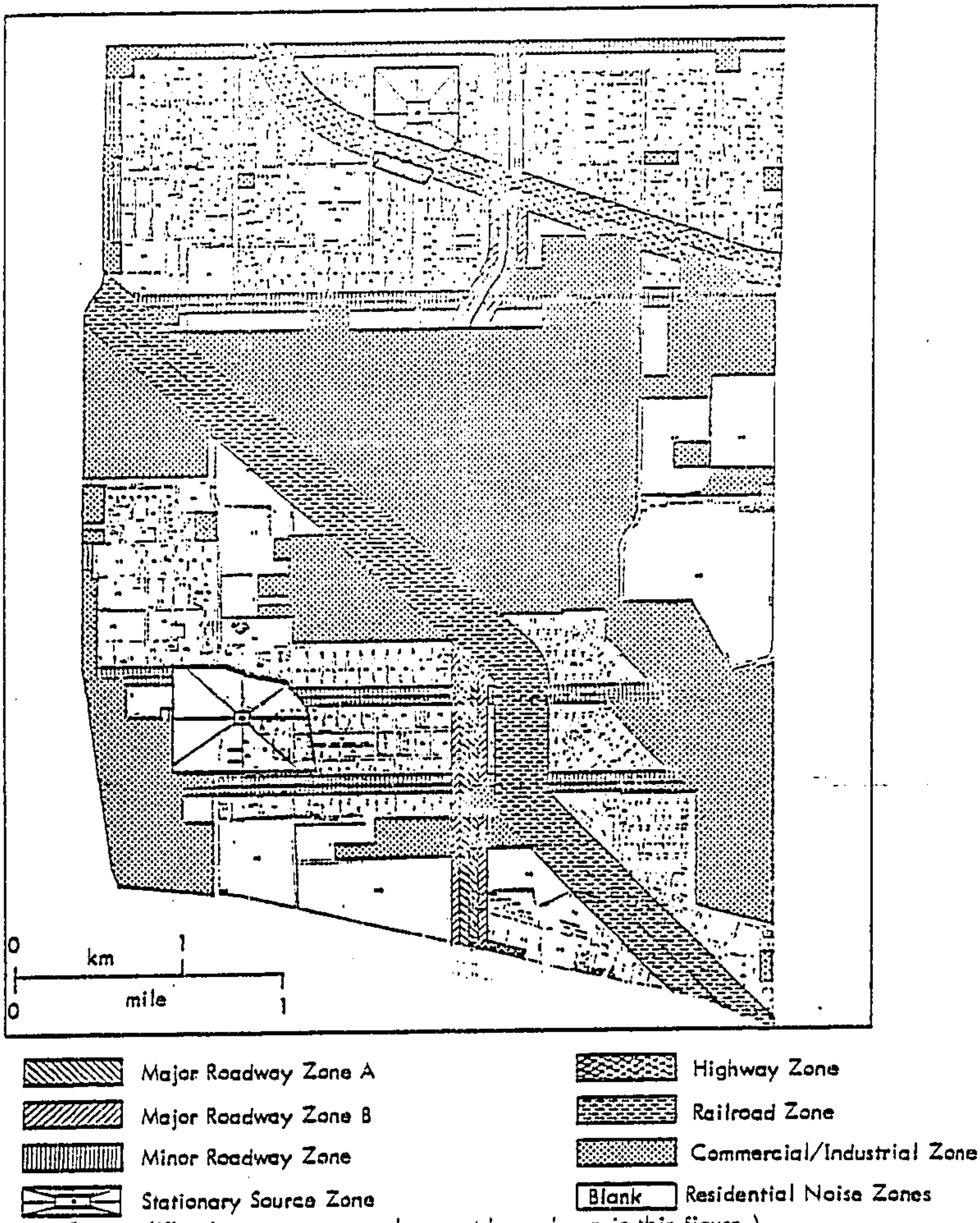
If the stationary noise source is a railroad yard, an alternate method may be used by applying the EPA manual "Calculation of L_{dn} from Railroad Yard Operations." The noise zone boundary can then be established at the 65 dB L_{dn} contour.

NOTE: Occasionally, during the "walk-away test," a roadway or highway noise zone will be encountered within which sounds from the stationary source are completely drowned out. If this occurs, be sure to continue the test on the far side of the roadway noise zone to check whether the noise from the stationary source becomes dominant once again as the roadway noise fades. If this is the case, the stationary source noise zone will consist of areas on either side of the road. If not, the stationary source noise zone will merely stop when it meets the roadway noise zone.

Similarly, "acoustical shadow areas" will be encountered, where a tall building or other large object will act as a noise barrier to shield a small area from the noise source. If such an area is entered during the test, continue past the shielding object for a distance of about five times its height to determine if the source noise becomes dominant beyond the shadow area. Include any such shadow areas in the stationary source noise zone.

Example 3-2 Stationary Source Noise Zone

Two areas make up the single stationary source noise zone for the example city, and are shown plotted in Figure 3-9. In each case, the paths of eight different "walk-away tests" in equally-spaced directions to determine the zone boundaries are shown. Note that the upper zone extends into and beyond a highway noise zone. This means that, for the covered portions of the highway zone, the source noise was audible at least half of the time during the test. Near the pavement, however, the highway noise was audible most of the time. Also notice that sound from the lower stationary source caused that



(Note: For simplification, vacant areas have not been shown in this figure.)

Figure 3-9. Example Plot of Stationary Source Noise Zones Added to Other Plotted Zones for the Example Community

Example 3-2 (Continued)

noise zone to extend over the commercial/industrial and minor roadway noise zones as well as the residential areas. The single residential noise zone has been taken for the purpose of this example as all the unmarked areas. In normal application, it would consist only of these unmarked areas determined to have residential land use in Step 7.

STEP 11 - Check for Accuracy and Correctness

Examine the most recent aerial photos of the survey region to verify that the plotted noise zone boundaries actually conform to what appear to be the appropriate land uses on the photos. Local knowledge or site visits should also be used to clarify areas of uncertainty.

Examine the noise zone plots carefully to check their correctness as follows:

Roadway noise zones should be plotted along each side of major roadways (inner and outer zones), minor roadways, and limited access highways in the areas where they would extend over areas of industrial or commercial land use as traffic noise in these areas is considered a result of the commercial/industrial activities and a contributor to that noise zone.

Railroad and airport type A or B noise zones should extend over any coincident residential or commercial/industrial areas as well as any roadway noise zones. Railroad noise zones should not be extended over airport zones. Residential and commercial/industrial noise zones will normally be shown on the base map in many areas between the other zone types. Finally, noise zones surrounding singular locally intrusive noise sources should extend from the sources outward across any other areas which they influence. Only one zone should be indicated for each type of stationary source, but this zone may consist of a number of separate areas, each surrounding one of the sources.

None of the noise zones, except for airport noise zones defined by airport noise contours or stationary source zones, should extend across large areas of vacant or open land.

3.2.2 Procedures for Plotting Noise Zones (Continued)

STEP 12 - Review Costs Based on Final Noise Zone Selection

During the program planning phases of Chapter 2, estimates of total noise measurement program cost were made by assuming an approximate number of noise zones. The preceding steps of Chapter 3 have allowed final selection of the number of noise zones to be included in the program, which may differ from the preliminary assumption made for costing purposes. If, as the number of zones become solidified in Chapter 3, this difference in number of zones has grown to more than two or three, it may be necessary to reestimate program costs based on this finalized form by applying the methods of Section 2.3 and Table 2-3. Such a check at this point will call early attention to unexpected cost increases arising from the program development done in this chapter, giving the opportunity for additional planning, funding, or administrative action if necessary.

Section 3.3 Select Noise Measurement Sites and Microphone Locations

3.3.1 Introduction

In this section, procedures are given for selecting noise measurement sites throughout the various noise zones previously established in Section 3.2. An outline of the section was given in Figure 3-1. The instructions include identification of the total number of sites required in each noise zone, methods for determining their exact locations, and methods for choosing which of these sites will undergo night or weekend measurements in addition to the normal weekday measurements. The site selection process is illustrated continuing with the same example community for which noise zones were established in Section 3.2. In this chapter, and for the remainder of the manual, the term noise measurement site will be used to designate a localized site or area within which the measurement is to be taken, and microphone location will signify the exact position of the noise measurement microphone. When the required microphone locations are established, proceed to Section 3.4 to accomplish the actual noise measurements.

If automatic 24-hour measurements are being employed in the noise monitoring program, guidance for the selection of measurement sites and microphone locations for this equipment should be taken from Appendix A.

3.3.2 Selection of Measurement Sites and Microphone Locations

Noise measurement sites will be selected using two methods. If social survey clusters for a companion QCP attitudinal assessment have been chosen and identified within a noise zone to be monitored, then these clusters will be selected first as noise measurement sites. A social survey cluster is simply an area of one or two blocks within which interviews are made at specific households to provide social data for assessment of community attitudes toward noise. Additional noise measurement sites will normally be required beyond the number of available clusters and these will be selected using a spatially random gridwork selection procedure described in Steps 1 through 4 below. Follow the given steps to select all measurement sites and microphone locations.

3.3.2 Selection of Measurement Sites and Microphone Locations (Continued)

STEP 1 - Overlay a Square Grid Onto the Base Map

a. Superimpose a square grid pattern onto the base map. This is best done by overlaying a grid previously prepared on tracing paper or transparent plastic to cover the entire area within city limits and any additional areas to be included in the survey. Be sure to place reference (registration) marks on the overlay and base map so the former can be relocated accurately on the map if removed.

b. The grid line spacing should be 0.32 km (0.2 mi) on the map scale, and the grid should be aligned so that grid lines do not coincide with any dominant parallel/orthogonal street patterns. Figure 3-10 shows a grid pattern overlayed onto the base map of the example city previously illustrated.

STEP 2 - Identify Cell Centers

a. Consider each 0.32 km x 0.32 km (0.2 mi x 0.2 mi) square within the boundaries of the noise measurement region to be a basic noise measurement area called a cell. These noise measurement cells will be used as a basis for selecting many of the measurement sites in residential noise zones, commercial/industrial noise zones, and stationary source noise zones.

b. Locate the center point of each cell. This can be found at the intersection of diagonals drawn from each corner across the cell. Now, place a dot at each cell center which falls within the residential noise zones. (Alternatively, it may be convenient to simply shift the grid pattern so its intersection points define the "cell centers.") If commercial/industrial or stationary source noise zones are being included in the survey, place a dot at cell centers that fall within these zones as well. Finally, if the cell center falls within vacant or open area, but the cell itself contains more than one-quarter residential, commercial/industrial, or stationary noise zone area, then place a dot along the edge of the noise zone in the cell which is at a point nearest the cell center. Dots at the proper cell centers are shown in Figure 3-10.

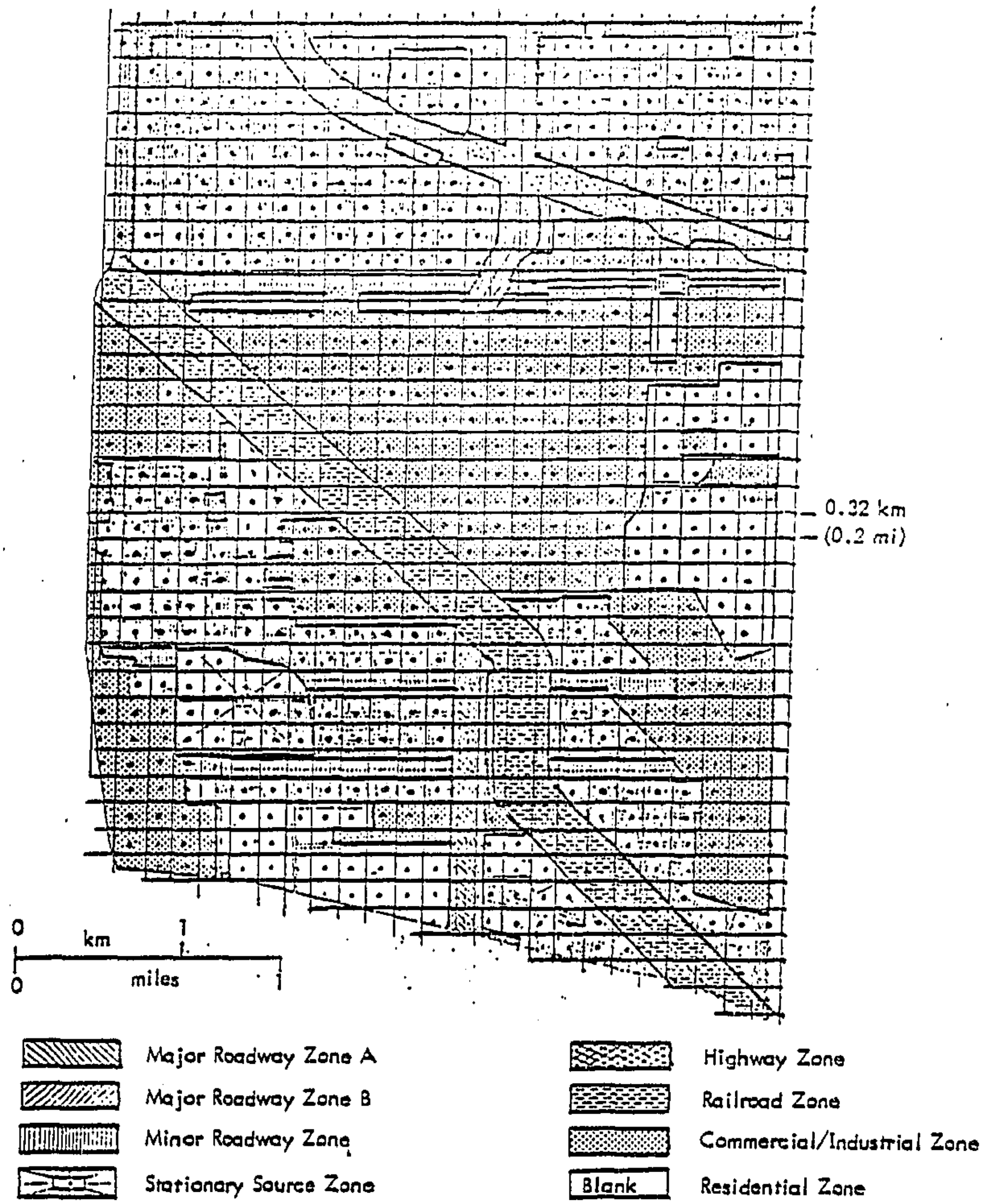


Figure 3-10. Grid and Cell Center Overlay Applied to the Example City Base Map

c. Consecutively number all of the cell centers which have been identified with dots within residential, stationary source, or commercial/industrial zones. Use a regular left-to-right numbering pattern, beginning with the left end of the highest row of dots on the map. Proceed numbering the dots in sequence across this row, skipping cells without dots, continuing in the next lower row when the last dot is reached. Remember, number only the cell centers within residential, stationary source, and commercial/industrial (if included) noise zones, and do not skip any numbers. Note the total number of cells numbered in these noise zones. Noise measurement sites will be selected for these noise zones from the numbered cell centers and, if appropriate, from the social survey clusters within these zones.

STEP 3 - Overlay Linear Intervals Along Roads on the Base Map

Divide each highway noise zone, major roadway noise zones A and B, and minor roadway noise zones into intervals of 0.32 kilometers (0.2 miles) beginning at the zone ends. Mark these intervals by lightly drawing them on a tracing paper or a clear overlay. These intervals are indicated by dots in Figure 3-11.

STEP 4 - Identify Road Interval Points

a. Consider each interval marking made in Step 3 as a potential site along the road for noise measurement. These interval markings will be called road interval points.

b. Consecutively number all of the road interval points which have been located along all of the road noise zones. Begin in the left-hand portion of the base map, following along the principal roads, and numbering the interval points of branch roads when their intersections are reached. After completing a branch road and its sub-branches, continue following along the principal road or begin a new one, progressing through the network of road noise zones in a generally left-to-right or top-to-

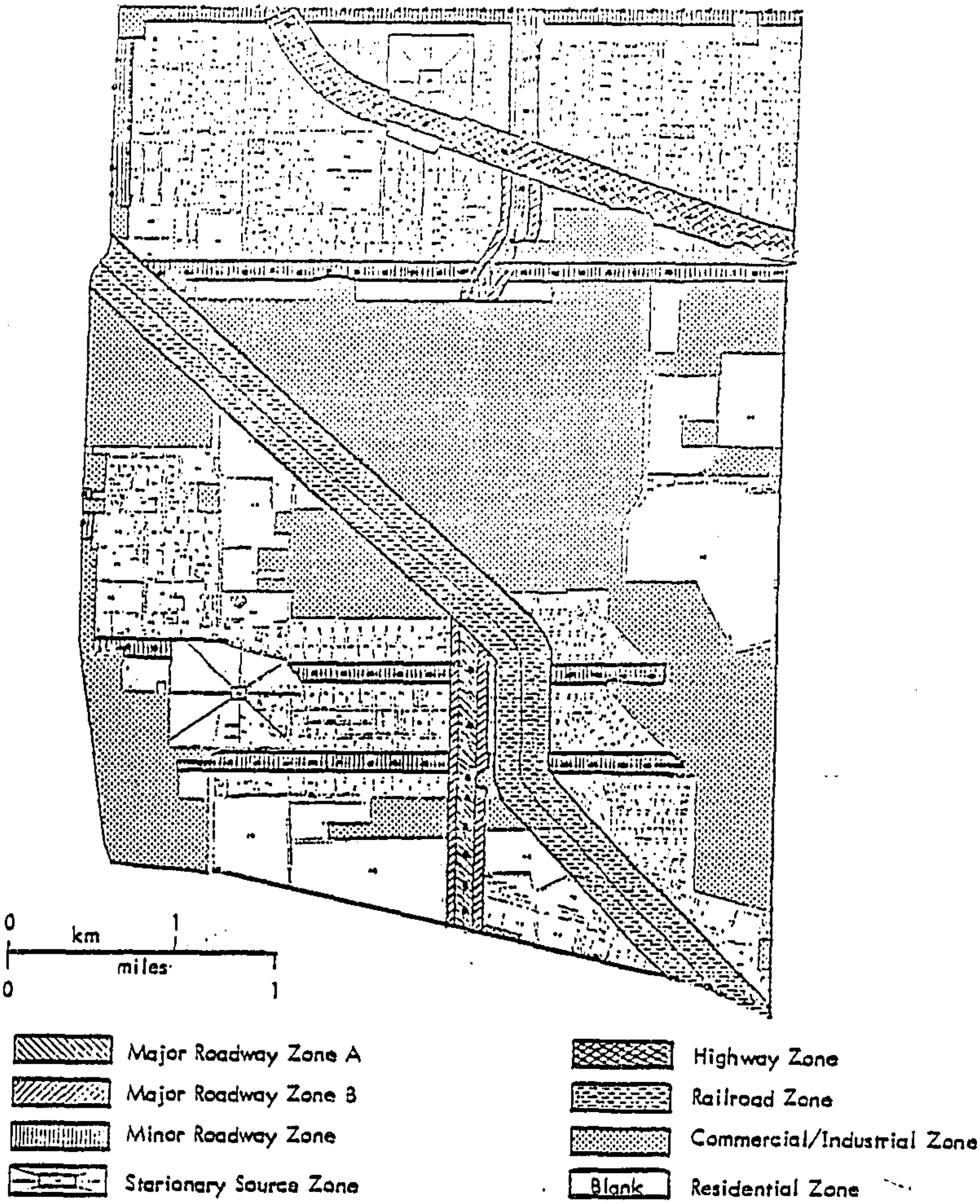


Figure 3-11. Interval Points Overlayed Along Highway and Roadway Noise Zones of the Example City Base Map

bottom pattern, until all interval points have been numbered. Do not skip any numbers. No distinction needs to be made between the different road noise zone types at this time, and a single sequence of numbers should be used. There are many possible numbering patterns which might result from this procedure, and the exact pattern obtained is not critical. It is sufficient merely to obtain a numbering pattern which progresses generally from left-to-right or top-to-bottom across the entire map. Note the final number of road interval points. Noise measurement sites for these noise zones will be selected from these interval points and, if appropriate from social survey cluster sites within these zones.

STEP 5 - Determine Required Number of Noise Measurement Sites

For each noise zone, noise measurements will be required at a certain number of sites. Determine this number from Table 3-3 for the noise zones and survey class of your program. Table 3-3 is based upon the application of statistical techniques as discussed in Appendix D to determine the minimum number of measurement sites required to obtain the spatial accuracy of a Class I or Class II survey. To allow for measurement difficulties at some sites, such as field errors, instrument failure, etc., the values given in Table 3-3 have been increased by 10 percent over the minimum number of statistically required sites. Thus, direct application of Table 3-3 should result in the collection of an adequate sample.

Table 3-3

Number of Noise Monitoring Sites to be Used for
the Survey Classes and Noise Zones

(includes minimum statistically required number of sites
plus 10 percent safety factor)

Noise Zone Type	Number of Sites Required	
	Class I Survey	Class II Survey
Residential (Very High, High, Medium or Low Density, or Other)	8	30
Highway	6	20
Major Roadway Type A	6	20
Major Roadway Type B	6	20
Minor Roadway (High or Low Volume)	6	20
Commercial and/or Industrial	9	42
Stationary Source	9	42
Airport Type A or B	0	0
Railroad	See Section 3.2.2, Step 9	

STEP 6 - Select Measurement Sites (Except Railroads)

If there has been a companion QCP attitudinal assessment, then social survey clusters will have been identified in several of the noise zones. These clusters will be selected first as noise measurement sites in each noise zone. In addition, the numbered cell centers highway and roadway interval points constitute a set of potential noise measurement sites for residential, commercial/industrial, stationary source, highway or roadway noise zones from which the remaining required sites will be selected. To select the required number of measurement sites for each noise zone, identify clusters and specific cell centers or interval points using the following procedure. Examples are given at the end of the procedure sequence.

a. Within each noise zone, identify all social survey clusters. Then subtract the number of clusters from the number of measurement sites required for the zone. This required number was obtained in Step 5. The differences will be the number of additional sites which must be selected in each zone using the gridwork methods. For these remaining sites, proceed through the remaining portions of this step for each noise zone.

   If no attitudinal assessment has been planned and no social survey clusters have been established, then proceed through this step selecting all required noise measurement locations based on the gridwork methods.

b. Pick a number at random which is between zero and the total number of cell centers noted in Step 2c. This will be called the start number for the selection of cell centers. Now pick a second random number between zero and the total number of interval points noted earlier in Step 4b. This will be the start number for the highway or roadway interval points.

c. Now list the number of additional measurement sites beyond the clusters required for all residential, commercial/industrial, and stationary source noise zones as determined in "b" above. Add these numbers, and divide this sum into the total number of cell centers in these zones. Discard any remainder. This quotient will be called the cell center increment number. In analogous fashion, add the total number of additional measurement locations required for the highway, major roadway A, and high and low volume minor roadway noise zones, and divide this sum into the total number of road interval points. Discard any remainder. This quotient will be called the interval point increment number.

d. Start and increment numbers have now been established for the cell centers and for the interval points. These will be used in selecting the additional measurement sites. Apply the following procedure first to the cell centers and then to the interval points to select final measurement sites.

1. Locate the cell center that was labeled in Step 2c, or the interval point that was labeled in Step 4b with the corresponding start numbers. This center (or interval point) will be the first additional measurement sites.

2. Now add the increment number to the labeled number of the first site. This sum is the number of the cell center (or interval point) which becomes the next site.

3. In this fashion, select succeeding cell centers (or interval points), advancing by the increment number each time. Continue this until the number of additional measurement sites required for each type of zone is reached.

4. When the quota for a particular type of zone is achieved, skip over any additional selections that fall within that zone, and continue the process, choosing sites only from zone types still having less than the necessary total number of measurement sites. (Also, see "e" below.)

5. If the quota for some zones is not reached on the first pass through the numbers, continue the increment process making as many passes as necessary.

6. If the second pass through the numbers leads to selection of the same locations, pick, at random, a new start number and continue with this using the same increment number until the required numbers of sites are selected. See "e" and "f" below for additional instructions regarding this process, and illustrative Examples 3-3 and 3-4.

e. If a stationary source noise zone is included in the survey, it will normally consist of a localized area containing a limited number of cell centers, and the selection process described in "c" above may not readily select the required number of sites from the stationary source zone. First, use social survey clusters and the sites in the zone which are identified by the interval procedure of the preceding step. However, when the required number of sites for the residential and commercial/industrial zones are chosen, do not use the interval procedure but rather focus on the stationary source zone itself. If the number of cell centers in the zone is less than the required number of sites for the zone, then simply plan to perform measurements at each cell center. If the number of cell centers in the zone exceeds the required number of measurement sites, then select the remaining sites from these in a random fashion.

f. Along major roadways, there will be only one set of interval points from which to select measurement sites for the two parallel noise Zones A and B. Thus, when interval points are selected in the major roadway zone, assign these points as sites for both major roadway noise Zone A and major roadway noise Zone B. Since the number of required sites for each zone is the same, continue selecting until the required number is achieved.

g. When the process of "c" has been completed, the required numbers of clusters and cell centers should have been identified as measurement sites in the residential, commercial/industrial, and stationary source noise zones. Similarly, the required numbers of clusters and interval points should have been chosen to indicate measurement sites along all highway and roadway noise zones. Mark these selected sites with a small dot directly on the base map.

Example 3-3 Measurement Site Selection from Cell Centers

In this example, illustrated in Figure 3-12, several cell centers have been chosen as measurement sites in the example city. The figure actually shows only about one-half of the city, and thus not all of the measurement sites which would have been selected for a survey in the entire city are included. Also, for clarity in illustrating the gridwork selection procedure, sites at clusters have not been shown. For this city, the start number for cell centers selected at random was 16, and according to the instructions of Step 6d, cell center number 16 was chosen as the first measurement site. The calculated increment number for a hypothetical survey in the sample city was 80 (total number of cell centers divided by the number of residential and commercial/industrial sites required for the survey). Thus, every 80th cell center beginning with number 16 was chosen as a measurement site. When the required number of sites for the residential noise zone was reached, the process of locating every 80th cell center continued until sufficient sites for the commercial/industrial noise zone were selected. During this process, additional cell centers located in the residential noise zone were disregarded. This occurred at two locations near the top of the map while the selection process was on its second pass through the map. When the required number of commercial/industrial sites had been selected, the number of selected sites in both of the stationary source noise zones was still deficient. Since continuation of the interval process would have taken a long time to locate a sufficient number of sites within the stationary source noise zones, the interval process was stopped and the required additional sites were selected at random from the remaining cell centers in each stationary source zone. This completed the process of selecting noise measurement sites in the residential, commercial/industrial, and stationary source noise zones.

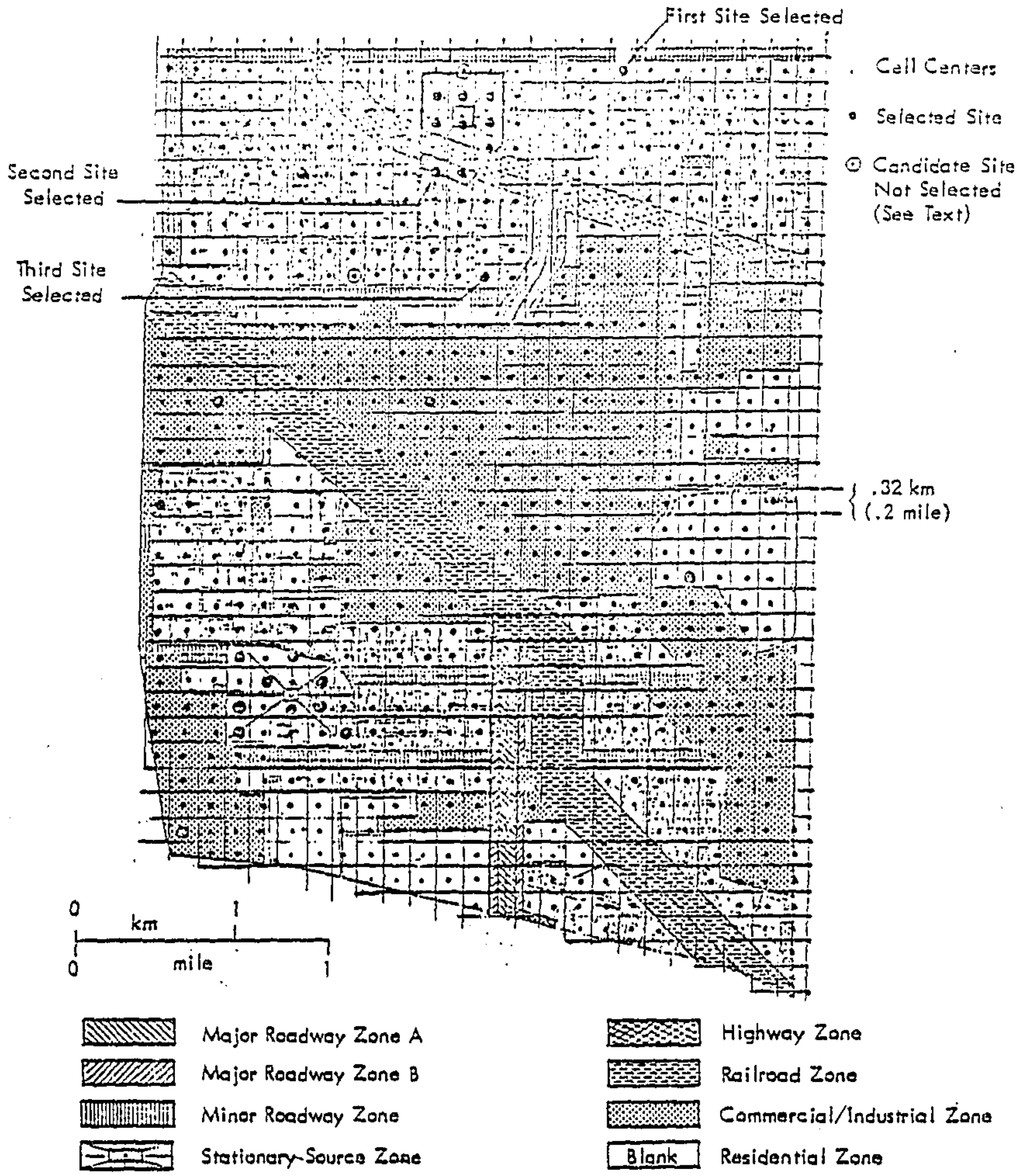


Figure 3-12. Example Site Selection Procedure for Stationary, Residential, and Commercial/Industrial Zones Using the Cell Center Method (Note: Only a Portion of the Sample Community is Shown. Cell Center Increment Number = 80. Social Survey Cluster Sites have been omitted for clarity.)

3.3.2 Selection of Measurement Sites and Microphone Locations, Step 6 (Continued)

Example 3-4 Measurement Site Selection from Road Interval Point

In this example, road interval points have been selected for measurement sites in our example community as shown in Figure 3-13. The entire procedure of selecting sites from the numbered road interval points for a Class I survey is illustrated. However, as with Example 3-3 above, the social survey clusters and associated sites have not been shown in order to illustrate the interval process most clearly. Interval points along roads were numbered in a generally top-to-bottom pattern. The assigned numbers are shown for every second interval point, and the start number selected was number 1. Next, an increment number was computed as follows:

$$\text{Increment Number} = \frac{\text{Total Number of Interval Points}}{\text{Number of Required Sites}} = \frac{115}{12} = 9.6$$

The remainder of 0.6 is discarded, and the increment number becomes nine. (Note that, we have assumed in this example that only three sites beyond presumed cluster sites were required for each of the four noise zones. Thus, the number of required sites is 12.) The site selection procedure began with the start point, number 1, and proceeded to advance nine points at a time through the assigned numbers. Thus, point numbers 1 and 10 were selected as the first sites for the minor roadway noise zone, 18 became the first highway zone measurement site, and 28 became the third and final site selection for the minor roadway zone, and so on. Following the sequence of selections, one can see that nearly three complete passes through the interval numbers were required to obtain three sites for each type of highway and roadway noise zone.

h. All of the selected noise measurement sites must now be renumbered with permanent site designations. For each noise zone, label the sites directly on the base map with consecutive numbers, beginning with the first site selected preceding each number with the zone prefix given in Table 3-4. This should be done for all sites, whether selected at clusters, cell centers, or interval points. For example, the first site in a simple residential noise zone would be labeled R1, and the next, R2, etc. The commercial/industrial

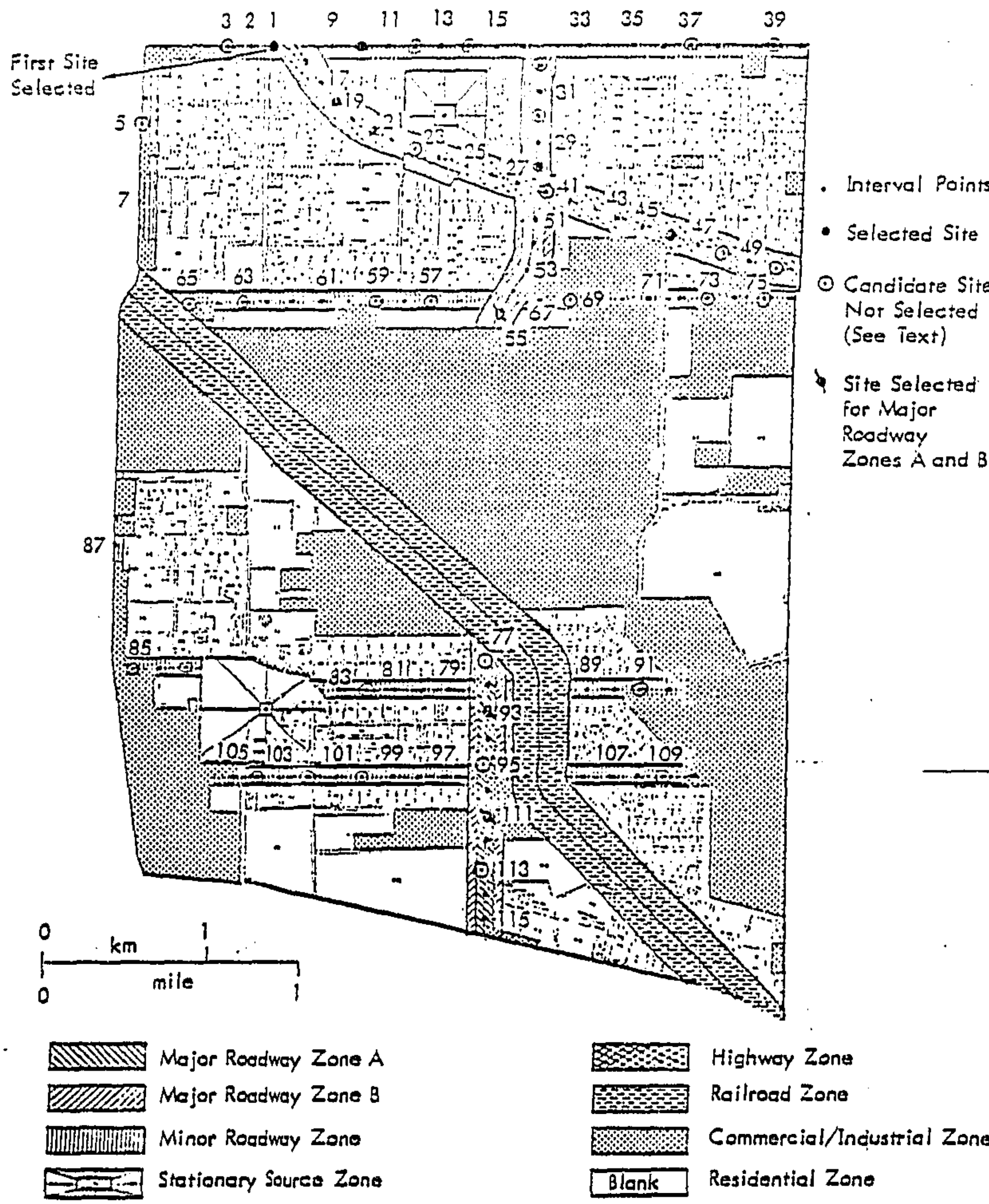


Figure 3-13. Example Site Selection Procedure for Roadway Zones Using the Interval Point Method (Note: only a portion of the sample community is shown. Interval point increment number = 9. Social survey cluster sites have been omitted for clarity.)

sites would be labeled CI 1, CI 2, and so on. It is particularly important to use the correct indicated prefixes for a Class II survey where a computerized method will probably be utilized for data reduction. Continue this process until all measurement sites for all noise zones are appropriately labeled as indicated for our example community in Figure 3-14.

Table 3-4

Noise Zone Prefixes for Noise Measurement Site Labeling*

Noise Zone Type	Prefix
Residential	R
Residential Low Density	RL
Residential Medium Density	RM
Residential High Density	RH
Residential Very High Density	RV
Highway	H
Major Roadway Type A	A
Major Roadway Type B	B
Minor Roadway	M
Minor Roadway High Volume	MH
Minor Roadway Low Volume	ML
Commercial/Industrial	CI
Commercial	C
Industrial	I
Stationary Source	S (SA, SB, etc., if more than one zone)
Railroad	RR

* Note: Prefixes are given for all zone types including both specific divisions which may not always be used, and also broader, more inclusive zones.

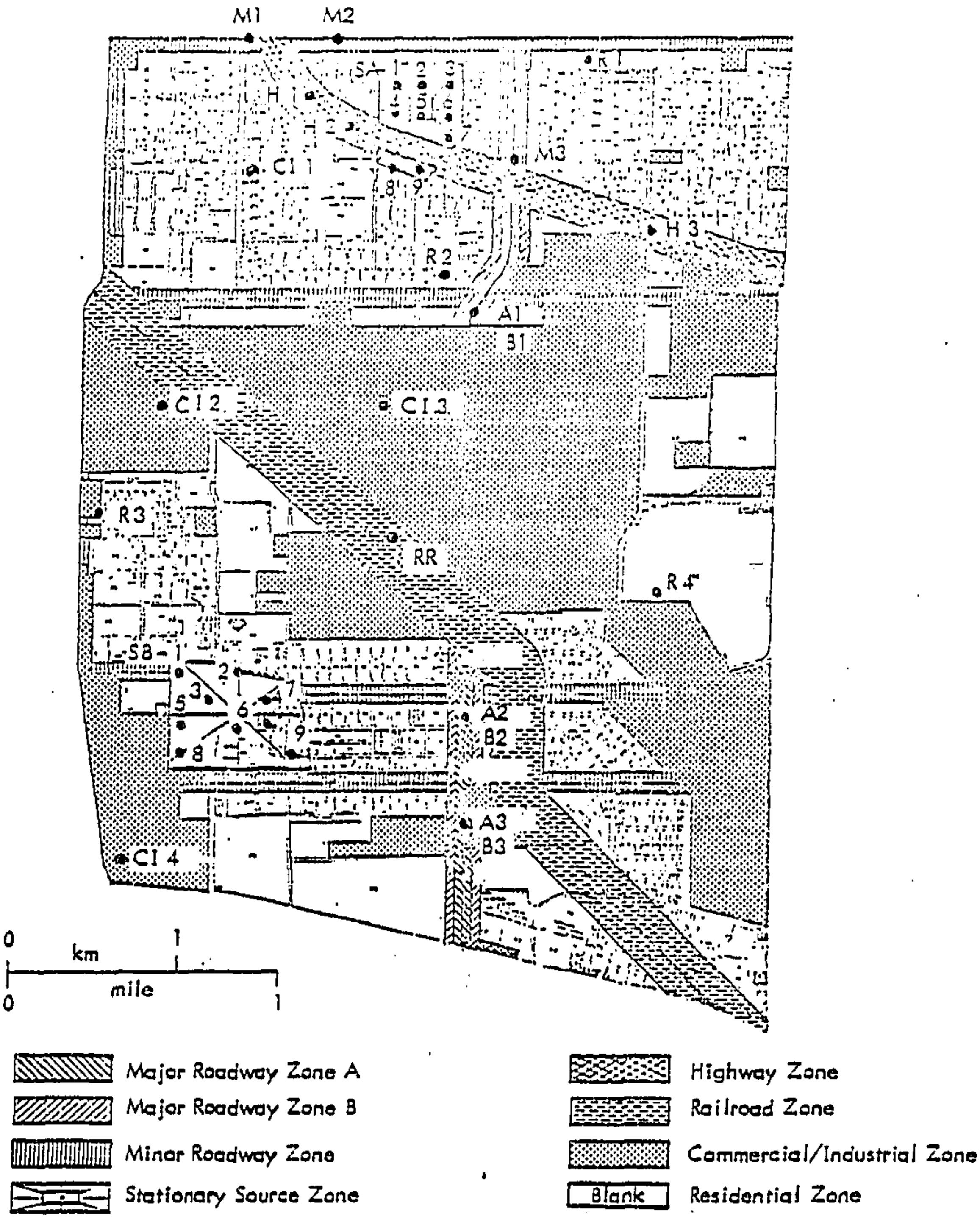


Figure 3-14. Labeled Measurement Sites Selected for the Example Community. (Note: Only a Portion of the Sample Community is Shown.)

3.3.2 Selection of Measurement Sites and Microphone Locations (Continued)

STEP 7 - Select Microphone Locations (Except Railroads)

In order to prepare explicit instructions for field personnel performing the noise measurements, an accurate microphone location must now be established to within just a few meters for each site, whether situated at clusters, cell centers, or interval points. The following procedures identify a specific microphone location for each of these selected measurement sites. Indicate the location for each site to within a few meters on a separate sketch, large scale map, or aerial photo of the immediate site area that is sufficiently detailed to show individual buildings, all roads, walls, driveways, trees, etc. (i.e., 1:2400 scale or larger). These sheets, at least one for each site, will be included in field noise measurement packets and used by field personnel to actually locate the microphones when performing measurements. (More than one may be required if the site is to be measured also at night or on weekends as explained later in Section 3.2.2, Step 8.) Thus, for each site, if a map or photo of sufficient resolution to allow an accurate positioning on paper is not available, a site sketch showing the necessary detail and microphone location should be prepared based on small scale maps or an actual site visit. On all site diagrams, show a "north" arrow.

a. For cluster sites, which may have been established in many or all noise zones, a microphone location must be selected at a position within the cluster that is most nearly representative of the average noise environment in the cluster. Ideally, such a position might be thought of as the centroid of the cluster block or area. In practice, however, selection of a representative location requires the judgment of noise levels, traffic flow, and other environmental influences on the cluster. For all clusters, the microphone should be located in front of one of the cluster households that was subjected to an attitudinal interview. (Normally, every seventh household will be interviewed.) To select the interview household having a noise exposure most typical or representative of the cluster, examine the surrounding noise sources for the cluster to identify an area with typical sound levels. This may require a site visit for listening or brief measurements with a hand-held sound level meter. For example, if there are no unusually dominant sources, and the cluster is surrounded by streets of approximately equivalent traffic flow causing a fairly uniform noise pattern, then one might select the interview household most near the cluster center. If, however, the cluster is bounded on one side by an unusually high volume road, a typical location would likely be found at the interview residence most nearly halfway from the busy road to the opposite side of the cluster. Likewise, if the cluster is exposed to a dominant noise source outside of the cluster area, such as an elevated highway, railroad, or airport, a representative household would be found approximately midway along the cluster proceeding away from the source. When selecting a microphone location in a cluster, be on the alert for the shielding effects of unusually tall buildings, intermittent local noise sources such as garages or small factories, and the operating schedules of all influencing noise sources. These factors must be taken into account when selecting a representative measurement site in the cluster. Avoid alleys or small, well-shielded alley-type streets unless the population directly fronting on them is sufficient to warrant representation. For specific instruction in the positioning of the microphone at the residence, see "c", Case 6, of this step, which follows.

b. For cell center type sites which have been established for residential and perhaps commercial/industrial and stationary source noise zones, identify a specific microphone location for each site that is as near as possible to the center of the selected site as represented by the center of the dot on the base map. This should be specified accurately to within a few meters. Normally, these sites will fall into one of four different cases:

3.3.2 Selection of Measurement Sites and Microphone Locations, Step 7 (Continued)

Case 1: Site is in Open Area – If the cell center falls on an area of accessible open ground farther than 1.8 m (6.0 ft) from buildings or vertical surfaces, then establish the microphone location at this exact point. If this location is in a backyard or other area directly shielded from a frontage street, then relocate as in Case 2 or 3.

Case 2: Site is on a Roadway – If the cell center falls on or beside a roadway, establish the microphone location at the nearest point which is 15 meters (50 feet) from the pavement of a surface street or 30 meters (100 feet) from a limited access highway. If a structure prevents this location, see Case 3.

Case 3: Site is on a Structure – If the cell center falls on a building or structure, then establish the microphone location between the building and nearest fronting road and 1.8 m (6 ft) from the building facade as indicated in Case 6 for roadway sites below.

Case 4: Site is Otherwise Inaccessible – If the cell center location is inaccessible for reasons other than interference by buildings (on a bridge, inaccessible private property, etc.), establish the microphone location at the nearest accessible spot, applying the rules above.

c. For interval point type sites along roads, an exact spot for measurement has still not been accurately determined. To do this, first arbitrarily decide on which side of the road the measurement will be taken. A coin-flipping procedure is adequate. Of course, if the road noise zone has been defined on only one side of the road, then use that side. Once this is determined, one of the following cases will apply.

Case 5: Open Roadside Land – If the land is vacant or open, establish the microphone site aligned with the interval point 15 meters (50 feet) from the pavement edge for all minor roadway noise zone sites and major roadway noise Zone A sites. For major roadway noise Zone B sites, establish the site 15 meters (50 feet) outward from the boundary of the noise Zone A. For highway noise zones, establish the site 30 meters (100 feet) from the highway right-of-way at the interval point.

Case 6: Roadside Structures – If there are buildings or structures along the road covering the desired location, choose a microphone site 1.8 meters (6 feet) toward the street out from one of the building corners facing the street. If the building has a driveway, use the corner opposite the side having the driveway. If there is no driveway, an arbitrary choice should be made. This location procedure is illustrated in Figure 3-15. This figure is also a good example of the microphone location sketch or photo which should be prepared for each site.

d. Measurements will normally all be made while standing at ground level with the sound level meter microphone at a height of 1.2 m (4 ft). However, in noise zones where at least one-fourth of the population lives or works at elevated locations, it may be possible to obtain a more representative noise sample by elevating an equivalent proportion of the measurement locations to higher building stories. Although this is not a necessary survey technique, it will enhance the meaningfulness of data acquired in a zone having a large population living in high-rise buildings. Whether sites are established at ground level or elevated levels, permission may be required to perform measurements on private property. Field personnel should be instructed in this as indicated later in the manual. In addition, microphone locations should never be closer than 1.8 m (6 ft) to any vertical wall or surface. For elevated locations, this might require mounting the microphone on a boom extended from windows, on a balcony, or on a vertical pole outside the structure, with a remote readout located in a convenient place.

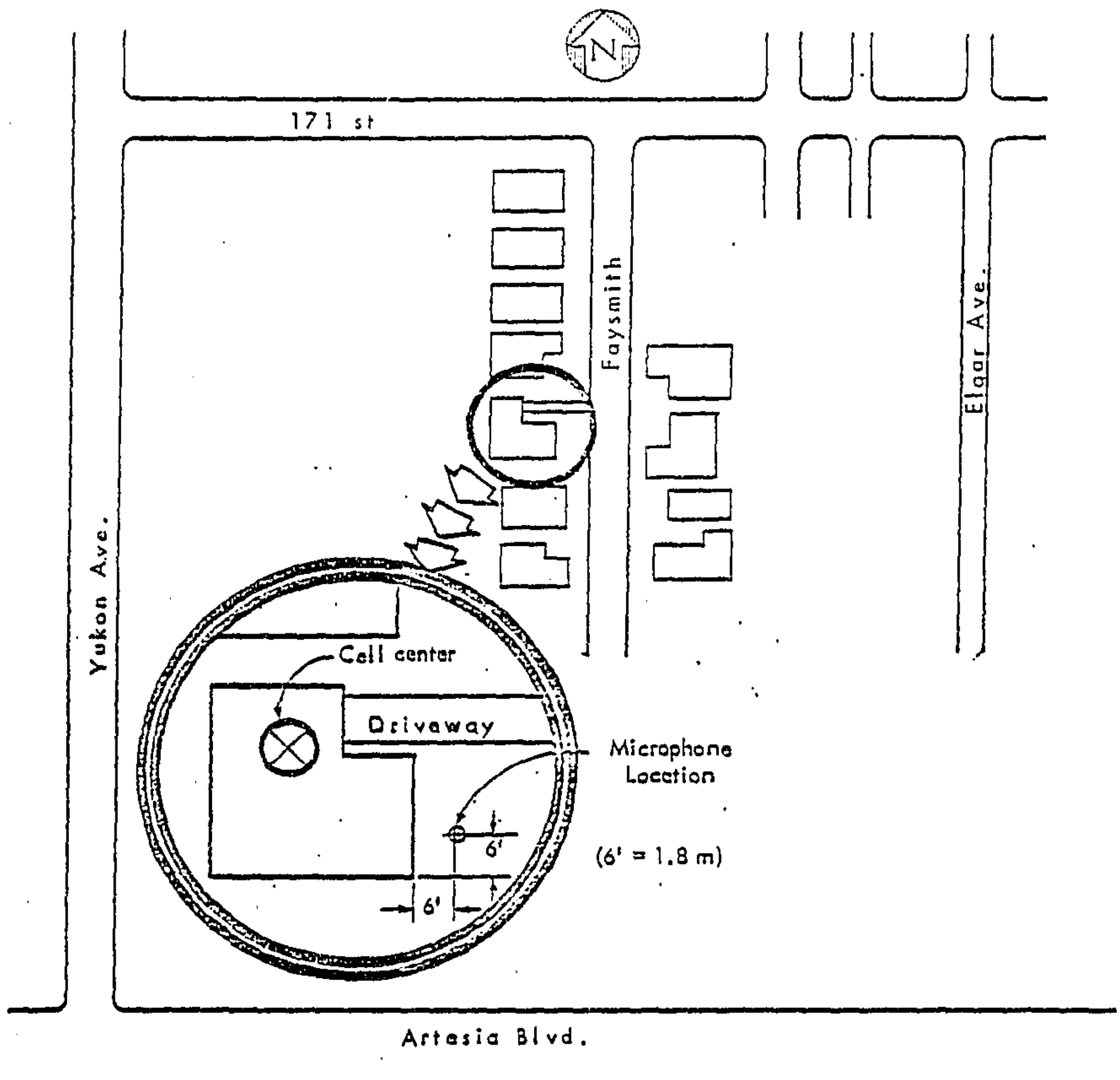


Figure 3-15. Sketch from Detailed Aerial Photograph (Scale ~1:1200) Illustrating Specific Method for Locating Microphone ~~Near Each~~ Cell Center.

STEP 3 - Select Sites for Night and Weekend Measurements

Each site chosen during Step 7 will be the site of a daytime noise measurement made during normal weekday hours. For a Class I survey, some of these sites will also be measured during week nights, and for a Class II survey, some of the selected sites will be used for nighttime measurements during the week and some for day and night measurements on weekends. Site usage for Class II surveys is shown in Figure 3-16. Follow the procedures of this step to select the sites to be used for night or weekend measurements.

a. For a Class I survey, check Table 3-5 to recall the number of sites which have been selected in each noise zone. Also determine from this table the number of these sites to be used for night measurements in addition to the day measurement. Then, from the sites already identified in each noise zone, choose the sites to be used also for nighttime measurements at random. Since all of the sites in each zone have been labeled with a letter prefix and number, a random selection from these numbers may be made using a simple blind selection process or hand calculator random number generator or table of random numbers.

b. For a Class II survey, consult Table 3-5 and select the required number of sites for weeknight measurements in each noise zone first by selecting sites which were chosen at social survey clusters, and the remainder randomly as in "a" above.

c. Also for a Class II survey, some of the sites must be designated for weekend day and night measurements as indicated in Figure 3-16. These may include sites already selected for measurements during weeknights. Determine the required number of weekend day measurements for each zone from Table 3-5, and select this number of sites first from sites chosen at social survey clusters, and any remainder on a random basis from the total number of sites in each zone. Likewise, from these weekend sites, choose the indicated number of

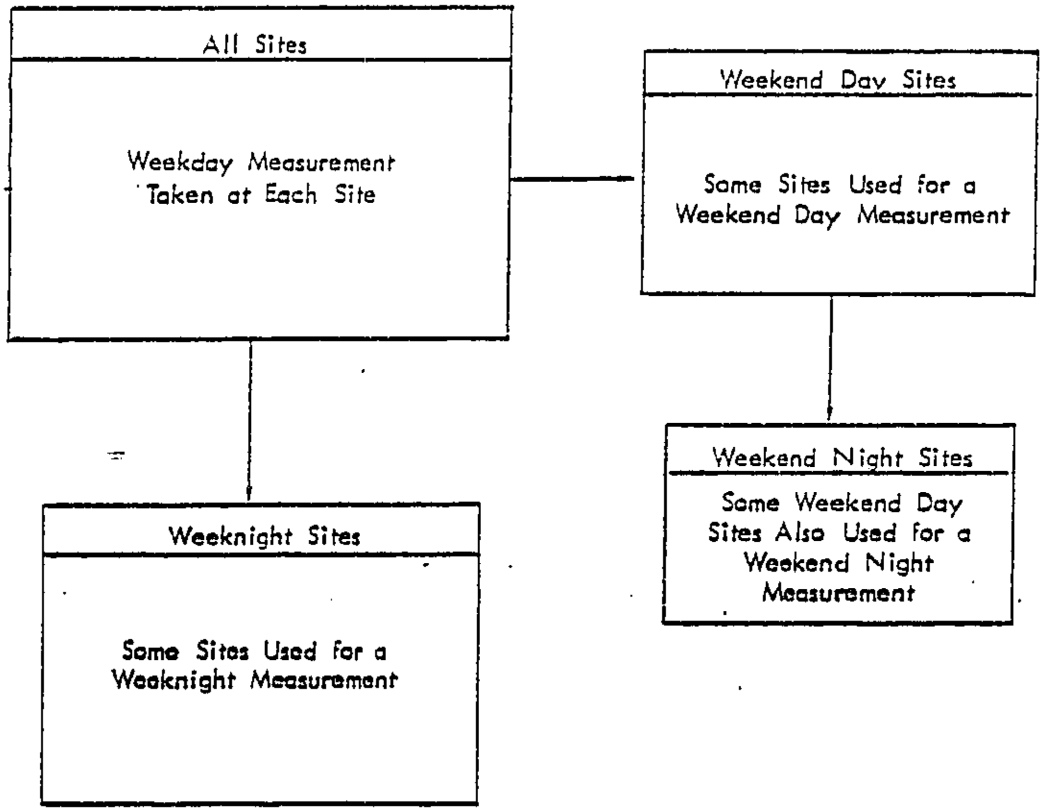


Figure 3-16. Measurement Site Usage for a Class II Survey (See Table 3-5 for Number of Sites Required for Each Usage)

Table 3-5

Required Numbers of Day and Night Measurements

Noise Zone	Class I Survey		Class II Survey			
	Total No. of Measurement Sites (week-daytime)	No. of Weeknight Measurements	Total No. of Measurement Sites (week-daytime)	No. of Weeknight Measurements	No. of Weekend Day Measurements	No. of Weekend Night Measurements
Residential (each residential type zone)	8	5	30	18	12	7
Highway	6	4	20	12	8	5
Major Roadway A	6	4	20	12	8	5
Major Roadway B	6	4	20	12	8	5
Minor Roadway (high or low volume)	6	4	20	12	8	5
Commercial/Industrial (or each)	9	5	42	25	17	10
Stationary Source	9	5	42	25	17	10

Note: If the number of measurement sites available in a noise zone is less than the required total number given in the table, select sites as follows:

- Consider all of the available sites as weekday sites to be measured.
- Choose a number of weeknight sites equal to 60 percent of the total number of sites, to the nearest whole number.
- For a Class II survey, choose a number of weekend day sites equal to 40 percent of the total number of sites, to the nearest whole number.
- For a Class II survey, choose a number of weekend night sites equal to 24 percent of the total number of sites, to the nearest whole number.

Some possible sources for field personnel were discussed earlier in Section 2.4, Step 1 of the manual. Establish a record of telephone numbers and addresses of the selected team members.

b. Establish a base of operations for the planning, supervision, and coordination of measurement activities. The location should ideally be easily accessible and central to the array of measurement sites. It will be used for equipment check-out and return, equipment calibration, data collection and filing, and training and debriefing of field teams. Thus choose an area large enough for instructional sessions and data storage, which contains facilities for safely securing the measurement equipment when not in use. If considering a public building, be sure that access can be gained at night for support of nighttime measurements.

STEP 2 - Prepare for Measurements

a. Obtain the equipment necessary for the noise measurements. The equipment package supplied to each simultaneously active team should include:

- Sound level meter
- Sound level meter calibrator (if calibration done in field)
- Calibration screwdriver (if calibration done in field)
- Stopwatch, sweep second hand watch, or electronic timer
- Time-of-day watch (can be supplied by personnel)
- Tripod
- Clipboard
- Microphone windscreen
- Lightweight portable chairs
- Lantern, flashlight or chemical light source (night measurements)
- Simple wind speed indicator
- Air temperature thermometer
- Extra batteries
- Writing pen (can be supplied by personnel)
- Data sheets

3.4.2 Noise Measurement Activities, Step 2 (Continued)

Unless weather conditions are severely cold, it is allowable to maintain a calibrator at the operations base and check calibration of the meters only as they are checked out and returned. If the planned survey will be accomplished using an L_{eq} type meter instead of a sound level meter, the stopwatch will not be needed. Some sources for sound measuring equipment were discussed earlier in Section 2.4, Step 1 of the manual.

b. Prepare a schedule of operations for the field measurement teams. Each team will enter the field for several hours and will require a maximum of 45 minutes per measurement site. The schedule should indicate the date and time period of each field session for each team, and the specific sites to be monitored during those sessions. All daytime measurements will be made between the hours of 9:00 AM to 5:00 PM and nighttime measurements between midnight and 5:00 AM. Since a team can more efficiently monitor several sites if the sites are near one another, select each day or night team assignment using the final site map as illustrated earlier in Figure 3-14 to separate the sites into localized sets for measurement. Note that, except for railroad sites, noise measurements can be made at sites from any noise zone in any order. Thus the primary criterion for assigning sites is that they be grouped as closely together as possible. A portion of an example measurement schedule is shown in Figure 3-17. This example schedule was made up using the measurement site map of Figure 3-14. In collecting sites together into measurement sessions and preparing a schedule, it may be convenient to prepare four separate base map overlays - one showing all sites, one showing weeknight sites, one showing weekend day sites, and a final one showing weekend night sites. These can be useful in making assignments as well as indicating completed sites for the four time periods.

3.4.2 Noise Measurement Activities, Step 2 (Continued)

If the available field personnel are part time, conditional, or not able to be scheduled for in advance, sites can be collected into groups for measurement, but scheduling of actual teams and measurement dates can wait until team availability is established.

Noise Measurement Schedule			
Team	Team Session No.	Sites	Date/Time Period
A	1	M1, M2, H1, H2, SA1, SA2, SA3, SA4	May 8/0900 to 1600
A	2	CI 1, SA5, SA6, SA7, SA8, SA9, R1, M3	May 9/0900 to 1600
A	3	H1, SA6, H3, R4	May 10/0000 to 0500
B	1	H3, R2, R1, CI 2, CI 3	May 8/0900 to 1600
B	2	R3, RR, R4, B1 A2	May 9/0900 to 1600
C	1	SB1, SB2, SB3, SB4, SB5, SB6, SB7, SB8	May 8/0900 to 1600

Figure 3-17. Portion of Example Noise Measurement Team Schedule

c. Prepare Measurement Packets

For each measurement session listed in the schedule, day, night, week, or weekend, prepare a field packet of measurement documents including:

- Cover sheet
- List of General Instructions
- Equipment Checklist
- Microphone placement figure (Figure 3-15)
- Microphone location detailed map (as prepared earlier in Section 3.3.2, Step 7 of the manual, similar to Figure 3-15).

- Example data sheet
- Blank data sheet for each site to be measured
- Two extra blank data sheets

Accompanying each packet should also be some form of identification on official letterhead which identifies the field personnel as members of an official municipal noise measurement team. Examples of the above listed documents are presented at the end of this chapter.

STEP 3 – Train Field Personnel

Assemble all field personnel for a full day training session. This session should include discussions and instruction concerning the following topics:

- Administrative matters – salary, mileage allowance, identification documents, etc.
- Program introduction and general description
- Basics of sound and community noise – decibels, decibel addition, propagation, shielding, etc.
- Overview of the noise sample within the city
- Instrumentation use and care
- Noise measurement procedures – 20-minute measurement technique, noise measurement field packets, equipment checkout, data return, etc.
- Measurement sites and microphone location – where to measure
- Measurement practice

Indoor instruction and measurement practice will require approximately 4 to 6 hours, and should be followed by another hour or two of actual outdoor field measurement practice.

The administrative, overview, and introductory topics can be addressed using materials from Chapters 1 and 2. Various Quiet Communities Program training materials that review these subjects and the more technical items may be available from EPA. A brief presentation of the technical aspects to be emphasized in the training is made below. The training session in general should provide a simple, clear picture of the overall program, and complete detailed instructions for each field operator. It is important to develop in the field personnel an understanding of the importance of the data they will acquire and the critical uses to which it will be put.

a. As the instructor or monitoring program manager, become completely familiar with the operation of the type of acoustical instrumentation to be used and the measurement procedure details. A thorough briefing on these items from a community noise expert as well as actual practice measurements under his guidance are almost essential in obtaining the proper indoctrination. The procedures take more ability and understanding than is at first apparent. The proper and intelligent use of sound measuring instrumentation requires a knowledge of the operation of the instrumentation functions, its inherent limitations and weaknesses, and the effect of various external influences on its accuracy. In addition to the obvious necessity for planning and training dictated by those guidelines, there is a golden rule for all operator supervisors – read the instruction manuals for the equipment. Most instrumentation manuals provide (1) a discussion on theory of operation, (2) operational procedures, and (3) basic performance specifications. This information is usually presented in a format which can be followed by an operator with only limited experience and training. A review of this information may prevent a costly error in the conduct of the program.

b. Describe to the field personnel the sound level meter or other measurement equipment being used including its main components and general use. Include these topics:

- Basic elements of the instrument.
- How to perform a battery check and change batteries.
- Calibration - emphasize that this must be done before and after each 20-minute measurement (or at check-out and check-in if field calibrators are not used).
- Always use a microphone windscreen.
- Instrument settings - A-weighting and slow response for all 20-minute measurements. (A "fast" setting is used for separate railroad noise level readings.) Set instrument range to include levels of noise present.
- Keep the instrument dry. Stop measurements in the event of rain, and never attempt to continue measurements under an umbrella.
- Stop measurements if the wind begins to regularly exceed 16 kmh (10 mph).
- The instrument is delicate — treat it gently.

c. Explain how to situate the instrument at the measurement site.

- The intended microphone location will be marked on a map included in the field packet. Select an actual microphone location as close as possible to the intended location if it is occupied by a new building, or is on inaccessible property, or is otherwise unusable. Do not locate the microphone closer than 2 m (6 feet) to any large reflecting surface such as a building. Discuss the various location cases presented in Section 3.3.2, Step 7, and indicate that a sketch of the final microphone location showing distance to a nearby object should be made on the site sketch or diagram included in the measurement field packet.

- The students in class should practice pacing off a measured distance of 15 meters (50 ft) at their normal pace so that this distance can be easily established in the field without the need for measuring equipment.
- Set the instrument on a tripod directly over the microphone location at a height of 1.2 meters (4 ft). Have the students locate the 1.2 m height on their bodies so that they can easily establish this position in the field without the need for measurement.
- Orient the meter for easy reading while sitting or standing at least an arm's distance from the microphone. The meter reader must be positioned out of the way of an imaginary line between any dominant source such as the nearby road, the microphone, and any nearby building facade.

d. Pass out the General Instructions and data sheet located at the end of this section. Explain that the above procedures account for all of the items through number 7 on the General Instruction sheet which will be included in each packet. Instruction number 8 is to complete the data sheet heading. Emphasize that:

- A sketch should be made on the site diagram to include the microphone location, and indicating wind direction.
- Weather measurements can be made shortly before or after the noise measurements.
- Be sure to record the post measurement calibration value on the data sheet if calibration is checked in the field. If not, the calibration value should be recorded on the packet cover sheet.
- Be sure tp record the instrument serial numbers on the packet cover sheet.
- The "cluster" and "area" spaces may be left blank, and will be completed later by project staff.

3.4.2 Noise Measurement Activities, Step 3 (Continued)

e. Explain the specific measurement procedures, which are instructions 9 and 10 on the general instruction sheet.

- At 15-second intervals during the 20-minute measurement period, and with the sound level meter set to "A-weighting" and "slow," the instantaneous sound level meter reading should be recorded. This must result in 80 individual readings.

  Imagine that, at each 15-second instant, a snapshot was taken of the meter to freeze the meter indication at that instant; that is, the value to be recorded. It is permissible to pause for a few readings occasionally in order to put on gloves, adjust equipment or stance, etc., but such breaks must be few and brief, and it is important that the finished data should still consist of 80 individual readings.

  With a two-member team, one person normally adjusts and reads the meter while listening to identify sources, and the other team member observes the watch to call time every 15 seconds, and records the readings and source identifications. If an electronic timer providing a light or tone every 15 seconds is used, the entire process can be accomplished by one person.

- The resulting values will normally be recorded by marking a box of the appropriate row in the data sheet (see end of Section 3). For example, a reading of 66.5 dB or 67.9 dB would be marked in the 66 to 68 row, and an even reading of 64.0 dB would be marked in the 64 to 66 row. Continue adding marks to the right, one mark per box, every 15 seconds as the data for each row is accumulated. If a row becomes filled with over 40 measurements in a noise level interval, continue on a second data sheet.

- If a particular source can be identified as the intrusive cause of any particular "snapshot" reading, the reading should be recorded on the data sheet with the appropriate symbol as shown on the data sheet instead of an "X". Follow these guidelines in order to identify a source:

1. Indicate a single type of source when it can be identified as principally responsible for the sound level existing at the measurement instant.

2. The source identified may be a single unit (i.e., one truck) or many items of the same type (i.e., several cars passing).

3. If several types of sources are present or audible at the measurement instant, either one type will clearly dominate and cause the measured noise level, or it will not be possible to select a dominant source, in which case no source identification can be made. Only specific sources such as are listed on the data sheet should be indicated.

4. Source identifications will often be possible for high noise levels above 65 dB where a single loud source type will be causing the level to rise above that caused by other sources or the normal background level. Also, identifications will be possible at very low levels, i.e., below 50 dB, when the background is very low, and a single source is noted at the time of measurement.

5. Sources should be identified by both listening and watching the sound level meter. If a particular source becomes audibly louder (i.e., truck passing, airplane flying over, etc.) with a corresponding increase in meter indication, then a regular 15-second interval noise measurement that

occurs during this condition should have that source identified with it if the source is perceived as dominating the sound level.

6. The identification can be made even if, at the measurement instant, the meter needle is not at its highest indication for the source, as long as it has not yet returned to the nominal background level which is attributable to no particular source. That is, if the measurement occurs while the meter is rising or falling in response to a source which is still dominant and audible, that source may be identified with the "snapshot" reading even though the reading was not taken at the highest level caused by the source.

7. An audible source which does not cause the meter reading to rise as the source is heard is not dominant and should not be identified. Such a source can be noted in the "comments" portion of the data sheet if frequent.

8. If a continuous intrusive source, such as the steady nearby operation of construction equipment, appears to be the principal source for most all of the readings, note this condition on the "comments" portion of the data sheet.

9. Mark only large commercial type trucks with a "T". Pickup trucks should be recorded as autos. Large garbage or refuse trucks, snow removal equipment or other non-construction service equipment should be marked with an "S".

10. If a dog is disturbed and begins barking when the noise measurement equipment is set up, wait until his initial excitement is over before beginning measurements. Further barking sounds made by the dog which dominate noise measurements but are evoked by stimuli other than the noise measurement activity should be recorded as dog sounds.

- Record the typical source responsible for the background noise in the space provided on the data sheet if it can be identified. General sources such as "traffic" are appropriate for this, and if many of the unidentified readings have been due to general traffic, indicate whether this has been principally highway or surface street traffic.

- If an energy averaging meter that reads L_{eq} directly is used, and if information on specific intrusive sources is not desired, then the source identification recording procedure just given need not be followed. Instead, simply operate the meter for 20 minutes and record the final L_{eq} value for the period under "comments" in the data sheet. Note, however, that source identifications will be of great importance if the acoustical data is used in the strategy assessment portion of the QCP program.

f. Continuing the list of general instructions after completion of 20 minutes of measurements:

- Check the level indicated by the meter with the calibrator immediately after measurement if possible. Otherwise, do this immediately upon returning to the operations base and record this value on each data sheet or packet cover sheet. This is instruction number 1 for "After Measurements" on the General Instructions sheet.

- Instruction number 2 is to complete any comments concerning noise sources, wind changes, or any other items which might have influenced the measurements such as wet streets causing unusual tire noise. For the "Description" and "Evaluation" portions of the data sheet, indicate your judgments considering the type of surrounding land use and activities.

- Upon returning to the operations base, and totaling the readings, have the operations manager check the data sheets so that any immediate questions regarding the data can be readily answered.

3.4.2 Noise Measurement Activities (Continued)

STEP 4 - Hold Practice Measurements

Upon completion of the classroom presentation, hold practice sessions in which field personnel actually use the equipment, first indoors, and then outdoors at selected sites as described in this step.

a. In the classroom or large indoor open area, have the students familiarize themselves with the project sound level meters, setting them up on tripods with windscreens and check calibration. Calibration should actually be practiced if it is to be accomplished at each measurement in the field. The students should also learn the proper position to stand or sit while reading the meter so as to avoid interference with the direct or reflected sound from the source or any nearby building facade. A sound source for measurement practice should be obtained - preferably a tape recording of roadside traffic noise - but other sources such as radio broadcasts can be useful for initial practice. The students should begin recording values using only "X" symbols and neglecting source identification, practicing only reading and recording the correct levels. At this stage, the instructor may adjust the meter range to maintain on-scale readings for the students. When the class has become familiar with reading and recording, vary the source volume up and down to simulate passing vehicles, requiring the students to perform their own range changing. Emphasize the importance of changing meter scales quickly enough so as not to miss or incorrectly record readings during periods of fluctuating level. When the group can easily change meter ranges to accommodate level fluctuations and read and record the "snapshot" levels accurately, proceed to the outdoor practice session.

b. Before actually beginning outdoor measurements, the personnel should be assembled into teams and go through the process of checking out equipment, picking up field packets (all prepared identically to include two sites for this practice), and locating the sites on a city map to plan a route to them. The Field Noise Measurement General Instructions should be followed in these and all subsequent activities, and the benefits of frequent reference to it should be emphasized throughout the training.

Upon arrival at the first site, go through the entire procedure of establishing the microphone as near as possible to the intended microphone location, reviewing the cases presented in Section 3.3.2, Step 7 of the manual, as necessary. Once the students have set up their equipment, checked calibration, made weather observations and completed the data sheet heading, begin a measurement period. First, record about 5 minutes of level data, neglecting sources, and compare results between the personnel. Then add the task of source identification and indication to the measurements, taking time to illustrate the source identification guidelines given in Step 3 while the personnel are actually listening to sources as they occur. Roadside sites are best for this kind of listening practice. Compare results of source identification measurements, and then move on to the next site, preferably with a different, nonvehicular environment, to complete the field training. At the end of these sessions, all personnel must be thoroughly competent in all of the set-up, data acquisition, and recording procedures. These activities should be repeated at this time or in a separate session for the benefit of those who are less than confident or competent.

3.4.2 Noise Measurement Activities (Continued)

STEP 5 - Perform Measurements

a. Disperse the teams into the field according to the schedule previously arranged in Step 2. If measurements are to be made by a single individual using a timer to indicate the 15-second intervals, it may be beneficial to complete the first day of measurements using teams of two to enhance initial problem solving ability and allow mutual encouragement. For the measurement program, which may extend for several days, monitor completion using a record such as Table 3-6 until all day, night and weekend data have been obtained. During the periods of measurement activity, an operations manager should be available at the operations base to distribute packets and equipment, assist in calibration, receive completed data and collect equipment, and deal with unexpected problems.

b. When field data are received, the operations manager should verify that all cover and data sheets are completed correctly before excusing the field personnel, and file them separately according to day or night, week or weekend. The packets themselves should remain assembled. For convenience in night measurements, it may be possible to distribute equipment to field personnel in the late afternoon, and have them return it and the data to a convenient location at the finish of the nighttime measurements.

c. An additional measurement activity not directly related to our standard method is measurement of railroad noise. Specially instruct a good team to monitor the railroad noise zone sites according to the following procedure. If there are only one or two railroad sites, this team can cover them along with several other sites in a day's work. However, the railroad measurement requires only one person, and depends on train schedules since the measurement at each site must be made during a train passby. Thus, if many railroad sites need to be covered, or if uncertain train schedules may require long periods of waiting, it may be more efficient to have one person visit all the sites. Assigning this task to a member of the project staff would avoid removing field personnel from the main measurement effort.

- Obtain approximate train passage schedules from the appropriate railroad personnel in order to effectively schedule railroad site measurements, and schedule them for train types that are most common along the route.

- Select an actual microphone location as near as possible to the intended location (see Section 3.3.2, Step 9) as is conventional for other sites.

- Set up the monitoring equipment in normal fashion except change the sound level meter to the "fast" meter movement, but still using the "A-weighting" position.

- Complete the data sheet heading.

- As the train passes, there will be a noise level peak as the engine goes by, followed by a fairly steady lower level due to passage of the train cars. This is illustrated in Figure 3-18. You need to record only these two sound levels — the maximum level that occurs as the engine passes, and the average steady level of the cars after the engine influence fades. These two levels can be recorded on a standard data sheet in the "comments" section, labeled as "engine" and "cars".

- Also, estimate the speed of the train as it passes, and record this value in the "comments" section.

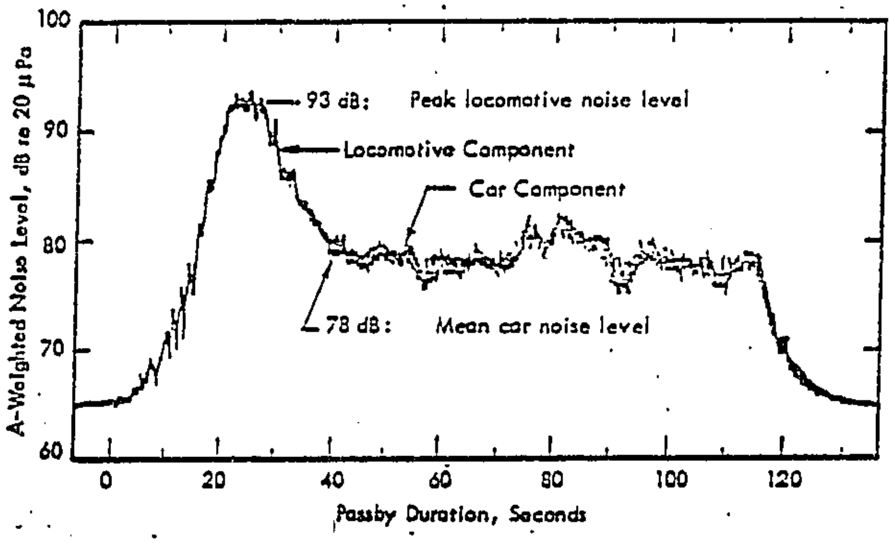


Figure 3-18. Typical Noise Level Time History of a Train Passby [8]

3.4.2 Noise Measurement Activities (Continued)

STEP 6 - Document All Procedures

After completion of the scheduled field measurements, all data must be reviewed and filed, and all procedural variances with the manual documented.

a. Survey all data sheets for measurements which appear unusual or are consistently high, low, or erratic. If problems are uncovered that render the data from a particular site questionable, revisit the site to repeat the measurement if possible. If the suspect data cannot be clarified or replaced, they should be discarded and excluded from the analysis procedures of Chapter 4.

b. Arrange the data in a sequence file which retains each packet and set of data sheets together as originally assembled. If a social survey has been conducted for which analysis of the noise data will be desired by social sampling cluster, indicate cluster on the data sheet for noise measurement sites that correspond to specific clusters.

c. Make a separate copy of each data sheet for use in data reduction and analysis. Take care that all writing and data indications are made legibly.

d. Record any special procedures used in general administration of the program or used to accommodate specific difficulties. For example, if special policies were adopted for the selection of alternate microphone locations, these must be fully recorded and explained. Likewise, special combinations or designations of noise zones, new approaches used to measure stationary sources, discarded measurement locations, or any other variations from the standard procedures presented in the manual should be described. Also, include all working papers, maps and overlays used for site selection, survey class selection, etc., in the files.

Section 3.5 Program Planning and Management

3.5.1 Introduction

Certainly by this point, the reader has realized that community noise measurement design, planning, and execution is neither an uncomplicated nor brief process. In order to maintain progress according to an orderly schedule, it is a must to anticipate key needs and initiate related activities or procurements with sufficient lead time. The following suggested critical areas and sequence of planning activities should be considered when establishing the noise monitoring program.

3.5.2 Procurement

A procedure and schedule for orderly procurement of materials and supplies must be one of the first things established. Anticipation of needs must be thorough so that procurements from municipal supplies or through the municipal purchasing department can be done in batches, avoiding numerous small requests or last minute "emergency" needs as much as possible. This will not only minimize program interruptions but will help maintain a coordinated, efficient program which can continue to receive support by city government. The following items are of critical importance in the procurement scheme:

- Office supplies and planning materials are certainly a prerequisite to even initial program stages. Items such as basic office materials, all maps, aerial photos, tracing paper or clear plastic for map overlays, large straight-edges for drawing gridworks, etc., should be obtained as quickly as possible. With these, sufficient planning can be done to determine the need for the following items.

- Printing of forms is another material requirement that must be fulfilled in a timely way. Once the planning process has established the class of survey, number of noise zones, and number of measurement sites, the data sheets, identification letters, and other field packet pages can be ordered in sufficient quantities to provide packets covering all of the

3.5.2 Procurement (Continued)

sites plus extras to allow for training, occasional repeat measurements, missed sites, etc.

- Noise measurement equipment procurement should be considered as soon as possible. If sound level meters, tripods, wind meters, timers, etc., can be obtained on loan through the regional EPA office, a local university, or some other source, arrangements for exact lists of equipment required and dates of use should be made. If equipment must be purchased, action can be taken soon after completion of program planning. In most cases, some equipment will be borrowed and some bought. Before equipment begins to arrive through either of these channels, establish a secure storage location and method to record the source of each item so that all equipment is returned to the proper party or department after survey activities are completed.

3.5.3 Manpower

Simultaneously with initial planning activities, establish the sources or arrangements for obtaining staff and field personnel, including administrative work needs. At least two staff members are required to plan and coordinate the activities for a Class II survey, and the number of field personnel will depend on program time limits, source and type of personnel, and program resources. When the required number of noise measurements becomes known and the number of "team-days" is established, interviews with prospective workers should be initiated with sufficient lead time for locating an adequate number of trainable people and for the hiring process.

3.5.4 Survey Administration

Preliminary survey administration and planning must be started and maintained as soon as the necessary materials are available. Selecting the survey class, plotting noise zones, and determining the number of measurements to be made are steps fundamental to smooth startup and operation of the program, and normally should not

3.5.4 Survey Administration (Continued)

be postponed in deference to other program aspects. In addition to continuing into the procurement and manpower aspects discussed above, arrangements and schedules should be established as early as possible for manual or computerized data reduction and report writing.

3.5.5 Survey Organization

Before measurements can begin, procedures must be set for the distribution and check-in of equipment, preparation and distribution of field packets, and scheduling of field items. These items can be time-consuming, and should be started as early as possible in the program.

Section 3.6

EXAMPLE DOCUMENTS TO BE INCLUDED
IN A
FIELD NOISE MEASUREMENT PACKET

- Cover Sheet
- General Instructions
- Equipment Checklist
- Microphone Placement Figure (not included here – same as Figure 3-15)
- Microphone Location Detailed Map (not included here – to be provided by the operations manager)
- Example Data Sheet
- Blank Data Sheet
- Example Letter of Identification, or
- Example Card of Introduction

NOISE MEASUREMENT DATA PACKET

Packet Number: ____________

Sites to be Measured: ____________ ____________ ____________

____________ ____________ ____________

____________ ____________ ____________

Schedule Time Period: ____________ / ____________

Date Hours

Team: ____________________________

Team Members: ____________________________

____

Sound Level Meter:

Manufacturer/Model: ____________ / ____________

Serial Number: ____________________________

Calibration: Set to ______ dB End ______ dB

Telephone Number for Assistance: ____________________________

FIELD NOISE MEASUREMENTS – GENERAL INSTRUCTIONS

Before Leaving for Field

1. Check equipment against equipment list for omissions.
2. Check meter batteries.
3. Calibrate meter if a calibrator is not taken into the field.
4. Check site maps for clarity – ask questions regarding proper microphone locations.
5. Plan sequence of site visits.

At Each Site

1. Locate the exact intended microphone location.
2. Adjust to a new location if necessary, as close as practical to the original one, but not closer than 3 m (10 ft) to large walls. See attached figure for microphone location near buildings along roads.
3. Park car at least 15 m (50 ft) from microphone location.
4. Test meter batteries.
5. Set meter to A-weighting, slow - (fast for railroad noise levels).
6. Calibrate meter (if calibrator available in field).
7. Set microphone on tripod with windscreen at 1.2 m (4 ft) height.
8. Fill out data sheet heading.
9. Begin measurements – "snapshot" reading every 15 seconds for 20 minutes.
10. Record identifiable intrusive sources causing the "snapshot" reading to rise 6 dB or more above the normal central tendency of the needle.
11. In case of rain – stop measurements at once and keep meter dry. Do not attempt to continue measurements under an umbrella.

After Measurements

1. Record meter calibration (if calibrator is available).
2. Complete comments and other information in data sheet heading.

After Return to Operations Base

1. Record meter calibration (if not done in field).
2. Total the noise level markings for each 2 dB range on each data sheet.
3. Have data sheets checked by operations supervisor before leaving.

FIELD NOISE MEASUREMENT EQUIPMENT CHECKLIST

Equipment Supplied by the Program

- ____ 1. Sound level meter
- ____ 2. Sound level meter calibrator (if calibration done in field)
- ____ 3. Calibration screwdriver (if calibration done in field)
- ____ 4. Stopwatch, sweep-second-hand watch, or timer
- ____ 5. Tripod
- ____ 6. Clipboard
- ____ 7. Microphone windscreen
- ____ 8. Simple wind speed indicator
- ____ 9. Air temperature thermometer
- ____ 10. Extra batteries for all equipment
- ____ 11. Identification card or letter

Equipment to be Supplied by Field Personnel

- ____ 12. Time-of-day watch
- ____ 13. Lightweight portable chairs, if desired
- ____ 14. Writing pens
- ____ 15. Lantern, flashlight or chemical lightstick (for night measurements)
- ____ 16. Personal identification
- ____ 17. Hat for sun protection
- ____ 18. Sunglasses

Example Identification Letter

City Letterhead

_________ COMMUNITY NOISE MEASUREMENT PROGRAM

The ___________ Community Noise Measurement Program is a study to measure noise levels in the local community. A noise measurement team will be conducting measurements of community noise throughout the City for the next several days. The resulting information will be used by community leaders so that they can more effectively reduce noise-related problems and improve the quality of life in ___________.

The noise measurement process requires only 20 minutes and is completely non-disruptive. We ask that you extend your cooperation for this short period so that we may perform a noise measurement nearby.

If you have any questions about our work, please call

The Quiet Communities Program

____

Thank you.

Example Identification Card

City Letterhead

To Whom It May Concern:

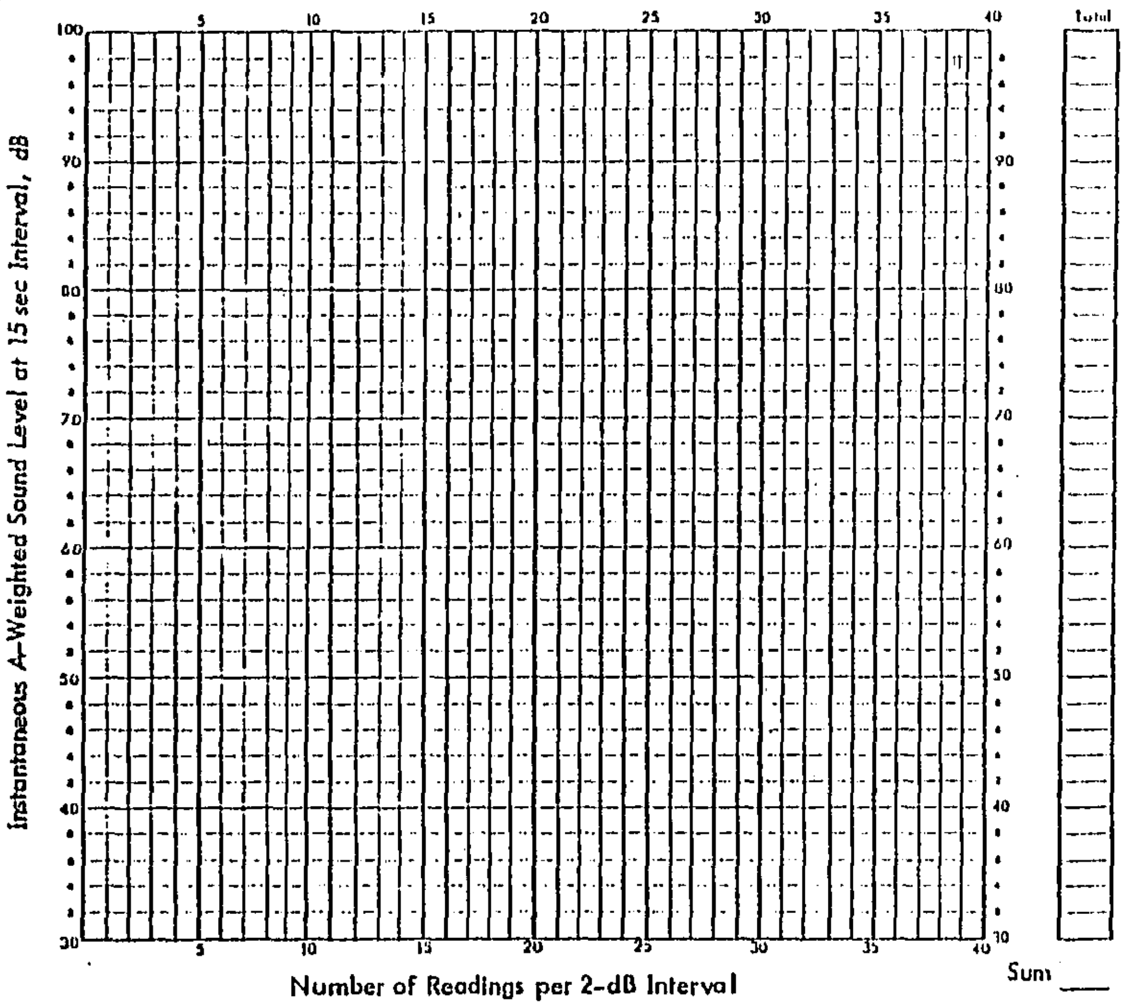
The persons presenting this letter are members of a municipal noise measurement team. They will be conducting measurements of community noise with other teams throughout the city for the next few days. The noise measurement process requires only 20 minutes and is completely non-disruptive. Any cooperation which you can extend to this team will be greatly appreciated.

Sincerely,

(City Official)

COMMUNITY NOISE MEASUREMENT DATA SHEET

SITE No. ____________ PACKET No. ____________ Cluster ______ Area ______



Location ______________________

Operator ______________________

Date __________ Day M Tu W Th F Sa S

Time ________ AM/PM To ________ AM/PM

Wind Speed ______ km/h (______ mph)

Air Temperature ______ °C (______ °F)

Meter Check (✓)

Battery: OK ______ Replaced ______

Settings: A ______ Slow ______

Calibration: Set to ____ dB, End ____ dB

Miscellaneous (After Data Collection)

Background Noise Sources ______________

Unusual Situations or Interferences ______________

____

Comments ______________________

____

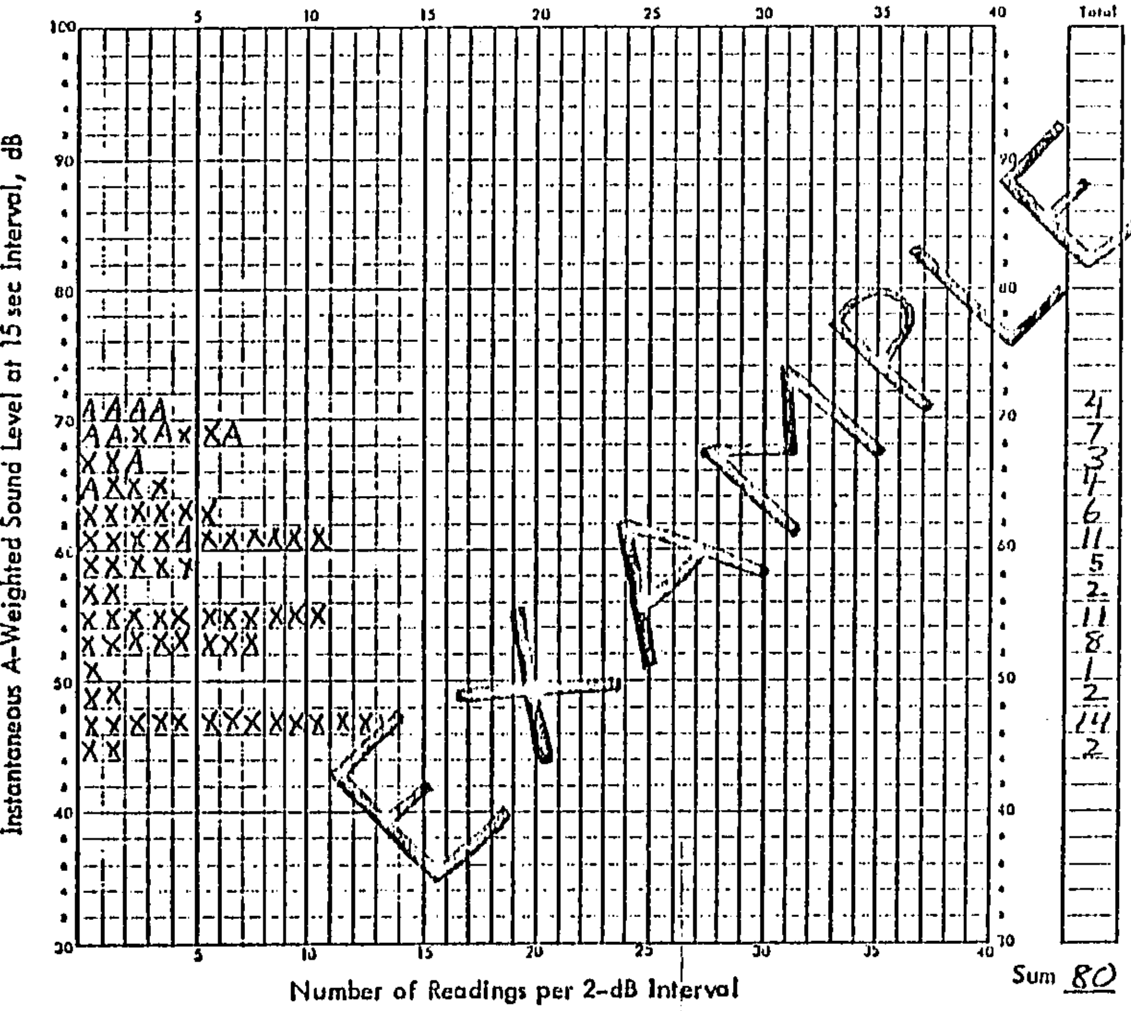
Description	Evaluation
___ V. QUIET	___ V. ACCEPT.
___ QUIET	___ ACCEPTABLE
___ M. QUIET	___ M. ACCEPTABLE
___ NOISY	___ UNACCEPTABLE
___ V. NOISY	___ V. UNACCEPTABLE

CODE FOR IDENTIFIABLE SINGLE NOISE SOURCES

TRANSPORTATION			MACHINERY		
E	____	EMER. VEH.	C	____	CONSTRUCTION EQUIP.
G	____	GEN. AVIA.	Y	____	YARD MAINT. EQUIP.
J	____	JET	F	____	FACTORY EQUIP.
H	____	HELICOPTER	Q	____	HOUSEHOLD EQUIP.
R	____	RAILROAD			**OTHER**
T	____	TRUCK	D	____	DOG
A	____	AUTO	P	____	PEOPLE NOISE
B	____	BUS	X	____	UNIDENTIFIABLE
M	____	MOTORCYCLE		____	
S	____	SERVICE VEH.		____	
V	____	OFF RD. VEH.			

COMMUNITY NOISE MEASUREMENT DATA SHEET

SITE No. P-14 PACKET No. 21 Cluster 6 Area 3



Location 1214 BISHOP ST

Operators SMITH / JONES

Date 5/10 Day M (Tu) W Th F Sa S

Time 10:05 (AM) PM to 10:25 (AM) PM

Wind Speed ____ km/h (3-5 mph)

Air Temperature ____ °C (72 °F)

Meter Check (✓)

Battery: OK ✓ Replaced ____

Settings: A ✓ Slow ✓

Calibration: Set to 94 dB, End 94.4 dB

Miscellaneous (After Data Collection)

Background Noise Sources TRAFFIC, CHILDREN

Unusual Situations or Interferences ____

Comments A FEW LOUD AUTOS

Description	Evaluation
___ V. QUIET	___ V. ACCEPT.
___ QUIET	X ACCEPTABLE
X M. QUIET	___ M. ACCEPTABLE
___ NOISY	___ UNACCEPTABLE
___ V. NOISY	___ V. UNACCEPTABLE

CODE FOR IDENTIFIABLE SINGLE NOISE SOURCES

TRANSPORTATION		MACHINERY	
E ___	EMER. VEH.	C ___	CONSTRUCTION EQUIP.
G ___	GEN. AVIA.	Y ___	YARD MAINT. EQUIP.
J ___	JET	F ___	FACTORY EQUIP.
H ___	HELICOPTER	O ___	HOUSEHOLD EQUIP.
R ___	RAILROAD		OTHER
T ___	TRUCK		
A ___	AUTO	D ___	DOG
B ___	BUS	P ___	PEOPLE NOISE
M ___	MOTORCYCLE	X ___	UNIDENTIFIABLE
S ___	SERVICE VEH.	___	
V ___	OFF RD. VEH.	___	

CHAPTER 4

DATA REDUCTION AND PRESENTATION

Section 4.1 Introduction

This chapter presents step-by-step procedures for the reduction of noise survey data to general descriptions of the community noise environment. Each section of the chapter treats a different specific portion of the data, or completes one or more of the extra survey features. Most of the procedures employ simple worksheets, tabulated information, or basic arithmetic calculations. The fundamental formulas for all procedures are furnished, allowing the user to bypass worksheets or tabulated methods, if desired, and perform the data reduction mathematically. A computerized procedure for performing the data reduction described in this section is available from the EPA Office of Noise Abatement and Control (ONAC). Within each section of the chapter, procedures are given to apply the selected extra survey features to Class I or Class II data. Section 4.2.2 describes the primary reduction of basic data from either class of noise survey, and the procedures of this section must be followed for any program. Beyond this, proceed to the additional sections which treat the extra survey features included in the program, and follow the steps for the class of data at hand. At the end of each section are instructions for the graphical portrayal of the resulting information.

Section 4.2 Reduction of Basic Data

4.2.1 General Approach

In this section, procedures are given for the primary reduction of basic survey data. The methods of Section 4.2.2 must be carried out for all surveys, regardless of the survey class or the number of extra features which have been incorporated. These methods summarize the information recorded on the field data sheets using simple worksheets and calculations to arrive at an average L_{dn} value representative of each noise zone measured. The sequence of operations is shown in Figure 4-1, which can be used as a guide when progressing through the step-by-step instructions and Worksheet 4-1. Many of the sections are written principally for Class I data, with additional procedures to accommodate data from a Class II survey. Section 4.2.3 can be used to determine approximate hourly variations in environmental noise levels, but this normally can only be accomplished for Class II data. At the end of the two sections are instructions for graphical portrayal of the reduced data.

4.2.2 Procedures for Determining L_{dn}

STEP 1 - Organize Data

a. The noise measurement survey data consist of one or more completed data sheets for each 20-minute measurement. Group these data sheets according to noise zone. Then within each noise zone group, separate the sheets for daytime and nighttime measurements. If a Class II survey has been performed, divide the daytime and nighttime groups according to weekday and weekend.

b. List each measurement site in Column 1 of Worksheet 4-1.

Use a separate worksheet (or group of worksheets, as required) for each noise zone. List each site only once even if it was measured twice (i.e., during the day and night). If a Class II survey was performed, use separate worksheets to list week and weekend measurements in each noise zone. Indicate the noise zone and week or weekend measurement in the spaces provided at the bottom of the worksheet.

STEP 2 - Calculate L_{eq} for Each Noise Measurement

Use Worksheet 4-2 to calculate and record the L_{eq} value for each 20-minute measurement according to the following procedure. These steps are repeated in abbreviated form on the worksheet along with a short example. L_{eq} values calculated for daytime measurements will be given the symbol L_d, and values for nighttime measurements will be symbolized as L_n. Normally, a site will have been subjected to a 20-minute

Worksheet 4-1

Basic Data Reduction for Class I or Class II Survey

1 SITE (Step 1)	2 L_d (dB) (from Worksheet 4-2, see Step 2)	3 L_n (dB) (from Worksheet 4-2, see Step 2)	4 Δ (dB) (from Table 4-1, see Step 3b)	5 MEASURED L_{dn} (dB) Col. 2 + Col. 4, Step 3c)	6 Δ_{ave} (dB) (Step 4b)	7 CALCULATED L_{dn} (dB) (Col. 6 + Col. 2, Step 5)	8 AVERAGE L_{dn} (dB) (Step 6)
							Total from Col. 5 ______
					Total from Col. 4 ______		Total from Col. 7 ______
					No. of Day-nite Sites ______		Sum of Above ______
							Total No. of Sites ______
					Δ_{ave} = Total ÷ No. Sites = ______		Average L_{dn} = Sum ÷ No. Sites = ______
			TOTAL ______	TOTAL ______		TOTAL ______	

This Sheet: Noise Zone ______ Page ____ of ____

☐ Week

☐ Weekend

Worksheet 4-2

Computational Worksheet to Hand-Calculate L_{eq} from Sound Level Meter Measurements Recorded on Data Log

A Noise Level Band, dB	B Count		C Relative Noise Energy		D Relative Total Noise Energy
100					
98		x	79,400	=	
96		x	50,100	=	
94		x	31,600	=	
92		x	20,000	=	
90		x	12,600	=	
88		x	7,940	=	
86		x	5,010	=	
84		x	3,160	=	
82		x	2,000	=	
80		x	1,260	=	
78		x	794	=	
76		x	501	=	
74		x	316	=	
72		x	200	=	
70		x	126	=	
68		x	79.4	=	
66		x	50.1	=	
64		x	31.6	=	
62		x	20.0	=	
60		x	12.6	=	
58		x	7.94	=	
56		x	5.01	=	
54		x	3.16	=	
52		x	2.00	=	
50		x	1.26	=	
48		x	.794	=	
46		x	.501	=	
44		x	.316	=	
42		x	.200	=	
40		x	.126	=	
38		x	.0794	=	
36		x	.0501	=	
34		x	.0316	=	
32		x	.0200	=	
30		x	.0126	=	

Sum B = ________ Sum D = ________

Sum D/Sum B = ________ L_{eq} = ________ dB

DATA REQUIREMENTS:

- Each noise reading is taken at a 15-second interval between measurements
- Each noise level recorded is the instantaneous or "snapshot" reading

STEP	PROCEDURE
a	Enter number of counts per noise level in Column B.
b	Multiply the counts in Column B by the number in Column C and enter the result in Column D. If the result is less than 100, round it off to the nearest tenth.
c	Add all values in Column B to determine Sum B, add all values in Column D to determine Sum D and divide Sum D by Sum B. If the quotient is less than 20, compute it to the nearest tenth.
d	Locate the value in Column C that is approximately equal to Sum D/Sum B. The corresponding value in Column A is equal to L_{eq}. Interpolate to the nearest half decibel.

EXAMPLE

Given the following count data, find L_{eq}

Noise Level	Number of Occurrences
84	
82	II
80	-
78	IIII
76	IIII IIII I
74	IIII
72	-

Using Steps a through d gives

A	B		C		D
84					
82	2	x	2,000	=	4,000
80	0	x	1,260	=	0
78	5	x	794	=	3,970
76	11	x	501	=	5,511
74	4	x	316	=	1,264
72	0	x	200	=	0

Sum B = 22 Sum D = 14,745

Sum D/Sum B = 670 $\boxed{L_{eq} = 78 \text{ dB}^*}$

*by linear interpolation in Column C and Column A.

Site: ________ ☐ Week ☐ Day ☐ Weekend ☐ Night measurement no more than once for each of four time periods – weekday and night, and weekend day and night. However, if a site does get measured twice during the same period, the extra data can be used by combining data from both measurements on the same Worksheet 4-2 to determine a combined L_{eq}.

a. From the measurement data sheet, enter the number of counts that were recorded in each 2 dB interval on that data sheet into the same interval on Worksheet 4-2. Make the entry into Column B using the intervals shown in Column A. In the example shown on the worksheet, the Column B entries were: two counts in the 82 dB to 84 dB interval, no counts in the 80 dB to 82 dB interval, five counts in the 78 dB to 80 dB interval, etc.

b. Now, for each 2 dB noise level interval, multiply the number of counts recorded in Column B by the Relative Noise Energy value given in Column C. Record the product in Column D. The resulting products will normally range from very small to very large numbers, but these multiplications can easily be handled by any small electronic calculator. Round off all products to the nearest whole number, except if the product is less than 100, round it off to the nearest tenth.

c. Continue by adding all of the count values which were entered into Column B and also adding all of the values in Column D. When a sum is obtained for each column, divide the sum from Column D by the sum from Column B. Record this quotient in the allotted space in the lower portion of the worksheet. For the given example the sum from Column D was 14,745 and that from Column B was 22. Thus, the quotient was 14,745/22 = 670 to the nearest whole number. If this quotient is smaller than 20, compute it to the nearest tenth.

d. To finally determine the L_{eq}, locate the Sum D/Sum B quotient among the values listed in Column C. The noise level value in Column A that corresponds to the position of the quotient value in Column C is the L_{eq} for the entire 20 minutes of data. Determine this noise level value to the nearest half decibel by interpolation. In the given example, the Sum D/Sum B quotient of 670 is between the Column C values of 501 and 794.

The Column C value of 501 corresponds to the middle of the 76 dB to 78 dB interval, which is 77 dB. Likewise, the Column C value of 794 corresponds to the Column A noise level of 79 dB. The interpolation would proceed as follows:

Column A Value	Column C Value
79 dB	794
L_{eq} to be found	670
77 dB	501

79 dB - 77 dB = 2 dB

794 - 501 = 293

670 - 501 = 169

$$L_{eq} = 77 \text{ dB} + \frac{169}{293} \times 2 \text{ dB} = 78.2 \text{ dB or } 78 \text{ dB.}$$

e. An alternative method for determining the L_{eq} of each measurement by direct computation instead of Worksheet 4-2 may be used if desired. The calculation can be performed easily on most scientific electronic calculators. The L_{eq} of a 20-minute measurement may be calculated as:

$$L_{eq} = 10 \log_{10} \left\{ \frac{1}{N} \sum_{i=1}^{N} n_i \cdot 10^{L_i/10} \right\}$$

where

n_i = Number of counts in the i^{th} 2 dB interval.

N = Total number of 2 dB intervals included in the data.

i = Summation index for the 2 dB intervals.

L_i = Middle noise level value for the i^{th} 2 dB interval (i.e., if the interval is 76 dB to 78 dB, the L_i is 77 dB).

f. When the L_{eq} value for a measurement has been determined, record it on the appropriate page of Worksheet 4-1 for its particular site. If the survey is a Class II, be sure to use the correct worksheet for week or weekend measurements. If the measurement was made during daytime hours, list the L_{eq} value in Column 2 of the worksheet headed L_d. For nighttime measurements, enter the L_{eq} value in Column 3 headed L_n. For sites that were measured both during the day and night, L_{eq} values should be entered for both L_d and L_n in the row for that site. Example: L_d and L_n values for a Class I survey are shown recorded in Figure 4-2. Note that, for the Class I survey, only eight measurement sites are used in the residential noise zone, and only five nighttime measurements are made. Also, go back and record the computed L_{eq} value directly on the measurement data sheet in the "comments" section using the form: L_{eq} = ______ dB.

Worksheet 4-1

Basic Data Reduction for Class I or Class II Survey

1 SITE (Step 1)	2 L_d (dB) (from Worksheet 4-2, see Step 2)	3 L_n (dB) (from Worksheet 4-2, see Step 2)	4 Δ (dB) (from Table 4-1, see Step 3b)	5 MEASURED L_{dn} (dB) Col. 2 + Col. 4, Step 3c)	6 Δ_{ave} (dB) (Step 4b)	7 CALCULATED L_{dn} (dB) (Col. 6 + Col. 2, Step 5)	8 AVERAGE L_{dn} (dB) (Step 6)
R1	62.5	54.5					Total from Col. 5 ____
R2	64	58			Total from Col. 4 ____		
R3	64	—					Total from Col. 7 ____
R4	65	56			No. of Day-nite Sites ____		Sum of Above ____
R5	59.5	—					Total No. of Sites ____
R6	61.5	55			Δ_{ave} =		
R7	66	51.5			Total ÷ No. Sites = ____		Average L_{dn} =
R8	62	—					Sum ÷ No. Sites = ____
			TOTAL ____	TOTAL ____		TOTAL ____	

This Sheet: Noise Zone RESIDENTIAL Page ___ of ___
☒ Week
☐ Weekend

Figure 4-2. Example L_d and L_n Values Recorded on Worksheet 4-1

STEP 3 – Determine L_{dn} for Sites with Day and Night Measurements

For each site listed on Worksheet 4–1 that has both an L_d and L_n value, determine the L_{dn} using the following procedure. The procedure is detailed and must be followed closely. The result will be an L_{dn} value derived directly from day and night measurements at the specific site, and thus will be called the measured L_{dn}. The entire procedure is illustrated in Figure 4–3 for our example Class I data.

a. Subtract the value of L_n from the value of L_d. Note that if the value of L_n is larger than L_d, then the resulting difference will be negative.

b. Locate the value of $L_d - L_n$ in Column 1 of Table 4–1, and read the corresponding Day-Night adjustment, Δ, from Column 2. Record Δ in Column 4 of Worksheet 4–1.

c. Now add this adjustment, Δ, to the value of L_d to obtain the measured L_{dn} for the site. Record this L_{dn} in Column 5 of Worksheet 4–1 to the nearest half dB.

STEP 4 Calculate the Average Day-Night Adjustment, Δ_{ave}, for Each Noise Zone

a. For each residential noise zone within a given survey area or, for other types of noise zones, for all zones in the city (i.e., all minor roadway zones), add all of the Δ values listed in Column 4 of Worksheet 4–1. Enter this total at the bottom of Column 4 on the last worksheet for each noise zone. The total should be shown to the nearest 0.5 dB. For a Class II survey, add the Δ values for week and weekend measurements separately, arriving at separate totals for each in each noise zone. An illustration of this addition based on example data is shown in Figure 4–4.

b. For each noise zone, calculate the average day-night adjustment using Column 6 of the worksheet. First enter the total which was recorded at

PORTION OF WORKSHEET 4-1

BASIC DATA REDUCTION FOR CLASS I OR CLASS II SURVEY

1 SITE (Step 1)	2 L_d (dB) (Step 2, Worksheet 4-2)	3 L_n (dB) (Step 2, Worksheet 4-2)	4 Δ (dB) (Step 3b, Table 4-1)	5 MEASURED L_{dn} (dB) (Step 3c)
R1	62.5	54.5	1.0	63.5
R2	64	58	2.0	66.0
R3	64	—	—	—
R4	65	56	0	65.0
R5	59.5	—	—	—
R6	61.5	55	2.0	63.0
R7	66	51.5	-1.0	65.0
R8	62	—	—	—
			TOTAL—	TOTAL —

This Sheet

PORTION OF TABLE 4-1

DAY-NIGHT ADJUSTMENTS

$L_d - L_n$ (dB)	Day-Night Adjustment, Δ (dB)
12.5 to 15.0	- 1.0
	- 0.5
9.5 to 10.5	0
8.5 or 9.0	
7.5 or 8.0	1.0
6.5 or 7.0	
6.0	2.0
5.0 or 5.5	2.5
4.5	3.0

EXAMPLE: Site R1

$L_d - L_n = 62.5 - 54.5 = 8$

$L_{dn} = L_d + \Delta = 62.5 + 1.0 = 63.5$ dB

Figure 4-3 Example Determination of Measured L_{dn}

Table 4-1

Day-Night Adjustments for Estimating Day-Night Sound Level, L_{dn} (dB)

1 $L_d - L_n$ (dB)	2 Day-Night Adjustment, Δ (dB)
19.5 to 40.0	-2.0
15.0 to 19.0	-1.5
12.5 to 14.5	-1.0
11.0 to 12.0	-0.5
9.5 to 10.5	0
8.5 or 9.0	0.5
7.5 or 8.0	1.0
6.5 or 7.0	1.5
6.0	2.0
5.0 or 5.5	2.5
4.5	3.0
3.5 or 4.0	3.5
3.0	4.0
2.5	4.5
1.5 or 2.0	5.0
1.0	5.5
0.5	6.0
0	6.5

1 $L_d - L_n$ (dB)	2 Day-Night Adjustment, Δ (dB)
- 0.5	7.0
-1.5 or 1.0	7.5
- 2.0	8.0
- 2.5	8.5
- 3.0	9.0
- 3.5	9.5
- 4.0	10.0
- 4.5	10.5
- 5.0	11.0
- 5.5	11.5
- 6.0	12.0
- 6.5	12.5
- 7.0	13.0
- 7.5	13.5
- 8.0	14.0
- 8.5	14.5
- 9.0	15.0
- 9.5	15.5
-10.0	16.0
-10.5	16.5
-11.0	17.0
-11.5	17.5
-12.0	18.0

Note: These values are based on the relationship:

$$\Delta = 10 \log \left[0.375 \times 10^{\frac{(L_d - L_n) - 10}{-10}} + 0.625 \right], \text{ dB}$$

and L_{dn} is estimated from $L_d + \Delta$, dB the bottom of Column 4 into the first space of Column 6. Now enter the number of sites at which day and night data were obtained into the second space in Column 6. Complete the calculation by dividing the total in the top space by the number of day-night sites, and record the quotient to the nearest 0.5 dB. In the example of Figure 4-4, the Δ_{ave} value is 0.8 dB and, rounded to the nearest half, is 1.0 dB. For a Class II survey, calculate Δ_{ave} separately for week and weekend measurements in each noise zone.

STEP 5 - Determine L_{dn} for Sites with Day Measurements Only

So far, Worksheet 4-1 has been used to calculate L_{dn} only for sites having a measured L_d and L_n. Also, an average day-night adjustment, Δ_{ave}, has been determined for each noise zone. Follow the procedure below to determine L_{dn} for the remaining sites using L_d and Δ_{ave}.

a. For each site in Worksheet 4-1 for which only L_d was measured, estimate L_{dn} according to the formula

$$L_{dn} = L_d + \Delta_{ave}$$

where

L_d is the measured daytime L_{eq} for the site and is recorded in Column 2,

and

Δ_{ave} is the average day-night adjustment for the noise zone of the site and is recorded in Column 6.

Record the calculated L_{dn} values in Column 7, headed "Calculated L_{dn}," to the nearest 0.5 dB.

b. In the example shown in Figure 4-4, sites R3, R5, and R8 require a calculated L_{dn} value. For site R5:

Worksheet 4-1

Basic Data Reduction for Class I or Class II Survey

1 SITE (Step 1)	2 L_d (dB) (from Worksheet 4-2, see Step 2)	3 L_n (dB) (from Worksheet 4-2, see Step 2)	4 Δ (dB) (from Table 4-1, see Step 3b)	5 MEASURED L_{dn} (dB) Col. 2 + Col. 4, Step 3c)	6 Δ_{ave} (dB) (Step 4b)	7 CALCULATED L_{dn} (dB) (Col. 6 + Col. 2, Step 5)	8 AVERAGE L_{dn} (dB) (Step 6)
R1	62.5	54.5	1.0	63.5			Total from Col. 5 322.5
R2	64	58	2.0	66.0	Total from Col. 4 4.0		
R3	64	—	—	—		65.0	Total from Col. 7 188.5
R4	65	56	0	65.0	No. of Day-nite Sites 5		Sum of Above 511
R5	59.5	—	—	—		60.5	Total No. of Sites 8
R6	61.5	55	2.0	63.0			
R7	66	51.5	-1.0	65.0	Δ_{ave} = Total ÷ No. Sites = 0.8 dB		Average L_{dn} = Sum ÷ No. Sites = 64
R8	62	—	—	—		63.0	
					Rounded to Nearest 0.5 dB, Δ_{ave} = 1.0 dB		
			TOTAL 4.0	TOTAL 322.5		TOTAL 188.5	

This Sheet

Noise Zone RESIDENTIAL

☒ Week

☐ Weekend

Page of

Figure 4-4. Example Completion of Worksheet 4-1 to Obtain Average L_{dn}

$$L_{dn} = L_d + \Delta_{ave}$$
$$= 59.5 + 1.0 = 60.5 \text{ dB}$$

to the nearest 0.5 dB.

c. For Class II survey data, separate Δ_{ave} values will have been calculated in Step 4 for week and weekend data in each noise zone. Be sure to apply the correct Δ_{ave} value when calculating L_{dn} for week and weekend measurements.

STEP 6 – Calculate Average L_{dn} for Each Noise Zone

a. For each noise zone, add the measured L_{dn} values listed in Column 5 of Worksheet 4-1. Enter the total to the nearest 0.5 dB in the space at the bottom of the column. In the same manner, add the calculated L_{dn} values listed in Column 7 and record the total. For Class II data, prepare separate totals for week and weekend measurements in each noise zone.

b. Calculate the average L_{dn} for each noise zone using Column 8 of the worksheet as follows. The completed example is shown in Figure 4-4. Enter the total from Column 5 into the top space of Column 8, and enter the total from Column 7 into the second space in Column 8, Add these two values, and record the sum to the nearest 0.5 dB in the indicated space in Column 8.

Now count the total number of sites listed on the worksheets and enter this number into the labeled space in Column 8. Compute the average L_{dn} for the zone by dividing the sum of all the measured and calculated site L_{dn} values by the number of sites as indicated in Column 8. This quotient, to the nearest whole decibel, is the average L_{dn}. In the example, the sum of all site L_{dn} values is 511 and there were eight sites providing these data. Thus, the spatial average L_{dn} is calculated as:

$\frac{511}{8}$ = 63.9 or 64 dB to the nearest decibel.

c. For Class II data, calculate average week and weekend L_{dn} values for each noise zone using the procedures of b. above. Then, combine the week and weekend values into an average L_{dn} value for the entire week according to the formula:

$$L_{dn} \text{ (entire week)} = L_{dn} \text{ (week)} + 10 \log \left[(5/7)\left(1 + 0.4 \cdot 10^{(\Delta W/E)/10}\right)\right]$$

where

$\Delta W/E = L_{dn}$ (weekend) $- L_{dn}$ (week).*

This value may be recorded at the bottom of Column 8 of the week or weekend worksheet if clearly labeled "7-day average L_{dn}." Recall the approximate 95% confidence limits of the L_{dn} value: ±6 dB for a Class I survey, and ±4 dB for a Class II survey.

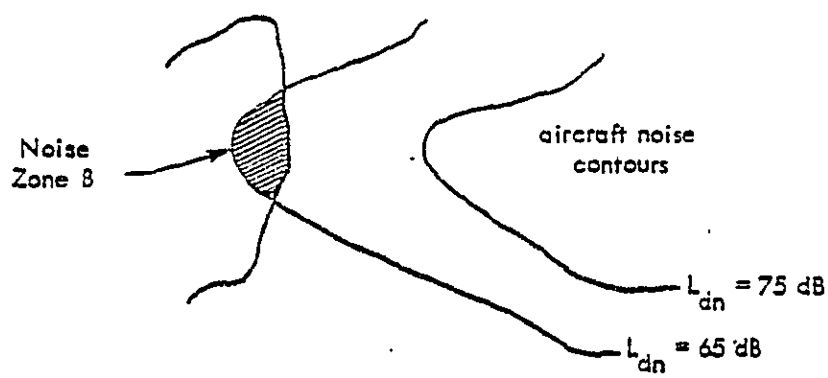
d. For airport noise zones, the L_{dn} value taken as representative of the zone must be based on the predicted airport noise contours which were used to establish the noise zone boundaries. For the purposes of this guide, the L_{dn} values in the airport noise zones will vary in the following approximate manner. For airport noise Zone A, the L_{dn} will change from 85 dB at the zone center to 75 dB at the outer boundary. For airport noise Zone B, the value will vary from 75 dB at the inner zone boundary to 65 dB at the outer boundary. Thus, if a noise zone extends completely between the airport noise contours that defined the zone, then assign the average noise level value as representative of the whole zone; i.e., 80 dB for Zone A or 70 dB for Zone B.

*For most community noise sites, the value of $\Delta W/E$ falls in the range of -3 to -10 dB and L_{dn} (entire week) is about 1 dB less than L_{dn} (week). Note that a weighted arithmetic average will normally be within 1.5 dB of the true energy average.

4.2.2 Procedures for Determining L_{dn}, Step 6 (Continued)

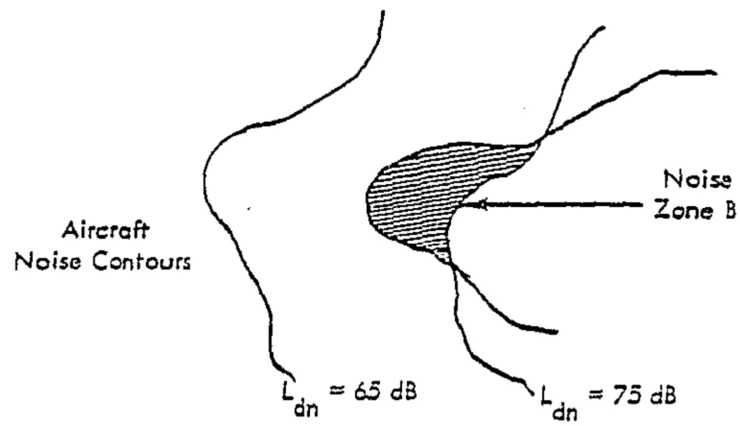
If, however, the noise zone boundary does not completely bridge the space between the airport noise contours, but includes only fringes or edge portions of the contour areas, then assign an average value based on the proportion of the contour interval included in the zone. For example, as seen in the illustration below, if the noise Zone B included only the outermost one-quarter of the distance between contours, then the approximate average L_{dn} value for this zone will be:

$$\frac{65 + [65 + (75 - 65) \times 0.25]}{2} = 66.25 \text{ or } 66 \text{ dB.}$$



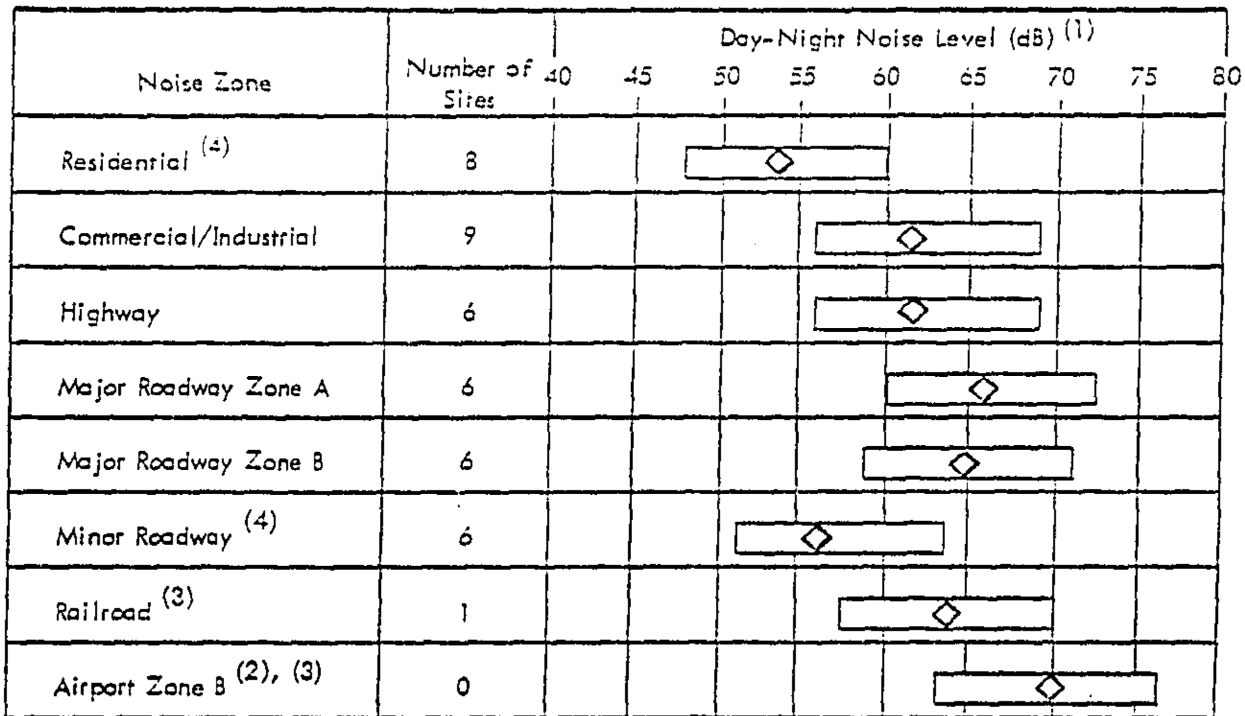
Alternatively (see illustration below), if only the inner one-quarter of the contour interval was included in the zone, the approximate average L_{dn} would be:

$$\frac{75 + [65 + (75 - 65) \times 0.75]}{2} = 73.75 \text{ or } 74 \text{ dB.}$$



STEP 7 - Prepare Presentation of L_{dn}

Once the L_{dn} values for the noise zones have been determined, they can be displayed in one of two ways. If extra survey features A and B or G have been incorporated, the method given in Section 4.3 for the display of L_{dn}, L_1, and L_{90} on the same chart should be used. If these extra features are not included, display the L_{dn} values as shown in Figure 4-5. This type of display illustrates the relative differences in L_{dn} between different noise zones, and also shows the relative accuracy attributed to the individual values.



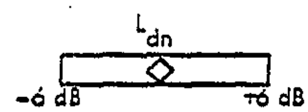
NOTES:

(1) Noise levels are the spatial (arithmetic) average over sites in each noise zone.

(2) Airport noise levels are estimated based on predicted airport noise contours.

(3) Confidence limits for airport and railroad zones are approximate.

(4) For simplicity, only one of the residential and minor roadway zones are illustrated here. However, the recommended sampling procedure outlined in Section 3 specifies more than one type of zone for each.



95 Percent Confidence Interval

Figure 4-5. Example L_{dn} Presentation for Class I Survey

4.2.3 Procedures for Determining Hourly Noise Level Variation

These procedures result in a display of the weekday hourly noise level variation in the community using only data from the basic noise survey. (Hourly variations during the nighttime and weekend are normally not considered since the basic temporal sampling plan is limited. However, hourly variations in noise level over these periods may be available from any 24-hour monitoring site employed.) The following sequence of steps will normally only be performed in conjunction with a Class II survey on a "per noise zone" basis. However, the procedure may be used with a Class I survey if all the data from all noise zones investigated are aggregated into one set.

For a Class II survey, it is recommended that the data from the roadway noise zones that were included in the survey be condensed, forming the following noise zone categories:

- Residential (High, Medium and Low Density)
- Highway
- Major Roadway (A & B)
- Minor Roadway (High and Medium Volume)
- Commercial/Industrial
- Stationary Source.

Follow these steps for each category.

STEP 1 - Prepare Tabulation Sheet

Prepare a data tabulation sheet for each hour of the day during which measurements were made; i.e., 9:00 to 10:00, 10:00 to 11:00...4:00 to 5:00. Each tabulation sheet should contain columns for L_{eq} and site designation. A set of hourly tabulation sheets should be prepared for each noise zone category as explained above.

STEP 2 - Review Data

In Section 4.2.1, the L_{eq} for each 20-minute data sheet was calculated and recorded back on the data sheet. Review the data sheets from weekday measurements, and record the site designation and L_{eq} of each measurement onto the tabulation sheet which contains the midpoint of the measurement time interval. For example, a measurement made during the 20-minute period of 12:55 PM to 1:15 PM would be listed on the tabulation sheet for 1:00 PM to 2:00 PM.

STEP 3- Calculate Average L_{eq} for Each Hour

For each hour (tabulation sheet), calculate the average measured L_{eq} by adding all of the L_{eq} values measured for that hour and dividing that sum by the number of measurements. Round the quotient to the nearest whole decibel. Record the average value on the tabulation sheet.

STEP 4- Display the Hourly Variation of L_{eq}

Once the average L_{eq} value for each hour has been calculated, this value along with all of the measured values for the hour can be effectively displayed in a chart similar to Figure 4-6. If daytime hourly values of L_1 and L_{90} are to be determined under extra survey features A and B, then present all three measures together as described in Section 4.3.

Section 4.3 Calculation of L_1, L_{90} and Cumulative Distribution (Extra Features A, B, and G)

4.3.1 General Approach

In this section, the calculation of statistical noise levels is performed using only basic survey data. A statistical level is that noise level that is exceeded a certain percent of the time; i.e., 90 percent for L_{90}. For the data reduction performed here, the time percentages will be represented by the percentage of "snapshot" noise level readings taken at a site for which a given noise level was exceeded. Thus, this section involves a counting of the number of readings which occurred in each 2 dB interval. The procedures of Section 4.3.2 can be followed using data from either a Class I or Class II survey, but section 4.3.3 should only be followed for Class II data. Due to the extensive manual counting process involved, the cumulative distribution calculations included in Section 4.3.2 require substantial labor effort and the results provide important data for only a few of the survey objectives. Thus, if available resources for data reduction are limited, this option can be omitted to save considerable labor and sacrificing only limited information. This consideration, however, is of no consequence if the computerized data reduction package is used. Each section concludes with methods for graphical presentations of the reduced data.

4.3.2 Calculation of Average L_{10}, L_{90} and Cumulative Distribution for Each Noise Zone

The determination of L_{10} and L_{90} can be done for Class I or II data. The procedures are written in terms of Class II data, and can be applied to Class I data by simply omitting the procedures indicated for weekend data. The cumulative distribution will normally not be determined for a limited survey effort such as a Class I program. Proceed through the following steps for each noise zone, referring to Figure 4-7 as required for sequence perspective.

STEP 1 - Sort Data
- Separate Week and Weekend
- List Day-Night Sites on Worksheet 4-3

↓

STEP 2 - Enter Day and Night Counts for Each Site
- Use Data Sheets and Worksheet 4-4

↓

STEP 3 - Add Day and Night Count Values
- Use Worksheet 4-4

↓

STEP 4 - Calculate Percentage of Total Counts
- Use Worksheet 4-4

↓

STEP 5 - Determine Statistical Noise Levels
- Use Worksheet 4-4

↓

STEP 6 - Determine Average Statistical Noise Levels Per Noise Zone
- For Both Week and Weekend
- Use Worksheet 4-3

↓

STEP 7 - Calculate Entire Week Statistical Noise Level For Each Noise Zone

↓

STEP 8 - Prepare Graphical Presentation

Figure 4-7 Data Reduction Sequence for Determining Statistical Noise Levels From Basic Data

4.3.2 Calculation of Average L_{10}, L_{90} and Cumulative Distribution (Continued)

STEP 1- Sort Data

a. For each noise zone, separate the data sheets into groups for week and weekday measurements.

b. The only data which will be used are those for sites at which both day and night measurements were made. Identify the data sheets for week sites having day and night measurements and also for weekend sites having day and night measurements.

c. Record these site designations on Worksheet 4-3. Prepare separate worksheets for week measurements and weekend measurements in each noise zone.

STEP 2- Count Numbers of Recordings

a. For each site, locate the day and night data sheet. On each sheet, the number of "snapshot" readings taken in each 2 dB noise level interval should have been entered by the field team into the column labeled "Total." If this was not done, compute the missing counts.

b. Prepare a Worksheet 4-4 for each site by writing the site designation and week or weekend in the lower portion, and enter the noise level counts from the daytime data sheet in Column 2 of the worksheet. Then enter the counts from the nighttime data sheet, multiplied by 0.6, into Column 3 of the worksheet. The nighttime counts must be factored by six-tenths since the night period they represent (10:00 PM to 7:00 AM) is only six-tenths the duration of the daytime period (7:00 AM to 10:00 PM). The counts from the sample daytime data sheet at the end of Section 3 are shown entered in the worksheet in Figure 4-8.

Worksheet 4-3

Calculation of Average Statistical Noise Levels in Decibels

Site (Step 1)	L_1	L_{10}	L_{20}	L_{30}	L_{40}	L_{50}	L_{60}	L_{70}	L_{80}	L_{90}	L_{99}
Sum											
Average											
(Total ÷ No. Sites)											

Total No. of Sites in this sheet ______ Noise Zone ______________ Page ____ of ____

Week

Weekend

Worksheet 4-4

Determination of Statistical Noise Levels for a Single Site

1 Top Value in Noise Level Band, dB	2 Day Counts (Step 2S)	3 + 0.6 × Night Counts = (Step 2B)	4 Sum (Col. 2 + Col. 3, Step 3A)	5 Cumulative Total (Step 3B)
100				
98				
96				
94				
92				
90				
88				
86				
84				
82				
80				
78				
76				
74				
72				
70				
68				
66				
64				
62				
60				
58				
56				
54				
52				
50				
48				
46				
44				
42				
40				
38				
36				
34				
32				
30				
			TOTAL ⇨	

6 Percentages (% × Col. 4 Total, Step 4)	7 L - Levels, dB (Step 5)
1% × Total = ____	L_1 = ____
10% × Total = ____	L_{10} = ____
20% × Total = ____	L_{20} = ____
30% × Total = ____	L_{30} = ____
40% × Total = ____	L_{40} = ____
50% × Total = ____	L_{50} = ____
60% × Total = ____	L_{60} = ____
70% × Total = ____	L_{70} = ____
80% × Total = ____	L_{80} = ____
90% × Total = ____	L_{90} = ____
99% × Total = ____	L_{99} = ____

SITE ____________________

☐ Week

☐ Weekend

1 Top Value in Noise Level Band, dB	2 Day Counts (Step 2S)	3 + 0.6 x Night Counts = (Step 2B)	4 Sum (Col. 2 + Col. 3, Step 3A)	5 Cumulative Total (Step 3B)
100				
98				
96				
94				
92				
90				
88				
86				
84				
82				
80				
78				
76				
74				
72				
70	4		4	4
68				
66	3		3	7
64	1		1	8
62	6		6	14
60	11		11	25
58	1		1	26
56	2	1	3	29
54	11	5	16	45
52	8	4	12	57
50	14	7	21	78
48	1	11	12	90
46	3	5	8	98
44	13	6	19	117
42	2	4	6	123
40		3	3	126
38		2	2	128
36				
34				
32				
30				
			TOTAL ⇨	128

6 Percentages (% x Col. 4 Total, Step 4)	7 L - Levels, dB (Step 5)
1% x Total = 1.3	L_1 = 71
10% x Total = ____	L_{10} = ____
20% x Total = ____	L_{20} = ____
30% x Total = ____	L_{30} = ____
40% x Total = ____	L_{40} = ____
50% x Total = ____	L_{50} = ____
60% x Total = ____	L_{60} = ____
70% x Total = ____	L_{70} = ____
80% x Total = ____	L_{80} = ____
90% x Total = 115.2	L_{90} = 45
99% x Total = ____	L_{99} = ____

SITE R-1

☒ Week

☐ Weekend

Figure 4-8. Example Use of Worksheet 4-4

4.3.2 Calculation of Average L_{10}, L_{90} and Cumulative Distribution (Continued)

STEP 3 - Add the Day and Night Count Values

a. For each 2 dB noise level interval, add the counts from Columns 2 and 3 and enter the sums in Column 4. This completed process is shown in Figure 4-8.

b. Now successively add the values in Column 4, beginning at the top, and enter cumulative total into Column 5 as shown in Figure 4-8.

STEP 4 - Calculate Percentages of Total Counts

For the desired statistical levels, calculate the associated percentages of the total number of counts in Column 5 to the nearest tenth. For example, suppose it is desired to determine L_1 and L_{90}, then 1 percent and 90 percent of the total number of counts should be calculated. In Figure 4-8:

Total Number of Counts (Column 5) = 128

1% of 128 = 1.3
90% of 128 = 115.2

STEP 5- Determine Statistical Noise Levels

a. To determine the statistical noise level for each percentage desired, compare the value calculated in Column 6 with the values of Column 5. Begin counting down Column 5 to a place where the cumulative total equals the value from Column 6. The noise level (Column 1) corresponding to the location of this value in Column 5 is the particular statistical noise level. Interpolate to the nearest whole decibel, and record the value in Column 7.

- Example (1)

  For L_1, the value from Column 6 in Figure 4-8 is 1.3. Counting down Column 5, we find that 1.3 is contained in the space between 70 and 72 dB. Interpolating in this end noise level interval,

Noise Level	Column 5 Count
72 dB	0
L_1 to be found	1.3
70 dB	4

72 - 70 = 2 dB   0 - 4 = - 4 dB

1.3 - 4 = -2.7 dB

$$L_1 = 70 + \left(\frac{-2.7}{-4}\right) \times 2 = 71.4 \text{ or } 71 \text{ dB}$$

- Example (2)

For L_{90}, the value from Column 6 is 115.2. Comparing 115.2 to Column 5, we see that it lies between 98 and 117. Now, let the count of 98 correspond to the middle of the 46 dB to 48 dB noise level range, which is 47 dB. Similarly, let the count of 117 correspond to a noise level value of 45 dB. Interpolating:

Noise Level	Column 5 Count
47 dB	98
L_{90} to be found	115.2
45 dB	117

47 - 45 = 2 dB   98 - 117 = -19 dB

115.2 - 117 = -1.8 dB

$$L_{90} = 45 + \left(\frac{-1.8}{-19}\right) \times 2 = 45.2 \text{ or } 45 \text{ dB.}$$

b. If an entire cumulative distribution is desired, Steps 4 and 5a above must be performed for each percentage listed in Column 6 of Worksheet 4-4.

c. For each site, record the statistical noise levels in the appropriate space of the Worksheet 4-3 for the correct noise zone and a week or weekend. When this step is completed, there should be a week and weekend Worksheet 4-3 for each noise zone containing the desired statistical noise levels for each site at which day and night measurements were made.

STEP 6 - Determine Average Statistical Noise Levels per Noise Zone

Using the Worksheets of 4-3 which have been prepared, calculate a numerical average week or weekend value of the statistical noise levels for each noise zone. This is done by adding all of the noise level values for each statistical value and dividing this sum by the total number of sites included on the sheet. Record this arithmetic average week or weekend value for each statistical noise level in each noise zone. For a Class I survey with no weekend data, these values are the final statistical noise level values. For a Class II survey including weekend data, proceed to Step 7.

STEP 7 - Calculate the Statistical Noise Level for the Entire Week in Each Noise Zone

a. For each noise zone, locate the Worksheet 4-3 for week and weekend values.

b. For each pair of worksheets, combine the week and weekend values of each statistical noise level according to the following equation which defines the weighted arithmetic average statistical level for the week.

$$L_x = \frac{L_{xw} + 0.4\, L_{xwe}}{1.4}$$

where

L_x = any week-long statistical noise level where x is the percentage exceedence;

L_{xw} = statistical noise level from week data;

L_{xwe} = statistical noise level from weekend data.

c. Record the resulting statistical noise levels for each noise zone for presentation in the next step.

STEP 8- Prepare Graphical Presentation

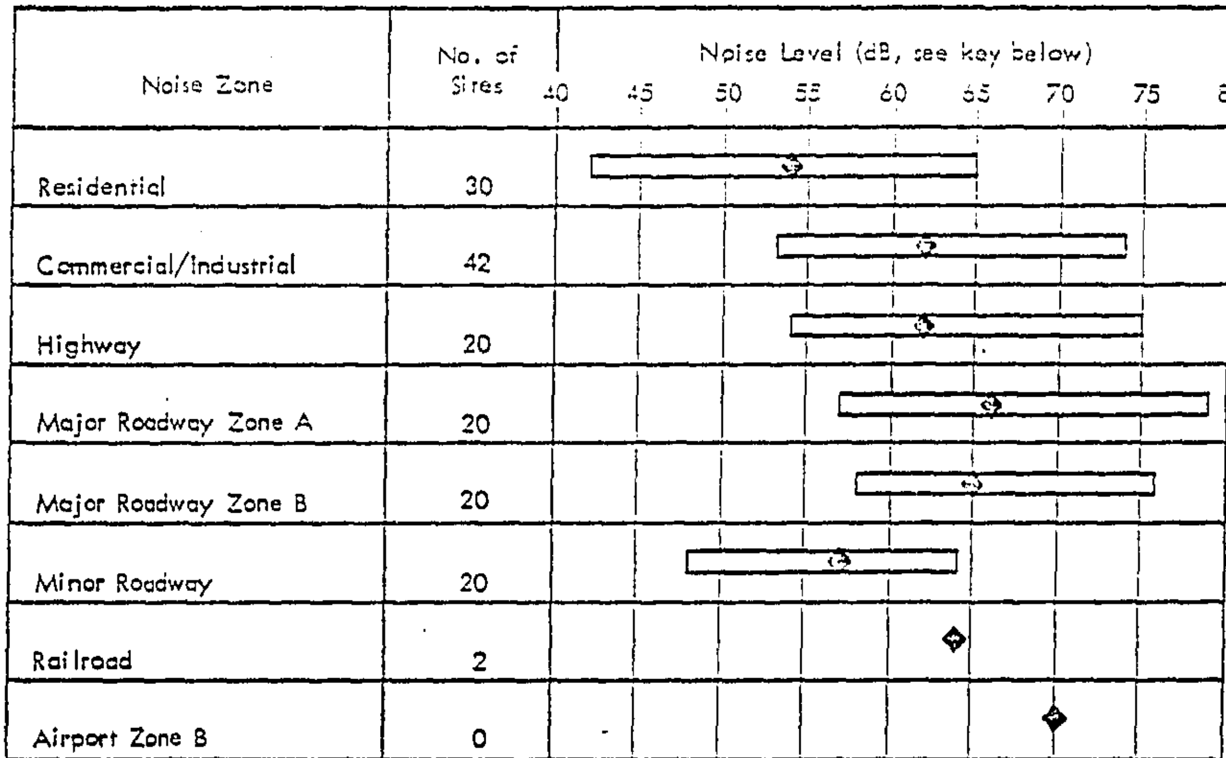
At this point in the data reduction, either an average L_1 or L_{90} have been determined for each noise zone, or a whole series of average statistical noise levels have been determined to allow plotting of a cumulative distribution for each noise zone.

a. If only the average L_1 and L_{90} values have been determined for each noise zone, these can be effectively presented along with the average L_{dn} as shown in Figure 4-9. This presentation provides a good visual description of the range of noise levels encountered in each noise zone.

b. If a cumulative distribution of noise levels is desired for one or more noise zones, it can be plotted through a series of statistical noise levels as shown in Figure 4-10(a). In lieu of the linear scale shown here for the cumulative percentage, it may be desirable to plot the cumulative distribution data on a standard statistical distribution graph such as illustrated in Figure 4-10(b). Further applications of this latter type of presentation are given in Appendix D.

4.3.3 Daytime Hourly Variation of L_{90} and L_1

In this section, the hourly variation in average weekday L_1 and L_{90} for each noise zone will be determined for comparison with hourly variations in weekday average L_{dn}. This procedure should be followed only for Class II survey data. The method borrows several steps from the previous section, utilizing Worksheets 4-3 and 4-4 once again. Follow the steps below for each noise zone.



NOTE:
- Noise Levels are the Arithmetic Average Over Sites in Each Noise Zone.
- Railroad Measurement Methods Allow Estimation of Average L_{dn} Only.
- Airport Noise Levels are Estimated Based on Predicted Airport Noise Contours.
- 95 Percent Confidence Interval for L_{dn} Values is ±4 dB.

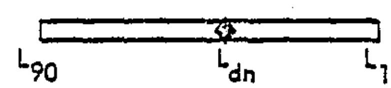


Figure 4-9. Example Presentation of L_{dn}, L_1, and L_{90} for a Class II Survey

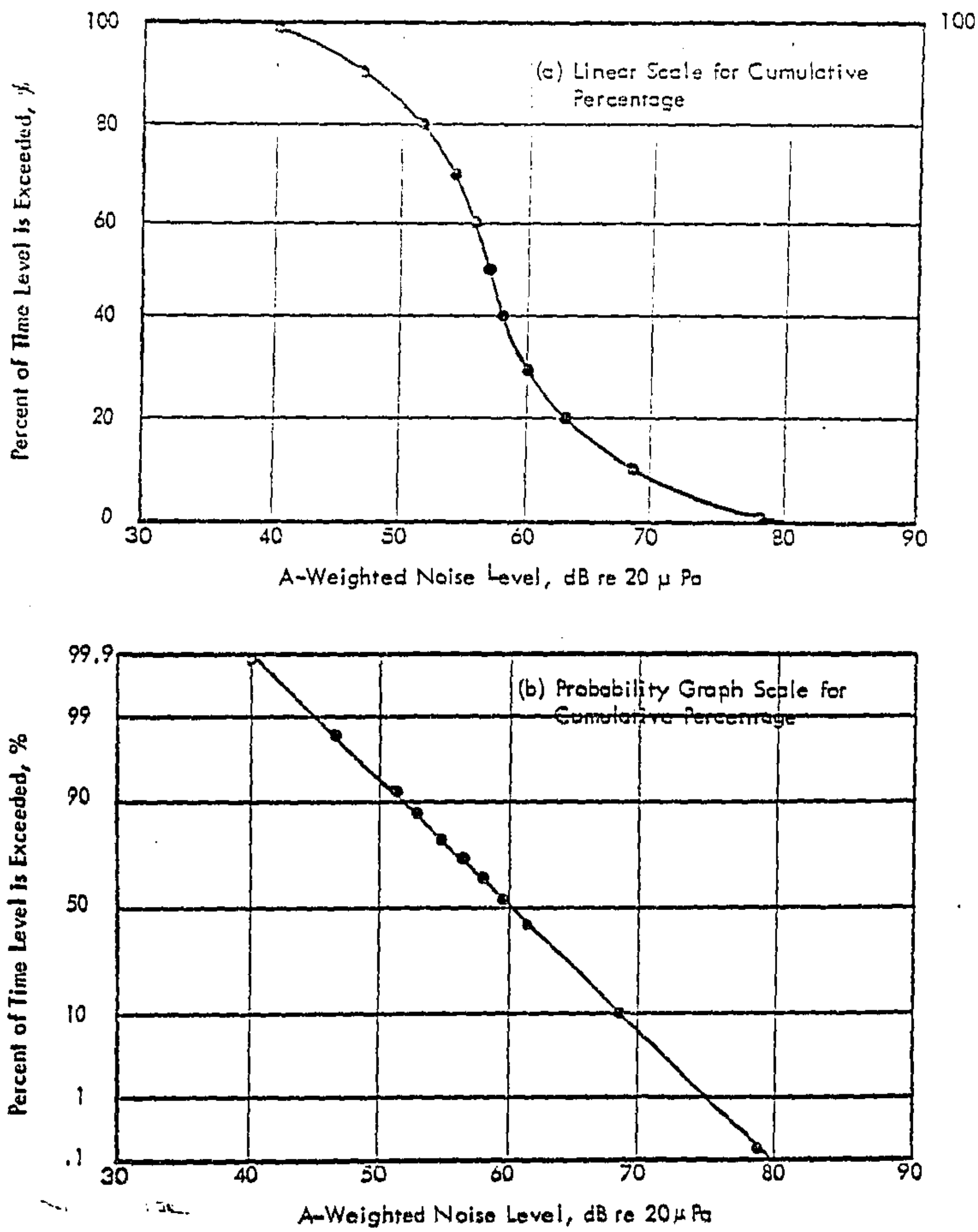


Figure 4-10. Example Presentation of Cumulative Noise Level Distribution

4.3.3 Daytime Hourly Variation of L_{90} and L_1 (Continued)

STEP 1 - Sort Data

For each noise zone, collect the data sheets for weekday (daytime) measurements and separate these according to the hour of the day that contains the middle of the 20-minute measurement involved. For example, measurements made from 1:24 PM to 1:44 PM and 1:45 PM to 2:05 PM would both be included in the 1:00 PM to 2:00 PM group.

STEP 2- Count Numbers of Recordings

For each 1-hour group of data sheets in each noise zone, repeat Step 2 of Section 4.3.2, omitting any consideration of nighttime data. Thus, only daytime noise level counts need to be entered onto Worksheet 4-4. No nighttime entries will be made in Column 3 of this worksheet. When completing this worksheet, be sure to note the time or hour as well as the site in the bottom portion.

STEP 3- Add the Count Values

In each worksheet, successively add the values in Column 2, and enter the cumulative total in Column 5. This is illustrated in Figure 4-11 for the example data presented at the end of Section 3.

STEP 4- Calculate Percentage of Total Counts

For L_1 and L_{90}, calculate 1 percent and 90 percent of the total cumulative count from Column 5, to the nearest tenth, and enter these numbers in Column 6.

STEP 5- Determine L_1 and L_{90}

a. To determine the value of L_1 and L_{90}, count down the numbers in Column 5 until the values in Column 6 are reached. The corresponding noise level in Column 1 can be determined by interpolation to the nearest decibel. For the example shown in Figure 4-11, the value of 0.8 is reached in the first noise level interval of 70 to 72 dB.

Worksheet 4-4
Determination of Statistical Noise Levels for a Single Site

1 Noise Level Band, dB	2 Day Counts (Step 2A)	3 + 0.6 x Night Counts = (Step 2B)	4 Sum (Col. 2 + Col. 3, Step 3A)	5 Cumulative Total (Step 3B)
100				
98				
96				
94				
92				
90				
88				
86				
84				
82				
80				
78				
76				
74				
72				
70	4			4
68				
66	3			7
64	1			8
62	6			14
60	11			25
58	1			26
56	2			28
54	11			39
52	8			47
50	14			61
48	1			62
46	3			65
44	13			78
42	2			80
40				
38				
36				
34				
32				
30				
			TOTAL ⇨	80

6 Percentages (% x Col. 4 Total, Step 4)	7 L - Levels, dB (Step 5)
1% x Total = 0.8	L_1 = 72
10% x Total = ____	L_{10} = ____
20% x Total = ____	L_{20} = ____
30% x Total = ____	L_{30} = ____
40% x Total = ____	L_{40} = ____
50% x Total = ____	L_{50} = ____
60% x Total = ____	L_{60} = ____
70% x Total = ____	L_{70} = ____
80% x Total = ____	L_{80} = ____
90% x Total = 72.0	L_{90} = 46
99% x Total = ____	L_{99} = ____

SITE R-1, 10:00 - 11:00 AM

☒ Week

☐ Weekend

Figure 4-11 Example Use of Worksheet 4-4 to Determine Daytime Hourly Value of L_1 and L_{90}

b. Record each L_1 and L_{90} on Worksheet 4-3 for the correct noise zone and hour. When this step is completed, there should be a Worksheet 4-3 for each daytime measurement hour in each noise zone containing the L_1 and L_{90} values measured during that hour in the zone.

STEP 6 - Determine Average Hourly L_1 and L_{90} for Each Noise Zone

Using the Worksheets of 4-3 which have been prepared, calculate a numerical average value of L_1 and L_{90} for each hour in each noise zone. This can be done by adding all of the L_1 or L_{90} values and dividing by the total number of sites for that hour and noise zone. These hourly averages should be rounded to the nearest whole decibel, and displayed as described in Step 7.

STEP 7 - Prepare Graphical Presentation

Hourly values of L_1 and L_{90} can be displayed along with values for hourly L_{eq} as shown in Figure 4-12. Note that the L_{eq} values used in this figure are the same as those shown in Figure 4-6, where hourly L_{eq} was displayed by itself. Note also that, in this example, all 30 measurements from the residential noise zone were used, and the same number of measurements were available to calculate L_1, L_{90} and L_{eq} for each hour since all data were properly recorded and usable.

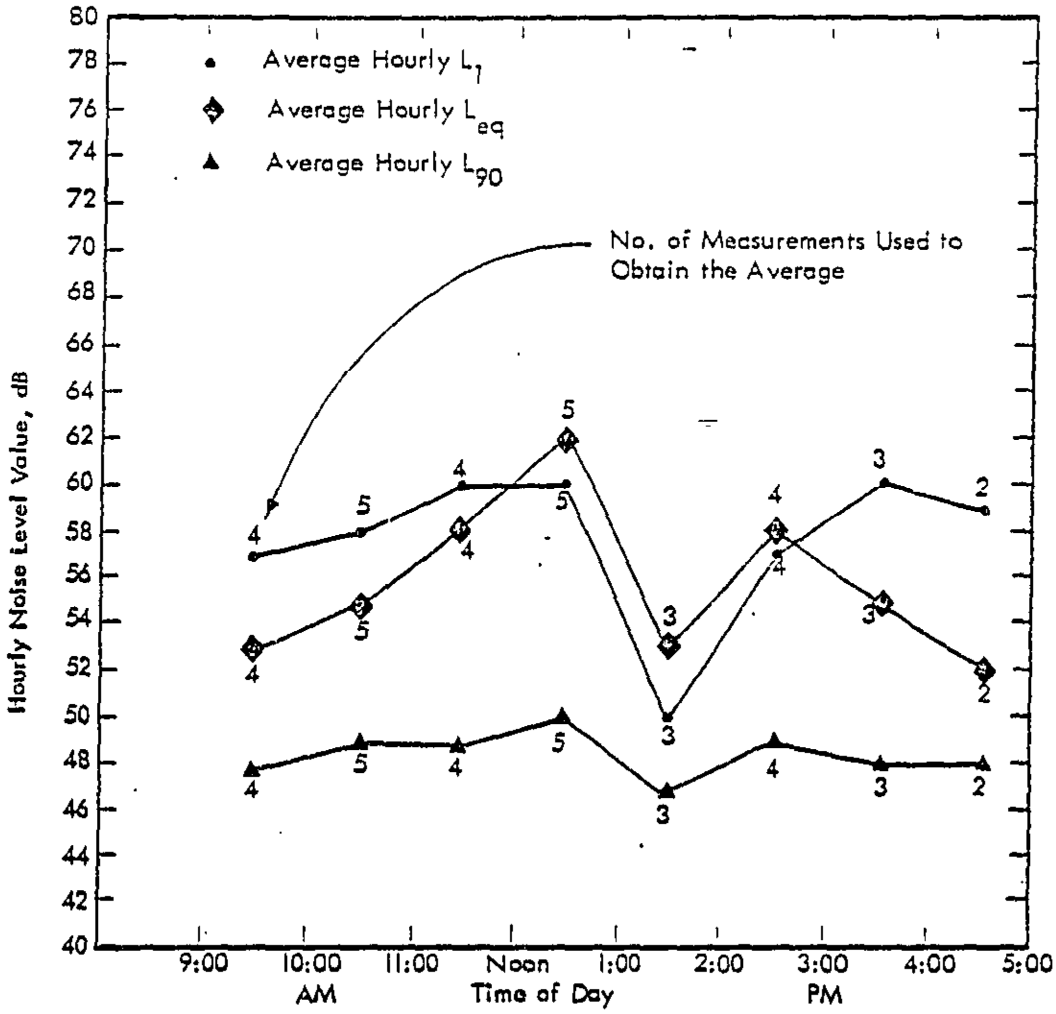


Figure 4-12. Example Presentation of the Hourly Variation of L_1, L_{90}, L_{eq} Averages for a Residential Noise Zone

4.4.1 Introduction

According to the procedures of Section 3.4.2, Step 5b, only one measurement will normally have been made in the railroad noise zone. If substantial portions of the zone contain markedly differing features, such as densely packed high-rise buildings and also low density single family residences, then a separate measurement for each region within the zone should have been made. The data for all measurements consist of two noise level values – one for the engine and one for the car portion of the train. In this section, these measured levels will be compared with predicted levels, and the differences used to adjust a predicted L_{dn} value to an estimated average L_{dn} value for each portion of the railroad noise zone. Follow the steps below for each railroad noise measurement to determine these values. A diagrammatic illustration of the process is given in Figure 4-13.

4.4.2 Railroad Data Reduction Procedure

STEP 1 – Predict Railroad L_{dn} Value, PL

An L_{dn} value for the measurement site will be predicted based on train characteristics which are nominally typical of all trains. This predicted value, called PL, may not by itself accurately represent the measurement site terrain, train types or other specific local conditions, and will ordinarily require the adjustments made in the following steps.

a. Recall the equivalent number of operations for the site, N, which was determined in Section 3.2.2, Step 5b. Also determine the zone width (tracks to zone boundary, either side) that was established in Section 3.2.2, Step 5c for the area containing the site.

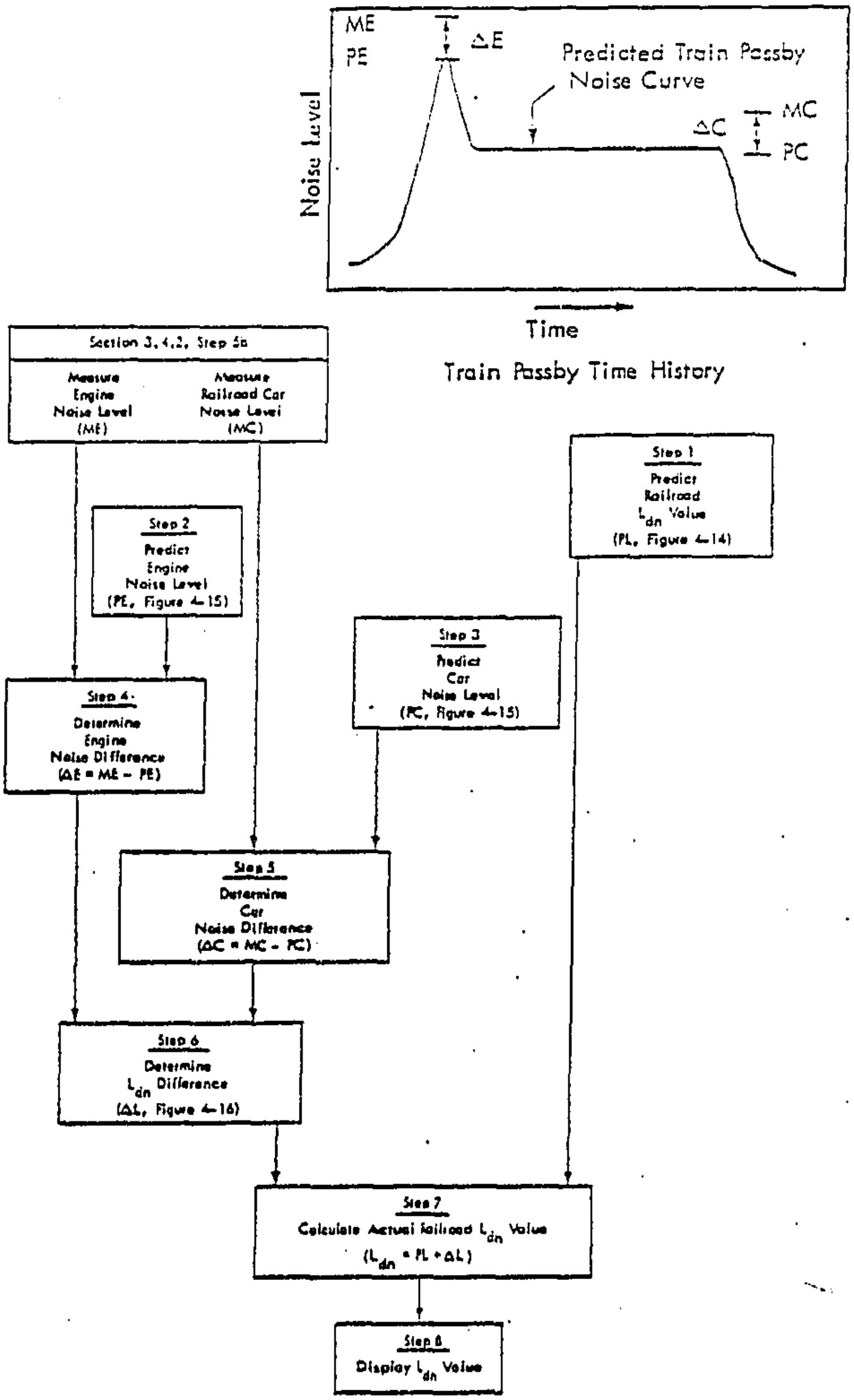


Figure 4-13. Sequence of Steps to Determine L_{dn} for Railroad Noise Zone

4.4.2 Railroad Data Reduction Procedure, Step 1 (Continued)

b. Use Figure 4-14 to predict the L_{dn} value by locating the distance from the track to the site on the bottom scale, proceeding vertically on the chart to the proper "equivalent number of operations" line, and then left horizontally to intersect with the left vertical scale. This intersection is at the predicted day-night average sound level value, symbolized PL. Read this level to the nearest half decibel. Note that the distance from the track to the site will normally be close to half the zone width as described in Section 3.3.2, Step 9.

• Example

As shown in Figure 4-14, assume the equivalent number of operations, N, is 40, and the distance from the track to the site is 61 meters (200 ft). Then follow a 61 m line vertically up until it meets the N = 40 curve, and proceed straight left to the vertical scale. The predicted value, LP, is 65.5 dB.

STEP 2 - Predict Engine Noise Level, PE

To establish a predicted engine noise level, PE, for the site, use the top portion of Figure 4-15.

a. Locate a point at the track-to-site distance along the upper horizontal scale. This scale is the same as the bottom horizontal scale, and has been repeated at the top for convenience.

b. Proceed from this point vertically downward until intersecting with the "Engine Line."

c. At the "Engine Line" location, begin extending a line straight across to the right vertical scale. This line will meet the scale at the predicted engine noise level. Read this level to the nearest half decibel.

As shown in the figure, if the distance from the track to the measurement site of the previous example is 61 m (200 ft), then the predicted noise level, PE, is 85 dB.

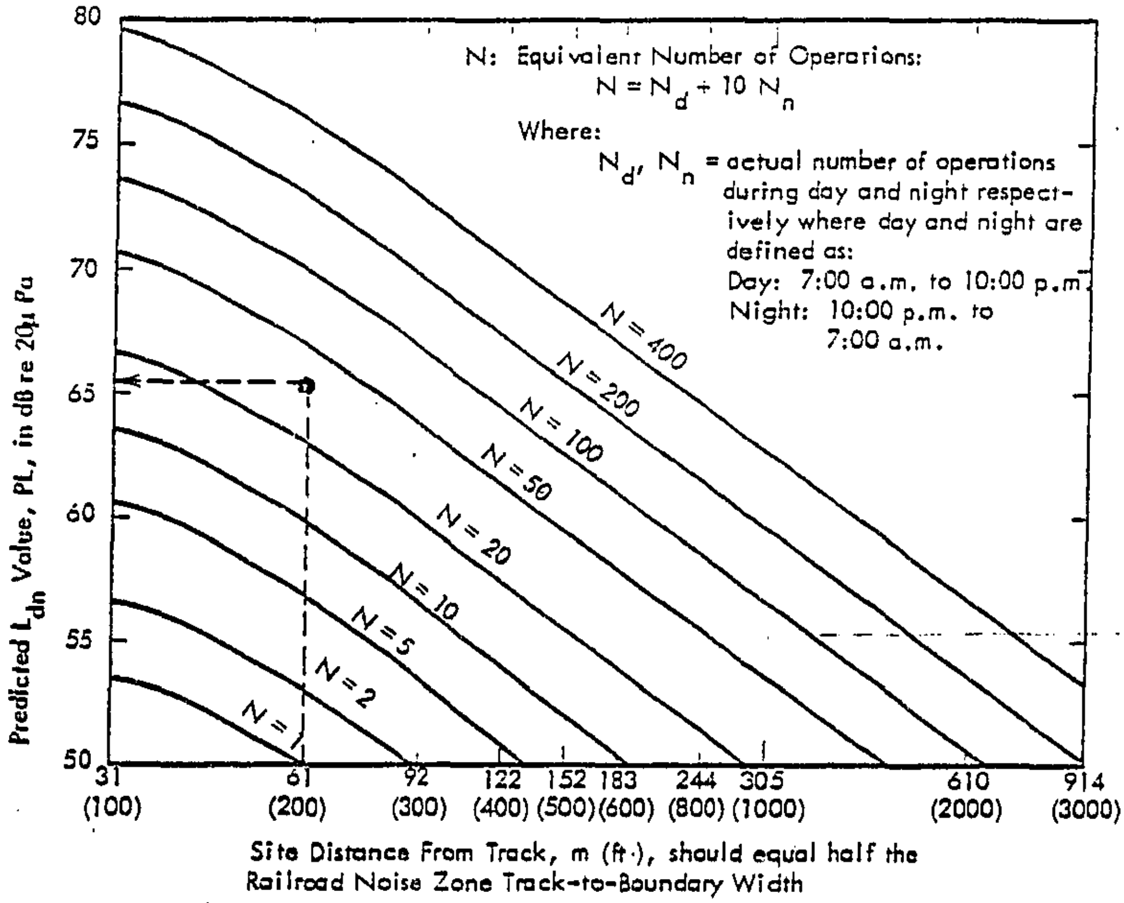


Figure 4-14 Predicted L_{dn} Values Due to Railroad Lines[8]

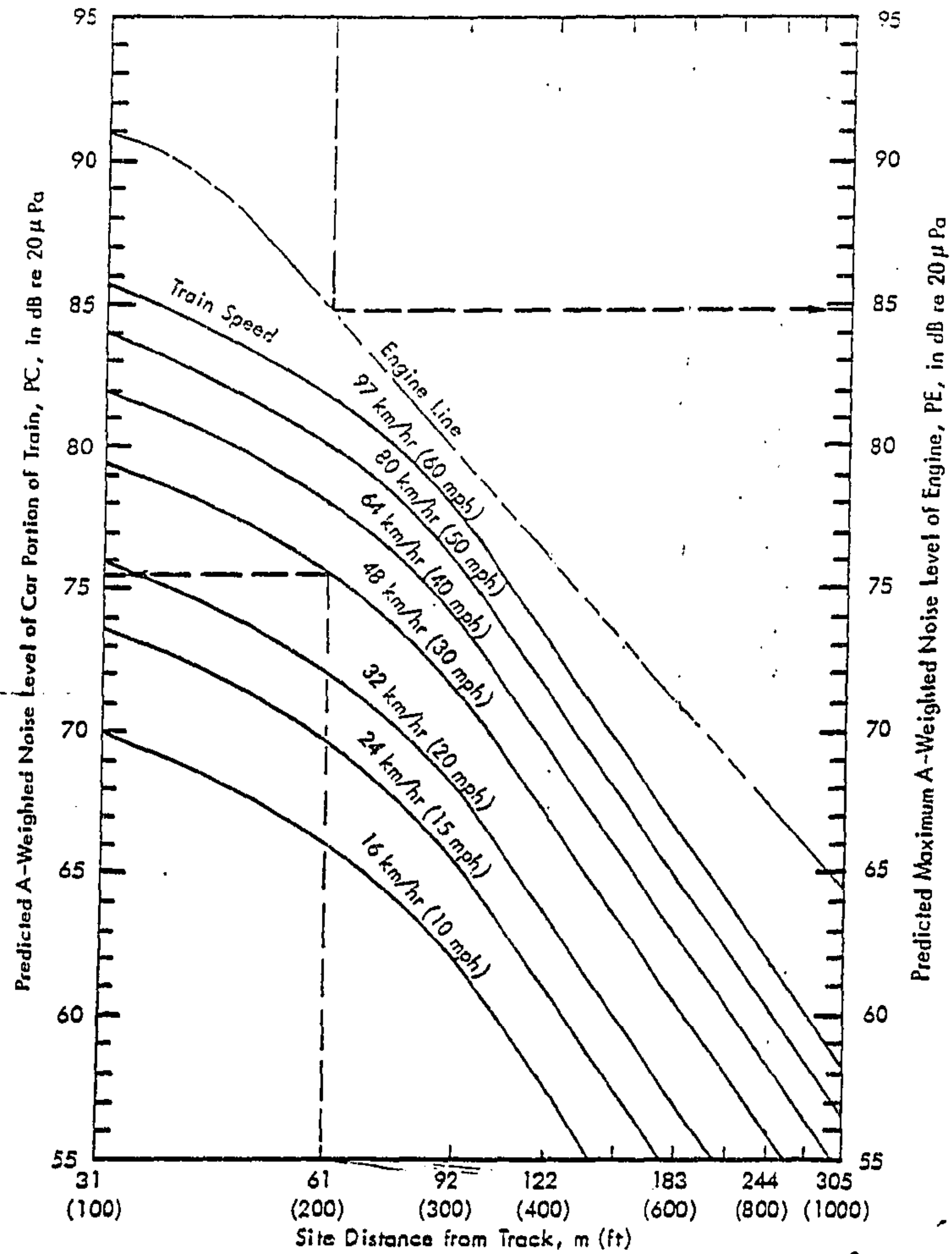


Figure 4-15. Predicted Noise Levels of Engine and Car Portions of Train Passby[8]

4.4.2 Railroad Data Reduction Procedure (Continued)

STEP 3 - Predict Car Noise Level, PC

The predicted noise level for the car portion of the train is also obtained using Figure 4-15.

a. Locate the distance from the track to the site on the lower horizontal scale.

b. Extend a line upward from this point until it intersects with the curve labeled with the proper train speed. This should have been recorded on the data sheet by the observer.

c. From this intersection at the train speed curve, proceed directly to the left, meeting the left vertical scale at the predicted noise level for the car portion of the train. Read this level to the nearest half decibel.

Continuing with the same example, if the site distance is 61 meters (200 ft), and if the train speed was approximately 48 km/h (30 mph), then the PC is 75.5 dB.

STEP 4 - Determine Engine Noise Difference

Determine the difference between the measured noise level for the engine, ME, and the level predicted in Step 2, PE, by subtracting according to the following algebraic formula:

$$\Delta E = ME - PE$$

where ΔE is the engine noise difference. Be sure to retain the minus sign if the difference as shown is less than zero.

Assume for the example we have been following that the measured engine noise level was 92 dB. Then,

$$\Delta E = ME - PE = 92 - 85 = +7 \text{ dB}.$$

4.4.2 Railroad Data Reduction Procedure (Continued)

STEP 5 - Determine Car Noise Difference

Determine the difference between the measured noise level for the car portion of the train, MC, and the level predicted in Step 3, PC, by performing the following subtraction:

$$\Delta C = MC - PC,$$

where ΔC is the car noise difference. Be sure to include a minus sign if ΔC is negative.

For example, if the measured car noise level is 78 dB and the value for PC is 75.5 dB,

$$\Delta C = MC - PC = 78 - 75.5 = +2.5 \text{ dB}.$$

STEP 6 Determine L_{dn} Difference, ΔL

The values of ΔE and ΔC will now be used with Figure 4-16 to determine the difference between the actual L_{dn} estimate for the noise zone, and the value predicted in Step 1.

a. Locate the ΔE value on the bottom scale of Figure 4-16. In our example, this was +7 dB.

b. Proceed up vertically from this location into the family of curves until the curve having the value of ΔC is reached. This is shown in Figure 4-16 with $\Delta C = 2.5$ dB.

c. Now extend a horizontal line from this point to the left-hand scale, where the difference between the predicted and final L_{dn} values can be read to the nearest half decibel. For our example, shown in the figure, ΔL is +6 dB.

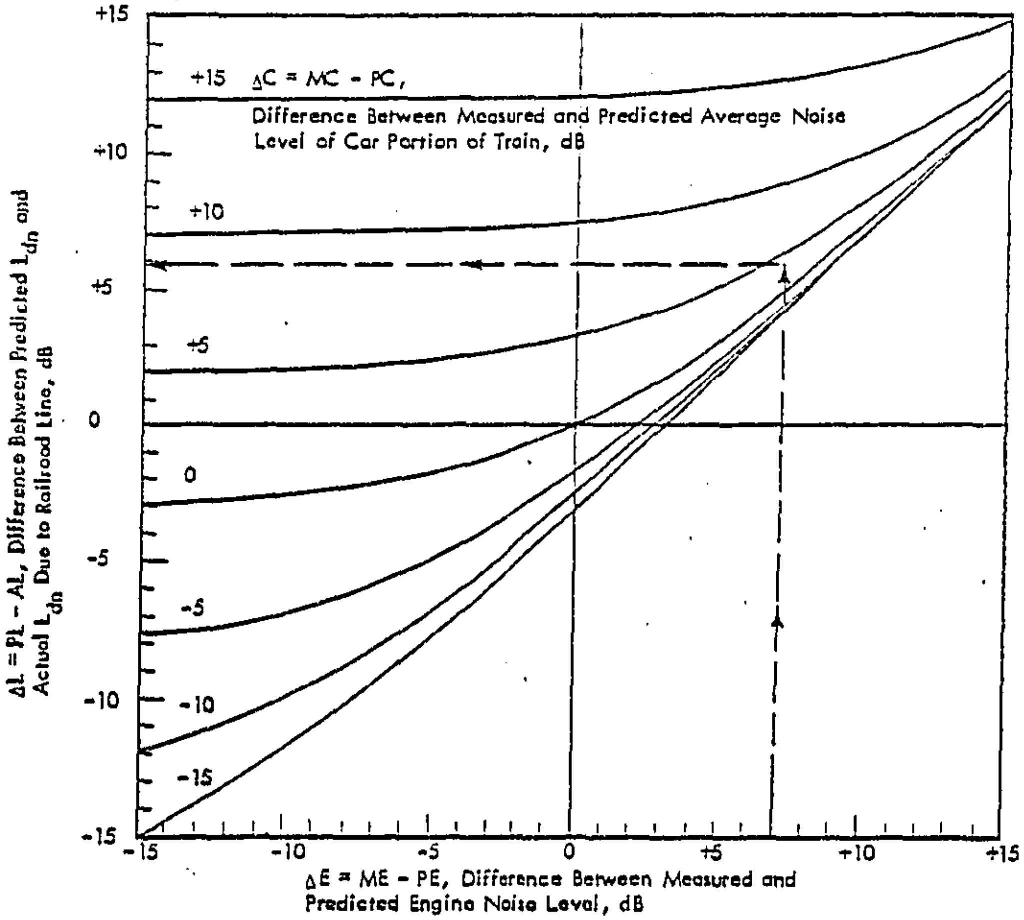


Figure 4-16. Difference Between Predicted and Actual L_{dn} of Railroad Noise Zone (Reference 8)

STEP 7 - Calculate Railroad Noise Zone L_{dn}

The L_{dn} value which will be taken as a nominal average for the railroad noise zone, or for the particular portion of the zone for which the measurement was taken, can be computed using this formula:

$$L_{dn} = PL + \Delta L.$$

Thus, if PL, the predicted L_{dn} value from Step 1, is 65.5 dB, and if ΔL is +6 dB, then $L_{dn} = 65.5 + 6 = 71.5$ dB or, rounded to the nearest decibel, 72 dB.

STEP 8 - Display L_{dn} Value

When the value for L_{dn} in a railroad noise zone or noise zone portion is obtained, it can be displayed in the basic data display formats as shown previously in Figures 4-5 or 4-9.

4.5.1 Introduction

In the recording of sound level data during the 20-minute measurements, identifiable noise sources which corresponded to the "snapshot" reading were indicated using letter symbols on the data sheet. In this section, these indications will be tallied to represent the average relative frequency of occurrence of identifiable intrusive noise sources throughout the community. The counts will be recorded on a simple worksheet, and can be displayed for the entire city or selected noise zones as desired. The following steps should be used to estimate the relative intrusiveness of common noise sources.

4.5.2 Procedure for Relative Intrusiveness of Noise Sources

STEP 1 - Sort Data

Separate all of the 20-minute noise measurement data sheets into groups according to noise zone.

STEP 2 - List Indicated Sources

a. For each noise zone, count the number of times that each particular source is identified as an intrusive source on each data sheet. Then, add these totals from each data sheet to find the number of times each source was identified in each noise zone. Note that intrusive sources will not be identified in the airport and railroad zones since separate 20-minute measurements were not performed for these zones.

b. Enter the total counts of each specific noise source for each noise zone under the appropriate Number ("No.") column in Worksheet 4-5.

STEP 3 - Compute Intrusive Source Totals

a. Compute relative source intrusiveness for the entire survey by adding all of the entries in each horizontal row of Worksheet 4-5 and placing the sum in the "No." portion of the "Total" column. These values

Worksheet 4-5

Tabulation of Intrusive Noise Source Frequency of Occurrence

Intrusive Noise Source	Residential[(1)] Noise Zone		Commercial/ Industrial Noise Zone		Highway Noise Zone		Major Roadway Noise Zone Type A		Major Roadway Noise Zone Type B		Minor[(1)] Roadway Noise Zone		Stationary Source Noise Zone		Stationary Source Noise Zone		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Emerg. Veh.																		
General Aviation																		
Jet																		
Helicopter																		
Railroad																		
Truck																		
Service Vehicle																		
Auto																		
Bus																		
Motorcycle																		
Off Road Vehicle																		
Construction Equip.																		
Yard/Maint. Equip.																		
Factory Equip.																		
Household Equip.																		
Dog																		
People Noise																		
Total																		

(1) For simplicity, only one type of each of these noise zones is shown here.

represent the total numbers of identifications (or presumed intrusions) of each noise source that were measured throughout all noise zones. Now add this column, entering the sum in the space provided at the bottom of the column.

b. Calculate the percentage of the total number of identified intrusions that is represented by each source using the following expression:

$$\text{Percentage} = \frac{\text{Number of Intrusions of Specific Source}}{\text{Total Number of Intrusions of all Sources}} \times 100.$$

- *Example*

  If the number of times trucks are identified is 65, and there were 195 total identifications of sources, then the percentage of trucks would equal:

$$\frac{65}{195} \times 100 = 33.3\%.$$

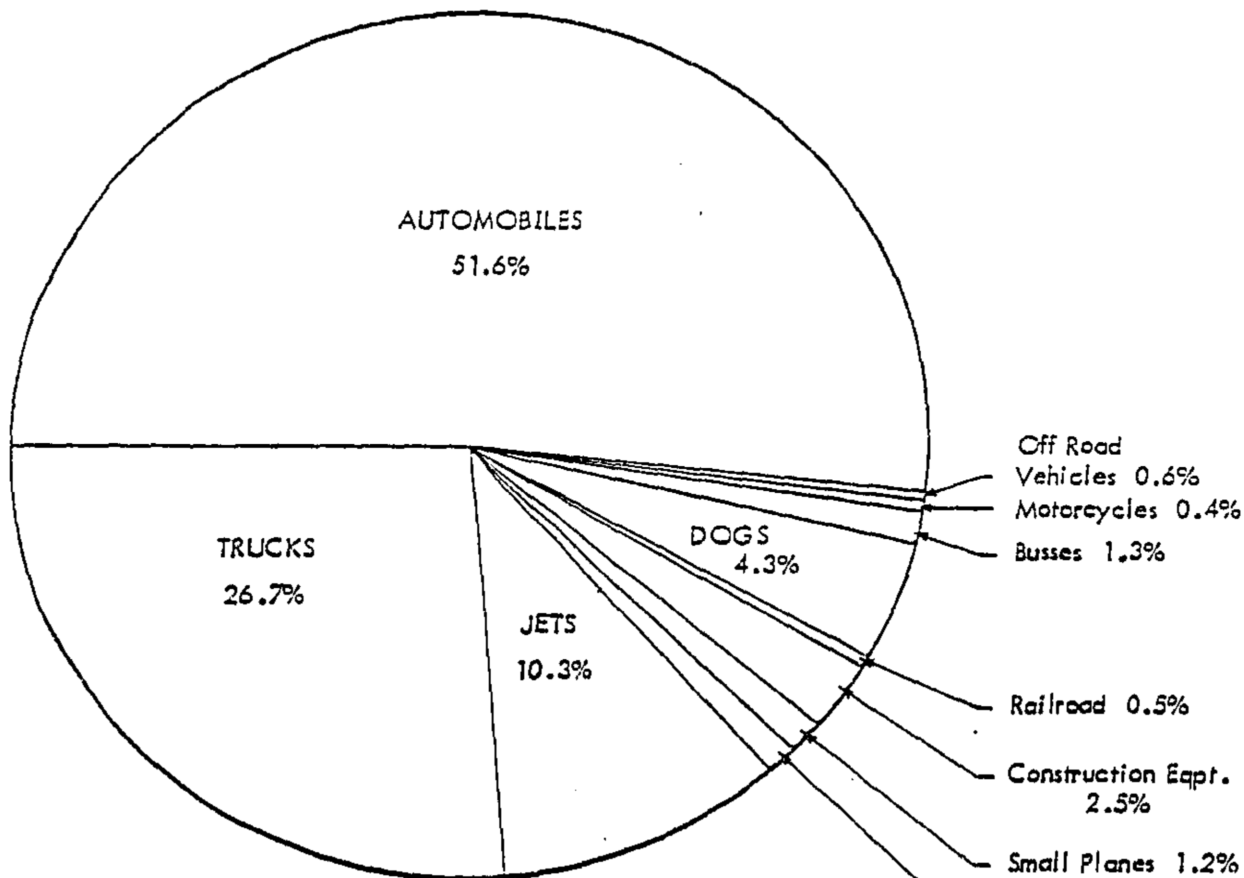
Record the percentage for each identified intrusive noise source to the nearest tenth in the portion of the "Total" column labeled "%." These percentages should total to 100 percent.

c. The percentages for the various intrusive sources can be developed for each noise zone by applying the methods of b. above to the column for the appropriate noise zone. In this case, the percentage of intrusion for any particular source would equal the number count for that source divided by the total of the counts for all sources in the column, multiplied by 100.

4.5.2 Procedure for Relative Intrusiveness of Noise Sources (Continued)

STEP 4- Display Noise Source Relative Intrusiveness

One effective way to present the relative numbers of measured intrusions by specific noise sources is shown in Figure 4-17. In this type of chart, each sector occupies a proportion of the circle that is equal to the percentage of intrusions for the indicated source. To determine the proper sector size for each source, multiply the percentage value for that source in percent times 3.60. This product will be the proper number of degrees for the sector angle. This presentation can be used to show relative numbers of measured intrusions by specific sources for individual noise zones or for the entire survey area. Alternatively, the same information can be presented with a bar chart using one bar for each identified source. The height of each bar is made directly proportional to the percent of time that source is identified.



Total No. of Identified Sources: 640

Figure 4-17. Display of Relative Numbers of Identified Intrusions by Specific Noise Sources for a Residential Noise Zone

4.6.1 Introduction to Noise Impacts

The adverse effects of noise in the community can take many forms. Conversations may be disturbed, sleep may be interrupted, or people may become more annoyed. These impacts may cause individuals to complain, file suits, or change their residence, or they may engender no observable community reaction at all. While the ability to predict a particular individual's response to noise in his or her own natural environment has not yet been achieved, the prediction of average overall community reaction is possible. While the relationship between levels of noise and adverse community response remains an imprecise one, quantitative methods have been developed which can be applied with sufficient accuracy to form the basis for effective community planning.

The procedure used here for estimating the impact of noise involves the concept of "Level Weighted Population" (LWP). The LWP is the equivalent number of people in a community who are "100 percent impacted" by community noise levels. A 100 percent impact, defined quantitatively below, can be thought of, for instance, as a situation in which speech is totally disrupted. As a result, if one person is only 25 percent impacted (25 percent of speech communication is disrupted) and another is 75 percent impacted (75 percent of speech is disrupted), then the total level weighted population is one equivalent person impacted.

The relative value of the noise impact is determined by the noise level and is expressed in terms of a weighting function W (L_{dn}) given by:

$$W(L_{dn}) = \begin{cases} 0.0232 \cdot L_{dn} - 1.088 \;\; 10^{-3} \cdot L_{dn}{}^{2} + 1.275 \;\; 10^{-5} \cdot L_{dn}{}^{3}, & L_{dn} > 45 \text{ dB} \\ 0. & L_{dn} \leq 45 \text{ dB} \end{cases} \quad (1)$$

where W (L_{dn}) is the fractional impact for a given population and L_{dn} is the day-night sound level to which the population is exposed.[9]

4.6.1 Introduction to Noise Impact (Continued)

To estimate the LWP of a community noise zone, the weighting function is multiplied by the population in the zone, as follows:

$$LWP = W(L_{dn}) \cdot P \tag{2}$$

where P is the population of the noise zone.[9]

According to Eq.(2), the LWP of a noise zone can be estimated once the population and L_{dn} of the zone are known. A procedure is described below to calculate the LWP of each zone using L_{dn} values developed earlier in the chapter and population figures from U.S. Census data. The procedure consists of six steps and uses some information from the City of Alexandria, Virginia (1970 population: 110,938) as the basis for an example.

4.6.2 Procedure for Calculating Noise Impact

STEP 1 – Collect Census Data and Estimate Census Tract Areas

The Bureau of the Census publishes a Block Statistics package for each urbanized area with cities of greater than 50,000 population (U.S. Bureau of the Census, Census of Housing: 1970, Block Statistics, Report HC (3)). Each "package" contains a set of maps which show the boundaries of all census tracts for the area. Census tracts are small subdivisions into which large cities and metropolitan areas are divided for statistical purposes. Boundaries of these subdivisions are generally designed to achieve some uniformity of population characteristics, economic status, and living conditions. A typical census tract has a population of 3000 to 7000 and, for cities, an area of 1 to 2 square miles (2-1/2 to 5 square km. Note: The primary measurement units in this section will be English, since census maps are marked in English dimensions). Obtain the Block Statistics Package for the urbanized area which includes the community under consideration. One source is: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

4.6.2 Procedure for Calculating Noise Impact, Step 1 (Continued)

The census tract map or maps which include the community under consideration can be found using an index which accompanies the Block Statistics package. Estimate the area from each census tract which is wholly or partially within the community's boundaries using the appropriate maps.

- Example

In the case of Alexandria, Virginia, the desired census data are contained in "Washington, D.C. - Md. - Va. Urbanized Area Block Statistics," (Report HC (3)-44). The index to the detailed maps in this statistics package, illustrated in Figure 4-18, shows that Map 18 includes the entire town of Alexandria. A section of Map 18 is shown in Figure 4-19. The area of each census tract can be estimated by applying simple geometric techniques as shown in Figure 4-19. As shown in the figure, the area of census tract 2006 is approximately 0.9 square miles (2.3 square km).

STEP 2 - Find the Population of Each Census Tract

The 1970 population of each census tract is supplied in the Block Statistics volume accompanying the statistics package. If they are known, values for more recent years can be substituted to allow use of more accurate estimates of the impacted population. As shown in Figure 4-20, according to the 1970 census data, the population of tract 2006 illustrated is 5,050.

STEP 3 - Compute the Average Population Density for Each Tract

Simply divide the population figures for each tract found in Step 2 by the associated area values estimated in Step 1. Thus, for the preceding sample, the population density of sample tract 2006 is

$$5050 \div 0.9 = 5610 \text{ people per square mile}$$
$$\text{(or 2170 people per square kilometer).}$$

METROPOLITAN MAP SERIES
WASHINGTON, D.C.-MD.-VA.
URBANIZED AREA

INDEX TO SHEETS

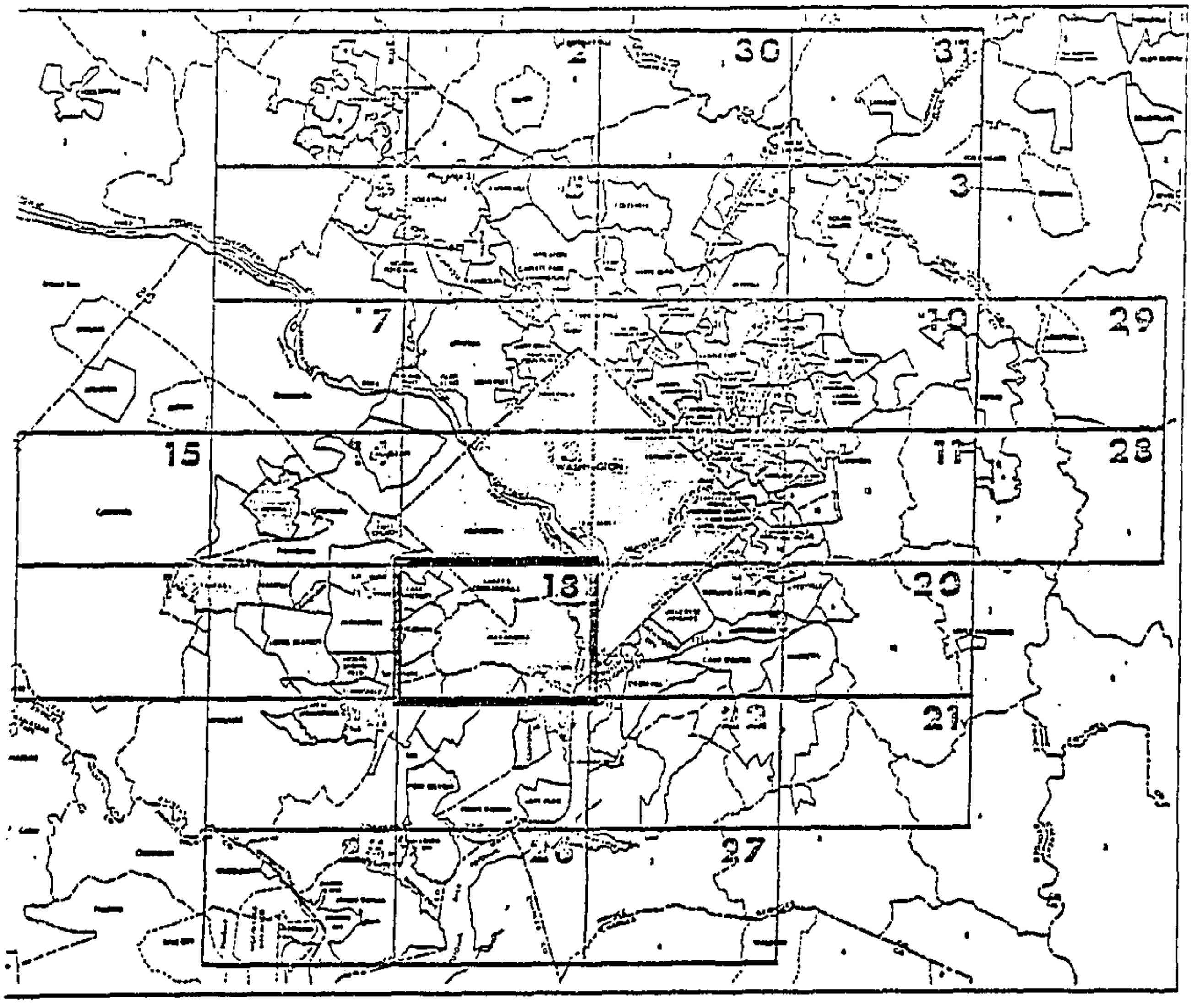
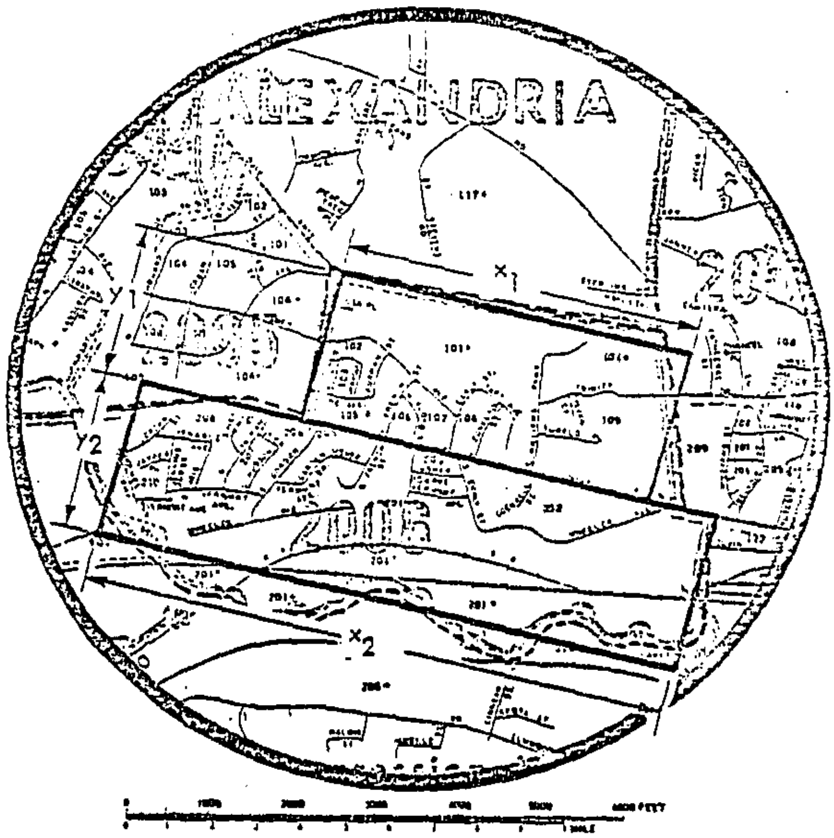


Figure 4-18. Index to Census Map Sheets for the Washington, D.C. - Md. - Va. Urbanized Area



Area of Census Tract # 2006

$$A \approx x_1 \cdot y_1 + x_2 \cdot y_2 = .9 \text{ square miles } (2.3 \text{ square km})$$

Figure 4-19. Section of Alexandria, Virginia Showing Computation of Approximate Area of a Typical Census Tract

Table 2. Characteristics of Housing Units and Population, by Blocks: 1970—Con. Alexandria

[Data exclude vacant seasonal and vacant migratory housing units. For minimum base for derived figures (percent, average, etc.) and meaning of symbols, see text]

Blocks Within Census Tracts	Total population	Percent of total population: Negro	Percent of total population: In group quarters	Percent of total population: Under 18 years	Percent of total population: 62 years and over	Year-round housing units: Total	Year-round housing units: Lacking some or all plumbing facilities	Units in—: One-unit structures	Units in—: Structures of 10 or more units	Occupied housing units: Owner: Total	Owner: Lacking some or all plumbing facilities	Owner: Average number of rooms	Owner: Average value (dollars)	Owner: Percent Negro	Renter: Total	Renter: Lacking some or all plumbing facilities	Renter: Average number of rooms	Renter: Average contract rent (dollars)	Renter: Percent Negro	1.01 or more persons per room: Total	1.01 or more persons per room: With all plumbing facilities	One-person households	With female head of family
105	1230	1	-	25	1	514	-	7	436	-	-	-	-	-	490	-	4.2	169	1	15	15	79	29
106	327	14	-	14	7	144	5	9	137	9	3	4.9	23200	89	118	2	3.2	183	3	4	4	64	4
109	276	5	15	18	7	158	4	5	148	5	2	4.8	...	40	151	2	2.7	164	1	7	7	93	8
110	1396	1	-	27	1	528	-	13	457	-	-	-	-	-	518	-	4.5	173	1	15	15	51	35
111	17	-	50	33	-	1	...	...	...	...	...	...	...	-	...	...	...	...	-	...	...	...	...
112	383	2	-	30	2	161	-	1	159	1	...	...	...	...	159	-	4.1	172	1	3	3	30	14
2005	5913	7	-	31	2	2454	2	102	1944	29	-	4.9	31000	3	2268	2	3.7	116	7	171	171	474	204
101	144	6	-	26	-	62	-	6	52	2	...	...	...	...	56	-	3.5	113	7	3	3	11	2
102	554	4	-	29	1	244	1	8	200	3	...	...	...	...	226	1	3.7	110	4	10	10	53	13
103	346	11	-	31	3	144	-	5	114	2	...	...	...	...	130	-	3.7	109	12	13	13	23	7
104	362	11	-	33	1	213	-	9	184	-	-	-	-	-	205	-	3.6	104	11	21	21	34	20
105	507	4	-	27	1	251	-	5	207	-	-	-	-	-	216	-	3.6	123	4	12	12	50	27
106	2090	6	-	32	3	814	-	52	584	20	-	6.7	28800	5	776	-	3.8	124	6	57	57	150	82
107	480	6	-	20	2	318	1	4	270	-	-	-	-	-	278	1	[illegible]	125	5	20	20	78	27
108	366	11	-	35	3	207	-	5	176	-	-	-	-	-	197	-	3.9	103	9	22	22	37	10
109	457	6	-	30	4	197	-	8	159	2	...	...	...	...	184	-	3.6	101	6	13	13	48	23
2004	[illegible]	-	-	34	4	1609	3	949	437	801	2	6.1	25300	-	777	1	4.5	173	-	90	90	188	97
101	[illegible]	-	-	37	7	104	-	103	-	90	-	6.7	30700	-	14	-	4.4	185	-	4	4	7	7
102	190	-	-	45	1	47	-	66	-	40	-	6.6	29700	-	6	-	4.5	200	-	3	3	2	3
103	69	1	-	51	4	17	-	16	-	15	-	6.6	31700	7	2	...	...	...	...	2	2	2	-
105	154	-	-	35	9	42	-	41	-	34	-	6.3	26400	-	7	-	4.9	178	-	4	4	2	4
106	42	-	-	24	5	14	-	14	-	12	-	5.3	23800	-	2	...	...	...	-	1	1	-	-
107	81	-	-	25	16	25	-	25	-	24	-	6.5	25400	-	1	...	...	...	-	-	-	-	3
108	118	-	-	36	4	33	-	33	-	29	-	5.8	22500	-	4	...	...	...	-	3	3	1	2
109	202	-	-	33	9	59	-	59	-	50	-	7.9	46400	-	9	-	6.9	219	-	2	2	2	1
201	1609	-	-	26	4	617	-	148	425	143	-	5.6	20500	-	456	-	4.1	197	-	22	32	133	42
202	507	-	-	28	5	194	1	77	12	26	1	4.7	25000	-	159	-	4.5	162	1	4	4	18	12
203	69	-	-	48	1	16	-	14	-	11	-	5.8	20000	-	3	-	5.2	159	-	3	3	-	2
204	123	-	-	53	2	28	-	23	-	18	-	5.5	20500	-	9	-	5.3	139	-	5	5	-	1
205	378	-	-	44	3	94	-	77	-	73	-	5.9	20700	-	21	-	5.9	140	-	9	9	4	5
206	303	-	-	28	-	85	-	70	-	57	-	5.3	17500	-	28	-	5.3	130	-	3	3	2	2
207	136	-	-	29	2	39	1	31	-	24	-	5.5	17300	-	15	1	5.2	129	-	4	4	1	1
208	316	-	-	37	4	92	1	77	-	67	1	5.5	20500	-	25	-	5.5	136	-	3	3	7	6
209	94	-	-	44	1	24	-	22	-	18	-	6.2	22600	-	6	-	5.7	134	-	2	2	3	2
210	297	-	-	40	5	79	-	73	-	70	-	5.8	24000	-	8	-	5.5	184	-	6	6	4	4

Figure 4-20. Excerpt from U.S. Bureau of the Census 1970 Block Statistics for Alexandria, Va. Showing Total Population of a Sample Tract

4.6.2 Procedure for Calculating Noise Impact (Continued)

STEP 4- For Each Noise Zone in the Community, Find the Portion of its Area Which Lies in Each Census Tract

The concept of "noise zones" has been used throughout the manual. Any one noise zone, such as a major roadway zone, may be made up of many discontiguous pieces of land and may be spread throughout the community. In order to estimate the population contained within an entire noise zone, the portion of the area of the zone which lies in each census tract must be found. This is accomplished in the following ways, depending upon the type of zone involved.

Highway Zone – Multiply the length of each highway noise zone segment in each tract by twice the zone width established in Section 3.2.2, Step 8h. For those highways which form tract boundaries, multiply each segment by only one zone width.

Major and Minor Roadway Zones – Multiply the length of each noise zone segment in each tract by twice the zone width established in Section 3.2.2, Step 8c, e, or f. Note that, for major roadways with over 36,000 Average Daily Traffic, the area of a second zone also must be computed. Again, use only a single roadway width if the road forms a tract boundary.

Residential Zones – Estimate the total area of all portions of each of the residential noise zones (i.e., high, medium or low density) in each tract using zone boundaries established in Section 3.2.2, Step 7. In cases where nearly all of the land in the community has been assigned to a noise zone of some type, this value may most easily be found by subtracting the areas of all nonresidential types of zones in a tract from the total area of the tract.

Commercial/ Industrial Zone	– Estimate the portion of the zone which lies in each tract from noise zone boundaries established in Section 3.2.2, Step 7.
Railroad Zone	– Multiply the length of the railroad line in each tract by twice the zone width derived in Section 3.2.2, Step 6c.
Airport Zone	– Estimate the portion of the airport zone which is within each tract using airport contour maps or the airport noise zone boundaries established in Section 3.2.2, Step 5.
Stationary Source Zones	– Estimate the area of all portions of stationary source noise within each tract using the zone boundaries developed in Section 3.2.2, Step 9b.

A hypothetical example in which some of these procedures are utilized is shown in Figure 4-21. The areas impacted by surface roadways are calculated based, for convenience, on a typical first property distance of 100 feet (30 m), and a second property distance of 200 feet (61 m). The railroad impact width is also assumed to be 100 feet in each direction for this example.

STEP 5 – Estimate the Population of Each Noise Zone

Obtain a population for each noise zone by multiplying the average population density of each tract (Step 3) by the area of the noise zone contained in that tract (Step 4), and then summing these noise zone populations from each tract to obtain the total.

For the example based on a population density of 5610 people per square mile (2170 people per square kilometer), the hypothetical results for census tract 2006 are as follows:

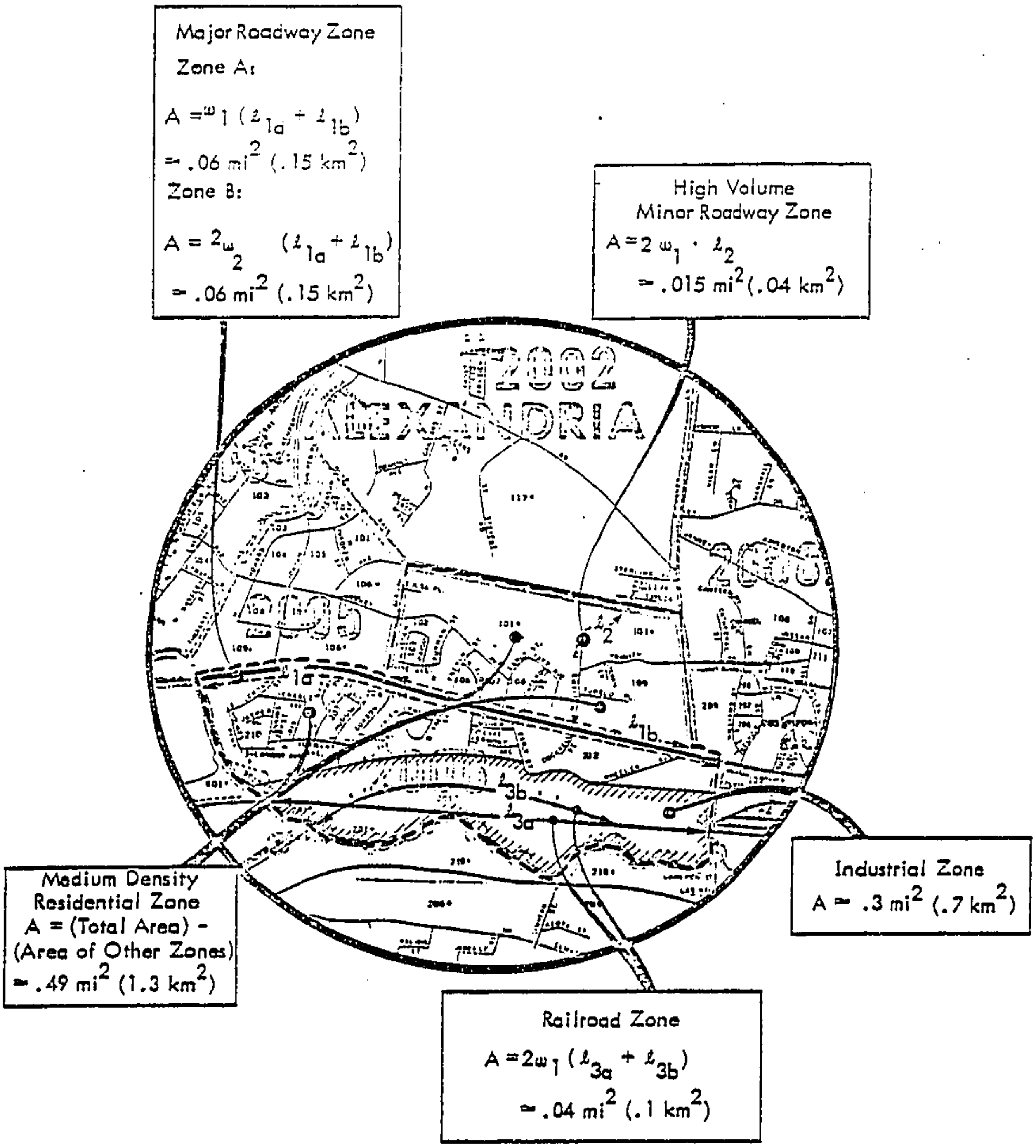


Figure 4-21. Hypothetical Apportionment of Noise Zones in a Sample Census Tract in Alexandria, Virginia

Zone	Area-Sq. Mi. (Sq. Km)	Population
Major Roadway Noise Zone A	.06 (.16)	337
Major Roadway Noise Zone B	.06 (.16)	337
Minor Roadway High Volume	.015 (.039)	84
Commercial/Industrial	.3 (.78)	1683
Railroad	.04 (.10)	224
Residential Medium Density	.49 (1.27)	2749

To find the population of a noise zone for the entire survey area, the populations of that zone in each tract would be summed.

STEP 6 - Estimate Noise Impact In Each Noise Zone

Estimate the Level Weighted Population (LWP) for each noise zone using the following equation:

$$LWP = P \cdot \begin{pmatrix} 0.0232 \cdot \overline{L_{dn}} - 1.088 \times 10^{-3} \cdot \overline{L_{dn}}^2 + 1.275 \times 10^{-5} \cdot \overline{L_{dn}}^3, & L_{dn} > 45 \text{ dB} \\ 0. & L_{dn} \leq 45 \text{ dB} \end{pmatrix}$$

where

P is the population of the noise zone, and

$\overline{L_{dn}}$ is the average day-night sound level in the noise zone calculated in Step 6, Section 4.2.2.

Section 4.7 The Noise Survey Report

Presentation of the results of a community noise survey should be considered at an early stage in the program. In fact, the display of results should be a factor in selecting the final survey design so that one may determine, as far in advance as possible, if the portrayal of results will provide meaningful and useful information to those responsible for acting on the results of the study. Several characteristics are required of a summary report:

1. Clear statements of the initiating causes for and objectives of the measurement program,
2. Simple, clear description of the program methods in language understandable to the nonspecialist,
3. Clear discussion of the meaning of results such that management personnel or others responsible for acting upon the results can do so knowledgeably.

These qualities can be achieved within the recommended report outline structure given below.

Recommended Community Noise Survey Report Outline

Chapter 1 Executive Summary

- Brief summary of the noise survey objectives and measurement plan.
- Average L_{dn} value for each noise zone with a map showing the zone boundaries.
- Description of all trends or general conclusions resulting from the various detailed data and display of results.

Chapter 2 Introduction

- Origin, purpose and objectives of the survey, including the history of noise related problems in the area.
- The nature of community noise described very briefly in simple terms. Some of the material in Section 1.3 of this manual may be useful.

- Utilization of Quiet Communities Program (QCP) procedures or materials.
- Responsible agencies
- Period of performance
- Agencies and bodies consulted in selection of the program and objectives.

Chapter 3 Program Structure

- Clear definition of the geographic area included in the study.
- Discussion of the program format and scope. Manual Section 2.1 can be expanded for this to include specifics of the particular program.
- Discussion of the method of sampling and selecting sites. Manual Sections 3.1, 3.2.1, and 3.3.1 will provide material for this section.
- Discussion of the method of noise measurement. Manual Sections 3.4.1 and 3.4.2 Steps 3 and 5 contain descriptions of the measurement method.

Chapter 4 Data Reduction and Results

- General description of data reduction approach. This is addressed in Section 4.1 of the manual.

  Detailed display of all results and outputs as prepared according to the various sections of manual Chapter 4. Interpretations should be included based on the guidance given in Chapter 4.

Glossary- A suitable glossary can be assembled from manual Table 1-1 and the manual Glossary.

Appendices

- Measurement System
  Detailed description of the instrumentation used for data acquisition and analysis.

4.7 <u>The Noise Survey Report (Continued)</u>

- Noise Survey Data

  Detailed results of the survey in the form of tables or charts which have already been summarized in Chapter 4 of the main body of the report.

- Non-Acoustic Data

  Other pertinent data such as vehicle traffic counts, population densities, etc., which were used in the main report and can be relegated to an Appendix for details.

GLOSSARY OF SOME ACOUSTICAL TERMS

Selected acoustical terms are defined here which are commonly encountered in the study of community noise. The list begins with the most fundamental terms, building upon these to conclude with the more complex definitions. Common symbols or abbreviations are given in parentheses.

Sound Pressure - The sound pressure at a point is the total instantaneous pressure at that point in the presence of sound minus the static pressure at that point.

Level - In acoustics, the level scale is used for describing the amplitude of acoustical quantities. In environmental acoustics, this is usually ten times the logarithm (base 10) of the ratio of an acoustical quantity which is proportional to power (i.e., sound pressure squared, sound intensity, etc.) to a reference quantity of the same kind. For a level value to be meaningful, the reference quantity must be specified. The level value is assigned the unit decibels.

Decibel (dB) - A unit for describing the amplitude or level of acoustical (or electrical) quantities - see level.

Frequency - The number of sound pressure fluctuations per second of a particular sound expressed in Hertz (cycles per second). Frequency is the property of sound that is perceived as pitch.

Hertz (Hz) - The preferred unit of frequency, equivalent to "cycles per second."

A-Weighting - A frequency weighting which selectively descriminates against high and low frequencies to approximate the auditory sensitivity of human hearing at moderate sound levels. Sound level meters normally contain an A-weighting network which can be used to filter the received sound. (See A-weighted Sound Level)

Sound Level Meter (SLM) - An electroacoustical instrument for measuring sound pressure level. The American National Standard Specification for Sound Level Meters, S1.4 - 1971, establishes performance criteria for three categories of meters of increasing degrees of precision that are used in community noise measurement. All of these meters normally include Fast and Slow meter movement and A-weighting features.

Sound Pressure Level - The instantaneous sound pressure level in decibels defined as $SPL = 10 \log (P^2/P^2_{ref})$ where P is the sound pressure and P_{ref} is 20 micropascals ($20\mu N/m^2$ or $2(10^{-4})$ microbar). In practice, this quantity is measured in decibels directly with a sound level meter, usually applying the A-weighting network of the meter (see Sound Level).

Sound Level - Strictly defined, sound level is the quantity in decibels measured by a sound level meter satisfying requirements of American National Standard Specification for Sound Level Meters.

A-Weighted Sound Level - A sound level determined using the A-weighting function. A-weighted sound levels can either be measured using a sound level meter with an A-weighted network, or can be calculated from unweighted sound levels given for frequency bands.

Maximum Sound Level - The greatest sound level during a designated time interval or event.

Background Ambient Sound Level - The Background ambient sound level is the level of the all-encompassing unidentifiable noise which remains after sounds from all specifically identifiable sources have been eliminated. It is usually perceived as a rushing sound of many indistinguishable sources. L_{90} is often used as an estimate of the background ambient noise level when no steady state identifiable noises are known to be present (see Statistical Sound Level).

Statistical Sound Level (L_x) - The sound level which is exceeded by a fluctuating sound level for a particular percentage of the time during a given period. The percentage of time exceeded corresponds to the subscript in the symbol. For example, the L_{90} of a period of environmental noise is a low level exceeded 90 percent of the time, but the L_{10} is a higher level which was exceeded only 10 percent of the time.

Equivalent Sound Level (L_{eq}) - Equivalent sound level is a measure which describes the sound level of a time period of fluctuating environmental noise with a single number. It is a sound level based on the arithmetic average energy content of the sound rather than an arithmetic average of the sound level. Thus, it is the constant sound level which would contain the same amount of acoustical energy as the actual (fluctuating) level for the given period. Its mathematical definition is:

$$L_{eq} = 10 \log_{10} \left[\frac{1}{T} \int_0^T 10^{L(t)/10} dt \right]$$

where $L(t)$ is the measured noise level as a function of time t and T denotes the duration of the measurement period. L_{eq} values are usually not measured directly, but are computed from measurements often taken over 1, 8, or 24-hour periods. These measurements, and the resulting L_{eq} values, are usually A-weighted when considering community noise.

Hourly Equivalent Sound Level ($L_{eq(1)}$) - Equivalent sound level, in decibels, over a 1-hour time period.

Day Sound Level (L_d) - The equivalent sound level over the 15-hour time period from 7 a.m. up to 10 p.m. (0700 up to 2200 hours).

Night Sound Level (L_n) - The equivalent sound level, in decibels, over the split 9-hour period from midnight up to 7 a.m. and from 10 p.m. to midnight (0000 up to 0700 and 2200 up to 2400 hours).

Day-Night Sound Level (L_{dn}) - This composite noise metric is recommended by the U.S. Environmental Protection Agency for specification of community noise from all sources. It is a calculated level, similar to an equivalent sound level over 24 hours, except that the sound levels occurring during the nighttime period, which extends from 10 p.m. to 7 a.m., are increased by a 10 dB weighting penalty before computing the 24-hour average.

Defined in the general way for application to continuous monitoring of community noise, L_{dn} is given by:

$$L_{dn} = 10 \log \left[\frac{15}{24} \cdot 10^{\left(L_d/10\right)} + \frac{9}{24} \cdot 10^{\left(L_n + 10\right)/10} \right]$$

where

L_d = day sound level during the daytime (7:00 a.m. to 10:00 p.m.)

L_n = night sound level during the nighttime (10:00 p.m. to 7:00 a.m.)

Noise Level - An informal term usually used loosely as a synonym for the A-weighted sound level.

Metric - A measure of environmental sound. Some metrics are complex and account for characteristics such as sound duration, sound level, frequency content, time of occurrence, or single events. Statistical noise levels, equivalent noise levels, L_{dn}, etc., are all noise metrics.

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APPENDIX A

PROCEDURES FOR 24-HOUR MEASUREMENTS

A.1 Introduction

The recent development and availability of several types of automatic equipment capable of continuous measurement and storage of environmental sound levels for periods of 24 hours or longer (see Appendix C) provides an extremely useful tool for any community noise measurement program. This type of instrumentation essentially removes the need for sampling considerations in the temporal domain, normally yielding results accurate to a fraction of a decibel for the location and time period measured. There are many possible applications for such equipment in the general survey of community noise, including:

- Measurement of day-night sound level or statistical metrics in localized problem areas where accurate 24-hour noise level values are desired.
- Accurate survey of levels within a single noise zone of importance, where each measurement location in the zone might become the site of a 24-hour measurement.
- A follow-up survey to check the effectiveness of noise mitigation measures instigated earlier.
- Accurate measurement of sound levels near locations sampled by an attitudinal survey to allow direct comparisons between the objective (noise) and subjective (attitudinal) data.

This appendix will review the application of 24-hour measurements, including sample and site selection, data reduction, and cost in sufficient detail for the reader to execute a program of 24-hour measurments. Throughout, it is assumed that the actual microphone position at any measurement will follow the same guidelines set forth in

Section 3.3 of the main text with respect to height above ground, distance from building facade, etc. Factors affecting the final locations of 24-hour equipment are availability of a building to provide security for the analysis unit, permission of occupants to locate on private property, practicality of mounting, etc. Normally, when checking hand measurements made according to Chapter 3, the microphone should be mounted at the first floor level. Attachment to front porch columns on a horizontal extension may be convenient. However, if security of the microphone is at all in doubt, an elevated location may be used for protection; i.e., with a pole mounting, a second story window mounting, etc. As an alternative approach, an elevated mounting, such as on the sloped roof of a single family dwelling, may be used as a single location from which to characterize the noise environment of an entire attitudinal sample cluster since it will experience direct combined exposure to most areas of the cluster. With this approach, locate the microphone to avoid excessive shielding from street level noise sources by the roof. In all cases the microphone should be no closer than 6 feet to the building roof, wall or any roofed-over front porch areas. There should be no objects directly between the microphone and fronting street. Actual measurement procedures should always be in accordance with the equipment operating instructions.

A.2 Sample Size and Measurement Locations

An important aspect in the utilization of 24-hour measurement is the number of locations at which the measurements will be taken. The total number normally becomes a compromise between the ideally desired sample and one that is practically achievable, since each site occupies a complete set of equipment for at least a 24-hour period. The following general guidelines can be used to establish sample size for most basic purposes.

Measurements in Local Impacted Regions

If it is desired to measure noise levels on a 24-hour basis in the local impacted vicinity near an important noise source, the number of measurement sites need not be great. The actual area of impact might be defined based on the complaint history, or by the "walk-away test" described in Section 3.2 of the manual for defining stationary source noise zones. If the defined impact region contains regions that are significantly different from each other (i.e., elevated or depressed terrain, many high-rise versus single level buildings, or any other desired discriminating factors), then at least one measurement should be made in each region at a location representative of the area. Note the distance from the noise source to the impact region being surveyed. If the depth of the impact region as it extends away from the source equals or exceeds the source-impacted region distance, then the noise level contributed by the source throughout the region may change significantly with distance from the source. In this case, several measurements should be made within the impacted region. When the source is not immediately adjacent to the impact region, initially plan a sample of the measurements across the region at intervals equal to the source-region distance. Then increase or decrease the number of locations using knowledge gained from a site visit so as not to locate the measurements unnecessarily close together, but still providing enough sites to establish the noise level gradient. Of course, any specific location of particular interest, such as a school, may also be monitored if desired.

Measurements to Verify Noise Survey Results

If a complete community noise survey has been carried out according to the manual procedures, it is desirable to check and verify the resulting noise level values with 24-hour measurements. A sample size of approximately one-third the number of weekday sites used in the survey should be selected for each noise zone. The selection should be made from sites having at least one day and night 20-minute measurement: sites measured only once during the survey should be excluded. From these sites, select at random the sample for 24-hour measurements. If possible, 30 percent of the selected sites should be measured during weekend periods, and the remainder during the work week. The elimination of temporal uncertainty by use of the 24-hour technique will compensate in part for the loss of spatial accuracy due to reduction of the spatial sample size. Thus, the use of 24-hour measurements at one-third the sites should produce results approximately comparable in accuracy to the complete survey, based on the 20 minute temporal samples, and will be adequate as a verification of the resulting levels.

Measurements in Critical Noise Zones

Any particular noise zone that is of special interest, or for which the data and resulting noise levels may be subject to close scrutiny, may be sampled at every measurement location for a 24-hour period. Measurements should be made at all sites, distributed through the five weekdays, and in addition, 30 percent of the sites should be selected at random and subjected to additional measurements during the weekend period. Such exhaustive sampling will remove temporal uncertainties up to the week time period, and achieve 95 percent confidence intervals for average L_{dn} of ± 4 dB for a Class II survey or ± 6 dB for a Class I survey (see Appendix D, Section D.3.2).

Measurements That Relate to an Attitudinal Survey

If a complete Quiet Communities Program is being followed (see manual introduction), a survey of community attitudes towards noise will be conducted as a companion to the noise survey. The attitudinal survey interviews in this program are grouped together in areas called sample clusters which consist of from one to four city blocks bounded by surface streets. These clusters are selected according to a population-weighted sampling process instead of the basically spatially-oriented sampling method used to select noise measurement sites. However, the purely random spatial sampling plan for selecting noise measuremement sites has been altered to insure that each of the attitudinal sample clusters is included in the noise measurement sample plan. Thus, when desired, another basis for selecting 24-hour measurement sites would be based on using only those noise measurement sites which correspond to the attitudinal cluster samples. As a minimum, at least one-third of the clusters in each noise zone should be measured. Detailed procedures for selecting a representative measurement location within a cluster are given below.

Guidelines for Noise Measurement in Social Survey Clusters

In general, locations for elevated measurements in clusters should be selected at buildings within clusters as near as possible to the representative location selected in Section 3.3.2, Step 7a of the manual. However, a more thorough assessment can be obtained according to the following procedures, keeping in mind the qualifications for microphone position given in the introduction to this appendix.

1. Survey the cluster for principle noise sources and traffic volume along all streets in or bordering the cluster.

   a. Note, by on-site observation, any intrusive noise sources located within or outside the cluster, and whether these sources are likely to be continuous (constant output all the time) or intermittent (emit noise during only portions of the 24-hour day). Frequently, the time pattern of an intermittent source would correspond roughly to day and night. Noise sources located outside the cluster (nearby freeway, factory, airport, etc.) are considered to have significant impacts if the source is audible and causes increased noise levels in all or part of the cluster.

   b. Check the approximate traffic volume along all streets bordering or passing through the cluster (except alley-type streets) by observation, familiarity, and reference to traffic flow data. If one or more of the streets carries a volume that appears to be about three or more times that of the least traveled street in the cluster, then all streets in the cluster should be assigned to one of two groups:

   High Volume Group - the high volume roads having on the order of three or more times the traffic volume of the remaining streets.

   Low Volume Group - all other low volume streets. If there is not a clear factor of three difference in flow volume between streets in the cluster, then no grouping is necessary.

2. Select a location for the 24-hour automatic monitoring system according to the following logic:

a. IF NO INTRUSIVE SOURCES ADD TO TRAFFIC NOISE AND CLUSTER STREETS HAVE <u>NOT</u> BEEN DIVIDED INTO THE TWO TRAFFIC VOLUME GROUPS: then a measurement site should be selected at random at a household along one of the cluster streets. However, if there appears to be a substantial difference in traffic flow, select the street with the highest volume, or if it appears that a particular street would present the highest L_{eq} due to a unique traffic mix (i.e., high percentage of trucks or buses, etc.) even though flow volume may not be greatest, this street should be chosen for the measurement. Make sure that the chosen street and block actually contains households that underwent the social survey. If it does not, choose the most similar street or block until one with interviewed households is identified.

b. IF NO INTRUSIVE NOISE SOURCES ADD TO TRAFFIC NOISE, AND THE CLUSTER STREETS <u>HAVE</u> BEEN DIVIDED INTO TWO GROUPS: then the measurement should be made along a high volume street which would be expected to present the highest L_{eq} value. If the traffic mix for the high volume streets is uniform, then this will be the street with the highest traffic flow. If traffic flow volumes are about the same, then select a street and block at random. The street and block chosen should contain social interview households.

c. IF EITHER a. or b. ARE TRUE: then the microphone should be placed along a street and block as near as possible to a point midway between a corner and the middle of the block. There will be two such "quarter points" on a block side, and one of these can initially be selected at random, with the other point being used if it becomes impractical to locate the microphone near the first selection.

d. IF THE CLUSTER IS EXPOSED TO A SIGNIFICANT INTRUSIVE NONTRAFFIC NOISE SOURCE LOCATED OUTSIDE OF THE CLUSTER: then locate the microphone along the bordering cluster street nearest to the outside source. This should be done regardless of street traffic flow volume, and the microphone should be as in c. above.

3. To provide additional detail of the spatial variation in level near the 24-hour measurement sites, select locations for 20 minute manual sound level measurements as may be indicated by the following guidelines. It should normally not be necessary to exceed a maximum of two 20-minute manual measurements per cluster. (Note: Certain models of automatic 24-hour measurement equipment will output data for 15 minute intervals, not 20 minute intervals. If this equipment is used, hand measurements should be reduced to 15 minutes to coincide with automatically measured intervals for direct comparison.

a. IF THE CLUSTER STREETS WERE CLASSIFIED INTO "HIGH" AND "LOW" TRAFFIC FLOW GROUPS PER "1b" ABOVE: then a manual measurement using the standard field procedure (one reading every 15 seconds) for 20 minutes should be made along the lowest volume street and block in the cluster than contains interview households. The measurement location should be selected according to "2c" above. The 20-minute measurement period should be synchronized with a corresponding 20-minute interval for data acquisition by the automatic (24-hour) monitoring system.

b. IF THE CLUSTER HAS SMALL ALLEY-TYPE STREETS CONTAINING INTERVIEW RESIDENCES: then a 20-minute manual measurement should be made at the midpoint of an alley street selected at random that contains interview streets. The site selected should not be a "T" intersection of two alleys.

c. IF A SIGNIFICANT NOISE SOURCE EXTERIOR TO THE CLUSTER WAS IDENTIFIED AS IN "2d" ABOVE: then a 20-minute manual measurement should be made on the bordering cluster street that is farthest away from the noise source and that contains interview residences. The measurement location should be as in "2c" above. If there are also high volume, low volume, and alley streets, then one additional 20-minute manual measurement (for a total of two such measurements) will be necessary. The second manual measurement should be made in an alley street as in "3b."

d. IF A CLUSTER CONTAINS BOTH HIGH AND LOW VOLUME STREETS AS DESCRIBED IN "1b" PLUS RESIDENTIAL ALLEY-TYPE STREETS: then two 20-minute manual measurements would be required (one in the low volume street, and one in the alley-type street) to complement the automatic 24-hour measurement.

e. IF ANY CLUSTER CONTAINS A SMALL INTRUSIVE NOISE SOURCE THAT IMPACTS AN AREA NEAR SEVERAL INTERVIEW RESIDENCES: then it will be desirable to perform a 20-minute manual measurement at a residence exposed to average levels from this source. Such a special measurement normally should be made only when practical; i.e., when less than two manual measurements are otherwise required by the cluster characteristics.

f. When manual measurements are made for any reason, check for local noise sources that vary with time that might affect the manual measurement noise levels. Such sources might be garages, industries, or local neighborhood activity such as schools, playgrounds, etc., that emit noise for only part of the 24-hour period. If it appears that an intermittent source might influence a manual measurement, repeat the measurement at a different time to obtain data during both emission and nonemission of the source. Determine as well as possible the times-of-day of regular source operation.

4. For each monitored cluster, prepare a sketch showing the following:

   - Indication of high volume and low volume streets.
   - Indication of alley streets.
   - Location and area of audibility of significant noise sources outside the cluster (as in "2d") and small noise sources within the cluster ("3f").
   - Times of operation of the noise sources shown.
   - All measurement locations.

A.3 24-Hour Data Utilization

A great deal of information can be obtained directly from 24-hour noise monitoring equipment without the necessity for many of the calculation procedures presented in Chapter 4 of the manual. Most equipment will readily output values for L_{dn}, various statistical metrics such as L_{10}, L_{50}, or L_{90}, and hourly equivalent noise levels for the site measured. These values may then be directly recorded in the field or obtained from data processing in the laboratory. When applied in one of the sampling schemes discussed in the previous section, average values of each of these metrics can be calculated for the noise zone or desired survey area by utilizing the appropriate procedures from Chapter 4. These average values can then be compared to the values obtained from the complete survey.

If the mean L_{dn} values for a noise zone obtained by the 24-hour measurement procedure differs from the value estimated from the 20-minute measurement by less than 3 dB, the two results can be considered complimentary and the true mean probably lies between the two values, but closer to the more accurate (24-hour) measurement. However, a difference of more than 3 to 5 dB can be taken to indicate a disparity which may result from significant noise patterns in time periods not sampled in the manual survey.

A way to test for this is to estimate a new L_{dn} value for each site based on the use of hourly equivalent levels from the 24-hour data which were obtained from the same time periods as the 20-minute manual measurements. Worksheets 4-1 and 4-2 from the manual can be used to calculate L_d, L_n, L_{dn}, and average L_{dn} according to the procedures given. Once this is done, two zone-average L_{dn} values will be available — one from manual measurements and one from automatic measurements — both based on the same time of day periods. If they match well, then the difference between the manually derived value and full 24-hour value is, indeed, very likely attributable to noise characteristics present during time periods not monitored by the manual survey. On the other hand, if these two time-matched estimates of L_{dn} do not agree, then the difference between the manual and full 24-hour L_{dn} values may not have a simple explanation. Review all details of each program that may have contributed to the differences, from field work to calculations. If 24-hour sites were chosen to coincide with a portion of the manual survey sites, consider calculating a new average L_{dn} based on manual data from only these sites to provide a direct comparison with the 24-hour based average. Do not overlook the possibility that the difference in results may be reflecting a true difference that existed in the noise level patterns due to weather or to seasonal effects, introduction of a new significant noise source (i.e., opening of a new highway), or some other influence. Resolution of the disparity may come from the discovery of several small contributing factors as well as from identification of a single important cause.

One feature provided by 24-hour measurements that does not result from the manual survey procedures is an accurate L_{dn} value for each site (representative, of course, only of the actual period measured). When plotted on a city map, preferably one on which noise zones are superimposed, these values will give a rough indication of noise level patterns across the survey area. Additionally, L_{dn} values for single sites can be related to survey results from overlapping social survey clusters with a precision much greater than possible with manual noise survey method results.

A.4 Cost Considerations

The costs incurred in the implementation of a survey program utilizing automatic 24-hour noise measurement equipment result from direct instrumentation costs, field labor time, and data reduction and analysis time. Only a minimal amount of effort should be necessary for planning since the effort will be based principally on the zones and siting already developed in the manual community noise survey. Automatic noise measurement instrumentation may be available on loan from the local U.S. Environmental Protection Agency regional office, or from the EPA Office of Noise Abatement and Control, Washington, D.C. If the permanent acquisition of equipment is of interest, a guide to approximate instrumentation costs can be found at the end of Appendix C.

The amount of field work required will vary with the program. For instance, if only one monitoring unit is in use, and pre-identified measurement locations are to be used, then field work will consist of one or two hours of movement and set-up per site-day. On the other hand, the monitoring of social survey clusters requires a time-consuming site selection process including observation of the cluster, identification of a suitable site where location of the equipment will be permitted, and possible performance of manual measurements in the cluster as well. This procedure can require up to 4 hours per site. The simultaneous use of more than one measurement unit will proportionately increase the required number of man-hours per day, but should likewise reduce the total duration of the measurement program.

The effort required for data reduction will be minimal for units that directly read out the desired metric values. In these cases, the calculation of simple arithmetic averages for the noise zone may be all that is required. Other types of units may require post-measurement data reduction, employing methods ranging from hand calculation to mini-computers to obtain all of the desired metrics. Man-hour requirements for reduction of data from these units will need to be estimated based on the specific necessary tasks. The time required for manual calculations, either in support of 24-hour instrument data or for reduction of supplementary hand measurements made in a cluster, can be estimated based on experience with data reduction for the manual survey. Finally, the amount of time expended for actual analysis or consideration of the 24-hour information will vary with the application. For example, the effort to evaluate the meaning of an accurately measured noise level for a single important noise zone will differ from that necessary to evaluate a large discrepancy between L_{dn} values measured according to the manual and 24-hour methods. Analysis cost, then, will need to be estimated based on the specific work to be done, as the final cost element of a 24-hour monitoring program.

APPENDIX B

PROCEDURES FOR NOISE MEASUREMENTS OF INDIVIDUAL NOISE SOURCES

B.1 Introduction

Occasionally it is desirable to establish the contribution to environmental noise made by one or two specific individual noise sources, without expending the cost and effort required for a comprehensive municipal noise survey as described in the main text of this manual. For example, the city may feel it is already aware of its few principal noise sources, and would simply like to quantify their contributions and estimate the effects of various levels of regulation. Certain aspects of the EPA Quiet Communities Program noise reduction strategy also require an assessment of the effect of various regulatory levels on specific noise sources. To accommodate these needs, this appendix has been provided as a guide to limited surveys of individual sources.

The types of sources addressed here include distributed isolated small units, such as automobiles or air conditioners, as well as larger stationary sources such as power plants, construction sites, or shopping centers that have a defined geographical boundary and can be identified as impacting the surrounding community with a characteristic noise environment. Discussions will deal primarily with sources which the local government is able to regulate;[1,2] i.e., construction sites, power tools, etc. An airport is a "source" over which a local government has very limited control except through control of airport operation, if it is the proprietor.[3]

B.2 Noise Event Types

Individual noise sources, whether consisting of many distributed small sources, or a single large stationary source, will normally produce three basic types of sound patterns. These three patterns, or noise events, are introduced below.

Single Noise Event

This type of noise event occurs over a short duration beginning with a steadily increasing noise level until the maximum level is reached and followed by a decrease in noise back to the background ambient level. An example would be the roadside sound level variation as a truck passes by. It is not important whether the source is moving or stationary, but only that the noise level rises and drops over a short time period – usually less than 1 or 2 minutes. Very short duration events like gunfire or impacts from a drop forge require special measurement equipment and receiver annoyance criteria to properly assess the noise environment.[4,5] These events usually last less than 1 second and are categorized as impulsive noises. Measurement and evaluation of impulsive noises will not be considered in this appendix.

Multiple Noise Event

The noise from a combination of similar or different sources operating within a defined boundary characterize this type of source. Noise from an auto repair shop is an example of multiple single events from different sources, such as air hammers, metal saws, and sanding equipment. This combination of single events constitutes the multiple event noise from an auto repair shop.

Figure B-1 illustrates a typical example of the complex pattern of multiple noises from a maintenance garage for buses.

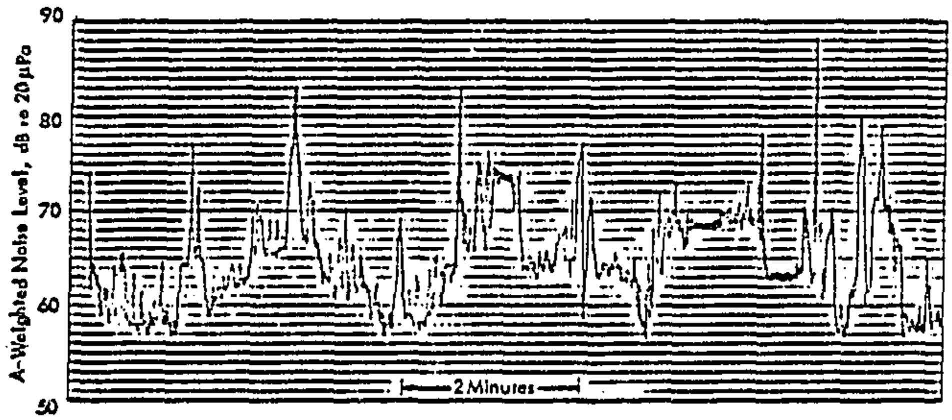

Figure B-1. Time History of a Typical "Multiple Event" Category of Noise Source – Measured at a Maintenance Garage for Transit Buses

Continuous Noise Level Event

A continuous noise level event neither increases nor decreases significantly over time. Relevant sources of continuous noise typically do not emit exceptionally high noise levels but generally control the background level for many local areas within a community. For example, a power plant may produce the predominant noise level over a community. However, an exterior household air conditioner may override the power plant noise within the property boundaries of one or more neighbors. Both of these sources, while operating, emit a steady noise level which constitutes part of the background community noise level but are identifiable single noise sources to a nearby resident.

Considerations in Categorizing Noise Events

Nearly all noise sources can be placed in more than one event category depending on the operation of the source and the desired interpretation of the noise data. For example, the single passby of a train generally falls in the single noise event category. This same train might travel further down the line and through a train yard located in some community. Noise emissions from this yard are collectively monitored as a multiple noise event and the passby is only a portion of the total noise environment. In addition, the locomotive could be left parked on a siding near a residential area with a diesel engine idling for several hours — it then becomes a continuous noise event.

Interrelationships between these three categories of noise sources, along with typical examples and the goal for monitoring the source are illustrated in Table B-1. The noise event category of a source is an important consideration in the monitoring of individual noise sources, and should be identified as a preliminary step in establishing a source noise monitoring program.

Table B-1

Typical Examples of Noise Source Types and Reasons for Monitoring

Noise Event Category	Specific Noise Source(s)	Reasons for Monitoring: Establish Long-Term Trends of Noise Impact	Conduct Short-Term Noise Impact Corrective Action	Noise Standard Enforcement
Single Noise Event	Single Aircraft Operation	X		X
	Single Motor Vehicle Operation	X		X
	Single Train Passby	X		X
	Single Operation at a Construction Site		X	X
	Garbage Compactor Operation		X	X
	Steam Valve		X	X
Multiple Noise Events	Aircraft Fleet Operation at an Airport	X		
	All Vehicles on a Road Section	X		
	Railroad Operations Throughout a Yard	X	X	X
	All Operations at a Construction Site		X	X
	Miscellaneous Noise from a Shopping Center	X		
Continuous Noise Level Events	Power Plant Generator	X	X	X
	Transformer Hum	X	X	X
	Air Conditioning Unit		X	X

B.3 Noise Measurement Procedures

For conducting a survey of an individual noise source or sources, one of two types of measurement procedures must be employed. These are either measurements according to standardized procedures made under repeatable specified conditions, or measurements to determine typical noise levels created during normal service in the community. The type of procedure followed will depend on the survey objectives. For example, if it is desired to compare the noise levels of motorcycles in the city with a proposed regulation that specifies an exact noise measurement procedure, such as a maximum acceleration passby procedure, then a sample of motorcycles in the city should be measured according to this procedure. On the other hand, if an assessment of noise levels typically caused by motorcycles in the community is desired, a sample of measurements should be made of the vehicles in their usual operating modes at various community locations. This section discusses each type of measurement as applied to noise sources that are either large and stationary or smaller but distributed at many locations throughout the community.

Large Stationary Noise Sources

These sources, such as railroad stations, power plants, shopping centers, etc., are usually of the multiple noise or continuous noise level type. The comparison of noise emitted by these sources with regulations, ordinances, or recommended practices will require noise measurements performed according to standard procedures at standard distances, times, and operating modes. These are normally specified in the ordinance or regulation, or can be taken from lists of standard adopted practices.[6] One common noise ordinance format, for example, specifies A-weighted noise levels not to be exceeded for various proportions of time at the source property line, and may indicate the number of locations and type of measurement equipment to be used. Certain of these methods are most easily followed using equipment more sophisticated than the sound level meter (such as the distribution analyzer; see Appendix C), but in general the application of methods and equipment is straightforward and thoroughly described.

If it is desired to make an assessment of the influence of a large stationary source on its surrounding area, one of two more general approaches can be taken. In order to establish the influence of the source in the community, the stationary noise source techniques described in the manual text may be applied. This involves establishing the zone of influence (noise zone - Section 3.2.2, Step 9, selecting measurement locations (Section 3.3,) and performing measurements and data reduction (Sections 3.4 and 4.1). Alternatively, a boundary or property line assessment can be made using the following technique. The boundary of a multiple event source could be a property line, a zoning boundary, or any other boundary between the multiple event source and incompatible land. To define this noise environment, measurements are made at appropriate intervals along the boundary — either surrounding the entire source, or separating the source from incompatible land. Measurements should be made to coincide with basic operating schedules of the source, with 20-minute samples taken at least once during the day and night at each measurement location as described in Section 3.4 of the manual text. Sampling for more than one day may also be required according to the source operating schedule. For long-term or before-and-after noise sampling at major construction sites which require detailed environmental analyses, care should be taken to maintain the same measurement positions and to ensure that an adequate number of samples are obtained to minimize the influence of random weather effects.

Although a precise standardization of boundary line noise surveys is considered impractical, due to the wide variety of situations likely to be encountered, the following are recommended guidelines for selecting noise monitoring sites at industrial locations.

1. Armed with a map or prior knowledge of the site, conduct an initial survey with a sound level meter, making short 1- to 2-minute readings every 30 paces (~ 25 m) along the periphery bordering on incompatible land. Note the central tendency of minimum (~ L_{90}) and maximum levels (~ L_{eq}) with the meter on "slow" response. When there is no bordering incompatible land, measure along that portion of the property line which is closest to nearby incompatible land.

2. Repeat these preliminary measurements at selected stations along this perimeter where necessary to cover large changes in temporal patterns.

3. Construct a plot of the minimum and/or maximum sound levels versus position along the perimeter based on these initial pilot survey results.

4. Select sites for more detailed measurements so as to define the noise variation along the perimeter at distance intervals covering noise level variations of no more than 5 dB and using at least 8 but no more than 32 equally spaced intervals.

In residential locations, as extensive a procedure may not be required. For example, assume there is a local air conditioner in a neighborhood which has caused complaints by residents. It could be evaluated under standard conditions to determine if the manufacturer was meeting industry standards when the unit was built and sold. However, to determine the impact on the community noise environment, property boundary measurements could be conducted according to measurement techniques of a local noise ordinance. In the absence of a local ordinance measurement procedure, one or more residential boundary positions closest to the source should be monitored.

Distributed Noise Sources

Sources of noise that are distributed throughout the community, such as heavy trucks or lawn mowers, must be dealt with in a slightly different manner. As before, measurement procedures must be selected or established, but then they must be applied to a sample of many individual sources of the type being investigated in the community. Most distributed noise sources will be of the single event type, causing a single rise and fall in sound level such as a vehicle passby. Existing standards and regulations specify procedures for performing repeatable staged measurements of single event noise from automobiles, trucks, and other sources.[6,7,8] These can be used to determine the distribution of standard sound levels of a source type within the city. However, in order to determine typical sound levels of the sources as received from normal operation in the city, measurements at several locations around the area of a sample of typically in-service sources must be made. In most cases with single event type sources, the maximum A-weighted sound level of each event, as noted with the "fast" sound level meter movement, is the quantity measured. For continuous or multiple noise level events, longer period measurements of L_{eq} should be made as discussed in Sections 3.4 and 4.2 of the manual text.

B.4 Sampling Procedures for Distributed Sources

When collecting a baseline data base for a distributed noise source, there are two potential sources of error. One is associated with equipment tolerances and field measurement technique, and the second with variations in the noise level emission from source to source. Both types of inaccuracies must be considered in any source noise survey. The latter is particularly important in specifying levels for a source noise regulation. The following paragraphs focus on specifying the sample requirements to minimize discrepancies between noise levels of the same type source. Equipment and measurement errors are covered in Appendices C and D. Appendix D also presents background for the sampling method presented here.

Defensible noise limits for specific sources require the type of basic data sample such as illustrated in Figure B-2. The data shown in this figure were obtained at an early stage in California's motor vehicle noise regulation program.[10] If noise regulations were to be established on the basis of this large sample, the expected rate of violations would be approximately as follows:

Noise Limit	Rate of Violations, %
85	0
82	0.044
80	0.15
78	0.35
75	1.16
72	5.16
70	16.16.

One point should be emphaised when considering the evaluation of large samples of noise data. It is clear from Figure B-2, for example, that the histogram of maximum levels is very nearly like a normal (bell-shaped) curve. This provides some guidance in

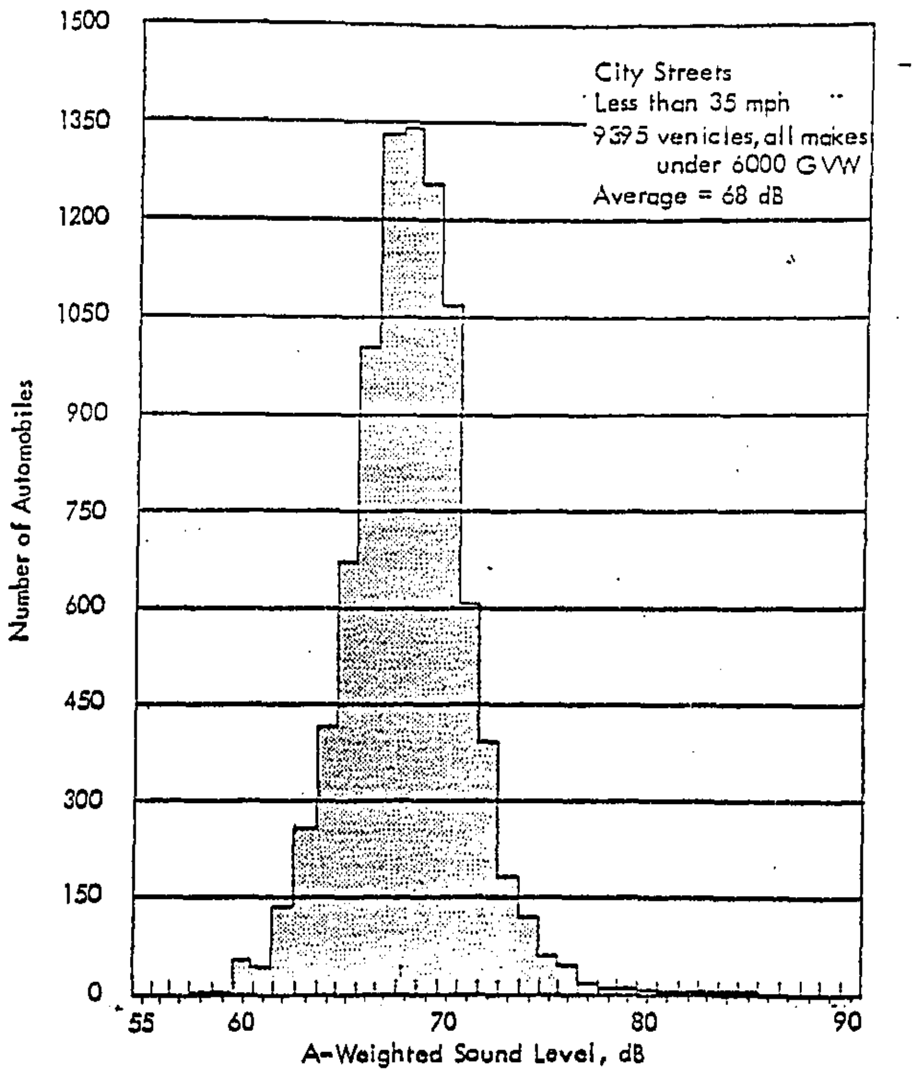

Figure B-2. Distribution of Maximum A-Weighted Noise Levels at 50 feet from Center of Automobile Path (Adopted from Reference 10) establishing the required sample design for subsequent surveys of similar sources. However, there is a definite very small "tail" on the upper end of the distribution which can be attributed to the few exceptionally noisy vehicles which would not be predicted if one assumed a perfectly normal distribution. Thus, an important aspect of evaluating source noise surveys for establishing noise limits, is to consider the actual shape of the upper end of the distribution curve of noise limits, over sources, in order to accurately define the anticipated violation rate. The latter is important for the purposes of administrative planning in any source noise enforcement program.

We are concerned with defining an adequate number of individual measurements required to accurately represent the noise generated by a particular type of source. In this case, the total number of such sources in existence is the "total population" and the number of individual single event sources actually measured is referred to as the "sample population." The histogram or "frequency distribution" of levels will now be over sources instead of over time or space. If the characteristics of the distribution are symmetrical above and below the median noise level of the sample, then we can assume that the sources have an approximately normal distribution of characteristic noise levels. We will find that, in general, this is approximately true.

The key parameter which defines sample size is the accuracy of the sample. The percent accuracy of the sample (Δ %) defines the precision with which the actual total population can be accurately represented by the sample. In other words, if a certain percentage of the sample (say, 5 percent) exceeds some noise level, then Δ % specifies the tolerance bands which this percent of the total population must fall within. For example, say a noise level of 82 dB was exceeded by 5 percent of the measurements in the sample population. If the sample was chosen so that Δ was 3 percent, then between 2 and 8 percent (5 ± 3) of the total population would be expected to exceed 82 dB. This concept is important for understanding the validity of a data base needed to establish a statistical record of source levels and for development of a noise regulation. If the example just mentioned pertained to motor vehicles, then the data sample measured would imply 2 to 8 percent of all vehicles have noise levels that exceed 82 dB.

The following procedure enables prediction of the required size of a sample to achieve a specified value of $\Delta\%$. For simplicity it is necessary to assume that both the sample and total population frequency distributions are approximately normally distributed. Also, we desire a 95 percent probability that the sample accurately represents the total population. In addition to choosing an acceptable value of $\Delta\%$, the particular statistical noise level of interest must be defined. This statistical level is called L^x and is designated by observing the noise level exceeded by "x" percent of the data samples.* L^5 = 82 dB would imply 5 percent of the measured samples exceeded 82 dB. Generally, L^5 and L^{50} are the most useful levels for source analysis, the former often being applied as the maximum noise level for a source type noise regulation, whereas L^{50} is simply the median level.

Assume a city wishes to pass a noise ordinance for lawn mowers in terms of noise measurements made at 15m (50 ft). To be feasible, such a law requires development of a data base for the existing noise levels. L^5 will be used, assuming the plan is to limit the levels of the noisiest 5 percent of the mowers. Assume it is desired that the L^5 calculated from the data sample should represent the entire population of lawn mowers with a sample accuracy of $\Delta\% = \pm 3$ percent. In other words, the L^5 measured should actually be the noise level that is exceeded by 2 to 8 percent of the total population of lawn mowers. Now, from Figure B-3, for $\Delta\% = 3$ percent on the horizontal scale, read the

*A superscript^x is used for the term L^x to distinguish x percent of number of sources from x percent of time for which a subscript is used in the term L_x.

corresponding value of n, the required sample size on the vertical scale using the L^5 curve. According to the latter, the minimum number of lawn mowers that can be measured under the criteria set forth is 203. For conservatism, it is recommended that 25 to 50 percent more than the ideal minimum number calculated from Figure B-3 be measured. Thus, 250 to 300 lawn mowers need to be measured and from this sample, the noise level exceeded by 5 percent of the sample (15 for a sample size of 300) would become the regulatory limit for L^5.

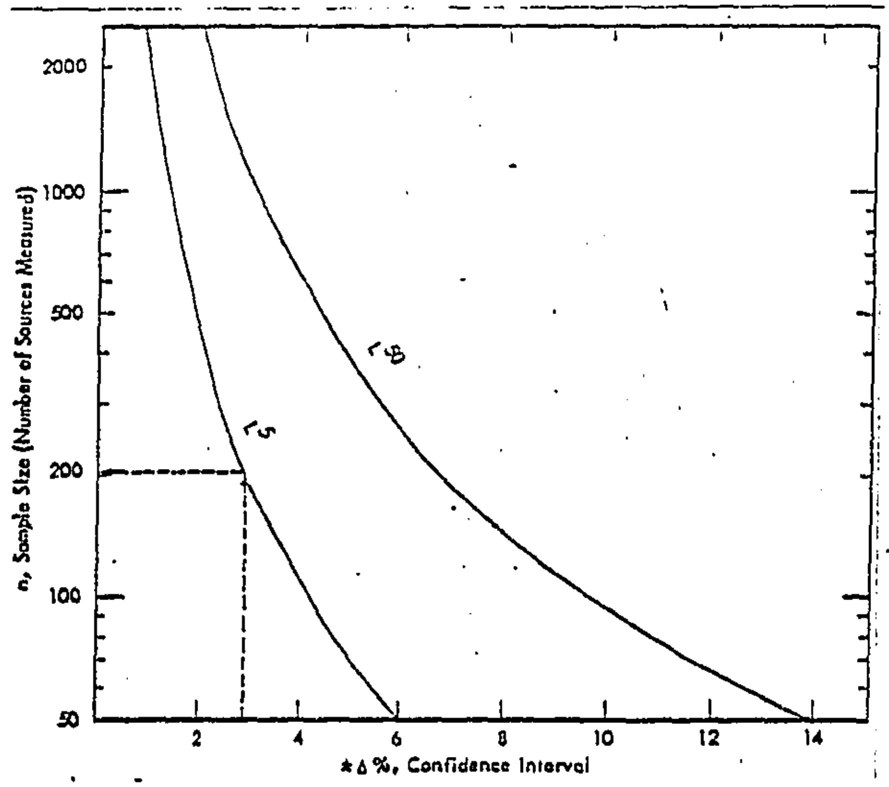

Figure B-3. Number of Samples Required to Achieve with 95 Percent Confidence a Specified Percent Accuracy for 5 Percent (L^5) and 50 Percent (L^{50}) Exceedence Noise Limits for a Population of Single Event Sources

It is important to point out that by specifying the sample accuracy criteria, or confidence limits, in terms of the absolute percentage (Δ) of the total population, the sample size decreases as the limiting percentage x in L^x decreases. Just the opposite trend in sample size occurs if the accuracy criteria is expressed in relative terms as the tolerance interval (Δ) divided by the limiting percentage x. In this case, as this limiting percentage decreases, the required sample size increases to maintain the same relative accuracy. For example, using the previous example where $\Delta = \pm 3$ % and x = 5%, the relative error would be (60%) = 100 · 3/5 for the ideal sample size of 203. Increasing the sample size by 4 would decrease the relative error by a factor of 2. This topic is considered in more detail in Appendix D.

Selection of the individual mowers to be measured must be on a random basis from the population. This implies that each member of the total population has an equal chance of being selected for the sample. Simply observing a convenient selection of lawn mowers that operate near the home base of the measurement team might bias the data because of unpredictable neighborhood differences or availability of one particular type of mower in that section of the city. Thus, a sampling plan must be instituted which first identifies the potential lawnmower population and then randomly selects the specific mowers to be observed in the sample. The more detailed discussion on random sampling of sites in Appendix D may be used in this case for guidance on random selection of single sources.

B.5 Influence of Other Sources on Noise Measurements

Noise from other sources can introduce an error into the measurement of a source under study. The magnitude of the error introduced will depend upon both the temporal and spatial separation of conflicting sources — the greater the separation, the lower the error.

Achieving Temporal Separation

While a great variety of conflicting temporal patterns can occur when attempting to isolate the time signature of one single event source in a stream of multiple events, one simple procedure may be used which is easily implemented with a sound level meter. The concept is illustrated in Figure B-4.

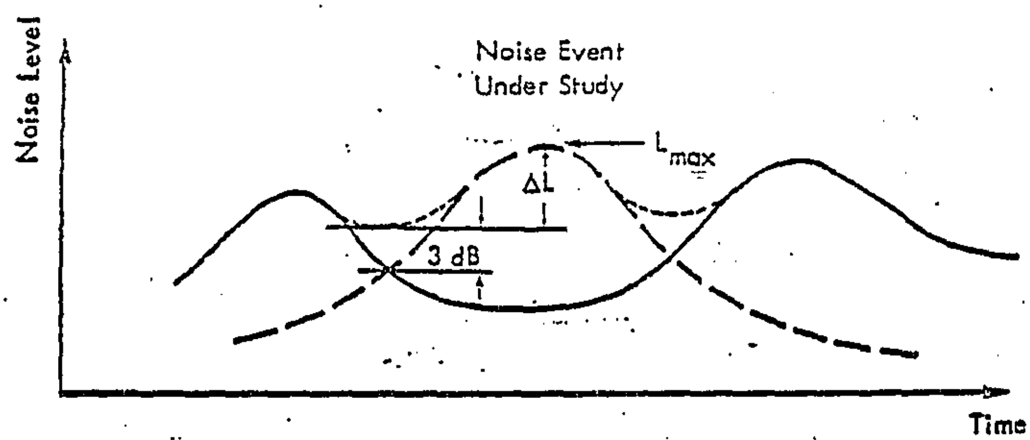

Figure B-4. Resultant Noise Level from a Series of Nearly Simultaneous Noise Events. (No Significant Interference to Noise Event Under Study if $\Delta L \geq 6$ dB.)

The time history signature to be measured is in the middle of two adjacent peaks due to other sources. Assuming that the latter do not generate a third "hidden" peak of noise during the time of occurrence of the one of interest, then a simple criterion for essentially negligible effect of these adjacent peaks is that before or after the noise peak of interest (L_{max}), the sound level should be at least 6 dB lower (ΔL in Figure B-4 $\geq$ 6 dB.)

Thus, by simply watching the sound level meter needle (in this case, set on "fast" response for single events as discussed in Section B-3) and ensuring that a noise event of interest rises or falls by at least 6 dB before or after its maximum, the combined single event and other noises will normally be separated by at least 9 dB and hence the noise event under study will not be in error by more than 0.5 dB. This procedure is primarily intended for monitoring of single vehicles in a moving stream of traffic; however, it can be employed as an approximate method for multiple event sources as well.

Combined Spatial and Temporal Separation from Other Sources

The extraneous background noises from nearby sources must be minimized to avoid influencing the source under investigation. The simplest approach is to move the source to a location completely isolated from other sounds. Such an approach is not feasible for most sources. Therefore, an overall analysis of the background noise is warranted.

Many times the situation can be handled by observation. This can entail no more than making a site visit and using judgment to determine whether or not the source of interest "seems" several magnitudes louder than the background. If not, acoustical measurement equipment needs to be used. Normally a sound level meter is adequate using, where applicable, the preceding technique to evaluate both the effective temporal and spatial separation when both source and background are essentially constant in level. The minimum allowable difference between the source and background levels is 9 dB. A lesser difference will produce inaccuracies of 0.5 dB or greater in the levels measured.

Special consideration should be given to multiple noise event siutations. Whereas comparing L_{max} with background levels is normally a straightforward task, as outlined above, analysis of extraneous background influences becomes more critical for average noise level measurements integrated over a longer time period. For instance, a section of highway adjacent to a construction site might prohibit either source from being measured due to similar noise levels from each source. A 9 or 10 dB difference between maximum levels emitted by the highway and construction site is not an adequate criterion in this situation when measuring average noise levels. A better criterion would be to compare the maximum level of the extraneous source(s) with a level that is typical of the lowest levels emitted by the source of interest. A 9 or 10 dB separation between these two would tend to ensure negligible influence on the measured average noise levels of the source under study.

Finally, presence of nearby reflecting surfaces which are not typical for the site can be considered as representing one form of interfering "pseudo-source" – the reflected noise can interfere with the desired direct sound. For measurement of highway vehicles, it can be stated that reflecting obstacles smaller than 2.4m long by 0.6m high (8 ft long by 2 ft high) in the immdeiate vicinity of the monitoring site do not produce any significant error in the measurement of A-weighted noise levels from highway vehicles. Neither, it appears, do bushes or even fairly dense hedges, unless they are situated between the vehicle and the microphone. Under these conditions, a reduction in the measured noise level is possible.[9]

REFERENCES FOR APPENDIX B

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APPENDIX C

NOISE MEASUREMENT INSTRUMENTATION BACKGROUND

This appendix provides (1) continuation of the introduction to community noise given in Section 1.3 of the manual text, (2) background information on measurement system specifications, and (3) a discussion of the function and use of specific items of equipment that can be utilized in the measurement and analysis of community noise data. Before using this appendix, be sure to read and become thoroughly familiar with the material presented in Section 1.3 of the manual introduction.

C.1 Measurement Terminology and Metrics

The term "metric" may be used to designate a specific scale for measuring properties of noise. Many metrics have been developed to identify various acoustic phenomena related to such things as noise source characteristics, the human perception of noise, and impact of a noise environment on people and communities. Several metrics, such as A-weighted sound level, equivalent sound level, and day-night sound level were introduced in Chapter 1 of the main text. This section continues with a few additional metrics which can be easily measured or calculated and which can provide a meaningful description of the noise environment for most communities.[1]

Sound Exposure Level

This term defines the noise signature of a single source as its noise level increases and is noted by an observer. Moving transportation sources - aircraft, cars, trains, etc. - typify this type of noise signature. Thus, the sound exposure level constitutes a measure of the time-integrated noise levels for the single event, which means it is a measure of the energy present in each event. For purposes of standardizing measurement procedures, this energy is normalized to a time scale of 1 second. The basic reason for measuring the sound exposure level is that it allows an incorporation of both the maximum value and the time duration of the single event. Experimental data indicate that the subjective reaction to intruding single event noises is dependent on both these parameters. Figure C-1 illustrates the time history of a single event and shows how the sound exposure level is computed to represent, essentially, the area under the curve of sound intensity versus time.

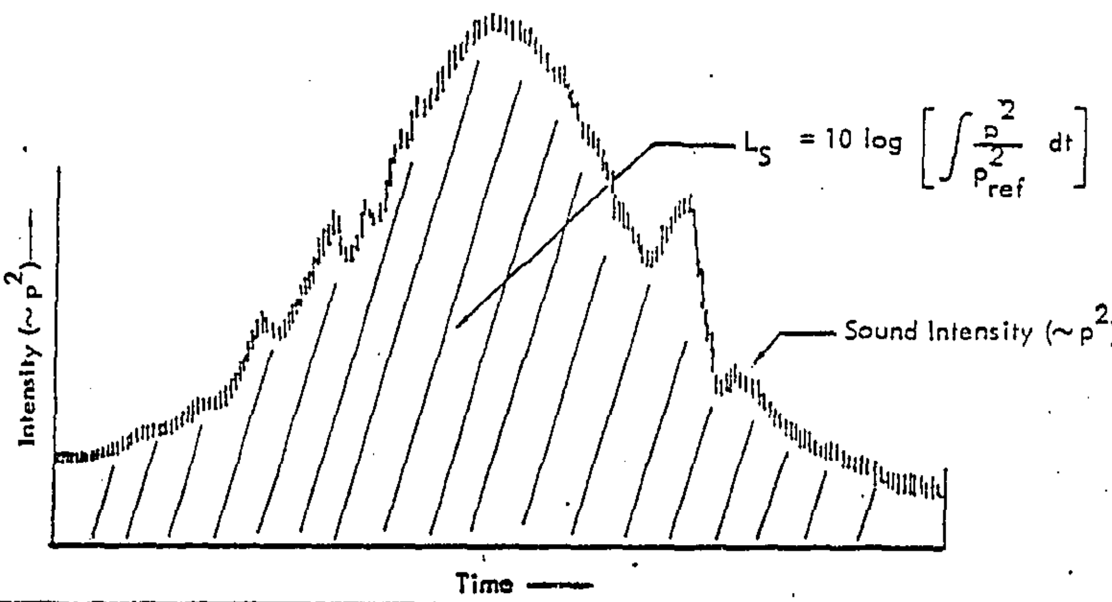

Figure C-1. Time History of a Single Event - Conceptual Illustration of Sound Exposure Level, L_S, has Logarithmic Measure of Sound Energy of a Single Noise Event Corresponding to Area Under Plot of Source Intensity Versus Time

Statistical Sound Levels (L_{10}...L_{90}...L_{50}, indicated by L_x where $x = 0$ to 100 percent)

Since the noise levels in a community vary considerably with time, a metric is needed which expresses both a magnitude and time relationship. Recognizing that over an extended period, the time variation in environmental noise occurs in a more or less random manner, an appropriate noise metric has been defined in statistical terms. The symbols L_{10}, L_{50}, and L_{90} represent, for example, the noise levels which are exceeded 10, 50, or 90 percent of the time during the noise measurement period. Each of these statistical noise metrics is suited for the measurement and definition of a particular characteristic of a community noise environment. For example, since the L_{10} noise level is exceeded 10 percent of the time, it is a commonly used indicator of the level of intrusive noises within a community. For this reason, it has been used by the Federal Highway Administration for the assessment of noise generated by vehicular traffic. The median noise level, or L_{50} itself, is a useful measure of average noise conditions in the sense that one-half of the time it is quieter and one-half of the time it is noisier than L_{50}. It is also a fairly simple noise metric to measure directly with a sound level meter. Since the L_{90} level describes the noise level exceeded for 90 percent of the time, it is an approximate indication of the more or less steady background or ambient noise level in a community.

Hourly Noise Metrics

Figure C-2 presents the hourly values for several of these noise metrics defining the noise environment at a suburban single-family residence in Simi, California.[1] The environment at this residence is characterized by noise from a nearby highway, railroad line, general neighborhood activity, and an occasional small aircraft overflight. The noise environment includes major intruding noise levels from railroad operations, while the background ambient level is established primarily from the noise generated by the heavy traffic volume on the nearby limited access highway.

The noise levels at this location range from 90 dB during the day to the background ambient noise levels, which drop to 30 dB in the morning hours. The hourly equivalent sound levels

(L_{eq}) may be combined on an energy basis to produce a 24-hour L_{eq} of 58.9 dB. Adjusting this value for the 10 dB penalty between 10:00 a.m. and 7:00 p.m. results in an L_{dn} of 65.5 dB.

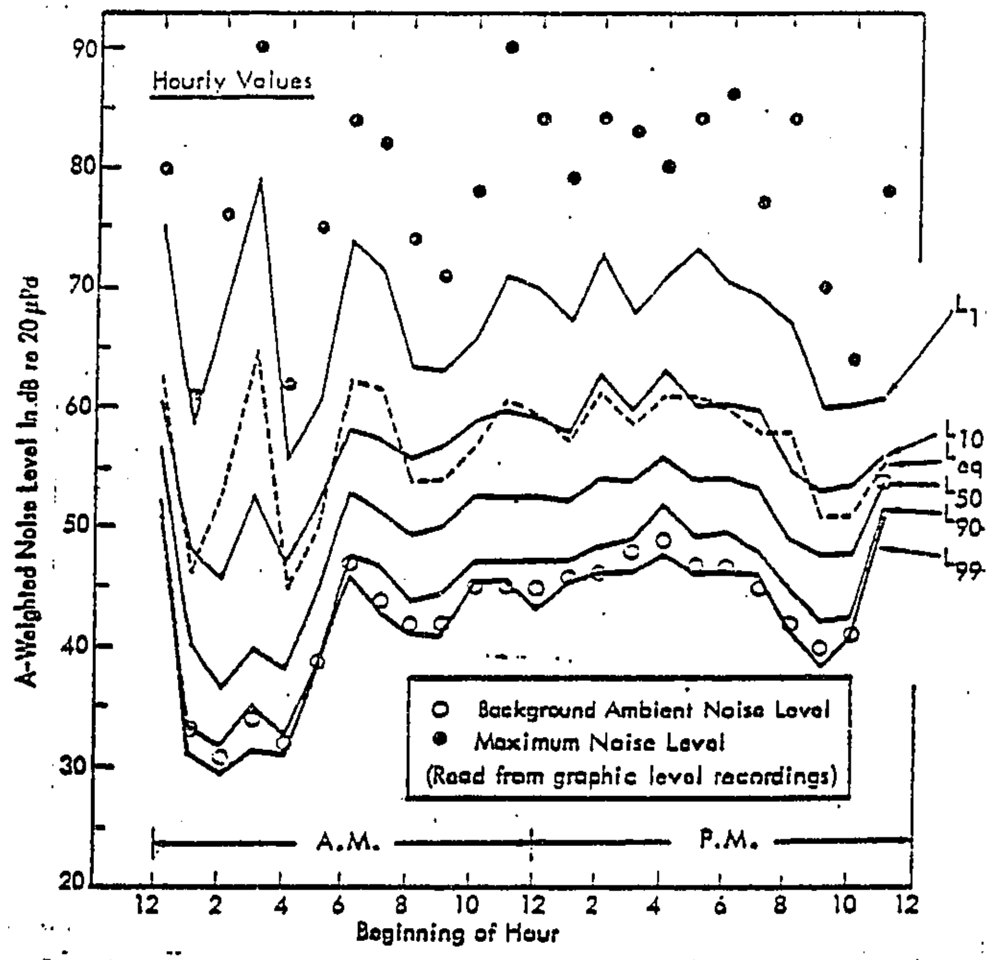

Figure C-2. Illustration of Various Metrics for Defining the Outdoor Noise Environment in Simi, California[1]

Octave/One-Third Octave Band Level

This metric is used to express information about the frequency content of a noise signal. The frequency content of the noise is determined by dividing the original noise signal, by electronic means, into a series of bands each covering specified frequency ranges. The most common frequency intervals or bands used in community noise evaluation are referred to as octave bands, each octave band covering a successive 2-to-1 range of frequency. This analysis yields a series of levels, one for each band, called "octave band sound pressure levels." The preferred series of octave bands for acoustic measurements cover the audible range of frequencies with 8 bands having center frequencies of 63 Hz to 8000 Hz, where each band-center frequency differs from its neighbor by a factor of 2 (i.e., 63, 125, 250, etc.). For a more detailed analysis of the distribution of sound energy as a function of frequency, one-third octave bands are often used — a frequency division which splits each individual octave band into three consecutive frequency bands. For the latter, the preferred one-third octave band frequencies normally extend from a center frequency of 50 Hz to 10,000 Hz, where each band center frequency differs from its neighbor by approximately the cube root of 2 (i.e., 50, 63, 80, 100, etc.). Figure C-3 illustrates an octave band and a one-third octave band spectrum of a typical outdoor noise event.

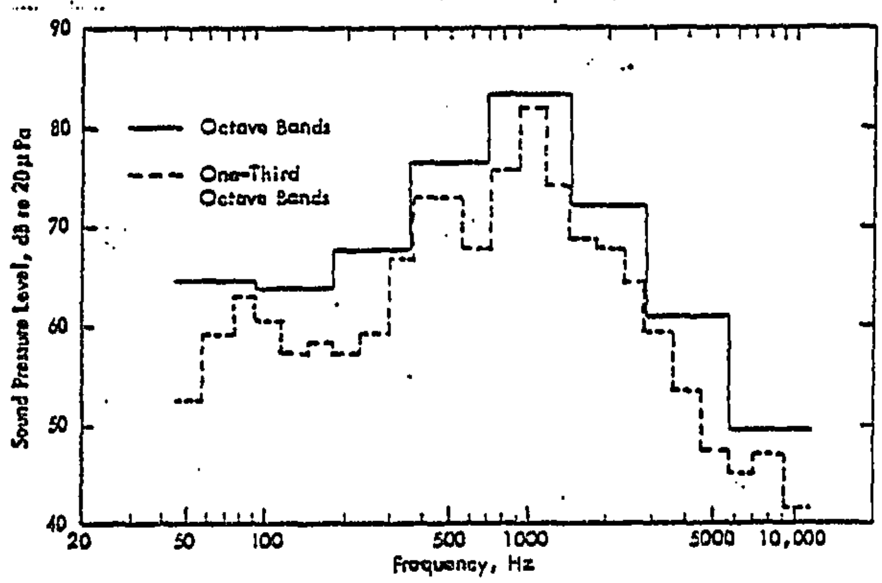

Figure C-3. Comparison of the Octave and One-Third Octave Band Spectrum of an Automobile Horn

C.2 Sound Fields and Sound Propagation

Point Source

The simplest form of sound source is a sphere that rapidly expands and contracts over its entire surface. One can think of this source as an air-filled spherical balloon. Now periodically pump air into and then out of this balloon. The surface of the balloon then expands and contracts, uniformly, at the rate at which air is pumped in and out.

If this rate of spherical expansion and contraction occurs at a rate within the frequency range of sound, this source will radiate sound equally in all directions from an apparent "acoustic center," which is actually the center of the balloon. It acts like a "point" source, insofar as sound radiation is concerned. This simple "point-source" model predicts the ideal decay in sound intensity as one moves far away from most single sound sources. This decay in sound level, called spreading loss, occurs due to the ever greater and greater area covered by the spherically spreading sound waves as they move away from the "point source." This spherical spreading loss amounts to a decrease in sound level of 6 decibels for every doubling of the distance from a source. Thus, if the sound level is 66 dB at 15 m (50 ft) from, say, a stationary car idling its engine, as illustrated in Figure C-4, the spherical spreading loss causes the automobile noise to decrease to 60 dB as one moves to a distance of 30 m (100 ft).

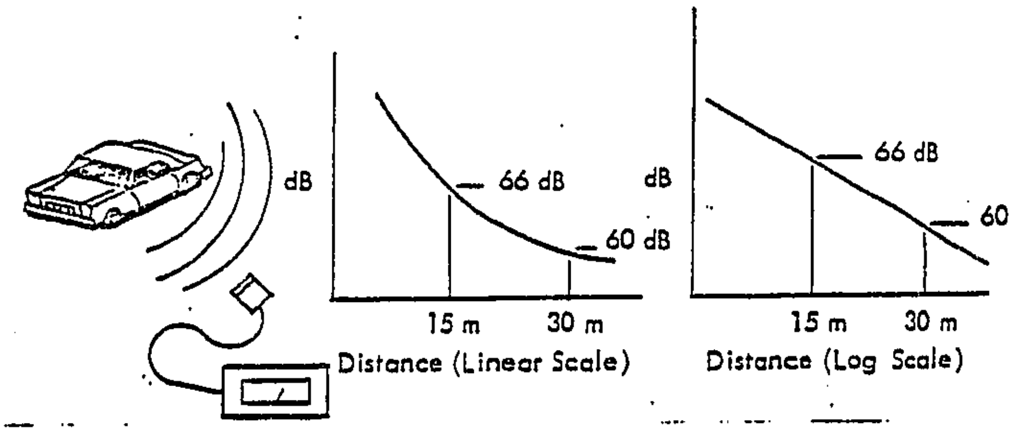

Figure C-4. Spherical Spreading Loss from a Point Source

Line Source

If a continuous string of pulsating balloons were all lined up in a row — so that the noise source now acted like a very long pulsating rubber pipe, the source begins to take on the character of a "line source" for which the sound level decays, in cylindrically spreading waves, by 3 dB for every doubling of distance from the source. This is the simple model for sound decay for, say, a long line of cars moving along fairly close together so as to act like a "line source," as illustrated in Figure C-5. The decay in level for a point source is shown for comparison.

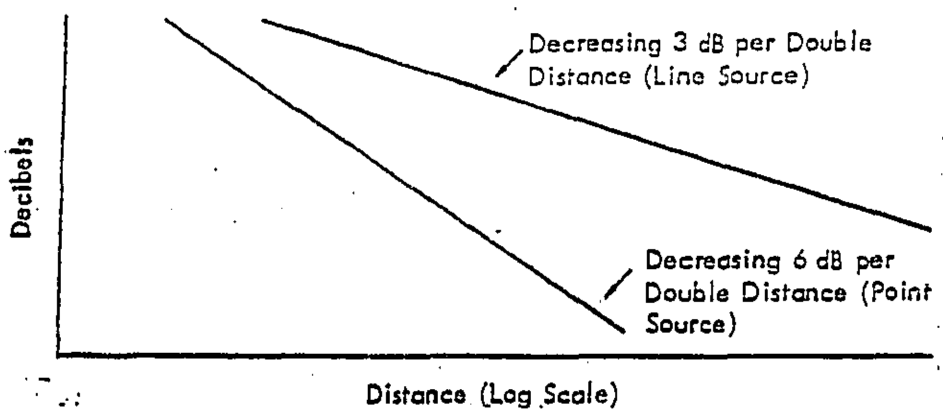

Figure C-5. Spreading Loss from a Line and Point Source

Directional Source

In actual practice, noise sources are not as simple as point or line sources. The sound is not radiated uniformly in all directions, either because the shape of the sound source is not spherical, or because the amplitude and timing of the vibrations of the different parts are not uniform, or both. The net result is that more sound is radiated in some directions than in others. In other words, as illustrated in Figure C-6, the sound level for a given distance is different in different directions.

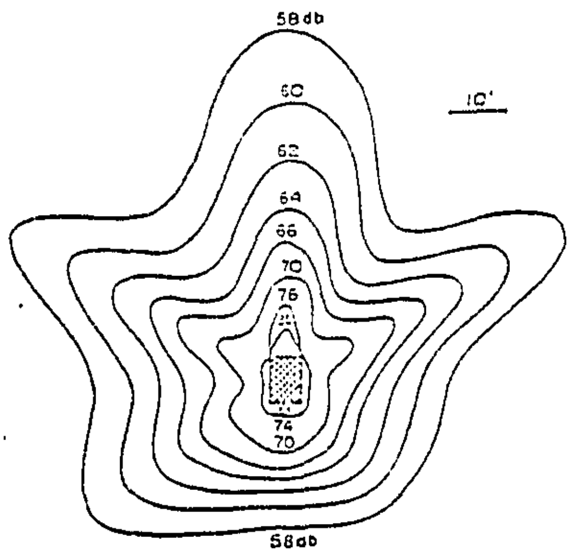

Figure C-6. Simplified Contours of Equal Sound Level Around a Large Power-Distribution Transformer

When such a directional sound source is far from any other objects, however, it behaves in some ways like a point source. For example, the sound level decreases 6 dB for each doubling of distance, provided we start our measurements at a distance away from the source that is at least as large as the largest dimension of the source, and provided we move along a straight line directly away from the source. In actual practice, this idealized behavior is upset by the effects of the local terrain, atmospheric conditions, and the interference of nearby objects.

Free Field and Reverberant Sound Field

There are several factors which will interfere or alter these patterns of sound decay from point or line sources. Reflecting surfaces such as building walls, will cause the sound to bounce back and forth so that the sound waves do not spread out as they do in a so-called free field (where there are no obstructions). Such sound fields, containing many reflections of the sound from a source, may become reverberant, like the sound inside a room with hard walls. Then, the sound energy decays near the source like in a free field, due to the spreading loss, but finally reaches a level at a distance from the source where the continuing reflections of the "reverberant field" cause the level to decrease much more gradually. Such a situation, which can occur in semi-enclosed areas, is illustrated in Figure C-7.

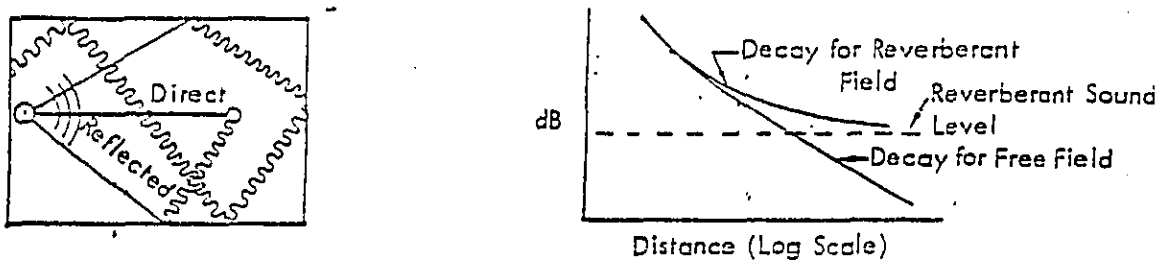

Figure C-7. Illustration of a Reverberant Sound Field Bounded by Reflecting Walls and the Resultant Change in Rate of Decay of Sound Level with Distance from a Point Source

There is a rather important parallel between the reverberant sound field inside a room and the sound levels one measures outdoors. Inside a hard-walled room, as one moves away from a specific source, the sound level decays to a plateau, called the reverberant level, due to the influence of the many reflections from the single source off the walls of the room. Outdoors, as one moves away from a single source, the level of this source decays like in a free field, but the total noise level observed again tends to level off to the so-called background ambient noise level which is due to the contributions from the many other outdoor sources that we hear.

Refraction of Sound

Outdoors, where the temperature is not uniform with height above the ground or when the wind speed varies with height above the ground, then sound waves do not spread out uniformly in radial directions from point or line sources. Instead, as the rays of sound travel they are bent by this nonuniform atmosphere to cause what can be very large changes in level between a fixed source and observer — changes in level which vary with the local weather and hence with time. Figure C-8 illustrates how this atmospheric refraction effect can result in acoustic "shadow" zones in regions where sound rays are diffracted upwards away from the ground. The result can be a decrease in sound levels of 10 dB or more below that for no diffraction.

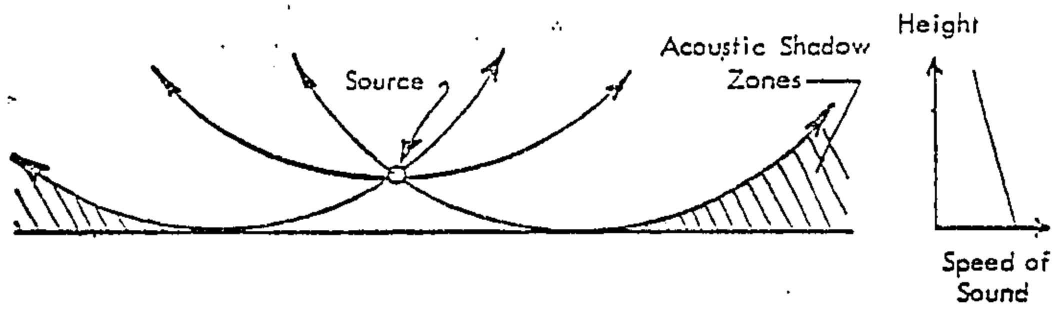

Figure C-8 . Refraction of Sound Rays by Normal Decrease in Temperature with Height

Absorption of Sound

Finally, sound actually loses energy as it travels, due to absorption by the ground or by absorption in the atmosphere so that at distances from a noise source greater than about 50 m, these losses cause the sound field to decay even more rapidly than the simple 6 dB or 3 dB per doubling-of-distance laws. This additional loss can be very roughly accounted for by including, for ground absorption, an additional 1 dB per doubling of distance in the spreading loss and, for the air absorption, decreasing the source levels by an additional 0.6 dB for every 100 meters of source-receiver path length. Thus, for the single stationary car generating a noise level of 66 dB at 15 meters, the level at 120 meters would be decreased by 7 dB per doubling of distance (for spreading and ground absorption loss) times three (the number of times the distance is doubled between 120 and 15 meters) and further decreased by 0.6 dB per 100 meters (or 0.7 dB) to give a total attenuation of $7 \times 3 + 0.7 \simeq 22$ dB and a resultant level of $66 - 22 = 44$ dB.

C.3 *Measurement and Analysis Systems*

There are several general types of instrumentation available for the measurement and analysis of community noise. The performance specifications of these various systems limit the range over which they can accurately perform their specified measurement or analysis function.

Any measurement or analysis system may be schematically described as consisting of three elements (see Figure C-9). There is (1) an input element which provides data to a system, (2) a functional element, which operates on the data in some manner to generate a desired metric, and (3) an output element which provides some type of visual or written record of the metric.

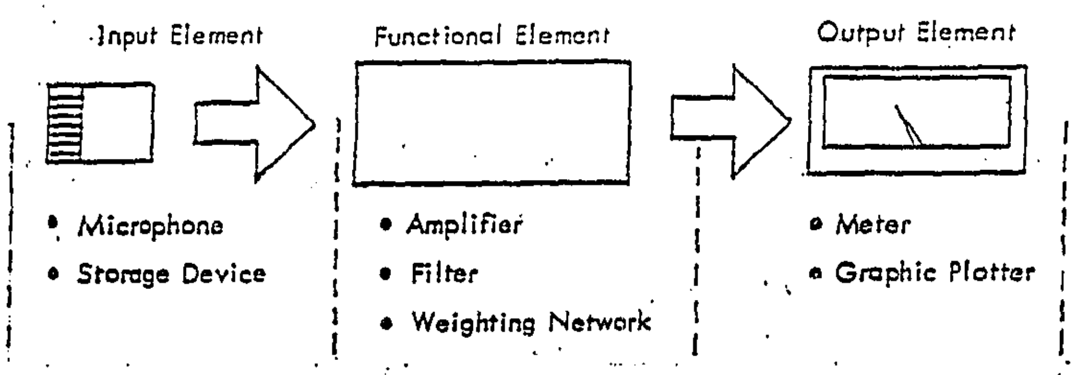

Figure C-9. Basic Elements of a Measurement or Analysis System

For the standard sound level meter, the input element is a microphone, which converts acoustical energy into electrical energy. The functional element is an A-weighting network and amplifier which shapes the frequency spectrum of this electrical signal (the converted acoustical signal) so that it approximates the response of the human ear. The output element is a meter with a scale graduated in decibels which provides a reading of the measured noise level.

For a laboratory data analysis system, the input is a tape recorder, used to play back data from field measurements. The functional element could be an octave band filter, which separates the recorded acoustical data into separate electrical signals for each of the octave bands. The output element might be a strip chart recorder which provides a written record of the sound pressure levels in each of the octave bands.

The concept presented here is that any single acoustic instrument, or system of instruments, may be represented by these three elements, regardless of the complexity of the individual system components involved.

C.3.1 Basic Specifications

The functions of an instrument, or system of instruments, are normally set forth in terms of performance specifications which describe the electrical and physical characteristics of the instruments under conditions representing the range of normal usage.

An extensive vocabulary of terms exists for defining the operating and performance specifications for measurement instrumentation. Many of these terms are in a mathematical format, or provide a level of detail in excess of that required for the field operator to have a functional understanding of his equipment. However, it is vital that the operator have a basic understanding of certain specifications which define the limitations of his equipment and therefore the credibility of the measurement and analysis tasks which he has undertaken. The following terms are commonly utilized to define these end-to-end performance specifications.

Accuracy - The closeness with which the output of a device actually represents the theoretical value which it is supposed to represent. The degree of accuracy is a practical compromise based on the measurement state-of-the-art and cost of producing the device. For example, measurement and analysis instruments must often be capable of providing an output accurate enough to serve as unambiguous evidence in any legal controversy concerning the noise environment. The noise measurement device must therefore be a "witness" whose testimony can be accepted by both sides of a noise controversy. Accuracy is commonly expressed in terms of the range, in decibels, within which the actual measured output falls as an approximation of the true environment. Ideally, this accuracy is also specified by its confidence limits. For example, an end-to-end accuracy of a complete high quality noise monitoring system might be specified by a 95 percent confidence that the measured value is within ±1 dB of the true value. This would be approximately equivalent to stating that the standard deviation of the (normally distributed) measurement errors would be 0.5 dB.

Frequency Response - Defines the range (limits) of frequencies which may be processed by the instrument without adversely affecting the resultant data. Two problems may be encountered when the signal being processed or conditioned by an instrument contains frequencies outside the range of the instrument. First, the data contained in these frequencies may be distorted or otherwise altered by the instrument — producing invalid output. Second, the energy contained in this signal, associated with these frequencies, may limit the range of noise levels which may be processed by the instrument. Frequency response is normally specified in terms of the frequency range (in Hz) within which the input/output amplitude response is quite uniform. A typical range for acoustical instrumentation is a uniform response, within ±1 dB, from 50 Hz to 15,000 Hz.

Dynamic Range - This is the most important single equipment specification for this manual. It defines the range of input noise levels which may be measured or analyzed by an instrument without degrading the accuracy of the measurement. An improper understanding of this specification may cause experienced measurement technicians to take "false" data, so that errors may be produced in the resultant data which are undetected by observing meter readings or listening to a noise source.

The dynamic range of an instrument, which measures or analyzes noise levels directly from a microphone may be set forth in terms of the lowest and highest noise levels which may be accurately measured. For an instrument which converts or stores an electrical signal, such as a tape recorder, the dynamic range is defined as the range of input voltages over which it will perform its design function.

The "high" end of an instrument's dynamic range is limited by distortion due to input levels in excess of the specification. Distortion is present in a measurement when the electrical signal waveform does not accurately represent the input acoustical waveform. When distortion is present to any great extent, it tends to invalidate the output data or measurements provided by the instrument.

The "low end" of an instrument's dynamic range is established by the electrical noise level of the instrument (sometimes referred to as noise floor). The electrical noise level is simply defined as that noise (voltage) which may be measured at the output of the instrument when there is no acoustic signal present at the input. If an operator is not aware of this limitation, he may assume that erroneous measurements (which actually represent the internal noise of the instrument) constitute valid data. Figure C-10 illustrates a typical example of how apparently low noise levels measured outdoors late at night can actually represent the electrical noise floor of the instrumentation.

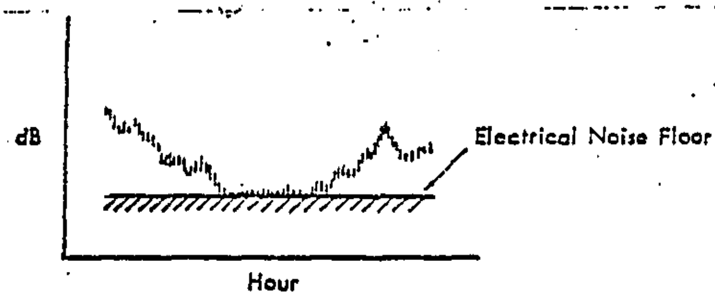

Figure C-10. Outdoor Measurement Which Drops Below Electrical Noise Floor of Measuring Instrument

Two types of noise may establish this lower measurement range of an instrument. The first is the "hum" which can be introduced into the instrument from the line power (usually 117 volts, alternating current) at the power line frequency of 60 Hz or its second or third harmonic (120 or 180 Hz). This type of noise can be minimized by careful electrical grounding of the instrumentation when it is connected to ac power or by careful electrical shielding of sensitive (low signal level) portions of the measurement system. The second type of noise is technically defined as "thermal agitation" and is generated by the random motion of electrons in devices within the electronic circuitry. This noise level has energy over the entire frequency spectrum and may therefore introduce errors at any frequency where the signal level is too low.

Figure C-11 illustrates the expected variation from site to site of the range between maximum and minimum instantaneous noise levels that one can expect to encounter in outdoor noise measurements in residential areas. The figure is based on data recorded continuously for 24 hours at 100 residential sites throughout the United States not located near airports or limited access highways.[2]

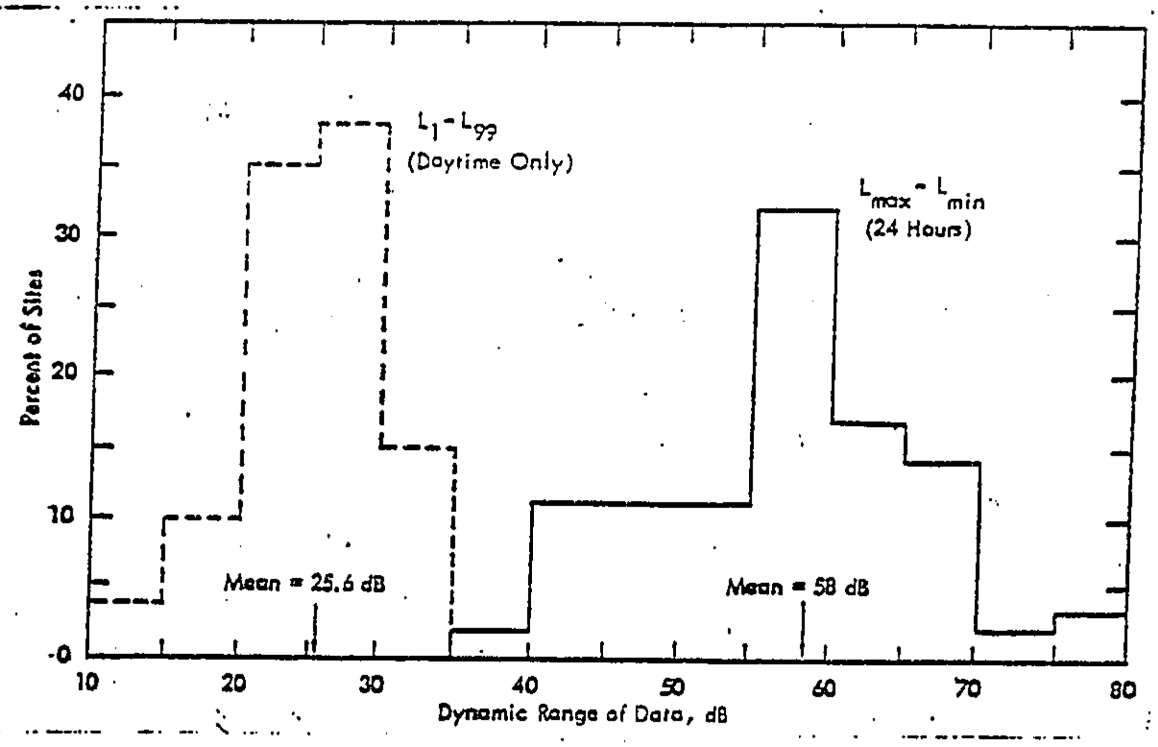

Figure C-11. Dynamic Range of Outdoor Noise Levels at 100 Sites in Major Urban Areas in the U.S. (from Reference 2)

The solid line on the right of Figure C-11 shows the extreme range over a 24-hour day between the maximum and minimum levels observed. The mean range is 58 dB, but 5 percent of the sites had a range between 75 and 80 dB — well beyond the normal dynamic range of conventional fixed-gain data recording systems. The extreme range for just the daytime hours (7:00 a.m. - 10:00 p.m.) from the same data was slightly less. The mean was 53 dB with 5 percent of the sites exceeding 70 dB. This is still beyond the normal dynamic range of most fixed-gain recording instrumentation. However, if the range is restricted to the levels between the minimum and the level exceeded only 1 percent of the time, the range of the data reduces drastically. A further reduction is achieved if only the middle 98 percent range of the data is considered (i.e., between L_1 and L_{99}). In this case, as shown by the dashed line in Figure C-11, the mean dynamic range of the data, considering daytime levels only, would be only 26 dB with 5 percent of the cases of $L_1 - L_{99}$ exceeding about 33 dB. The maximum value of $L_1 - L_{99}$ (daytime) was 34 dB. Thus, allowing for decreased noise levels at night, a minimum dynamic range of 40 to 45 dB will be required for a fixed-gain measurement system and this range would usually have to be positioned carefully to coincide with the actual dynamic range of the data to avoid clipping levels below the L_1 limit.

It should be pointed out that very few of the community noise studies conducted up to now have incorporated sufficient dynamic range in the instrumentation to encompass the full dynamic range of outdoor noise levels that is indicated in Figure C-11. However, the dynamic range within the statistical levels of, say, L_1 to L_{99} is usually well within available instrumentation capabilities.

Measurement Range - Clearly, some feature of the measurement system must be defined which allows careful positioning of the dynamic range of the instrument to match that of the data. This feature can be identified as the measurement range. This defines the capability for an instrument to accurately operate over a wide dynamic range of noise levels at a given time. Instruments which cannot be operated in a fixed measurement range configuration can cover a broad dynamic range of data in several smaller incremental ranges through the use of internal range switching of their amplifier components, commonly accomplished with attenuators.

For example, a standard sound level meter is provided with the following specifications:

Measurement Range:	30 dB to 120 dB
Meter Range:	-10 to 10 dB

which means the sound level meter will accommodate a range of noise levels from 30 dB to 120 dB; however, attenuator switching is required for the indicating meter to measure this range of noise levels.

Figure C-12 illustrates the concept of dynamic range, applied to a sound level meter. On the right side of the figure, the entire measurement range of the instrument is indicated. On the other side, the range of meter levels which may be read from the meter is illustrated.

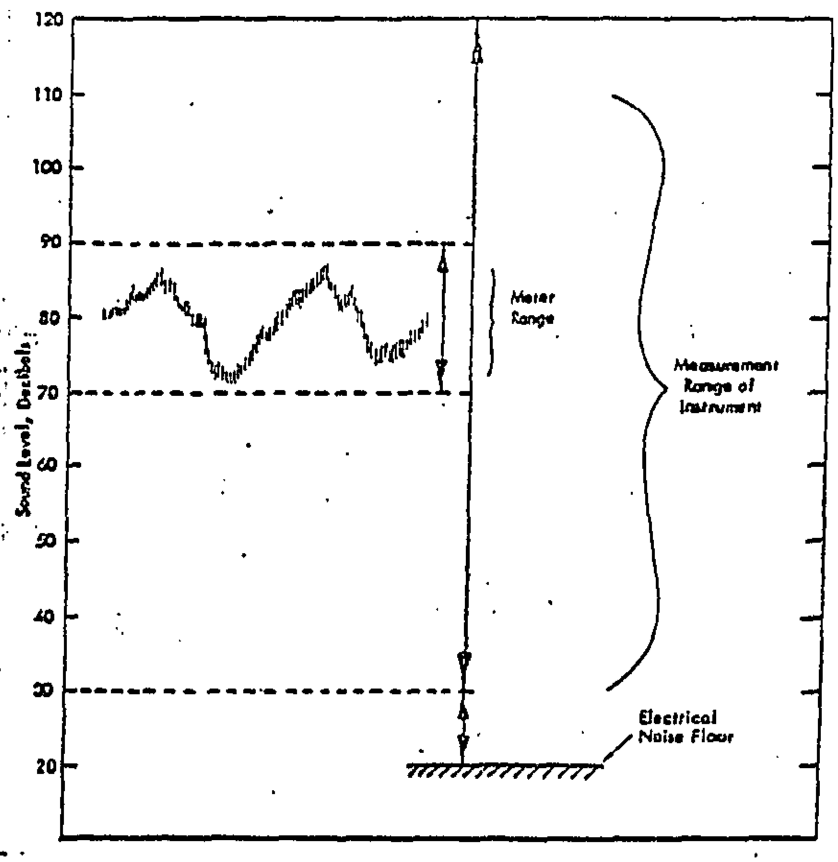

Figure C-12. Simplified Illustration of the Dynamic Range of a Sound Level Meter

Environmental Characteristics - These define the extent to which an instrument will meet its measurement performance specifications while operating in an adverse physical environment. This is a significant specification for equipment which must be operated outdoors, and frequently be left unattended for prolonged periods of time. Specifications are set forth in terms of resistance to moisture, wind, rain, salt spray, temperature extremes, resistance to electromagnetic interference and, for unattended systems, resistance to tampering or vandalism. Equipment is therefore either designed for outdoor use or laboratory operation, since requirements for application to outdoor unmanned sites can impose costly environmental requirements not needed for laboratory instruments.

C.3.2 Measurement and Analysis Instrumentation

There is a broad range of instrumentation available for the measurement and analysis of community noise to obtain the noise metrics defined earlier. Some instrumentation units will perform an entire "measurement/analysis" function without the necessity for recording and laboratory processing - as with the hand-held sound level meter. To obtain other metrics, or records of data taken over extended periods of time, it is frequently necessary to assemble an "instrumentation system" with which data are recorded, taken to a laboratory, and analyzed with various items of instrumentation and possibly a computer.

The single integrated instruments, as well as the instrument components of various measurement and/or analysis systems are discussed in the following paragraphs.

C.3.2.1 The Microphone

The microphone will be considered as an integral element of other measurement instruments to be considered here, such as the sound level meter. However, the microphone is possibly the most important single component in an acoustic measurement system, and improper use and/or treatment of the microphone can readily produce significant measurement errors which may be virtually undetectable in measured and analyzed data; therefore, some specific discussion of this device is in order.

A microphone is a device that translates acoustical energy into electrical energy in a way that substantially preserves the shape of the acoustic waveform. Many types of microphones exist, with characteristics to suit particular applications, as there is no single microphone that will always satisfy all possible measurement requirements. A microphone is, of necessity, a delicate instrument component and thus requires care in handling and usage.

When considering a microphone for a specific purpose, one must consider the nature of the sound field, the important characteristics of the sounds to be measured, the environmental conditions under which the microphone will be operated, and the precision expected of the measurements. It is especially important that the selection of the microphone and the accompanying measurement system match the frequency characteristics of the sound source. For example, for precision measurements at high frequencies, it is important to choose a microphone designed to measure correctly in "free field" environments for outdoor measurements. Sound diffraction effects around the microphone can cause differences in measured sound levels at frequencies above 10,000 Hz of as much as 10 to 15 dB.

At the present time, the following types of microphones are being utilized for community noise measurements:[3]

1. Ceramic Microphones

The ceramic microphone uses a piezoelectric ceramic (lead-titanate, lead-zirconate) as the voltage-generating element. (The term piezoelectric indicates that the material produces a voltage when it is strained.) A diaphragm fastened to the ceramic transfers the sound-pressure variations into a corresponding varying force that strains the ceramic element thus producing a voltage.

This microphone is stable and rugged, has a reasonably smooth frequency response, and is relatively unaffected by normal temperature and humidity changes.

It is commonly supplied with medium quality sound level meters. It can be mounted directly on the instrument or separately, with connection by extension cable. Because of its characteristics and ease of use, this type of microphone is generally preferred for many sound measurement applications.

2. Condenser Microphones

Another type of microphone, known as the condenser, electrostatic or capacitor microphone, is also used for measurement purposes. Again a diaphragm is used and it is set in motion by the sound pressure. Here, the variation of an electrical capacitance, formed between the thin, stretched diaphragm and a backplate, is used to develop an electrical signal when a high polarizing voltage is applied to the capacitor. These microphones have excellent frequency response and are preferred for high precision measurements and applications requiring higher frequency response.

3. Electret Microphones

Another microphone of the condenser-type, using a thin, plastic film as a diaphragm, has a conductive coating on one side. The film rests on a perforated, metallic backplate with many small, supporting raised points. The sound pressure causes the film to move with respect to the backplate, thus varying the capacitance between the conductive coating and the backplate. By the use of a suitable plastic and proper treatment, the microphone maintains its own polarization and the capacitance change generates a corresponding electrical voltage. When the microphone is self-polarized in this manner, it is called an "electret microphone." This microphone can also be built to have an excellent combination of frequency response and sensitivity characteristics, although it tends to have slightly less stability over time than a condenser microphone.[3]

4. The Hydrophone

This microphone was designed originally for underwater measurements, but in recent years has been refined for general purpose outdoor community noise and aircraft noise measurements. The hydrophone utilizes piezoelectric ceramic sensing elements. The normal problems of humidity and temperature sensitivity are minimized by sealing and electronic compensation. Because of low sensitivity, this microphone is not suited for measurements at the low noise levels that normally occur in non-airport communities.

C.3.2.2-Sound Level Meter

The sound level meter is a portable acoustic measurement instrument — small enough to be carried by hand — and utilized for measuring noise levels for a wide variety of applications.

Figure C-13 is a schematic illustration of a typical sound level meter. It contains the following devices in a single integrated package.

- A microphone to convert acoustic energy (noise) into an electrical signal.
- An amplifier to increase the voltage from the microphone for measurement.
- A "weighting network" to convert the signal from the microphone from a voltage proportional to sound pressure level, to a voltage proportional to noise level (A-weighting). Other types of weighting networks, not addressed in this manual, are also provided.
- An attenuator for selecting the range of noise levels to be measured.*
- A meter — with a scale in decibels — for reading the noise level being measured.
- A windscreen — this device protects against wind-induced noises created at the microphone.
- Some sound level meters also come equipped with octave band filter sets — permitting the measurement of individual octave band noise levels in the field.

*For sound level meters that use two attenuators, care must be taken to set them properly to avoid degrading the dynamic range of the meter.

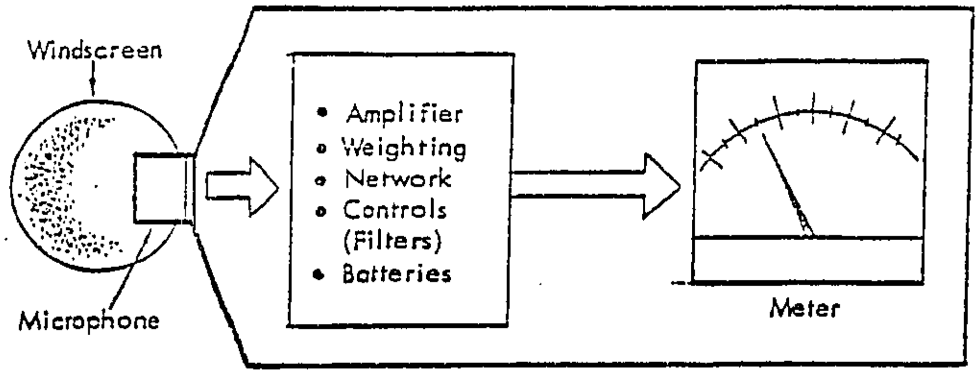

Figure C-13. Illustration of Typical Sound Level Meter Elements

American National Standard Specifications establish uniform standards for certain types of noise measurement. Such standards have been defined for four types of sound level meters:[4] Type 1 - "Precision ," Type 2 - "General Purpose," Type 3 - "Survey," and Type 4 - "Special Purpose." The first three types differ in their performance requirements, with the requirements being most strict for the precision type, and less strict for the others. A new type, called an Impulse Sound Level Meter, is also available with substantially more accuracy for highly variable and impulsive sounds.

C.3.2.3 Other Basic Elements of Acoustic Instrumentation

1. Outdoor Microphone System

In survey applications where it is necessary to make measurements for extended periods of time in outdoor environments, an outdoor microphone system is frequently utilized. This instrument contains several of the features included in the sound level meter, but is housed in a weatherproof case to protect the electronics from adverse weather environments. A typical outdoor microphone system provides the following features:

- Microphone, windscreen and protective device against birds
- Mounting pole for the microphone
- Weather- and tamper-proof case containing the appropriate electronics
- The output from this system may be recorded and/or analyzed in the field or transmitted to a centralized control station for processing.

2. Magnetic Tape Recorder

The most widely used data storage device is the magnetic tape recorder. Noise data may be fed to this device from either a sound level meter or an outdoor microphone system and continuous permanent recordings made on magnetic tape for periods normally 1 to 2 hours long, depending on the tape speed and reel size. The tape may be replayed later in a laboratory for analysis by other instruments to obtain the desired metrics or a time history of the recorded data. Precision portable recorders are available which incorporate many of the features of a sound level meter, while some constitute complete self-contained measurement and recording systems allowing two or more data channels to be recorded at the same time. Accurate knowledge and proper utilization of the dynamic range of a tape recorder is, perhaps, one of the most important aspects of their use for community noise measurements.

3. Graphic Level Recorder (GLR)

This device provides a visible chart record of electrical data fed into it. It may be connected to a measurement device, a tape recorder, or a frequency analyzer. It usually has variable recording speeds and can be used to obtain permanent records of the time history of most types of noise environments encountered. An important operating parameter of a graphic recorder is its writing speed, which should normally be adjusted to track noise levels at the same rate as would be observed visually on a sound level meter set to "slow" or "fast."[5] Manufacturers of graphic recorders normally provide the proper writing speeds to accomplish this, although the actual correspondence between graphic recorder and sound level meter readings will only be approximate.

4. Full Octave/One-Third Octave Spectrum Analyzer

Until the advent of high speed digital data analysis systems, the octave and one-third octave band frequency analyzer was one of the most popular laboratory analysis instruments. This device is still frequently used in conjunction with a graphic level recorder to provide full octave or one-third octave data analysis of the frequency spectrum of noises. The unit may also contain other useful conditioning and analysis features. It is always important to know the limitations of the frequency response characteristics of filters in a spectrum analyzer when measuring very unusual spectra with single frequency components. However, for many outdoor noises, the frequency discrimination of most analyzers is usually adequate to provide an approximate indication of frequency content.

5. Distribution Analyzer

This instrument is fed noise level data from a measurement device or a tape recorder. It records the elapsed time of the varying noise levels in noise level bands — equally spread over a specified dynamic range. Thus, it divides the distribution of noise levels in terms of the cumulative time the level falls within any one of these bands of noise level. The device may be left unattended for up to 24 hours or more, or the readings may be manually recorded at the end of every hour and the elapsed time meters for each noise level band reset to zero. The resultant data may be used to derive most of the relevant noise metrics discussed in this manual.

One model of this instrument is supplied with an external microphone for continuous outdoor noise monitoring and includes a battery and a waterproof case. Another model is designed for operation in conjunction with a graphic level recorder. This is primarily a laboratory instrument, but may be utilized in surveys with proper environmental protection.

6. Real Time Analyzer (RTA)

This versatile instrument has come into extensive use in recent years for the laboratory analysis of acoustic and vibration phenomena. The data signal to be processed —

from a tape recorder or microphone — is fed to a set of one-third octave band filters covering a frequency range of 25 Hz to 20 kHz. The levels of the individual bands are displayed simultaneously across the face of a large cathode ray tube (CRT) — a tube similar to a television tube. In addition to the frequency analysis, the noise levels based on various frequency weighting networks are also displayed on the CRT. Extensive controls are supplied to permit a variety of methods for storing, averaging, and sampling of the data. Electrical signals representing the analyzed data may be used to operate recording devices — such as level recorders. There is also a digital output for operation of the RTA with a computer. When operated in conjunction with a computer, the data processing capabilities of the analyzer are further expanded to permit the calculation of a series of complex noise metrics and to provide a variety of data presentation formats.

7. Community Noise Analyzer

This device, when used in conjunction with an outdoor microphone system or with tape recorded data, will acquire, calculate, and display L_{eq}, L_{dn}, and L_x for any period up to 24 hours or greater. Certain models are equipped with outdoor microphones, weather protection, and batteries, and may be left unattended for periods up to several days in the field to measure community noise metrics. One instrument of this type will directly provide data equivalent to that which previously required a separate microphone, recording and analysis instruments.

8. Digital Computer

A digital computer is a device which can store (in memory) extensive amounts of data, perform high speed arithmetical calculations on these data in accordance with instructions given it by an operator (programs) and present the analyzed data on a typewriter, high-speed line printer, plotter, or cathode ray tube (CRT). The speed of a computer is such that, in addition to its "computing" function, it can simultaneously control auxiliary devices such as measurement devices, tape recorders, and analyzers — telling these devices when to operate, when to supply it data, and how and where to display the processed data.

The principal application of digital computers to this manual is that of large computers located in data processing facilities where tapes or tabulated data are sent and processed to accommodate either a large volume processing and/or highly sophisticated calculations. This type of computer operation is referred to as "batch processing."

C.3.3 Measurement and Analysis Methods

Measurement and analysis methods based on these systems are described in the following paragraphs. The systems are grouped according to the measurement methods only, since there are a wide variety of analysis methods generally available for each type of measurement system.

Sound Level Meter

When the only instrument required is a sound level meter, data analysis can be performed by hand, even though some complex metric calculations may be involved. Measurements are made, and data presented, in accordance with the program plan for the specific survey. For pilot surveys, the sound level meter is read by visually averaging a characteristic position of the sound level meter indicator over a specified period of time, (i.e., central tendency of the minimum for background ambient level, or central tendency of the maximum for average sound level using "slow" meter movement). For application to baseline area noise surveys, the sound level meter should be read and the resulting data recorded according to the procedure defined in more detail in Section 3.4 of the manual text. The resulting data can be analyzed manually or by computer to obtain the various community noise metrics L_{eq}, L_{dn}, L_x, etc.

Digital Sound Level Meter

Other than providing a digital readout for a conventional sound level meter, these devices also can provide one major important additional feature — the ability to measure the energy average of a sound level over a preselected time interval (say, 10 seconds or 1 hour) and provide the output in terms of the equivalent noise level (L_{eq}) directly in digital form in a simple unambiguous reading. While these types of units are not widely available now, they are state-of-the-art and can be expected to become more popular in the future.

Outdoor Microphone and Tape Recorder

Identical in principle to the above, except the desired samples are recorded at each site, or at each source, and returned to the laboratory for playback into laboratory analysis equipment. A substantial amount of data manipulation, manual or automatic, is usually required with this method. Unless the tape recorder is equipped with an automatic on/off time-sampling switch, allowing unattended operation, this direct-recording type of data acquisition system requires an operator in full attendance during all measurements to set up the equipment, calibrate, change tape reels, and remove equipment after the survey. Slack time during recording can be used by the operator to maintain a log of intrusive sources. Data from either the manual or automatic (microsampling) microphone/tape recorder measurement system can normally be analyzed by any one of the analysis systems briefly discussed below.

- Frequency Analyzer - Level Recorder

This system is used primarily to provide graphic records of frequency spectrum analysis of noises and time histories of the overall noise levels. It is possible to utilize the graphic time history records to estimate the statistical levels over any period of time. However, manual processing of graphic records for this purpose is very tedious and is not recommended. Early distribution analyzers were attached to the graphic recorder pens to accomplish this type of analysis automatically. However, this procedure is not recommended considering current capabilities of statistical distribution analyzers which operate directly from the output of a sound level meter.

- Distribution Analyzer - Computer

This is an uncomplicated technique for obtaining data in terms of the basic community noise metrics L_x, L_{eq}, and L_{dn}. When used in conjunction with a level recorder, L_{max} measurements may be introduced into the data. Hourly or daily summaries of the level distributions are recorded from the distribution analyzer (by hand or by photographic record) and manually entered on forms for computer processing.

- Real Time Analyzer (RTA), With and Without Computer

This efficient and flexible analysis instrument is commonly used with either an analog recording device — such as a level recorder — or with a small computer. With the level recorder, the analysis capabilities are similar to those given for the frequency analyzer, except the RTA provides substantially greater flexibility in the manipulation and presentation of the data and provides a continuous CRT display of the one-third octave frequency spectrum.

When utilized with the small computer, automated control of the entire data reduction is possible and the advantages of data manipulation and presentation capabilities of computer processing are realized.

- Analog to Digital Converter* and Small Computer

This method utilizes the control capabilities of the small computer to convert analog tape noise level data to digital form, and process this data to obtain the desired community noise metrics. It is an efficient technique for reducing a large volume of data from several field measurement stations where identical recorders — using identical calibrating techniques — are utilized to record long duration noise environments.

Outdoor Microphone/Digital Recording and Processing

This is an efficient system for recording and processing data from sites where a recorder must be left unattended for long periods. High-density data storage is needed to allow a continuous sampling of data over the entire period of measurement, consisting of an hour, day, or, in some cases, a week. Digital recording techniques generally permit the acquisition and storage of sampled data over longer periods than is possible for an analog recorder even though for both, the recording time is limited by the length and speed of magnetic tape on a reel.

*This unit is usually custom designed for particular applications and prices therefore can only be very roughly estimated.

Outdoor Microphones and Community Noise Analyzers*

When performing a survey where the metrics of interest are L_{eq} and L_{dn} – and there is not a requirement to define statistical levels or to identify particular intruding sources – this system is one of the most efficient approaches available. The procedure is to set the microphone and analyzer in place and perform a system calibration. The system may then be left unattended for the desired measurement period – at the end of this period, L_{eq} and/or L_{dn} metrics are automatically calculated by the community noise analyzer and their values displayed by the instrument. No processing or data manipulation is required.

Multichannel Permanent Data Acquisition

This definition pertains to permanently installed instrumentation to provide continuous monitoring of all significant area and source noise. Existing systems of this type are almost exclusively limited to monitoring in the vicinity of airports; however, the data they generate are relevant to the entire spectrum of outdoor noise environments.

There are two disadvantages in the application of this type of system to the area and source monitoring tasks addressed by this manual. First is the substantial cost – the purchase and installation of a 12-channel system could range from $100,000 to $150,000. Second, it is not practical to relocate monitoring stations frequently, once the system is installed. However, for application to long-term monitoring, the low labor cost of operation when permanent sites are required can make this type of system quite attractive.

Table C-1 provides the approximate price range for the individual measurement instruments discussed in this appendix. Table C-2 provides approximate initial investment costs for most of the measurement systems described.

*An environmental noise classifier, which is a field version of the distribution analyzer, discussed earlier may be used in similar applications, and L_{eq} calculated from its output readings.

Table C-1

Price Range for Individual Measurement and Analysis Instruments (1977 Dollars)

Instrument	Approximate Price Range	Comments
Sound Level Meter	$450-2300 (6)*	Price range includes both precision and nonprecision instruments and includes microphone. All higher-priced units include A, B, C weighting; some include octave band filter sets.
Digital Sound Level Meter	$1800 (1)	Filters and computerized averaging circuits available as options. This is a precision unit with same basic features as precision analog units. Microphone included.
Outdoor Microphones	$1200-3000 (2)	Complete self-contained unit - microphone, windscreen, calibrator, battery.
Instrumentation Tape Recorder for Survey and Laboratory	$2000-8500 (3)	Portable two-channel recorder. Provision for operating with instrumentation microphones. One unit includes A, B, C and D weighting networks. Full range of tape speeds.
Digital Tape Recorder/Playback System	$8000 (1)	All digital field/laboratory system.
Community Noise Analyzer	$3000-6000 (3)	Different units have different specifications - all give L_{eq}, L_{dn} for 24-hour periods. Some units give statistical descriptors; some average over several time periods; some provide data tapes.
Frequency Analyzer	$5000-6000 (2)	Full octave and one-third octave filter sets - A, B, C and D weighting. Automatic or manual operation. Both operate with level recorders.
Level Recorder	$2500-4200 (2)	Basic units record acoustic data on strip chart records. Higher-priced unit provides many useful features for laboratory analysis.
Distribution Analyzer	$2000-3000	One unit is provided with microphone and will perform SLM functions. The other unit is for operation with a level recorder. Both give level distribution in 12 bands.
Real-Time Analyzer	$14,000-15,000 (2)	Units very similar. Measure and display one-third octave bands and weighted frequency data. Many automatic features. Digital and analog outputs provided.
Small Computer w/Interface to Real-Time Analyzer	Very Approximate $12,000 to 20,000 (2)	Price highly dependent on supplier, peripheral equipment and software. Price range given includes basic application programs for acoustic data analysis.

* Size of sample upon which price range is based.

Table C-2

Representative Measurement/Analysis System Prices

(1977 Dollars)

Instrumentation System	Typical Price*
Sound Level Meter	$ 1,500
Digital Sound Level Meter	$ 1,800
Microphone - Tape Recorder - Frequency Analyzer - Level Recorder	$17,500
Microphone - Tape Recorder - Level Recorder - Distribution Analyzer	$14,000
Microphone - Tape Recorder - Real-Time Analyzer - Level Recorder	$26,500
Microphone - Tape Recorder - Real-Time Analyzer - Lab Computer	$37,000
Microphone - Tape Recorder - Digital/Analog Converter - Lab Computer	$33,000
Microphone - Digital Recorder and Playback - Lab Computer	$25,000
Microphone - Community Noise Analyzer	$ 5,000

*Prices include allowance for test and calibration equipment and system integration. Medium to high precision equipment was selected.

REFERENCES FOR APPENDIX C

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3. Hruska, G.R., Magrab, E.B., and Penzes, W.B., "Environmental Effects on Microphones of Various Constructions." J. Acoust. Soc. Am. (to be published).

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APPENDIX D

TECHNICAL BACKGROUND ON SAMPLING OF COMMUNITY NOISE

D.1 Introduction

The technical material developed in this manual has drawn upon the extensive information contained in the literature on:*

- The design of community noise studies for local communities[1-4] and national baseline data bases.[5, 6]
- The design of source measurement programs.[7]
- Analysis of community noise sampling methods, particularly in the area of temporal sampling.[6, 8-14]
- Analytical models for evaluating results of community noise measurements.[15, 16]

In addition, results of specific community noise studies, many of which have been cited in the main body of this manual, were utilized.

This appendix will provide technical details only in those areas of community noise sampling theory which are necessary to support the methods outlined in the manual. For additional details on the above subjects, the reader is referred to the literature identified above and to related literature on sampling design[17-19] and statistics.[20, 21]

Since the concepts in statistics are a vital part of the basis for a sample design, a few of the essential principles in statistics are briefly defined first (Section D.2). This is followed by a technical discussion on the basis for the spatial sampling method chosen (Section D.3), and the influence of temporal variations on sampling accuracy (Section D.4). Next, the overall spatial and temporal accuracy of the surveys are considered (Section D.5) and, finally, the sampling requirements for source sampling surveys is discussed (Section D.6).

*All references identified are listed at the end of this appendix.

D.2 A Bit of Statistics - Predicting the Unpredictable

The spatial and temporal pattern of community noise is complex enough to be considered a random process. That is, the noise at any one point and time is the net summation of many seemingly unpredictable factors related to the noise sources themselves, the sound propagation paths, and the objective methods used to measure the noise. These three basic elements are, in turn, governed by the more or less random patterns of people's activity, their surroundings, and weather. Notwithstanding this seemingly unpredictable basis for random variation of community noise, the science of statistics shows us that there is a structure to this "unpredictability" which, in fact, makes it possible to specify community noise in terms of expected values. Statistical theory thus allows one to establish some order or predictability to the seemingly disordered structure of random processes.

For example, if one tosses a handful of coins, say nine, up in the air many times, the number of "heads" which occur in each toss (anywhere from zero to nine) will vary randomly. However, after a large-number of such tosses, an order emerges in the frequency with which none, one, two . . . nine heads occur so that one can eventually expect that the number of heads in the next toss will be predicted by the probabilities illustrated with the histogram in Figure D-1.

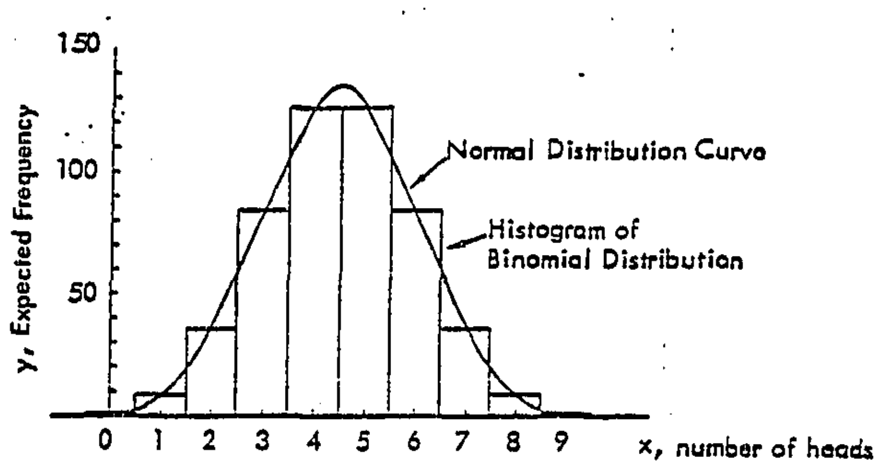


Figure D-1. Histogram and Normal Curve for Expected Frequencies (y) in Number (x) of Heads in Tossing Nine Coins 512 Times (from Reference 20)

The actual expected number of heads, indicated by this stairstep histogram, follows a distribution or probability function called the binomial distribution.[20]

D.2.1 Normal Distribution

When the number of intervals along the horizontal axis of this histogram becomes very small - equivalent to the distribution of heads when tossing many more than nine coins at once (or like examining a range of noise levels in small intervals of, say, 1 dB) - the step-wise histogram distribution approaches what is called the normal distribution. Two characteristic parameters define this smooth curve - its mean value (m) and a measure of its horizontal spread, which is called the standard deviation (σ). If one considers, again, the coin tossing histogram and asks the question, how many times out of 512 tosses will I get 3, 4, 5, or 6 heads, the answer can be found by adding the heights of the pedestals over the numbers 3, 4, 5, or 6. (The answer is 420.) This is equivalent to adding up the area under this portion of the distribution curve to obtain a measure of the expected number of heads within this range. The corresponding process can also be carried out for any desired interval for a normal distribution curve, as illustrated in Figure D-2.

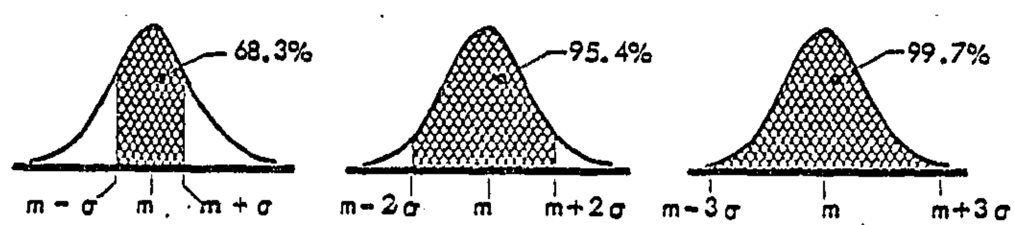


Figure D-2. Relative Areas Under a Normal Distribution Curve Within the Limits of ± One, Two, or Three Standard Deviations About the Mean

The shaded areas under this curve are proportional to the probability of an event falling within ±1 standard deviation about the mean (68.3 percent), ±2 standard deviations about the mean (95.4 percent), or ±3 standard deviations about the mean (99.7 percent).

Later on, accuracy criteria for noise level samples will be discussed which are approximately equivalent to the second case, that is, about 95 percent of the time, the expected mean value of a sample of noise levels will be within ±2 standard deviations of the true value.

D.2.2 Sampling Distribution

Consider, again, the coin tossing experiment. The histogram in Figure D-1 shows the ideal expectation of the number of heads for a very large number N of trials (strictly speaking, for N approaching infinity). Each trial can be considered just one element of the population of all N trials. If we had no prior knowledge of the outcome of our coin-tossing game, we would like to make a relatively small number of tosses in order to estimate the distribution in number of heads. That is, we would like to draw a sample of only 100 tosses with which to draw conclusions about the true population. For example, the sample mean, $\bar{x}$, is what statisticians call an unbiased estimate of the true population mean m.[20]

The distribution of the deviation of any sample parameter, say, its mean, from the corresponding population value, is defined by its sampling distribution and, based on the central limit theorem, this is usually closely approximated by a normal distribution regardless of the actual distribution of the population itself.[20] This situation is illustrated in Figure D-3.

This figure illustrates the case when one attempts to estimate the level exceeded 10 percent of the time (L_{10}) in a highly skewed distribution of noise levels (one which is unsymmetrical about its peak value) by drawing several independent samples of noise levels from the total population. If many such samples are drawn, the distribution of the ensemble of L_{10} values estimated from each of these samples is described approximately by a normal sampling distribution curve centered about the true population value of L_{10}.

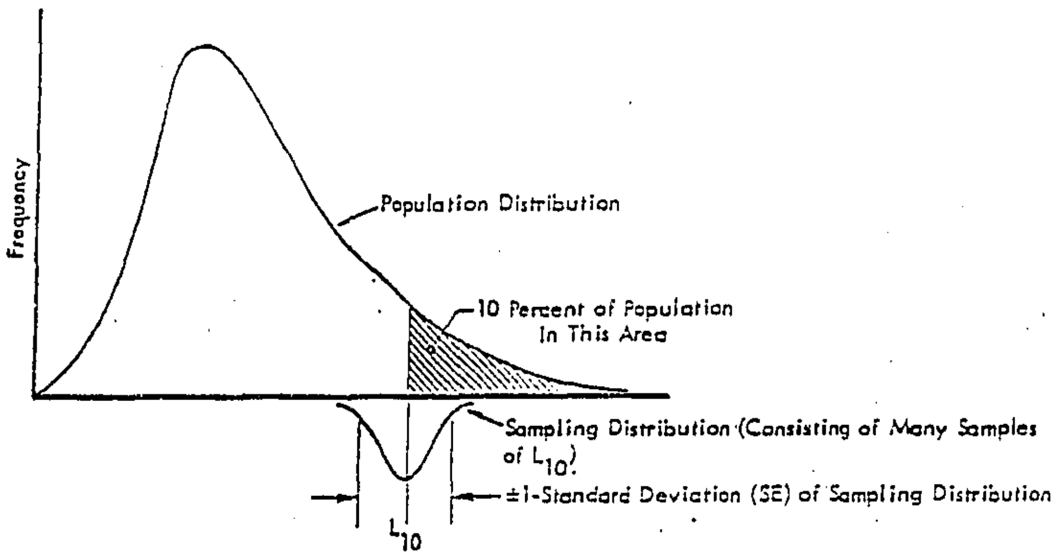


Figure D-3. Illustration of the Fact That the Sampling Distribution of a Statistical Parameter for a Population with a Skewed Distribution Tends to Have a Normal Distribution

The standard deviation of this normal distribution of sample estimates is called the <u>standard error</u> (SE) and for large sample sizes is very closely approximated by

$$SE \approx \sigma_s/\sqrt{n} \qquad (D\text{-}1)$$

where

n = size of each sample

σ_s = standard deviation for the population parameter being sampled

When the population parameter is the mean, then σ_s is the same as the standard deviation σ for the population. This basic relationship provides the essential foundation for selecting the size of an ideal sample. Thus, if we wish to be sure, with a specified degree of confidence, that a sample estimate of a population mean falls within a given confidence interval, $\pm\delta$, we get

$$\delta = t \cdot (SE) = t\sigma/\sqrt{n} \quad \text{(D-2)}$$

where t is the confidence parameter (from Student's "t" distribution)[20] which depends upon the degree of confidence desired in our sample and on the sample size, for small samples. When the sample is large, say, > 40, then t is approximately 2 for 95 percent confidence. Then, for 95 percent confidence that the sample estimate of the true mean is within $\pm\delta$ units of the true value, the required size of the sample n, to be drawn from a normally distributed population with a standard deviation, σ is given by

$$n \simeq 4(\sigma/\delta)^2 \quad , n > 40 \quad \text{(D-3)}$$

In the case where the sample is to be used to estimate a statistical noise level L_x other than the value, then it can be shown that the standard error for the sampling distribution of this population parmeter is approximately equal to $\sqrt{n(x/100)(1 - x/100)}$ where x is the percent exceedence level to be sampled. The corresponding sample size n becomes

$$n \simeq \left(\frac{t}{\Delta/100}\right)^2 \left(x/100\right) \left(1 - x/100\right) \quad \text{(D-4)}$$

where $\pm\Delta$ is the confidence interval in percent.

Equations (D-2) and (D-4) were used to estimate sample sizes for this manual. Figure D-4 shows one example of applying Equation (D-2) for determining the sample size to define a population mean noise level within the 95 percent confidence limits shown.[20]

D.2.3 Sampling Community Noise

There are two primary reasons to consider sampling for evaluating community noise:[1]

- It provides the only practical method for evaluating community noise in dimensions of both space and time.

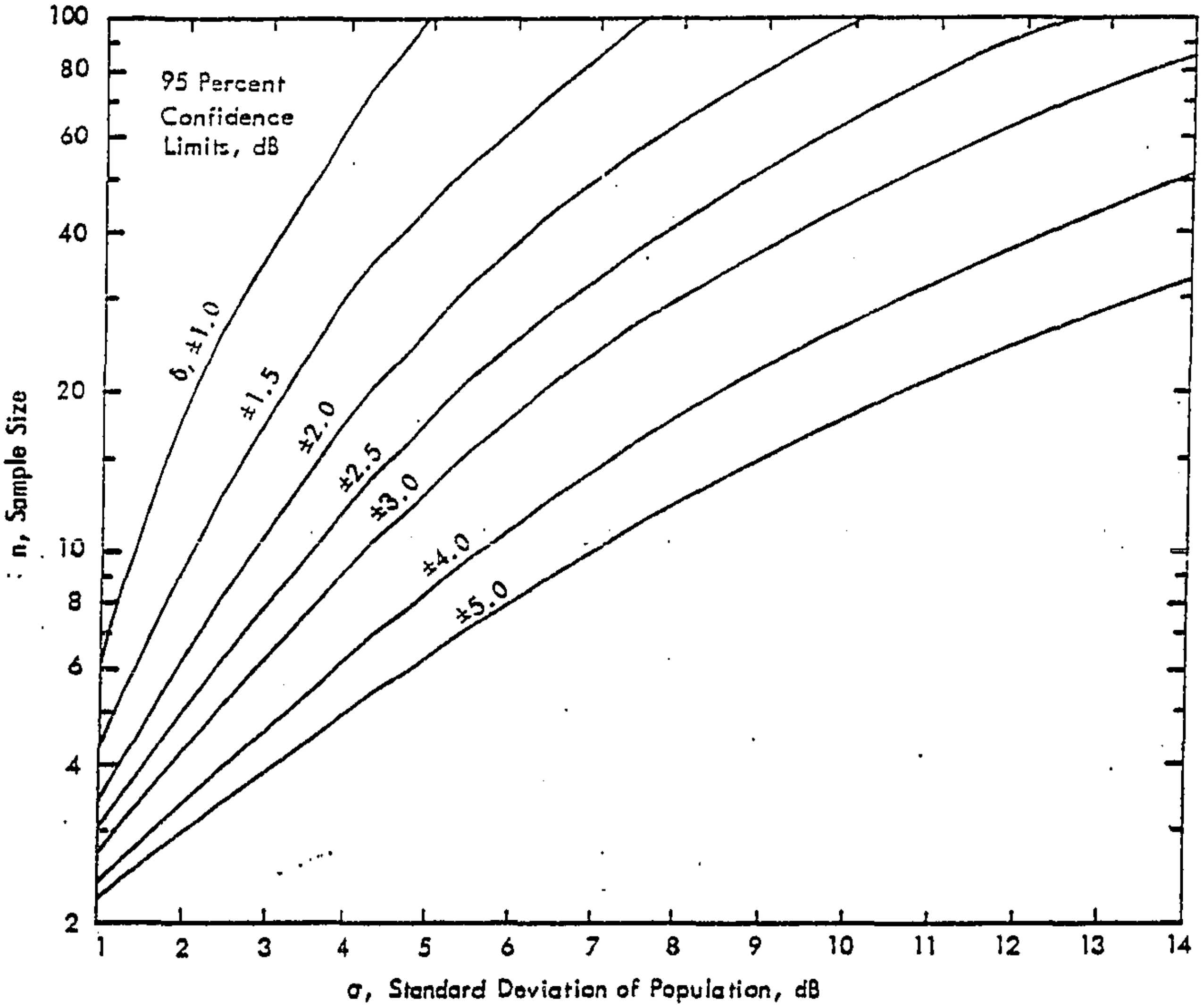


Figure D-4. Sample Size Needed to Measure a Population Mean within the Specified 95 Percent Confidence Interval (based on Equation (D-2)

- Proper construction of a sample will: (a) provide the basis for carrying out a statistical analysis of the results, (b) minimize unintentional bias, and (c) reduce fixed errors due to an inadequate sample.

Three general types of samples are applicable to community noise measurements. Deterministic samples of land areas may be selected on the basis of their known significance as noise problem areas. This is clearly the most practical approach for any small scale noise survey which is not attempting to evaluate the noise environment in an entire area. This type of sampling requires nothing more than common sense attention to potential or known offending noise sources or noisy areas and is not considered further here. Random samples of measurement sites may also be selected in a rigorous fashion following techniques similar to a procedure used in a random selection of interview households in a city for social surveys.[17, 18] This sampling method is fairly complex when carried out properly and is not considered practical for noise measurement sampling unless a social survey is also involved. If a social survey is involved, then it is essential that noise measurement sites be selected to coincide with the randomly selected social sample. Thus, this random sampling method is inherently employed in Section 3.3.2 of the manual where initial measurement sites are selected to coincide with attitudinal survey clusters whenever a social survey is conducted. However, as outlined in Section 3.3.2, additional noise measurement sites beyond those selected at survey clusters are ordinarily required. Finally, periodic or grid sampling may be used to select essentially random sites in a given area. This form of sampling, which is essentially equivalent to random sampling, is the one suggested in this manual for the additional sites that are required beyond those selected at social survey clusters. When no social survey is conducted, all of the noise measurement sites would be selected by this periodic grid sampling procedure.

D.3 Basis for the General Survey Spatial Sampling Method

The steps suggested for obtaining a proper spatial distribution of community noise measurement locations have been discussed in Section 3.3. The basis for this sampling procedure involves two basic statistical fundamentals which are considered here. They are: (1) the spatial standard deviation in noise levels for various types of noise zones, and (2) the identification of accuracy limits for each of the two survey classes (e.g., Class I and Class II).

D.3.1 Spatial Standard Deviations in Outdoor Noise Levels

The establishment of typical standard deviation values for noise levels measured in various community zones enables the number of samples required for the proper execution of a noise survey to be found using Figure D-4.

Three recent studies have been performed which are appropriate to consider in establishing the standard deviations for the type of noise zones defined in this manual. One study was conducted in Boise, Idaho, by the City of Boise, EPA, and Wyle Laboratories,[23] and two studies were conducted in Torrance, California, by Wyle and R.K. Miller Associates,[24] respectively. The Boise study evaluated noise in both residential and commercial/industrial areas; whereas the Torrance studies focused primarily on residential areas. In each study, the noise zones were selected on the basis of their acoustical homogeneity. For residential areas this homogeneity was characterized by the average daily traffic on neighboring streets.

Table D-1 shows the standard deviations for daytime L_{eq} values found in various noise zone categories by the three studies. Corresponding with the terminology used in this manual, the data are grouped into three types of noise zones: "Residential," "Roadway," and "Commercial/Industrial." The standard deviation values chosen for the purposes of this manual represent the central tendency of these data and are also shown in Table D-1.

It will be noted that these chosen values correspond with the results of the studies fairly accurately (±1 dB) with two exceptions. Measurements over all the residential zones in Boise were found to have a standard deviation of 8.6 dB, whereas similar measurements in Torrance and measurements in strictly light traffic areas in Boise average 4.7 dB. This discrepancy may be attributed to the low ambient noise levels

Table D-1

Spatial Standard Deviations of Noise Levels (L_{eq})
Measured for Three Studies, by Noise Zone

Type of Zone	Spatial Standard Deviation, dB			
	Wyle		Miller	Values Chosen for this Manual
	Boise[23]	Torrance[24]	Torrance[24]	
Residential				5
General	8.6	4.3	4.8	
Light Traffic[(1)]	5.1	-	-	
Roadway				4
Moderate Traffic[(2)]	4.3	3.5	2.1	
Heavy Traffic[(3)]	5.1	3.3	2.1	
Commercial/Industrial				6
Commercial	5.8	-	-	
Industrial	6.3	-	-	
Central Business Dist.	6.2	-	-	

(1) Roads with less than 6000 average daily traffic.

(2) Roads with between 6000 and 18,000 average daily traffic - Wyle studies; roads with between 6000 and 36,000 average daily traffic - Miller study.

(3) Roads with more than 18,000 average daily traffic - Wyle studies; roads with more than 36,000 average daily traffic - Miller study.

Note: A dash indicates no measurements were made.

in Boise ($L_{90} \approx 42$ dB) and to the wider range in residential population density over the large number of samples taken (170). Roadway area measurements made by Miller in Torrance yielded a standard deviation of only 2.1 dB. This is due, in part, to the regular traffic flow in the area during the short measurement period employed.

The information in Table D-1 is limited to the only three studies for which noise measurements were available which were obtaining using the noise zone concept outlined in this manual. However, the data in Table D-1 are consistent with spatial standard deviations from a large number of other community noise studies, conducted by a variety of spatial sampling methods, including period (grid) sampling and deterministic sampling. Spatial standard deviations from a number of these studies, identified in References 24 and 25, are shown in Figure D-5. These spatial standard deviations range from about 3.5 dB to 9.5 dB and have a mean value of 5.4 dB - a value that is well within the range of chosen values of 4 to 6 dB, given in the last column of Table D-1.

D.3.2 Identification of Spatial Accuracy Limits

As discussed in Section D.2.2, the region in a sampled domain within which the population mean is expected to lie is called the "confidence interval." The probability that the mean is in fact within the confidence interval is called its "degree of confidence." For this manual, the two survey classes have been assigned different spatial sampling confidence intervals: for the Class I survey the interval is ±5 dB, and for the Class II survey the interval is ±2 dB. Thus, the sampling plan is designed so that, ignoring for the moment any temporal sampling errors, the true mean noise levels for each type of noise zone considered by these surveys are expected to fall within these limits (centered around the mean measured values in 95 percent of the cases).

To attain this degree of confidence, a minimum number of sample sites must be chosen, depending on the standard deviation of noise levels in each noise zone. The required number of samples is found from Figure D-4, above, in combination with the chosen spatial standard deviation for noise zones given in Table D-1. The resulting

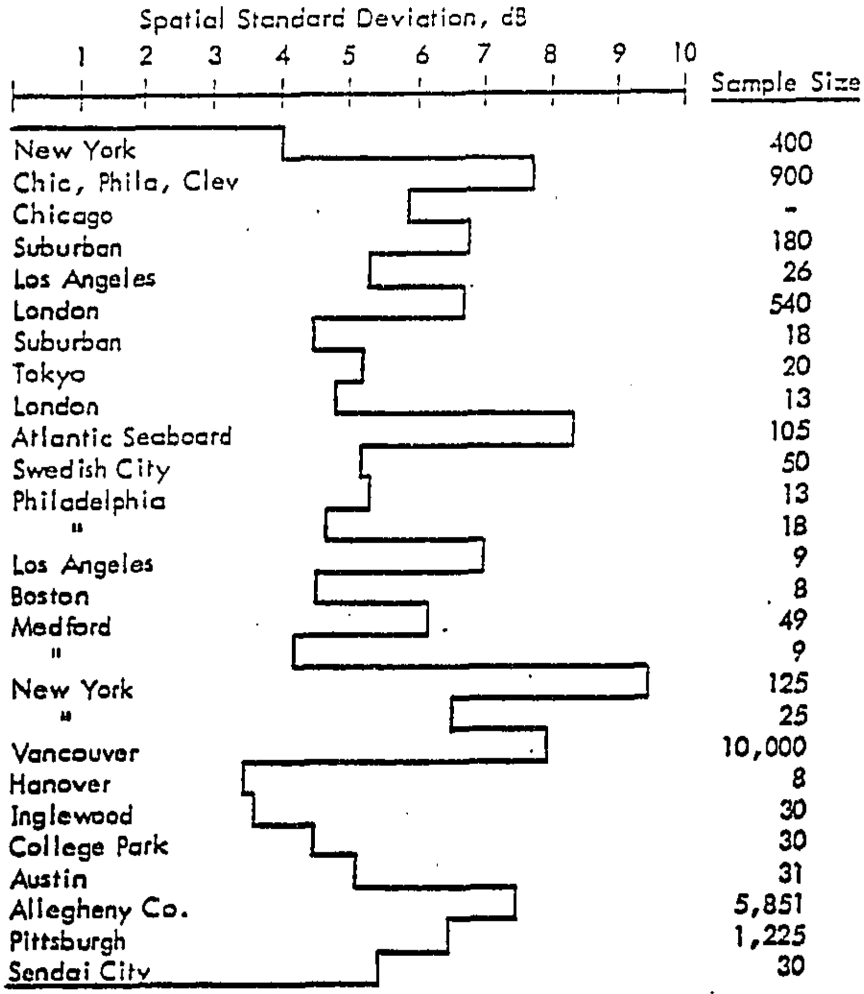


Figure D-5. Range of Spatial Standard Deviation for Median or Average Noise Levels for Daytime Periods in Residential Areas from Previous Noise Studies Conducted in the Cities Indicated (Data from References 24 and 25) number of sites is shown in Table D-2. If a city were not broken down into more than one survey area and if only one type of residential, one roadway, and one commercial/industrial zones were used, the Class I survey would require a total of only 20 measurement sites and the Class II survey would require 83 sites, according to Table D-2. However, since most cities would probably use more than one survey area and more than one type of residential zone (low and medium density, for example), and more than one type of roadway zone (Minor low volume, Minor high volume and Major, for example), there will usually be substantially more sites required to cover all survey areas and all noise zones within these areas.

Table D-2

Number of Sites Required for Actual Daytime Mean Noise Level to Lie Within Confidence Interval Mean of Values from Measurement Locations, by Noise Zone and Survey Class

Noise Zone	Spatial Standard Deviation, dB	Number of Sites Required	
		Class I	Class II
		95 Percent Confidence Interval = ±5 dB	95 Percent Confidence Interval = ±2 dB
Residential*	5	7	27
Roadway*	4	5	18
Commercial/ Industrial	6	8	38
Total	-	20	83

*Includes only one type of residential and roadway zone.

Sample sizes similar to those shown in Table D-2 have provided good results during tests in cities with populations in the 100,000 range.[23, 24] The actual size or surface area of the noise zone to be sampled, although not a direct variable in the spatial sampling plan used here, should be taken into consideration. This area effect has been partially accounted for in the sampling plan by requiring that the city first be broken down into several survey areas. For cities of 50,000 to 150,000 population of typical (5000 people per square mile) population density, which is the size for which this manual was designed, these subdivisions will tend to inherently limit the total area of each type of noise zone to reasonable proportions. For larger cities with a much larger population and land area, the same effect could be achieved by breaking the city down into a larger number than the four to seven survey areas suggested in Chapter 3.

On the other hand, a small noise zone such as a single industrial installation which influences an area of only a few blocks should not require the 38 measurement locations for a Class II noise survey as suggested in Table D-2, and some smaller number must be settled on. The manual provides forthis instance by allowing the user to choose no more measurement sites than there are "cell centers" or "interval points" as have been etablished at 0.32 kilometer (0.2 mile) spacing in the noise zone. It has been shown that sites more closely spaced than this may be simultaneously affected by the same noise sources, and hence, may not provide truly independent samples.[24] Hence, when the noise zone is small (i.e., comparable to the grid spacing itself), the number of measurements sites can be reduced accordingly. Thus, it can be seen that there are several ways the physical size of the area to be sampled can influence the sampling technique as applied in the manual.

D.3.3 Spatial Gradients in Sound Levels

Although not required as a basic part of the procedures in this manual, it may be desirable, for certain areas, to explore the spatial variation in average noise levels to establish the homogeneity of the environment within the immediate area around a measurement site. Results of such measurements, presented here, provide further indication of the relative accuracy of the spatial sampling concepts in this manual.

Horizontal Gradients

To evaluate horizontal noise gradients, one simple procedure simply requires two people each using a sound level meter. By having one person stay in a fixed reference location and the other person move away, time-coordinated readings of the two observers provide an effective acoustic "rod and chain" noise gradient mapping technique.[5] Application of this technique to observe the gradient in background ambient noise level ($\sim L_{90}$) near a limited access highway is illustrated in Figure D-6.

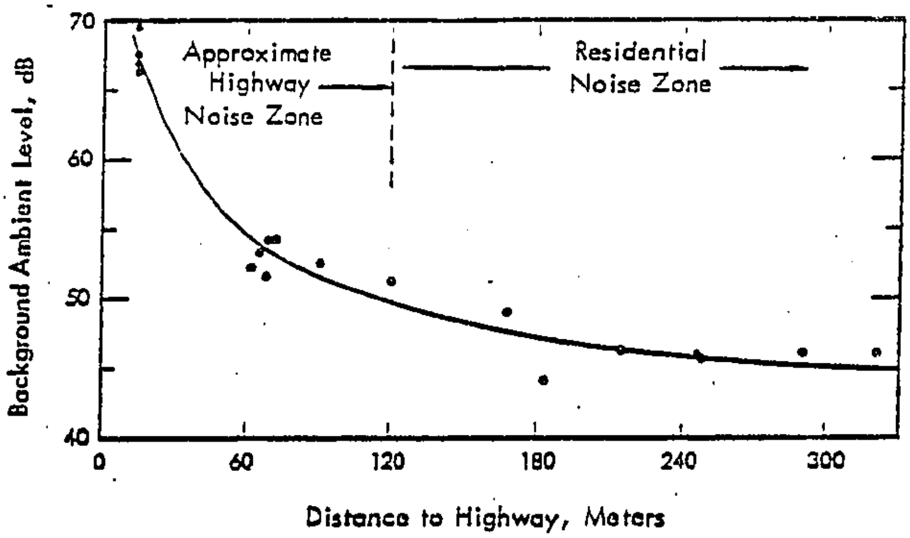


Figure D-6. Gradient of Residual Noise Level Near Limited Access Highway Measured with Short 2 to 4 Minute Samples with Two Sound Level Meters (Data from Reference 5)

The obvious and subtantial gradient in noise level near this highway is one example of the rationale for development of the noise zone concept. The approximate boundaries of the two noise zones that would be involved in this situation are shown in the figure. Clearly, any attempt to lump the entire region next to the highway into one noise zone would have failed to recognize the deterministic structure of community noise levels near major identifiable sources.

Vertical Gradients

While measurement of vertical noise gradients in areas with high density, high-rise residential structures may be desirable, as suggested in Section 3.3.2, previous experimental and analytical studies have indicated that such vertical gradients are not substantial.[5, 26] Typical values for the vertical gradient along the outside of a high-rise apartment building range from nearly zero[5] to about 0.082 dB/meter.[26]

There is one application of elevated noise measurements which has potential practical application. This involves the use of a single noise monitor located at the top of a tall building to provide umbrella-like integration of an area-wide noise environment.[27] This procedure was successfully employed in a major noise survey in London, England,[28] as shown in Figure D-7, and has been briefly explored experimentally by others.[29, 30] The potential cost savings by using such a single-point monitor for evaluating long-term trends in community noise level is obvious. This technique was suggested for use with 24-hour monitoring equipment in Appendix A.

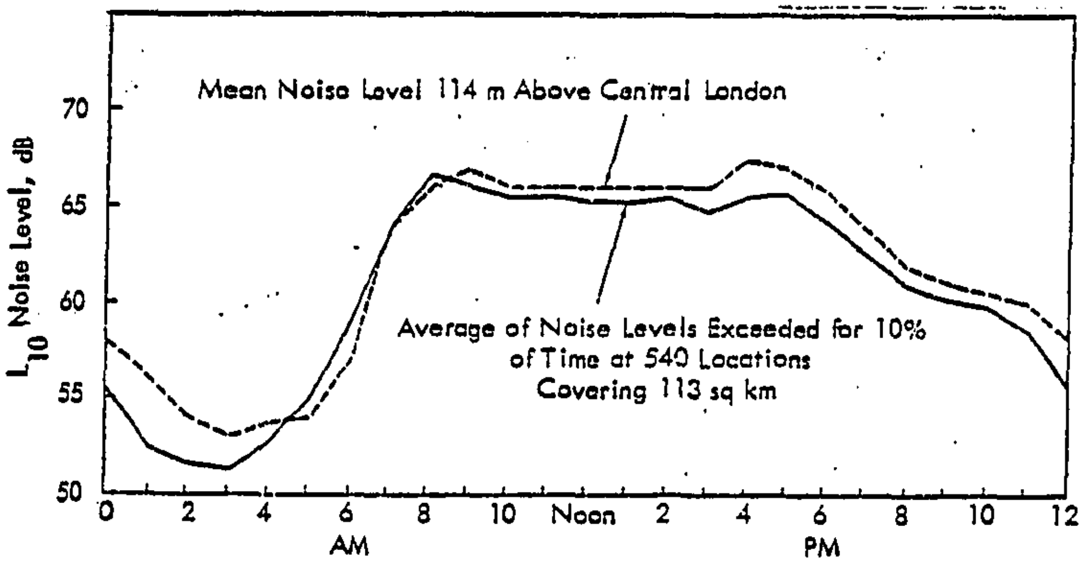


Figure D-7. Comparison of Average A-Weighted Noise Level at all 540 Measured Points with Value Measured at 375 ft in Central London on Top of GPO Tower (Data from Reference 28)

D.4 Influence of Temporal Variations on Sampling Accuracy

The spatial sampling methods described in Section D.3 yield noise levels which are expected to be within specified limits of the "true" value for the sampled area. These accuracy limits do not take into account temporal variations which may occur during the time period the measurements are intended to cover.

Temporal variations occur on many levels. At one extreme, there may be variations from year to year - some years may be slightly more noisy than other years due to increased traffic, imposition of a new community noise ordinance, or the start-up of a new industrial facility. At the other extreme, there are instantaneous variations in noise level which may be due to vehicle passbys, aircraft overflights, dogs barking, or human voices which may or may not be contained in the basic 20-minute measurement interval.

A discussion of some of these types of temporal variation is presented below, along with an indication of the magnitude of the variations involved.

D.4.1 Seasonal Variations

Trends in transportation vehicle flow provide one indication of seasonal effects on outdoor noise level. Figure D-8 shows monthly averages of transportation vehicle operations throughout a year. In this case, the transportation system activity is on the order of 50 percent higher (equivalent to an increase of about 2 dB in noise level) during the summer over the minimum in winter.

The few studies which have covered seasonal effects occasionally show higher levels in the winter (due to tire chains, for instance). However, the overall trend is for lower levels in the wintertime, typically by 5 to 8 dB.[31, 32] The larger noise reduction in the wintertime seems to be quite dependent on the presence of snow. Clearly, any atypical weather anomalies in an area should be considered when planning the timing of a noise survey.

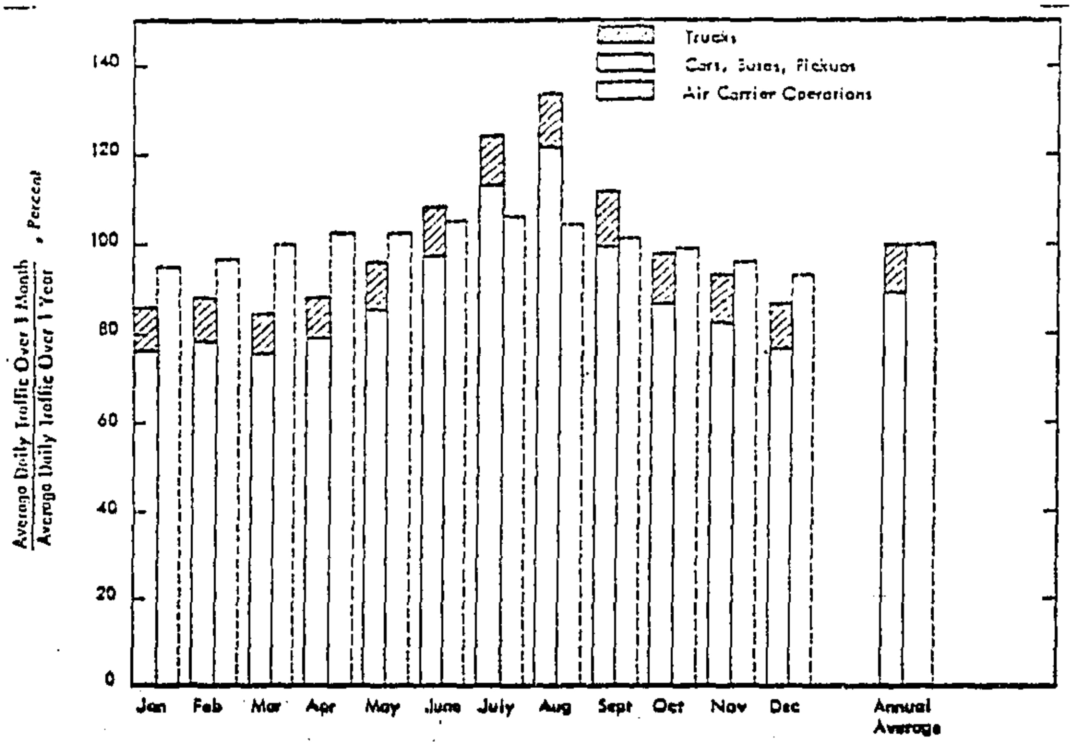


Figure D-8. Representative Monthly Variations in Motor Vehicle Traffic Over Interstate Highways in California (1967 Average) and Air Carrier Operations at Los Angeles International Airport (1968 Data) (from Reference 5)

Changes in prevailing weather conditions can also have a potentially major influence on long-term temporal variations in outdoor noise levels in the general vicinity of large extended noise sources such as industrial plants. For example, as illustrated by the unique data shown in Figure D-9, the effect of wind direction on community noise levels near a large factory becomes quite apparent when sufficiently long-term measurements are available. These data were obtained from periodic noise measurements every 4 hours each day over a 16-month period.[33]

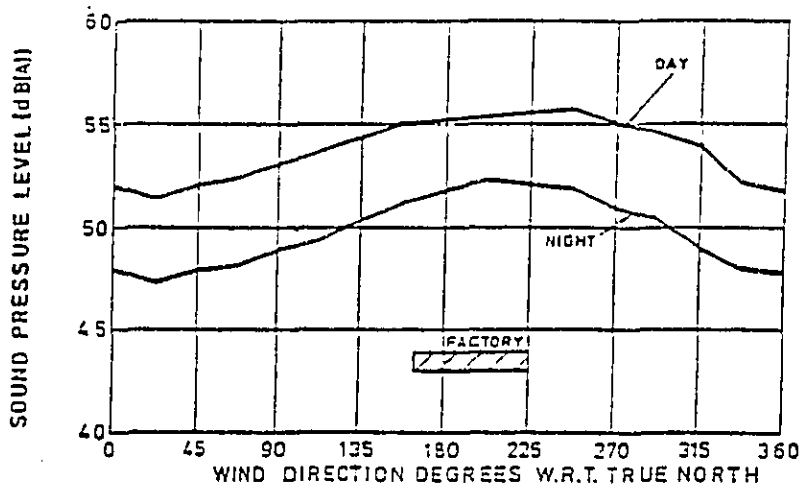


Figure D-9. Average Effect of Wind Direction on Noise Levels About 1.6 km (1 mile) from the center of a Large Factory as Observed Daily Over a 16-Month Period (from Reference 33)

D.4.2 Day-to-Day Variations

Since the basic metric L_{dn} is a measure of the energy average noise level over a 24-hour period, one immediate question is, "What is the proper day to measure?" The results of one systematic study over weekdays and weekends showed a mixed pattern of decreasing or increasing noise level between weekdays and weekend days, depending on the characteristic life cycle in each community area.[34] Typical results are given in Table D-6. In general, the available data indicate lower levels on weekend days, but exceptions invariably occur.

Other evidence as to cyclic patterns of noise in a week which should be considered for community noise monitoring can be provided by records of transportation vehicle activity. For example, as shown in Figure D-10, the relative change in daily operations, throughout a week, of aircraft and highway vehicles shows significant differences - yet when converted to expected changes in noise level on the decibel scale, these variations in activity of transportation vehicles do not in themselves indicate noise level changes greater than about 1 decibel - a "day" effect roughly consistent with observed data.[16, 34]

Table D-6

Typical Weekday-Weekend Variation in Community Noise Levels Based on the Differences in Daytime Median (L_{50}) Levels Observed at 57 Sites in London and Woodstock, Ontario (from Reference 34)

Land Use Category	$\Delta \overline{L_{50}}$, dB	
	Weekday - Saturday	Weekday - Sunday
Residential - Quarry	1.1	3.6
Residential - Single Family	-0.1	-1.5
Residential - Institutional	3.0	3.0
Residential - Commercial	3.1	4.7
Residential - Mixed	-0.4	2.9
Residential - Industrial	1.1	3.1

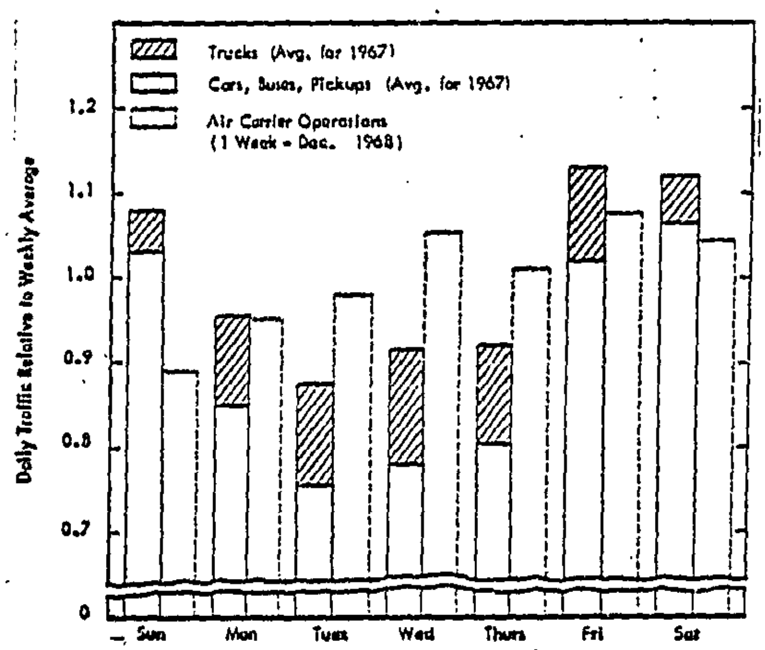


Figure D-10. Representative Daily Variation in: Motor Vehicle Traffic on California Intercity Highways (1967 Average) and Air Carrier Operations from Los Angeles International Airport (From Reference 5)

In light of these potential differences in noise level, it is indicated in the manual that some sites be measured on weekends. The resulting measurements can then be weighted to give the estimated energy average L_{dn} for the entire week as follows.

$$L_{dn}\text{ (entire week)} = L_{dn}\text{ (week)} + 10 \log \left[(5/7)\left(1 + 0.4 \cdot 10^{(\Delta W/E)/10}\right)\right], \text{ dB} \quad \text{(D-5)}$$

where

$$\Delta W/E = L_{dn}\text{ (weekend)} - L_{dn}\text{ (week)} \quad , \text{ dB}$$

For most community noise sites, the value of Δ W/E falls in the range of -3 to -10 dB and L_{dn} (entire week) is about 1 dB less than L_{dn} (week).

D.4.3 Hour-to-Hour Variations

Consider now the variation in noise level within a day. Figure D-11 shows the hourly variation in level from three different studies. Part a illustrates the mean and standard deviation in hourly equivalent noise level, $L_{eq(h)}$ relative to the day-night sound level L_{dn} from data at 100 sites in residential urban sites throughout the United States.[22] The average value of this relative measure of hourly noise level during a day is nearly constant at -3 dB from the hours of about 10 a.m. to 5 p.m., but has an average standard deviation of ±4 dB.

Part b of Figure D-11 compares the relative statistical level L_{10} from two large surveys in two very different areas[28, 35] indicating that while average trends in diurnal noise patterns may be defined, each community can be expected to exhibit its own unique "noise pulse" depending on its characteristics community life cycle. (Note that the data in Figure D-11b for the Allegheny County survey are based on only one 10-minute sample during the day. However, due to the large number of sites throughout each hour of the day, any systematic error due to this time sampling should average out.)

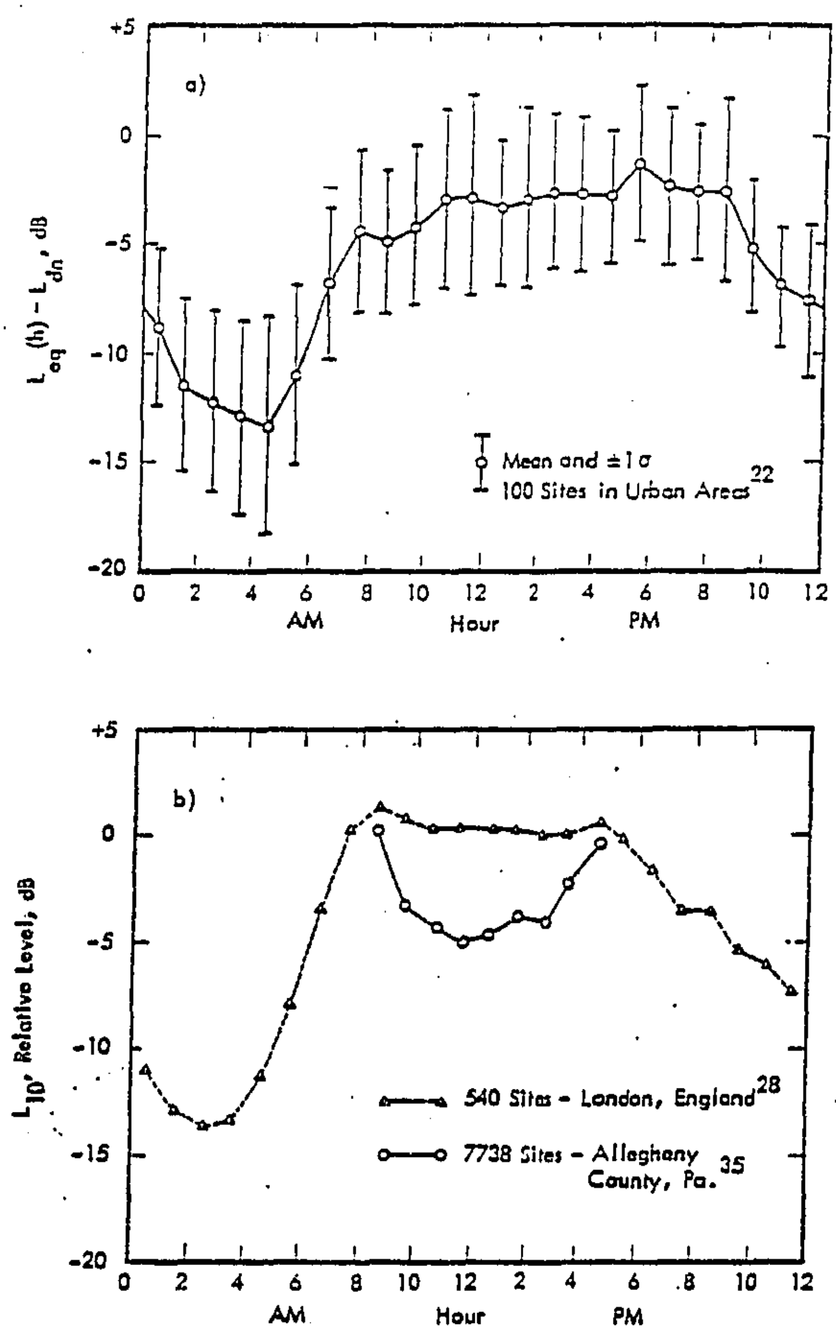


Figure D-11. Typical Hourly Variation in Noise Level from Three Major Surveys. The First Part (a) is the Average Variation in Hourly L_{eq} Relative to L_{dn} Averaged Over 100 Sites in 14 Cities in the U.S.[22] Part (b) Surveys in Two Very Different Areas.

The general trend in these diurnal cycles provided the basis for selection of the "day" and "night" time periods specified for noise measurements in Chapter 3 of the manual. Sampling during these periods avoids the short duration (and therefore difficult to accurately sample at random) "rush hour" activity periods of the morning and evening. The method has shown reasonable accuracy for representing noise levels over a 24-hour period.[23, 24]

According to the manual procedures, each site is sampled once for 20 minutes during the defined weekday daytime hours, and many sites are also sampled during the nighttime period. Since the individual samples in each noise zone typically become distributed throughout the time periods as the sampling progresses, the aggregate zone sample is considered to represent the hourly noise level fluctuations within the zone. Hence, hourly temporal representation is derived intrinsically from straightforward application of the spatial sampling technique. In the previous Boise, Idaho study, a zone-wide numerical average value for 8-hour daytime L_{eq} achieved in this manner agreed with average values obtained by continuous 8-hour monitoring within 2 dB for residential, airport, and commercial type noise zones, and within 4.5 dB for a minor roadway type zone. The minor roadway area in this case was large, but contained only six 20-minute measurement sites, whereas the other zones were more substantially sampled with respect to size and typical noise level distribution. It is felt that the more extensive sample indicated in this manual would have substantially decreased the error for the roadway type of zone to that observed in the other zones. Thus, this method of sampling no more than once per time period at each site is employed in this manual as an expedient and effective way to include the temporal domain the basic spatial sampling method.

The numbers of samples indicated in the manual to be taken at night or during weekend periods are less than the total number of weekday sites by factors equivalent to the proportions of time contained in the weekday, weeknight, weekend day, and weeknight periods during a seven day week. This is reflected in Section 3.3.2, Step 8. The purpose of this factoring is to allow the number of counts on data sheets of noise levels and intrusive sources from these periods to be added directly without factoring when hand-calculating statistical metrics and source contributions in Chapter 4. The resulting smaller samples for the night and weekend periods are intended to extend the complete weekday measurements to include the entire day, night and weekend periods in seven-day average, and are thus not considered to upset the sampling accuracy in view of the smaller time periods represented.

D.4.4 Variations Within an Hour

Statistical Distribution of Instantaneous Levels

The next stage in our review of temporal sampling brings us to the problem of sampling the noise within one hour. The manual indicates that individual samples of 20 minutes duration are to be made. Community noise samples much shorter than 20 minutes have been shown to give good accuracy for situations where the noise level fluctuation is small such as near a busy highway with a steady stream of traffic. Figure D-12, however, shows a typical histogram (in this case, a probability density curve) and the corresponding cumulative distribution for a temporal sample (sampled at more than two times per second) over a full hour at a residential location adjacent to a local street and 213 m (700 ft) from a busy limited access highway.[5] Note that the histogram is highly skewed towards the higher noise levels and is not at all like a so-called "normal" distribution curve which is often stated to be the distribution shape for temporal samples. In fact, most histograms of good temporal samples (~ 500 or more samples over a full hour) will show a wide variety of shapes and many will have the type of skewed non-normal distribution shown.

Figure D-13 shows the actual average cumulative distribution of levels from continuous recordings over daytime hours at 116 different residental locations excluding airport sites.[5, 8, 22] The statistical noise levels in Figure D-13 are plotted in a normalized form represented by the ratio $(L_x - L_{50})/\sigma$ where L_x is the statistical level at the x percent exceedence level, L_{50} is the median level (exceeded 50 percent of the time) and σ is the standard deviation of the instantaneous levels over each hour. The values shown are averages over all the sites for each data set for all the 15 hours

(7 a.m. to 10 p.m.) at each site. As indicated, these normalized data do not fall along the theoretical straight line of the normal distribution curve, but rather are more closely approximated by a so-called Rayleigh distribution. Thus, in general, community noise levels can be expected to exhibit this type of skewed statistical distribution for their instantaneous levels instead of the normal distribution frequently assumed.

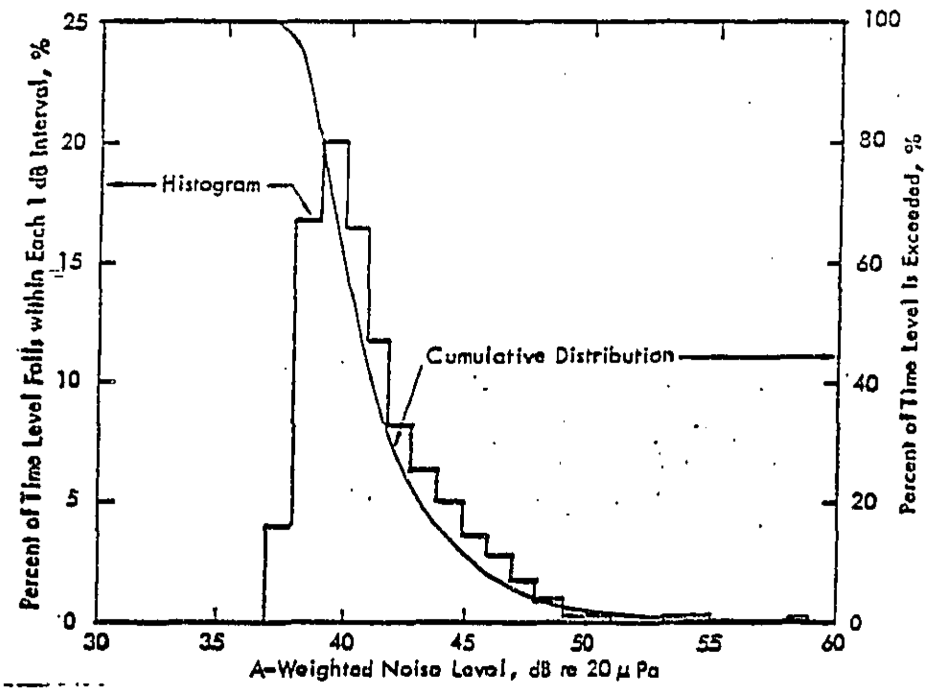


Figure D-12. Example of a Temporal Sample Histogram and Corresponding Cumulative Distribution Showing the Highly Skewed Nature of the Data. Based on 7800 Temporal Samples Over One Hour at a Site Near a Limited Access Highway. (From Reference 5.)

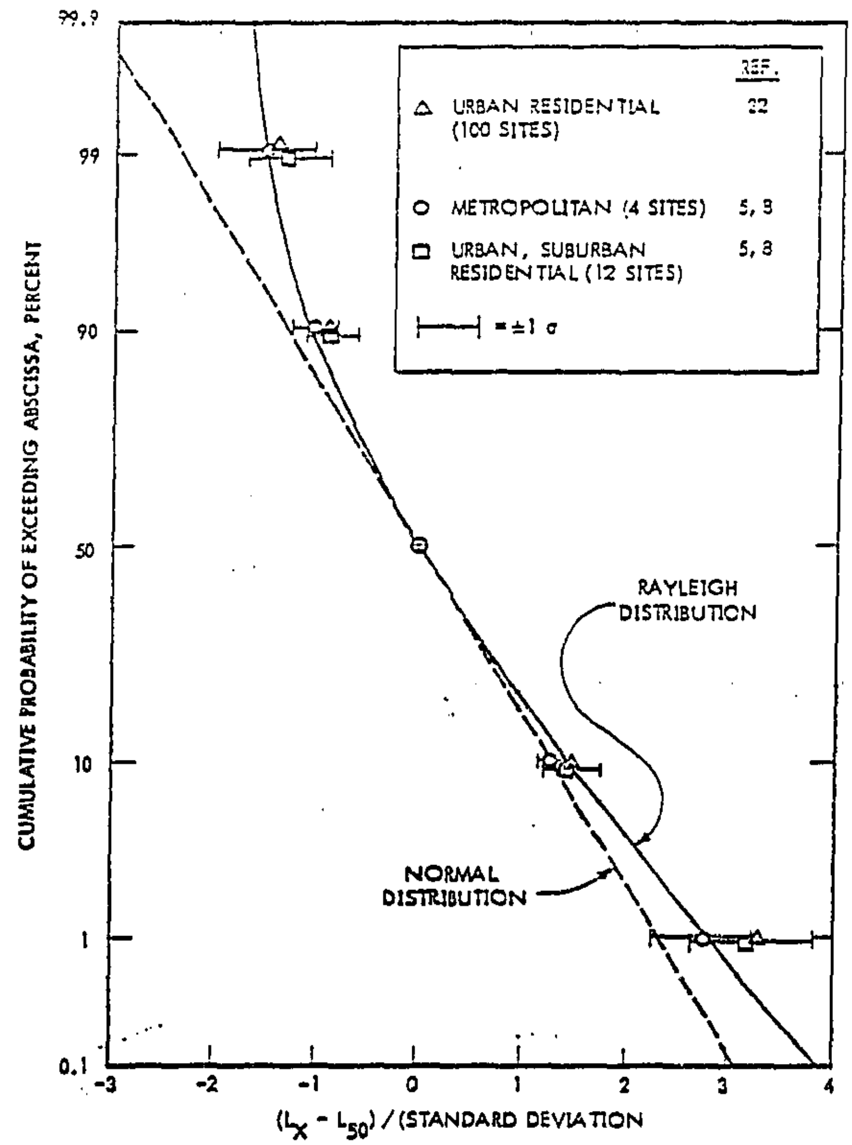


Figure D-13. The Cumulative Distribution of Normalized Statistical Levels Measured Continuously over 15-Hour Daytime Period (7 p.m. to 10 p.m.) at 116 Residential Sites (Airport Sites Excluded). Clearly Shows that Temporal Fluctuations of Outdoor Noise Do Not, On the Average, Follow a Normal Distribution.

Sampling Within an Hour

The error in short continuous samples less than one hour when compared to full hour samples has been evaluated in References 8, 9, 10 and 25 for several types of noise signals. For highly-skewed noise recordings, a longer time sample is required. From Reference 8, at least 13.3 minutes out of 53.3 minutes were required to achieve less than 1 dB average error in the average noise level for a recording near an airport. From Reference 10, the average deviation for 20-minute samples out of three one-hour tapes indicated a sampling error ranging from about -2 to +2 dB, but this error range more than doubled when the sample duration decreased to 10 minutes. In Reference 25, the first 20 minutes of each of thirty one-hour tapes of industrial and airport noise was sampled at a rate of 12.5 seconds per sample - comparable to the 15 second per sample rate called for in the manual. When the L_{eq} of each twenty minute sample was compared with the "true" hourly value (determined for the entire hour at a rate of ten samples per second), the standard deviation of the differences between sample and true values was 1.62 dB, and 95 percent confidence limits about the sample L_{eq} were approximately +4 to -5 dB. On the basis of all these data, a minimum duration of 20 minutes was elected to provide a sample of hourly noise levels.

D.4.5 Visual Temporal Sampling Rate with a Sound Level Meter

The final step in the temporal sampling structure is the actual field monitoring procedure applied within the 20 minute sample period. For the Class I and Class II temporal sampling methods employing a sound level meter, it was felt that the visual averaging method evaluated in References 9 and 11 for reading a sound level meter would not be suitable for application as a standard procedure in communities which may employ untrained people for a field noise survey. Rather, the visual "snapshot" approach and manual data logging procedure specified in Section 3.4 of the manual was selected. The time interval of 15 seconds provides 80 samples for a 20-minute observation period. A higher manual sampling rate is possible (up to about one reading every 5 seconds), but intervals less than 15 seconds become increasingly demanding and would tend to result in observer fatigue and a high error rate.

It was deemed unnecessary to attempt higher sampling rates based on results presented in Reference 25. In this investigation, 42 tapes of one to four hour samples of industrial and airport noise from 14 sites were analyzed at various sampling rates using digital sampling equipment. Comparison of L_{eq} values obtained for each tape at a sampling rate of 12.5 seconds per sample (near the rate applied in the manual) and at a standard sampling rate of 10 samples per second revealed a standard deviation of differences in L_{eq} of 0.99 dB. A 95 percent confidence interval about the true L_{eq} value from the 12.5 second rate of approximately +2 to -3 dB was also obtained. In a second analysis, 30 similar tapes were analyzed for L_{eq} at 10 seconds per sample and compared against standard analysis at 10 samples per second. The standard deviation of L_{eq} differences in this case was 1.32 dB. Considering these results, it was seen that a sampling rate of 15 seconds per sample was nearly an optimum rate for manual sampling, being a rate high enough to give satisfactory results, yet just low enough to allow accurate manual data acquisition.

D.5 Overall Survey Accuracy

The previous sections have addressed the subject of confidence for several elements of the spatial and temporal sampling schemes used in the survey method given in the manual text. It is appropriate to make an assessment of overall accuracy of the sampling method in this section of the appendix. New material presenting increasingly creative and thorough approaches to the evaluation of overall community noise survey accuracy is continually being published. The method explained herein for assessing the accuracy of the surveys described in this manual will constitute a conservative approach to the issue. However, the influences of certain factors on the measurement of truly long-term average environmental noise levels, such as seasonal weather patterns or the effects of high activity holidays, are quite difficult to quantify on a reasonably useful basis since the influences can be highly variable and area-specific. Hence, there will be no attempt here to account for such variations. The influence of these factors can best be minimized by conducting the survey during a time period that does not include unusual seasonal or other conditions that can affect the noise environment.

The survey methodology presented in the manual is intended principally for the determination of a mean L_{dn} value representative of each noise zone as defined. In considering the question of accuracy, we must develop limits about this measured sample mean within which the actual true value will be expected to lie with a specified level of confidence. The level of confidence used for this analysis will be 95 percent.

Development of this overall confidence interval must consider both survey sampling domains - spatial and temporal, and must also include the accuracy of the actual measurement technique - in this case manual reading of a sound level meter. The variance for all these elements must be combined to yield limits for the complete process. In this case, the temporal and spatial influences occur quite independently from one another, and thus no correlation between them or with the measurement error is expected. The resulting estimated combined accuracy may thus be obtained by taking the square root of the sum of the variances of each of these effects as expressed by the following equation:

$$\sigma_c = \sqrt{\sigma_S^2 + \sigma_T^2 + \sigma_I^2} \qquad \text{(D-6)}$$

where

σ_c = standard deviation of sample means about the true mean considering the combined accuracies of the sampling and measurement methods.

σ_S^2 = variance due to the spatial sampling method

σ_T^2 = variance due to the temporal sampling method

σ_I^2 = variance due to measurement instrumentation and its use.

Thus, we need to identify the variance (standard deviation squared) of the spatial, temporal and measurement influences on the survey results.

Confidence limits for the spatial sampling component were chosen as a criterion for identifying the required sample size as thoroughly discussed in Section D.3. These 95 percent confidence limits about the sample mean were ±5 dB for the Class I survey and ±2 dB for the Class II survey. As explained earlier in Section D.2.2, the distribution of many estimates of the true mean value will closely approximate a normal distribution. This being the case, the selected 95 percent confidence limits will represent approximately two sample standard deviations from the mean as was shown in Figure D-2. Thus, the standard deviation of sampled means, due to the spatial sampling scheme, will equal half this value, or 2.5 dB for a Class I survey and 1 dB for a Class II survey.

The standard deviation about the sample mean due to the accumulated temporal factors discussed in previous sections of this appendix must be approximated. Several independent temporal elements have been previously considered; for example: the 95 percent confidence limits in sampling the L_{eq} of 20 minutes of environmental sound with samples approximately 15 seconds apart are about ±1 dB, and the 95 percent confidence limits in an hourly L_{eq}, based on a 20-minute sample of measurements approximately 15 seconds apart, are about ±1.6 dB. Based on these and the other available temporal data discussed in Section D.4, a conservative estimate of the standard deviation due to the combined effect of the temporal sampling influences on a sample mean L_{dn} has been chosen as 1.5 dB. The choice of this value will be supported later in this appendix when overall results from two previous community noise surveys are discussed.

In order to complete the accuracy calculation, consideration must be given to instrument and instrument reading error. In this case, a reasonable assumption is that the standard deviation in field sound level meter readings will be ±1 dB. Using this and the above values, we can calculate the composite standard deviation from Equation (D-6) as follows:

For a Class I Survey:

$$\sigma_S = 2.5 \qquad \sigma_c = \sqrt{2.5^2 + 1.5^2 + 1.0^2}$$

$$\sigma_T = 1.5 \qquad = 3.1 \text{ dB, and 95 percent confidence limits are}$$

$$\sigma_I = 1.0 \qquad \text{approximately } 2\sigma_c \approx \underline{6 \text{ dB.}}$$

For a Class II Survey:

$$\sigma_S = 1.0 \qquad \sigma_c = \sqrt{1.0^2 + 1.5^2 + 1.0^2}$$

$$\sigma_T = 1.5 \qquad = 2.1 \text{ dB, and 95 percent confidence limits are}$$

$$\sigma_I = 1.0 \qquad \text{approximately } 2\,\sigma_c \approx \underline{4 \text{ dB.}}$$

These confidence limits have been used throughout the manual text, and appear conservative when considered in light of the following results.

Two previous studies have produced results tending to indicate that the survey confidence limits developed in this appendix are adequately conservative for the noise zones encountered in the sizes of city for which this manual is intended. A previous community noise survey in Boise, Idaho,[23] shows extremely good correspondence between mean L_{dn} values determined with 20-minute measurements at randomly distributed sites and with continuous 24-hour measurements at other distributed sites, as indicated in Table D-7. The variations are well within the confidence limits developed above for the sample sizes used.

The previous community noise survey conducted in a portion of Torrance, California,[24] shows similar results. In one area of the city, 65 sites in predominantly residential areas were each sampled for 20 minutes using a sound level meter according to the procedures presented in this manual. The mean L_{eq} over all 65 sites was 58 dB. Then, four independent sub-samples of nine sites each were drawn at random from the 65, and mean L_{eq} values calculated. The results are shown in Table D-8. For three of the

Table D-7

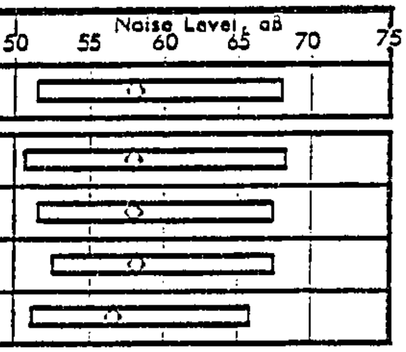
Differences Between Mean L_{dn} Values Measured with 24-Hour Equipment and Manual Methods[23]

Land Use	24-Hour Measurements		20-Minute Measurements		Absolute L_{dn} Difference
	No.	Mean L_{dn}	No.	Mean L_{dn}	
Residential	5	52.5 dB	170	53.7 dB	1.2 dB
Arterial < 6000 ADT	3	58.0 dB	6	54.2 dB	4.2 dB
Central Business District	1	65.7 dB	5	66.4 dB	0.7 dB

Table D-8

Differences Between Mean Values of a Large Sample and Sub-Samples of Community Noise Measurement Sites[24].

Zone(s)	Percent Sample	Number of Sites	Noise Level, dB
ALL	100	65	
ALL	14	9	
ALL	14	9	
ALL	14	9	
ALL	14	9	



Notation: Noise levels are the arithmetic average over sites in each zone of the temporal metric indicated.

four cases, agreement between the partial and total samples is within 0.5 dB, with approximately 1.5 dB deviation for the last sub-sample. This very good agreement between the mean of a small sample of randomly selected sites measured according to the 20-minute sound level meter procedure and a true population mean serves to further support the confidence intervals developed in this appendix as conservative indications of the survey accuracy.

D.6 Basis for the Source Sampling Method Given in Appendix B

The desirable sample size for establishing any regulatory noise limit L^x with specified confidence limits, $\pm\Delta$, expressed as a percentage, can be computed from Equation (D-4) given earlier. Thus, for a 95 percent degree of confidence ($t \simeq 2$) and a confidence interval of ± 2 percent, the level not to be exceeded by more than 5($\pm$2) percent of a population, can ideally be estimated from the L^5 level measured on a sample size (n) of 475. That is, from Equation (D-4),

$$n = \left(\frac{2}{2/100}\right)^2 (5/100)\,(1 - 5/100) = 475.$$

Thus, if the total population size is 20,000 units, one expects that 5 percent of these units (1000) will exceed the L^5 level estimated by the sample and one is 95 percent sure that the actual number of units exceeding this limit may differ from 1000 by no more than ± 2 percent of 20,000 or ± 400.

Clearly, this indicates a large relative error in the sample so when it is necessary to satisfy a sampling accuracy criteria in terms of the relative error ($100\,\Delta/x$) of the sample, the sample size n, for 95 percent confidence, is approximately equal to

$$n \simeq 4\,\frac{(1 - x/100)}{(x/100)}\,(x/\Delta)^2 \qquad \text{(D-7)}$$

where ($100\Delta/x$) is the desired relative accuracy, in percent, of the sample. If a relative accuracy criteria for the sample of 20 percent is imposed, $100\Delta/x = 20$ percent and the sample size n is

$$n \simeq (4)\,\frac{(1 - 5/100)}{(5/100)} \cdot (100/20)^2 = 1900 \text{ units.}$$

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APPENDIX E

NOISE SURVEY DATA REDUCTION BACKGROUND

E.1 Introduction

This appendix provides background supportive material for selected data reduction procedures given in the manual text. It has been supplied for the benefit of those not sufficiently familiar with community noise measurement so that they might develop a better understanding of the underlying factors in the data reduction process and hence aiding in the interpretation of the survey and its results. The two data reduction procedures discussed are used in Section 4 of this manual and are defined in more detail here for the benefit of the reader.

E.2 L_{dn} Calculation Procedure

The primary objective of the survey procedures given in the manual is to determine the most likely L_{dn} value to be found at any randomly selected location throughout a noise zone. Based on the results of many previous community noise studies,[1,2] it has been found that the statistical distribution of spatial variation in outdoor noise levels within the same general land use area is roughly a normal distribution curve. Even where mixed land use is involved, when the sample is large, an approximately normal distribution is found.* Figure E-1 shows an example of such data—a distribution of L_{10} noise levels measured from 10 minute samples during the same hour over several weeks at 946 separate locations in one county and covering all types of land use.[2] In this case, the histogram is closely approximated by a theoretical normal distribution curve indicated by the dashed lines. Thus, for our sample of L_{dn} values spatially distributed throughout a noise zone, the best estimate of the "correct," "true," or most likely L_{dn} value in the zone will be the numerical average or mean of the sample values.[4] Applying this, the data reduction procedures given in Chapter 4 of the manual have been developed to

* Recent work has shown that a more accurate description of the spatial distribution of outdoor noise levels is given by a Gamma distribution[3] however, for purposes of this manual, a normal distribution for spatial variation is an adequate approximation.

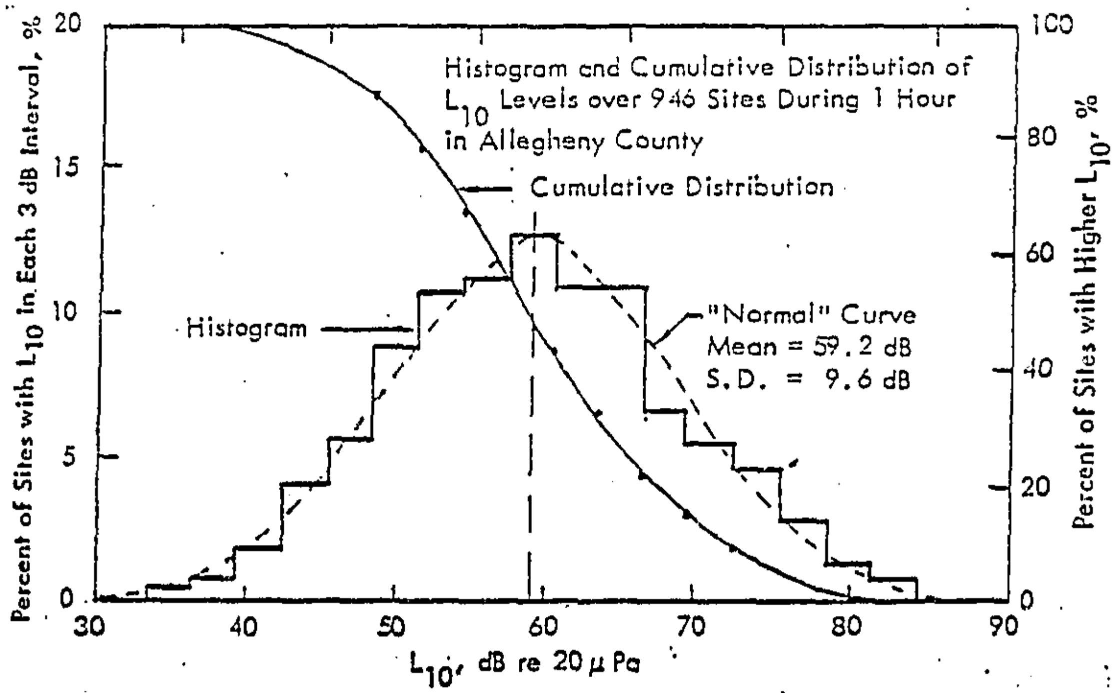

Figure E-1. Histogram and Corresponding Cumulative Distribution Illustrating a Case with a Normal Distribution of Spatial Samples (Data From Reference 2) include a numerical averaging technique for combining values of various metrics (L_{dn}, L_x, etc.) from sites within the noise zones.

The hand calculation method given for averaging the L_{dn} values is a simplified method which yields identical values to those that would result from a rigorous calculation averaging the L_{dn} values determined for all sites based on their week and weekend measurements. The variation is that two separate L_{dn} values are calculated for each site—one for the five day work week and one for the weekend. Each of these values are then arithmetically averaged over all sites within a noise zone, and the resulting mean values are then energy averaged using weightings proportionate to the week and weekend time spans to define a best estimate of the mean L_{dn} for a given noise zone. This method reduces the amount of hand calculation necessary by eliminating the weighted average calculation from the handling of each site.

E.3 Railroad Data Reduction Procedure

For community noise survey purposes, the manual assumes that railroad activities will be the dominant source establishing the L_{dn} value for the narrow railroad noise zone defined along railroad routes. Given this, the determination of L_{dn} values in the zone due to railroad operations is all that is required of the noise measurements. This determination is based on a combined predictive and measurement method derived from previous railroad noise studies.[5,6] The self-adjusting method presented in manual Section 4.4 is outlined in Figure 4-8, and is embodied in Figures 4-14, 4-15 and 4-16, the origins of which will be briefly described. The reader should become completely familiar with these figures and their use before proceeding.

As outlined in Figure 4-13, the self-correction process involves first predicting the overall L_{dn} of typical railroad lines using Figure 4-14. The maximum noise levels of the engine and rail cars are then predicted from Figure 4-15. These same levels are then measured and an overall correction factor ΔL computed for the train noise L_{dn}. This correction is determined from the differences between the predicted and measured engine and rail car noise levels respectively with the aid of Figure 4-16. Finally, this overall correction factor is then applied to the predicted L_{dn} for the train obtained earlier from Figure 4-14 to provide a final corrected L_{dn} value for the train noise.

The L_{dn} values given in Figure 4-14 were analytically developed based on the measured engine and car data with considerations for train length and speed.[5] The results are then normalized to a distance of 31 m (100 ft). Several offsetting conditions, (such as the increases in noise level accompanied by decreases in passby duration which both result with increasing train speed) allowed treatment of the time factors involved in the definition of L_{dn} such that expected L_{dn} values could be developed simply from the numbers of day and night train operations. It is this particular formulation that is the basis for the entire railroad data reduction procedure. The maximum engine and rail car noise levels in Figure 4-15 are typical values based exclusively on extensive measured train operation sound level data.[5] The values shown reflect typical measured values of the maximum noise levels as a function of distance from the rail line and of speed for the rail cars. Railroad engine noise tends to be approximately independent of speed since the entire manual procedure for assessing L_{dn} values due to train operations employs survey data taken at railroad sites in the community to adjust the predicted levels from Figures 4-14 and 4-15. The final L_{dn} determined for each site is not sensitive to the accuracy of the typical noise attenuation curves in Figure 4-15 as the method self-adjusts for the typical local train sound levels and attenuation along the particular track-to-site path.

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APPENDIX F

NOISE SURVEY COST CONSIDERATIONS

F.1 Introduction

This appendix presents background for the noise monitoring program cost and manpower requirements given in Schedule 2-B. This is used in Chapter 2 of the manual to incorporate costs into the final program design. It must be borne in mind, however, that regardless of the method and data used, prediction of the costs of a one-time technical effort such as a community noise monitoring program involves many significant uncertainties. Because of these, initial estimates can be in error by as much as 100 percent, and it is recommended that the program manager frequently review expenditures and update projected completion costs in view of ongoing program experience.

Uncertainties in the cost prediction process stem principally from the fact that no two communities will approach the establishment, design, administration, and execution of the measurement program in exactly the same way. Individual variations in availability and use of field personnel, funding allocation procedures, administration, equipment procurement and supply procedures, etc., will vary appreciably with the total program effort required. An additional factor critical to administrative efficiency is whether the program will be executed through or under the auspices of an existing municipal agency, or whether the effort must be undertaken by a new organizational entity. Hence, to the cost estimations used for program planning in Chapter 2, one must apply corrections to accout for variations in local approaches.

The estimates of required man-hours and costs which are given in Schedule 2-B have evolved from experience with several monitoring programs of this type. These estimates should be considered as the <u>minimal</u> expenditure required. For a well administered program, managed by a person thoroughly familiar with all procedures, and backed by a cooperative city administration, the activities for most program phases can be completed within the estimated costs or labor man-hours. Man-hour uncertainties for the phases indicated in Schedule 2-B as "Preparation and Planning," "Data Analysis," and "Report Preparation" are particularly acute as these activities can not be entirely specified in the manual and are quite subject to local administrative procedures. An additional uncertainty affecting the listed estimates for "Data Acquisition" is weather. Periods of bad weather can easily double the required field time when field personnel are able to measure only one or two sites per excursion. These delays estend program duration with resulting increases in program costs.

The basis for the estimates provided in Schedule 2-B are given in the next two sections of this appendix. Despite the approximate nature of this information, it will be quite useful to city planners in establishing the scope of resources required to implement a measurement program.

F.2 Bases for Basic Noise Survey Labor Estimates Given in Schedule 2-B

Preparation and Planning	Estimated No. of Man-Hours Class I	Class II
Select and organize project staff, locate and set-up quarters, obtain basic supplies	56	60
Identify Monitoring Program Objectives (Section 2.2), establish municipal contacts and interview appropriate officials	64	80
Select Preliminary and Final Survey Methods (Sections 2.3, 2.4), identify available resources and extra-municipal assistance programs, design program	40	100
Total Hours:	160	240
Data Acquisition		
Estimate Noise Zone Boundaries (Section 3.2), obtain data and prepare base map	120	120

	Estimated No. of Man-Hours	
	Class I	Class II
Selection Noise Measurement Sites (Section 3.3), complete mapping procedures	16	24
Assign Measurement Team (Section 3.4, Step 1), identify low cost employment programs, interview, etc.	32	72
Organize equipment handling procedures (Section 3.4, Step 2) and prepare field packets	24	48
Train field personnel (Section 3.4, Steps 3 and 4)	8	32
Perform Measurements (Section 3.4, Step 5), based on five basic noise zones, 55 individual measurements for Class I and 247 for Class II, nominally six measurements per day; and including one and two day's time for filing and sorting are assumed.	80 (10 days)	336 (42 days)
Document procedures (Section 3.4, Step 6); this will consume time in an ongoing manner	8	24
Total Hours	288	656

Data Reduction

Basic Data Reduction (Section 4.2) based on time required for noise surveys in Boise, Idaho and Allentown, Pennsylvania. Assumes computerized data reduction for Class II Survey.	72	56
Total Hours	72	56

Data Analysis

Comparison of acoustical data with complaint histories, enforcement records, and local knowledge to determine the most heavily impacted areas and most important noise

	Estimated No. of Man-Hours	
	Class I	Class II
sources. Discussions with municipal agencies to determine feasible noise reduction measures	165	280
Total Hours	168	280
Other Materials and Costs		
Office supplies, mileage allowances, minor equipment, map and manuscript reproduction, etc.	\$500	\$1500
Report Preparation		
Writing, reviewing, and printing	80	160
Total Hours	80	160

F.3 Bases for Noise Survey Extra Feature Estimates Given in Schedule 2-B

	Estimated No. of Man-Hours	
	Class I	Class II
Extra Feature A. Calculation of L_{90}	40	N/A*
This calculation must be carried out for each site, thus, becomes lengthy.		
Extra Feature B. Calculation of L_1	4	N/A
Assumes Extra Feature A has been completed first.		
Extra Feature C. Comparison L_1 with L_{dn}	4	N/A
Assumes Extra Feature A has been completed first.		
Extra Feature D. Determination of Common Noise Sources	40	N/A
Data reduction, tallies including each individual data sheet must be made.		

* N/A items automatically included in computerized data reduction for Class II Survey.

	Estimated No. of Man-Hours	
	Class I	Class II
Data Analysis, comparison of data for various important noise sources in each noise zone, devising feasible noise reduction measures	40	N/A
Total Hours	80	

Extra Feature E, Extra Noise Zones	Class I	Class II
Preparation and planning, selection, mapping, sample drawing.	8	8
Data Acquisition, based on the large sample required for commercial or industrial areas, at six measurements per day.	24	128
Data Reduction, based on the requirements per noise zone for the basic survey.	16	8
Data Analysis, based on the requirements per noise zone for the basic survey	32	48
Total Hours	80	192

Extra Feature F, Stationary Source Noise Zone

Preparation and Planning, selection of sources for which to define zones, field survey to identify zone boundaries, mapping, sample selection	16	16
Data Acquisition, based on the large sample required for commercial or industrial noise zones, sampling rate of six per day	24	128

	Class I	Class II
Data Reduction, based in requirements per noise zone for the basic survey	16	8
Data Analysis, based on the requirements per noise zone for the basic survey	32	48
Total Hours	88	200
Extra Feature H, Impact Evaluation		
Data Acquisition, collect census data.	N/A	8
Data Reduction, determine census tract population densities, noise zone population, and equivalent noise impact values.	N/A	64
Data Analysis, consider impact values in conjunction with complaint data, noise level values, and source contributions to determine principal noise problems and solutions	N/A	16
Total Hours		88

* This item not recommended for Class I Survey