CHARLES E. DARE
R. L. CARSTENS
APRIL 1973

FINAL REPORT
ISU–ERI–AMES–73039

CEDAR RAPIDS I-380:

FREEWAY NOISE, MULTIPLE LAND USE, AND AESTHETICS STUDY

Submitted to the City of Cedar Rapids

ERI Project 1000-S

ENGINEERING RESEARCH INSTITUTE
IOWA STATE UNIVERSITY
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The conclusions and opinions expressed in this document are those of the investigators and not necessarily those of the City of Cedar Rapids Planning and Redevelopment Department.

1. INTRODUCTION

The primary objective of this study was to determine the environmental impact of Interstate Highway I-380 on certain residential areas of Linn County, Iowa, through which the freeway will pass. The factors of traffic noise level, multiple land use potential, and freeway corridor aesthetics were of particular concern in these analyses.

This study was conducted with the premise that the freeway design had been essentially established and accepted; and that the recommendations evolving from this investigation would primarily pertain to areas immediately outside the I-380 right-of-way. The freeway design is documented in the report entitled the Cedar Valley Expressway, (1), although several changes have been incorporated in the ultimate design with regard to interchange configuration and service road location.

The recommendations contained in this report are intended to serve as guidelines for the Cedar Rapids Department of Planning and Redevelopment as they strive to make the freeway more compatible with its surroundings. In addition to this report, two other items were prepared and submitted to the Planning and Redevelopment Department under separate cover. Substantial effort was expended in developing a scroll map (Scale 1 inch equals 200 feet) showing the predicted traffic noise levels along the freeway corridor for the design year. A supplemental or technical report was also prepared containing a model municipal noise ordinance and a documentation of the noise level prediction techniques.

2. SCOPE OF THE PROJECT

This investigation included a comprehensive review of previous reports concerning the urban highway noise problem, multiple land use and joint development projects along freeways, and the principles of freeway corridor aesthetics. These previous investigations, as well as the fundamentals of acoustics, are summarized in Chapter 3 of this report. Readers already familiar with those subjects may wish to forego detailed study of Chapter 3. Activities performed during this investigation are described in Chapter 4, and recommendations to the City appear in Chapter 5.

2.1 Summary of Project Activities

To achieve the goals of this investigation, seven major activities were carried out:

1. A survey was conducted to evaluate the reaction of residents to a recently constructed freeway in Iowa. The I-235 corridor in Des Moines and West Des Moines was the subject of this study phase. The survey included a mail-out and return questionnaire as well as personal interviews.
2. A request for information was sent to highway and transportation agencies to obtain current data regarding policies and practices for controlling noise from freeways, experiences related to multiple land use and joint development projects, and techniques used for creating an aesthetically pleasing roadside.
3. Existing noise levels were recorded at several locations in Cedar Rapids close to and in the I-380 corridor. These data indicated the noise exposure level of residents at this time and provide some basis for estimating the influence of the new freeway on community noise.

4. Predictions were calculated for the traffic noise levels to be anticipated along the I-380 corridor during peak traffic flow periods of the design year, 1994. These analyses were carried out to the extent of providing noise estimates at all adjacent property lines, and typically for a distance of two blocks into the surrounding residential areas on each side of I-380. Traffic noise estimates were developed along the corridor from a location approximately 2,000 feet north of County Road 78 in Linn County to a location about 400 feet north of Emmons Street in Hiawatha, Iowa, excluding a central area in Cedar Rapids extending from 2nd Ave., S.W. to 10th Street, N.E.
5. Three separate field reconnaissance trips were taken by study personnel along the I-380 corridor to assist in developing rational land use recommendations.
6. In view of the land use planning reports, transportation studies, neighborhood development programs, urban renewal programs and other information obtained for this study, specific multiple land use or joint development projects were evaluated for their suitability along the I-380 route.
7. An evaluation of current traffic noise legislation and its potential influence on urban traffic noise was performed. Several federal, state, and municipal noise regulations were obtained and reviewed for their applicability and influence on this project.

The results of each aforementioned activity appear in Chapter 4.

2.2 Summary of Recommendations

The following recommendations were formulated as a result of the reviews of previous investigations and the activities performed in this study:

1. Adoption of a strict motor vehicle noise control ordinance.
2. Recommendations concerning general land use programs.
3. Recommendation of a specific policy prohibiting truck stop facilities in residential areas.
4. A suggested freeway corridor beautification program.
5. A suggested study of fringe area parking lot-freeway transit service for the I-380 corridor.
6. Noise control provisions to be incorporated in subdivision and building codes.
7. Traffic noise abatement procedures for each section of the I-380 corridor.

The seven recommendations are discussed in detail in Chapter 5.

3. PREVIOUS STUDIES AND GENERAL BACKGROUND

The previous research and field studies pertinent to a proper evaluation of the I-380 corridor in Cedar Rapids are presented in this section. Major topics to be considered are the basic principles of sound generation, traffic noise characteristics, multiple land use along freeways, freeway aesthetics, and the general impact of the urban freeway on the urban community.

3.1 Sound and Traffic Noise

A fundamental knowledge of acoustics, the science of sound, is essential background for a meaningful assessment of any traffic noise situation. To best serve the purpose of this report, only those aspects of acoustics associated with the generation, measurement, and impact of vehicular sound are presented.

3.1.1 The Nature of Sound

Sound may be defined as "the sensation perceived by the sense of hearing." In order for a sound to be generated, transmitted and heard, three elements must be present, namely: the source, the transmitting medium, and a receiver. The sound source could be a vibrating object, such as a violin string or radio speaker. The medium most commonly employed for transmitting sound is air, our familiar atmosphere. The receiver is usually a human eardrum, but could be an electronic measuring device such as a sound level meter.

A basic characteristic of sound is that its generation depends on the source establishing a very small air pressure differential that varies from the normal pressure of the surrounding atmosphere. (Normal air pressure is about 14.7 pounds per square inch.) The vibratory activity of a sound source will create a series of air pressure differentials, which will rapidly alternate between being higher than, and then lower than the normal atmospheric pressure. In reality, sound may be generated from any source which causes an air pressure differential of the proper magnitude. This requirement is met by most objects moving through air, as a moving vehicle; or a blast of constrained gas emitted at a high velocity from an exhaust pipe.

Once the air pressure differential is created by the source, it is transmitted through the medium by virtue of the fact that the pressure differential will radiate through our atmosphere. In essence, the original air pressure differential starts a series of similar pressure differentials which are propagated much like a "chain reaction."

As the air pressure differentials travel away from the source, their strength gradually dissipates with increasing distance. Upon striking a human eardrum, pressure differentials of the correct magnitude will impart a vibration to the eardrum. These vibrations in turn stimulate the sensitive hearing mechanisms of the middle and inner ear. The sensation of "hearing the sound" is finally achieved when nerve impulses are received in the brain from the inner ear.

It is important to recognize that sound tends to become omnipresent due to the manner in which it is transmitted, radiated, and reflected through the atmospheric medium. It is this characteristics which limits the effectiveness of an obstacle or barrier placed between the source and the receiver for the purpose of intercepting the sound.

3.1.1.a The Sound Wave

To describe the movement of sound through air, a sound that is known as a pure tone will be illustrated. The air pressure variations associated with a pure tone are related to distance from their source as shown in Figure 3.1. In actuality the pressure variations form a regular and slightly decaying pattern as they fluctuate around the normal reference pressure, P_{ref}. A sound

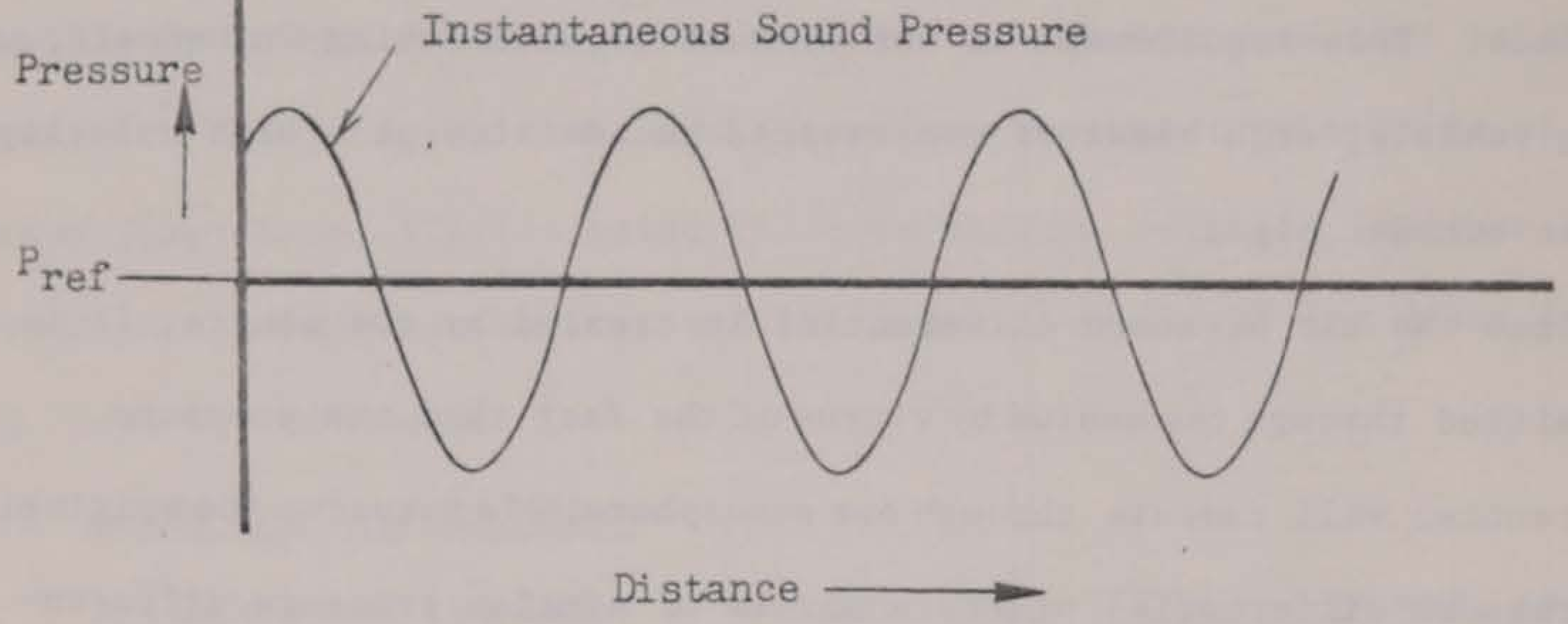


Figure 3.1 SOUND PRESSURE PATTERN FOR A PURE TONE

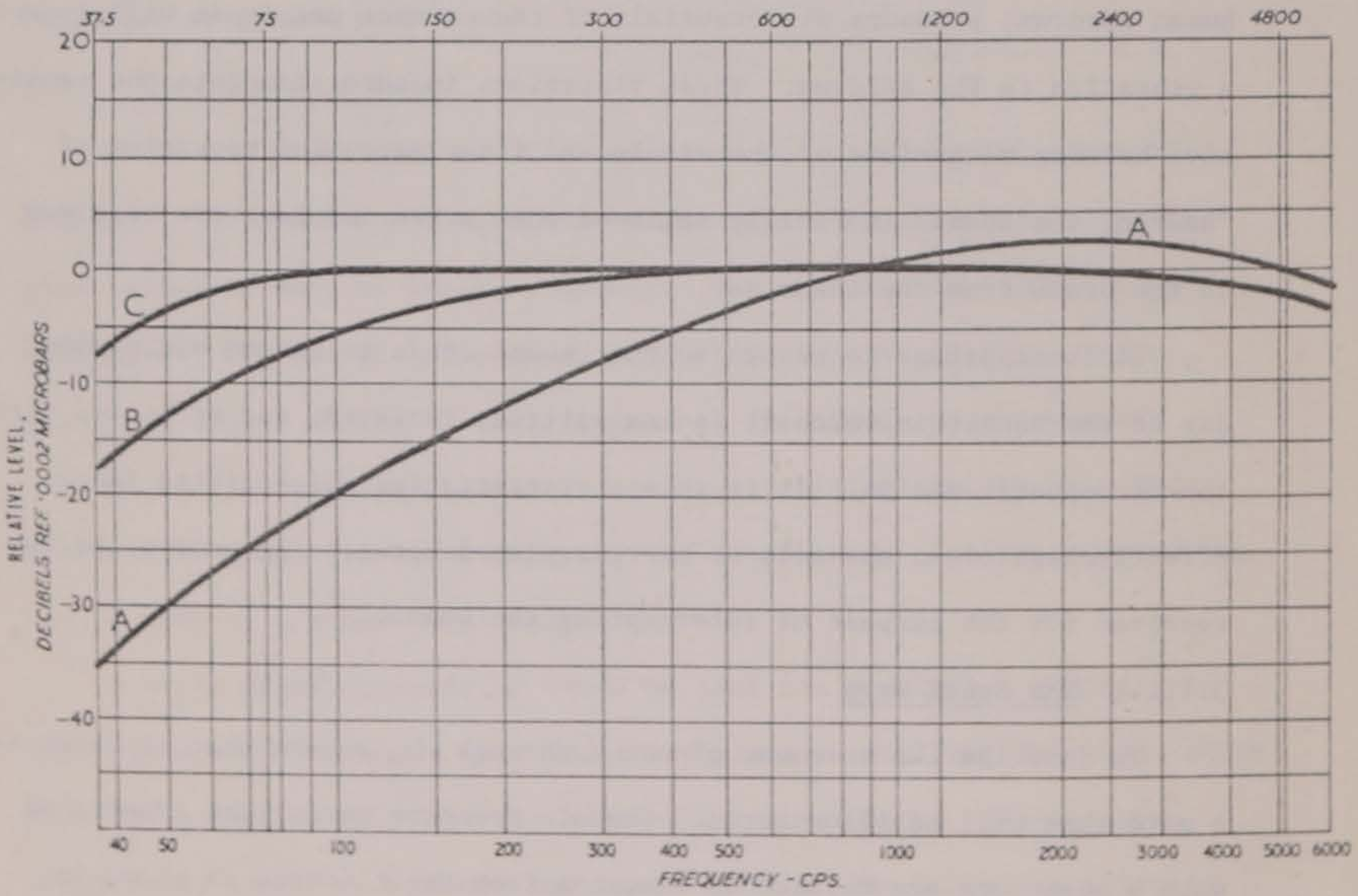


Figure 3.2 SOUND LEVEL WEIGHTING NETWORKS
(Source: Warring, R. H., Handbook of Noise and Vibration Control, First Ed., Trade and Technical Press, Ltd.)

pressure wave possesses a measurable intensity depending on the deviation between p and p_{ref}. One scale that is used to measure air pressure variations is the "microbar" which is approximately one-millionth of normal atmospheric pressure. The lowest detectable pressure variation for a person with normal hearing is usually a pressure of 0.0002 microbar. The characteristic of sound pressure is important since it is the primary contributor to the perceived "loudness" of a sound.

Another basic characteristic of a sound wave is the rapidity with which the "peaks and valleys" are created. This property is known as the frequency of the sound. Until recently, frequency was expressed in terms of cycles per second (cps). The new standard unit for frequency is the "hertz" abbreviated Hz., and one Hz. corresponds to one cps. The human ear is sensitive to a wide range of sound frequencies. Depending on the individual, the lowest audible frequency is about 20 Hz., while the highest audible frequency is approximately 20,000 Hz. The frequency of a sound primarily determines the characteristic known as its "pitch."

3.1.2 The Decibel (dB)

Due to the extremely large range of the physical characteristics of sound in our environment, it has been found convenient to utilize a simplified, yet meaningful, scale for measuring sound pressure levels. The decibel, abbreviated dB, is the scale commonly employed for measuring sound pressure. The decibel is a ratio between two sound levels, one level being an established reference level. Mathematically, the decibel may be expressed as in Equation 1:

$$\text{Sound Pressure Level (in dB)} = 20 \text{ Log}_{10} \frac{P}{P_{ref}} \qquad \text{(Eq. 1.)}$$

where P is the perceived sound, and P_{ref} is a reference sound. In the decibel computation P_{ref} is the pressure level associated with the threshold of hearing. Thus, the decibel compares a perceived sound to the faintest sound that may be heard by a person with normal hearing. Table 3.1 illustrates the relationship that exists between effective sound pressure level in microbars and decibels, and it is apparent that the decibel is a much more convenient scale. Further relationships existing among sound sources, decibel levels, human responses and conversational equivalents are shown in Table 3.2.

It is beyond the scope of this discussion to fully document all of the reasons for using the dB in measuring sound pressure levels; however, it has been verified by numerous researchers that the dB scale meaningfully describes human responsiveness to the vast range of sound levels in our environment. One basis for this finding is that the decibel equation entails a logarithmic operation, and this is the manner in which the ear responds to perceived sound waves.

On the decibel scale a sound level change of at least 2 dB is necessary before the human ear may be capable of detecting any change in the sound. A rapid change of 3 dB from one sound level to another is usually detectable by the human ear, while a change of 5 dB is a clearly identifiable sound level change for those with normal hearing. By reference to Table 3.1 it may be seen that an increase in sound level of 20 dB represents a multiplication of effective sound pressure level by a factor of 10, and that an increase of 40 dB represents a multiplication of effective sound pressure level by a factor of 100.

3.1.2.a Frequency Content of Sound

As shown earlier, a pure tone radiating from a single source will have a simple wave form. The wave form will be consistent and repetitive, so that it is possible to speak of the frequency of the wave. In most situations

Table 3.1. RELATIONSHIP BETWEEN DECIBELS AND EFFECTIVE SOUND PRESSURE LEVEL.

Effective sound pressure level, micro bars	Sound pressure level, decibels (dB)
10,000.0	154
1,000.0	134
100.0	114
10.0	94
1.0	74
0.1	54
0.01	34
0.001	14
0.0002	0

Table 3.2. SOUND SOURCES, DECIBELS, HUMAN RESPONSES, AND CONVERSATIONAL EQUIVALENT.

Sound source	Noise level, dB(A)	Human response criteria	Conversational equivalent
Carrier deck jet operation	140		
		Painfully loud	
	130	Limit amplified speech	
Jet takeoff (200 ft)	120	Discomfort threshold	
discotheque			
Auto horn (3 ft)			Maximum vocal effort
Riveting machine	110		
Jet takeoff (2000 ft)			
	100		Shouting in ear
N.Y. subway station		Very annoying	
Heavy truck (50 ft)	90	Hearing damage (8 hrs)	Shouting at 2 ft
Pneumatic drill (50 ft)			
	80	Annoying	Very loud conversation at 2 ft
Freight train (50 ft)			
Freeway traffic (50 ft)	70	Telephone use difficult	Loud conversation at 2 ft
		Intrusive	
Air conditioning unit (20 ft)	60		Loud conversation at 4 ft
Light auto traffic (50 ft)			
	50	Quiet	Normal conversation at 12 ft
Livingroom			
Bedroom	40		
Library			
	30	Very quiet	Soft whisper at 15 ft
Broadcasting studio	20		
Leaves rustling	10	Just audible	
	0	Threshold of hearing	

a person will be receiving sounds from several sources simultaneously, or one source might be emitting sounds of differing frequency content. Each sound wave and each frequency within each sound wave will contribute to the total sound level perceived by the observer.

Electronic devices (sound level meters) are available for measuring the frequency content of sound and assessing the contributions of the different frequencies to the overall sound pressure level. At least three weighting systems (2) are commonly employed in sound frequency analyses and the characteristics of these weighting networks, designated the A, B, and C networks, are shown in Figure 3.2. Each weighting network emphasizes frequencies in a slightly different manner in order to arrive at a final composite of all frequencies denoted as being a certain sound level in decibels. Of the three networks, the A-scale has become the most commonly used in relation to traffic noise studies since its frequency response characteristics most closely correspond to the manner in which the human ear perceives sound. Both the ear and the A-scale emphasize the frequencies in the range from 1,000 to 6,000 Hz. Conforming to the practice of designating which scale was used to weigh the sound frequencies, decibel levels cited herein should indicate the network used in parenthese, such as dB(A), for an A-scale reading.

3.1.3 Sound and Noise

A sound which is not desired by the receiver becomes a noise to that individual. Sound and noise are identical in terms of physical definitions and acoustical characteristics. The human element, however, establishes the existence of a noise, and this judgment varies considerably among individuals. What might be a highly irritating 90 decibel noise to one individual, could be completely acceptable to another person, if the sound happened to be from a favorite record playing on a stereo.

3.1.4 Ambient Noise

Ambient or background noise level is important in determing the impact of a noise radiating from a specific source. Ambient noise may be viewed as the "all encompassing noise present at a given location, usually consisting of a combination of background noises from sources both near and far." Typical community ambient noise levels (3) are shown in Figure 3.3, where it is indicated that ambient noise can range from 41 to 55 dB(A) during the daytime in urban residential areas and from 61 to 73 dB(A) in commercial zones with heavy traffic. Of course, these levels would vary from day to day and from one community to another.

The importance of ambient noise level may be illustrated by the following:

> If the receiver of a noise radiating from a specific source, as a passing automobile, is situated in an environment with a high ambient noise level, he may not be able to detect the sound from that source. On the other hand, if the same vehicle were to pass when the ambient noise level was rather low, it is likely that the vehicular noise would be considered an annoying intrusion.

3.1.5 Combining Noise Levels

The total sound, or noise, existing at a location represents a simultaneous combination of sounds from many sources. The total noise level perceived at a specific urban property may be determined by evaluating the sound from each source and combining the decibels from each to yield a composite decibel rating. The procedure for combining decibels, however, is not a straightforward algebraic summation of individual decibel levels. That is, a sound of 80 decibels superimposed on another sound of 80 decibels does not yield a total sound level of 160 decibels. Actually,

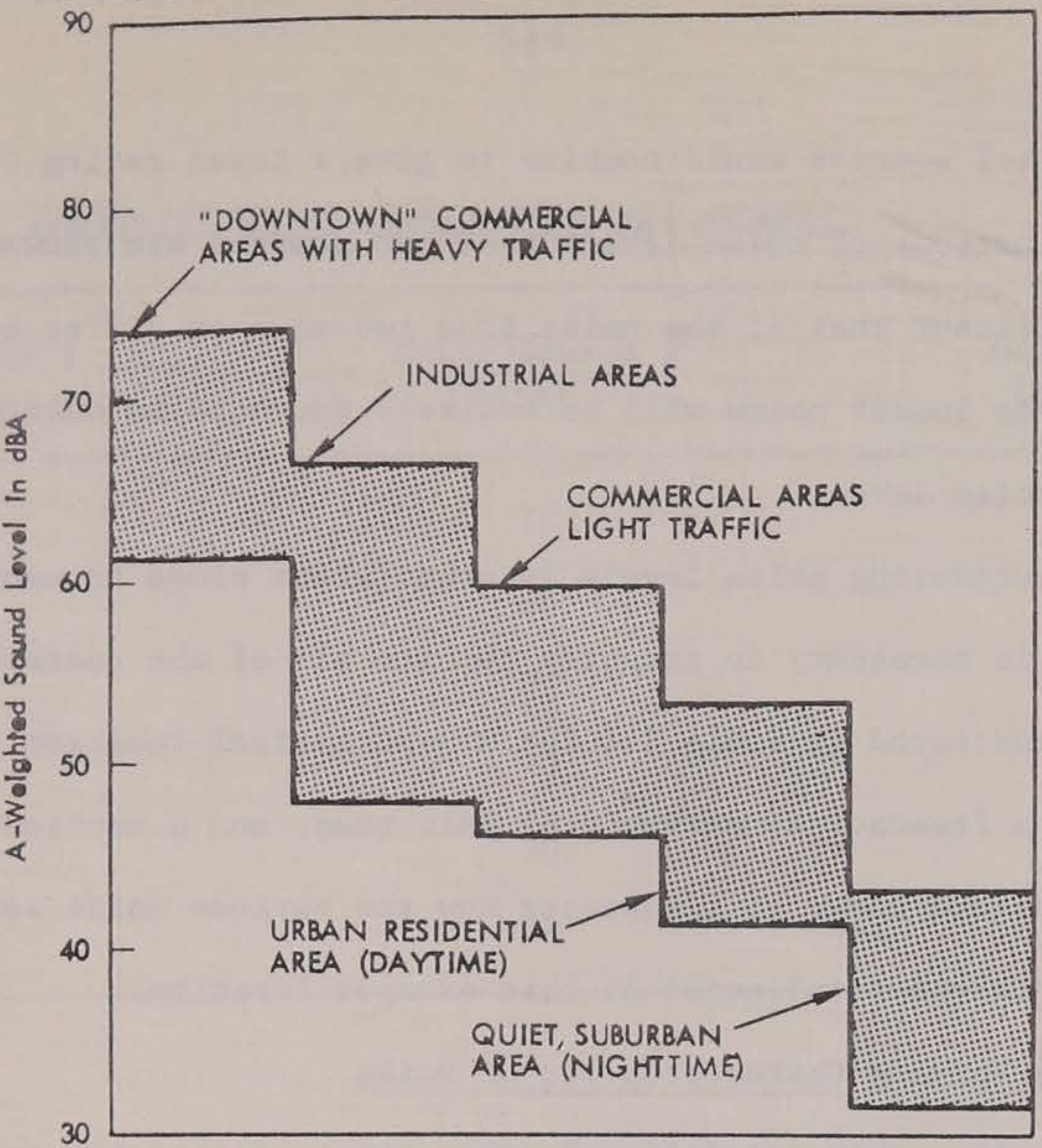


Figure 3.3 TYPICAL AMBIENT NOISE LEVELS (Source: Bolt, Beranek, and Newman, Highway Noise: A Design Guide for Highway Engineers, NCHRP 117.)

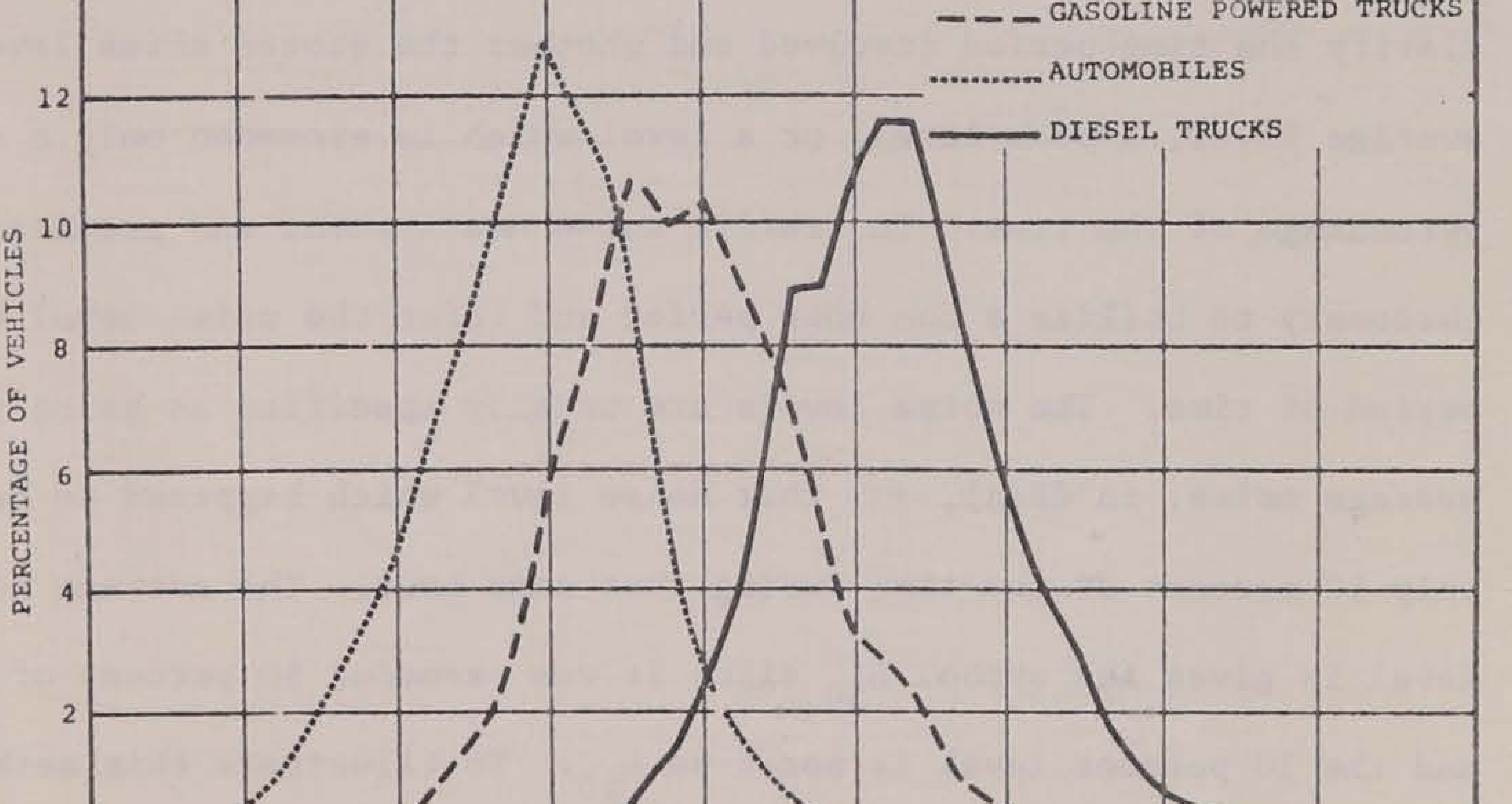


Figure 3.4 DISTRIBUTION OF MEASURED NOISE LEVELS FOR THREE TYPES OF VEHICLES (Source: Serendipity Inc., A Study of the Magnitude of Transportation Noise Generation and Potential Abatement, Vol. IV.)

two 80 decibel sources would combine to give a total rating of 83 decibels. Other combinations of noise levels from two sources are shown in Table 3.3. It is significant that if the noise from two sources differ by about 10 decibels, the louder noise will be entirely dominant in determining the total noise level.

When estimating noise levels in urban areas close to many noise sources it is necessary to properly combine all of the contributory sources. This is illustrated in Table 3.4 for a hypothetical location which receives noise from a freeway, an entrance or exit ramp, and a service road. The computations are shown to illustrate how the various noise sources might contribute to the total noise at this example location.

3.1.6 Time-Varying Characteristics of Noise

One obvious characteristic of urban noise, especially traffic noise, is that it is subject to large fluctuations as time passes. It is therefore, difficult, if not impossible, to state that the noise at a specific property is exactly "X decibels." Some futher explanation is required to clarify the time period involved and whether the quoted noise level is an average level, a peak level, or a level which is exceeded only a certain percentage of the time. In traffic noise measurement and prediction it is customary to utilize a one hour period and refer the noise level to that period of time. The noise levels are usually specified as being the average noise, in dB(A), or that noise level which happened to be exceeded only 10 percent of the time during that same hour. The average noise level is given the symbol L_{50} since it was exceeded 50 percent of the time, and the 10 percent level is noted as L_{10}. To illustrate this method for describing noise exposure, a hypothetical set of data is provided in Table 3.5. These data are assumed to be the results of 300 sound level meter observations taken during a one hour period. The noise level ranges from

Table 3.3. COMBINING NOISE LEVELS FROM TWO SOURCES.

Noise source 1 dB(A)	Noise source 2 dB(A)	Combined noise level dB(A)
60	70	70.4
62	70	70.6
64	70	71.0
66	70	71.5
68	70	72.1
70	70	73.0

Table 3.4. EXAMPLE OF COMBINING NOISE LEVELS FROM SEVERAL TRAFFIC SOURCES.

Example location number	Noise sources decibel contribution and computations			Total noise level, dB(A)
	Freeway	Ramp	Service road	
I	68.0	60.0	60.0	
	68.0 + 60.0 = 68.6			
		68.6 + 60.0 =		69.1
II	68.0	65.0	60.0	
	68.0 + 65.0 = 69.8			
		69.8 + 60.0 =		70.4
III	68.0	65.0	65.0	
	68.0 + 65.0 = 69.8			
		69.8 + 65.0 =		71.0
IV	68.0	68.0	65.0	
	68.0 + 68.0 = 71.0			
		71.0 + 65.0 =		72.0
V	68.0	68.0	68.0	
	68.0 + 68.0 = 71.0			
		71.0 + 68.0 =		72.8

Table 3.5. SAMPLE NOISE LEVEL DISTRIBUTION.

Observed value, dB(A)	Number of times observed	Cumulative number of observations	Cumulative percent of observations
76	3	3	1
75	3	6	2
74	12	18	6
73	33	51	17 > Includes → L_{10}
72	54	105	35
71	60	165	55 > Includes → L_{50}
70	45	210	70
69	36	246	82
68	30	276	92
67	18	294	98
66	6	300	100

66 up to 76 dB(A). The average level, L_{50}, would be one of the 71 dB(A) readings, and that level which was exceeded only 10 percent of the time would be: L_{10} = 73 dB(A).

The L_{10} level is important in determining traffic noise impact since it is a reasonable approximation of the peak noise level reaching a property. Also, when L_{10} is compared to L_{50} an indication is gained regarding the variability of the noise at the site.

3.1.7 Traffic Noise

The sounds produced by vehicles operating on highways vary considerably according to the type and age of the vehicles, their operating speed, the roadway gradient and surface (4, 5). Figures 3.4 and 3.5 show the results of several studies which evaluated the noise generated by different vehicle types. It is indicated that the noise radiating from all vehicles, especially passenger cars, increases with operating speed. Also, it is evident that for these data that the noisiest automobiles were not as loud as the average diesel truck. Since the noise generation characteristics of major vehicles types are so widely different, separate discussions of the noise created by trucks, automobiles, buses, and motorcycles will be presented.

3.1.7.a Truck Noise

Two types of truck engines are in common use, the diesel and the gasoline engine. Diesel engines create high noise levels regardless of their operating speed, while gasoline powered trucks tend to be quieter than the diesel especially at low to medium speeds.

Figure 3.6 illustrates the frequency analysis of diesel trucks under three operating conditions measured at a 50 foot distance (5). Of the three conditions for a typical diesel truck it is apparent that the accelerating mode of operation, which yields 92 dB(A), is far noisier than the average

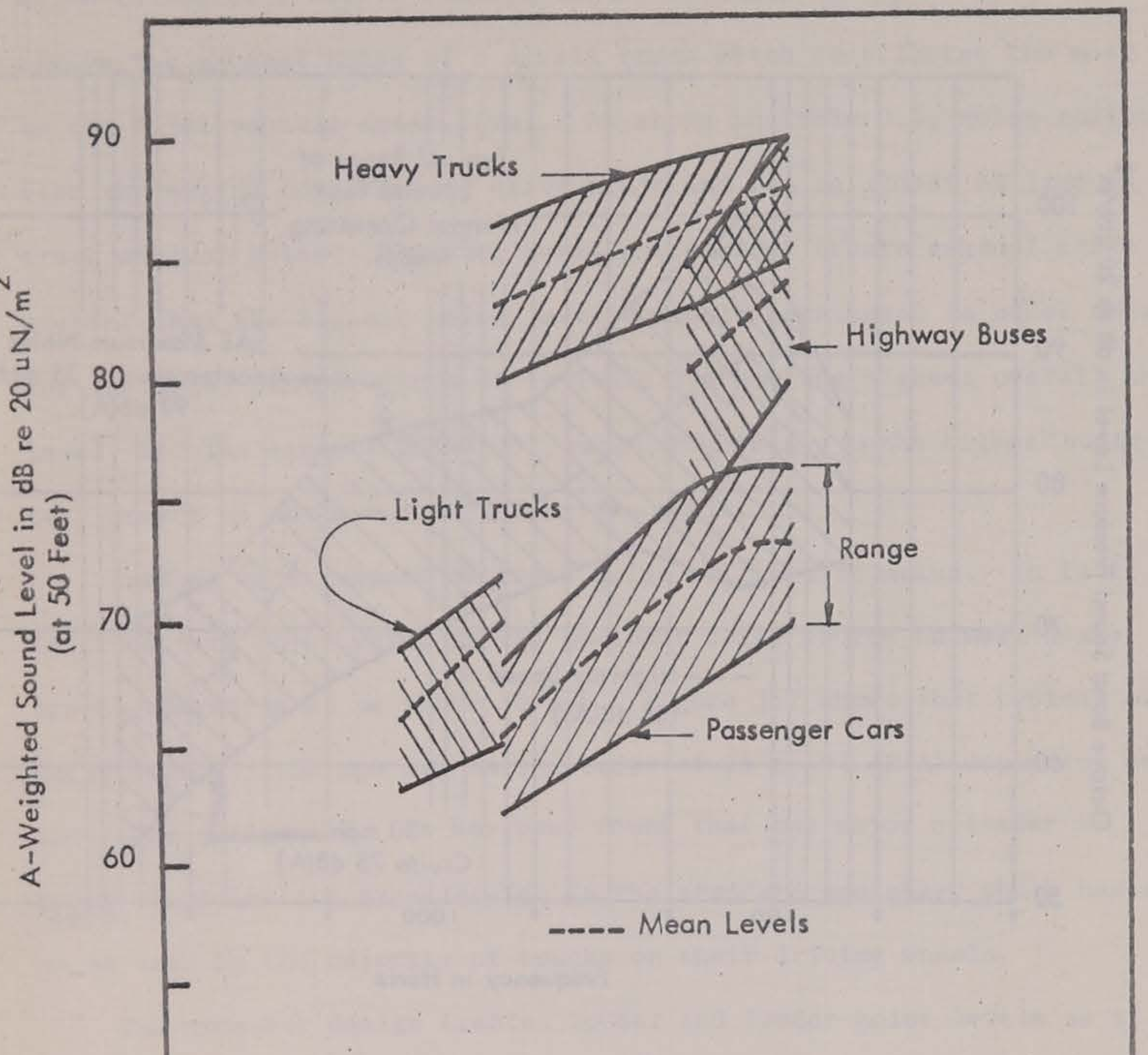


Figure 3.5 NOISE OUTPUT FROM INDIVIDUAL VEHICLES AS RELATED TO SPEED (Source: Wyle Laboratories, Transportation Noise and Noise From Equipment Powered by Internal Combustion Engines, Prepared for U.S.E.P.A.)

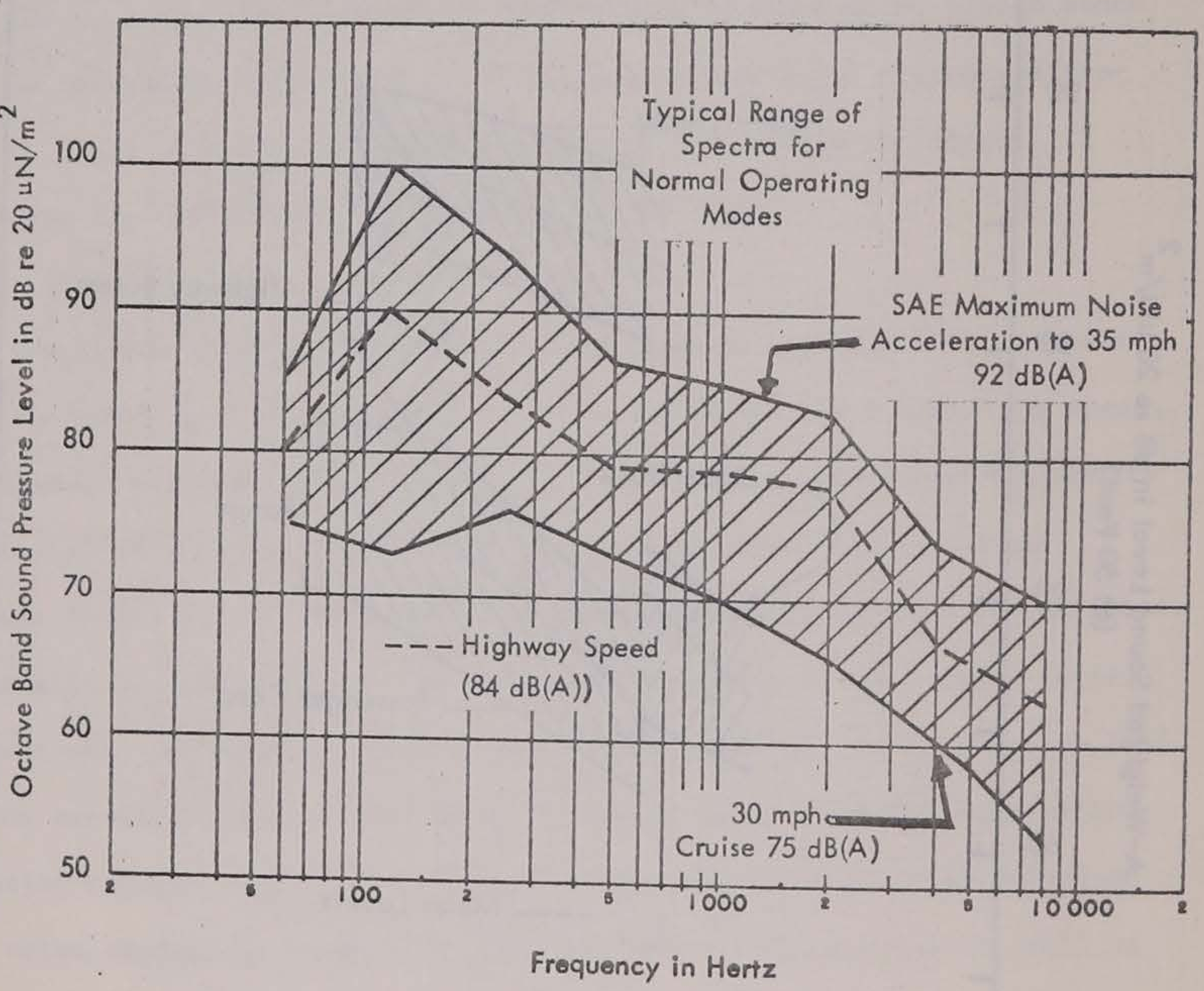


Figure 3.6 NOISE OUTPUT FROM INDIVIDUAL DIESEL TRUCKS
(Source: Wyle Laboratories, ibid.)

highway condition (constant velocity) where the noise is 84 dB(A). Several components of the vehicle contribute significantly to the overall noise rating of a diesel truck. Contrary to popular opinion, it is not always the exhaust noise of a diesel truck which contributes the most to the total vehicle noise level. As shown in Table 3.6, noise radiating from the engine compartment, drive train and fan is almost as loud as the truck exhaust noise. However, certain trucks do create exhaust noise far greater than the highest noise level commonly attributed to other sources. For instance, Example Truck #7 in Table 3.6 has the highest overall noise level, and its exhaust noise (5), rated at 86 dB(A), is the highest contributory source of any shown in the entire table.

Another major aspect of truck noise is the tire noise. In fact, it is truck tire noise which is the dominant noise source on most heavy trucks operating at or above 50 mph. Figure 3.7 shows that typical tire noise levels at 50 mph are on the order of 75 to 94 dB(A) depending on the tread design (5). It has been found that the major offender in terms of truck tire tread design is the standard crossbar, which happens to be used by the majority of trucks on their driving wheels.

The crossbar design creates louder and louder noise levels as it becomes worn, and as shown in Figure 3.7 when half-worn it generates 86 dB(A) at 50 mph at 50 feet. The retread tires used in the trucking industry exhibit even more undesirable characteristics, creating noise levels over 92 dB(A) at 50 mph at 50 feet.

3.1.7.b Automobile Noise

Although not as noisy as trucks on an individual vehicle basis, the contribution of automobiles to environmental noise is substantial due to their large numbers. To complicate the situation automobiles tend to become noisier as they become older especially if the exhaust system is

Table 3.6. EXAMPLES OF DIESEL TRUCK NOISE COMPONENT CONTRIBUTIONS TO MAXIMUM NOISE LEVELS AT 50 ft FROM VEHICLE[a].

Truck examples	Contributing subsource				Total vehicle noise level, dB(A)
	Engine mechanical	Exhaust	Intake	Cooling fan	
#1	81	84	75	82	88
#2	85.5	81	74	81	87.5
#3	83	86	80	81	89
#4	85	82	80	83	89
#5	83	83	72	78.5	87
#6	81	77	70	82	85.5
#7	82.5	86	79	82	89.5
#8	85	82	80	83	89
#9	83	83	72	78.5	87
#10	81	77	70	82	85.5
#11	83.5	82.5	74	78	87

[a] E.P.A., Transportation noise and noise from equipment powered by internal combustion engines, Dec. 1971.

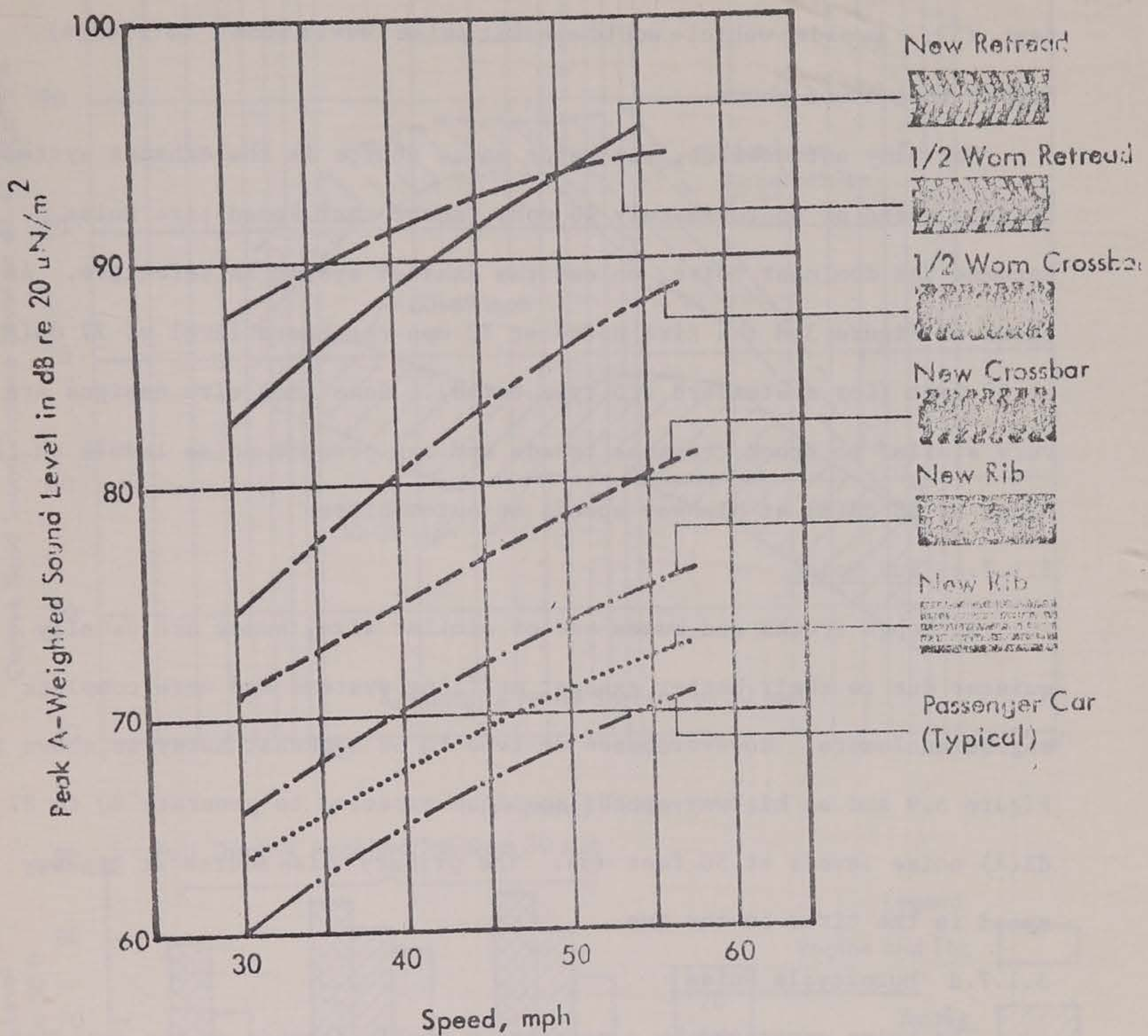


Figure 3.7 EFFECT OF TIRE TREAD DESIGN AND WEAR FOR VARIOUS TIRES MOUNTED ON THE DRIVE AXLE. Loaded Single Chassis Vehicle Operating on Concrete Road Surface Measured at 50 Feet. (Source: Wyle Laboratories, ibid.)

poorly maintained. Figure 3.8 is a frequency analysis of a typical passenger car operating under differing conditions at a distance of 50 feet (5). An older vehicle would exhibit noise levels from 2 to 3 dB(A) higher than those shown.

For many automobiles, the major noise source is the exhaust system up to a speed of approximately 40 mph. Above that speed tire noise becomes the dominant noise, unless the exhaust system is defective. As shown in Figure 3.8 the tire noise at 70 mph reaches a level of 77 dB(A) at 50 feet (for a standard rib type tread). Some snow tire designs are very similar to truck crossbar treads and can produce noise levels on the order of 85 dB(A) at highway speeds on automobiles.

3.1.7.c Bus Noise

Although trucks and buses are of similar size, buses are usually quieter due to their better exhaust muffling systems and more complete engine enclosure. However buses do tend to be somewhat noisy as shown in Figure 3.9 and at highway speeds could be expected to generate 80 to 87 dB(A) noise levels at 50 feet (5). The primary noise source at highway speed is the tires on the bus.

3.1.7.d Motorcycle Noise

The noise generated by a motorcycle highly depends on the speed of operation and whether or not the vehicle is accelerating. These tendencies are shown in Figure 3.10, where it also is indicated that the motorcycle noise exceeds 100 dB(A) at 50 feet during the acceleration test (5). At 60 mph the motorcycle approaches the noise levels created by the larger diesel trucks, over 90 dB(A) at 50 feet.

3.1.8 Traffic as a Line Source of Noise

Previous discussions have dealt with noise generated by single vehicles in which case the noise is assumed to radiate from a "point" source. When the traffic flow on a highway becomes dense, the noise

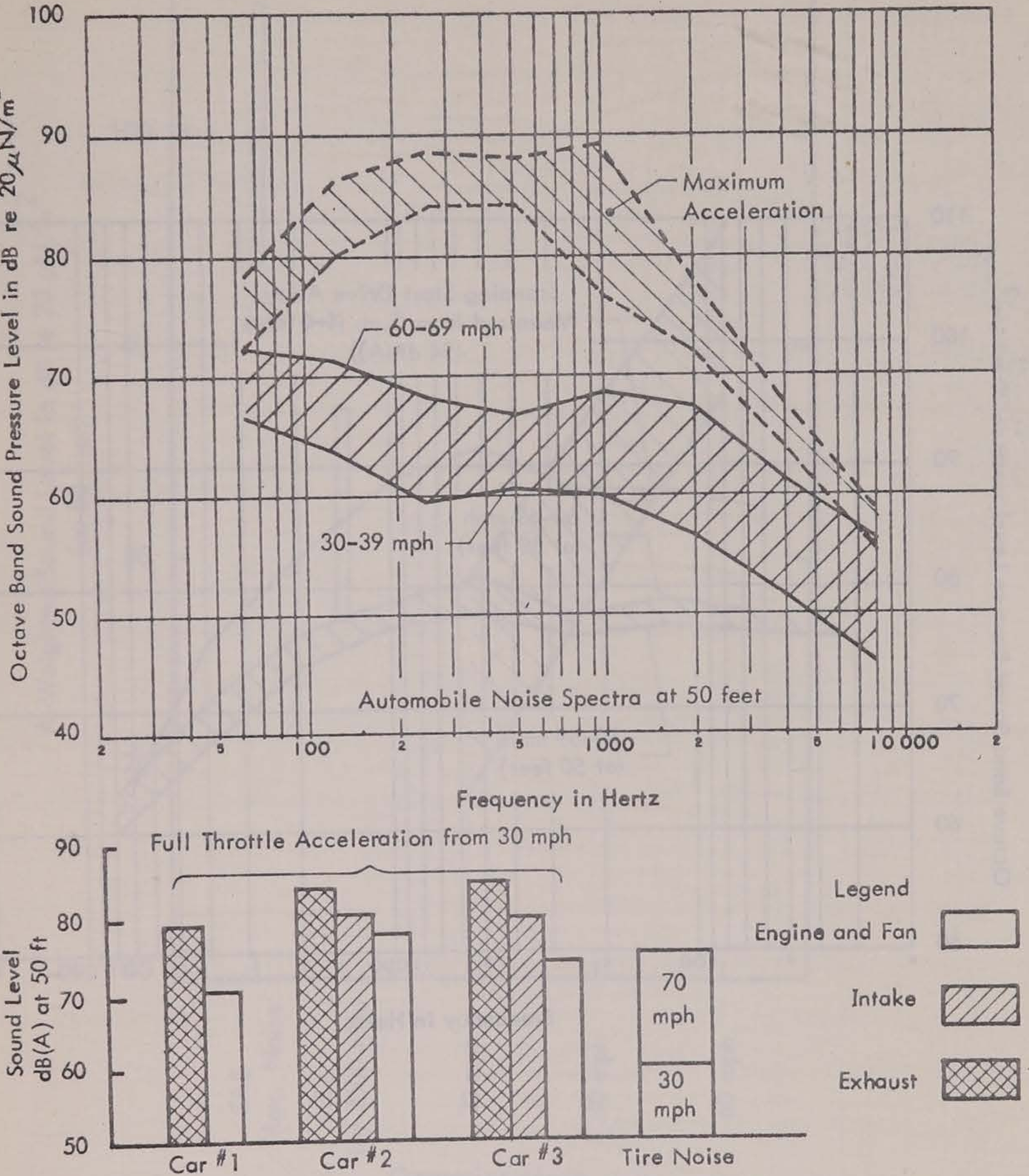


Figure 3.8 NOISE OUTPUT FROM INDIVIDUAL PASSENGER CARS
(Source: Wyle Laboratories, ibid.)

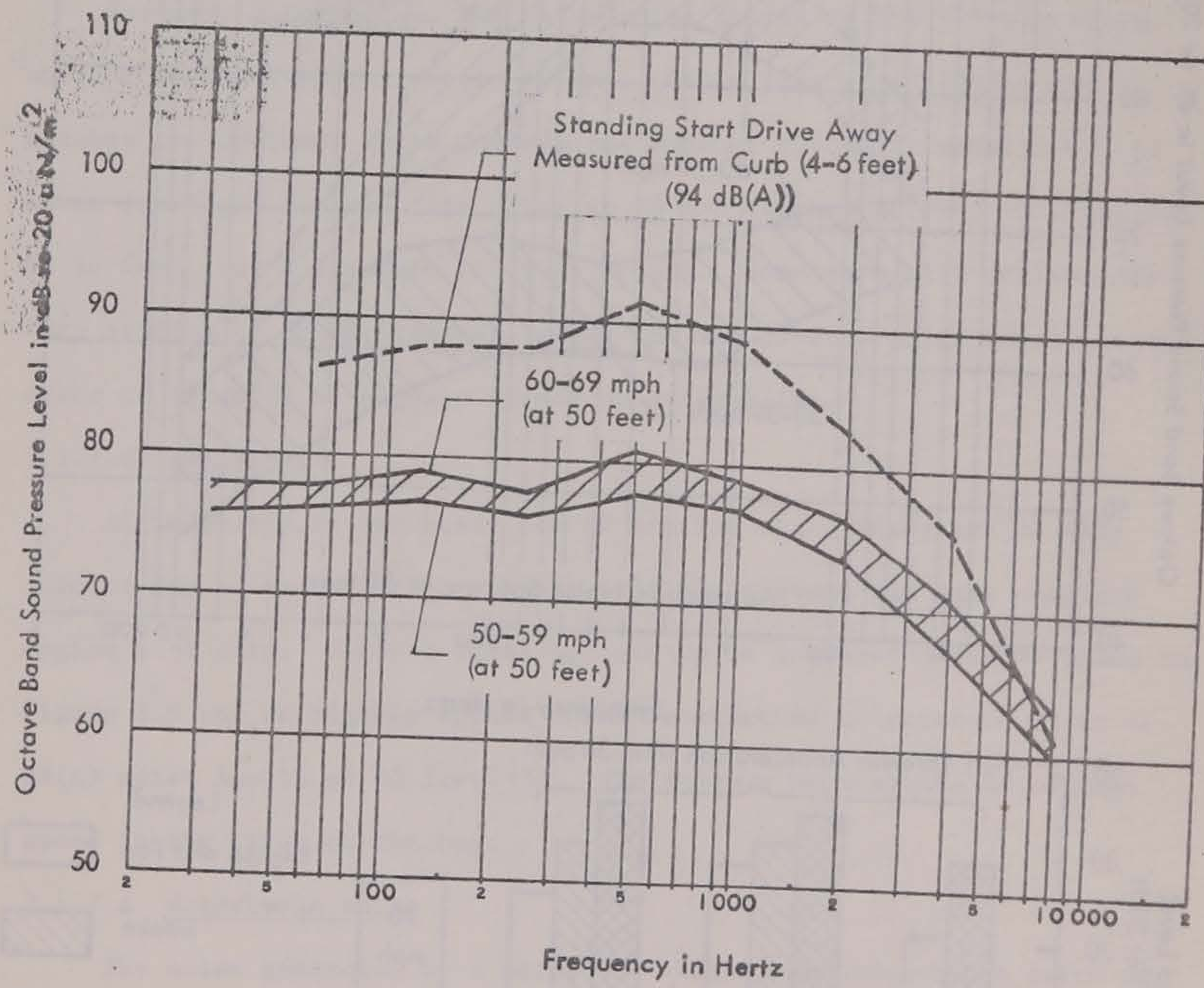


Figure 3.9 NOISE OUTPUT FROM INDIVIDUAL HIGHWAY BUSES
(Source: Wyle Laboratories, ibid.)

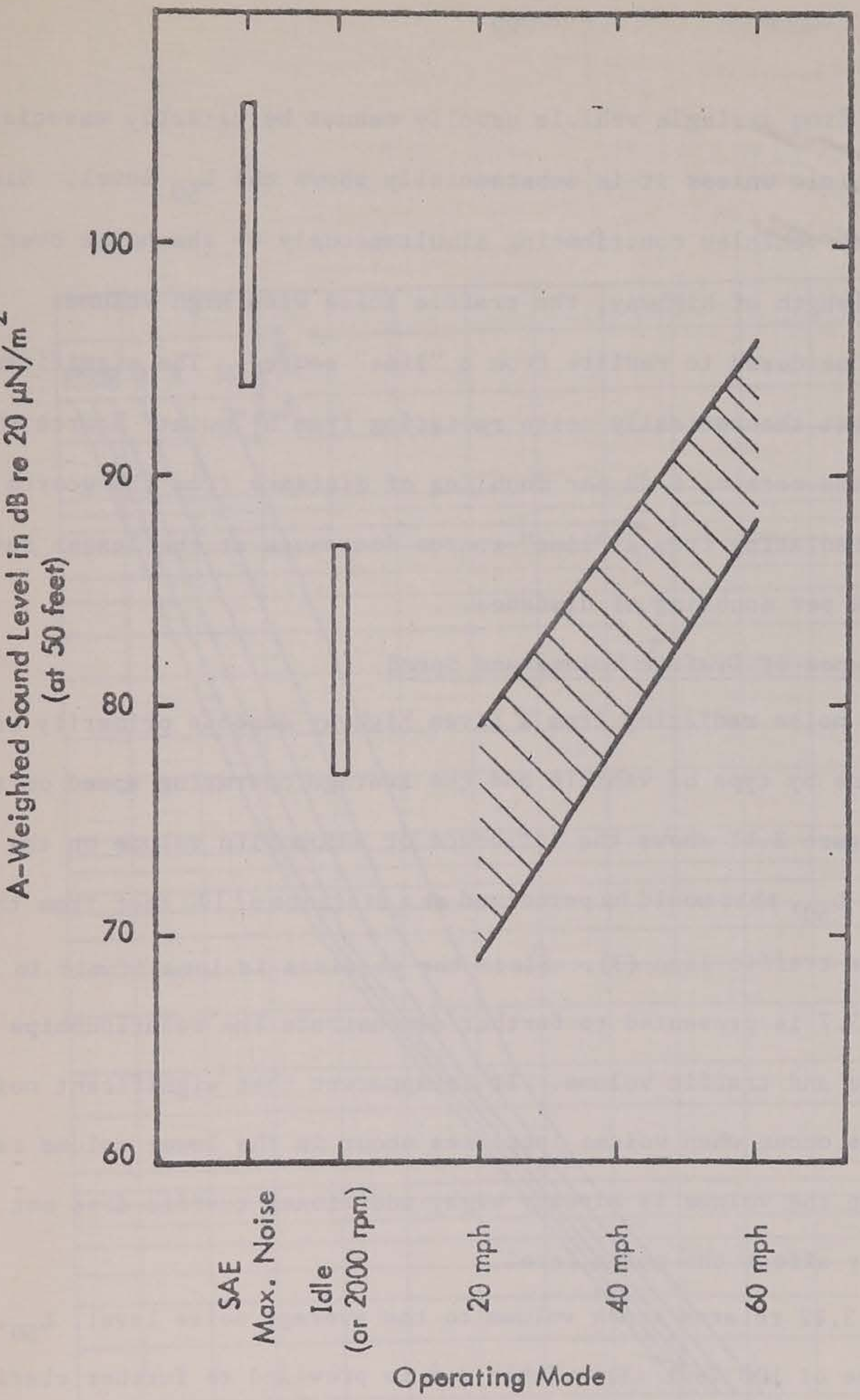


Figure 3.10 NOISE OUTPUT FROM INDIVIDUAL MOTORCYCLES
(Source: Wyle Laboratories)

contribution from a single vehicle usually cannot be directly associated with that vehicle unless it is substantially above the L_{50} level. Since there are many vehicles contributing simultaneously to the noise over a substantial length of highway, the traffic noise with high volumes present is considered to radiate from a "line" source. The significance of this is that theoretically noise radiating from a "point" source will decrease at the rate of 6 dB per doubling of distance from the source, while noise radiating from a "line" source decreases at the lesser rate of about 3 dB per doubling of distance.

3.1.9 Influence of Traffic Volume and Speed

Traffic noise radiating from a given highway depends primarily on the vehicle volume by type of vehicle and the average operating speed on that highway. Figure 3.11 shows the influence of automobile volume on the average noise level, L_{50}, that would be perceived at a distance of 100 feet from the center of the traffic lane (3). Since the abscissa is logarithmic in Figure 3.11, Table 3.7 is presented to further demonstrate the relationships between noise and traffic volume. It is apparent that significant noise level changes occur when volume increases occur in the lower volume range. However, when the volume is already high, additional traffic does not substantially affect the noise level.

Figure 3.12 relates truck volume to the average noise level, L_{50}, at a distance of 100 feet (3). Table 3.8 is provided to further clarify the influence of truck volume. Similar to the situation with automobiles, there is a marked influence in noise level when truck volume increases in the lower volume range; and with truck volume already high, additional trucks added to the traffic flow have diminishing influences on the noise level. A comparison of Tables 3.7 and 3.8 reveals the fact that it requires a flow of almost 1,000 automobiles per

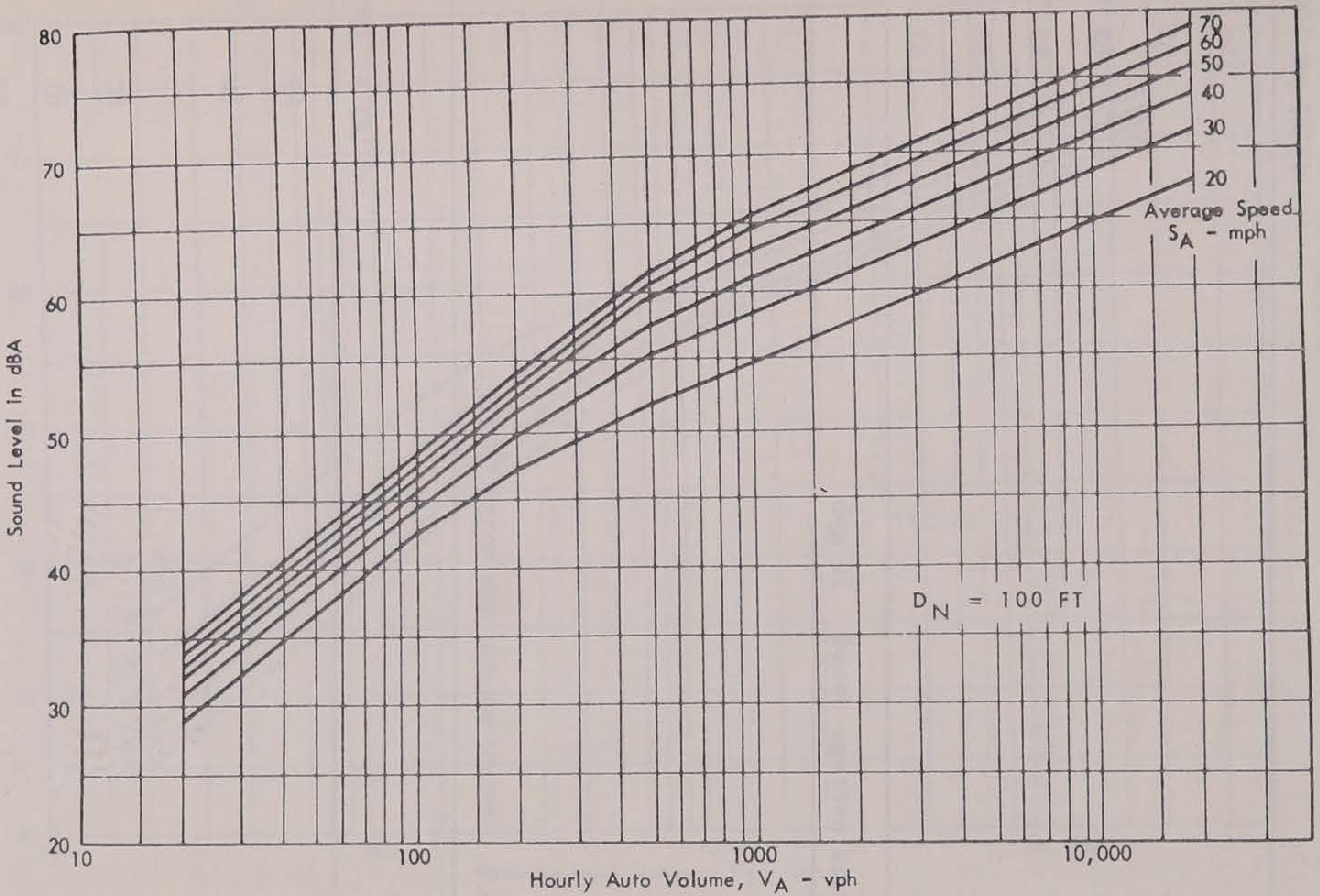


Figure 3.11 AVERAGE NOISE LEVELS FROM AUTOMOBILES AS RELATED TO VOLUME AND SPEED (Source: Bolt, Beranek, and Newman, ibid.)

Table 3.7. AUTOMOBILE VOLUME AND NOISE LEVEL.

Automobile volume, vph	dB(A) at 100 ft[(a)]
100	46
500	59
1000	63
1500	65
2000	66
2500	67

(a) Assumed average speed: 50 mph

Table 3.8. TRUCK VOLUME AND NOISE LEVEL.

Truck volume, vph	dB(A) at 100 ft[(a)]
100	62
500	74
1000	78
1500	80
2000	81
2500	82

(a) Assumed average speed: 50 mph

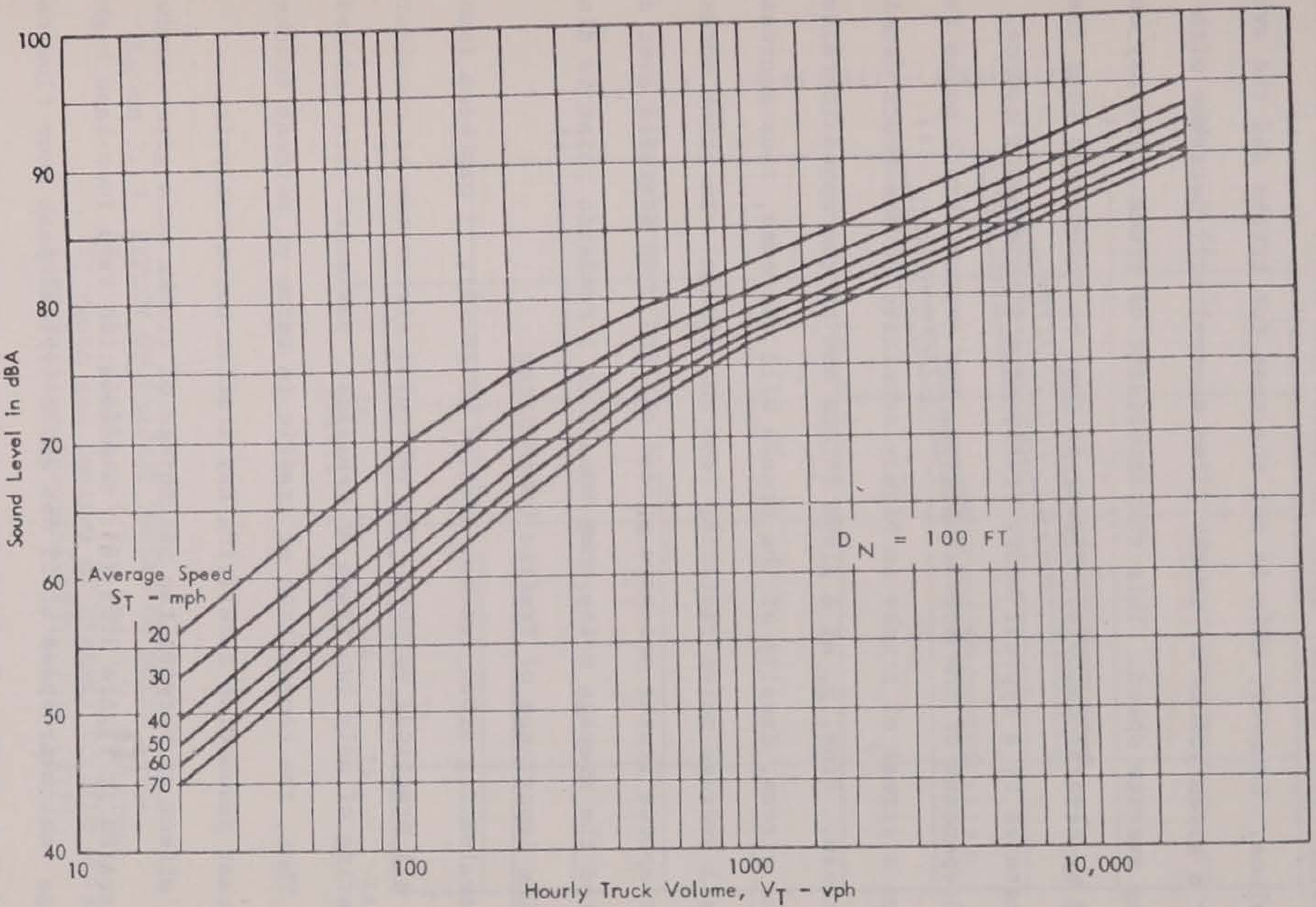


Figure 3.12 AVERAGE NOISE LEVEL FROM TRUCKS AS RELATED TO VOLUME AND SPEED
(Source: Bolt, Beranek, and Newman, ibid.)

hour to equal the average noise generated from only 100 trucks per hour.

The influence of vehicular speed on average noise radiating from a traffic lane is also shown in Figures 3.11 and 3.12. It is clear that as automobile (line source) speed increases the noise level will increase at any volume. However, this is not the case for trucks and the average noise for a given volume of trucks (line source) will decrease with increasing average speed. This characteristic of truck noise may be explained by several factors. First, it must be remembered that the noise generated by a typical heavy truck, as a single point source, is almost independent of the speed. Second, the average truck noise radiating from a stream of trucks is highly sensitive to the truck density in the stream. Finally, at a given volume and as the speed increases within the stream, density of the trucks will decrease, thus decreasing the overall average noise radiating from the stream. In other words, at higher speeds trucks are more spread out and when measured over a long time period the average noise they impart to a roadside point is diminshed.

3.1.10 The Importance of Traffic Composition

In evaluating urban freeway traffic noise (3), it has been found that for all practical purposes the vehicular stream may be considered as consisting of only two types of vehicles: passenger cars and heavy trucks. Thus, the composition of traffic in terms of percent trucks is an important assumption underlying any traffic noise analysis.

The effect of varying the percentage of trucks on a given roadway is illustrated in Figure 3.13 (6). The location is a four-lane highway with an average vehicular speed of 55 mph and a typical peak hour flow rate (Level of Service C). It is indicated that both the L_{10} and L_{50} dBA levels are substantially influenced by the percent trucks present. For instance, L_{10} at 200 feet increases from 69 dBA for 0% trucks up to 77 dBA for 15% trucks.

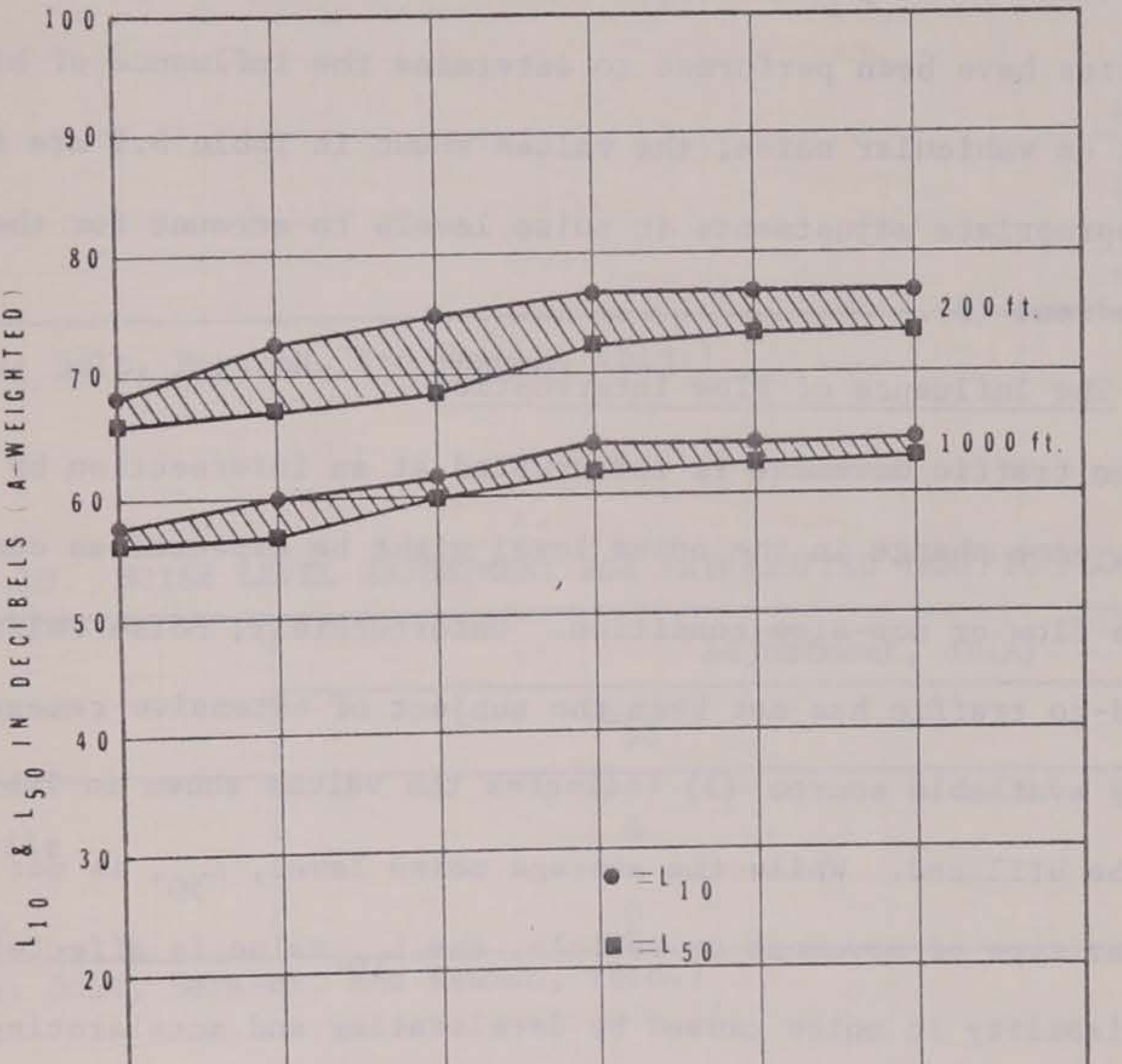


Figure 3.13 EFFECT OF PERCENT TRUCKS ON NOISE LEVEL
(Source: Shahan, J. E., and G.W. Kamperman, "Effects and Control of Highway Traffic Noise," ASCE Meeting Preprint 1731, July 1972)

3.1.11 The Influence of Roadway Gradient

The noise of automobiles on highways is not noticeably affected by the gradient or longitudinal slope of the road. However, truck noise will increase as they are forced to climb hills. Although relatively few studies have been performed to determine the influence of highway gradient on vehicular noise, the values shown in Table 3.9 are thought to be appropriate adjustments in noise levels to account for the presence of a gradient (3).

3.1.12 The Influence of Flow Interruption

When traffic movement is interrupted at an intersection by a signal or sign, some change in the noise level might be expected as compared to the free flow or non-stop condition. Unfortunately, noise emitted from stop-and-go traffic has not been the subject of extensive research, and the only available source (3) indicates the values shown in Table 3.10 should be utilized. While the average noise level, L_{50}, is not influenced by either type of movement or vehicle, the L_{10} value is affected due to the variability in noise caused by decelerating and accelerating vehicles.

3.1.13 The Influence of Roadway Surface

The variation in traffic noise generated by vehicles on different pavement surfaces has been evaluated by Bolt, Beranek, and Newman (3). Their findings are summarized in Table 3.11 where it is shown that the pavement surface can affect the noise level by a range of 10 dB(A) from the smoothest to the roughest type of paved highway. The normal condition in this table means a moderately rough asphalt and concrete surface; the smooth condition is a seal-coated asphaltic pavement; the rough condition corresponds to gravel concrete or rough asphalt with voids of size ½ inch in diameter.

Table 3.9. NOISE LEVEL ADJUSTMENT FOR TRUCKS ON UPHILL GRADIENTS.

Gradient, %	Noise adjustment, dB(A)
0 – 2	0
3 – 4	+2
5 – 6	+3
7 +	+5

(Source: Bolt, Beranek, and Newman, ibid.)

Table 3.10. NOISE LEVEL ADJUSTMENT FOR INTERRUPTED TRAFFIC FLOW.

Vehicle type	Adjustment, dB(A)	
	L_{50}	L_{10}
Automobile	0	+2
Truck	0	+4

(Source: Bolt, Beranek, and Newman, ibid.)

Table 3.11. NOISE LEVEL ADJUSTMENT FOR TYPE OF ROAD SURFACE.

Surface type	Description	Adjustment dB(A)
Smooth	Very smooth, seal-coated asphalt pavement	-5
Normal	Moderately rough asphalt and concrete surface	0
Rough	Rough asphalt pavement with large voids ½ inch or larger in diameter or grooved concrete	+5

(Source: Bolt, Beranek, and Newman, ibid.)

3.1.14 The Influence of Roadway Configuration: Number of Lanes, At-Grade, Elevated, and Depressed Highways

In freeway situations, noise will be generated from several traffic lanes simultaneously. The number of lanes and median width will vary from location to location, as will the elevation of the freeway with respect to the observer. Each of these factors must be considered in estimating the noise level at any point along the freeway.

3.1.14.a The Basic Influence of Distance

The rate of noise reduction with respect to distance is shown in Figure 3.14 (7). As previously mentioned in Section 3.1.8, the noise from a line source decays at the rate of 3 dB(A) per doubling of distance, and the noise from a point source decays at the more rapid rate of 6 dB(A) per doubling of distance. The influence of atmospheric conditions (temperature, humidity, and wind) will influence noise reduction rate for either type of source.

3.1.14.b The Influence of Roadway Width and Distance

For situations where the observer is within 1,000 feet of the roadway, it is necessary to consider the effect of the width of the traveled road or number of lanes in estimating the rate of noise reduction. Figure 3.15 has been developed (3) using a single lane of traffic with a noise reduction rate of 4 dB(A) per doubling of distance as a standard rate. Then, depending on the perpendicular distance from the observer to the middle of the near lane (D_N in feet), and the roadway width or number of lanes, other dissipation rates can be estimated. Compared to the reference adjustment of 0 dB(A) for a 12 foot lane at D_N = 100, the adjustment along an 8 lane freeway, at a distance of 100 feet, would be − 2 dB(A).

3.1.14.c The Influence of Relative Elevation of the Roadway

Vertical displacement of the traveled path to a position either above

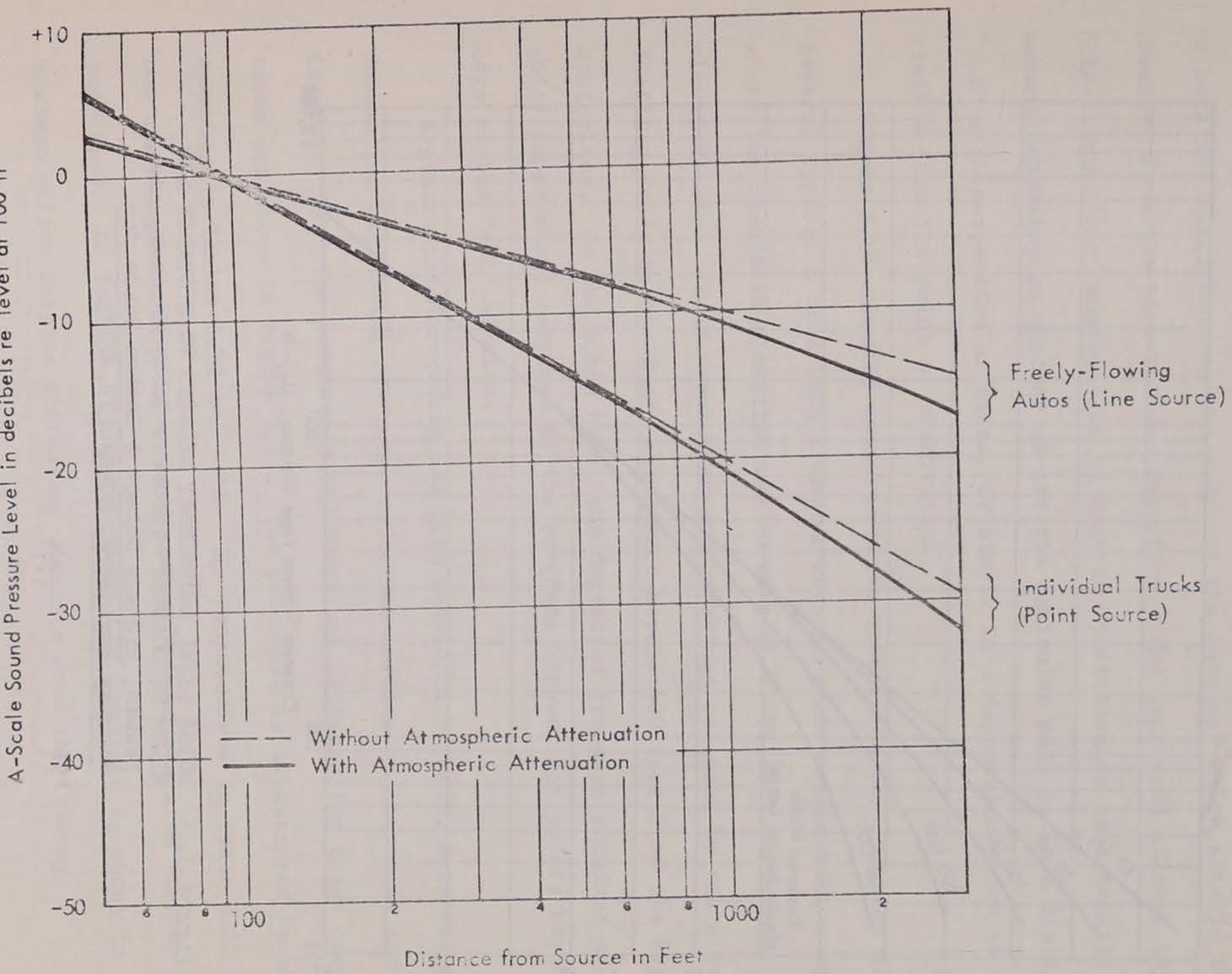


Figure 3.14 DISSIPATION OF TRAFFIC NOISE WITH RESPECT TO DISTANCE (Source: Bolt, Beranek, and Newman, Noise Environment of Urban and Suburban Areas, prepared for Federal Housing Administration, U.S. Dept. of Housing and Urban Development, 1967.)

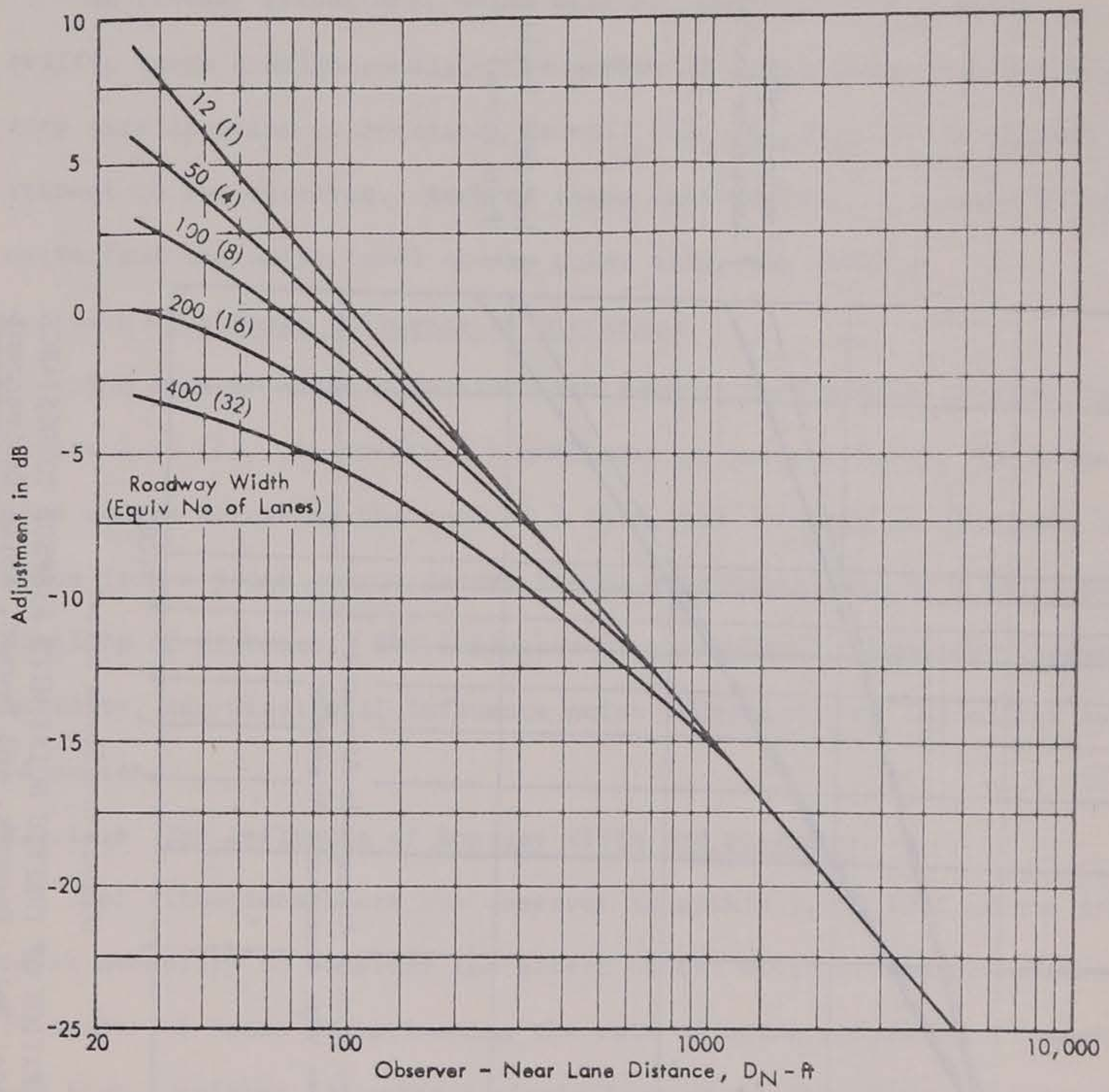


Figure 3.15 NOISE LEVEL ADJUSTMENT RELATED TO DISTANCE AND WIDTH OF ROADWAY (Source: Bolt, Beranek, and Newman, <u>Highway Noise: A Design Guide for Highway Engineers</u>, NCHRP 117, 1971.)

or below the observer will offer some degree of protection from the vehicular noise. The noise reduction ability of the elevated highway depends on both its elevation and the width of the shoulder which shields the observer from the tire-roadway interface. The depressed highway may offer noise reductions ranging from as much as 15 dB(A) down to a negligible amount depending on whether or not the vehicular path is in a distinct "cut" with perpendicular sides, or simply in a depression which is readily visible from the point of observation.

Figure 3.16 compares measured noise reductions (8) observed along several typical 6 or 8 lane freeways with at-grade configuration and where the change in elevation was 20 feet (i.e. 20 feet depressed, or 20 feet elevated) (8). It is shown that any advantage realized by the elevated facility tends to be of no consequence beyond 400 feet from the highway centerline. On the other hand, the depressed freeways retained a 7 or 8 dB(A) improvement compared to the at-grade highway for points beyond the edge of the "cut" section.

A generalized procedure has been developed by Bolt, Beranek, and Newman for estimating the noise reduction ability of depressed and elevated freeways (3). The parameters and nomograph utilized for these computations are shown in Figure 3.17. The procedure is illustrated by the examples in Tables 3.12 and 3.13. The computations in Table 3.12 shows how the reduction diminishes as distance from an elevated freeway is increased. In Table 3.13 the depressed configuration is shown to its maximum effect despite increasing distance from the freeway.

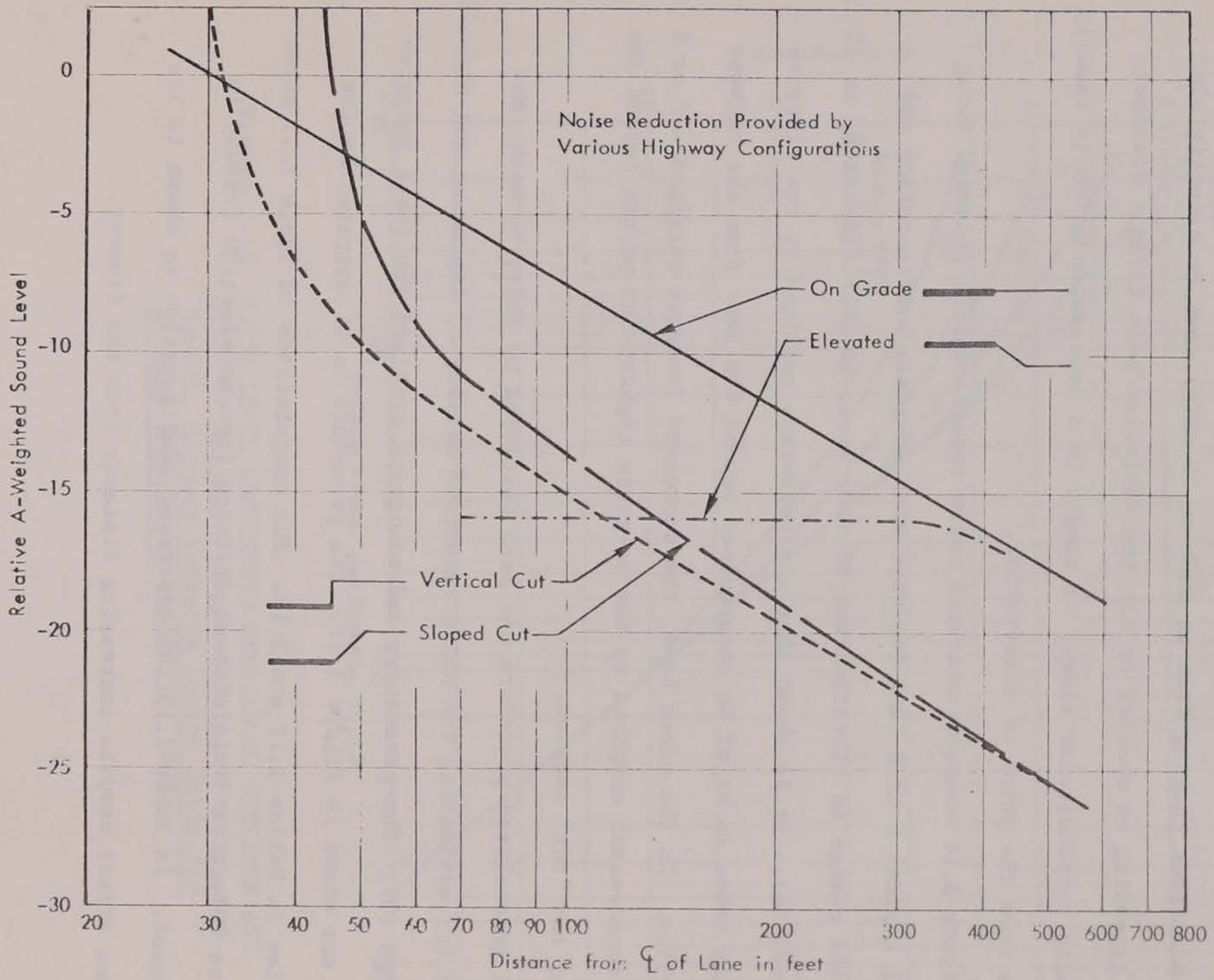


Figure 3.16 TRAFFIC NOISE REDUCTION PROVIDED BY VARIOUS HIGHWAY CONFIGURATIONS (Source: Bolt, Beranek, and Newman, Highway Noise: Measurement, Simulation and Mixed Reactions, NCHRP 78, 1969.)

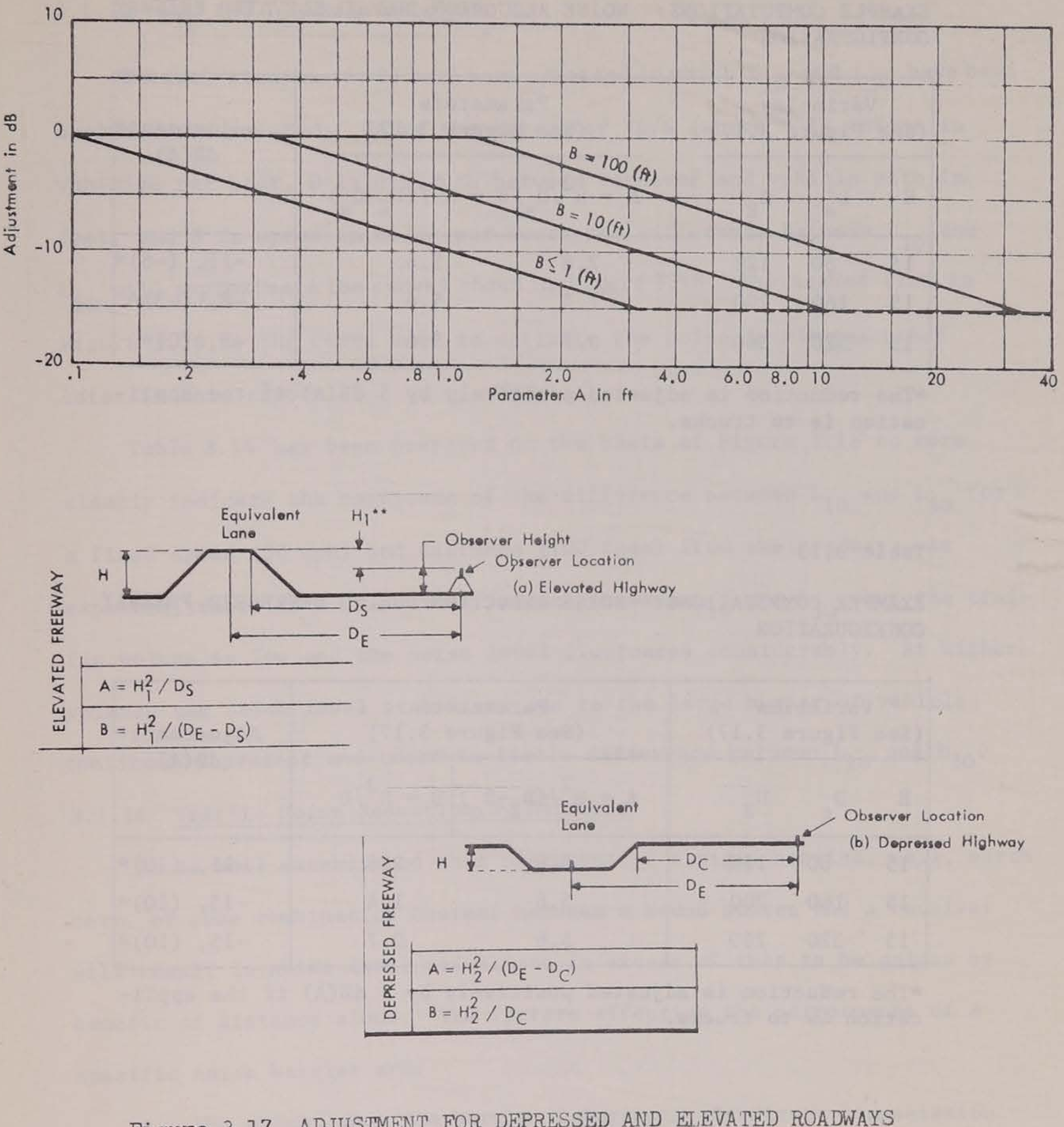


Figure 3.17 ADJUSTMENT FOR DEPRESSED AND ELEVATED ROADWAYS (Source: Bolt, Beranek, and Newman, *Highway Noise: A Design Guide for Highway Engineers*, NCHRP 117, 1971.)

Table 3.12

EXAMPLE COMPUTATIONS: NOISE REDUCTION DUE TO ELEVATED FREEWAY CONFIGURATION

Variables (See Figure 3.17)			Parameters (See Figure 3.17)		Adjustment* dB(A)
H	D_s	D_E	$A = H^2/D_s$	$B = H^2/(D_E-D_s)$	
15	80	120	2.8	5.6	-11, (-6)*
15	160	200	1.4	5.6	-8, (-3)*
15	320	360	0.7	5.6	-5, (0)*

*The reduction is adjusted positively by 5 dB(A) if the application is to trucks.

Table 3.13

EXAMPLE COMPUTATIONS: NOISE REDUCTION DUE TO DEPRESSED FREEWAY CONFIGURATION

Variables (See Figure 3.17)			Parameters (See Figure 3.17)		Adjustment* dB(A)
H	D_c	D_E	$A = H^2/(D_E-D_c)$	$B = H^2/D_c$	
15	80	120	5.6	2.8	-15, (10)*
15	160	200	5.6	1.4	-15, (10)*
15	320	260	5.6	0.7	-15, (10)*

*The reduction is adjusted positively by 5 dB(A) if the application is to trucks.

3.1.15 L_{10} and L_{50} Relationships

Several studies (8, 9) have been reported in which L_{10} and L_{50} have been analyzed and related. Using the parameter VD/S (where V is volume in vehicles per hour, D is distance between receiver and vehicle path in feet, and S is speed in miles per hour) the difference between L_{10} and L_{50} will approximate the curves shown in Figure 3.18. The dashed line in Figure 3.18 is the curve used to estimate the noise levels described later in this report.

Table 3.14 has been prepared on the basis of Figure 3.18 to more clearly indicate the magnitude of the difference between L_{10} and L_{50} for a fixed speed (50 mph) and distance (100 feet) from the roadway. As expected, there is a greater difference between L_{10} and L_{50} when the traffic volume is low and the noise level fluctuates considerably. At higher volumes the noise level stabilizes due to the large number of vehicles continually present and there is little difference between L_{10} and L_{50}.

3.1.16 Traffic Noise Reduction by Barriers

It is well established that placement of a rigid barrier, wall, earth berm, or some combination thereof between a sound source and a receiver will result in noise level reductions in excess of that to be gained by benefit of distance alone. The factors affecting the performance of a specific noise barrier are:

A. The extent that the barrier interrupts the direct transmission path from the source to the receiver;

B. The distance from the source to the barrier and from the barrier to the receiver;

C. The length of the barrier with respect to the length of the noise source (traffic noise is considered a line source);

D. The frequency content of the noise (barriers are most effective

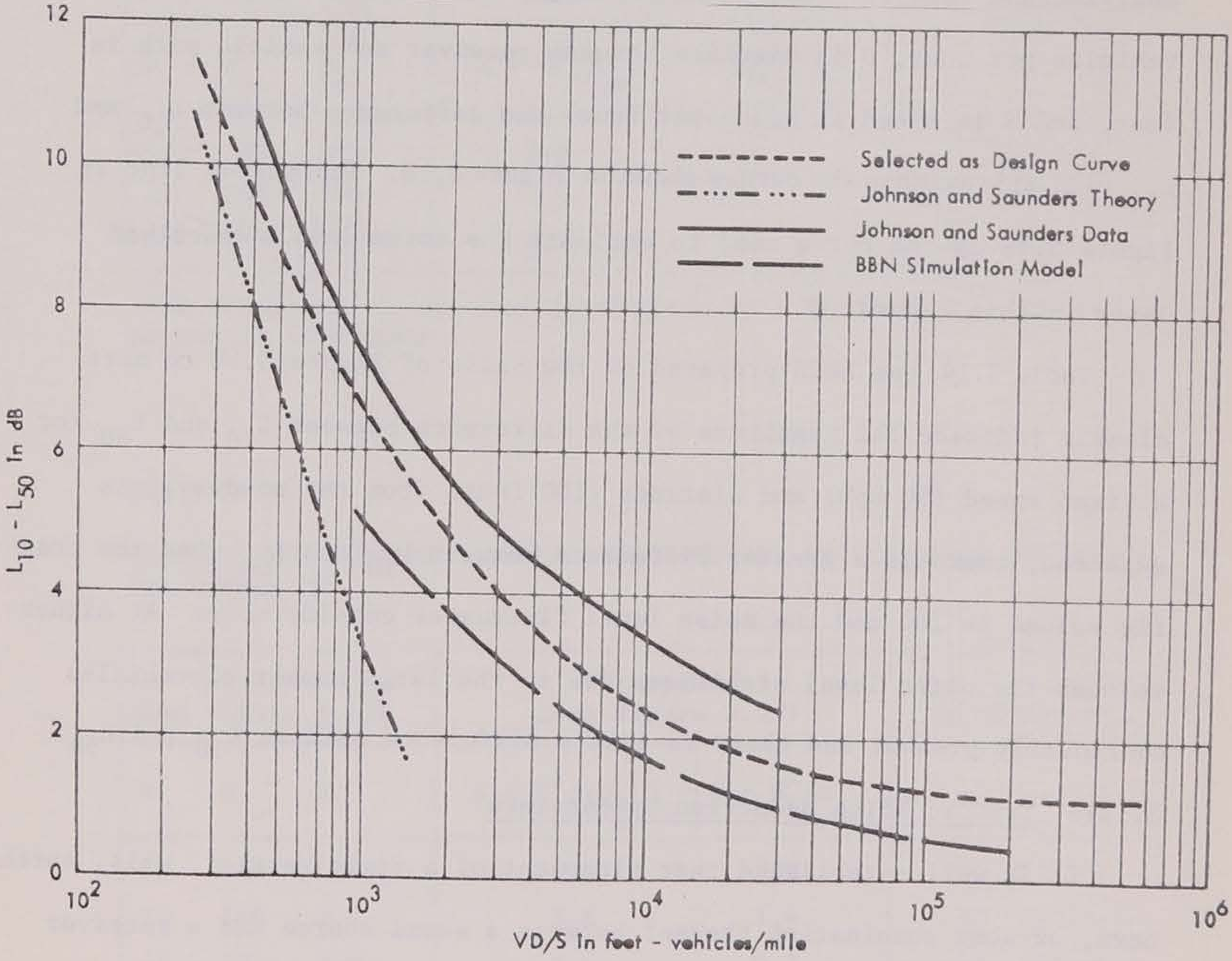


Figure 3.18 RELATIONSHIP BETWEEN L_{1o} and L_{50}

(Source: Bolt, Beranek, and Newman, ibid.)

Table 3.14

SELECTED L_{50} TO L_{10} ADJUSTMENTS

VOLUME (VPH)	PARAMETER* VD/S	L_{50} TO L_{10} ADJUSTMENT dB(A)
150	300	+ 11
300	600	+ 8
450	900	+ 7
600	1200	+ 6
900	1800	+ 5
1800	3600	+ 4
3600	7200	+ 3
7200	14400	+ 2

*Distance Fixed at 100 feet = D, and Speed Fixed at 50 mph = S for this example in reducing higher frequency sounds);

E. Density of the material used to construct the barrier and porosity (or roughness) of the surface, and;

F. Other environmental factors as the type of ground cover in the vicinity, the amount of air turbulence or wind, etc.

The first three factors are of primary interest in this report and their influence on traffic noise reduction will be emphasized.

On the basis of research performed by Purcell (10) and Rehr (11) the variables shown in Figure 3.19 theoretically determine barrier performance for a very long sound barrier. The height, H in feet, above the line of sight, line A - B, in Figure 3.19 is critical. For a given value of H, it has been shown that the most effective barrier is one placed either close to the source or close to the receiver, the least effective position being mid-way between the two. Using the relationships developed by Purcell and Fehr, a computer program was developed by Young and Woods (12) to document the performance of a very long barrier. Figure 3.20 shows the noise reduction capabilities predicted by the computer program by varying the distances "a" and "b" when the barrier height is fixed at 10 feet. The indicated reductions are in addition to the reduction that would be achieved by considering the influence of distance alone. The highest reductions occur where either "a" or "b" is short, and the maximum reduction is attained when both "a" and "b" are short.

Figures 3.21 and 3.22 describe noise reductions for different barrier heights and for distances a = 25 ft., and 100 ft., respectively. Each of these figures verifies that the impact of a barrier is noticeably decreased when the distances "a" or "b" become large.

Another method for computing noise level reductions due to barriers developed by Bolt, Beranek, and Newman (3) is shown in

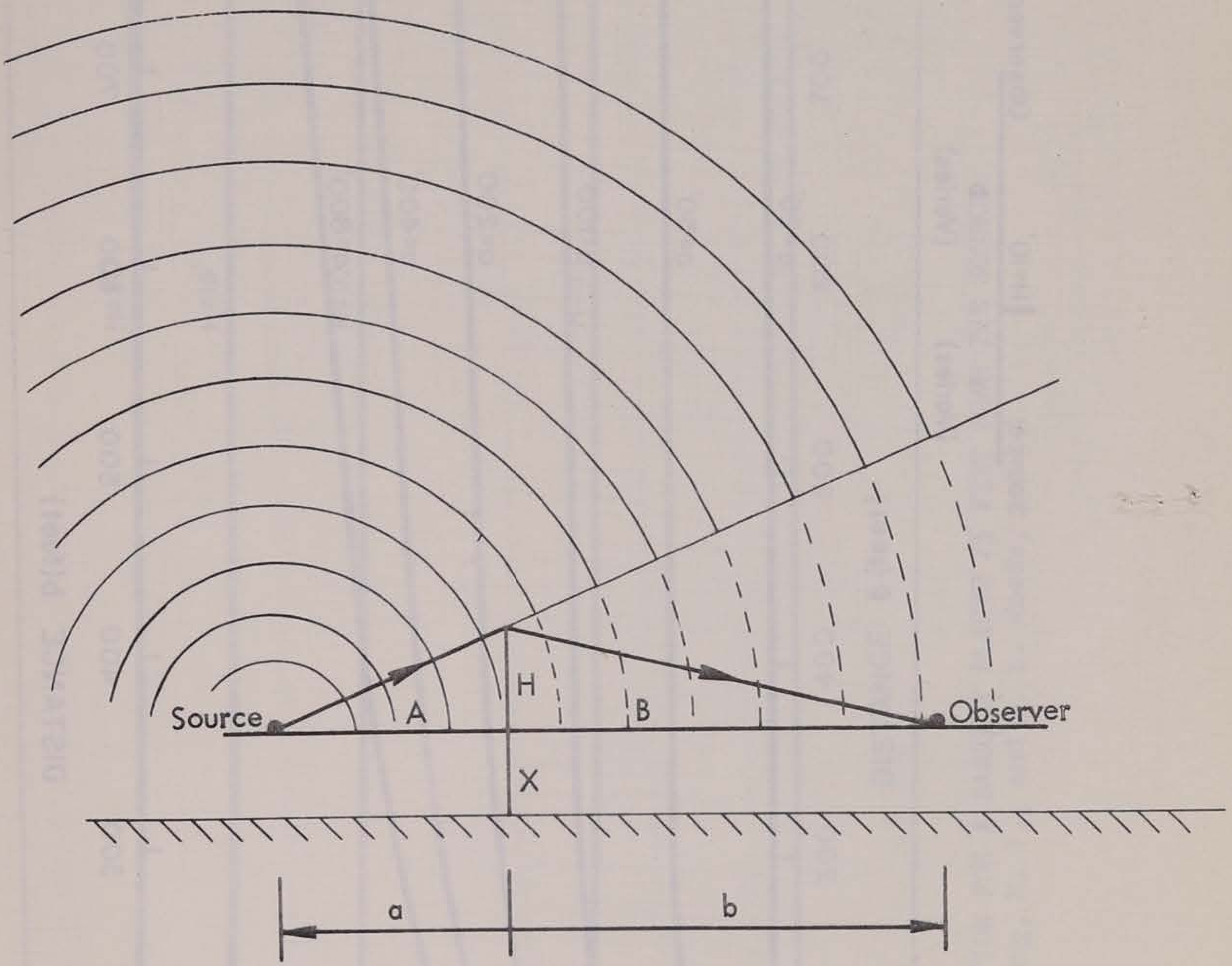


Figure 3.19 VARIABLES ASSOCIATED WITH NOISE BARRIER PERFORMANCE (Infinite Barrier)

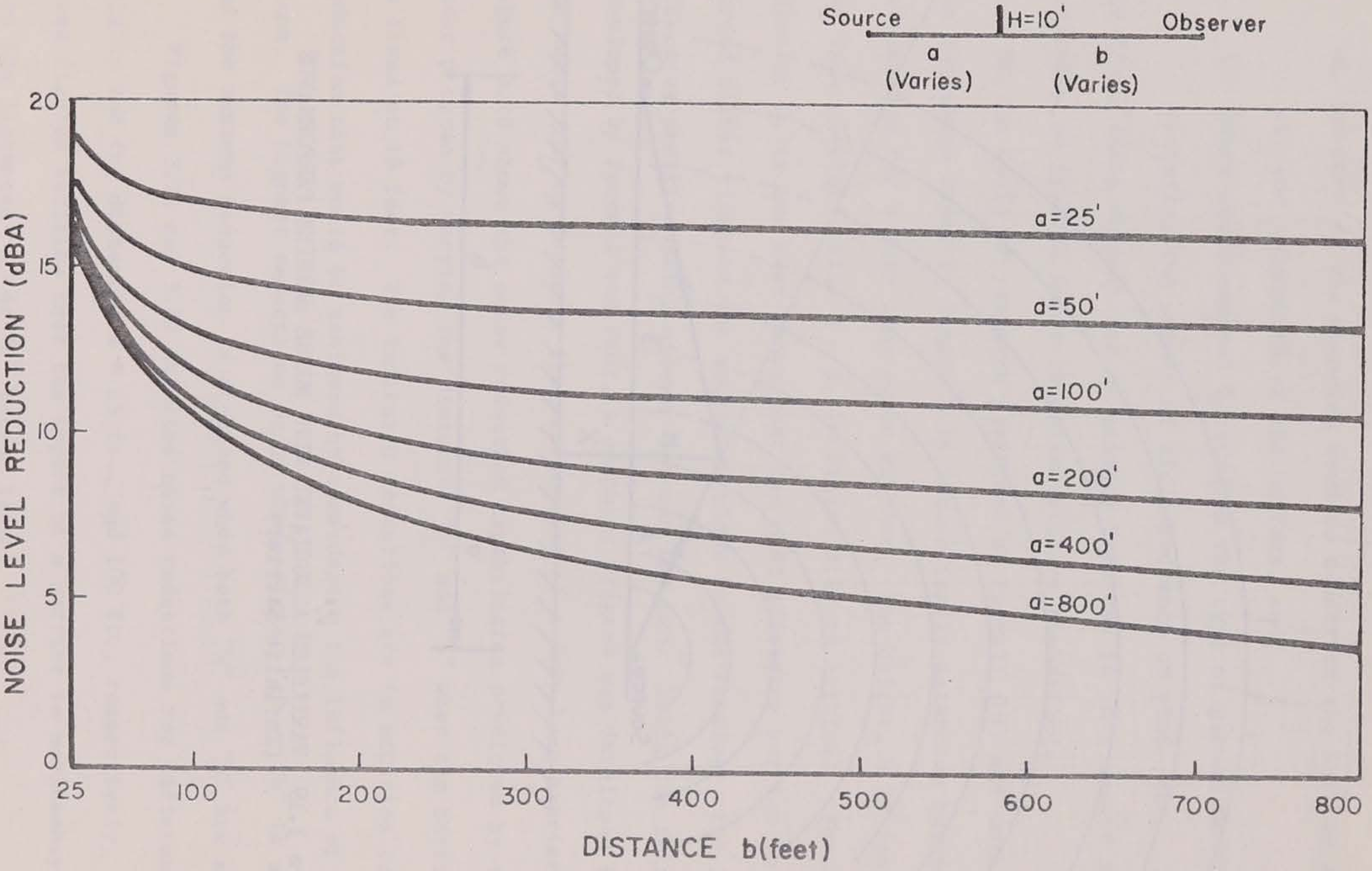


Figure 3.20 NOISE REDUCTION FOR A TEN FOOT BARRIER
(Source: Young, M.F., and D. L. Woods, Highway Noise Reduction by Barrier Walls, Res. Rpt. No. 166-3 Texas Transportation Institute, 1971.)

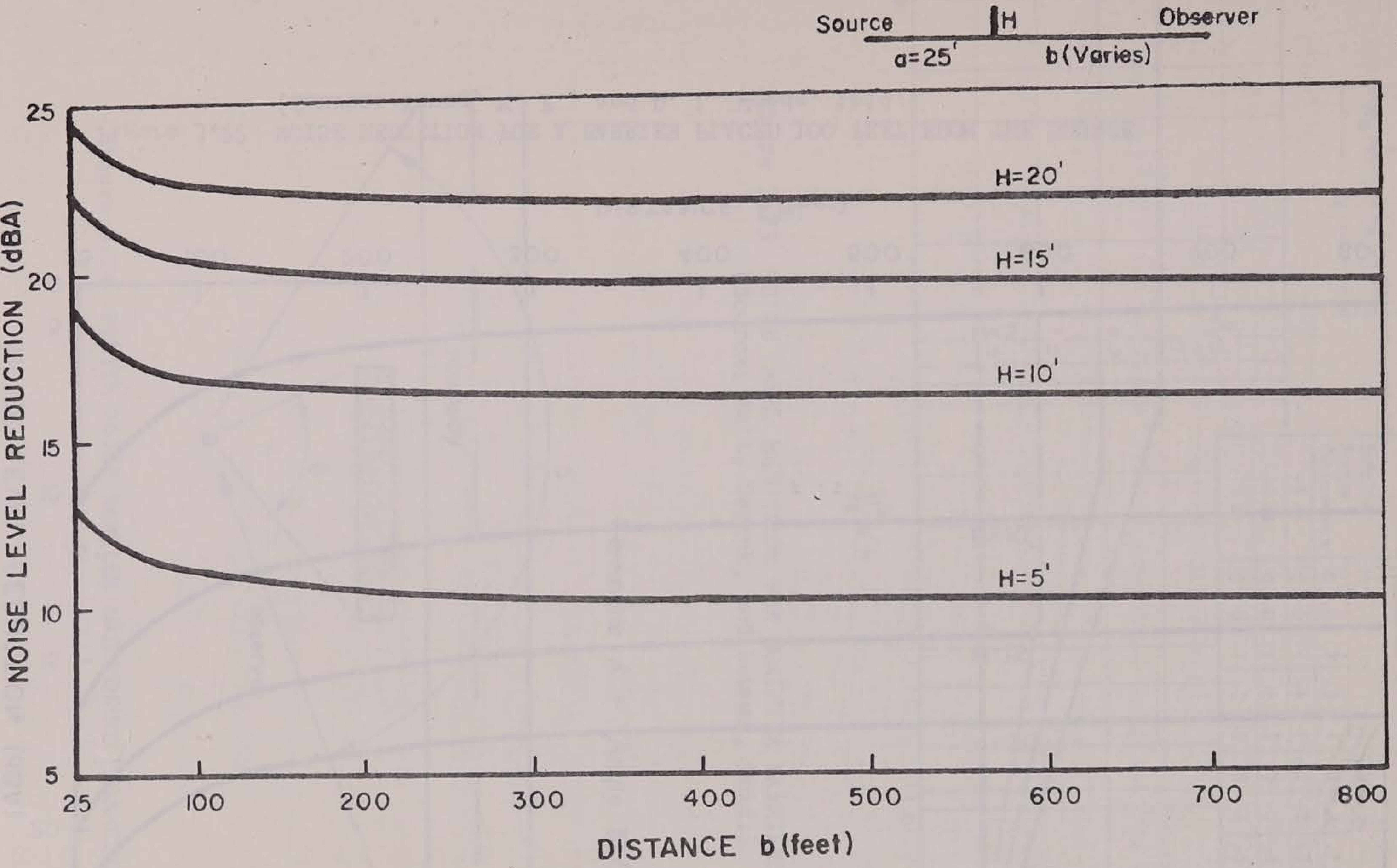


Figure 3.21 NOISE REDUCTION FOR A BARRIER PLACED 25 FEET FROM THE SOURCE (Source: Young, M. F., and D. L. Woods, ibid.)

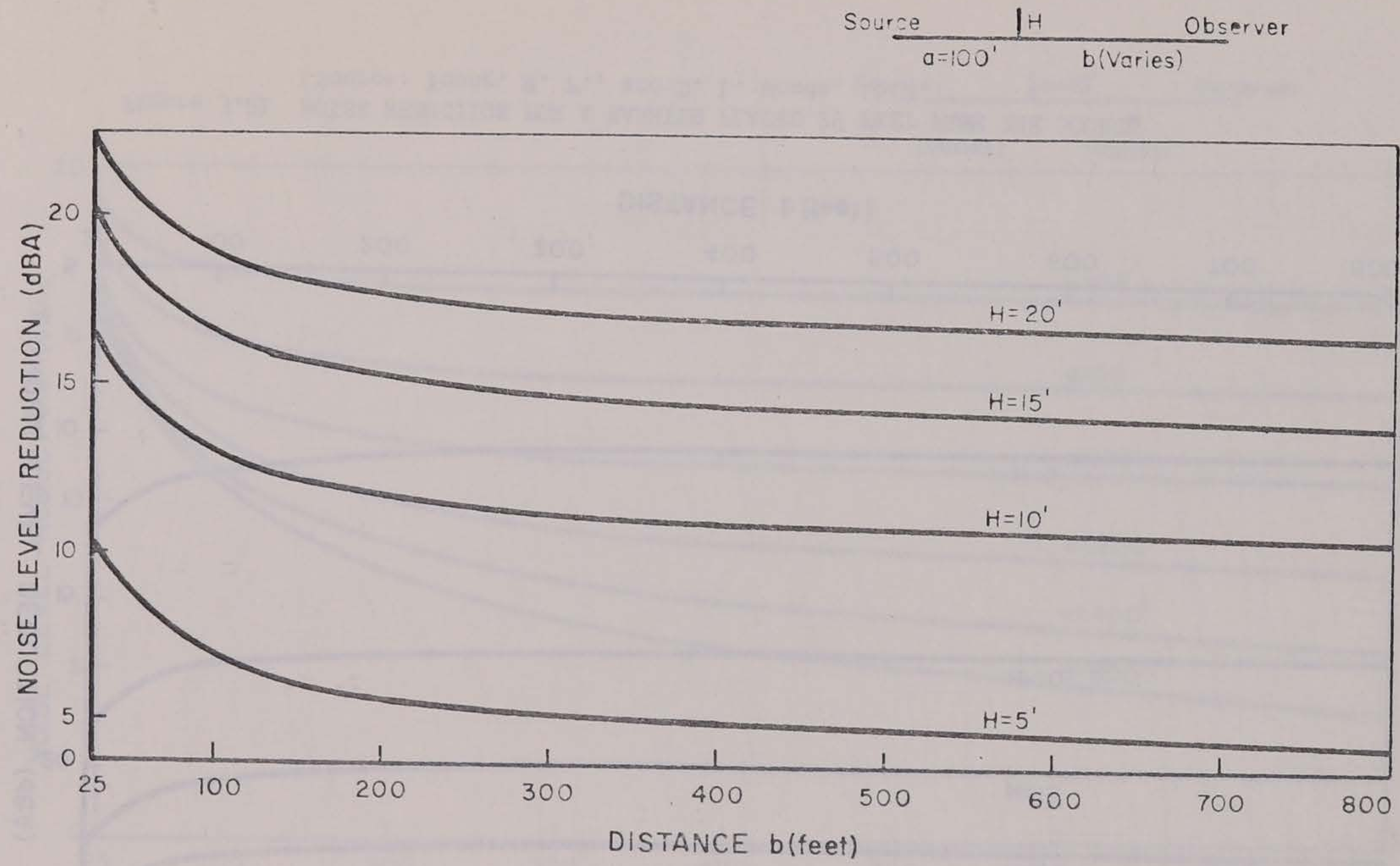
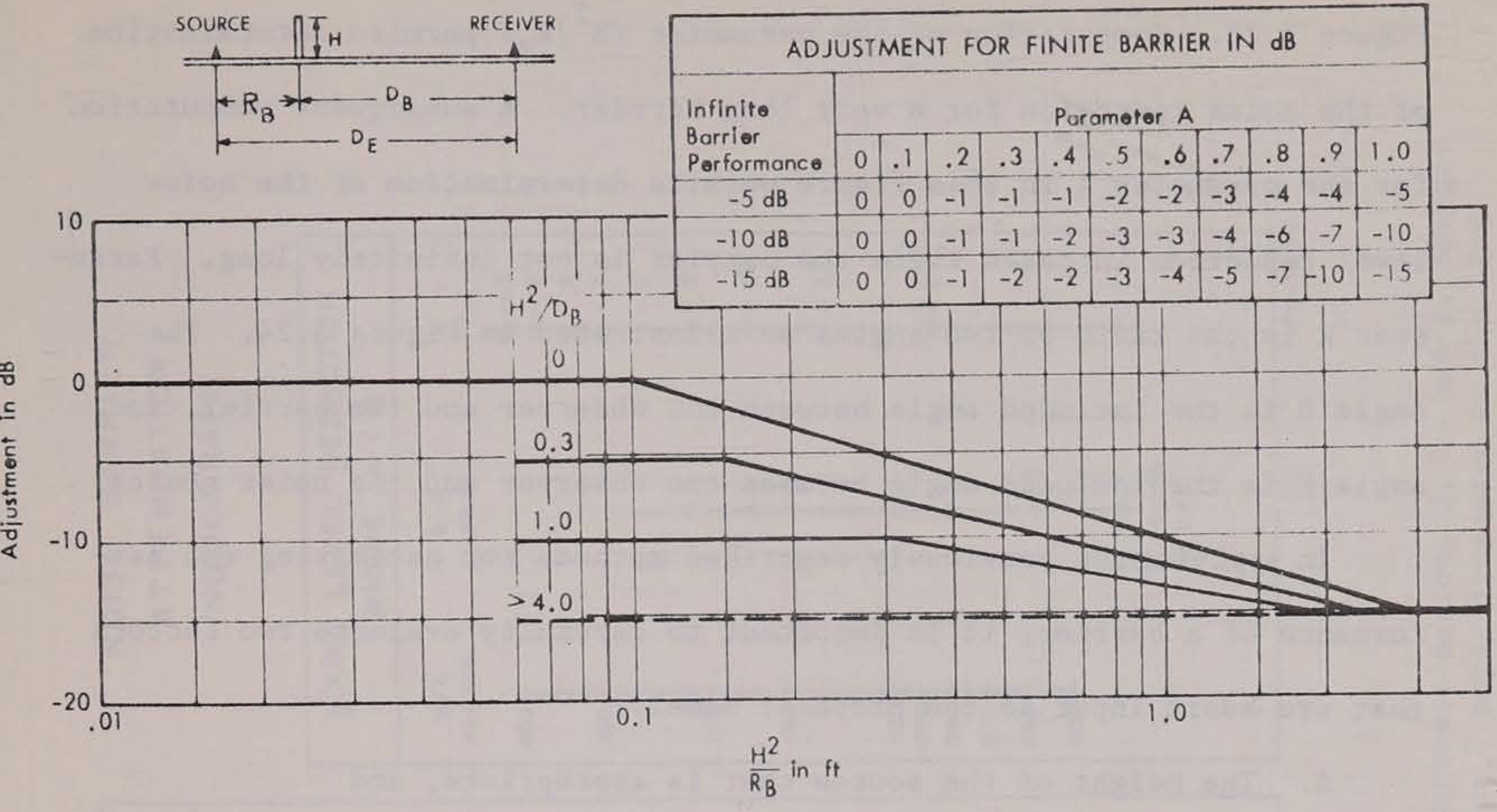


Figure 3.22 NOISE REDUCTION FOR A BARRIER PLACED 100 FEET FROM THE SOURCE (Source: Young, M. F., and D. L. Woods, ibid.)



ADJUSTMENT FOR FINITE BARRIER IN dB

Infinite Barrier Performance	Parameter A										
	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
-5 dB	0	0	-1	-1	-1	-2	-2	-3	-4	-4	-5
-10 dB	0	0	-1	-1	-2	-3	-3	-4	-6	-7	-10
-15 dB	0	0	-1	-2	-2	-3	-4	-5	-7	-10	-15

Figure 3.23 NOISE LEVEL REDUCTION FOR ROADSIDE BARRIERS
(Source: Bolt, Berank, and Newman, ibid.)

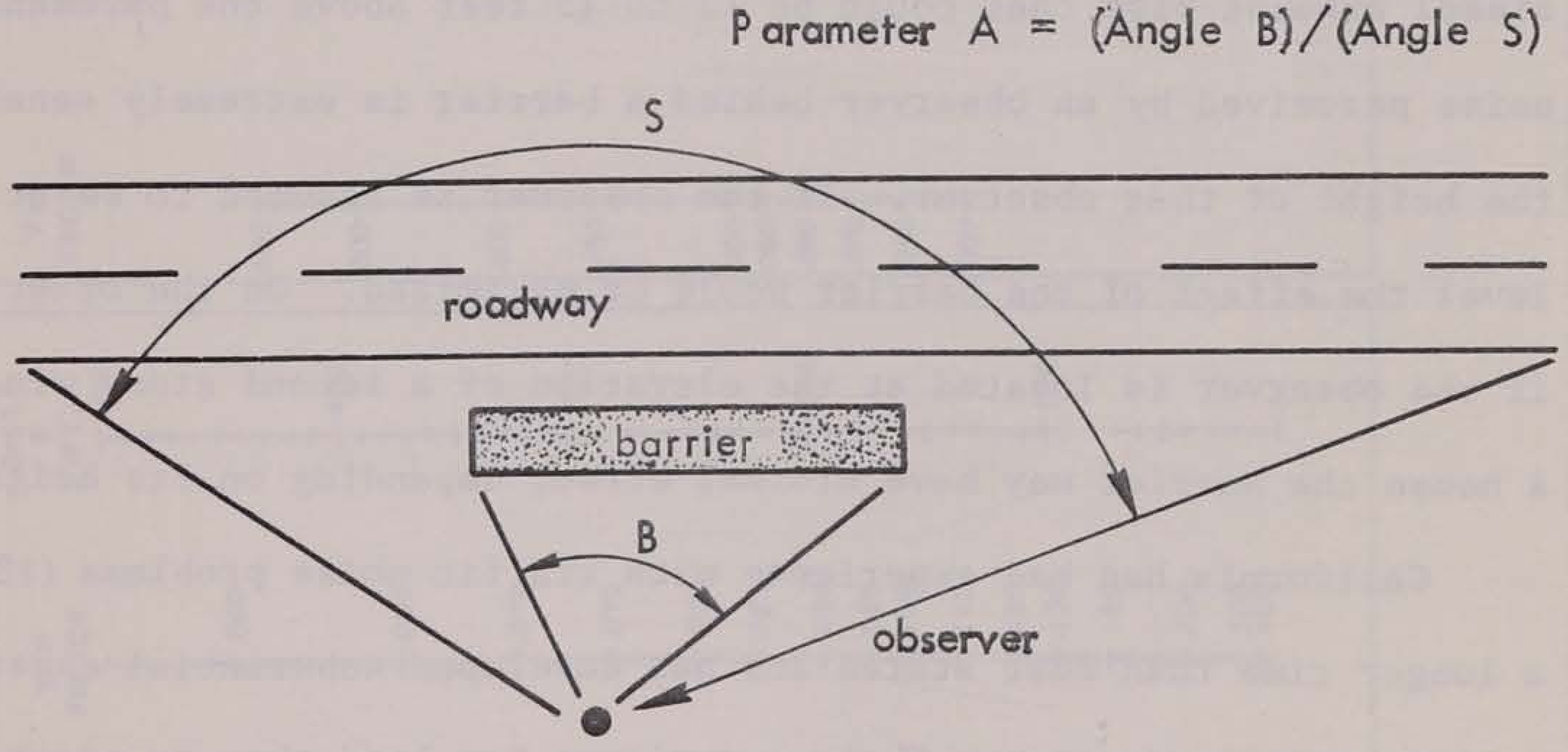


Figure 3.24 FINITE NOISE BARRIER ADJUSTMENT PARAMETER

Figure 3.23. Computation of the parameter (H^2/R_B) permits determination of the noise reduction for a very long barrier. A subsequent computation for the parameter A in this figure permits determination of the noise level reduction in cases where the barrier is not infinitely long. Parameter A is the ratio of two angles as illustrated in Figure 3.24. The angle B is the included angle between the observer and the barrier, and angle S is the included angle between the observer and the noise source.

In applying the previously described methods for estimating the performance of a barrier, it is important to carefully evaluate two factors that are basic input to the process; namely:

A. The height of the source that is appropriate, and

B. The height of the receiver that is appropriate.

The height of a traffic noise source can range from the pavement level where the tire-roadway interaction occurs up to as high as the top of a diesel exhaust pipe that could be 12 to 15 feet above the pavement. The noise perceived by an observer behind a barrier is extremely sensitive to the height of that observer. If the observer is assumed to be at ground level the effect of the barrier would be maximized. On the other hand, if the observer is located at the elevation of a second story window on a house the barrier may have minimal effect depending on its height.

California has had experience with traffic noise problems (13, 14) for a longer time than most states and has developed substantial expertise in traffic noise reduction. Their experience has lead them to adopt a traffic noise reduction nomograph, shown in Figure 3.25, which is based on the work of Rettinger (15) and Foss (16). On the basis of extensive field measurements, California has adjusted the nomograph so that it now predicts the sound level reduction from peak truck noise. Their practice is to assume the noise source epicenter for a truck to be 8 feet above the

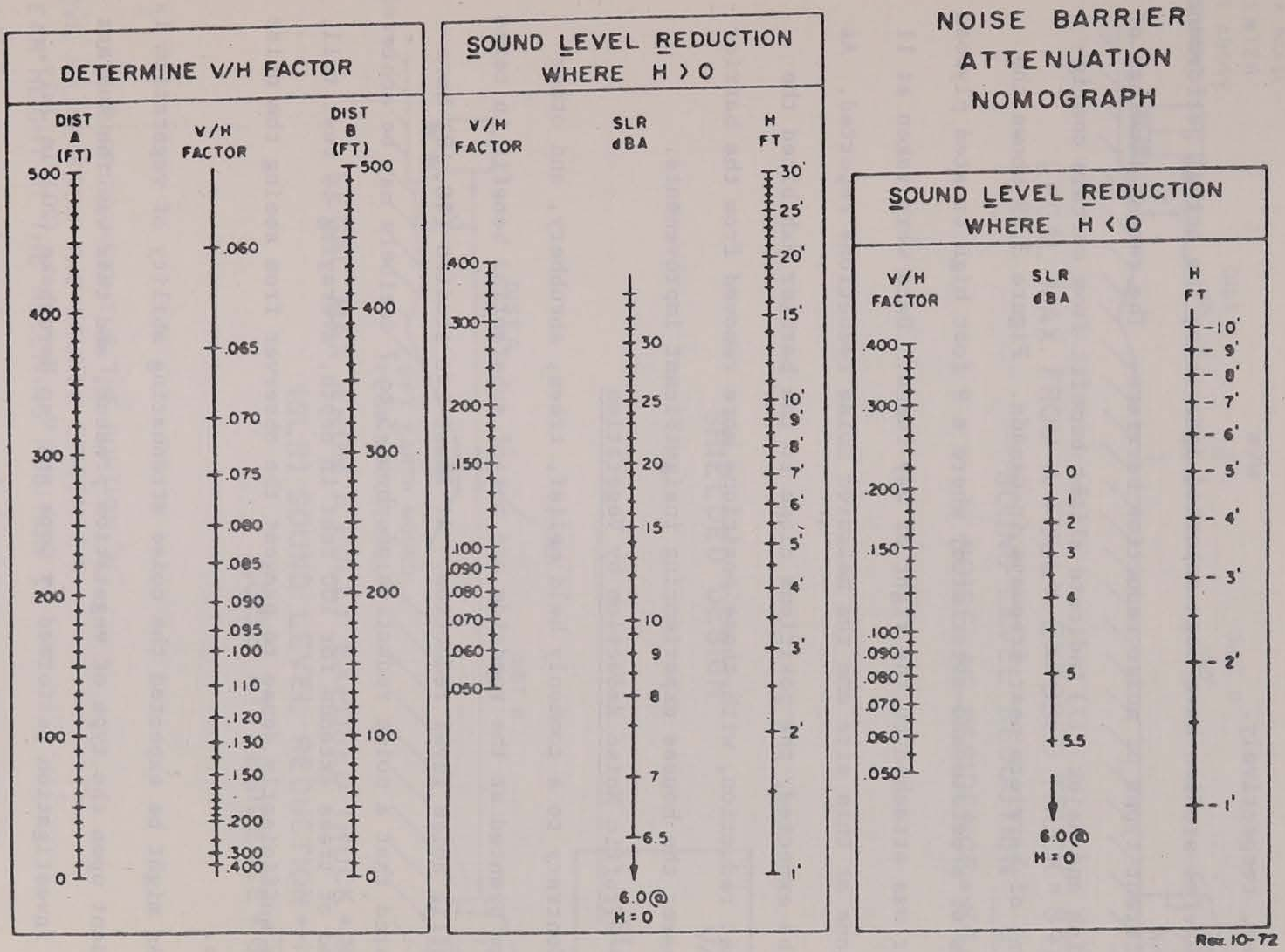


Figure 3.25 CALIFORNIA NOISE BARRIER ATTENUATION NOMOGRAPH (Source: Beaton, J. L. and L. Bourget "Traffic Noise near Highways Testing and Evaluation," paper presented at the 52nd Annual Meeting of the Highway Research Board, January 1973).

pavement surface, and the height of a receiver as typically being 7 feet above the ground level. Figures 3.26, 3.27, and 3.28 illustrate the use of their nomograph for at-grade, elevated, and depressed highway configurations, respectively.

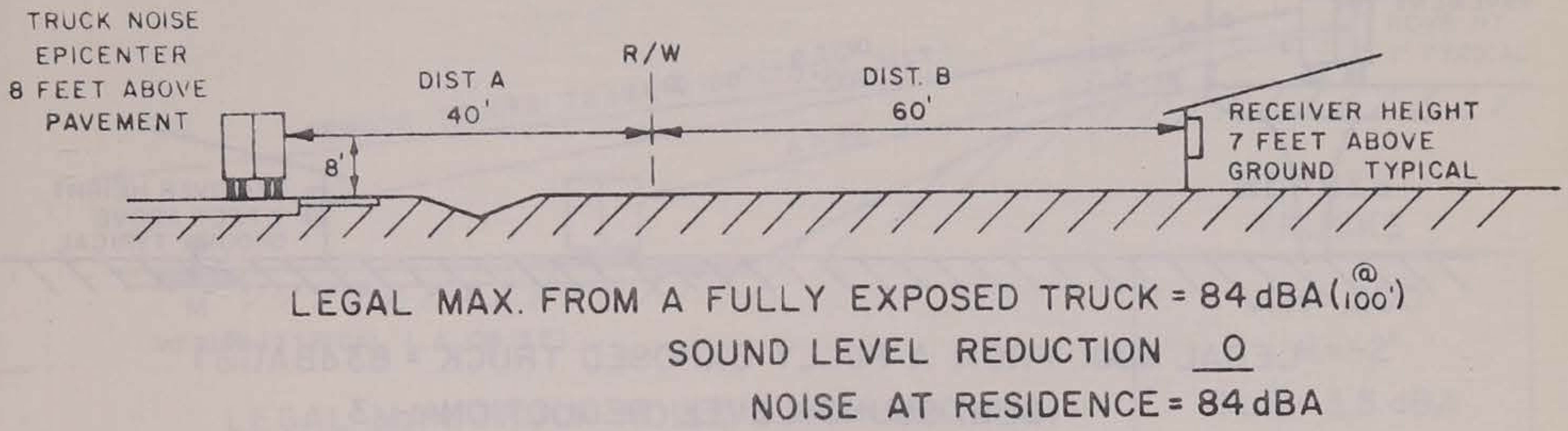
Several studies have been reported describing the actual performance of different types of noise reduction barriers. The recent findings of Harmelink and Hajek (17) indicate slight benefit from certain configurations of barriers near freeways in Canada. Figure 3.29 shows the results of a before-and-after study where a 9 foot high treated plywood barrier was attached to the right of way fence. Data were taken at 11 locations at this site and the measured noise reductions reported. As might be expected, the positions close to the barrier exhibited the greatest reduction, with those positions more removed from the barrier and nearer the houses experiencing insignificant improvements.

3.1.17 Traffic Noise Reduction by Vegetation

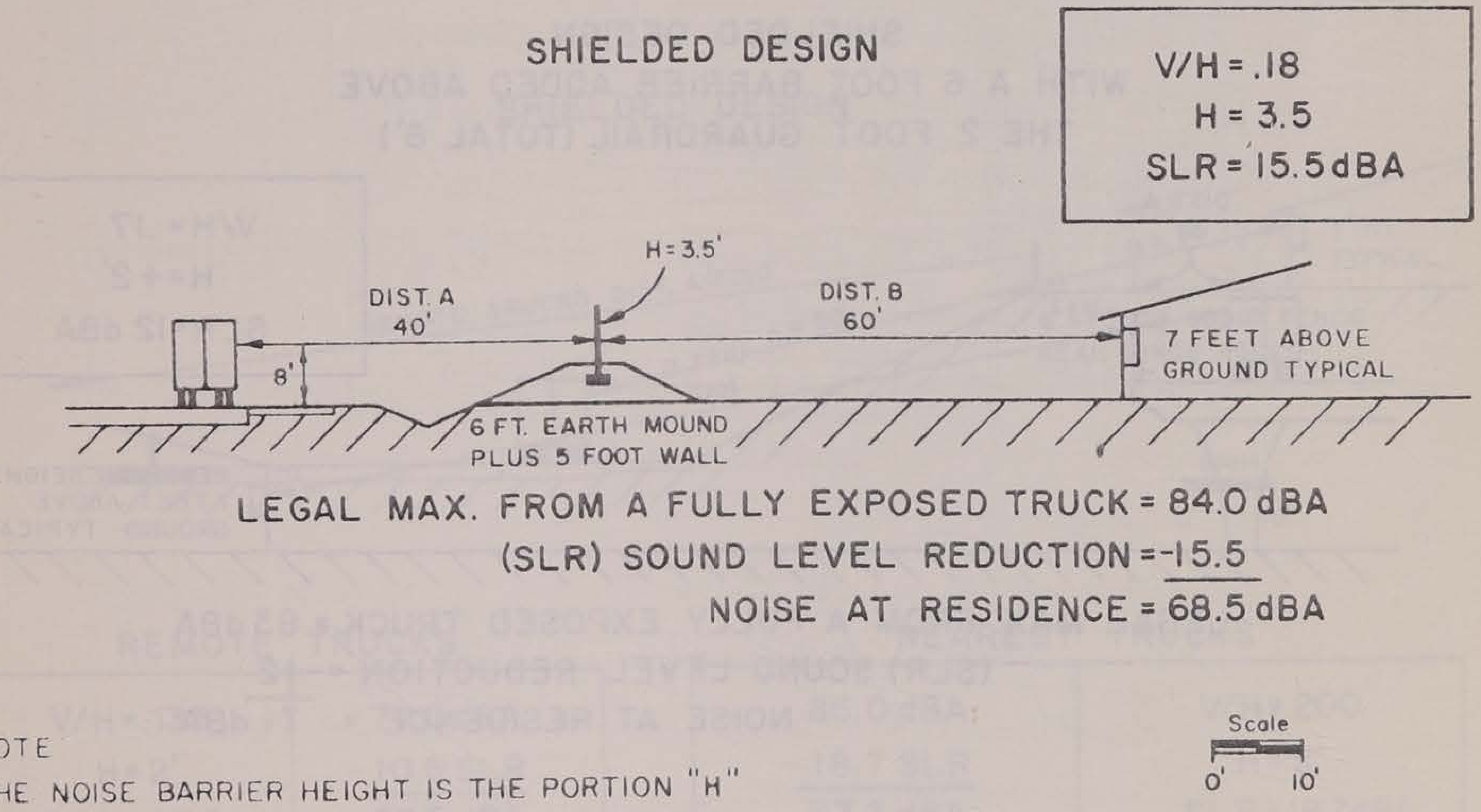
Contrary to a commonly held belief, trees, shrubbery, and other foliage planted at the roadside are not of substantial benefit in terms of traffic noise level reduction. At least two studies (18, 19) have indicated that a noise reduction of about 5 to 7 decibels may be achieved if a stand of trees extends for 100 feet in depth, averaging 15 feet tall, and is sufficiently dense to prevent the observer from seeing the noise source.

As might be expected the noise attenuating ability of vegetation is dependent upon the type of vegetation present, and this was the subject of an investigation performed by Cook and Van Haverbeke (20) in July, 1971. Several different vegetation belts were evaluated in terms of their ability to reduce noise from different types of vehicles as presented by an electronic amplifying system placed in front of the vegetation. With

CONVENTIONAL DESIGN



SHIELDED DESIGN



NOTE
THE NOISE BARRIER HEIGHT IS THE PORTION "H" ABOVE A LINE FROM THE SOURCE EPICENTER TO EAR HEIGHT AT THE RECEIVING POSITION

Figure 3.26 APPLICATION OF CALIFORNIA NOISE BARRIER NOMOGRAPH FOR HIGHWAYS IN FLAT TERRAIN (Source: Beaton, J.L., and L. Bourget, ibid.)

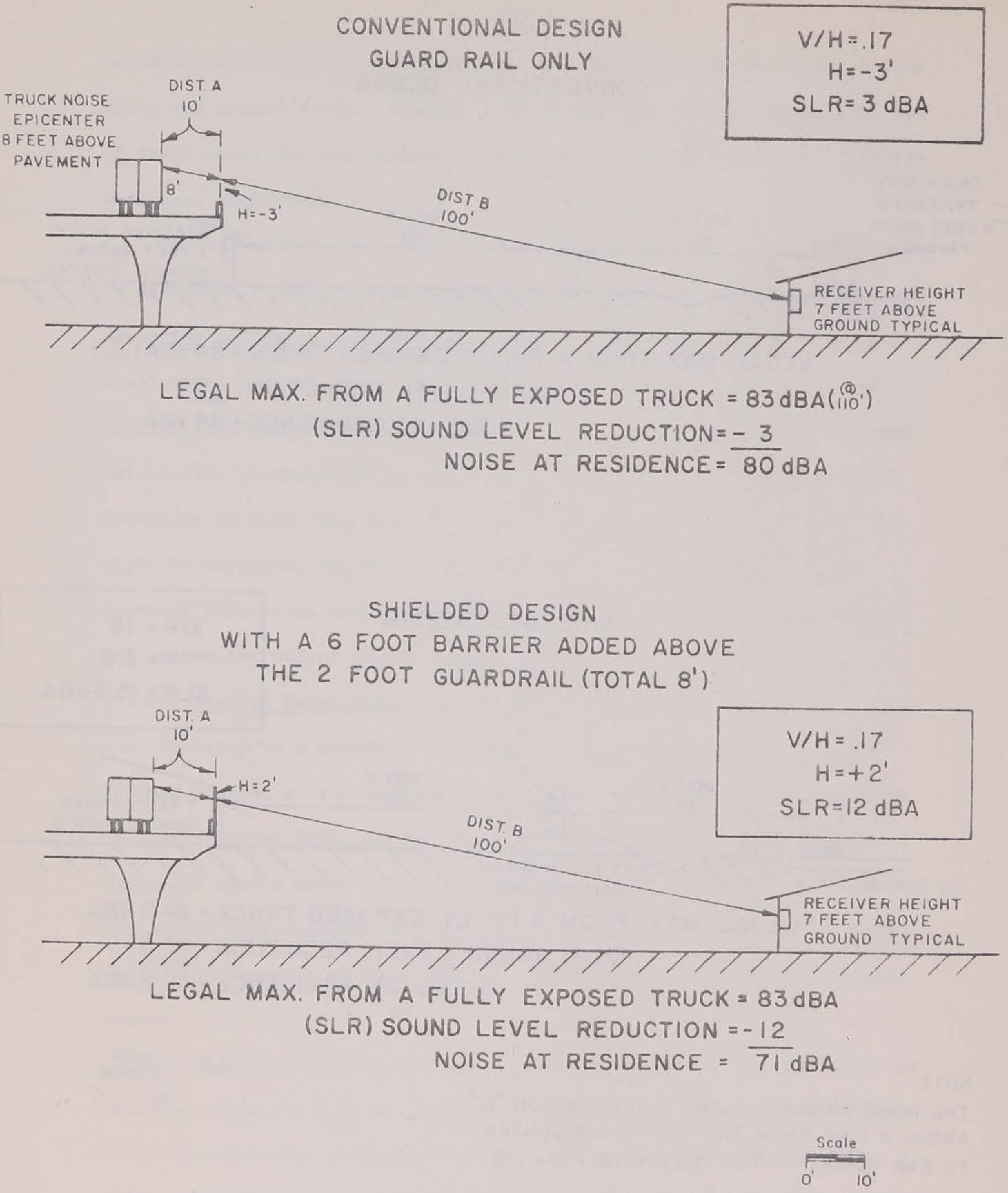


Figure 3.27 APPLICATION OF CALIFORNIA NOISE BARRIER NOMOGRAPH TO ELEVATED HIGHWAYS (Source: Beaton, J. L., and L. Bourget, ibid.)

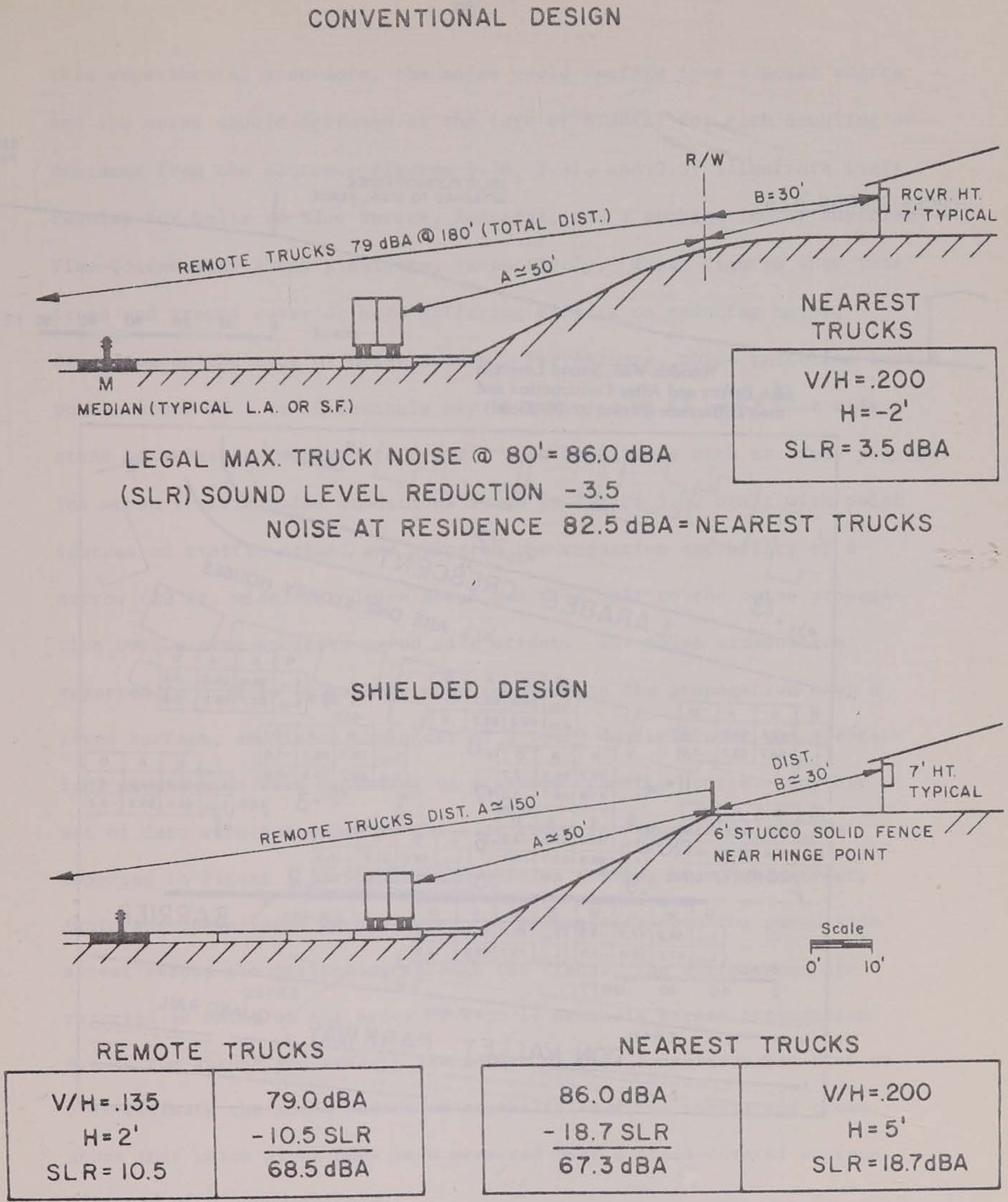
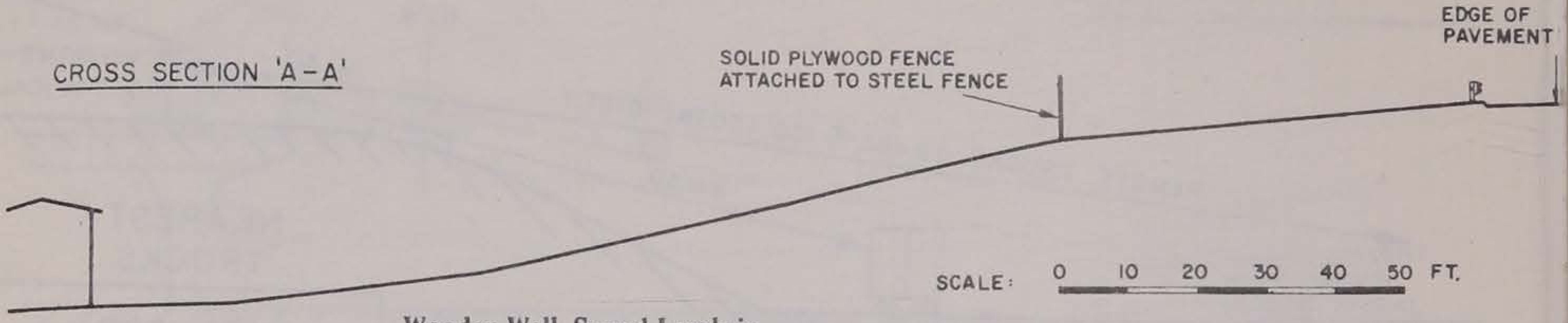
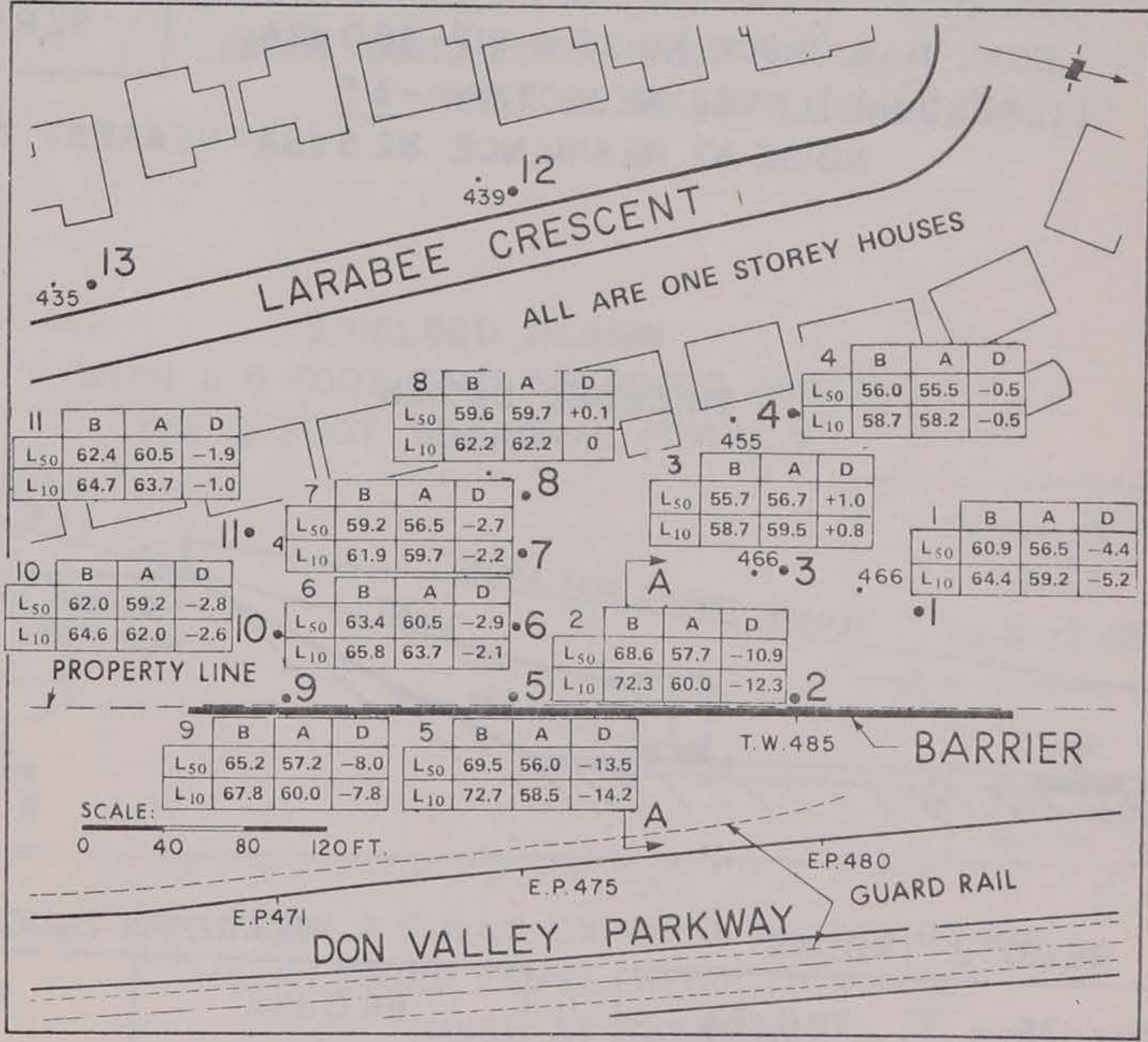


Figure 3.28 APPLICATION OF CALIFORNIA NOISE BARRIER NOMOGRAPH TO DEPRESSED HIGHWAYS (Source: Beaton, J. L., and L. Bourget, ibid.)



Wooden Wall, Sound Levels in dBA Before and After Construction and their Difference (Period 22:00-23:00)



11	B	A	D
L_{50}	62.4	60.5	−1.9
L_{10}	64.7	63.7	−1.0

8	B	A	D
L_{50}	59.6	59.7	+0.1
L_{10}	62.2	62.2	0

4	B	A	D
L_{50}	56.0	55.5	−0.5
L_{10}	58.7	58.2	−0.5

7	B	A	D
L_{50}	59.2	56.5	−2.7
L_{10}	61.9	59.7	−2.2

3	B	A	D
L_{50}	55.7	56.7	+1.0
L_{10}	58.7	59.5	+0.8

10	B	A	D
L_{50}	62.0	59.2	−2.8
L_{10}	64.6	62.0	−2.6

6	B	A	D
L_{50}	63.4	60.5	−2.9
L_{10}	65.8	63.7	−2.1

1	B	A	D
L_{50}	60.9	56.5	−4.4
L_{10}	64.4	59.2	−5.2

2	B	A	D
L_{50}	68.6	57.7	−10.9
L_{10}	72.3	60.0	−12.3

9	B	A	D
L_{50}	65.2	57.2	−8.0
L_{10}	67.8	60.0	−7.8

5	B	A	D
L_{50}	69.5	56.0	−13.5
L_{10}	72.7	58.5	−14.2

Figure 3.29 RESULTS OF A SELECTED CANADIAN NOISE BARRIER EFFECTIVENESS TEST (Source: Harmelink, M. D., and J.J. Hajek, "Noise Barrier Evaluation and Alternatives for Highway Noise Control," Ministry of Transportation and Communications, Ontario.)

this experimental procedure, the noise would radiate from a point source and the noise should decrease at the rate of 6 dB(A) for each doubling of distance from the source. Figures 3.30, 3.31, and 3.32 illustrate their results for belts of Blue Spruce, Redcedar, and a combination of Austrian Pine-Cotoneaster Shrub plantings, respectively. These figures show that trees and ground cover do have differing effects on reducing noise, depending on the type of noise source. Furthermore, noise reduction levels on the order of 4 to 10 decibels may be achieved by 63 to 67 foot wide stand of trees as compared to control test conditions with no trees present. The urban traffic noise conditions shown in Figure 3.32 dealt with point sources of traffic noise, and compared the reduction capability of a narrow (20 ft. wide) but dense shrub and tree belt to the noise propagation over a tree-enclosed paved side street. The noise attenuation reported in 3.32 is quite high when compared to the propagation over a paved surface, and is on the order of 3 to 10 decibels over the theoretical attenuation rate depending on distance from the source. Another set of data were collected at the site shown in Figure 3.32 and are reported in Figure 3.33 for actual vehicles driving along the street. Again the comparisons were between the propagation down the paved side street versus the projection through the trees. The differences are reported as being on the order of 7 to 11 decibels excess attenuation due to the shrubs and trees. The nature of this comparison may tend to over-estimate the noise reduction capabilities of the shrubs and trees, above that which might have been measured over a grass-covered surface (instead of a paved surface).

3.1.18 Traffic Noise Reduction by Buildings

The presence of a continuous structure as a building along a freeway could act as a tall noise barrier for the properties further removed from

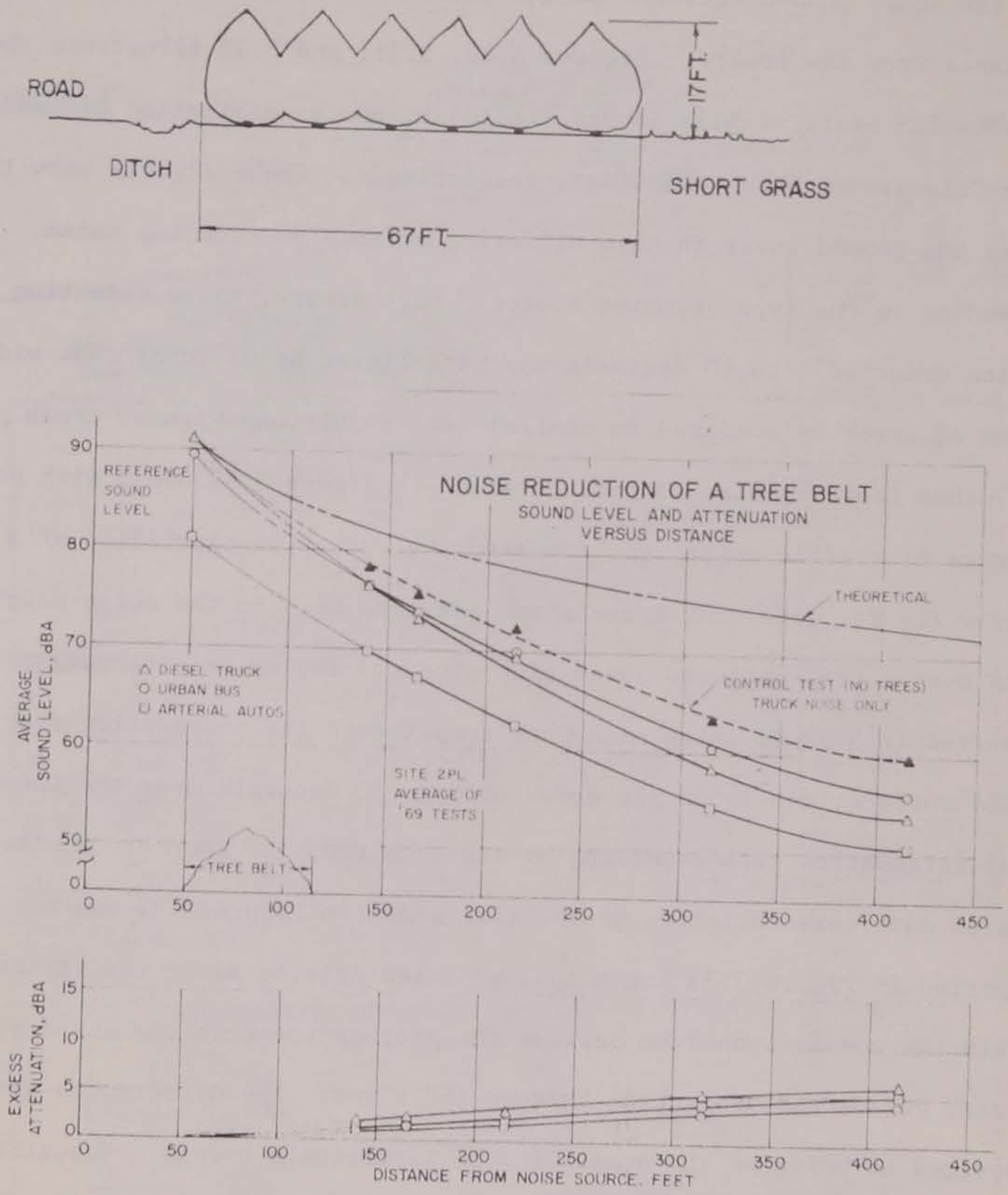


Figure 3.30 NOISE REDUCTION CAPABILITY OF SIX ROWS OF BLUE SPRUCE 17 FEET TALL WITH A BELT WIDTH OF 67 FEET (Source: Cook, D. I., and D. F. Van Haverbeke, "Trees and Shrubs for Noise Abatement," Res. Bull. 246, Agricultural Experiment Station, Univ. of Nebraska, 1971.)

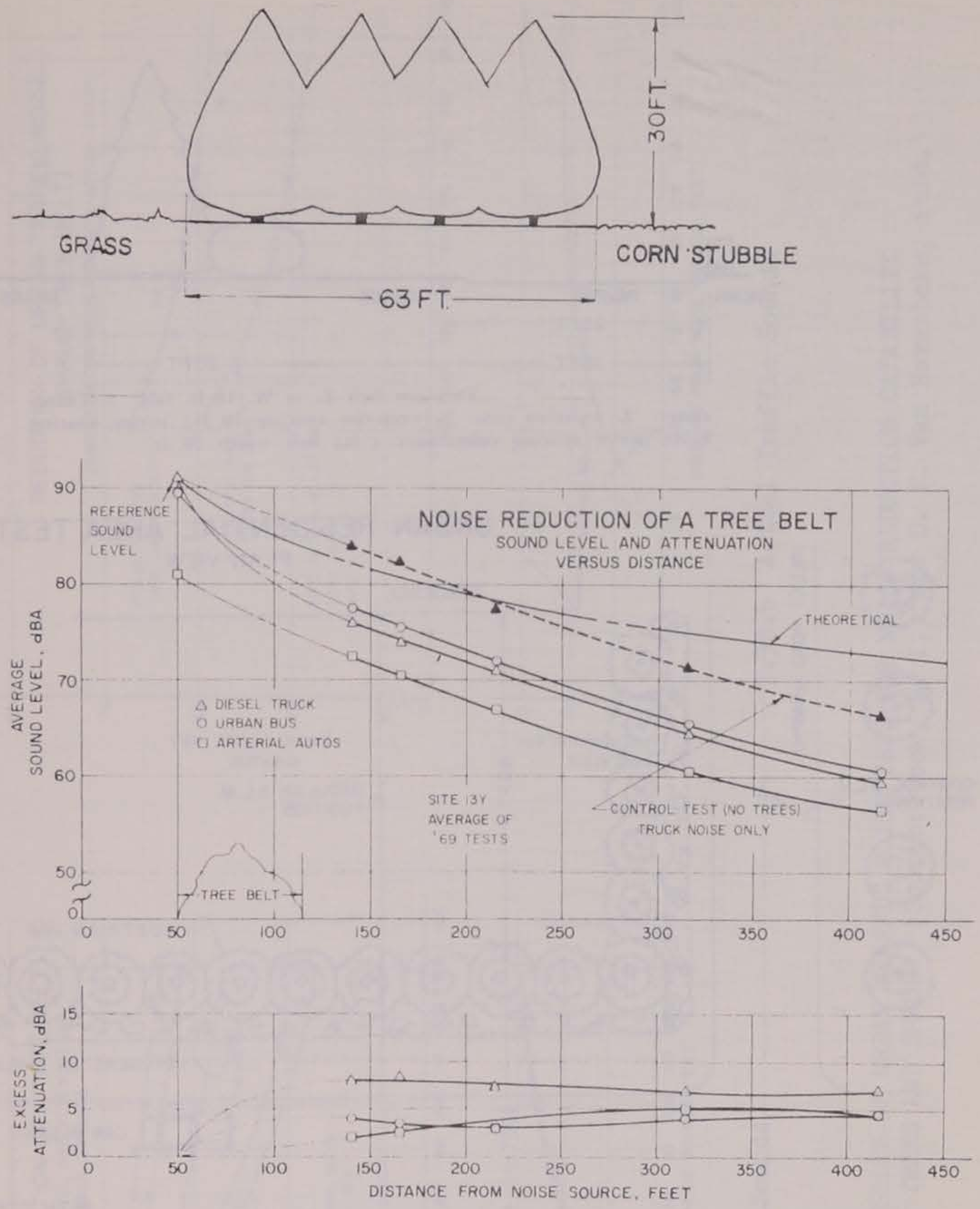
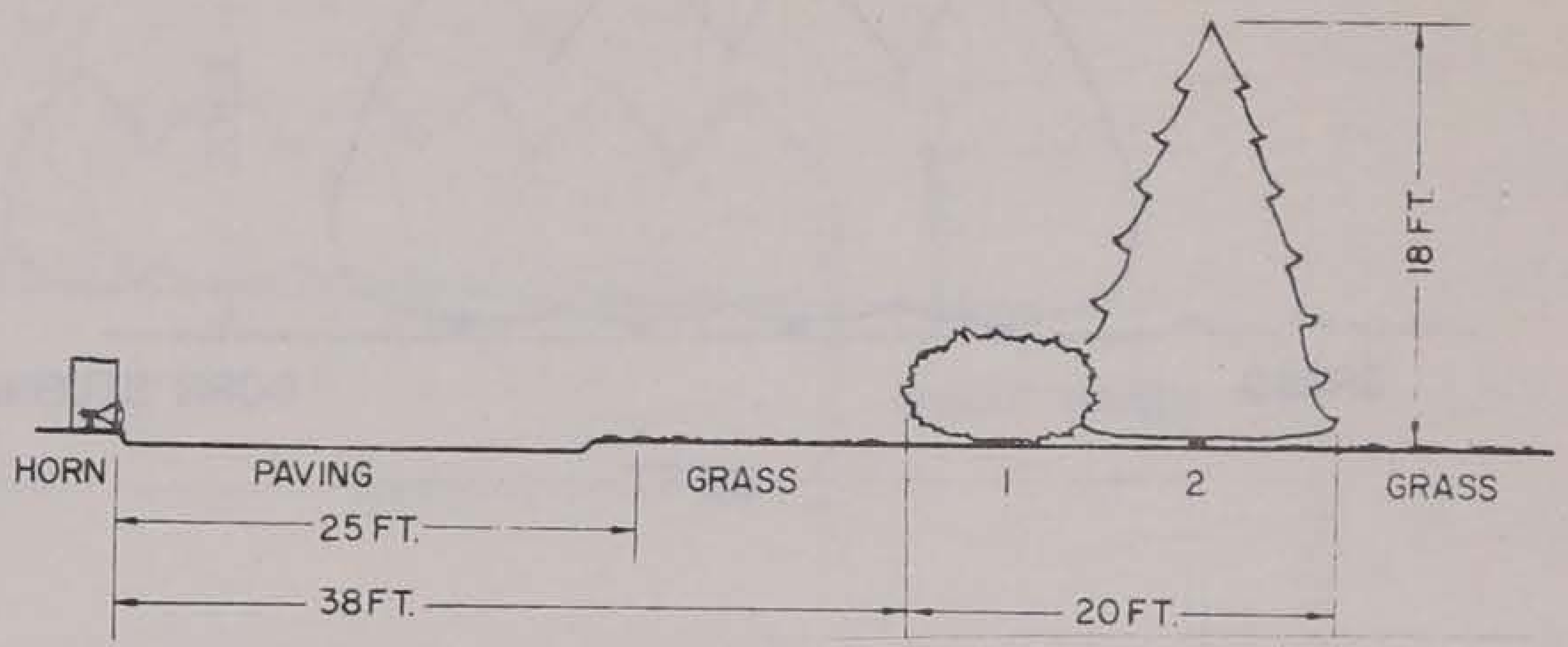


Figure 3.31 NOISE REDUCTION CAPABILITY OF FOUR ROWS OF EASTERN REDCEDAR 30 FEET TALL WITH A BELT WIDTH OF 63 FEET (Source: Cook, D. I., and D. F. Van Haverbeke, ibid.)



Two row belt E. to W. 18 ft. tall. 1. Cotoneaster. 2. Austrian pine. Between-row spacing 10 ft.; in-row spacing 9 ft.; in-row spacing cotoneaster 4 ft.; belt width 20 ft.

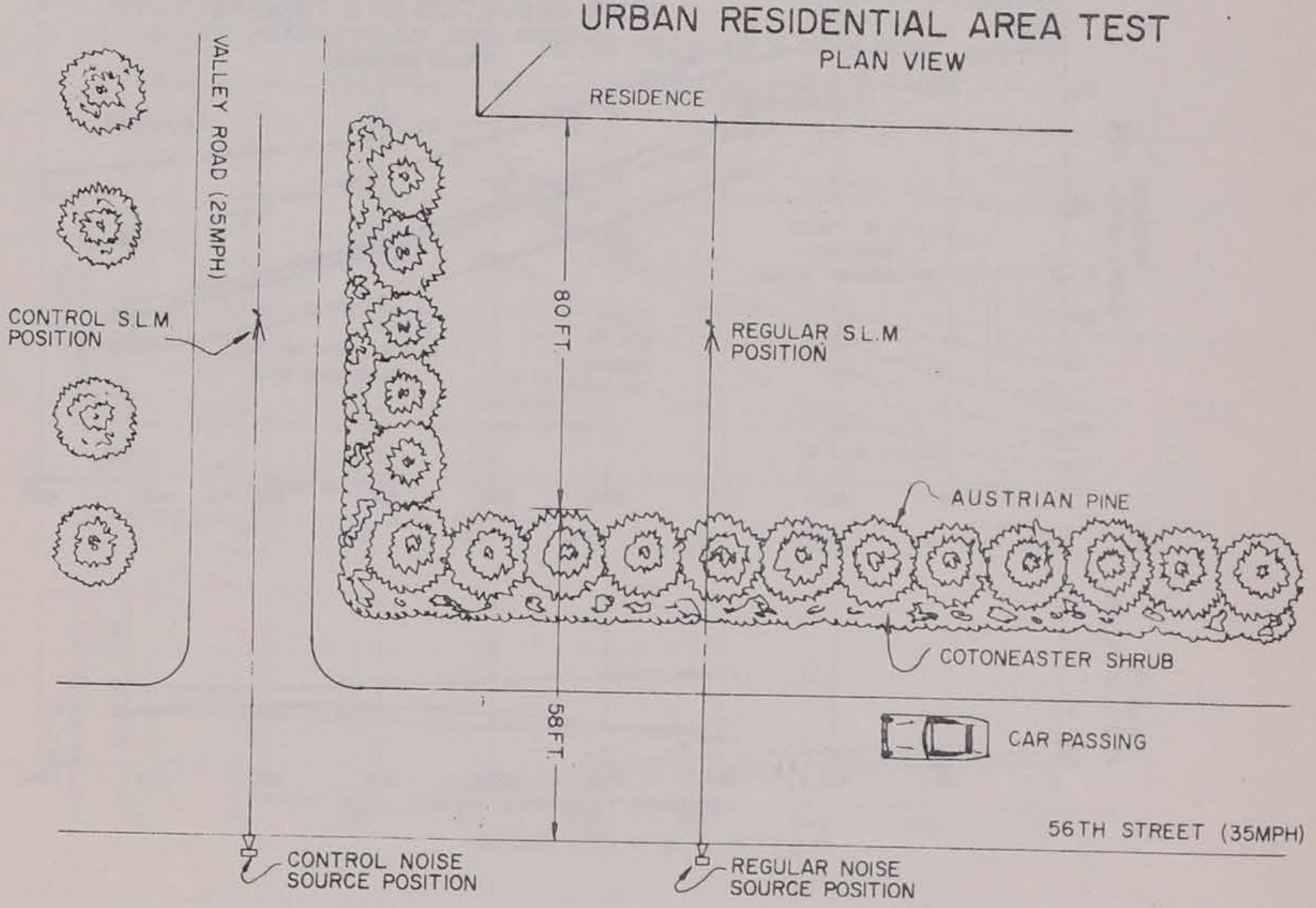
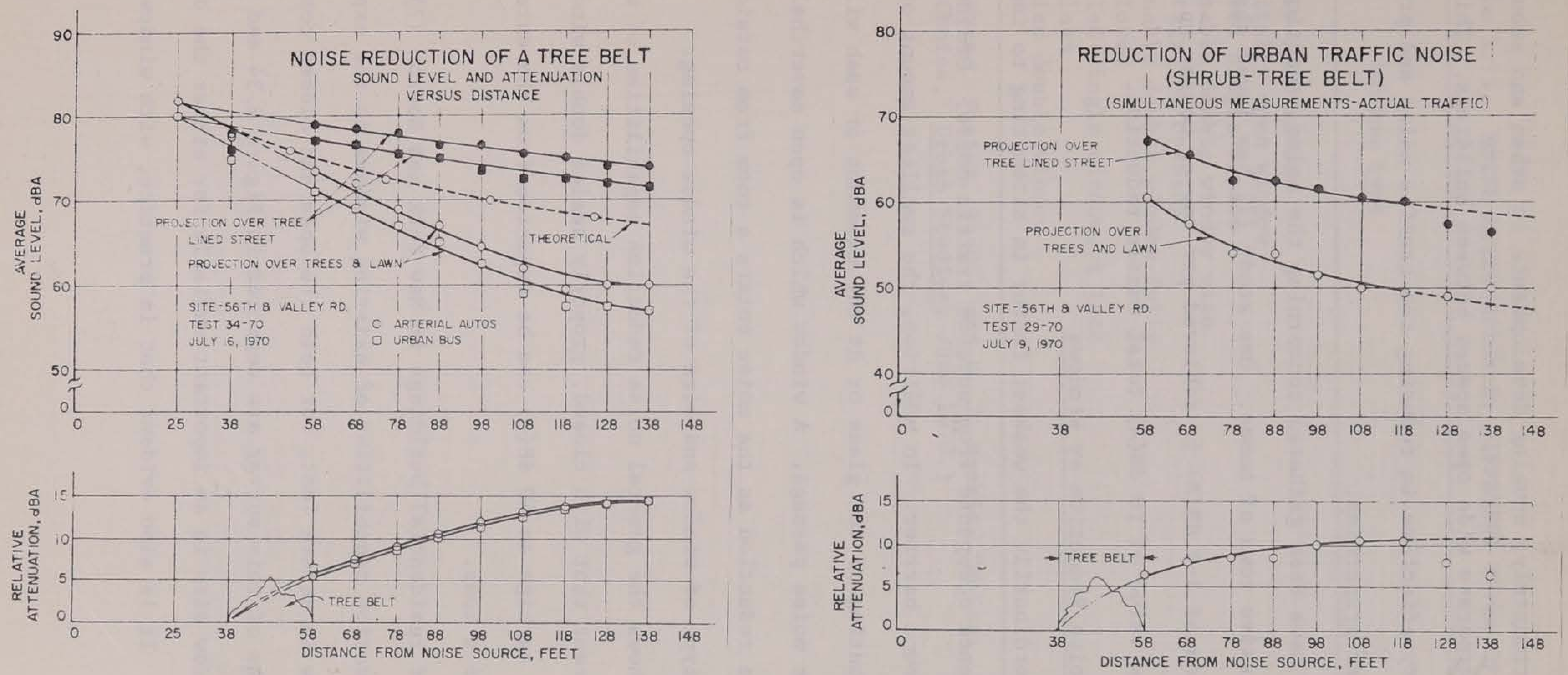


Figure 3.32 DETAILS OF URBAN RESIDENTIAL AREA TEST SITE FOR MEASURING NOISE REDUCTION CAPABILITY OF TREES AND SHRUBS (Source: Cook, D. I., and D. F. Van Haverbeke, ibid.)



3.33.a Recorded Traffic Sounds

3.33.b Actual Traffic Sounds

Figure 3.33 RESULTS OF URBAN TRAFFIC NOISE TEST FOR NOISE REDUCTION CAPABILITY OF TREES AND SHRUBS (Source: Cook, D. I., and D. F. Van Haverbeke, ibid.)

the source. Unfortunately, housing developments in urban and suburban areas usually incorporate wide open spaces between buildings. This pattern is not very effective in reducing the traffic noise and providing shielding for other properties.

Limited data have been gathered concerning the noise reduction achieved by successive rows of homes. One study (7) has found that an excess reduction of 3-5 dB(A) is achieved per row of houses up to a maximum limiting value of 10 dB(A) total excess reduction.

3.1.19 Traffic Noise Reduction by Windows

Windows are ordinarily the weakest factor in attempting to insulate building or residence occupants from outside traffic noise. Ordinary glass is a poor sound barrier. In addition, the smallest amount of opening in the mounting of the glass or at the casement or sash will readily accomodate noise passage. A window which is open nevertheless affords some noise reduction as the noise enters a room from outside depending on the type of window and size of the window opening.

Table 3.15 shows the general noise reduction capabilities of windows. It is apparent that with closed, properly sealed double windows, a noise reduction as high as 40 dB(A) can be expected from the exterior to the interior of a home.

One survey of residential buildings in New York and Boston (7) related noise reduction capabilities of existing windows to the exposed area of the window in square feet, for both the open and closed conditions. The results of this survey are depicted in Figure 3.34 and it is apparent that window size is an important variable for either the open or closed condition. It is also evident that in practice, with windows

Table 3.15. NOISE ATTENUATION BY DIFFERENT TYPES OF WINDOWS.

Window type	Noise attenuation dB(A)
Fully open window	5
Partially open window	10-15
Closed single window	20
Openable double window with staggered opening	20
Openable double window fully closed	30
Sealed single window, ¼ inch glass	30
Sealed double window	40

(Source: Foster, C. D., and P. J. Mackie, "Noise: Economic Aspects of Choice," Urban Studies, June 1970.)

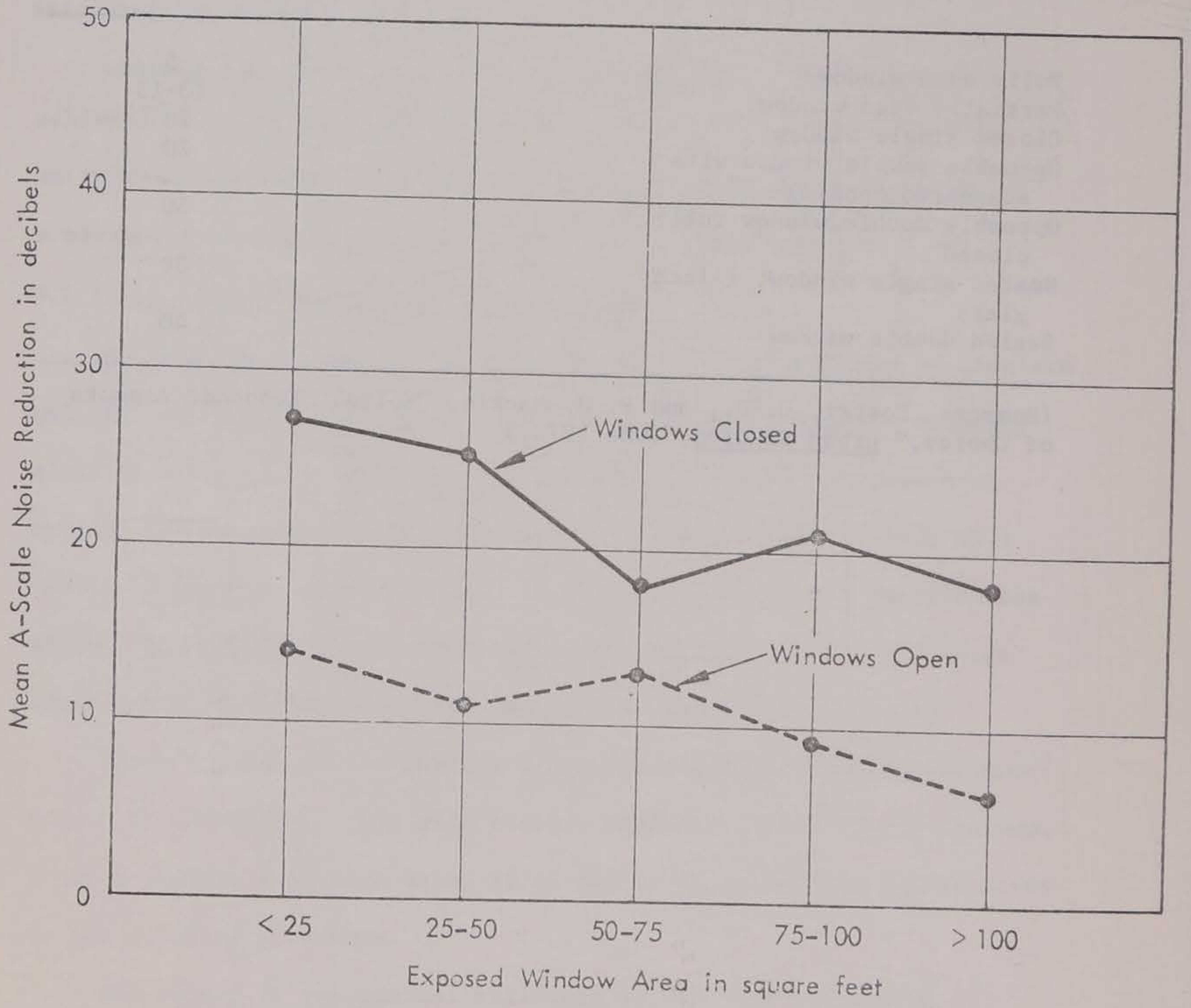


Figure 3.34 TRAFFIC NOISE REDUCTION RELATED TO WINDOW AREA (Source: Bolt, Beranek, and Newman, Noise Environment of Urban and Suburban Areas, 1967)

closed, residences typically receive a noise attenuation of 20 to 25 dB(A).

3.1.20 The Effects of Traffic Noise on People

There is considerable disagreement regarding the nature, extent, and significance of the effects of noise on people (8, 21, 22, 23, 24). Noise impact is a subjective problem involving human values and feelings. Individuals vary considerably in their susceptibility to noise and with regard to their ability to adapt to noise.

In a study of urban traffic noise, attention could be given to three general categories of the various effects of noise on people; namely:

A. Annoyance or bothersome effects of noise,

B. Behavioral effects, such as speech interference or sleep interference of noise, and

C. Physiological effects of noise which occur during or immediately after noise exposure.

With regard to annoyance, numerous studies (8, 25, 26) have established that:

A. Past experience of the individual influences the degree to which he is annoyed,

B. The meaning of the sound source and the individual's attitude toward that source affect the responce,

C. Annoyance is not well correlated with measured sound pressure level, but may be accounted for by the individual's self-rating of noise susceptibility,

D. The activity of the listener at the time of occurrence of the noise influences the degree of annoyance, and

E. The meaning or significance of the sound will influence annoyance since people are more annoyed with intelligible speech occurring at low sound level than with unintelligible noise.

The behavioral effects of noise differ only slightly from the annoyance affects, and are equally difficult to quantify. One of the most widespread effects of traffic noise is interference with communication processes. Noise interference with communication is essentially a masking of speech efforts by noise such that complete understanding of the communication is not achieved. Figure 3.35 shows the relationships between distance separating speaker and listener, decibel level, and the type of voice utilized to achieve communication. It is apparent from this chart that if both the speaker and listener are in a 70 dB(A) environment, face-to-face communication is possible with a "normal voice" when two feet or less separate the individuals; but that communication may take place using a "communicating voice" effort for a distance as great as seven feet between them.

Several studies (25, 27) concerning sleep interference have found vast differences (35 db(A)) in the noise level which may awaken individual subjects. Thiessen (27) reported that 5% of his subjects awakened when exposed to a 40 dB(A) recording of a passing truck, and 30% awakened when the recording was played at 70 dB(A).

The physiological effects of urban traffic noise are not considered to be harmful within the normal conditions encountered. However, an unexpected noise, such as a backfire, screeching brakes and tires, as well as sirens, will provoke startle or fright reactions in people and it has been suggested (28) that too frequent an occurrence of such events might be detrimental to health.

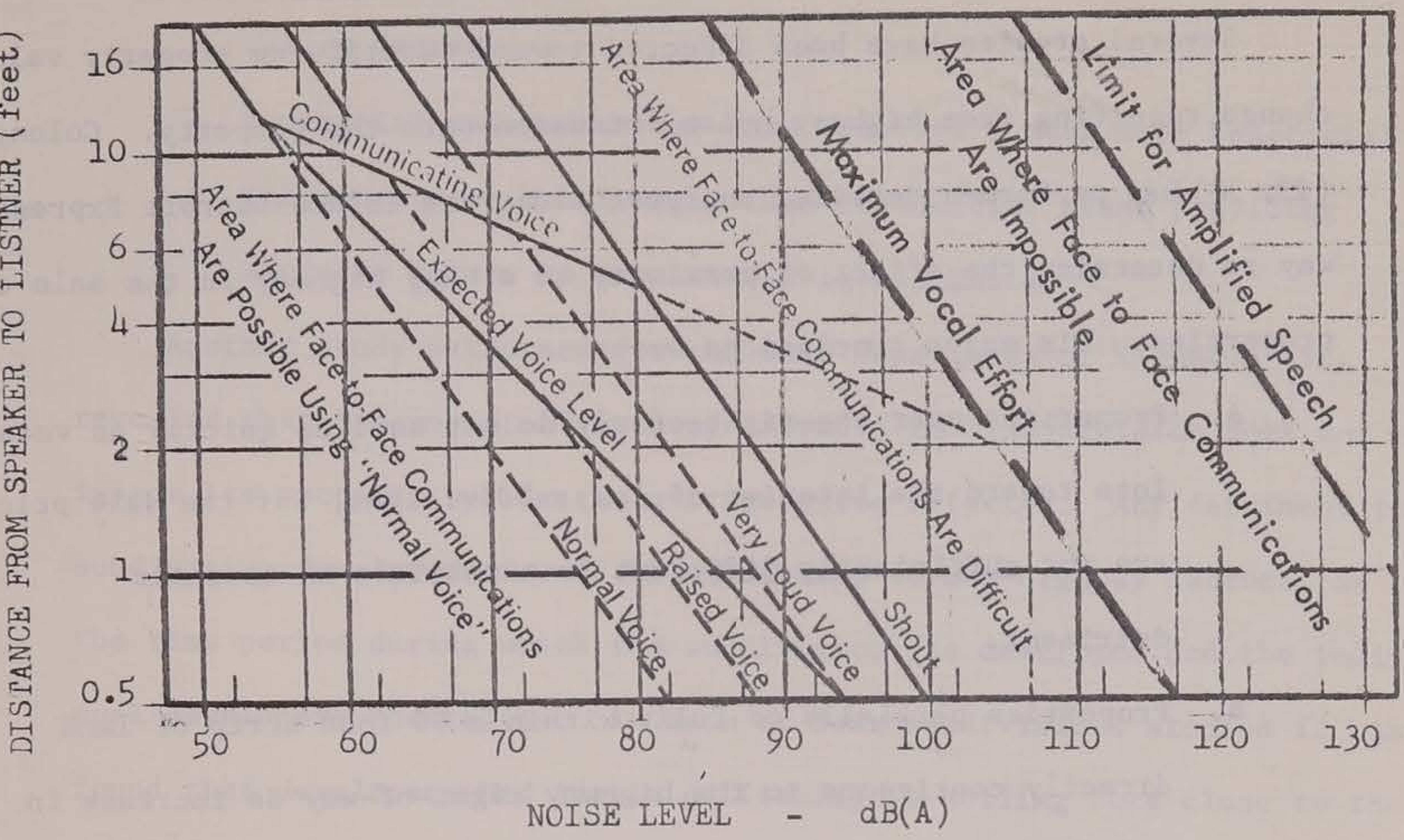


Figure 3.35 VOICE LEVEL AND DISTANCE FOR SATISFACTORY COMMUNICATION AS LIMITED BY AMBIENT NOISE (Source: Webster, J. C., "SIL - Past, Present, and Future," Sound and Vibration, August, 1969.)

3.1.21 The Effects of Traffic Noise on Adjacent Property Values

Several studies have been directed toward quantifying property value change resulting from highway noise intrusion onto the property. Colony (29, 30) has performed detailed analyses along the Toledo-Detroit Expressway to determine the effect of proximity to a busy highway on the sale of properties. His major conclusions were:

A. Properties near the right-of-way do not sell as quickly as vacant lots toward the interior of new subdivisions, but the sale prices are not sufficiently different to constitute an economic detriment.

B. Properties partially or fully within a 50 foot strip of land directly contiguous to the highway right-of-way do increase in value as time passes, but at a lower rate than properties more than 50 feet from the highway.

C. Properties within a band ranging from 50 to 200 feet from the highway right-of-way have increased in value at an average rate greater than any other group of parcels within a band extending for 1,000 feet from the expressway.

D. Where strong pre-expressway influences were present either for the benefit or detriment of a neighborhood, the impact of the expressway has been slight and has been confined to a narrow band of properties within 100 or 200 feet of the expressway right-of-way. Thus, depressed or blighted neighborhoods tend to retain the same rate of deterioration regardless of the added presence of an expressway.

E. In the opinion of professional realtors, properties directly abutting a freeway can expect to incur a 20 to 30% loss in value as compared to identical properties not situated close to the freeway. This rate of loss was estimated to decrease as property values increased.

F. Commercial and industrial land receives a much more beneficial influence from the freeway than residential areas providing adequate access to the freeway is available.

Another study performed for the Ohio Department of Highways (31) revealed that the amount of freeway exposure to a subdivision does not impede its success, nor is the average price affected. Any detriment to subdivision development could be attributed to non-highway factors, as the time period during which the subdivision was developed and the individual developers themselves. In each of four subdivisions studied it was found that developers had little difficulty in selling lots close to the freeway for the same price as lots toward the subdivision interior. It was also stated that insulated windows and air conditioning make the freeway less noisome, and the impersonal nature of the freeway were reasons offered by developers to explain the willingness of people to buy or build along a freeway.

Brinton and Bloom of the Franklin Institute have reported extensive nationwide studies of highway noise, landscaping and property values (32). Their findings included the following:

A. Sound from trucks is the most objectionable highway disturbance to persons living in homes, apartments, and farms next to limited access highways regardless of geographic location.

B. Lack of proper maintenance of highway right-of-way was the second most frequent objection to the highway.

C. Presence of a limited-access highway does not devalue adjacent properties, as shown in Table 3.16. Statistical tests applied to these data did not reveal any significant differences in the

COMPOSITION OF ECONOMIC-STUDY DATA SAMPLE

AREA	HIGHWAY	NUMBER OF RESALES		RANGE OF PRICES (1000's OF $)				RANGE OF YEARS BETWEEN SALES	
				SALE		RESALE			
		N[a]	A[a]	N[a]	A[a]	N[a]	A[a]	N[a]	A[a]
Woodbury, N.J. Cherry Hill, N.J.	New Jersey Turnpike Interstate 295	29	25	13.5 to 25.0	13.5 to 25.0	14.0 to 26.5	14.0 to 26.5	1.0 to 7.0	1.5 to 7.0
King of Prussia, Pa.	Schuylkill Expressway	9	18	19.3 to 22.0	18.5 to 26.5	21.5 to 25.5	20.0 to 26.5	2.33 to 7.75	1.5 to 7.5
East Toledo, Ohio	Detroit-Toledo Expressway	4	9	10.5 to 11.0	9.5 to 17.0	11.5 to 13.5	11.5 to 15.5	6.0 to 10.0	0.5 to 8.0
Los Angeles, Cal.	San Diego Freeway Ventura Freeway San Bernardino Freeway	10	8	13.0 to 33.0	7.0 to 25.0	13.0 to 31.0	6.5 to 45.0	0.5 to 4.5	0.5 to 6.5
Long Island, N.Y.	Long Island Expressway Northern State Parkway	84	52	11.0 to 25.5	10.7 to 25.0	12.0 to 30.0	13.0 to 28.6	0.5 to 15.0	0.5 to 16.0
Baltimore, Maryland	Baltimore Beltway	20	24	12.0 to 17.5	12.5 to 17.8	12.5 to 17.5	13.0 to 19.0	1.0 to 8.0	0.5 to 9.0
	TOTAL	156	137	10.5 to 33.0	7.0 to 26.5	11.5 to 31.0	6.5 to 45.0	0.5 to 15.0	0.5 to 16.0

[a] N = next to highway; A = away from highway.

RESULTS OF STATISTICAL TEST ON RELATIONSHIP OF PROPERTY-VALUE CHANGE TO DISTANCE FROM HIGHWAY

AREA	HIGHWAY	PERCENT VALUE		SIGNIFICANT DIFFERENCES (a)
		NEXT TO HIGHWAY	AWAY FROM HIGHWAY	
Woodbury, New Jersey Cherry Hill, New Jersey	N.J. Turnpike Interstate 295	2.00	2.08	No
King of Prussia, Pa.	Schuylkill Expressway	3.16	2.13	No
East Toledo, Ohio	Detroit-Toledo Expressway	2.01	1.89	No
Los Angeles, California	San Diego Freeway Ventura Freeway San Bernardino Freeway	9.83	9.65	No
Syosset, Long Island	Long Island Expressway	7.83	9.71	No
Mineola, N.Y.	Northern State Parkway	6.07	6.97	No
Baltimore, Maryland	Baltimore Beltway	2.20	2.50	No

Table 3.16 EFFECT OF FREEWAYS ON PROPERTY RESALE VALUE (Source: The Franklin Institute Research Laboratories, <u>Effect of Highway Landscape Development on Nearby Property</u>, NCHRP Report 75, 1969.)

change of property values for properties next to the highway compared to those away from the highway. It was found that there was a slight relationship between noise and depreciation of property value, but not a sufficiently pronounced relationship to satisfy a statistical test. These data are summarized in Table 3.17, and it is apparent that higher average noise levels are not consistently associated with the low rates of property value increase.

D. Presence or absence of landscaping on the right-of-way of a limited access highway does not affect the value of adjacent properties. However, people living next to freeways indicated they would accept its presence more readily if it were concealed from view by landscaping.

E. Attitudes relating to disturbance factors of people living next to a highway vary greatly even in the same geographic location. People living in older, less expensive homes next to freeways tended to accept disturbances more readily than people living in more expensive homes. Los Angeles residents, however, did not follow this trend as their acceptance of the freeway was not related to their property value.

F. A supplementary study of highway noise levels concluded that depression of the roadway is potentially the greatest single reducer of sound level.

3.1.22 Traffic Noise Level Acceptibility Criteria

The community response to noise from a new source, as an urban freeway, depends on the noise conditions existing inside and outside of dwellings prior to the existence of the new source. The degree of intrusion of the new source could be evaluated for each resident affected by that

CODE	AREA	HIGHWAY	HOUSES NEXT TO HIGHWAY	
			MEAN % Δ V/YR	MEAN DBA
1	Woodbury, New Jersey Cherry Hill, New Jersey	New Jersey Turnpike Interstate 295	2.00	72.00
2	King of Prussia, Pennsylvania	Schuylkill Expressway	3.16	73.40
3	East Toledo, Ohio	Detroit-Toledo Expressway	2.01	76.00
4	Los Angeles, California	San Diego Freeway Ventura Freeway San Bernardino Freeway	9.83	77.67
5	Long Island, N.Y.	Long Island Expressway	7.83	69.80
6		Northern State Parkway	6.07	57.10
7	Baltimore, Maryland	Baltimore Beltway	2.20	71.88
8	Norwalk, Connecticut	Connecticut Turnpike	0.55	74.50

Table 3.17 RELATIONSHIP OF AVERAGE NOISE LEVEL TO PROPERTY VALUE CHANGE (Source: The Franklin Institute Research Laboratories, ibid.)

source in terms of both indoor and outdoor activities. The interpretation of a highly detailed analysis of this nature is complicated due to the difficulty in evaluating the results according to a meaningful scale or criteria. Assessing the degree of intrusion by a noise is a complex task primarily due to the wide range of individual perceptions of what constitutes an intrusion.

3.1.22.a Noise Acceptibility Criteria Proposed by Bolt, Berank and Newman

On the basis of task interference, with special concern for retaining a reasonable environment for conversation, Bolt, Beranek, and Newman (3) have developed the traffic noise design levels shown in Table 3.18.a. These criteria pertain to several land use categories and specify average noise levels as well as L_{10} values which should not be exceeded. These levels may be interpreted as being "Maximum noise levels that would be considered by the average individual as acceptable with regard to speech, sleep interference, and annoyance for various community situations."

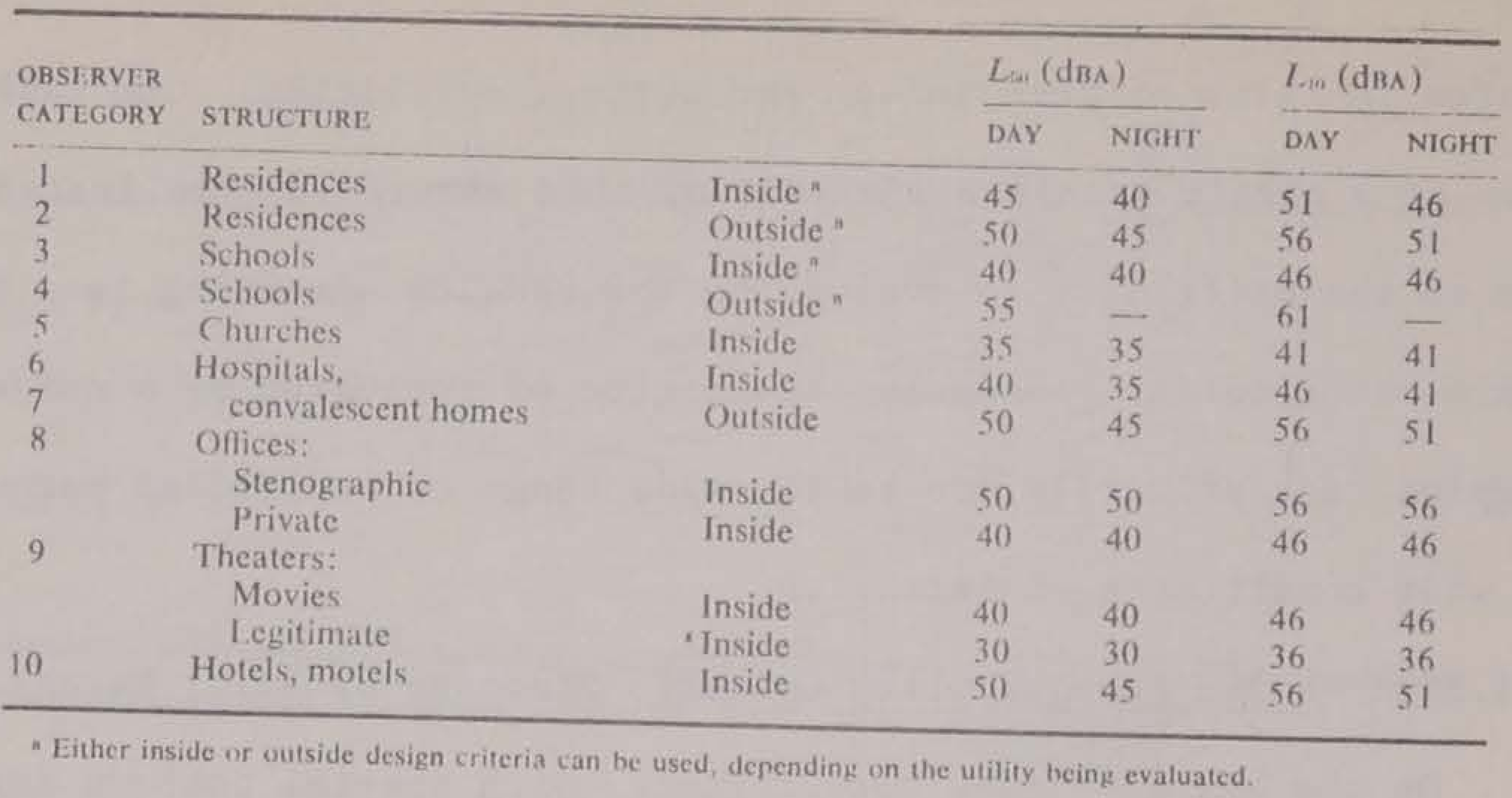
To account for the existing noise at a specific site, it is recommended that these criteria be compared with the existing noise and that the predicted noise levels from the new source also be compared to the criteria. The chart shown in Table 3.18.b is utilized in making these comparisions. To illustrate the procedure for determining noise impact using the criteria, existing, and predicted noise levels, a hypothetical example is given in Table 3.19.

It is concluded in the example of Table 3.19 that "Some Impact" and "Great Impact" might be expected from the new source. This is interpreted according to the following definitions:

A. Great Impact: Strong individual comment and group action may be expected

B. Some Impact: Some individual comment and reaction is expected

3.18.a



OBSERVER CATEGORY	STRUCTURE		L_{50} (dBA)		L_{10} (dBA)	
			DAY	NIGHT	DAY	NIGHT
1	Residences	Inside [a]	45	40	51	46
2	Residences	Outside [a]	50	45	56	51
3	Schools	Inside [a]	40	40	46	46
4	Schools	Outside [a]	55	—	61	—
5	Churches	Inside	35	35	41	41
6	Hospitals,	Inside	40	35	46	41
7	convalescent homes	Outside	50	45	56	51
8	Offices:					
	Stenographic	Inside	50	50	56	56
	Private	Inside	40	40	46	46
9	Theaters:					
	Movies	Inside	40	40	46	46
	Legitimate	Inside	30	30	36	36
10	Hotels, motels	Inside	50	45	56	51

[a] Either inside or outside design criteria can be used, depending on the utility being evaluated.

3.18.b

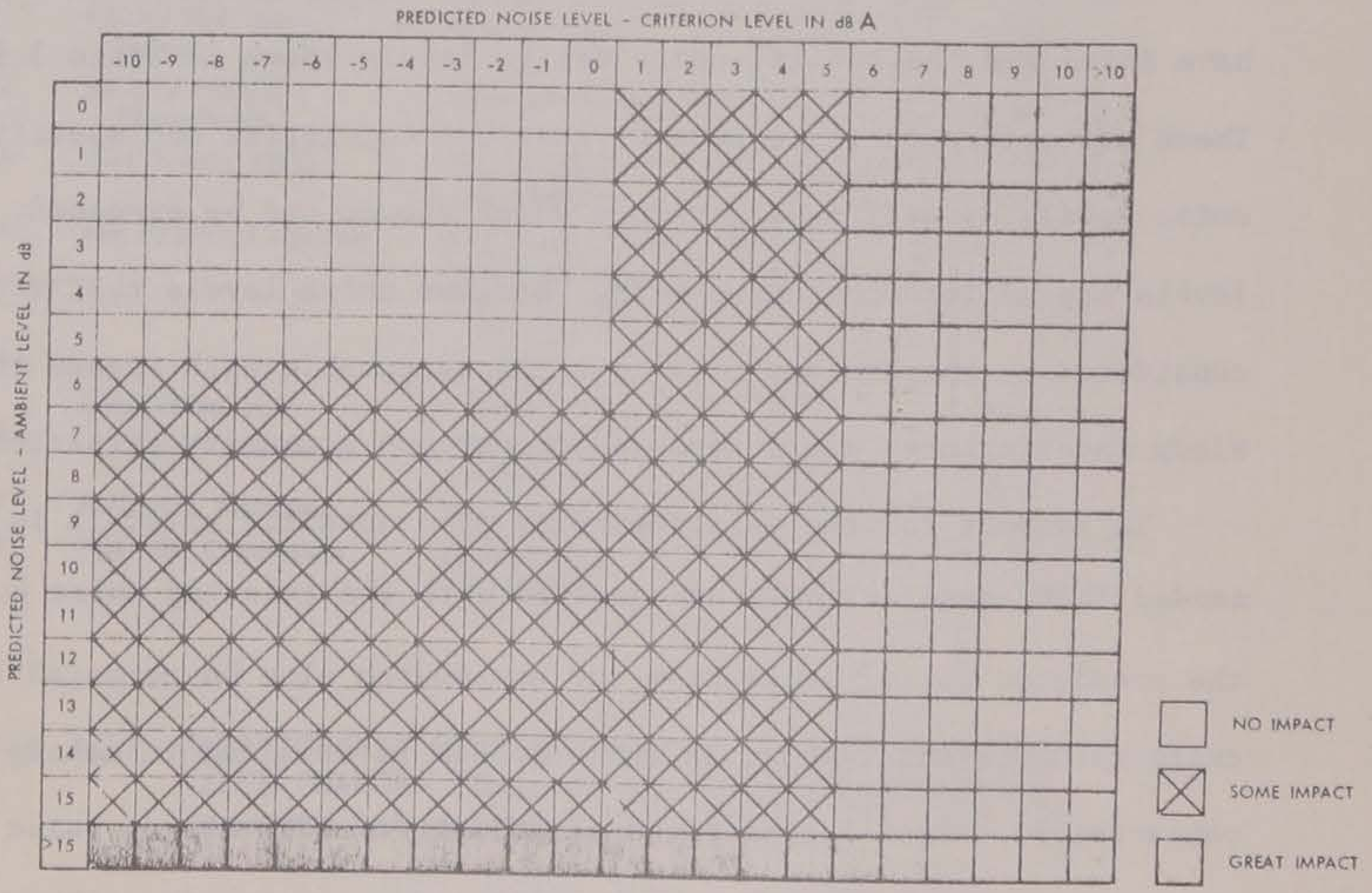


Table 3.18 NOISE LEVEL CRITERIA AND IMPACT EVALUATION
(Source: Bolt, Beranek and Newman, ibid.)

Table 3.19. EXAMPLE NOISE IMPACT EVALUATION.

	L_{50}:DAY	NIGHT	L_{10}:DAY	NIGHT
PREDICTED NOISE	53	51	60	59
CRITERIA NOISE	50	45	56	51
AMBIENT NOISE	49	41	59	45
PREDICTED − AMBIENT	4	10	1	14
PREDICTED − CRITERIA	3	6	4	8
IMPACT	Some	Great	Some	Great

but no group action is likely

C. No Impact: Very little comment or individual reaction is expected.

It is interesting that in this example, negative impact was predicted despite the relatively small differences between the ambient noise and the criteria. One recent report (33) where these criteria were applied addressed this problem and stated that "if the ambient level exceeds or is within 5 dB of the criterion level, the evaluation...is not valid." If this guideline is applied to the example in Table 3.19, it is apparent that the only valid comparison is the L_{10} for night conditions.

3.1.22.b Federal Highway Administration Criteria

The exterior design noise level standards issued by the Federal Highway Administration (FHWA), U.S. Department of Transportation (34), are presented in Table 3.20. These standards establish maximum L_{10} values in dB(A) which should not be exceeded in the design year along any federally funded project passing through an outdoor area having regular human use. FHWA states that: "Projects for which location was approved prior to July 1, 1972: Compliance with noise standards shall not be a prerequisite to any subsequent approval provided design approval is secured prior to July 1, 1974."

It is significant the FHWA mentions that predicted noise levels should be compared to existing noise levels as well as the design noise levels where a project is being planned, and that the existing noise will be considered in determining the anticipated impact upon land use and activities. The procedure for obtaining existing noise levels is not specified and it must be assumed that any reasonable field measurement technique with proper acoustical equipment would be acceptable.

Description of Land Use	Exterior Design Noise Levels, L_{10}
Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particular parks or portions of parks, or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.	60 dBA
Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, picnic areas, recreation areas, playgrounds, active sports areas, and parks.	70 dBA
Developed lands, properties or activities not included in categories A and B above.	75 dBA
For requirements on undeveloped lands see paragraphs 5.a(5) and (6) of PPM 90-2.	Unlimited
Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums.	55 dBA (Interior)

Table 3.20 FEDERAL HIGHWAY ADMINISTRATION DESIGN NOISE LEVELS (Source: PPM 90-2, FHWA, USDOT, Feb. 8, 1973)

3.2 Multiple Use and Joint Development of Urban Freeways

Many examples have occurred in urban areas over the past several years wherein freeways have been conceived and developed so that their right-of-way is integrated with other harmonious land uses. The actual area involved may be limited only to the freeway right-of-way or the integrated development may be broadened so that adjacent land and the highway are treated as an entity.

As indicated above, this is not a new concept. The literature is replete with applications of multiple use or joint development that were conceived many years ago. Earlier examples include the use of air rights over a freeway in New York City for an apartment complex and a bus terminal. The placement of a freeway in Chicago under a large post office is another example.

3.2.1 Areas under structures

A comprehensive summary of integrated use of highway right-of-way is presented in Highway Joint Development and Multiple Use (35), a publication of the Federal Highway Administration issued in 1970. Of the examples noted, all completed before 1970, some 200 projects involved joint or multiple use of land under highway structures. As could be anticipated, the majority of these (57 percent) were devoted primarily to automobile parking. However, other uses were listed in the following categories (in order of frequency of occurrence):

- Parks and playgrounds
- Transportation terminals and facilities
- Industrial plants or facilities
- Miscellaneous storage
- Warehouses and miscellaneous buildings

- Highway maintenance facilities
- Other public buildings
- Commercial facilities, stores

As is evident from the above listing, some precedent exists for virtually any kind of use for land beneath urban highways that can be considered compatible with the surrounding environment. The multiple use of land in this manner appropriately recognizes that urban land is a valuable resource. It also affords the planner and designer opportunities to soften what otherwise would be harsh and abrupt changes in land use between a highway and its immediate surroundings.

3.2.2 Land Adjacent to Highways

Land bordering highways, both within and outside the right-of-way, offers further opportunity for uses that will help to blend a highway with its surroundings. Multiple use and joint development projects listed in the Federal Highway Administration publication referred to above include, among others, the following types of facilities that have been completed, at least parts of which lie within highway rights-of-way:

- Parks, playground, mini-parks, tot lots
- Marinas, boat launching areas, fishing access
- Historic sites, public monuments
- Outdoor classrooms, bird sanctuaries
- Public buildings of several types
- Parking for purposes listed above or for other uses
- Railroads, mass transit facilities, truck loading docks
- Snow disposal area

The above summary is not exhaustive, but the items listed are indicative of some of the varied uses reported for land adjacent to highways and are representative of earlier practice among highway designers. Where permitted by an administrative framework, current practice is more likely to extend well beyond the right-of-way limits. Increasingly, designers attempt more completely to integrate the highway and adjacent land uses.

As indicated in a subsequent section of this report, there are several examples of planning for very large developments in which a freeway, residential and commercial buildings, other facilities, and the related open spaces are conceived and built as an entity. Obviously, opportunities for these massive developments are limited. However, the development on a smaller scale of remainder parcels along with land within the right-of-way affords excellent opportunities for a community to enhance the effects from new highways.

3.2.3 Pertinent Federal Guidelines

The 1970 National Highway Needs Report (36) to the Congress of the United States (Committee Print 91-27) contains the following statement:

> "In recent years the highway planning process has become increasingly interwoven into the general planning effort through which urban and rural communities identify their public and private projects which best fulfill each localities needs and desires for future development. This has resulted in the identification and provision of highway facilities which blend well with neighboring land uses of all types. Among the tools with which Federal and State highway administrators can achieve these desired ends are the concepts of joint development and multiple land use. Others, such as improved standards, beautification program and scenic enhancement, also contribute to optimal use of resources.
>
> "Joint development is an approach which stresses the importance during highway route location and design, of effectively planning for the future of the entire transportation corridor to insure that the highway facility is integrated into a harmonious arrangement of compatible land uses. Multiple land use involves making provision for complementary nonhighway facilities, such as parking and other terminals, park and recreation areas, and various commercial or public buildings to share the highway right-of-way above, below, and alongside the highway itself."

The Federal Highway Administration is charged with carrying out the intent of Congress in respect to the "wise and orderly development and use of environmental resources" (from Committee Print 91-27, U.S. Congress) relative to highways. This Congressional intent has been reiterated in some form in each Federal Aid Highway Act starting in 1962. (The 1962 Act called for a comprehensive, continuing, cooperative transportation planning process in each urban area of at least 50,000 population.) Specific federal guidelines promulgated by the Federal Highway Administration include the following:

- Interim Policy and Procedure Memoradum 21-19 (January 17, 1969), Joint Development of Highway Corridors and Multiple Use of Roadway Properties (37).

  Describes procedures for joint development planning activities for new highway facilities in urbanized areas

- Policy and Procedure Memorandum 80-10 (November 15, 1971), Use of Airspace (38).

  Sets forth policies on use of space within highway right-of-way and located above or below the highway gradeline for nonhighway purposes

- Policy and Procedure Memorandum 90-1 (August 24, 1971), Guidelines for Implementing Section 102(2)(c) of the National Environmental Policy Act of 1969, Section 1653(f) of 49 U.S.C., Section 470f of U.S.C., and Section 309 of the Clean Air Act of 1970 (39).

  Describes measures "to assure that the human environment is carefully considered and national environmental goals are met when developing federally financed highway improvements"

- Policy and Procedure Memorandum 90-3 (June 12, 1972), Landscape and Roadside Development (40).

  Furnishes guidelines and prescribes policies and procedures for implenting laws relating to landscaping and scenic enhancement

- Policy and Procedure Memorandum 90-4 (September 21, 1972), Process Guidelines (Economic, Social, and Envinronmental Effects on Highway Projects) (41).

    Provides guidelines for consideration of possible social, economic and environmental effects of highways to help assure that project decisions" are made in the best overall public interest"

- Instructional Memorandum 21-1-69 (January 16, 1969), Guidelines for Administering Demonstration Fringe Parking Facility Projects (42).

    Provides for parking facilities on highway right-of-way and/or adjacent land in conjunction with public transportation systems

- Instructional Memorandum 21-2-69 (January 17, 1969), Federal Participation in the Development of Multiple Use Facilities on the Highway Right-of-Way (43).

    Sets forth procedures for carrying out federal policy relating to multiple use of highway right-of-way

- Circular Memorandum of October 1, 1969, Application of Joint Development and Multiple Use Concepts of Freeways and Utilities (44).

    Sets forth provisions for accomodating utility facilities along and within a freeway right-of-way

3.3 Freeway and Corridor Aesthetics

As indicated in a subsequent section of this report, highway design agencies have become increasingly sensitive to the appearance of major highway improvements. This sensitivity is essential throughout the location and design processes since the aesthetic effect of a freeway is dependent upon both its location and its detailed design.

Because each freeway in each urban area represents a unique situation, it is not feasible to develop rigid standards that can assure an aesthetically pleasing highway and highway corridor. However, there are numerous guidelines, which if adhered to, will enhance the visual effect of any urban freeway. Many such design and location principles have been set forth by the American Association of State Highway Officials in A Guide for Highway Landscape and Environmental Design, 1970 (50).

The purpose of this section is not to point out those elements of aesthetic design that are beyond the control of the City of Cedar Rapids. Rather, the intent here is to suggest some of the principles relative to land within the freeway corridor, but primarily dealing with that outside the right-of-way, with application after the initial decisions of location and design have been made. It is possible to guide subsequent development within the corridor so that it will enhance a view of the freeway and a view from the freeway.

The discussion that follows is adapted in part from A Study of the Social, Economic, and Environmental Impact of Highway Transportation Facilities on Urban Communities. This 1968 publication of the College of Engineering Research Division, Washington State University (45), presents "procedures and 'tools' for locating and building highways that will not only serve the traffic but satisfy the needs of the community and the public with regard to appearance and social needs and amenities." Many of the recommended standards included in that study are pertinent only to the location and design of an urban freeway. However, those that follow suggest actions that can be taken after location and design have been fixed.

1. Use of space under an elevated freeway. Possible uses of space under a freeway are discussed in more detail later. Failure to use areas under freeway structures suggests a potential for neglect with a likelihood that the resultant wasteland will become an eyesore and a hazard to health. On the other hand, joint use of this space in a manner that is harmonious with its surroundings can improve the appearance of a community as well as being of significant economic benefit.

2. Compatible design of buildings close to the freeway. Problems of visual scale can be anticipated when a freeway is superimposed upon a community. The massiveness of highway structures often is out of proportion to existing buildings in the corridor. Thus, subsequent new construction, if carefully designed, can help to adapt the structure of a community to the presence of the highway and to reduce the apparent width of a freeway. Appropriate zoning controls can guide development in this direction with results that should provide a more pleasing visual experience from the road and help to soften the effect of the highway ribbon as viewed from nearby.

3. Integration of the highway ribbon into the city structure. Integration of the freeway right-of-way into the city structure implies other factors in addition to the design of nearby buildings referred to above. Landscaping of nearby areas may be planned in such a way that it is compatible with plantings within the right-of-way itself. Open spaces adjacent to the freeway should be planned with consideration for their

appearance as viewed from the road. Moreover, the most interesting and attractive views from the road often are of natural areas or man-made structures at some distance from the right-of-way. These vistas frequently may be enhanced by the location of nearby buildings and by judicious use of plantings to control views from the highway. The same form of control may be used to hide that which is unattractive.

4. Attention to visual transitions across the freeway. The barrier effect of an urban freeway may be one of its most critical features. This effect may be used to advantage if the land uses on opposite sides are not compatible and should have a buffer between them. However, in many cases the discontinuity imposed by the wide freeway right-of-way is objectionable. This problem may be ameliorated by careful attention that the transition from one side to another is not more abrupt than necessary, that structural forms are not made inconsistent with one another, and that landscaping is planned consistently on both sides of a freeway. Too often the removal of mature trees in the course of land-use changes that may follow freeway construction will tend to accentuate the barrier effect. Thus, it is usually helpful in this respect if trees that remain in proximity to the highway can be preserved.

5. Provision of visual terminations at dead-end streets. The appearance of ends of streets dead-ended by freeway construction often tends to reinforce the barrier effect referred to previously. These unused dead ends often afford nothing better than a view of the right-of-way fence. A sense of place and a softening of the barrier effect is possible if the view, as well as the street, is terminated short of the freeway. It may be that the dead end is a suitable location for a building that is in character with the rest of the street. Lacking this

solution, an appropriate visual termination may be afforded by a group of trees or other plantings.

6. Elimination of unwanted urban accessories. Construction of a freeway often opens up to view unattractive aspects of a community that previously may have been obscured in the usual clutter of an urban area. Their presence detracts from the view from a road and tends to create the impression that their ugliness should be blamed upon the construction of a freeway. Attrition and decline of certain areas and structures is inherent in the natural growth processes of an urban area. These changes present an opportunity for orderly planning of improvements that, without the necessity for wholesale destruction so often associated with urban renewal, can serve to enhance the aesthetics of the entire urban area. Freeway construction may also suggest the opportunity for removal of unwanted advertising signs, communications lines, and other accessories.

4. PROJECT ACTIVITIES

4.1 Des Moines I-235 Study

The purpose of this activity was to obtain information describing the highway related impressions and experiences of residents living in an urban freeway corridor in Iowa. It was not the intent of this activity to be a highly technical population sampling study which would culminate in statistical hypothesis testing, but rather a study concerned with individual reactions and comments that might be of value to the City of Cedar Rapids in evaluating the impact of the I-380 freeway.

The urban freeway selected for this activity was a 13-mile length of I-235 located in Des Moines and West Des Moines, Iowa. The survey was conducted in two phases. Initially, a mail-out questionnaire was prepared and sent to selected addresses along the I-235 route. This was followed up by a personal interview of certain individuals replying to the questionnaires. Several previous investigations (7, 8, 30, 32, 46, 47, 48) of a similar nature were reviewed prior to preparing the initial questionnaire to guide the investigators in constructing the questions and in conducting the personal interviews.

4.1.1 Mail-Out Survey

Potential participants for the mail-out survey were selected during a preliminary reconnaissance trip covering all the residential areas along the I-235 route. House numbers were chosen at that time according to several criteria, namely: estimated property value, proximity of the home to the freeway, and relative elevation of the home to the freeway.

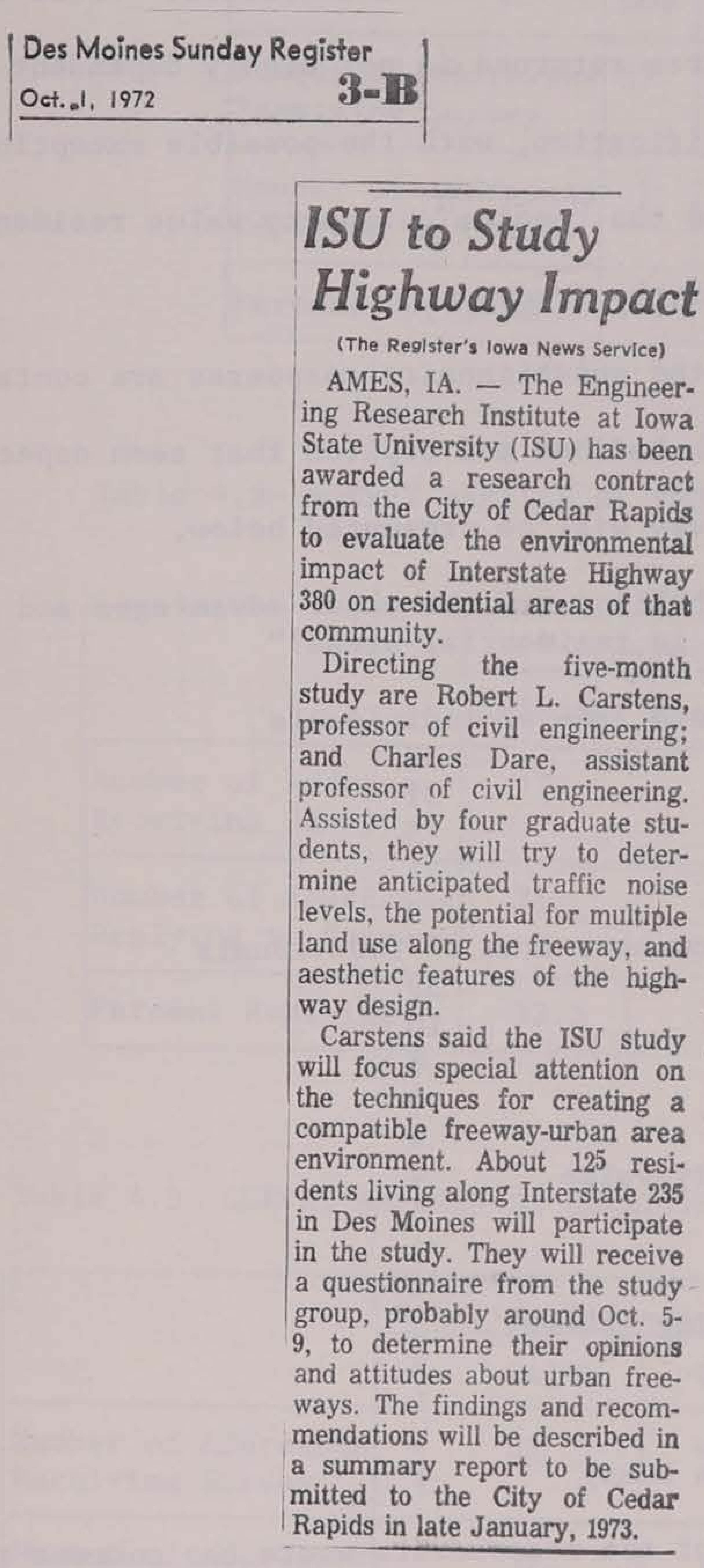
Three property value categories, low, medium, and high, were established for rating the residences. The investigators categorized each property based on its appearance and the condition of the immediate neighborhood.

Proximity of the home to the freeway was a variable that not only included distance separating the property from the freeway, but also the orientation of the house with respect to the freeway. The first category, noted "adjacent," consisted of all homes where the property directly abutted the freeway right-of-way. The second category, noted "perpendicular," included properties where the home faced a side street that was oriented perpendicularly with respect to the general freeway path. The final category, noted "removed," included properties that were more than 400 feet away from the freeway and properties located so that at least one row of houses existed between the freeway and the subject property.

Elevation of any property relative to the freeway was classified either at-level, above, or below. A property was classified as being either above or below the freeway only if there was substantial differences (more than 15 feet) between the elevation of the traveled lanes and the elevation of the first story windows of the home.

A total of 127 residences along I-235 received questionnaires. Each address was supplied with two questionnaires so that both the wife and husband could reply. The mailing occurred during October following an announcement in the October 1, 1972, edition of the Des Moines Sunday Register. (See Figure 4.1.)

Sixty-seven completed questionnaires were returned, representing 41 separate addresses and a return rate of 32 percent based on the original number of addresses receiving questionnaires.



Des Moines Sunday Register
Oct. 1, 1972 **3-B**

ISU to Study Highway Impact

(The Register's Iowa News Service)

AMES, IA. — The Engineering Research Institute at Iowa State University (ISU) has been awarded a research contract from the City of Cedar Rapids to evaluate the environmental impact of Interstate Highway 380 on residential areas of that community.

Directing the five-month study are Robert L. Carstens, professor of civil engineering; and Charles Dare, assistant professor of civil engineering. Assisted by four graduate students, they will try to determine anticipated traffic noise levels, the potential for multiple land use along the freeway, and aesthetic features of the highway design.

Carstens said the ISU study will focus special attention on the techniques for creating a compatible freeway-urban area environment. About 125 residents living along Interstate 235 in Des Moines will participate in the study. They will receive a questionnaire from the study group, probably around Oct. 5-9, to determine their opinions and attitudes about urban freeways. The findings and recommendations will be described in a summary report to be submitted to the City of Cedar Rapids in late January, 1973.

Figure 4.1 DES MOINES I-235 SURVEY ANNOUNCEMENT

Tables 4.1, 4.2, and 4.3 summarize the relationships among the number of questionnaires sent out, number completed, and percent returned according to each subclassification of property characteristics. These tables show that the portion of questionnaires returned is not highly dependent on any of the primary variables of classification, with the possible exception of the greater proportionate response from the "medium" property value residents and from those living "removed" from the freeway.

Detailed analyses of the questionnaire responses are contained in Appendix A. Only those tabulations and replies that seem especially pertinent to the purpose of this survey will be presented below.

Question 9: "What do you believe are the major advantages and disadvantages of having freeways located in residential areas?"

Advantages: 69 comments from 67 individuals

Convenience	32
Speed	31
Safety	5
Less congestion	1

Disadvantages: 107 comments from 67 individuals

Noise	59
Odor (fumes)	10
Vibrations	8
Appearance	6
Lack of privacy	4
Decreased property value	4
Dirty	4
House settling	3
Lights	2
Difficulty crossing freeway	2
Property damage	2
Confusing ramps	1
Damage to health	1
Cracked walls (in home)	1

(Note: Almost 50 percent of the respondents wrote the comment that convenience or the ability to reach the downtown or other areas quickly were advantages. Almost 90 percent stated that noise was the greatest disadvantage, which might be attributed somewhat to the suggestive nature of subsequent questions.)

Table 4.1 SURVEY REPLIES BY PROPERTY VALUE CLASSIFICATION

	Property Value		
	Low	Medium	High
Number of Addresses Receiving Survey	37	64	26
Number of Addresses Replying to Survey	7	26	8
Percent Replying	18.9	40.6	30.8

Table 4.2 SURVEY REPLIES BY PROXIMITY TO THE FREEWAY

	Proximity to Freeway		
	Adjacent	Perpendicular	Removed
Number of Addresses Receiving Survey	77	35	15
Number of Addresses Replying to Survey	25	10	6
Percent Replying	32.5	28.6	40.0

Table 4.3 SURVEY REPLIES BY RELATIVE ELEVATION TO FREEWAY

	Relative Elevation of House to Freeway		
	Below	Level	Above
Number of Addresses Receiving Survey	39	45	43
Number of Addresses Replying to Survey	9	16	16
Percent Replying	23.1	35.5	37.2

Question 10: "In general, would you say the advantages outweigh the disadvantages of freeways?"

Yes 26 Not Certain 16 No 25

Question 11: "If you have lived at this address both before and after the nearby freeway was built, how would you describe the change in the general noise level in your neighborhood?"

Much noisier with freeway	42
Slightly noisier	5
No change	1
Slightly quieter	0
Much quieter with freeway	0
Not here both before and after freeway was built	19

Question 12: "Would you ever buy or rent another home as close to the freeway as your present home?"

Yes 13 Not Certain 9 No 45

Question 13: "Does noise from the freeway hinder your family outdoor activitie

Yes 36 Sometimes 8 No 23

"Which activities?" The most frequently mentioned activities were: use of porch and patio, yard activities, conversation, relaxing with reading, and gardening.

Question 14: "Does noise from the freeway hinder your indoor activities?"

Yes 17 Sometimes 23 No 27

"Which activities?" The most frequently mentioned were: conversation, use of the telephone, sleep, listening to TV, or simply "general" activitie

Question 15: "For each time period of a weekday, please circle the letter that most closely describes the noise you hear from the freeway. (A means definitely annoying; B means slightly bothersome; C means occasionally noticeable, D means you do not notice the noise; E means you are usually away from home at that time The replies were tabulated as follows:

	Noise condition				
Time of Day	A	B	C	D	E
6- 8 a.m.	22	12	16	9	7
8-12 noon	10	9	9	14	24
12- 4 p.m.	9	9	10	14	24
4- 6 p.m.	30	11	11	11	3
6-12 midnight	27	13	5	11	10
12- 6 a.m.	21	8	8	17	12

Question 16: "At times when the freeway traffic noise seems to bother you, is it possible to identify specific vehicles that create the disturbance?"

Yes, vehicles causing noise are: 69 comments from 67 individuals

Large trucks	58
Motorcycles	13
Car with noisy exhaust	12
Emergency vehicles	6
Can't identify specific vehicles	6

No, vehicle noise does not bother me 3

(Note: It was found that each person who was able to identify specific vehicles causing noise did identify large trucks as being one of the sources.)

Question 18: "Have you changed your home or anything on your property specifically for the purpose of reducing the freeway noise that you hear?"

Yes 22 No 18 No reply 1

The changes mentioned most frequently were installing air conditioning, planting more trees, shrubs, or hedges, constructing a privacy fence, keeping the windows closed all seasons, and purchasing heavier drapes. One resident relocated a bedroom seemingly to no avail. The only consistently effective countermeasures were the installing of air conditioning and keeping the windows closed at all times.

Question 20: "Would you like to have city laws enforced to reduce vehicle noise?"

Yes, more strictly enforced	54
Yes, adequately enforced already	7
No, enforcement not needed	2

Question 24: "Should a barrier or wall be built close to the freeway to reduce the traffic noise?"

Yes, all along the freeway	27
Yes, only in the noisiest places	9
Probably not needed	28
No reply	3

Question 25: "Should many trees and shrubs be planted between your home and the freeway to hide it from your view?"

Yes, they are needed	45
No, probably not needed	9
No, trees already present	10

Question 27: "If you had control of state and local highway funds, in what ways would you like to spend it?

	Many $	Few $	No $
Beautify highways	18	19	2
Buy buses	7	10	12
Improve city streets	29	16	1
Control traffic noise	29	16	2
Improve traffic safety	37	13	1
Build new highways	15	17	9

Other: Most frequently mentioned projects were: comprehensive mass transit, improve or repair existing highways, and complete the interstate system.

(Note: Although the people replying to this survey are very well acquainted with the traffic noise problem, their primary concern definitely is the improvement of traffic safety.)

4.1.2 Personal Interviews

Of the 41 addresses responding to the mail-out survey, 20 were selected for a more detailed personal interview. Interviewees were chosen to permit on-site evaluation of different circumstances with respect to proximity of the freeway to the interviewee's property, value of the property, and relative elevation of the freeway. Occupation and apparent willingness to further participate in this study as judged by reviewing the mail-out responses were also important factors in selecting addresses for the personal interviews.

Appointments were established by telephone several days prior to each interview so the residents could be properly prepared for further discussion of the study. All personal interviews were conducted by the principal investigator during the morning, afternoon, and evening of Wednesday, November 22, or Saturday, November 25, 1972. An average time of 45 minutes was spent at each address.

The interviews were initiated by further explaining the purpose of the study and asking several questions pertinent to the interviewee's mail-out survey reply. The participants were encouraged to freely discuss their attitudes toward the freeway, its impact on their neighborhood, the extent to which they were affected by noise from any source, and the suitability of certain traffic noise abatement devices, especially noise barriers. This approach to the interview proved to be extremely valuable since numerous insights were gained into individual situations which most likely would not have emerged from a rigidly structured question-and-answer format. During each discussion the interviewer was granted permission to photograph the property and the view of the freeway from the property.

The detailed summaries of each personal interview have been placed in the technical supplement to this study report. The more significant and frequent comments and opinions which have been extracted from the interview summaries are listed below:

A. The most readily identified noise all along the freeway was the noise from large trucks. Most residents believed that trucks were traveling at unnecessarily high speeds and several expressed the opinion that trucks should be required to travel the outer freeway around Des Moines rather than taking I-235 through the community

B. Several residents removed from the freeway stated that loud vehicles on their local streets were more disturbing to them than the freeway traffic noise.

C. Few people favored constructing a noise barrier between their propert and the freeway once they learned that the wall would have to be at least 10 to 15 feet high to be effective. Most residents felt they would prefer to see the moving traffic on the freeway as opposed to having an unchanging view of a permanent wall outside their window

D. Several residents expressed concern for safety along the freeway since the chain link fence had been damaged or penetrated by errant vehicles on several occasions.

E. People living adjacent to the freeway regretted the loss of their yards for activities involving conversation. Several residents commented that they had ceased having outside bar-b-ques since the freeway had been constructed due to the annoyance when attempting to eat outside. Exceptions to this comment did occur in two locations where the nearby freeway was noticeably depressed.

F. Ambulance sirens were mentioned by several residents as being especially annoying during the early morning hours. The necessity for using sirens when the freeway was almost void of other vehicles was questioned.

G. The area with the most consistently negative replies concerning truck noise was in the vicinity of an interchange in a residential neighborhood where a truck stop was located. Residents reported a high level of noise intrusion was present at all hours of the day and night. Trucks could be heard idling in the parking lot for long periods during the night and trucks using the I-235 entry and exit ramps were especially annoying as they shifted gears and occasionally backfired.

H. Several people who had moved recently to a location along the freeway stated that the noise was less intrusive in their new location than it had been in their previous location along a busy street or close to a railway.

I. Without exception, residents felt that more plantings should be utilized to improve the appearance of the freeway corridor.

J. During interviews with two professional truck drivers it was stated that large trucks operating on the freeway often had no mufflers, or at best a poorly maintained exhaust system and that in their opinion trucks in this condition should not be permitted on the highway. One driver pointed out that he was less bothered by noise while driving his own truck than he was as he sat in a residence along I-235 listening to other drivers going by with loud vehicles.

K. Most individuals recognized the benefits of the freeway in terms of convenience for making trips in a large urban area, but felt that more emphasis should have been placed on planning the freeway to fit into its location in a more pleasing manner.

L. Residents had mixed feelings about moving away from their present locations regardless of how negative their reaction was to the freeway and its noise. Several were reluctant to move because they liked thei neighborhood very well; however, more were concerned about the unlikelihood of receiving a fair price for their property if they were to move. One individual reported that on several occasions he had attempted to sell a reasonably large vacant lot next to his home facing the freeway, but he met with no success. Another stated that he had listed his property with a real estate agent and had shown the home several times, but that prospective buyers were always concerned about the closeness of the freeway.

M. Another resident in the same neighborhood where several had tried to sell their homes, or were considering their sale, stated that he was completely satisfied with his location and that he would prefer to stay exactly where he was (adjacent to the freeway) even if he could receive a fair price for his home. He further stated that they had become accustomed to the freeway noise in this location and it no longer seemed to bother them. It was also mentioned that the resident owned property outside the community in a recreation area and visited there frequently on the weekends, so that loss of the yard for any activity was not of concern to them.

N. A real estate agent was interviewed who lived adjacent to the freeway in a new residential area. It was reported on the basis of personal experience that nearness of a property to the freeway in no way hindered the sale of the newer suburban homes.

O. Comments volunteered at five separate households indicated that the residents occasionally sat and watched the freeway traffic from a vantage point either inside the home or outside on their porch. These remarks were offered at sites where noise was not judged to be annoying since there was a reasonable distance separating the viewing location from the traffic.

P. At two of the newer dwelling units visited, the residents specifically pointed out that their windows were of the double pane type which has proven to be extremely effective in attenuating the traffic noise. One resident at a property adjacent to the freeway volunteered to demonstrate the effectiveness of the double pane windows by opening them for a period so the traffic could be distinctly heard and then closing them, the effect being that one was not aware that the freeway traffic was in existence. With the windows open it was easy to identify each vehicle as it passed by; with the windows closed the loudest diesel truck was barely audible as it passed by on the freeway.

Of the numerous photographs taken on the personal interview trips, eight have been included in this report to assist in describing the study area and in attempting to account for the comments received from residents along the route.

Photographs 1 and 2 in Figure 4.2 show an at-level section of I-235 which was located through an existing residential area. In this section most residents were highly concerned about the truck noise, the loss of their yards for

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Photo 1

Photo 2

Photo 3

Photo 4

Figure 4.2 I-235 CORRIDOR PHOTOGRAPHS

activities involving conversation, and the lack of success in attempting to sell property. It is significant that one interviewee whose property is visible in Photo 2 was not disturbed by the truck noise and was not interested in moving from his location even if it would be at no cost to him. The phenomenon of widely differing reactions to the freeway was found to exist throughout the entire I-235 route. Acceptance or rejection of the freeway was not a characteristic that remained constant for a given neighborhood. At one location it was found that people living in neighboring houses had diametrically opposed reactions to the freeway and completely different impressions of the annoyance the freeway traffic caused them. Findings such as this must lead to the conclusion that individual differences may be the single most important variable in determining people's reactions toward freeways.

Photos 3 and 4 show new suburban housing being constructed along I-235. Although these homes were not visited as a part of the survey, it seems reasonable to assume they do have double pane windows so the interior noise level will be acceptable. However, excellent windows will be of no value in terms of providing a quiet yard for outdoor activities. The area shown in Photo 3 is being further developed so that yet another row of homes will be constructed between those shown and the freeway right-of-way. The partially completed home shown in Photo 4 is situated so that a freeway entrance ramp is at the termination of its back yard. It would seem that homes similar to those shown in Photos 3 and 4 would be difficult to sell on the real estate market due to their location; however, it is exactly this type of home which the real estate agent claimed was no problem insofar as obtaining a sale was concerned.

In Figure 4.3, Photo 5 is a view of the truck stop located at an I-235 interchange in a residential area. It was in this neighborhood that the most

Photo 5

Photo 6

Photo 7

Photo 8

Figure 4.3 I-235 CORRIDOR PHOTOGRAPHS

emphatic and consistent comments were received concerning truck noise problems. On-site observation of this location for several hours at various times of the day verified the comments from the residents concerning the magnitude of the noise intrusion into the neighborhood.

Photo 6 illustrates the loss of privacy that results in a residential area where the freeway is slightly elevated and where the homes are not even partially hidden from freeway view by plantings or trees. At the residence shown in Photo 7, the owner had constructed a patio fence in his yard to achieve some privacy especially for patio activities as eating outside. This patio fence was the most significant private effort seen during the survey where an individual had taken definite action on the outside of his home to partially block the view of the freeway.

A frontage road, light poles, and a chain link fence along a slightly elevated section of I-235 are illustrated in Photo 8. It must be concluded that even minimal plantings at this location would immeasurably improve the aesthetic appeal of this corridor.

4.1.3 Applicability of the I-235 Study to the I-380 Corridor

Extending the findings of the Des Moines I-235 study to the evaluation of the I-380 corridor must be carried out with some restraint. The reason for this is that the preliminary designs for I-235 (62) had been prepared eight years prior to those for I-380 (1), and noteworthy changes occurred in urban freeway design practice during that time period. Especially significant is the fact that plans indicate I-380 will be constructed with a substantially wider minimum right-of-way width than the minimum right-of-way for I-235. Certain sections of I-235 lie within a right-of-way only 150 feet in width, while the minimum right-of-way for I-380 in Cedar Rapids and Hiawatha is projected to be approximately 300 feet. The greater separation between traffic and residences will significantly alleviate the impact of I-380 on the adjoining properties and provide much more latitude for blending the freeway with the environment. There are, however, several results of the Des Moines survey that do appear to have meaningful application to the I-380 route and these will be discussed.

It is quite likely that Cedar Rapids residents will share the concern of Des Moines residents pertaining to the intrusion or disturbance created by the larger and noisier trucks operating on the freeway and its ramps. In Des Moines it was clearly established that residents believed many trucks to be unnecessarily loud, and this reaction will occur along I-380 unless effective truck noise regulation programs are initiated.

Another reaction of residents along I-235 that seems significant in terms of the I-380 corridor is the resentment that was created by incompatible freeway related land use being zoned for and then established in a residential district. The outstanding example of this is the truck stop discussed in the previous section of this report. There is no justification for a zoning practice of this nature which is so obviously inconsiderate of the established property owners along the freeway. The appropriate governmental agencies in Cedar Rapids, Hiawatha, and Linn County would be well advised to reject any zoning proposals which might lead to incompatible land use situations along I-380.

One rather unexpected factor detected in the personal interviews was the reluctance of residents to favor constructing traffic noise barriers along the freeway. The sentiment was against building the noise barriers due to the "walled-in" impression that would be created. Although this reaction cannot be predicted with certainty, it seems likely that a similar response would be obtained from the majority of property owners along I-380 since few people favor fences on the order of ten or more feet in height at the edge of their yard. This finding is significant since it does imply that other means should be found to counteract any noise problems occurring along the I-380 route.

Undoubtedly, the concern of Des Moines residents for creating a more aesthetically pleasing freeway corridor is another response that should have some applicability to I-380. Reasonable attempts to create a harmonious freeway-residential area environment seem almost obligatory and programs for planting and beautifying the route will be essential. In addition to plantings, the concept of the sitting park should be developed as a part of a beautification program. This statement is based on the fact that several Des Moines residents had mentioned that they occasionally engage in sitting and watching the freeway traffic from some vantage point on their property for relaxation. Providing facilities so that many residents may engage in this activity would be worthwhile and valuable for promoting acceptance of the freeway, and it would also provide an asset for the neighborhood.

It is somewhat difficult to establish further suggestions for enhancing the I-380 corridor based on the Des Moines I-235 study due to numerous inconsistencies in the opinions expressed by those living along I-235. In several instances directly contradicting opinions concerning some aspect of the freeway were obtained from residents living on the same block in Des Moines. Only those findings already discussed were supported by the overwhelming majority of residents. However, those findings which are presented herein are of great significance and should form the basis for meaningful programs pertaining to I-380.

4.2 Survey of Highway and Transportation Agencies

A questionnaire was mailed to all state highway organizations and to several similar agencies in foreign countries. A copy of the questionnaire is included in Appendix B of this report. Responses were received from 43 states, the District of Columbia, four provinces and one city in Canada, the British Road Research Laboratory, and the Organization for Economic Cooperation and Development. Additional communications with further information were received from several transportation consultants and a number of subdivisions of state highway organizations.

Material received in response to the questionnaire included policy statements and environmental statements formulated by various states. Many respondents also forwarded project reports and plans for specific improvements that are intended to enhance the effect or to lessen the impact of urban highways.

An objective of the questionnaire was to help ascertain the extent to which highway agencies are addressing themselves to problems arising from the introduction of major highway facilities into an urban environment. A further objective was to obtain from practitioners in highway design as much information as possible on the existing state of the art and on current practices relating to enhancement of a freeway environment. The questionnaire responses were extremely helpful in the accomplishment of these objectives.

4.2.1 State of the rt

Questionnaire responses from state highway organizations indicate that there is increasing interest in improving the environmental and aesthetic qualities of urban highways. This same level of interest is apparent from respondents in other countries. For example, questionnaire responses from the states indicate the following:

1. Fifty percent have adopted standards or other guidelines relating to acceptable freeway noise levels. Other states are dependent upon guidelines set forth by the Federal Highway Administration in Policy and Procedure Manual 90-2.
2. Twenty percent have guidelines that cover aesthetic design of urban freeway corridors.
3. Seventeen percent have established specific standards or guidelines dealing with multiple use of land close to freeways.
4. Sixty percent either installed noise attenuating barriers along freeways or are planning to do so.
5. Seven percent have purchased additional right-of-way along a freeway route because the existing or anticipated traffic noise would tend to lessen the attractiveness of a property for residential use.
6. Forty percent have recently developed landscaping techniques or other methods that they consider unusual for enhancing the aesthetic value of a freeway route through an urban residential area.
7. Fifty-eight percent either have recently completed or are planning a project that would involve some innovative multiple use of land along an urban freeway.

It should be pointed out that there are applicable federal guidelines in cases where, as indicated above, a state has not specifically adopted standards of their own.

The questionnaire responses and supplementary documents received from the respondents address some of the particular areas of concern as indicated below.

4.2.1.1 Aesthetics Highway agencies consider aesthetic treatment of a highway as viewed from outside the roadway while at the same time increasing attention is being devoted to the enhancement of the view from the road. Appearance of a highway is a function of its horizontal and vertical alinement, treatment of slopes in the median and border areas, the use of vegetation, and the relationship of these to the surrounding culture. Responses from highway organizations indicate that considerable effort is being expended by designers to integrate a freeway into the urban environment so that it is as unobtrusive as possible. Obviously, the manner in which this may be done varies with each roadway section and with each urban area.

Careful design of a highway facility is properly concerned with the view of natural surroundings and man-made development as seen by vehicle occupants. It is recognized that highways can either be located so as to enhance the visual experience of the traveler or, if thought is not given to this aspect of design, can obscure the inherent attractiveness of a community. Many of the environmental statements for highways that were reviewed as part of this study emphasized strongly the view from the road in making comparisons among alternatives.

4.2.1.2 Noise barriers As indicated in the summary of responses, over half of the state highway organizations responding to the questionnaire indicated that they have either installed noise barriers or were actively planning to do so. Experience acquired from these pioneering efforts will point the way for future developments in the attenuation of roadway noise by use of artificial barriers.

Among the several examples for which information was supplied by state highway organizations is the earth berm topped with a wood fence constructed along I-35W in Minneapolis, Minnesota. Other examples include the considerable length of berm and acoustic fence built in Baltimore, Maryland, and the test section of kinematic sound screen of an innovative design that has been installed in Phoenix, Arizona. Other sound barrier installations are in place or are planned in Boulder, Colorado; Hartford, Connecticut; Little Rock, Arkansas; Louisville, Kentucky; Syracuse, New York; as well as other cities. The states also report continued research in developing more attractive and economical designs for sound barriers.

4.2.1.3 Multiple land use Many examples of multiple land use of freeway right-of-way were reported by states responding to the questionnaire. Space under, over, or adjacent to freeways is being utilized for many types of public-use areas including parks and playgrounds, basketball courts, bicycle trails, and automobile parking. More significantly, there are many current examples wherein planning for a freeway is carried out concurrently with planning for compatible uses for land adjacent to the freeway for residential and commercial purposes. The I-480 Joint Use Study for Omaha, prepared by the Omaha City Planning Department (49), for example, envisions a comprehensive development of the freeway corridor with parking, a bus terminal, a hotel, and other highway-related commercial uses, as well as shops, apartments, and an office tower. Other plans or reports were made available that describe in some detail the multiple development planned for the corridors of I-35 in Duluth, Minnesota; I-80 in Reno, Nevada; I-81 and I-690 in Syracuse, New York; and I-90 in Wallace, Idaho; among others. One of the more unusual joint uses reported is the plan to utilize right-of-way under an elevated freeway in Florida for an 800-pupil elementary school.

4.2.2 Applicability of Questionnaire Results to I-380

The questionnaire responses indicate a concern on the part of highway agencies for care in the location and design of urban freeways. Each freeway section and each urban area obviously represent a unique situation and thus call for a unique solution. However, the state of the art as exemplified by the reported experience of highway agencies has applicability to I-380 in Cedar Rapids.

The several sound barriers that have been installed serve to demonstrate that the attenuation of highway noise is possible if the line of sight between noise source and listener is interrupted by a reasonably solid object. It is also apparent from the questionnaire responses that this same barrier may be an unpleasant visual intrusion into the urban scene and, if not carefully designed, may well be less desirable than the problem it is intended to alleviate.

The Iowa State Highway Commission has expressed its concern for aesthetic treatment of new highways in a paper Visual Values in Rural and Urban Highway Corridors , Division of Planning, October 2, 1972 (51). Considerations expressed therein are manifested in the design of I-380. Nevertheless, the art of highway design at its best cannot assure in every instance that an urban freeway will be welcomed by each resident or will have no unwanted effects. The many existing examples of pleasing design and effective integration of freeways with adjacent land uses afford helpful guidance, however. They suggest a substantial potential for reducing the intrusive effects of a new freeway and perhaps actually enhancing the urban environment with the improvements that may take place concurrently with the highway development.

4.3 Cedar Rapids Traffic Noise Survey

The impact of a new freeway in terms of noise generated highly depends on the noise levels already existing along the freeway route. It is possible for a freeway to significantly raise the noise level in a quiet residential area, thus having a great impact on the environment. On the other hand, it is possible for a freeway to reduce the noise level reaching properties in a specific area, if the customary stop-and-go traffic from surface streets is converted to smooth flow on the freeway and if adequate separation or shielding is provided between the freeway and the properties.

To provide a measure of the current noise levels at properties along the route of I-380, or in the vicinity of I-380, noise studies were conducted at 10 sites in Cedar Rapids and one site in Hiawatha. Data were collected on two separate days by means of observing a General Radio Co. Sound Level Meter at the sites.

Table 4.4 summarizes the field observations and specifies for each location the average noise level as well as the level exceeded 10 percent of the time. The procedure differed slightly from the first day (sites 1 thru 4) to the second day (sites 5 thru 11). On the first day the procedure was to observe the meter continuously for 10 seconds with notations being made of the lowest and highest noise levels and the best estimate of the central tendency during that period. This process was repeated 36 times at each site, thus giving 108 data points for each location. Since this proved to be a rather difficult procedure to follow, it was decided to obtain 100 observations using a 6 second sampling interval at each location visited on the second day.

Following the gathering of the 100 observations, the sound level meter was set on "FAST" response and observed continuously for two minutes

Table 4.4 SUMMARY OF CEDAR RAPIDS TRAFFIC NOISE SURVEY

Location	Time of Day	L_{50} dB(A)	L_{10} dB(A)	Peak dB(A)
1. 42nd St. N.E. near I.C.R.R., 25 ft. south of curb	4:50 to 5:15 p.m.	68	76	Not Recorded
2. Center Point Road at Shiloh Cemetry, Hiawatha, 25 ft. west of curb	4:03 to 4:33 p.m.	68	76	Not Recorded
3. U.S. Highway 218 at 28th Ave., 50 ft. east of curb	1:27 to 2:25 p.m.	71	80	Not Recorded
4. Center Point Road at Arizona, 25 ft. east of curb	7:38 to 8:08 p.m.	70	77	Not Recorded
5. Coe College-Armstrong Hall, 25 ft. east of 12th Street curb	4:19 to 4:29 p.m.	68	73	86 (whistle)
6. 10th St. and A Ave. N.E., across from St. Luke's Hospital, 25 ft. south of A Ave. curb	8:38 to 8:48 a.m.	67	71	83
7. Center Point Road at Collins Road, 25 ft. west of Center Point Road curb	11:58 a.m. to 12:13 p.m.	67	73	82
8. 1st Ave. and 3rd St., S.W. 25 ft. north of 1st Ave. curb	7:46 to 7:58 a.m.	68	75	90 (diesel trucks)
9. 3rd Ave. and 3rd St., S.W. 25 feet north of 3rd Ave. curb	4:44 to 4:55 p.m.	66	70	78
10. 8th Ave. and 3rd St., S.W. 20 ft. east of 3rd St. curb	5:02 to 5:12 p.m.	67	72	83 (whistle)
11. 16th Ave. and L St., S.W. 25 ft. south of 16th Ave. curb	8:06 to 8:16 a.m.	66	72	79

to obtain some indication of the peak noise at the site. The peak noise was of interest in terms of its relationship to the L_{10} levels that had been recorded.

As indicated in Table 4.4 a noise level of 70 dB(A) for L_{10} was found to exist at all 11 locations. This result is not unusual for noise level readings taken in the front yards of properties adjacent to medium or heavily travelled arterial streets. These results will be of importance in assessing the noise impact of I-380 and of some value insofar as indicating the magnitude of noise reaching properties that is ordinarily experienced in Cedar Rapids along busy streets.

It is interesting to note the wide divergence between the peak noise levels recorded and the L_{10} values at sites 5 thru 11. These peak sounds represent either unusually loud vehicles or noises from a non-highway source which yields a noise that is short in duration, yet likely to be extremely bothersome and annoying.

4.4 I-380 Design Year (1994) Traffic Noise Projections

A major project effort was to predict the traffic noise levels anticipated along the I-380 corridor during a typical week day peak hour flow of the design year, 1994. Traffic noise contour lines were calculated and plotted on a scroll map showing L_{10} levels in dB(A). The procedure followed in this activity was obtained from National Cooperative Highway Research Project Report Number 117 (3) which has been approved for studies of this nature by the Federal Highway Administration (34). The traffic noise analyses extended to the side of I-380 for a sufficient distance to always show the L_{10} values at the property lines adjacent to the freeway, and typically for distances of two city blocks further into the surrounding residential areas.

4.4.1 Assumptions Underlying Noise Level Projections

The following list documents the data and basic assumptions required for predicting the traffic noise levels according to the NCHRP 117 (3) procedure:

A. The design hour traffic volumes for a 1994 average summer week day peak hour were obtained from the Urban Department, Iowa State Highway Commission, for use in this study. These volumes are presented in Appendix C and are in substantial agreement with those volumes projected for the recommended transportation network in the 1990 Linn County Transportation Plan (52), although they are updated to allow four additional years of traffic growth.

B. Truck volumes are estimated to be 5 percent of each traffic movement.

C. Traffic speeds were selected in accordance with the Highway Capacity Manual (53), except speeds on ramps. Ramp speeds were arbitrarily assigned an average value of 20 mph or 35 mph depending on the ramp configuration and terminal conditions.

D. The pavement surface was assumed to be normal with no special adjustment being allowed for roughness or smoothness.

E. The noise reductions associated with elevated and depressed freeway sections were estimated according to NCHRP 117 procedures. Bridges were treated simply as elevated highway sections, since no specific methodology has been developed for treating these structures.

F. Noise level adjustments for roadway gradient, and interrupted flow were applied as necessary based on plan and profile views of the freeway and the presence of regulated intersections.

A sample of the noise contour scroll map is shown in Figure 4.4.

4.4.2 Selected Traffic Noise Projections along I-380

Traffic noise projections along the I-380 corridor selected for inclusion in this report are shown in Table 4.5. These noise projections are extracted from the computations upon which the noise contour maps were developed. They are representative of the noise levels predicted at the property lines along the freeway corridor.

The sites are listed according to freeway station number, with direction from the I-380 centerline also specified. The table includes 14 sites where the main lanes of I-380 were the principal noise source, and 10 sites where several sources as intersection streets or freeway ramps contributed substantially to the total noise level at the property.

Upon inspecting Table 4.5 it is apparent that the truck noise level primarily, and in most cases completely determines the total L_{10} noise level at the nearest property lines. For instance, at Station 264 in a direction west of I-380, L_{10} for cars is 63 dB(A) and L_{10} for trucks is 74 dB(A). Upon summing the noise from these two sources by combining decibels, it is apparent that the 74 dB(A) truck noise completely

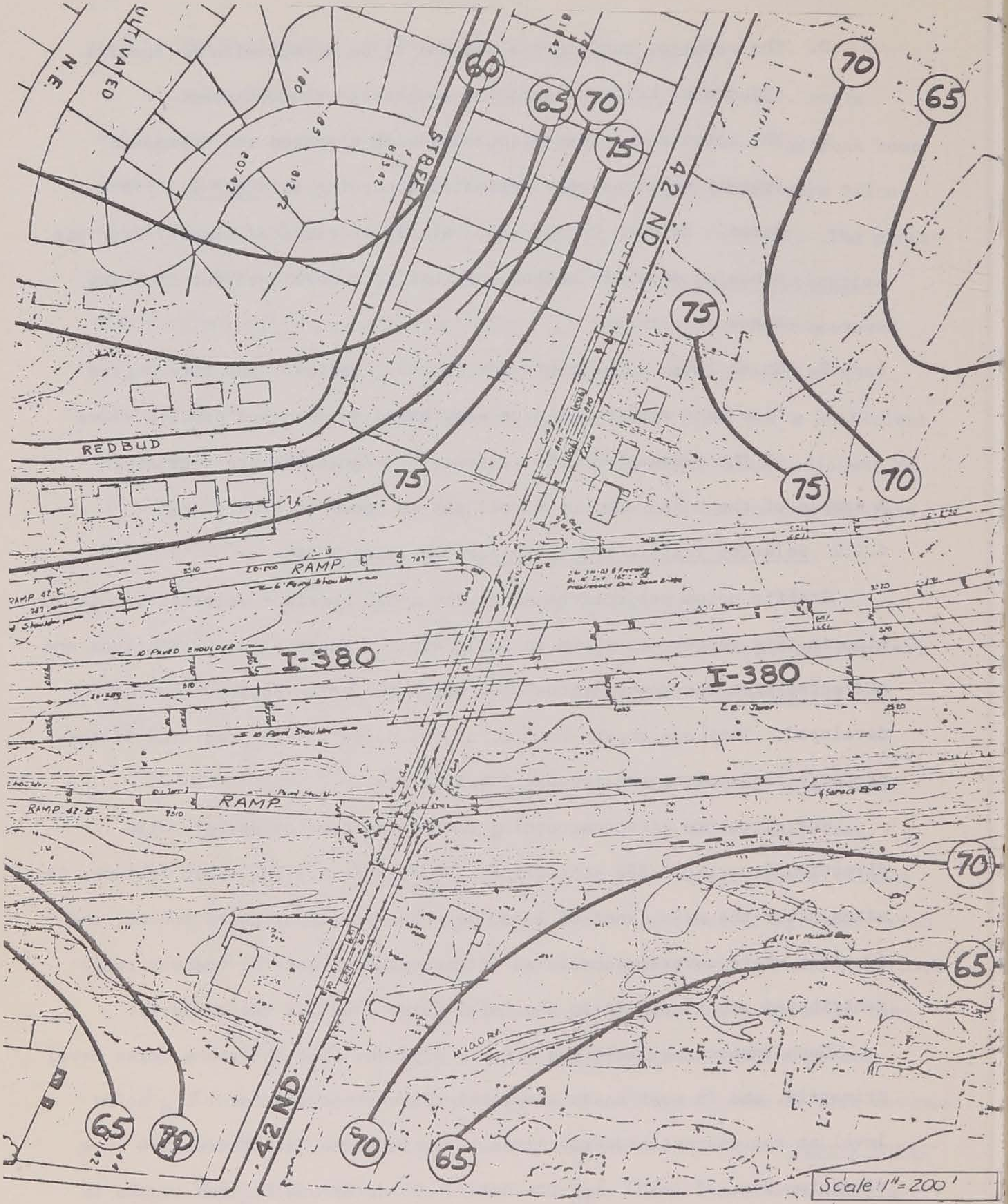

Figure 4.4 NOISE CONTOUR MAP EXAMPLE: I-380 at 42nd Street, N. E.

Table 4.5 SELECTED I-380 DESIGN HOUR TRAFFIC NOISE PROJECTIONS

STATION NUMBER AND DIRECTION TOWARD PROPERTY	LOCATION DESCRIPTION ALONG I-380	ESTIMATED 1994 TRAFFIC VOLUMES (VEHICLES PER HOUR)		NOISE PROJECTIONS (dBA) AT PROPERTY LINE				
				L_{50}		L_{10}		
		AUTOS	TRUCKS	CARS	TRUCKS	CARS	TRUCKS	TOTAL
150 EAST	PRAIRIE HIGH SCHOOL, BASEBALL FIELD, FREEWAY DEPRESSED	2337	123	61	55	64	65	67
158 EAST	PRAIRIE HIGH SCHOOL, MAIN BUILDING, FREEWAY DEPRESSED	2337	123	53	52	56	61	62
210 EAST	PARK, SOUTH OF LINCOLNWAY VILLAGE, FREEWAY DEPRESSED	2337	123	51	50	53	57	59
217 EAST	LINCOLNWAY VILLAGE FREEWAY AT-GRADE	2337	123	60	54	62	61	64
234 WEST	NORTH OF 27TH AVE., S.W., FREEWAY DEPRESSED	4499	236	52	59	54	65	65
234 EAST	NORTH OF 27TH AVE., S.W., FREEWAY DEPRESSED	4499	236	50	57	52	63	63
264 WEST	BETWEEN 17TH & 18TH AVE., S.W., FREEWAY ELEVATED	5620	296	61	69	63	74	74
264 EAST	BETWEEN 17TH & 18TH AVE., S.W., FREEWAY ELEVATED	5620	296	58	67	60	73	73
286 WEST	BETWEEN 10th & 12TH AVE., S.W., FREEWAY ELEVATED	5620	296	53	62	55	68	68
286 EAST	BETWEEN 10TH & 12TH AVE., S.W., FREEWAY ELEVATED	5620	296	53	62	55	68	68
381 S.E.	ST. LUKES HOSPITAL, FREEWAY LOWER THAN RECEIVER, HOWEVER NOISE PATH IS DIRECT	7570	398	61	66	63	70	71

Table 4.5 SELECTED I-380 DESIGN HOUR TRAFFIC NOISE PROJECTIONS (CONTINUED)

STATION NUMBER AND DIRECTION TOWARD PROPERTY	LOCATION DESCRIPTION ALONG I-380	ESTIMATED 1994 TRAFFIC VOLUMES (VEHICLES PER HOUR)		NOISE PROJECTIONS (dBA) AT PROPERTY LINE				
				L_{50}		L_{10}		
		AUTOS	TRUCKS	CARS	TRUCKS	CARS	TRUCKS	TOTAL
428 EAST	BETWEEN J & H AVE., N.E., FREEWAY AT-GRADE	7062	372	65	69	67	74	75
495 WEST	BETWEEN 32ND & 42ND ST., N.E., FREEWAY ELEVATED	5377	283	60	64	62	69	70
495 EAST	BETWEEN 32ND & 42ND ST., N.E., FREEWAY ELEVATED	5377	283	53	60	54	64	64
	STATIONS WHERE PROPERTIES ARE SUBJECT TO MULTIPLE NOISE SOURCES							
212 EAST	CEDAR VALLEY APTS., FREEWAY DEPRESSED Source: I-380 Source: Ramp B-4 Source: 33rd St.	 3429 710 1852	 181 37 98	 50 45 36	 56 53 46	 52 51 40	 62 69 56	 62 69 56
						GRAND TOTAL FOR L_{10}:		70
216 WEST	GATEWAY GARDENS, FREEWAY DEPRESSED Source: I-380 Source: Ramp B-3 Source: 33rd St.	 3429 710 747	 181 37 39	 50 40 29	 56 48 35	 52 46 33	 62 64 46	 62 64 46
						GRAND TOTAL FOR L_{10}:		66
310 EAST	BETWEEN 4TH & 5TH AVE., S.W., FREEWAY ELEVATED Source: I-380 Source: 3rd. St.	 4032 1604	 212 84	 56 68	 63 70	 58 73	 69 83	 69 83
						GRAND TOTAL FOR L_{10}:		83

Table 4.5 SELECTED I-380 DESIGN HOUR TRAFFIC NOISE PROJECTIONS (CONTINUED)

STATION NUMBER AND DIRECTION TOWARD PROPERTY	LOCATION DESCRIPTION ALONG I-380	ESTIMATED 1994 TRAFFIC VOLUMES (VEHICLES PER HOUR)		NOISE PROJECTIONS (dBA) AT PROPERTY LINE				
				L_{50}		L_{10}		
		AUTOS	TRUCKS	CARS	TRUCKS	CARS	TRUCKS	TOTAL
310 WEST	BETWEEN 4TH & 5TH AVE., S.W., FREEWAY ELEVATED							
	Source: I-380	4032	212	56	63	58	69	69
	Source: 4th St.	1673	88	61	63	64	73	73
	Source: 5th-8th Ave. (Proposed Connector)	1450	76	57	58	60	67	68
				GRAND TOTAL FOR L_{10}:				75
466 EAST	BETWEEN COLDSTREAM AND 32ND ST., N.E., FREEWAY DEPRESSED							
	Source: I-380	4685	250	59	61	61	65	67
	Source: Ramp Connection	489	26	40	42	44	53	53
				GRAND TOTAL FOR L_{10}:				67
466 WEST	BETWEEN COLDSTREAM AND 32ND ST., N.E., FREEWAY DEPRESSED							
	Source: I-380	4685	250	53	60	55	66	66
	Source: Ramp Connection	489	26	63	63	73	75	77
				GRAND TOTAL FOR L_{10}:				77
531 WEST	INTERCHANGE I-380 AND COLLINS ROAD, FREEWAY DEPRESSED							
	Source: I-380	2284	120	41	45	43	51	51
	Source: Ramp C	837	44	42	55	44	64	64
	Source: Collins Road (extended)	2605	137	52	61	54	69	69
	Source: Service Road	323	17	57	47	65	64	68
				GRAND TOTAL FOR L_{10}:				73

Table 4.5 SELECTED I-380 DESIGN HOUR TRAFFIC NOISE PROJECTIONS (CONTINUED)

STATION NUMBER AND DIRECTION TOWARD PROPERTY	LOCATION DESCRIPTION ALONG I-380	ESTIMATED 1994 TRAFFIC VOLUMES (VEHICLES PER HOUR)		NOISE PROJECTIONS (dBA) AT PROPERTY LINE				
				L_{50}		L_{10}		
		AUTOS	TRUCKS	CARS	TRUCKS	CARS	TRUCKS	TOTAL
543 WEST	BETWEEN COLLINS ROAD AND BLAIRS FERRY ROAD, FREEWAY ELEVATED							
	Source: I-380	3048	160	56	60	58	67	67
	Source: Collins Road (extended)	2605	137	46	55	49	63	63
				GRAND TOTAL FOR L_{10}:				69
573 EAST	NORTH OF BLAIRS FERRY ROAD, FREEWAY ELEVATED							
	Source: I-380	916	48	49	48	52	59	60
	Source: Blairs Ferry Road	1615	85	47	52	50	60	60
				GRAND TOTAL FOR L_{10}:				63
573 WEST	NORTH OF BLAIRS FERRY ROAD, FREEWAY ELEVATED							
	Source: I-380	916	48	47	46	51	58	58
	Source: Blairs Ferry Road	1615	85	47	52	51	61	61
				GRAND TOTAL FOR L_{10}:				63

dominates the car noise and the noise level at the property line will be 74 dB(A).

The highest noise levels in Table 4.5 are found to occur at locations where one or more traffic noise sources are present in addition to the main traveled lanes of I-380. At station 310 East, it was found that the noise generated from 3rd Street traffic would contribute much more to the noise level at the property line than would the I-380 traffic. This is explained by the fact that 3rd Street is much closer to the property line than is I-380. Furthermore, some shielding is afforded this location from I-380 due to the elevated configuration of the freeway.

At Station 466 West, the ramp connection between two interchanges constitutes a completely dominant noise source at the nearby property. This occurs even though the traffic volume on the ramp connection is only 10% of the main freeway lane volumes due to the proximity of the ramp connection to the property.

At Station 531 West the L_{10} value at the property line was estimated at 73 dB(A), despite the low 51 dB(A) contributed by traffic on I-380. Noise from other traffic, especially the vehicles on the anticipated extension of Collins Road, completely determine the noise that will be perceived at the property.

4.4.3 Noise Barrier Example

To illustrate the potential effect of a traffic noise barrier, a hypothetical 1,200 foot long installation was evaluated for properties along the West side of I-380 and south of the 42nd Street interchange. It was arbitrarily assumed that the barrier would be a ten foot high fence (probably wood) placed on the property line between the houses and the freeway. An observer height of 5 feet above ground level was assumed, while the source elevation was the elevation of the freeway or ramp pavement surface.

Noise level reductions calculated for backyard locations approximately 25 feet toward the home from the fence are presented in Table 4.6. This general area had been estimated to be subject to L_{10} noise levels ranging from 70 to 75 dB(A) in 1990. With a 10 foot high barrier in place it is indicated the noise reaching the back yards would be reduced on the order of 6 to 12 dB(A) depending on the terrain and freeway elevation at various sites in this area.

4.4.4 Accuracy of Noise Predictions

There are numerous potential sources of error associated with almost any process where a traffic related characteristic is being predicted for a point in time 20 years in the future. Insofar as the development of traffic noise level estimates is concerned, the problem of accuracy or reliability of the estimate should be carefully assessed to assure that unwarranted actions are not initiated. The major sources of error in generating traffic noise level predictions could be classified as follows:

A. Potential errors due to the procedures employed.

B. Potential errors due to inaccurate input data.

C. Potential errors due to changing noise generation characteristics of the source.

4.4.4.a Potential Errors due to the Procedure

Traffic noise level predictions obtained by the Bolt, Beranek, and Newman methods published in NCHRP 117 (3) have been evaluated for accuracy in at least two studies (12, 17) and have been found to provide satisfactory results. It may be assumed that traffic noise estimates for situations with observer heights up to 4 or 5 feet above the ground, either with or without noise barriers, will be accurate within ± 3dB(A) of the value obtained by actual field measurement. However, it has been found

I-380 Station Number Opposite Property	Effective Noise Barrier Height	Noise Reduction dB(A)
495	5.0	10
500	3.5	6
505	5.0	10
511	6.3	12

Table 4.6 NOISE BARRIER INSTALLATION EXAMPLE:
I-380 AT 42ND STREET

(17) that the procedure could yield errors on the order of 5 to 10 dB(A) for projections where the observer elevation is substantially above ground level.

Another area of difficulty encountered when preparing noise projections concerns the treatment of stop-and-go traffic. This aspect of traffic noise estimation has not been explored in great detail. Although it is pure speculation, it is conceivable that near regulated ramp termini along freeways, the noise projections could be somewhat low due to the stop-and-go traffic.

4.4.4.b Potential Errors due to Input Data

Data concerning traffic volumes, average operating speeds, and traffic composition during the design year are essential input to the noise prediction process. When dealing with high traffic volumes, as on an urban freeway, substantial errors in the estimated volume have almost negligible affect on the noise level projections. Furthermore, the assumptions concerning average vehicular operating speed are not especially critical since passenger car noise and truck noise responses are related in opposite manners to speed changes. That is, for passenger cars L_{10} dB(A) levels increase with speed, and for trucks L_{10} dB(A) levels decrease with speed for a specified traffic volume.

The assumption concerning traffic composition is critical in preparing noise level projections because the percent trucks in the stream will highly influence the estimated L_{10} dB(A) levels along most sections of urban freeways. In this study 5 percent of all traffic flow was assumed to be heavy trucks. This is a reasonable and common value to observe on urban freeways during peak hours. Difficulties are encountered, however, in extending this assumption to all ramp movements and to all pertinent traffic streams. Any ramp, intersecting route, or paralleling service road could conceivably be carrying almost no trucks, or it could be handling as high as 15 to 20 percent trucks during the peak hour of the design year. The uncertainty associated with the assumption of traffic composition could lead to errors on the order of 5 to 10 dB(A) for the design year projection. Unfortunately, there is no practical means for accurately determining this traffic characteristic twenty years in advance on a ramp-by-ramp basis.

4.4.4.c Potential Errors due to Changing Vehicular Noise Characteristics

The subject of magnitude of noise level reduction by regulating the source is presented in Section 4.7 of this study. It is therein reported that significant traffic noise reductions are possible if appropriate legislation is enacted and enforced. The immediate impact of improved highway vehicle noise regulation would most likely be to provide reductions of 3 to 5 dB(A) for trucks and automobiles. The long-term potential, depending on the research effort expended, could provide noise level reductions of 7 to 12 dB(A) for trucks and automobiles.

It is therefore possible that significant progress will be achieved in regulating the source before the I-380 design year, 1994. These changes in noise generation characteristics of the source should be carefully considered in evaluating the impact of any freeway.

4.4.4.d Potential Errors in Traffic Noise Predictions - Summary

It may be concluded that the procedure employed for noise level predictions along I-380 yields results correct to within ± 3dB(A) for elevations of the observer not exceeding 5 feet above ground. A greater potential source of error in the projections is the assumption that all freeway, service road, intersecting street and ramp movements will contain 5% trucks during the peak hour flow 20 years hence. The percent trucks in each of these movements will remain an elusive figure until after the freeway is in operation and volume trends have been established.

The most significant source of error in these analyses is contained in the assumption that noise generation characteristics of highway vehicles will remain unchanged during the next two decades. The potential for overestimating traffic noise levels by virtue of this assumption appears to overshadow the variations introduced by the other variables.

4.5 Reconnaissance Trips and Determination of Impacted Areas

Personnel engaged in the study of I-380 had access to land-use planning reports, transportation studies, urban renewal plans, and other similar material made available by the Cedar Rapids Department of Planning and Redevelopment. To supplement these resources, several reconnaissance visits were made by research personnel to the areas in Cedar Rapids traversed by I-380. The purpose of these visits was to become more familiar with those portions of the city that will be most directly affected by the freeway and to aid in an evaluation of the highway's probable effects. It should also be noted that study personnel had a background of familiarity with Cedar Rapids.

Most of the effects of an urban freeway are a function of right-of-way width, gradient, and the relative elevations of roadway and surrounding areas. Thus, it was helpful that the right-of-way was cleared and some construction work was underway on portions of I-380 in Cedar Rapids during the period of the reconnaissance visits. It was necessary to depend upon drawings of the proposed construction to envision the relationship between the highway and the adjacent culture on remaining portions of the freeway. Plans for I-380 are available in sufficient detail so that conceptualization of the freeway-community interaction is not difficult.

It is apparent from a study of the areas that will be most affected by the freeway that some adverse effects are unavoidable. In one or two instances, deterioration of an already deteriorating neighborhood will probably be accelerated. This will result in part from the barrier effect of a facility as massive as a freeway. In other cases, a few residences in stable and attractive neighborhoods will remain in such close proximity to the highway that effective measures to alleviate the problem of vehicle noise may not be practicable. However, adherence to the recommendations that follow would be expected to assure that the net effect of I-380 on Cedar Rapids will be beneficial.

As indicated in some detail in the following section of this report, there will be several freeway segments where unique relationships between highway and adjacent land afford opportunities to integrate the two. Such an integration of land uses will serve to improve the area by the freeway. Exploiting these opportunities will enable I-380 to contribute in a positive manner to the city, not only through improved mobility, but also by creating a better quality environment.

4.6 Potential for Multiple Land Use and Joint Development Projects

The configuration of I-380 in Cedar Rapids affords significant opportunity to enhance the effect of the freeway by integrating the highway right-of-way harmoniously with adjacent land. To a considerable extent an effort to do so must be conducted jointly by the Iowa State Highway Commission and the City of Cedar Rapids. The Commission will hold title to the highway right-of-way and must exercise control over that land. The city and private interests can act unilaterally only in respect to adjacent land that is outside the right-of-way. Such actions must be consistent with the controls on access exercised by the Commission.

Hence, the discussion that follows, with some exceptions, is devoted primarily to the potential for multiple land use projects that could be carried out by the City of Cedar Rapids. It is thus largely concerned with areas outside the freeway right-of-way. The right-of-way itself obviously affords some opportunity for development, either in and of itself or in conjunction with adjacent land. Any linear area such as a freeway lends itself to development as a greenbelt or perhaps a linear park that might include bicycle trails throughout at least part of its length.

This discussion is also limited in that the exact right-of-way limits are not known. With negotiations for purchase of right-of-way not yet completed, the possibility exists that entire parcels may be procured where plans indicate only partial takings. Furthermore, right-of-way plans for some northerly parts of the freeway corridor are not available as this is being written.

Additionally, the development of a system of parks and recreational facilities for an urban area requires a systematic appraoch and the consideration of many factors that are beyond the scope of this study. Hence, recommendations that a particular parcel should be utilized for a playground or park would be inappropriate. Rather, suggestions will be made that certain parcels could well serve as a playground or park if this would be consistent with the overall development of a citywide system of such facilities.

4.6.1 West of Cedar River

The area from the south corporate limits to Lincolnway Village is largely agricultural land. Development in this area is not sufficient to warrant any changes in plans for land use at this time as a result of construction of the freeway. However, it is suggested that plantings of wild rose or osage orange bordering the existing pockets of development, such as at Prairie High School, would be appropriate. This would serve the following functions when such a hedge has achieved mature growth:

- Help preclude encroachment upon the highway right-of-way by persons or large animals
- Serve as a visual screen
- Act as a windbreak

The highway right-of-way in the vicinity of Lincolnway Village similarly involves land that has been devoted to agricultural use. Access from the freeway to the subdivision and to remaining land parcels will be quite circuitous. Thus any significant intensification of the level of development is not recommended. There would be some advantage, however, in permitting or perhaps encouraging the construction of a relatively continous row of medium density housing (two-story garden apartments for example) to border the existing development at its frontage on the highway and, where appropriate, along interchange ramps. Such row-housing would have the advantage of shielding the rest of the subdivision from freeway noise. With acoustic treatment and sensitive design, this housing would be attractive to many potential occupants for whom proximity to a freeway is not objectionable.

The area from U.S. Highway 30 to 33rd Avenue currently is zoned for industrial or commercial uses. No specific multiple uses are suggested for this portion of the corridor. However, land bordering Prairie Creek offers potential for development as a natural area or outdoor classroom and if this is done, integration of the I-380 right-of-way into such an area would be desirable.

Much of the land bordering the freeway between 33rd Avenue and 27th Avenue is devoted to apartment complexes. One vacant area east of I-380 and just north of these apartments is suitable for development with medium-density housing. This would serve as a transition from the apartments to the south to the single-family residences to the north. Such a development would also serve as a buffer between the freeway and the residential area to the east. This parcel affords an excellent view of the Prairie Creek Valley and is partially covered with spruce and deciduous trees. Any planned development in this location should be designed to exploit these distinctive natural features with some land reserved for a small park.

Adjacent to I-380 between 27th Avenue and Wilson Avenue two irregularly shaped remainder parcels west of the freeway (near Sunset Court) and a vacant lot east of the highway are attractive locations for mini-parks or similar public-use facilities. In addition to permitting an observation of the freeway, all of these parcels afford a view of the central part of the city to the north.

Joint development of the land lying under and adjacent to the elevated structure over 15th and 16th Avenues is urged. The residential character of this neighborhood suggests that exploitation for commercial or industrial purposes would be inappropriate. Nor is there an apparent need in this vicinity for the type of park or playground facilities that could be developed on this site. Hence, some public use would seem to be indicated. It is suggested that contacts be made to explore possibilities such as the following for this block:

- Municipal equipment storage (street maintenance equipment and materials, for example)
- Vehicle impound lot
- Municipal office or community center

The first two uses would require suitable screening so that the facility would be compatible with its surroundings. Ample space available for on-site parking is a distinct advantage of this location for any public or semi-public use. A suitable arrangement would have to be effected with the Iowa State Highway Commission for the kind of joint development suggested.

Right-of-way including the structure crossing Eighth Avenue and the nearby railroad tracks similarly offers an excellent opportunity for joint or multiple usage. The greater than usual overhead clearance required for the railroad crossing, proximity to rail transportation, and the industrial character of this area all suggest that this parcel should be attractive for commercial or industrial use.

Land lying south and east of the curved I-380 alinement between First Avenue West and the Cedar River would lend itself to the type of joint use exemplified by that cited earlier adjacent to I-480 in Omaha. The type of effort necessary to define specific facilities that could be developed in this area is beyond the scope of this study. However, proximity to the central business district and governmental center and good access from the freeway suggest that this area would be extremely attractive for highway-related and other commercial uses as well as for high-density housing.

4.6.2 East of Cedar River

Elevated highway structures close to a central business district are generally quite attractive for automobile parking. Where they are in proximity to warehouses or truck-loading facilities, those same uses can take place under and adjacent to these structures if suitable arrangements are effected with the Highway Commission.

One or two small remainder parcels lying south of the freeway from Fifth to Eighth Streets would desirably be developed as sitting parks. This area, in addition to affording a view of I-380, overlooks the cereal mill, the Cedar River, Cedar Lake, and Shaver Park. If developed as attractive places to sit and watch, such small parks would be helpful additions to the central portion of Cedar Rapids.

Construction of I-380 in Cedar Rapids will tend strongly to focus attention on Cedar Lake. The lake has not often been though of an an asset to the city and is generally forgotten by most residents. However, the freeway alinement will sweep past the lake and bring it to the attention of tens of thousands of local residents and visitors each day. It is therefore important that the potential be exploited for converting a forgotten resource to an attractive attribute. The lake and its surroundings have a unique long-established ecology that is based on the existence of a power generating plant to constantly heat the lake water and of railroad tracks to supply feed for wildlife by spillage of grain from rail cars. To the extent practicable, this ecological balance should remain undisturbed.

However, land between the highway and the east shore of the lake should be considered for its potential as a public area with picnic facilities, access to the lake, and vegetative cover generally similar to that of nearby undeveloped land. The fairly narrow band of development in this area that will remain after I-380 is constructed is of such nature that it is not likely to be enhanced by proximity to the freeway. Hence, some pressures for change in land use might be anticipated. The action suggested at this time is for the city to assure that any such changes are considered in terms of possible future development of this area as a lakeshore rather than as a location for intensive use of land.

Much of the freeway right-of-way between J Avenue and Blairs Ferry Road lies in what currently is open space. It is likely that some excess purchases will take place in the process of right-of-way procurement. These remainder parcels and any other undeveloped land that will abut the freeway right-of-way should remain undeveloped. To the extent that this land can be formed into linear parks and connected with footpaths and bicycle trails, this should be considered. A few neighborhood playgrounds could also be established. An important point, however, is that the development of this land for commercial or industrial purposes would be out of character with the residential use that is predominant in the area. Furthermore, residences placed any closer to the freeway than those remaining after the right-of-way is cleared would be subjected to quite high noise levels. However well intentioned a builder and a purchaser might be, these will not be desirable homesites. As much land as possible should be left open so that the noise attenuating effects of distance from the freeway may be exploited as much as possible.

4.7 Survey of Current Traffic Noise Legislation

Recognizing that community noise levels have been consistently rising and that noise could present a hazard to an individual's health, specific noise control legislation of an increasingly strict nature has been enacted by numerous states and municipalities. Significant impetus has recently been provided to this movement by the Federal government in the form of Public Law 92-574, known as "The Noise Control Act of 1972" (54).

A review of the trend in traffic noise regulation and a discussion of its potential influence on community noise levels are included in this study to serve two purposes. First, it is significant that the 1994 traffic noise projections along I-380 as reported in Section 4.3 are based on noise generation characteristics of vehicles commonly found on the highways in the early 1970's. It seems unlikely that with the current concern for environmental problems, including that of "noise pollution," vehicles operating in 1994 will have noise generation characteristics resembling the noise characteristics of vehicles 20 years their predecessors. It is not only possible, but almost inevitable that the noise contours developed for the I-380 will be noticeably shifted as the environment becomes quieter due to strict noise control legislation. It is realized that the potential for noise level reduction by controlling or regulating the source is only one aspect of the noise reduction problem. But it seems that legislation along these lines would be of tremendous benefit to the overall environment existing even beyond urban freeway corridors and it seems that this is the initial step that should be taken in dealing with a pervasive problem.

A second reason for including a discussion of traffic noise control legislation is the fact that the areas of Cedar Rapids studied in the traffic noise survey yielded sufficiently high dB(A) values that one could conclude that Cedar Rapids already has a "noise climate" corresponding to an unduly annoying situation. While the traffic noise survey reported in Section 4.2 certainly does not represent a comprehensive community survey, the consistently high noise readings found in separate areas of Cedar Rapids indicate that countermeasures are in order at the present time.

4.7.1 The Noise Control Act of 1972, Public Law 92-574

The Noise Control Act of 1972 is formidable legislation that incorporates a comprehensive approach to solving the noise problem in general, with specific attention allocated toward transportation system noise. The Act directs the EPA[1] publish "proposed noise emission regulations for motor carriers engaged in interstate commerce." Following a ninty-day review period the final regulations will be established and from that time any motor carrier including common carriers, contract carriers, and private carriers operating across state boundaries as to constitute their involvement in interstate commerce will be subject to noise emission standards that are to be established. Furthermore, EPA will promulgate regulations for products distributed in commerce including transportation equipment and recreational vehicles. Section 11 (a) of the Act provides that violators "shall be punished by a fine of not more than $25,000 per day of violation, or by imprisonment for not more than one year, or by both."

It remains to be seen what the noise standards will be, since Congress allowed EPA up to nine months after the date of enactment (October 27, 1972) for development of the permissible noise emission levels.

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[1] United States, Environmental Protection Agency

4.7.2 State Motor Vehicle Noise Legislation

The California (55) legislature has adopted several vehicle codes prescribing noise limits for highway vehicles. Section 23130 concerns maximum permissible noise levels for vehicles operating on their highways, Section 27150 concerns vehicle exhaust systems, and Section 27160 sets maximum noise limits for new vehicles. These standards were not unilaterally developed but evolved by cooperating with vehicle manufacturers and the SAE Acoustic Committee (56).

Excerpts from California Vehicle Code Section 23130 covering vehicles in service follow:

23130. (a) No person shall operate either a motor vehicle or combination of vehicles of a type subject to registration at any time or under any condition of grade, load, acceleration or deceleration in such a manner as to exceed the following noise limit for the category of motor vehicle within the speed limits specified in this section:

	Speed Limit of 35 mph or less	Speed limit of more than 35 mph
(1) Any motor vehicle with a manufacturer's gross vehicle weight rating of 6,000 pounds or more and any combination of vehicles towed by such motor vehicle:		
(A) Before January 1, 1973	88 dB(A)	90 dB(A)
(B) On and after January 1, 1973	86 dB(A)	90 dB(A)
(2) Any motorcycle other than a motor-driven cycle	82 dB(A)	86 dB(A)
(3) Any other motor vehicle and any combination of vehicles towed by such motor vehicle	76 dB(A)	82 dB(A)

*(b) The noise limits established by this section shall be based on a distance of 50 feet from the center of the lane of travel within the speed limit specified in this section.

*23130.5.(a) Not withstanding the provisions of subdivision (a) of Section 23130, the noise limits, within a speed zone of 35 miles per hour or less on level streets, or streets with a grade not exceeding plus or minus 1 percent, for the following categories of motor vehicles, or combinations of vehicles, which are subject to registration, shall be:

(1) Any motor vehicle with a manufacturer's gross vehicle weight rating of 6,000 pounds or more and any combination of vehicles towed by such motor vehicle..........................82 dB(A)

(2) Any motorcycle other than a motor-driven cycle........77 dB(A)

(3) Any other motor vehicle and any combination of vehicles towed by such motor vehicle................................74 dB(A)

No person shall operate such a motor vehicle or combination of vehicles in such a manner as to exceed the noise limits specified in this section.

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Vehicles equipped with at least two snowtread tires are exempt from this section.

Excerpts from California Vehicle Code Section 27150 and 17151 concerning vehicle exhaust systems follow:

27150.(a) Every motor vehicle subject to registration shall at all times be equipped with an adequate muffler in constant operation and properly maintained to prevent any excessive or unusual noise, and no muffler or exhaust system shall be equipped with a cutout, bypass, or similar device.

*27151. No person shall modify the exhaust system of a motor vehicle in a manner which will amplify or increase the noise emitted by the muffler originally installed on the vehicle and the original muffler shall comply with all of the requirements of this chapter. No person shall operate a motor vehicle with an exhaust system so modified.

The provisions specifying maximum noise levels for new vehicles are summarized below and include criteria that are substantially lowered by the year 1987. These are excerpted from Section 27160 of the California Vehicle Code.

27160.(a) No person shall sell or offer for sale, a new motor vehicle which produces a maximum noise exceeding the following noise limit at a distance of 50 feet from the centerline of travel under test procedures established by the department:

(1) Any motorcycle manufactured before 1970................92 dB(A)

(2) Any motorcycle; other than a motor-driven cycle, manufactured after 1969, and before 1973...........................88 dB(A)

(3) Any motorcycle, other than a motor-driven cycle, manufactured after 1972, and before 1975...........................86 dB(A)

*(4) Any motorcycle, other than a motor-driven cycle, manufactured after 1974, and before 1978...........................80 dB(A)

*(5) Any motorcycle, other than a motor-driven cycle, manufactured after 1977, and before 1988...........................75 dB(A)

*(6) Any motorcycle, other than a motor-driven cycle, manufactured after 1987...70 dB(A)

*(7) Any snowmobile manufactured after 1972..................82 dB(A)

(8) Any motor vehicle with a gross vehicle weight rating of 6,000 pounds or more manufactured after 1967, and before 1973 ....88 dB(A)

(9) Any motor vehicle with a gross vehicle weight rating of 6,000 pounds or more manufactured after 1972 and before 1975.86 dB(A)

*(10) Any motor vehicle with a gross vehicle weight rating of 6,000 pounds or more manufactured after 1974, and before 1978 ....83 dB(A)

*(11) Any motor vehicle with a gross vehicle weight rating of 6,000 pounds or more manufactured after 1977, and before 1988 ....80 dB(A)

*(12) Any motor vehicle with a gross vehicle weight rating of 6,000 pounds or more manufactured after 1987................70 dB(A)

(13) Any other motor vehicle manufactured after 1967, and before 1973..86 dB(A)

(14) Any other motor vehicle manufactured after 1972, and before 1975..84 dB(A)

*(15) Any other motor vehicle manufactured after 1974, and before 1978..80 dB(A)

*(16) Any other motor vehicle manufactured after 1977, and before 1988..75 dB(A)

*(17) Any other motor vehicle manufactured after 1987.......70 dB(A)

(b) Test procedures for compliance with this section shall be established by the department, taking into consideration the test procedures of the Society of Automotive Engineers.

The California Highway Patrol performs the tests to determine if vehicles conform with Section 27160, as well as the enforcement of maximum noise levels specified in Section 23130 and the muffler provisions in Sections 27150 and 27151.

*REV 2-72
ANNEX A
HPM 83.3

4.7.3 Municipal Motor Vehicle Noise Legislation

Provisions to preserve public peace and tranquility and to prevent nuisances as loud noise have been incorporated in municipal ordinances for many decades. However, their applicability to vehicle noise violations meets with difficulty due to vagueness of the ordinances and lack of suitable criteria for determining when motor vehicle noise violations have actually occurred. These difficulties have prompted several communities to adopt ordinances containing specific decibel levels measured under standardized conditions to establish whether or not a vehicle is in violation.

The National Institute of Municipal Law Officers has created a <u>Model Noise Ordinance</u> (57) based on a study of over 100 existing municipal noise ordinances. The Model Noise Ordinance contains optional decibel limits for motor vehicles in operation as shown in Table 47. A complete copy of the model ordinance is provided with the technical summary to this report.

Several communities including Chicago (58) and New York City (59) have recently adopted comprehensive noise control ordinances with substantial fines levied for violations. A summary of the motor vehicle provisions of the Chicago ordinance are shown in Tables 4.8 and 4.9 . The noise limits for operating vehicles shown in Table 4.8 set criteria according to speed and do incorporate future noise limit reductions to be implemented in 1978. Table 4.9 presents noise criteria that must be met by manufacturers of new vehicles to be offered for sale in Chicago. These criteria are scheduled for incremental reductions so that by 1980 the maximum noise from any vehicle shall not exceed 75 dB(A) measured at 50 feet.

The New York City noise ordinance has vehicle noise limits comparable to the Chicago criteria. Convictions under the New York City ordinance can result in fines up to as much as $1,000 per day for a violation, with the provision that a complainant may receive 50 percent of the fine as a bounty.

A municipal Noise Bylaw adopted by the City of Calgary, Alberta (60), is of particular interest since a study of the percent of different vehicle types not meeting the proposed maximum noise standards was determined by field tests. The proposed vehicle noise limits are shown in Table 4.10

Table 4.7. NATIONAL INSTITUTE OF MUNICIPAL LAW OFFICERS MODEL NOISE ORDINANCE: OPTIONAL DECIBEL LIMITS (Source: National Institute of Municipal Law Officers, 1970, Washington, D.C.)

Vehicle type	Maximum dB(A)	Measuring distance (ft)
Trucks and buses:		
Over 10,000 lb	87	50
	93	25
Under 10,000 lb	80	50
	86	25
Passenger cars	78	50
	84	25
Motorcycles and other vehicles	87	50
	93	25

Type of Vehicle	Noise Limit in Relation to Posted Speed Limit	
	35 MPH or Less	Over 35 MPH
(1) Any motor vehicle with a manufacturer's GVW rating of 8,000 lbs. or more, and any combination of vehicles towed by such motor vehicle		
before 1 Jan. 1973	88 dB (A)	90 dB (A)
after 1 Jan. 1973	86 dB (A)	90 dB (A)
(2) Any motorcycle other than a motor-driven cycle		
before 1 Jan. 1978	82 dB (A)	86 dB (A)
after 1 Jan. 1978	78 dB (A)	82 dB (A)
(3) Any other motor vehicle and any combination of motor vehicles towed by such motor vehicle		
after 1 Jan. 1970	76 dB (A)	82 dB (A)
after 1 Jan. 1978	70 dB (A)	79 dB (A)

Section 17-4.7 (c) of the Chicago Noise Ordinance states that: no person shall operate within the speed limits specified in this section either a motor vehicle or combination of vehicles of a type subject to registration at any time or under any condition of grade, load, acceleration or deceleration in such manner as to exceed the above noise limit for the category of motor vehicle, based on a distance of not less than 50 feet from the center line of travel under test procedures established by Section 17-4.25 of the Ordinance. This section applies to the total noise from a vehicle or combination of vehicles and shall not be construed as limiting or precluding the enforcement of any other provisions of the code relating to motor vehicle mufflers for noise control.

Table 4.8 NOISE LIMITS FOR OPERATING VEHICLES: CHICAGO
(Source: Caccavari, C., "A New Comprehensive City Noise Ordinance ," Proceedings of the Purdue Noise Control Conference, July 14 - 16, 1971)

Type of Vehicle	Date of Manufacture	Noise Limit
(1) Motorcycle	before 1 Jan. 1970	92 dB (A)
Same	after 1 Jan. 1970	88 dB (A)
Same	after 1 Jan. 1973	86 dB (A)
Same	after 1 Jan. 1975	84 dB (A)
Same	after 1 Jan. 1980	75 dB (A)
(2) Any motor vehicle with a gross vehicle weight of 8,000 pounds or more	after 1 Jan. 1968	88 dB (A)
Same	after 1 Jan. 1973	86 dB (A)
Same	after 1 Jan. 1975	84 dB (A)
Same	after 1 Jan. 1980	75 dB (A)
(3) Passenger cars, motordriven cycle and any other motor vehicle	before 1 Jan. 1973	86 dB (A)
Same	after 1 Jan. 1973	84 dB (A)
Same	after 1 Jan. 1975	80 dB (A)
Same	after 1 Jan. 1980	75 dB (A)

Under Section 17-4.7 (b) of the Chicago Noise Ordinance, no person shall sell, or offer for sale, a new motor vehicle that produces a maximum noise exceeding the above noise limits at a distance of 50 feet from the center line of travel under test procedures established by Section 17-4.24 of the Ordinance. The manufacturer, distributor, importer, or designated agent shall certify in writing to the Commissioner that his vehicles sold within the City comply with the above provisions.

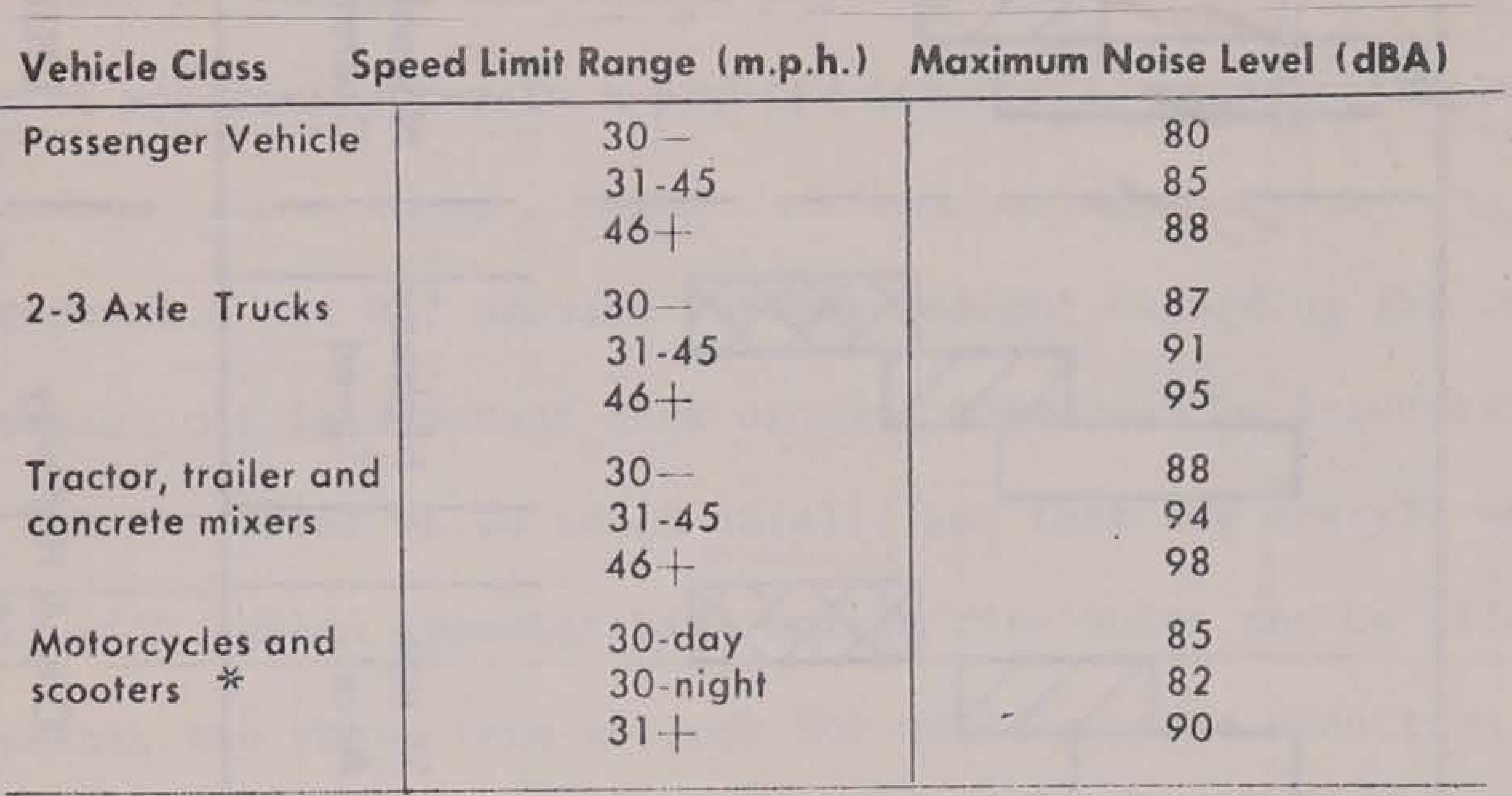
Table 4.9 NOISE LIMITS FOR NEW VEHICLES: CHICAGO
(Source: Caccavari, C., ibid.)

and the results of measuring the noise from 2,250 motor vehicles are shown in Table 4.11 . Since the tests were performed in the winter it was not possible to quantify noise from operating motorcycles and scooters. The results in Table 4.11 indicate significant failure rates (percent vehicle exceeding the noise limits) with the maximum rate occurring at several speed levels for heavier vehicles. In adopting the vehicle noise limits, the Calgary City Council selected those values shown in Table 4.10 with the exception that motorcycle and scooter levels were dropped to the maximum levels for passenger vehicles.

4.7.4 The Potential for Vehicle Noise Reduction Via Legislation

It is unreasonable to assume that all highway vehicle noise problems will be completely eliminated by legislation enacted at any or all levels of government. As the Automobile Manufacturers Association (now the Motor Vehicle Manufacturers Association of the U.S.) states: "Vehicle noise legislation should be based on a thorough study of all aspects of the problem. It must delegate responsibility for solutions in the most effective manner, and it must consider the social benefit gained for the cost premium placed on the owner or operator" (61). A definite problem exists with regard to reasonableness of the noise level maxima that have been established, especially the long-range goals currently being specified.

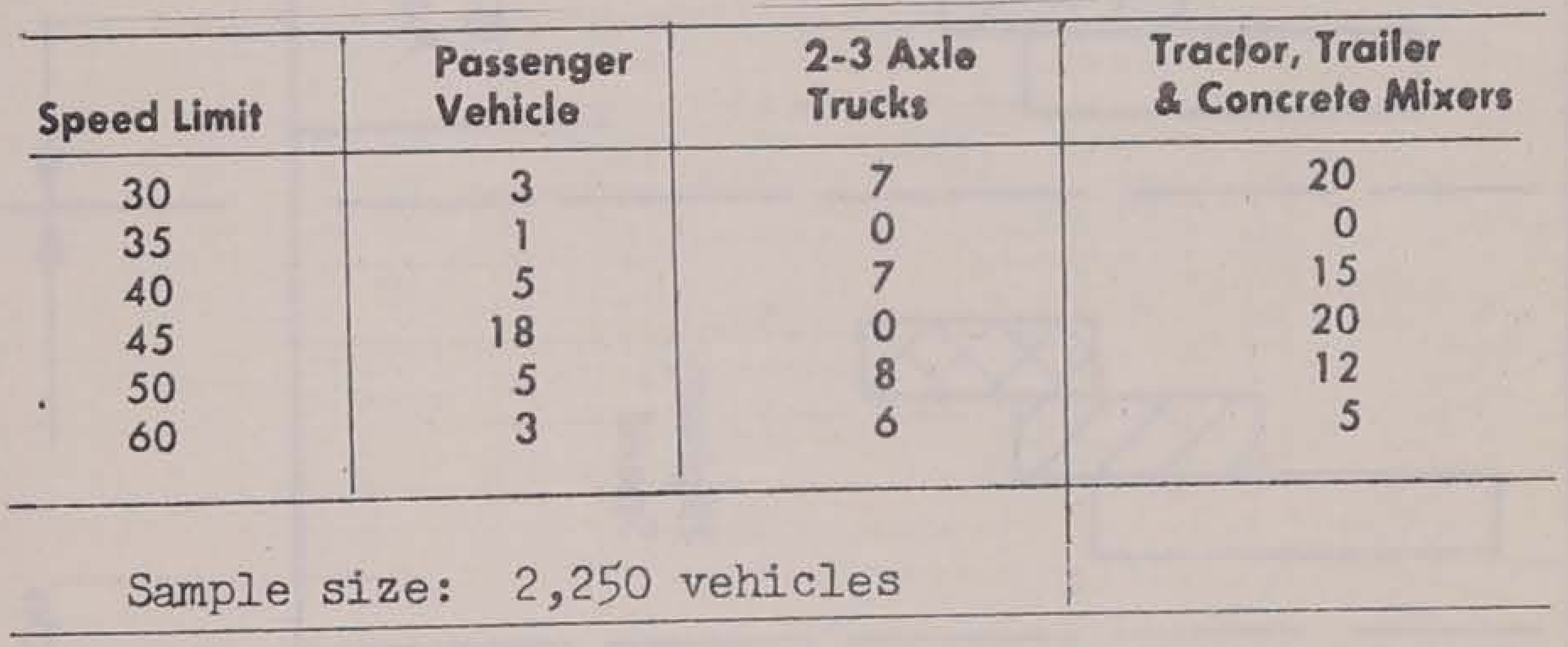
Wyle Laboratories, with the authorization of the Environmental Protection Agency, has evaluated the potential for highway vehicle noise reduction for two possible future courses of action (5). Their first consideration was the potential for immediate or short term noise reduction for existing vehicle concepts applying current technology; while their second projection was for the long range improvement that could occur if further research and development efforts were encouraged. A summary of their findings is presented in Figure 4.12. It is indicated that



Vehicle Class	Speed Limit Range (m.p.h.)	Maximum Noise Level (dBA)
Passenger Vehicle	30 –	80
	31-45	85
	46+	88
2-3 Axle Trucks	30 –	87
	31-45	91
	46+	95
Tractor, trailer and concrete mixers	30 –	88
	31-45	94
	46+	98
Motorcycles and scooters *	30-day	85
	30-night	82
	31+	90

* Limits adopted for Motorcycles and scooters were identical to those for passenger cars

Table 4.10 NOISE LIMITS FOR OPERATING VEHICLES: CALGARY (Source; Swanson, H. A., "Motor Vehicle Noise Research and Legislation," Traffic Engineering, July, 1971)



Speed Limit	Passenger Vehicle	2-3 Axle Trucks	Tractor, Trailer & Concrete Mixers
30	3	7	20
35	1	0	0
40	5	7	15
45	18	0	20
50	5	8	12
60	3	6	5

Sample size: 2,250 vehicles

Table 4.11 PERCENT VEHICLES FAILING TO MEET CALGARY NOISE BYLAW LIMITS (Source: Swanson, H. A., ibid.)

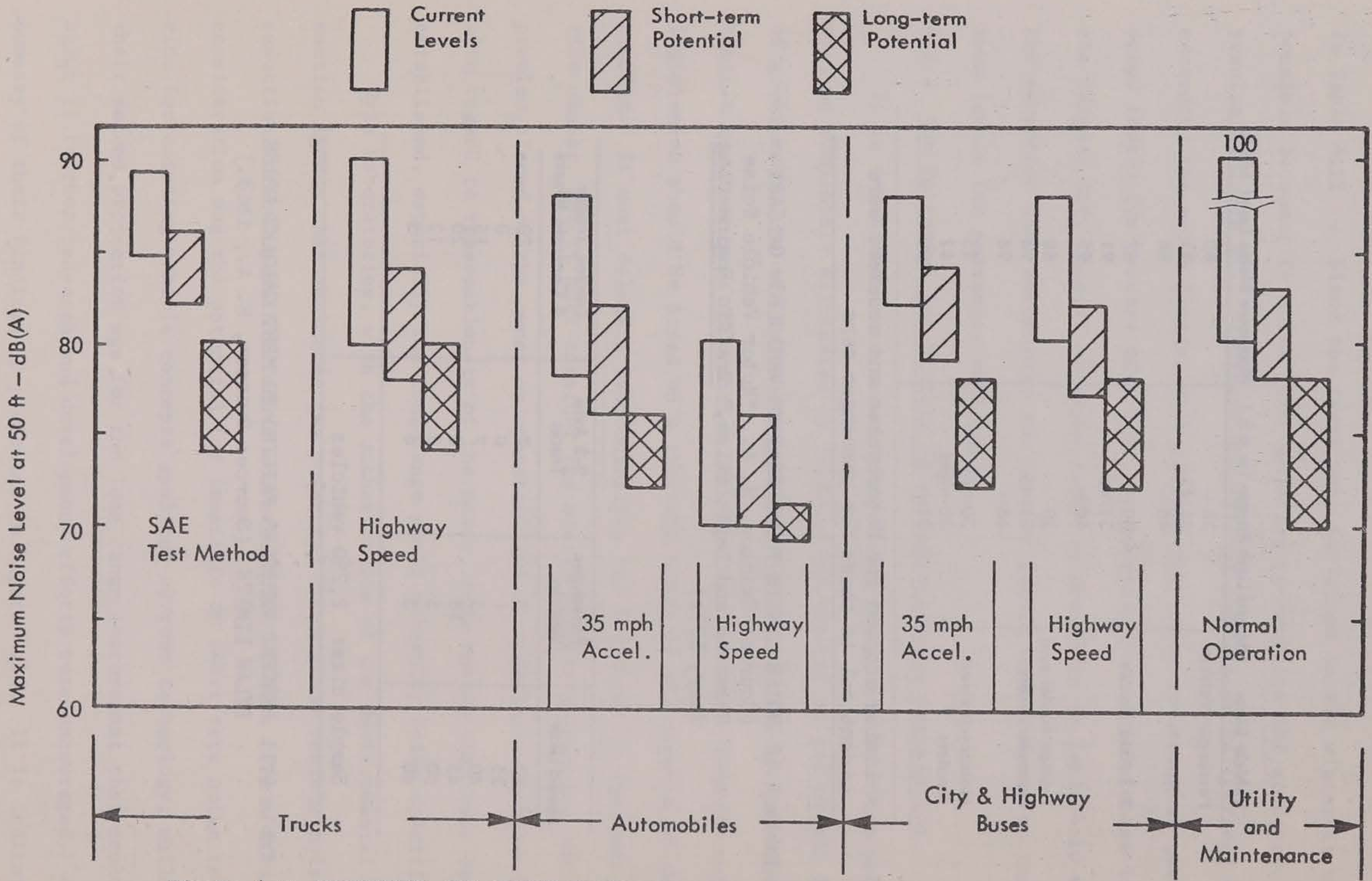


Figure 4.2 POTENTIAL FOR NOISE REDUCTION OF HIGHWAY VEHICLES
(Source: Wyle Laboratories, ibid.)

both the average noise level and the range of noise levels generated by each type of highway vehicle can be expected to drop noticeably in terms of short term potential, and rather significantly in the long term. Trucks will apparently remain a problem insofar as creating highway noise peaks.

Figures 4.6 and 4.7 provide further insight regarding the truck noise levels. It is apparent that exhaust noise can be drastically reduced (on the order of 10 to 12 dB(A)), but that the overall noise level of trucks will remain somewhat high unless tire noise can be alleviated. In any event, the short term outlook for vehicle noise reduction via legislation is favorable with application of existing knowledge. However, any long range drastic reduction in truck noise will depend on reducing the noise generated at the tire-roadway interface.

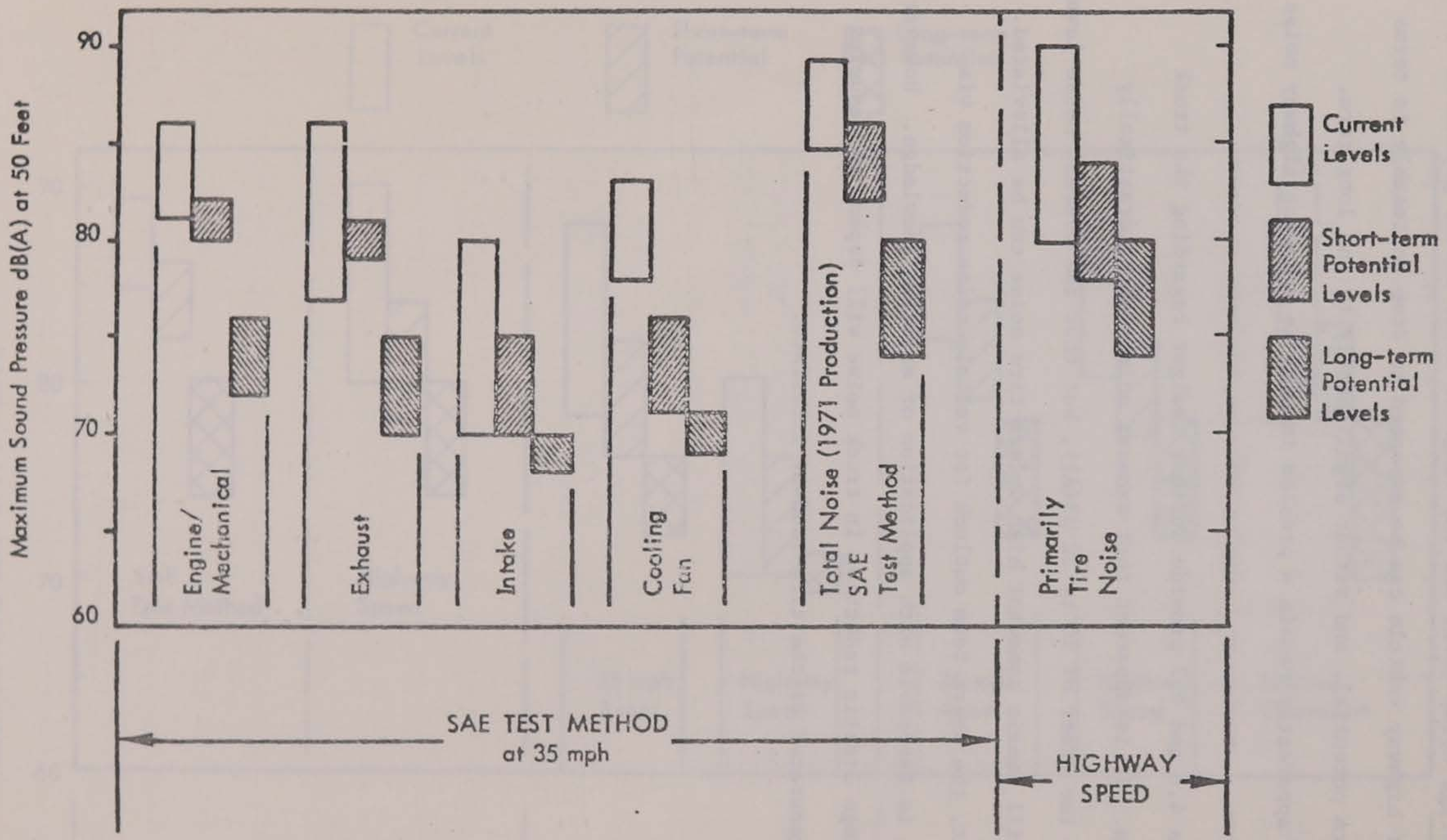


Figure 4.6 POTENTIAL FOR NOISE REDUCTION OF DIESEL TRUCKS BY COMPONENT (Source: Wyle Laboratories, ibid.)

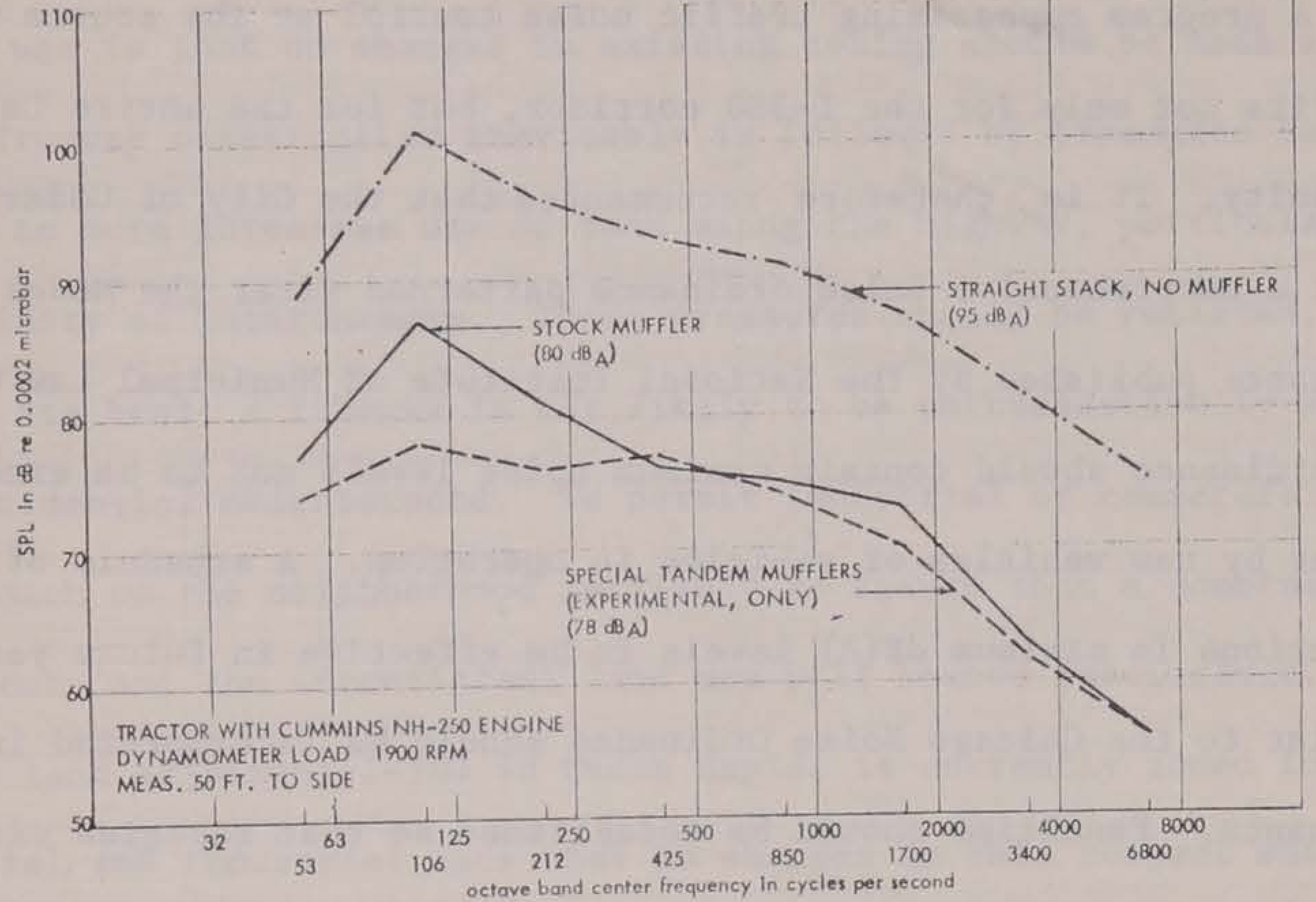


Figure 4.7 DIESEL TRUCK EXHAUST NOISE WITH THREE DIFFERENT MUFFLER SYSTEMS (Source: Bolt, Beranek, and Newman, ibid.)

5. RECOMMENDATIONS

5.1 Municipal Vehicle Noise Ordinance

A program emphasizing traffic noise control at the source will yield benefits not only for the I-380 corridor, but for the entire Cedar Rapids community. It is therefore recommended that the City of Cedar Rapids adopt a comprehensive noise ordinance patterned after the Model Noise Ordinance published by the National Institute of Municipal Law Officers. The ordinance should contain maximum noise levels not to be exceeded either by new vehicles or vehicles in operation. A schedule of gradual reductions in maximum dB(A) levels to be effective in future years similar to the Chicago Noise Ordinance should be incorporated in the ordinance. Penalties should be established so that repeated violations would meet with substantial monetary fines. The ordinance should also contain a procedure by which a citizen may file a complaint against a suspected violator. It is suggested that the U.S. Environmental Protection Agency be contacted to determine the extent to which federal assistance may be utilized in formulating the ordinance and creating the necessary enforcement agency.

5.2 Land Use Programs

The principal recommendation growing out of this study in respect to land use is that no changes in existing zoning should be made at this time. Freeway construction inevitably is followed by pressures for changes to more intensive use of land along the highway, particularly in the vicinity of interchanges. These pressures should be resisted.

At its best, a freeway is not likely to be enthusiastically welcomed in a residential neighborhood. To permit industrial or commercial uses to encroach on the neighborhood is likely to assure that a combination of the freeway and the inconsistent land use will become intolerable. Sufficient land adjoining I-380 in Cedar Rapids is currently zoned for commercial and industrial uses that no changes in this respect should be necessary in the immediate future.

Available analytical techniques permit an evaluation, albeit somewhat imprecise, of the effects of a freeway, including noise. Such an analysis for I-380 in Cedar Rapids indicates that some residential areas will probably be more adversely affected than would be desired. The most affected areas generally are those closer to the central business district where peak-hour traffic volumes are the highest. These areas also are those most likely to be deteriorating today. This suggests that some further deterioration of these areas may be anticipated.

Hence, a continuous monitoring of land uses adjacent to the freeway will be necessary. An active program of building inspection is also assumed. As the affected properties reach an apparent "point of no return," consideration should be given to each property on an individual basis and a determination made as to zoning changes that would permit a highest and best use. Such determination, of course, must be consistent with the intended urban development and also must be legally correct and fair to the property owner. The pattern, for organizing and financing such an effort exists in current Urban Renewal Programs. It is therefore recommended that the extent of the currently designated renewal area on the southwest side of the city be redefined. For example, where the freeway is indicated as the boundary, such boundary should be relocated to include the next block abutting the freeway.

Possible acceptable land uses for renewal properties include the following:

- It could remain as open space landscaped and developed in a manner consistent with the city plan and compatible with the surrounding land.
- It could be utilized for residential purposes, perhaps more intensively than previously, but with structures designed to reduce interior noise levels and so located as to help shield other nearby properties.
- It could be utilized for commercial or public buildings where such development is not inconsistent with projected surrounding land use and where attention is given to soundproof construction.

In summary, it must be recognized that some land use changes are inevitable in any dynamic urban area such as Cedar Rapids. The existence of I-380 will affect the nature and location of these changes. A responsibility of the city is to guide the occurrence of such changes in land use and to exploit them so that benefits from the freeway are maximized and that adverse effects are reduced as much as possible.

5.3 Policy on Truck Stop Location

Supplementing the aforementioned general policy pertaining to land use along I-380, it is specifically recommended that the Planning and Redevelopment Department exert their influence to assure that construction of truck stop facilities will not occur in or close to any residential areas. In applying this guideline, it must be remembered that a truck stop along a freeway has a far reaching impact due to the noise created by trucks as they decelerate to leave the freeway and as they accelerate to enter the freeway and regain speed. Truck stop facilities have an important function in serving the transportation industry; however, selection of an improper location for this type of facility must be avoided. This policy is also appropriate for application to other limited access highway facilities envisioned by the City of Cedar Rapids.

5.4 Beautification of Corridor

To achieve a more pleasing visual impression that will assist in blending the freeway with the residential environment, it is recommended that the City adopt a program of planting and maintaining those areas of open public property that will exist as narrow strips of land between the freeway chain-link fence and the local street or service road curb. These areas will exist in numerous locations in the freeway corridor. The space available for planting will be on the order of 10 to 15 feet in width; however, this will be adequate for establishing two rows of shrubs and evergreen trees. Care must be taken to avoid trees which are readily ascended by children.

The planting program should commence as soon as possible following freeway construction, with provisions for proper maintenance once the foliage is established. It is expected that the primary benefits of this program would be aesthetically oriented and that the freeway would be more readily accepted by its neighbors along the corridor. The belt of trees would be expected to have minimal influence on the noise reaching the properties from I-380 traffic.

5.5 Freeway Transit Evaluation

A subject warranting detailed study in cooperation with the Iowa State Highway Commission and the Federal Highway Administration is the potential for initiating an urban highway public transportation system complete with terminal facilities along the I-380 corridor. With several high-density rental developments located adjacent to I-380, and the possibility for further similar construction, it is likely that a system of freeway transit buses operating from fringe area terminals could be a viable transportation mode for commuters and shoppers traveling to the Cedar Rapids central business district. Furthermore, a complete freeway transit system could conceivably serve many traffic generators such as Prairie High School, Kirkwood Community College, the Cedar Rapids Municipal Airport, St. Luke's Hospital, and Hawkeye Downs during certain seasons. Properly planned multiple land use projects creating fringe parking and transit terminal facilities along I-380 could represent an effective and highly beneficial use of land that would otherwise be of minimal value to the City and its residents.

5.6 Subdivision and Residential Area Control

To achieve compatibility between I-380 and future residential developments, subdivision codes and building codes should be altered to include the following provisions.

5.6.1 Subdivision Code

A 50- to 100-foot wide open space should be provided between all subdivision parcels and any freeway right-of-way. This space should be utilized for service roads, bicycle paths, trees and shrubbery, sitting parks, recreational areas, and any required noise reduction devices.

Houses should be located on their respective lots as far from the freeway as prudently possible, especially in that row of homes closest to the freeway.

Whenever possible, enclosed porches, garages, or other detached buildings should be placed between the freeway and the main living quarters.

The first row of private homes closest to the freeway should be restricted to single level dwelling units, unless specifically requested to be otherwise by a purchaser of the property.

Where interchanges are placed in subdivisions, the subdivision layout should include an intervening development of higher density rental units to serve as a buffer between the interchange and the single family residential properties.

5.6.2 Building Code

Whenever practical, the most noise sensitive rooms of a home, as the bedroom, should be placed as far away from the freeway corridor as possible, with the less critical areas such as garages, kitchens, storage areas, and bathrooms placed closest to the freeway.

Windows, particularly those on the side of the house facing the freeway, should be the double glass type, preferably mounted in rubber gaskets with an STC (Sound Transmission Class) rating of at least 36.

Doors should be of solid core wood or hollow metal construction with a weight of 5 lb/sq ft with a minimum STC rating of 29. Doors should be fitted with insulation strips around all edges, top and bottom.

Exterior walls of homes closest to the freeway should be constructed of masonry, either hollow or solid, with a minimum STC rating of 41.

Ventilation openings to the outside should be through acoustically lined air ducts on those homes adjacent to the freeway.

5.7 Traffic Noise Abatement Procedures

The procedures and recommendations presented in this section will supplement and coincide with other recommendations presented in this chapter.

5.7.1 Comprehensive Truck Route Evaluation

The traffic noise analyses performed in this study determined that noise levels created along I-380 will depend highly on the volume of trucks operating on the freeway, its ramps, and paralleling service roads. The most critical noise problems will occur near interchanges where trucks frequently utilize the ramps and in areas close to those service roads carrying significant numbers of trucks. It is therefore recommended that shortly after I-380 becomes operational an evaluation of truck movement patterns along the freeway corridor be performed. The objective of this analysis would be to establish appropriate truck routes leading to and from I-380 so that sensitive residential areas will not be unnecessarily exposed to truck noise from ramps and service roads.

5.7.2 Utilization of Traffic Noise Barriers

It is recommended that traffic noise barriers not be considered initially as a solution for noise reduction at properties along I-380. This recommendation is based on the fact that almost the entire route is poorly suited for noise barrier installation due to the predominantly elevated configuration and the frequent interruption of the freeway be interchanges and other bridges. Other factors limiting the desirability of barriers are their high initial costs, maintenance problems that may develop, and the difficulty of blending high fence structures with the landscape.

Any future considerations of noise barrier installation at the few sites where they might be effective should involve detailed noise studies in the field to verify the existence of a noise impacted area, and then further calculations to determine exactly what height barrier would be required to achieve the desired noise reduction.

5.7.3 General Description of Noise Levels and Abatement Procedures

This discussion concerns the extent of the traffic noise problems likely to exist in various sections of the I-380 corridor, as well as specific noise abatement measures that might be of value in each section. The noise levels cited in each instance are the L_{10} levels projected for the 1994 peak hour traffic.

- South of the I-380-U.S. 30 Interchange:

This section is primarily in agricultural use with some residential development near U.S. Highway 30. The noise levels at all except two residences in the immediate vicinity of the I-380-U.S. 30 interchange will be less than 65 dB(A) and shielding should not be required. At Prairie High School the noise levels will be in the range of 60-67 dB(A), during peak hour traffic flows. Since the freeway is depressed at this location traffic noise barrier construction would be feasible if the traffic noise is found to disrupt school activities. Future residential developments in this section should be established with adequate buffer zones or open spaces between the residences and the freeway.

- U.S. 30 Interchange to Wilson Avenue Interchange:

Noise levels will exceed 70 dB(A) only at several private properties closest to the Wilson Avenue interchange where shielding by barriers would have small benefit. Most of this section is in commercial and industrial use. It would seem appropriate to retain this policy and exclude residential development from any area adjoining the freeway.

- Wilson Avenue Interchange to 5th Avenue Interchange:

The freeway is elevated in this section and noise barrier construction would not be feasible. Noise levels at adjacent properties would range from 65 to 75 dB(A), with the higher values occurring close to the interchanges and in the vicinity of the 15-16th Avenue overpass. The status of the neighborhoods in this section, especially those closest to the railway and those closest to the 5th Avenue to 8th Avenue connector should be monitored to detect any potential areas for redevelopment by constructing new multi-family structures. This is not to suggest large-scale purchase and demolition of any structures that are in good repair. This section of the corridor would benefit from planting shrubs and trees whenever possible along the route for the purpose of promoting freeway acceptance.

- 5th Avenue Interchange to 1st Street, S.W.:

Several blocks in this area will be exposed to noise levels exceeding 7t dB(A). Shielding the properties by use of freeway noise barriers is not recommended due to the elevated configuration and the fact that high noise levels will be generated from the surface street system, service roads and numerous ramps. Redevelopment that occurs in this area should not be residential, but rather some land use not substantially affected by traffic noise.

- St. Luke's Hospital Area to Coldstream Interchange:

Most properties in this section will be exposed to noise levels less than 70 dB(A), one exception being the front row of properties on the east side of I-380 from H Avenue to J Avenue. Shielding of these properties by barriers is again impractical due to the elevated freeway configuration. Several properties on the west side of I-380 south of the Coldstream interchange will be subjected to noise levels reaching 75 dB(A). These properties are situated such that noise barriers would offer some benefit if they were constructed to a height of 10 feet or more and placed between the properties and the freeway ramp.

- Coldstream Interchange to 42nd Street Interchange:

The majority of developed properties will be exposed to less than 70 dB(A) in this section. Exceptions to this will occur at properties abutting service roads and those very close to interchanges. The only possible location for installing a noise barrier in this section exists on the west side of I-380 immediately south of the 42nd Street interchange.

- 42nd Street Interchange to Blairs Ferry Road Interchange:

The land use in this section is primarily commercial and open space, although some residential development has already occurred. Wherever possible a buffer area should be reserved between the freeway right-of-way and any contemplated residential development. Properties closest to the interchanges will be subjected to noise levels greater than 75 dB(A), however, there is no practical means to provide shielding for these residences since the freeway is elevated and the properties also face the surface street system.

- North of I-380-Blairs Ferry Road Interchange:

Most properties will be exposed to less than 60 dB(A) noise levels, except for those in the immediate vicinity of the interchange where levels up to 75 dB(A) may be experienced. Noise barriers will be of marginal value in this section due to the elevated freeway configuration and the inability to provide a long uninterrupted noise barrier.

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APPENDIX A: SUMMARY OF DES MOINES I-235 SURVEY RESULTS

Iowa State University, Ames, Iowa

SURVEY OF FREEWAYS IN IOWA RESIDENTIAL AREAS

Iowa State University is studying the opinions of people concerning freeways located in urban areas. It is hoped that information gathered in this survey will be useful in planning future cities and transportation systems.

Your assistance would be greatly appreciated and we would like for you to complete and return this questionnaire at your earliest convenience. We have provided a stamped envelope addressed to Iowa State University, Ames, Iowa, 50010. Your individual responses will be strictly confidential. Two identical forms have been provided so the husband and wife may both reply. Thank you for your interest in this project.

1. Name (67 individuals replied)
2. Address (41 separate households replied)
3. Length of time you have lived at this address (4 3/4) (years). (average)
4. Age (45). (Median) 5. Are you a licensed driver: Yes (62) No (5).
6. Occupation (24 were retired or full-time homemakers)
7. Number of vehicles owned by family: (Totals)

   Cars (69) Pick-up trucks or campers (2)

   Motorcycles (5) Bicycles (63)
8. Do you own (40) or rent (1) your home?
9. What do you believe are the major advantages and disadvantages of having freeways located in residential areas?

   Advantages (if any)

   A. Convenience (32), Speed (31)

   B. Safety (5), Less congestion (1)

   Disadvantages (if any)

   A. Noise (59), Odor (10)

   B. Vibrations (8), Appearance (6)
10. In general would you say the advantages outweigh the disadvantages of freeways?

    Yes (26) Not certain (16) No (25)

11. If you have lived at this address both before and after the nearby freeway was built, how would you describe the change in the general noise level in your neighborhood?

(0)	(0)	(1)	(5)	(42)
Much Quieter With Freeway	Slightly Quieter	No Change	Slightly Noisier	Much Noisier With Freeway

Not here both before and after freeway was built (19).

12. Would you ever buy or rent another home as close to the freeway as your present home? Yes (13) Not certain (9) No (45)

13. Does noise from the freeway hinder your family outdoor activities?
Yes (36) Sometimes (8) No (23)
Which activities Conversation, picnics, gardening, porch use.
Question does not apply (no outdoor activites) (0)

14. Does noise from the freeway hinder your indoor activities?
Yes (17) Sometimes (23) No (27)
Which activities Conversation, use of telephone, sleep, TV viewing.

15. For each time period of a weekday, please circle the letter that most closely describes the noise you hear from the freeway (A means definitely annoying; B means slightly bothersome; C means occasionally noticeable; D means you do not notice the noise; E means you are usually away from home at that time).

Time of day	Noise Condition				
6 - 8 a.m.	A-22	B-12	C-16	D-9	E-7
8 - 12 noon	A-10	B-9	C-9	D-14	E-24
12 - 4 p.m.	A-9	B-9	C-10	D-14	E-24
4 - 6 p.m.	A-30	B-11	C-11	D-11	E-3
6 - 12 midnite	A-27	B-13	C-5	D-11	E-10
12 - 6 a.m.	A-21	B-8	C-8	D-17	E-12

16. At times when the freeway traffic noise seems to bother you, is it possible to identify specific vehicles that create the disturbance? Loud autos (12)
Yes, vehicles causing noise are: Large trucks (58), Motorcycles (13)
I hear the traffic but can't identify specific vehicles (4)
No, vehicle noise does not bother me (3)

17. Do you find other noises in your neighborhood to be as disturbing to you as the freeway noise?
Yes (15) Source of other noise Trucks, motorcycles, cars
Seldom (19) Source of other noise Aircraft, barking dogs, construction, lawn mowers.
Never (33)

18. Have you changed your home or anything on your property specifically for the purpose of reducing the freeway noise that you hear? Did the change reduce the noise? Yes (22) No (18) No reply (1)

If yes, please describe the change and whether it helped to reduce noise:

Effective actions were running air conditioners and closing all windows.

19. Do you believe the presence of the freeway changes the value of your property?

Freeway probably decreases property value (29)

Freeway does not affect property value (6) No reply (1)

Freeway probably increases property value (5)

20. Would you like to have city laws enforced to reduce vehicle noise?

Yes, more strictly enforced (54)

Yes, adequately enforced already (7) No reply (4)

No, enforcement not needed (2)

21. Is you home air-conditioned? Yes (51) No (15) No reply (1)

If yes, it is for comfort (45) or for noise reduction (6). Both (28)

22. How many houses are between your home and the freeway? None (30), One or more (

23. Can you clearly see the freeway from your home? Yes, from the house (66)

Yes, from the yard (55) No clear view of freeway (0)

24. Should a barrier or wall be built close to the freeway to reduce the traffic noise?

Yes, all along the freeway (27)

Yes, only in noisiest places (9) No reply (3)

Probably not needed (28)

25. Should many trees and shrubs be planted between your home and the freeway to hide it from your view?

Yes, they are needed (45)

No, probably not needed (9) No reply (2)

No, trees already present (10)

26. If you answered yes to either question 24 or 25, who do you think should pay for these improvements?

City or state gov't. (33) Federal gov't. (13)

27. If you had control of state and local highway funds, in what ways would you like to spend it?

	Many$	Few $	No $
Beautify highways	(18)	(19)	(2)
Buy buses	(7)	(10)	(15)
Improve city streets	(29)	(16)	(1)
Control traffic noise	(29)	(16)	(2)
Improve traffic safety	(37)	(13)	(1)
Build new highways	(15)	(17)	(9)
Others Mass Transit (6)			

28. Would you like to see the land along the freeway close to your home used for some specific purpose?

Yes: Bicycle trail (27) Picnic areas (8)

Tennis courts (5) Playgrounds (9)

Parking lot to catch bus (9)

Other suggestions Trees and/or shrubs (13)

No other use (20)

29. How frequently do you use the freeway as a driver or passenger for the following purposes?

Frequency of Freeway use	Transportation to:		
	Work	Shopping	Recreation or Visit
Regularly	30	24	31
Occasionally	6	29	23
Seldom	3	5	3
Never	11	1	0

30. In what size city were you raised during most of your childhood?

Raised outside of town (9)

Small town, under 2,500 (10)

Medium size town, 2,500-10,000 (9) or name of town

Large town, 10,000-50,000 (5)

Small city 50,000-100,000 (4) (we can look up population)

Medium sized city 100,000-250,000 (24)

Large city, 250,000 and over (6)

31. Do you generally like your present location?

Neighborhood: Yes (56) Why Neighbors (11), Nearby shopping (8)

No (7) Why Freeway (7)

Community: Yes (48) Why Hometown (5), Size (4), Schools (2)

No (6) Why Freeway (1), Housing (1)

32. Would you have any comments of your own concerning the subjects covered in this questionnaire?

33. Would you consent to a personal interview as time might permit us on this project?

Yes (62) No (3) No reply (2)

Could noise level readings be taken on your property? Yes (65) No (0)

No reply (2)

APPENDIX B: HIGHWAY AND TRANSPORTATION AGENCY SURVEY FORM

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY
Ames, Iowa 50010

October 12, 1972

ENGINEERING RESEARCH INSTITUTE

Gentlemen:

The Engineering Research Institute at Iowa State University is conducting a research study concerning the means by which urban freeways might be made more compatible with residential environments. A major effort within this project involves contacting highways and transportation agencies to determine current policies and practices regarding traffic noise abatement, aesthetic development of the corridor, and multiple-use of the land in or along the right-of-way. We hope that you will be able to assist us by completing this questionnaire and adding any appropriate suggestions or comments of your own.

1. Has your agency adopted specific standards or guidelines relative to:

   A. Acceptable urban freeway traffic noise levels: Yes ☐ No ☐
   B. Aesthetic design of urban freeway corridors: Yes ☐ No ☐
   C. Multiple-use of land close to freeways: Yes ☐ No ☐

   If the answer to any of the above is yes, could you enclose a copy of the pertinent documents when returning this survey? Yes ☐ No ☐

   Or tell us where a copy of the documents may be obtained? ____________________

   ____

   ____

2. Have you installed, or are you planning to install any barriers, earth berms, or other noise attenuating devices along freeways to reduce traffic noise levels in residential areas? Yes ☐ No ☐

   If yes, could you: A. Send a report to us giving details_______
   B. Tell us where to obtain a pertinent report_______
   C. Describe the installation, its cost, and effect_______

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

3. Has your agency ever purchased additional property along an established or planned freeway route because the existing or anticipated traffic noise would make the property undesirable as a residence? Yes ☐ No ☐

   If yes, could you describe the physical features involved, the value of the property, and the estimated noise levels (dBA):____________________

   ____

   ____

   ____

   ____

   ____

   ____

   ____

4. Have you recently developed any unusual landscaping techniques or other methods to enhance the aesthetic values of a freeway routed through an urban residential area? Yes ☐ No ☐

If yes, could you: A. Send a report to us giving details_______
B. Tell us where to obtain a pertinent report_______
C. Describe the techniques employed_______

5. Have you recently completed, or do you have plans for projects where a relatively new or unique multiple-use of land along urban freeways has been attempted? (As bicycle path, picnic area, etc.) Yes ☐ No ☐

If yes, could you: A. Send a report to us giving details_______
B. Tell us where to obtain a pertinent report_______
C. Describe the projects and their cost_______

6. Would you like to submit comments of your own concerning this survey?

7. Would you be interested in receiving a summary of the survey results? Yes ☐ No ☐

If yes, please provide name and address of recipient:

THANK YOU for your time and interest in this project.

Robert L. Carstens
ROBERT L. CARSTENS
Professor of Civil Engineering

Charles E. Dare
CHARLES E. DARE
Assistant Professor of Civil Engineerin

Please return questionnaire and information to:

Transportation Engineering
Rm. 382, Engr. Bldg. No. 2
Iowa State University
Ames, Iowa 50010

APPENDIX C: I-380 DESIGN HOUR TRAFFIC VOLUME ESTIMATES

The traffic volumes shown in this appendix were obtained from the Urban Department of the Iowa State Highway Commission on October 9, 1972. The volumes represent typical peak hour flow for an average summer week day of the design year, 1994. Only those volumes shown on Figure C.1 of this appendix were used in predicting the 1994 noise levels along I-380.

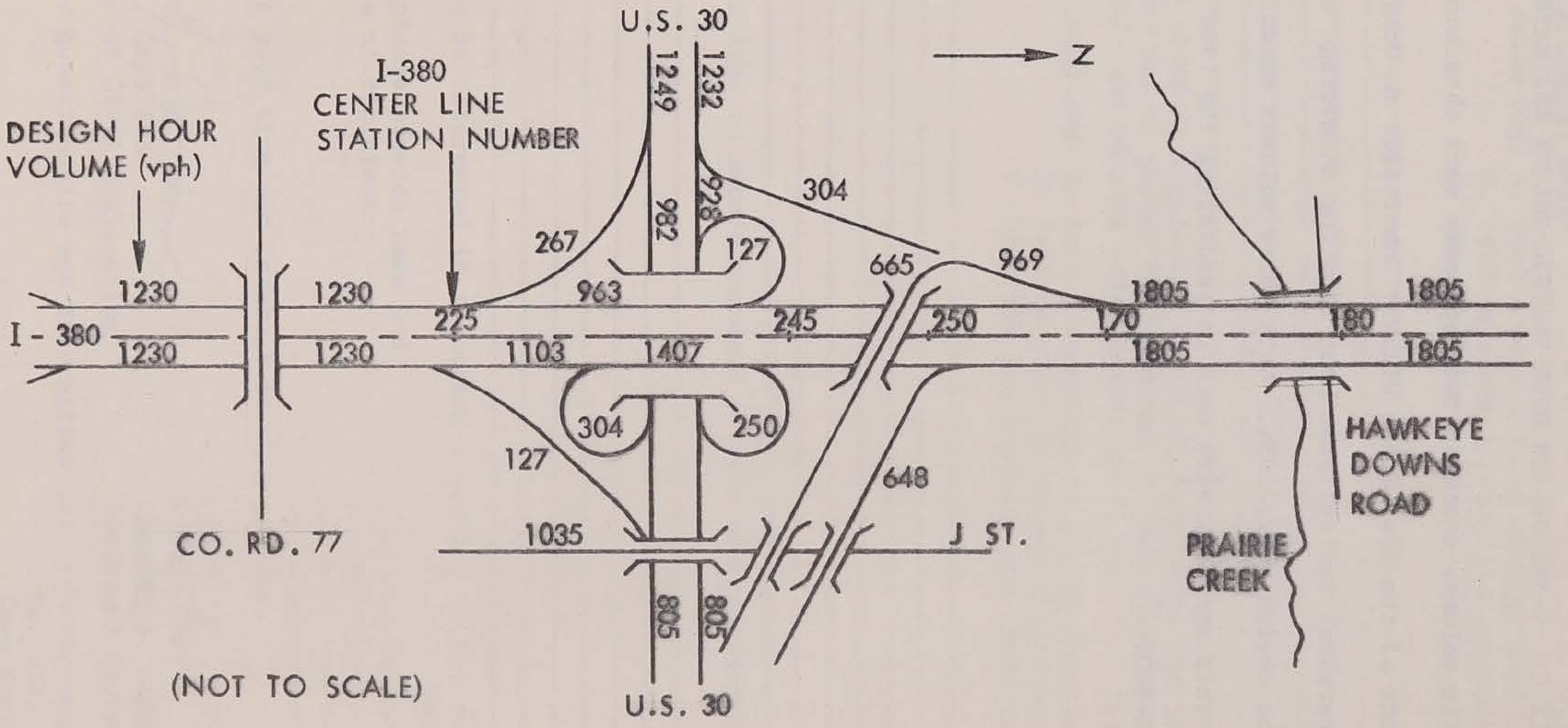
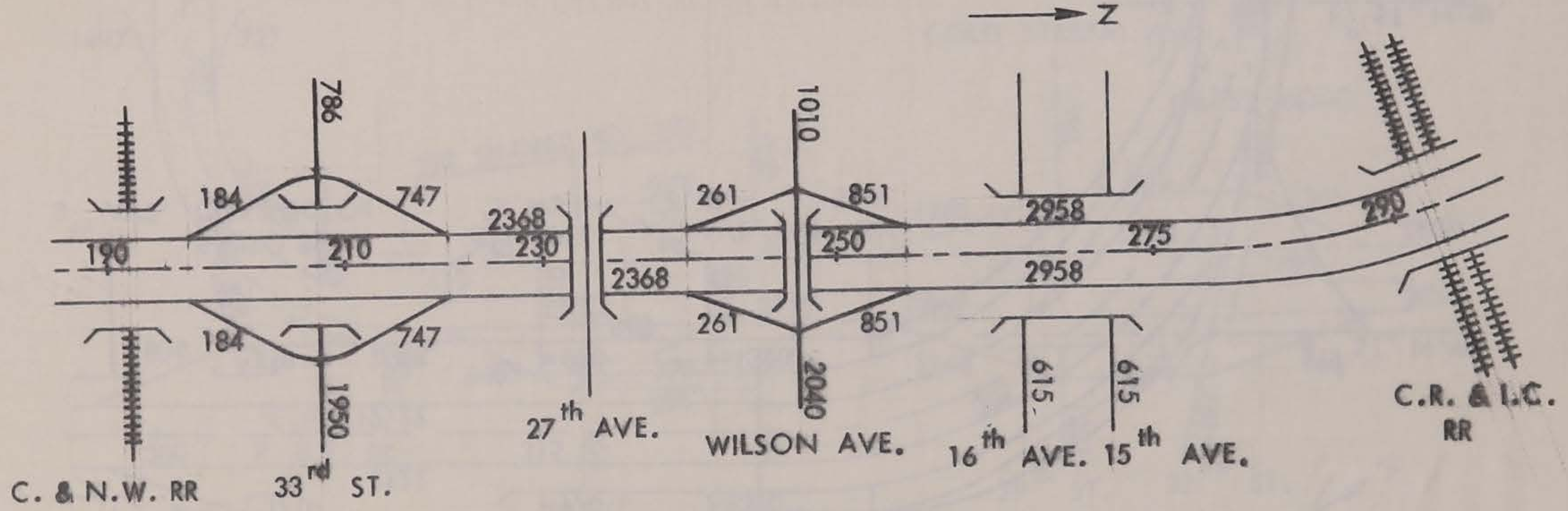
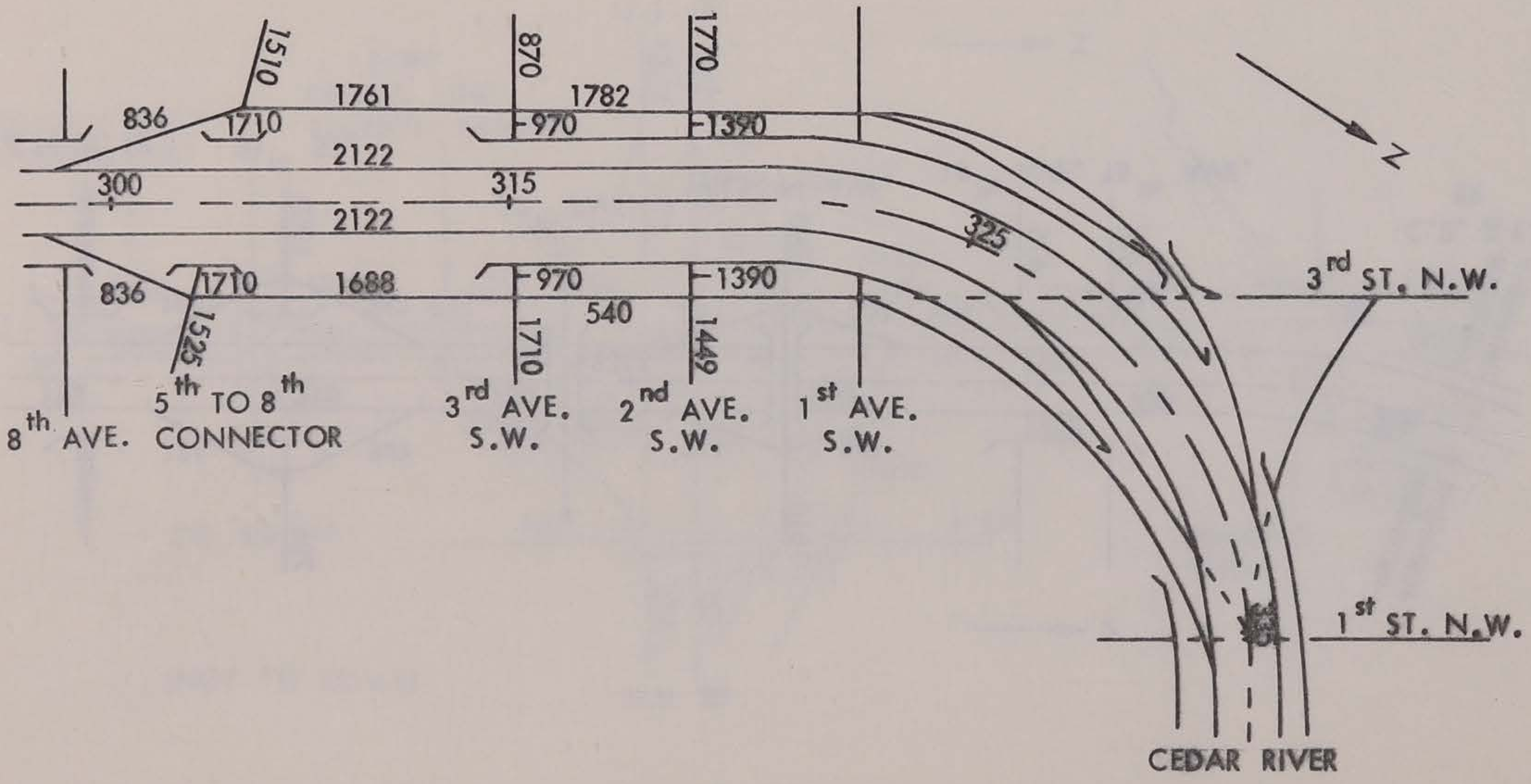
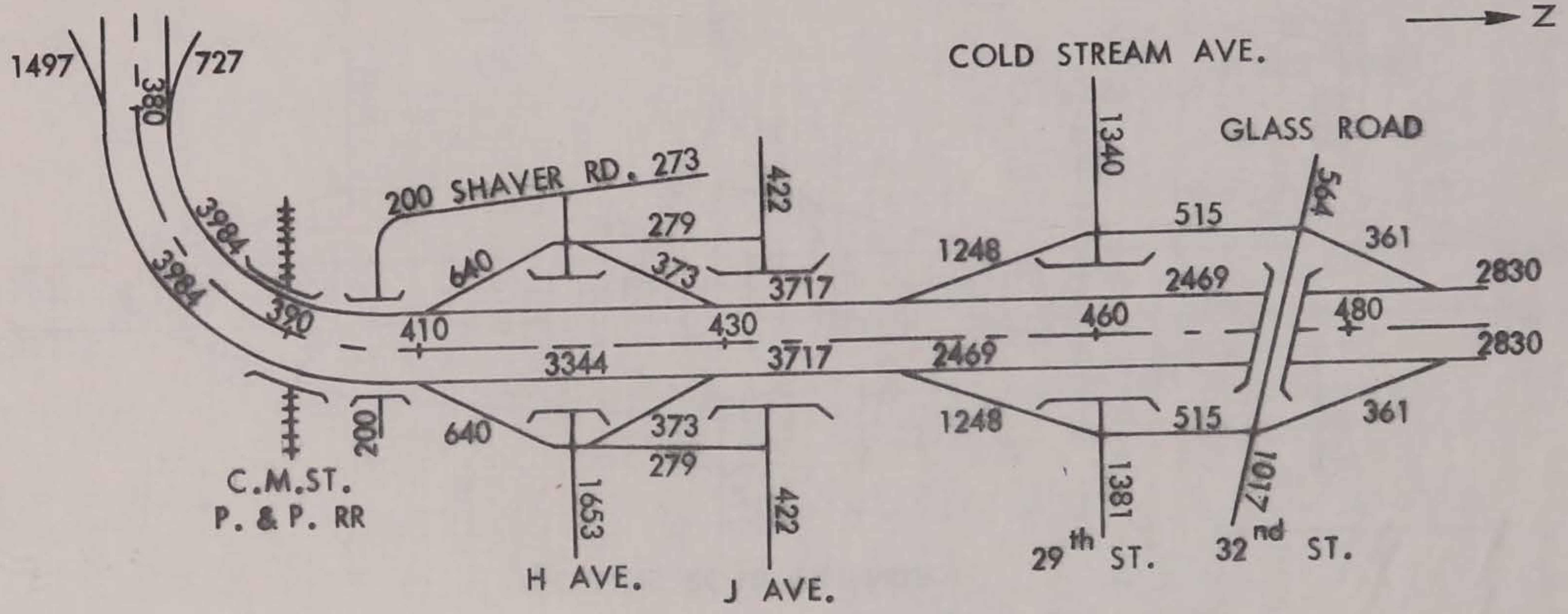
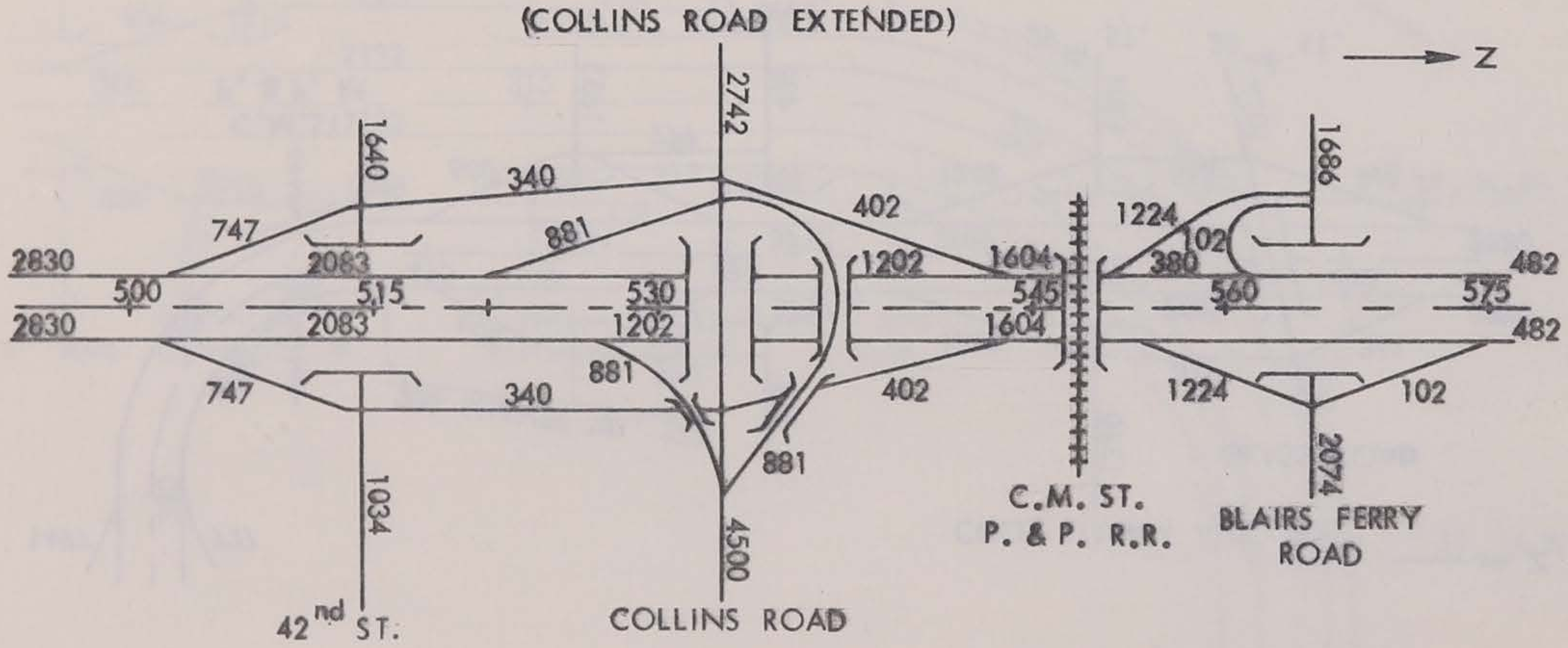


Figure C.1 1994 Design Hour Traffic for I-380.


Z
C. & N.W. RR
33rd ST.
27th AVE.
WILSON AVE.
16th AVE.
15th AVE.
C.R. & I.C. RR
786
1950
184
747
184
747
190
210
2368
230
2368
261
851
261
851
1010
2040
250
2958
2958
275
615
615
290


1510
870
1770
N
836
1761
1782
1710
970
1390
2122
300
315
2122
325
836
1710
1688
970
1390
3rd ST. N.W.
540
1525
1710
1449
5th TO 8th CONNECTOR
8th AVE.
3rd AVE. S.W.
2nd AVE. S.W.
1st AVE. S.W.
1st ST. N.W.
CEDAR RIVER


Z
1497
727
380
COLD STREAM AVE.
1340
GLASS ROAD
564
200 SHAVER RD. 273
422
279
515
361
3984
3984
640
373
3717
1248
2469
2830
390
410
430
460
480
3344
3717
2469
2830
640
373
279
1248
515
361
200
1653
422
1381
1017
C.M.ST.
P. & P. RR
H AVE.
J AVE.
29th ST.
32nd ST.


(COLLINS ROAD EXTENDED)
→ N
2742
1640
1686
340
747
881
402
1224
102
380
2830
2083
500
515
530
1202
1604
545
560
575
482
2830
2083
1202
1604
482
881
747
340
402
1224
102
881
1034
4500
2074
C.M. ST. P. & P. R.R.
BLAIRS FERRY ROAD
42nd ST.
COLLINS ROAD